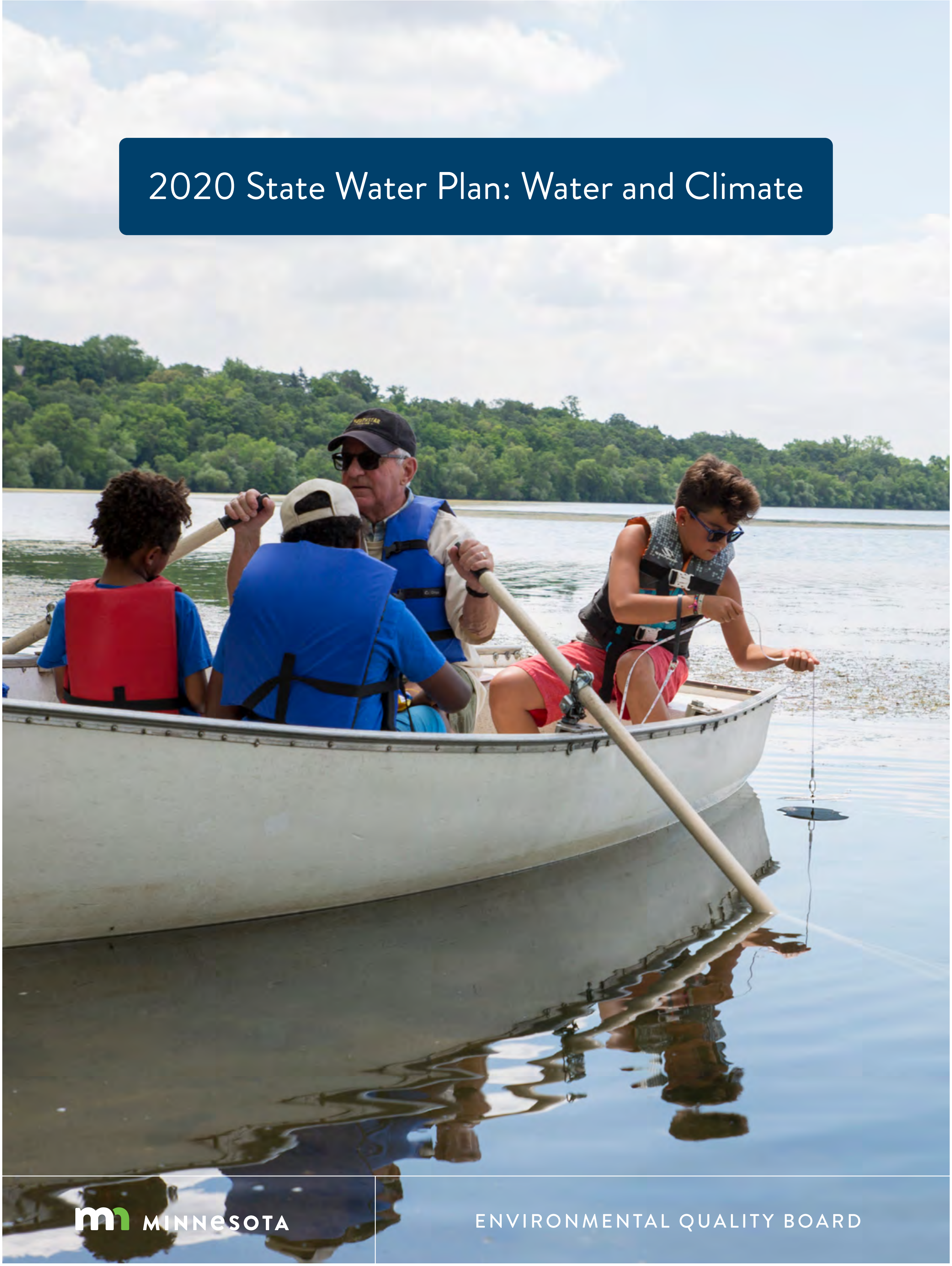
2020 State Water Plan: Water and Climate



MINNESOTA

ENVIRONMENTAL QUALITY BOARD

Table of Contents

The Environmental Quality Board is mandated to produce a 10-year state water plan pursuant to Minnesota Statutes, 103B.151, 103A.43, 103A.204.

This report was prepared by the Environmental Quality Board with the Board of Water and Soil Resources (BWSR), Department of Agriculture (MDA), Department of Commerce, Department of Health (MDH), Department of Natural Resources (DNR), Department of Transportation (MnDOT), Metropolitan Council, Pollution Control Agency (MPCA), University of Minnesota.

Edited by Mary Hoff
Designed by Amanda Scheid

Cover photo: Two generations of MPCA volunteers monitor water clarity in Lake Harriet, Minneapolis. Citizen volunteers measure the clarity of lakes and streams, collecting valuable data the MPCA uses to make decisions on watershed protection and restoration.

Letter From the Board

Minnesota's way of life is intertwined with water. We depend on water for drinking, food production, healthy ecosystems and emotional well-being. We swim, fish, play and celebrate in and around water. Climate change is already impacting our more than 10,000 lakes, 100,000 miles of rivers and streams, abundant groundwater, and all of us. The effects of climate change are expected to accelerate in the coming decades.

In 2008, Minnesotans showed that we value water with passage of the Clean Water, Land and Legacy Amendment, creating a stable funding source for and a watershed-based approach to protection and restoration of our water resources. Since then, increased investments in monitoring, evaluation, watershed planning and implementation of projects have enabled us to do much more to protect, enhance, and restore water quality in lakes, rivers and streams and to protect groundwater from degradation. However, many challenges remain. Climate change is one, and we are only just beginning to understand how it is impacting Minnesota's waters and the challenges it will pose for the future.

The goal of this report is to shine a spotlight on actions Minnesota can take to protect our waters from climate change. In order to protect our waters, we must also take decisive action to reduce greenhouse gas emissions to curb the worst effects of climate change. We are releasing this report at a time when Minnesota is reckoning with multiple stressors, including a pandemic and the resulting economic fallout, and a legacy of economic and racial inequities. Black, Indigenous and people of color are particularly vulnerable to threats at the intersection of water and climate change. This Board, and the agencies responsible for implementing this plan, must increase our efforts to address these systemic inequities and engage with these communities openly, respectfully and transparently.

Planning for the future of Minnesota's water must include an honest appraisal of the effects our changing climate is having on this vital resource and how these changes will impact Minnesotans, wildlife, habitat and landscapes across the state. Fortunately, the actions we take to improve water quality and manage water quantity, from soil health to water storage, can also reduce greenhouse gas emissions and help us adapt to a changing climate.

What we collectively aim for and accomplish over the next 10 years will have ripple effects over the next 100 years. As a headwaters state, our actions will impact not only our neighboring states and provinces, but also the major water basins downstream, from the Gulf of Mexico to the Great Lakes to Hudson Bay. Likewise, our partnerships with local, state, regional and national governments and organizations both outside and inside our boundaries will be critical in realizing the aspirations and goals of this plan.

Laura Bishop, EQB Chair
Commissioner, Minnesota Pollution Control Agency

Margaret Anderson Kelliher
Commissioner, Department of Transportatioin

Kristen Eide-Tollefson
Public Member, Congressional District 2

Alan Forsberg
Public Member, Congressional District 1

Julie Goehring
Public Member, Congressional District 7

Steve Grove
Commissioner, Department of Employment and Economic Development

Steve Kelley
Commissioner, Department of Commerce

Jan Malcolm
Commissioner, Department of Health

Bryan Murdock
Public Member, Congressional District 8

Thom Petersen
Commissioner, Department of Agriculture

Alice Roberts-Davis
Commissioner, Department of Administration

Sarah Strommen
Commissioner, Department of Natural Resources

Gerald Van Amburg
Chair, Board of Water and Soil Resources

Sue Vento
Council Member, Metropolitan Council

2020 Water Plan purpose

The Minnesota Legislature has directed the Environmental Quality Board (EQB) to coordinate comprehensive long-range water resources planning and policy through a State Water Plan every 10 years (Minnesota Statues 103B.151, 103A.43, 103A.204). This plan fulfills the legislative mandate.

The purpose of the 2020 State Water Plan is to establish a framework for aligning state agencies, legislative priorities, and local government policy, programs and actions for the coming decade. EQB developed this plan to set an agenda for tackling the stubborn and complex water problems that climate change will intensify for Minnesotans. In preparation for this report, EQB convened state agencies, met with over 250 people from 44 public and private organizations, and conducted two informal surveys to learn about concerns related to water and climate and thoughts on what actions local and state government should take. The plan defines goals, strategies and actions. It highlights key water issues related to climate, but it is not an exhaustive list of the challenges we face or the solutions to implement. Ideas set forth in this plan can help establish priorities and inform decision-making, and they underscore the need to take actions with multiple benefits across several goals to move beyond our current trajectory.

Source: DNR

A Look Back: Water Policy and Planning Highlights

1982: Metropolitan Surface Water Management Act is enacted, requiring local governments in the 7-County metro region to form watershed management organizations to plan for surface water management across municipal boundaries.

1987: County Comprehensive Water Planning Program is established, funding county development of water management plans.

1989: The Groundwater Protection Act is enacted, creating new incentives and requirements for state and local groundwater management.

1991: EQB prepares first decennial Minnesota Water Plan: Directions for protecting and conserving Minnesota's waters.

2000: EQB completes Minnesota Watermarks: Gauging the flow of progress, 2000–2010.

2008: Minnesota voters demonstrate their commitment to working together on water issues by passing the Clean Water, Land and Legacy Amendment.

2010: EQB completes Minnesota Water Plan: Working together to ensure clean water and healthy ecosystems for future generations.

2011: The University of Minnesota releases Minnesota Water Sustainability Framework, a comprehensive report designed to protect and preserve Minnesota's lakes, rivers and groundwater for the 21st century and beyond.

2014: Minnesota Nutrient Reduction Strategy outlines how Minnesota will reduce nutrient pollution in its lakes and streams and reduce the impact downstream. The strategy specifies goals and provides a framework for reducing phosphorus and nitrogen by an interim target date of 2025 and final date of 2040.

2014: Minnesota's Clean Water Roadmap sets long-range goals for Minnesota's water resources over the 25-year life of the Clean Water, Land and Legacy Amendment (through 2034).

2015: The Minnesota Legislature passes a law to protect water quality by requiring buffers on more than 100,000 acres of land adjacent to public waters and public drainage systems. EQB prepares Beyond the Status Quo Water Policy Report. Legislation directs state and local governments to accomplish a ten-year transition to use a Comprehensive Watershed Approach to achieve accelerated and coordinated water management (aka One Watershed, One Plan).

2017: Governor Mark Dayton asks Minnesotans for their input on how to increase the pace of progress toward clean water, setting a goal of 25% improvement by 2025.

2019: Governor Walz signs EO 19-37 establishing the Climate Change Subcabinet and the Governor's Advisory Council on Climate Change to promote coordinated climate change mitigation and resilience strategies.

How to use the plan

This plan is organized in three sections. The first two provide background information on water and climate connections, the importance of engaging Minnesotans to develop equitable solutions to our water challenges, and collaboration between the state and Tribal Nations in water efforts. The third section contains five goals. These goals represent focus areas for Minnesotans to become more resilient to climate change and prepare for its impacts on water in the coming decade. Each goal contains recommended strategies and actions to achieve it. The goals overlap and interrelate, so many of the strategies apply to multiple goals.

Goal 1: Ensure drinking water is safe and sufficient

Goal 2: Manage landscapes to protect and improve water quality

Goal 3: Manage built environment and infrastructure for greater resiliency

Goal 4: Manage landscapes to hold water and reduce runoff

Goal 5: Promote resiliency in quality of life

Additional resources related to the plan are available on the EQB website (*eqb.state.mn.us*).

Principles Underlying This Plan

Several principles and assumptions shape this plan. Some of these have shaped water policy in Minnesota for decades, while others are new, based on increasing awareness of the threats climate change poses.

- We have a responsibility to consider the needs of all natural systems, including wildlife and plants. Human impacts to water threaten many species and habitats in Minnesota. Healthy lakes, rivers, streams, wetlands, springs and aquifers are all essential for thriving ecosystems.
- We recognize the value of nature-based solutions. Promoting biodiversity and investing in the health of ecosystems is critical for our resilience to climate change. We need to protect water in areas with high biodiversity and increase biodiversity where it is lacking. As we select and implement solutions to water issues, we can choose to mimic natural systems wherever possible.
- We recognize the interconnection between land use and water quality and quantity, as well as connections between air and water. How we use and manage land affects water quality and quantity and can result in real costs, from increased drinking water treatment to repair or replacement of roads and bridges.
- We recognize that surface water and groundwater, while frequently discussed separately in this report, are interconnected and interdependent.
- We have a responsibility to consider the needs of downstream users. Minnesota sends water to three of North America's major drainage basins: the Mississippi River, the Great Lakes and the Red River of the North.
- We acknowledge that our water resources, while abundant, are not evenly distributed or unlimited and that demands on those resources are likely to increase.
- We have a responsibility to address water injustices. We recognize that the impacts of climate change on water resources will be experienced differently in different regions of the state and by different populations, and we seek equitable solutions. Existing inequities in Minnesota limit the ability of some populations to confront the impacts described throughout this report on infrastructure, water quality, recreation and more. These vulnerable populations include but are not limited to:
    - people in floodplains or at risk from localized flooding
    - residents with private wells vulnerable to contamination, with infants, children and the elderly facing the greatest risks
    - people in communities facing high water treatment costs or inadequate drinking or wastewater treatment infrastructure
    - Black, Indigenous and people of color, who already face multiple stresses that can affect resilience, from housing costs to educational inequities
    - people in poverty and those facing financial, language or educational barriers, limiting their ability to recognize and respond to threats
    - people in urban areas who lack adequate or safe access to water-based recreation.
- We have a responsibility to welcome and support culturally diverse voices and different ways of knowing and relating to water in inclusive community engagement, science, management, planning and policy.

Source: Charles Robinson

Water and climate change

Climate and water shape our lives

Minnesota is almost as famous for its climate, which swings from hot, humid summers to frigid, snowy winters, as it is for its abundant waters. Just as we cannot imagine our state without lakes and rivers, we also would not recognize a year without cold winter nights, heavy snow, summertime thunderstorms, or numerous warm and sunny days. Minnesotans depend on both climate and water for our way of life, from recreation like hunting, fishing and paddling, to our agricultural, tourism and industrial economies.

Minnesota's climate and water are closely connected in many ways:

- The amount and timing of precipitation influences how much water soaks into the ground or runs off into lakes, rivers and wetlands.
- Precipitation patterns also determine the availability and demand for water.
- Temperature patterns control the timing of snowmelt, the duration of ice cover on lakes and streams, and the beginning and end of Minnesota's growing season.
- Climate influences water temperatures, along with many of the chemical, physical and biological processes that shape aquatic resources.

What's the difference between climate and weather?

Somebody has probably said to you, "If you don't like the weather, wait five minutes," but you cannot say the same for climate. Weather and climate both describe the condition of the atmosphere in a location, but weather is short term, whereas climate refers to the effect of weather patterns averaged over seasons, years and decades. Climate shapes our expectation that it will be cold in Minnesota in the winter; weather determines what we experience on a given day.

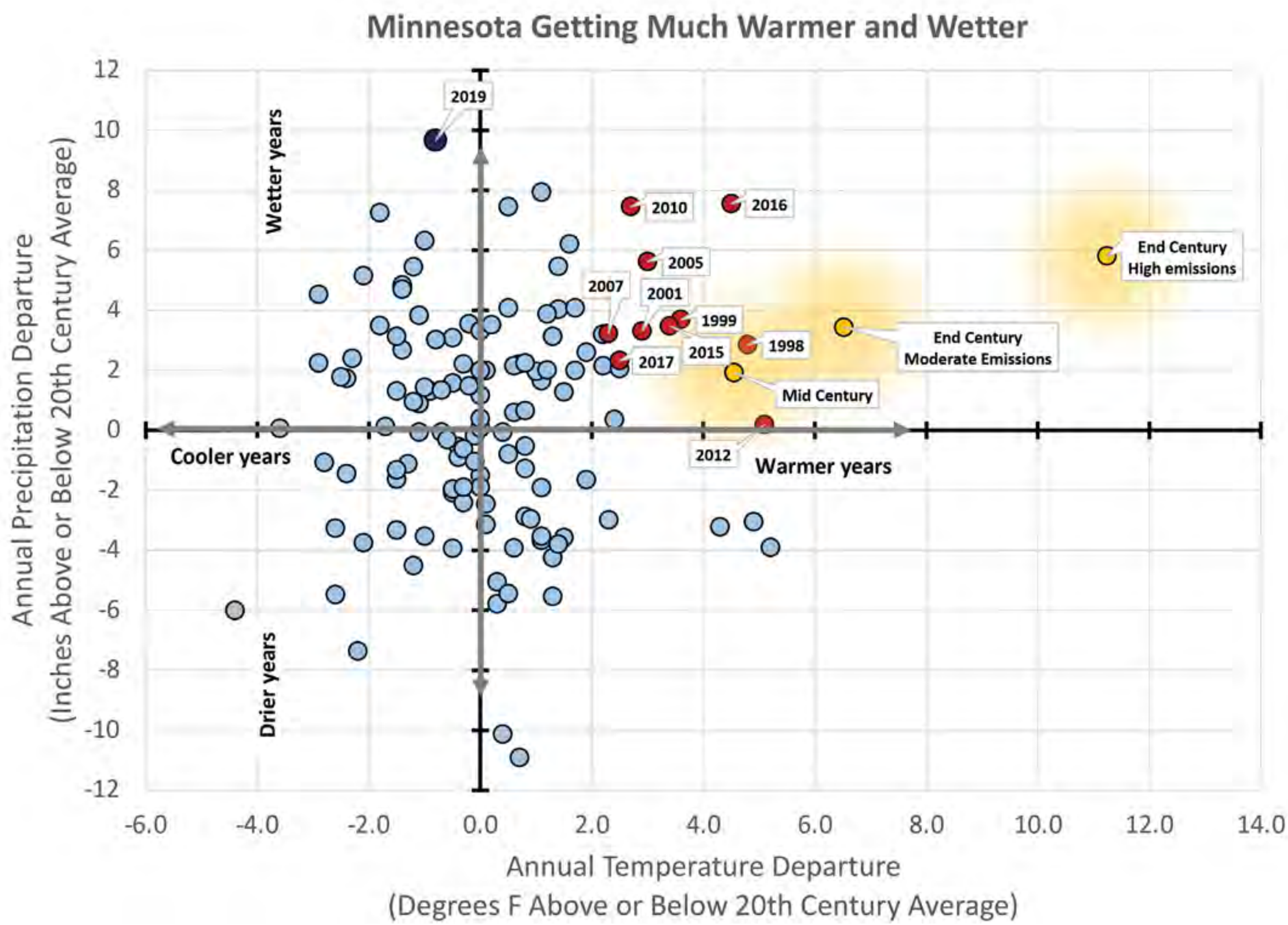
Source: MnDOT

Source: MPCA

How our climate is changing

We know that some seasons can be far warmer, colder, wetter or drier than normal. The high variability we expect from Minnesota's climate can make it difficult to notice where, when and how climate has changed in our state. However, rapid, widespread changes are already underway, and more changes are coming. In the past several decades, our state has seen substantial warming that is most pronounced during winter and at night, increased precipitation and heavier downpours.

An overwhelming base of scientific evidence projects that Minnesota's climate will see additional, significant changes through the end of this century, with even warmer winters and nights and even larger rainfalls—along with the likelihood of increased summer heat and the potential for longer dry spells. Although we will experience occasional cool or dry years, climate scientists expect these increases to continue through the 21st century.



Source: DNR State Climatology Office & University of Minnesota

All but two years since 1970 have been wetter and/or warmer than 20th century averages, and the 10 combined wettest and warmest years (red dots) on record all occurred from 1998 onward. Each blue and red dot represents a given year's statewide temperature and precipitation departure from 20th century averages, 1895–2019. Yellow dots represent projections for the middle and end of the 21st century with moderate and high greenhouse gas emissions, based on 20-year averages; therefore, some individual years are warmer and wetter than the values shown.

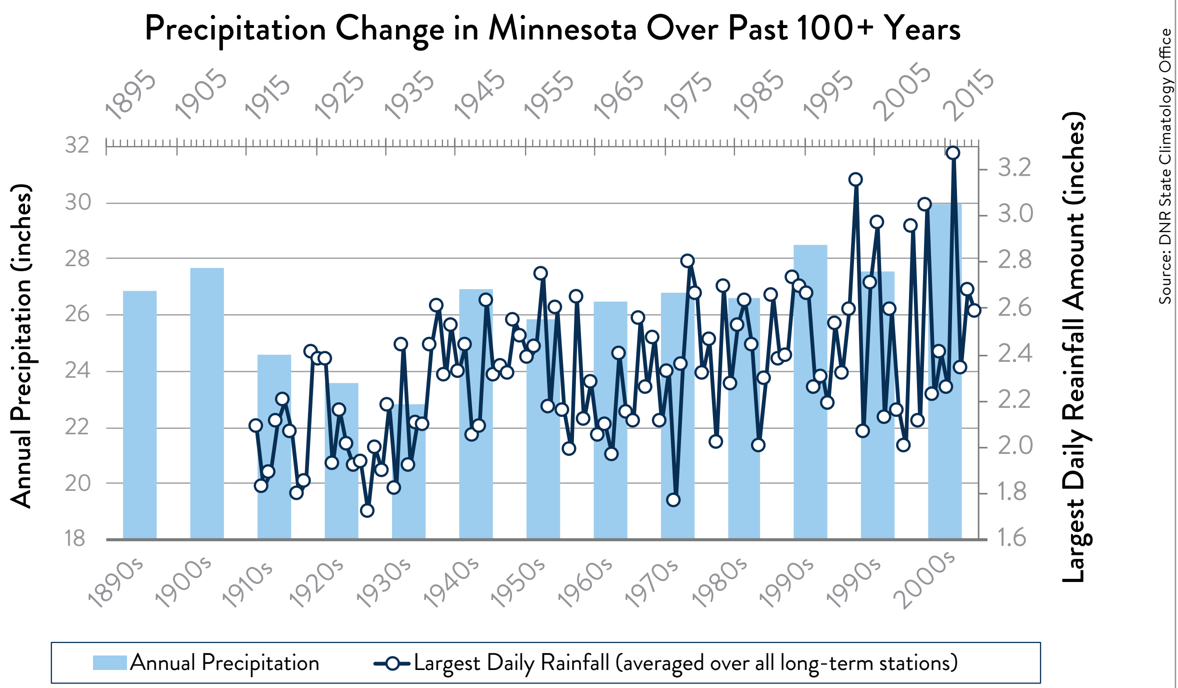
Unprecedented wetness

Minnesota's climate swings naturally from relatively dry to relatively wet periods, but wet conditions have dominated recent decades. Years with precipitation above historical averages have become increasingly frequent, and departures from those averages have grown as well, leading to sustained record-breaking precipitation surpluses. June 2014 was Minnesota's wettest month on record, with severe flooding in many areas. During 2019, more precipitation fell across the state than any other year on record back to 1895. The precipitation increases have been most pronounced in southern Minnesota. In 2016, Waseca broke Minnesota's annual precipitation record, only for Harmony and Caledonia to surpass it in 2018. Snowfall has been increasing too, with several stations setting seasonal snowfall records during the 2010s, and dozens of monthly records falling as well.

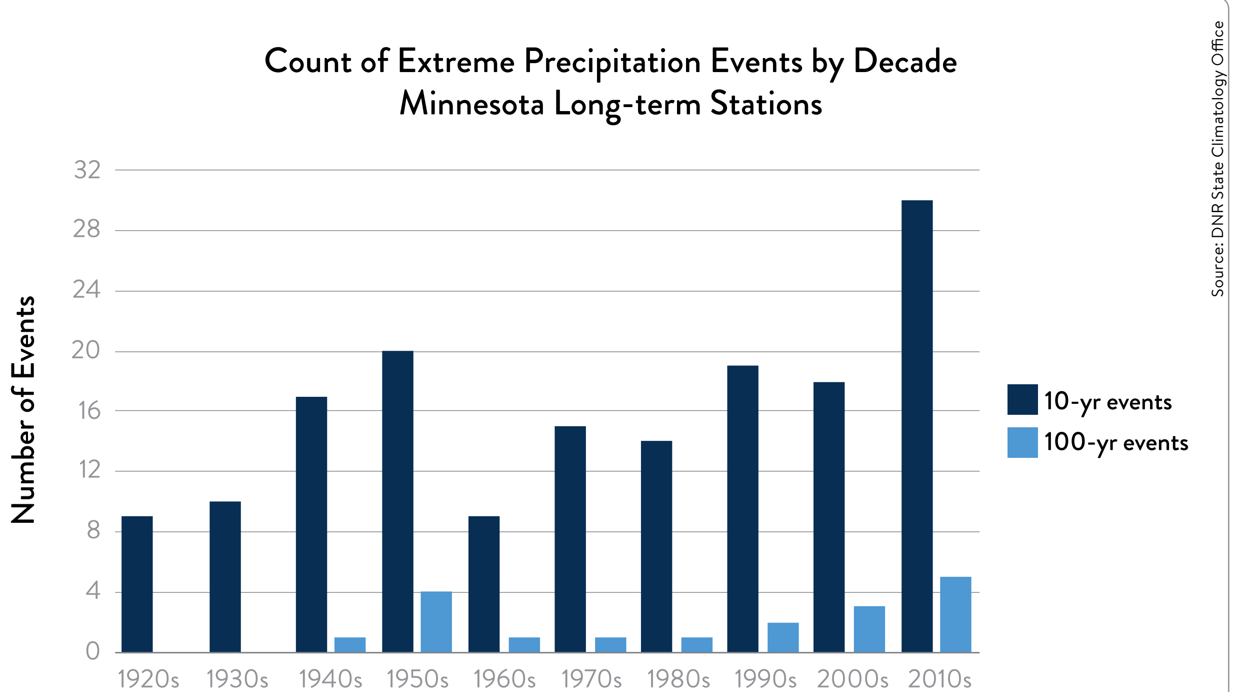
Source: MPCA

"Mega-rains"

"Mega-rains" are events in which six inches of rain covers more than 1000 square miles and the core of the event tops eight inches. Minnesota has experienced 11 mega-rains in the 20 years since 2000 (including one in July 2020), versus six in the 27 years from 1973 through 1999.



This chart shows changes in Minnesota's annual precipitation, averaged by decade, along with the average value of the largest daily rainfall of the year from Minnesota's 39 long-term weather stations. The 2010s finished as Minnesota's wettest decade on record on.



Minnesota's long-term climate stations recorded more 10-year and 100-year rainfall events during the 2010s than in any other decade.

More damaging rains and heavy snowfalls

Minnesota now sees more extreme precipitation than at any other time on record. Minnesota's long-term climate stations recorded more "10-year" daily rainfall events—those exceeding 3.5 inches in the northwest and 4.5 inches in the southeast—during the 2010s than in any other decade. The annual heaviest daily rainfall total anywhere in the state now averages about 20% higher than it did historically. In August 2007, a catastrophic rainfall in southeastern Minnesota produced a 24-hour total of 15.10 inches in the town of Hokah, breaking the statewide daily rainfall record by nearly 40%. Heavy snowfall has increased during this period as well, with many stations setting all-time 24-hour records during the 2010s, and the decade setting high marks across the state for the frequency of 4-inch snowfalls.

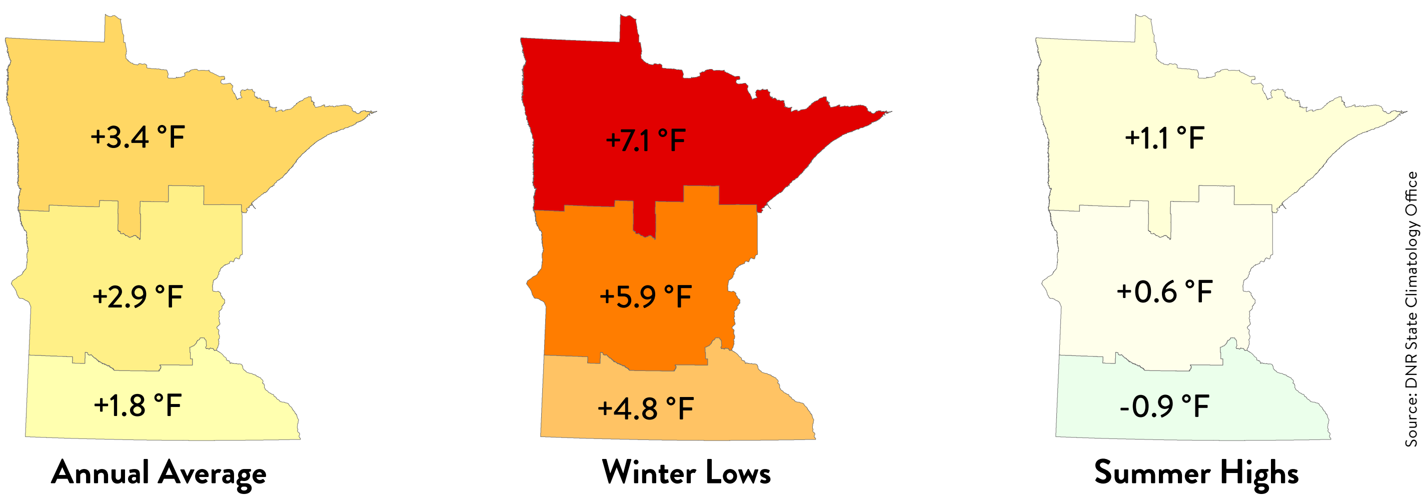
Warmer, but not yet hotter

Minnesota has warmed considerably, but mostly during nights and winter. Annual temperatures have climbed 2.9 °F since 1895, but winter low temperatures have increased by 6.1 °F, with only modest increases or even slight decreases in summer high temperatures. Winter cold extremes have become less frequent and less severe across the state, but we have observed no change in the frequency or severity of heat extremes. Over 85% of Minnesota's warming occurred since 1970, indicating that the state is currently facing rapid climatic changes.

Daily precipitation increases

At climate stations with over 100 years of observation, daily precipitation totals of 1, 2 and 3 inches have increased by an average of 21%, 31% and 62%, respectively.

Total temperature change, 1895–2019



Since 1895, winter lows in northern Minnesota have increased 40% faster than in southern Minnesota.

> *"[Someone once asked], 'You've lived here your whole life, when is the skiing reliable?' and I said 'Oh, by Thanksgiving, no question.' … And now, I mean, Thanksgiving we're still paddling."*
>
> –North Shore interviewee

Minnesota's future climates

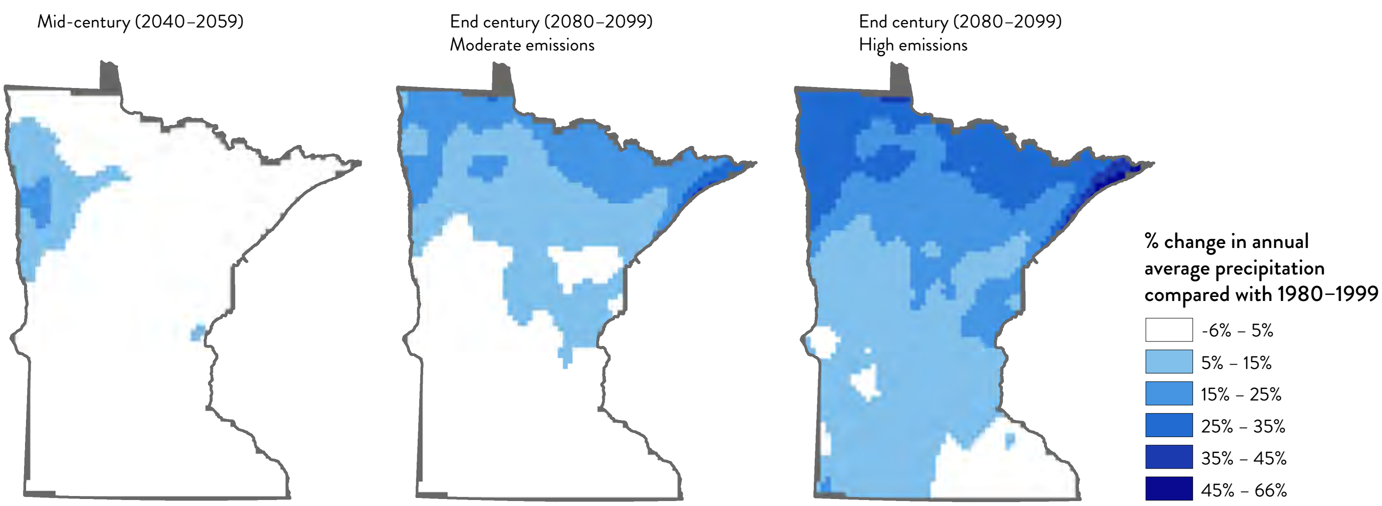
Located in the middle of a continent, halfway between the equator and the North Pole, Minnesota is highly sensitive to large-scale climatic changes, and since 1970 has warmed 40% faster than the global average. With continued global temperature increases expected, virtually all climate model scenarios at a wide variety of scales project that Minnesota will get much warmer in the decades ahead, including during the summer, with increased heat extremes by the middle of this century, if not sooner.

Precipitation is slightly more complicated because the extra moisture resulting from rising temperatures is distributed unevenly by global wind and weather patterns, leading to a range of slightly dry to very wet projections.

Climate model projections made specifically for Minnesota generally suggest we will see more precipitation by the end of this century, with continued increases in heavy rainfall and longer intervening dry spells. The projections favor wetter spring months, followed by drier late-summer conditions. Under a high greenhouse gas emissions scenario, the wettest day in a typical year at the end of this century is projected to be 20% wetter than during the 1990s. Individual years may have even larger increases in extreme precipitation. Even as the amount of precipitation increases, we expect the longest time between precipitation events to increase, indicating more precipitation is coming in fewer events.

With aggressive reductions in greenhouse gas emissions, we can avoid the more drastic climate changes represented by the high emissions projections in the following maps.

Modeling Minnesota's Future Climate: Annual Precipitation



Source: University of Minnesota

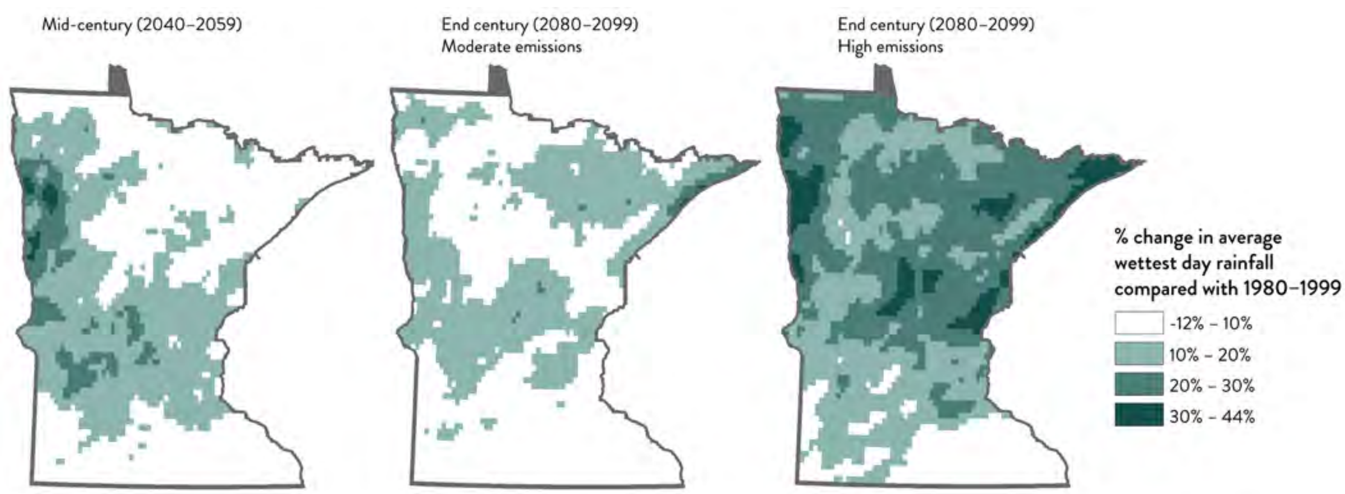
Background on Modeling: Looking at Minnesota in the Future

Climate scientists have produced numerous global and national climate model data sets, but until recently, none had been specific to Minnesota. University of Minnesota scientists, however, have used supercomputers and physical equations to "downscale." The modelers used the average of seven global models to produce localized climate projections for the state. This report uses the averages of those models to represent future climate scenarios in Minnesota.

The models cover changes relative to baseline climate data for 1980–1999 for two future periods—"mid-century" (2040–2059) and "end century" (2080–2099).

The mid-century model shows a single scenario. Two end-of-century projections represent moderate and high greenhouse gas emission scenarios. It is clear from these two that society can still avoid more drastic long-term changes in climate by reducing emissions in the near term.

Modeling Minnesota's Future Climate: Wettest Day Rainfall



Source: University of Minnesota

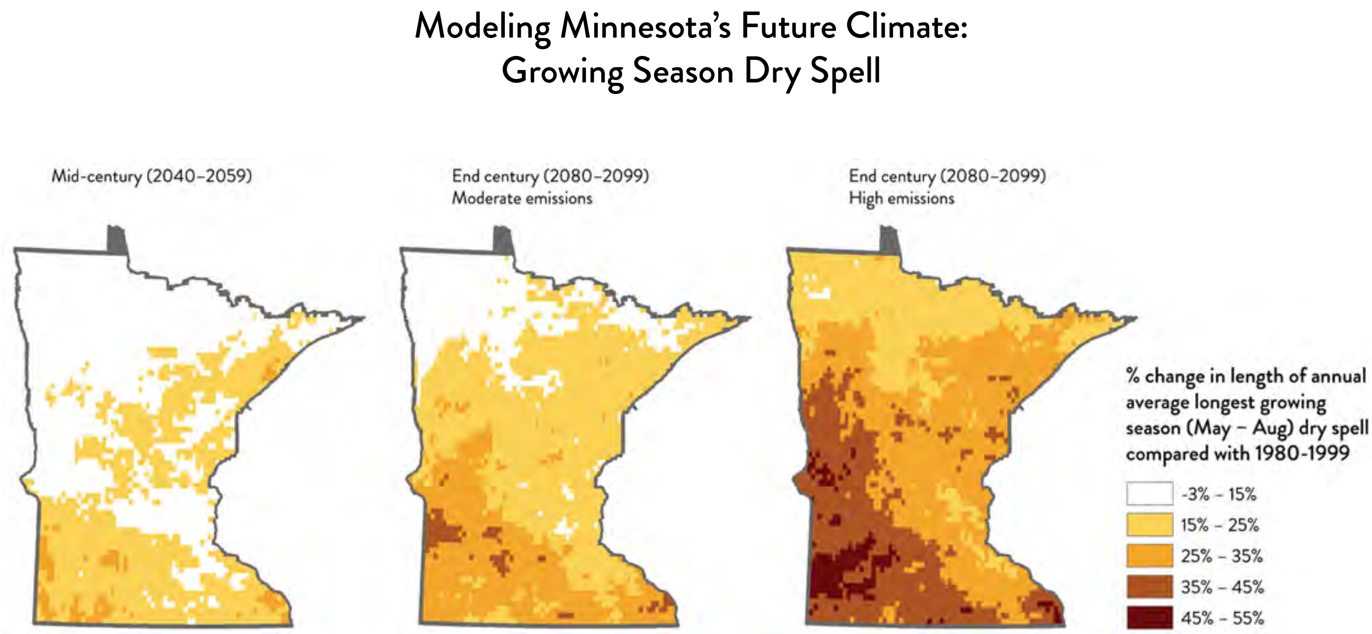
Data were produced by the University of Minnesota under the direction of Tracy Twine, Department of Soil, Water, and Climate, with analysis support from Ryan Noe, Humphrey School of Public Affairs. Funding was provided by the Environment and Natural Resources Trust Fund and Minnesota Invasive Terrestrial Plants and Pests Center.

"I've been living here 25 years, and I do feel like the climate has changed since I've been here. ... [T]he moisture patterns, the way we get snow, the way it comes our way, the temperatures—I feel like that's a very natural assumption to make."

–Duluth area interviewee

Don't count drought out

Minnesota has not seen increased drought severity, duration or geographic coverage over the past few decades. Although not equivalent to drought, climate projections suggest that the length of the longest dry spell in the growing season may increase. Minnesota should expect at least occasional episodes of severe drought, even with a wetter climate.



Source: University of Minnesota

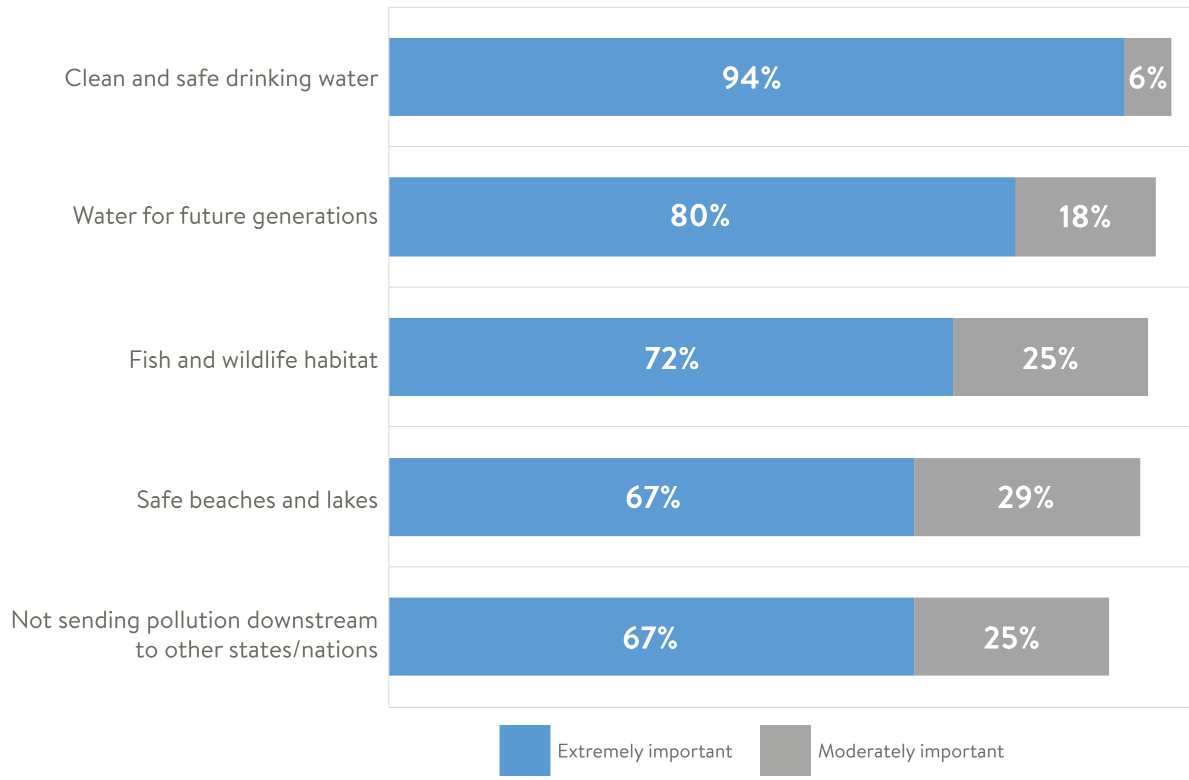
Protecting water together

Protecting and improving water quality in Minnesota in the face of climate change will yield important rewards: clean drinking water, resilient landscapes, fishable and swimmable surface waters, and more. However, it will be a complex, challenging, and long-term process that requires "all hands on deck," with EQB agencies, Tribal Nations, local governments, businesses, communities, NGOs/nonprofits and individuals working together.

Fortunately, Minnesotans care deeply about water and are concerned about the impacts of climate change. To successfully collaborate and produce equitable results, decision makers must engage a diversity of voices that reflect the priorities and values of communities across Minnesota. Investment in environmental literacy is essential to develop the understanding, skills and motivation to enact informed strategies for managing water and climate.

Source: DNR

What water values are most important to Minnesotans?



Source: Davenport et. al. 2019, University of Minnesota

Minnesotans value water

Understanding shared and diverse values can help decision makers align policies, practices and programs with the interests and values of area residents.

A 2018 University of Minnesota statewide survey of more than 1,400 residents affirmed that Minnesotans value clean water. Respondents most valued:

1. clean and safe drinking water
2. water for future generations
3. fish and wildlife habitat
4. safe swimming beaches and lakes
5. not sending pollution downstream to other states or nations.

More than 90% of Minnesotans surveyed believe drinking water is extremely important, with women tending to rate many values more highly than men. A smaller Twin Cities metro area study found that Black, Indigenous and people of color value equitable access to water and using water for gardening and cultural or religious practices in addition to drinking water.

More than 75% of Minnesotans surveyed believe water resources in the state need better protection. Minnesotans are worried about impacts of degraded or depleted water resources on human health, future generations and aquatic life.

Source: DNR

More than 80% of respondents support multiple actions to protect and restore water, including:

- conserving household water
- monitoring the health of Minnesota waters
- increasing water education and outreach
- enforcing existing land use laws and regulations.

Source: MPCA

Minnesotans believe the climate is changing

Minnesotans are concerned about climate change. According to a 2019 Yale University nationwide telephone poll, 66% of Minnesota residents believe the climate is changing. This is slightly lower than the national average of 70%. University of Minnesota survey research documented higher proportions of Minnesotans who believe climate change is occurring.

- More than 80% of residents on the North Shore of Lake Superior in Cook and Lake counties believed climate change is happening.
- When asked what concerns them most about climate-related impacts to the North Shore, effects on fish, wildlife and forest health were among the top concerns. Only 13% of North Shore residents said their communities are prepared for climate change.

“I am concerned. For instance, if we keep having years with these bad windstorms, or droughts, or floods, the more damage that’s happening to our natural environment here, the more impact it’s going to have on our tourism.”

–North Shore interviewee

Source: USFWS

- Of Central Minnesota farmers surveyed in a 2019 University of Minnesota study, 73% believe the climate is changing, and 42% believe their farm operations will be harmed by climate-related impacts in the future. These farmers' biggest concerns for the next 10 years are:
    - decreased groundwater access
    - more frequent dry periods and droughts
    - increased heat stress on crops.
- A survey of people in the Twin Cities metropolitan area found that more than 90% believe that the climate is changing. The vast majority (89%) are at least moderately concerned about climate change impacts, including:
    - drinking water contamination
    - degradation of lake and stream water quality
    - unequal access to public waters.

Building local capacity

Local governments will play a key role in building resilient communities. In 2020, EQB conducted an informal survey of local government staff and other water professionals to gauge their capacity, concern and readiness. Most respondents (83%) are moderately or extremely concerned about the effects of climate change on water issues in the communities they serve. However, fewer than half of respondents report that their organization has water plans or planning efforts underway that specifically address climate change.

Source: MPCA

Three statewide surveys of local government staff conducted by the University of Minnesota identified capacity-building needs for two climate-related challenges: managing stormwater and protecting groundwater. While 93% of survey respondents reported beliefs that climate change is occurring, only 15% believed their communities are prepared to address climate change impacts. In addition, 78% of staff viewed an increase in the frequency and intensity of storm events as a significant challenge. This group also identified flooding, aging or insufficient stormwater infrastructure, and road salting or deicing practices as significant problems. While the staff surveyed felt prepared to develop long-term plans to address water issues from a technical and educational perspective, they felt least effective at regulating existing land uses and restoring hydrology for stormwater management. These communities need resources and assistance to move forward with resilience planning, including increased capacity for community member engagement.

Engagement, equity and education

The goals and strategies that appear in this report can all be strengthened by increasing the level of public engagement and education and keeping equity top of mind.

Source: USFWS

CASE STUDY: We Are Water Minnesota

We Are Water MN is a traveling exhibit and community engagement initiative that explores the science, history, story, culture and relationships of water in Minnesota. It's a successful and proven model for building strong local and statewide networks to promote positive social norms and enable the development of a communitywide vision for water stewardship.

The 2018–2019 cohort, which included eight host sites, achieved the following:

- Over 34,000 people attended the exhibit, including 1,500 school children. A large percentage of 457 attendees surveyed spoke to the value of the exhibit:
    - 51% identified that they learned something new from the exhibit
    - 54% expressed they felt a greater responsibility to water resources as a result of visiting the exhibit
    - 48% felt motivated to take personal action regarding the personal use of water.
- Communities gathered together. Over 9,000 individuals attended 28 community events. These events strengthen informal social bonds, facilitated knowledge exchange and provided a shared sense of community and responsibility.
- There were 240 partnerships across eight sites to plan and promote the exhibit. We know these networks are new and different than before the project—30% were described as new relationships and nearly 40% were described as relationships with an organization or community not normally represented in the host site's work.

We Are Water MN is supported by a unique collaboration among the Minnesota Humanities Center, MPCA, the Minnesota Historical Society, MDA, MDH and DNR.

Source: MPCA

Minnesota's existing targets for watershed restoration and protection require significant resources and strong strategies to achieve. Investments like the Legacy Amendment and the Clean Water Fund it established have allowed us to create a strong base of knowledge about water quality in Minnesota. Yet progress to restore and protect our water is slow and difficult because of complex challenges and uncertainties due to climate change, development and other factors.

One of the biggest challenges is the social dimension. Sustainable water management must go beyond a purely technical approach and consider human beliefs and behaviors, including social norms, emotional connections to people and places, and beliefs about one's ability to make change. Engagement can help ensure that:

- a diversity of perspectives informs all policies, programs and processes
- solutions are co-created with the public and aligned to local values and needs.

Public engagement is key to protecting and improving Minnesota's water resources. Currently, local water plans tend to focus on conservation rather than outreach and engagement, despite significant social barriers to success. In addition, staff capacity, funding and lack of expertise limit the ability of local government staff to include outreach and engagement in efforts to protect water.

Water professionals need to build capacity for engagement, outreach and education in agencies, local governments, universities and other organizations. They also need to provide locally relevant and community-driven education and outreach to elected officials to build support and buy-in for plans.

Minnesota's water protection planning and programs must include multiple ways of knowing water and represent a broad range of experiences. Experiences with water differ across race, gender, ethnicity, place of origin, socioeconomic status, religion, profession and hobbies. State agencies and others working on water quality goals will be most successful when people of many different backgrounds see themselves in the work and actively participate in planning.

"I think women of color and people of color in natural environments are a lot less rare than people think. Representation is definitely a huge part of the problem of whiteness in the outdoors. And, you know, it's self-perpetuating; people don't see folks that look like them represented and they don't think that the outdoors is a place for them. So that's a big part of the reason that I've been motivated to continue working in the outdoors and doing this work that I do, because as a marketer I can help shape that narrative and that representation—or lack thereof, rather."

— Alora Jones
We Are Water MN program, 2018

Working with people is key to solving water challenges. It includes not only understanding environmental issues and natural systems, but also developing skills to address environmental problems as well as active participation in civic life for the benefit of the environment and others.

We develop our relationship with water through home and family life, school, and a variety of lifelong opportunities. Minnesotans need regular access to information, conversations, experiences and skill-building to support this growth. Expanding opportunities to learn about water is important in achieving the level of participation needed to address the challenges we face.

Education can include:

- experiential learning opportunities in nature
- building relationships that increase resiliency and shared understanding
- boosting a sense of efficacy and mental health through volunteer opportunities
- encouraging participation in creating goals, policies and plans.


Source: DNR

Potential Pathways in Education

The Minnesota GreenStep Schools pilot program supports K–12 climate and water education. Free and voluntary, the program offers a beginner-friendly framework building on the successful model of Minnesota GreenStep Cities and the nationally recognized Green Ribbon Schools program. Minnesota GreenStep Schools connects public and private experts with schools and districts to share best practices for reducing environmental impacts and costs, improving health and well-being of students and staff, and providing effective environmental and sustainability education. www.mngreenstepschools.org

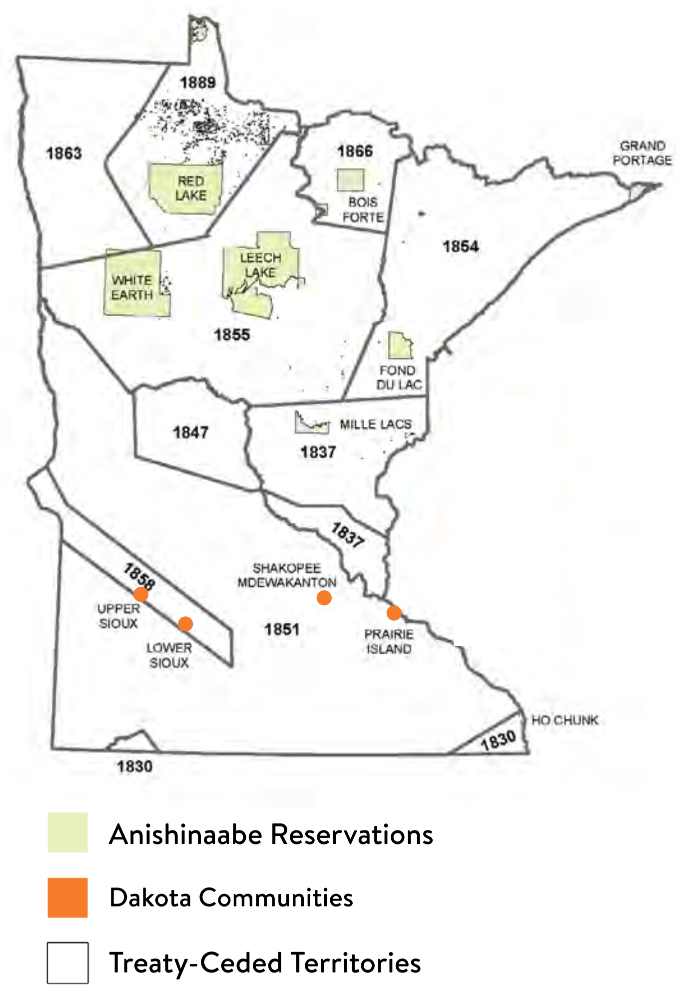
Tribal Nations, Water and Climate Change

Tribal Nations depend on clean water for healthy communities, economic security and cultural survival. Water is central to Ojibwe and Dakota cultures and has been since long before the state was established.

Climate change threatens the waters and ecosystems tribes depend on. Species with aquatic habitats such as wild rice, black ash and walleye are important for health, sustainability and cultural well-being. These species are also highly sensitive to climate change. Tribes are actively studying the challenges climate change brings to the lands and waters of Minnesota. Learning from tribes and collaborating on solutions is essential for protecting Minnesota's waters from climate change.

Source: Tina Shaw/USFWS

Minnesota Indian Tribal Land



Source: MnDOT

Tribes in Minnesota

Minnesota is home to 12 federally recognized Tribal Nations:

- seven Anishinaabe (Chippewa, Ojibwe) reservations
- four Dakota (Sioux) communities
- the Minnesota Chippewa Tribe, composed of the Bois Forte, Fond du Lac, Grand Portage, Leech Lake, Mille Lacs and White Earth reservations.

Each is a separate sovereign nation with its own government and is distinct from all other federally recognized tribes.

Reservations and communities are segments of land that were retained or reserved by American Indian tribes after ceding large portions of their original homelands to the United States through treaty agreements. Boundaries of these lands have changed over time and across the United States, with some still under dispute today.

While treaties with the United States set aside reservations as tribes' permanent homes, in Minnesota, the Ojibwe reserved the right to hunt, fish and harvest natural resources from ceded lands and waters. The ability to exercise those treaty rights depends on clean water and healthy ecosystems.

Treaty rights, environmental health and tribal culture are all interconnected. Tribal members remain connected to ancestral generations through subsistence living, maintaining cultural practices, and exercising treaty rights to hunt, fish and harvest natural resources. Tribal Nations manage lands, resources and economies; protect people; and build a more secure future for generations to come.[1]

[1] *Portions of text courtesy of Fond du Lac Resource Management Division*

Water: More than a resource

A 2016 report on climate change developed through a collaboration among the Bois Forte, Fond du Lac and Grand Portage Bands and the 1854 Treaty Authority opens:

> *To the Ojibwe, natural resources are cultural resources. There is no separation between how the bands manage and interact with a resource and how their culture endures: one is dependent on the other. Climate change, however, is threatening the very viability of many natural resources important to the Ojibwe.*[2]

The fundamental relationship between ecosystems and cultural survival is central to how Minnesota tribes approach science and management of water resources. *Why Treaties Matter*[3] points out that for Ojibwe and Dakota people, environmental values center on an ethic of responsibility, rights and relationships. They view themselves as *participants* in the natural world, continually in relationship with everything that surrounds them. The natural world has intrinsic rights that humans have responsibility to uphold. Beings in the natural world are connected to humans through familial relations. Ojibwe language reflects this: *nibi*, the word for water, means *life-giving force*. This worldview contrasts with economic and political systems that value private property and often view land and water as commodities to buy, sell and use.

Disproportionate impacts

Impacts to water from climate change will disproportionately affect Minnesota tribes. Increased risk of flooding and extreme weather could place additional burdens on reservations already struggling with infrastructure challenges. For subsistence and cultural survival, tribes also depend on native species with aquatic habitats that are vulnerable to the effects of rising temperatures and increased precipitation. Loss of these species could harm health and well-being.

The Prairie Island Indian Community is an example of a Tribal Nation that is vulnerable to increased precipitation from climate change. The community is located on the shores of the Mississippi and Vermillion Rivers between Hastings and Red Wing. The tribe has long dealt with flooding that causes everything from washed out roads to evacuations, and it has invested in flood mitigation infrastructure. Climate change could make flooding more frequent and severe, putting additional strain on community resources.

Aquatic habitat species that tribes depend on for subsistence and cultural survival are also at risk from climate change, which disproportionately impacts tribal health and well-being. As the 1854 Treaty Authority points out in its climate change vulnerability and adaptation plan,[4] the boundaries of reservations, communities and ceded territories are geographically defined. Tribes cannot follow shifts in natural resources that may come with climate change, and might lose access to culturally, economically and nutritionally important species. Many health issues American Indians face today can be traced to historic displacement from traditional foods and healthy cultural practices. Climate change could cause yet more displacement from these foods and practices.

---

[2] Stults, M., Petersen, S., Bell, J., Baule, W., Nasser, E., Gibbons, E., & Fougerat., M. (2016). *Climate Change Vulnerability Assessment and Adaptation Plan 1854 Ceded Territory Including the Bois Forte, Fond du Lac, and Grand Portage Reservations.* 146.

[3] *Why Treaties Matter.* http://treatiesmatter.org/exhibit/ accessed July 15, 2020.

[4] Stults, M., Petersen, S., Bell, J., Baule, W., Nasser, E., Gibbons, E., & Fougerat., M. (2016). *Climate Change Vulnerability Assessment and Adaptation Plan 1854 Ceded Territory Including the Bois Forte, Fond du Lac, and Grand Portage Reservations.*

WILD RICE

Wild rice (*manoomin*-Ojibwe, *psiŋ*-Dakota) has been central to the lives and identity of Dakota and Ojibwe for centuries. Today, it is used in religious practices and ceremonies, and hand harvesting is an important ritual that builds community and helps tribes remain culturally resilient. Wild rice is also critical for the health and subsistence of tribes. Harvesting and consuming wild rice promotes health and enhances tribal food sovereignty.[5]

Minnesota has the largest concentration of wild rice remaining in the United States. Still, wild rice occupies only a fraction of its historic range. Dakota and Ojibwe people are actively working to restore and preserve this resource on tribal waters and in ceded territories. Meanwhile, wild rice faces multiple threats, including altered hydrology, water quality issues and invasive species. Climate change is making these threats worse. Impacts to wild rice could bring cascading effects because rice wetlands provide habitat and food for waterfowl, fish and other wildlife.

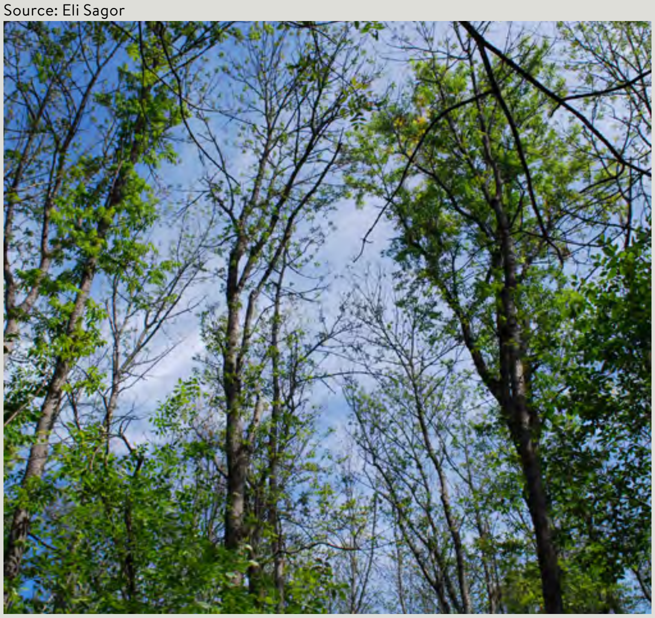
Source: MPCA

Food sovereignty

Food sovereignty is the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define *their own* food *and agriculture systems.*

– Declaration of Nyéléni, the first global forum on food sovereignty, Mali, 2007

Source: Eli Sagor



BLACK ASH

Black ash (*baapaagimaak*) is a tree that thrives in swamps, floodplains, ravines and small, poorly drained areas with high water tables. For the Ojibwe, black ash is important for crafting traditional baskets and snowshoes.

Increasing temperatures and disruptions to hydrology are altering the ecological conditions that black ash depends on to survive. In addition, emerald ash borer (EAB), an invasive insect, threatens black ash. Climate change is impairing efforts to slow EAB's spread. Minnesota has 1 million acres of black ash–dominated forests, and EAB threatens all of them. Black ash trees act like water pumps—without them, water accumulates on the land. Losing black ash means overlapping impacts to tribal culture, wetland ecosystems and water storage on the land.

[5] Minnesota Tribal Wild Rice Task Force. (2018) 2018 *Tribal Wild Rice Task Force Report.*

Fond du Lac Band of Lake Superior Chippewa. (2018). *Expanding the Narrative of Tribal Health: The Effects of Wild Rice Water Quality Rule Changes on Tribal Health. Health Impact Assessment.*

WALLEYE

Walleye (*ogaa*), native to most of Minnesota, is an important source of food for American Indians. Fishing for walleye is also an important cultural activity. Climate change, management practices and invasive species have contributed to recent population declines in the Mille Lacs Lake area, part of the 1837 ceded territory.

Warming water temperatures have led to an expansion of walleye habitat in Lake Superior. However, temperature increases will likely create competition from warmer water fish species in southern and shallow lakes and reduce populations of prey species such as cisco. Later freeze-ups and ice-out dates on lakes could also affect walleye spawning. The complex interactions among these factors make it difficult to assess the vulnerability of walleye to climate change.

Source: Joe Ferguson

Mercury and climate change

Mercury can accumulate in fish to levels toxic to the fish and to those who eat them. Fish provide an important food source for Minnesota tribes and other subsistence anglers, but many fish species have consumption advisories due to contamination from mercury. Mercury is a neurotoxin to humans and can cause a range of health effects.

Almost all the mercury in Minnesota's lakes and rivers comes from outside the state and is delivered by the atmosphere. Mercury moves from air to land and water by attaching to vegetation or washing out with rain and snow. Bacteria transform some into methylmercury, a substance that can accumulate in animals.
Despite a decline in mercury emissions over the past three decades, average mercury levels in northern pike and walleye have increased. Scientists believe this is because there are existing stores of mercury in water bodies, and increasing temperature and precipitation is causing more uptake of methylmercury in animals.

Tribes are decision makers

Under the federal Clean Water Act (CWA), tribes are eligible to implement programs that protect water quality and prevent pollution. The Fond du Lac and Grand Portage Bands have established an environmental regulatory program under the CWA. This means they set water quality standards for tribal waters, which the U.S. Environmental Protection Agency (EPA) approves. These tribes periodically review their standards and propose changes based on science and public input.

Tribes also have management authorities on tribal waters and in ceded territories, and they view their treaty rights as a responsibility to manage resources to ensure their future use. Tribal environmental departments carry out monitoring, water treatment, infrastructure development, pollution prevention, habitat restoration, invasive species control and other activities. Tribes regularly work together to set priorities, share best practices and influence policy. Tribes also collaborate with other jurisdictions such as cities, counties and the state to manage water resources.

The United States and the State of Minnesota have a unique legal relationship with federally recognized tribes, which is set forth in the Constitution of the United States, treaties, statutes, Executive Orders, administrative rules and regulations, and judicial decisions.

In Minnesota, Executive Order 19-24 directs state agencies to conduct government-to-government consultation with tribes and to look for mutually beneficial solutions. Similar federal executive orders affirming tribal sovereignty have been issued under multiple presidents including Clinton, G.W. Bush and Obama. Complex issues like protecting waters from climate change will require ongoing consultation with Tribal Nations in Minnesota.

Tribal knowledge and experience

Tribes hold extensive scientific expertise about managing waters and ecosystems that is critical for sustainable water management in the face of climate change. They also offer perspectives from Indigenous knowledge systems, which are perhaps an even more significant asset for addressing climate change. Indigenous ways of knowing that have been passed down through generations are sensitive to subtle changes and attuned to unique qualities of a place. Moreover, tribes have already survived and adapted to centuries of environmental, cultural and political change. They have much to offer as Minnesotans work to protect waters from the impacts of climate change.

The goals and strategies that appear in this report can all be strengthened with deliberate attention to the knowledge, priorities and needs of tribes in Minnesota. Specifically, advancing goals 1–5 in this plan should involve:

- government-to-government consultation with Tribal Nations:
  - Follow Executive Order 19-24, which directs state agencies to recognize the unique legal relationship between the State of Minnesota and Minnesota Tribal Nations and to “accord Tribal Governments the same respect accorded to other governments.”
  - Initiate government-to-government consultation at the beginning of policy or program development and not in the final stages when decisions have already been made.
  - Work with tribal liaisons to distinguish between consultation, collaboration and cooperation and engage with Tribal Nations at the appropriate level.

- integration of tribal knowledge and expertise into state strategies and actions:
  - Value Tribal Ecological Knowledge on equal footing with other forms of scientific knowledge.
  - Integrate tribal knowledge early in planning and policy development processes.
  - Seek to engage tribal knowledge in multiple ways and look beyond usual sources of information. Tribal knowledge may be represented in a variety of formats and venues, including consultation and coordination with Tribal natural resource departments and technical staff, oral histories, published papers and reports, white papers, blogs, works of art, historical documents, undergraduate and graduate research reports, and more.

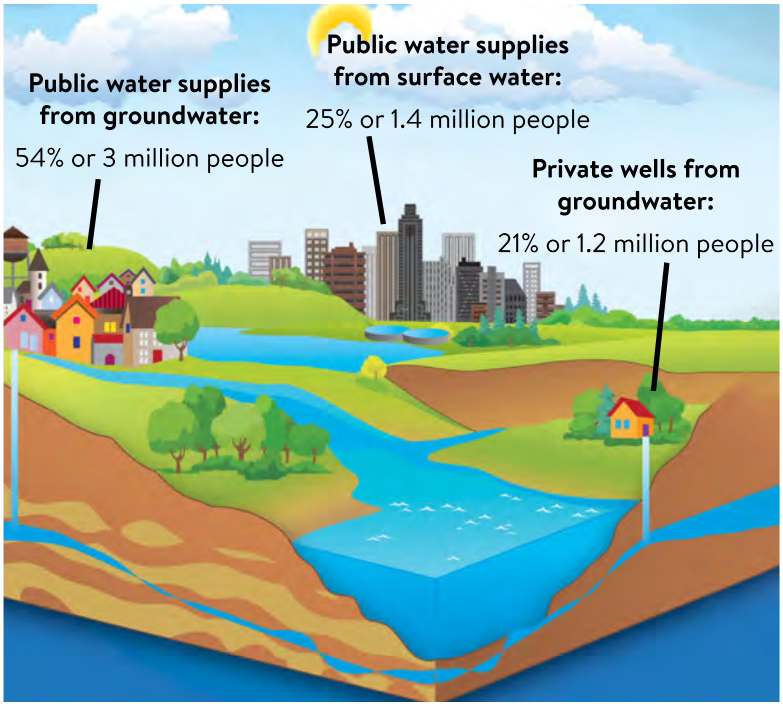
- collaboration with tribes to protect culturally important water habitats and species that are vulnerable to climate change:
  - Recognize that species and habitats have multiple benefits for Minnesota tribes, including economic, cultural, nutritional and ecological benefits.
  - Consider the presence of culturally important habitats and species within ceded territories, reservations, allotments and land that is federally supervised and set aside for the use of tribes, (usually found on trust land).
  - Consider opportunities to restore culturally important species and habitats in areas where they have been lost or degraded.

Source: DNR

GOAL 1:
Ensure drinking water is safe and sufficient

Minnesota's demand for water continues to grow along with our population and economy. By 2030, Minnesota's population of 5.6 million is expected to grow to more than 6 million. As Minnesota's population and economy grow, so does the need to protect drinking water. And as Minnesota's climate changes, bringing more intense and frequent precipitation, the challenge of protecting that water is becoming more complex than ever.

Climate is a primary driver of Minnesota's drinking water supply, influencing precipitation, evapotranspiration, runoff and groundwater recharge. Climate change is bringing more intense and frequent precipitation, which can lead to fluctuations in drinking water quality and quantity.



Source: MDH

Source Water in Minnesota

"Source water" refers to surface waters (streams, rivers, lakes) and groundwater that provide drinking water for public water systems and private wells. Some 79% of Minnesotans get their drinking water from a community public water supply, while 21% use private wells.

In many parts of Minnesota, drinking water is vulnerable to contamination from the land surface. Increased precipitation and runoff due to climate change can increase the amount of nutrients, pesticides and other contaminants in drinking water. Warmer and wetter conditions can increase growth of toxin-producing algal blooms in source waters. Flooding can wash pathogens from the land into public and private wells.

Nitrate contamination of drinking water can pose serious health concerns, especially for infants and pregnant women. Although nitrate occurs naturally, it can also come from human-made sources such as human waste, animal manure and commercial fertilizer. One of the main sources of nitrate is fertilizer used to grow annual row crops like corn. Nitrate not used by crops easily moves by water through the soil into groundwater in areas dominated by coarse soils or underlain by eroded limestone (karst), which forms underground drainage systems.

Increases in precipitation are likely to move more nitrate into drinking water sources. Increasing the acreage of perennial crops such as alfalfa can reduce nitrate leaching. However, these crops must be economically viable for farmers to grow.

STRATEGY 1: Accelerate source water protection for community water systems.

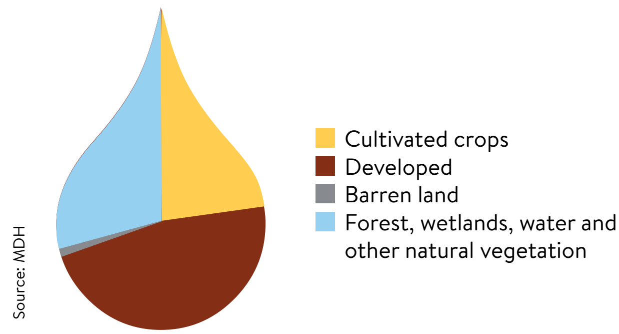
Action 1.1: Prioritize protection of the 400,000 acres of vulnerable land in DWSMAs.

Source: MDH

Out of approximately 1.2 million acres of land in Drinking Water Supply Management Areas (DWSMAs) in Minnesota, 36% (about 400,000 acres) is considered vulnerable to contamination. Public water systems have limited ability to influence management of private land within DWSMAs, especially land outside city boundaries, so public-private partnerships are important.

- Where feasible, protect vulnerable areas in DWSMAs with easements or grants for permanent changes in land use from row crops to prairie/woodland/wetland. Currently, roughly 9,000 DWSMA acres are permanently protected through easements.
- Where permanent protection is not immediately feasible or desirable, use tools such as cover crops, conservation crop rotations, perennial crops and advanced nitrogen management practices.
- Provide incentives where high-level protection requires land use changes that pose economic barriers for landowners.
- Use the statewide Source Water Protection Collaborative to provide local resource managers and community members a nexus for long-term collaboration, collective learning and strategic planning aimed at protecting source water.

Drinking Water Supply Management Areas (DWSMAs) are defined as areas surrounding public water supply wells from which a contaminant can travel to the well within 10 years.



Approximately 30% of land in DWSMAs has a protective land use such as forestry or wetlands.

Action 1.2: Assess and monitor the safety and resiliency of surface DWSMAs.

- Prioritize drinking water protection activities for the 23 community public water suppliers that rely on surface water for drinking water. Point source management is most critical closest to the intake, whereas nonpoint source management is important throughout the watershed. Land use, physical settings and potential contaminant sources vary, and interventions should be specific to local needs.
- Prioritize watershed management plan creation and implementation in watersheds upstream from surface water intakes. Thirty-eight watersheds include surface water intakes or are upstream from an intake. These watersheds should have plans in the works or in place by 2025.

Action 1.3: Protect, restore, and increase perennial cover in the highest priority areas of the Mississippi River watershed.

- Identify protection strategies for those lands most vulnerable to contamination within the Mississippi watershed drinking water supply area. Thousands of square miles upstream of St. Cloud and Minneapolis–St. Paul contribute to the seven-county Twin Cities metro area drinking water supplies. Many land uses in the watershed are associated with potential contaminants that can travel downstream and affect drinking water quality. Forests in the watershed are being converted to irrigated agriculture. The largest proportion of these conversions occurred in critical water supply source areas for St. Cloud and Twin Cities metro area communities.

STRATEGY 2: Emphasize source water protection in watershed management.

Source: MPCA Communications

Minnesota has 80 major watersheds located within the 10 major water basins of the state.

Over a decade ago, Minnesota began transitioning to managing water on a major watershed basis.

The state has a goal of completing comprehensive watershed management plans through the One Watershed One Plan (1W1P) program by 2025. These plans, as well as Twin Cities metro area watershed management plans (in place since the 1980s), address protection and restoration of surface and groundwater quality (including source water) as well as other issues such as flooding and habitat.

Local governments have begun to implement high-priority actions from their comprehensive watershed management plans. Implementing activities in vulnerable source water areas within watersheds can help protect drinking water.

Action 2.1: Emphasize source water protection in implementing watershed management plans.

Watershed management plans developed under the 1W1P program, as well as many of the Twin Cities metro area and other watershed management plans, already identify vulnerable acres within public and private well supply areas for improved management.

- Private wells: Prioritize watershed management plan implementation for townships in which private wells exceed the health risk limit of 10 milligrams per liter (mg/L) for nitrate. Statewide, approximately 9% of private wells tested by the MDA township testing program exceed this limit.
- Public water systems: Prioritize watershed management plan implementation for vulnerable areas within groundwater DWSMAs. Conservation practices within the 400,000 vulnerable acres can yield immediate benefits for drinking water quality and long-term gains for groundwater quality.

Action 2.2: Leverage the use of state dollars to protect drinking water.

- Use funding programs such as BWSR's Watershed Based Implementation Funding, Projects and Practices Drinking Water Grants and Wellhead Protection Partner Grants to protect vulnerable land near public and private drinking water wells.

Action 2.3: Increase routine testing of private well water.

MDH recommends that private well owners test their wells at least once for lead, arsenic and manganese; every year for coliform bacteria; and every other year for nitrate.

- Promote nitrate testing kits and educate well owners as part of implementation of watershed plans; this may increase private well testing.
- Provide free nitrate testing kits to households with infants.

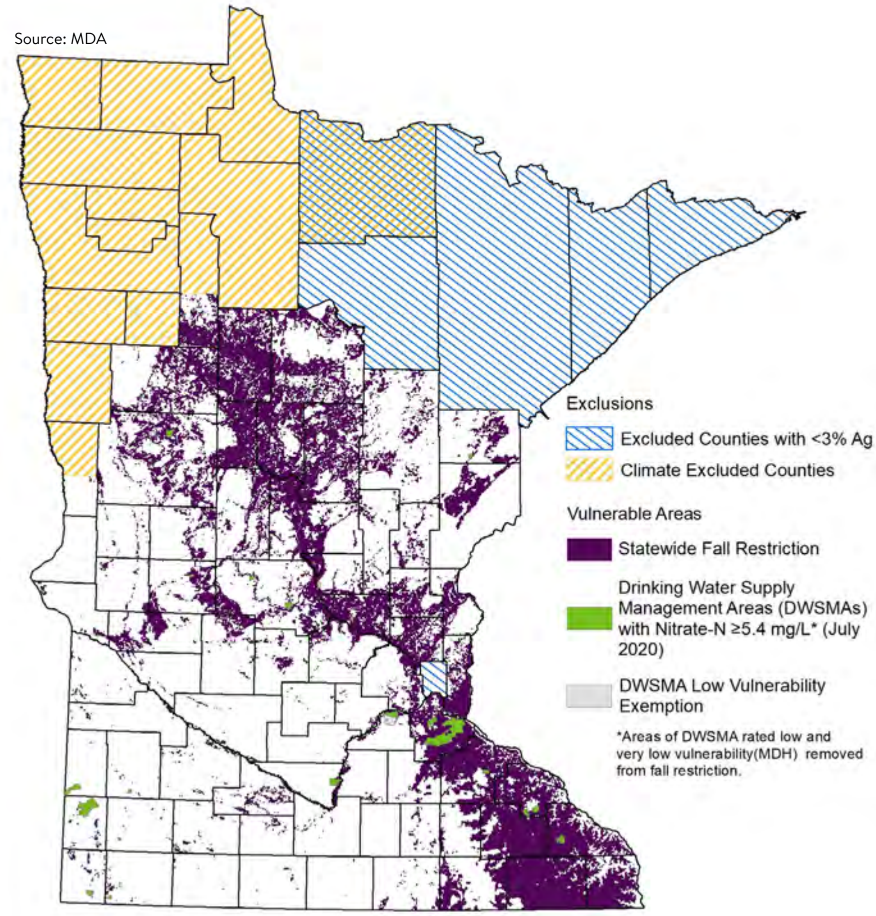
Source: MDH

STRATEGY 3: Prevent nitrate contamination of drinking water and groundwater.

The Nitrogen Fertilizer Management Plan (NFMP) is the state's blueprint for minimizing impacts of nitrogen fertilizer on groundwater. The NFMP process includes forming local advisory teams, using computer modeling to identify and target high-priority practices, monitoring groundwater for long-term trends, and implementing groundwater-protecting practices.

The Groundwater Protection Rule (GPR) restricts the application of nitrogen fertilizer in the fall and on frozen soils in areas vulnerable to contamination, increases the adoption of nitrogen fertilizer BMPs, involves farmers in adopting practices that reduce nitrate in groundwater, and reduces the severity of nitrate pollution in DWSMAs where nitrate in public water supply wells is equal to or greater than 5.4 mg/L.

While the GPR process is designed for use in DWSMAs of public water supplies, the NFMP applies this process to private wells in townships. In combination, the NFMP and GPR provide a comprehensive effort to address nitrate in groundwater through voluntary adoption of practices and regulation if necessary.



Nitrogen fertilizer restrictions in vulnerable groundwater areas (purple) and DWSMAs with elevated nitrate (green). Additional detail is available at www.mda.state.mn.us/nfr

Action 3.1: Fully implement Minnesota GPR in DWSMAs with nitrate concentrations above defined thresholds.

- Focus implementation funding on ensuring that no additional public water supply wells exceed the drinking water standard for nitrate. The rule includes regulatory and voluntary measures to work with farmers to adopt nitrogen fertilizer BMPs and other practices such as vegetative cover, to address nitrate in groundwater within DWSMAs.
- Use new modeling techniques being developed by University of Minnesota researchers and MDA to forecast water quality outcomes of potential implementation activities.

Action 3.2: Implement the NFMP in vulnerable areas as defined by township testing results.

NFMP implementation is voluntary and prioritizes private wells in townships where more than 10% of wells have nitrate concentrations over 10 mg/L. Perennial crops and cover crops are important components of the NFMP.

- Work with farmers to voluntarily adopt practices to reduce nitrate contamination of groundwater.

Action 3.3: Ensure compliance with the Minnesota Feedlot Rule.

Improper manure management can contaminate water and lead to harmful algae blooms. MPCA's Feedlot Program monitors animal feedlots and land application of manure to ensure compliance with the Minnesota Feedlot Rules (Chapter 7020) protecting groundwater and surface water. The Feedlot Program also issues permits that ensure that rules governing manure storage system construction and design standards are met.

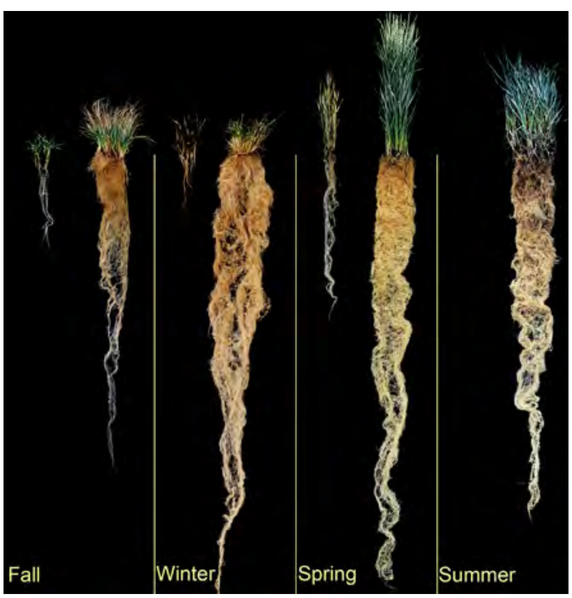
Federal National Pollutant Discharge Elimination System (NPDES) and State Disposal System (SDS) permits are issued to the larger feedlots in Minnesota for construction and operation. Proposed revisions to the 2021–2026 Feedlot General NPDES/SDS permit are intended to mitigate nitrate leaching from manure application and to prevent manure-contaminated runoff by requiring the use of additional BMPs and imposing seasonal restrictions on manure application.

- Strengthen and prioritize MPCA's regulatory oversight of these permits and rules in areas that receive high precipitation.

Source: MDA

The Minnesota Agricultural Water Quality Certification Program (MAWQCP) is designed to accelerate adoption of on-farm practices that protect Minnesota's waters.

Kernza ®



Source: Courtesy of the Land Institute (landinstitute.org)

Kernza® grain is the world's first commercially viable perennial grain crop. Kernza grain is harvested from intermediate wheatgrass, a forage crop that is being domesticated for grain production and human consumption by The Land Institute in Salina, Kansas, and the Forever Green Initiative at the University of Minnesota. As a crop with a deep, dense root system that provides year-round living cover, Intermediate Wheat Grass has been shown to reduce nitrate leaching to groundwater and reduce soil erosion and may increase carbon storage compared with annual crops. Research on these benefits is ongoing. Kernza has attracted increasing interest from growers, processers and food manufacturers. Early uses of Kernza include brewing, crackers, baked goods, cereals and other food products. Kernza can be managed as a dual-use crop for grain and forage to reduce risk and support grower profitability.

The first Kernza variety, MN-Clearwater™, was released by University of Minnesota in 2019, and seed supplies will allow about 1,000 acres to be planted in fall 2020. Regional seed and grain processing capacity is currently limited to several local seed companies, a promising Minnesota-based start-up business, and a processor in North Dakota. However, demand for cleaning, dehulling, milling and malting Kernza is increasing, and Kernza production, supply chains, and markets are poised to scale quickly in the coming years.

Source: MPCA

GOAL 2:

Manage landscapes to protect and improve water quality

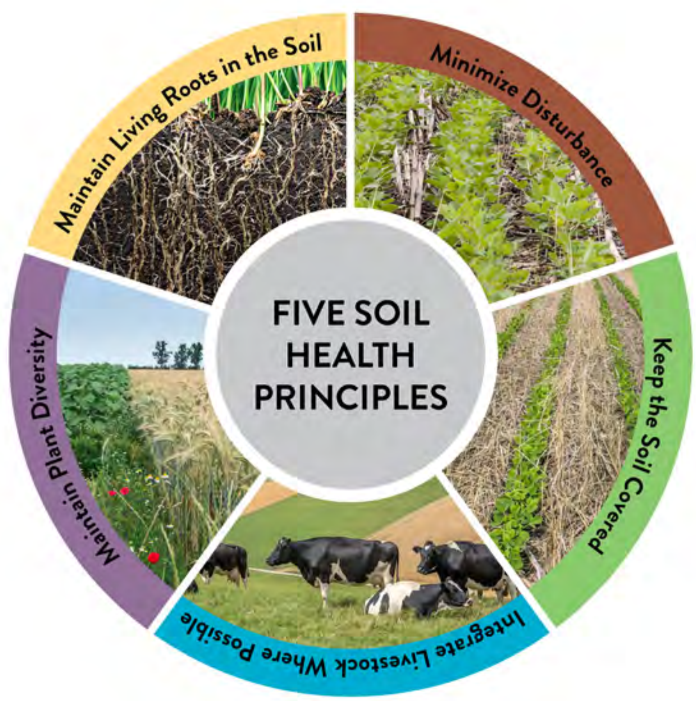
Source: Courtney Celley/USFWS

Increased intensity and duration of rain due to climate change can reduce surface and groundwater quality by increasing nutrient and sediment runoff. Water quantity is also expected to be impacted, with more erosion and flooding (see Goal 4). Healthy soil provides many benefits:

- It contains organic matter that retains water, reducing runoff and the need for structural water storage.
- It increases the availability of water to plants, which can increase yield and improve resilience to dry spells, reduce the need for supplemental irrigation, reduce the speed and volume of runoff, and reduce nutrient losses into surface water and groundwater.
- It can store large amounts of carbon, which means that soil health improvements have great potential to reduce greenhouse gas emissions across Minnesota's 20 million acres of cropland.

Agricultural BMPs that contribute to soil health include no till or reduced tillage, cover crops, crop rotations that include perennials, responsible manure application and installation of vegetative buffers along streambanks and lakeshores. Minnesota's Nutrient Reduction Strategy calls for one or more of these practices to be newly adopted on approximately one-third of cultivated lands to achieve interim goals for surface water quality.

While public investment may be needed to incentivize practices that boost soil health, such practices should eventually begin to pay for themselves because they are marketable, add value to the product or service provided, and can result in higher yields and/or lower inputs.



"I think agriculture has really evolved. In my father's and grandfather's time, you plowed the soil and planted your crop. I think due to technology and what we've learned, we can practice no-till, strip-till, vertical tillage, where we're leaving more residue on the soil. We don't need to leave it exposed. We can use cover crops so we have the ability to retain and keep that soil in place so that we don't have runoff. So we keep the nitrogen and nutrients in place to make sure that our surface water does stay clean."

–Randy Spronk, Edgerton

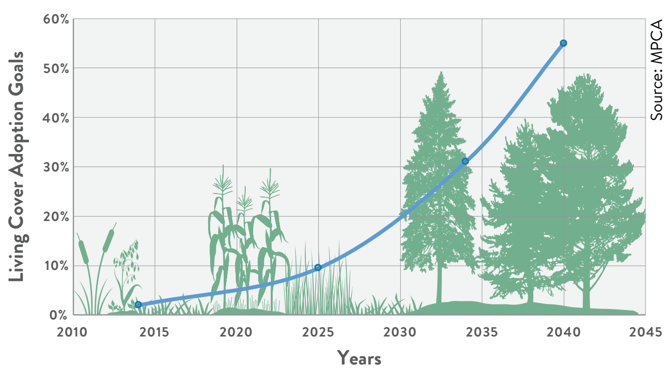
STRATEGY 1: Increase soil health.

Action 1.1: Work to meet state goals for expanding the acreage of cover crops and continuous living cover.

- Keep fields covered with vegetation for much of the year. Practices such as cover cropping and incorporation of perennial vegetation (known as continuous living cover) protect soil from water and wind erosion and reduce nutrient loss to surface and groundwater. However, cover crops are grown mainly for soil health purposes rather than as a primary commodity crop and can take time and resources to establish. USDA farm census data indicate that less than 2% of Minnesota producers use cover crops on their land. The Clean Water Council Strategic Plan identifies a goal of 5 million acres of row crop agriculture using cover crops or continuous living cover by 2034. Minnesota's Nutrient Reduction Strategy scenarios identify cover crop needs of 1.9 million new acres by 2025 and over 10 million acres by 2040. When combined, goals for escalating these "living cover" practices in Minnesota look like the curve below.

Living Cover Adoption Goals

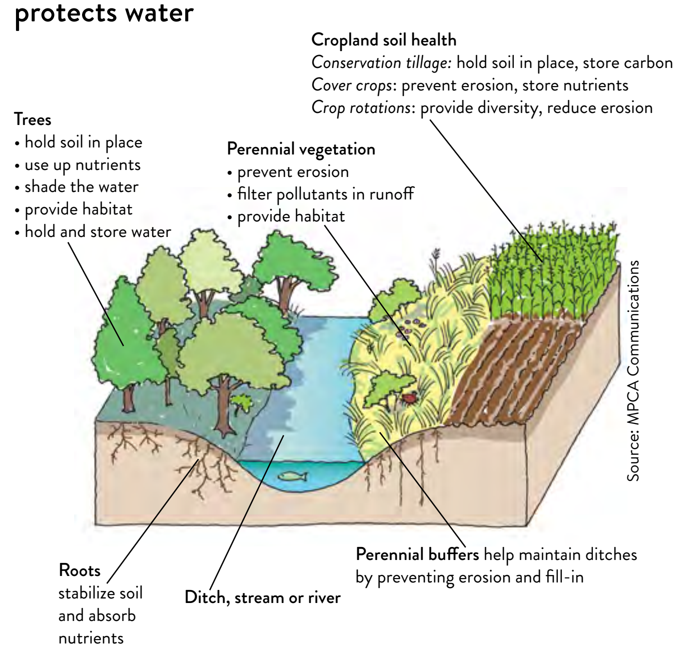
Nutrient Strategy and CWC Strategy



Less than 2% of Minnesota producers currently use cover crops on their land. The "living cover" adoption goals aims to increase the percentage of cropland by the year 2040.

- Accelerate existing grant and cost-share programs (see next page). Priority lands should include:
    - o drinking water source areas, as discussed under Goal 1
    - o sloping land and highly erodible soils
    - o subwatersheds or other areas identified as priorities in local watershed plans.

How continuous living cover protects water



Action 1.2: Improve monitoring and metrics for soil health based on statewide research and modeling.

- Work with the Minnesota Office for Soil Health (MOSH) at the University of Minnesota to monitor and evaluate soil health statewide.
- Work with MOSH to develop standard metrics for soil health under a range of climate and soil conditions, including both laboratory tests (e.g., organic matter, biological activity) and in-field measurements (e.g., soil properties, earthworms).
- Increase resources for on-farm and regionally specific research on and demonstrations of conservation tillage, cover crop systems, crop rotations, management intensive grazing and other conservation practices in order to generate more regionally specific data.
- Determine how much the improvement of soil health at a subwatershed scale can reduce the need for water retention structures to hold water on the landscape.

Programs That Support Soil Health

In addition to the many federal funding options available through the National Resource Conservation Service, Minnesota has established a number of pioneering programs supporting agricultural BMPs that advance soil health.

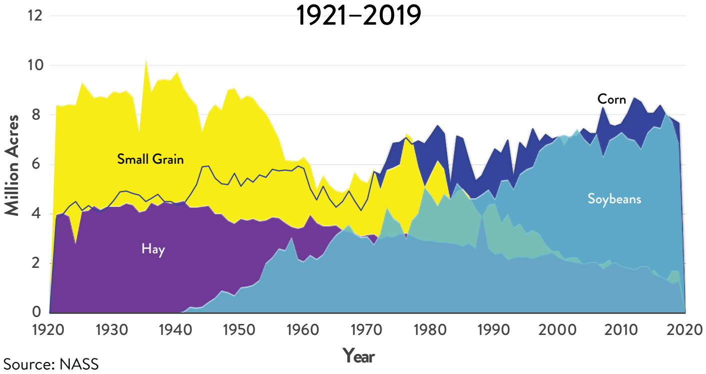
- The MAWQCP is a national demonstration project developed with the USDA in partnership with public and private collaborators, including Soil and Water Conservation Districts (SWCDs), BWSR, MDA, DNR, MPCA and private industry. Certification systematically identifies and mitigates risks to water quality on a field-by-field basis. Participants receive individualized technical and financial assistance to implement practices and improve soil health and may further obtain a soil health endorsement for exemplary management.
- BWSR's State Cost Share Program provides funds to SWCDs to share costs of conservation practices with producers for high-priority erosion, sedimentation or water quality problems. Structural or vegetative practices must be designed and maintained for a minimum effective life of 10 years.
- The Projects and Practices grant is a competitive grant supported by the Clean Water Fund that invests in projects and practices that will protect or restore surface water quality or protect groundwater or drinking water. Eligible activities include many agricultural BMPs that promote soil health.
- A Cover Crop Demonstration Grant program established in 2019 provides funds to five SWCDs to offer technical and financial assistance to new adopters of cover crops.
- The AgBMP Loan Program provides low-interest loans to farmers, rural landowners and agriculture supply businesses to encourage agricultural BMPs that prevent or reduce runoff from feedlots or farm fields and other pollution problems identified in local water plans.
- The Nutrient Management Initiative promotes cover cropping, manure crediting and other practices for corn and wheat producers. Participating farmers work with crop advisers to set up field trials.
- The Clean Water Research Program recently provided funds to MOSH to develop a guide for establishing cover crops in Minnesota based on local data. The program has also funded research on cover crop establishment and water quality benefits.
- Sustainable Agricultural Research and Education grants combine federal and state funds to help MDA, SWCDs and growers collaboratively assess the impact of cover crops on soil health.

Source: BWSR

Examples of crops used as a living cover to support soil health.

Action 1.3: Diversify crops and agricultural practices that support soil health.

Long-Term Trends for Corn, Hay, Soybeans and Small Grains 1921–2019



Source: NASS

- Since about 50% of agricultural land is rented, target both landowners and producers with outreach and assistance on conservation contracts (including MAWQCP comprehensive conservation management contracts) to reflect the value of soil health practices and increase adoption.
- Promote the reintroduction of small grains—wheat, oats, barley and rye, which were once staple crops in Minnesota. Such short-season crops make it much easier to establish cover crops than is the case for corn and soybeans, and they can provide other soil health benefits. However, markets and supply chains for small grains need further development and support to make these crops economically viable.
- As discussed under Goal 1, continue to build markets and supply chains for crops that provide continuous living cover, such as those developed through the University of Minnesota's Forever Green Initiative. Emerging perennial crops, notably Kernza, and winter annual cover crops (camelina and pennycress) provide soil health and water quality benefits and are beginning to gain footholds in the marketplace.

Action 1.4: Reduce social and financial barriers to implementation of soil health practices.

- Encourage and support programs such as the Minnesota Soil Health Coalition that offer farmer-to-farmer communication and mentorship to help farmers successfully transition to conservation-tillage and cover-crop systems, crop rotations, continuous living cover crops, and other soil health practices.
- Support the establishment and work of local soil health teams and networks. Numerous teams are providing demonstrations and field days at county, multi-county or watershed scales, but they need further financial and personnel support.
- Invest in regional equipment purchasing and sharing programs for agricultural cooperatives or SWCDs to reduce the burden of investing in cover crop and perennial/small grain planting and harvesting equipment.

Action 1.5: Establish soil health demonstration watersheds.

- Fund incentives, local promotion and water monitoring related to intensively adopting soil health practices in selected small subwatersheds to identify how barriers can be overcome and demonstrate multiple benefits.
- Use demonstration watersheds to promote soil health and living cover practices to other watersheds.
- Facilitate farmer-to-farmer sharing of learning experiences and ways to overcome technical, financial and social barriers.

CASE STUDY: Statewide Soil Health Database

The Mower and Stearns county soil and water conservation districts (SWCDs) are collaborating with the University of Minnesota on a statewide soil health project measuring soil properties under contrasting management systems. The project, which is funded by a Conservation Innovation Grant from the NRCS, will collect soil health indicator data from 26 working farms in Mower County, the Minnesota River Valley, Stearns County and the Red River Valley. At the end of the project, the partners will have a database of regional soil health measurements, a suite of case studies highlighting farmers who have adopted soil health practices, and a detailed economic analysis of soil health management systems on 10 farms.

Source: MDA

STRATEGY 2: Expand opportunities to participate in ecosystem services markets.

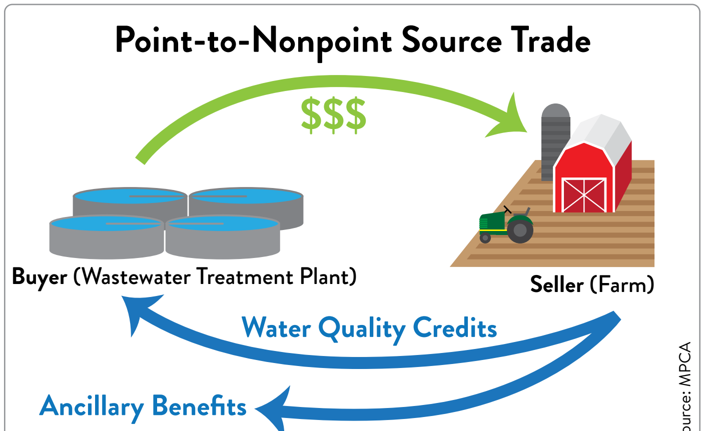
Offset markets, which offer compensation for providing ecosystem services, can help landowners finance sustainable practices. Offsets fall into two primary "buckets": carbon and water quality.

1) Carbon offsets, which fund projects that sequester carbon (e.g., reforestation, improved forest management, avoided conversion, improved land management) have been traded in voluntary markets for decades. Primary markets include the California Compliance Offset program and voluntary markets for activities such as reforestation and regenerative agricultural practices.
2) Water quality offsets typically take the form of water quality trading. An entity facing high costs to control a pollutant trades with another entity paying lower costs for pollution control. Part of the permittee's required reduction in pollutant load is offset by improvements made elsewhere in the watershed. The watershed still benefits from the reduction in the surface water pollutant—it just comes from a different source. For example, an upstream landowner implements agricultural BMPs that reduce pollution or nutrients to levels below legal requirements. Once those nutrient reductions are verified, they are translated into credits that may be sold in water quality trading markets. Downstream cities or industries can then purchase those credits to reduce the cost of compliance with their pollutant load reduction requirements.

Action 2.1: Develop accounting protocols and data foundations for ecosystem services trading.

- Evaluate agriculture and forestry-based BMPs to establish consistent protocols for an ecosystem services trading system that includes both carbon and water quality elements. Useful resources include MPCA's *Greenhouse Gas Reduction Potential of Agricultural Best Management Practices* and the *Minnesota Nutrient Reduction Strategy*.

Source: BWSR



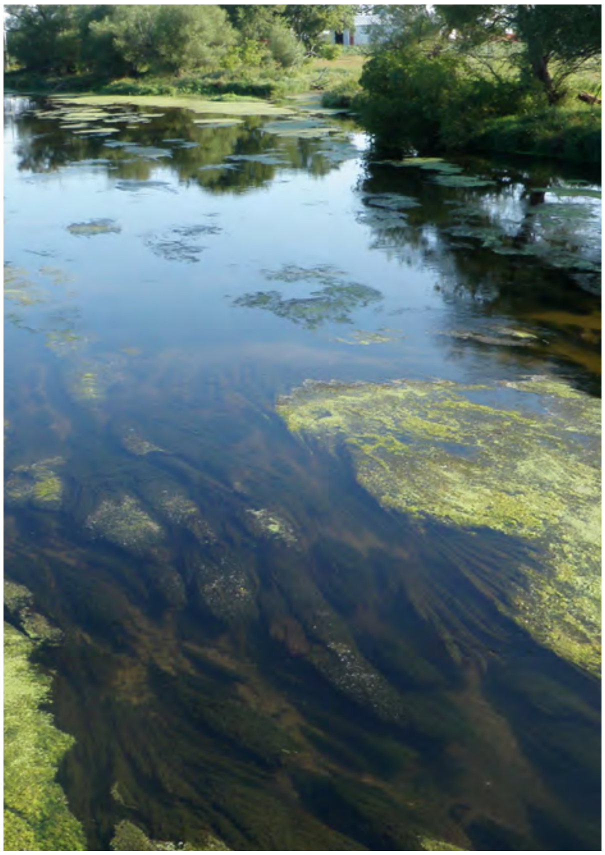
An example of water quality trading.

Action 2.2: Pursue emerging options for ecosystem service markets using water quality trading as a starting point.

- Participate in a pilot project launched by the Ecosystem Services Market Consortium (ESMC), a collaboration of members from across the agricultural supply chain and value chain working to build a viable, scalable and cost-effective ecosystem service marketplace. The ESMC views "soil health as the nexus through which they can most effectively address climate change, water quality degradation, and water scarcity." ESMC is currently engaged in research and development of pilot projects leading up to a projected 2022 full-scale market launch. A Minnesota pilot project is being launched in the Sauk River watershed.

- Expand the water quality trading program managed by the MPCA. The MPCA allows water quality trading on a case-by-case basis as a voluntary part of the permitting process for pollutant discharges. Trades have been conducted in several ways in Minnesota:
  - Point-to-point: trades between two or more point sources such as wastewater treatment plants. For example, in 2014 the City of Redwood Falls entered into a trading agreement with the City of New Ulm to offset part of the phosphorus discharge from its wastewater treatment facility to the Minnesota River, a trade that remains in effect.
  - Point-to-nonpoint: trades between a point source and one or more nonpoint sources. For example, Rahr Malting in Shakopee implemented five trades with four sites on the Minnesota River and its tributaries, mainly focused on streambank revegetation and bluff stabilization, to offset increased wastewater discharges. The Southern Minnesota Beet Sugar Cooperative in Renville County implemented trades with multiple sites that include cover crops planted on beet fields to offset increased discharges to a county ditch.

CASE STUDY: The Shell Rock River Watershed District



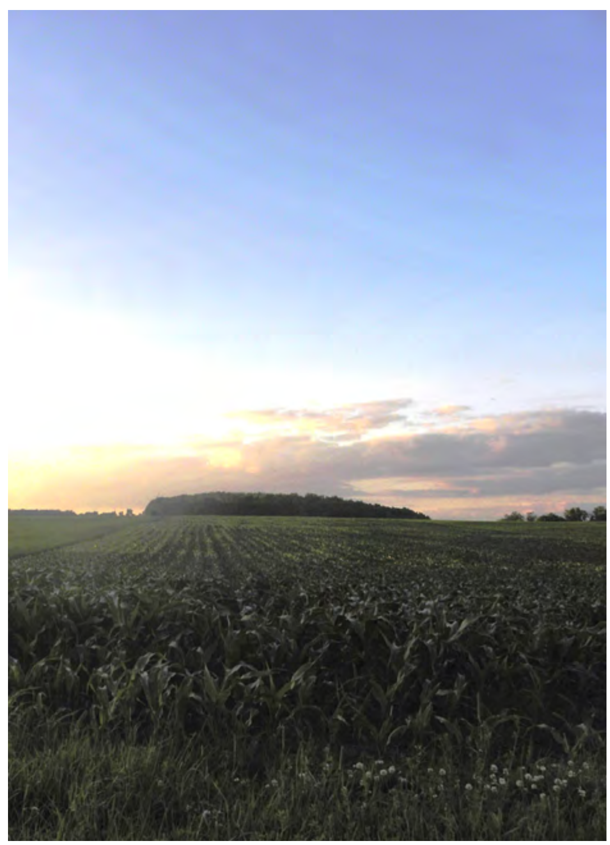
Source: MPCA

Shell Rock River

The Shell Rock River Watershed District, located in Freeborn County, forms the headwaters for the Cedar and Upper Iowa rivers. The watershed, located in and around Albert Lea, includes several impaired lakes and stream segments. Fountain Lake, a major recreational amenity in the city, is impaired by excess nutrients such as phosphorus from both urban and agricultural sources. While phosphorus reduction projects in a developed city are very expensive, there are ample opportunities to reduce phosphorus in the surrounding agricultural parts of the watershed. In 2018, the Legislative-Citizen Commission on Minnesota Resources (LCCMR) provided funding to develop a pilot credit trading system for stormwater. The program will establish an approach to sediment and nutrient credit trading for stormwater permits that could be used across Minnesota.

CASE STUDY: Wisconsin's Water Quality Trading and Adaptive Management Programs

Wisconsin's Water Quality Trading and Adaptive Management programs help Wisconsin Pollutant Discharge Elimination System permit holders meet water quality–based effluent limitations through water quality trading between point sources and nonpoint sources within the same watershed. It is implemented through an agreement between government agencies rather than a credit transaction. One large-scale example aims to reduce phosphorus in the Yahara River Watershed, which surrounds the capital city of Madison. All sources of phosphorus in the watershed collaborate to reduce phosphorus. Partners pool their resources and fund practices that reduce nutrient runoff. Yahara Pride Farms, a farmer-led, not-for-profit organization, acts as a technical service provider, engaging farmers to implement BMPs and track progress. The work began in 2012 and, following a four-year pilot effort, has transitioned to full-scale implementation over 20 years.



Source: Yahara Pride Farms

Source: MDA

Pictured is ForageScape Farm LLC (https://www.foragescape.com)

The Minnesota Agricultural Water Quality Certification Program

The MAWQCP is a noteworthy example of the two Goal 2 strategies in action.

With respect to the strategy aimed at increasing soil health, MAWQCP implements soil health practices across more than 600,000 certified acres under 10-year contracts. MAWQCP also offers a soil health endorsement developed with the Minnesota Soil Health Coalition, MOSH and others.

Since April 2019, MAWQCP has worked with MPCA to estimate greenhouse gas emission reductions from 21 practices related to changing land use, cropping practices and nutrient reduction. Between 50% and 60% of new water quality practices implemented by MAWQCP-certified growers are among the 21 climate practices identified by MPCA, including increased perennial cover and cover crops, nutrient management, and reduced tillage. The average emission reduction is 37 tons of greenhouse gas (CO_2-equivalent) emissions per practice per year.

Related to expanding opportunities to participate in environmental services markets, the MAWQCP, as a partner to the ESMC Minnesota pilot project, helps lay the groundwork needed for a functional market-based water quality trading system. First, MAWQCP's certification process establishes a baseline assessment of water quality risks associated with the management and practices for every crop grown on a farm. Second, it documents improvements above baseline of new clean water and climate-specific practices and management activities under a 10-year contract. Third, certification is a documented demonstration by growers of comprehensive management and practices achieving superior stewardship across their entire farm.

Source: MPCA

GOAL 3:

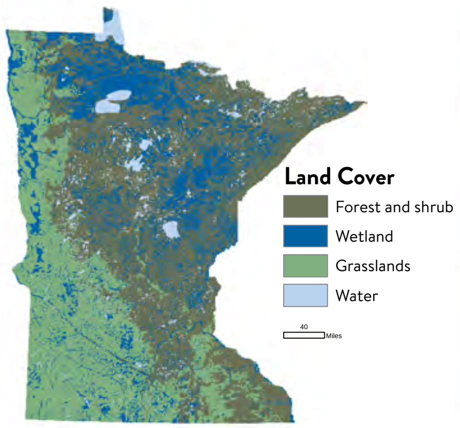
Manage built environments and infrastructure for greater resiliency

Source: MPCA

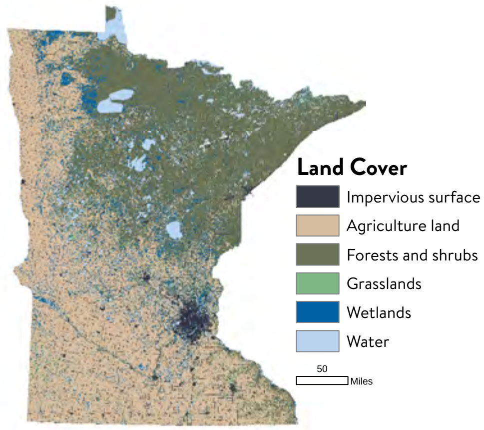
In the past, we built stormwater infrastructure while only considering its main job—moving water away from developed areas to prevent flooding—and not accounting for the associated harms. We now know that the way we have developed our built environment has disrupted the natural water cycle and led to flooding and water pollution. Aging wastewater collection systems are vulnerable to inflow and infiltration of clear water, potentially overwhelming infrastructure like lift stations and treatment plants and causing sewer backups. In addition, much of the drinking water infrastructure in Minnesota is old and outdated and may not address future needs for capacity or treatment.

Climate change threatens to make these problems worse, with higher annual precipitation and more frequent, heavier rainstorms as well as extended dry periods. Much stormwater, drinking water and wastewater infrastructure needs rehabilitation or replacement to handle more extreme conditions. While this is a clear financial challenge, it is also an opportunity to invest in infrastructure built for climate resiliency. Appropriately sized gray infrastructure built to work with green infrastructure can be designed to provide multiple benefits related to stormwater management, air quality, urban heat island mitigation, greenhouse gas reduction and overall quality of life. However, communities need better support in the form of funding and data in order to achieve these goals.

Pre-European settlement



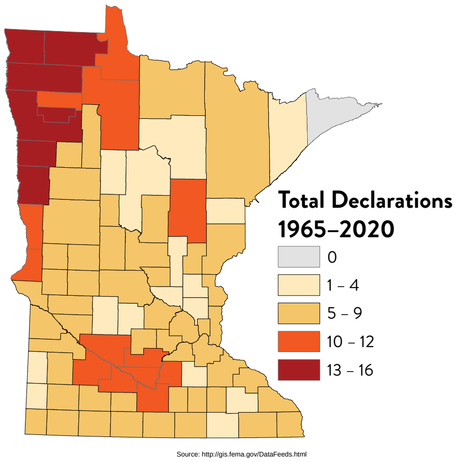
Today's land cover



Minnesota has experienced numerous floods

Number of flood disasters by county (1965–2020)

Source: HSEM/DPS



Minnesota's land cover has changed dramatically since European settlement. Loss of wetlands, increasing impervious surface, and the alteration of natural hydrology in both urban and rural settings create vulnerability to flooding.

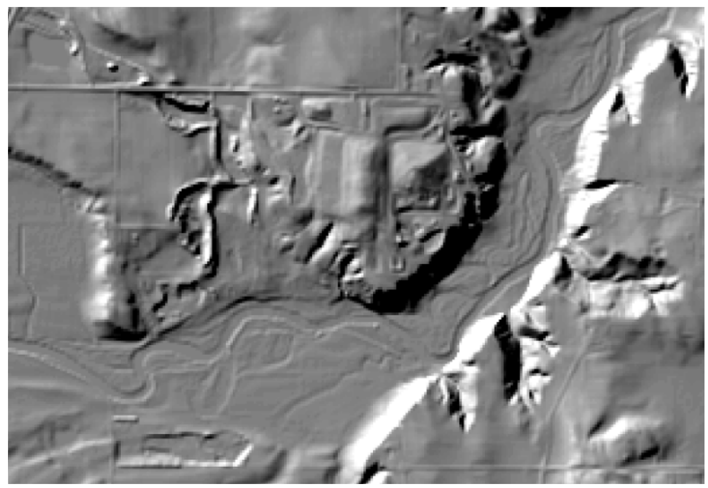
STRATEGY 1: Improve data sources and modeling.

Minnesota needs accurate climate data to assess vulnerabilities to the changing climate and guide planning for new and replacement infrastructure. Climate change means that models based on past data must be coupled with tools incorporating current conditions and future projections. Several agencies are using remote sensing to determine where to put infrastructure, what kind of pollutant load a water body may experience or which areas of a city have the greatest risk for flooding. Large-scale models and data sets exist for climate projections and for remote sensing but do not provide enough detail to understand local impacts. We have the technology we need to obtain finer-scale data; however, agencies, organizations and communities require funding and resources to use it.

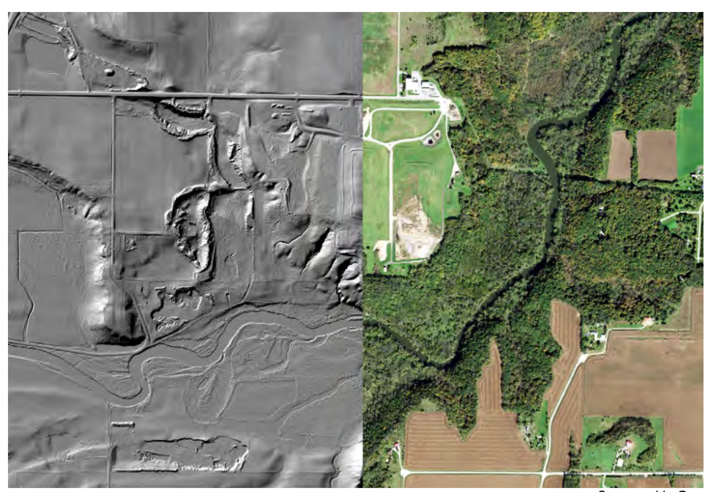
Action 1.1: Pursue and fund next-generation LiDAR.
LiDAR creates detailed models of an area by sending out laser pulses from a transmitter and receiving light particles that bounce back. We can use LiDAR to identify the size of depressions and estimate how much water they can hold. Minnesota's LiDAR data are at or approaching 10 years old.

- Initiate a five-year-plus effort to acquire higher resolution LiDAR data to reflect the reality of our landscapes, following the Minnesota Geospatial Advisory Council's plan for capturing LiDAR data across the state.
    - Submit a cost-share grant request to the federal government through the U.S. Geological Survey (USGS) each year.
    - Acquire data from all land in Minnesota.
- Engage partners at all levels of government, tribal nations, academia, nonprofit and private sectors to contribute to planning and funding.
- Consider the Minnesota Geospatial Information Office (MnGeo) as the likely aggregator and distributor for the data products generated.

30-meter DEM



10-meter DEM



1-meter DEM continuing into aerial photos

Source: MnGeo

LiDAR becomes increasingly useful to gather data as we increase the resolution. In the 30-meter digital elevation model (DEM), you can barely make out that it's a landscape, but as we move to 1-meter DEM, you can see the details in topography even more clearly than in the aerial photo.

CASE STUDY: New Models to Determine Flooding Risk

As part of its Climate Vulnerability Assessment, the Metropolitan Council used the Danish Road Institute's Blue Spot model along with the state's LiDAR data to identify low-lying areas in the Twin Cities metro area that could fill with water and cause localized flooding. The Blue Spot assessment evaluates risk to public transportation, wastewater treatment plants and other infrastructure. The Metropolitan Council staff could strengthen the Blue Spot assessment with updated LiDAR data, standardized stormwater information, and inclusion of current stormwater infrastructure and BMPs. Communities across the state could adopt this methodology to create their own models.

A similar predictive model was released by the First Street Foundation in 2020. Unlike typical flood models, which are based purely on statistical analysis of historical records of rainfall and stream gages, the foundation's flood risk model projects future climate scenarios and incorporates local adaptation projects such as levees and green infrastructure. The model shows localized flooding potential and projections of increased flood threats due to climate change over the next 30 years.

Metropolitan Council's outward-facing Localized Flood Map Screening Tool uses the Blue Spot assessment technique to provide communities with an opportunity to determine which of their assets and areas may experience localized flooding risks during short-term, extreme rain events.

COMMUNITY HIGHLIGHTS:
Improving Watershed Resilience by Leveraging Advances in Monitoring and Data Science

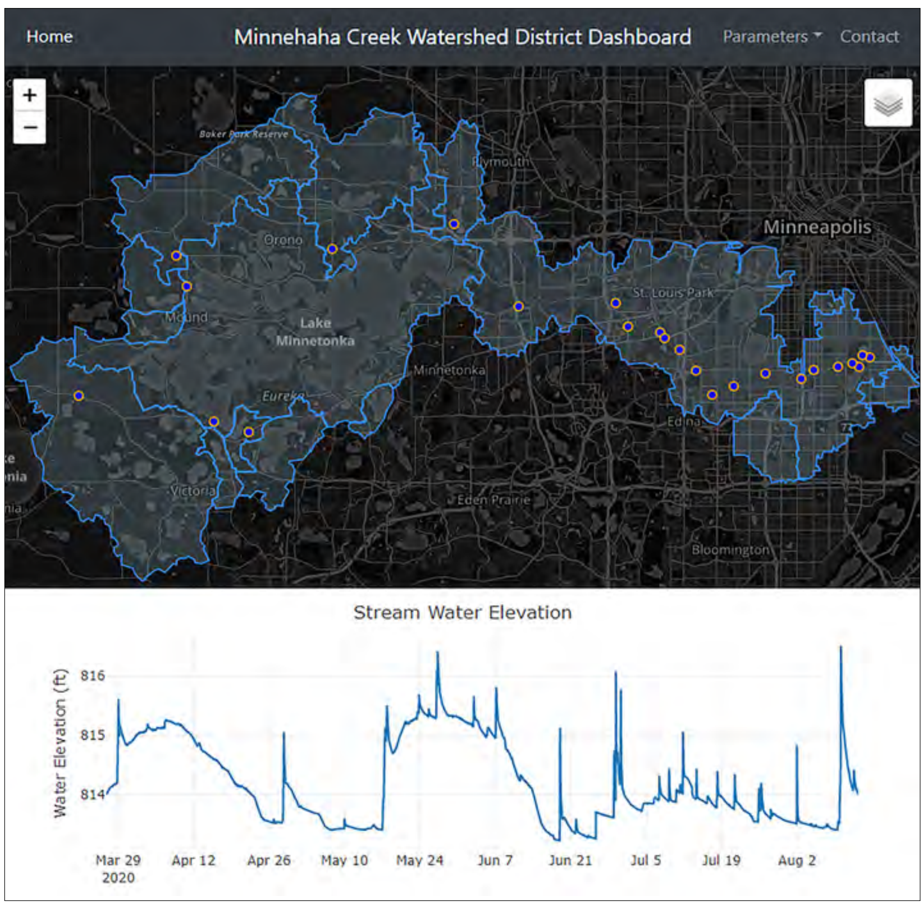
Changes in the frequency and intensity of rainfall due to climate change are increasingly stressing the capacity of hydrologic systems. The flooding and high-water issues that result have wide-reaching impacts on water quality, ecology, infrastructure, property and recreation.

Recognizing the need to maximize existing storage capacity in its systems, the Minnehaha Creek Watershed District (MCWD) formed a multi-agency partnership with the National Weather Service (NWS), USGS and Hennepin County to leverage advances in remote sensing, machine learning and modeling to better predict, observe, manage and communicate about water levels across the Minnehaha Creek watershed.

The NWS provides seven-day precipitation forecasts, in six-hour increments, tailored to the watershed. The NWS also provides data from its hydrologic model to predict how this precipitation will impact Lake Minnetonka's water level. Hennepin County provides data from seven weather stations across the watershed that track real-time precipitation, soil moisture and other weather conditions. USGS sensors at the outlet of Lake Minnetonka and along Minnehaha Creek provide real-time water level data. MCWD's own real-time sensor network of more than 20 water-level sensors supplements the USGS sensors to gauge how the watershed responds to rain events in real time.

This information allows MCWD to optimize how it operates the Gray's Bay dam, which controls flow from Lake Minnetonka into Minnehaha Creek, in order to maximize capacity in both water bodies and reduce flood risk. It also allows MCWD to proactively communicate flood risk to its communities and residents. In 2021, MCWD will begin developing a new machine-learning model and a two-dimensional model using the large and growing data sets on both predicted and measured rainfall and watershed response. The robust machine-learning model will further refine dam operations and improve flood forecasting and emergency response, and the two-dimensional model will improve project planning.

By leveraging the unique expertise and combined data sets of these agencies and deploying advances in monitoring and data science, this multi-agency partnership has increased the resiliency of the watershed in a changing climate. Since the partnership formed after historic floods in 2014, there has not been significant flooding in the watershed, despite experiencing the wettest six-year period on record. Like many data-driven solutions, the benefits of this system are likely to compound over time as the data sets grow and the tools improve.



CWD's Real-Time Sensor Network (RESNET) allows them to control flow from Lake Minnetonka into Minnehaha Creek through Gray's Bay Dam in response to changes in stream and lake water elevations.

Action 1.2: Obtain dynamically downscaled climate projections.

Agencies and local partners currently rely on historical weather trends to make decisions, which are less useful as climate changes. New and innovative modeling methods make it possible to downscale climate projections from global models to project local changes. Such projections are valuable for planning and implementing strategies for maintaining and protecting the natural environment, built infrastructure, economy and public health. Perhaps most importantly, they will help agencies and communities model hydrology and hydraulics, identify vulnerabilities in wastewater treatment plants and stormwater management systems, develop feedlot runoff storage pond standards, enhance soil and water BMPs, and understand how climate change may affect human health. Reliable, local climate projections will help communities plan and prioritize adaptation and resiliency practices.

- Produce high-resolution (areas equivalent to a quarter of a township) climate model projections for the entire state.
- Create a publicly accessible web-based portal for viewing and using the projection data.
- Provide educational resources and training materials for professionals on using the projections to plan and adapt.

Source: MnDOT

Action 1.3: Support modeling efforts and risk management that consider climate change impacts.

The Federal Emergency Management Administration's (FEMA) floodplain maps have been the standard for land use planners for over 50 years. Municipalities, townships and counties use them in land use planning and culvert and bridge design. Historically, developers of these maps have not considered land use changes or climate change when determining the 1%-annual-chance (100-year) floodplain. Recently, FEMA has required that all models used for mapping incorporate the 1%-plus storm event, which takes into account any potential errors when calculating the hydrology for a stream or river. This 1%-plus event can also be used to evaluate areas that are now more likely to flood due to land use or climate change.

- Communities can compare the 1%-annual-chance floodplain to the 1%-plus floodplain to find areas more vulnerable to climate change.
- Communities can compare the 1%-annual-chance-floodplain to the Flood Factor model for any specific location—by checking properties at risk on the Score Map, and by looking at projected flood risk at 1% flooding likelihood using the Flood Risk Explorer—to find areas now more likely to flood due to climate change.
- DNR can assist communities learning to use FEMA's other new products, such as depth grids or velocity grids, to identify potential erosion or additional hazard areas.

For many individuals and businesses, insurance functions as a risk management tool. Improved climate data provides a more accurate assessment of risk and better inputs for developing effective insurance products.

- Expand communication with residents and businesses about understanding their baseline insurance coverage for water and flood damage.
- Improve access to risk mitigation for flood and water damage by encouraging the development of new insurance products that rely on improved, data-driven flood risk mapping.

Accounting for climate risk in municipal bond markets

While financial incentives in the commercial and residential insurance industry integrate climate data, municipal bond markets have not absorbed these climate-data signals. Without accounting for climate data, there is little financial incentive to manage climate risk.

However, credit-rating agencies are beginning to take climate risk more seriously, with bond rating agencies considering the impacts of climate change in their credit quality evaluations. In addition, buyers of municipal bonds are beginning to ask about how municipalities and water utilities are considering climate and extreme weather risks in their planning and operations.

Expanded integration of climate data into financial risk assessment for public infrastructure will help drive informed decision-making and risk mitigation.

STRATEGY 2: Support communities with asset management and resiliency planning for wastewater, stormwater and drinking water infrastructure.

Much of the water-related infrastructure in Minnesota is old, inadequate for meeting future needs and increasingly vulnerable to climate change.

Source: MPCA

Drinking water and wastewater treatment plants and the infrastructure networks that convey treated and untreated water are complex, expensive and necessary systems. Much of this infrastructure across Minnesota needs repair or replacement in the next 20 years

Asset management is a method that public water and wastewater systems can use to assess their infrastructure, evaluate vulnerabilities, and plan for long-term maintenance and protection. An asset management inventory should include all water infrastructure and consider source water vulnerability and protection needs. As weather patterns change and storms intensify, asset management becomes increasingly important in planning and preparing for potential emergencies.

Small communities often lack the staff needed to thoroughly inventory their water system assets. MDH and the Minnesota Rural Water Association (MRWA) can help smaller public water systems inventory their assets and identify vulnerabilities. However, MRWA assistance is limited by funding constraints. Priority funding is needed to support asset management in small community drinking water systems.

Action 2.1: Fund a comprehensive asset management program across Minnesota.

- Provide funding so small public water systems can develop asset management plans and assess potential climate change impacts on infrastructure and source water. Funding can also be used to aid other utilities during disasters through the Minnesota Water/ Wastewater Utilities Agency Response Network (MnWARN).

Action 2.2: Provide training and technical assistance to smaller communities on tools to assess risk and vulnerability.

- Evaluate and adopt elements of CREAT, a tool developed by EPA to help wastewater, stormwater and drinking water utilities plan for and adapt to extreme weather, and to help small water and wastewater systems track inventory items, assess critical infrastructure, and evaluate vulnerabilities to climate change and extreme weather.
- Communities can use CREAT or similar tools to evaluate stress on their equipment, assess risk of equipment failure, and identify and compare costs of risks and mitigation measures. They can also incorporate climate projections from CREAT into aquifer models to understand climate change impacts on water availability.

Action 2.3: Adopt a stormwater data standard and fund digitization.

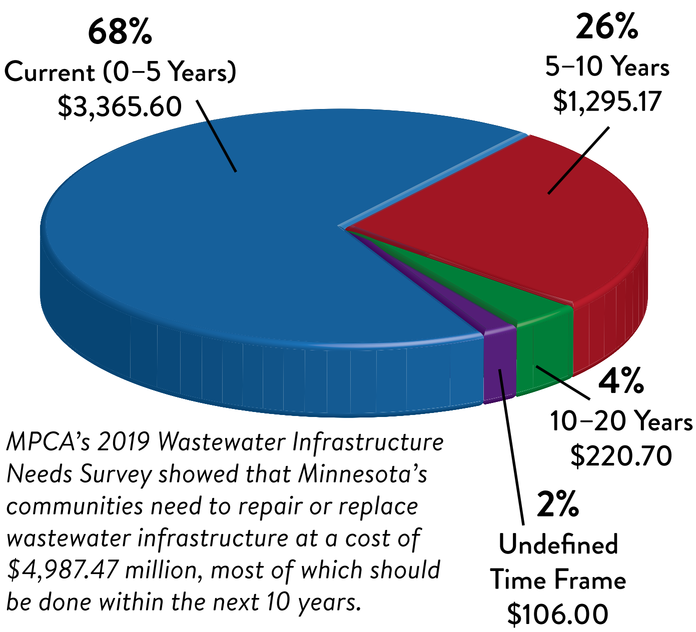
Cities, townships, counties and other municipal separate storm sewer system (MS4) permit holders must have their stormwater system mapped. However, data collection is not standardized across municipalities, so it is difficult to include infrastructure in wider watershed-based modeling and assessments. In 2019, MnGeo's Standards Committee approved a draft standard for exchange of stormwater system data that provides a clear method to digitize maps and data collection for ease of sharing, but is expensive and time-consuming and requires specialized skills.

- Provide grants to MS4 permit holders to digitize their maps. With standardized data across the state, planners will have more access to create vulnerability assessments, model pollutant loads, determine the best places for BMP installations and build more resilient communities.

STRATEGY 3: Develop new and updated resiliency financing mechanisms.

As precipitation increases and becomes more extreme and dry periods lengthen, communities need to modify how they manage water. Infrastructure is expensive, and communities lack funding to move forward with assessments and planning, especially for wastewater, stormwater and drinking water utilities. We need to develop consistent and stable funding for local governments and other entities responsible for infrastructure so they can develop climate vulnerability assessments and/or climate adaptation and resiliency plans to help with prioritization, budgeting and applications for funding resilient infrastructure.

Statewide wastewater infrastructure needs by time frame (millions)



MPCA's 2019 Wastewater Infrastructure Needs Survey showed that Minnesota's communities need to repair or replace wastewater infrastructure at a cost of $4,987.47 million, most of which should be done within the next 10 years.

Action 3.1: Develop and fund climate planning grants to communities for drinking water, wastewater and stormwater infrastructure.

- Develop an MPCA-administered grant program with a 50% match by the local unit of government to support local planning to help prepare for and recover from climate change risks. Initiatives could include vulnerability studies, asset management, training and data development, or implementing tools from EPA or nongovernmental organizations.
- Award grants on a competitive basis through an application process. Local governments that are participating in climate vulnerability assessments, or developing climate adaptation and resiliency plans, updating existing plans to address climate adaptation, or that have adopted a regional climate adaptation plan, would be eligible to apply.
- Provide additional funding to address identified needs.
- Update the Wastewater Infrastructure Needs Survey to include consideration of climate resiliency needs. This will help agencies determine future needs for programmatic funding and infrastructure bonding.

CASE STUDY:
South Washington Watershed District Climate Resiliency Plan

The South Washington Watershed District (SWWD) worked with a consultant to develop information strategies and implement climate adaptation practices that increased the District's climate resilience. The District completed a risk analysis of over 24,000 stormwater pipes and promoted groundwater protection, ravine stabilization and reduction in chloride loading. In addition to directing district resiliency activities, the plan broadens eligibility for projects funded with a 50% cost share through the Coordinated Capital Improvement Program. Resiliency projects identified in the plan are eligible for funding that was previously available only to municipal projects enhancing water quality benefits.

SWWD conducted workshops with city officials, state and local government staff, and members of the public to identify climate risks and vulnerabilities and develop strategies for mitigation.

Action 3.2: Authorize and fund Public Facilities Authority (PFA) programs to support resilient infrastructure projects.

Minnesota municipalities lack comprehensive funding to address water quantity. The PFA has programs to help finance wastewater, drinking water and stormwater infrastructure, but they do not fully address climate resiliency.

- Provide a new funding stream at PFA for stormwater work so cities can address sanitary sewer, storm sewer and drinking water improvements at the same time. A large share of PFA funding goes to help cities replace aging sanitary sewer and water mains. Cities often want to make storm sewer improvements when they replace or repair drinking water and wastewater utilities, but currently must fund that portion on their own.
- Include climate resiliency criteria in PFA funding considerations. PFA eligibilities and project priorities are based on public health and water quality but do not directly address water quantity or climate resiliency issues. It is important for climate change resiliency projects related to water quantity, like stormwater storage or infiltration, to be planned and implemented in a coordinated fashion with traditional gray infrastructure.

Action 3.3: Expand the Minnesota Property-Assessed Clean Energy (MinnPACE) program to include water conservation and hazard mitigation projects.

MinnPACE currently funds energy conservation and renewable energy projects by providing funding to commercial property owners while the local government adds a corresponding assessment to the tax rolls. Similar programs in some other states also finance upgrades that help conserve water and/or protect against storm damage.

- Provide statutory authorization of MinnPACE financing for water efficiency and storm protection projects on private property.

Climate Resiliency Grant Program

An appropriation would allow MPCA and PFA to administer a program to help communities boost climate resiliency. A pilot program would prioritize stormwater infrastructure, including creating stormwater storage, improving infiltration and increasing conveyance capacity.

Under a permanent program, eligible projects could also include energy-saving retrofits and construction, public infrastructure retrofits or replacements, and resilient energy projects. The pilot would seek to fund five to 10 pilot projects with bond appropriations and a 25–50% match from the grant recipients.

Source: Metropolitan Council

STRATEGY 4: Design transportation infrastructure in floodplains for long-term resiliency.

Minnesota has over 65,000 culverts that allow natural rivers and streams to flow under roadways, and many more at intermittent channels. Inadequately sized culverts harm both the natural watercourse and the road. As climate change alters precipitation frequency and severity, it is important to address long-term resiliency of both the watercourse and roadway when replacing infrastructure. The DNR encourages the geomorphic approach to culvert design to reduce impacts to roadways from extreme rainfall and enhance channel and floodplain connectivity. Despite increased up-front costs compared with traditional designs, the DNR expects long-term benefits to outweigh added costs.

Source: MnDOT

Action 4.1: Design culverts with future climate conditions in mind.

- Apply the geomorphic approach to culvert design where appropriate to reduce impacts to roadways from extreme rainfall and enhance channel and floodplain connectivity.
- Maintain natural flows and habitat connectivity. Traditional culvert design limits flow to a channel alone, but the geomorphic approach allows floods to spread across a natural floodplain, creating the potential for a more natural flow, to reduce erosion and property damage, increase resiliency and improve aquatic and terrestrial habitat connectivity while addressing public safety and compliance with local, state and federal floodplain requirements.
- Continue MnDOT efforts to train culvert designers and implement stream connectivity measures from the Minnesota Guide for Stream Connectivity and Aquatic Organism Passage Through Culverts.
- Provide funding to allow DNR, MnDOT and public road authorities to cooperatively implement pilot projects that test and demonstrate the effectiveness of this approach. DNR would be responsible for monitoring the success of these pilot projects and developing future project guidance and selection.
- Select appropriate pilot project sites based on multiple factors, including impacts to adjacent landowners, culvert owner liability and resource impacts.

Source: MnDOT

Action 4.2 Prioritize climate adaptation actions across Minnesota's road systems.

- Prioritize adaptation measures so investments minimize life-cycle and road-user costs. MnDOT has used the Federal Highway Administration's Climate Change and Extreme Weather Vulnerability Assessment Framework in northeastern and southeastern Minnesota to identify facilities at greatest risk of flash flooding damage. In 2019, it also began a study to develop methodology for characterizing the vulnerability of the entire state's bridges, large culverts and pipes to flooding.

More Green, Less Gray

Under natural conditions, precipitation filters through soil to the water table and returns to the air as plants release it through their tissues. Impervious surfaces alter this cycle in ways climate change exacerbates. We need to implement all of the tools that we have for resiliency, using green and gray infrastructure in tandem.

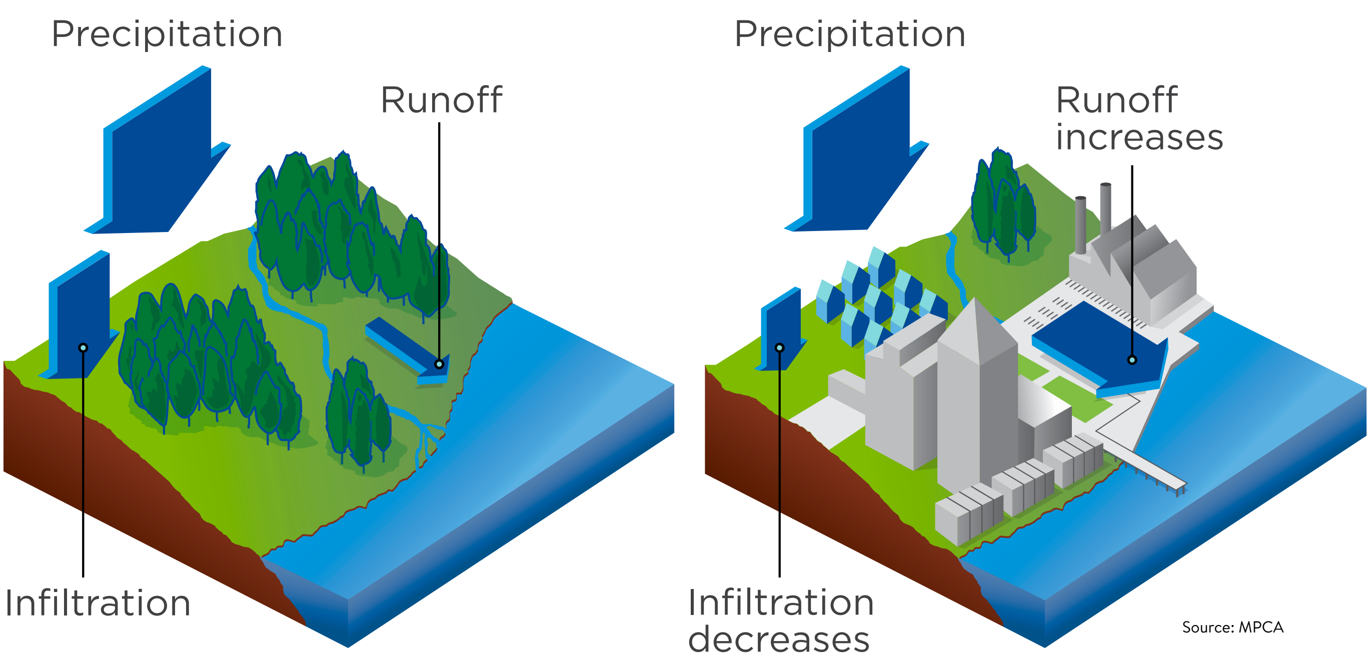
With more frequent intense rainfalls, green infrastructure is a key component in climate resiliency planning for infrastructure. However, we need to think beyond engineered BMPs. Creating and maintaining natural areas, especially in cities and in areas vulnerable to localized flooding, can lower risks of damage to property and human health.

Programs like Milwaukee Metropolitan Sewerage District's Greenseams have proven this method effective in preventing problems like sewage system backups or overflows. Greenseams buys undeveloped private properties containing open space along streams, shorelines and wetlands in areas with projected major growth over the next 20 years.

While BWSR has similar programs in predominantly agricultural areas, a program like this could be useful in suburban and exurban areas experiencing rapid growth.

Cost is always a concern for developments and for infrastructure. Green infrastructure generally complements a gray infrastructure system to improve water quality outcomes. While green infrastructure cost and implementation is site-specific, it is often more expensive up front than gray infrastructure. However, it comes with additional benefits lacking in gray infrastructure. Green infrastructure often includes a variety of vegetation, which can provide water quality improvements, water retention and storage, urban heat island effect and energy use reductions, and CO_2 sequestration, among other benefits. EPA and the Minnesota Stormwater Manual include case studies and information about costs and benefits of green infrastructure projects. Additionally, several tools exist for cost-benefit analysis and potential siting of green infrastructure, including but not limited to:

- Metropolitan Council's Surface With Purpose tool
- Green Roofs for Healthy Cities Green Roof Energy Calculator
- Natural Capital Project's Urban InVest calculator
- Center for Neighborhood Technology's National Green Values™ Calculator.



Increasing impervious surfaces causes more water to run off into water bodies when it cannot infiltrate into the ground. The increased volume of water also tends to bring pollutants like sediment, phosphorus and nitrogen that it picks up over paved and built surfaces.

Source: MPCA

GOAL 4:

Manage landscapes to hold water and reduce runoff

Source: MDA

Climate change increases extreme rainfall events, which in turn increase the volume and speed of runoff, resulting in more erosion and damage to roads, bridges and other infrastructure. More rain, combined with increased surface and subsurface drainage, also moves more pollutants from land to waterways. By enhancing the ability of land to hold water and slow runoff, we can reduce erosion, damage to infrastructure and water pollution.

Source: MPCA

STRATEGY 1: Identify opportunities to retain and store water and manage drainage.

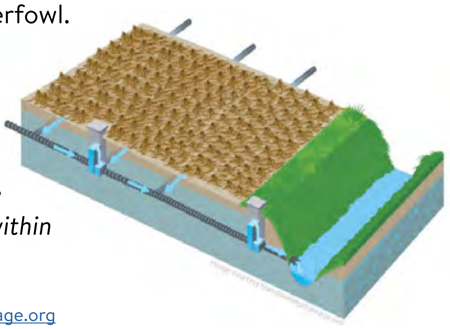
The Minnesota River Valley has been particularly hard hit by increases in rainfall and streamflow. The river's flows have increased 75% during the past two decades compared with the previous six decades. One of Mankato's drinking water supply wells now sits within 8 feet of the river's edge, and nearby roads and homes have been undermined by high flows.

For the Minnesota River and other agriculture-dominated watersheds, achieving state water quality standards for nutrients and sediment will require investment in water storage that increases infiltration, removes nitrate, and reduces runoff volume contributing to high river flows and bluff erosion. Surface water storage can be increased through water impoundments, grass waterways, vegetated buffers, controlled drainage outlets and wetlands. Soil water storage capacity can be increased through improved soil health and drainage water management.

According to the U.S. Army Corps of Engineers 2020 Minnesota River Basin Interagency Study, "the most critical needs are for actions to store water on the landscape using BMPs, build soil health and stabilize ravine erosion." Impoundment structures and reservoirs can provide large-scale water storage. "Basin-wide improvements in soil health and water storage will require ongoing partnerships between landowners, governments, and private organizations."

Action 1.1: Identify and pursue opportunities for temporary and permanent water storage across agricultural landscapes.

- Identify opportunities to store water on the landscape, including storage basins and wetlands, managed drainage, saturated buffers, and other conservation practices that improve soil health.
- Establish landscape priority areas such as former wetlands that could be restored.
- Implement multipurpose drainage methods such as two-stage ditches, control devices near tile outlets and upland storage to reduce flooding.
- Investigate and test existing and novel approaches to water storage and test other strategies for temporarily storing runoff water. Consider multipurpose benefits of storage, such as crop irrigation and creating habitat for migrating waterfowl.



Controlled drainage stores more water within the soil profile.

Source: Transformingdrainage.org

Action 1.2: Establish standards for technology, flow reduction, detention locations and sizing, drainage system design, culvert sizing, and flood staging.

- Develop design standards and practices to reduce peak flows, including strategic metering of flows in drainage systems, to address water quantity issues and consider downstream impacts. Developing these standards will require further study by the multi-stakeholder Drainage Work Group (see page 48) and all agencies working with drainage issues.
- Study distributed detention as a new approach to determine where storage will reduce runoff and flood peaks to meet watershed goals. Examples include on-channel or off-channel storage, large- and small-scale retention and/or detention in restored or created wetlands and impoundments, and private in-field constructed storage.
- Invest in technology such as LiDAR and hydro-conditioning that can better identify flood risk areas and guide management of water resources.
- Combine updated statewide LiDAR with Blue Spot analysis (see Goal 3) to identify high-risk flooding locations outside of FEMA regulatory floodplains. This will be particularly valuable for locations that intersect transportation infrastructure.
- Expand the Central Minnesota Ag Weather Network from 12 stations in central Minnesota and Dakota County to provide statewide coverage. Enhanced coverage will allow for better water management and climate data collection.

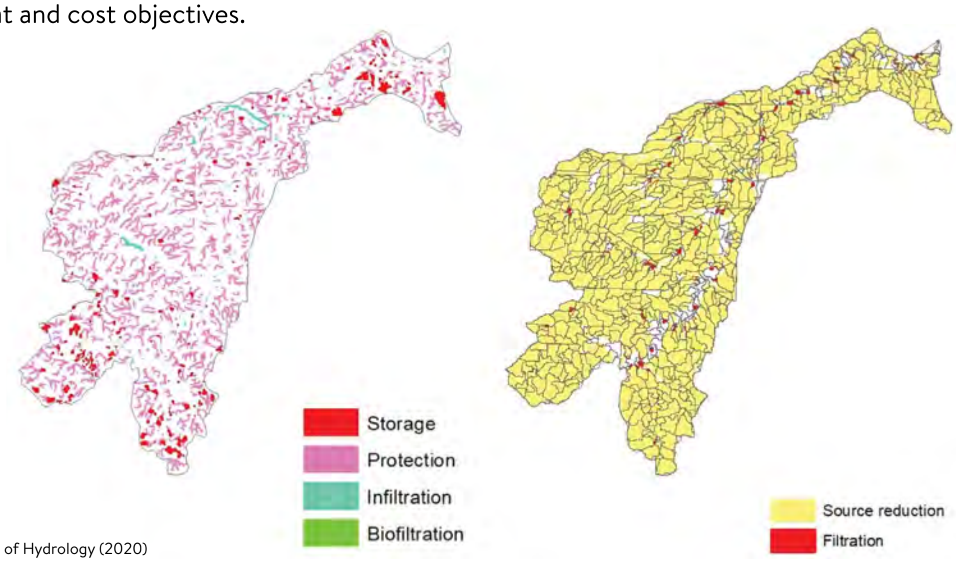
Action 1.3: Investigate and develop mechanisms to pay for water retention and detention.

- Determine the costs of the most cost-effective water storage that meets water quantity and quality goals while determining the technical feasibility and regulatory constratints of practice installations.
- Develop funding mechanisms to pay for water retention and detention. Define regional legal entities that can serve as fiscal agents and hold permits and easements for water storage and impoundment structures. (Note that watershed districts, where present, have the authority to establish a water management district that can collect revenue to fund water storage projects.)

Combining Multiple Models to Site Conservation Practices

There are multiple models for siting conservation practices in places on the landscape where they will be most effective, identified by acronyms such as ACPF, PTMApp, and HSPF-SAM. Each model focuses on different scales, from the individual field to the catchment to the stream and watershed. Research from the University of Minnesota and BWSR integrates aspects of these models to identify multiple opportunities for structural practices, such as multistage ditches or water and sediment control basins, and nonstructural practices, such as cover crops or stream buffers, in a single small watershed. The combined model also factors in costs and pollutant reductions of each practice and can incorporate landowner preferences. Local conservation partners can use the model to balance soil health, water quality, habitat and cost objectives.

The study site is the Plum Creek watershed in Cottonwood County. Plum Creek is a tributary of the Cottonwood River.



Source: Srinivas, Drewitz and Magner, Journal of Hydrology (2020)

How Is Drainage Managed in Minnesota?

The first drainage laws in Minnesota go back as early as 1883 and were enacted to effectively drain low, wet areas for agricultural production. Minnesota has approximately 19,150 miles of drainage ditches and untallied miles of subsurface tile installed and maintained under drainage law (Minnesota Statutes, chapter 103E. Drainage).

Drainage law enables multiple landowners to collectively construct, improve and repair drainage systems across property boundaries and governmental boundaries. These systems are managed by public drainage authorities. Drainage authorities include county boards, joint county boards and watershed district boards with jurisdiction over a drainage system or project. Private drainage, such as tile drainage on individual properties, is managed by private landowners.

Beginning in the late 1990s, drainage projects increased substantially as existing drainage systems needed major repairs, land prices increased and subsurface tiling became more economical. As systems expanded, water quality concerns grew. In 2014, drainage law was modified to include consideration of water quality and multipurpose drainage management options for drainage projects.

State agencies have limited authority over drainage systems, largely focused on oversight of buffer requirements and review of projects that affect public waters. Several interagency and stakeholder groups play important advisory roles in drainage management:

- The interagency Drainage Management Team (DMT) includes state and federal agencies, the University of Minnesota, and the Minnesota State University, Mankato, Water Resources Center. The DMT coordinates and shares relevant scientific and technical information on agricultural drainage management.
- The Drainage Work Group (DWG) is an advisory body comprising representatives of state agencies, research institutions, agricultural organizations, watershed districts, engineering firms, environmental groups and other stakeholders. The DWG works to foster science-based understanding about drainage topics and to recommend best practices for drainage system management, as well as updates to drainage law.
- The Local Government Water Roundtable is an affiliation of three local government associations, the Association of Minnesota Counties, Minnesota Association of Soil and Water Conservation Districts and Minnesota Association of Watershed Districts. The roundtable helped develop the 1W1P program and advises state agencies on other watershed funding and related management issues.
- Consultants to drainage authorities, including engineering and legal consultants, also play important advisory roles.

Source: MPCA

STRATEGY 2: Develop multipurpose drainage water management standards, guidelines and incentives.

In many parts of Minnesota, drainage is critical for agricultural production and protection of roads and other infrastructure. However, practices must now also accommodate increasing precipitation amounts and intensity of individual rainfall events.

Drainage can affect water quality and quantity by increasing annual flows, peak flows and nutrient transport. Increases in peak runoff flows upstream can contribute to downstream erosion and flooding. Future drainage should simultaneously support agricultural production, protect water quality, reduce flood damage and protect habitat.

Drainage in Minnesota is managed primarily by county and multi-county drainage authorities and watershed districts (see previous page) and private landowners. State agencies can advise drainage authorities, provide incentives such as funding and offer technical assistance. Therefore, the following actions will require a collective effort among state, local, academic and private entities.

Action 2.1: Develop mechanisms to incentivize drainage BMPs.

Financial and technical assistance is available for drainage water management (DWM) plans and a variety of drainage BMPs, including control structures, biofilters and saturated buffers. However, adoption of drainage BMPs is not widespread. State assistance should be directed to:

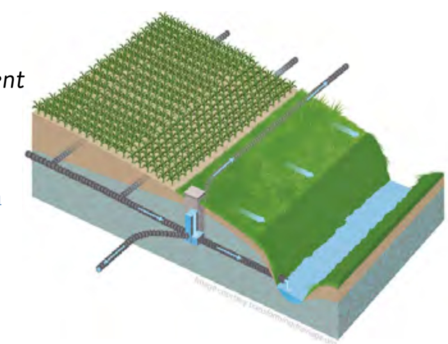
- identify and evaluate benefits and socioeconomic barriers to adoption of on-farm water storage
- support a position with University of Minnesota Extension for DWM outreach and education
- develop a DWM endorsement within the Minnesota Agricultural Water Quality Certification Program to include administrative, regulatory or other benefits for local drainage authorities and landowners.

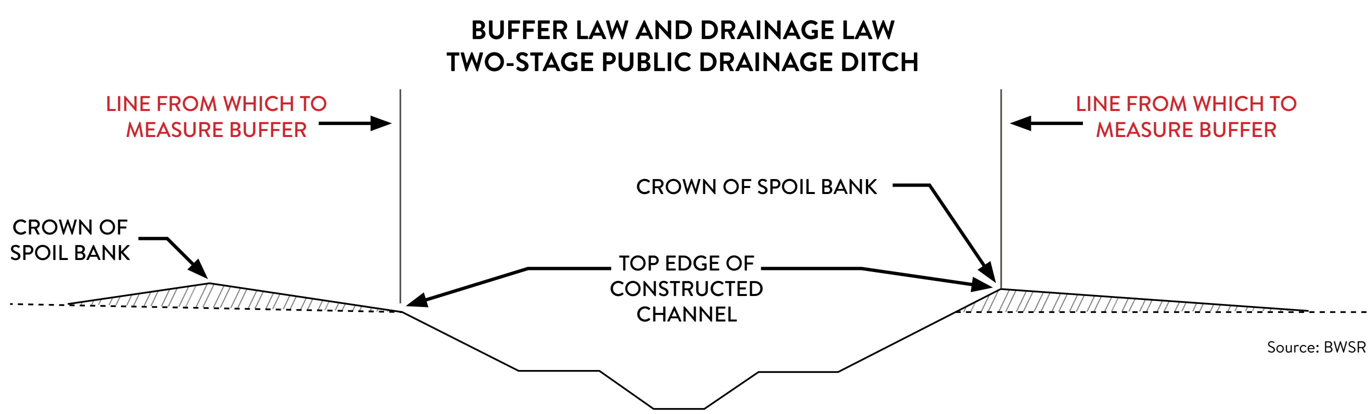
Action 2.2: Develop/expand technical and financial assistance.

- Incentivize drainage authorities, watershed managers, farmers and landowners to use DWM practices through grants and technical assistance.
- Work with drainage authorities (counties, watershed districts) and private-sector engineers and contractors to provide technical assistance.

A saturated buffer delays water movement from a subsurface drainage system.

Source: Transformingdrainage.org





A two-stage drainage ditch meeting the requirements of buffer law.

Action 2.3: Establish a consistent approach to drainage system design.

Other than voluntary guidance provided by the [Red River Basin Technical and Scientific Advisory Committee], guidance to drainage authorities regarding pattern tile or surface drainage is not standardized. The [Drainage Management Team] (DMT, see page 48) should work to establish standards and guidance for drainage authorities on the following topics, with review by the [Drainage Work Group] (DWG), Local Government Water Roundtable and other stakeholders:

- water storage opportunities designed to ensure adequate outlets (potentially including estimating drainage tile coverage, focusing on locations where tile may not be functioning well)
- consistent regional approaches to ditch design and culvert sizing
- establishment of standards for drainage coefficients, which measure the capacity of a drainage system and can be used during design to quantify or measure discharge at a watershed scale
- practices for overall system management during floods or times of high flow
- best practices for developing systemwide culvert inventories, using methods developed by DNR and local drainage authorities
- best practices for outreach to landowners and other stakeholders.

Action 2.4: Increase the number of research and demonstration sites.

- Establish additional sites to facilitate implementation of DWM practices, show projects to landowners, monitor and assess water quantity and quality impacts, and evaluate management, cost and agronomic impacts. For example, [Discovery Farms Minnesota] paired watershed comparisons continue to generate new information on the interactions among farm management, seasonal weather conditions and drainage water quality.
- Provide funding to recruit more growers to test new drainage practices under different combinations of dominant soils and crop production in Minnesota.

Source: MDA

STRATEGY 3: Incorporate drainage water management into local water planning

Without watershed or basin-wide planning, it is challenging to coordinate across scales and develop funding mechanisms. A potential solution includes creation of standards specific to major watersheds. Some watershed organizations are already doing this.

Action 3.1: Use the One Watershed One Plan (1W1P) process to establish watershed-scale standards.

The 1W1P approach brings stakeholders together on a watershed basis, facilitating multipurpose water management. Such cooperation can build the support of citizens and agencies, achieve water quality and quantity goals, and produce environmental benefits that healthy watersheds provide while preserving a vibrant agricultural economy.

- Develop and apply flow reduction and water retention goals across all watersheds using watershed district law (MS 103D) and public drainage system law (103E) to subsidize and incentivize planning.

CASE STUDY: Long-Term Flood Solutions for the Red River Basin

The Red River Basin is an international watershed of 45,000 square miles, with 80% of the basin in the United States and 20% in Canada. Eighteen Minnesota counties and 22 North Dakota counties lie wholly or partially in the basin. Faced with recurring and increasing flooding, including record floods in 1997 and 2009, the Red River Basin Commission developed long-term flood solutions for the Red River and its tributaries.

The study established a 20% peak flow reduction goal for the main stem of the Red River across the entire basin. It is up to local watershed organizations to implement practices that can achieve this goal. Practices can include retention and detention ponds and metering of ditch and tile drainage runoff via control structures and pumps.

Within the Red River Basin, the Bois de Sioux Watershed District implements the 20% goal by restricting tile drainage projects to a ¼-inch-per-day drainage coefficient at the outlet, unless the system has storage offsets or can be controlled in case of downstream flooding. The district requires tile pump and gate closures during spring snowmelt based on regional and local conditions.

Several other activities of Red River Basin water management agencies are worth highlighting:

- Since the late 1970s, the Red River Watershed Management Board has helped fund approximately 181,588 acre-feet of storage in the Minnesota portion of the Red River Basin, consisting mainly of constructed flood impoundments ranging from a few hundred to thousands of acre-feet. Some of the storage is gated to allow for detention times on the order of weeks, reducing flood volume during peak flow periods.
- The Red River Basin Technical and Scientific Advisory Committee has established best practice recommendations with the goal of balancing the positive and negative effects of agricultural surface drainage. Most crops grown in the Red River Basin can tolerate standing water for 24–48 hours. The primary objective of the design guidance is to remove water from a 10-year summer rainfall before it damages crops. During larger events, some longer inundation is expected, but damage would be distributed as equitably as possible. The design guidance is implemented by sizing culverts, adding floodwater storage (preferably gated) and avoiding drainage of non-contributing areas. While voluntary, the best practices have been adopted by several watershed districts. The guidance works best on relatively flat drainage systems and on systems smaller than 10 square miles.

Source: Two Rivers Watershed District

Ross Impoundment Project storing approximately 3,400 acre-feet during the 2019 fall flood. Project details:

- *total storage to emergency spillway—3,611 acre-feet*
- *water surface area to emergency spillway—1,312 acres*

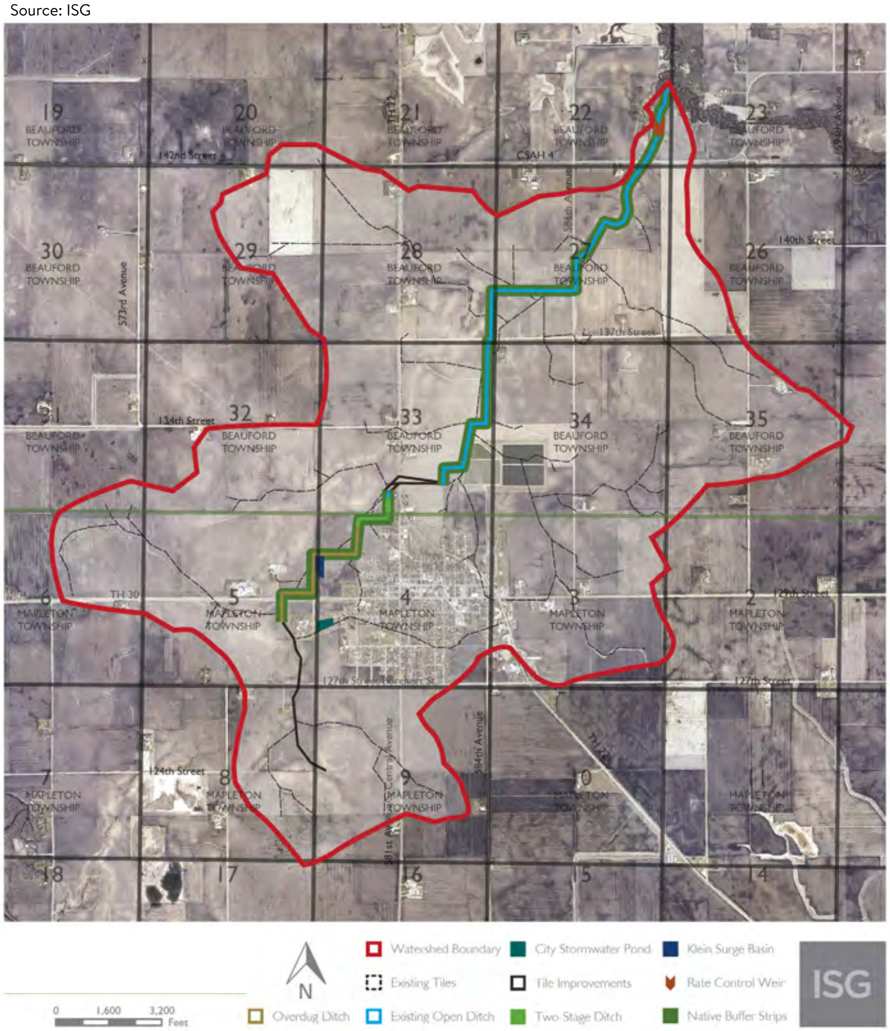
CASE STUDY: Blue Earth County Ditch No. 57

Blue Earth County has over 100 county-administered drainage systems, with over 160 miles of open ditches and over 500 miles of tile systems. Approximately 50% of all the land in Blue Earth County drains to a county ditch. The remaining land drains to natural drainage systems such as rivers or streams. Blue Earth County Ditch No. 57 (CD 57), a public drainage system near Mapleton, exemplifies a successful multipurpose approach to drainage water management.

The CD 57 drainage system is a 6,041-acre watershed comprising farmland and the city of Mapleton. The system has been public since 1921, with some portions installed privately prior to 1900 and the only repairs completed in the mid-1970s. By 2007, portions of the system had failed, and landowners petitioned the drainage authority for repairs. As the petition was being developed, downstream landowners voiced flooding concerns. By implementing a range of water storage methods, the Blue Earth County Drainage Authority and its partners were able to meet the needs of both upstream and downstream landowners. The project design included:

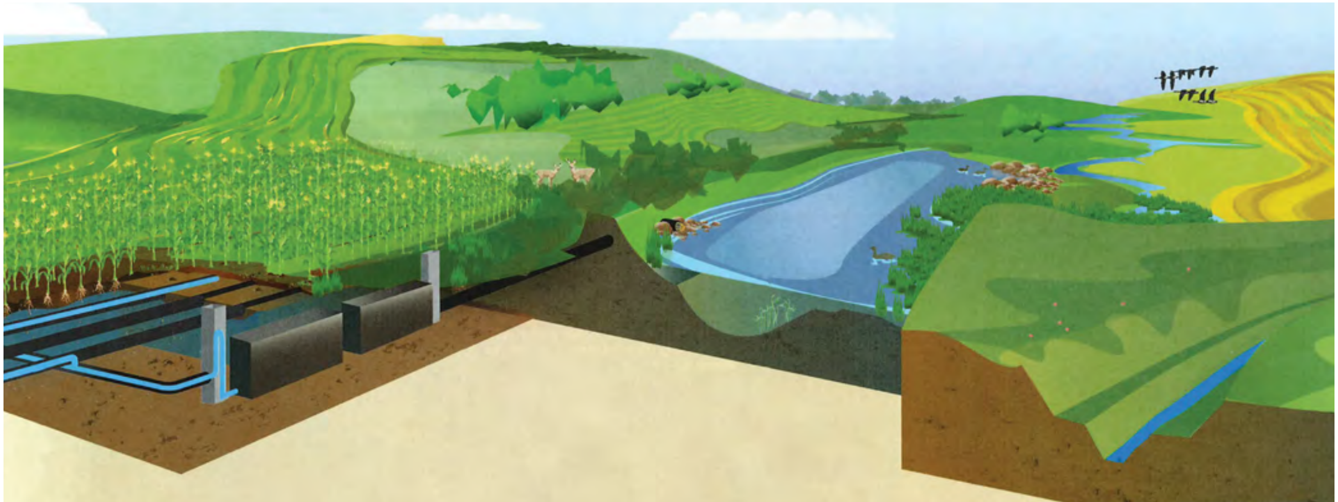
- surge basins, also known as sediment or storage ponds, that provide storage with a reduced outlet size
- a two-stage ditch (an open ditch designed to maintain flow that mimics that of natural streams)
- an over-dug ditch (a widened ditch with a lowered bottom to allow sediment to settle)
- buffer strips along open ditches, planted with deep-rooted native vegetation to provide wildlife habitat and increase erosion protection
- a rate-control weir at the outlet of the ditch system to create temporary ponding.

Source: ISG



The CD 57 reconstruction is an extremely successful project, providing increased agricultural production and crop yields while decreasing downstream flooding and levels of sediment and nutrients. Pollutant (nutrient) reductions have been as high as 50%, with averages near 25%. Over 70 dump-truck loads of sediment have been kept out of public waters.

Source: ISG, Mankato, MN



The Scale of Drainage Practices

Drainage practices can be considered at multiple scales, beginning with managing the rain where it falls and then as it moves to the drainage system and into the broader watershed.

- At the field scale, consider soil health practices, grassed waterways, water and sediment basins, and other surface drainage practices. Managed drainage practices may include saturated buffers, water capture and reuse, alternative surface inlets, and bioreactors. A few field-scale examples include the Red River Valley Drainage Water Management project and the Clay County drainage site.
- If field-scale practices are insufficient, the focus moves outward to the drainage system—the ditch/watercourse scale. Practices such as filter strips, two-stage ditches, side inlets and check dams can slow flows and reduce erosion. The County Ditch No. 57 case study is a good example of coordinated drainage system management.
- At the watershed or subwatershed scale, practices such as wetland construction and restoration, stream bank and shoreline protection, restoring stream channel meanders, and creating short- and long-term water storage can alleviate flooding and erosion problems. Watershed management plans offer opportunities to consider these larger-scale solutions.

Source: BWSR

Source: Courtney Celley/USFWS

GOAL 5:

Promote resiliency in quality of life

Water is vital for meeting basic human needs such as drinking, washing and growing food. But water provides benefits beyond basic needs—it enhances our quality of life. Water is part of Minnesota's identity and is integral to the recreation, livelihoods, spirituality and sense of well-being of many Minnesotans.

Source: DNR

Outdoor recreation is an essential part of Minnesota culture and contributes nearly $17 billion to Minnesota's economy. Climate change is altering fishing, skiing, hunting, boating, swimming and other activities. For example:

- Winter activities such as cross-country skiing, ice skating, snowshoeing, ice fishing and snowmobiling face shorter seasons and more inconsistent conditions.
- Some outdoor activities attract more participants as temperatures warm more quickly in the spring and stay warm longer in the fall, straining capacity on popular water bodies and recreation areas.
- Trails, beaches and other recreational facilities face increased wind and flood damage from storms.
- Erosion along rivers and slope destabilization from heavy precipitation can damage rare plant and animal communities and cultural resources.
- Invasive species are becoming more prevalent and new species are arriving, threatening native plant and animal communities.
- Higher water temperatures increase the likelihood of harmful algal blooms and levels of bacteria in recreational waters.
- Changes to animal populations affect fishing, hunting and wildlife watching.

More changes are expected; additional research is needed to understand how climate change will affect winter and summer recreational opportunities and the economic and social benefits they bring.

Changes in precipitation and water quality due to climate change are also affecting plant communities, wildlife and diverse landscapes across Minnesota. This in turn affects the mental and spiritual health benefits we receive from nature.

Many Minnesotans feel connected to a specific body of water and have traditions and memories associated with it. Changing seasons provide a signal for certain subsistence, recreational and economic activities, such as the beginning and end of the ice-fishing season, planting and harvesting times, and tourism to ski areas. Our attachment to places—and the environments, traditions and customs tied to these places—are very deep and part of our identity.

For this reason, disruptions in our sense of place from environmental changes and natural disasters can be distressing. These feelings and experiences of loss can contribute to emotional distress, strain relationships and weaken community cohesion.

STRATEGY 1: Adapt and mitigate infrastructure planning, design and development for recreational needs.

In order to support recreational activities, recreation infrastructure will need to withstand Minnesota's changing climate. Design of new recreation infrastructure must take new realities of climate change into account. Funding will be required to deal with repairs, closures and cleanup following extreme weather damage at existing facilities.

At the same time climate is changing, Minnesota is seeing increased interest in water-based recreation. Motorized water activities and fishing are projected to increase more than 20% between now and 2060. This has the potential to further stress water resources.

Climate change and increasing recreational demands will have profound impacts on how agencies, resource managers and recreational providers handle infrastructure, manage natural landscapes and provide outdoor opportunities. Additionally, travel, tourism, sport and adventure education industries will need information and support to help prepare for these changes. Planning, design, and development must become more inclusive to address cultural needs, including identity, recreational and subsistence activities.

Action 1.1: Incorporate the ability to withstand greater rainfall and wind events into infrastructure design and construction (e.g., docks, marinas, shelters), consulting climate projection data for local areas.

Action 1.2: For existing facilities, anticipate the need for funding to deal with emergency repairs, closures and cleanup following damage from more frequent and unpredictable extreme weather events.

Action 1.3: Minimize the introduction and spread of invasive species through appropriate protective strategies and infrastructure utilizing existing programs, such as the DNR Watercraft Inspection Program.

Source: DNR

STRATEGY 2: Improve monitoring and public communication regarding water quality and safety of beaches.

Climate change threatens the quality of Minnesota's beaches and recreational waters. Warmer temperatures are more conducive to the growth of algae and bacteria. With more frequent, intense rainfall events, increased stormwater runoff can wash more bacteria from the land surface into recreational waters. Some beaches are experiencing high numbers of closures in wet years due to increased bacterial levels in the water. Harmful algal blooms are a particular concern because they produce cyanotoxins, which can make humans and animals sick.

Minnesota state law does not require beach monitoring. However, some local public health departments or cities regularly monitor beach water quality, providing periodic snapshots of water conditions.

Source: DNR

No single entity tracks public beach monitoring or closures statewide. An online statewide recreational water testing portal would give Minnesotans convenient access to information on recreational water monitoring, beach closures and dangers such as harmful algal blooms or major pollution events. Similarly, there is no dedicated funding to monitor algal toxins in Minnesota. Understanding which algal toxins are present in Minnesota waters, and when and where they occur, will help state and local officials protect the public. Algal toxin monitoring can also warn cities that draw drinking water from surface water sources when they may be vulnerable to contamination.

Action 2.1: Develop state web portal and activation of beach alerts system.

Action 2.2: Develop dedicated funding for increased monitoring of algal toxins.

Source: MDH

Not all algal blooms are toxic, and not all harmful algal blooms are visible to the naked eye. These are additional reasons more algal toxin monitoring is needed.

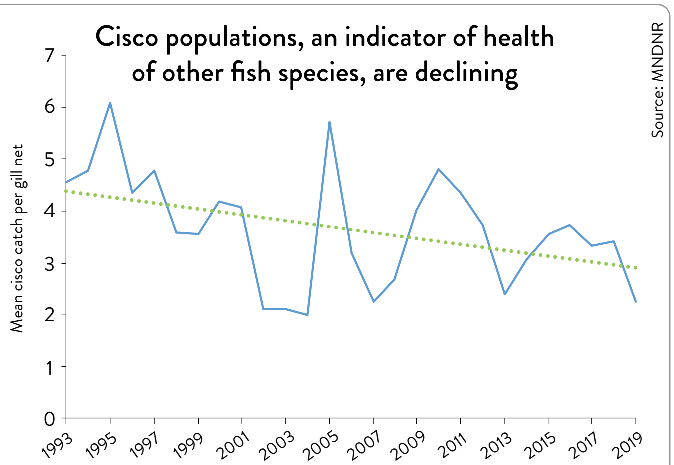
STRATEGY 3: Manage fish and aquatic habitat for resilience.

Fishing connects Minnesotans to the water for both sustenance and recreation, reinforcing seasonal cultural traditions. Climate change is altering fisheries in Minnesota due to warming waters, increasing heavy rain events, and shorter and milder winters. This could mean more fish harvest opportunities for some species but fewer opportunities for others. Furthermore, climate change exacerbates existing issues such as excessive nutrients and invasive species.

Source: Courtney Celley/USFWS

Climate change impacts to fishing include:

- displacement of cold-water and cool-water fish by fish species that tolerate warmer waters
- lower reproductive success of some species
- changes to habitats and fish behavior
- decreased fishing opportunities due to flooding
- reduced ice fishing due to diminished ice cover and ice quality.

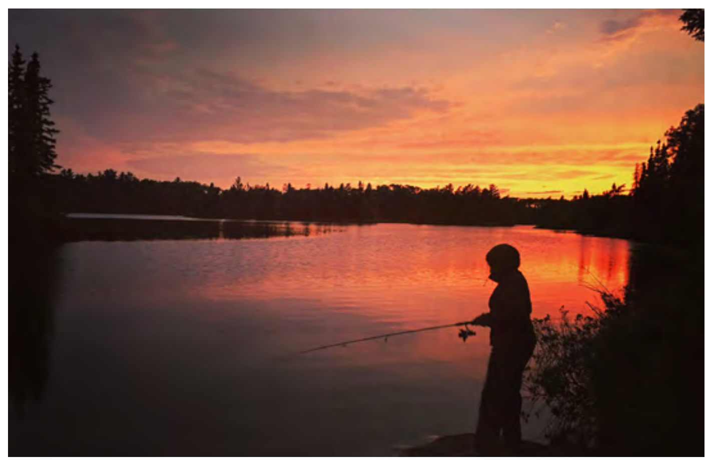


Cisco, an important food source for walleye and trout, are declining in Minnesota as temperatures rise.

Fishery managers will need to alter fish and habitat management based on current and future conditions.

Mercury contamination leading to consumption advisories is another issue affecting fishing. Mercury levels in fish depend on fish species, their size and the water bodies in which they live. More research is needed to understand why mercury isn't declining in some water bodies despite lower emissions, and how climate change and other factors may affect mercury contamination in fish.

Though most of the mercury deposited in Minnesota comes from outside the state, we can do our part to reduce mercury emissions. Sources of mercury emissions in Minnesota include energy production (mostly burning coal), taconite processing, other industrial processes and forest fires. For larger predatory fish to be safer to eat, MPCA scientists say that we must reduce mercury emissions to 789 pounds per year, a 76% reduction from 2005 levels. Working with stakeholders, the MPCA has developed a plan to meet this goal by 2025.



Source: DNR

Action 3.1: Manage fisheries to recognize and adapt to climate change trends, including altering fish stocking programs and harvest opportunities based on current and expected future conditions.

Action 3.2: Manage aquatic ecosystems to create, promote and maintain quality habitat, climate refuges and habitat connectivity.

Action 3.3: Monitor and research aquatic wildlife populations over time in variable conditions.

Action 3.4: Continue efforts to reduce mercury emissions and conduct research to better understand how climate change affects mercury contamination in fish.

STRATEGY 4: Conduct research and engagement to address impacts of changing water resources and ecosystems on mental health and well-being.

Emerging research seeks to better understand the psychological and emotional impacts of climate change. As climate change impacts water resources, Minnesotans may experience a sense of loss, anxiety or despair linked to these impacts, including:

- loss of habitat for native plants and wildlife
- water shortage and drought
- loss of livelihood for those whose career depends on stable and expected climate conditions (e.g., farming, tourism)
- threats to cultural or family traditions tied to water, such as wild rice harvesting, ice fishing or skiing
- loss of property or possessions due to a disaster, such as flooding.

As our communities face increasing strain from climate change, we need to consider mental health and well-being as we work to find solutions.

Source: DNR

Action 4.1: Research the mental and emotional impacts of changing water resources and ecosystems due to climate change, particularly among those who may be uniquely impacted (e.g., Indigenous persons, farmers and subsistence anglers), and identify strategies and resources to support psychological resiliency.

Action 4.2: Research community values and beliefs surrounding water, including those of particularly vulnerable communities, and work to integrate those values and beliefs into water resource planning.

Action 4.3: Strengthen networks and build community around water resources through cultural activities and community science (also known as "citizen science").

Action 4.4: Improve coordination between state and local emergency managers to identify communities impacted by climate-related water hazards, and better target resources to reduce physical, emotional and mental stressors.

Spotlight on Lake Superior

Minnesota borders one of the most beautiful and extraordinary ecosystems on Earth: Lake Superior. This global gem contains 10% of the world's surface fresh water and is in the best ecological condition of all the Great Lakes. Minnesotans depend on Lake Superior for benefits such as drinking water, recreation, transportation, commerce, and the iconic views and vistas that characterize the North Shore.

Today the lake and its basin face direct and indirect impacts from climate change. The direct impacts from warming temperatures, increased precipitation and frequent storm events have numerous indirect effects. These include increased flood risks, reduced ice cover, altered shoreline habitats and intensified nonpoint source pollution. These changes threaten this magnificent and complex ecosystem.

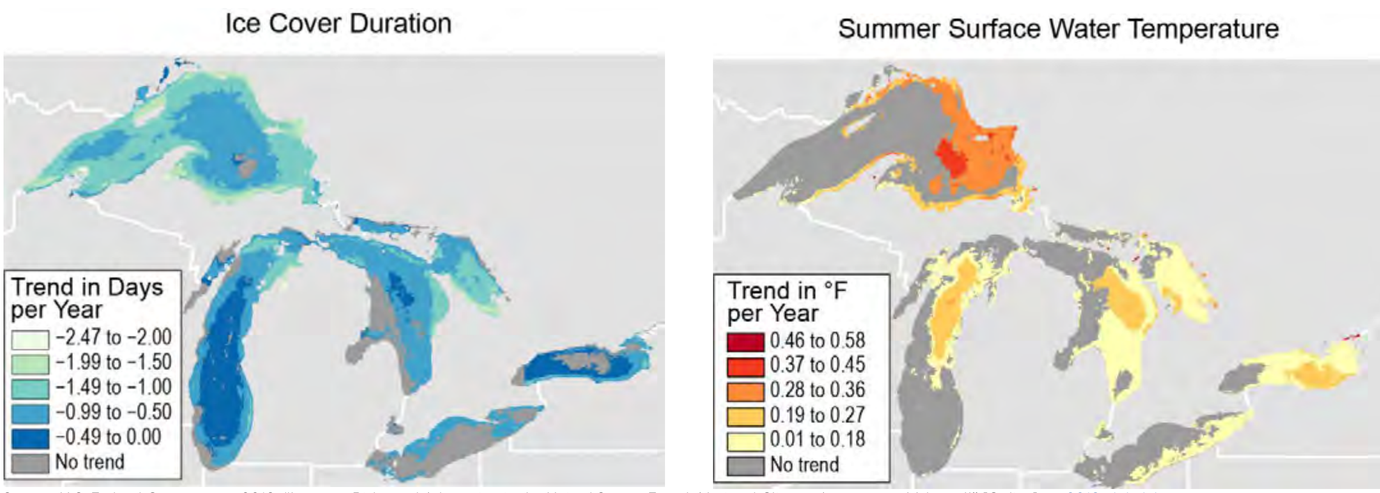
Source: DNR

Minnesota's rugged Lake Superior coast.

Climate change impacts and forecasts

Climate change is expected to produce increased air and water temperatures, decreased extent and duration of ice cover, and more frequent storm events across the Lake Superior basin. Recent studies forecast increased annual precipitation and more frequent large precipitation events in northeastern Minnesota throughout the 21st century, bringing significant impacts on local hydrology and Lake Superior water levels.

These climate effects will impact Lake Superior's complex ecosystem and the services it provides. Temperature changes, for example, could favor aquatic invasive species such as the sea lamprey, alter plankton communities that sustain the entire food web and threaten cold-water fish communities. Warmer water temperatures, more frequent storms and pollution may increase the likelihood of harmful algal blooms, which could degrade water quality, hurt local tourism-dependent economies and negatively affect human health.



Source: U.S. Federal Government, 2018: "Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II" [Online] nca2018.globalchange.gov.

Trends in ice cover duration (1973–2013) and summer surface water temperatures (1994–2013) across the Great Lakes

Lake Superior hydrology and water levels

Lake Superior water levels have fluctuated dramatically over the past 50 years, as demonstrated by a 6-foot increase in water levels between 2013 and 2019 . Water levels largely reflect changes in precipitation and evaporation rates, since the lake's only outlet at the Soo Locks provides only moderate regulation.

Fluctuating water levels affect coastal and near-shore environments and public and private infrastructure. They also increase vulnerability to coastal storms and flooding. Models predict highly variable water fluctuations in the future.

Community planning and adaptive management

It is vital to recognize the interaction between community planning and natural resource management within the context of climate change. Deliberate decision-making is necessary in response to more frequent and intense precipitation events, storm damages, and ongoing development pressures. Local communities benefit from guidance and support in adaptively managing their infrastructure, water resources and recreational amenities.

Current efforts in community planning, hazard mitigation and natural resource management at state and local levels identify existing concerns and recommendations for improving community resilience. Existing regional management plans, such as the Lake Superior Lakewide Action Management Plan and the State of Minnesota Hazard Mitigation Plan, can guide science-based adaptive management of coastal areas. In conjunction with local community level plans, these regional plans help identify shared priorities to protect the Lake Superior ecosystem.

Source: DNR

Larger and more frequent storm events along Lake Superior shoreline have caused significant damage.

Example collaboration:
St. Louis River area of concern

The St. Louis River Area of Concern (AOC), encompassing over 1,000 square miles of the river's estuary and tributaries in Minnesota and Wisconsin, has been the focus of years of collaborative restoration efforts by federal, state, tribal and local partners. The AOC is a long-term effort to address past industrial pollution and contamination and restore degraded habitat. While the AOC program focuses on historical disturbance, partners are now looking at adapting these habitats toward conditions that are more resilient to projected climatic and hydrologic changes.

Source: DNR via Richard Hamilton Smith

St. Louis River Estuary, looking upstream toward the Fond du Lac neighborhood of Duluth.

Highlighted Resources and Programs

- The Chester Creek Project highlights the economic and environmental benefits of using green infrastructure to reduce flooding risks in the Chester Creek watershed in Duluth.
- Duluth Urban Watershed Advisory Committee (DUWAC) brings together local governments and researchers to collectively manage urban watersheds, protect water quality and reduce flooding risks.
- Minnesota's Lake Superior Coastal Program supports local planning and coastal management that balance community needs with sustainable use and protection of natural resources.
- Minnesota Sea Grant provides a wealth of climate-related resources, including brochures, an interactive map and a "Climate Conversations" series on topics affecting the Twin Ports.

Implementation of the 2020 State Water Plan and state agencies involved.

The purpose of this table is to summarize the types of actions needed to implement strategies in the 2020 State Water Plan. Primary state agencies involved are identified, recognizing that multiple agencies and many local and regional partners are also involved in each action and may be the parties implementing them. As these strategies evolve, this table will be updated periodically over the 10-year lifespan of this plan.

Strategy	Statute change	Rule change	Policy change	Additional funding/ reallocation	Planning	Research	Education and awareness	Other	Primary state agencies
GOAL 1: Ensure drinking water is safe and sufficient									
Strategy 1: Accelerate source water protection for community water systems.									
Action 1.1: Prioritize protection of the 400,000 acres of vulnerable land in DWSMAs.			●	●	●		●		MDH, BWSR, MDA
Action 1.2: Assess and monitor the safety and resiliency of surface DWSMAs.			●	●	●		●		MDH, MPCA
Action 1.3: Protect, restore, and increase perennial cover in the highest priority areas of the Mississippi River watershed.			●	●	●		●		MDH, BWSR, MDA
Strategy 2: Emphasize source water protection in watershed management.									
Action 2.1: Emphasize source water protection in implementing watershed management plans.				●	●				BWSR, Met Council, MDH
Action 2.2: Leverage the use of state dollars to protect drinking water.			●	●					BWSR
Action 2.3: Increase routine testing of private well water.				●	●	●	●		MDH
Strategy 3: Emphasize source water protection in watershed management.									
Action 3.1: Fully implement Minnesota GPR in DWSMAs with nitrate concentrations above defined thresholds.		●		●	●		●		MDA
Action 3.2: Implement the NFMP in vulnerable areas as defined by township testing results.			●	●	●	●	●		MDA
Action 3.3: Ensure compliance with the Minnesota Feedlot Rule.			●	●	●		●	Permit renewal	MPCA

Implementation of the 2020 State Water Plan and state agencies involved.

The purpose of this table is to summarize the types of actions needed to implement strategies in the 2020 State Water Plan. Primary state agencies involved are identified, recognizing that multiple agencies and many local and regional partners are also involved in each action and may be the parties implementing them. As these strategies evolve, this table will be updated periodically over the 10-year lifespan of this plan.

Strategy	Statute change	Rule change	Policy change	Additional funding/ reallocation	Planning	Research	Education and awareness	Other	Primary state agencies
GOAL 2: Manage landscapes to protect and improve water quality									
Strategy 1: Increase soil health									
Action 1.1: Work to meet state goals for expanding the acreage of cover crops and continuous living cover.					●	●	●		BWSR, MDA, MPCA
Action 1.2: Improve monitoring and metrics for soil health based on statewide research and modeling.			●	●	●	●	●		BWSR, MDA
Action 1.3: Diversify crops and agricultural practices that support soil health.				●	●	●	●		MDA, BWSR
Action 1.4: Reduce social and financial barriers to implementation of soil health practices.				●		●	●		BWSR, MDA, MPCA
Action 1.5: Establish soil health demonstration watersheds.				●	●	●	●		MDA, BWSR
Strategy 2: Expand opportunities to participate in ecosystem services markets									
Action 2.1: Develop accounting protocols and data foundations for ecosystem services trading.	●		●	●	●		●		MDA, BWSR, MPCA
Action 2.2: Pursue emerging options for ecosystem service markets using water quality trading as a starting point.				●	●	●	●		MDA, BWSR, MPCA

Implementation of the 2020 State Water Plan and state agencies involved.

The purpose of this table is to summarize the types of actions needed to implement strategies in the 2020 State Water Plan. Primary state agencies involved are identified, recognizing that multiple agencies and many local and regional partners are also involved in each action and may be the parties implementing them. As these strategies evolve, this table will be updated periodically over the 10-year lifespan of this plan.

Strategy	Statute change	Rule change	Policy change	Additional funding/ reallocation	Planning	Research	Education and awareness	Other	**Primary state agencies**
Goal 3: Manage built environments and infrastructure for greater resiliency									
Strategy 1: Improve data sources and modeling.									
Action 1.1: Pursue and fund next-generation LiDAR.				●			●		DNR
Action 1.2: Obtain dynamically downscaled climate projections.				●	●		●		All state agencies
Action 1.3: Support modeling efforts and risk management that consider climate change impacts.				●		●			All state agencies
Strategy 2: Support communities with asset management and resiliency planning for wastewater, stormwater and drinking water infrastructure.									
Action 2.1: Fund a comprehensive asset management program across Minnesota.	●			●	●		●		MPCA, MDH
Action 2.2: Provide training and technical assistance to smaller communities on tools to assess risk and vulnerability.				●	●		●		MDH, MPCA
Action 2.3: Adopt a stormwater data standard and fund digitization.				●	●		●		MPCA
Strategy 3: Develop new and updated resiliency financing mechanisms.									
Action 3.1: Develop and fund climate planning grants to communities for wastewater and stormwater infrastructure.	●			●					MPCA, MDH, Met Council
Action 3.2: Authorize and fund Public Facilities Authority (PFA) programs to support resilient infrastructure projects.	●	●		●	●		●		PFA, MPCA, MDH
Action 3.3: Expand the Minnesota Property-Assessed Clean Energy (MinnPACE) program to include water conservation and hazard mitigation projects.	●		●				●		Commerce
Strategy 4: Design transportation infrastructure in floodplains for long-term resiliency.									
Activity 4.1: Design culverts with future climate conditions in mind.	●			●	●	●	●		DNR, MnDOT
Activity 4.2 Prioritize climate adaptation actions across Minnesota's road systems.						●			MnDOT

Implementation of the 2020 State Water Plan and state agencies involved.

The purpose of this table is to summarize the types of actions needed to implement strategies in the 2020 State Water Plan. Primary state agencies involved are identified, recognizing that multiple agencies and many local and regional partners are also involved in each action and may be the parties implementing them. As these strategies evolve, this table will be updated periodically over the 10-year lifespan of this plan.

Strategy	Statute change	Rule change	Policy change	Additional funding/ reallocation	Planning	Research	Education and awareness	Other	**Primary state agencies**
GOAL 4: Manage landscapes to hold water and reduce runoff									
Strategy 1: Identify opportunities to retain and store water and manage drainage.									
Action 1.1: Identify and pursue opportunities for temporary and permanent water storage across agricultural landscapes.	●		●	●	●	●	●		BWSR, DNR
Action 1.2: Establish standards for technology, flow reduction, detention locations and sizing, drainage system design, culvert sizing, and flood staging.			●	●	●	●	●		BWSR, DNR
Action 1.3: Investigate and develop mechanisms to pay for water retention and detention.	●		●	●		●			BWSR
Strategy 2: Develop multipurpose drainage water management standards, guidelines and incentives.									
Action 2.1: Develop mechanisms to incentivize drainage BMPs.				●	●	●	●		BWSR, DNR, MDA
Action 2.2: Develop/expand technical and financial assistance.				●					BWSR
Action 2.3: Establish a consistent approach to drainage system design and permitting.	●		●						BWSR
Action 2.4: Increase the number of research and demonstration sites.				●		●	●		MDA, BWSR
Strategy 3: Incorporate drainage water management into local water planning.									
Action 3.1: Use the 1W1P process to establish watershed-scale standards.			●		●		●		BWSR, MPCA, DNR

Implementation of the 2020 State Water Plan and state agencies involved.

The purpose of this table is to summarize the types of actions needed to implement strategies in the 2020 State Water Plan. Primary state agencies involved are identified, recognizing that multiple agencies and many local and regional partners are also involved in each action and may be the parties implementing them. As these strategies evolve, this table will be updated periodically over the 10-year lifespan of this plan.

Strategy	Statute change	Rule change	Policy change	Additional funding/ reallocation	Planning	Research	Education and awareness	Other	Primary state agencies
GOAL 5: Promote resiliency in quality of life									
Strategy 1: Adapt and mitigate infrastructure planning, design and development for recreational needs.									
Action 1.1: Incorporate the ability to withstand greater rainfall into infrastructure design and construction (e.g., docks, marinas, shelters).				●	●				DNR, MnDOT
Action 1.2: For existing facilities, anticipate the need for funding to deal with emergency repairs, closures and cleanup following damage from more frequent and unpredictable extreme weather events.				●	●				DNR
Action 1.3: Minimize the introduction and spread of invasive species through appropriate protective strategies and infrastructure utilizing existing programs such as the DNR Watercraft Inspection Program.			●		●	●	●		DNR
Strategy 2: Improve monitoring and public communication regarding water quality and safety of beaches.									
Action 2.1: Develop state web portal and activation of beach alerts system.				●	●	●	●		MDH
Action 2.2: Develop dedicated funding for increased monitoring of algal toxins.				●	●	●			MPCA, MDH
Strategy 3: Manage fish and aquatic habitat for resilience.									
Action 3.1: Manage fisheries to recognize and adapt to climate change trends, including altering fish stocking programs and harvest opportunities based on current and expected future conditions.					●	●			DNR
Action 3.2: Manage aquatic ecosystems to create, promote and maintain quality habitat, climate refuges and habitat connectivity.				●	●	●	●		DNR
Action 3.3: Monitor and research wildlife populations over time in variable conditions.				●	●	●	●		DNR, MPCA
Action 3.4: Continue efforts to reduce mercury emissions and conduct research to better understand how climate change affects mercury contamination in fish.				●	●	●	●		DNR, MPCA, MDH

Strategy	Statute change	Rule change	Policy change	Additional funding/ reallocation	Planning	Research	Education and awareness	Other	**Primary state agencies**
GOAL 5: Promote resiliency in quality of life (continued)									
Strategy 4: Conduct research and engagement to address impacts of changing water resources and ecosystems on mental health and well-being.									
Action 4.1: Research the mental and emotional impacts of changing water resources and ecosystems due to climate change, particularly among those who are vulnerable to the effects of climate change (e.g., farmers and Indigenous persons), and identify potential strategies and resources that support mental health.					●	●	●		All state agencies
Action 4.2: Research community values and beliefs surrounding water, including those of particularly vulnerable communities, and work to integrate those values and beliefs into water resource planning.					●	●	●		All state agencies
Action 4.3: Strengthen networks and build community around water resources through cultural activities and citizen resource monitoring opportunities.					●	●	●		All state agencies
Action 4.4: Improve coordination between state and local emergency managers to identify communities impacted by climate-related water hazards to better target resources and reduce associated physical, emotional and mental stressors.					●	●	●		All state agencies

Water Governance in Minnesota

Water management in Minnesota is complex. Various state, local and federal agencies play roles in every aspect of water management, from water quality to water use to drinking water safety. At the state level, different agencies are charged with distinct but interactive water management roles. These differing purposes (public health, natural resource conservation, pollution prevention, etc.) sometimes overlap and occasionally conflict.

The Clean Water Legacy Act of 2006, which established the Clean Water Fund and the Clean Water Council, and the 2008 Clean Water, Land and Legacy Amendment have served as powerful incentives for state agencies to collaborate and improve the integration of their programs. Collaboration is yielding results in areas as diverse as watershed planning, wetlands management and drinking water protection. However, the sheer number of programs and permit requirements, including those of federal agencies and local governments, can still result in confusion and frustration.

The following chart is a generalized overview of the major water-related programs and authorities of the primary state water management agencies, the Public Facilities Authority (multi-agency) and the Metropolitan Council. Many programs are collaborative efforts among state and federal agencies and local government partners, and funding is frequently passed through to these local partners. The table only shows the primary state agency "home" of each program.

AGENCY	PROGRAM TYPE: Education, Outreach	Planning	Financial Assistance	Technical Training	Oversight	Monitoring	Regulation, Enforcement	Acquisition, Development	Research
Board of Water & Soil Resources									
Wetland Conservation Act	●	●		●	●	●	●	●	
Watershed District and SWCD Oversight, Funding	●		●	●	●				
Watershed Planning (1W1P, Metro, etc.)	●	●	●	●	●				
Conservation Easements			●			●		●	
Multipurpose Drainage Management	●		●	●					
Buffer Program	●		●			●	●		
Environmental Quality Board (EQB)									
State Water Policy Coordination	●	●							
Department of Agriculture (MDA)									
Groundwater Protection Rule	●	●			●		●		
Nitrogen Fertilizer Management Plan	●	●	●	●		●			●
MN Ag Water Quality Certification Program	●		●		●				
Minnesota Water Research Digital Library (MnWRL)	●								
Water Quality Monitoring (Surface and Groundwater) for Agricultural Chemicals	●	●				●			
CWF Technical Assistance and Research	●	●	●	●	●				●
AgBMP Loan Program			●		●				

AGENCY	Education, Outreach	Planning	Financial Assistance	Technical Training	Oversight	Monitoring	Regulation, Enforcement	Acquisition, Development	Research
Department of Health (MDH)									
Source Water Protection Programs	●	●	●	●		●	●		●
Community and Noncommunity Public Water Supply Programs				●	●	●	●	●	
Groundwater Restoration and Protection Strategies	●	●		●					●
Well Management Program	●		●	●	●	●	●		●
Health Risk Assessment Program	●		●	●			●		●
Minnesota Lake Superior Beach Monitoring Program	●					●			
Waterborne Diseases Program	●				●	●			●
Department of Natural Resources (DNR)									
Water Use (Appropriation)	●	●		●	●		●		
Work in Public Waters (Permitting)	●				●		●		
Invasive Species Management	●	●	●	●	●	●	●		●
Floodplain Management, Dam Safety	●	●	●		●	●	●	●	
Shoreland and River-Related Management	●	●		●	●				
Climate Monitoring and Research	●	●		●		●			●
Groundwater Hydrology Programs	●	●	●	●	●	●			●
Surface Water Hydrology Programs	●			●	●	●			●
Lake Superior Coastal Program (Federal-State-Local)	●	●		●	●				
Water Recreation Programs (Fisheries, Waterfowl, Etc.)	●	●	●	●					
Aquatic Habitat Restoration Programs	●		●	●					
Metropolitan Council									
Water Quality Monitoring and Assessment of Metro Area Lakes, Rivers and Streams				●		●			●
Water Supply Planning (Regional Research and Planning, Review of Local Water Supply Plans)	●	●	●	●	●				●
Local Surface Water Management and Planning (Review of City and Township Local Surface Water Management Plans)	●	●		●	●				
Wastewater Treatment	●	●		●			●		●
Watershed Planning (Review and Comment on Local Watershed Management Plans)		●		●					

AGENCY	Education, Outreach	Planning	Financial Assistance	Technical Training	Oversight	Monitoring	Regulation, Enforcement	Acquisition, Development	Research
Pollution Control Agency (MPCA)									
Water Quality Standards	●					●			●
TMDLs, Watershed Restoration and Protection Strategies (WRAPS)	●	●	●	●	●	●	●		●
Stormwater Program (MS4, Construction, Industrial Permitting)				●	●		●		
Wastewater Program, Septic Systems (SSTS)		●		●	●		●		
Feedlot Program				●	●		●		
Water Quality Monitoring and Assessment of Surface Water and Groundwater		●	●	●		●			
Nutrient Reduction Strategy		●			●				
Clean Water Council (Multi-agency)		●	●						
Federal 319 Nonpoint Source Pollution Program			●		●				
Clean Water Partnership Loan Program			●		●				
Chloride Reduction and Prevention	●	●		●					
St. Louis River Area of Concern Lake Superior Lakewide Action and Management Plan (LAMP) (with DNR)	●	●			●	●			●
Public Facilities Authority (PFA) – DEED/MPCA									
Public Facilities Authority (PFA) – DEED/MPCA			●						
Clean Water Revolving Fund			●						
Drinking Water Revolving Fund (PFA/MDH)			●						
Wastewater Infrastructure Fund			●						
Small Communities Wastewater Treatment Program			●						
TMDL Funds			●						
Phosphorus Reduction Grants			●						

PROGRAM TYPE

Source: MPCA

Acknowledgments:

Jeff Berg (MDA)
Kenneth Blumenfeld (DNR)
Erik Cedarleaf Dahl (EQB)
Randall Doneen (DNR)
Annie Felix-Gerth (BWSR)
Andrea Hendrickson (DOT)
Claudia Hochstein (MPCA)
Pooja Kanwar (DNR)
Jennifer Kostrzewski (Met Council)
Faith Krogstad (EQB)
Laura Millberg (MPCA)
Louise Miltich (COMM)
Alycia Overbo (MDH)
Bob Patton (MDA)
Katie Pratt (EQB)
Suzanne Rhees (BWSR)
Jeff Risberg (MPCA)
Judy Sventek (Met Council)
Giuseppe Tumminello (EQB)
David Wall (MPCA)

Edited by:

Mary Hoff, MA

Designed by:

Amanda Scheid (MPCA)

Contributions by:

Kate Brauman, PhD
Barrett Colombo, MS
Bonnie Keeler, PhD
Ryan Noe, MS
Institute on the Environment
University of Minnesota

Mae Davenport, PhD
Amelia (Emily) Kreiter, MS
Center for Changing Landscapes and Department of Forest Resources
University of Minnesota

More Information/References

Source: MPCA

General

Bailey, P. (2020). *Emerging Farmers in Minnesota.* Minnesota Department of Agriculture, Emerging Farmer Working Group. https://www.mda.state.mn.us/emerging-farmer-working-group

Center for Changing Landscapes. (n.d.). University of Minnesota. Retrieved September 02, 2020, from https://www.changinglandscapes.umn.edu/

Fellows, S., Pradhananga, A., Meier, H., Davenport, M., & Pfeifer, S. (2018). *Groundwater Management: Capacity Assessment at the Local Level: A Survey of Minnesota Local Government Units.* Center for Changing Landscapes, University of Minnesota. https://www.changinglandscapes.umn.edu/sites/changinglandscapes.umn.edu/files/mn_lgu_capacity_assessment_for_groundwater_final_technical_report_2018.pdf

Keeler Lab (2020). *Exploring Water Futures Under Climate Change (2016–2019)*. University of Minnesota. https://keeler.umn.edu/portfolio/23-2/

Leiserowitz, A., Maibach, E., Rosenthal, S., Kotcher, J., Bergquist, P., Ballew, M. T., ... Gustafson, A. (2019). *Climate Change in the American Mind: November 2019.* New Haven, CT. https://doi.org/10.31234/osf.io/z3wtx

Minnesota Pollution Control Agency. (2019). *Climate Adaptation Planning Survey*. State of Minnesota. https://www.pca.state.mn.us/sites/default/files/p-gen4-15.pdf

Olson, B., & Davenport, M. A. (2017). An inductive model of farmer conservation decision making for nitrogen management. *Landscape Journal 36*(1), 59–73. https://doi.org/10.3368/lj.36.1.59

Goal 1

Hoppe, B. O., Raab, K. K., Blumenfeld, K. A., & Lundy, J. (2018). Vulnerability assessment of future flood impacts for populations on private wells: utilizing climate projection data for public health adaptation planning. *Climatic Change 148(4)*, 533–546.

Interagency Coordination Team. (2020). *2020 Clean Water Fund Performance Report*. State of Minnesota.

Minnesota Department of Agriculture (2020). *Vegetative Cover in Minnesota: Prospects and Challenges*. State of Minnesota. https://www.mda.state.mn.us/environment-sustainability/additional-clean-water-resources

Minnesota Department of Agriculture. *Groundwater Protection Rule (GPR)*. Retrieved September 02, 2020, from https://www.mda.state.mn.us/nfr

Minnesota Department of Agriculture (2015). *Minnesota Nitrogen Fertilizer Management Plan (NFMP)*. https://www.mda.state.mn.us/pesticide-fertilizer/minnesota-nitrogen-fertilizer-management-plan

Minnesota Department of Agriculture. *Township Testing Program*. https://www.mda.state.mn.us/township-testing-program

Minnesota Department of Health. (2020). Water Quality / Well Testing / Well Disinfection. https://www.health.state.mn.us/communities/environment/water/wells/waterquality/index.html

Minnesota Department of Health. (2019). *Minnesota Drinking Water Annual Report for 2018*. State of Minnesota.

Niehoff, E., & Houseknecht, M. (2020). *Exploring the Development of a Source Water Collaborative*. Environmental Initiative.

University of Minnesota. Forever Green Initiative. (n.d.). *Intermediate Wheatgrass (Kernza)*. https://www.forevergreen.umn.edu/crops-systems/perennial-grains-oilseeds-pulses/kernza

Goal 2

Minnesota Department of Agriculture. (2020) Minnesota Agricultural Water Quality Certification Program (MAWQCP). https://www.mda.state.mn.us/environment-sustainability/minnesota-agricultural-water-quality-certification-program

Minnesota Pollution Control Agency. (2019). *Greenhouse Gas Reduction Potential of Agricultural Best Management Practices*. State of Minnesota. https://www.pca.state.mn.us/air/agriculture-and-climate-change-minnesota

Minnesota Pollution Control Agency. (2014). *The Minnesota Nutrient Reduction Strategy*. State of Minnesota. https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf

Goal 3

Henrick, M., Lenhart C., Kozarek, J., & Nieber, J. (2019). *Minnesota Guide for Stream Connectivity and Aquatic Organism Passage Through Culverts*. University of Minnesota. http://www.dot.state.mn.us/research/reports/2019/201902.pdf

Minnesota Department of Transportation. (2014). *Flash Flood Vulnerability and Adaptation Assessment Pilot Project*. Parsons Brinckerhoff & Federal Highway Administration. http://www.dot.state.mn.us/sustainability/pilotproject.html

Minnesota Department of Transportation (2020). *Transportation Resilience: Current Practices and Opportunities for MnDOT*. http://www.dot.state.mn.us/sustainability/docs/resilience-report-2020.pdf

Minnesota Water and Wastewater Agency Response Network. (2020). *MnWARN—Utilities Helping Utilities*. http://www.mnwarn.org/

Goal 4

Board of Water and Soil Resources. (2020). *Understanding Minnesota Public Drainage Law (UMPDL) Overview*. State of Minnesota. https://bwsr.state.mn.us/understanding-minnesota-public-drainage-law

Conservation Drainage Network. https://conservationdrainage.net/

Minnesota Agricultural Water Resource Center. Discovery Farms Minnesota. https://discoveryfarmsmn.org/

Lewandowski, A., Everett, L., Lenhart, C., Terry, K., Origer, M., & Moore, R. (2015). *Fields to Streams: Managing Water in Rural Landscapes. Part One, Water Shaping the Landscape.* Water Resources Center, University of Minnesota Extension. Retrieved from the University of Minnesota Digital Conservancy. http://hdl.handle.net/11299/177290. *Part Two, Managing Sediment and Water.* Water Resources Center, University of Minnesota Extension. Retrieved from the University of Minnesota Digital Conservancy. http://hdl.handle.net/11299/177291

Minnesota Department of Agriculture. (2020). *Red River Valley Drainage Water Management.* https://www.mda.state.mn.us/protecting/cleanwaterfund/onfarmprojects/rrvdwmproject

Minnesota Department of Agriculture. (2017). *Agricultural Best Management Practices (BMP) Handbook for Minnesota, 2nd edition.* https://www.mda.state.mn.us/protecting/cleanwaterfund/research/handbookupdate

Srinivas, R., Drewitz, M., & Magner, J. (2020). Evaluating watershed-based optimized decision support framework for conservation practice placement in Plum Creek Minnesota. *Journal of Hydrology* 583. https://doi.org/10.1016/j.jhydrol.2020.124573

Transforming Drainage. (2020). *Transforming Drainage: Managing Water for Tomorrow's Agriculture.* https://transformingdrainage.org/

Goal 5

Minnesota Department of Health. (2020). Beaches and Recreational Waters in Minnesota. https://www.health.state.mn.us/communities/environment/recreation/beaches/monitoring.html

Minnesota Department of Health. (2019). *Minnesota Department of Health Climate & Health Strategic Plan: An Update on Program Successes and Next Steps.* State of Minnesota. https://www.health.state.mn.us/communities/environment/climate/docs/progressreport.pdf

Minnesota Department of Health. (2020). Wellbeing & Climate Change. https://www.health.state.mn.us/communities/environment/climate/wellbeing.html

Minnesota Department of Natural Resources. (2020). Climate Change and Minnesota. https://www.dnr.state.mn.us/climate/climate_change_info/index.html

Minnesota Department of Natural Resources. (2019). *Minnesota Statewide Comprehensive Outdoor Recreation Plan.* State of Minnesota. https://files.dnr.state.mn.us/aboutdnr/reports/scorp_final_2024.pdf

Minnesota Pollution Control Agency (2020). Plan to Reduce Mercury Releases by 2025. https://www.pca.state.mn.us/water/plan-reduce-mercury-releases-2025

Water quality

September 2020

Appendix A: Five-year Assessment of Water Quality Trends and Prevention Efforts

MINNESOTA POLLUTION CONTROL AGENCY

Prepared by:
Dave Tollefson, Mike MacDonald, Kim Kaiser, Brennon Schafer, Jeff Berg (Minnesota Department of Agriculture, Pesticide and Fertilizer Management Division) and, Pam Anderson, Sharon Kroening, Erik Smith, Andrew Streitz (Minnesota Pollution Control Agency, Environmental Outcomes and Analysis Division) for the Minnesota Environmental Quality Board.

Minnesota Pollution Control Agency
520 Lafayette Road North, Saint Paul, MN 55155-4194
http://www.pca.state.mn.us
651-296-6300 or
800-657-3864 toll free
TTY 651-282-5332 or
800-657-3864 toll free
Available in alternative formats

Minnesota Department of Agriculture 625 Robert Street North, Saint Paul, MN 55155-2538
http://www.mda.state.mn.us 651-201-6141 or
800-967-2474 toll free
TDD 800-627-3529 toll free
Available in alternative formats

Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 |

651-296-6300 | 800-657-3864 | Or use your preferred relay service. | Info.pca@state.mn.us

This report is available in alternative formats upon request, and online at www.pca.state.mn.us.

Document number: lrwq-gw-1sy20

Contents

Tables

Figures

Introduction and Executive summary

This Minnesota Pollution Control Agency (MPCA) and the Minnesota Department of Agriculture (MDA) water quality assessment provides an overview of relevant monitoring data and efforts to reduce, prevent, minimize, and eliminate sources of water pollution to Minnesota's groundwater and surface water resources. This report consolidates information from a number of the most recent reports on the status and trends of Minnesota's water resources. Because of the large amount of information available on this subject, this report is summary in nature and directs the reader to additional information provided through web-based links.

The report was last published in September of 2015 as Appendix A: Five-year Assessment of Water Quality Trends and Prevention Efforts, in conjunction with Beyond the Status Quo: 2015 EQB Water Policy Report and can be found at: https://www.eqb.state.mn.us/sites/default/files/documents/App%20A%20Five-year%20Assessment%20of%20Water%20Qual%28final%29.pdf.

This report includes much of the work completed as part of the Clean Water, Land and Legacy Amendment (Clean Water Fund) investment, which includes the Minnesota's Clean Water Roadmap and the 2020 Clean Water Fund Performance Report. These two reports represent the efforts of six state agencies and the Metropolitan Council, receiving Clean Water Funding, to set long range goals to protect, enhance, and restore the state's water resources. Information on the Clean Water Fund can be found at: http://www.legacy.leg.mn/funds/clean-water-fund.

Information on groundwater quality is presented first, highlighting nitrates, pesticides, arsenic, chlorides, and contaminants of emerging concern. The groundwater information is followed by descriptions of the efforts to prevent and eliminate groundwater degradation through program activities conducted by the MPCA and MDA.

Surface water quality information is presented next by water resource type (lakes, streams, and wetlands) and emphasizes the status and trends of Minnesota's surface water quality. Lake transparency data, pesticide detections, trends in water quality indicator parameters, and impaired waters listings are presented to highlight Minnesota's surface water quality condition.

For both groundwater and surface water, efforts to reduce and minimize resource degradation involve multiple program activities conducted by the MPCA and MDA. Efforts summarized in this report include the Pesticide and Fertilizer Registration and Outreach Programs, Agricultural and Pesticide Best Management Plan Programs, Nitrogen Fertilizer Management Plan, Clean Water Partnership Program, regulation of wastewater discharges and subsurface sewage treatment systems (SSTS), Animal Feedlot Program, Stormwater Program, and MDA and MPCA monitoring and assessments efforts.

Within the last 20 to 30 years, most of the pollution originating from point sources (municipal and industrial facilities discharging to state waters) has been controlled, largely due to remediation programs, pollution prevention activities, and permit regulations. Water quality is mainly degraded by the pollutants entering surface waters from non-point sources derived from runoff from land, particularly from watersheds dominated by agricultural and urban land use. This report will focus primarily on non-point sources of pollution of anthropogenic (human) origin that require our continued efforts to realize our state's water quality goals.

It is important to remember that groundwater and surface waters are part of a single, interconnected hydrological system. Therefore, while monitoring assessment and reporting techniques may vary between groundwater, lakes, streams and wetlands, these water resources should not be viewed in isolation from each other.

Overview: Water resources – Benefits of information

The MPCA and MDA conduct water quality assessments to protect the environment and, more specifically, to provide decision makers with good information about the status of water resources, to prevent and address problems, and to evaluate how effective management actions have been. Water quality assessments are also useful in planning and implementing prevention and mitigation efforts to protect water resources, and as a means of tracking the impacts of human activity.

This report provides access to a variety of water quality reports, documents and agency plans, and highlights the status of our water quality resources, in addition to efforts to reduce and minimize water resource degradation.

Five-year water assessments are prepared directly by the agencies and integrated by the Environmental Quality Board (EQB) every five years. The frequency of reports was changed from two- years to five-years in 2015 because groundwater and surface water trends typically do not change within shorter periods of time, thus frequent reporting is not effective or useful. In addition, the five-year cycle will tie monitoring results to planning and management efforts via state water planning and be in accordance with Minn. Stat. 103A.43.

Groundwater basics

Groundwater provides nearly 75% of Minnesotans with their primary source of drinking water and nearly 90% of the water used for agricultural irrigation (estimated by the Minnesota Department of Health (MDH) and the Minnesota Department of Natural Resources (MDNR), respectively). For these reasons, alone it is important that we protect, monitor and report on the quality of this valuable natural resource.

The MPCA and MDA collect large amounts of groundwater quality data. Much of this is collected through contamination cleanup or landfill programs and is considered investigation and compliance monitoring. However, data is also collected through ambient or “condition” groundwater monitoring efforts. Ambient monitoring has two primary objectives: to determine the status and quality of the groundwater resources, and to identify trends in water quality over time.

To understand groundwater quality, it is important to recognize that groundwater occurs everywhere in Minnesota within water-bearing soil or rock formations called aquifers (Figure 1). These aquifers create a complex matrix of groundwater resources in many areas of the state that may yield either abundant or very limited water supplies. The water quality in these aquifers is influenced by both natural processes and anthropogenic (human) ones. This report focuses on reporting the ambient condition of groundwater quality in Minnesota as influenced by anthropogenic effects, with less emphasis on natural processes which affect groundwater quality.

Monitoring of Minnesota’s groundwater has identified contamination in many vulnerable aquifers from non-point sources such as agricultural fertilizers and pesticides, urban runoff, manure applications, septic systems, road salt, and stormwater infiltration. The most common contaminants detected include nitrates, pesticides, and, in urban areas, road salt. In addition, chemicals that are not commonly monitored or regulated are being identified at low concentrations in groundwater, including: antibiotics, fire retardants, detergents, and plasticizers. This group of chemicals is referred to as contaminants of emerging concern (CECs) and includes endocrine active chemicals (EACs).

Surface water basics

With more than 10,000 lakes, 100,000-river and stream miles, and about 9.3 million wetland acres, water is a major part of Minnesota's culture, economy, and natural ecosystems. Streams, rivers, lakes, and wetlands are all "surface waters" in Minnesota. State agencies and their partners have an important function in assessing surface waters for contaminants and documenting surface water quality trends.

The MPCA follows a 10-year rotation for assessing waters of the state in Minnesota's 80 major watersheds (Figure 2). This is supplemented by annual monitoring at the outlets of the major watersheds to provide an overview of statewide water quality and identify trends. The first iteration of this monitoring cycle has been completed and monitoring is returning to watersheds in order to track progress towards meeting water quality goals. About 56% of surface waters do not meet basic water quality standards. The MDA focuses on agricultural and urban areas where agricultural chemicals, like pesticides, are used and may impact surface water resources. The major watershed approach provides an important unifying focus for all stakeholders. More detail on the watershed approach can be found at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/basins-and-watersheds/watershed-approach.html.

Minnesota's surface water monitoring has identified that in many vulnerable hydrogeologic settings the source of contamination within a watershed can be attributed to several of the same non-point sources affecting groundwater, e.g., agricultural fertilizers and pesticides, urban runoff, and septic systems, as well as to municipal and industrial wastewater. Some of the most common impacts to surface water come from sediment, phosphorus (agricultural, industrial and residential), coliform bacteria, nitrate, mercury and pesticides. As with groundwater, CECs are commonly being found, even in remote surface waters. Concerns for these pollutants in surface waters include the potential effects of endocrine disrupting compounds that affect aquatic life and reproduction, and human health impacts from bioaccumulation of chemicals, particularly per- and polyfluoroalkyl substances (PFAS), in fish tissue.

Figure 1. Minnesota groundwater provinces

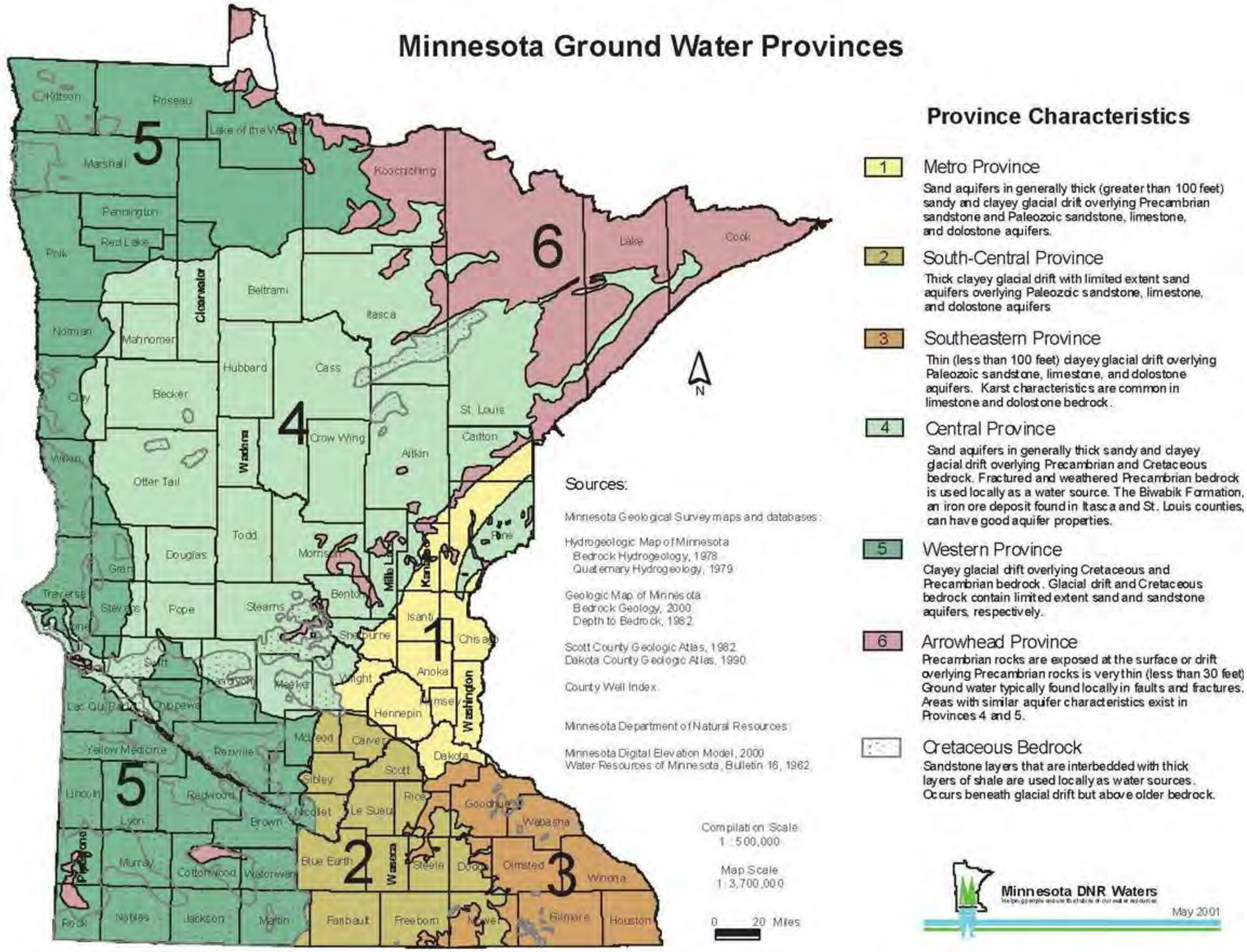
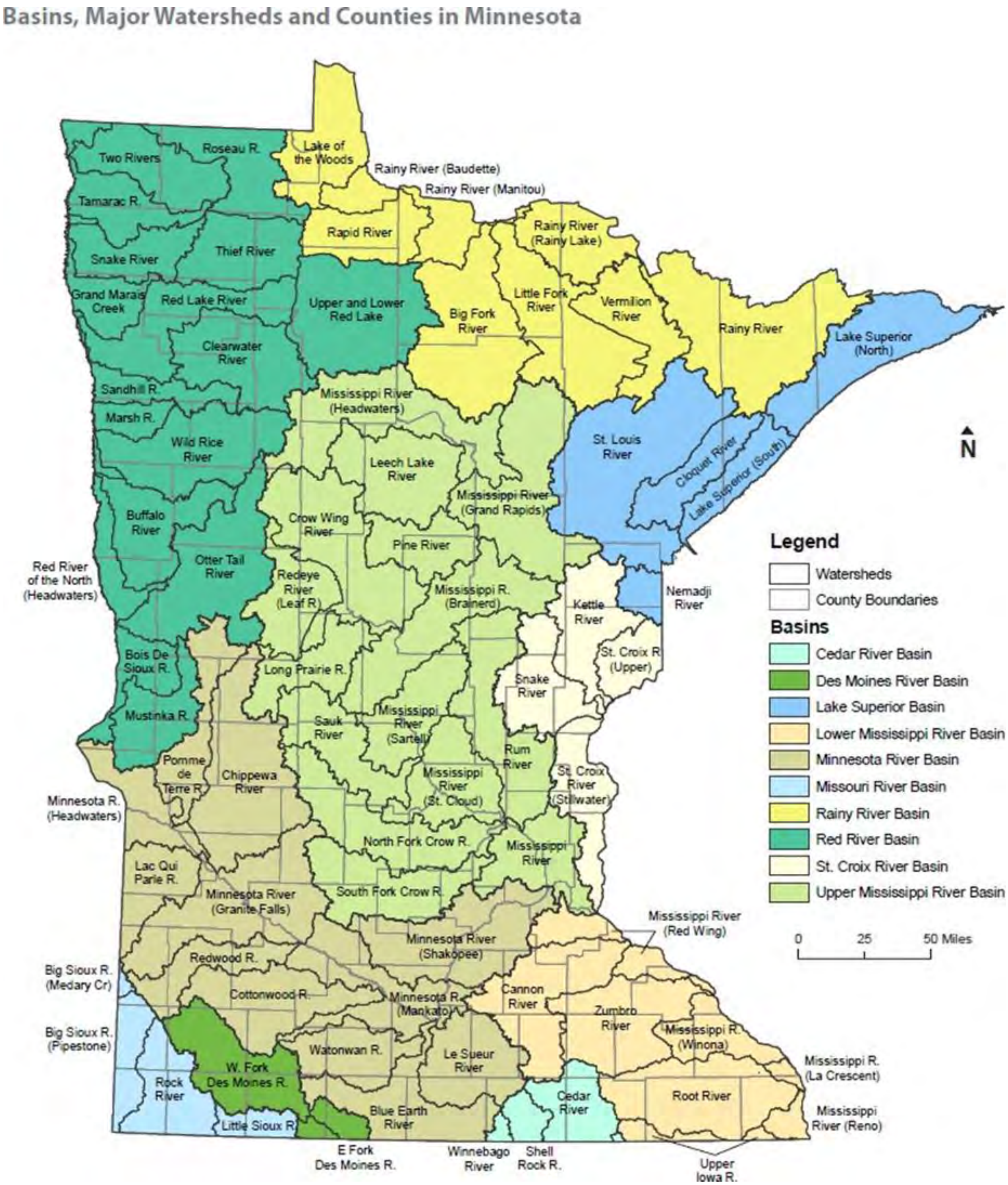


Figure 2. Basins, major watersheds and counties in Minnesota



Water quality concerns

Water resource contaminants can come from human or natural sources. Some contaminants, like arsenic, occur naturally due to geologic materials dissolved in aquifers. Arsenic can also come from human sources like industrial processes and products. Some contaminants are primarily a concern for groundwater (e.g., nitrate, arsenic and chloride) while others are primarily a concern for surface water (e.g., phosphorus and sediments).

The MPCA and MDA have tracked several key contaminants for years, while other contaminants of emerging concern have recently been discovered, in part due to new analytical capabilities, and are just beginning to be studied. The water quality analyses contained in this summary include both historical key contaminants and those of emerging concern.

Important water resource contaminants reviewed in this summary, include: nitrate/nitrogen, chloride, arsenic, pesticides, PFAS, and CECs in groundwater aquifers. The status of surface water quality is reported by water resource (lakes, wetlands, streams,) and includes summaries of impairment status and surface water quality trends for several contaminants. Additional information about these and other contaminants can be found in the source documents cited throughout this summary.

The distinction between various groundwater and surface water resources – and their contaminants – can at times be difficult to make, due the many interactions between lakes, wetlands, streams, and aquifers. However, the statutes that guide MPCA and MDA monitoring and reporting requirements are often aligned along specific water resources and related terms. Thus, while a contaminant may principally be assessed in a surface water resource (e.g., lakes and wetlands), that same contaminant may also move to groundwater resources via infiltration from the surface water body to the aquifer. Similarly, a groundwater contaminant could migrate to surface water through upwelling.

Complicating matters, the impacts to groundwater (drinking water concerns, etc.), and the rate of contaminant degradation in the aquifer may be different from those associated with surface water resources, and subject to unique monitoring methods, spatial and temporal considerations, and risk evaluation.

This report provides an overall picture of water quality with respect to several contaminants, while recognizing statutory requirements for different agencies to monitor and protect specific water resources from specific contaminants.

Groundwater quality: Assessment and analysis

Presented below is information on groundwater quality and trends for select contaminants of known or emerging concern. Additional detail and data for various groundwater monitoring projects and other contaminants in state aquifers and watersheds can be found in MPCA publications at: https://www.pca.state.mn.us/water/groundwater-data and in the MDA publications at: https://www.mda.state.mn.us/pesticide-fertilizer/pesticide-overview.

Nitrate/nitrogen

Nitrogen in groundwater is primarily present in the form of nitrate (represented chemically as NO_3^-) and occurs naturally at low concentrations of less than 1.0 mg/L. Studies of groundwater quality in Minnesota over the last two decades have linked elevated nitrate concentrations to land uses where there are anthropogenic (human-caused) sources of nitrate in combination with vulnerable geology.

Most nitrate which enters groundwater comes from anthropogenic sources such as animal manure, fertilizers used on agricultural crops, failing subsurface sewage treatment systems (SSTS), fertilizers used at residences and commercially, and nitrous oxides from the combustion of coal and gas. With this array of sources, it is not surprising that nitrate is one of the most common contaminants of groundwater in Minnesota.

Nitrate concentrations in groundwater are monitored by the MPCA and MDA, in urban and rural settings, as a part of their ambient groundwater monitoring programs. The MDA, MPCA, MDH work collaboratively on a number of fronts to address nitrate contamination and assist state and local efforts aimed at protecting drinking water supplies and preventing further groundwater contamination. Other state and federal agencies such as the MDNR and United States Geological Survey (USGS) have also generated groundwater nitrate data through regional studies of the groundwater.

The MPCA's involvement with nitrate contamination includes providing a framework for local administration of SSTS programs, and administration of the feedlot and storm water programs. The MPCA also monitors nitrate in the ambient groundwater underlying urban parts of the state and has conducted several studies of nitrate concentrations in groundwater relative to non- agricultural land uses.

The most recent MPCA report on ambient groundwater quality (Kroening and Vaughan 2019) found that the amount of nitrate contamination in the state's groundwater remained the same over time. Trends were tested over 2005-2017 using over 100 wells, and the majority of the tested sites showed no significant trend.

High nitrate concentrations primarily were an issue in agricultural parts of the state, where 49 percent of the tested wells installed near the water table exceeded 10 mg/L, the MDH health risk limit (HRL)[1] that sets the safe level of nitrate in drinking water. In contrast, less than five percent of the sampled wells installed near the water table in urban areas had nitrate concentrations that exceeded 10 mg/L.

[1] An MDH-derived HRL is the concentration of a chemical in drinking water that, based on the current level of scientific understanding, is likely to pose little or no health risk to humans, including vulnerable subpopulations. HRLs are promulgated in rule.

The high nitrate concentrations observed near the water table most likely resulted from human activities. Concentrations in the groundwater generally decreased with depth, which suggests the source was applied to the land surface.

Geology also has a large influence on nitrate transport to the state's groundwater. In 2013, the Minnesota Geological Survey and MPCA partnered to investigate the geologic controls on nitrate transport to the bedrock aquifers underlying southeastern Minnesota. Thick sand and gravel or clay deposits (> 50 feet) were found to sufficiently retard the flow of water and any associated contaminants like nitrate, resulting in low concentrations in the underlying bedrock aquifers. The transport of nitrate to underlying bedrock aquifers also was influenced by the confining units that separate them like the Dubuque, Decorah, or Glenwood shales. These confining units generally limit the vertical transport of water and any nitrate contamination and results in low concentrations in the underlying aquifers.

For agricultural uses, nitrate is included as an analyte in MDA monitoring efforts, as described and reported at: https://www.mda.state.mn.us/pesticide-fertilizer/monitoring-nitrate-groundwater

Nitrate sampling from the MDA's 2019 annual ambient monitoring programs showed that 89% of the shallow groundwater samples collected had detectable levels of nitrates, with 37% exceeding the MDH HRL of 10 mg/L. The Central Sands and East Central portions of Minnesota had the highest percent detection at concentrations exceeding the HRL (58 and 38 percent, respectively). These settings represent the most sensitive conditions and may not be representative of some deeper, local aquifer systems used for drinking water.

Private well nitrate monitoring

To evaluate nitrate concentrations and trends in groundwater, MDA and local partners have established regional networks that monitor nitrate in private wells. Currently there are two regional networks established, one in the southeast karst region and one in the central sands areas. These areas of the state are the most vulnerable to groundwater contamination. Sampling of private wells within these areas provides a systematic basis to evaluate nitrate concentrations using the same private wells over several years. The data collected from private well owners is useful for evaluating long-term trends and indicates whether nitrate in groundwater is a concern in these vulnerable aquifers. Participation by homeowners is voluntary. One challenge in this design occurs when homeowners decide to drop out. This tends to be most prevalent when nitrate levels are either non-detectable or very high, introducing inconsistency, and possible bias into the data set. Nevertheless, regional monitoring of private wells provides a logical way to monitor groundwater contamination by monitoring the same wells over multiple years.

Southeast volunteer nitrate monitoring network results

Drinking water quality is a concern across southeastern Minnesota due to highly variable hydrogeologic conditions that allow for rapid movement of water and contaminants in groundwater. In 2008, the Southeast Minnesota Water Resources Board (SEMNWRB), and several partners (MPCA, MDA, MDH) began collecting data from the "volunteer nitrate monitoring network" (VNMN). This region was selected as a pilot because of its vulnerable and complex geology. The network was developed to assess the practicality of establishing a cost-effective, locally driven means of obtaining long-term data on nitrate concentrations in private drinking water supplies. Nitrate concentrations were tested in approximately 600 private drinking water wells across nine counties in southeastern Minnesota. The wells were monitored to determine the impact that well construction and local land use have on drinking water quality, and to describe the regional distribution of nitrate concentrations and any temporal trends.

Between February 2008 and August 2019, 14 sampling events occurred representing approximately 5778 samples. During this period, the percentage of wells exceeding the HRL for each sampling event ranged between 7.5 and 14.6 percent (Table 1). Additional information can be found at: https://www.mda.state.mn.us/southeast-minnesota-volunteer-nitrate-monitoring-network and https://wrl.mnpals.net/islandora/object/WRLrepository%3A3395/datastream/PDF/view.

Table 1. Summary of nitrate-N concentration results for the Southeast Volunteer Nitrate Monitoring Network 2008-2019

Southeast Volunteer Nitrate Monitoring Network					
Year	Total Wells	50th Percentile (Median)	90th Percentile	% of Wells ≥10	% of Wells <10
		Nitrate-N mg/L			
2/1/2008	519	0.3	12.0	14.6%	85.4%
8/1/2008	510	0.3	11.0	11.4%	88.6%
2/1/2009	494	0.2	11.0	11.1%	88.9%
8/1/2009	471	0.3	11.5	11.0%	89.0%
8/1/2010	422	0.7	9.5	9.2%	90.8%
8/1/2011	428	0.6	10.0	10.3%	89.7%
8/1/2012	411	0.4	8.8	7.5%	92.5%
8/1/2013	315	0.1	8.8	8.3%	91.7%
8/1/2014	361	0.2	9.4	8.9%	91.1%
8/1/2015	373	0.2	9.4	8.8%	91.2%
8/2/2016	387	0.3	10.8	10.9%	89.1%
8/1/2017	341	<0.25	10.1	10.0%	90.0%
8/1/2018	389	0.3	9.5	9.0%	91.0%
8/1/2019	357	<0.25	9.0	8.7%	91.3%

MDA central sands private well monitoring network results

Due to the success of the southeast volunteer nitrate monitoring network, as well as the availability of funding from the Clean Water Legacy Amendment, the MDA launched a similar project in the Central Sands area of Minnesota. The MDA determined that because high levels of nitrate have been measured in Central Sands monitoring wells, it was important to expand nitrate monitoring to private drinking water wells. If the concentrations were similar to concentrations found in the monitoring wells, there could be concern for human health. In the spring of 2011, the MDA began the Central Sands Private Well Monitoring Network (CSPWN). The goals of this project were to evaluate nitrate concentrations in private wells across the Central Sands region and assess nitrate concentration trends over time using a representative subset of this data.

Homeowners from 14 counties in agricultural areas in the Central Sands were randomly invited to participate in the network. By July 1, 2011, the MDA had analyzed 1,555 samples for nitrate. Over 88% of the wells sampled had nitrate-N concentrations below 3 mg/L, 6.8% of the wells ranged from 3-10 mg/L of nitrate-and 4.6% were greater than the 10 mg/L nitrate HRL (Table 2).

Table 2. Summary of nitrate-N concentrations for the Central Sands Private Well Network (2011)

Number of Samples	Min (mg/L)	Median (mg/L)	75th Percentile (mg/L)	90th Percentile (mg/L)	Maximum (mg/L)	% ≤ 3 mg/L	% 3<10 mg/L	% ≥10 mg/L
1,555	<0.03	0.01	0.66	4.15	31.9	88.6%	6.8%	4.6%

Starting in 2012, approximately 550 homeowners volunteered to participate in long-term annual sampling of their private wells. These 550 homeowners were a subset of the original testing population of 1,555. Results from 2011 through 2019 indicate minimal variation in nitrate concentration over time. The 2019 results indicate 2.3% of the wells had nitrate concentrations greater than or equal to 10 mg/L nitrate-N (Table 3). Overall, 95.5-97.8% of wells in the CSPWN have been below the 10 mg/L HRL for nitrate-N. The highest nitrate result was detected in a well with an unknown aquifer source, however, elevated concentrations can be found throughout the water table to the buried quaternary aquifers. Further information about this project can be found at: https://www.mda.state.mn.us/central-sands-private-well-network and at: https://wrl.mnpals.net/islandora/object/WRLrepository%3A3395/datastream/PDF/view

Table 3. Summary of nitrate-N concentration results for the Central Sands Private Well Network (2011 – 2019)

Year	Total wells	50th Percentile (median)	90th percentile	% ≥ 10	% < 10
		nitrate-N (mg/L)			
2011	534	<0.03	3.3	3.9%	96.1%
2012	506	0.20	3.6	3.2%	96.8%
2013	487	0.20	3.6	2.7%	97.3%
2014	432	<0.03	3.2	3.5%	96.5%
2015	402	<0.03	3.5	4.5%	95.5%
2016	397	<0.03	3.0	3.5%	96.5%
2017	367	<0.03	3.3	2.2%	97.8%
2018	338	<0.03	3.0	3.0%	97.0%
2019	305	<0.03	3.1	2.3%	97.7%

Township testing program

The MDA conducted a major revision of the Nitrogen Fertilizer Management Plan (NFMP). The plan calls for an assessment of nitrate conditions at the township scale. The MDA determines current nitrate-nitrogen concentrations in private wells through the Township Testing Program. The MDA has identified townships throughout the state that are vulnerable to groundwater contamination and have significant row crop production. More than 90,000 private well owners have been offered nitrate testing in 344 townships since 2013 (Figure 3 presents the township testing schedule).

The MDA works with local partners such as counties and soil and water conservation districts (SWCDs) to coordinate private well nitrate testing using Clean Water Funds. Each selected township is offered testing in two steps, the "initial" sampling and the "follow-up" sampling.

In the initial sampling, all township homeowners using private wells are sent a nitrate test kit and the homeowner takes the sample. If nitrate is detected in their initial sample, the homeowner is offered a follow-up nitrate test, pesticide test and well site visit. Trained MDA staff visit willing homeowners to resample the well and then conduct a site assessment. The assessment helps to identify possible non-fertilizer sources of nitrate and to see the condition of the well. A well with construction problems may be more susceptible to contamination.

Initial results

As of March 2020, 344 vulnerable townships from 50 counties participated in the TTP from 2013 to 2019 (Table 4). In the 344 townships tested, 143 townships (41%) have 10% or more of the wells over the HRL for nitrate. In contrast, it was determined that in 133 townships less than 5% of the wells were over the HRL for nitrate.

Overall, 9.1% (2,925) of the 32,217 wells exceeded the HRL for nitrate. Table 5 shows the percentage of wells over the HRL for each township during the initial sampling. These results reflect nitrate concentrations in private well drinking water regardless of nitrogen sources, or well construction. The final percentage of wells over the HRL may change based on follow-up sampling and site visits.

Table 4. Number of townships in each nitrate concentration range.

Nitrate concentration criteria	Number of townships (2013-2019)
<5% of wells in a township ≥10 mg/L*	133
5%-9.9% wells in a township ≥10 mg/L	68
≥10% wells in a township ≥10 mg/L	143
Total	344

*nitrate - mg/L or parts per million (ppm)

Table 5. Initial Township testing well results of nitrate 2013-2019.

Total wells	<3 mg/L* Number of wells	3 - <10 mg/L* Number of wells	≥10 mg/L* Number of wells	≥10 mg/L* percent
32,217	24,791	4,501	2,925	9.1%

*nitrate - mg/L or parts per million (ppm)

Next steps

Once the follow-up sampling is completed, the MDA conducts an analysis of the results and prepares a final report for each county. In Figure 4, townships with hash lines are not yet final (first year) and townships without hash lines are final. Final results are determined using two rounds of sampling and a process to remove wells with construction concerns, insufficient construction information and those near potential non-fertilizer sources of nitrate. Wells are also removed from the final data set if homeowners do not participate in the second round of testing. Final results represent wells that are potentially impacted by a fertilizer source, while initial results represent private well drinking water regardless of source or the condition of the well. Detailed sampling results are available at: www.mda.state.mn.us/townshiptesting.

The MDA uses the results to prioritize future work to address nitrate concerns, as described in the NFMP. Find more information about the NFMP at: www.mda.state.mn.us/nfmp.

Figure 3. Township testing schedule (2013-2019)

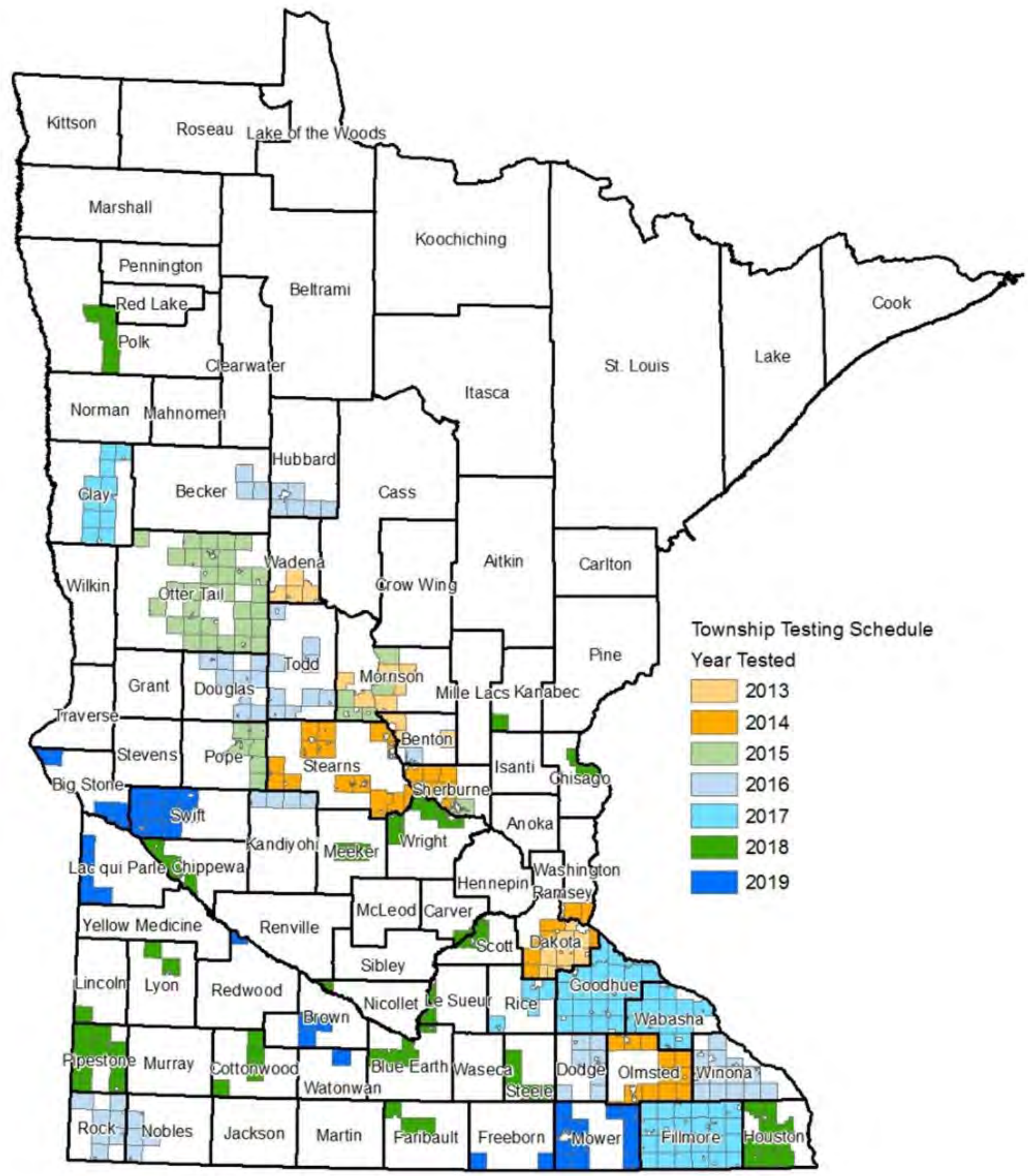
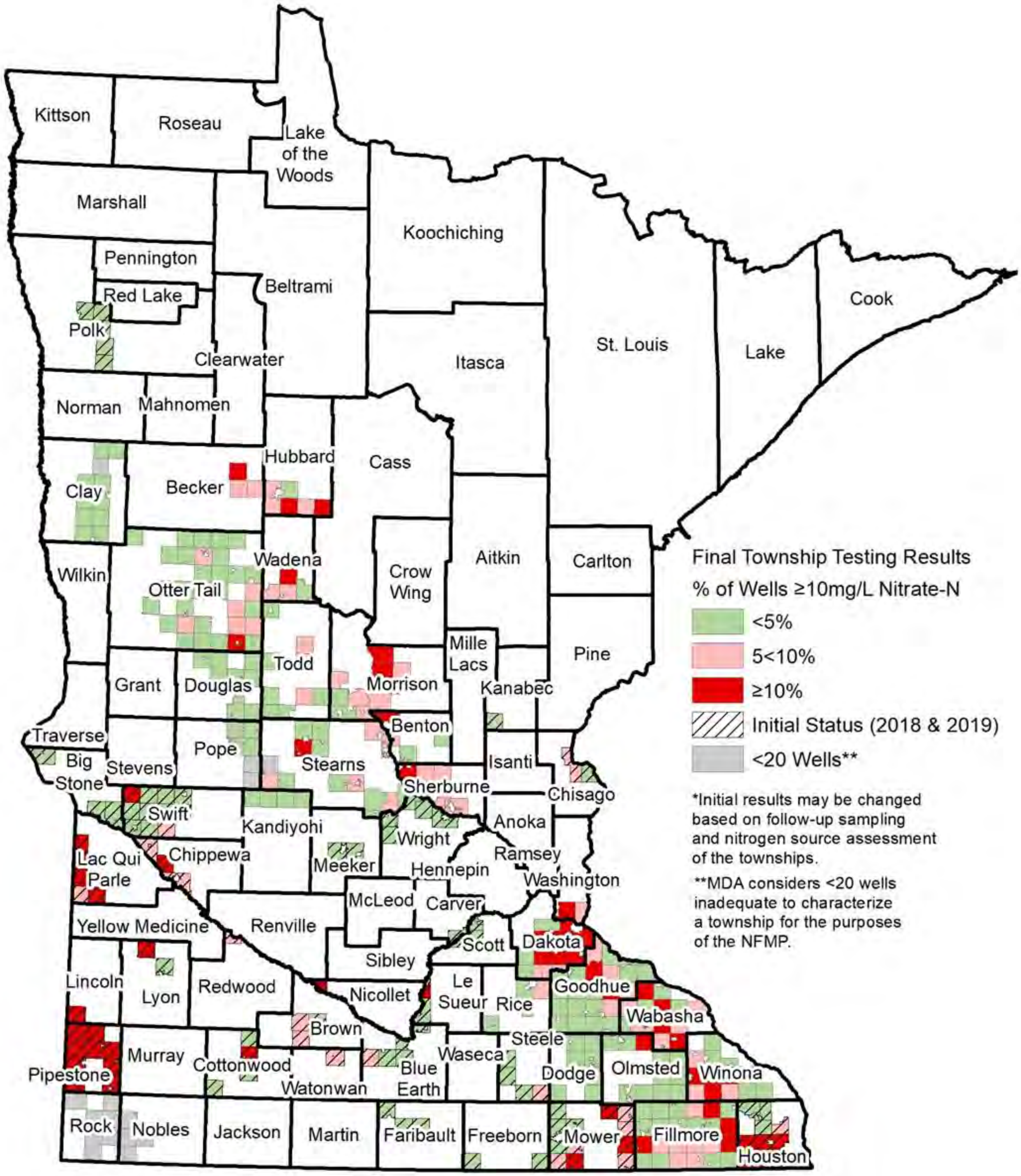


Figure 4. Final Township testing results



Pesticides

Ambient Groundwater Monitoring Network

MDA's groundwater monitoring network provides information on impacts to the state's groundwater from the routine use of agricultural chemicals. Information is made available so management decisions can be made to reduce or eliminate impacts to groundwater. The MDA began monitoring groundwater in 1985 and redesigned the program in 1998. New wells were installed in 1999, and the MDA began sampling the re-designed network wells in 2000.

Samples were collected from 166 groundwater monitoring sites in 2019 (Figure 5). Of these sites, 142 consisted of one or more specifically designed and installed monitoring or observation wells, 11 were private drinking water wells, and 13 consisted of naturally occurring springs emerging from bedrock formations of interest in the southeastern karst area of the state. All of the locations are considered sensitive to contamination from activities at the surface. Network design and sampling protocols are available in the program's groundwater design document on the MDA website at: [https://www.mda.state.mn.us/monitoring.](https://www.mda.state.mn.us/monitoring)

The MDA Laboratory has continued to expand their analytical capabilities, resulting in an increase in the number of compounds evaluated. In 2014, 133 different pesticide compounds were evaluated; by 2019, that number rose to 166. The MDA laboratory has also been able to lower the detection limit for some pesticides, meaning lower concentrations can be found and measured. Forty-seven different pesticides or pesticide degradates were detected in groundwater in 2019. Although exceedances of established reference values (which denote levels of pesticides that could possibly have adverse effects) have historically been very rare, in 2019, the total concentration of cyanazine and its degradates exceeded the cyanazine HRL in one sample collected from a spring in southeastern Minnesota. A subsequent sample had concentrations below the HRL. Cyanazine degradates were added to the MDA Laboratory method in 2019.

In accordance with statutory requirements in the Groundwater Protection Act (Minn. Stat. chapter 103H) and the Pesticide Management Plan, the MDA has determined that five pesticides are commonly detected in groundwater, leading to the development of Best Management Practices to prevent or reduce ongoing degradation of groundwater resources. The five "common detection" pesticides are agricultural herbicides including: acetochlor, alachlor, atrazine, metolachlor and metribuzin.

Figure 5 presents the number of "common detection" pesticides detected at each sampling site in 2019. The locations showing the greatest number of pesticides per site are concentrated in the central sand plains (Pesticide Monitoring Region 4), east central (Pesticide Monitoring Region 5), and in southeastern Minnesota (Pesticide Monitoring Region 9).

Metolachlor ESA (a degradate of the herbicide metolachlor) was the most commonly detected pesticide compound within the MDA dataset in 2019. The most extensive dataset for assessing changes in metolachlor ESA impacts to groundwater over time is the concentration data from Pesticide Monitoring Region 4. Concentration and detection frequency time-trend data for metolachlor ESA is presented in Figure 6 using the median, 75th percentile, and 90th percentile concentration and detection frequency values for 2002 through 2019. Time-trend analysis on median values is the most widely accepted measure on which to base decisions. The median values indicate a statistically significant increasing trend in concentrations for this period. The trend of the frequency of detection for metolachlor ESA in PMR 4 has also risen in a statistically significant fashion for this period. In 2019, the highest concentration measured for metolachlor ESA was 12,500 ng/L in PMR 4, which is substantially lower than the Health Risk Limit of 800,000 ng/L.

Neonicotinoid insecticides were first analyzed by the MDA in groundwater samples in 2010. Currently, MDA analyzes water samples for six neonicotinoid parent pesticides and two degradates including: acetamiprid, imidacloprid, thiamethoxam, clothianidin (analysis began in mid-2011), dinotefuran (analysis began in 2012), thiacloprid (analysis began in 2014), and the degradates imidacloprid-urea and imidacloprid-olefin (analysis began in 2017). Clothianidin, imidacloprid, and thiamethoxam have been detected in groundwater in agricultural areas. Imidacloprid has been detected twice in urban groundwater samples. All detections have been below applicable reference values. Acetamiprid, the imidacloprid degradates, dinotefuran, and thiacloprid have not been detected in groundwater.

Additional information about detections, concentrations and time-trend analysis for pesticides can be found in the MDA's annual monitoring reports under "Reports and Resources" at: https://www.mda.state.mn.us/monitoring.

Private well pesticide sampling

The MDA is conducting monitoring to assess impacts of pesticides to private drinking water wells in vulnerable areas (see Township Testing Program section above for details) and provide information to well owners about pesticide presence in their drinking water. The MDA began collecting samples for pesticide analysis in private wells where nitrate was previously detected through the Township Testing Program in 2014. The sampling is scheduled to continue through the summer of 2020. A summary of the results is reported in the MDA's annual monitoring report (https://www.mda.state.mn.us/monitoring).

During the 2014-2015 Private Well Pesticide Sampling (PWPS) Project monitoring effort, a pesticide analytical method was used which was limited to 22 different pesticide compounds. Pesticides were detected above the laboratory method reporting limits in six of the private drinking water well samples (0.3%). Pesticide detections occurred in one well in Benton, Olmsted, Sherburne, and Stearns Counties and two wells in Washington County.

Based on the results of the 2014-2015 sampling, the MDA contracted with a different analytical laboratory capable of analyzing for approximately 125 pesticide related chemicals with lower reporting limits. The MDA plans to offer retesting to well owners in the counties sampled in 2014-2015 using the new laboratory method.

Approximately 4,966 wells were sampled in 2016-2019 using the new laboratory method. All samples were analyzed for at least 125 pesticide and pesticide degradates. Results indicate that pesticides or pesticide degradates were detected in 75% of the wells tested. There were 73 different pesticides and degradates found. Consistent with the MDA's ambient network monitoring, metolachlor ESA was the most frequently detected compound. During the 2016-2018 sampling, three wells exceeded a drinking water reference value (for diuron (herbicide), methyl parathion (insecticide), and cyfluthrin (insecticide)). Verification samples from these three wells were non-detect. During the 2019 sampling, 29 wells exceeded a HRL for total cyanazine. Verification sampling from the same locations indicated that most of the water samples at these locations continued to be above HRLs.

In 2019, the MDA began analyzing the samples in both the ambient program and the PWPS Project for cyanazine degradates. Cyanazine was a popular corn herbicide that was discontinued from use after 2002. Dakota County Environmental Resources Department has sampled wells within the county for cyanazine and cyanazine degradates and has detected concentrations of these degradates that, when added together, exceeded the HRL for cyanazine. Until 2019, the United States Geological Survey (USGS) Organic Geochemistry Research Laboratory was the only laboratory in the United States that was able to analyze for these compounds. In 2019, the MDA Laboratory developed an analytical method to test for these compounds. The cyanazine degradates were added to the regular suite of pesticide compounds analyzed for by the ambient monitoring program. The MDA contract laboratory used for the PWPS

Project also added these compounds to their analyte suite. In 2019, approximately 3% of PWPS wells were found to have cyanazine degradate concentrations that exceeded the HRL for total cyanazine. The MDA is working with MDH to develop a comprehensive plan to assess the extent of these compounds in drinking water. Additional information on cyanazine monitoring including an evaluation of reverse osmosis point-of-use water treatment systems can be found at: https://www.mda.state.mn.us/cyanazine-monitoring.

Figure 5. Number of common detection pesticides detected in MDA groundwater samples per site in 2019. (The MDA's 10 Pesticide Monitoring Regions are outlined in bold).

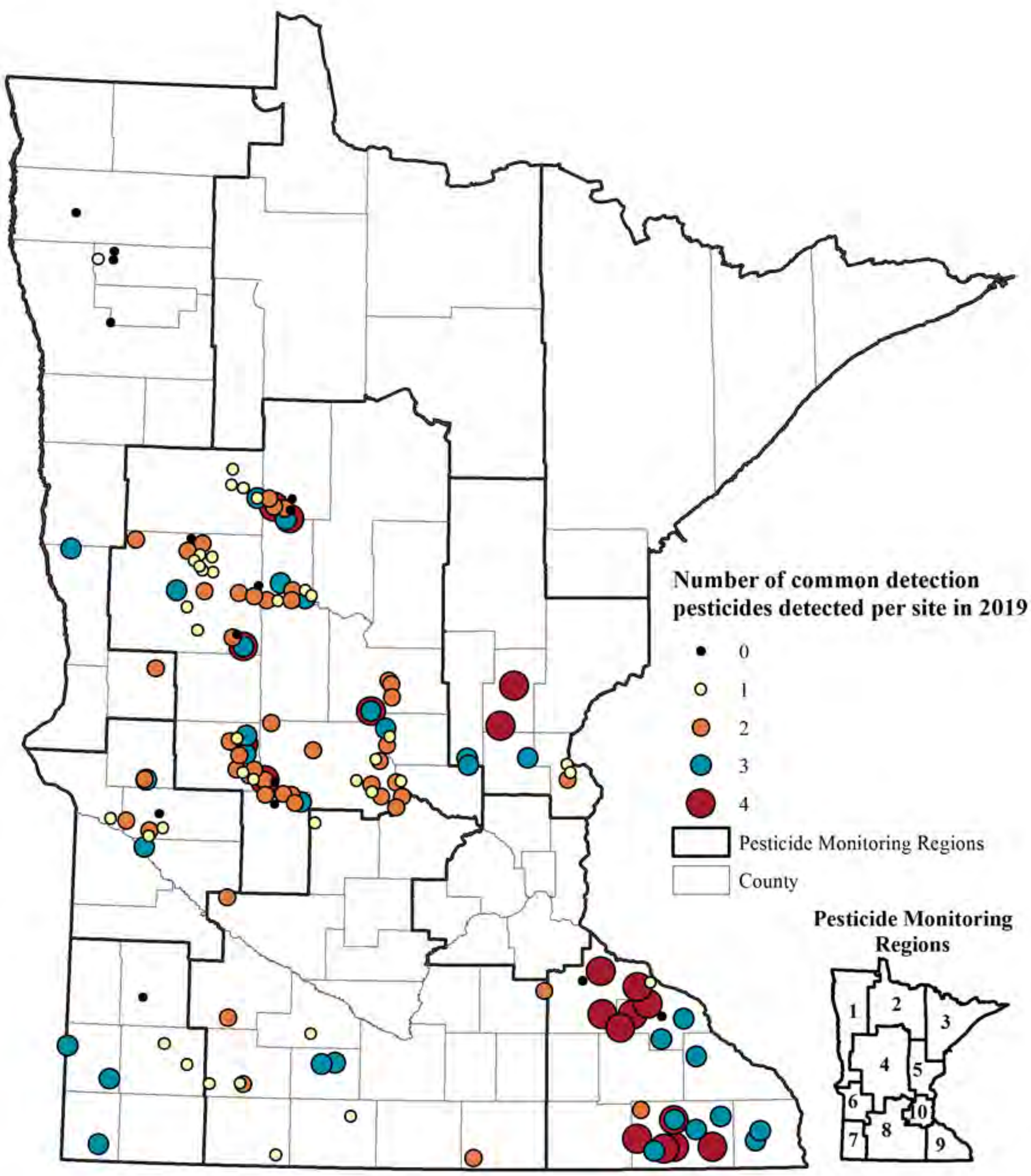
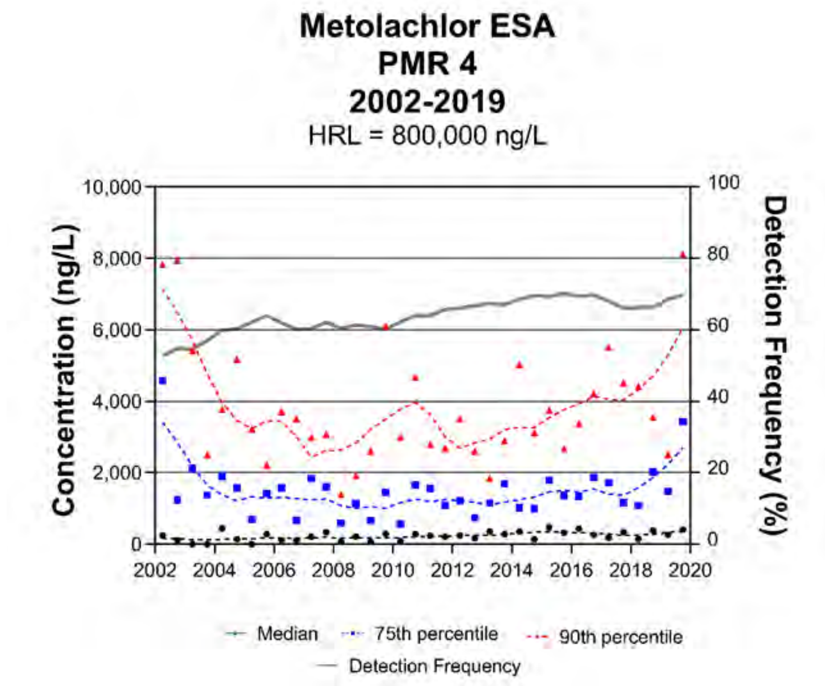


Figure 6. Metolachlor ESA, a Metolachlor degradate, groundwater sample analysis results over time for the Central Sands monitoring network (PMR 4). Trend analysis performed for this period indicates a statistically significant increase in median concentration and detection frequency.



Arsenic

Arsenic is an element that occurs naturally in soil and rock and can dissolve into groundwater, the primary drinking water source for Minnesota residents. Arsenic can occur in groundwater just about anywhere in Minnesota, but the highest concentrations generally occur in the Twin Cities area and western Minnesota. Consuming water containing low levels of arsenic can be detrimental to human health. The US EPA has set a Maximum Contaminant Level (MCL) of 10 µg/L for arsenic in drinking water. The MDH estimates that, based on monitoring data, about 10 percent of all wells in Minnesota have natural arsenic levels above the MCL. More information on arsenic in Minnesota's groundwater is available from the MDH at: https://apps.health.state.mn.us/mndata/arsenic_wells.

Most monitoring and research on arsenic in the state's groundwater is conducted by the MDH due to the effects on some of the state's drinking water. Since 2008, the MDH has required all new water-supply wells be tested for arsenic contamination, and about 10 percent of these wells have arsenic concentrations exceeding 10 µg/L.

The MDH recently partnered with the US Geological Survey (USGS) on several studies to better understand how much arsenic is in the water at newly-constructed wells, best ways to collect arsenic samples from wells, and the factors that affect arsenic concentrations in the groundwater. Testing newly-constructed wells for arsenic is complicated by the well construction process, which can temporarily change whether arsenic is dissolved from the aquifer material into the groundwater. This occurs because the drilling process used at most water-supply wells temporarily changes the geochemical conditions in the aquifer that affect arsenic mobilization. A recent study by the MDH and USGS examined how much arsenic concentrations changed over the course of one year in the well water from 250 newly-drilled wells (Erickson et al, 2019). This study found that arsenic concentrations did not significantly change in the bedrock aquifer wells tested during the study, but concentrations increased by 16 percent or more in one-quarter of the in the sand and gravel aquifer wells.

The sample collection process also affects the amount of arsenic measured in the water taken from a new water supply well. Currently, a variety of methods and sampling points are used to collect arsenic samples from newly-constructed water-supply wells because the sampling protocol is not specific in the state well code. Another recent study by the USGS and MDH examined the effect of the sample collection protocol on arsenic concentrations from newly-installed water-supply wells (Erickson et al, 2018). This study found that the variability in measured concentrations was reduced when the samples were filtered, collected from the household plumbing instead of the drill rig pump, and collected several months after well installation (instead of within 4 weeks of well installation).

The USGS and MDH also partnered together to develop a statistical model that assessed the relation between arsenic concentrations in the groundwater and hydrogeologic, geochemical, and well construction factors (Erickson et al, 2018). Smaller distances between the top of the well screen and the overlying till or glacial lake deposit confining unit and shorter well screen lengths were associated with higher probabilities of elevated arsenic concentrations in the groundwater. Variables describing aquifer properties and materials, position on the hydrologic landscape, and soil geochemistry were among the most influential for predicting the probability of elevated arsenic in the groundwater.

Chloride

Excessive chloride concentrations in groundwater restrict its use for drinking and can be harmful to fish and other freshwater aquatic life if transported to surface waters. Chloride is highly mobile in the environment and once in the environment, is extremely difficult to remove. MPCA's monitoring of Minnesota's groundwater has detected elevated concentrations of chloride within specific land use settings.

The most recent MPCA report on statewide groundwater quality found that high chloride concentrations result generally from the human use of this substance, such as pavement de-icing or water softening. The distribution of chloride concentrations in the state's various aquifers and the chemical signature of the water suggest a human-caused chloride source in most locations where chloride was found. Concentrations generally are stratified in the groundwater, with the highest concentrations near the water table and the lowest in the deepest aquifers. This distribution suggests the chloride was transported into the groundwater from a land surface source. The chemical signature also suggested that most chloride of the groundwater in the majority of the tested wells in urban areas resulted from sources such as salt used to de-ice pavement or soften water.

Concentrations are typically highest in the groundwater near the water table in the Twin Cities Metropolitan Area (TCMA). Most of the tested water table wells with chloride concentrations greater than the state's drinking water standard of 250 mg/L were located in the TCMA. In the Prairie du Chien-Jordan aquifer, an important drinking water source in southeastern Minnesota, the highest chloride concentrations generally occur where the aquifer is close to the land surface and overlain by a thin layer of unconsolidated deposits. These areas include the eastern TCMA and the Prairie du Chien Plateau.

MPCA's monitoring also found that chloride concentrations were highest in water table wells underlying urban parts of the state. The highest median concentration (81.9 mg/L) was found in wells underlying commercial/industrial areas, and the second highest median concentration was found in wells underlying sewered residential areas. The lowest median concentration (1.1 mg/L) was in wells underlying undeveloped forested parts of the state.

The MPCA also routinely examines whether chloride concentrations are changing in the groundwater. The last analysis focused on recent changes from 2005-2017. Overall, 40 percent of the wells included in this trend analysis had an upward trend in chloride concentrations. The wells with upward trends were not just restricted to the water table; the majority of them were installed in bedrock aquifers.

Additional details of chloride in Minnesota's groundwater are presented in the MPCA's most recent report on groundwater quality at: https://www.pca.state.mn.us/sites/default/files/wq-am1-10.pdf.

Contaminants of Emerging Concern (CECs) and Per- and Polyfluoroalkylsubstances (PFAS)

Contaminants of Emerging Concern (CECs) have been identified in both Minnesota's groundwater and surface water. The MPCA has analyzed for CECs in the ambient groundwater since 2009. The monitoring has targeted shallower wells to provide an early warning of groundwater contamination, focusing on different urban land use settings. To date, the agency has sampled over 250 wells in its monitoring network for over 200 different CECs.

CECs were detected in a substantial number of the network wells, which mainly are located in settings that are naturally vulnerable to human-caused pollution. From 2013-2017, CECs were detected in 124 of the 262 sampled wells. Ninety-five percent of the sampled wells had seven or fewer CECs in the water, and the average number of CECs detected per well was 1.6.

The most commonly detected CECs in the groundwater are chemicals that are known to be persistent in the environment. The most-frequently detected CECs in the groundwater from 2013-2017 were sulfamethoxazole, tris(1,3-dichlroro-2-propyl) phosphate (TDCPP), iopamidol, and branched p-nonylphenols. Sulfamethoxazole is an antibiotic used to treat bacterial infections. TDCPP is commonly used as a flame retardant as well as a pesticide, plasticizer, and nerve gas. Iopamidol is a radio-opaque contrast agent, which is used for x-ray imaging. Branched p-nonylphenols is a mixture of chemicals that are used to manufacture nonanionic surfactants.

The CEC concentrations measured to date have generally been low; no concentrations exceed any established human-health guidance values. However, many of the CECs measured in groundwater do not have established human-health guidance.

The MDA collaborates with and provides assistance to the MPCA and MDH as appropriate and when agricultural chemical use and regulation overlap with interagency CEC concerns.

Additional details of CECs occurring in Minnesota's environment can be found at MPCA http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and- pollutants/endocrine-disrupting-compounds.html and at MDA www.mda.state.mn.us/monitoring.

PFAS are a family of over 6,000 synthetic chemicals that have been used for decades to make products that resist heat, oil, stains, grease, and water.[2] Since the early 2000s, some companies in the fluorochemical industry have worked with the Environmental Protection Agency to phase out the production and use of the long-chain perfluoroalkyl compounds and their precursors, but chemicals in this class are still used in many products, including fire-fighting foams, lubricants, packaging, metal-plating, clothing, and other consumer and industrial products.

The presence of PFAS in the environment and the resulting exposure is a concern because these chemicals accumulate in humans and animals and several of them are known to be toxic. PFAS

[2] PFAS were previously called perfluorochemicals, or PFCs.

have been found in fish, reptiles, and mammals all over the globe, and these chemicals biomagnify in birds and marine mammals. Toxicity studies indicate that some PFAS cause developmental problems to fetuses, cancer, liver damage, and immune and thyroid effects. In Minnesota, the MDH has set human health guidance for five PFAS: perfluorobutanoic acid (PFBA), perfluorobutane sulfonate, perfluorohexane sulfonate, perfluorooctanoic acid (PFOA), and perfluorooctane sulfonate (PFOS).

The MPCA sampled the ambient groundwater for PFAS in 2013, 2017, and 2019. The 2013 sampling event was statewide and included almost 200 wells. The 2017 event was smaller and focused on the 12 wells that had the highest concentrations measured in 2013, in order to determine whether concentrations changed. Both sampling events measured a small number of PFAS, primarily 13 perfluoroalkyl carboxylates and sulfonates. The 2019 sampling included all 261 testing sites in the ambient network and revealed that 60% of wells had detectable PFAS, with nine wells showing concentrations of PFOA or PFOS exceeding health-based guidance values. This monitoring effort has revealed that PFAS are present in areas with no known sources of contamination.

The 2013 sampling event found that PFBA was the most commonly detected PFAS in the ambient groundwater. This chemical was found in almost 70 percent of the sampled wells. The highest PFBA concentration (1,680 ng/L), which was well below the 7,000 ng/L human health guidance set by MDH, was measured in a domestic water supply well in Washington County.

PFAS detections and concentrations in the ambient groundwater also were associated with urban land use. The 2013 study found that one or two PFAS typically were detected in the ambient groundwater in urban areas, but these chemicals typically were not detected in the groundwater underlying undeveloped, forested areas. This pattern suggests that most of the PFAS measured in the ambient groundwater originated from chemicals disposed to the land surface rather than atmospheric deposition.

PFOA was detected in about 30% of the wells tested in 2013. Eight of these wells contained water with concentrations that exceeded the health based value (HBV) of 35 ng/L set in 2017.[3]

PFOS was detected in about 12% of the wells tested in 2013. Seven of the well contained water with concentrations that exceeded the 15 ng/L HBV set by MDH in 2019.

The MPCA and MDH also continued to sample drinking water supply wells in the eastern TCMA. In 2020, both agencies expect to sample approximately 1,500 wells. Sampling or resampling wells is prioritized based on wells not previously sampled, but in areas where: 1) currently data indicates groundwater exceeds human health guidance, 2) wells where PFAS were detected in a previous sample and future monitoring is needed, and 3) wells already on regular monitoring schedules near PFAS waste disposal sites and in areas with changing PFAS concentrations.

Additional details of PFAS occurring in Minnesota's ambient groundwater can be found at: https://www.pca.state.mn.us/sites/default/files/wq-am4-02.pdf.

[3] MDH derives HBVs using the same methods as HRLs. Thus, an HBV is also the concentration of a chemical in drinking water that, based on the current level of scientific understanding, is likely to pose little or no health risk to humans, including vulnerable subpopulations. However, HBVs have not yet been promulgated in rule.

Information on PFAS investigation and cleanup can be found at: http://www.pca.state.mn.us/index.php/waste/waste-and-cleanup/cleanup/superfund/perfluorochemicals-pfc/perfluorochemicals-pfcs.html.
More information on the MPCA and MDH's water-supply well sampling for PFAS in the eastern TCMA can be found at: https://www.pca.state.mn.us/waste/well-sampling-east-metro-area.

Groundwater quality: Reducing, preventing, minimizing and eliminating degradation

Minnesota has been a leader in addressing many sources of ground-water contamination such as Superfund sites, leaking underground storage tanks (LUST), agrichemical incident cleanup, voluntary investigation and cleanup (Brownfield) sites, landfills, and more. Additionally, examples of Minnesota's strong pollution prevention programs include effective permitting and secondary containment requirements for a variety of industrial and public activities. Minnesota has long had one of the strongest pesticide groundwater monitoring programs in the nation, dedicated to the establishment of long-term monitoring well networks in diverse agricultural regions, as well as individual studies to assess specific issues.

In the past, Minnesota has focused its limited state resources on cleanup, source control, and direct protection efforts, and required groundwater monitoring at many sites to determine individual facilities' compliance. More resources are now dedicated to monitoring for changes in local and regional groundwater quality as a result of these efforts. In recent years, Minnesota has increased its emphasis on nonpoint sources, which should result in increased implementation of Best Management Practices (BMPs) that address nonpoint source pollution concerns such as feedlots, manure management, and agrichemical application. A copy of the updated report, "Best Management Practices and Data Needs for Groundwater Protection, April 2019", is available at:
https://www.pca.state.mn.us/sites/default/files/wq-gw1-08.pdf

Efforts to reduce, minimize, prevent and eliminate the degradation of Minnesota's groundwater resources are in almost all cases directed at the source of a specific contaminant or group of contaminants (point source or non-point source) and conducted on a programmatic level by the responsible government agency. The following discussion presents the efforts of MDA and MPCA programs to control (reduce, minimize, prevent and eliminate) specific contaminants or groups of contaminants by their source.

Nitrate/nitrogen

The MPCA and MDA manage a number of different programs that prevent and reduce nitrate impacts to waters of the state. The MPCA and MDA also partner with the MDH in source water protection area program efforts. To prevent water quality degradation MDA, MPCA and MDH programs use a combination of regulatory tools that include: discharge limits, permit requirements, environmental and technical reviews, facility inspections, operator training, technical assistance, compliance and enforcement, guidance documents, fact sheets, BMPs, and more. Some examples of these programs are described below:

Animal Feedlots – Animal manure contains significant quantities of nitrogen which, if improperly managed, can lead to nitrate contamination of surface and groundwater. The animal feedlot program regulates the land application and storage of manure in accordance with Minnesota Rules Chapter 7020 for approximately 25,000 registered feedlots, as well as 5,000 to 10,000 unregistered smaller feedlots in Minnesota. The feedlot program requires that the land application of manure and its storage in manure storage basins is conducted in a manner that prevents nitrate contamination of waters of the state. A new permit for feedlots to take effect in February of 2021 contains requirements meant to mitigate nitrate leaching and prevent manure-contaminated runoff. Details are available on the MPCA website at: https://www.pca.state.mn.us/water/2021-npdes-general-permit.

Manure management plans, facility inspections, permitting, technical assistance and record keeping are all used to manage nitrogen impacts to water quality. In general, there are more feedlot sites than can be evaluated for groundwater degradation, beyond a few of the larger facilities.

Additional information on the Feedlot Program can be found on the MPCA website at: http://www.pca.state.mn.us/index.php/topics/feedlots/feedlots.html.

Subsurface Sewage Treatment Systems (SSTS) – As of 2017, there are approximately 537,354 septic systems across the state. SSTS that do not provide adequate separation between the bottom of the drainfield and seasonally saturated soil are considered to be systems that are failing to protect groundwater. The percent of systems failing to protect groundwater decreased from 117,000 (25%) in 2008 to 74,451 (12%) systems in 2017; a decrease of 42,549 systems. The wastewater in SSTSs contains bacteria, viruses, parasites, nutrients and some chemicals. SSTSs discharge treated sewage into the soil for treatment, ultimately traveling to the groundwater. In some cases the sewage is pretreated before soil dispersal. Additionally, non-compliant SSTSs located adjacent to surface waters can discharge untreated contaminants to these surface waters and cause excessive aquatic plant growth leading to degradation in water quality. Therefore, SSTSs must be properly sited, designed, built and maintained to minimize the potential for disease transmission and contamination of groundwater and surface waters.

The SSTS program is engaged in a number of different efforts to prevent and minimize impacts to water quality degradation that can be found on the MPCA website at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/subsurface-sewage-treatment-system-ssts/index.html.

Nutrient Management – The MDA nutrient management programs help identify potential sources of nitrate contamination and evaluate and implement practices and tools to reduce nitrate in groundwater**.** The goal of these programs is to prevent or minimize nitrate losses from nitrogen fertilizer in accordance with the Ground Water Protection Act (Minn. Stat. chapter 103H). The Ground Water Protection Act requires that MDA work to properly manage nutrients and to adequately protect groundwater from their impacts.

Nitrogen Fertilizer Management Plan**:** The Nitrogen Fertilizer Management Plan (NFMP) outlines how the MDA addresses elevated nitrate levels in groundwater. The purpose of the NFMP is to prevent, evaluate and mitigate nonpoint source pollution from nitrogen fertilizer in groundwater. The NFMP provides the blue print for the MDA's activities to address nitrate in groundwater. It outlines three major activities: 1) prevention, 2) monitoring and prioritization and 3) mitigation.

Nutrient management programs occur statewide, however, there is a greater focus in areas of the state that are vulnerable to groundwater contamination. Much of this effort is directed to implementation of the NFMP and development of best management practices (BMPs) for nitrogen fertilizer use. The MDA works with many important partners including soil and water conservation districts, counties, farmers, agricultural dealers, the University of Minnesota and local communities.

In March 2015, the MDA completed the revised NFMP. First developed in 1990, the NFMP is the state's blueprint for prevention or minimization of the impacts of nitrogen fertilizer on groundwater. This revision process updated the plan to reflect current water protection activities and integrate new scientific information about groundwater protection. In addition, the revision better aligns the plan with current water resource programs. The plan was updated in 2019 to reflect the passage of the groundwater protection rule, which can be found at: www.mda.state.mn.us/nfr.

Groundwater Protection Rule: The state's new Groundwater Protection Rule (GPR) became effective on June 24, 2019. The GPR will reduce the risk of nitrate from fertilizer impacting groundwater in areas of the state where soils are prone to leaching and where drinking water supplies are threatened. Nitrate is one of the most common contaminants in Minnesota's groundwater. Elevated nitrate levels in drinking water can pose serious health concerns for humans. The rule restricts fall application of nitrogen fertilizer in areas vulnerable to contamination, and it outlines steps to reduce the severity of the problem in areas where nitrate in public water supply wells is already elevated. More details on the rule, can be found at: https://www.mda.state.mn.us/nfr.

Research and Technical Assistance to develop and promote nitrogen fertilizer BMPs: The MDA is the lead agency for developing and evaluating agricultural best management practices. The MDA works closely with University of Minnesota (U of M) to develop, promote, and provide education on nitrogen fertilizer BMPs.

Research: The MDA supports applied research projects to identify processes that affect water quality and evaluate the costs and benefits of specific agricultural practices. As a result, best management practices (BMPs) are developed and evaluated to protect and restore water resources. Since 2008, the MDA has supported 40 research projects through their Clean Water Research Program; 16 of these projects have elevated practices to reduce nitrate-nitrogen loss. Examples of these practices include nitrification inhibitors, optical sensing tools, perennial and vegetative cover for water quality benefits, and treatment of agricultural drainage systems.

The MDA supports additional research projects that will provide a better understanding of nitrogen fertilizer management and the associated water quality impacts on irrigated, sandy soils. Information on these projects at Rosholt Farm in Westport can be found at: https://www.mda.state.mn.us/protecting/cleanwaterfund/gwdwprotection/rosholtfarm.

To further understand nitrate in groundwater, the MDA is supporting an ongoing research project to calibrate and refine computer-based modeling tools to estimate nitrate leaching losses to groundwater from different cropland and nitrogen management scenarios. Groundwater modeling (EPIC and SWAT) is being conducted to evaluate nitrate losses to groundwater in Drinking Water Supply Management Areas (DWSMA) where nitrate in groundwater is a concern. These predictive tools estimate changes in nitrate loading based on changes in cropland use and a range of nitrogen management practices and will help the MDA in implementation of the GPR and the NFMP.

Technical Assistance: The MDA supports three positions at the University of Minnesota-Extension to develop and promote best management practices. This includes two Agricultural Water Quality Protection positions located in areas with vulnerable groundwater (southeast and central Minnesota) and an irrigation water quality specialist who develops guidance and provides education on irrigation and nitrogen BMPs. The irrigation position was requested by the irrigator community to provide greater outreach and education. Details can be found at: https://www.mda.state.mn.us/node/1313

The MDA works with local partners to assess groundwater in agricultural areas and works directly with farmers and agri-business in areas that are vulnerable to nitrate contamination. These activities include technical assistance and on-farm demonstration sites. Overall, the MDA works with 38 local partners on nitrate monitoring and reduction activities. For example, the MDA partners with East Otter Tail Soil and

Water Conservation District to support activities in central Minnesota. Partners offer an irrigation scheduler program and access to local weather data (Ag Weather Network).

***Nutrient Management Initiative*:** The Nutrient Management Initiative (NMI) provides a simple tool for farmers to evaluate their current nutrient management practices compared with an alternative practice on their own field. Participants often work with a certified crop adviser, who assists with site design, and validates cropping information, and yield results. The goal is for farmers to evaluate practices that may improve nitrogen efficiency by lowering fertilizer inputs. Farmers can compare nitrogen rates, timing or use of a stabilizer product. Many of the NMI sites are located in southeast Minnesota and complement the Southeast Region Grant that is supporting on farm BMP demonstrations, U of M fertilizer BMP trials, and farmer-to-farmer nitrogen management learning groups. More information can be found at: https://www.mda.state.mn.us/protecting/cleanwaterfund/onfarmprojects/nmi.

Discovery Farms Minnesota is a farmer-led effort to gather field scale water quality information from different types of farming systems, in landscapes all across Minnesota. The goal is to provide practical, credible, site-specific information to enable better farm management. Discovery Farms is a collaborative program between farmers, the Minnesota Agricultural Water Resources Center (MAWRC), the MDA, the University of Minnesota Extension, soil and water conservation districts and watershed districts throughout the state. The program began in 2010 and currently has 12 farms in 12 counties throughout Minnesota. The program is designed to collect accurate measurements of sediment, nitrogen and phosphorus movement over the soil surface and through subsurface drainage tiles. This work leads to a better understanding of the relationship between agricultural management and water quality. More information about the program can be found at: http://www.discoveryfarmsmn.org/.

Arsenic

Since 2008, state regulations have required all newly constructed drinking water wells be tested for arsenic before being placed into service. If no arsenic is detected, further testing is not necessary. If arsenic is detected above the MCL of 10 µg/L in water used for drinking and cooking, the MDH recommends installing a treatment system or finding an alternate source of drinking water and provides an instructional Q&A on the MDA website at:
https://www.health.state.mn.us/communities/environment/water/wells/waterquality/arsenic.html.

Chloride

The MPCA recently developed a draft statewide chloride management plan (CMP). The statewide CMP characterizes the water resources across Minnesota, the overall impacts of chloride on them, and includes implementation strategies, monitoring recommendations, and measurement and tracking of results in a performance-based adaptive approach for the entire state of Minnesota. The statewide CMP is an adaption of the Twin Cities Metropolitan Area chloride management plan and includes all statewide chloride sources, stakeholder groups, and management techniques.

Streams interact with groundwater and the causes of chloride contamination to surface waters in the seven county TCMA are in part due to contributions from groundwater with elevated chloride concentrations discharging into streams. Implementation of the BMPs in the statewide CMP will help protect groundwater as a source of drinking water and its contribution to stream baseflow and other surface water bodies.

The draft statewide CMP is available at: https://www.pca.state.mn.us/water/draft-statewide-chloride-management-plan, in addition to the project website at: https://www.pca.state.mn.us/water/statewide-chloride-resources.

Hazardous waste site clean-ups

Efforts to prevent and reduce hazardous substance degradation of Minnesota's groundwater resources have included the cleanup of soils, groundwater and soil vapors at VOC contaminant release sites, in addition to pollution prevention (P2) programs.

Cleanup (Remediation) – Over the past 30 years, MPCA's cleanup (Remediation) programs including the petroleum remediation, Superfund, Hazardous Waste, Closed Landfill, Spills, and voluntary investigation and cleanup (Brownfields) programs have addressed the contamination of groundwater from hazardous substances at thousands of chemical release sites. The main focus of remediation activities is the cleanup of soil, groundwater and soil vapor to control human exposure to hazardous substances. This includes insuring that the quality of the groundwater we drink meets drinking water standards.

Emerging issues for the remediation programs include vapor intrusion into homes and other buildings as a result of historic releases of volatile organic compounds (VOCs) into soil and groundwater and the reduction of drinking water quality standards for a number of hazardous substances that require additional efforts at sites that previously were considered safe.

The remediation programs have worked on a cumulative total of 28,945 sites since 1990. There are 2,017 sites that remain open, where cleanup activities (remediation) have yet to be completed. The reduction in these groundwater contaminant sites has been a result of remediation efforts, preventative programs and a change in societal and business knowledge and ethics. The number of contaminant sites that are "open" compared to the cumulative number of sites on a per program basis are provided on a program-by-program basis in Table 2.

Several of the remaining cleanup sites have long-term operation and maintenance activities such as the CLP - Closed Landfill Program, where all 110 sites are under operation and maintenance. Overall, the remediation of these sites in tandem with pollution prevention and environmental regulation have prevented and reduced most controllable causes of hazardous substance releases to the environment, however, hazardous substance releases may continue to occur as a result of spills and other accidents. Historic releases along with emerging concerns will continue to require significant effort by the remediation programs into the future to limit risk to human health and the environment.

Table 6. Number of remediation contaminant sites that are "open" compared to the cumulative number of sites on a per program basis

Program	Open	Cumulative
Petroleum Remediation	616	19,780
Superfund Program	263	547
VIC (Brownfields)	1,075	8,119
RCRA (Haz. Waste sites)	58	389
CLP (Closed Landfills)	5	110
Total	**2,017**	**28,945**

Additional details of efforts to prevent and clean-up hazardous substances in the environment can be found on the MPCA website at: https://www.pca.state.mn.us/waste/superfund-program#:~:text=Superfund%20Program,human%20health%20or%20the%20environment, and in the

Superfund 2017 - 2018 bi-annual legislative report at: https://www.pca.state.mn.us/sites/default/files/lrc-s-1sy19.pdf

Pollution Prevention – Pollution prevention is the best way to avoid the risk posed by contaminants to groundwater resources. Pollution prevention means eliminating or reducing at the source, the use, generation or release of toxic chemicals, hazardous substances and hazardous waste. Examples of pollution prevention include waste reduction and use of less persistent and less toxic chemicals. Some of the Best Management Practices (BMPs) to decrease the risk of contamination include: proper storage of VOC-containing chemicals; proper disposal of VOC-containing waste; locating water supply wells upgradient of VOC sources; and locating industries in areas where aquifers are less sensitive.

The MPCA in partnership with the Minnesota Technical Assistance Program (MnTAP) and Retired Engineers Technical Assistance Program (ReTAP) provides technical assistance and financial assistance for businesses and institutions seeking ways to reduce waste to achieve pollution prevention goals. For 2008 and 2009, pollution prevention technical assistance efforts resulted in 6.8 million pounds of waste reduced, 1.3 million pounds of materials reused, 104 million gallons of water conserved, 15.5 million kWh and 780,000 therms of energy conserved for a savings of $8.7 million. By January 1, 2013, technical assistance at specific facilities is projected to reduce the amount of pollution generated by 10% from 2008 levels. Current reporting of pollution prevention efforts can be found on the MPCA webpage for Pollution Prevention activities at: https://www.pca.state.mn.us/quick-links/pollution-prevention.

Agricultural chemical site clean-ups

The MDA actively prevents and reduces degradation of Minnesota's groundwater resources from investigations and cleanups at agricultural chemicals at storage, manufacturing and distribution sites.

Cleanup (Remediation) – Since 1989, MDA's cleanup programs including the Superfund, Comprehensive, Emergency Response (Spills) and Voluntary Investigation and Cleanup (Brownfields) programs have addressed the contamination of groundwater from agricultural chemicals at hundreds of primarily pesticide and fertilizer storage, manufacturing or distribution sites, and at thousands of emergency spill sites. This is accomplished through the oversight of investigation and cleanup of agricultural chemicals in groundwater, surface water, soil, sediment and air from historical releases at these agricultural chemical sites, and the immediate cleanup of spilled agricultural chemicals. These activities help to ensure that the concentrations of agricultural chemicals in groundwater at these sites are reduced and meet drinking water guidance values.

Emerging issues for the MDA remediation programs include the analysis of newer pesticides that require more advanced and expensive laboratory analytical methods to ensure that these pesticides are included in site investigations and cleanups.

The MDA remediation programs have worked on a cumulative total of over 7000 sites. Work on these sites has included the elimination or reduction of agricultural chemical contamination of groundwater, surface water, soil, sediment, air and private and municipal drinking water or industrial supply wells. The MDA has additional sites that are not currently active in remediation programs but will be addressed as time and staffing allow. The MDA works with other programs to promote pollution prevention through improved storage and operational practices. Agricultural chemical facilities that have gone through a cleanup often construct new facilities with features that promote pollution prevention.

Historic releases along with emergency concerns will continue to require significant effort by the MDA remediation programs into the future to limit risk to human health and the environment to agricultural chemical incidents.

Additional information on MDA remediation programs can be found on the MDA website at:

https://www.mda.state.mn.us/pesticide-fertilizer/spills-cleanup , and in the joint MPCA-MDA Superfund 2017-2018 bi-annual legislative report at: https://www.pca.state.mn.us/sites/default/files/lrc-s-1sy19.pdf .

Pesticides

The MDA has developed the Minnesota Pesticide Management Plan (PMP): A Plan for the Protection of Groundwater and Surface Water (revised in 2007and is scheduled to be updated in 2020). The PMP is the primary tool for preventing, evaluating and mitigating pesticide impacts to water resources, and it established the delineation of Pesticide Management Areas (PMAs) based on similar hydrologic, geologic, and agricultural management characteristics occurring within a region/area of the state. The PMRs provide the MDA with a framework for outreach and education to agricultural stakeholders, further described in the PMP (Chapter 8: Prevention) at: https://www.mda.state.mn.us/sites/default/files/inline-files/pmp-nov2007.pdf

The PMP establishes a multi-stakeholder Pesticide Management Plan Committee to annually review pesticide water quality data and provide comment to the Commissioner of Agriculture regarding the detection and concentration of pesticides in vulnerable aquifers, as well as the need for BMP development to minimize and prevent pesticide contamination of water resources. The PMP also establishes a Pesticide BMP Education and Promotion Team made up of state and local pesticide and water quality specialists, along with others interested in developing and delivering consistent messages to pesticide users about BMPs and water quality protection.

In 2004, the MDA developed “core” BMPs for all agricultural herbicides, and separate BMPs specific to the use of the “common detection” herbicides acetochlor, alachlor, atrazine, metolachlor and metribuzin.

These BMPs have been revised and updated since they were first developed. The most recent revisions occurred in 2018-2019. The MDA has also developed core BMPs for insecticides and fungicides, as well as specific BMPs for the insecticide chlorpyrifos and for neonicotinoid insecticides.

The MDA has a program of conducting special registration reviews of pesticides that might have specific concerns to use in Minnesota, including water quality protection. Chlorpyrifos is being reviewed under this process as this report is being finalized due to the number of impairment designations (current or pending) and its potential to pose a substantial human health risk. The scope of these special registration reviews varies depending on the potential education, outreach, and enforcement needs identified by the MDA. The MDA reviews new active ingredients recently approved by the U.S. Environmental Protection Agency along with currently registered pesticides that have significant new uses or have undergone a major label change. At times, more in-depth reviews are necessary to provide stakeholders and the MDA Commissioner with more information about specific pesticide products and issues. Additional information can be found at: https://www.mda.state.mn.us/pesticide-special-registration-reviews.

Contaminants of Emerging Concern (CECs) and Per- and polyfluoroalkyl substances (PFAS)

Currently, the MPCA ambient groundwater monitoring program is monitoring for CECs in the groundwater as part of its efforts to address the rising concerns associated with these chemicals in Minnesota's environment. This monitoring will significantly expand the existing knowledge of the occurrence of CECs in the groundwater and this information will help to evaluate the sources of any contamination found in the groundwater. The MDA shares these objectives as it coordinates with other state agencies its own pesticide-related CEC monitoring and response activities.

The MDH has a CEC program to identify contaminants in the environment for which current health-based standards do not exist or need to be updated to reflect new toxicity information. Through the CEC program, the MDH investigates the potential for human exposure to these contaminants, and develops guidance values. Information on the CEC program and a list of chemicals that have been evaluated is available at: https://www.health.state.mn.us/cec.

PFAS is an important and complex emerging contaminant. The MPCA has been working on issues related to PFAS since the early 2000s when we started addressing what were then called PFCs (perfluorinated chemicals) at four waste disposal sites in Washington County used by the 3M Company. There have since been several periods of renewed interest and activity as we learned more about these chemicals and their potential effects on human health and the environment. While PFAS were once seen as a problem primarily related to manufacturing and disposal of waste, PFAS are ubiquitous in the environment and latest research shows health effects at lower levels than previously thought. The MPCA is working in an integrated way, across the MPCA and involving MDH, MDNR, and MDA, to develop approaches to effectively address this complex environmental problem statewide. MPCA is also partnering with other states. For more, see: https://www.pca.state.mn.us/waste/what-minnesota-doing-about-pfas

Efforts continue in the eastern TCMA to supply drinking water with safe levels of PFAS and other contaminants and clean up contaminated sites under the 2018 settlement between 3M and the State of Minnesota. On February 20, 2018, the State of Minnesota settled a Natural Resources Damage lawsuit with the 3M Company for PFAS contamination in the eastern TCMA. Under the terms of the settlement, the 3M Company made an $850 million grant to the state to be used for clean drinking water and natural resources protection projects, and to pay for the state's lawsuit and other expenses. The MPCA and DNR are co-trustees of these funds. The top priority for the 3M settlement funds are to enhance the quality, quantity, and sustainability of drinking water in the eastern TCMA. The second priority is to restore and enhance the area's water resources, wildlife, habitat, fish and other aquatic resources, and outdoor recreation in the eastern TCMA and on the Mississippi and St. Croix Rivers downstream of these areas. Any remaining grant funds will be used for statewide environmental improvement projects. The 2018 settlement also preserves the 3M Company's obligations under the 2007 Consent Order negotiated between the MPCA and 3M. To ensure clean drinking water in the eastern TCMA, the MPCA, DNR, and other stakeholders are developing a drinking water supply plan for the area. Biannual reports and spending plan updates on the 3M settlement are completed by MPCA and DNR. The plan for fiscal year 2020 is available at: https://www.pca.state.mn.us/sites/default/files/lrc-pfc-3sy19.pdf. Information on cleanup of the four sites is at: https://www.pca.state.mn.us/waste/pfas-waste-sites.

Groundwater Summary

The MPCA and MDA continue to lead the way in addressing sources of groundwater contamination, particularly through monitoring, remediation, permitting and BMP activities. It is critical, though, to maintain a continued concern for this valuable resource.

Some of the most common contaminants detected include nitrates and specific pesticides in rural settings, and chloride from road salt in urban areas. State agencies continue to monitor from the forefront, identifying new contaminants of emerging concern to groundwater quality and continuing to manage known risks.

Continued effort is needed to fully realize the state's groundwater quality goals. In particular, ongoing monitoring of vulnerable aquifers is critical to identify and track trends and evaluate the success of management efforts.

Long-term commitment to the collection and analysis of groundwater data is necessary to identify changes in water quality and quantity over time and provide information needed to effectively manage and protect this critical resource. Continued monitoring efforts by the MPCA and MDA provide the baseline from which to base critical decisions and future analyses.

Surface Water Quality: Assessment and Analysis

Presented below is information that defines the status and trends of water quality in Minnesota's streams, lakes and wetlands. Somewhat different from the groundwater quality data presented in the previous section, the surface water quality data includes a combination of water chemistry, water clarity and measures of fish and aquatic insect health (biological integrity); which are used to determine a waterbody's suitability for drinking, swimming, and fishing.

A large number of reports have been published on Minnesota's surface water condition over the past decade, providing baseline information at a watershed scale. To guide the reader, report summaries are provided, accompanied by figures, graphs and tables of some of the more relevant monitoring and assessment data contained in these reports. Web-based links are also provided for additional information on the following surface water quality topics:

- The Impaired Waters List and Watershed Approach,
- Lake and Stream Water Quality Trends - clarity, swimming & recreation, pesticides,
- Minnesota Milestone historic data - pollutants & clarity in streams and rivers,
- Stream water quality - pesticides, fish & aquatic life,
- Metro Area Surface Waters - nutrients & chlorides,
- Wetland water quality trends,
- Statewide Nitrogen Study,
- CECs and PFAS, and
- Pesticide Water Quality Monitoring Report.

Impaired Waters Listings and Watershed Approach

Impaired Waters – The Clean Water Act of 1972 requires states to adopt water quality standards to protect waters from pollution. These standards define how much of a pollutant can be in a water and still allow it to meet designated uses, such as drinking water, fishing, swimming, irrigation or industrial purposes. Impaired waters are those waters that do not meet water quality standards for one or more pollutants, thus they are “impaired” for their designated use(s). In 2006, the passage of Minnesota’s Clean Water Legacy Act and the 2008 Clean Water, Land and Legacy Constitutional Amendment provided policy framework and money for state and local governments to accelerate efforts to monitor, assess, and restore impaired waters, and to protect unimpaired waters.

Starting in 2008, the MPCA began a 10-year cycle to monitor and assess about eight of Minnesota’s 80 watersheds each year, to identify impaired and “unimpaired” waters. The first iteration of this monitoring cycle has been completed and monitoring is returning to watersheds in order to track progress towards meeting water quality goals. Details can be found at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/watershed-approach/index.html.

The MPCA assesses waters and lists the impaired waters every two years in accordance with the Clean Water Act. The table below provides the *draft* 2020 Impaired Waters List (as placed on public notice) and the number of impaired waters that need total maximum daily load (TMDL) plans to restore protection of fish and swimming uses. Further details can be found on page 33 of the 2020 Integrated Report to Congress at: http://www.pca.state.mn.us/index.php/water/water- types-and-programs/minnesotas-impaired-waters-and-tmdls/impaired-waters-list.html.

Table 7. Impaired Waters and TMDL-Listed Waters for Minnesota

2020 Inventory of Impaired Waters Summary

Pollutant in 2020 draft Waters List	Total number of impairments	Number of impairments requiring a TMDL
Mercury in fish tissue & mercury in water column	1653	413
Nutrient/Eutrophication Biological Indicators	746	317
Escherichia coli / Fecal coliform	833	338
Total suspended solids (TSS) & Turbidity	410	206
Aquatic Macroinvertebrate Bioassessments	836	756
Fishes Bioassessments	895	838
PCB in fish tissue	77	77
Oxygen, Dissolved	171	127
Chloride	50	9
Nitrates	19	4
Aquatic Plant Bioassessments	12	12
Perfluorooctane Sulfonate (PFOS) in fish tissue	11	11
pH	6	4
Arsenic	8	0
Aluminum	7	3
Ammonia (Un-ionized)	4	4
Copper	1	0
DDT	5	5
Dieldrin	5	5
Lack of a coldwater assemblage	3	2
Dioxin (including 2,3,7,8-TCDD)	3	3
Toxaphene	3	3
Chlorpyrifos	14	14
Acetochlor	1	1
Temperature, water	1	0
Total	**5774**	**3152**

Lake and Stream Water Quality Trends

One of the goals of MDA and MPCA water quality monitoring efforts is to identify and track trends in Minnesota waters. The following sections highlight available trend information for Minnesota's lakes and streams. As a part of this assessment, it is important to note that trend analysis can be very challenging, in part due to the amount of data needed over multiple years to detect a trend.

Lake Water Quality – Minnesota has about 12,200 lakes greater than 10 acres in size and another 50 lakes greater than 5,000 acres, totaling roughly 4.5 million acres. Detecting changes (trends) in water quality over time is a primary goal for many monitoring programs. Secchi transparency is a good indicator of lake water clarity and a preferred parameter for monitoring lake water quality trends as it relates to recreational use.

Data collected from 1973 through 2019, show that 517 lakes had improving trends, 180 had declining trends and 974 had no clear trend, for lakes with sufficient data for trend analysis as shown in the table below. A map showing the locations of these lakes is provided at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/citizen-lake-monitoring-program/secchi-transparency-trend-lists.html.

Table 8. Secchi disk trends in Minnesota lake water quality

Description	Number of Lakes	% Lake Clarity Trend
Assessed for Trends	1,671	
Improving	517	31%
Degrading	180	11%
No Clear Trend	974	58%

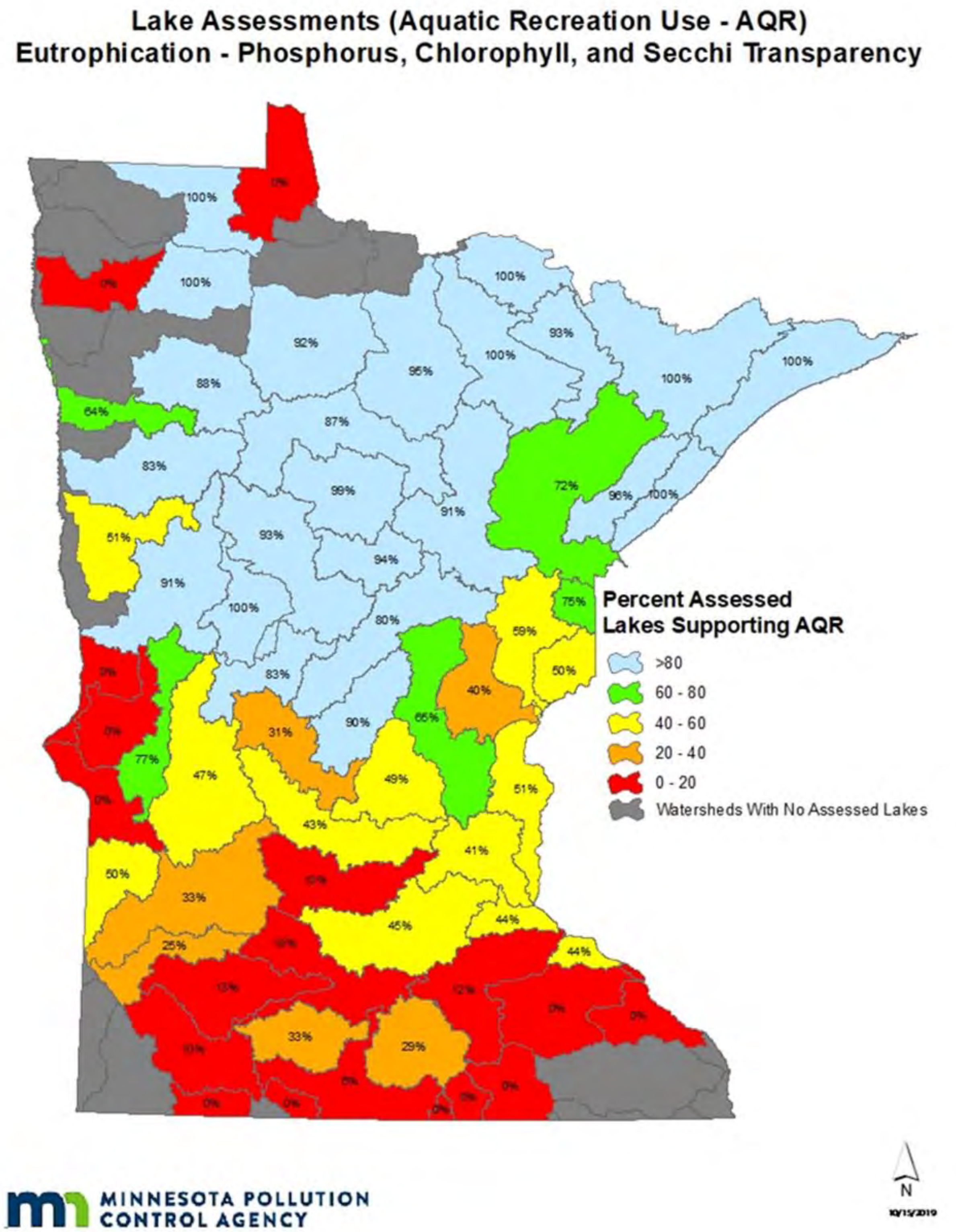
In general, water clarity is poorer in southern Minnesota, and both increasing and decreasing trends are scattered throughout north and south central Minnesota. Water clarity has stayed the same in roughly two- thirds of the lakes, as presented on page 26 of the Clean Water Fund Performance Report located at: https://www.legacy.mn.gov/2020-clean-water-fund-performance-report.

Lakes – swimming and recreation - The MPCA and partners have assessed a total of 3,821 lakes under the watershed approach. The map below shows color shading for the percentage of lakes that fully support swimming and recreation in half of Minnesota's watersheds tested to date. The fact that a lake does not fully support swimming does not mean no one should ever swim there. However, during at least part of the summer, the lake is green and slimy with algae – to the point where swimming is not desirable. In some cases, the algae growth is so bad that a "bloom" forms that can release toxins harmful to pets and people.

Watersheds with just half or fewer of the lakes fully supporting swimming tend to be dominated by agricultural land that is known to contribute excessive phosphorus to water bodies. Phosphorus is the primary driver of algae in lakes.

Higher percentages of lakes fully support swimming in the more forested and wetland rich landscape of the north-central and northeastern part of the state. Natural watershed characteristics such as soil type also play a role in lake phosphorus levels. More details can be gound at: https://www.pca.state.mn.us/water/state-lakes document.html?gid=22760.

Figure 7. Percentage of lakes by watershed that fully support swimming and recreation



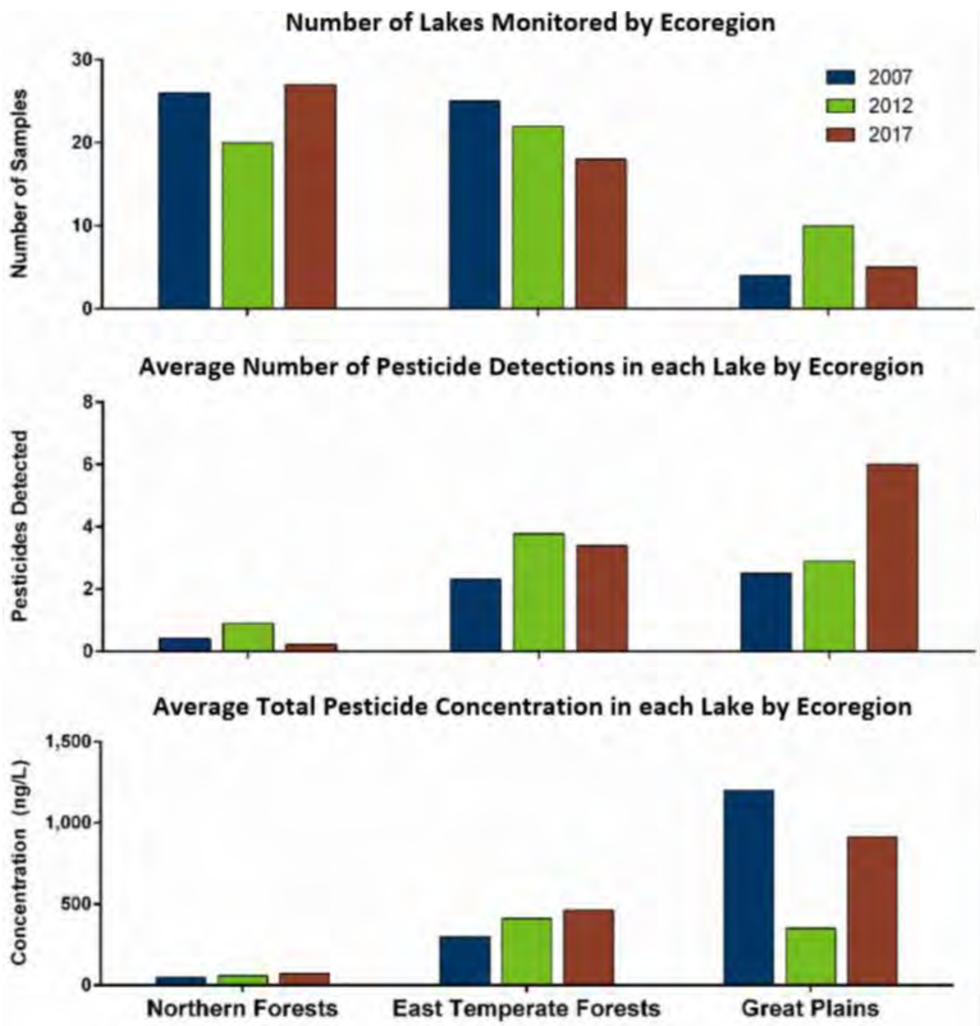
Lake Pesticide Monitoring

Pesticide water quality samples were collected from randomly selected lakes in Minnesota in 2007, 2012 and 2017 in conjunction with the United States Environmental Agency's (USEPA) National Lake Assessment (NLA). With the exception of two detections of the insecticide chlorpyrifos in 2017, all other pesticide detections were very low compared to the applicable water quality reference values. In each of the NLA years, the majority of detections were herbicide degradates and herbicides. The number of pesticide compounds detected and associated concentration of those compounds tended to increase with an increasing amount of row crop production in a lakeshed. In contrast, increasing amounts of forest in a lakeshed lead to fewer pesticide detections and lower pesticide concentrations.

There was little variability in the pesticides that were detected, and the concentration of detected pesticides, between the 2007, 2012 and 2017 NLA (Figure 8). The full report, Pesticides in Minnesota Lakes, is available online from the MDA website at: https://www.mda.state.mn.us/pesticide-fertilizer/water-monitoring-reports-resources.

MDA will align future lake pesticide monitoring efforts with the USEPA National Lakes Assessment that occurs every 5 years. This shift to the 5-year cycle allows MDA to look at many lakes in a single year, and to have comparable data over time for trend analysis.

Figure 8. Analysis of lakes sampled by Minnesota ecoregion during the 2007, 2012 and 2017 National Lakes Assessment



Watershed Pollutant Load Monitoring Network - pollutants & clarity in streams and rivers

Stream Water Quality – Some of the best available information on pollutant trends in rivers and streams comes from Watershed Pollutant Load Monitoring Network sites, citizen-collected stream transparency data, MDA pesticide monitoring sites, and watershed biological conditions for fish and aquatic life.

Watershed Pollutant Load Monitoring Network – This program pairs flow monitoring with water chemistry monitoring to determine trends over time. This network covers sites at basin, major watershed and subwatershed scales. The sampling is designed to capture major runoff and rainfall events and baseflow to allow for the calculation of annual yields, loads, and flow weighted mean concentrations. Parameters include total suspended solids, nitrogen, and phosphorus.

Table 9. Pollutant long term trends in rivers and streams.

	Total Number of Sites	Decreasing	Increasing	Trend Not Detected
Total Suspended Solids	50	4	1	45
Nitrate	38	0	14	24
Total Phosphorus	50	24	0	26

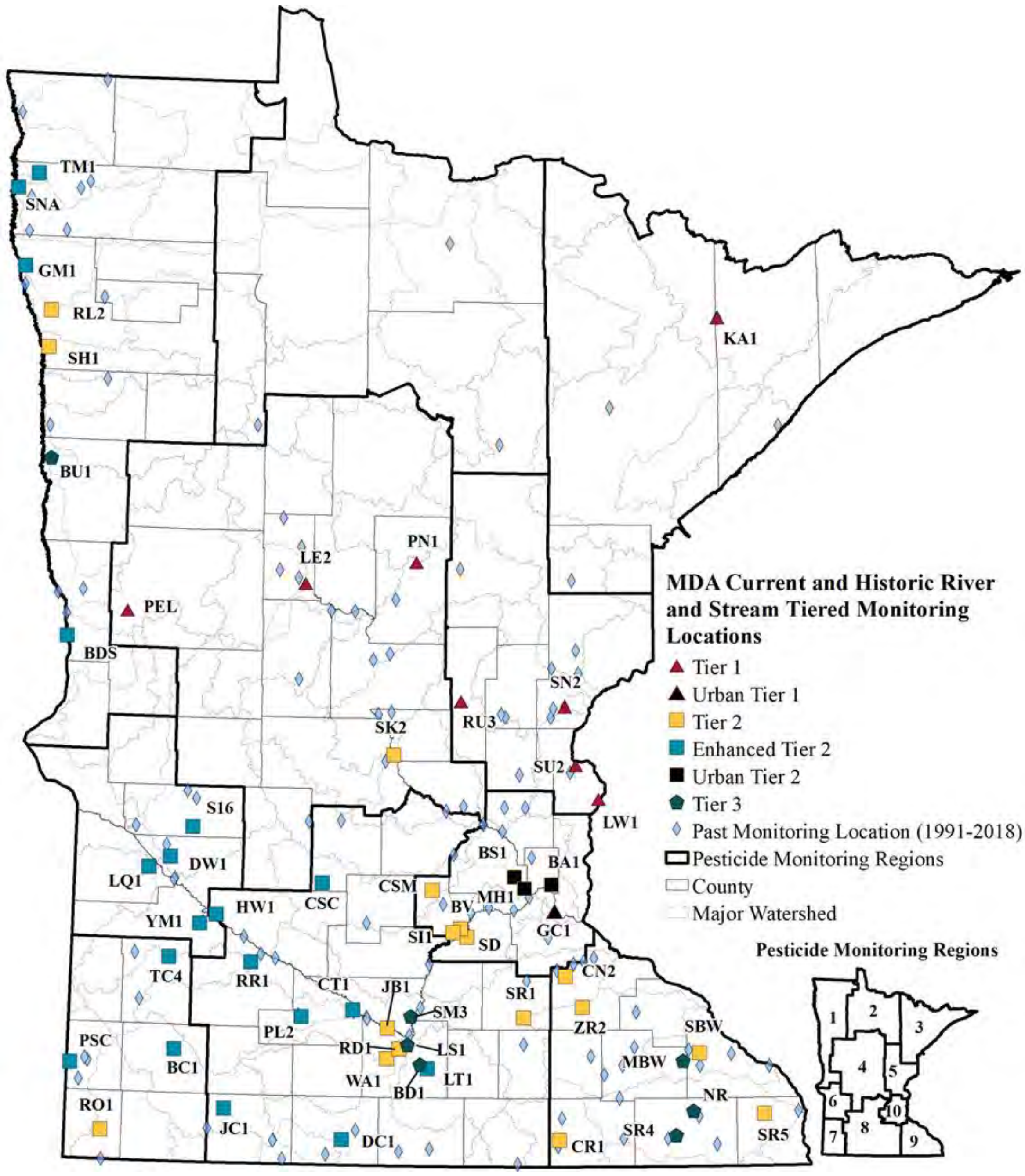
Citizen Stream Monitoring - Trend analysis of stream water clarity data (Table 9) has been done using transparency-tube measurements collected by volunteers through the MPCA's Citizen Stream Monitoring Program (CSMP). For data collected through 2019, no clear water quality trend was exhibited in 256 of the assessed stream sites, 240 exhibited improvement, and 269 exhibited statistically significant declines in transparency. Of note, 538 additional sites had water quality that was too clear to determine a trend. This indicates high quality water at these locations, with very clear water. A map showing the locations of these streams is provided in the following link. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/citizen-lake-monitoring-program/secchi-transparency-trend-lists.html.

Table 10. Trends in Minnesota stream water clarity.

Description	Number of Streams	Percent of Streams with Trend
Assessed for Trends	765	
Improving	240	31%
Declining	269	35%
No Clear Trend	256	34%

MDA Pesticide Monitoring - The MDA began monitoring surface water for pesticides in 1991. Monitoring is conducted within a framework of Pesticide Monitoring Regions (PMRs) shown in Figure 13. In 2006, the MDA began monitoring surface water utilizing a tiered structure defined and described in the MDA Surface Water Quality Monitoring Design Document, which can be found at: https://www.mda.state.mn.us/sites/default/files/inlinefiles/2007%20MAU%20SW%20Design%20Document.pdf

Figure 9. Current and historic surface water sampling location.

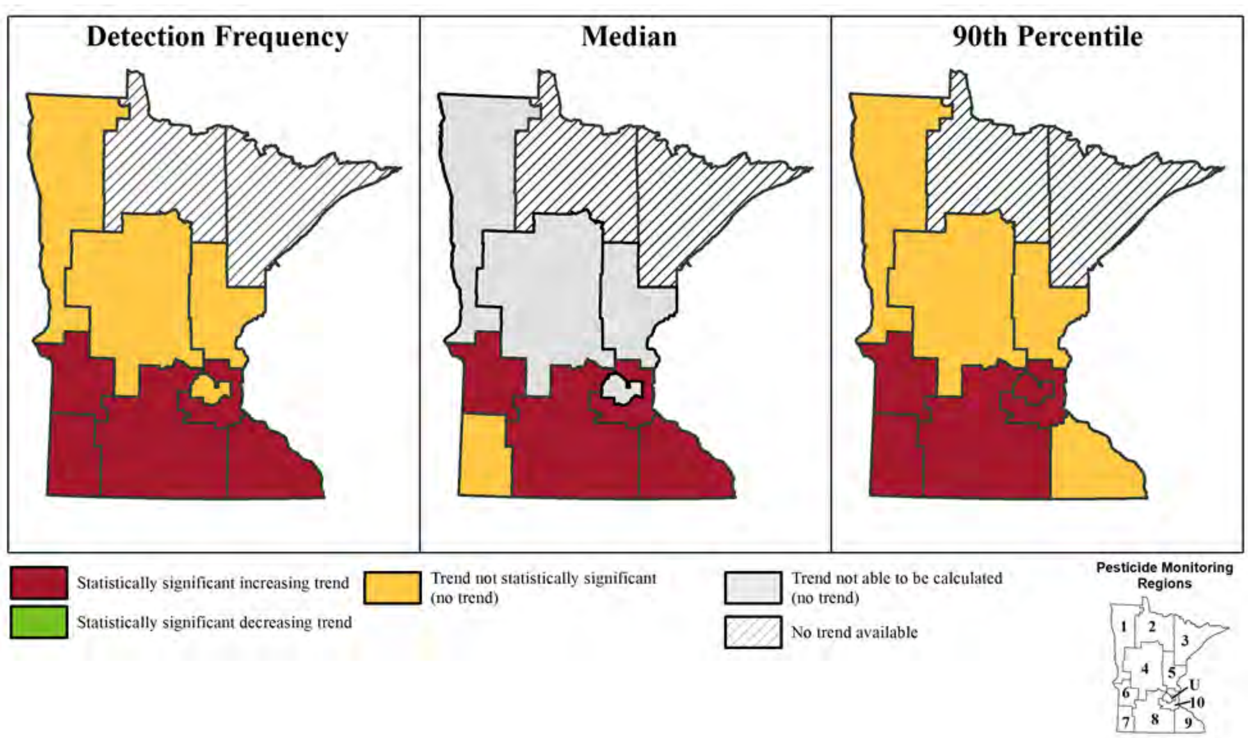


The MDA's tiered structure allows for increased monitoring intensity at locations that have exhibited elevated pesticide concentrations. Pesticide detections at concentrations above the applicable reference values or standards are rare; and MDA works with MPCA annually to review all water quality data for possible water quality impairments.

Three pesticide active ingredients have been designated by the Commissioner of Agriculture as a concern for surface water quality. Acetochlor and atrazine, both herbicides, were designated as "pesticides of concern" for surface water in 2003. In 2012, chlorpyrifos, an organophosphate insecticide, was designated a "pesticide of concern" for surface water. The criteria for such designations are summarized in the Pesticide Management Plan (PMP). The designation initiates several actions including pesticide BMP development and promotion, and increased water quality data analysis.

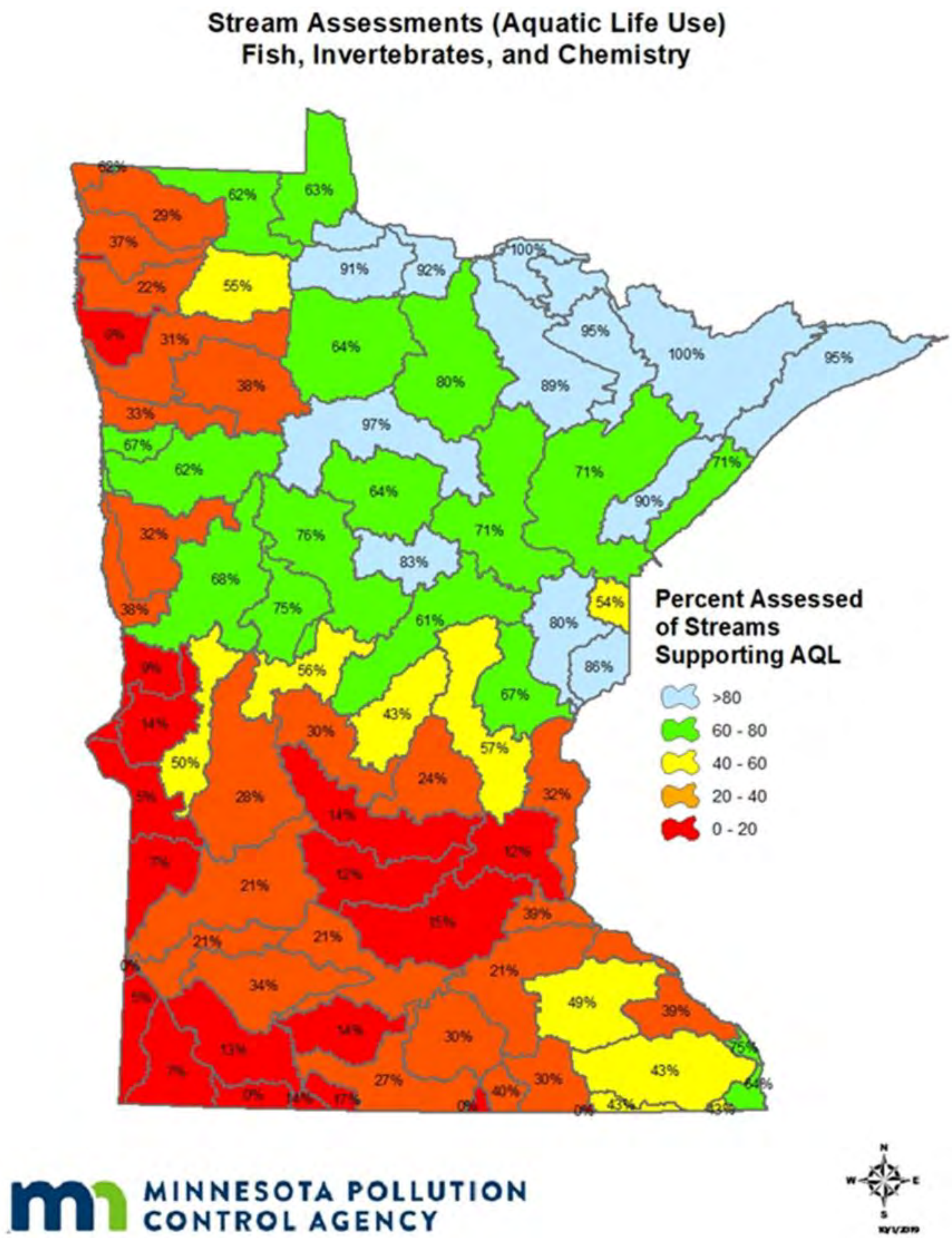
Because pesticides, especially agricultural and home and garden pesticides, are typically applied to coincide with the seasonal need to control weeds, insects and other pests or plant diseases, the presence of pesticides in streams and rivers is often linked to application timing, and subsequent rainfall and runoff events. The MDA analyzes data from its network of sampling locations to track statistics regionally for the surface water "pesticides of concern". Figure 10 presents regional May and June 2007-2019 detection frequency and concentration statistics for acetochlor. The MDA monitored for 166 different pesticide and pesticide breakdown products in surface water in 2019. A complete review of all detections are available in the MDA 2019 Water Quality Monitoring Report available under "Reports and Resources" at: https://www.mda.state.mn.us/monitoring.

Figure 10. May and June acetochlor water monitoring trend results, 2007 through 2019



Streams and rivers – fish and other aquatic life - The MPCA and partners have assessed a total of 2,681 stream and river sections statewide for fish and other aquatic life under the watershed approach. The map below shows the percentage of streams and rivers that fully support fish and aquatic life by watershed. Patterns in this map are similar to the previous map for swimming and recreational suitability, and for watersheds that have been identified as needing pollutant source reductions.

Figure 11. Percentage of streams and rivers by watershed that support fish & aquatic life



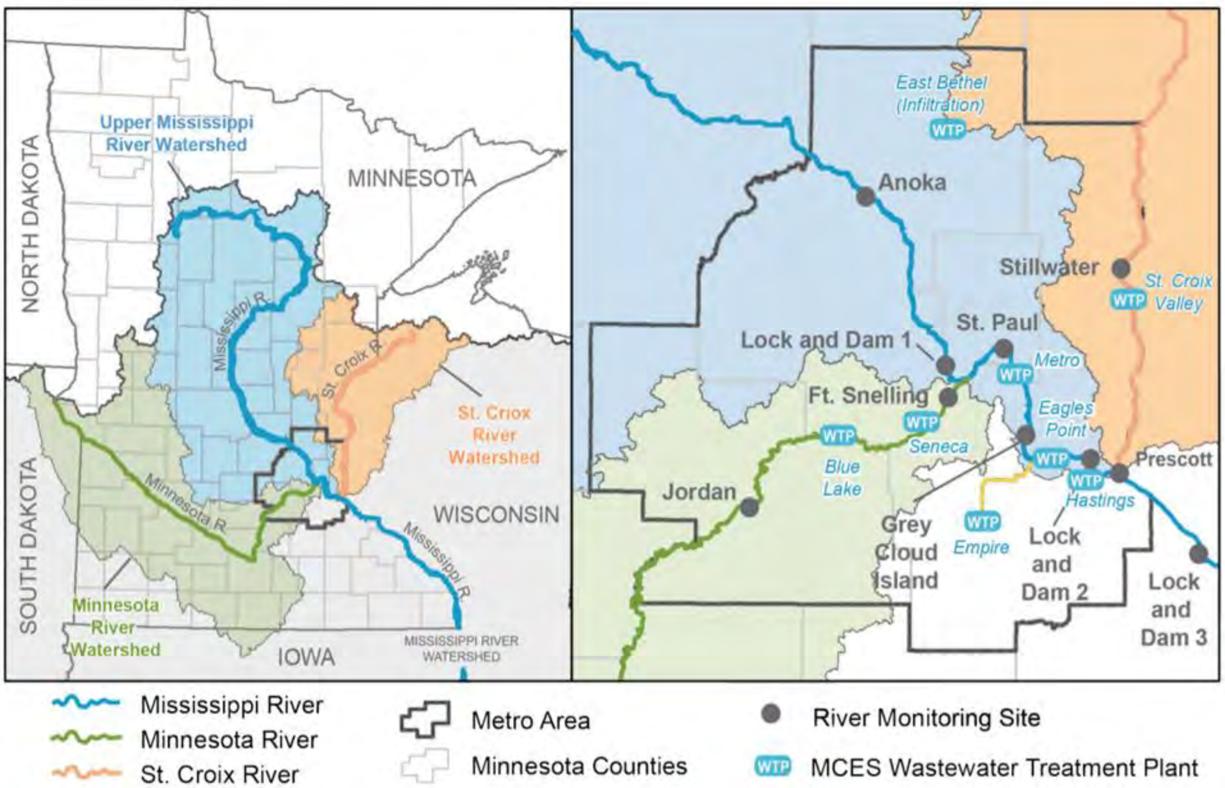
The northwest exhibits somewhat better conditions for recreation, while showing poor stream life. The southeast on the other hand shows somewhat better stream life, with poor conditions for recreation. This may be due to the steeper landscape of southeastern Minnesota, which facilitates runoff of bacteria and other pollutants, but results in better habitat for aquatic life. For further information, please see https://www.pca.state.mn.us/water/state-rivers-and-streams.

Metro Area Surface Waters – nutrients & chloride

The Metropolitan Council, MPCA and numerous local government units have studied the water quality of streams, lakes and wetlands within the seven county Twin Cities metropolitan area (TCMA) for over 40 years.

In 2018, Metropolitan Council Environmental Services published a report documenting recent conditions and changes of water quality in the Mississippi, Minnesota, and St. Croix rivers in the metro area from 1976 to 2015. That report can be found at: https://metrocouncil.org/Wastewater-Water/Services/Water-Quality-Management/River-Monitoring-Analysis/Regional-Assessment-of-River-Quality-(2).aspx.

Figure 12. Location of assessed sites in the Metropolitan Council Study



The report found that generally, concentrations of sediment, bacteria, and phosphorus (Figure 13) decreased (conditions improved) from 1976 to 2015, but nitrogen (Figure 14) and chloride increased (conditions declined).

Likely contributing factors to the decrease of many water quality pollutants in the river include:

- Water quality standards set by the Minnesota Pollution Control Agency, which protect the state's waters by targeting levels of pollutants such as sediment, phosphorus, bacteria, and chloride.
- Completion of projects designed to meet water quality standards.
- Investments in wastewater treatment technology, reducing levels of sediment, phosphorus, and bacteria in treatment plant discharges.
- Legislation banning the use of phosphorus in laundry detergents, automatic dishwasher detergents, and lawn fertilizer.
- Improvements to sanitary and storm sewer systems.

- Regulations and management of urban stormwater runoff.
- Changes in agricultural practices, including conservation tillage and manure management.
- Implementation of best management practices, like erosion control and raingardens, that reduce pollution entering water bodies.

Likely contributing factors to the increase of some water quality pollutants in the river include:

- An increase of hard, impervious surfaces, such as paved roads and parking lots that prevent water from naturally seeping into the ground. The runoff can carry pollutants into water bodies and increase sediment erosion.
- Increased use of de-icing salts that contain chloride.
- Increased number of drain tile systems in agricultural fields to remove water off the land. Drain tiles increase the amount of water that enters streams and rivers, which can lead to streambank and gully erosion.
- Improper use of fertilizers in urban and agricultural settings.

Figure 13. Flow-adjusted total phosphorus trends, 1976-2015

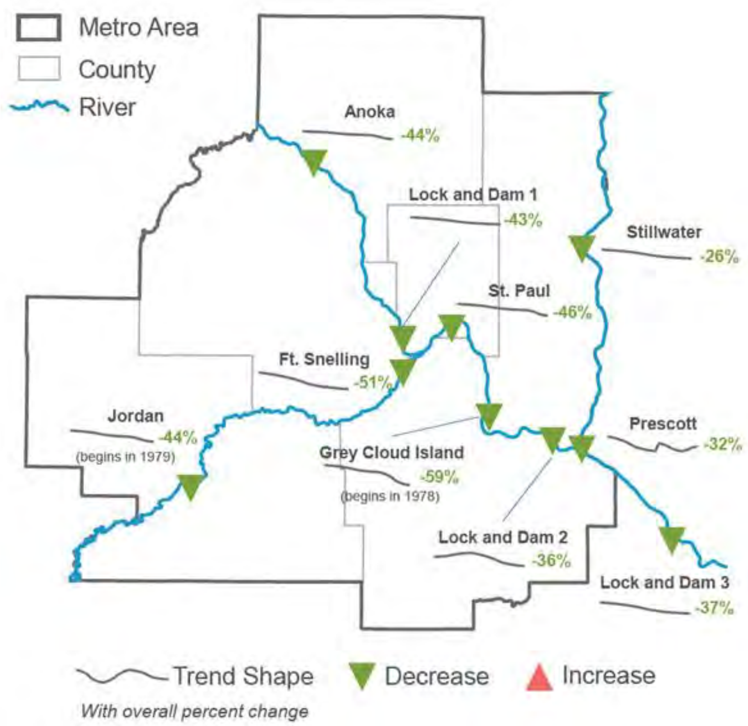
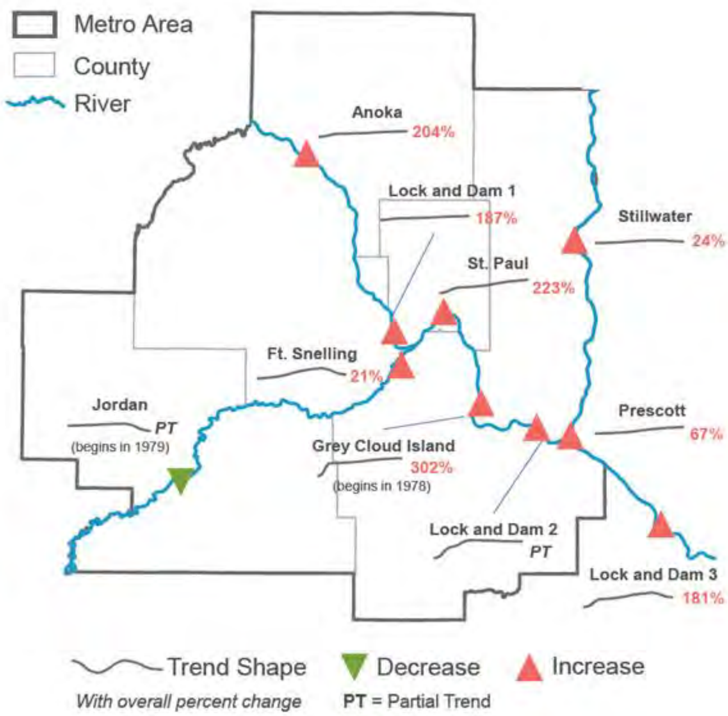


Figure 14. Flow-adjusted nitrate trends, 1976-2015



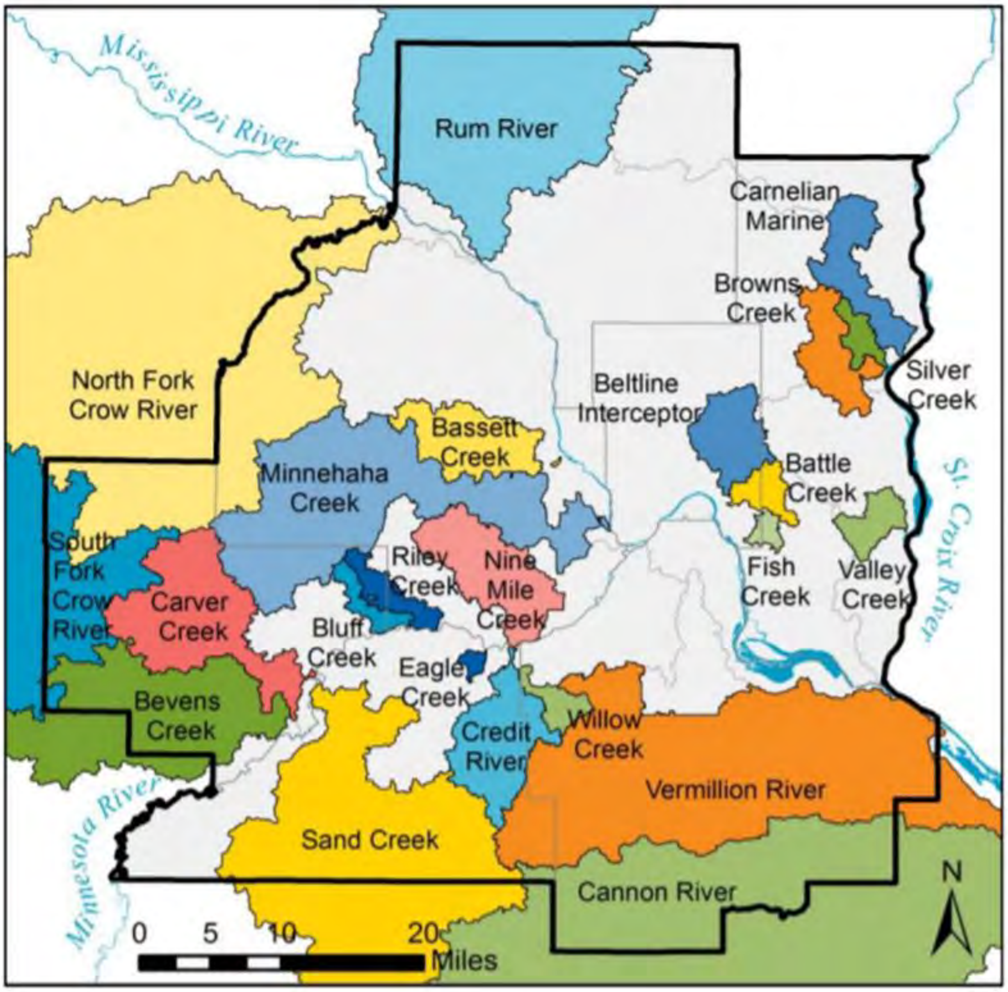
In 2014, Metropolitan Council Environmental Services (MCES) staff completed an assessment of water quality in 21 creeks, streams and rivers and their associated watersheds in the TCMA. Their report, titled a Comprehensive Water Quality Assessment of Select Metropolitan Area Streams, Technical Executive Summary, December, 2014, focused on four primary pollutants of concern: sediment, nitrogen, phosphorus and chloride and can be found at: http://metrocouncil.org/METC/files/d7/d7b81f85-a1f1-4201-acff-781d9b02590f.pdf.

In the streams study, MCES identified elevated concentrations of nitrogen, phosphorus and sediment in a number of different streams, and associated this with specific land use activities and natural conditions within a watershed. However, in many of these streams the same pollutants showed improving water quality trends for the most recent five years of their data set. These water quality improvements were thought to be due to multiple projects and actions taken over the past several decades by cities, watershed districts, watershed management organizations, state agencies, farmers, business owners and private citizens and are identified in the report on page 14.

In 2014, Metropolitan Council Environmental Services (MCES) staff completed an assessment of water quality in 21 creeks, streams and rivers and their associated watersheds in the TCMA (see Figure 15). Their report, titled a Comprehensive Water Quality Assessment of Select Metropolitan Area Streams, Technical Executive Summary, December, 2014, focused on four primary pollutants of concern: sediment, nitrogen, phosphorus and chloride and can be found at: http://metrocouncil.org/METC/files/d7/d7b81f85-a1f1-4201-acff-781d9b02590f.pdf.

In the streams study, MCES identified elevated concentrations of nitrogen, phosphorus and sediment in a number of different streams, and associated this with specific land use activities and natural conditions within a watershed. However, in many of these streams the same pollutants showed improving water quality trends for the most recent five years of their data set. These water quality improvements were thought to be due to multiple projects and actions taken over the past several decades by cities, watershed districts, watershed management organizations, state agencies, farmers, business owners and private citizens and are identified in the report on page 14.

Figure 15. Location of assessed watersheds in the Metropolitan Council Study



MCES was not able to complete chloride trend analysis at the time of this report, due to the length of available chloride record being too short. An update to this study is currently ongoing and trend analysis of chloride in these streams should be completed by the end of 2020.

Chloride - At present, there are a total of 37 chloride impairments in the Twin Cities for streams, lakes and wetlands as shown on the Twin Cities Metro Area Chloride Assessment map at: http://www.arcgis.com/home/webmap/viewer.html?url=https%3A%2F%2Fpca-gis02.pca.state.mn.us%2Farcgis%2Frest%2Fservices%2Fagol%2Fchloride%2FMapServer&source=sd.

The Twin Cities Metropolitan Chloride Management Plan provides a detailed analysis of the status, sources and trends of chloride observed in many Twin Cities streams, lakes and groundwater, please see the report at: http://www.pca.state.mn.us/index.php/view-document.html?gid=22754. A summary of the data analysis from this report shows that:

1. Chloride use increased in the TCMA in the latter half of the 20th century, 1950-2000,
2. Levels of chloride are continuing to increase in both groundwater and surface waterbodies in the TCMA,
3. The highest chloride concentrations have been found during snowmelt conditions during

winter months and low flow periods in streams,
4. Chloride levels tend to be higher in the bottom of a lake versus the surface,
5. Chloride concentrations in TCMA waterbodies are positively correlated to road density in the contributing watersheds,
6. There is a lot that is not known about chloride concentrations in TCMA waterbodies, since a large majority of the TCMA waterbodies do not have any data and do not have data that would represent critical conditions, and

Winter maintenance activities as well as wastewater treatment plants tend to be the primary sources of chloride to TCMA waters.

Chloride impacts are not limited to the Metro Area, and to address this, the MPCA in collaboration with several partners has drafted the State Chloride Management Plan (CMP). The CMP outlines a comprehensive strategy to reduce salt (chloride) use from a variety of sources to protect Minnesota's lakes, rivers, and other water resources. It is intended to provide guidance to local government units, winter maintenance professionals, decision-makers, among others. Stakeholders were shown a draft version of the plan in mid-2019. MPCA is currently revising the plan based on feedback and there will be a public comment period before the plan is published. A summary of the draft plan is available at: https://www.pca.state.mn.us/sites/default/files/wq-s1-94a.pdf.

Wetlands water quality trends

Beginning in 2011, the MPCA has worked in conjunction with EPA on the National Wetland Condition Assessment (NWCA) in Minnesota. Statewide and regional intensification surveys have been completed in 2011/2012 and 2016 to provide wetland vegetation quality status and trends information. Overall, Minnesota's wetland vegetation quality is high; however, condition varies widely in different parts of the state. Wetland vegetation is predominantly in exceptional/good quality in the northern part of the state (where most of Minnesota's wetlands occur) and predominantly in fair/poor quality in the remainder of the state. The MPCA anticipates continuing this survey on the 5-year NWCA schedule and is prepping for the next iteration beginning in 2021.

In addition, the MPCA conducts an independent survey of depressional wetland quality. These wetlands occur in a distinct basin, have marsh type vegetation, and typically some open water. There are approximately 160,000 wetland basins across the state, but in terms of acreage they only account for about 6% of Minnesota's wetland resource. Three depressional wetland surveys have been completed (2007-2009, 2012, and 2017) in the Mixed Wood Plains and Temperate Prairies ecoregions—where depressional wetlands are more common. According to the latest survey, depressional wetland vegetation across these two ecoregions is in poor condition (or absent) in 38% of the basins and macroinvertebrate community condition is poor in 40% of the basins. No significant wetland quality trends in have been detected over the survey iterations. The MPCA anticipates continuing the depressional wetland survey in 2023.

Additional details on either study can be found at: https://www.pca.state.mn.us/water/wetland-monitoring.

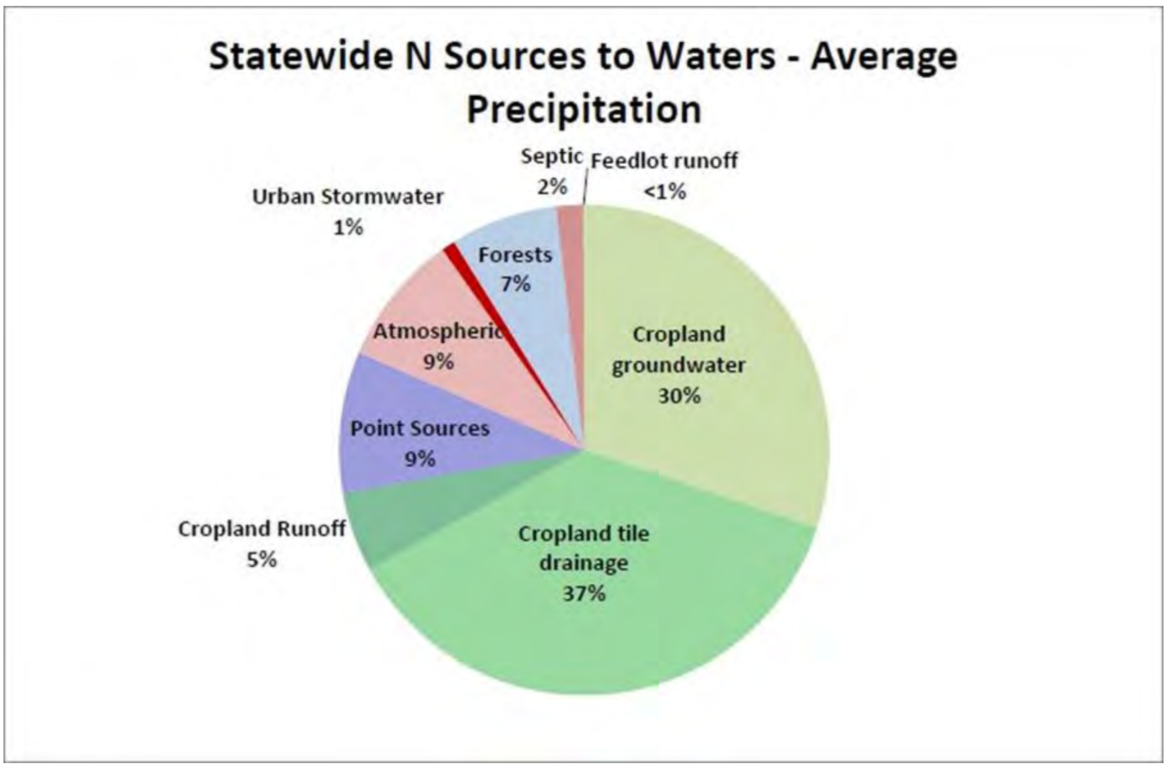
In 2014, MDA collaborated with MPCA on the collection of water column and benthic sediment samples from 19 wetlands across Minnesota for pesticide analysis. Water column samples collected in each wetland were analyzed at the MDA Laboratory using the GC-MS/MS and LC-MS/MS laboratory methods, and analytes included a total of 133 different pesticides and pesticide degradates. The MDA Laboratory developed an insecticide sediment analysis method that included 14 neonicotinoid related pesticide compounds for this project. This was the first time wetlands were analyzed for pesticides in Minnesota, and future wetland monitoring will allow for trend analysis. A summary of the project is included in the 2014 Water Monitoring Report available at:. http://www.mda.state.mn.us/chemicals/pesticides/~/media/Files/chemicals/maace/wqm2014rpt.pdf.

Statewide nitrogen study

The MPCA, working in collaboration with the University of Minnesota and U.S. Geological Survey, completed a study in 2013 to characterize total nitrogen loading to Minnesota's surface waters. The Minnesota Legislature provided funding for the study, which used more than 50,000 water samples collected at 700 streams sites, 35 years of monitoring data, and findings from 300 published studies. The resulting report, titled **Nitrogen in Minnesota Surface Waters – conditions, trends, sources and reductions**, provides a scientific foundation of information for developing and evaluating nitrogen reduction strategies. The report executive summary can be found at http://www.pca.state.mn.us/index.php/view-document.html?gid=19623 and complete report at http://www.pca.state.mn.us/index.php/view-document.html?gid=19622.

An estimated 73% of statewide nitrogen (N) entering surface waters is from cropland sources and 9% is from wastewater point sources, with several other sources adding the other 18% (see figure below). Most of the cropland N reaches waters through subsurface agricultural tile drainage and groundwater pathways, with a relatively small amount in overland runoff.

Figure 16. Estimated statewide N contributions to surface waters during an average precipitation year



The study concluded that surface water N concentrations and loads are high throughout much of southern Minnesota, contributing to the N enriched hypoxic zone in the Gulf of Mexico, nitrate in excess of drinking water standards in certain cold water streams, and a potential to adversely affect aquatic life in a large number of Minnesota rivers and streams. Northern Minnesota has relatively low river N levels, and pollution prevention measures should be adopted in this area as landscapes and land management change. Additionally, nitrogen loss reductions are needed in the Red River Valley so that Minnesota can do its part to reduce algal blooms in Lake Winnipeg.

Reducing nitrogen levels in rivers and streams in southern Minnesota will require a concerted effort over much of the land in this region, particularly tile-drained cropland and row crops over permeable soils and shallow bedrock. Nitrogen reduction strategies and BMPs can be found in the **Minnesota Nutrient Reduction Strategy** at: https://www.pca.state.mn.us/water/nutrient-reduction-strategy .

Contaminants of Emerging Concern (CECs) and Per- and Polyfluoroalkylsubstances (PFAS)

In the last decade, national and statewide studies have revealed that in addition to toxicological effects, many chemicals found in the aquatic environment have known or suggested endocrine-disrupting potential. These chemicals include pharmaceuticals, personal care products, chemicals associated with wastewater effluent, and a variety of industrial compounds. There is a growing concern that even at low concentrations chemicals, or mixtures of them, may adversely affect fish, wildlife, ecosystems and possibly human health.

A recent study on pharmaceuticals and chemicals of concern in Minnesota lakes shows that pharmaceuticals and micro-pollutants are more ubiquitous in surface water than was previously suspected. This study was the third in a series of large-scale, probabilistic investigations that were designed to understand the extent to which these chemical contaminants are present in surface water on a statewide level. Of the 163 chemicals tested, 55 were found in lakes at least once. All 50 lakes contained at least one contaminant. Twenty-one of these chemicals may pose a risk to aquatic ecosystems, with five of these – the frequently detected insect repellant DEET, the hormone estrone, bisphenol A, 4-nonylphenol, and 4-n-octylphenol – of the greatest level of concern due to their toxicity, potential for bioaccumulation, frequency of detection, persistence, and the concentrations at which they were found. The March 2020 report – Pharmaceuticals and chemicals of concern in Minnesota Lakes, can be found at: https://www.pca.state.mn.us/sites/default/files/tdr-g1-21.pdf

Additional information can be found on the MPCA webpage at: http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/endocrine-disrupting-compounds.html.

Per- and Polyfluoroalkylsubstances (PFAS)

PFAS constitute an important and complex class of emerging contaminants. The MPCA has been working on issues related to PFAS since the early 2000s, when we started addressing what were then called PFCs (perfluorinated chemicals) at four waste disposal sites in Washington County used by the 3M Company. There have since been several periods of renewed interest and activity as we learned more about these chemicals and their potential effects on human health and the environment. While PFAS were once seen as a problem primarily related to chemical manufacturing and disposal of waste, thanks to improvements in analytical methods and new toxicological data, we now understand that PFAS are ubiquitous in the environment and potentially harmful to health at low levels.

In the 2000s, the MPCA, MDA and MDH jointly reviewed known and potential sources of PFAS from industrial, agricultural and other human activities. Over time, continued research and monitoring efforts in surface water, biota, groundwater, and waste streams have helped MN gain a stronger understanding of potential exposure routes and health risks associated with this diverse class of compounds.

Some PFAS compounds build up in fish tissue, potentially causing harm to consumers. MPCA studies detected perfluorooctane sulfonate (PFOS) at elevated concentrations in fish taken from the Mississippi

River near the 3M Cottage Grove plant and downstream. These fish tissue PFOS concentrations prompted the MDH to issue a one-meal per month fish consumption advisory for certain species in Pool 2. The lower reach of Mississippi River Pool 2, which received 3M Cottage Grove effluent during the years of PFOS and perfluorooctanoic acid (PFOA) manufacturing, is listed as an impaired water due to PFOS in fish tissue and water. Other fish harvested from Twin Cities Metro Area lakes, some with no known connections to 3M's manufacturing or waste disposal, also contained elevated concentrations of PFOS. Subsequent investigation revealed that PFAS emitted from a metal plating facility contributed significant amounts of PFOS to these Metro Area waterbodies. Currently, a total of 11 waters are impaired for PFOS in fish tissue based on fish consumption advice. This fish contamination and subsequent consumption advice disproportionately impacts Minnesotans who rely on locally harvested fish as a free and healthy source of protein for themselves and their families.

Concern over PFAS exposure from fish consumption has motivated continued monitoring of fish tissue and surface water around the state. In 2018, paired water and fish samples were collected in 70 waters statewide (a mix of previously tested waters and untested metro waters) and evaluated for 13 PFAS. Based on those results, there are more than 60 waters with PFAS concentrations warranting retesting and further investigation. The MPCA intends to continue sampling previously tested waters and untested waters. In 2021, MPCA will sample fish tissue, water, and sediment at 20 total sites – 15 previously tested sites that showed elevated higher levels of PFOS and 5 previously untested sites. Analysis will include 33 PFAS compounds and lower reporting limits than previous studies.

There is significant work to be done in continuing to monitor PFAS in Minnesota's water resources and developing strategies to ensure that PFAS levels in water are safe for human health and aquatic life. The MPCA is working in an integrated way, across the MPCA and MDH, MDNR, and MDA, to develop approaches to effectively address this complex environmental problem statewide. MPCA has hired a PFAS Coordinator to lead the PFAS Lateral Team and guide the development of a cross-agency PFAS Action Plan. MPCA is also partnering with other states to share information on environmental monitoring results, regulatory strategies, and solutions to the unique technical challenges posed by PFAS. MN is member of the PFAS Great Lakes Taskforce, which includes representatives from US States and Canadian Provinces in the Great Lakes Watershed. MN is also regularly sharing information with New England State associations working on PFAS and other national groups like the Environmental Council of States (ECOS) and the Interstate Technology and Regulatory Council (ITRC). Finally, MPCA and MDH are actively partnering with EPA's Office of Research and Development (ORD) to conduct state of the art research and develop new tools that will be implementable in our State. More details can be found at: https://www.pca.state.mn.us/waste/what-minnesota-doing-about-pfas

Additional information on PFAS in Minnesota may be found on the Minnesota Department of Health website at: https://www.health.state.mn.us/communities/environment/hazardous/topics/pfcs.html and on page 19 of the 2020 Integrated Report: https://www.pca.state.mn.us/sites/default/files/wq-s7-52.pdf.

Surface water quality: Reducing, preventing, minimizing and eliminating degradation

The major goal in preserving water quality is to enable Minnesotans to protect and improve the state's rivers, lakes, wetlands and groundwater so that they support healthy aquatic communities and designated public uses such as fishing, swimming and drinking water. The key strategies for accomplishing this goal include regulating point source discharges, controlling nonpoint sources of pollution, and assessing water quality to provide data and information to make sound environmental management decisions.

Land use is a major factor in our current water quality problems — agricultural drainage, urban and rural runoff, and erosion caused by removing vegetation from shorelines. MPCA **How's the water**? Website

describes what the MPCA is doing and what you can do to prevent pollution, rather than just controlling it. Found at: https://www.pca.state.mn.us/hows-the-water.

The MDA also considers the watershed approach for water quality protection, and has been guided for pesticides by the 2007 Minnesota Pesticide Management Plan (PMP): A Plan for the Protection of Groundwater and Surface Water can be found at: http://www.mda.state.mn.us/protecting/waterprotection/pmp.aspx and for nitrate by the Nitrogen Fertilizer Management Plan at: https://www.mda.state.mn.us/pesticide-fertilizer/minnesota-nitrogen-fertilizer-management-plan.

The PMP established the delineation of Pesticide Monitoring Regions (PMRs) and Pesticide Management Areas (PMAs) as indicated earlier in this report. The PMRs and PMAs are generally identical and are based on similar hydrologic, geologic, and agricultural management characteristics occurring within the region/area. The PMAs provide the MDA with a framework for outreach and education to agricultural stakeholders and is further described in the Pesticide Management Plan (Chapter 8: Prevention).

The watershed approach involves multiple program efforts focused on water quality protection and restoration. Information on the following efforts to prevent surface water quality degradation are provided below:

- Wastewater Discharges (point sources),
- Nonpoint Source Pollution:
  - Minnesota's Nonpoint Management Plan (2013),
  - Watershed Achievements Report (2014),
  - Clean Water Partnership Program,
  - Nitrogen in Minnesota's Surface Waters; Conditions, trends, sources and reductions (2013),
  - The Minnesota Nutrient Reduction Strategy
  - Swimmable, fishable, fixable?, and
  - Chloride (road salt)
- Agricultural Best Management Practices Loans
- Pesticides and Fertilizers

Wastewater Discharges **(point sources)** – The MPCA regulates the discharge of treated wastewater to surface waters of the state (primarily rivers and streams) from both municipal and industrial facilities through NPDES/SDS permits. Minnesota has been successful in controlling end-of-pipe (point source) discharges from wastewater treatment plants to our state's surface waters.

Improvements to wastewater treatment plants and a high level of regulatory compliance in meeting effluent standards are improving the overall quality of discharges to Minnesota's surface waters. For more details, please see the **2020 Pollution Report to the Legislature. Point source pollutant loading trends,** pages 22-28, located at: https://www.pca.state.mn.us/sites/default/files/lrp-ear-1sy20.pdf.

In addition, significant wastewater mercury loading reductions have been achieved since 2005/2006. (Mercury loads prior to 2005 are no longer referenced because of changes in the ability to detect mercury in effluent. Mercury loading fell from 4 kg per year in 2005/2006 to 2.35 kg per year in 2018/2019. Information on mercury in fish and mercury reductions in air emissions can be found in the **2020 Clean Water Fund Performance Report** on pages 31-32, located at: https://www.legacy.mn.gov/sites/default/files/resources/lrp-f-1sy20.pdf.

Nonpoint Source Pollution - Water quality in Minnesota is mainly degraded by the pollutants entering surface waters from nonpoint sources derived from both air pollution and runoff from land, particularly from watersheds dominated by agricultural and urban land use. Nonpoint source pollution is the major cause of degradation of Minnesota's surface and groundwater.

Minnesota's Nonpoint Source Management Program Plan 2013 - describes Minnesota's five-year plan to control nonpoint sources of water pollution and the numerous activities directed towards this effort; located at: https://www.pca.state.mn.us/sites/default/files/wq-cwp8-15.pdf.

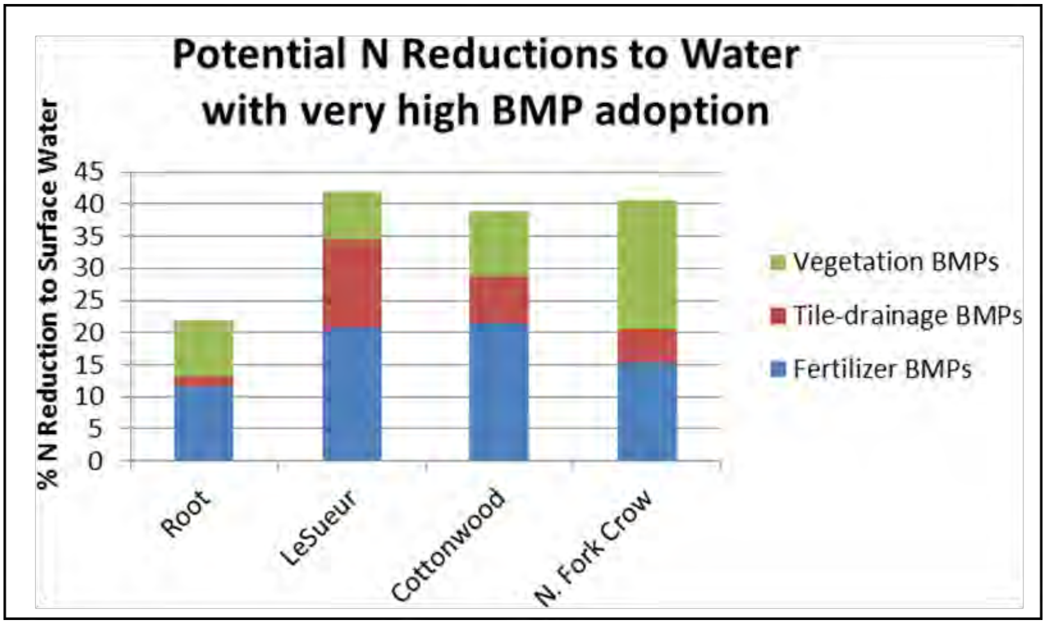
Watershed Achievements Report - The 2019, **Watershed Achievements Report** describes statewide and watersheds-based projects being implemented that are cleaning up nonpoint sources of pollution, mainly through funding from the Section 319 Grant Program and the Minnesota Clean Water Partnership Program.

The Report presents numerous examples of BMP implementation that have led to reductions in nonpoint source pollution, including: shoreline restoration, sedimentation ponds, manure management, conservation tillage, terraces, new ordinances, wetland restoration, fertilizer management, and education. The information is presented in a user-friendly manner, using maps, tables, figures and numerous case studies to describe pollution prevention projects at: https://www.pca.state.mn.us/sites/default/files/wq-cwp8-23.pdf.

Additional information on the **Clean Water Partnership Program** can be found on the MPCA's web page at: https://www.pca.state.mn.us/water/clean-water-partnership-program#:~:text=for%20water%20projects-,Clean%20Water%20Partnership%20program,and%20ground%20water%20in%20Minnesota.

Nitrogen in Minnesota Surface Waters - The Statewide Nitrogen Study, referenced above, concluded that reducing nitrogen levels in rivers and streams in southern Minnesota will require a concerted effort over much of the land in this region, particularly tile-drained cropland and row crops over permeable soils and shallow bedrock. The figure below depicts the potential nitrogen reductions needed in four southern Minnesota watersheds with a very high adoption of BMPs.

Figure 17. Potential N reduction to water with BMP adoption



The Minnesota Nutrient Reduction Strategy – is a guide for Minnesota to reduce excess nutrients in water to meet both in state and downstream water quality goals. The strategy sets goals and milestones to meet phosphorus and nitrogen reductions for the Great Lakes, Lake Winnipeg, the Mississippi River, and the Gulf of Mexico. The Nutrient Reduction Strategy report, executive summary, and summary are on the MPCA website at: [http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/nutrient- reduction/nutrient-reduction-strategy.html](http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/nutrient-reduction/nutrient-reduction-strategy.html).

The strategies are included in Watershed Restoration and Protection Strategies (WRAPS) reports. To date, 52 watersheds have approved WRAPS, with 4 more watersheds out for public comment or approval. For more details please link to the MPCA website at: https://www.pca.state.mn.us/water/watershed-restoration-and-protection-strategy-status

For the 52 watersheds (as of June 2020) that have completed the WRAPS, some general themes have emerged:

- In watersheds where agriculture dominates the landscape, prominent strategies for restoration include: stream buffers; nutrient and manure management; wetland restorations; drainage management and other forms of water storage and soil health practices including reduced tillage, cover crops and extended crop rotations.
- In watersheds where forest dominates the landscape, strategies focus more on protection and include: shoreland protection practices; forest management; and in lake management such as aquatic invasive species management, aquatic vegetation management and fish management.
- For more urbanized areas, strategies focus on stormwater runoff controls ranging from reduction of impervious surfaces, site planning and rain gardens, to the construction of stormwater ponds and wetlands. In many heavily urbanized areas, chloride management's strategies are also needed.
- Not all strategies relate to traditional water pollutants. Throughout Minnesota, common strategies include improving habitat and reducing barriers (connectivity) for fish and other aquatic life such as the replacement of perched or undersized culverts. Addressing altered

hydrology is the most common need across Minnesota as nearly 50% of the stream miles in Minnesota have been altered by humans and are greatly affecting water quality across the state.

- Most of the changes that must occur to improve and protect water resources are voluntary; therefore, communities and individuals ultimately hold the power to restore and protect waters in Minnesota. Meaningful civic engagement is key to achieve clean water in a system that relies heavily on voluntary-adoption. By engaging in greater civic engagement in watershed planning, more citizens become leaders for change in their communities and individuals become personally responsible for making needed changes that could reduce water pollution.

Beyond voluntary-adoption, some strategies call for stronger and more targeted application of state and local laws on feedlots, wastewater, stormwater, shoreland, drainage and septic systems.

Chloride - The Twin Cities Metropolitan Chloride Management Plan (CMP) highlights the impacts of chloride on Twin Cities Metropolitan Area water quality with an overarching purpose to: set goals for restoration and protection of water quality, improve winter maintenance practices and policy needs, and demonstrate the success and economic benefits of improved practices. The CMP is available at: http://www.pca.state.mn.us/index.php/view-document.html?gid=22754.

The CMP provides in-depth strategies for reducing chloride through pollution prevention activities and BMPs that will help protect and restore water quality in Twin Cities' streams, lakes and groundwater.

Additional information can also be found on road salt and water quality on the MPCA website at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/metro-area-chloride-project/road-salt-and-water-quality.html.

Pesticides and Fertilizers– The foundation of the MDA's programs to reduce, prevent minimize and eliminate degradation of water resources from pesticides and fertilizers begins with the registration of products and, for pesticides, EPA's risk assessments and development of product labels. Pesticide regulation also includes the certification and licensure of certain commercial and private applicators, and education and regulatory oversight of label use provisions (e.g., restrictions on use rate per acre and according to soil type; application setbacks from water bodies; and other water resource-related use restrictions or hazard statements) through outreach and inspections.

The MDA surface water programs for prevention, evaluation and mitigation of pesticide and fertilizer impacts adhere to guidance documents and plans (i.e., the Pesticide Management Plan (PMP) at: http://www.mda.state.mn.us/protecting/waterprotection/pmp.aspx], or other efforts that are implemented through monitoring, assessment and multi-stakeholder committees that review the activities of MDA and cooperators. These plans, along with cooperator assistance, guide the MDA in evaluating Best Management Practices established to prevent and minimize agricultural chemical impacts to water resources. In addition, groups external to the MDA play a role in advancing key issues related to environmental protection and farming profitability. Information about the Pesticide Management Plan Committee is available at the PMP link above, along with links to the biennial PMP Status Reports required under statute. The PMP Status Reports provide additional detail about MDA prevention, evaluation and mitigation efforts to protect Minnesota's water resources from pesticide impacts. Information about nutrient-related research and outreach conducted via the Agricultural Fertilizer Research & Education Council is available at: http://www.mda.state.mn.us/afrec

Once pesticides are observed in water resources, the MDA's PMP provides guidance for evaluating monitoring results and addressing any impacts through voluntary or regulatory actions supported by the Pesticide Control Law (Minn. Stat. chapter 18B), and the Clean Water Act as administered by the MPCA (Minn. Rules chapter 7050).

Other examples of MDA programs and efforts related to protecting water resources from pesticide and fertilizer impacts include:

Education and promotion of pesticide BMPs https://www.mda.state.mn.us/pesticide-fertilizer/pesticide-best-management-practices;

Protection of public drinking water supplies from nitrogen fertilizers https://www.mda.state.mn.us/nfr;

Guidance to homeowners on testing domestic wells for pesticides; https://www.mda.state.mn.us/private-well-testing-testing-laboratories-home-water-treatment;

The Nutrient Management Initiative (NMI) program provides a framework for farmers to evaluate their current nutrient management practices compared with an alternative practice on their own field. https://www.mda.state.mn.us/protecting/cleanwaterfund/onfarmprojects/nmi cting/nmi/nmi-brochure.pdf;

General pesticide management education and outreach https://www.mda.state.mn.us/pesticide-management

General guidance on nutrient management https://www.mda.state.mn.us/pesticide-fertilizer/fertilizers;

MDA Clean Water Fund activities https://www.mda.state.mn.us/environment-sustainability/clean-water-fund

Surface water summary

Within the last 5 to 10 years, there has been a renaissance of environmental monitoring and assessment, which has resulted in the numerous reports cited above. To a large degree, this has been the result of the Clean Water Legacy Act and amendment. Because of this, we now have a better understanding of the water quality conditions of our lakes, streams and wetlands, than ever before.

Most of the pollution originating from point sources (municipal and industrial facilities discharging to a state water) has been controlled for total phosphorus, ammonia, and bacteria, as cited in the reports above. Surface water quality is mainly degraded by the pollutants entering surface waters from nonpoint sources derived from runoff, particularly from watersheds dominated by agricultural and urban land use. Nonpoint source pollution is the major cause of degradation of Minnesota's surface water; impairing recreation, fish consumption, drinking water use, and aquatic life (2014 Integrated Report).

Starting in 2008, the MPCA began a 10-year cycle to monitor and assess about eight of Minnesota's 80 watersheds each year, to identify impaired and "unimpaired" waters. The first iteration of this monitoring cycle has been completed and monitoring is returning to watersheds in order to track progress towards meeting water quality goals. In some regions of the state, our major watersheds are characterized as moderately to severely polluted. Constituents of concern often include: suspended sediments, excess nutrients (primarily nitrogen and phosphorus), pesticides, pathogens and biochemical oxygen demand. The sources of pollutants have been defined by major watershed for the areas studied during the first 10-year cycle of monitoring and assessment of the state's watersheds.

The challenge now will be to implement the strategies to restore and protect our water resources to meet the water quality goals and nutrient load reductions, defined in our reports and planning documents; that include:

- The Minnesota Nutrient Reduction Strategy,
- Minnesota's Clean Water Roadmap, Setting long-range goals for Minnesota's water resources,
- Watershed Restoration and Protection Strategies (WRAPS),
- Total Maximum Daily Load (TMDL) Reports, and
- Nitrogen in Minnesota Surface Waters, conditions, trends, sources, and reductions.

Finally, implementation of all of the tools available for reducing and preventing pollution, from regulatory permits to voluntary BMPs, is key to achieving water quality standards and ensuring that the designated uses of Minnesota's surface waters are restored and maintained.

Conclusion

In accordance with 2008 legislation that modified state agency reporting requirements for water assessments and reports, this report summarizes relevant water quality monitoring data for both groundwater and surface water in Minnesota from the MPCA and MDA.

The MPCA and MDA collect water quality information in response to both broad and specific statutory mandates to explore water quality issues of current and emerging concern, and in accordance with formal interagency agreements, and through continuous cooperation and open communication.

Significant progress has been made by MPCA, MDA and stakeholders in addressing sources of groundwater contamination, particularly through remediation, permitting and BMP activities. However, concerns still exist, and continued effort is needed to fully realize the state's groundwater quality goals.

Improvements in state surface water quality have also been significant, along with voluntary and regulatory reduction of point and nonpoint sources of pollution through MDA and MPCA programs and stakeholder support. Coupled with these gains are opportunities for continued improvements, and additional actions are needed to realize Minnesota's surface water quality goals.

For both groundwater and surface water resources, ongoing monitoring is required to characterize vulnerable aquifers and landscape settings. Additionally, MDA and MPCA must continue to identify and investigate contaminant problems, including the presence and extent of emerging contaminants.

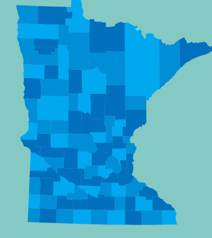
Ongoing monitoring provides the trend data that is critical to evaluating progress and refining management actions. Protection strategies – whether regulatory or voluntary –must be developed that avoid the occurrence of new problems, and all strategies should be periodically re-evaluated and refined in order to adapt to changing situations in chemical and land use.

Groundwater monitoring

September 2020

Appendix B: 2020 Groundwater Monitoring Status Report

MINNESOTA POLLUTION CONTROL AGENCY



Prepard by:

Dave Tollefson, Mike MacDonald, Kim Kaiser, Brennon Schafer, Jeff Berg, Bill VanRyswyk (Minnesota Department of Agriculture, Pesticide and Fertilizer Management Division), Joy Loughry (Minnesota Department of Natural Resources), Steve Robertson (Minnesota Department of Health) and, Mark Ferrey, Sharon Kroening, Bruce Monson, Erik Smith, Andrew Streitz (Minnesota Pollution Control Agency, Environmental Outcomes and Analysis Division) for the Minnesota Environmental Quality Board.

Minnesota Pollution Control Agency
520 Lafayette Road North, Saint Paul, MN 55155
http://www.pca.state.mn.us
651-296-6300 or
800-657-3864 toll free
TTY 651-282-5332 or
800-657-3864 toll free
Available in alternative formats

Minnesota Department of Agriculture
625 Robert Street North, Saint Paul, MN 55155
http://www.mda.state.mn.us
651-201-6141 or
800-967-2474 toll free
TDD 800-627-3529 toll free
Available in alternative formats

Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 |

651-296-6300 | 800-657-3864 | Or use your preferred relay service. | Info.pca@state.mn.us

This report is available in alternative formats upon request, and online at www.pca.state.mn.us.

Document number: lrwq-gw-1sy20a

Contents

Introduction

The 1989 Groundwater Protection Act (GWPA) (Minnesota Statutes, Chapter 103H.175) requires the Minnesota Pollution Control Agency (MPCA), in cooperation with other agencies participating in the monitoring of water resources, to provide a draft report on the status of groundwater monitoring to the Environmental Quality Board (EQB) for review every five years. This report is written to provide an update of groundwater monitoring activities in Minnesota to fulfill the MPCA's 2020 GWPA reporting requirements. For additional information on the background and history of groundwater monitoring in Minnesota, see *The Condition of Minnesota's Groundwater, 2013-2017* (Kroening and Vaughan 2019), at: https://www.pca.state.mn.us/sites/default/files/wq-am1-10.pdf.

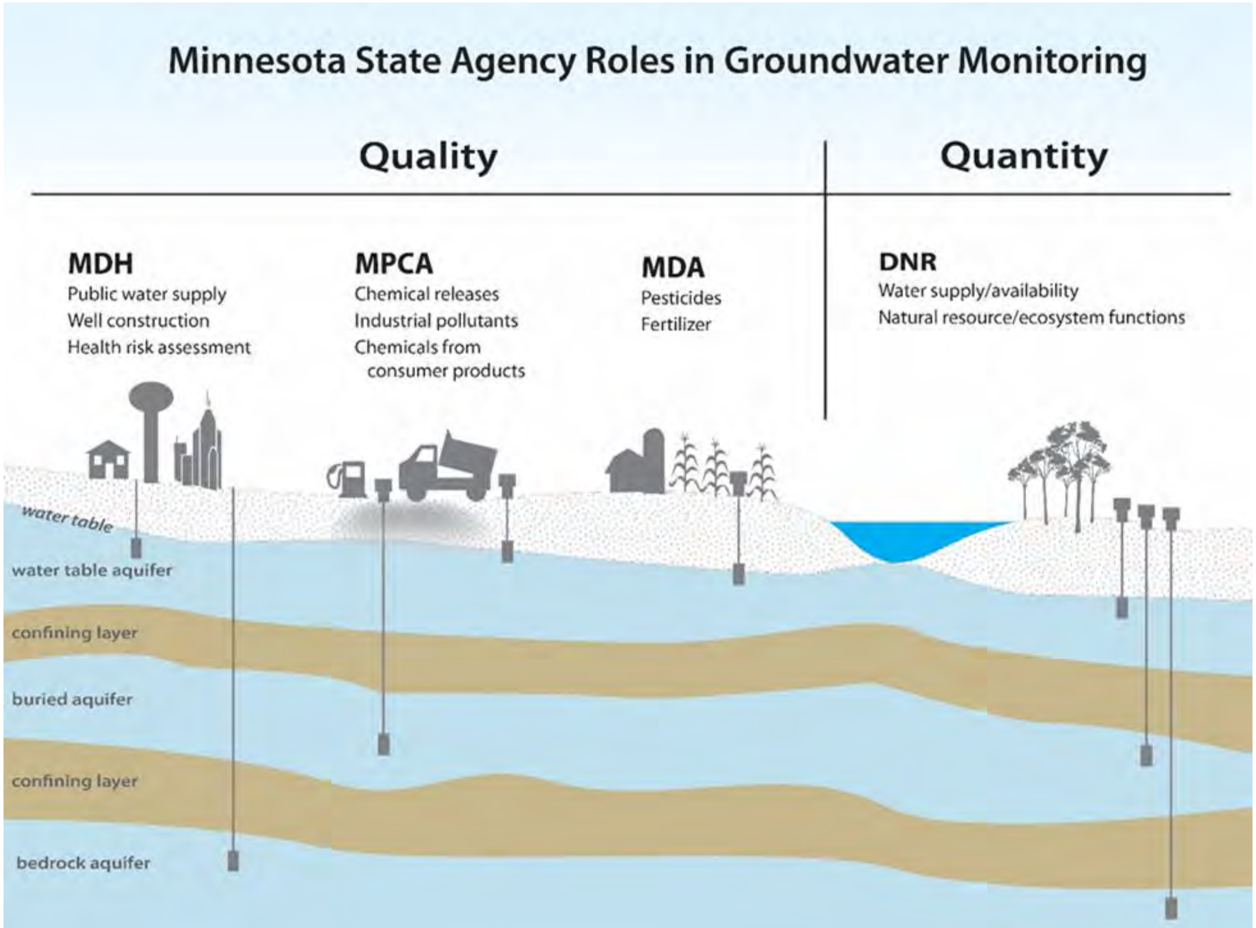
Agency roles in groundwater monitoring and assessment

Minnesota state law splits the groundwater monitoring and protection responsibilities among several state agencies. Each of the agencies involved handles a unique facet of groundwater monitoring and protection. It takes the concerted effort of all these agencies, along with local and federal partners, to build a comprehensive picture of the status of the state's groundwater resources.

Three state agencies, the MPCA; Minnesota Department of Agriculture (MDA); and Minnesota Department of Health (MDH), have important statutory roles and responsibilities in protecting the quality of Minnesota's groundwater as shown in Figure 1. The MPCA and MDA both conduct statewide ambient groundwater quality monitoring for non-agricultural chemicals and agricultural chemicals, respectively. These two agencies share many monitoring resources, including the computer database that stores the data that is collected, the technical staff that manage this information, and occasionally the sampling staff that collects the state's groundwater samples. For example, each year MPCA field staff collects pesticide samples from 20 wells in their network for the MDA. MDH conducts monitoring to evaluate and address the human health risk of contaminants in the groundwater that is used for drinking. In addition to these agencies, the Minnesota Department of Natural Resources (DNR) monitors groundwater quantity conditions across the state through a network of groundwater monitoring wells, and the Metropolitan Council conducts regional water supply planning using the information collected by the MPCA, MDA, MDH, and DNR.

A 2004 Memorandum of Agreement (MOA) between the MPCA, MDA, and MDH clarifies the agencies' roles in operating a statewide-integrated groundwater-quality monitoring system

Figure 1. State agency roles in groundwater monitoring [Graphic courtesy of the Minnesota Department of Natural Resources



Water quality monitoring and assessment

Between 2015 and 2020, groundwater quality monitoring in Minnesota mainly was conducted by state agencies in partnership with local entities and the federal government. The following sections provide more detail about these monitoring activities.

National water quality monitoring

The National Groundwater Monitoring Network (NGWMN) is the primary National-scale groundwater monitoring program operated by the federal government from 2015-2020. The NGWMN is a National-scale monitoring effort that was started by the Subcommittee on Groundwater (SOGW) of the Federal Advisory Committee on Water Information (ACWI). The ACWI is an administratively inactive committee that advised the federal government on the effectiveness of the current National programs to meet water information needs. The federal government also collected a substantial amount of groundwater information as part of the National Water Quality Assessment (NAWQA) program, which was discontinued in 2019.

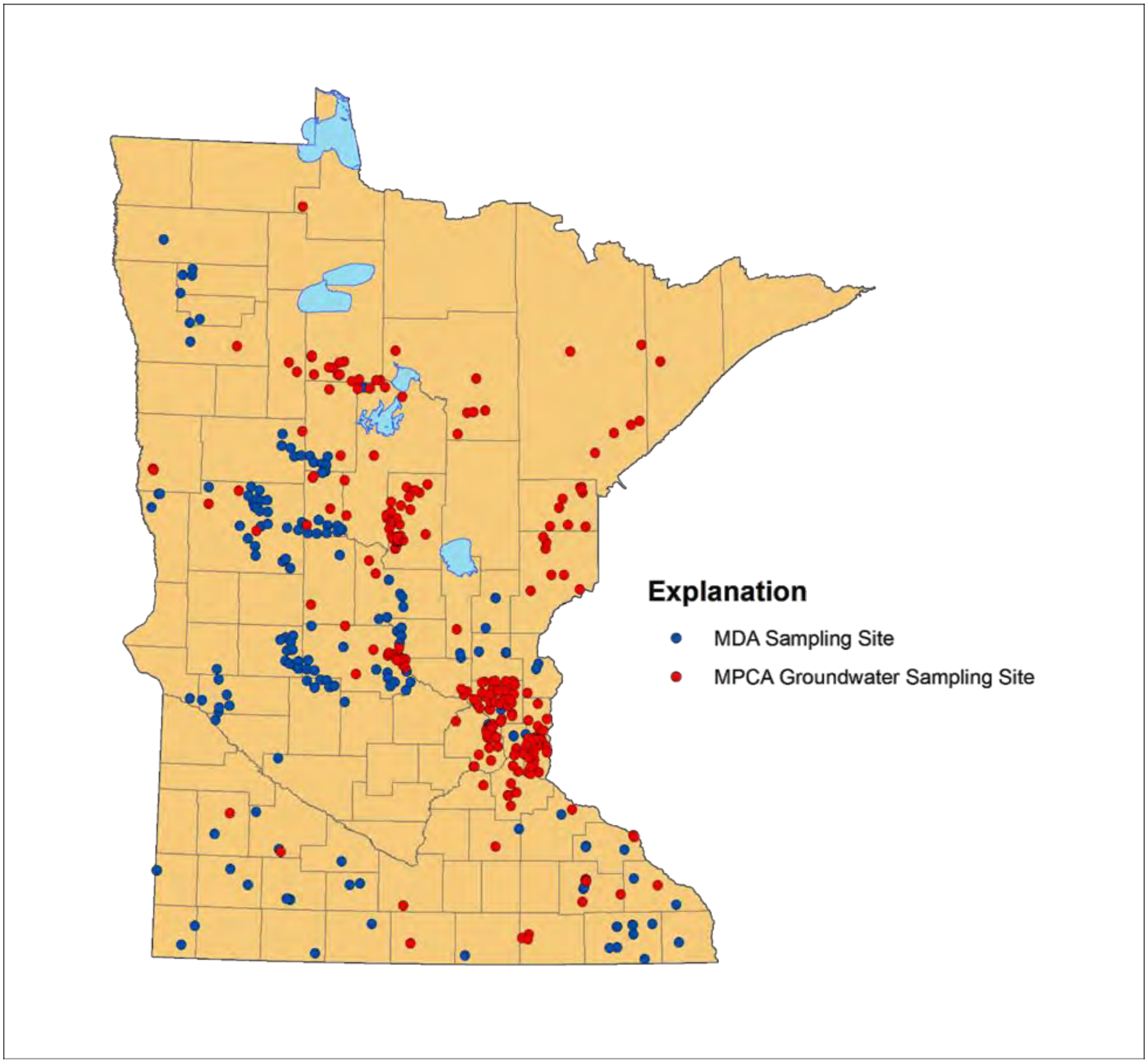
The NGWMN provides information needed for planning, management, and development of groundwater supplies to meet current and future needs and ecosystem requirements. The NGWMN differs from the NAWQA program in that it focuses on the principal and major aquifers of the United States; these are the primary aquifers used for potable water supplies. Additionally, the NGWMN will use information from all 50 states. The NGWMN generally does not collect new information. Instead, the network typically uses data that already is collected by the states, tribes, and other local units of government. The NGWMN initially was developed using data from five pilot studies, one of which was jointly conducted by the MPCA and DNR, available athttps://files.dnr.state.mn.us/publications/waters/mn_ngwmn_pilot_project_final_report_march_2011.pdf . As of 2020, the NGWMN continued to receive federal funding to encourage other partners, including those in Minnesota, to participate in the network and for the long-term operation and maintenance of the network.

Statewide water quality monitoring

The MPCA and MDA continued statewide ambient groundwater quality monitoring during 2015-2020. This monitoring still focused on aquifers that are vulnerable to anthropogenic (manmade) contamination from the land surface. Monitoring groundwater in vulnerable aquifers increases the likelihood that human impacts on groundwater quality will be detected within a reasonable time frame. The MPCA ambient monitoring efforts were conducted in non-agricultural areas of the state with a majority of samples collected in quaternary (glacial) sand and gravel aquifers. The MDA monitoring focused on agricultural regions in quaternary sand and gravel aquifers, with additional samples collected from springs and domestic wells in the southeastern part of the state where little or no quaternary deposits are present. The ambient monitoring targets pesticides and also collects nitrate samples. The locations for both MPCA and MDA monitoring programs are shown in Figure 2.

MDH water-quality monitoring efforts continued to focus on assessing public water supplies, which often utilize groundwater. The MDH facilitated the water quality sampling of the state’s finished drinking water in cooperation with the public water supply systems to determine contaminant concentrations as part of the Safe Drinking Water Act regulations. MDH also conducts additional groundwater monitoring in support of public water supply protection to evaluate potential threats in wellhead protection areas and where groundwater may be recharged by surface water.

Figure 2. Statewide Ambient Groundwater Monitoring Networks maintained by the Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Agriculture (MDA)



Minnesota Pollution Control Agency

The MPCA currently monitors a network that includes almost 270 wells, which mostly are located in typical urban settings. The majority of the wells are sampled to provide an early warning of groundwater contamination within different urban land use settings. This allows the agency to better understand how groundwater quality varies with land use and quickly detect any changes over time. The early warning network wells intersect the water table and are located in commercial/industrial and residential areas served by centralized sewer systems and subsurface sewage treatment systems. The agency also samples some deep wells in areas vulnerable to groundwater contamination; these primarily are domestic wells that supply water to private residences.

From about, 2010-2015, the MPCA enhanced its early warning network. This network originally was developed in 2004 solely using existing wells to minimize costs. Most monitoring wells originally sampled by the MPCA's network were installed for the purposes of remedial investigations; the wells that were installed "upgradient" of the suspected contamination (usually a few hundred feet) were also used for ambient monitoring to minimize network installation costs. Using remediation wells resulted in a bias towards detecting gasoline-related volatile organic compounds in surficial aquifers and likely was not representative of ambient groundwater conditions. The network enhancements focus on the groundwater quality underlying vulnerable, shallow sand and gravel aquifers to provide an early warning of groundwater contamination. The well installation associated with these network enhancements is nearly complete, and almost 140 new monitoring wells have been added to the MPCA's network from about 2010-2015.

MPCA staff test the groundwater contained in these wells each year for over 100 chemicals, including nutrients, inorganic compounds, volatile organic compounds, and contaminants of emerging concern (CECs), such as prescription and non-prescription medicines and chemicals in commonly-used household products. Assessing CECs in the groundwater is part of the MPCA's larger efforts to determine the occurrence, distribution, sources, and fate of these contaminants in the hydrologic system.

MPCA has conducted special projects to leverage the existing Ambient Groundwater Monitoring Well Network to monitor for Per- and Polyfluoroalkylsubstances (PFAS). In 2013, the roughly 200 wells that comprised the network at that time were sampled for PFAS, followed by a more limited sampling in 2017. The results of this were reported in *The Condition of Minnesota's Groundwater Quality, 2013-2017* (Kroening and Vaughan, 2019) available at: https://www.pca.state.mn.us/sites/default/files/wq-am1-10.pdf. Most recently, another full sampling of the network was conducted in 2019. Preliminary review of those results reveal that 60% of wells had detectable PFAS, with nine wells showing concentrations of PFOA or PFOS exceeding health-based guidance values. This monitoring effort has revealed that PFAS are present in areas with no known sources of contamination.

The MPCA Sentinel Lakes groundwater monitoring network is an offshoot of the larger ambient monitoring network and is focused on the movement of groundwater near lakes enrolled in the Department of Natural Resources' SLICE program (Sustaining Lakes in a Changing Environment). These lakes are called Sentinel Lakes and represent the state's most common aquatic environments. The DNR is studying the lakes to develop management approaches that can reduce and mitigate negative effects of agriculture, residential development, invasive species and climate change. By placing monitoring wells next to selected Sentinel Lakes, the MPCA can better understand the interaction of groundwater and surface water, contribute to the DNR project, and help protect these important resources.

Thirteen wells have been installed next to Sentinel Lakes from 2012-2015 in St. Louis, Stearns, Blue Earth, and Lincoln Counties. Transducers have been placed in all wells to collect continuous records of barometric pressure, groundwater temperature, and groundwater elevation. The land use near the monitored lakes selected ranges from farming country with a high density of large capacity groundwater irrigation systems, to isolated North Country lying entirely within the boundaries of a State Park. The data collected from this monitoring effort has been used to build groundwater models, augment groundwater reviews of selected watersheds, and highlight the relation between groundwater use and lake levels and quality. Most recently, this data is being used to evaluate a sudden resurgence of eutrophic conditions in Lake Shaokatan after conditions had been steadily improving in the years prior.

In addition to monitoring ambient groundwater conditions, the MPCA continues to collect groundwater quality information at contaminant spill and release sites, permitted landfills, and land treatment facilities. The MPCA remediation programs alone have investigated a cumulative total of 28,945 sites since 1990, with the main focus of protecting groundwater resources. Approximately 2,017 of these sites have ongoing corrective actions, many of which include groundwater monitoring. Petroleum product spill sites and voluntary investigation and cleanup sites (brownfields) make up the majority of these sites, followed by Superfund, RCRA, and closed landfills. The most common contaminants detected at remediation sites are volatile organic compounds and major and trace inorganic elements.

Minnesota Department of Agriculture

The MDA began monitoring pesticides in groundwater in November 1985 and redesigned its network in 1998. New wells were installed in 1999, and the MDA began sampling these wells in 2000. Wells were first installed in the vulnerable aquifers located in the central sand plains (Pesticide Monitoring Region (PMR) 4) for the purpose of tracking pesticide trends over time. Pesticide monitoring of other PMRs of the state began in 2004, including sampling of naturally occurring springs in the southeast portion of the state (PMR 9). In 2009, natural spring monitoring was augmented with the sampling of domestic drinking water wells. Groundwater in the north central and northeastern part of the state are not currently monitored for pesticide due to very limited agricultural production in these heavily forested regions.

The MDA collected pesticide samples from 166 wells and springs in 2019. Of the total sites, 142 were monitoring or observation wells, 11 were private drinking water wells, and 13 consisted of naturally occurring springs emerging from karst bedrock formations in southeastern Minnesota. All locations are considered sensitive to contamination from activities at the surface. These locations are considered the MDA's ambient groundwater network, shown as blue dots on Figure 2. Pesticide concentrations in MDA's ambient groundwater network are generally detected well below drinking water standards, although some of the pesticide degradates do occur frequently in some areas. Additional detail can be found in the MDA's annual Water Quality Monitoring Report. Current and past annual monitoring reports can be found under "Reports and Resources" at the following link: https://www.mda.state.mn.us/monitoring.

The MDA began evaluating pesticide presence and magnitude in private drinking water wells in 2014 as part of the Private Well Pesticide Sampling (PWPS) Project. The PWPS Project is a companion project to the nitrate focused Township Testing Program (TTP), where sampling is targeted in townships with both vulnerable groundwater and row crop agriculture. Homeowners with a nitrate detection in their drinking water well as part of the TTP can have their well water sampled for pesticides free of charge. A follow-up sample collected from their well, by the MDA, is analyzed again for nitrate and for a suite of pesticides similar to the list used in the MDA's ambient monitoring network. Through 2019, the PWPS Project has sampled approximately 6,100 wells in 42 counties. The MDA estimates approximately 840 wells will be sampled in eight additional counties by the time the PWPS Project concludes on June 30, 2021. With the exception of the degradates of the herbicide cyanazine (discussed below), concentrations of detected pesticides are generally well below drinking water standards but can occur frequently in certain regions. For details of the PWPS Project, see: https:https://www.mda.state.mn.us/pesticide-fertilizer/private-well-pesticide-sampling-project

In 2019, the MDA began analyzing samples in both the ambient program and the PWPS Project for cyanazine degradates. Cyanazine is an herbicide that was discontinued from use in 2002. The Dakota County Environmental Resources Department has sampled private wells within the county for cyanazine and cyanazine degradates and detected concentrations of these chemicals that, when added together (total cyanazine), exceed the Minnesota Department of Health (MDH) established Health Risk Limit (HRL) for cyanazine. Until 2019, the United States Geological Survey (USGS) Organic Geochemistry Research Laboratory was the only laboratory in the United States that was able to analyze for these compounds. In 2019, the MDA Laboratory developed methods to test for these compounds and they were added to the regular suite of compounds analyzed for the ambient program. The MDA contract laboratory used for the PWPS Project also added these compounds to their analyte suite. In 2019, approximately 3% of PWPS wells were found to have cyanazine degradate concentrations that exceeded the HRL for total cyanazine.

The MDA is working with MDH to develop a comprehensive plan to assess the extent of these compounds in drinking water. Additional information on cyanazine monitoring including an evaluation of reverse osmosis point-of-use water treatment systems can be found at: https://www.mda.state.mn.us/cyanazine-monitoring.

The MDA also manages a remediation program which oversees the collection of a large volume of groundwater quality information from contaminant spill and release sites. Over 800 sites have been investigated and one of the main priorities of these investigations is to protect groundwater resources. Soil corrective actions are completed at most sites, and groundwater monitoring is completed at many of these sites. Typical sites include agricultural chemical storage and distribution cooperatives in rural Minnesota, agricultural chemical manufacturing facilities and wood treating facilities. Groundwater monitoring also is conducted at sites managed by the MDA, including the former Kettle River Creosoting Company site in Sandstone, Minnesota. Common constituents that are monitored at MDA remediation sites include fertilizers, herbicides and insecticides and wood treatment compounds.

The revised Nitrogen Fertilizer Management Plan (NFMP) outlines a Township Testing Program (TTP), designed to identify agricultural areas with elevated nitrate concentrations in groundwater. Townships with greater than 20% row crop agriculture and vulnerable groundwater are sampled. All private wells in these townships are offered a free nitrate test, with the results summarized and prioritized for further action. Further details of the TTP are presented under nitrate below.

The state's new Groundwater Protection Rule (GPR) became effective on June 24, 2019. The GPR will reduce the risk of nitrate from fertilizer impacting groundwater in areas of the state where soils are prone to leaching and where drinking water supplies are threatened. Nitrate is one of the most common contaminants in Minnesota's groundwater. Elevated nitrate levels in drinking water can pose serious health concerns for humans. The rule restricts fall application of nitrogen fertilizer in areas vulnerable to contamination, and it outlines steps to reduce the severity of the problem in areas where nitrate in public water supply wells is already elevated.

For more details on the rule, see: https://www.mda.state.mn.us/nfr

Minnesota Department of Health

Groundwater quality monitoring activities support the mission of the MDH, "to protect, maintain, and improve the health of all Minnesotans," by providing data that are used to evaluate the level of contaminants in groundwater used for drinking water. These data help verify compliance with federal and state regulations, establish baseline water quality conditions for drinking water sources, inform the process for producing health based guidance, and guide development of groundwater models and vulnerability assessments for source water protection and other water supply planning efforts to safeguard our drinking water. The following paragraphs provide additional information about MDH's groundwater quality monitoring activities.

MDH assists approximately 6700 community and non-community public water systems to provide safe and adequate drinking water as outlined in the federal Safe Drinking Water Act (SDWA). Most of these systems utilize a groundwater source of supply. MDH staff and laboratory personnel collect and analyze water samples from public water systems for required parameters on a schedule that is dependent on the type of water system. Factors that influence the schedule and required parameters conform to SDWA criteria. They include well vulnerability, system type (community or non-community) and population served.

MDH routinely monitors public water supply systems for a number of different contaminants, including pesticides and industrial compounds, bacterial contamination, nitrate/nitrite, radioactive elements (radium), disinfection by-products, arsenic, lead, copper, and other inorganic chemicals. MDH reviews monitoring results to determine if they meet applicable federal or state drinking water standards. In the event of an exceedance, the people who use the water are notified and appropriate steps are taken to correct the problem.

MDH reviews nitrate/nitrite, coliform bacteria, and arsenic data collected by well drillers from newly installed private drinking water wells to determine the potability of the water. Approximately 20% of Minnesotans are served by private water systems (almost entirely wells). State regulations, administered by MDH, require licensed water well contractors (and anyone constructing a new well for personal use) to have the water from each new drinking water well tested once for arsenic.

MDH continues to administer the state's wellhead protection program which is designed to protect drinking water from sources of contamination. Public water supply systems serving places where groups of people live (municipalities, subdivisions, etc.) or spend much of their time (offices, schools, etc.) are required to develop and implement wellhead protection plans. MDH reviews, approves and audits the 10-year plans.

MDH is also involved in other source water protection monitoring initiatives that are focused on specific issues or geographic areas. Several of these are highlighted below.

Unregulated Contaminants Monitoring

From the standpoint of MDH and drinking water utilities, unregulated contaminants are those that lack specific water quality standards (e.g., Maximum Contaminant Levels or MCLs). MCLs exist for approximately 100 compounds. The set of compounds that are known to exist in the environment is far larger and grows regularly because research into contaminants of emerging concern is active and on-going. Some of these contaminants have known health impacts to humans. Investigative monitoring to assess the occurrence and distribution of contaminants of emerging concern is important to help understand the scope and scale of such contamination, to guide the development of health-based guidance, to inform other best management practices to avoid or limit occurrence in drinking water sources, and to provide solid information to maintain trust and confidence in public drinking water systems.

MDH currently lacks firm capacity to conduct CEC monitoring on a regular basis. Instead, current efforts have been carried out as part of specific projects, some of which are described below.

Federal Unregulated Contaminants Monitoring Rule Sampling (UCMR)

Federal rules require public water systems meeting certain size criteria to collect samples and have them analyzed for approximately 30 unregulated contaminants as identified in a national nomination and vetting process. Sampling sites consist of public water systems served by both surface water and groundwater. MDH coordinates UCMR sampling in Minnesota. Up to 2020, there have been four rounds of this mandated sampling. A fifth is in the planning stage and will start in 2023. MDH obtains the data and evaluates the results – EPA compiles results on a national level. See: https://www.epa.gov/dwucmr.

Minnesota's Unregulated Contaminants Monitoring Project (UCMP)

With the support of the Environment and Natural Resources Trust Fund, MDH initiated a project in 2018 to sample selected public water systems at risk of impact from several different classes of unregulated contaminants. Three networks of sampling sites comprised of public water system sources (wells or intakes) was established. The first consisted of systems that use surface water for supply. Public water systems with vulnerable wells in close proximity to potential wastewater sources comprise the second network. The third network is made of vulnerable wells in close proximity to agricultural land uses. Parameters selected for analysis varied depending on the network and the likely types of sources. Sampling was conducted at both the source and at the entry point. Major parameter classes included pharmaceuticals, personal care products, pesticides, industrial contaminants, and hormones. Sampling was completed in 2019. Results and reporting are expected to be complete in 2021. For more information, see:

https://www.health.state.mn.us/communities/environment/water/unregcontam.html

Pathogen (aka Virus) Project

From 2014-2016, MDH sampled 145 public water supply wells for 23 pathogens and microbial indicators, including viruses, bacteria, and protozoa. The results indicate that genetic material from these organisms is widespread in groundwater, although transient in nature. On-going projects are currently underway to assess the potential pathways for microbial occurrence in wells so MDH can better safeguard consumers of well water from pathogen exposure.

Pesticides (2010, 2015)

MDH and MDA cooperated on two projects in 2010 and 2015 to evaluate occurrence and distribution of pesticides in selected public water system wells deemed to be most vulnerable to water quality impacts in vulnerable parts of the state. Sampling sites were selected statewide due to varying agricultural practices across the state. Full reports on this work are available at: https://www.mda.state.mn.us/sites/default/files/inline-files/2015PesticideReconReport_0.pdf.

Per- and poly-fluorinated alkyl substances (PFAS)

MDH collaborates with public water systems, other state programs, federal partners and local governments on the investigation and response to potential threats to water supplies from emerging contaminants, such as PFAS. Various strategies are being employed to sample all community water systems for selected PFAS compounds by 2025. These efforts will start in 2020 in a targeted fashion. This work will rely on data and information of known PFAS presence in the environment from MPCA and others to identify high-risk locations for sampling.

In the eastern portion of the Twin Cities Metro Area, the MDH has collaborated with the MPCA to sample over 1,000 private wells in multiple areas of Washington County to determine the extent of PFBA (i.e. one of the PFAS compounds) in the aquifers, and continues to work with the MPCA to monitor over 400 of those wells.

Water quantity monitoring and assessment

The DNR continued statewide and regional groundwater quantity monitoring and assessments during 2015-2020. The DNR conducted statewide groundwater level monitoring and developed more county-scale groundwater sensitivity maps during this period.

Department of Natural Resources

The MDNR's statutory responsibilities with regard to groundwater are centered on monitoring and managing groundwater levels, groundwater availability and the long-term sustainability of Minnesota's groundwater and surface water resources. MDNR maintains a Groundwater Observation Well Network, conducts aquifer tests, develops county groundwater atlases and administers the preliminary well assessment program and a water appropriations permit program. As part of this work, the MDNR collects groundwater quality data under specific circumstances, which are described below.

The DNR maintains a groundwater level monitoring network across the state with approximately 1,140 actively measured wells, over 700 of which are instrumented to record level data hourly. Data collected from the network is used to assess groundwater resources, determine long-term trends in water levels, interpret impacts of pumping and climate, plan for water conservation, and evaluate water conflicts.

Starting in the late 2000s dedicated funding allowed for planned network expansion to study specific aquifers and areas of groundwater management concern. LCCMR funds were used to install wells to study the edge of the Mt. Simon aquifer and Clean Water Funds were specifically dedicated to fill gaps in the bedrock aquifers located in the Twin Cities Metro Area. MDNR's goal is to add 50 new observation wells each year; prioritized around the state in areas of known high use, areas that serve public water supplies, and areas with little information. When possible and as funding allows, new wells in the network are intended to be constructed to enable water quality sampling in addition collection of water level data.

Water level monitoring is also conducted at approximately 400 locations associated with groundwater appropriations permits. Information from these wells helps inform if pumping of groundwater is causing adverse impacts to surface water features or other water users. An ongoing water supply planning effort is guiding establishment or improvement of monitoring plans for all 650 public water suppliers.

Since 1995 the DNR, in collaboration with the Minnesota Geological Survey (MGS) has produced county geologic atlases. The DNR part of this atlas series (Part B) have been recently completed for Anoka (2016) Blue Earth (2016), Brown (2020), Clay (2018), Kanabec (2020), Meeker (2019), Morrison (2019), Nicollet (2016), Redwood (2019), Renville (2017), Sherburne (2017), Sibley (2017), Washington (2019), and Wright (2019) counties. As a part of all these projects, groundwater sampling is done at selected wells to better understand groundwater movement and support groundwater sensitivity mapping. Approximately 80-100 wells are sampled in each investigated county to determine major ion and trace element concentrations. In addition, tritium values, and values of oxygen and hydrogen stable isotopes, are evaluated to help understand groundwater recharge rates and possible surface water body sources, respectively. Additional groundwater samples are collected from a few wells in each county for analysis of carbon-14 age dating at locations and in aquifers that likely have very old water in the range of thousands to tens of thousands of years.

MDNR offers access to the observation well network for water quality studies. A recent example is partnering with MDH for their Pathogen Project using a well in Cottage Grove. USGS has installed real-time data equipment and MDH is using that data to determine when they need to sample the well for water quality.

MDNR and MPCA have partnered with the USGS in their National Ground-Water Monitoring Network (NGWMN) since their pilot in 2010. The (NGWMN) is a network of selected wells from Federal, multistate, State, and local ground-water monitoring networks brought together under a set of defining principles and is designed to provide information essential for national and regional scale decisions to be made about current ground-water management and future ground-water development. MDNR created a database connection to the NGWMN and supplies information for approximately 375 wells in

Minnesota. NGWMN also has awarded MDNR funds to drill new observation wells in areas of interest for both networks.

Current and emerging groundwater quality issues

Chloride

Excessive chloride concentrations in groundwater limit its use for drinking and can be harmful to fish and other freshwater aquatic life if transported to surface waters. Chloride is highly mobile in the environment and once in the environment, is extremely difficult to remove. MPCA's monitoring of Minnesota's groundwater has detected elevated concentrations of chloride within specific land use settings.

The most recent MPCA report on statewide groundwater quality (Kroening and Vaughan, 2019) found that high chloride concentrations result generally from the human use of this substance, such as pavement de-icing or water softening. The distribution of chloride concentrations in the state's various aquifers and the chemical signature of the water suggest a human-caused chloride source in most locations where chloride was found. Concentrations generally are stratified in the groundwater, with the highest concentrations near the water table and the lowest in the deepest aquifers. This distribution suggests the chloride was transported into the groundwater from a land surface source. The chemical signature also suggested that most chloride of the groundwater in the majority of the tested wells in urban areas resulted from sources such as salt used to de-ice pavement or soften water.

Concentrations are typically highest in the groundwater near the water table in the Twin Cities Metropolitan Area (TCMA). Most of the tested water table wells with chloride concentrations greater than the state's drinking water standard of 250 mg/L were located in the TCMA. In the Prairie du Chien-Jordan aquifer, an important drinking water source in southeastern Minnesota, the highest chloride concentrations generally occur where the aquifer is close to the land surface and overlain by a thin layer of unconsolidated deposits. These areas include the eastern TCMA and the Prairie du Chien Plateau.

MPCA's monitoring also found that chloride concentrations were highest in water table wells underlying urban parts of the state. The highest median concentration (81.9 mg/L) was found in wells underlying commercial/industrial areas, and the second highest median concentration was found in wells underlying sewered residential areas. The lowest median concentration (1.1 mg/L) was in wells underlying undeveloped forested parts of the state.

The MPCA also routinely examines whether chloride concentrations are changing in the groundwater. The last analysis focused on recent changes from 2005-2017. Overall, 40% of the wells included in this trend analysis had an upward trend in chloride concentrations. The wells with upward trends were not just restricted to the water table; the majority of them were installed in bedrock aquifers.

MPCA will continue to make chloride sampling a focus of its groundwater monitoring efforts, specifically evaluating the potential for downward migration from surficial sand and gravel aquifers to the sedimentary aquifers underlying the TCMA and southeast Minnesota.

Nitrate

Nitrate continues to be one of the state's main groundwater quality issues, especially since a few communities have spent millions of dollars to ensure their water supplies do not contain excessive levels of this chemical. Most groundwater quality monitoring in the state includes a nitrate analysis, and these data were summarized in several recently-published reports.

Assessments by the MPCA (Kroening and Ferrey 2013; Kroening and Vaughan 2019) found that nitrate concentrations in the state's shallow groundwater still vary with land use. The most recent assessment, based on data collected from 2013-2017. The most recently analyzed found the median concentration in the groundwater near the water table in agricultural areas was 10 mg/L; whereas, the median concentration in the shallow groundwater underlying various urban land uses ranged from 1.1-1.8 mg/L.

The MPCA assessment also noted that the shallow sand and gravel aquifers, which usually are the uppermost aquifer in most parts of the state, contained the highest nitrate concentrations. Median concentrations in the aquifers underlying southeastern Minnesota ranged from 1.7 mg/L in the sand and gravel aquifers to 0.03 mg/L in the Wonewoc, the deepest aquifer with available data. Kroening and Ferrey (2013) found that about 40 % of the shallow sand and gravel aquifer wells that were tested in Central Minnesota contained nitrate concentrations that were greater than the Maximum Contaminant Level (MCL) of 10 mg/L set by the US Environmental Protection Agency for drinking water. Groundwater data collection was more limited in Southwestern Minnesota. However, the available data suggested that about 20% of the tested wells contained nitrate concentrations that exceeded the MCL.

Trends in nitrate concentrations in the groundwater also were quantified as part of the MPCA's groundwater quality assessments. The most recent study used data from over 100 wells across the state, which primarily tapped the shallow sand and gravel aquifers to determine whether nitrate concentrations changed. The nitrate concentrations in most of these wells had no significant change from 2005-2017.

MDA maintains three different private well nitrate monitoring efforts; the Southeast Volunteer Nitrate Monitoring Network (VNMN), the Central Sands Private Well Network (CSPWN) and the Township Testing Program. The CSPWN and the Southeast VNMN are designed to be sampled annually long term, while the Township Testing is a short term program and is nearing completion.

The South East Volunteer Nitrate Monitoring Network (VNMN)

In 2008, the Southeast Minnesota Water Resources Board (SEMNWRB), and several partners (MPCA, MDA, MDH) began collecting data from the "volunteer nitrate monitoring network" (VNMN). This region was selected as a pilot because of its vulnerable and complex geology. The network was developed to assess the practicality of establishing a cost-effective, locally driven means of obtaining long-term data on nitrate concentrations in private drinking water supplies. Nitrate concentrations were tested in approximately 600 private drinking water wells across nine counties in southeastern Minnesota. The wells were monitored to determine the impact that well construction and local land use have on drinking water quality, and to describe the regional distribution of nitrate concentrations and any temporal trends.

Before data collection began, well network coordinators (county staff) enrolled volunteers (well owners) into the program by collecting detailed information about well location, well construction, and nearby nitrate sources. Between February 2008 and August 2019, 14 sampling events occurred representing approximately 5,778 samples. During this period, the percentage of wells exceeding the Health Risk Limit (HRL) for each sampling event ranged between 7.5 and 14.6%.

MDA Central Sands Private Well Monitoring Network (CSPWN)

The MDA's CSPWN testing indicated that only a small percentage of the tested domestic wells in Central Minnesota had nitrate concentrations that exceeded the HRL. Of the 1,555 wells tested in 2011, only 4.6% of the wells had a nitrate concentration that exceeded the HRL of 10 mg/L (Kaiser, 2012). Almost 89% of the wells had a concentration that was less than 3 mg/L. The measured concentrations varied by county. The highest percentage of wells with nitrate concentrations exceeding the HRL were in Morrison County. In contrast, no tested wells had nitrate concentrations exceeding the HRL in Cass, Crow Wing, and Douglas Counties. Not surprisingly, almost one-half of the wells with nitrate concentrations greater than the HRL were shallow, with depths less than 50 feet.

Approximately 550 homeowners from the first Central Sands sampling event (2011) volunteered to participate in long-term annual sampling of their private wells. These 550 homeowners were a subset of the original testing population of 1,555. Between 2011 and 2019, nine sampling events occurred with approximately 3,768 samples collected from the long term volunteers. During this time, the percentage of wells exceeding the HRL for each sampling event ranged between 2.2 and 4.5%.

A report with the data from 2008-2018 from both networks can be found here: https://www.mda.state.mn.us/sites/default/files/2019-06/ntrendinwellnetwork.pdf.

Township Testing Program (TTP)

The MDA works with local partners such as counties and soil and water conservation districts (SWCDs) to coordinate private well nitrate testing using Clean Water Funds. Each selected township is offered testing in two steps, the "initial" sampling and the "follow-up" sampling.

In the initial sampling, all township homeowners using private wells are sent a nitrate test kit and the homeowner takes the sample. If nitrate is detected in their initial sample, the homeowner is offered a follow-up nitrate test, pesticide test, and well site visit. Trained MDA staff visit willing homeowners to resample the well and then conduct a site assessment. The assessment helps to identify possible non-fertilizer sources of nitrate and to see the condition of the well. A well with construction problems may be more susceptible to contamination.

As of March 2020, 344 vulnerable townships from 50 counties participated in the TTP from 2013 to 2019. In the 344 townships initially tested, 143 townships (41%) indicated 10% or more of the wells over the HRL for Nitrate-N.

Overall, 9.1% (2,925) of the 32,217 wells exceeded the HRL for Nitrate-N. These results reflect nitrate concentrations in private well drinking water regardless of nitrogen sources, or well construction. The final percentage of wells over the HRL may change based on follow-up sampling and site visits.

Once the follow-up sampling is completed, the MDA conducts an analysis of the results and prepares a final report for each county. Final results are determined using two rounds of sampling and a process to remove wells with construction concerns, insufficient construction information and those near potential non-fertilizer sources of nitrate. Wells are also removed from the final data set if homeowners do not participate in the second round of testing. Final results represent wells that are potentially impacted by a fertilizer source, while initial results represent private well drinking water regardless of source or the condition of the well. Detailed sampling results are available at: www.mda.state.mn.us/townshiptesting. The MDA uses the results to prioritize future work to address nitrate concerns, as described in the Nitrogen Fertilizer Management Plan (NFMP). Find more information about the NFMP at www.mda.state.mn.us/nfmp

Contaminants of Emerging Concern

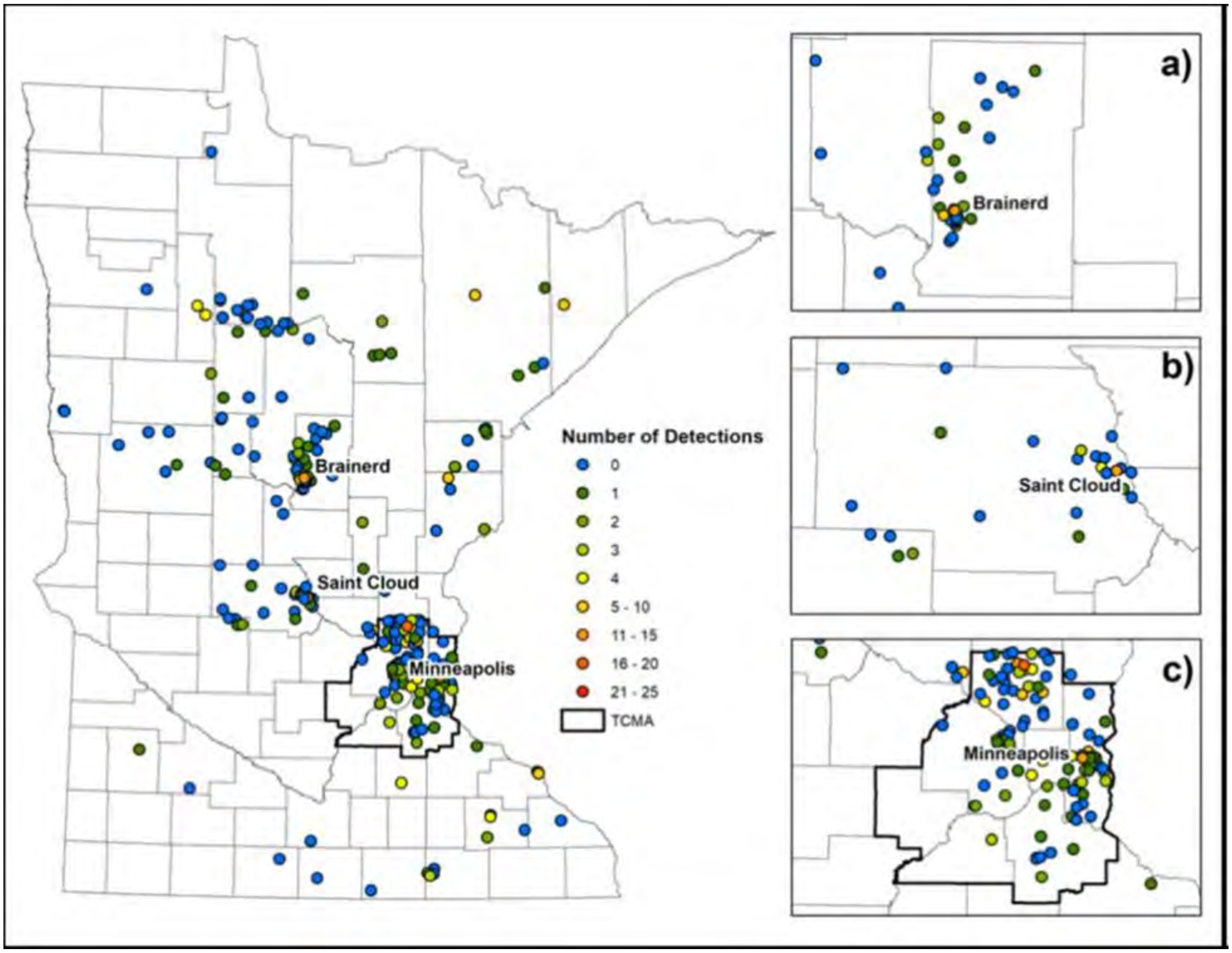
The MPCA has analyzed water samples collected from its Ambient Groundwater Monitoring Network for CECs since 2009 .To date, the agency has sampled over 250 wells in its monitoring network for over 200 CECs. From 2009-2014, this monitoring was conducted in cooperation with the USGS. In 2015, the MPCA contracted with AXYS Analytical Laboratories in British Columbia, Canada to analyze for CECs in the groundwater samples collected for its network. This change was made to align the agency's groundwater and surface water monitoring activities.

The CEC data collected in the groundwater across the state from 2013-2017 was interpreted in a report (Kroening and Vaughan, 2019). From 2013-2017, CECs were detected in 124 of the 262 wells sampled for these chemicals (Figure 3). The number of CEC detections in these wells ranged from one to 23. The two wells with the greatest number of detections specifically were installed to monitor contamination near old, unlined landfills, which are a known CEC source. The number of CEC detections was smaller in most of the other sampled wells. Ninety-five percent of the sampled wells had seven or fewer CEC detections in them, and the average number detected in a well was 1.6.

The most commonly detected CECs in the ambient groundwater were chemicals that are known to be persistent in the environment. Seventy-seven CECs were detected in the groundwater from 2013-2017 with frequency of 1.0% and greater. The most-frequently detected CECs were sulfamethoxazole, tris (1,3-dichloro-2-propyl)phosphate (TDCPP), iopamidol, and branched p-nonylphenols (Figure 22). These chemicals have very different uses. Sulfamethoxazole is an antibiotic used to treat bacterial infections. Iopamidol is a radio-opaque contrast agent, which is used for x-ray imaging, such as computed tomography (CTs), projectional radiography, and fluoroscopy. TDCPP is a chlorinated organophosphate and is commonly used as a flame retardant as well as a pesticide, plasticizer, and nerve gas.

The CEC concentrations measured to date have generally been low; no concentrations exceed any established human-health guidance values. However, many of the CECs measured in groundwater do not have established human-health guidance.

Figure 3. Number of Contaminants of Emerging Concern detected in ambient groundwater statewide and in three urban areas, 2013-2017. a)Brainerd, b) Saint Cloud, and c) Minneapolis-St. Paul Metropolitan Area



Groundwater data access and management

Data from the MPCA's ambient groundwater monitoring network, previous monitoring efforts, and the open, closed, and demolition landfills are available on the MPCA's website through the Environmental Data Access (EDA) system. The MDA ambient groundwater data can also be accessed through the EDA system. The EDA system was developed to improve access to environmental data and is available at the following web address (URL): http://www.pca.state.mn.us/index.php/data/environmental-data-access.html. The MPCA's and MDA's ambient groundwater information is also available through the Water Quality Portal (https://www.waterqualitydata.us), which is a partnership of the USGS, EPA and National Water Quality Monitoring Council.

The MPCA and MDA now store the groundwater quality data that they each collect in the same database. The database is commercially available from EarthSoft Inc. and called the Environmental Quality Information System or EQuIS. The DNR's County Well Atlas Program also is in the process of transitioning the storage of their groundwater quality data to this same database. The EQuIS database is managed as follows; a MnIT staff person serves as the EQuIS database administrator, and both the MPCA and MDA employ separate data coordinators to assist the data users in managing the information. The storage of these large sets of groundwater quality in the same database greatly simplifies regional or statewide analysis of groundwater quality conditions since the data are now stored in the same format. The MDH Environmental Laboratory, which analyzes a large number of the samples collected by the MPCA, and the MDA Laboratory have modified their systems and processes so the data generated by the laboratories can be easily uploaded to EQuIS.

Needs and conclusions

The ambient monitoring conducted by the MPCA, MDA, and others continues to provide valuable, long-term information on the water-quality conditions in aquifers vulnerable to contamination across Minnesota. As the demands for the state's groundwater change and variables such as climate change are introduced, this record of groundwater quality will become increasingly important for the proper use and management of this resource. A long-term commitment to the collection and analysis of groundwater data is necessary to identify changes in water quality and quantity over time and provide information needed to effectively manage and protect this critical resource. Groundwater movement is generally slow and often requires years of monitoring to assess the trends and direct and indirect impacts of human activities on this resource.

Recent groundwater quality assessments have confirmed that the chloride levels in the state's groundwater need to be watched. The high chloride concentrations present in some aquifers, especially in the shallow ones in the TCMA, either will be discharged into streams and lakes, or this chloride-laden groundwater will move downward into the deep aquifers that supply the state's drinking water. The inflow of groundwater containing chloride concentrations that exceed the chronic water-quality standard (230 mg/L) to streams may cause any chloride impairments to occur during baseflow conditions as well as during the usual winter period. Recent assessments have indicated that chloride concentrations have increased over time in the TCMA, in the shallow aquifers as well as parts of some bedrock aquifers. If these trends continue, more bedrock aquifer wells may be impacted by chloride in the future, and the water eventually may become unsuitable for drinking. Efforts are underway to fill identified, existing gaps in chloride monitoring. A large amount of the groundwater monitoring in the TCMA focuses on conditions at the water table. Additional deep wells are slated to be installed to track how the depth to which chloride has penetrated into the groundwater system.

Nitrate concentrations in the state's groundwater also should continue to be tracked, especially since some communities have had problems with high concentrations in their water supplies. The state's ambient monitoring networks should continue to monitor for nitrate in the groundwater, and MDA's nitrate-testing programs should continue to be funded to complete this important work. The newly implemented Groundwater Protection Rule should reduce the risk of nitrate from fertilizer impacting groundwater.

The presence of CECs, including PFAS, in the groundwater deserves continued watching. Although monitoring to date has found these chemicals are low in concentrations, it still is important to assess the presence of these chemicals because this monitoring identifies chemicals in the groundwater for which there are relatively few available human-health guidance values. Similarly, efforts by the MDH to develop human-health guidance values for these chemicals are invaluable because it allows scientists to determine whether the presence of these chemicals makes water unsuitable for drinking.

DEPARTMENT OF NATURAL RESOURCES

Water Availability and Assessment Report

Appendix C to the 2020 EQB Water Plan

09/15/2020

Minnesota Department of Natural Resources
500 Lafayette Road St. Paul
St. Paul, MN 55155-4025
(651) 296-6157
Email: info.dnr@state.mn.us
www.dnr.mn.us

As requested by Minnesota Statute 3.197: This report cost approximately $75,500 to prepare in staff time.

Report Contributors

Editors
Pooja Kanwar, Water Policy Consultant
Ellen Considine, Hydrologist Supervisor
Brian Stenquist, Communications and Planning Supervisor
Jason Moeckel, Inventory and Monitoring Analysis Section Manager

Subject-matter Experts
Kenny Blumenfeld, Senior Climatologist
Ian Chisholm, River Ecology Supervisor
Jay Frischman, Hydrogeologist Supervisor
Tom Hovey, Water Regulations Supervisor
Sean Hunt, Water Use Information Analyst
Steve Kloiber, Lake Ecology Supervisor
Joy Loughry, Water Monitoring and Surveys Supervisor
Dan Miller, Water Use Consultant
Zachary Moore, Hydrologist
Carmelita Nelson, Water Conservation Consultant
Dan O'Shea, River Ecology Scientist
Paul Putzier, Hydrologist Supervisor
Paul Radomski, Research Scientist
Jen Sorenson, Public Waters Hydrologist

Data visualizations and graphics
Rosalyn Krog, Hydrogeologist

Accessibility and design
Ruth MacDonald, Information Officer

The Clean Water Fund supported the data collection and analysis efforts described in this report.

Table of Contents

Table of Figures

Introduction

Minnesota's water resources are part of the very identity of our state: the land of 10,000 lakes. Our water resources provide habitat, recreational opportunity, drinking water supply and economic vitality. These resources are valued by Minnesotans and are part of our way of life.

This report is an exploration of water in relation to Minnesota's economy, communities, landscapes, and atmosphere. The report will describe how individuals, businesses and communities have been using water. The report will present data and information on the amount of water present and flowing through Minnesota over the recent past. The report will also present information on the Minnesota Department of Natural Resources' (DNR's) efforts to ensure the sustainable use of water in Minnesota.

The data and information on water resources in this report lead us to the following conclusions:

1. Climate: Minnesota's climate is changing. Our rainfall events are heavier and more intense and our winters are warmer. This trend fits with climate forecasts, which predict overall warmer and wetter conditions and more extreme weather such as damaging, intense rains. Although we are now in a wet cycle, droughts will return, and climate change models predict they will be longer and more severe than before.
2. Water Use: The total volume of water used has decreased over the last ten years, most notably in the energy sector due to the reduction of water use in power plants.
3. Streams: Streamflows have been high around the state, reflecting increased precipitation.
4. Lakes: Lake levels have been generally higher around the state, also reflecting increased precipitation.
5. Wetlands: There has been a slight increase in the acreage of wetlands around the state, and some wetlands are shifting toward wetter types. This is likely due to wetland restoration policies and programs, and increased precipitation.
6. Groundwater: Groundwater levels have been generally high around the state, although some locales will continue to have limited groundwater availability. Groundwater is limited in some places because the aquifers are poorly producing. In other areas, the aquifers recharge slowly and may not keep pace with the rate of use.
7. Programs: Sustainable water use continues to be supported through DNR programs by engaging with water users to support their water supply planning and water conservation efforts, collecting and using water resource and ecosystem data, and effectively applying Minnesota's water laws.

Section I: Assessment and Availability of Minnesota's Waters

Water availability in this report is described in terms of the elements we see on the landscape: climate and precipitation, streams, lakes, wetlands, and groundwater, and how we use water. Precipitation either soaks into the ground or runs off into lakes, rivers, and wetlands. Much of the water that soaks into the ground is stored in soil to be taken up by plants. Evaporation from plants and from the land and water surfaces returns moisture to the atmosphere, which perpetuates the hydrologic cycle. Each of these components is influenced to some degree by human actions at or near the land surface. Streamflow, storage in wetlands, and groundwater use can be controlled by human actions; however, natural variability of other components such as drought, flood, and geographic distribution of aquifers cannot be controlled. This variability presents challenges for the long-term sustainability of both human and ecological water needs. The following sections describe Minnesota's water availability from 2015 – 2019 through the trends of our climate, surface waters, groundwater systems and water use.

Climate Trends and Projections

Minnesotans are accustomed to cold and snowy winters, along with warm and humid summers, but also know that any season can be far warmer, colder, wetter or drier than normal. The high variability that we expect from Minnesota's climate can make it difficult to notice where, when, and how climatic conditions have changed in our state. **However, over 125 years of consistent climate data make it clear that widespread changes, outside the range of normal variations, are already underway in Minnesota.**

Indeed, Minnesota's climate is changing rapidly, and more changes are coming. In the past several decades, our state has seen increased rainfall, heavier downpours, and substantial warming, especially during winter and at night. These changes have already affected not just our water resources, but also how we interact with and use them. An overwhelming base of scientific evidence projects that Minnesota's climate will see additional, significant changes through the end of this century, with even warmer winters and nights, and even larger rainfalls—along with the likelihood of increased summer heat and the potential for longer dry spells. Planning for the future of Minnesota's water must include a thorough appraisal of the effects our changing climate will have on this vital resource.

Wetter and warmer conditions

Minnesota has experienced much wetter and warmer weather in the past several decades. All but two years since 1970 have been some combination of wetter and/or warmer than historic averages. **Compared to 20th century averages, all of the ten wettest and warmest years on record occurred after 1998** (Figure 1). Just last year, 2019, was the wettest year on record in Minnesota.

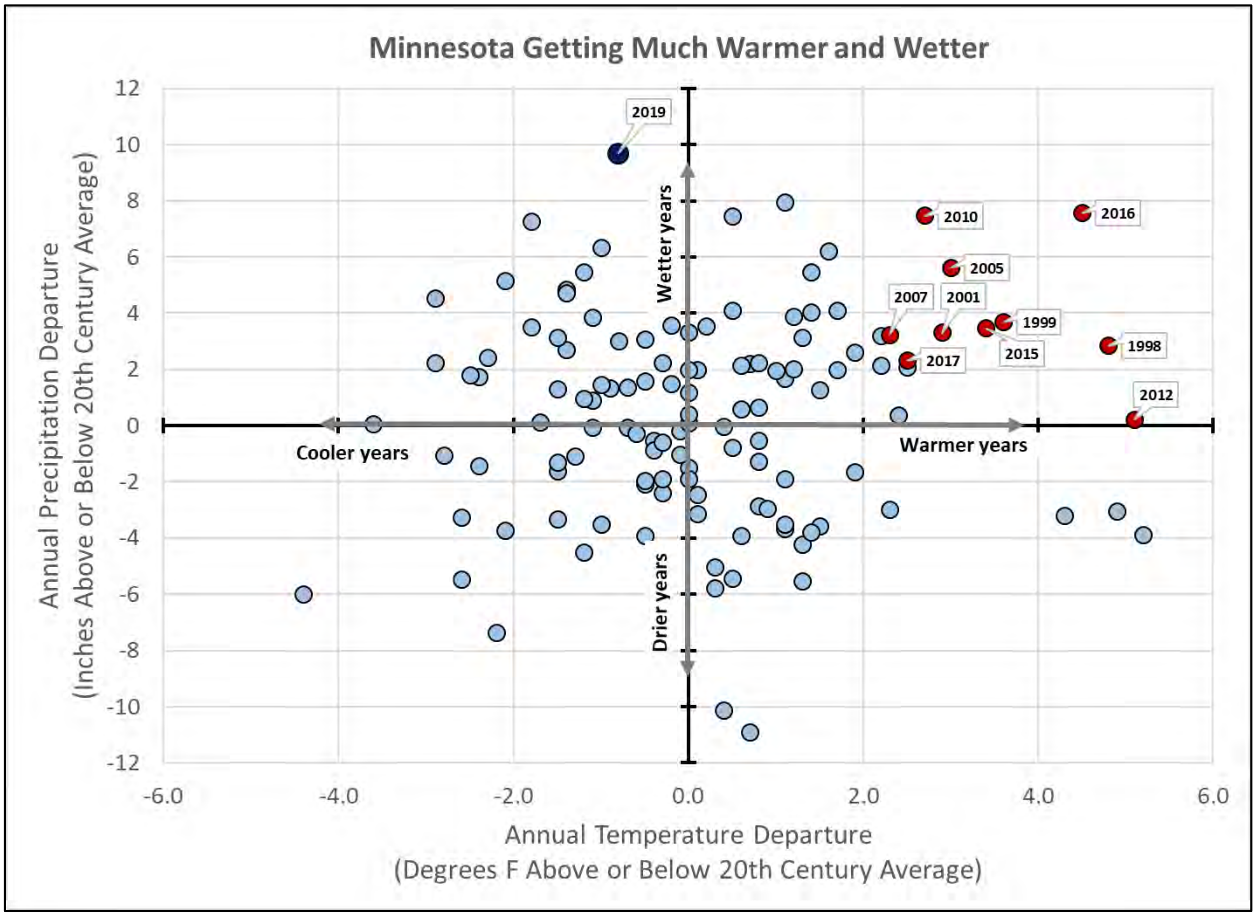


Figure 1. Plot of annual temperature and precipitation in Minnesota

Although the climate will vary from year to year, with occasional cool or dry years, climate scientists expect these increases to continue through the 21st century.

Unprecedented precipitation

Minnesota's climate swings naturally from relatively dry to relatively wet periods, but the wet conditions have dominated recent decades. Years with precipitation above historical averages have become increasingly frequent, and departures from those averages have grown as well, leading to sustained precipitation surpluses never before documented in the state (Figure 1, Figure 2).

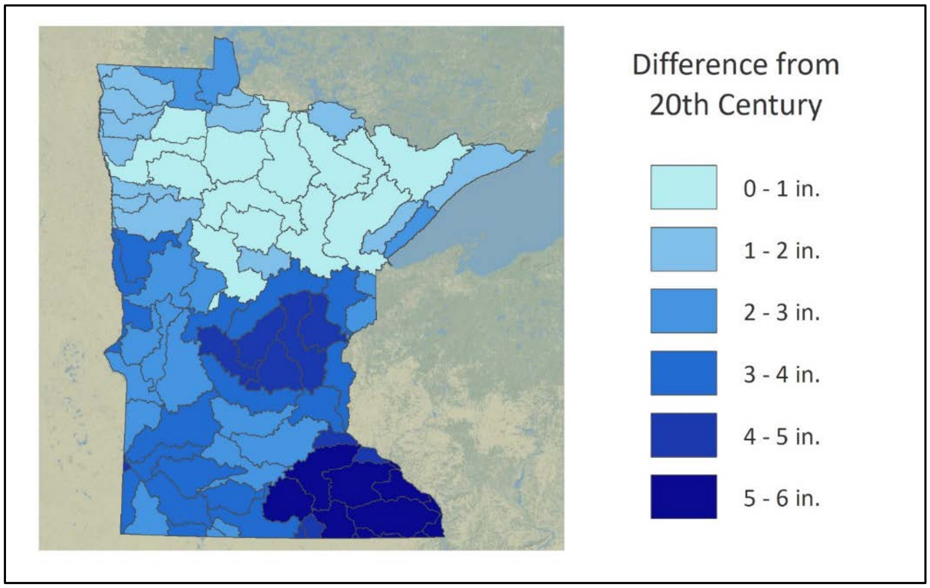


Figure 2. Annual precipitation increase since the 20th century

Modified map from DNR Watershed Health Assessment Framework.

June of 2014 was Minnesota's wettest month on record, with widespread severe flooding in many areas. In 2016, the town of Waseca broke Minnesota's annual precipitation record, only to have that record broken by both Harmony and Caledonia in 2018. During 2019, more precipitation fell across the state than any other year on record back to 1895, and the 2010s finished as Minnesota's wettest decade, by a wide margin. The precipitation increases have been most pronounced in southern Minnesota (Figure 2).

More damaging rains

Minnesota now sees more heavy precipitation than at any other time on record. At climate stations with over 100 years of observation, daily precipitation totals of 1, 2, and 3 inches have increased an average of 21%, 31%, and 62%, respectively. Measurements of the annual heaviest rainfall now average 20% greater than historical readings across the state. In August 2007, a catastrophic rainfall in southeastern Minnesota produced 15.1 inches of rainfall in just 24 hours in the town of Hokah. This is 39% more rainfall than ever had been recorded at any station in the state. Seasonal snowfall has been running near historical high marks also; in the 2010s, stations all over the state broke records for heavy snowfall.

Warmer but not hotter, yet

Minnesota is warming quickly but mostly during nights and winter. Annual temperatures have climbed 2.9 degrees since 1895, but 80% of that warming has been since 1970. During those five decades, winters have warmed by 5° F, winter nights have warmed by 6° F, but summers have warmed by just a half a degree F, and summer daytime high temperatures have decreased slightly in southern Minnesota (Figure 3).

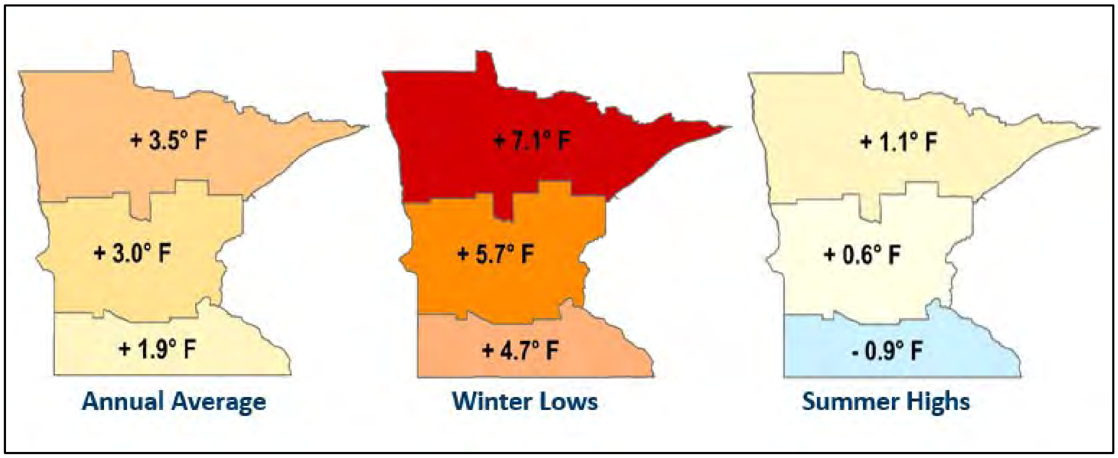


Figure 3. Temperature Change by Region

NOAA, National Center for Environmental Information

Winter cold extremes have become less frequent and less severe, while the state has observed no change in the frequency or severity of heat extremes. Climate models suggest, however, that summers will eventually get warmer, and that Minnesota will see increased heat extremes by the middle of this century, if not sooner.

Don't count drought out

Water is a defining resource for Minnesota, central to our economy, communities, and identity; so we always will be quite sensitive to dry conditions and drought. While Minnesota continues to experience periods of drought in specific regions, those periods have not increased in severity or length. Recent surges in precipitation have meant the state has not seen any increases in drought severity, duration, or areal coverage over the past few decades. **However, the extremely wet period from the 2010s will end eventually.** A shift towards a dry regime should be expected, as climate change will not eliminate wet and dry periods in Minnesota. Indeed, although climate projections depict that Minnesota will continue getting wetter in general, those same projections indicate that future dry spells may start to get longer too, especially once our summer heat intensifies. Even with a generally wetter climate, Minnesota should expect occasional episodes of severe drought, and these drought events could happen immediately following or may even occur in specific areas of the state *during* a wet period.

Water Use Trends

Whereas water use in Minnesota generally increased over the last decades of the 20th century, water use in the 21st century has been declining. In total*,* **Minnesota's water use has decreased over the past ten years from about 1400 billion gallons in the first decade of the century to about 1060 billion gallons at the end of the second decade** (Figure 4). This translates to approximately a 28% decline in water use while our population increased by approximately 7%.

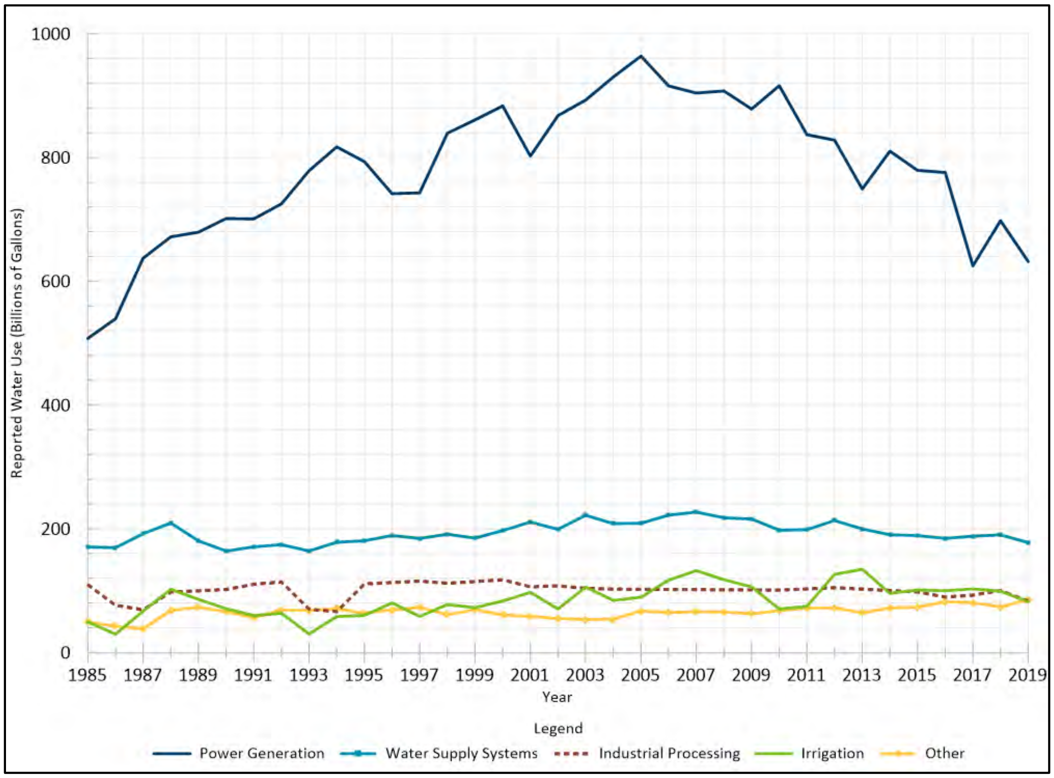


Figure 4. Reported water use by category of use

Decreasing water use for generating electricity

The largest portion of Minnesota's water use is from surface water for power generation. The majority of the decrease in the state's water use can be attributed to a decrease in water needed for power plant cooling – a use reduction of 33% from 2005 to 2019.

- This reduction occurred even as the overall demand for electricity remained constant.
- A number of large power plants converted from coal to natural gas. Natural gas plants require less cooling water. The share of the state's electricity produced by coal-fired electric plants declined from 53% to 31% over the period from 2011 to 2019.
- The amount of electrical power generated from wind and solar power has increased. These sources of electricity do not require cooling water. In 2019, the state's wind farms generated 19% of the state's total net electricity generation. Minnesota is a national leader in energy efficiency, and renewable energy has accounted for 84% of all new generation capacity since 2010.

Water use for non-power generation also declined from 2007 through 2019 (Figure 5). This decline is attributable to adopting water saving technologies, increased industrial water reuse, and implementation of irrigation best management practices. Additionally, recent wet years have likely contributed to the decline, as Minnesotans use less water for lawn and crop irrigation during times of ample precipitation.

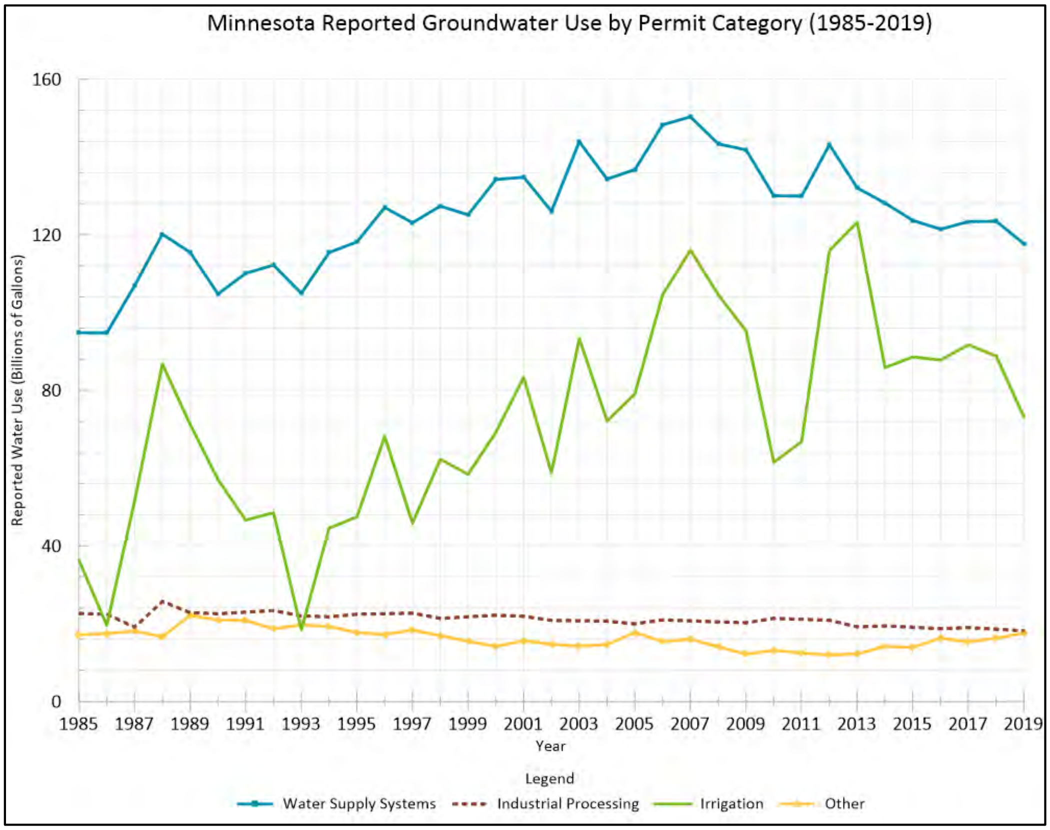


Figure 5. Reported water use by category of use, for non-power generation uses

Leadership in per capita water use

Minnesota has been making important strides in conservation, and individuals, businesses, and communities have all contributed to Minnesota's water conservation excellence. In 2018, 92% of water suppliers achieved the DNR residential water conservation goal of using less than 75 gallons per capita daily (GPCD). The statewide average residential GPCD is 52 (Figure 6).

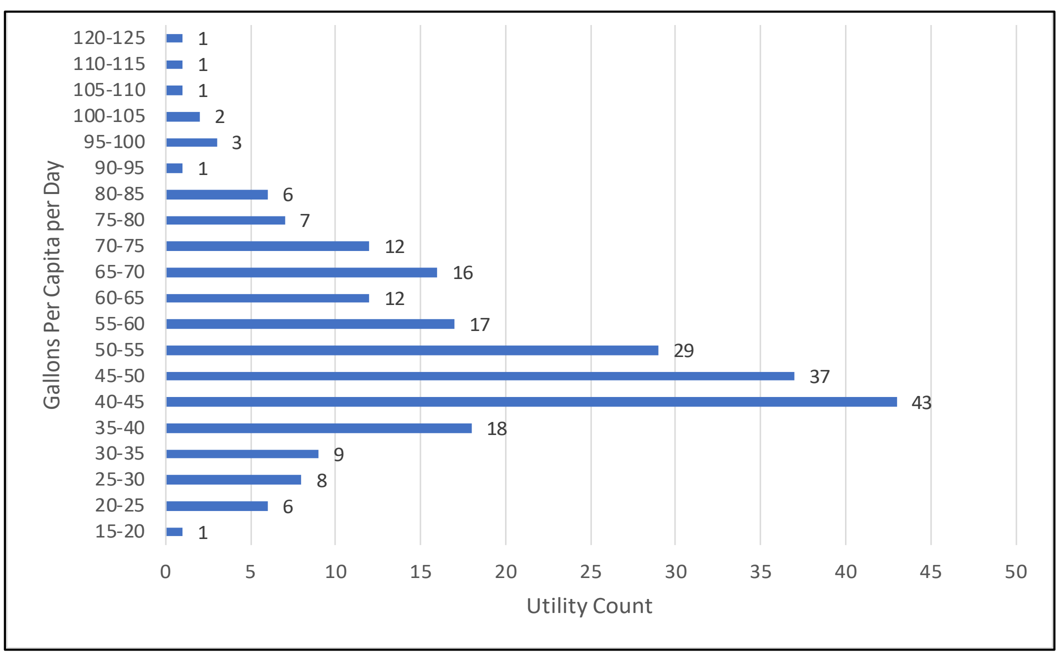


Figure 6. Residential gallons per capital per day (GPCD) of water supply use in 2018

Making waves in water efficiency

Many Minnesota companies lead the way in water and energy efficiency. For example, Chippewa Valley Ethanol Company in Benson has steadily reduced the amount of water used in its production. In 2007, the company used 3.7 gallons of water per gallon of ethanol produced. By 2019, that figure dropped to 2.8 gallons of water per gallon of ethanol, ahead of the industry water use benchmark. In 2019, Chippewa Valley constructed a water/wastewater treatment plant to treat and reuse boiler blowdown and cooling tower blowdown water that would otherwise be discharged. This will save 132,500 gal/day and help conserve the area's limited groundwater supply. Photo from the Chippewa Valley Ethanol Company.

Status of Minnesota's Streams

There is a direct correlation between a wetter Minnesota and changes to streamflow across most of the state. Compared to historical patterns, streams are now flowing higher in the spring, floods are bigger, bankfull flows last longer, and summer baseflow is increasing in some parts of the state. Climate models project increasingly intense, frequent floods, which are already manifested in our streams. These changes from climate are compounded by land use changes. The leading land use factors are those associated with a conversion to a primarily corn and soybean cropping system. As a result, drainage and tiling increase streamflows that subsequently cause stream channel erosion and instability, which degrades the instream habitat. Larger floods increase damage to infrastructure like roads, bridges, and buildings.

Streamflow in many watersheds across Minnesota has shifted over the past 20 years. **Comparing flow in streams to historic records reveals that our streamflow is higher than it used to be.** From water years 2000 through 2009, flow in 54% of watersheds ranked as *above normal* or *high* compared to historic records. From water year 2010 through water year 2019, flow in 75% of watersheds ranked as *above normal or high*. Of the 81 watersheds examined from 2010 through 2019, none had *below normal or low* flows (Figure 7).

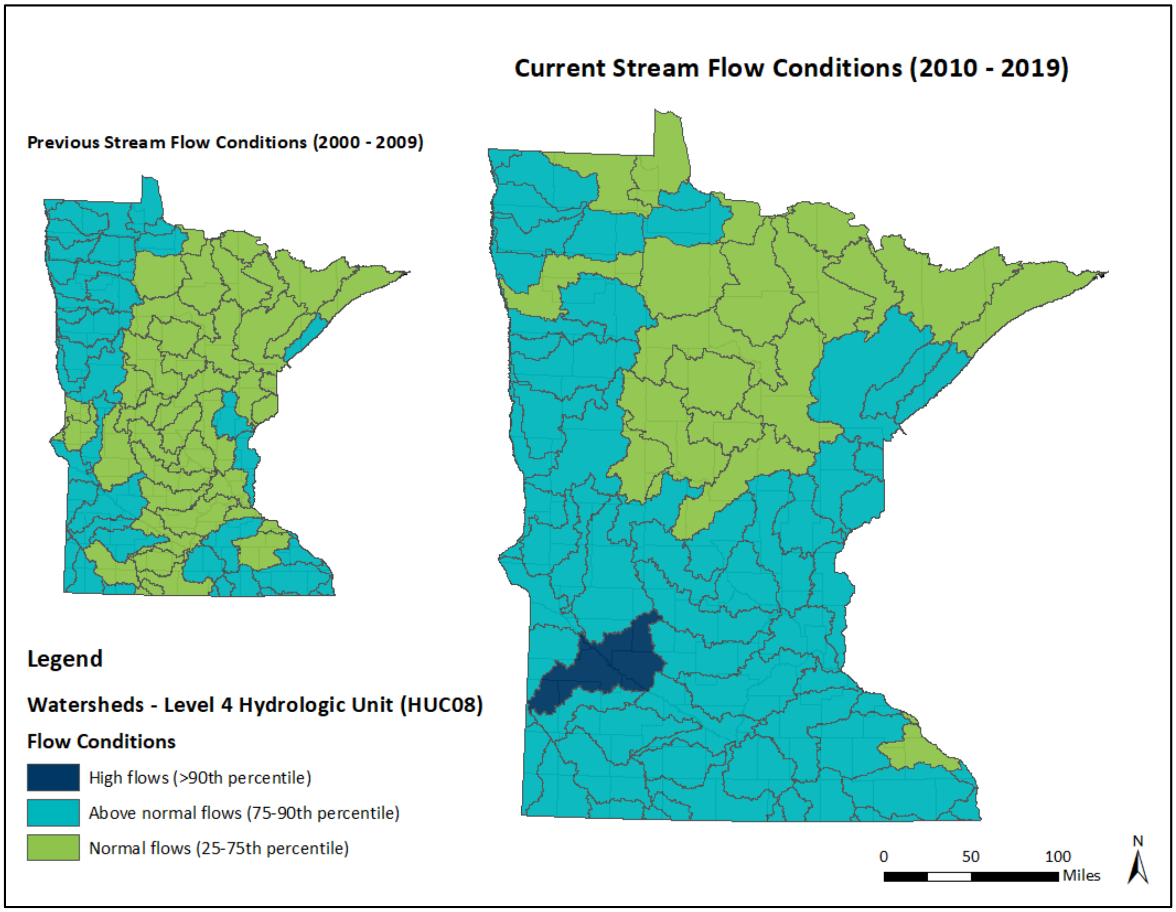


Figure 7. Overall stream flow data compared to historic records

In some watersheds, we are seeing both an unprecedented magnitude of annual precipitation and mean annual discharge in the years after 1991 (Figure 8). Coincident with the precipitation pattern is the change in land use land cover. While climate change has resulted in consistent increases in streamflow across the US, it does not reflect the complete change in streamflow measured as mean annual discharge. Primarily in the Midwest, additional increases in streamflow has come from human activities including land practices associated with conversion to row crop systems and urbanization. Several studies specific to the Midwest have examined the combined influence of climate change and land use change on streamflow. These found that land use change is responsible for a significant proportion of the increase, ranging from 32% to 40% to roughly equivalent with climate change.

These changes are illustrated at four streams where we conducted detailed case studies of streamflow conditions. We chose the case study sites to represent the breadth of Minnesota's variable geography: the Mississippi River (near Royalton), the Le Sueur River (in the Minnesota River watershed), the Buffalo River (in the Red River watershed), and the Rainy River. Five metrics of streamflow were evaluated for each site: flow magnitude, seasonality, flood flows, baseflows, and bankfull flow (Appendix A, found on the DNR web page "River Ecology Unit" under "Research").

Overall, each of the four streams is measurably wetter than in years past. Precipitation and mean annual flow have increased on all of the streams studied.

On the Le Sueur River, mean annual flow has increased. This change correlates with higher precipitation. Floods are also bigger and more variable, driven by both increased precipitation and land use changes. Flows are notably higher in the spring (April, May and June) than in previous years (Figure 8). Overall changes in flow on the Le Sueur River are showing impacts of climate change and land use change – specifically increased drainage and loss of perennial vegetation.

On the Mississippi River, flood flows have increased significantly since 1940, likely a result of increasing precipitation. Mean annual flow has increased markedly since 1940, which is also a result of increasing precipitation (Figure 9). August baseflow has increased. The patterns of precipitation and flows by season match closely, which indicates that changes in precipitation, rather than land use, are driving changes in streamflow on the Mississippi River.

On the Buffalo River, August baseflow has been consistently higher since 1990. Floods have also been slightly larger. Like the Le Sueur River, streamflow in the spring has also increased, which is likely the result of increased runoff from bare cropland at that time of year. Mean annual flow has increased, although that change preceded the increase in precipitation (Figure 10). Because the streamflow change preceded the precipitation change, land use changes may have affected this watershed prior to climate change impacts. The data suggest that land use changes may be adding to the hydrologic alteration due to climate change.

The Rainy River generally shows less change than other watersheds, but even there annual mean flow has increased coincident with increasing precipitation (Figure 11).

These findings align with climate change models, which project increasingly intense, frequent floods. Land use changes, including urban development and agriculture, can magnify the effects of climate change. Degraded stream channels caused by flooding make the ecosystems in our streams less diverse and less resilient. Damage to stream ecosystems can take time to accumulate and become apparent but will eventually effect our recreational use of streams. Our agricultural economy is especially vulnerable to more intense precipitation and larger floods. For example, climate change is resulting in significant increases in rainfall erosivity, therefore causing potential soil and nutrient loss. Additionally we are seeing an increase in frequency of higher flows responsible for flooding riparian areas potentially impacting crop production by waterlogging.

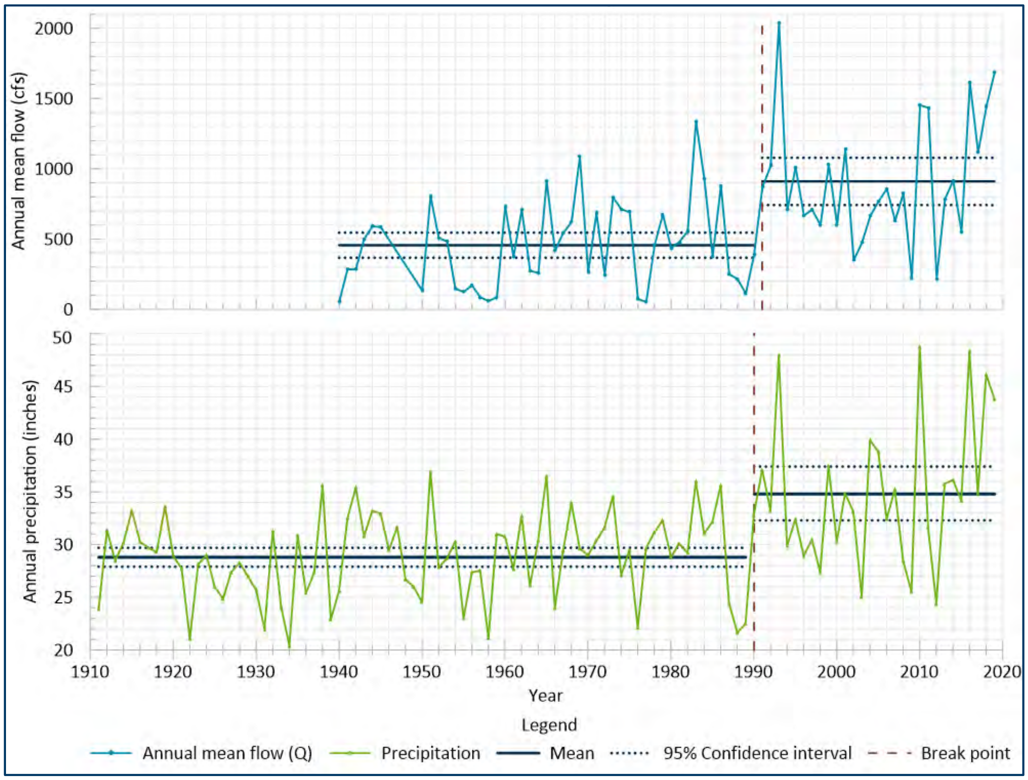


Figure 8. Mean annual flow on the Le Sueur River compared to precipitation

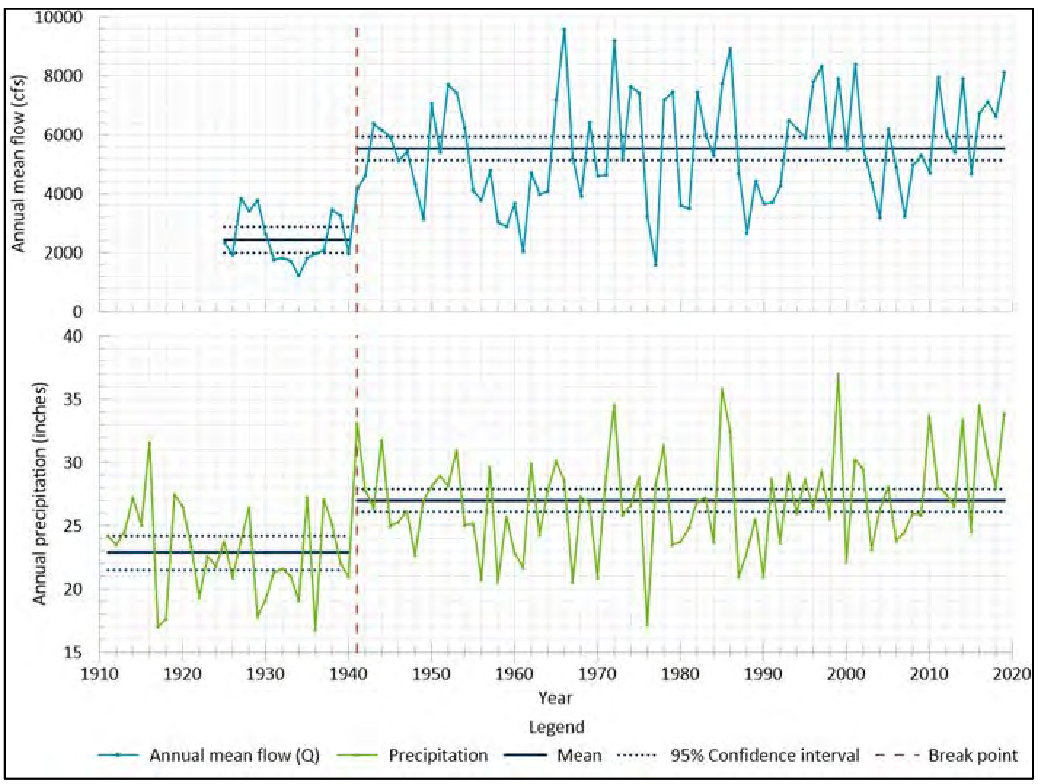


Figure 9. Mean annual flow on the Mississippi River compared to precipitation

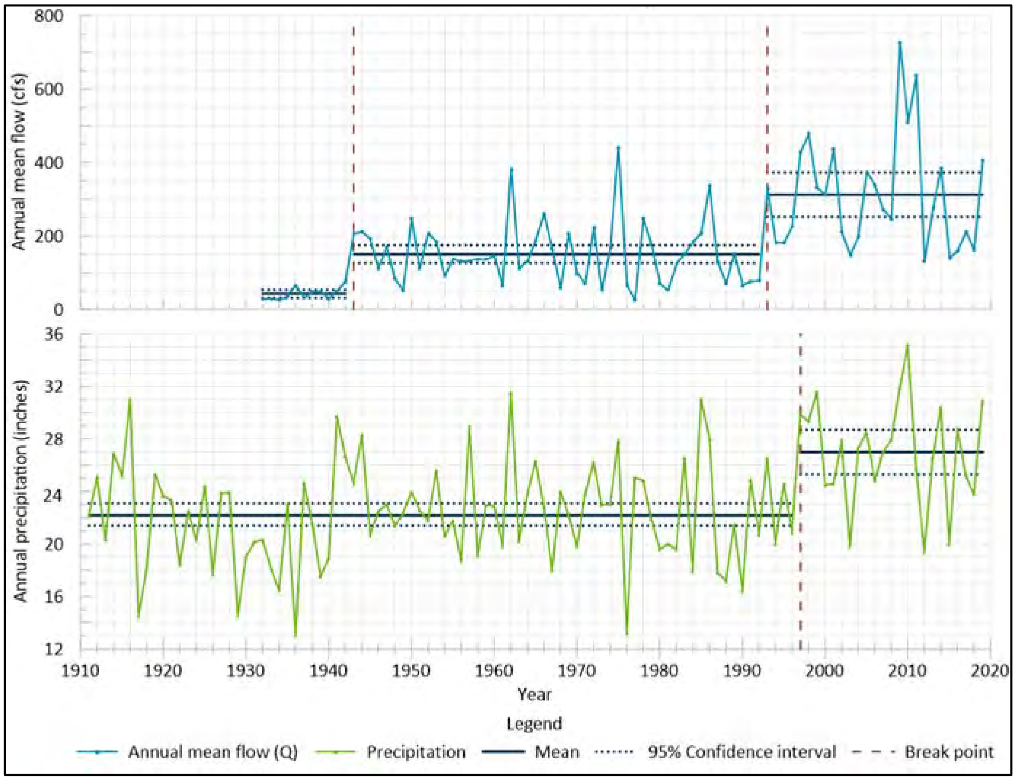


Figure 10. Mean annual flow on the Buffalo River compared to precipitation

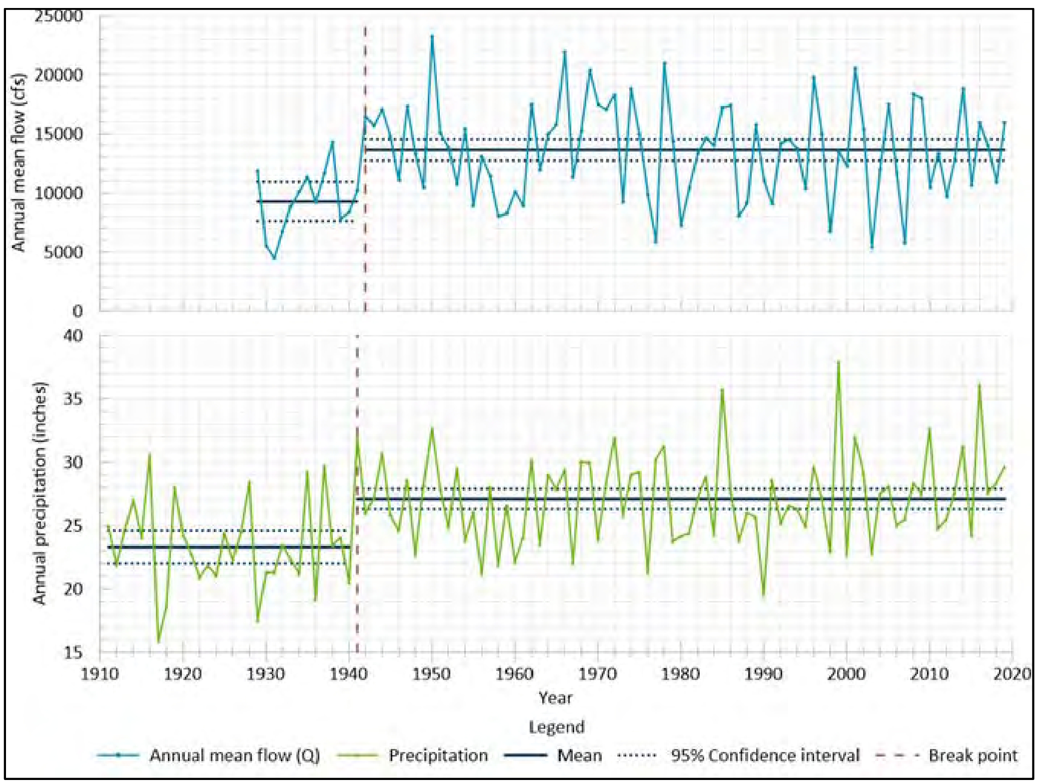


Figure 11. Mean annual streamflow on the Rainy River compared to precipitation

Status of Minnesota's Lakes

Lakes hold a special place in Minnesota's history, culture, and identity. They provide recreational opportunities, support a thriving tourism industry, help modulate the impacts of high and low precipitation, and enhance real estate values. Lakes are also important ecosystems that support fish and wildlife. They are one of the most visible and valued aspects of Minnesota's water resources.

One of the defining characteristics of lakes is their ability to slow down and store water. We benefit from lakes storing water, trapping sediment, and slowing runoff. Water levels in lakes are the difference between water coming in (such as precipitation or inflow from streams and groundwater) and water leaving (such as evaporation, human use or outflow to streams and groundwater). Most lakes naturally experience variability in water levels, but climate change, land use changes, and structures like weirs and dams can alter the normal range of water levels in lakes.

In 2019, most lakes that DNR monitors had higher-than-normal water levels (Figure 12)**.** Of Minnesota's 570 monitored lakes, 22 had water levels that ranked *very high* or *very low* compared to historic levels. Twenty-one of those 22 lakes had water levels more than two feet above the long-term median lake level, and only one lake was two feet below its long-term median. This broad shift toward higher lake levels is the result of increased precipitation and land use changes.

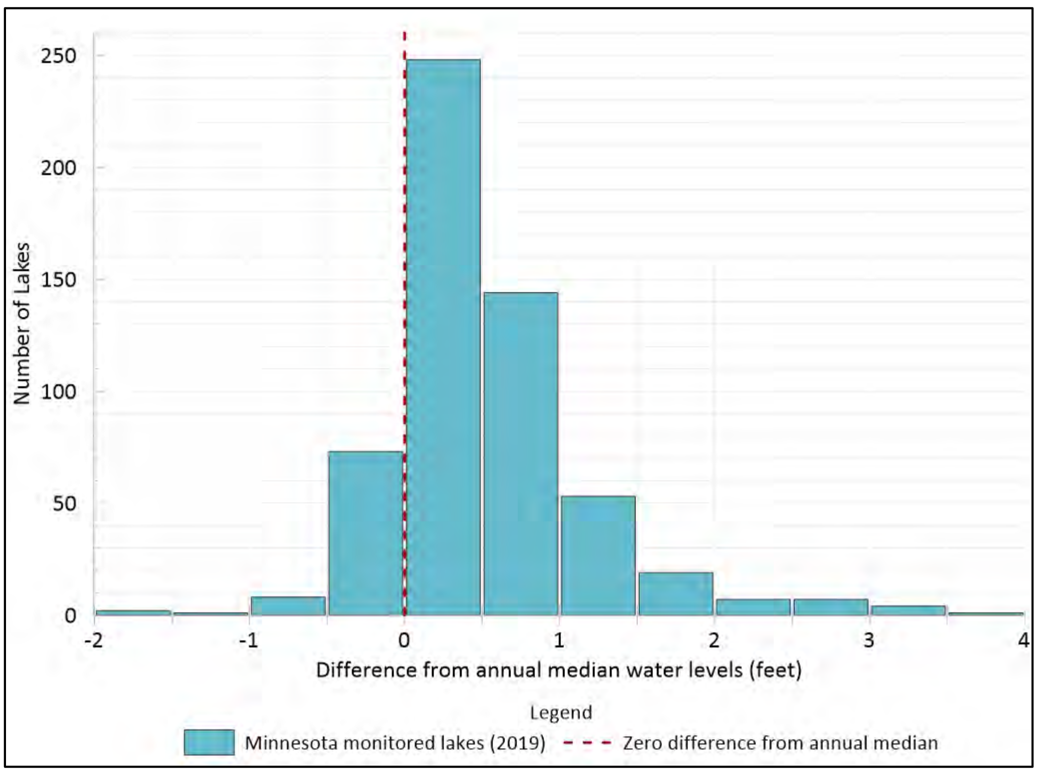


Figure 12. Departure from annual median water levels in 570 lakes

Human development along lakeshores leads to increased public expectations for managing lake levels to a very narrow range. In most cases, water resource managers have limited ability to control lake levels. As our climate becomes wetter overall, we will experience more problems due to high lake levels, unless we begin to plan and build for climate extremes. Although we have been in a historic wet period, drought will come and with it will come low lake levels.

Extremely high and low lake levels can cause property damage and temporarily impact recreational activities. However changing lake levels may be beneficial for lake ecosystems. Many lakes naturally have fluctuating water levels, and their aquatic plants have evolved with large water level fluctuations. For example, three-square bulrush protects shoreline from erosion by buffering waves and stabilizing sediments. It also provides important aquatic habitat for fish and wildlife. However, three-square bulrush requires periodic large water level fluctuations, i.e., long periods of wet and long periods of dry. Similarly, lowering the lake level of an impounded lake can improve water clarity and habitat for fish and migratory birds.

Property damage on Lake Superior

Following a period of low lake levels, Lake Superior has more recently reached near record high levels. High water levels are eroding the shoreline, damaging coastal infrastructure and property, flooding marinas, creating navigational hazards, shrinking recreational beaches, and harming coastal habitat.

Status of Minnesota's Wetlands

Minnesota's wetlands are critical our state's hydrology. Wetlands store water from snowmelt and spring rains, thereby preventing water from overwhelming floodways. The water stored in wetlands is a source of groundwater recharge as well as necessary wildlife habitat. Wetland plants take up nutrients, which improves water quality in downstream lakes and rivers. The plants also store carbon, provide habitat, and forage for wildlife.

Minnesota has 12.2 million acres of wetlands, second in total acreage among the 48 states coterminous states, behind only Florida. However, we have lost about half of our original wetlands. In southern and western Minnesota, millions of acres of our historic wetlands were lost to drainage and development, leaving most of those remaining in the north and east. This loss has resulted in a loss of water storage capacity, groundwater recharge, and other ecological benefits.

More recently, we have observed small, consistent net gains in wetland area (Figure 13). The DNR's wetland status and trends monitoring program shows that Minnesota had a net gain of 8,460 acres of wetland from 2006 through 2017. Wetland protection programs reduced wetland losses, including the passage of the Minnesota Wetland Conservation Act in the early 1990s. In addition, several state and federal programs are actively restoring wetlands.

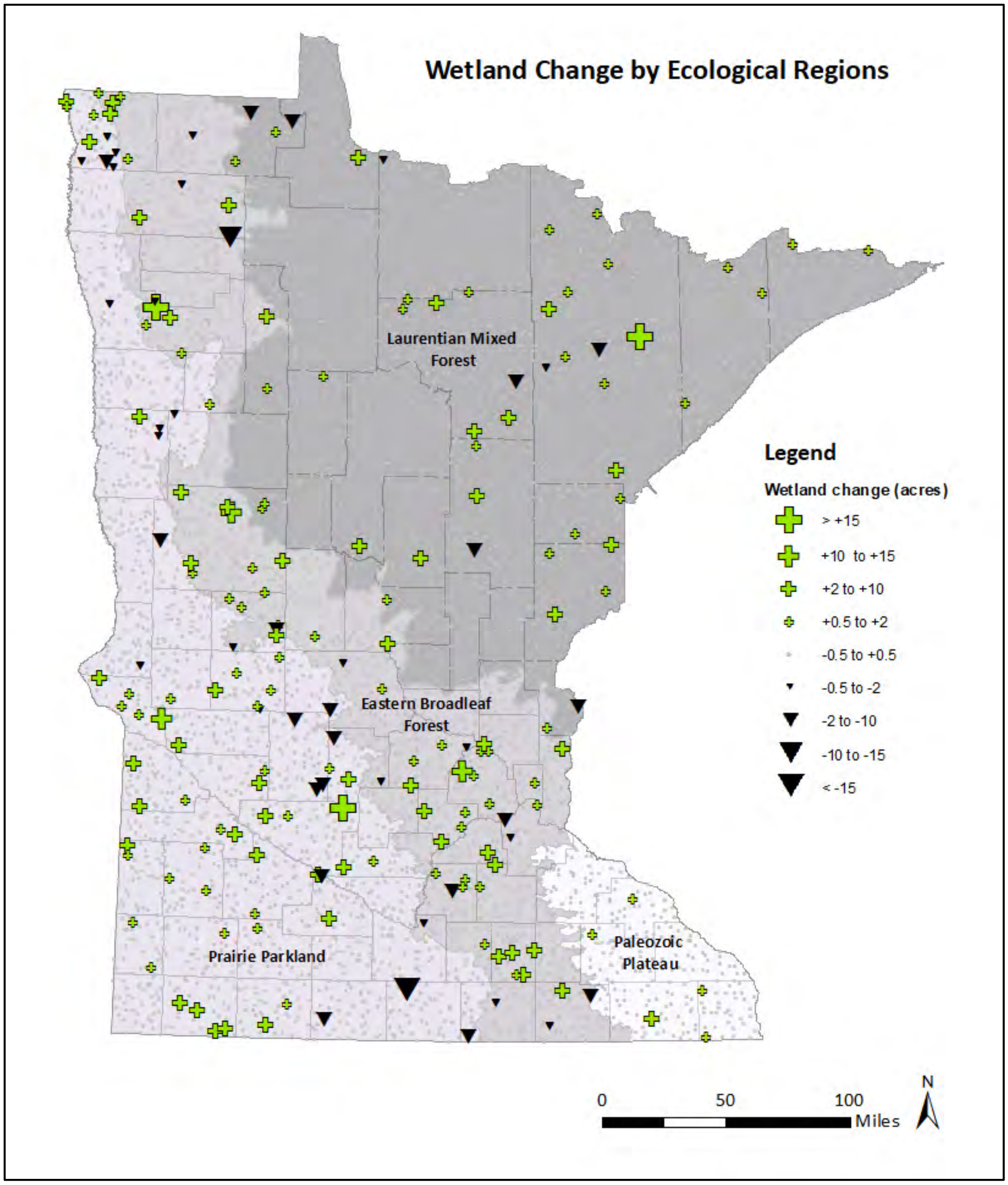


Figure 13. Wetland gains and losses from 2006 - 2017

A deeper look at the data shows that wetlands in Minnesota are changing. In addition to tracking total wetland acreage, the DNR wetland monitoring program tracks changes by wetland type. Although there have been small net gains in wetland acreage, the changes in wetland type suggest some potential areas of concern. Much of the observed gains were open-water-type wetlands (ponds), which typically have less wildlife habitat value than many other wetland types. Furthermore, the data also show conversions between wetland types, such as emergent wetlands converted to cultivated wetlands or ponds. Rather than a loss of wetland area, this is a loss of wetland function. Natural wetland vegetation is responsible for many of the important benefits of wetlands. Wetlands without significant vegetation, such as ponds, or those where the natural vegetation has been removed for growing cultivated crops, do not provide these benefits at the same level.

Historical wetland losses were due primarily to drainage for development, mostly agricultural production. Recent wetland changes are the result of climate, human activities, and groundwater use.

- Climate - A wetter climate in recent years may have allowed areas that were farmed during dry periods to revert to wetlands. It also has likely resulted in some wetlands shifting to wetter community types (e.g. wet meadows transitioning to shallow marsh).
- Human activity – Drainage and filling for urban or agricultural development are examples of direct impacts to wetlands, but wetlands may also be indirectly impacted. For example, development may lead to increased runoff and pollutant loading to wetlands.
- Groundwater appropriation – Many wetlands are directly connected to groundwater, and increased use of groundwater can cause wetlands to dry out. While water levels in wetlands often fluctuate naturally, groundwater appropriations can reduce water levels further and for longer periods of time. In turn, the wetland plant communities' change and ecological function is diminished. This has been observed in the Bonanza Valley and other areas where groundwater use in close proximity to wetlands has increased.

Status of Minnesota's Groundwater

Approximately three out of every four Minnesotans rely on groundwater for their drinking water. Minnesota's aquifers also support agriculture, industry and the natural resources that are vital to Minnesota's quality of life (streams, wetlands and lakes). Our aquifers are recharged by percolation of precipitation through soil. Some aquifers receive precipitation readily and can recharge quickly. Other aquifers are buried deep in the ground and can take years or decades to recharge. The DNR maintains a statewide network of approximately 1,100 observation wells to monitor our 'hidden' groundwater resource (Figure 14).

From 1993 to 2016, 37% of observation wells in Minnesota showed downward trends. **Now only 6% of wells statewide show downward trends**. These trend reversals are a direct result of increased precipitation and the implementation of robust conservation measures by local water users. Across Minnesota's varied geography, there are differences in groundwater trends:

- In the metro area, all observation wells show upward or stable trends over the past 20 years. This is a change from previous periods, when groundwater levels in the metro area were declining. The reversed trend in the metro area is likely due in part to the 1991 Groundwater Act, which banned the practice of Once-Through-Cooling with groundwater.
- In the central part of the state, 3% of observation wells are trending downward. In the western part of the state, 16% of wells are trending downward. Downward trends can result from a combination of factors, such as local drier conditions in the later years of the analysis period, increased groundwater use, or changes in land use and groundwater recharge. These wells may show where groundwater use is exceeding the rate of groundwater recharge.
- In the northeast and southeast portions of Minnesota, our observation well network is too sparse to draw conclusions about the overall state of the aquifers in those areas.

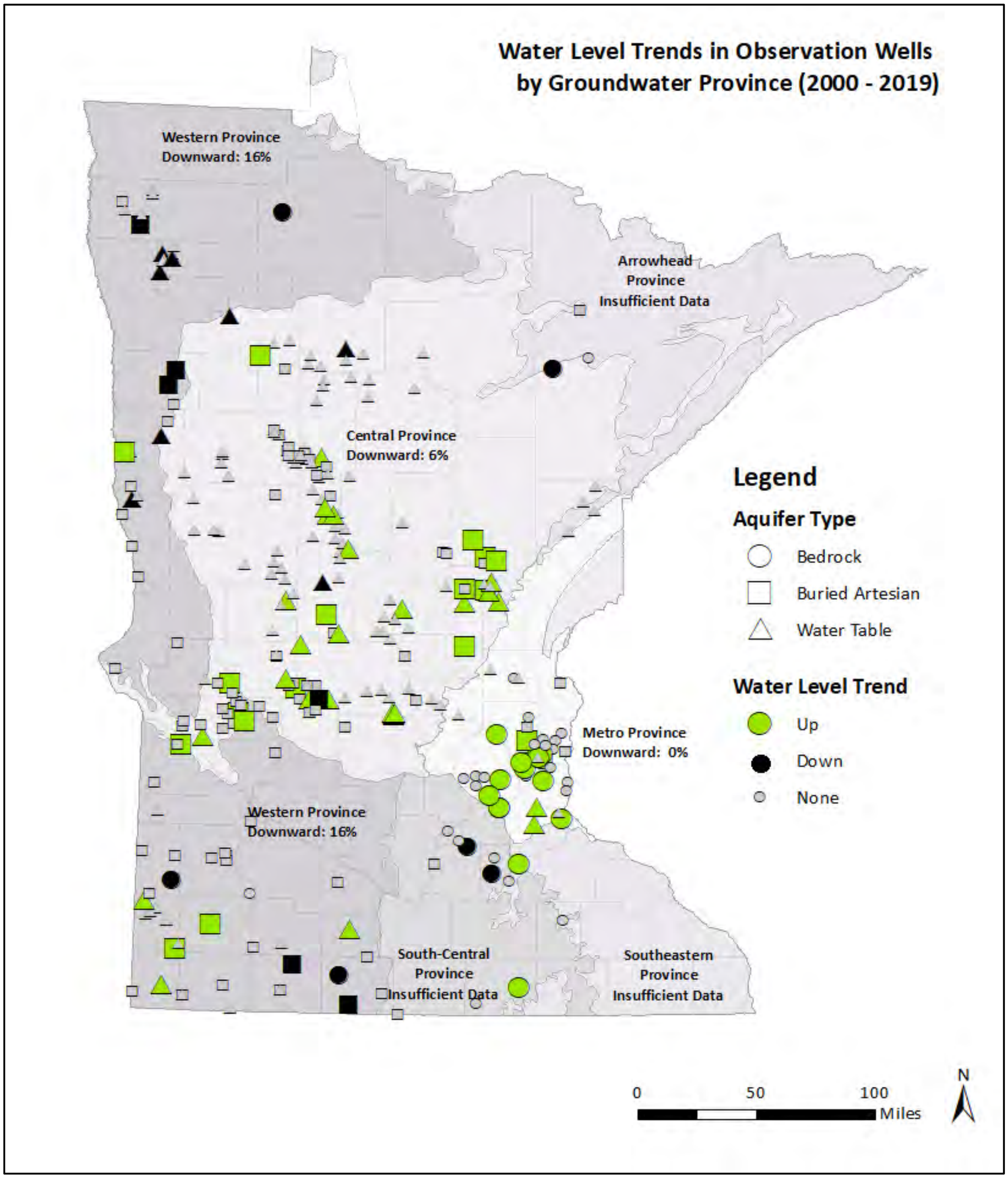
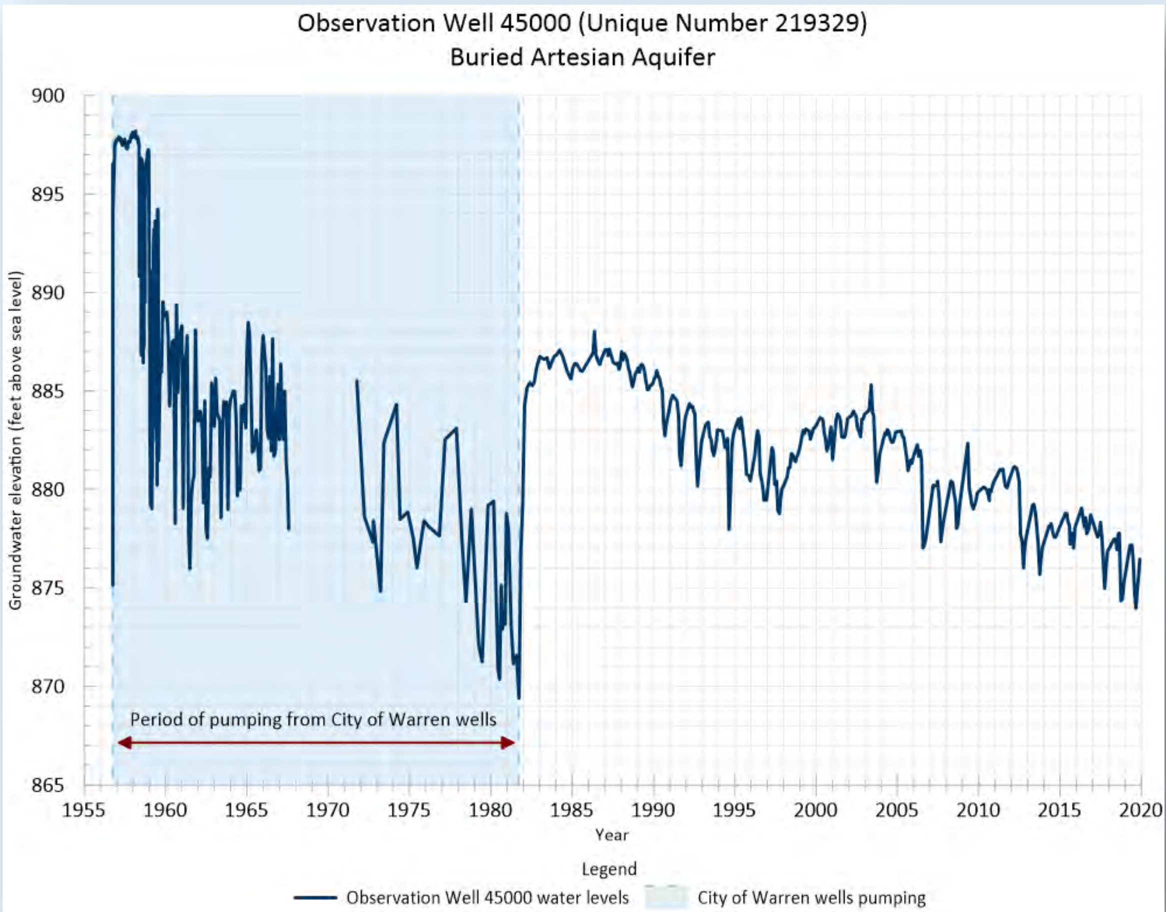


Figure 14. Water level trends in DNR observation wells, 2000 - 2019

Limited aquifers near Warren, Minnesota

Aquifers are scarce near Warren, Minnesota. In an observation well which monitors the primary aquifer, water levels have been slowly declining since 1991. Water levels also declined from 1956 to 1981 as a result of municipal pumping. When pumping was shifted to a different aquifer, water levels rose but did not return to pre-pumping levels. This partial recovery indicates the aquifer was pumped at a rate that exceeded its recharge rate. DNR hydrologists are investigating the source of the current water level decline and developing strategies to manage this aquifer.



Section II: The DNR's Role in Supporting Water Use

The Minnesota Department of Natural Resources plays an important role in supporting sustainable water use through its permit programs, data collection and analysis activities, law enforcement responsibilities, education, and technical assistance services. The DNR and other agencies in the executive branch have adopted a three-pronged approach to sustainable water resource management. This approach involves mapping, monitoring, and managing water resources adaptively over time. In the five years since the previous Water Availability and Assessment Report, the DNR's approach to water management has continued to evolve.

Implementation of Minnesota's water laws

Thus far, this report has provided data and information on water in relation to our economy, communities, landscapes, atmosphere and geology. This section of the report examines how the DNR continues to support the development of sustainable water use by individuals, businesses, and communities.

The DNR efforts are mandated under a variety of statutes. Here are highlights of some of the most important statutes and rules that govern DNR work, as well as how the DNR has applied those statutes into programs:

- **MN STATUTE: 103A.201 REGULATORY POLICY**
  - To conserve and use water resources of the state in the best interests of its people, and to promote the public health, safety, and welfare, it is the policy of the state to regulate Minnesota's public waters, subject to existing rights, and control the appropriation and use of waters of the state.
- **MN STATUTE: 103A.43: WATER ASSESSMENT AND REPORTS**
  - The DNR shall provide an assessment and analysis of the quantity of surface and groundwater and the availability of water to meet the state's needs.
- **MN STATUTE: 103G.101 WATER CONSERVATION PROGRAM**
  - The commissioner shall develop a water resources conservation program for the state
  - The program must include conservation, allocation, and development of waters of the state for the best interests of the people
  - The commissioner must be guided by the program in issuing permits for the use and appropriation of the waters of the state
- **MN STATUTE: 103G.255 ALLOCATING AND CONTROLLING WATERS OF THE STATE**
  - Directs the commissioner to administer the use, allocation and control of waters of the state; establish, maintain and control lake levels and water storage reservoirs; and determine ordinary high-water level of waters of the state.
- **MN STATUTE: 103G.261 WATER ALLOCATION PRIORITIES**
  - Directs the commissioner to adopt rules for allocation of water based on six priorities for the consumptive appropriation and use of water. Outlines where and when use of surface water should be encouraged or discouraged.
- **MN STATUTE: 103G.265 WATER SUPPLY MANAGEMENT**
  - Requires DNR to manage water resources to assure an adequate supply to meet long-range seasonal requirements for domestic, municipal, industrial, agricultural, fish and wildlife, recreational, power, navigation and quality control purposes. This law also requires DNR approval for large volume water diversions to places out of state and diversion from the Great Lakes.
- **MN STATUTE: 103G.285 SURFACE WATER APPROPRIATIONS**
  - Limits appropriation from watercourses during periods of low flow, requires protective elevations for lakes, restricts use of trout streams, and requires contingency plans.

- **MN STATUTE: 103G.287 GROUNDWATER APPROPRIATIONS.**
  - Identifies information needed an evaluation to be done for groundwater appropriation permits and allows for the designation of groundwater management areas. Also describes sustainability criteria: The commissioner may issue water-use permits for appropriation from groundwater only if the commissioner determines that the groundwater use is sustainable to supply the needs of future generations and the proposed use will not harm ecosystems, degrade water, or reduce water levels beyond the reach of public water supply and private domestic wells.
- **MN STATUTE: 103G.291 PUBLIC WATER SUPPLY PLANS; APPROPRIATIONS DURING DEFICIENCY**
  - Every public water supplier serving more than 1,000 people must submit a water supply plan to the commissioner that must address projected demands, adequacy of the water supply system and planned improvements, existing and future water sources, natural resource impacts or limitations, emergency preparedness, water conservation, supply and demand reduction measures, and allocation priorities. Plans must be updated every 10 years.
- **MN RULE: CHAPTER 6115, PUBLIC WATER RESOURCES and WATER APPROPRIATION AND USE**
  - These rules exist to provide for the orderly and consistent review of permit applications in order to conserve and utilize the water resources of the state in the best interest of its people.
  - These rules set forth minimum standards and criteria pertaining to the regulation, conservation, and allocation of the water resources of the state, including the review, issuance, and denial of public water work permit applications and water appropriation applications and the modification, suspension, or termination of existing permits.

Water Appropriation Permitting

The DNR is required to administer a permit system to manage the use of groundwater and surface water throughout the state and conserve these same waters for everyone to enjoy. In times of shortage, this may include restricting permitted water use, consistent with legislatively established priorities. A water appropriation (use) permit is required for anyone who uses more than 10,000 gallons of water per day or 1 million gallons of water per year. The number of water use permits for irrigation of agricultural crops represents 63% percent of all permits issued. Today the DNR manages more than 10,000 water use permits throughout the state. All of water users must submit annual reports of their monthly water use to the DNR. These reports assist DNR in managing the resource, especially during times of drought.

The DNR has established three groundwater management areas (GWMA) in locations with heavy use to ensure that groundwater resources remain sustainable: North and East Metro GWMA in 2015, Bonanza Valley GWMA in 2016, and Straight River GWMA in 2017. The DNR followed guidance contained in Minn. Stat. 103G.287 in creating these GWMA. DNR staff, in collaboration with local stakeholders in those areas, have developed implementation plans to improve the management of groundwater for all users and for the natural resources and fish and wildlife habitat that depend on that same water.

Over the past several years, the DNR has received a few requests for appropriating water in Minnesota and moving it across major watershed boundaries, and even out of the state. Minn. Stat. 103G.265 includes restrictions on moving water out of the state to ensure the remaining water in the area will be adequate to meet the needs of that area over the life of the diversion project. Minnesota is a member of the Great Lakes Compact and must follow the terms of the compact for any requests to divert water from the Great Lakes Basin. In addition, Minnesota and the signatory states of the Upper Mississippi River Basin, have agreed to give one another notice of any interbasin diversions that exceeds 5 million gallons per day average in any 30-day period.

MPARS: MNDNR Permitting and Reporting System

DNR uses the online MNDNR Permitting and Reporting System (MPARS) to manage a variety of water permits. This system allows the public to apply online for five DNR permit types (water appropriation, public waters work, dam safety, aquatic plant management and invasive aquatic plant management), as well as request changes to existing permits, pay permit-related fees, report water use, and communicate with DNR staff. DNR staff use the system to record the decision-making process for water permits. Over 10,000 customers, DNR water regulations staff, and interagency partners statewide use this system. Using MPARS, the DNR processes an average of 1100 water appropriation permits annually and receives 10,500 water use reports. This system helps streamline much of the administrative work that comes with water regulatory programs, allowing DNR employees to devote more time to assisting applicants, gathering the information needed to inform decisions, and related work. The DNR is currently working to expand MPARS to include aeration permits.

Regulatory Lake Protection

Minnesota's lakes are protected by a variety of laws and ordinances administered by various units of government. The DNR protects public waters, which include most lakes and many wetlands and watercourses, under the statutory authority of M.S. 103G.245. Alterations to public waters, such as fill placement, excavation, water level controls, restoration, culvert and structure placement, and mining, are regulated through the DNR public waters permitting program. Regulating activities on other public waters such as wetlands and watercourses upstream of lakes in the watershed has profound positive impacts to the lakes downstream. Activities that are categorically harmful or unreasonable are prohibited, while most other activities are conditionally allowed to some degree. This program seeks to balance protection and use of the water resource.

Shoreland Protection

With Minnesota experiencing more precipitation and fluctuating water levels, many lakes are experiencing high water resulting in shoreline erosion and flooding. In response, many property owners are seeking ways to protect their property, including hard armoring the shoreline and filling low areas. These actions can have negative impacts, including displacing natural vegetation that is important for fish and wildlife and reducing water storage capacity, increasing flood risk. The DNR administers the state shoreland program in cooperation with local governments that implement the state shoreland rules through local zoning. The DNR provides technical support and training services to local governments to help staff, planning commissions, and boards of adjustments make decisions consistent with the state's shoreland laws.

Engagement with water users

The DNR actively engages with water users to ensure thoughtful planning and water conservation efforts. Highlights of our engagement work are listed below.

Water Supply Planning

Planning for the future is a key tool to ensuring sustainable water supplies. Minnesota Statute 103G.291 requires all water suppliers serving more than 1,000 people to submit a water supply plan to the DNR every 10 years. These plans encourage communities to proactively consider how they will sustain water supplies to keep up with future growth and during times of shortage.

The DNR works with the Metropolitan Council to support the development of municipal water supply plans within the Twin Cities Metropolitan Area. We work directly with cities and towns throughout greater Minnesota to ensure their water supply plans emphasize water conservation and efficient use.

Local water utilities and communities are becoming leaders in water conservation strategies to ensure protection of their own local and regional supplies. We expect new water conservation efforts and innovations in the future. For example, as water utilities face mounting pressure to “do more with less,” smart water technologies will be more widely used, such as advanced metering infrastructure. Also, many cities are turning to green infrastructure and reuse projects to manage stormwater. There are several benefits of green infrastructure, including reduced costs over conventional stormwater infrastructure, water quality improvement, flood reduction, groundwater recharge, and water reuse opportunities.

Sustainability and resilience produce a good return on investment in the form of both economic and natural resource benefits. In working with water suppliers, the DNR will continue to encourage planning work to incorporate resilience and adaptability to climate change and extreme weather.

Water Conservation

Water conservation is any action that reduces the amount of water withdrawn from water supply sources, reduces consumptive uses, reduces the loss or waste of water, improves the efficiency of water uses, or increases recycling and reuse of water. Water conservation is integrated into all aspects of DNR water regulations and permitting through Minnesota Statute 103G.101, including statewide water conservation education and outreach.

Minnesota is the first state in the nation to have developed software that allows all of permitted high-capacity water users, which number 10,000 in Minnesota, to track and compare their water efficiency and conservation efforts and trends over time. The Minnesota Water Conservation Reporting System’s annual reports help various sectors to learn more efficient and cost-effective ways to conserve our water resources. The state benefits from MPARS collecting and aggregating the information from all cities and commercial, industrial, and institutional businesses, irrigation and other agricultural uses. The data will continue to guide water use decisions in the future. As our population grows and climate changes, we may experience increased use and seasonal intensity of use in some parts of the state. Our efforts to strive for water efficiency and conservation in all sectors will help protect Minnesota’s water supplies, industry, economies and natural resources well into the future.

Water resources science in decision making

The following sections describe the DNR efforts that contribute to better understanding the water availability in Minnesota through collecting, understanding, and applying water resource data to our decisions, and making that data available for others to use.

Climatology

The DNR State Climatology Office (SCO) collects, maintains, analyzes, and shares information about Minnesota’s climate with the state’s citizens, communities, organizations, and units of government at all scales[1]. From 2015 – 2019, the DNR improved the visibility of its climatology program by fostering collaboration, investing in new equipment, improving the ability to share data with the public, and prioritizing climate change as a major issue affecting natural resources. During this period, the DNR expanded real-time climate monitoring capabilities, developed new online climate analysis tools, enhanced its capacity to disseminate climate change information to Minnesotans, increased the scope of partnerships between climatology staff and those reliant on climate information, and committed to the update of the statewide drought plan.

The DNR will continue to maintain the monitoring networks, relationships, technologies, and delivery systems that enable it to provide important climate services to Minnesotans. The National Center for Environmental Information will release new climate averages or "normals" during 2021, and the SCO will need to update many of its materials and tools to reflect the changes. Additionally, the University of Minnesota will have completed intermediate and perhaps advanced climate modeling for Minnesota. New information from those projects will need to be integrated into the DNR's existing messages and products, along with relevant information from forthcoming global, national, and regional climate assessment reports. The SCO also faces the challenge of maintaining statewide precipitation observer numbers; this is always a challenge. The DNR relies heavily on a core group of volunteers but has struggled to expand that core and recruit replacement volunteers as others transition out of the program.

Water Resource Data Collection

The DNR collects hydrologic data across the state to facilitate resource management decisions related to our statutory responsibilities. These data are collected from a variety of networks and include data on lake levels, stream flow, groundwater levels, precipitation and climate. The DNR relies heavily on partners and volunteers in our data collection efforts. Soil and Water Conservation Districts are contracted to measure groundwater levels at observation wells and also record precipitation data for our volunteer precipitation observation program. MNgage is a volunteer driven program that monitors daily precipitation, it began in the 1960s and has consisted of approximately 1,500 volunteers for the past 4 decades. Similarly, the Lake Level Minnesota program consists of approximately 1,000 volunteers and cooperative organizations like lake associations that take readings throughout the summer at DNR-surveyed gages.

Since 2015, the DNR has continued to improve our hydrologic monitoring networks, hydrologic database, and websites. In 2018, streamflow and groundwater data were migrated into our new hydrologic database Water Information System KISTERS (WISKI), and our cooperative stream flow and groundwater websites were updated to allow users better access to more types of data. A new network of 40 climate stations was installed in 2015 to provide data to agricultural producers to inform irrigation schedules and to improve

---

[1] Climatology staff maintain the nation's largest in-state precipitation monitoring network (in collaboration with Soil & Water Conservation Districts); oversee 40 automated hydro-climate stations around the state; partner with the National Weather Service and DNR hydrologists to quality-control real-time and archived precipitation data; develop and run databases, web pages, and applications offering users access to a wide variety of climate data; contribute to and produce weekly and monthly hydro-climatic conditions reports; co-lead Minnesota's drought planning efforts; educate Minnesotans about the state's changing climate; train DNR staff on climate change science; and engage users across the state with annual presentations, frequent website updates, and regular social media posts.

coverage of climate data across the state. Long term wetland monitoring was added in 2019 and consists of a network of reference quality wetlands that will provide information on the eco-hydraulic requirements of different wetland types in Minnesota. Stream flow monitoring stations were added to groundwater management areas and other areas of concern, and 253 new groundwater observation wells were added to the network.

As resources allow, the DNR will continue to maintain and improve its hydrologic monitoring networks, hydrologic databases and websites. Migration work will continue to move precipitation and lake level data into the WISKI database and web products will enhance users' access to data and analytical tools. Goals have been set to expand the observation well and wetland networks.

Stream Ecological Thresholds

The DNR has been collecting data on fish habitat associations on numerous streams across Minnesota since 1987, to be used in conjunction with models of stream hydraulics and discharge. The information generated will be used to establish the relationship between stream flow and ecological function. This data and information is fundamental to understanding the potential impact of cumulative water appropriations on the natural stream environment and ecology, a key to sustainable management of our water resources.

In 2017, the DNR began a stream modeling study to examine the impacts of groundwater withdrawals on Little Rock Creek and its aquatic community. Data were collected from the stream to examine the hydraulic changes that occur as water decreases and examine the impact on stream habitat for aquatic organisms. This study integrates with stream flow gaging work on Little Rock Creek and associated groundwater modeling, which help establish the amount of change in stream flow caused by groundwater pumping. Together, these studies have helped establish sustainable use limits (called sustainable diversion limits) for long-term water management at this site and serve as a demonstration of a viable approach for connecting all of the department's statutory responsibilities.

Further study and demonstration of the ecological thresholds approach for setting sustainable diversion limits will occur. This includes continuing statewide collection of aquatic habitat requirements for fish and mussel species. The information will be used to refine and expand our ability to manage water resources. During the next five years, the Little Rock Creek thresholds study will be completed, and the concepts and insights gained there will be used to inform our work in other watersheds where water use may be exceeding sustainability thresholds.

Wetland Science Program

The DNR wetland programs provide important information to help understand wetlands and their role in Minnesota's water protection and management efforts. Wetland science programs include maintaining a statewide wetland inventory, ongoing operation of a wetland status and trends program to track gains and losses, and developing a wetland hydrologic monitoring program. This information is being used to inform decisions about wetland policy as well as to guide wetland protection and restoration efforts.

In 2019, the DNR completed the first statewide update of the National Wetland Inventory for Minnesota in over 30 years. The DNR partnered with Minnesota Pollution Control Agency in this effort. In addition, in effort to address wetland impacts as well as ensure sustainable groundwater resources, the DNR has developed an online mapping tool that helps identify potential wetland restoration opportunities in the Bonanza Valley Groundwater Management Area. Unlike other restorable wetland prioritization tools, this tool focuses specifically on the potential for restored wetlands to promote groundwater recharge.

The DNR has begun to establish a wetland hydrology monitoring program. The purpose of this program is to define the normal water level range needed to support healthy wetlands. Monitoring sites are selected to be representative of healthy wetlands with native vegetation across a range of different wetland types. Since 2019, the DNR has established 20 long-term wetland water level monitoring stations in wetlands around the state. The DNR plans to expand this effort, contingent on funding, to include an additional 40 sites for water level monitoring in wetlands. These data will allow the DNR to develop science-based groundwater appropriation thresholds that protect wetlands and will be useful to other organizations for their own wetland management efforts.

Watershed Health Assessment Framework (WHAF)

With ongoing support from the Clean Water Fund, the DNR continues to develop and enhance the web-based tool WHAF for accessing data and information on watershed health and natural resource context. The WHAF includes information on water availability, wetland loss, stream alterations, and groundwater, as well as many other variables, for any user-selected location in Minnesota. The WHAF allows users to view a summary of health scores from five components (hydrology, geomorphology, water quality, connectivity, and biology) across watershed boundary scales.

In this way, users can note patterns and relationships between ecological context, health conditions, and the system's response. The WHAF is intended to provide information and guidance to natural resource managers, but also has been used by teachers, landowners, city planners, and other natural resource professionals.

The WHAF had several highlights from 2015 – 2019, including:

- *Watershed Context Reports* - These context reports, developed for all 81 major watersheds in Minnesota, provide an overview of ecological conditions and human influences in each watershed.
- *Climate Summary* - These reports, also available for all 81 major watersheds, provide an overview of climate conditions based on data collected from 1895 through 2018. The reports focus on conveying trends in seasonal and annual temperature and precipitation, summarize data using 30-year averages, and compare the averages to the entire climate record average.
- *WRAPS (Watershed Restoration and Protection Strategy)* – In conjunction with Minnesota Pollution Control Agency, the DNR developed protection strategies for streams during the last 5 years using the WHAF. This WHAF product establishes data-driven priorities for protection of stream reaches.

DNR's WHAF team is pursuing several enhancement efforts in the coming years:

- GRAPS *(Groundwater Restoration and Protection Strategies)* - In 2020, groundwater and drinking water information was added to the WHAF tool, allowing users to make informed land management decisions for groundwater protection.
- *Forecasting Climate Data* - Over the next 5 years, it is anticipated that climate data forecasts will be downscaled appropriately and the data made available for use. Once completed, efforts to incorporate forecasted climate change data into the WHAF will be undertaken.
- *Lake Health* - One area of expansion for the WHAF over the next 5 years will be to develop indices for assessing and tracking lake health. This includes developing on-demand hydrologic assessment tools capable of identifying the timing of significant hydrologic changes and trends.

Groundwater Modeling

Since 2015, the DNR has used groundwater flow models to examine the sustainability of groundwater use in several parts of the state, including the North and East Metro, the Little Rock Creek watershed in Benton and Morrison Counties, and the area around Cold Spring Creek in Stearns County. DNR groundwater modelers are working closely with managers at the City of Rochester and the City of Moorhead to guide their efforts to sustainably expand their water supply systems. DNR staff are starting to construct a groundwater model that will help quantify and understand how groundwater pumping affects aquifers and surface water in the Bonanza Valley.

Groundwater Atlas Mapping

The DNR is developing better maps to identify areas of groundwater availability. Since 1995 the DNR, in collaboration with the Minnesota Geological Survey (MGS) has produced a series of County Geologic Atlases. A completed county atlas consists of two parts. The MGS produces Part A, which describes the county geology, while the DNR produces Part B, which details the county's groundwater resources. These atlases help identify areas where groundwater resources may be available for future large volume users or to sustain existing high densities of users. Atlases are complete for most metro areas, southeast and central counties, and are in process for over 15 other counties, mainly in western and northern Minnesota. The GIS data sets and maps, which are available to the public, detail our current understanding of the aquifer systems, along with pollution sensitivity maps that show the interaction of groundwater and surface water.

The atlas is a critical tool for a broad range of resource managers. It provides comprehensive information for planners, managers, scientists, researchers and individuals statewide for a wide variety of projects such as water supply planning, land use decisions, resource development, resource protection, transportation planning, agricultural water supply, groundwater research/studies, and Environmental Impact Statements. Since 2015, the DNR has published 11 new and one revised Part B atlases. Atlases in nine previously un-mapped counties and revisions of two county atlases are underway.

Conclusion

Minnesota's climate is already changing, and that change is evident on our landscape. In the past several decades, we have seen increased precipitation, more extreme rainfall events, and substantial warming. In response, streamflow is increasing, floods are bigger, and our lakes are higher. Some wetlands are getting wetter. We also have more wetlands now than a decade ago – likely due to state and federal programs that protect and restore wetlands. Groundwater levels are generally stable; some areas with falling water levels in 2010 and 2015 have now stabilized – likely due to increased rainfall and improved water conservation. Nonetheless, we have areas where groundwater levels are falling, and the groundwater supply is limited. The energy sector and water suppliers have improved water conservation over the past decade, and consequently Minnesota's water use has declined, even as our population has grown.

We have been in a climatic wet regime recently. Although climate change forecasts predict an overall wetter climate, we will still experience droughts in the future, within the overall trends driven by climate change. DNR programs continue to support sustainable water now and prepare for the climate of the future by:

- engaging with water users to support planning resilient water supply systems and water conservation;
- collecting, understanding, and applying water resource data to our decisions, as well as making that data available for others to use;
- effectively implementing Minnesota's water laws.

The DNR is working with other regulators and water users to enhance resiliency and sustainability in face of these trends and anticipated future changes.

References

Anderson, J.P. and W.J. Craig. 1984. Growing Energy Crops on Minnesota's Wetlands. The Land Use Perspective. University of Minnesota – Center of Urban and Regional Affairs, Minneapolis, Minnesota. 95.

Angel, J., Swanston, C., Boustead, B., Conlon, K., Hall, K., Jorns, J., Kunkel, K., Lemos, M., Lofgren, B., Ontl 2018. In: Reidmiller, E. Avery, C., Easterling, D., Kunkel, K., Lewis, K., Maycock, T., Stewart, B., Editors. Midwest. Impacts, Risks, and Adaptation in the United States. Fourth National Climate Assessment, Volume II. Washington (DC): U.S. Global Change Research Program. 872–940.

Biasutti, M. and Seager, R., 2015. Projected changes in US rainfall erosivity. *Hydrol. Earth Syst. Sci, 19*,2945-2961.

Birkland, T.A., R.J. Burby, D. Conrad, H. Cortner, and W.K. Michener. 2003. River ecology and flood hazard mitigation. Natural Hazards Review. 4(1): 46-54.

Chippewa Valley Ethanol Company. 2019. Report of Water Conservation Measures Implemented. Compiled by Robert Jewell, Energy Systems Chief.

David Bronaugh and Arelia Werner for the Pacific Climate Impacts Consortium. 2019. Zyp - Zhang + Yue-Pilon Trends Package, R package version 0.10-1.1, https://CRAN.R-project.org/package=zyp

Bunn, S.E. and A.H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30(4):492-507.

Clean Water Fund Performance Report. 2014. A report of Clean Water Funds invested, actions taken and outcomes achieved, 59.

Clean Water Fund Performance Report. 2018. A report of Clean Water Funds invested, actions taken and outcomes achieved, 71.

Foufoula-Georgiou, E., Z. Takbiri, J. A. Czuba, and J. Schwenk. 2015. The change of nature and the nature of change in agricultural landscapes: Hydrologic regime shifts modulate ecological transitions, Water Resources Research. 51, 6649–6671.

Hamilton, M.C., W. Goldsmith, R. Harmon, D. Lewis, B. Srdjevic, M. Goodsite, J.H. Lambert, and M. Macdonell. 2014. Sustainable water resources management: challenges and methods. I. Linkov (ed.), *Sustainable Cities and Military Installations*, NATO Science for Peace and Security Series C: Environmental Security.

Helsel, D.R. and Hirsch, R.M. 2002. *Statistical Methods in Water Resources*, Techniques of Water Resources Investigations of the United States Geological Survey: Book 4, Hydrologic Analysis and Interpretation, Chapter A3, 510.

Kloiber, S.M. and Norris, D.J. 2017. Monitoring changes in Minnesota wetland area and type from 2006 to 2014. Wetland Science and Practice, 34(3), 76-87.

Kloiber, S.M., Norris, D.J., and Bergman, A.L. 2019. Minnesota Wetland Inventory: User Guide and Summary Statistics [June, 2019]. Minnesota Department of Natural Resources, St. Paul, Minnesota. 66.

Minnesota Department of Administration. Minnesota State Demographic Center. Accessed August 2020. Population Data.

Minnesota Department of Natural Resources, 2016. Definitions and Thresholds for Negative Impacts to Surface Waters: Report to the Legislature 2016, 52.

Minnesota Department of Natural Resources. Lakes Database. Accessed April 2020. Data on lake water levels. Accessed by Tim Martin.

Minnesota Department of Natural Resources. MN Cooperative Groundwater Monitoring database. Accessed July 2020. Water elevation data for observation wells maintained by MNDNR.

Minnesota Department of Natural Resources. MPARS Database. Accessed July 2020. Data on water appropriations from lakes. Data contact was Sean Hunt.

Nichols, M. 2020. Analysis of impaired water lists. MPCA. Unpublished data, pers. Comm., August 10, 2020.

Nelson, C. and L. Steidel. 2019. *Annual Minnesota Water Conservation Report*. Minnesota Department of Natural Resources.

Novotny, E.V., and H.G. Stefan. 2007. Stream flow in Minnesota: indicator of climate change. Journal of Hydrology 334:319-333.

Pryor, S., Scavia, D., Downer, C., Gaden, M., Iverson, L., Nordstrom, R., Patz, J., Robertson, G. 2014. Midwest. In: Mellio, J., Richmond, T., Yohe, G., Editors. Climate Change Impacts in the United States: The Third National Climate Assessment. Washington (DC): U.S. Global Change Research Program. 418-440.

R Core Team. 2020. R - A language and environment for statistical computing: R Foundation for Statistical Computing, Vienna, Austria, https://www.R-project.org/.

Rao, R. and Li, Y. 2003. Management of flooding effects on growth of vegetable and selected field crops. *HortTechnology*, *13*(4), 610-616.

Schilling, K.E. and Helmers, M. 2008. Effects of subsurface drainage tiles on streamflow in Iowa agricultural watersheds: Exploratory hydrograph analysis. *Hydrological Processes: An International Journal*, *22*(23), 4497-4506.

Schilling, K.E. and Libra, R.D. 2003. Increased Baseflow in Iowa Over the Second Half of the 20th Century. *JAWRA Journal of the American Water Resources Association*, *39*(4), 851-860.

Schilling, K.E., Chan, K.S., Liu, H. and Zhang, Y.K. 2010. Quantifying the effect of land use land cover change on increasing discharge in the Upper Mississippi River. *Journal of Hydrology*, *387*(3-4), 343-345.

Schilling, K. E., Jha M. K., Zhang Y.-K., Gassman P. W., and Wolter C. F. 2008. Impact of land use and land cover change on the water balance of a large agricultural watershed: Historical effects and future directions. *Water Resources Research*. 44, W00A09.

Schottler, S.P., Ulrich J., Belmont P., Moore R., Lauer J. W., Engstrom D.R., and Almendinger J.E. 2014. *Hydrlogical Processes*. 28: 1951-1961.

Segura, C., Sun, G., McNulty, S. and Zhang, Y. 2014. Potential impacts of climate change on soil erosion vulnerability across the conterminous United States. *Journal of Soil and Water Conservation*. 69(2), 171-181.

Tyler, J. 2016. Sustainable hazard mitigation: exploring the importance of green infrastructure in building disaster resilient communities. Consilience. *The Journal of Sustainable Development*. 15(1): 134-145.

U.S. Energy Information Administration (EIA). Accessed August 2020. Minnesota State Profile and Energy Estimate.

The Upper Mississippi River Basin Charter. 1989. Principles for the management of the Upper Mississippi River Basin Water Resources and Notification and Consultation Process Guidelines.

Wang, D. and Hejazi, M. 2011. Quantifying the relative contribution of the climate and direct human impacts on mean annual streamflow in the contiguous United States. *Water Resources Research*. *47*(10).

Warner, B.P., R.E. Schattman, and C.E. Hatch. 2017. Farming the Floodplain: Ecological and Agricultural Tradeoffs and Opportunities in River and Stream Governance in New England's Changing Climate. *Case Studies in the Environment*. 1-9. Regents of the University of California.

Xu, X., Scanlon, B.R., Schilling, K. and Sun, A., 2013. Relative importance of climate and land surface changes on hydrologic changes in the US Midwest since the 1930s: Implications for biofuel production. *Journal of hydrology*. *497*, 110-120.

Yue, S., P. Pilon, B. Phinney. 2003. Canadian streamflow trend detection: impact of serial and cross-correlation. *Hydrological Sciences Journal.* 48: 51-63.

Yue, S., Pilon, P., Phinney, R., and Cavadias, G. (2002) The influence of autocorrelation on the ability to detect trend in hydrological series. *Hydrological Processes* 16. 1807-1829.

WATER SUPPLY PLANNING IN THE TWIN CITIES METROPOLITAN AREA (2005-2020)

Metropolitan Council report on findings, recommendations and continuing planning activities completed under Minnesota Statutes 473.1565

METROPOLITAN
COUNCIL

September 2020

The Council's mission is to foster efficient and economic growth for a prosperous metropolitan region

Metropolitan Council Members

Charles Zelle	Chair	Raymond Zeran	District 9
Judy Johnson	District 1	Peter Lindstrom	District 10
Reva Chamblis	District 2	Susan Vento	District 11
Christopher Ferguson	District 3	Francisco J. Gonzalez	District 12
Deb Barber	District 4	Chai Lee	District 13
Molly Cummings	District 5	Kris Fredson	District 14
Lynnea Atlas-Ingebretson	District 6	Phillip Sterner	District 15
Robert Lilligren	District 7	Wendy Wulff	District 16
Abdirahman Muse	District 8		

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide housing opportunities for low- and moderate-income individuals and families. The 17-member Council board is appointed by and serves at the pleasure of the governor.

Table of contents

About this report

The Twin Cities seven-county metropolitan area is home to three million people, over half of Minnesota's population. Securing residents' safe and plentiful water – while protecting the region's diverse water resources – requires coordinated, interdisciplinary and ongoing effort.

Although the seven-county region is relatively water-rich, the region's steady population growth, increased groundwater pumping, changing land use, and variable weather and climate is challenging some communities' ability to meet current and future water demand.

This report summarizes findings, recommendations, and continuing planning activities that address the water supply needs of the metropolitan area. It also documents work done since 2005 by Metropolitan Council (Council), with the Metropolitan Area Water Supply Policy (MAWSAC) and Technical Advisory Committees (TAC), and other partners, to fulfill the requirement of Minnesota Statute 473.1565.

Activities include:

1) Support for **collaboration**

2) Development and maintenance of a **base of technical information** including:
   a) Surface and groundwater availability analyses
   b) Water demand projections
   c) Water withdrawal and use impact analyses
   d) Modeling
   e) Similar studies

3) Development and periodic update of a **Metropolitan Area Master Water Supply Plan (Master Plan)** that:
   a) Provides guidance for local water supply systems and future regional investments
   b) Emphasizes conservation, interjurisdictional cooperation, and long-term sustainability
   c) Addresses the reliability, security, and cost-effectiveness of the metropolitan area water supply and its local and subregional components

4) **Recommendations**:
   a) Clarify the appropriate roles and responsibilities of local, regional, and state government in metropolitan area water supply
   b) Streamline and consolidate metropolitan area water supply decision-making and approval processes
   c) Fund ongoing and long-term metropolitan area water supply planning activities and capital investments

The Council considers the work and recommendations of the policy and technical advisory committees as the Council prepares regional development framework updates.

CLEAN WATER LAND & LEGACY AMENDMENT

Minnesota's Clean Water Fund supports two Metropolitan Council programs that increase communities' implementation of projects to help achieve sustainable water supplies.

Twin Cities metropolitan area water supply at a glance

Water supply sources, demand, and infrastructure

Twin Cities metropolitan area water supply sources include four extensive underground layers of rock, gravel and sand (aquifers) which hold and transport billions of gallons of water for over two million people; the Mississippi River which supplies huge volumes of water for commercial, industrial and residential uses; and treated stormwater and wastewater which could potentially provide water for non-drinkable uses such as cooling or irrigation. A variety of factors must be considered when using any of these sources.

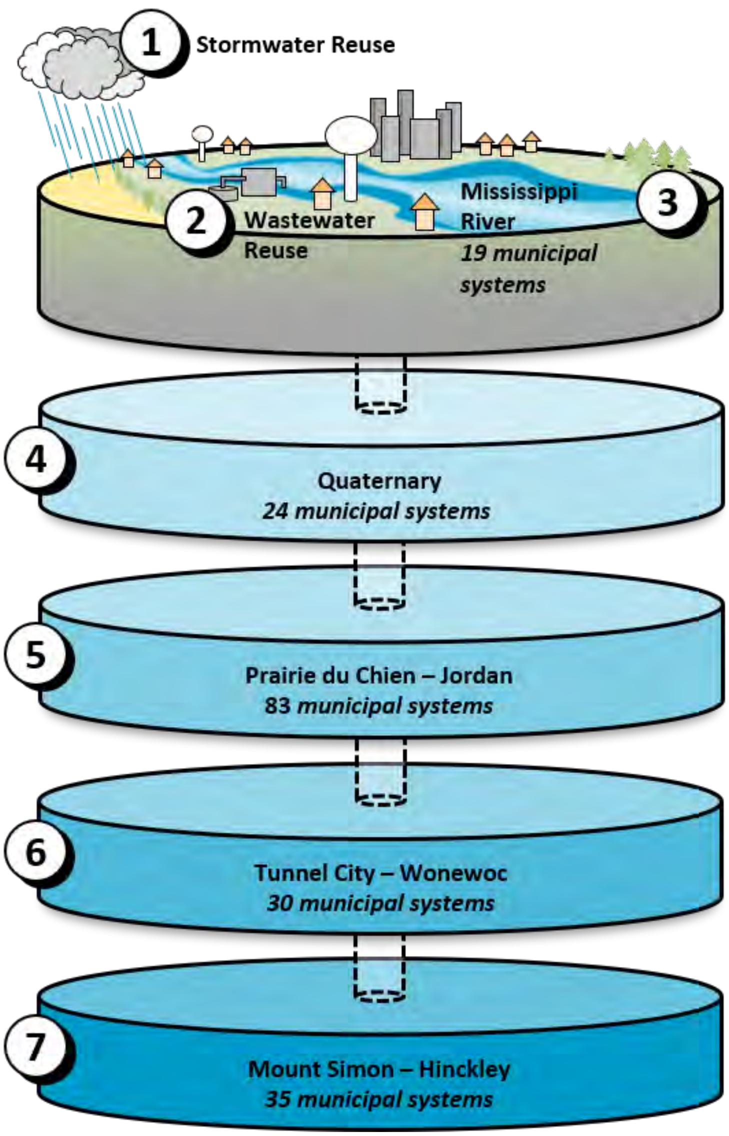


Figure 1. Water supply sources of the Twin Cities metropolitan area.

Water supply source considerations include:

- Access to the source – not all sources are equally available or productive across the region
- Seasonal variability of the supply – stormwater is not available in the winter
- Recharge rates – some aquifers replenish more quickly than others
- Nearby competing demands
- Vulnerability to contamination and/or existing natural or manmade contamination (examples: nitrate, PFAS, TCE, arsenic, radium, chloride)
- Regulated withdrawal limits and treatment requirements to protect public and environmental health
- Funding challenges

The Twin Cities metropolitan area water supply environment is large and complex. Figure 2 highlights some of the key factors shaping the Council's and partners' approach to water supply planning.

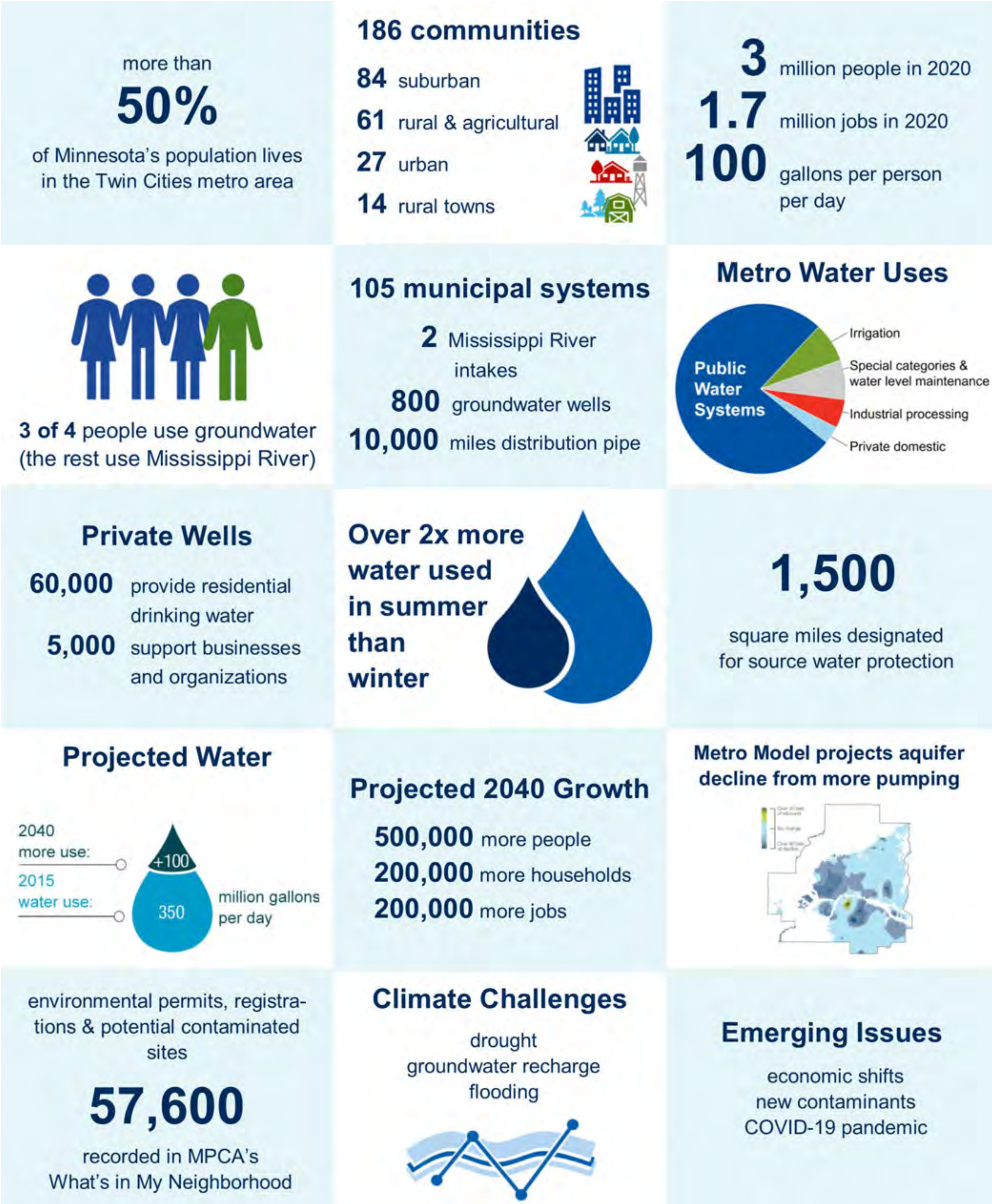


Figure 2. Selected information about water supply conditions in the Twin Cities metropolitan area.

Metropolitan Council has a unique role as a planning agency, not a regulator or utility

Bringing together the many different and changing facets of water supply into a regional picture is outside the scope of any one community, yet it is necessary to adequately plan for the region's growth and economic development. The Metropolitan Council, as the regional planning agency for the seven-county Twin Cities metropolitan area, provides this role in collaboration with communities and state agencies under the advisement of several committees.

The Council has a unique role regarding water supply planning; it is not a regulator nor a water supplier. The Council's regional water supply work has been designed and applied to ensure local water suppliers have control of and responsibility for their water supply systems, while at the same time assuring state agency oversight is effective and efficient. This program supports municipality and industry efforts to address threats to drinking water supplies, provides cost-effective regional solutions, boosts inter-jurisdictional coordination, supports local implementation of water supply reliability and water quality protection projects, and protects groundwater for current and future use. Through its work, the Council helps to bolster the livability of the region, foster economic growth and prosperity, and alleviate competition and conflict over water supply. No other agency or unit of government provides this.

The Council's role is authorized in Minnesota Statutes (Minn. Stat. 473.1565) and supported by Council policies. Specifically, the Council:

1) Maintains a database of technical information, based on analysis of regional and local issues
2) Identifies approaches for addressing emerging issues
3) Develops and updates a metropolitan area Master Water Supply Plan (Master Plan) with partners
4) Assists communities with developing their local water supply plans and other local plans
5) Facilitates cooperation between communities and supports local and subregional efforts

Figure 3. In collaboration with partners, the Council investigates, plans, and implements water supply projects and programs.

LOCAL PERSPECTIVES SHAPE REGIONAL PLANNING

"Water Supply Planning since 2005 reflects a partnered approach between the Council, local governments as well as other water-specific agencies/ entities. To me, the greatest value in this partnered approach is that documents like the Master Water Supply Plan (2015) are informed by the real experiences and expertise of the local water suppliers that the public has come to trust for safe and sustainable delivery of drinking water. The incorporation of those local government assets in MAWSAC, TAC, and water supply workgroups have added value and credibility to the necessary water supply planning efforts of the Metropolitan Council."

Mark Maloney, Public Utilities Director, City of Shoreview

Metro Area Water Supply Advisory Committee and Technical Advisory Committees shape the work

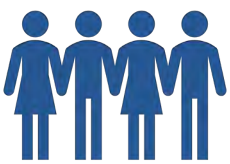
The Metropolitan Area Water Supply Advisory Committee (MAWSAC) and the Technical Advisory Committee (TAC), policy and technical committees established by Minn. Stat. 473.1565, are responsible for assisting the Metropolitan Council with its water supply planning activities.

MAWSAC responsibilities and membership

MAWSAC is responsible for:

1) Assisting the Council in its planning activities identified in Minn. Stat. 473.1565
2) Approving the Master Plan developed in cooperation with the Council
3) Appointing and consulting with the Technical Advisory Committee (see below), established to inform MAWSAC’s work
4) Reporting to the Council, the Legislative Water Commission, and the chairs and ranking minority members of the Minnesota House of Representatives and Senate committees’ divisions with jurisdiction over environment and natural resources, and providing the information required under this statutory section; MAWSAC's report and recommendations must include information provided by the TAC

The membership of MAWSAC is specified by Minn. Stat. 473.1565. The committee includes representatives of the Metropolitan Council, state water agencies, water utilities, and local and/or county governments from each county in the 11-county metropolitan area. Members are appointed in consultation with the Association of Minnesota Counties, Association of Metropolitan Municipalities (Metro Cities), and the League of Minnesota Cities, as appropriate.



Since 2005, more than 50 people have served on MAWSAC, bringing perspectives from more than a dozen different communities in all 11 metro counties.

TAC responsibilities and membership

TAC is responsible for informing MAWSAC’s work by providing scientific and engineering expertise.

Most of the 15 committee members represent single-city and multicity public water supply systems in the metropolitan area and include experts in water resources analysis and modeling; hydrology; and the engineering, planning, design, and construction of water systems or water systems finance. Members are appointed by MAWSAC with input from the Association of Metropolitan Municipalities (Metro Cities), as appropriate.

Since its creation in 2015, 17 people have served on TAC, bringing perspectives from communities and utilities in the seven-county metro area.

See Tables 1 and 2 in the appendix for MAWSAC and TAC membership history.

Regional water supply work is based on shared principles

Although attention often focuses on "what" water supply planning activities the Metropolitan Council has done under Minn. Stat. 473.1565, equally important is "how" that work is done. Guided by stakeholders during the development of *Thrive MSP 2040* – the Council's long-range vision and plan for the region over the next 30 years – the Council identified three principles to carry out all its work, including water supply planning:

Collaboration recognizes that shared efforts advance our region most effectively toward shared outcomes. Addressing the region's issues—particularly the emerging challenges of climate change, economic competitiveness, racial disparities, and water sustainability—requires collaboration because no single entity has the capacity or the authority to do the work alone.

Integration is the intentional combining of related activities to achieve more effective results, leveraging multiple policy tools to address complex regional challenges and opportunities.

Accountability includes a commitment to monitor and evaluate the effectiveness of our policies and practices toward achieving shared outcomes and a willingness to adjust course to improve performance.

Collaboration sets direction and drives results

Metropolitan Council's water supply planning activities support both local stakeholder goals and progress toward the regional outcomes put forth in *Thrive MSP 2040,* shown in Figure 4.

Figure 4. Regional outcomes put forth in Thrive MSP 2040 include stewardship, prosperity, equity, livability, and sustainability.

Since 2005, the Council has connected with hundreds of water supply leaders in the State government's water agencies, local governments, public water utilities, academic institutions, environmental advocacy groups, businesses, and neighborhoods (Table 3 of the appendix). Working together to tackle challenges has better equipped communities to meet current and future needs:

- Scoping and contributing to technical projects at subregional water supply work groups, MAWSAC and TAC meetings, inter-agency coordination team meetings and focus groups
- Shaping regional plans and related local plan requirements through input to and approval of Master Plan and development of local water supply and comprehensive plans
- Demonstrating new approaches through projects such as rainwater harvesting and stormwater reuse at CHS field in Saint Paul and turfgrass demonstration site at the Minnesota Landscape Arboretum
- Building capacity through new programs such as industrial water efficiency audits through Minnesota Technical Assistance Program (MnTAP) intern program, community grants for water efficiency rebates, and the water conservation efforts of the Freshwater Society Water Stewards program

Collaboration milestones

2005 and 2015 Convened metropolitan area water supply policy and technical advisory committees (MAWSAC and TAC), which guide the Council's water supply work and approve the Master Plan.

2006-2015 Engaged stakeholders in water supply-related plan and policy updates including scoping workshops, technical forums, and formal public review processes.

2009-2017 Convened subregional water supply work groups, which serve as a cornerstone for collaboration. More than 70 communities have received technical and financial support from the Council through their work in these groups.

2013-2020 With partners, hosted several engagement events such as: the 2013 Our Water, Our Future workshops, 2014 forums and technical workshops to guide policy and plan updates, 2017 and 2018 tours of the University of Minnesota turfgrass research site, Water Bar on opening day of the 2019 Minnesota State Fair, and a 2020 webinar series for water efficient landscapes.

LOCAL SUPPORT FOR WORKING TOGETHER

"Groundwater doesn't know community boundaries. We can have a greater impact if we work together on water supply sustainability."

Russ Matthys, Public Work Director, Eagan

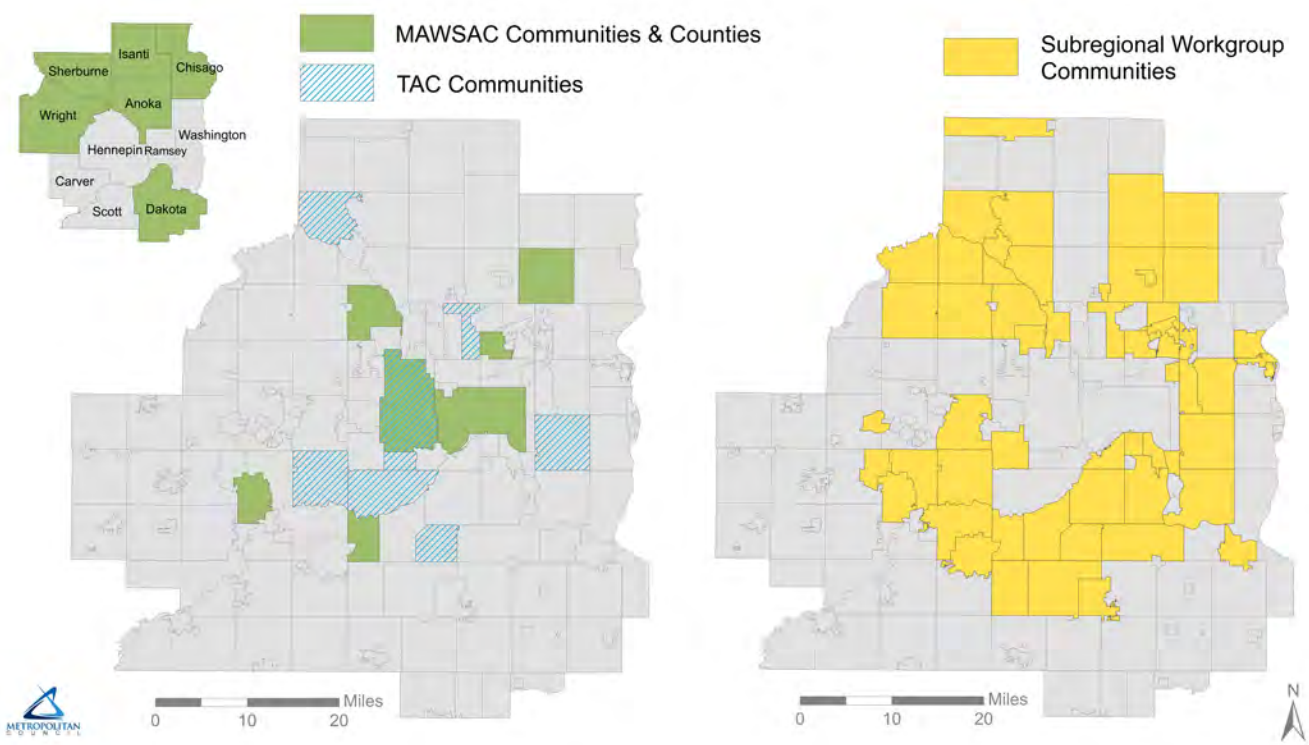


Figure 5. Communities represented in MAWSAC, TAC and subregional water supply work groups.

Technical investigations provide a foundation for planning and implementation

Since 2005, the Council has worked with its partners to develop and maintain a base of technical information including analyses of surface and groundwater availability, water demand projections, water withdrawal and use impact analyses, modeling, and similar studies.

In its technical work, the Council taps into extensive scientific and engineering expertise available in the region through contracts with engineering consultants, partnerships with academic institutions and the research branches of water agencies, and engineering and research support from across all divisions of the Council itself. The work – guided by MAWSAC, TAC, subregional water supply work groups, and others as appropriate – shapes regional policy plans, the Master Plan, and local programs and projects.

WORKING TOGETHER FOR SHARED RESOURCES

"Council funding of studies and projects was important because it isn't always easy to get local city councils to commit funds to something that reaches beyond their borders."

Steve Albrecht, Former Burnsville Public Works Director

Technical investigation milestones

2005-2020 Projects to collect and analyze new geologic, water level, and water chemistry information improve the conceptual understanding of groundwater and surface water sources. Examples: 2007 mapping of metro surficial geology and geochemistry; 2009 synoptic groundwater measurement of the metro area; 2015 analysis of enhanced recharge potential.

2009-2017 Developed and updated a regional groundwater flow model (Metro Model 2 and 3) to understand the cumulative and long-term implications of planned growth and related water demand.

2010 and 2020 Evaluations of groundwater and surface water interaction to better understand potential water supply impacts of regional growth, land use changes, and climate change.

2015-2020 Guided by water supply work groups and partners, completed subregional analyses of alternative water supply approaches, to inform future planning and project scoping. For example, in 2016 the Council and partners completed evaluations of recharge and stormwater reuse in the northeast, northwest, and southeast metro areas.

2013-2020 Water demand management analyses, including 2014 assessment of industrial water conservation barriers and opportunities, 2016 water billing analysis, 2018 study of efficient water use on Twin Cities metro area lawns). This work supports new programs such as Freshwater Society's Master Water Stewards Water Conservation Advisors, University of Minnesota Extension Turfgrass research and education.

For a more detailed list of technical investigation activities, see Table 4 in the appendix.

Key findings: challenges, opportunities and changing conditions

With partners, the Council's water supply collaboration and technical investigations have highlighted challenges in several areas, summarized below. For more information, refer to the Master Plan and technical studies included in the bibliography.

Socio-economic conditions

By 2040, the region is projected to grow by 500,000 people; 200,000 households; and 200,000 jobs compared to 2010. Understanding changing water supply needs and securing a sustainable supply of plentiful, clean water for these growing communities is the primary goal of the Council's water supply planning work.

Funding and finance

High-quality drinking water, wastewater treatment, and stormwater systems are a critical, and costly, component of community planning. Costs include planning and design, capital costs, operation and maintenance costs, and costs to monitor and report compliance with regulatory requirements. Public water suppliers, wastewater utilities, community planners, and elected officials stress the need for financial support for infrastructure changes to achieve sustainable solutions. Examples of challenges:

- Balancing short- versus long-term needs and costs when planning to rebuild or build new infrastructure
- Equitably balancing utility revenue versus affordability, particularly if decreased water demand impacts revenue while water supply system maintenance costs go up
- Addressing the need for more intense monitoring and treatment in water supply systems with mixed water sources
- Lacking reliable and adequate funding sources for implementing many stormwater reuse opportunities

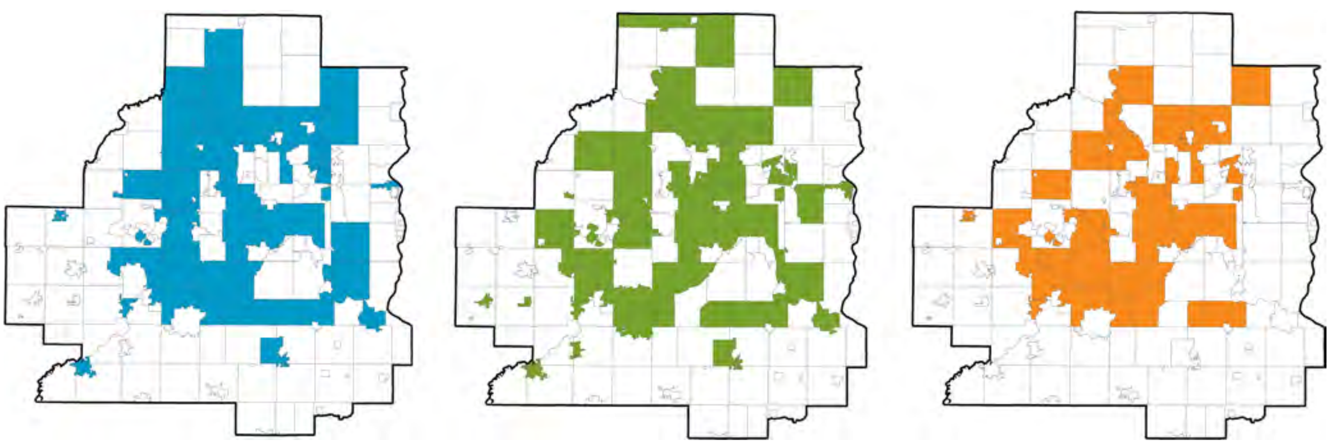


Figure 6. Based on information submitted to the Council in local comprehensive plan updates, by 2040 more than 50 communities plan to drill new municipal wells (left), more than 60 communities plan to improve and/or expand their distribution systems (middle), and more than 35 communities plan to enhance their water supply treatment processes (right). Note: Not all local plan updates have been submitted to the Council as of August 31, 2020 and this information will be revised as plans are received.

Water quality

Contamination issues vary throughout the region, primarily driven by differences in hydrogeologic setting and in level of development. The most cost-effective way to address contamination is usually to prevent it through protection of source waters. However, such protection in the metro area is complicated when drinking water management areas extend outside communities' jurisdictions or overlap with one another. Opportunities exist for more coordinated plans and implementation.

Aquifer water levels and groundwater-surface water relationships

Aquifer levels are useful for providing information about groundwater flow directions, relationships between groundwater and surface water systems, and water levels near wells. Aquifer water level issues are closely related to issues like water quality, relationships between surface water and groundwater, and well interference. A regional evaluation of hydrogeologic conditions suggests that about half of the surface water features in the metropolitan area are likely to be directly connected to the regional groundwater flow system, highlighting opportunities for more integrated surface water and groundwater planning.

Land use

Land use is expected to change to reflect the changing population, economy, and community needs. Changes on the landscape, particularly in Drinking Water Supply Management Areas, can affect downstream drinking water sources and lead to increased treatment needs and public health risks.

Regulatory considerations

The regulatory complexity of water management in Minnesota has been identified as a key challenge by public water suppliers, communities and watersheds for decades. Examples include:

- Missed opportunities to coordinate water-related plans to more efficiently use resources and achieve multiple benefits
- Supplying, treating and distributing water to consumers in compliance with Safe Drinking Water Act standards, water appropriation permits and the well code
- Agency codes and permit requirements that may contradict one another such as source water protection guidance limiting stormwater infiltration or plumbing code that confuses reuse options
- Minnesota rules preventing use of wells for injection to enhance recharge

Reliability

Approximately 50 communities in the metropolitan area use only one source (either groundwater or surface water) to supply all their water demands. Communities already use federal and state regulations and programs to identify and establish protocols for protecting the safety, security and reliability of their water supplies. However, there are still opportunities in some areas to improve the protection of water supplies as a priority for ensuring the reliability of water supply in the region.

Managing water demand

Water demand is the driving factor for water resource planning. Water demand is shaped by various socioeconomic and climate factors but planning and maintaining efficient systems are common goals. Analysis of historical and projected data on water use and population shows that decreasing the regional average total municipal water use to 90 gallons per person per day would accommodate 2040 population growth, with no regional increase in water use by municipal public water supply systems.

Uncertainty

Uncertainty is a constant factor. Several current questions remain unanswered, and other questions will inevitably emerge. Water supply planning must be done so that plans can adapt to factors such as climate changes, technology and emerging contaminants, and changing cultural priorities and attitudes.

Climate change

Mounting evidence shows that Minnesota's climate is changing, including in the metro area, and stakeholders have raised the following question: How might changes in precipitation patterns, longer growing seasons and increased risk of drought change the region's water demand, sustainable limits and quality of surface and groundwater supply sources, and the priorities set by decision-makers?

Regional planning and local planning assistance provide a framework for coordinated work

Developed and updated in collaboration with hundreds of stakeholders across the region, the Twin Cities Metropolitan Area Master Water Supply Plan (Master Plan) provides the framework for the Council's water supply activities and guides local plan updates.

First adopted in 2010, the plan and supporting technical information shaped the 2040 metropolitan development guide (Thrive MSP 2040) and regional policy and system plans. The Master Plan was then updated in 2015 to support implementation of the new regional policies – providing guidance so that communities can take the most proactive, cost-effective approach to long-term planning and permitting to ensure plentiful, safe, and affordable water that supports the prosperity and livability of the region for future generations.

Both local water supply plans and local comprehensive plans are informed by the Master Plan.

Planning milestones

2010	Adopted first Master Plan, shaped by information gathered and reviewed by staff and in partnership with stakeholders.
2014 & 2015	Adopted *Thrive MSP 2040* and Water Resources Policy Plan; their content reflects information developed in the 2010 Master Plan.
2015	Updated Master Plan to reflect new information and stakeholder priorities and to support implementation of *Thrive* and the Water Resources Policy Plan.
2015-2020	Provided local planning assistance to help communities update local plans. Examples: "PlanIt" conference, tutorials and webinars.
2016-2018	Communities updated local comprehensive plans, including local water supply plans, to align with regional policy and system plans.

For a more detailed list of planning activities, see Table 5 in the appendix.

LOCAL SUPPORT FOR REGIONAL WATER SUPPLY PLANNING

"The County is supportive of the Met Council's role in coordination and the provision of technical assistance, financial assistance, and regional facilitation. The Board and County Staff look forward to continuing discussions as we continue to define our regional vision and implement Thrive MSP 2040."

Randy Maluchnik, Chair, Board of Commissioners, Carver County

Implementation is guided by a shared vision of sustainability

The Master Plan has a single goal: a sustainable water supply now and in the future. Together, the Council and stakeholders who contributed to the Master Plan said that the region's water supplies will be considered sustainable when:

1. The use of existing water supply infrastructure and investments is maximized (within sustainable limits of available sources)
2. Use of surface water is planned and implemented in a way that maintains protected flows (Minnesota Rule 6115.0630)
3. Use of groundwater is planned and implemented in a way that:
    a. Maintains aquifer levels consistent with safe-yield conditions (Minnesota Rule 6115.0630) and protected surface water flows and water levels
    b. Minimizes impacts to groundwater-flow directions in areas where groundwater contamination has, or may, result in risks to the public health
4. Water demand that exceeds sustainable groundwater withdrawal rates is supplied by the most feasible combination of efficiency and conservation, surface water, and/or wastewater and stormwater reuse
5. Legislative changes are made that align agency directions on all aspects of water supply
6. Water users and suppliers recognize uncertainty and seek to minimize risk

Implementation milestones

2007	Changes made to Minn. Stat. 473.859, Subd. 3 and to Minn. Stat. 103G.291 to clarify and consolidate water supply planning requirements.
2009-2020	Leveraged outside funding for implementation of projects and programs identified in the Master Plan with guidance from MAWSAC, TAC, and subregional water supply work groups. Examples: Clean Water Fund; interagency cost-sharing agreements; and local matching funds for Council water efficiency grants.
2014	Initiated industrial water efficiency intern program with MnTAP to promote water efficiency in metro area industries and organizations.

COUNCIL PROGRAMS ARE SUPPORTING LOCAL RESULTS

"The City of Hugo has allocated all [water efficiency grant] funds. We are still having residents call and ask if our program is still available and we are looking forward to the time that we have more funds to allocate. We believe it has really made a significant impact on the amount of groundwater being used in Hugo."

City of Hugo Community Development

"Metro Cities' policies recognize the importance of an adequate and sustainable water supply for the metropolitan region. Many communities have benefited from these programs as they strive to use water more efficiently, and stand to further benefit in important ways from continued support of these programs."

Patricia Nauman, Director, Metro Cities

2015 Created water efficiency grants to support municipal rebate programs, funded with Clean Water Fund appropriation; began awarding grants to promote innovative stormwater reuse, funded by the Council general fund (also grants in 2016, 2017, and 2019).

2018 Developed water conservation advisory training with Freshwater Society to empower residents to be leaders in their own neighborhoods.

2020 Added water supply content to the Council's Climate Vulnerability Assessment, a tool that assists the Council and communities to prepare and adapt to climate change.

For a more detailed list of implementation activities, see Table 6 in the appendix.

Outcomes: the water supply picture in 2005 versus 2020

Through the Council's work in partnership with stakeholders across the region, we have achieved:

1. Better understanding of shared water resource conditions and challenges
2. Subregional collaborative platform to advance water sustainability goals
3. Better management and long-term resiliency of shared resources
4. More technical and financial resources focused on regional water supply challenges
5. Better equipped to pursue next steps

The following pages highlight examples of the work that has generated the achievements above.

Future work

In addition to the ongoing implementation of the Master Plan, the Council and its partners have identified some topics for further study and policy exploration. These topics arose out of the shared experience accrued through the regional and local water supply work done so far (summarized in part on pages 12-13).

At recent meetings of the Council's Environment Committee, MAWSAC and TAC, and the Land Use Advisory Committee (LUAC), these questions were raised:

- How could equity be implemented in water supply activities?
- What is the impact of climate change on our resources and operations in the water supply sector?
- How can we strengthen land use and water supply planning connections?
- What can we do to prevent contamination of our water supply sources and respond more effectively to emerging contamination (recent examples: PFAS, chloride)?

By supporting local leadership and collaboration, our shared water supplies will sustain us through the challenges ahead.

Highlights: What success looks like

The Twin Cities metropolitan area Master Water Supply Plan lays out the following strategies to achieve sustainable water supplies:

Figure 7. Master Plan strategies: funding; collaboration; technical investigations; planning; and water efficiency and reuse.

The Council was given new water supply planning responsibility in 2005 (Minn. Stat. 473.1565) but was not given dedicated funding to support that work. Instead the Council uses several sources to fund its various water supply activities.

The primary source of funding for the past 10 years has been the Clean Water Fund (CWF), which supports two Metropolitan Council programs that increase communities' implementation of projects to help achieve sustainable water supplies:

1. **Water demand reduction grant program:** Providing grants for communities to implement water demand reduction measures to ensure the reliability and protecting of drinking water supplies (Figure 9).

2. **Metropolitan area water supply sustainability support:** Implementing projects that address emerging drinking water supply threats, provide cost-effective regional solutions, leverage inter-jurisdictional coordination, support local implementation of water supply reliability projects, and prevent degradation of groundwater.

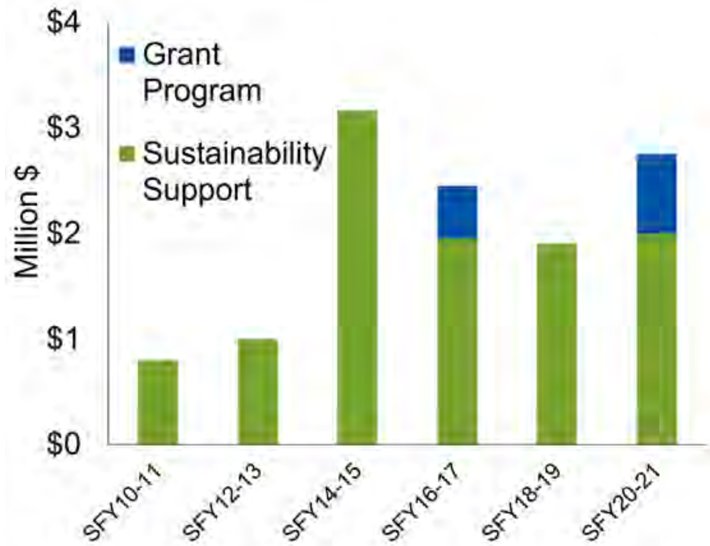


Figure 8. Council Clean Water Fund appropriation history.

CWF, however, cannot be used for the following water supply-related planning activities:

- Review of local water supply plans, comprehensive plan updates and amendments, or wellhead protection plans
- Technical support for communities in developing local plans
- Coordination and support for MAWSAC, TAC, or subregional water supply work groups
- Coordination and development of the Master Plan

Therefore, planning work has been funded through limited Council funds. For a brief time (2015-2016), the state general fund supported plan development and stakeholder engagement for the 2015 Master Plan and related Water Resources Policy Plan updates.

While wastewater rates revenue is not used for water supply *planning* activities – this source is restricted for use on activities directly tied to wastewater utility operation – this source does support work such as reuse investigations, which indirectly support the water supply sustainability of the region.

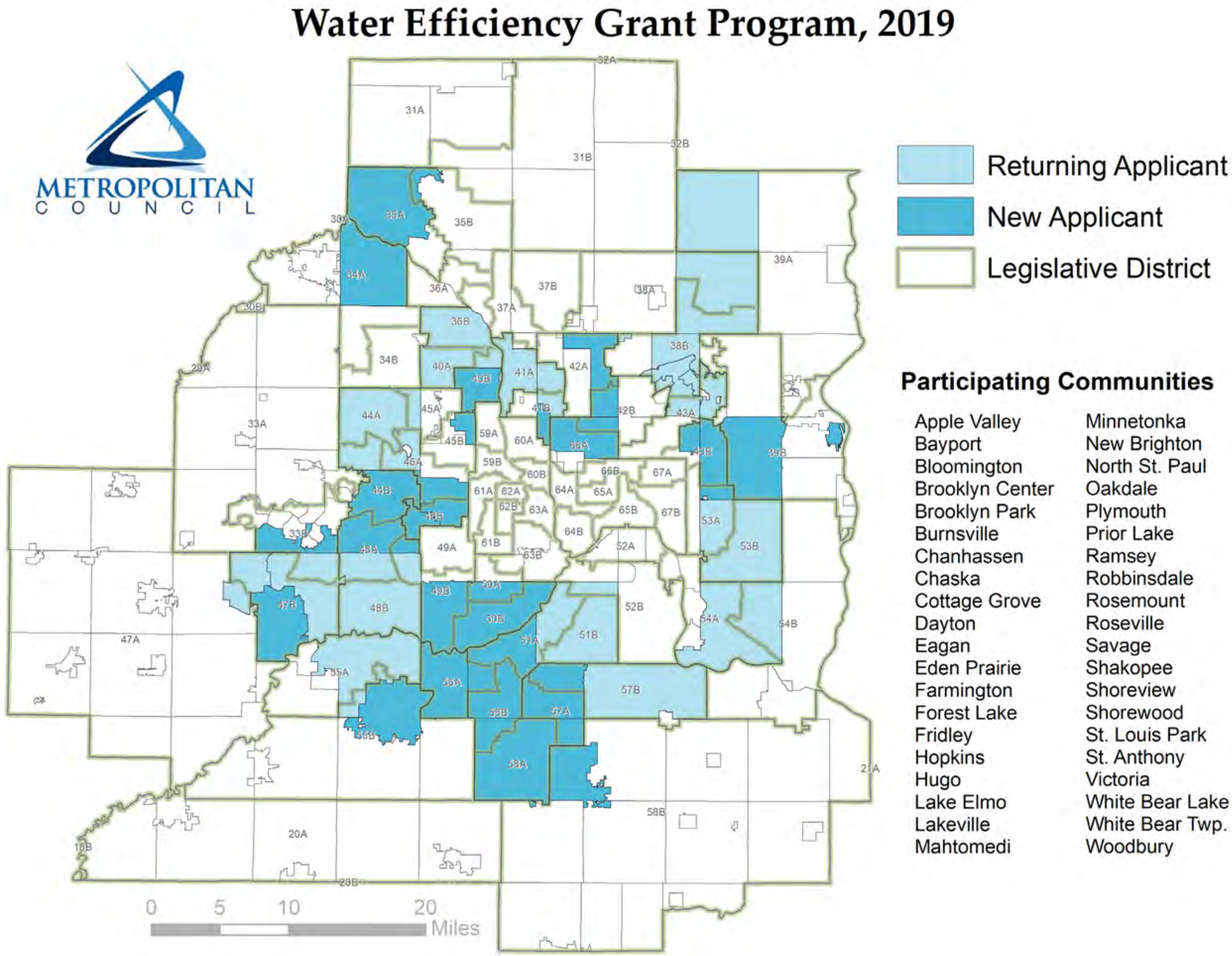


Figure 9. Communities participating in the Council's Clean Water Fund-supported water efficiency grant program, by Minnesota Legislative district.

Funding Highlight: Metropolitan Council Water Efficiency Grant Program

Through the Council's water supply planning activities since 2005, the Council and its stakeholders have worked to promote water conservation and efficiency so that communities, businesses, and residents are more equipped to support better management for long-term resiliency of shared water supply resources.

One program that highlights this work is the Council's Water Efficiency Grant Program. Begun as a pilot in 2015, this Clean Water Fund-supported program has been very successful and was reestablished with Clean Water Fund support for 2019-2022.

The Council covers 75% of the program cost; the municipality must provide the remaining 25%. Municipalities use the combined Council and municipality funds to run their own grant or rebate programs.

Objective

Support technical and behavioral changes that improve municipal water use efficiency through local water efficiency rebate programs for WaterSense-labeled fixtures:

- Irrigation controllers, spray sprinkler bodies, and system audits
- Toilets
- Clothes washers

Participants

Apple Valley, Bayport, Bloomington, Brooklyn Park, Brooklyn Center, Burnsville, Chanhassen, Chaska, Circle Pines, Cottage Grove, Dayton, Eagan, Eden Prairie, Farmington, Forest Lake, Fridley, Hopkins, Hugo, Lake Elmo, Lakeville, Mahtomedi, Minnetonka, New Brighton, Newport, North St. Paul, Oakdale, Plymouth, Prior Lake, Ramsey, Robbinsdale, Rosemount, Roseville, Savage, Shakopee, Shoreview, Shorewood, St. Anthony, St. Louis Park, Victoria, White Bear Lake, White Bear Township, Woodbury

2015-2017:
- 19 communities established local water efficiency programs
- **Estimated water saved:** 52 million gallons/year

2019-2022:
- 17 returning communities enhanced local water efficiency programs
- 23 new communities established local water efficiency programs

LOCAL SUPPORT FOR THE COUNCIL'S WATER EFFICIENCY GRANT PROGRAM

"Many communities, including Hugo, have benefited from these programs and will continue to benefit from the expansion of these programs."

Tom Weidt, Mayor of Hugo

"The Program is valuable for several reasons beyond the obvious water conservation benefits. The public awareness the Program creates is important … As more residents become aware of the Program, we believe it will be important to continue it into the future."

Mark Burch, Former White Bear Lake Public Works Director

Funding Highlight: Twin Cities Regional Water Billing Analysis

Through the Council's water supply planning activities since 2005, the Council and its stakeholders have worked to support better understanding of shared challenges and better management for long-term resiliency of shared water supply resources. Public water suppliers, wastewater utilities, community planners, and elected officials stress the need to consider the local financial aspects of this work.

One project that highlights this is the 2015 Twin Cities Regional Water Billing Analysis.

Partners

126 metro municipal utilities, Minnesota Department of Natural Resources, Metropolitan Council

Objective

Determine if the rates and rate structures used by water utilities in the Twin Cities metropolitan area to bill their customers have any affect on water consumption. Socioeconomic and land use factors also were considered in this analysis.

Findings and next steps

- Water is relatively inexpensive
- Wealthier households use more water
- Lower prices are associated with greater summer water use
- Inclined block rate structures are not necessarily water conservation rate structures
- Significant room for improvement in rate structures across the metro area
- Water savings realized could be substantial
- Continue to track and share *metro area water rate information* and work with communities to create resources to understand the relationships between rates, water conservation, and long-term utility budgets

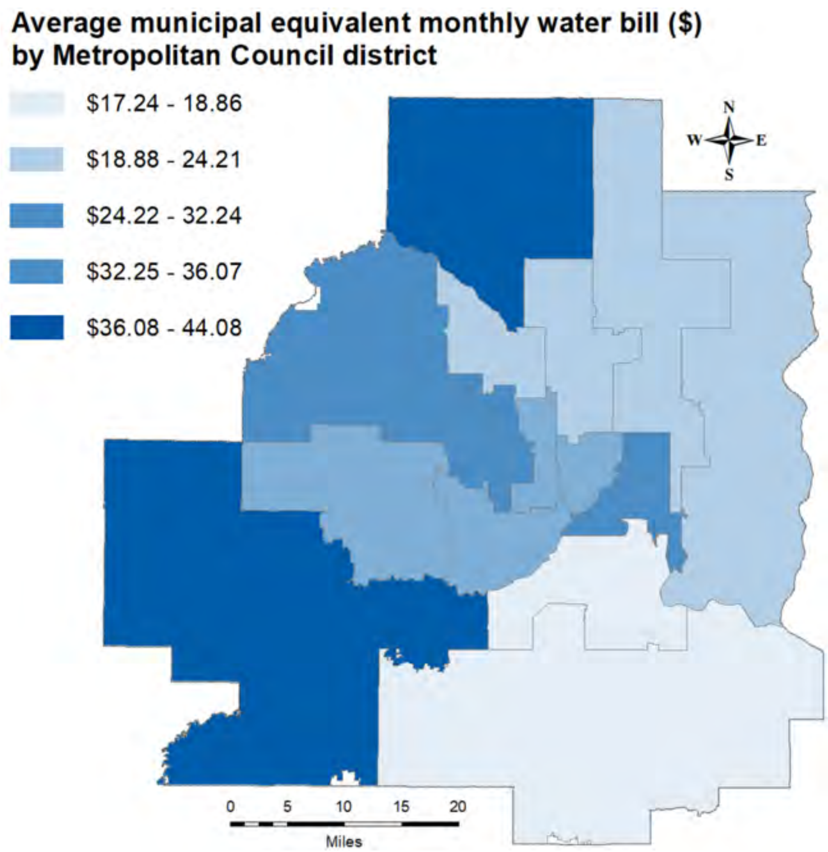


Figure 10. The 2015 Twin Cities Regional Water Billing Analysis includes a range of information about municipal water rates and other factors for 126 communities in the metro area. This information improved understanding of the impacts of rates on water consumption and supported subsequent projects. This figure is an example of the report content.

Collaboration Highlight: Northwest Metro Area Water Supply System Study

Through the Council's water supply planning activities since 2005, a successful subregional collaborative platform has been established to advance regional and local water sustainability goals. For example, participation in subregional water supply work groups has increased from 20 communities in 2005 to more than 70 communities in 2020.

One project that highlights the collaborative and long-range work being done by these groups is the 2020 Northwest Metro Area Water Supply System Study.

Partners

Corcoran, Dayton, Ramsey, Rogers, Metropolitan Council

Objective

Understand the relative costs and implementation considerations of different approaches to a multi-community water supply in the northwest metro area.

The study evaluates four approaches to water supply:

1. Multi-community surface water treatment plant
2. Multi-community groundwater treatment plant
3. Multi-community conjunctive use system (surface water augmented with groundwater)
4. Status quo

The study does not provide "shovel-ready" projects for implementation. Rather, the project defined by each approach are at a concept-level with the intent to compare relative differences in costs between approaches and, more importantly, to explore the implementation issues associated with each approach.

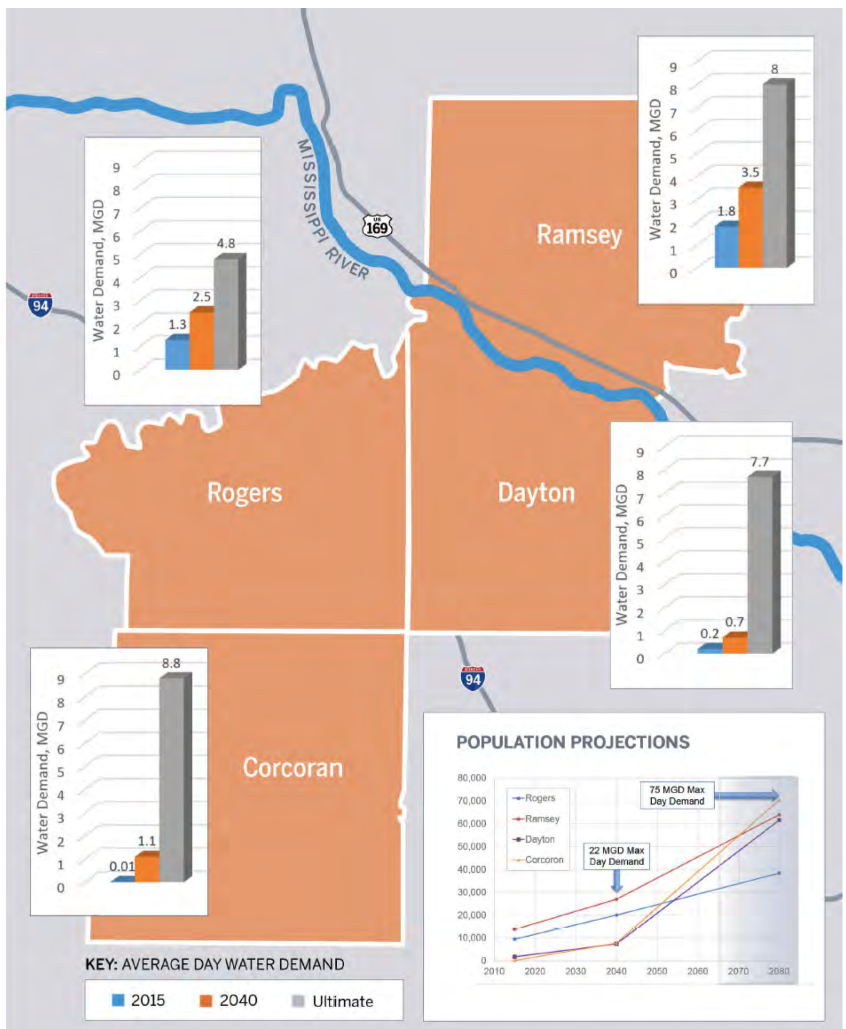


Figure 11. The 2020 Northwest Metro Area Water Supply System Study includes a range of information about projected population water demand and other water supply system components for the cities of Corcoran, Dayton, Ramsey and Rogers. This information is used to explore the costs and implementation considerations for four different water supply approaches. This figure provides an example of the report content.

Technical Investigations Highlight: Metro Model

Through the Council's water supply planning activities since 2005, the Council and its stakeholders have a better understanding of shared resources and challenges.

One project that highlights cumulative and long-term changes to aquifers (the water supply source for 75% of the metro area population) is the regional groundwater flow model – Metro Model (versions 2 and 3).

Partners

The technical advisory group providing guidance during this project included representatives of the University of Minnesota, University of Wisconsin, MN Department of Health, MN Department of Natural Resources, MN Department of Agriculture, MN Pollution Control Agency, MN Geological Survey, U.S. Geological Survey, City of Woodbury, Dakota County, Shakopee Mdewakanton Sioux Community, and the consulting firms Antea Group, Braun Intertec, HDR, and LGB.

Objective

Help address a broad range of regional planning questions and to be as flexible as practical to accommodate new questions or scenarios, while still incorporating the best available data. Some examples of questions the model is intended to help address include:

LOCAL SUPPORT FOR COUNCIL GROUNDWATER MODELING

"Encourage the continued development of a metropolitan groundwater model, as a tool to define aquifers and aquifer recharge areas and as a basis for aquifer protection and management."

Bloomington 2040 Comprehensive Plan Update

- Given projected water demands, what impacts may be expected on groundwater levels and groundwater-dependent surface-water features?
- What combinations of source aquifers, well locations, and withdrawal rates can be used to achieve sustainable water consumption?

Metro Model is a fundamental part of the Council's water supply planning efforts. It has also served as a starting point for other local and subregional modeling efforts such as local wellhead protection planning and groundwater modeling in the northeast metro groundwater management area.

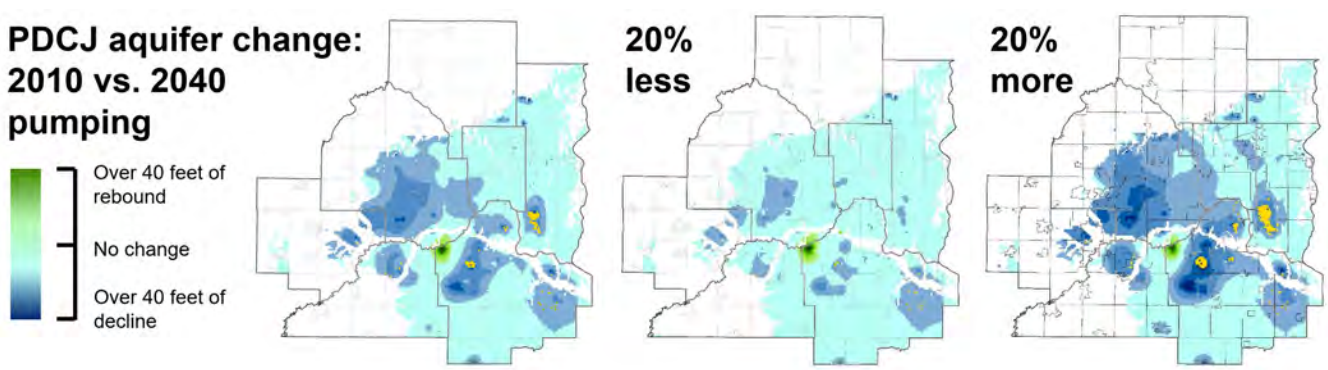


Figure 12. Model-projected water level change in the Prairie du Chien-Jordan (PDCJ) aquifer – which is used by most communities in the Twin Cities metro area – based on estimated 2040 groundwater pumping rates (left), 20% less than the 2040 estimate (middle), and 20% more than the 2040 estimate (right).

Planning Highlight: Climate Vulnerability Assessment – Water Supply

Through the Council's water supply planning activities since 2005, the Council and its stakeholders have worked to improve the water supply process and planning tools for better management for long-term resiliency of shared water supply resources.

One project that highlights this work, led and funded by the Council's Local Planning Assistance group is the addition of water supply content to the Council's *Climate Vulnerability Assessment* (CVA).

Evidence is mounting that Minnesota's climate is changing, including in the Twin Cities metro area and Minnesota Governor Tim Walz is urging bold action across the state to address climate change. The CVA is a tool that can assist in Council and community planning efforts in preparing and adapting to climate change because the CVA can reveal system vulnerabilities to currently occurring and, to some extent, expected climatic changes. The CVA project consists of Council-related analysis and recommendations as well as tools for communities and other stakeholders.

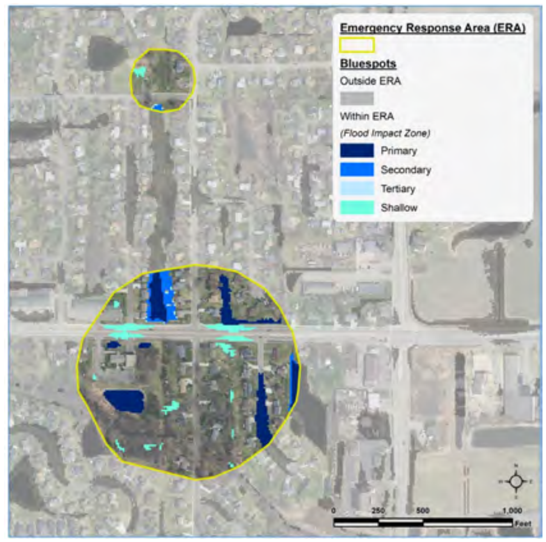
Objective

Include water supply content in the Climate Vulnerability Assessment, specifically the identification of areas around wells that are most at risk of flooding and potential strategies to improve management in these areas.

Findings

Private and public wells across the region are at risk of being overtopped by flooding during extreme events. This analysis provides information about where that risk may be most likely.

Local communities and other stakeholders may conduct similar analyses to assess conditions and vulnerabilities that may inform adaptive strategies for local system assets.



Analysis Layer	Total (Acres)	Total Analysis Layer in FIZ*	Flood Impact Zone % for Analysis Layers in a FIZ			
			Primary	Secondary	Tertiary	Shallow
Domestic Wells (50ft Buffer)	12,054	7.6%	37.2%	19.2%	29.4%	14.2%
Inner Wellhead Management Zone (200ft Buffer Around Public Well)	2,539	13.1%	40.8%	19.5%	25.4%	14.3%
Emergency Response Areas (1-year Time-of-Travel to Public Well)	39,562	16.3%	46.2%	18.5%	22.6%	12.7%

Figure 13. Results of the Climate Vulnerability Assessment analysis of potential localized flood impacts to private domestic and public (municipal and nonmunicipal) water supply wells, based on a calculation of the acres around wells that overlap a Flood Impact Zone (FIZ).

Implementation Highlight: MnTAP Water Efficiency Intern Program

Through the Council's water supply planning activities since 2005, the Council and its stakeholders have worked to promote water conservation and efficiency so that communities, businesses, and residents are more equipped to support better management for long-term resiliency of shared water supply resources.

One program that highlights this work is the Council's partnership with the University of Minnesota's Minnesota Technical Assistance Program (MnTAP) to support an industry-focused intern program focused on water efficiency.

Objective

This program, launched in 2012, places student interns in metro area industries and other organizations. The students get hands-on experience and the organizations benefit as opportunities to operate more efficiently are identified.

Participants

Aqseptence, Anoka-Hennepin ISD11, Aveda Inc., Bailey Nurseries, Ball Corporation, Boston Scientific, Cemstone, CertainTeed Roofing, City of Plymouth, City of Woodbury, Electric Machinery, Federal Cartridge Company, Fulton Beer, Gedney Foods Company, GE Water & Process Technologies, HCMC, Health Systems Cooperative Laundries, Kapstone Containers, Lloyd's BBQ, Minnesota Zoo, Northern Star Co., North Memorial Health, R&D Systems, Sanimax, Science Museum of Minnesota, TEL FSI Inc., Thomson Reuters, TreeHouse Foods, Xcel Energy

2013-2017:

- 20 projects making 159 recommendations
- **Total intern recommendations implemented as of 2018:** 87 million gallons/year
- **Realized cost savings:** $486,000/year

Learn more! Information about *intern projects* and *industrial water conservation research in the metro area* is on the MnTAP website.

Figure 14. MnTAP water efficiency interns working in local businesses.

Implementation Highlight: Rainwater Harvesting and Reuse Demonstration Project at CHS Field

Through the Council's water supply planning activities since 2005, the Council and its stakeholders have built strong partnerships that allow for new approaches to water supply and shared learning.

One project that highlights this work is a rainwater harvesting and reuse demonstration project in downtown Saint Paul. The construction of CHS Field, home of the Saint Paul Saints, immediately next to Metro Transit's Green Line Operations and Maintenance Facility (OMF) in downtown Saint Paul created a unique opportunity to capture rainwater from a portion of OMF roof and convey it to CHS Field for ball field irrigation and toilet flushing.

Partners

Capital Region Watershed District, City of Saint Paul, Saint Paul Saints, Metropolitan Council/Metro Transit

Objective

Reduce potable water use as well as pollution runoff flowing to the river from CHS Field, home of the Saint Paul Saints

Results

- Approximately 450,000 gallons/year of municipal water saved
- Value of water conservation and reuse is promoted
- Freshwater Society 2015 Clean Water Champion

Figure 15. Stormwater reuse is showcased on tours of the cistern that holds rainwater captured from the roof of Metro Transit's Green Line Operations and Maintenance Facility, for use at CHS Field.

STRONG PARTNERSHIPS LEAD TO SUCCESS

"There were so many challenges to incorporating stormwater management into CHS Field, it couldn't have happened without the strong partnerships between CRWD, the City, Met Council, and the Saints. The ballpark demonstrates how water conservation can be achieved when people make it a priority, and are willing to think creatively."

Nate Zwonitzer, Project Manager

Implementation Highlight: Exploring Impacts of Infiltrating Reclaimed Water on Groundwater and Surface Water in the Southeast Metro

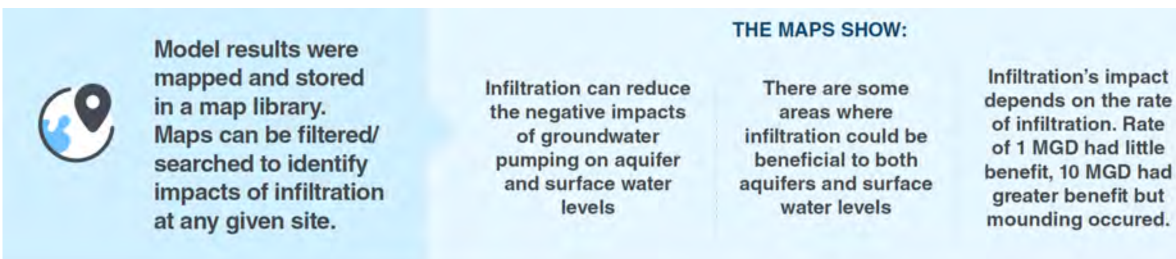
The Twin Cities metropolitan area Master Water Supply Plan identifies investigating the reuse of wastewater as a strategy for achieving sustainable water supplies and supporting the Water Resources Policy Plan policy on conservation and reuse.

One project that highlights this work, led and funded by the Metropolitan Council Environmental Services Technical Services group, was an analysis exploring the impacts of infiltrating reclaimed water on groundwater and surface water in the Southeast Metro.

Objective

Answer Metropolitan Council Environmental Services' Southeast Metro customers' question: can infiltrating water lessen projected future groundwater level drawdown and surface water level impacts?

Southeast Metro communities depend on groundwater for drinking water. They have sought ways to avoid or lessen potential future issues such as groundwater level drawdown. Infiltrating highly treated wastewater (reclaimed water) may be one method that helps avoid or lessens potential future groundwater level drawdown and surface water impacts due to pumping.



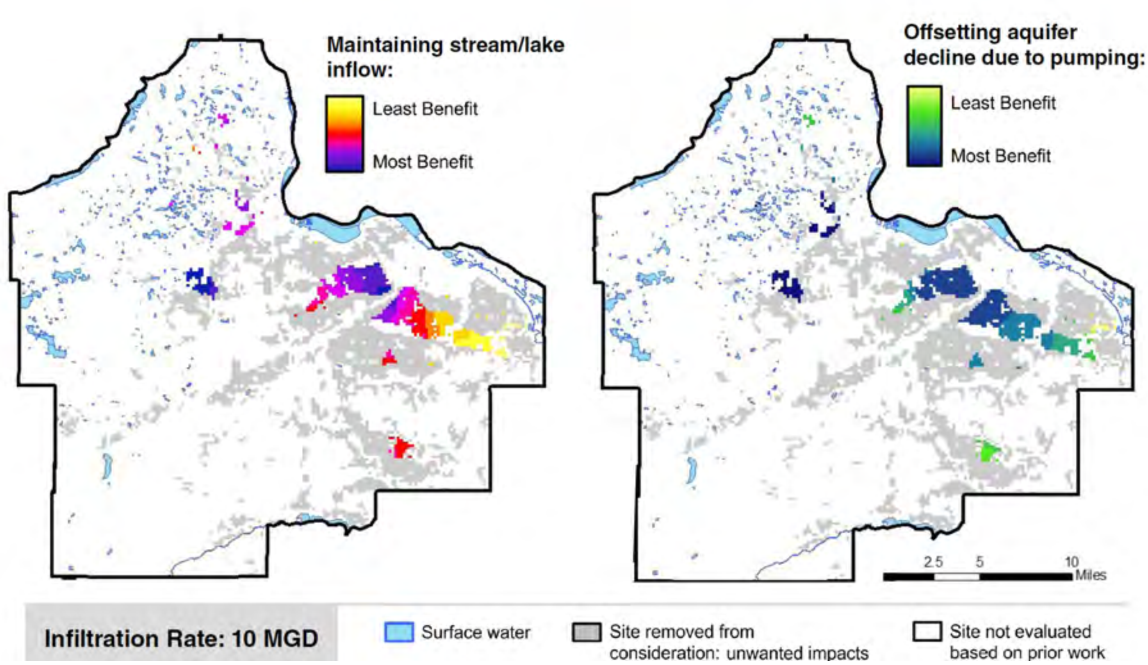


Figure 16. Process steps (above) and examples of maps generated by this project (left).

Appendix

Commonly used acronyms & abbreviations

CVA – Metropolitan Council Climate Vulnerability Assessment

CWF – Clean Water Fund

DNR – Minnesota Department of Natural Resources

DWSMA – Drinking Water Supply Management Area

GWMA – Groundwater Management Area, as designated by the DNR

LUAC – Land Use Advisory Committee

Master Plan – Twin Cities metropolitan area Master Water Supply Plan

MAWSAC – Metropolitan Area Water Supply Policy Advisory Committee

MDA – Minnesota Department of Agriculture

MDH – Minnesota Department of health

MM3 – Metro Model 3, the regional groundwater flow model

MnTAP – Minnesota Technical Assistance Program at University of Minnesota

MPCA – Minnesota Pollution Control Agency

MWSP – Twin Cities metropolitan area Master Water Supply Plan

PFAS – Broad group of perfluoroalkyl and polyfluoroalkyl substances

TCE – Trichloroethylene, a volatile organic compound

TAC – Metropolitan Area Water Supply Policy Advisory Committee

WRPP – Water Resources Policy Plan

U of M – University of Minnesota

History of Metro Area Water Supply Policy and Technical Advisory Committee membership

Table 1. History of Metro Area Water Supply Policy Advisory Committee membership (MAWSAC).

Statutorily required MAWSAC representative	Current and past MAWSAC representatives
Commissioner of Agriculture or Designee	**Jeff Berg (current)** Dan Stoddard Bob Patton Quinn Cheney Greg Buzicky Gene Hugoson
Commissioner of Health or Designee	**Sandeep Burman (current)** Karla Peterson Randy Ellingboe Chris Elvrum Diane Mandernach John Stine Doug Mandy
Commissioner of Natural Resources or Designee	**Jack Gleason (current)** Jeanne Daniels Julie Eckman Terrie Yearwood Dale Holmuth James Japs Gene Merriam
Commissioner of Pollution Control Agency or Designee	**Catherine Neuschler (current)** Katrina Kessler Sheryl Corrigan Faye Sleeper Galen Reetz Brad Moore Sherri Kroening
Metro area county official #1	**Valerie Grover, Dakota County (current)** **Georg Fischer, Dakota County (2013-2020)** Joseph Harris, Dakota County (2005-2013)
Metro area county official #2	**Jamie Schurbon, Anoka County (current)** Beverly Aplikowsky, Ramsey County (2005-2007) Dennis Berg Anoka Co/Ramsey (2005-2012)

Statutorily required MAWSAC representative	Current and past MAWSAC representatives
Metro area noncounty LGU #1	**Phillip Klein, Hugo (current)** Chuck Haas, Hugo (2005-2016)
Metro area noncounty LGU #2	**Tonja West-Hafner, Brooklyn Park (current)** Dean Lotter, New Brighton (2015-2019) Sandy Colvin Roy, Minneapolis (2012-2014) Linda Loomis, Golden Valley (2005-2012)
Metro area noncounty LGU #3	**Mike Huang, Chaska (current)** Todd Gerhardt, Chanhassen (2015-2019) Tom Furlong, Chanhassen (2005-2015)
Metro area noncounty LGU #4	**Brad Larson, Savage (2020-Present)** Barry Stock, Savage (2005-2018)
Metro area noncounty LGU #5	**Kevin Watson, Vadnais Heights (2020-Present)** Patty Acomb, Minnetonka (2015-2018)
Chair of the Metropolitan Council or Designee	**Wendy Wulff (2019-Present)** Sandy Rummel (2012-2019) Peggy Leppick (2010-2011) Peter Bell (2005-2010)
Chisago County official	**Michael Robinson (current)**
Isanti County official	**Susan Morris (current)** Greg Anderson (2014-2015)
Sherburne County official	**Lisa Volbrecht (current)**
Wright County official	**Mark Daleiden (current)** Elmer Eichelberg (2012-2013)
Representative of St. Paul Regional Water Services	**Steve Schneider (current)**
Representative of Minneapolis Water Department	**Glen Gerads (current)**

Table 2. History of Metro Area Water Supply Technical Advisory Committee membership (TAC).

TAC member organization	Representative (tenure)
Single-city public water supply system	Jim Westerman, Woodbury (2017-Present)
	Klayton Eckles, Woodbury (2016-2017)
	Jessica Levitt, Cottage Grove (2016-2018)
	Matt Saam, Apple Valley (2017-Present)
	Scott Anderson, Bloomington (2017-Present)
	Robert Ellis, Eden Prairie (2017-Present)
	Bruce Westby, Ramsey (2016-Present)
	Kristin Asher, Richfield (2016-Present)
	Mark Maloney, Shoreview (2016-Present)
	Lon Schemel, Shakopee (2016-2017)
Multicity public water supply system	Dale Folen, Minneapolis Water Works (2016-Present)
Not public water supply system	Ray Wuolo, Barr Engineering (2016-Present)
	John Dustman, Summit Envirosolutions (2016-Present)
	Crystal Ng, U of M (2016-Present)
	Jamie Wallerstedt MPCA (2016-Present)
	Lih-in Rezania, MDH (2016-Present)
	Jim Stark, Legislative Water Commission/USGS (2016-Present)

History of collaboration

Table 3. History of collaboration in Metropolitan Council's water supply work.

YEAR	Metropolitan Council Water Supply Collaboration Activity
2006	Convened Metropolitan Area Water Supply Advisory Committee (MAWSAC)
2008	Convened stakeholders to shape/draft scope of master water supply plan
2009	Convened East Metro water supply work group Coordinated with DNR to streamline water use data sharing Joined Clean Water Fund Interagency Coordination Team, to ensure funding requests to support water supply planning are aligned with other water agencies' work
2010	Convened Seminary Fen work group
2011	Convened South Washington Co. water supply work group
2012	Received Governor's Continuous Improvement Award as part of Clean Water Fund Performance and Outcomes team
2013	Collaboration between Council and DNR water supply leadership on shared projects, water supply plan requirements Hosted Our Water Our Future workshop series in the northeast metro Hosted stormwater reuse guide tour and workshops
2014	Hosted forums and technical workshops for water supply stakeholders to provide guidance and share information shaping the update of regional water supply policies and the MWSP Convened Southeast Metro water supply work group
2015	Convened Metropolitan Council Water Supply Technical Advisory Committee (TAC)
2016	Reconvened West Metro water supply work group after a hiatus of several years Convened West Metro water supply work group
2017	Completed workshop series with southeast metro stakeholders to draft a water conservation and efficiency assessment tool Convened a forum of all the subregional water supply work groups to share experiences and water supply planning priorities Hosted tours of U of M Turfgrass research site Published online tutorials to guide local water supply plan updates as part of the Council's PlanIt program Convened Council's land use and water supply advsiory committees to begin collaboration on overlapping land use-water supply issues

YEAR	**Metropolitan Council Water Supply Collaboration Activity**
2018	Hosted tours of U of M Turfgrass research site Council Co-hosted the 2018 One Water Summit with local and national partners and supported MAWSAC and TAC member participation
2019	Completed education and outreach to reduce lawn water use Hosted a Water Bar on the first day of the MN State Fair, with city and agency partners
2020	Hosted webinar series for water efficient landscapes

History of technical investigations

Table 4. History of technical investigations in Metropolitan Council's water supply work.

YEAR	Metropolitan Council Water Supply Planning Activity
2007	Completed mapping of metro area surficial geology and geochemistry
2008	Piloted project with Dakota County to map groundwater contamination
2009	Completed synoptic groundwater measurement of the metro area Completed Metro Model 2, the regional groundwater flow model
2010	Completed analysis of Mississippi River low-flow characteristics Filled gaps in metro area hydrostratigraphic and hydrogeochemical data Completed evaluation of groundwater-surface water interaction Completed East Bethel groundwater analysis
2011	Completed mapping bedrock recharge and Platteville Formation hydrostratigraphy
2013	Updated Soil Water Balance (SWB) model to estimate recharge Surveyed private industrial water users regarding conservation barriers and opportunities
2014	Completed assessment of stormwater infiltration impacts on groundwater Updated the regional groundwater flow model to Metro Model 3 Completed assessment of industrial water conservation barriers and opportunities
2015	Drafted study of Turtle Lake augmentation (Shoreview, MN) Completed groundwater modeling to explore sustainable groundwater limits Completed joint water utility feasibility study for six northwest metro communities Completed regional enhanced recharge study
2016	Completed water billing analysis Oversaw completion of USGS Scientific Investigations Report Completed recharge and stormwater reuse study in the northeast, northwest, & southeast metro areas Completed water supply feasibility assessment for Washington County Water Coalition Completed research on industrial water conservation in the north and east GWMA
2017	Contributed technical assistance to screening level evaluation of the impacts of infiltrating reclaimed water on groundwater and surface water in the southeast metro

YEAR	**Metropolitan Council Water Supply Planning Activity**
	Updated transient regional groundwater flow model
2018	Completed study of efficient water use on Twin Cities lawns Completed water efficiency study for Washington County Municipal Water Coalition
2019	Completed assessment of economic benefits of residential-focused water efficiency programs Installed turfgrass irrigation research and demonstration plots at MN Landscape Arboretum
2020	Updated evaluation of groundwater and surface water interactions Completed preliminary assessment of metro area municipal water supplier data reporting

History of planning

Table 5. History of Metropolitan Council water supply-related planning activities.

YEAR	Metropolitan Council Water Supply Planning Activity
2005	Minnesota Statutes 473.1565 enacted
2007	Council supported changes to MS 473.859, Subd. 3 and 103G.291 to clarify and consolidate water supply planning requirements
2010	Council adopted Master Water Supply Plan (Master Plan), shaped by information gathered and reviewed by staff and in partnership with stakeholders
2014	Council adopted Thrive MSP 2040, the updated metropolitan development guide
2015	Adopted Water Resources Policy Plan Supported guidance, webinars, and workshops for planners working on water supply information for local comprehensive plans, included in the Local Planning Handbook and PlanIt program Updated Master Water Supply Plan based on Metro Model 3, conservation and reuse projects, and feasibility assessments
2016	Technical assistance to communities updating local water supply plans
2018	Council amended the 2040 Water Resources Policy Plan to clarify wastewater reuse policy
2020	Council launched development of Met Council Climate Action and Resilience Plan

History of implementation

Table 6. History of Metropolitan Council water supply-related implementation activities.

YEAR	Metropolitan Council Water Supply Planning Activity
2007	Reported to MN Legislature on progress: water supply planning in the Twin Cities metro area, including technical findings
2009	One-time funding for Master Water Supply Plan implementation from Clean Water Fund ($400K)
2010	Awarded Clean Water Fund appropriation for specific water supply projects ($400K)
2011	Awarded Clean Water Fund appropriation for Master Water Supply Plan implementation ($1M)
2012	Award from American Society of Landscape Architects for Stormwater Reuse Guide
2013	Awarded Clean Water Fund appropriation for regional groundwater planning ($2M) + agreement with USGS to investigate White Bear Lake ($537K)
2014	Awarded appropriation for grant to Shoreview to study Turtle Lake ($75K) + Plan for the North and East Metro GWMA ($400K) + Investigation to treat stormwater in NE metro ($100K)+ Partnership with MnTAP ($50K)
2014 2014	Initiated industrial water efficiency intern program with MnTAP Reported to Minnesota Legislature: Metropolitan Council water supply activities supported by CWF
2015	Created water efficiency grant program to support community programs Awarded Clean Water Fund appropriation to implement projects ($1.95M) + water demand reduction grant program ($500K) Council awarded grants for innovative stormwater reuse Fresh Water Society's Clean Water Champion Award for Council and partners' work to help communities reduce demands on groundwater by harvesting and reusing rainwater at CHS Field, home of the St. Paul Saints baseball team in St. Paul
2016	Updated Water Conservation Toolbox
2017	Awarded Clean Water Fund appropriation to implement projects ($1.9M)
2017	Supported MAWSAC report to Legislature: summary of water sources, challenges, goal, and planned activities
2018	Developed water conservation advisory training with Freshwater Society Released Climate Vulnerability Assessment, a planning tool to help Twin Cities prepare for climate change
2019	Awarded Clean Water Fund appropriation to implement projects ($2M) + water demand reduction grant program ($750K) Council awarded grants to communities for stormwater management, including reuse

History of legislative recommendations

Table 7. History and status of Metropolitan Council-supported water supply recommendations to the Minnesota Legislature.

Recommendation to the Legislature		Status
2007:	Approve statutory changes clarifying agency roles in water supply plan review and consolidate into one statute the requirements of community water supply plans in the metropolitan area.	Completed MS 473.859, Subd. 3 and 103G.291, subdivision 3 were revised so that DNR local water supply plan now fulfills MC comp plan requirements for water supply content and WHP no longer required part of comp plan
2007:	Support an appropriate level of state funding, upon the request of local governmental units, for interconnections and other physical water system improvements to ensure water supply reliability, natural resource protection, and/or safety and security, including economic security, of the region and state. Consistent with this recommendation, support an appropriate level of state funding for the proposed Minneapolis and St. Paul water supply systems interconnection.	Partially completed Burnsville-Savage interconnection funded
2008:	Provide funding for implementation of the metropolitan area Master Water Supply Plan	Completed Received $400K for one year from CWF
2009:	Provide funding for implementation of the metropolitan area master water supply plan	Partial – received $400K for one year, with additional stipulations to include protection of Seminary Fen and Valley Branch Trout Stream and other work from CWF
2010:	Provide funding for implementation of the metropolitan area Master Water Supply Plan	Completed Received $1M over two years from CWF
2010:	Eliminate the sunset date for the Metropolitan Area Water Supply Advisory Committee, because it provides valuable guidance to the Council in its water supply planning efforts	Partially completed (extended)
2012:	Recommended, with CWF Interagency Coordination Team, the legislature provide funding for groundwater planning to achieve water supply reliability and sustainability	Completed – received $2M over two years
2013:	Extend the sunset date for the Metropolitan Area Water Supply Advisory Committee from 12/31/12 to 12/31/16	Completed

Recommendation to the Legislature		Status
2014:	Provide funding to implement projects that address emerging drinking water supply threats, provide cost-effective regional solutions, leverage interjurisdictional coordination, support local implementation of water supply reliability projects, and prevent degradation of groundwater resources in the metro area. (Co-recommended by CWF Interagency Coordination Team)	Completed Received $1.95M over two years
2016:	Provide funding to continue implementing projects that address emerging drinking water supply threats, provide cost-effective regional solutions, leverage interjurisdictional coordination, support local implementation of water supply reliability projects, and prevent degradation of groundwater resources in the metro area. (Co-recommended by CWF Interagency Coordination Team)	Completed Received $1.9M over two years
2017:	Provide necessary funds to plan and collaborate, for conserving, protecting our water supply (stakeholder-identified projects that provide regional benefit, increased collaboration, improved local assistance, source water protection). (Co-recommended by MAWSAC)	Ongoing
2017:	Support boosting efficiency and wise use of water so the region can grow (region-wide messaging, grants and tools to reduce regional per capita water use). (Co-recommended by MAWSAC)	Ongoing
2017:	Support work that leads to solutions (multi-community water supply analyses, feasibility assessments of innovative approaches) (Co-recommended by MAWSAC)	Ongoing
2018:	Provide funding to continue implementing projects that address emerging drinking water supply threats, provide cost-effective regional solutions, leverage interjurisdictional coordination, support local implementation of water supply reliability projects, and prevent degradation of groundwater resources in the metro area.	Completed Received $1.9M over two years

Bibliography of Metropolitan Council Water Supply Projects 2005-2020

Resources are listed in alphabetical order by Author/Owner, then by year produced.

Technical Projects

Barr Engineering Company. *Evaluation of Groundwater and Surface-Water Interaction: Guidance for Resource Assessment in the Twin Cities Metropolitan Area, Minnesota (Prepared for Metropolitan Council)*. Metropolitan Council, 2010.

Barr Engineering Company. *East Bethel Groundwater Analysis (Prepared for Metropolitan Council)*. Metropolitan Council, 2010.

Barr Engineering Company. *Technical Memo: Metro Pumping Optimization (Prepared for Metropolitan Council)*. 15 August 2014.

Barr Engineering Company. *Technical Memo: Metro Pumping Optimization 2 (Prepared for Metropolitan Council)*. 13 October 2014.

Barr Engineering Company. *Technical Memo: Metro Pumping Optimization 3 (Prepared for Metropolitan Council)*. 2 April 2015.

Barr Engineering Company. *Technical Memo: Metro Model 3 Transient Model Update (Prepared for Metropolitan Council)*. Metropolitan Council, 2017.

CDM Smith. *Twin Cities Regional Water Billing Analysis (Prepared for the Metropolitan Council)*. Metropolitan Council, 2015.

Davis, Bill and Jodi Polzin. *Technical Memo: Water Efficiency Project – Maximizing Benefits from Community Water Efficiency Programs (Prepared for Metropolitan Council)*. April 2019.

Dakota County Water Resources Department. *Mapping Groundwater Contaminant Investigations: Project Summary Report to Metropolitan Council*. Dakota County, 2008.

Freshwater Society. *Water Conservation Advisor Training Program: Program Status Report and Sustainability Plan Phases 1-4 (Prepared with Metropolitan Council)*. Freshwater Society, 25 February 2019.

Kessler, Erich, and Lorenz, D.L. *Low-flow characteristics of the Mississippi River upstream from the Twin Cities Metropolitan Area, Minnesota, 1932–2007*. U.S. Geological Survey Scientific Investigations Report 2010–5163, 2010.

Metropolitan Council. *Water Supply Planning in the Twin Cities Metropolitan Area: Report to the 2007 Minnesota State Legislature – Technical Report*. Metropolitan Council, January 2007.

Metropolitan Council. *Twin Cities Metropolitan Area Regional Groundwater Flow Model Version 2.00: Technical Report in Support of the Metropolitan Area Master Water Supply Plan*. Metropolitan Council, 2009.

Metropolitan Council. *Assessing the Opportunity and Barriers for Water Conservation by Private Industrial Water Users: For the Twin Cities Metropolitan Area – A Report Detailing the Development and Execution of the Electronic Survey Strategy Conducted Beginning March 2012 (Prepared by Minnesota Technical Assistance Program)*. Metropolitan Council, 2013.

Metropolitan Council. *Using a Soil Water Balance Model to Estimate Recharge for Version 3 of the Twin Cities Metropolitan Area Groundwater Model (Prepared by Barr Engineering Company)*. Metropolitan Council, 2013.

Metropolitan Council. *Assessing the Opportunity and Barriers for Water Conservation by Private Industrial Water Users: For the Twin Cities Metropolitan Area – A Final Report Detailing the Development and Execution of all the Project Assistance Deliverables from December 9, 2011 to December 31, 2013 (Prepared by Minnesota Technical Assistance Program)*. Metropolitan Council, 2014.

Metropolitan Council. *Twin Cities Metropolitan Area Groundwater Flow Model Version 3.0 (Prepared by Barr Engineering Company)*. Metropolitan Council, 2014.

Metropolitan Council. *Feasibility Assessment of Approaches to Water Sustainability in the Northeast Metro (Prepared by Short Elliott Hendrickson Inc.)*. Metropolitan Council, 2014.

Metropolitan Council. *Industrial Water Conservation in the North and East Metro Groundwater Management Area: Data Research Report (Prepared by MnTAP)*. Metropolitan Council, 2015.

Metropolitan Council. *Industrial Water Conservation in the North and East Metro Groundwater Management Area: Project Final Report (Prepared by MnTAP)*. Metropolitan Council, 2016.

Metropolitan Council. *Joint Water Utility Feasibility Study (Prepared by Barr Engineering Co.)*. Metropolitan Council, 2015.

Metropolitan Council. *Washington County Municipal Water Coalition: Water Supply Feasibility Assessment (Prepared by Short Elliott Hendrickson Inc.)*. Metropolitan Council, 2016.

Metropolitan Council. *Twin Cities Regional Water Billing Analysis 2016 (Prepared by CDM Smith)*. Metropolitan Council, 2016.

Metropolitan Council. *Twin Cities Area Enhanced Groundwater Recharge Study (Prepared by HDR)*. Metropolitan Council, 2016.

Metropolitan Council. *Regional Groundwater Recharge and Stormwater Capture and Reuse Study: North and East Metro Study Area (Prepared by HDR)*. Metropolitan Council, 2016.

Metropolitan Council. *Regional Water Supply, Enhanced Groundwater Recharge, and Stormwater Capture and Reuse Study: Northwest Metro Study Area (Prepared by HDR)*. Metropolitan Council, 2016.

Metropolitan Council. *Regional Drinking Water Supply, Groundwater Recharge, and Stormwater Capture and Reuse Study: Southeast Metro Study Area (Prepared by HDR)*. Metropolitan Council, 2016.

Metropolitan Council. *Efficient Water Use on Twin Cities Lawns through Assessment, Research, and Demonstration: Objective 1 Report (Prepared by University of Minnesota Extension Turfgrass Science)*. Metropolitan Council, 2016.

Metropolitan Council. *Efficient Water Use on Twin Cities Lawns through Assessment, Research, and Demonstration: Final Report (Prepared by University of Minnesota Extension Turfgrass Science)*. Metropolitan Council, 2018.

Metropolitan Council. *Industrial Water Conservation Motivations Report: A Summary Report Outlining Industry Reasons for Success of, or Barriers to, Water Conservation Recommendations and Findings Developed by the Minnesota Technical Assistance Program for Assistance Clients and Intern Host*

Companies in the Eleven-County Metropolitan Area from 2012-2017 (Prepared by MnTAP). Metropolitan Council, 2018.

Metropolitan Council. *Water Conservation and Efficiency Assessment Tool: Summary of Results – Southeast Metro Groundwater Work Group (Prepared by HDR Engineering)*. Metropolitan Council, 2018.

Metropolitan Council. *Reducing Water Use on Twin Cities Lawns Through Research, Education and Outreach (Prepared by University of Minnesota Extension)*. Metropolitan Council, 2019.

Metropolitan Council. *Municipal Water Supplier Data Reporting in the Twin Cities Metropolitan Area: Phase 1 – Background and Discovery (Prepared by CDM Smith)*. Metropolitan Council, 2020.

Metropolitan Council. *Interactions of Groundwater and Surface Water Resources: Phase 1 – Potential Hydraulic Connections between Bedrock Aquifers and Surface Water in the Twin Cities Metropolitan Region (Prepared by HDR)*. Metropolitan Council, 2020.

Metropolitan Council. *Interactions of Groundwater and Surface Water Resources: Phase 1 – Potential Hydraulic Connections between Bedrock Aquifers and Surface Water in the Twin Cities Metropolitan Region (Prepared by HDR)*. Metropolitan Council, 2020.

Minnesota Geological Survey. *Surficial Geologic Mapping and Groundwater Geochemistry Assessment (Prepared for Metropolitan Council).* Metropolitan Council, 2007.

J L Nieber, C N Arika, L. Lahti. *The Impact of Stormwater Infiltration Practices on Groundwater Quality (Prepared for Metropolitan Council)*. University of Minnesota Departments of Civil Engineering and Bioproducts and Biosystems Engineering, 2014.

Tipping, Robert G. *Distribution of Vertical Recharge to Upper Bedrock Aquifers: Twin Cities Metropolitan Area (Prepared for Metropolitan Council)*. Minnesota Geological Survey, 2011.

Anthony C. Runkel, Julia R. Steenberg, Robert G. Tipping. *Hydraulic Conductivity and Hydrostratigraphy of the Platteville Formation, Twin Cities Metropolitan Area, Minnesota (Prepared for Metropolitan Council)*. Minnesota Geological Survey, 2011.

Sanocki, C.A., Langer, S.K., and Menard, J.C. *Potentiometric surfaces and changes in groundwater levels in selected bedrock aquifers in the Twin Cities Metropolitan Area, March–August 2008 and 1988–2008*. U.S. Geological Survey Scientific Investigations Report 2009–5226, 2009.

SEH. *Turtle Lake Augmentation Study: City of Shoreview, Minnesota (Prepared for the City of Shoreview)*

SEH. *Water Efficiency Study: Washington County Municipal Water Coalition (Prepared for Metropolitan Council).* Metropolitan Council, 2018.

Planning & Progress Report Documents

Metropolitan Council. *Water Supply Planning in the Twin Cities Metropolitan Area: Report to the 2007 Minnesota State Legislature*. Metropolitan Council, January 2007.

Metropolitan Council. *Metropolitan Area Master Water Supply Plan: Twin Cities Metropolitan Area, Minnesota*. Metropolitan Council, 2010.

Metropolitan Council. *Stormwater Reuse Guide: A Guide for city planners, engineers, homeowners and green thinkers (Prepare by CDM Smith)*. Metropolitan Council, 2011

Metropolitan Council. *Progress Report on Water Supply Planning*. Metropolitan Council, 2014.

Metropolitan Council. *Thrive MSP 2040: One Vision, One Metropolitan Region*. Metropolitan Council, 2014.

Metropolitan Council. *2040 Water Resources Policy Plan*. Metropolitan Council, 2015.

Metropolitan Council. *Metropolitan Area Master Water Supply Plan: Twin Cities Metropolitan Area, Minnesota (Update)*. Metropolitan Council, 2015.

Metropolitan Area Water Supply Advisory Committee. *Water Supply Now and for the Future: Steps Toward Sustainable Water Supplies*. Metropolitan Council, 2017.

Training, Education & Outreach

Metropolitan Council. *2017 PlanIt "Beyond the Basics" Webinar Series: Water Resources Planning*. Metropolitan Council, July 21, 2016. https://metrocouncil.org/Handbook/PlanIt/Webinars.aspx

Metropolitan Council. *2017 PlanIt Tutorial: Reporting Water Use by Major Categories*. Metropolitan Council, 2016. https://youtu.be/s4QqjAKYVJ0

Metropolitan Council. *2017 PlanIt Tutorial: Working with the Local Water Supply Plan Template*. Metropolitan Council, 2016. https://youtu.be/MYbEwTOe6Z4

Metropolitan Council. *2017 PlanIt Tutorial: Considering Source Water Protection in Your Plan*. Metropolitan Council, 2016. https://youtu.be/42a1BjPjTTI

Metropolitan Council. *2017 PlanIt Tutorial: Tools and Resources to Complete Your Local Water Supply Template*. Metropolitan Council, 2016. https://youtu.be/0IMZMOFpT84

University of Minnesota Extension and Metropolitan Council. *Video: Green Grass with Less Blue*. University of Minnesota, 2017. https://turf.umn.edu/news/green-grass-less-blue-new-video

Metropolitan Council. *Video: Too Much of a Good Thing*. Metropolitan Council, 2017. https://www.youtube.com/watch?v=zO_I7USYE6s&feature=emb_logo

University of Minnesota. *Education Signs: Mow High, Give Your Lawn a Brain, Cement Won't Grow, Grow Easy Peasy Lawns, and Green Grass with Less Blue*. Metropolitan Council, 2017. https://turf.umn.edu/lawn-info/irrigation-resources

University of Minnesota Extension Turfgrass Science. *Watering Wisdom Webinar Series: Outdoor Water Use in the Twin Cities – Am I Using Too Much?*. https://turf.umn.edu/video-outdoor-water-use-twin-cities-am-i-using-too-much

Metropolitan Council. Climate Vulnerability Assessment: Localized Flood Risk. Metropolitan Council 2018. https://metrocouncil.org/Communities/Planning/Local-Planning-Assistance/CVA/Localized-Flood-Risk.aspx

390 Robert Street North
Saint Paul, MN 55101-1805

651.602.1000
TTY 651.291.0904
public.info@metc.state.mn.us
metrocouncil.org

Follow us on:
twitter.com/metcouncilnews
facebook.com/MetropolitanCouncil
youtube.com/MetropolitanCouncil