2025 Groundwater Policy Report

MINNESOTA
ENVIRONMENTAL QUALITY BOARD

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Prepared by

Minnesota Environmental Quality Board

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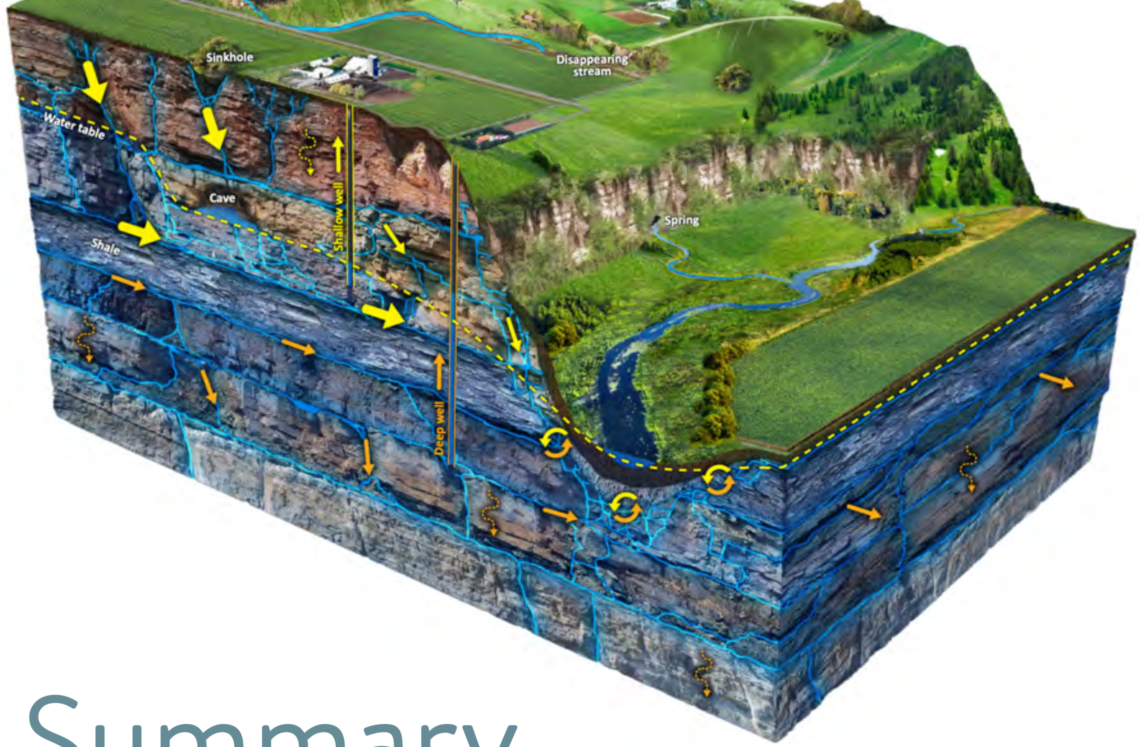
Contents



Summary

Minnesota's groundwater is an important resource. It supplies a significant amount of the water used by households and businesses, supports important ecosystems, and has spiritual, cultural, and aesthetic benefits. It can be difficult to grasp the scope and scale of groundwater resources, and to understand their condition and how it may be changing, because we largely cannot see groundwater. Instead, we may become aware of groundwater only when something changes dramatically — such as water becoming too contaminated to drink, a well running dry, or lake or stream levels dropping.

Minnesota's strong groundwater protection act and other parts of our water law are designed to prevent both sudden and long-term changes, articulating important goals to maintain groundwater in its natural condition and ensure the sustainability of groundwater resources. The state agencies work together to implement groundwater protection programs with an overarching goal of ensuring that Minnesotans have equitable access to and use groundwater sustainably to meet our common needs, both now and into the future. Sustainable groundwater means that across Minnesota, people, businesses, communities, and ecosystems have access to and receive safe and sufficient groundwater.

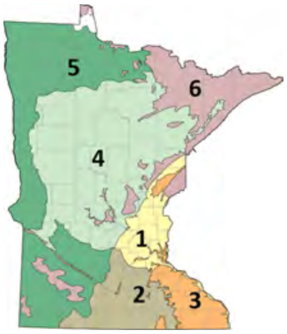
There are challenges to reaching this goal and the risk of overuse and contamination are real. Pollutants such as nitrate, pesticides, PFAS, chloride and salts, and are impacting water quality (to a different extent in different places across Minnesota). Contaminants, like manganese and arsenic, that come from rock formations that hold groundwater can also threaten people's health. Although groundwater is plentiful in many parts of Minnesota, it is not inexhaustible. Droughts and large, intense water use can stress aquifers and raise concerns about local water availability. We also know that not all residents of Minnesota have the same experience of, or access to, groundwater. These challenges are all connected and may be exacerbated by climate change.

This report describes the key challenges to groundwater sustainability identified by the state agencies. Tackling those challenges is a central driver of our collective work today and is likely to remain so in the next 10 to 50 years.

Successes

The state agencies and partners have achieved significant successes in our work towards achieving the groundwater protection goal. Our strong groundwater monitoring network allows us to understand Minnesota's groundwater quality and quantity and, increasingly, how it is changing. This further supports our understanding of groundwater issues and the actions that need to be taken to mitigate the concerns and manage our groundwater resources for sustainability. Some specific general areas of success include:

- **Funding**: Many of the advancements in our groundwater programs over the last 15 years are supported by the additional funding provided by the Clean Water, Land, and Legacy Amendment.
- **Coordination**: Multiple coordinating structures and frameworks support strong connection and collaboration across agencies with different authorities and responsibilities around groundwater.



- **Data and information**: We have extensive groundwater data and are building out tools and systems to understand new issues, such as emerging contaminants. The county geologic atlas work provides a wealth of information about the geology and groundwater resources. The state has also made progress in providing groundwater data to local governments for their water planning.
- **Implementation structures**: Minnesota has established strong systems and programs supporting on-the-ground implementation of actions to protect groundwater and drinking water. Minnesota has frameworks for taking a broad range of actions to protect groundwater, from research; education programs and training; to planning and technical assistance; to grants and cost share; through direct cleanup of contaminated sites. This includes both regulatory and voluntary programs with direct state action and extensive support of local implementation.
- **Actions**: These implementation structures have supported wide-ranging actions to protect groundwater quality and quantity. Each section of this report highlights the successful implementation of programs and actions that improve groundwater quality and management of groundwater quantity, moving the needle towards our ultimate goal. We are making progress.

Gaps and opportunities

To build on our successes and keep moving towards achieving the groundwater protection goal, there remain gaps to be filled and opportunities that need to be taken up. There is more to do across the board to scale up and innovate in our work for groundwater sustainability.

- **Funding**: The Clean Water, Land, and Legacy Amendment and associated funding continues through 2034; reauthorizing this funding is critical to ongoing support of the state's water programs. Significant additional funding will also be needed to implement actions that protect groundwater at the scale needed.
- **Coordination**: The agencies have a strong opportunity to continue to improve communication about our substantial cross-agency collaboration and coordination, and to demonstrate this connection in the ways we provide data and programmatic information.
- **Data and information**: Groundwater monitoring and information remains less robust than Minnesota's extensive surface water monitoring network. Geologic atlases are not yet available for all counties, and this work needs to continue. We need to improve our ability to characterize groundwater quality at the aquifer scale and to provide groundwater data and synthesized information in a way that is accessible, comprehensible, and easily integrated with the way water quality planning and project implementation are delivered on a watershed basis.
- **Implementation structures**: The programs and systems in place to implement groundwater-protecting actions will need continued support and likely expansion to ensure they can continue to deliver results at the scope and scale needed.
- **Actions**: The scope and scale of the actions being taken to protect groundwater need to be increased. Some of the solutions to our groundwater challenges may be technological — new ways to remove contaminants or more efficient ways of using water for irrigation or in industry — but increased implementation of other solutions is likely to require shifts in larger systems and understandings. In many areas, actions at the scale needed will require changes to the ways things have always been done. That might mean thinking about a circular (rather than once-through) water economy, changing market incentives and systems in the agricultural economy, or other similar changes that require a level of communal buy-in and collective action.
- **Equity**: We need to fill gaps so that Minnesotans have equitable access to groundwater and its benefits, particularly drinking water. This includes a need to focus on equity in information, water protection, and financing for private well owners, small water systems, and communities disproportionately exposed to contaminants in drinking water.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Introduction

Minnesota is a land of water. Minnesota's legislature has recognized the importance of protecting groundwater — both quality and quantity — in several statutes that set out an overall vision and guiding policy for protecting Minnesota's water quality and water quantity. The state agencies implement this vision through multiple programs.

Purpose

This report fulfills the requirements of Minn. Stat. 103A.204 — for the Environmental Quality Board (EQB) to report on policy issues related to its responsibilities for "coordination of state groundwater protection programs". The Appendices fulfill the requirements of Minn. Stat. 103A.43 for assessments related to the water quality and quantity.

The report is also meant to support informed decision making on groundwater issues by:

- Providing foundational information about groundwater in Minnesota
- Describing the state's collaborative approach to protecting groundwater
- Describing important threats to Minnesota's groundwater
- Describing the actions being taken to mitigate the threats to groundwater
- Identifying successes achieved and gaps and opportunities to be addressed

Groundwater protection goal

The state agencies have multiple responsibilities and objectives, as detailed in statute, for groundwater protection programs. All of these can be summarized into an overarching goal ensuring that Minnesotans have equitable access to and use groundwater sustainably to meet our common needs.

The agencies that worked together to develop this report construe the word "sustainable" broadly, applying to both water quality and water quantity. Water quality and water quantity are tightly connected; if water quality degrades so that the water is no longer safe for certain uses, then there may no longer be sufficient water quantity available. When groundwater resources are limited in quantity, there is often extra incentive to protect and maintain groundwater quality.

Sustainable groundwater means that across Minnesota, people, businesses, communities, and ecosystems have access to and receive safe and sufficient groundwater.

- Safe groundwater has water quality that allows it to be used for drinking water (safe for human health), irrigation (safe for plant and soil health) and animal watering (safe for livestock), industry and other uses; and which does not damage or degrade ecosystems.

- Sufficient groundwater means having adequate, accessible groundwater available in the quantity needed for desired uses.

Reaching the overarching goal also means that groundwater is available to all — regardless of location, income, or other condition that tends to result in disparities — to meet diverse current and future needs. Finally, the agencies recognize that this is likely to require balancing needs across multiple uses, grounded in the state's water allocation priorities, sustainability standard, and commitment to reducing and eliminating disparities.

Importance of groundwater

Although our slogan is "land of 10,000 lakes", Minnesota also has extensive groundwater resources. Groundwater is water that is held and moves in the spaces within the rocks under our feet (known as pore spaces). When there is enough water in those spaces to extract and use, it is known as an aquifer. It can be difficult to grasp the scope and scale of groundwater resources because we cannot see them, but from the deep Mount Simon aquifer to shallow sand and gravel deposits holding water near the surface, there is water underground.

Ensuring that Minnesota has sustainable groundwater to equitably meet our common needs is critical because groundwater is used and valued in several ways and for many reasons across Minnesota.

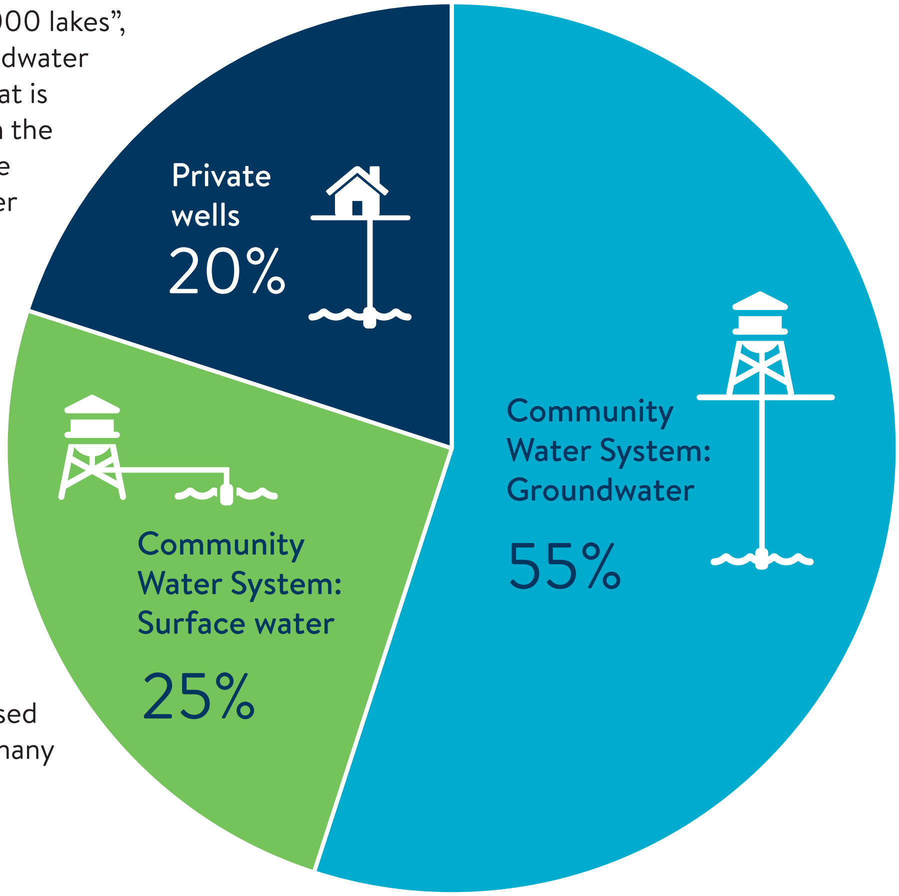


Figure 1. Percent of population served in Minnesota by drinking water source

Household use

Groundwater is the source of a significant amount of the water provided to Minnesota households, much of which is used for drinking. According to the Minnesota Department of Health (MDH), most of Minnesota's community water systems are served by groundwater and about 75% of the state's residents drink water that comes from groundwater.[1]

Drinking contaminated water can result in health risks, depending on the level of the contaminant and the amount of time over which it is consumed. Microorganisms like *E. coli* or *Giardia* can cause immediate issues such as intestinal distress and diarrhea. Other pollutants and geogenic contaminants — from arsenic to pesticides to PFAS and many others — can have various adverse impacts to the human body, from neurological and immunological changes to an increased risk of cancer.[2]

In addition to drinking water, household use of water includes cooking, bathing, washing clothes and dishes, flushing toilets, and watering residential landscapes. The average Minnesotan uses 52 gallons of water per day.[3]

Drinking Water Action Plan

As discussed throughout this report, a key reason to protect groundwater is that it is an important source of drinking water in Minnesota. The [2025 Minnesota Drinking Water Action Plan] sets out a 10-year framework to meet the vision that everyone, everywhere in Minnesota has safe and sufficient drinking water. It discusses many of the same contaminants and issues described in this report through the specific lens of drinking water.

Agricultural, industrial, and other uses

Water is also important to Minnesota's economy, supporting agricultural and industrial production and a wide variety of commerce, including tourism. Much of the water used for these purposes around Minnesota comes from groundwater.

In the agricultural sector groundwater is used to irrigate crops and water livestock. Not only do farmers need sufficient water for these activities, but the water also needs to be of the right quality. The presence of certain contaminants (such as boron or high levels of salts) could have directly detrimental effects on crops or soils. Other pollutants (such as PFAS or persistent organic pollutants) could adversely impact the health of the livestock or accumulate to levels that might be of concern to humans ultimately eating the livestock or related products (such as milk or eggs).

Water is also important in commercial and industrial processes ranging from food production to semiconductor manufacturing. Similarly, these processes also need sufficient water of the right quality. Any water used for food production has to be just as clean as drinking water. In certain industrial processes, water might need to be treated before being used — such as to prevent corrosion or scaling within industrial piping.

Ecosystems and non-use values

It is easy to focus on the importance of groundwater when it is being used or consumed by people. However, surface water and groundwater and the ecosystems they support also have intrinsic value, which may include spiritual, cultural, and aesthetic values and benefits.

For example, water is important to maintaining healthy and thriving ecosystems, which in turn support Minnesota's tourism economy. People visit many of Minnesota's unique landscapes and habitats for activities such as fishing, foraging, birdwatching, boating, swimming, or other kinds of recreation.

Thriving ecosystems are also important to support inherent rights reserved to Tribal Nations under treaties, such as hunting, trapping, fishing, and gathering.

The area we now call Minnesota is the traditional homelands of the Dakota and Ojibwe people. The name comes from the Dakota phrase Mni Sóta Makoce, which means "land where waters reflect the sky". Multiple treaties related to lands that are now part of Minnesota were signed between the United States and Tribal Nations. Treaties guarantee a Tribal Nation's ability to access and manage their lands and resources and preservation of native lands and ways of life. Although treaty rights are complex and beyond the scope of this report, many treaties ceded territory to the United States and granted its citizens the ability to access those lands while signatory Tribal Nations retained their sovereign rights to use lands to hunt, fish, and gather.[4]

The cultural and spiritual practices of this area's indigenous people are, broadly, connected to and a part of the landscape. Certain areas, however, have more specific significance and spiritual and cultural value.

One example of a significant location that is supported by groundwater is *Maka Yusota* (Boiling Springs). Located within Eagle Creek (a trout stream in Scott County), *Maka Yusota* is a spot where upwelling groundwater from a spring pushes sand upwards, making the water seem to "boil".[5] *Maka Yusota* is sacred to the Dakota people as a place where the water spirit *Unktehi* resides.[6] The area is listed on the National Register of Historic Places.[7]

Maka Yusota (Boiling Springs). Located within Eagle Creek in Scott County.

Another significant location with cultural and spiritual value is *Mni Owe Sni* (Coldwater Spring). Located near Bdote — a sacred place where the Minnesota and Mississippi River meet — *Mni Owe Sni* is a traditional gathering place for the Dakota and other indigenous peoples, likely due to the presence of the groundwater fed spring. It is designated as a traditional cultural property and is on the National Register of Historic Places.

Laws, roles, and collaboration

Groundwater statutes

Minnesota Statutes chapters 103A, 103B, 103C, 103D, 103E, 103F, and 103G make up Minnesota's general "water law", while Minnesota Statutes, chapter 103H is the Minnesota Groundwater Protection Act. These statutes set out an overall vision for protecting Minnesota's water quality and water quantity and allocating water across multiple priorities. More detailed statutes and implementing rules further develop Minnesota's general framework for protecting water.

Minn. Stat., ch. 103H sets forth "the goal of the state that groundwater be maintained in its natural condition, free from any degradation caused by human activities," while recognizing that "for some human activities the degradation prevention goals cannot be practicably achieved." The emphasis is on keeping groundwater in its natural condition because it is so difficult to clean up once contaminated.

In Minn. Stat., ch. 103G, the legislature sets out "priorities for the consumptive appropriation and use of water" which apply to both surface and groundwater. These priorities emphasize the primary importance of protecting and maintaining water for drinking or general use in households.

Chapter 103G also includes requirements for groundwater appropriation and ensuring the long-term availability of water. Minn. Stat. 103G.287 includes a groundwater sustainability standard that allows water appropriation to be permitted only if "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."

Roles in protecting groundwater

The close partnership of multiple agencies and organizations, at multiple levels of government, is critical to the protection of groundwater.

State agencies

Minnesota laws (Minn. Stat. 103A.204) specifically set forth a "multiagency approach" to groundwater management, resulting in multiple state agencies having complementary authorities and programs related to water protection.

As laid out in the Minnesota Water Management Framework[8], the agencies work together to coordinate and deliver work across five areas:

- Monitoring, assessment, and characterization
- Problem investigation and applied research
- Restoration and protection strategy development
- Comprehensive water management planning
- Implementation

This approach to groundwater protection leverages each agency's expertise to provide a comprehensive evaluation of important issues and ensures that each issue area has a "champion" focused on that area. Strong coordination brings the multiple perspectives together and aligns the work across all areas.

Minnesota Department of Agriculture (MDA)

MDA's mission is to enhance all Minnesotans' quality of life by equitably ensuring the integrity of our food supply, the health of our environment, and the strength and resilience of our agricultural economy. MDA's primary responsibilities related to groundwater described in Minn. Stat., ch. 103A are "sustainable agriculture, integrated pest management, water quality monitoring, and the development of best management practices and regulatory mechanisms for protection of groundwater from agricultural chemical contaminants". In addition, under Minn. Stat., ch. 103H, MDA has the responsibility to develop best management practice for agricultural chemicals and practices.

MDA's programs connected to groundwater include:

- Pesticide monitoring and assessment of both groundwater and surface water
- Sampling of private wells and township testing
- Groundwater monitoring for nitrate in vulnerable areas
- Implementing the Nitrogen Fertilizer Management Plan (NFMP) and Groundwater Protection rule
- Projects to reduce nitrate by promoting best management practices and working with local partners on nitrate monitoring and reduction projects
- Technical assistance, research, and on-farm projects to address water quality concerns in agricultural areas; including the Minnesota Agricultural Water Quality Certification Program

Minnesota Board of Water and Soil Resources (BWSR)

BWSR is the state soil and water conservation agency charged with helping meet the state's goals for clean water, clean air, and abundant fish and wildlife. Their mission is to work with partners to improve and protect Minnesota's land and water resources. BWSR's primary responsibilities described in Minn. Stat. 103A.204 are "reporting on groundwater education and outreach with local government officials, local water planning and management, and local cost-share programs."

BWSR is a key agency in supporting programs and practices to mitigate nonpoint source water pollution. They provide resources through grants and contracts for on-the-ground implementation of actions that protect surface water, groundwater, and drinking water. BWSR also provides support to local governments in water planning, including the One Watershed One Plan program, now in effect in all the state's major watersheds, as well as Metro area watershed management plans and Metro County Groundwater Plans.

Minnesota Environmental Quality Board (EQB)

The EQB's mission is to support informed decision-making that protects and enhances Minnesota's environmental quality. EQB works to facilitate interagency coordination so that state agency programs are aligned to support the state's overall policy goals for public health and environmental protection, and its role in Minn. Stat. 103A.204 is described as "coordination of state groundwater protection programs". EQB's role includes development of this policy report, development of the Minnesota Water Plan, and consolidation of various water assessment reports.

Minnesota Department of Health (MDH)

MDH's mission is protecting, maintaining and improving the health of all Minnesotans. MDH's primary groundwater responsibilities described in Minn. Stat. 103A.204 are "regulation of wells and borings, and the development of health risk limits" for contaminants found in groundwater.

MDH's programs connected to groundwater and drinking water are:

- Administering and enforcing the federal Safe Drinking Water Act
- Working with public water systems and communities to protect drinking water sources through source water protection planning and grants
- Monitoring and testing drinking water, including for unregulated contaminants
- Developing guidance values and standards (health-based values, health risk limits, and risk assessment advice) to protect people's health from contaminants in drinking water, including contaminants of emerging concern
- Regulating drilling, construction, modification, repairs and sealing of wells and borings (Minn. Stat., ch. 103I) and implementing the Minnesota well code and rules for wells and borings, including testing of new wells and sealing of unused water supply wells
- Maintaining data systems (County Well Index/Minnesota Well Index) that provide data to a broad cross section of groundwater resource professionals
- Providing education, outreach, and support to Minnesota's 1.1 million private well users

Minnesota Department of Natural Resources (DNR)

DNR's mission is to work with Minnesotans to conserve and manage the state's natural resources, to provide outdoor recreation opportunities, and to provide for commercial uses of natural resources in a way that creates a sustainable quality of life.

DNR's primary groundwater responsibilities described in Minn. Stat. 103A.204 are "water quantity monitoring and regulation, sensitivity mapping, and development of a plan for the use of integrated pest management and sustainable agriculture on state-owned lands." In addition, DNR has legal authority around large water users in Minnesota.

DNR's programs connected to groundwater include:

- Creating county groundwater atlases in collaboration with the Minnesota Geological Survey
- Establishing Groundwater Management Areas
- Monitoring aquifer levels through a network of observation wells (often done in partnership with local governments)
- Water appropriation permitting
- Well interference investigation and resolution of water use conflicts
- Climate data and information

Minnesota Pollution Control Agency (MPCA)

The MPCA's mission is to protect and improve the environment and human health. MPCA's primary responsibilities described in Minn. Stat., ch. 103A are "water quality monitoring and reporting and the development of best management practices and regulatory mechanisms for protection of groundwater from nonagricultural chemical contaminants".

In addition, MPCA has broad authorities related to environmental protection including the protection of water quality through facility permitting and oversight of "spilled, leaked, or otherwise released petroleum and hazardous substances, pollutants, or contaminants. These releases can contaminate soils, surface water, sediment, and groundwater."[9]

MPCA's programs connected to groundwater include:

- Groundwater quality monitoring and assessment
- Investigation and cleanup of contaminated sites, including maintaining the Groundwater Contamination Atlas
- Reporting on BMPs and groundwater protection
- Permitting for sources of pollution such as feedlots, landfills, etc.

MPCA also sets water quality standards, and Minn. R., ch. 7060 on underground waters mirrors several of the state's goals for groundwater. Minn. R. 7060.0100 establishes as its purpose "to preserve and protect the underground waters of the state by preventing any new pollution and abating existing pollution". Similarly, Minn. R., ch. 7060 lays out the MPCA's policy "to consider the actual or potential use of the underground waters for potable water supply as constituting the highest priority use and as such to provide maximum protection to all underground waters."

Metropolitan Council

The Metropolitan Council (Met Council) is the regional policy-making body, planning agency, and provider of essential services in the seven-county Twin Cities metro area. Its mission is to foster efficient and economic growth for a prosperous region. The Met Council's many regional planning responsibilities that help guide growth and development

— including land use, transportation, housing, parks, and water — are all connected to protecting water resources, including groundwater. Specifically for water, the Met Council is the regional wastewater system operator and plans for wastewater, surface water, and water supply in collaboration with local government units.

The Minnesota Legislature has directed the Met Council to take a regional approach to water supply planning. To assist the Met Council in this work, the legislature also established the Metropolitan Area Water Supply Advisory Committee (MAWSAC) with members who bring together perspectives across state agencies, counties, cities, and water utilities.

While the Met Council is responsible for essential regional services such as regional water planning and wastewater treatment, local governments focus on planning for their communities, including source water protection, surface water management, and municipal water supply and wastewater planning. Together, the Met Council and local governments work as a team to ensure clean water for the region.

Every ten years, the Met Council develops a long-range vision for the region called the *Regional Development Guide*, with input from local governments. The current guide, *Imagine 2050*, includes policy plans for each regional planning area — like the 2050 Water Policy Plan, which establishes regional water policy and includes the regional wastewater system plan and the metro area water supply plan.

To align with this regional vision, the seven counties and 181 cities and townships in the metro area must submit updated local Comprehensive Plans. These plans include local strategies for land use, sewer service, surface water, and water supply — all of which help ensure clean, sustainable water for current and future generations.

Minnesota Geological Survey

Established in 1872, the Minnesota Geological Survey (part of the University of Minnesota) provides “systematic geoscience information to support stewardship of water, land, and mineral resources.” MGS works closely with the state agencies to provide foundational geologic information. They maintain the county well index and prepare county geologic atlases.

Local governments

Local governments and institutions — whether cities, counties, or special purpose units of government — play an important role in water planning, management, and implementation of actions that address water pollution. This includes land use authorities, since inappropriate land use is often a cause of groundwater contamination.

Soil and Water Conservation Districts (SWCDs)

Established under Minn. Stat., ch. 103C to support implementation of the state’s policy to maintain and enhance “the quality of soil and water for the environmental and economic benefits they produce” and to restore soil and water resources, SWCDs work on key natural resource issues at the local level. They provide technical and financial assistance to landowners to improve their local soil and water resources. SWCDs are key on-the ground implementers of practices that improve soil health and prevent water pollution. They also collaborate in areas like working with DNR to monitor aquifer levels and can be delegated to prepare county groundwater plans, implement water management plans, and execute other important surface and groundwater protection programs and practices.

Watershed districts

Established under Minn. Stat., ch. 103D to “conserve the natural resources of the state by land use planning, flood control, and other conservation projects”, watershed districts develop management policies and watershed management plans. Watershed districts have multiple purposes related to land and water, ranging from flood mitigation, providing water supply for multiple purposes, controlling erosion, managing drainage, protecting surface water quality, and “to provide for the protection of groundwater and regulate its use to preserve it for beneficial purposes” (Minn. Stat. 103D.201). Watershed districts are required to develop and implement a water management plan which includes addressing groundwater.

Water management organizations

Minn. Stat., ch. 103B establishes the metropolitan watershed management program for multiple purposes, including to “effectively protect and improve surface water and groundwater quality” and to “promote groundwater recharge”. In the metro area, watershed management organizations (WMOs) made up of multiple local governments develop and implement watershed management plans. Under Minn. Stat. 103B.255, counties may adopt groundwater plans.

Metro Counties

Under Minn. Stat. 103B.255, counties within the seven-county Twin Cities Metropolitan area may adopt groundwater plans. These plans allow counties to set priorities, address issues, and build local capacity for the protection and management of groundwater. Three counties currently have groundwater plans: Carver, Dakota, and Washington.

Local and regional water utilities

Across Minnesota, local and regional water utilities provide drinking water and wastewater services.

Tribal governments

Minnesota also shares geography with 11 federally recognized Tribal Nations. These sovereign nations have various authorities, programs, expertise, and interest in protecting groundwater. Although every Tribal Nation’s government is unique, each one has an office or program devoted to natural resources and environmental protection. Other inter-tribal groups and commissions like the 1854 Treaty Authority and the Great Lakes Indian Fish and Wildlife Commission also support natural resource and environmental management.

Federal government

While this report focuses on the coordination of state programs to protect groundwater, it is important to recognize that federal statutes, research, assistance, and funding are also critical. The Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA) are key regulations to protect human health and the environment from contaminants in our water. The U.S. Environmental Protection Agency (EPA) supports monitoring and research on emerging contaminants, sets national primary drinking water standards, and funds water infrastructure projects through the Clean Water State Revolving Fund and Drinking Water State Revolving Fund programs. The U.S. Department of Agriculture (USDA) oversees several technical and financial assistance programs and activities that address groundwater quality and quantity. Changes in these systems and structures — particularly funding — can impact states' abilities to fulfill their responsibilities.

Agency collaboration

The agencies have worked closely together on groundwater issues for decades, particularly since the passage of the Groundwater Protection Act in 1989. The multiagency approach to groundwater protection, with responsibilities detailed to specific agencies (as described above) was put in place in 1994 (Laws of Minnesota 1994, chapter 557, section 11).

The collaboration has continued to grow and strengthen through the years. Since passage of the Clean Water, Land and Legacy Amendment in 2008 — which provided significant additional funding for groundwater work — the agencies have implemented a robust interagency governance framework, beginning with the Interagency Coordination Team (ICT).

The ICT coordinates the use of Clean Water Fund dollars and has chartered several subteams for specific areas of work, including the Interagency Groundwater and Drinking Water subteam. Through the ICT and its subteams, the agencies implement the Minnesota Water Management Framework. This document clarifies roles, making it easier for state and local partners to work together for water protection. It lays out key areas of work that are delivered through an adaptive management approach (plan-do-check-adapt) and promote effective collaboration around all the components of ensuring clean water for Minnesota.

In addition to the ICT, other formal and informal interagency collaborations further the protection and management of our groundwater. Statewide, an interagency team, under the direction of MDH, works to create Groundwater Restoration and Protection Strategies (GRAPS) reports. These reports identify local groundwater concerns and strategies and programs to address them, supporting local governments in considering groundwater as part of their water management plans. In the metro area, the Metropolitan Area Water Supply Advisory Committee, its supporting Technical Advisory Committee, and subregional groups act as policy makers and stakeholders to advance collaborative management of water supply systems.

The agencies also work together through collaborations like Minnesota Business First Stop, which provides information about environmental issues and permitting to business developers, helping deliver both a healthy economy and a healthy environment in Minnesota.

Successes

The creation of the ICT and the chartered subteams, which bring together staff from multiple agencies around specific areas of work, has tremendously increased the collaboration and connections (both formal and informal) between state agencies that work on water issues.

The agencies have made strides in the integration of groundwater in overall watershed management work, as described above in the creation of the water management frameworks. These frameworks are clear successes that support collaboration.

Gaps and opportunities

Building on the successes we have had in interagency coordination and collaboration, there are opportunities to continue to improve. These opportunities include:

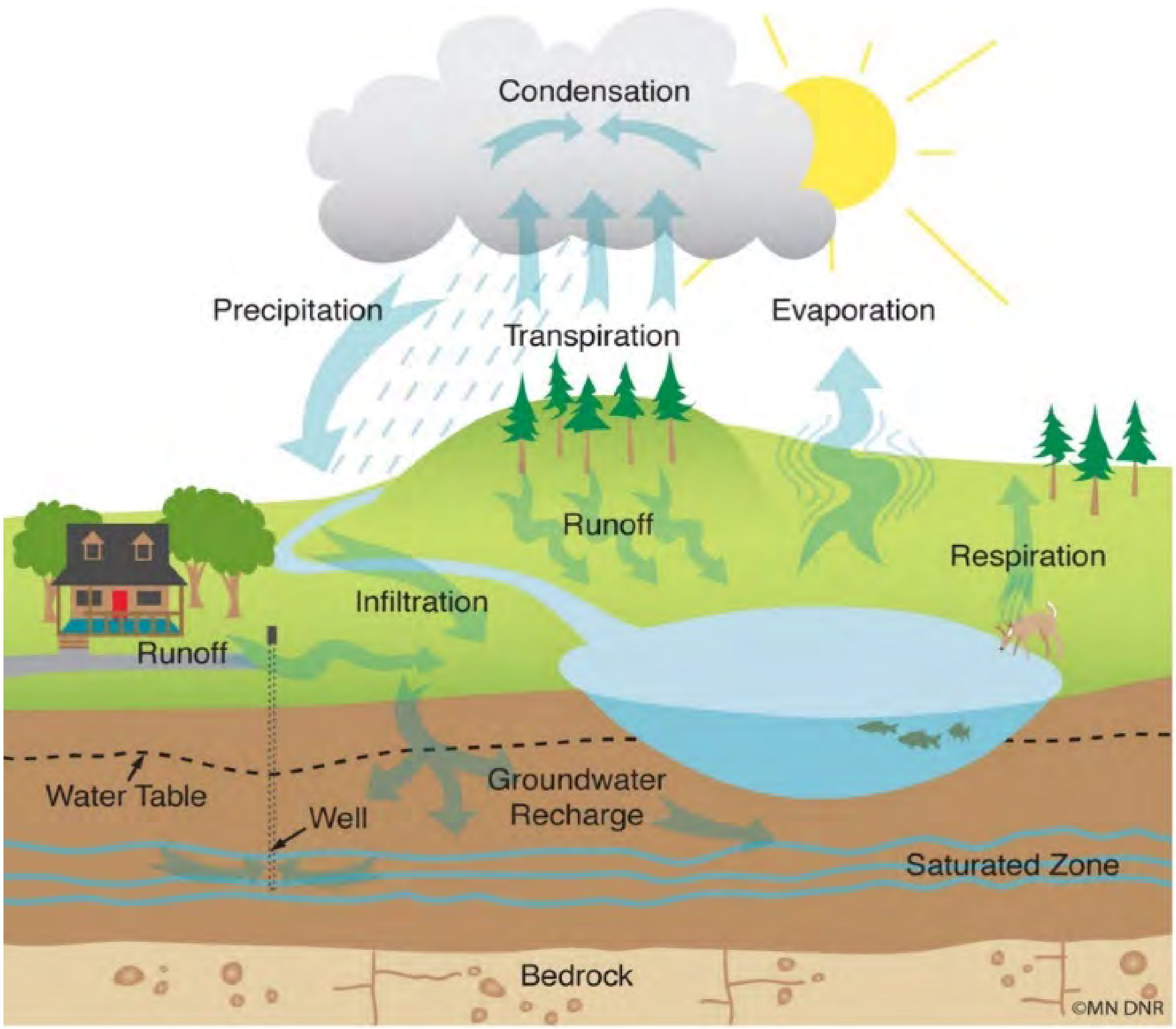
- Extending funding — Key to state's work around groundwater protection and interagency collaboration will be the extension of funding provided by the Clean Water, Land and Legacy amendment (set to expire in 2034). The Clean Water Fund provides critical support to interagency collaboration tools and structures that sustain the state's water protection work.
- Improving information sharing — The agencies can continue to improve how we share information about our roles and responsibilities related to the protection of groundwater quantity and quality, and how we work together in our water programs. Providing more, easy to understand information will help the public, local governments, and all those interested in water better connect to our work. Sharing stories of the ways in which the agencies work together, leveraging our expertise to manage Minnesota's water, will also support trust and accountability.
- Improving provision of environmental information to business development — We have opportunities to continue to improve our provision of environmental information into the business development space. Given the potential for high water use industries coming to Minnesota, the agencies intend to work to improve the use of Minnesota Business First Stop (MBFS) to provide early information to project proposers about groundwater quality and quantity issues that might impact their success.

Minnesota's statewide climate plan (Climate Action Framework) and strong collaborative structures support our work on climate mitigation and climate resilience. This includes the Governor's climate subcabinet, a climate action framework steering team, and teams working on each one of the seven major goals in the CAF, which is being updated through 2025. These teams ensure we work in a holistic and cross-cutting way on climate issues.

Introduction to groundwater

This report focuses specifically on groundwater; however, it is important to recognize that all water is connected and groundwater is part of the overall water cycle (see Figure 3). Precipitation refills surface waters like lakes and streams, but it also infiltrates into groundwater and refills aquifers in a process called groundwater or aquifer recharge. What is happening on the land surface where the water falls can have a big impact on the quality and quantity of groundwater.

Figure 3. The water cycle[10]



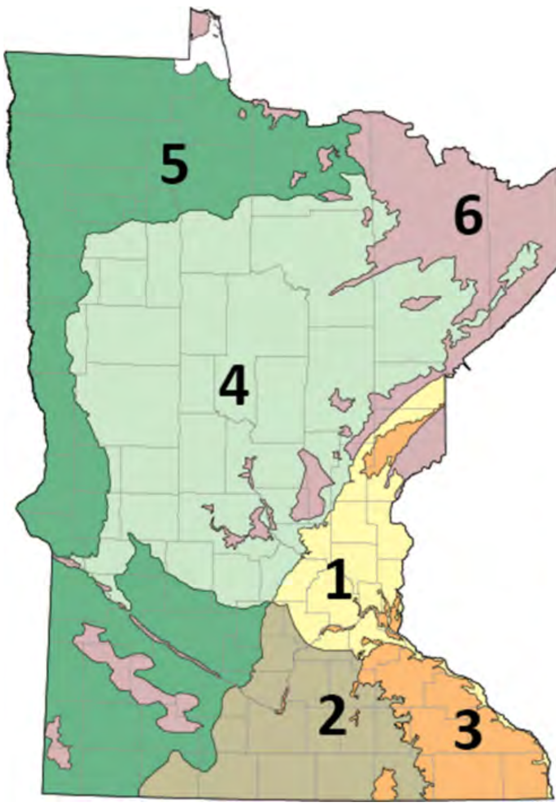
Location of groundwater

Groundwater — where it is, how much there is, and how old it is — varies across the state. Groundwater is held in aquifers. There are two main types of aquifers:

- Unconfined aquifers are just beneath the land surface and get water directly from that land surface; they are also known as water table aquifers and can easily rise and fall.
- Confined aquifers are usually farther underground, and the water within them is confined by a layer of clay or rock that either slows down or prevents the water from passing through or contaminants from entering. [11]

Minnesota has six "groundwater provinces" that are generally characterized by their specific geology. Each province has its own combination of groundwater sources and availability.[12]

Figure 4. Map of groundwater provinces and table of water availability



General availability of groundwater by source			
Prov.	Surficial sands	Buried sands	Bedrock
1	Moderate	Moderate	Good
2	Limited	Moderate	Good
3	Limited	Limited	Good
4	Good	Moderate	Limited
5	Moderate	Limited	Limited
6	Limited	Limited	Limited

The Minnesota Department of Natural Resources (DNR) defines three different types of aquifers in the groundwater provinces:

- Surficial sands — These are unconsolidated or loose sediments (e.g., sand, gravel) that are close to the surface, deposited by glaciers, streams, and lakes.
- Buried sands — These are unconsolidated sand and gravel that are buried under other rocks or sediments and therefore are farther away from the surface.
- Bedrock aquifers — These aquifers are fractures within the solid bedrock (such as sandstone and limestone) under the ground's surface; they can be quite deep.

Each of Minnesota's groundwater provinces has different availability of water from these distinct kinds of aquifers (Figure 4, and explained more in the section on groundwater quantity and geography). That impacts not only the overall availability of groundwater, but also the infrastructure needed to access the water.

Age of groundwater

Across the state, groundwater also varies by its age — a unique concept that we do not apply to surface water. Understanding the age of the groundwater in an aquifer is important to understanding both its current quality and quantity and the potential for future changes.

The age of groundwater refers to the length of time since it infiltrated down from the land surface. As described by the U.S. Geological Survey (USGS),

> *"As additional recharge continues to enter the aquifer, older recharge is pushed deeper by the newer recharge, resulting in a trend of increasing groundwater age with depth. Groundwater moves slowly...*
>
> *Young groundwater is more likely than old groundwater to have contaminants from recent manmade sources, such as pesticides, nitrate, and solvents, because those chemicals were applied to or released on the landscape when the young groundwater recharged the aquifer... On the other hand, old groundwater is more likely than young groundwater to have contaminants from natural sources, such as metals and radionuclides, because old groundwater can spend thousands of years in contact with and reacting with aquifer rocks and minerals that might contain these elements...*
>
> *Groundwater usually is young—often only a few decades old—in shallow, unconfined aquifers with high rates of recharge...Groundwater can be thousands of years old in aquifers where recharge rates are low (arid regions), where the aquifer is very thick, or where aquifers are separated by confining units."*[13]

Some of the water in Minnesota's deeper bedrock aquifers has been there a long time; for example, some of the water in the Mount Simon aquifer has been estimated to be 30,000 years old.[14]

Minnesota's groundwater policy and programs emphasize "nondegradation" or keeping groundwater in its natural state because it is so difficult to clean up once contaminated. A key reason for this — closely related to the age of groundwater — is the concept of groundwater residence time. This refers to how long water remains in the aquifer once it gets there.

The USGS says "It can take tens, hundreds, or even thousands of years for groundwater to travel through an aquifer..."[88] While water in rivers, streams, and lakes can move through that system quickly — on the order of days or months — water moves through most groundwater aquifers more slowly. That means water that gets into the aquifer carrying pollution can remain there for a long time. This makes it even more important to prevent pollution in the first place.

There are various age dating techniques that can be used to understand the age of water within aquifers, including the proportion of water of various ages (some water might be older and some younger). Aquifers with younger water likely tend to recharge more quickly but can be vulnerable to contamination because of the short time it takes for water to reach them from the land surface.

Aquifers with a lot of old water may refill or recharge very slowly, providing challenges to ongoing water supply; due to the length of time it takes to recharge these aquifers, once contaminated they are likely to stay that way for a long time.

Connection to surface water

The land surface and groundwater are connected through the process of infiltration and recharge. Surface water and groundwater are also connected — not just through the big picture of our hydrologic cycle, but also in specific locations — such as springs, lakes and streams.

Springs are perhaps the most noticeable feature, where groundwater emerges directly onto the land surface. Springs have been found across Minnesota.[15]

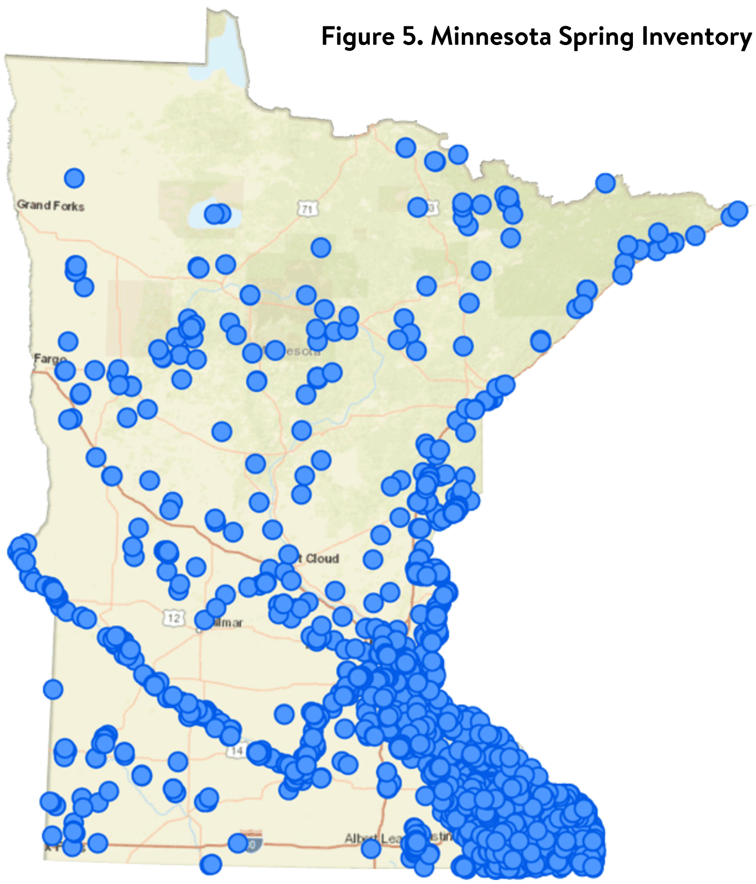


Figure 5. Minnesota Spring Inventory

According to the USGS, “Nearly all surface water features (streams, lakes, reservoirs, wetlands, and estuaries) interact with groundwater.”[16] The direction and degree of the connection between groundwater and surface water in an area often influences the quality and quantity of both surface and groundwater.

Across Minnesota, many surface waters receive incoming groundwater that supports the flow of the river or stream or the level of a lake. Incoming groundwater has different characteristics than surface water — it is usually a more constant cool temperature and generally has higher levels of dissolved minerals. Incoming groundwater may bring these minerals into surface water, impacting the aquatic environment.[17]

The DNR estimates that many of Minnesota’s lakes, maybe even all of them, receive some water from groundwater sources.[18] An example of a lake supported by groundwater is White Bear Lake. Lakes that receive a lot of incoming groundwater may have localized cold spots in the summer, or may have more open water in the winter — both due to the consistent year-round groundwater temperature of about 47 degrees. Similarly, many rivers and streams receive at least some incoming water from groundwater. Those that do are often referred to as “gaining streams”. The relationship between a stream and groundwater is an important factor for what kinds of fish and insects live in the stream. For example, Minnesota's best trout streams are fed by groundwater springs, keeping the water at the cool temperatures needed to support trout and other cold-water dependent fish.[19] Without an adequate supply of clean and cold groundwater, these ecosystems are at risk.

These all represent natural connections of groundwater feeding surface water. However, human actions can also influence this connection. Where there is a large use of groundwater for our homes, businesses, and other uses, groundwater is often used and then moves into the wastewater system, where it is discharged to surface water. This can also be a way in which the dissolved minerals from groundwater travel into surface water, where they may cause environmental concerns (such as increasing sulfate levels in the surface water).

Sometimes the connection runs in the other direction, with surface waters draining or seeping into and recharging the groundwater. Surface water quality can be more changeable and is more likely to have sediment, nutrient, and microbial contamination. In some areas, such as where bedrock is close to the surface, the groundwater can be directly influenced by the surface water and show similar water quality characteristics.[20] Areas with karst topography and sinkholes are particularly likely to have a strong surface to groundwater connection.

Minnesota is also home to many wetlands. Like lakes and streams, wetlands are usually connected to groundwater and can gain or lose water through that connection. Many or most of the types of wetlands found in Minnesota need groundwater either seasonally (early in the growing season), throughout the growing season, or continuously.[21] Some of the most unique wetlands in Minnesota are calcareous fens, an ecosystem that is dependent on a constant supply of mineral-rich groundwater. Constantly upwelling, cold, calcium-rich groundwater in these fens creates conditions uniquely suited to a diverse assemblage of native plants.

Groundwater monitoring and tools

Groundwater monitoring and assessment provides the critical foundation to our work to ensure Minnesota has sustainable groundwater to equitably meet our common needs. The state agencies work together to understand our groundwater quality and groundwater quantity through monitoring; we provide data, and evaluate and assess conditions, trends, and emerging threats.

This work helps us understand emerging challenges and where they occur, and to track changes to groundwater quality and quantity — and to communicate that information to those with an interest in and responsibilities for understanding Minnesota's groundwater and helping to protect it.

This section provides an overview, with additional information provided in:

- Appendix A: Five Year Assessment of Water Quality Trends and Prevention Efforts (MPCA and MDA)
- Appendix B: Groundwater Monitoring Status Report (MPCA-led under Minn. Stat. 103H.175)
- Appendix C: Water Availability and Assessment (DNR, under Minn. Stat. 103A.43)

Groundwater monitoring

MPCA, MDA, and MDH have primary responsibility for monitoring the quality of groundwater statewide, with different, yet closely related purposes for conducting groundwater monitoring. A Memorandum of Agreement between the three agencies established the current integrated groundwater quality network and sets out the agencies' roles in operating the statewide system.[22] (More information is available in Appendix B.) DNR conducts water quality monitoring for resource characterization as part of County Geologic Atlas work.

All three agencies use monitoring data to provide information necessary to assess, and ultimately restore or protect, the quality of Minnesota's groundwater and drinking water resources. Types of monitoring can be broadly described as condition, problem investigation, and effectiveness monitoring. An overview is provided here, and more information can be found in the appendices.

The MPCA's ambient groundwater condition monitoring focuses on aquifers in urban and undeveloped parts of the state that are vulnerable to anthropogenic contamination. The MPCA monitors the condition in two key aquifers: 1) the Prairie du Chien-Jordan aquifer, a bedrock formation present across most of east-central and southeast Minnesota; and 2) the shallow sand and gravel aquifers that are used by many domestic wells throughout the state. These are the two most heavily used aquifers in the state in terms of the amount of groundwater that is withdrawn to supply water for domestic use and agricultural purposes. The MPCA analyzes the collected ambient groundwater quality data to determine the groundwater's suitability to serve as drinking water, describe the condition of the state's groundwater, and quantify any changes in the quality of this resource. A variety of visualization and statistical methods are used to meet these varied goals.

The primary goal of the MDA's pesticide groundwater monitoring is to provide detailed information on the occurrence and concentrations of pesticides in Minnesota's groundwater resources. Protection of Minnesota's citizens and water resources from agricultural chemicals is a fundamental goal of this program. Direction for groundwater monitoring by the MDA is derived from the Minnesota Groundwater Protection Act and the Minnesota Pesticide Control Law (Minn. Stat., ch. 18B).

The MDA also monitors nitrate and pesticides in groundwater utilizing private drinking water wells through three different programs: 1) Township Testing; 2) Private Well Pesticide Sampling; and 3) two regional private well monitoring networks. Between 2013 and 2020, the Township Testing Program (TTP) analyzed nitrate concentrations in private wells in areas with vulnerable groundwater and row crop agriculture. (More information is provided in the section of this report focusing on nitrate.)

MDH is responsible for monitoring groundwater that is used as drinking water. These 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. Sampling is broadly grouped into four categories:

1. Regulatory compliance monitoring at public water systems to ensure drinking water meets federal regulations
2. Non-regulatory investigative sampling that includes digging deeper into known or suspected issues
3. Conducting vulnerability monitoring to assess the condition and contamination susceptibility of source waters
4. Unregulated contaminants monitoring conducted under the Drinking Water Ambient Monitoring Program (DWAMP).

The 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 DNR's statutory responsibilities for groundwater are centered on monitoring groundwater levels, managing groundwater use, and ensuring the long-term sustainability of Minnesota's groundwater. In work connected to groundwater monitoring and information, DNR maintains a Groundwater Observation Well Network, conducts aquifer tests, maintains a database with information about aquifers (the Aquifer Properties Database), and develops county-scale groundwater atlases. As part of this work, the DNR collects groundwater quality data under certain circumstances.

Monitoring for emerging contaminants

Most of this report focuses on contaminants that are known to be present in Minnesota's groundwater, whose risks are generally well understood, and that are driving our collective work. There are many other chemicals in the environment that are less well-known; they are unregulated, rarely monitored, and little is known about the risks they may pose to human health and the environment.

The state agencies work together to understand the presence and potential risk of these emerging contaminants (also known as contaminants of emerging concern or CECs) in water. CECs are chemicals that are known or expected to have adverse health or environmental effects, or those that have been widely detected in the environment but whose effects are unclear. Examples include personal care products and pharmaceuticals, flame retardants, disinfection byproducts, and microplastics.[23] Over the last two decades, the agencies have begun to more systematically monitor for CECs in groundwater around the state, widely finding various compounds to different extents.

The MPCA monitors select CECs on an annual basis in its ambient groundwater monitoring network and sometimes completes special projects, such as a legislatively funded effort to monitor microplastics in groundwater that began in 2020. Between 2018 and 2023 MPCA collected 108 samples from its ambient network for analysis of 135 different CECs. At least one CEC was detected in almost 90% of the samples, with 16 CECs being the most observed in one well. Overall, 68 of the 135 CECs analyzed for were detected.

In drinking water, contaminants that are subject to EPA's national primary drinking water standards (94 in total) are routinely monitored at public water systems, and therefore there is abundant occurrence data for regulated contaminants in groundwater used for drinking. By contrast, there is relatively little monitoring data available for CECs. MDH is working to improve this.

From 2019 to 2021, MDH conducted the Unregulated Contaminant Monitoring Project (UCMP), which scanned for a wide variety of CECs and regulated chemicals in systematically chosen public groundwater wells around the state. The results illustrate the widespread and varying nature of CEC occurrence in groundwater. For example, lithium, an unregulated metal, was detected in 100% of groundwater systems; bromoform (a disinfection byproduct) and metalochlor SA (a degradate of a regulated pesticide) were detected at a majority of the groundwater wells in which they were tested; and several PFAS and regulated pesticide compounds were detected in at least 20% of groundwater wells in which they were tested.

Overall detections included 84 distinct pesticide compounds, 51 pharmaceuticals, 43 wastewater indicators, 15 PFAS, eight benzotriazoles, and one inorganic compound (lithium). However, most of the compounds tested were not detected in groundwater at *any* system. Importantly, the findings indicated that groundwater in vulnerable geologic settings was more likely to contain detectable CECs than groundwater in nonvulnerable settings.

The UCMP serves as the basis for a new program to survey CECs in groundwater on an annual basis, the DWAMP. Under this program, MDH will continue to test for CECs in groundwater and drinking water sourced by groundwater in a more focused manner, with large-scale testing performed every five years.

Continued monitoring and follow-up is important in order to proactively address potential impacts to human health and the environment that will not be mitigated by current regulatory frameworks. We may well find that an emerging contaminant today will become a strategic driver of our work to protect groundwater moving forward.

Successes

Assessing and characterizing groundwater quality is a resource intensive process. It requires gaining access to groundwater through wells (although sometimes springs can be used). Wells, whether monitoring wells or water supply wells, are expensive to construct and can be difficult to sample. Utilizing private wells in monitoring networks is risky as ownership and participation interest may change over time, limiting the ability to track long-term trends.

The Clean Water Fund has provided significant support to allow the state agencies to build out strong groundwater monitoring networks; many of those networks have now generated sufficient data to begin to allow for the analysis of contaminant trends.

The addition of new contaminants to drinking water monitoring — including the new focus on CECs — is another success. Findings from past and current CEC monitoring efforts have already resulted in the development of health risk assessments for certain contaminants in water, follow-up monitoring when CECs are detected in groundwater supplying public water systems, and helped prepare drinking water systems for the transition to a regulatory framework, as was the case with proactive PFAS monitoring at public water supplies.

Gaps and opportunities

Monitoring information is a key tool in understanding groundwater quality across the state and at different scales. While we have good groundwater data, we do not have the same degree of monitoring data and information on groundwater as we do for surface water across the state at multiple scales.

Efforts to characterize groundwater quality in Minnesota are typically focused on specific concerns, like understanding the effects of 1) fuel leaks from an underground storage tank, 2) a leaking landfill, 3) agricultural impacts in vulnerable settings at the edge of fields, or 4) ambient conditions in urban settings representing many potential land uses. These kinds of site-specific or detailed assessments are very important for management actions in those specific areas and have contributed greatly to our understanding of individual settings.

However, when viewed at a statewide or regional scale, such efforts are widely and irregularly scattered and there are gaps in our understanding of groundwater quality at certain geographical scales. Groundwater quality assessments at the aquifer scale can be lacking, except in those counties in which geologic atlases have been completed. Completing county geologic atlases is important work to continue, as is additional work to make the comprehensive information more accessible and understandable.

Regional scale aquifer water quality characterizations would be especially helpful because the state conducts most water and natural resource protection planning at a watershed scale. Such characterizations are commonly done for surface water resources. These assessments and evaluations are instrumental to local watershed managers in setting priorities and identifying partners for implementation activities, and having groundwater assessments at a similar scale would support integrated water protection planning. Additionally, aquifer scale characterizations could be a tool for well drillers and others to use in helping homeowners and public water systems find safe and adequate sources of drinking water.

Groundwater data and information sharing

Groundwater monitoring and evaluation generates significant amounts of data that need to be managed and shared to support informed decision making for groundwater protection. The state agencies play an important role in making sure the data and information gathered is available to all — such as local governments — that need to understand and make decisions about groundwater.

The state agencies store and make groundwater data available in several common databases. The MPCA, MDA, MDH, and MDNR place most of the groundwater quality data they obtain through periodic sampling, and some other data, into a database called Environmental Quality Information System (EQuIS). Groundwater level and quality data that is continuously collected by instruments deployed in wells such as pressure transducers or conductivity sensors are stored in a database called Water Information System from Kisters (WISKI). Aquifer property data obtained by the MPCA, MDH, and DNR by performing pumping tests is put in an aquifer properties database maintained by the DNR. Finally, information such as location and depth for wells drilled in Minnesota is stored in a database called the County Well Index.

The information stored in most of these systems is made available through online tools. MPCA makes data available for download through the Environmental Data Access website and a map-based search, while MDH provides web-based access to drinking water quality data.[24] Water quality data collected from the MPCA and MDA's ambient monitoring networks are submitted to the EPA using a procedure similar to the one for surface water data collected for the Clean Water Act; the water quality data are available from the national Water Quality Portal database. Continuous groundwater level data collected by the DNR's Observation Well Network are available for download through the Cooperative Groundwater Monitoring website, and well information is available through the Minnesota Well Index website.

Data is reviewed, summarized, and interpreted in various reports and on program specific websites. For example, MDH issues annual reports about the state of drinking water. The MDA publishes various reports of monitoring results, generally on an annual basis, and MPCA regularly reports on the condition of Minnesota's groundwater quality. The MDA and MPCA reports are made available at the Minnesota Digital Water Research Library. MDA reports also are available on MDA's Water Monitoring Reports and Resources webpage, and the most recent MPCA reports are available on the Groundwater monitoring webpage.

Interpretation of groundwater, aquifer properties, and geologic data is synthesized in the DNR's Groundwater Atlas Program, which provides hydrogeologic information for the state in GIS products. This program also uses the common EQuIS database. DNR

curates groundwater elevation data, groundwater trends, and groundwater use data at the watershed level and makes it available in Groundwater Restoration and Protection Strategies (GRAPS) reports for use by municipalities and watershed organizations. DNR also provides information through the suite of tools known as the Watershed Health Assessment Framework (WHAF); as an example, the WHAF includes watershed context reports that describe the physical characteristics of a watershed, including groundwater information.

Specialized data evaluations and summaries are provided by each agency.

Successes

Each agency has significant amounts of groundwater data; that data has not always been easily interoperable or accessible to the public. Although there are still legacy data storage systems in use for some types of data that have less external accessibility, much progress has been made in making data and information publicly available.

The move to housing more water quality data in the common EQuIS database hosted by the MPCA provides improved access to public data for state agencies, interested parties, consultants, and local government partners. Based on this shared database, programs are able to pull out relevant data sets for specific purposes and visualizations. Access to this data allows for targeted interventions, program improvements, and measurement of trends over time.

Gaps and opportunities

As noted above, there remain legacy data systems and some types of data that are less accessible to the public. Improved data and information accessibility is, and will likely remain, an ongoing need. One particular gap is the availability of data and information about private wells through the Minnesota Well Index. MDH is beginning work to modernize well index data systems; this work is discussed further in the section on private wells.

Groundwater challenges and response

This section lays out key challenges identified by the state agencies as potential barriers to meeting our groundwater protection goal today and over the next ten to fifty years. These challenges include natural and human-caused or -influenced threats to both groundwater quality and groundwater quantity.

In addition, this section covers the ways in which water infrastructure impacts progress towards groundwater protection goals and discusses the inequities that exist in the way Minnesotans experience and access sustainable groundwater. Throughout, there is discussion of how climate change interacts with the threats, often exacerbating the issues and making meeting groundwater protection goals even more challenging.

This report is not a comprehensive accounting of every possible concern related to groundwater quality and quantity. Our intent with this report is to focus on those threats that most need a coordinated response, and which we see as most likely to drive our collective work over the next ten to fifty years.

Groundwater quality

When contaminants in groundwater reach certain levels, they can make the water unsuitable for particular uses. If too much water — whether in a specific aquifer, a certain area of the state, or generally — has levels of contaminants that prevent it from being used for specific purposes, that may not align with the degradation prevention goal (103H.001).

Groundwater quality concerns are largely driven by contaminant levels and trends. Concerns arise when we see concentrations that might present harm to people drinking or using the water or ecosystems that depend on it, or when levels are trending towards those concentrations of concerns.

Reference values

To protect human health and the environment, the state and federal agencies have developed and use a range of guidance values and standards for contaminants in water. These may be referred to as reference values or health-based values.

MDH sets health-based water guidance values for concentrations of contaminants in drinking water. These reference values represent the level of a contaminant that is likely to pose little to no health risk to people drinking the water. Health-based water guidance values consider the chemical's toxicity (the minimum quantity that will cause health effects), how much water people drink, and how long their exposure is likely to be; they are also adjusted for uncertainty. MDH has set levels for contaminants from acetaminophen (a pharmaceutical) and acetochlor (a pesticide) to xylenes (solvents) and zinc (a metal). Water with levels of contamination above these values can be unhealthy to drink. Other contaminants at certain levels might not cause harm but might cause water to be unpleasant to drink due to its taste or smell.

Values for contaminants in drinking water set by MDH and EPA and mentioned in this report include:

- **Maximum Contaminant Levels (MCLs)** — Set by EPA, these are regulatory levels that must be met by public water systems.
- **Health-Based Values (HBVs)** — Set by MDH, these are guidance values that set the level of a contaminant that can be present in water and pose little or no health risk to a person drinking that water.
- **Health-Risk Limits (HRLs)** — Set by MDH, these are developed in the same manner as HBVs but have gone through a formal rulemaking process.

Reference values might also include water quality standards to protect surface waters or values for levels of a contaminant in fish tissue.

This report focuses on those water quality issues that currently present the greatest challenge to meeting our groundwater protection goals and therefore are driving coordinated state actions and program work. Some of the key characteristics of these water quality challenges are:

- Contaminants that are relatively widespread in parts or all of Minnesota
- Contaminants that we see at levels at or close to relevant guidance values or standards
- Pollutants that get into groundwater through regular use practices rather than spills or accidents
    - Minnesota law calls these "common detection" pollutants; they include pesticides and nitrate
- Contaminants that need a multi-agency approach to understand and address

These pollutants include nitrate, pesticides, PFAS, chloride and salts, and geogenic contaminants.

Groundwater quality and geography

Even when talking about broad concerns that drive our strategic groundwater work, it is important to recognize that groundwater quality concerns differ across Minnesota, since groundwater conditions are strongly influenced by local geologic conditions and land use activities.

As shown previously (Figure 4), six groundwater provinces have been designated in Minnesota. Within each province, geologic conditions are generally similar. In some environments, the groundwater resources are vulnerable to pollutants that infiltrate from the ground surface, meaning they can be adversely affected by pollutants from the land surface over short time frames (days, months, years). In other settings, geologic materials provide a great deal of protection for groundwater from pollutants in recent recharge. In such settings, groundwater is recharged over long time frames (i.e., decades and centuries).

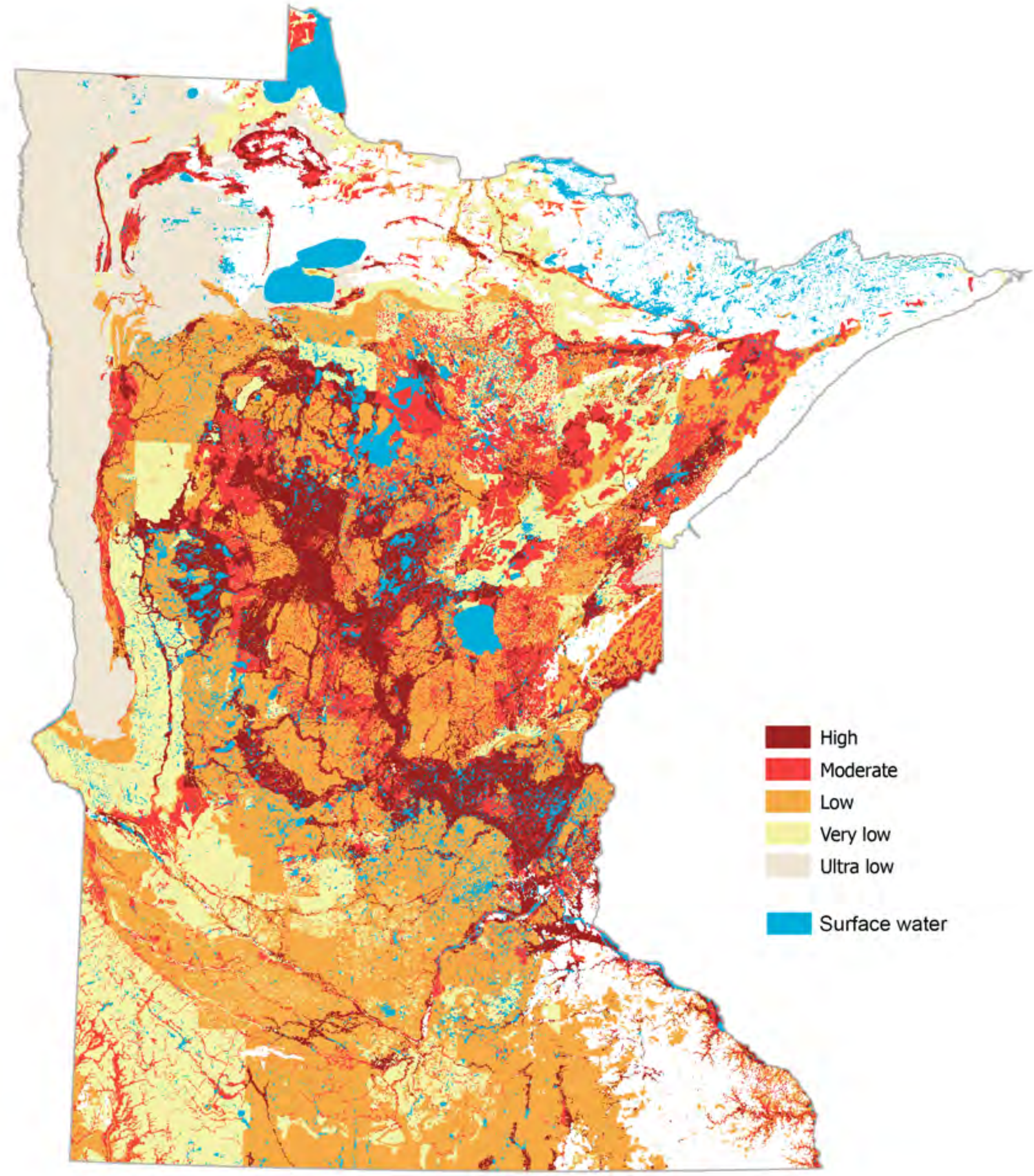
This report does not emphasize site-specific concerns that are generally managed through permitting, compliance and enforcement, and cleanup programs. Individual sources — from landfills to tailings basins to underground fuel tanks or dry cleaners — have the potential to leach pollutants into groundwater and cause local water quality impacts, depending on the site-specific conditions. Understanding, communicating, and working to clean up site-specific groundwater contamination is important. For information about specific sites that have contaminated groundwater, visit MPCA's Groundwater Contamination Atlas.

Groundwater is most sensitive to pollution from the land surface in specific geologic settings; Figure 6 shows groundwater pollution sensitivity based on the near-surface geology. Five relative classes of geologic sensitivity are based on the time of travel from the surface; very high sensitivity means pollutants reach groundwater very quickly (hours to months). As shown, areas of high sensitivity exist across the state. More information is available at DNR's webpage on groundwater pollution sensitivity.

The potential pollutants that might infiltrate to groundwater in each part of the state depend on land use activities. Broad land use activity classifications include agricultural use, residential, urban-commercial, forestland and parkland. Land use activities vary widely across the state and even within each groundwater province. Although land use classification is important, the details within these classifications matter more. Agricultural practices, for example, vary from one part of the state to another, as do commercial and industrial activities.

In some areas of the state, it is not land use that is a concern but rather the geologic materials themselves. Groundwater interacting over years and decades with geologic materials can create water quality that is harmful to human health. Such contaminants are called geogenic contaminants; common examples in Minnesota are arsenic and manganese.

Figure 6. Groundwater pollution sensitivity based on near-surface geologic materials.



Nitrate

Nitrate, a form of nitrogen that both occurs naturally and has many human-made sources, such as fertilizers and manure, is a common surface and groundwater pollutant. Nitrogen is critical for crop production, but it is prone under certain conditions to leach away from where it is useful — the crop root zone where it contributes to plant growth — and into surface and groundwater.

Nitrate levels in groundwater are a particular concern because of the large number of Minnesota residents that rely on groundwater as their source of drinking water. High nitrate concentrations in drinking water are harmful to human health, especially for pregnant women and infants who are under six months old. Consuming nitrate at levels above 10 mg/L can affect how blood carries oxygen around the body, resulting in methemoglobinemia (also known as a blue baby syndrome). Emerging science indicates the *possibility* of health impacts — such as thyroid problems, adverse pregnancy outcomes, and colorectal cancers — from long-term exposure to nitrate at lower levels.[25] While additional research is needed, these possible health effects may become another reason for concern about nitrate in our drinking water supply.

The issue of nitrate in Minnesota's groundwater is long-standing and complex. The state agencies have been working together over time to:

- Monitor and characterize nitrate levels in groundwater across Minnesota
    - Including understanding where there are most likely to be levels of concern (with a particular focus on drinking water) and how levels of nitrate are changing over time)
- Respond to levels of nitrate in groundwater by:
    - Identify sources of nitrate
    - Identifying, developing, and supporting implementation of actions to reduce nitrate in groundwater
- Tracking progress in reducing nitrate, in order to adapt the response as needed

Detailed information on nitrate levels; the drivers of nitrate pollution; key actions for reducing nitrate; and the programs and strategies necessary to implement those actions are documented in multiple state reports and action plans.[26]

The goal of this section is to bring together the story of the state's coordinated work to understand the scope of the problem and develop and implement approaches to addressing it, and then to summarize what has been achieved and what else is needed.

Monitoring and characterizing nitrate

The first step to managing any contaminant is developing an understanding of its presence in the environment. Driven by multiple factors, work to understand nitrate in Minnesota's groundwater began in the 1970s and 1980s. That initial work found some aquifers — surficial aquifers and those sensitive to pollution from the land surface — where concentrations of nitrate were greater than the Maximum Contaminant Level (MCL) of 10 mg/L.[27]

The Minnesota Groundwater Association has called out the "widespread detection of nitrate in water table aquifers" as an important driver of the legislation that established Minnesota's groundwater protection act in 1989.[28] Through this period and into the 1990s and early 2000s, the state agencies focused on continuing monitoring to develop a baseline understanding of groundwater quality and the impact of land use and sources like feedlots and septic systems.[29]

However, in the early 2000s it was clear that more work needed to be done to monitor groundwater and characterize nitrate conditions throughout the state. EQB's *Minnesota Water Priorities 2003 – 2005* report called for improvements in groundwater condition monitoring, and specifically identified the need to learn more about trends in nitrate contamination of groundwater. Throughout the 2000s, the agencies worked to improve groundwater monitoring. Groundwater monitoring work was greatly accelerated and scaled up due to funding from the Clean Water Land and Legacy Amendment and implementation of collaborative structures (such as the interagency groundwater/drinking water team).

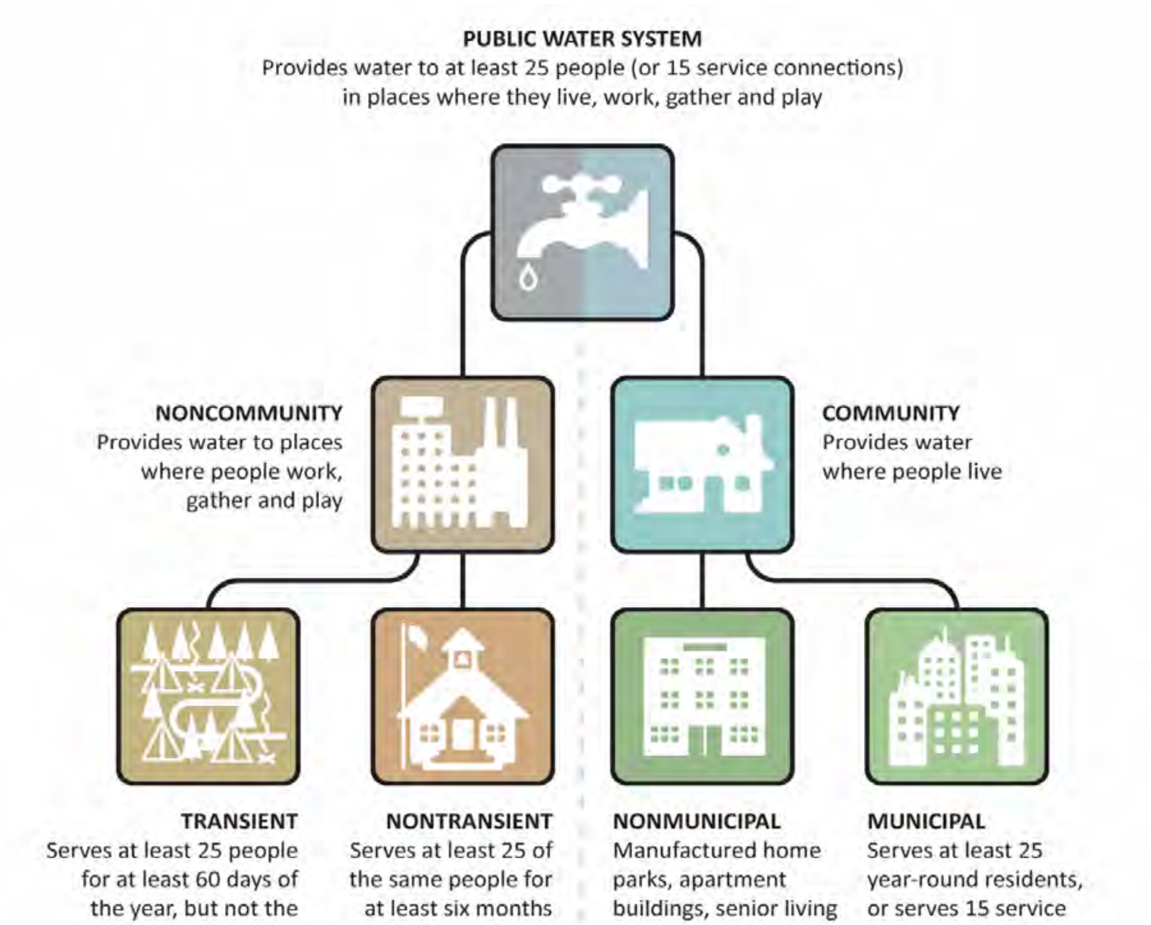
Today — with the significant work done by MPCA, MDA, MDH, and others — Minnesota has much more data available to help us understand and characterize the scope of the nitrate issue. We know that groundwater is most susceptible to nitrate pollution when two factors coincide: vulnerable geology — which provides a quick path for pollutants to move from the land surface to the groundwater — and the presence of sources of nitrogen.

Concentrations of nitrate in Minnesota groundwater from natural conditions are generally quite low. For many years, a nitrate level of 3 mg/L or above was commonly used as an indicator of human impacts. However, a recent review of information shows that 1 mg/L is likely to be a better threshold for identifying these impacts.[30]

Multiple groundwater assessments over time have shown consistently that "nitrate concentrations are highest near the water table in agricultural areas and are lower in the underlying aquifers", demonstrating that combination of vulnerable geology and a nitrogen source leading to higher concentrations.[31] Recent information shows that median nitrate concentrations near the water table in agricultural areas are higher than those found in the state's urban lands, and that almost 40 percent of the water table wells tested in the agricultural areas exceeded 10 mg/L.[32]

In summary, nitrate contamination most affects aquifers (or parts of aquifers) that are subject to recent recharge and where the overlying land uses can leach nitrogen. However, recent work is also showing that as younger groundwater containing nitrate

Figure 7. Types of Public Water Systems



moves through aquifer systems and increases in residence time, nitrate conditions may increase in deeper aquifers.[33]

Monitoring and assessment work shows that large areas of elevated nitrate occur in vulnerable groundwater environments in southeast, southwest, and central Minnesota, and that some aquifers that supply drinking water have elevated nitrate concentrations.

Nitrate levels in drinking water

It is especially important to understand levels of nitrate in aquifers that supply drinking water and in finished drinking water, due to the potential for human health impacts.

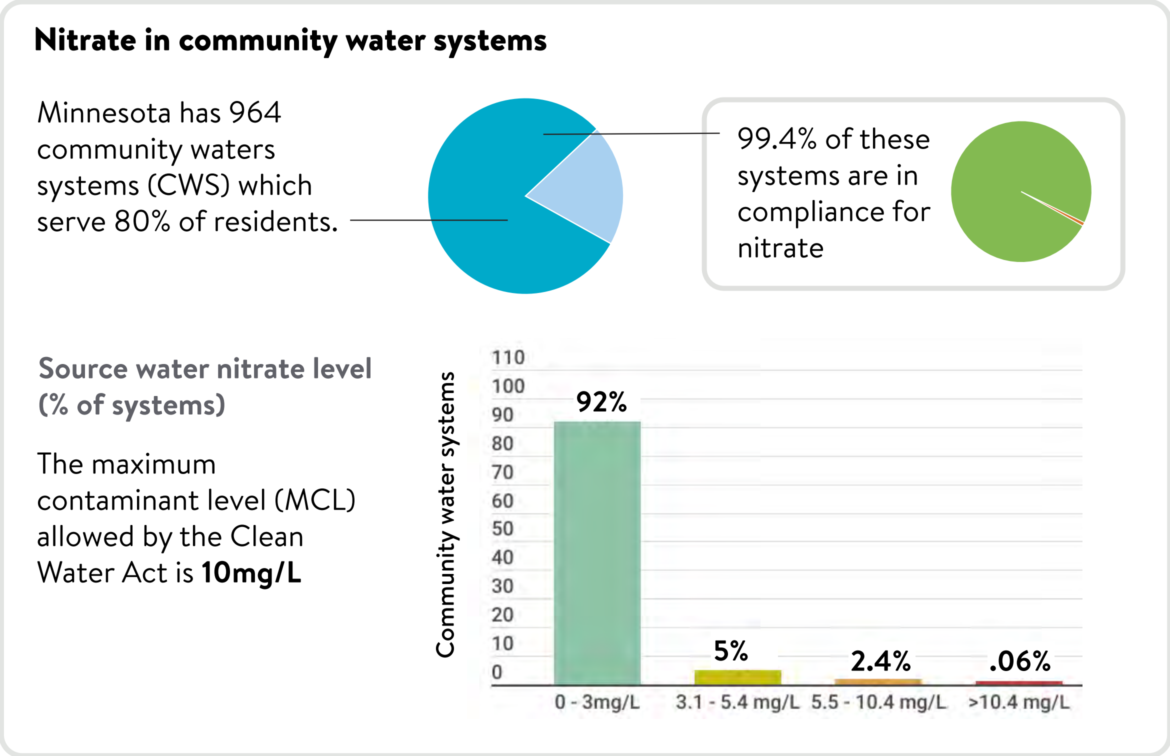
Public water systems (those subject to the Safe Drinking Water Act and its 10 mg/L MCL) are required to regularly test for nitrate in both their source water and their finished water. MDH regularly compiles the data to produce annual drinking water reports, and has electronic data records going back to 1994.[34]

The results are largely good. In 2022, MDH reported that over 99% of community public water systems were in compliance with the MCL and most systems (92%) had source water with nitrate levels below 3 mg/L.

The most recent report (2024) showed two out of 965 community water systems (0.21%) and 10 out of 5,620 noncommunity water systems (0.18%) exceeded the nitrate standard of 10 mg/L for finished drinking water.[35]

Nine community water systems currently have nitrate levels above 10 mg/L in their source water. Community water systems with elevated nitrate levels (above 3 mg/L) tend to be in the state's southwestern, southeastern, central, and north-central areas. Broadly, systems

Figure 8. 2022 Nitrate summary (community public water systems)



with nitrate concerns are taking measures to reduce it. This can include activities like drilling a new well, shifting production to other wells, or simply blending water to lower nitrate in the finished water that goes out to users. It can also include actions to reduce nitrate in source water.

The following map shows those public water systems — both community and noncommunity — that in 2023 and 2024 showed levels of nitrate in their source water greater than 5 mg/L.

While 80% of Minnesota residents get their drinking water from a public water system, the remainder get water from private wells. Because regular monitoring of private wells is not required, information on nitrate in drinking water coming from this source has lagged; the state agencies are working to improve monitoring and information gathering for private wells.

From 2013 to 2019, the MDA, supported by the Clean Water Fund, conducted private well nitrate testing through the Township Testing Program (TTP). The goal of TTP was to characterize nitrate concentrations at the township scale to guide BMP promotion and provide education and outreach to private well owners in at-risk areas. Local partners (County and SWCD staff) were engaged and coordinated with MDA on much of the initial well owner outreach.

That testing, conducted in agricultural parts of the state where the groundwater is naturally vulnerable to contamination, covered over 30,000 wells in its initial round.[36] It showed that over 9% of the tested wells had nitrate concentrations exceeding 10 mg/L. These initial results reflect nitrate concentrations in private well drinking water regardless of nitrogen sources, or well construction.

Follow-up testing and other resources were offered to homeowners who had private wells where any level of nitrate was detected. Final results were 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. Final results (Figure 11) represent wells that are potentially impacted by a fertilizer source, and are used for prioritizing work through the Nitrogen Fertilizer Management Plan (NFMP).

Figure 9. Public Water Systems Nitrate (source water) > 5 mg/L

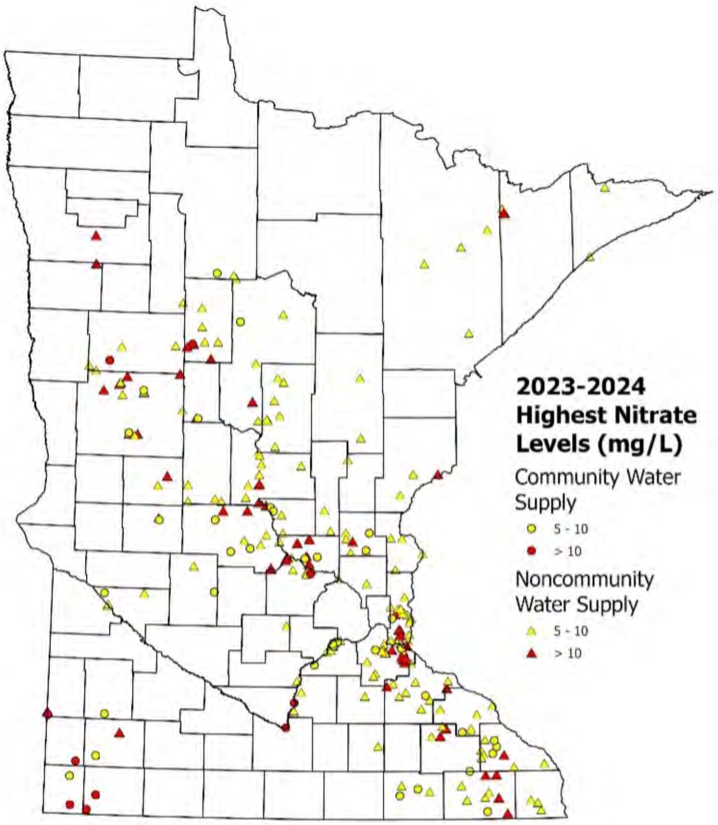


Figure 10. Initial Township Results Updated May 2022

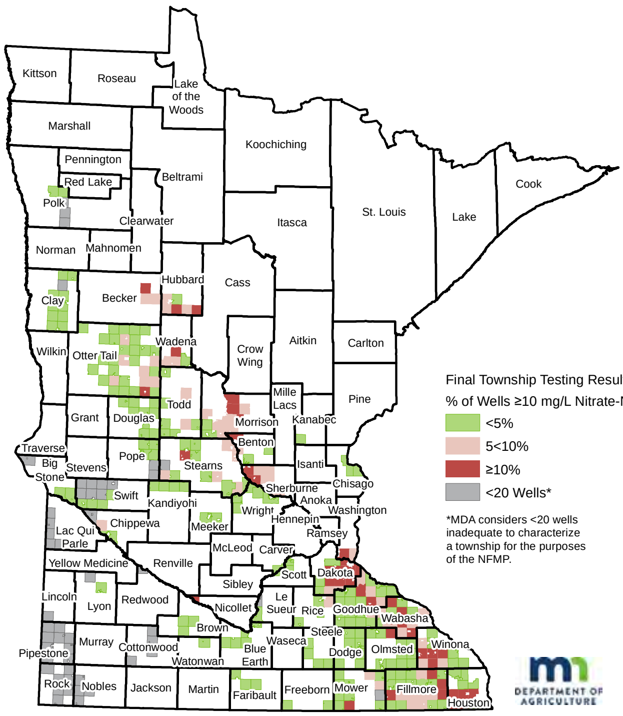
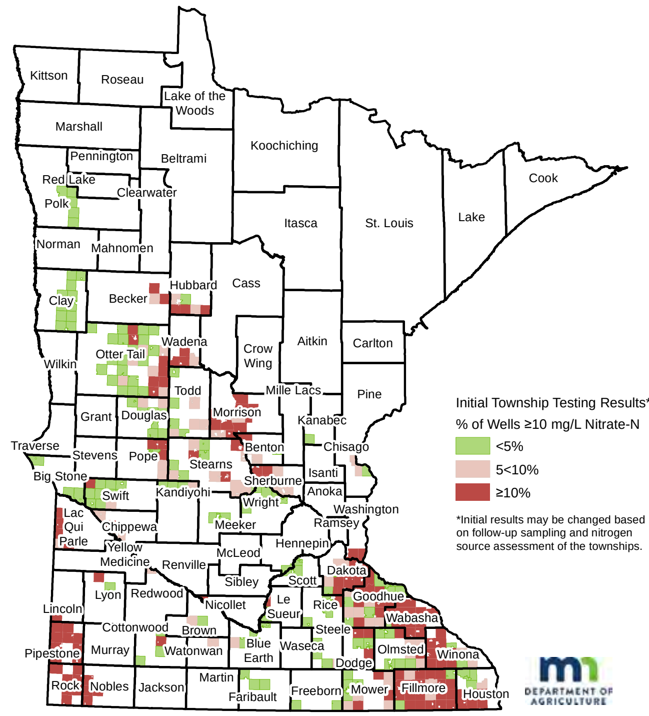


Figure 11. Final Township Testing Results May 2022



Appendix A — Assessment of Water Quality Trends and Prevention Efforts - provides more information about nitrate levels and trends.

Changes in nitrate levels

As the state has established and built out groundwater monitoring, the additional data allows for more analysis. Having at least 10 years of data in a location enables trends analyses — allowing understanding not just of nitrate concentrations but whether they are staying the same, increasing, or decreasing.

Trend analysis (using data from MDA and MPCA's ambient monitoring programs) indicates that nitrate concentrations in most shallow monitoring wells have not changed significantly in the last 10 years; 75% of the sites had no observable trend.[37] Where a trend was detected, it was typically downward. However, several sites with downward trends still had nitrate concentrations above 10 mg/L; and there are sites with a trend of increasing nitrate concentrations. The ability to monitor and analyze trends over time will help assess the impacts of programs intended to reduce nitrate.

Figure 12. Nitrate concentration trends in 180 upper aquifer wells (domestic and monitoring wells) sampled at least five times between 2013 and 2023 across Minnesota

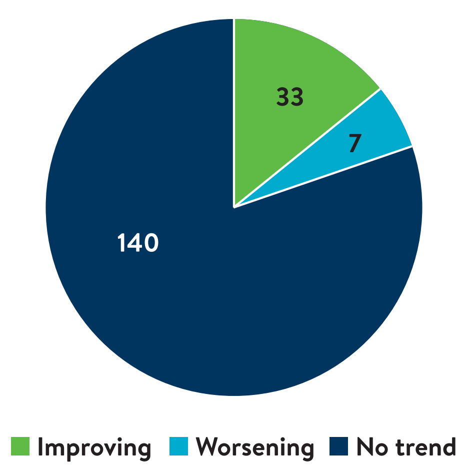
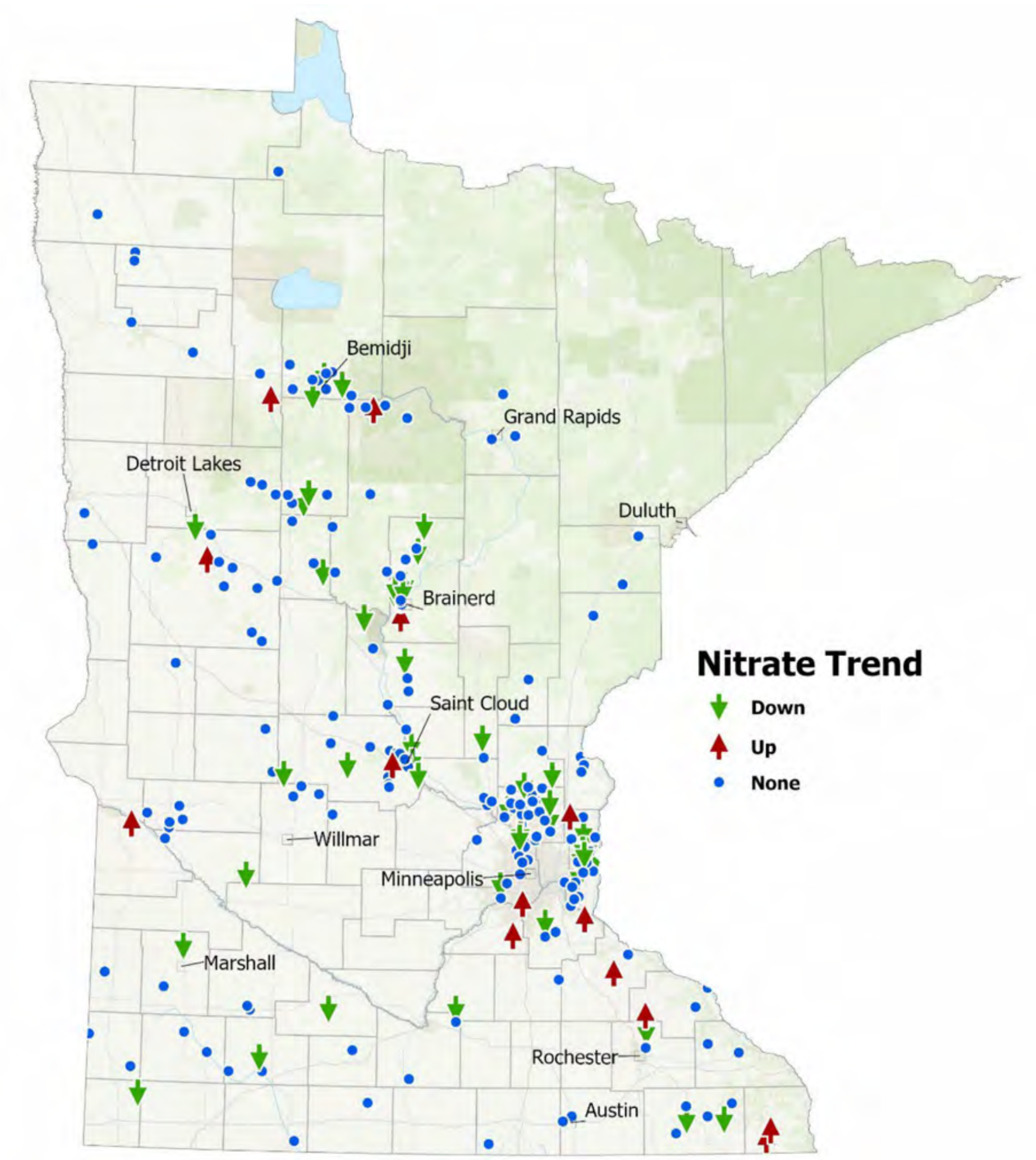


Figure 13. Nitrate trends in Minnesota's groundwater, 2013-2023 [Data from the MPCA and MDA ambient groundwater monitoring networks].



Although trend analysis shows indications that nitrate in groundwater in some areas of that state is declining, the overall lack of trends suggests that additional measures are needed to reduce nitrate concentrations in the state's groundwater.

Nitrate response

Once monitoring data makes clear that there is a pollution problem, the next phase of work includes understanding the source of the pollution; identifying the actions needed to reduce the pollution; and then developing programs and mechanisms to implement those actions. It is also critical to track progress to iterate and adapt the response as needed.

Over the past ten to fifteen years, multiple reports on Minnesota's water resources have recognized the challenge presented by nitrate pollution and the need to take action to reduce nitrate in groundwater, its connection to actions on the landscape, and set forth goals and strategies for reducing nitrate in our groundwater and drinking water.

Developing the response

Over the past ten to fifteen years, multiple reports on Minnesota's water resources have recognized the challenge presented by nitrate pollution and the need to take action to reduce nitrate in groundwater, its connection to actions on the landscape, and set forth goals and strategies for reducing nitrate in our groundwater and drinking water.

A foundational report in developing the state's nitrate response is Minnesota's Nutrient Reduction Strategy (NRS). First written in 2014, the NRS is the state's long-term strategy for reducing nitrate pollution and contains goals for reducing nitrate in groundwater to protect both groundwater used as drinking water and to reduce nitrate moving into surface waters from groundwater.[38]

The 2014 NRS identifies priority geographic areas where nitrate pollution reduction is needed — focusing on areas with greater than 20% of the land in row crop agriculture and with high geologic vulnerability to pollutants on the land surface.[39] The NRS also summarized work done to characterize the sources of nitrogen to Minnesota's waters; it identified agricultural tile drainage and cropland nonpoint sources, and wastewater point sources as priority sources of nitrogen to be addressed. (Since wastewater point sources discharge to surface waters, the nonpoint sources of tile drainage and cropland are key to addressing nitrate in groundwater.)

There are a variety of practices that can be implemented on the landscape (particularly in cropland) to reduce nitrate moving into groundwater. The practices — those that ensure the right amount of nitrogen is used and that keep it in place in the soil — are well known. They include:

- Making land use changes that result in less pollution
- Using the right amount of manure or fertilizer on cropland and applying it at the right time
- Using crops and cropping systems that minimize nitrogen losses and promote soil health:
  - Cover crops that uptake nitrogen (or add and recycle nitrogen)
  - Conservation crop rotations
  - Perennial crops like Kernza®, camelina, and alfalfa
- Managing landscapes to hold water and reduce runoff

The 2014 NRS, the 2015 EQB Water Policy Report, the 2020 State Water Plan, and other documents include goals and strategies for reducing nitrate pollution over time. They identify the need to develop tools and programs that support the implementation of these practices on the landscape, recognizing that state agencies will largely not be the ones taking the actions.

Guided by these plans, state agencies are working together to get nitrate-reducing actions in place — whether that is through providing financial support, implementing regulatory mechanisms, or effecting other long-term strategies for reducing nitrate pollution of groundwater across Minnesota. Over the last ten to 15 years, there has been significant work to implement the strategies described in these reports and to support establishment of on-the-ground practices. Some of the key areas of work are described below.

Fertilizer and Manure Practices

Managing the application of fertilizer and manure in agricultural systems is one of the many practices that can reduce nitrate in groundwater. Minnesota is making improvements both through voluntary changes and through regulatory mechanisms related to fertilizer and manure practices. These regulatory mechanisms are now in place, both aimed at mitigating nitrate leaching loss to groundwater from agricultural systems.

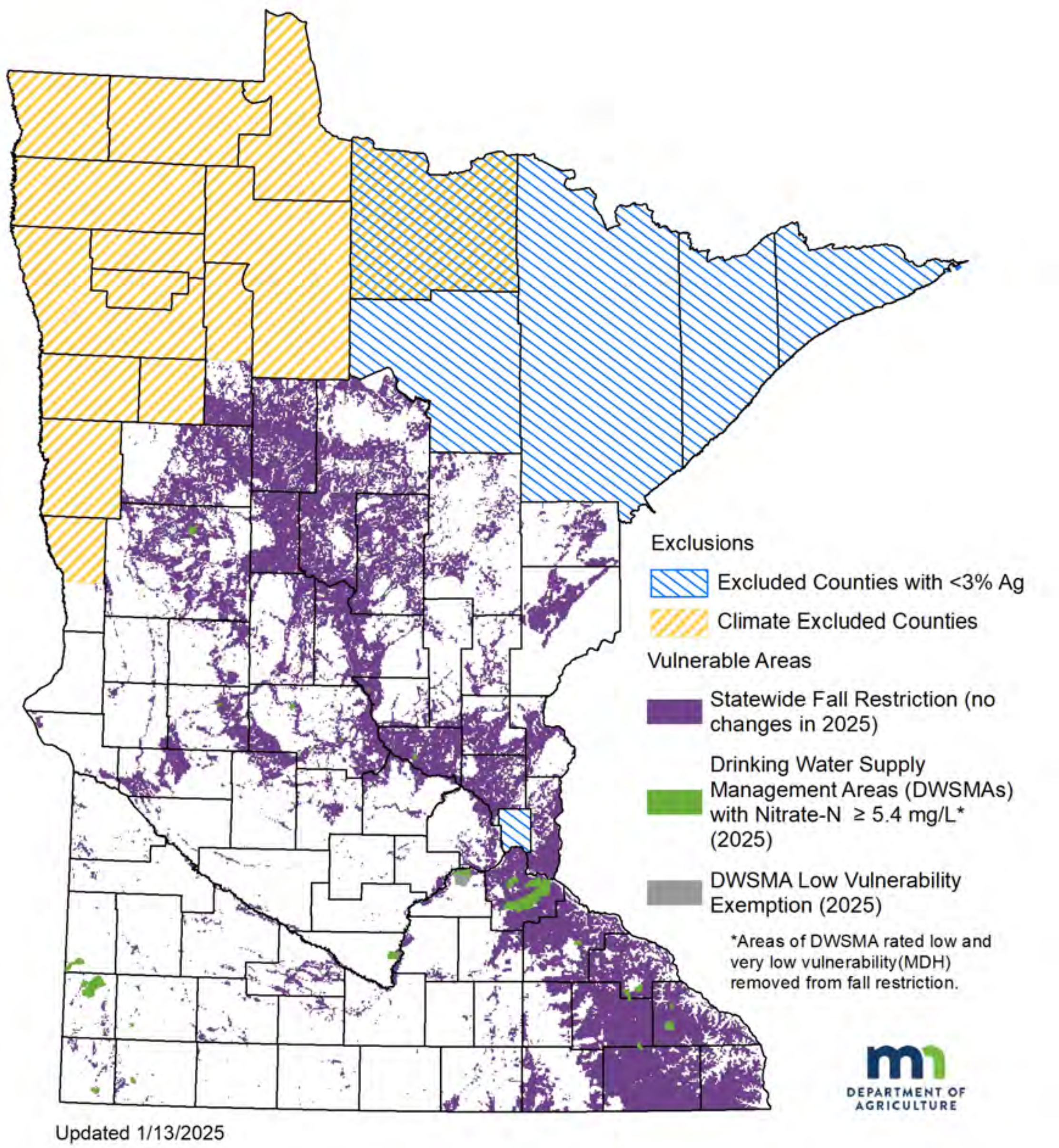
Nitrogen Application

University of Minnesota Extension offers the Nitrogen Smart educational program that provides fundamental information to growers on how to maximize economic return on nitrogen investments while minimize nitrogen losses. MDA also promotes nitrogen fertilizer application best management practices (BMPs), which are closely aligned with University of Minnesota extension recommendations for application rates that maximize farmers' profit while protecting the environment. The BMPs focus on ensuring the right source of nutrients is applied at the right rate and right time in the right place — a concept known as "4R". A private industry "4R" nutrient stewardship certification program was launched in Minnesota in 2022, and a study for developing recommendations for establishing an incentive-based program to support and encourage agricultural retailers in promoting 4R nutrient management practices was funded this legislative session.[40]

Groundwater protection rule and fall fertilizer restrictions

MDA has been working since 1990 to prevent and minimize potential sources of nitrate pollution to the state's groundwater and protect drinking water. This work began with the Nitrogen Fertilizer Management Plan (NFMP), which is the state's blueprint for preventing or minimizing impacts of nitrogen fertilizer on groundwater. An extensive revision process occurred between 2010 and 2015, resulting in a revised Minnesota Nitrogen Fertilizer Management Plan (March 2015). Critical components of the NFMP include characterization of nitrate conditions in groundwater, working with the local agriculture community, on-farm demonstrations, and the development and implementation of nitrogen fertilizer best management practices and other practices protective of groundwater, such as cover and perennial crops, land set-asides, and others.

Figure 14. Fall fertilizer restrictions in 2025 (showing vulnerable groundwater areas)



Building on the work of the NFMP, the Minnesota Groundwater Protection Rule went into effect in June 2019. The rule includes two parts: 1) it restricts nitrogen fertilizer applications in the fall and on frozen soils in both vulnerable groundwater areas and drinking water supply management areas (DWSMAs)[41] with elevated nitrate, and 2) it includes a process to address public water supply wells with elevated nitrate. The rule combines voluntary and regulatory efforts and emphasizes working with local farmers and their agronomists, and local communities on solutions tailored to the specific area and situations.

Implementation of part 2 of the rule involves four “mitigation levels”; the actions taken depend on the mitigation level. Mitigation levels 1 and 2 involve voluntary actions, while levels 3 and 4 are regulatory. The response always starts at a voluntary level, with

DWSMAs going into level 1 or level 2 depending on the amount of nitrate measured in the community water supply wells. The response moves to a regulatory level if recommended nitrogen fertilizer practices are not adopted, or if nitrate concentrations increase in the public wells or groundwater monitoring network.

In Mitigation Level 2, the MDA will work with local advisory teams to:

- Promote the adoption of nitrogen fertilizer BMPs and other practices (i.e. the 4Rs) that may reduce nitrate levels in groundwater
- Promote the adoption of other practices protective of groundwater (precision agriculture, perennial crops, forages, cover crops, nitrification inhibitors, new hybrids, real-time sensors, or taking targeted land out of production)
- Conduct modeling to evaluate the impact of nitrogen fertilizer practices and cropping systems
- Evaluate the adoption of nitrogen fertilizer BMPs and alternative practices
- Publish a list of fertilizer BMPs for a DWSMA and conduct an evaluation to determine if these practices are followed on cropland acres

The MDA is working to ensure that DWSMAs with elevated nitrate are highly prioritized for implementing nitrate-reducing actions. The goal is that no additional community public water supply wells will exceed the drinking water standard for nitrate.

Manure Management

The MPCA regulates the land application of manure, another source of nitrate to land and water, through Minn. R., chapter 7020 and related National Pollution Discharge Elimination System (NPDES) and State Disposal System (SDS) general water permits for feedlots.

The MPCA recently finalized updates to the NPDES and SDS general permits for large feedlot operations. Large feedlot operations in parts of southeast Minnesota will be required (starting in 2027) to implement best management practices aimed at mitigating nitrate leaching from fields that receive manure applications. The practices include applying manure to growing perennial or row crops; planting a cover crop prior to or within 14 days of application; nitrogen stabilizers; and ensuring perennial crops are included in the rotation at least two years within any five-year period. MPCA has developed a factsheet on minimum requirements for land application of manure.

In addition, these changes include requirements to use a new Nutrient Management Tool to develop manure management. Together the changes aim to enhance protections for Minnesota's water resources, particularly nitrate leaching loss to groundwater from fields that receive manure applications.[42] The MPCA is also proposing to amend the rules governing animal feedlots to improve practices for land application of manure to address nitrate and fish kills and establish additional technical standards to protect water quality.

Crops and cropping practices for soil health

Because healthy soil is more able to hold on to nutrients, soil health is a key factor in reducing nitrate losses to groundwater. The state agencies — especially BWSR and MDA — are working to support implementation of agricultural practices that sustain soil health, such as: no-till and reduced tillage; cover cropping, continuous living cover through crop rotations that add perennials; and vegetative buffers.

Cover crops and continuous living cover are particularly important. In 2014, the NRS called for cover crops on 1.9 million new acres of land by 2025 and over 10 million acres by 2040. Since then, there has been significant development of multiple state programs to incentivize the installation of cover crops, continuous living cover, and other soil health practices, including:

- Minnesota Agricultural Water Quality Certification Program - This program is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices. The program uses a risk assessment tool to evaluate every field within a farm operation and provide guidance on conservation practices that protect surface water and groundwater. To date, over 1600 producers and 1,175,000 acres are certified.
- Forever Green Initiative — This program researches and aims to commercialize winter-hardy annual and perennial crops that will help build soil health. There are many components to this initiative, including the 2023 Environmental and Economic Clusters of Opportunity program, which provided financial and technical assistance for including Kernza®, winter camelina, winter barley, or hybrid winter rye; a premium on financial assistance was provided to growers in DWSMAs.
- Minnesota Office for Soil Health — This collaboration was established with a mission of protecting and improving soil resources and water quality through supporting local experts.
- Financial assistance — Multiple state programs provide financial assistance in the form of grants, loans, or cost sharing to support the implementation of soil health practices.
    - Watershed Based Implementation Funding (WBIF) grants, administered by BWSR, provide funds to implement water quality projects identified in eligible local plans for watershed and groundwater management, including projects to protect drinking water sources and address sources of groundwater degradation.
    - BWSR has offered multiple soil health focused grants to local governments, including soil health practices grants, soil health supplemental staffing grants, and soil health delivery grants.
    - MDA's soil health financial assistance program includes cost-share grants for equipment necessary to adopt soil health practices.
- MDA provides low-interest loans to encourage adoption of best management practices that prevent and reduce pollution through the Agriculture Best Management Practices loan program.
- Conservation easements and acquisition for groundwater protection — BWSR offers programs including Reinvest in Minnesota (RIM) Drinking water easements that retire land from agricultural production in certain vulnerable DWSMAs and Conservation Reserve Enhancement Program (CREP) to establish permanent conservation practices.

Drinking water protection

MDH works to ensure that human health is protected from nitrate in drinking water by looking at both source water and finished water (after treatment).

Protect source waters

Protecting groundwater that is a source of drinking water relies on the same actions as protecting all groundwater, implementing them on specific land areas that influence the aquifers used to supply drinking water. Minnesota has a goal to protect land vulnerable to contamination within DWSMAs statewide by 2034, and is also working to protect lands that are important for private well protection.

Protection methods generally involve ensuring that the land use within the DWSMA (or area that impacts the water recharging the aquifer) is protective of water quality, and can include land acquisition, long-term easements and incentives for crops that protect groundwater, and planning and zoning land use ordinances that benefit water quality.

Technical assistance

Public water systems may treat source water before it is distributed to customers. If a public water system has an elevated concentration of nitrate in finished water, MDH engineers will work with the system to ensure that appropriate mitigation measures, potentially including treatment, are put in place to reduce the nitrate concentration.

MDH provides technical assistance to private well users with high nitrate on how to address nitrate. The 2024 Minnesota legislature provided funding to the MDA to provide home water treatment for private well households in eight southeast Minnesota counties with elevated nitrate. At this point, that is the only area of the state with dedicated funding to address nitrate in private wells.

Local planning and implementation

Reducing nitrate moving into groundwater relies on local action. While the state agencies provide data and information, set goals, develop strategies, and provide funding and technical assistance — ultimately it is organizations and people at the local level that implement the practices in the key locations, recognizing that multiple practices will need to be integrated to reduce nitrate losses from the same land area.

Local planning is a key first step to this local action, and usually takes place on a watershed level. The state agencies aim to provide a suite of tools that support local governments in incorporating groundwater priorities (such as source water protection) into local planning.

MDH coordinates with other agencies on the development of Groundwater Restoration and Protection Strategies (GRAPS). These reports identify local groundwater concerns and potential strategies to address them, to support local governments in prioritizing actions to protect and restore their groundwater.

The agencies have also made a strong effort to ensure that information and support is available for incorporation of groundwater and drinking water strategies into local comprehensive watershed management plans developed under BWSR's One Watershed, One Plan (1W1P) program. These plans are required to address groundwater quality protection, restoration, and improvement; groundwater recharge; and preservation of drinking water sources.

As of 2022, all 25 completed plans addressed groundwater and drinking water, identifying concerns, setting goals such as reducing the risk of groundwater contamination, and including actions to meet the goals. [84] As of 2025, there are 54 completed plans. Based on BWSR's plan content requirements, all plans should be including this kind of information, particularly drinking water sources.[85]

Supporting local best management practice implementation and conservation project delivery through technical and finance resources will be critical to success.

Accelerating the response

In 2020, the state agencies compiled the 5-year Progress Report on Minnesota's Nutrient Reduction Strategy. That report notes substantial progress towards implementation of strategies to reduce nutrients between 2014 and 2020.

Despite the progress, there remain too many places where nitrate in groundwater is over 10 mg/L and there is significant work to do to establish nitrate-reducing practices on the land. At this moment, in 2025, much of the state's response to the nitrate challenge is actively being refined, adapted, and updated. New strategies incorporate improved information and will help us accelerate and scale up the response to meet overall and location-specific goals and needs.

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Seeing changes in nitrate concentrations

Minnesotans want to see not just success in implementing practices and actions designed to reduce nitrate, but to see the outcome of these practices in lower levels or downward trends for nitrate in groundwater.

Many of our nutrient reduction programs are relatively new, and it will take time to see the results. The impact on groundwater can be hard to judge, due to how long it takes for water to travel from the land surface to the groundwater. This affects not only how long it takes for nitrate to get into groundwater, but also how long it will take to see the impacts of actions on the land surface in reducing nitrate levels within aquifers. Groundwater across the state has different ages, which will affect when results may be seen in certain areas.

A recent study by researchers at the MDA, the University of Minnesota's Minnesota Geological Survey, and the DNR demonstrated that in southeast Minnesota there is a mix of groundwater ages — ranging from 10 — 40 years old in shallower aquifers to much older water in deeper aquifers. This study helps us understand where nitrate levels from the past are still percolating through (to the deeper aquifers) and that changes made now at the land surface can take 10 – 40 years to be seen in shallow aquifers. This study is important in contextualizing information about nitrate concentrations and trends in SE Minnesota's aquifers and helps set expectations for when we will begin to see the outcome of all our strategies and programs to implement nitrate-reducing practices on the land.

2025 Nutrient Reduction Strategy

The state is updating the long-term strategy for reducing nitrate through a 10-year revision to the Nutrient Reduction Strategy. The draft 2025 NRS was released for public feedback in July 2025 and final documents will be posted on the MPCA's website by December 2025. Its goal is to assess the foundation laid in 2014 and identify where work to reduce nutrients should be intensified.

The 2025 NRS includes detailed discussion of nitrogen sources and transport; nitrogen loads and trends; the most recent science on nitrogen best management practices; priority areas for working on nitrogen reduction; and examples of the level of adoption of BMP combinations that would make progress toward nitrate reduction goals.

It emphasizes the ongoing critical need for nitrate reduction from cropland, especially nitrate leaching reduction in areas with vulnerable groundwater under row crop production, including sandy soils, karst geology, and other shallow soils above bedrock. It identifies that "Minnesota still needs an average nitrogen reduction of approximately 40% (in [total nitrogen] loads and nitrate concentrations), especially in areas with row crops and vulnerable groundwater or tile drainage."

Best management practices to keep nitrogen on fields continue to be the best ways to reduce nitrate, but millions more acres of practices will need to be installed across the state to achieve significant reductions. The NRS specifically emphasizes the need for diversification of crop rotations and more continuous living cover; expanding and scaling up programs that improve agricultural practices; demonstration projects and pilot programs for BMPs; and continued study of nutrient reduction practices.

The 2025 NRS will serve as a guide to specific strategies for increasing nutrient reduction efforts as the state works to accelerate and scale up the nitrate response.

Southeast Minnesota

In April 2023, several parties filed a Safe Drinking Water Act petition asking EPA to address nitrate contamination posing a risk to the health of residents in the eight counties in the southeastern corner of Minnesota. The state agencies (MDH, MDA, MPCA), have responded with a three-phase work plan outlining actions to address this nitrate issue. The first two phases of the work plan focus on providing safe drinking water to private well users, while phase three focuses on long-term strategies for nitrate.

A workgroup of local leaders came together to build consensus on ways to strengthen long-term nitrate reduction strategies. This group produced a final report, released in July 2025, that outlines recommendations for improving, prioritizing, and implementing strategies to accelerate nitrate prevention and mitigation activities. In general, the recommendations include approaches to scaling up adoption of nitrate BMPs (with a particular focus on increasing continuous living cover) and speak to the need for meaningful support of markets and infrastructure for alternative crops to move the needle further and faster on nitrate reduction in the region.

Successes

Minnesota has come a long way in understanding nitrate and its presence in groundwater. We are making progress on getting nitrate-reducing practices implemented on the landscape, and in providing information about the practices.

Establishing practices

Nitrate reducing practices have been established around the state, using multiple sources of funding (as described in the response section).

Southeast Minnesota

Because the karst topography makes groundwater in southeast Minnesota particularly vulnerable, it has long been a focus for implementation of practices aimed at nitrate reduction. There has been significant funding and establishment of these practices through multiple pathways.

BWSR estimates that over $10 million from WBIF has been granted to watersheds in the southeast Minnesota karst region for projects to improve water quality. The types of actions funded that protect drinking water and groundwater include support of agricultural BMPs (such as soil health outreach and cover crop promotion and installation); septic system inventories; well inventories and testing; feedlot practices; and similar projects. The most common practice implemented with these funds has been cover crops, which have been implemented on more than 10,000 acres in the region.

Other grant funding has also supported on-the-ground implementation of nitrate reducing practices, generally targeted towards specific drinking water concerns. A few examples include:

- City of Chatfield — To protect its drinking water, the city of Chatfield partnered with Minnesota Rural Water Association, Forever Green, and MDA on a project to plant Kernza®, on several acres of city- and privately-owned lands in the DWSMA. Data shows that Kernza®, was effective in preventing nitrate leaching into groundwater, and more perennial crops have been added. For more information, see MDH's storymaps on local solutions for protecting vulnerable drinking water sources.
- City of Goodhue — The city of Goodhue has seen nitrate levels in their municipal well trending up since the mid-1990s, to a current level around 7 mg/L. To prevent further increases in nitrate, the Goodhue SWCD applied for a soil health grant from BWSR. The grant was received in 2023, and the SWCD has now achieved 97% of its goal to implement soil health practices on 1,600 of the overall 2,000 acres in the DWSMA. The most common practice implemented was cover crops, which are now installed on close to 1,400 acres.[43]

Other locations

While there has been a lot of focus on southeast Minnesota, work on nitrate has been done around the state.

- Rock County – The Rock County Rural Water DWSMA had one or more public wells exceed nitrate levels of 8 mg/L between 2010 and 2020. Multiple state agencies (BWSR, MDH, MDA) and local governments and water suppliers (Rock SWCD, Rock County, Rock County Rural Water) collaborated in 2020 to establish groundwater-protecting easements within an important highly vulnerable wellhead protection area. Close to 400 acres of land near the two main wells have been placed into permanent cover through CREP and RIM wellhead easements. Earlier easements resulted in drops in nitrate levels, and the additional permanent cover is expected to further reduce nitrate levels.[44]
- Dakota County – Between Hastings and Vermillion, coarse and sandy soils allow river water to enter the groundwater supply. Nitrate levels in groundwater near Hastings have been increasing over the last 20 years, even with the addition of agricultural BMPs. The Vermillion River Watershed Joint Powers Organization and Dakota County worked together to install a wood chip-enhance wetland designed to filter runoff from a little over two miles of agricultural land. This project went online in 2019 and was estimated to annually remove over 13,000 pounds of nitrate.[45]

The above projects are simply examples of the kind of work that can be done; there are many more success stories around the state.

Sharing data

Ultimately, determining the overall success of Minnesota's response to nitrate in groundwater requires tracking the implementation of the actions and practices and monitoring nitrate levels in groundwater to see if the actions are resulting in the needed changes to nitrate concentrations.

In the last decade, there has been improvement in the availability of information about agricultural practice adoption as well as increased gathering of groundwater monitoring data. Much of the information about BMP adoption is available as part of tracking NRS progress. BWSR's eLink BMP locations map allows anyone to look up state funded conservation practices that have been established around the state, including ones that protect groundwater. MPCA's Healthier Watersheds tracking webpage pulls information from BWSR's eLink, along with any other available data, to show (by watershed) how many BMPs have been installed in a user defined time frame. As part of the next phase of the 2025 NRS work, agencies will be working on an NRS dashboard, which will be critical to determining and communicating success on a broad scale.

Gaps and opportunities

Minnesota is well positioned to make progress on reducing nitrate in groundwater. We have very good science on the sources of nitrate and its transport in the environment; we have funding for implementation of practices to reduce nitrate. But there are gaps to fill and opportunities to take up in responding to the challenge of nitrate in groundwater, and the scope and magnitude of the work needed to meet the challenge is large.

Our collective work to reduce nitrate in Minnesota's groundwater needs to accelerate and scale up, and we need to find innovative ways to implement nitrate-reducing practices. The NFMP, the 2025 NRS, and the Recommendation Report from the Southeast Minnesota Nitrate Strategies Collaborative Work Group clearly identify where work should be intensified and what actions need to be prioritized.

Reducing nitrate leaching in areas with vulnerable groundwater under row crop production is a priority area for ongoing work. The NRS identifies continuous living cover as a critical practice to implement and emphasizes the need to make transformative changes to cropping systems rotations to support this goal. Supporting the level of continuing living cover needed will likely take systemic changes to policies, markets, and financial incentives.

Collaboration in this area will be critical. There are some gaps that the state can help fill, but implementation of the actions to reduce nitrate depends on others. The state can support implementation and encourage others to undertake actions to reduce nitrate, by supporting programs that provide funding, incentives, technical assistance and education for project implementation. Potential opportunities include:

- **Funding** — The 2025 NRS identifies the need for *significant* funding to implement nutrient reduction strategies. Funding for BMP implementation needs to remain in place to support implementation. Furthermore, while additional support and funding has been provided in response to the concerns in Southeast Minnesota, dollars are needed for implementation in other parts of the state, including funding for private well testing and mitigation.
- **Conservation delivery** — The state can provide more support for conservation delivery programs, funding the people and organizations that get BMPs installed. This includes providing guidance and technical assistance and funding.
- **Market development** — Support initiatives that work to develop a market and infrastructure for continuous living cover crops.
- **Education** — The state can continue to support education and information on nitrogen BMPs. For example, the Nitrogen Smart education program has been in place for several years. We should evaluate its performance, build on the success, and determine if there are ways to improve.
- **Sharing Data** — As noted above, while progress has been made in sharing data on both the implementation of practices to reduce nitrate and nitrate conditions in groundwater — there is more to do. There remains a need to share groundwater data so that it is useful to everyone making decisions about groundwater protection. This includes providing overarching understanding information about groundwater conditions and the impact of nitrate reducing practices, how groundwater might impact wastewater and discharge, and other information.

Pesticides

Pesticides are another groundwater pollutant of concern, particularly in areas of Minnesota with vulnerable groundwater resources and where pesticides are used. Minnesota's Pesticide Management Plan (PMP) — developed beginning in 1990 and revised since — guides the MDA in its efforts to coordinate activities necessary to protect Minnesota's groundwater and surface water resources from pesticide contamination.

Monitoring and characterizing pesticides

The MDA operates a regional ambient groundwater monitoring network designed to target the uppermost groundwater that is most likely to be impacted by the routine application of pesticides in vulnerable geologic settings.

The MDA monitors and evaluates pesticides to identify if and where pesticides and pesticide degradates may exceed reference values that are developed to protect human health. In 2023, the MDA analyzed for 186 pesticide related chemicals in groundwater; in 2023 a total of 49 different pesticides were found in groundwater from samples taken at 168 sites in this network.[46] Following guidance in the PMP, the MDA has designated 5 pesticides as a groundwater "common detection" pesticides - acetochlor, alachlor, atrazine, metolachlor, and metribuzin.[47] These designations are primarily based on the detection of compounds formed when the parent compound degraded (known as breakdown compounds).

Another of MDA's key water monitoring programs is the Private Well Pesticide Sampling (PWPS) project. MDA began to analyze water samples through this project in 2014, to characterize the presence of pesticides in private wells with nitrate detections in areas of the state with vulnerable groundwater and row crop agriculture. Between 2016 and 2021, MDA sampled 5,700 private wells in 50 counties for up to 133 different pesticides or degradates. Pesticides or pesticide degradates were detected in 76% (4,324) of the vulnerable wells sampled in the early years of the PWPS Project. Seventy-five different pesticides or pesticide degradates were detected at least once. Most detections of pesticides or pesticide degradates were at low concentrations in comparison to reference values.

Regional trend analysis of the "common detection" pesticides shows stable or improving conditions in most regions of Minnesota. Some breakdown compounds of acetochlor and metolachlor are increasing in some regions; however, the concentrations are low relative to the MDH human health reference values. A detection of any currently registered pesticide approaching or over the MDH human health reference value is extremely rare in Minnesota.

Neonicotinoid insecticides have received notable attention in recent years. These insecticides are used to manage pests on a wide variety of agricultural crops (such as soybeans, corn, sugar beets, and potatoes) as well as plants in other setting (such as residential lawns, trees, and ornamentals). They can be applied in multiple forms, including seed treatments, soil drenches, granular products, and sprays. Neonicotinoids are soluble in water and do have the potential to leach into groundwater and surface water; they are a particular concern in surface water due to toxicity to aquatic insects.[48]

The MDA began analyzing water samples for neonicotinoids in 2010. Statewide ambient groundwater results since 2010 indicate that four of the neonicotinoids have been detected in groundwater in agricultural areas. These are: clothianidin (16% of samples), dinotefuran (<1%), imidacloprid (8%), and thiamethoxam (7%). Three detections of Imidacloprid over the human health-based reference value occurred in 2012, 2015 and 2016, however, in the region where these elevated detections were reported, detection frequency and 90th percentile trends are now decreasing. No other neonicotinoids were detected at or above reference values.

MDA is also finding degradates of cyanazine in groundwater in some areas of Minnesota, at concentrations above the health risk limit. Cyanazine (an herbicide) was commonly used on corn in Minnesota from the 1970s through the 1990s. It has not been registered for use since 2002 and therefore it and its degradates are considered "legacy" contaminants in groundwater. Although the parent compound is rarely detected in groundwater, the health risk limit is set for "total cyanazine", which adds together the parent and the degradates.

From 2019-2023, the MDA collected close to 4,000 samples from private wells to be tested for total cyanazine; it was detected in approximately 30% of the targeted wells. During this period, 176 private drinking water wells were identified with total cyanazine concentrations above the chronic HRL. A majority of the total cyanazine exceedances occurred in private wells completed in the Prairie du Chien or Jordan aquifers located in Dakota, Goodhue, Scott, and Washington counties.

MDA continues to offer testing to better define the local extent and magnitude in areas with known clusters of wells, or "hotspots", exceeding the total cyanazine HRL. MDA also shares cyanazine sampling results with MDH to inform MDH follow-up sampling at public water supply wells in the vicinity of total cyanazine exceedances in private wells.

In 2024, the MDA implemented a Private Well Mitigation Program to coordinate providing reverse osmosis (RO) systems to well owners previously identified as having high levels of cyanazine in their water (a HRL exceedance).

Successes

- **Strong monitoring network** — The MDA has well-developed and long-running regional monitoring networks that can track trends overtime, and allow for context for any pesticide detection
- **Low concentrations** — Detections of currently registered pesticides, and associated breakdown compounds over a human health reference value is rare.
- **Tackling cyanazine** — The MDA has been able to identify "hot spots" for the legacy pesticide cyanazine and has increased monitoring of private wells in these areas. MDA has also implemented a Private Well Mitigation Program to coordinate providing RO systems to well owners with levels of cyanazine in their water that exceeded the HRL exceedance.
- **Collaboration** — The MDA annually convenes a Pesticide Management Plan Committee which reviews monitoring results and provides recommendations for future actions. Committee recommendations have resulted in designating five pesticides as a "common detection" pesticide, and initiated the development of pesticide specific BMPs for them.
- **Pesticide Best Management Practices** — The MDA continues to promote pesticide Best Management Practices for the common detection pesticides and neonicotinoids in surface waters.

Gaps and opportunities

- **Changing pesticide use patterns** — The management of weeds that have developed resistance to glyphosate is changing pesticide use, including what products are used. Glyphosate has never been detected by the MDA in groundwater, whereas replacement herbicides are more likely to enter groundwater from routine use.
- **Statewide work** — Private well pesticide testing is concentrated in areas of the state with vulnerable groundwater resources and agricultural land use. Increased

resources could allow this to be expanded to other agricultural regions of the state to provide residents with the opportunity to test their well water.

- **Support for measuring pesticides effectively and consistently** — Lab testing for pesticides often requires expensive specialized equipment and testing methods, therefore testing is often limited. Additional funds could be used to expand laboratory capacity to analyze more samples or look for additional pesticide compounds in the samples.
- **Risk assessment** — For some detected pesticide compounds, a Health Risk Limit value is not available to assess risk from consuming the water.

Per- and polyfluoroalkyl substances (PFAS)

As described in Minnesota's PFAS Blueprint, published in 2021, per- and polyfluoroalkyl substances, commonly known as PFAS, are an enormous family of chemicals and now pervasive in the environment. Called "forever chemicals", they do not break down and can bioaccumulate in both humans and other living organisms, with some known to be toxic. With more than 5,000 structures and over 9,000 identified chemistries, PFAS are present in the environment and will remain so for generations.

In Minnesota, the first "discovery" of PFAS contamination occurred in the early 2000s, when drinking water contamination was found in the eastern Twin Cities metropolitan area. Since then, PFAS have been detected in water, sediment, soil, and fish in different places around Minnesota. In addition, as we have learned more about PFAS compounds, the science shows that PFAS is harmful at lower concentrations than previously thought.

Minnesota's groundwater is affected by both industrial and diffuse sources of PFAS, and significant work is being done to characterize and respond to the PFAS problem.

Monitoring and characterizing PFAS

There is well-known contamination in the eastern Twin Cities metropolitan area resulting from the disposal of fluorochemical manufacturing wastes primarily at four locations. The contamination in this area from this site extends over 150 square miles and affects the drinking water supplies of over 140,000 Minnesotans.

There have been detections of PFAS in groundwater outside of this large, well-known area of industrial contamination, including detections at concentrations higher than health-based guidance values and standards set by both the MDH and EPA for drinking water.

The MPCA has assessed PFAS contamination in the groundwater since 2006, with the largest sampling campaigns occurring in 2013, 2019, and 2024. The most frequently detected chemicals in these sampling efforts were a type of PFAS called perfluoroalkyl acids, which includes the two most well-known PFAS compounds — PFOA (perfluorooctanoic acid) and PFOS (perfluorooctane sulfonate). These two PFAS compounds have been largely phased out of use, and other PFAS compounds have been used as substitutes. MPCA sampling has shown monitoring wells with PFOA and PFOS concentrations in excess of the health-based guidance values. Most of these exceedances were in shallow wells specifically designed for monitoring, and this water is not consumed. More recent MPCA sampling campaigns have looked for PFOA and PFOS substitutes, but these have not been detected in any samples collected to date.

MDH recently tested over 900 community water supply systems for PFAS and found that some systems had PFAS concentrations in their water that were in excess of the health risk index based on MDH guidance values. Some of these systems are outside of the Twin Cities metropolitan area.

MDH began monitoring 150 private wells for PFAS in 2024, as part of an effort to characterize groundwater on a watershed-scale around the state. In three watersheds representing southwest, central, and southeast Minnesota, PFAS were detected in approximately 20% of wells. In 2025, PFAS will be monitored in private wells in southeast Minnesota and the central sands region.

PFAS response

Minnesota state agencies are working to respond to the overall threat of PFAS contamination by preventing PFAS pollution wherever possible; managing PFAS pollution when prevention is not feasible, or pollution has already occurred; and cleaning up PFAS contaminated sites.

Minnesota's PFAS Blueprint recognizes that significant actions are needed to prevent adverse effects on human health and the environment from PFAS pollution. The Blueprint identifies ten priority areas for addressing PFAS as the state agencies work to incorporate PFAS into their existing suite of tools and programs and to identify new actions that are needed.

Several of the priority areas directly involve actions to address PFAS contamination in groundwater. These include:

- **Measuring PFAS effectively and consistently**. MPCA and MDH are working together to develop and update sampling and analytical guidance for PFAS compounds and to measure PFAS levels around Minnesota.
- **Quantifying PFAS risk to human health.** MPCA and MDH evaluate the human and environmental toxicity of various PFAS compounds.
- **Limiting PFAS exposure from drinking water.** The agencies work together to reduce exposure to PFAS in drinking water by implementing regulatory standards and human health-based water guidance values. MPCA continues to address PFAS contamination in private wells associated with known sources of PFAS.
- **Remediating PFAS contaminated sites.** MPCA's Remediation program partners with MDH and state contractors to sample for PFAS in groundwater near contaminated sites where drinking water wells may be impacted.
- **Preventing PFAS pollution.** The agencies are working to implement multiple statutory prohibitions on PFAS, including Amara's Law, which prohibits the sale of products with intentionally added PFAS and prohibitions on PFAS in Class B firefighting foams, food packaging, and pesticides. State agency enforcement of PFAS in product prohibitions is the crux of tackling PFAS in Minnesota.
- **Protecting ecosystem health.** Understanding the fate and transport of PFAS compounds throughout the environment is crucial for our understanding of how to address (and prevent) groundwater contamination.
- **Managing PFAS in waste**. MPCA programs are addressing how to reduce or eliminate PFAS from entering the environment through permitted waste releases.

Other priority areas are to reduce PFAS exposure from fish and game consumption; understand risks from PFAS air emissions; and limiting PFAS exposure from food.

Successes

Since the publication of Minnesota's PFAS Blueprint, state agencies have had some significant successes in moving our work on PFAS contamination in groundwater forward.

- **Measuring PFAS effectively and consistently.** Together, the agencies are expanding monitoring and understanding of PFAS levels in groundwater across Minnesota. MDH has expanded analytical capacity for PFAS at their Public Health Lab, which is responsible for analyzing PFAS samples from community water systems and state-sampled private wells across Minnesota, and now has capacity to analyze PFAS samples using a variety of analytical methods.

  Analysis of PFAS has been incorporated into regular drinking water and groundwater monitoring programs. MDH has been a leader in sampling for PFAS in drinking water since 2006; they have now sampled for PFAS compounds at over 99% of the community water systems in Minnesota and have recently started sampling noncommunity water systems. In 2024, MDH also conducted nontargeted analysis of PFAS in source and finished water at public drinking water systems sourced by groundwater, with an emphasis on systems that have PFAS treatment in place. The goal of this monitoring and analysis is to understand the presence of the vast array of PFAS compounds that cannot be measure through conventional analytical methods, as well as to characterize the effectiveness of PFAS removal systems on these compounds.

  MPCA's ambient groundwater monitoring program successfully sampled all network wells for PFAS in 2024 and as of 2025 the program will include annual sampling and analysis for PFAS across the entire well network.

- **Quantifying PFAS risk to human health.** MDH has been actively reviewing new toxicological data about the risks of PFAS as they become available. MPCA and MDH continue to evaluate the human and environmental toxicity of various PFAS compounds, including through exposure from drinking water. MDH has published health-based values for six PFAS in drinking water and is in the process of finalizing a rulemaking that would solidify those values as health risk limits in Minnesota rule.

- **Limiting PFAS exposure from drinking water.** A key tool in limiting exposure to PFAS in drinking water is working to implement regulatory standards and human health-based water guidance values that protect human health.

  MDH is working with community water systems to, if needed, come into compliance with EPA's maximum contaminant levels (MCLs) for five PFAS and one PFAS mixture, which went into effect as part of the Safe Drinking Water Act in June 2024. MDH is also in the process of developing implementation guidance for the health-based values (HBVs) and health risk limits (HRLS) that they have derived for PFAS, some of which are significantly lower than EPA's MCLs.

  MPCA has incorporated EPA's MCLs into Minnesota rule as water quality standards that need to be met in Class 1 waters. Class 1 waters include groundwater and surface waters used for domestic consumption.

MPCA also continues to administer 3M Settlement funds in the East Metro to help impacted communities gain access to safe drinking water. Broadly, MPCA's Superfund programs continue to provide safe drinking water to impacted communities across the state where wells have been contaminated by PFAS.

- **Remediating PFAS contaminated sites.** The MPCA continues to address PFAS contamination in groundwater, including piloting new technologies to remove and destroy PFAS in-situ and providing treatment options for Minnesotans with contaminated private wells.
- **Preventing PFAS pollution.** The passage of Amara's Law, which prohibits the sale of products with intentionally added PFAS, is a major success in preventing PFAS pollution. Amara's Law went into effect in January 2025. The prohibition includes consumer products in eleven categories, with a full prohibition on almost all products with intentionally added PFAS slated to begin in 2032. Minnesota also has statutory prohibitions on PFAS in Class B firefighting foams, food packaging, and pesticides.

  MPCA has been working with stakeholders to implement statutory prohibitions on intentionally added PFAS in firefighting foams, food packaging, and consumer products. Product testing to enforce prohibitions on PFAS in food packaging is underway, and plans for product testing for PFAS in consumer goods subject to Amara's Law are in development. MDA has published two legislative reports detailed what is known about PFAS in pesticides, and is preparing to implement statutory prohibitions on intentionally added PFAS in pesticides, fertilizers, and other agricultural products and educating affected parties about upcoming changes.
- **Protecting ecosystem health.** MPCA and partners are conducting several projects looking at PFAS in the environment. This includes two MPCA-led projects supported by the Legislative-Citizen Commission on Minnesota Resources to

Surface Active Foam Fractionation

In 2022, MPCA began a pilot-scale study of Surface Active Foam Fractionation (SAFF), which is a PFAS separation and concentration technology. The result is a highly concentrated liquid waste which can then be further processed to achieve either mineralization (conversion of the PFAS molecules to salts and other non-toxic products) or destruction of PFAS. MPCA worked with multiple contractors to complete bench-scale tests of various PFAS destruction technologies using SAFF concentrate. Four technologies were tested including electrochemical oxidation, UV-activated photoreduction, supercritical water oxidation (SCWO), and thermal arc plasma. Based on the results of these initial bench-scale tests, the four destruction technologies evaluated have the potential to destroy or mineralize at least 99% of PFAS (with some variation). An in-depth discussion of the SAFF pilot test and destruction bench-scale results, which took place in the Project 1007 area of the East Metro, will be published in the 3M Settlement Feasibility Study.

investigate PFAS in air (deposition) and ambient soil concentrations of PFAS across Minnesota. The MPCA has committed to considering aquatic life water quality standards for at least some PFAS compounds as part of the draft water quality standards workplan for 2025-2027, developed under the MPCA's Triennial Standards Review (TSR).

- **Managing PFAS in waste.** In 2022, MPCA published the PFAS Monitoring Plan, which outlined a path forward for programs to understand and address PFAS at municipal and industrial facilities across the state. Following that work, MPCA staff began working with facilities to identify whether PFAS were present in discharge, and Findings were published in 2024. Based on those findings and evolving research, programs are developing and implementing strategies to reduce or eliminate PFAS discharges to the environment.

Gaps and opportunities

Dealing with PFAS pollution is a large and complex undertaking. The PFAS Blueprint identifies many key areas of opportunity for moving forward on addressing PFAS; although progress has been made on several and the agencies are continuing to work to integrate PFAS into existing tools and programs, much more progress is needed.

First and foremost, addressing the current and future impacts of PFAS — broadly and in groundwater — will require continued resources and support from state leadership. Ongoing support is critical because this is an area of rapidly evolving knowledge growth, from understanding human health effects, treatment technologies, to replacement chemistries and avoidance approaches.

Some specific opportunities that are especially important to take advantage of in relation to PFAS and groundwater include (but are not limited to) the following:

- **Support for measuring PFAS effectively and consistently.** Despite significant progress, increased analytical lab capacity is needed both in Minnesota and for commercial labs across the country (and internationally). There needs to be continued support and funding for MDH's Public Health Lab, the Minnesota Environmental Laboratory Accreditation Program, and support for commercial labs to expand to meet future analytical demand. Continued support and funding for monitoring PFAS across Minnesota's ambient well network is also critical for detecting new or spreading (previously unknown) groundwater contamination.
- **Support for limiting PFAS exposure from drinking water.** In a recent legislative report on PFAS removal, MPCA and MDH identified four strategic priorities to address PFAS contamination in drinking water. Supporting these priorities would help reduce PFAS exposure from groundwater used as drinking water.
    - Focus on providing safe drinking water in communities not party to legal settlements or with assigned Responsible Parties under the Superfund law.
    - Expand access to private well testing for PFAS (some of this work is already beginning through MDH's DWAMP).
    - Plan for drinking water treatment needs at contaminated non-community water systems.
    - Subsidize or cover the costs of point-of-entry treatment at any residences with PFAS-contaminated wells.

- **Resources for quantifying PFAS health risks.** Like most contaminants of emerging concern, the availability of toxicological data for assessing the human health impacts of PFAS is limited for most PFAS compounds. Having additional human health risk assessors or epidemiologists to further integrate New Approach Methodologies (NAMs) into current risk assessment practices will aid in the development of additional risk assessment guidance to further protect Minnesotans from drinking contaminated groundwater.
- **Resources to implement PFAS prohibitions.** Implementing Amara's Law and other PFAS prohibitions will continue to need staff and funding resources to support rulemaking and compliance and enforcement. These prohibitions are essential to preventing future groundwater contamination.
- **Research on PFAS fate and transport.** Research to understand the fate and transport of PFAS through Minnesota's environment will better inform how to manage and remediate impacted areas and protect ecosystem health. This includes transformation of PFAS, bioaccumulation in various plants and animals, how PFAS moves through food webs, and how PFAS moves, particularly in air and through soil.
- **Investigation into PFAS in waste.** Continued investigation into the industrial sources and subsequent releases of PFAS into wastewater, landfill leachate, landfill gas, through fugitive or stack emissions, and other wastes are necessary to understand how to prevent those PFAS from entering the environment. MPCA programs are addressing how to reduce or eliminate PFAS from entering the environment through permitted waste releases.
- **Research into PFAS treatment.** A better understanding of the potential PFAS treatment and destruction technologies that could be used prior to environmental releases is critical for addressing PFAS that are currently in the waste stream.

Chloride and salts

Excessive chloride and other salts in groundwater may restrict its use for drinking and can also degrade aquatic habitat if it is transported to surface waters. This pollution is considered "permanent" because once in the groundwater, chloride is not broken down by typical environmental processes and will remain there until it is transported either downward to deep aquifers or to streams, lakes, and wetlands as groundwater inflow.

High chloride concentrations impart a salty taste in the water that consumers find objectionable and can change the chemistry of the water such that metals like lead and copper can be leached from plumbing fixtures.

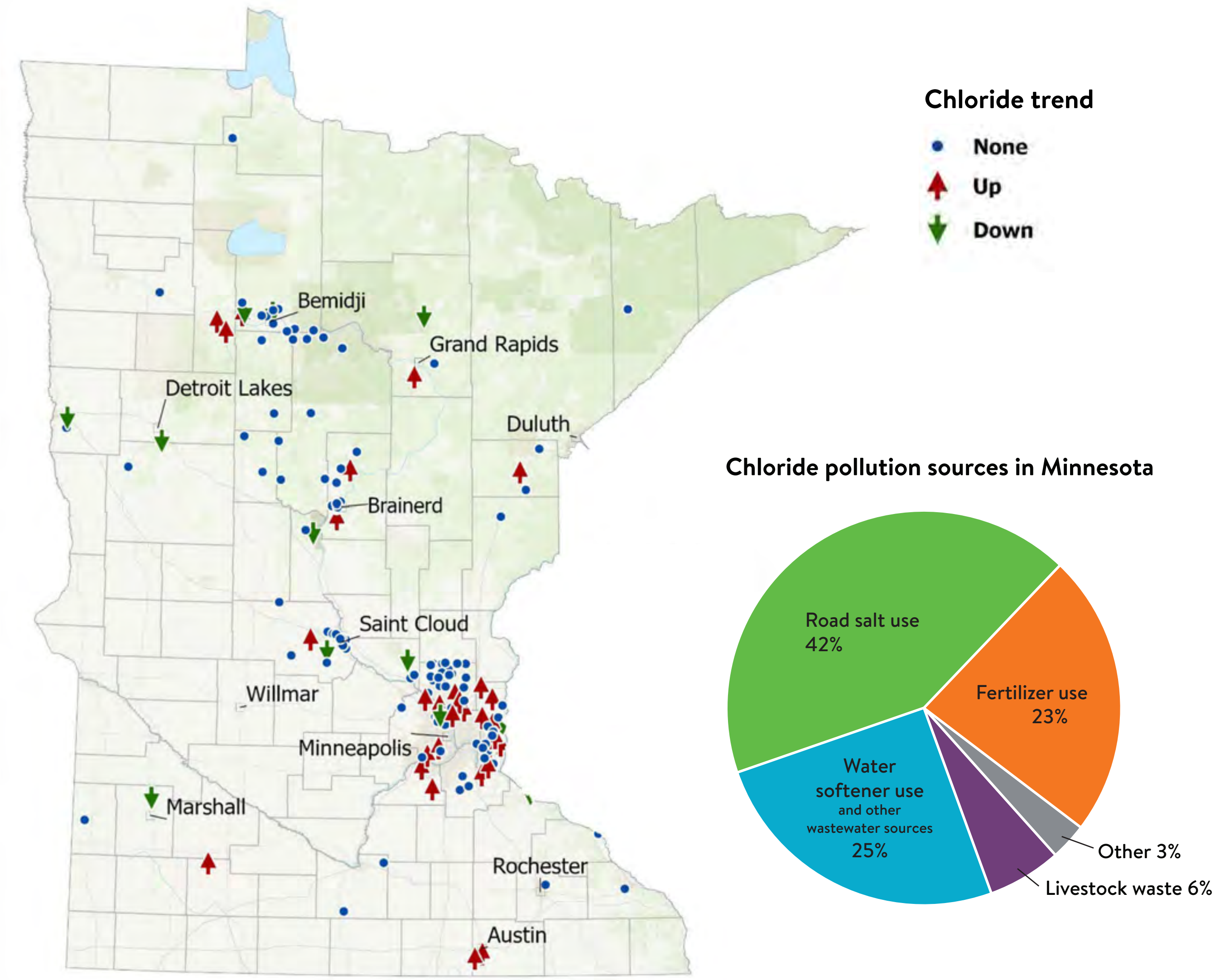
Monitoring and characterizing chloride

The 2015 EQB Water Policy Report identified chloride pollution as an emerging issue, coming from winter deicing chemicals and water softeners. Since that time there has been significant work to further understand and address chloride pollution. For example, MPCA has identified additional sources of chloride, including fertilizer and dust suppressants. Much more information on chloride is available in the MPCA's statewide Chloride Management Plan.

The MPCA and MDA ambient networks and the DNR's County Geologic Atlas Program sampled over 1,900 wells for chloride from 2018-2023. The two ambient networks generally focused on sampling wells located near the water table. These data showed that chloride concentrations continued to be highest in the surficial sand and gravel aquifers, with concentrations as high as 1,370 mg/L measured in the state's surficial quaternary water table aquifers. When chloride trends occurred, they were generally upward or worsening.[49]

These results indicate that efforts need to be made to address this contamination. Over 65 of the state's streams and lakes are impaired due to excessive chloride concentrations in the water.

Figure 15. Chloride trends in Minnesota's groundwater, 2013 - 2023
(From MPCA's ambient groundwater monitoring network)



Source: University of Minnesota, 2019

Chloride response

The MPCA's chloride reduction program, created in 2019, works to reduce chloride pollution entering Minnesota's water. Work across four key areas — collaboration and partnerships; training and education; direct assistance; and resources — provides communities and organizations across Minnesota with assistance and support to identify sources of chloride and take steps to reduce chloride pollution at the source to protect water resources. A wide range of tools, resources, training and assistance are offered to achieve the program's goal.

Successes

Much of the chloride reduction program's success can be traced to collaboration and strong partnerships with MPCA programs, MnDOT, local cities, counties and watershed organizations, and out of state environmental agencies. Collaborations have allowed the program to have a larger impact and make faster progress than would otherwise have been possible. These partnerships are a critical part of the work being done to reduce chloride pollution and have had a direct benefit to Minnesota's water resources. Some specific programmatic success include:

- **Expansion of Smart Salting training program.** Smart Salting training helps improve operator effectiveness educate property owners, plumbers, environmental professionals and policy makers and reduce chloride pollution while keeping roads, parking lots, and sidewalks safe. State funds and the authority to charge a small fee for the program have allowed the training program to operate statewide with a range of training platforms, materials, and audiences educated. Participating organizations have been able to reduce their salt use by 30-70 percent.

Figure 16. MPCA Smart Salting Certifications

- **Chloride reduction grant program.** In 2021 the MPCA created a grant program to provide financial assistance to communities with elevated chloride conditions to reduce them at the source. The MPCA Chloride Reduction grants have allowed communities to reduce chloride from water softening activities by up to 68%.
- **Partnership with Minnesota GreenCorps.** The MPCA Chloride Reduction Program worked with the Minnesota GreenCorps program to integrate and encourage chloride reduction into the work of GreenCorps members. This partnership has resulted in 59 communities and organizations across Minnesota getting direct assistance in educating and developing local programs and materials to reduce chloride pollution.
- **Expansion of the Smart Salting Tool (SST).** The SST is a free online resource that provides estimates of the specific sources of chloride, education about each source, guidance and support to users for reducing chloride from all sources at the community level. Collaboration with MPCA permit programs provides users opportunities to help fulfill chloride permit requirements.

Climate and groundwater quality

As noted in the 2020 State Water Plan, Minnesota's climate and water are closely connected. "The amount and timing of precipitation influences how much water soaks into the ground... precipitation patterns also determine the availability and demand for water."

Although the impact of climate change on groundwater systems is not well studied, precipitation patterns will affect how water-soluble contaminants move from the land surface into the groundwater. Precipitation runoff is also the key path for moving pollutants from the land surface into groundwater. Minnesotans collectively plan and implement numerous water quality practices designed to reduce the pollutants going from our land into our waters (both surface and groundwater).

As noted in Minnesota's Climate Action Framework, "climate change is happening now, and we are on course for more frequent, widespread, and intense weather events with cascading and complex effects." Extreme weather changes hydrology and how water cycles through our systems.

Climatic conditions directly affect groundwater because the timing, persistence, and intensity of weather conditions influences how water infiltrates from the ground surface into subsurface aquifer systems. Climate change is projected to result in larger rainfalls more often, more frequently creating the conditions that mobilize large amounts of pollution from the land surface into groundwater. As noted by Johnson, et al., "Climate change can also directly affect water quality practices and systems. In many locations, practices designed for historical climatic conditions may not have the capacity to handle increases in heavy precipitation or otherwise function as intended."[86] Heavy precipitation may therefore impact the effectiveness of our practices to support water quality, raising challenges to achieving our goals. Water quality practices will need to be designed and implemented to be resilient to extreme weather impacts now and into the future.

Climate change can also result in the potential for longer dry spells and drought. Dry periods often lead to more intense pumping of groundwater, which can mobilize geogenic contaminants like manganese and move contaminants between aquifers that are usually separate but are temporarily connected due to aquifer drawdown.

Climate change may also impact the use of certain chemicals on the land surface. For instance, warmer winter temperatures may also affect (likely increasing) salt applications made to de-ice paved surfaces, especially if the state's winter precipitation consists of more freezing rain or ice compared to snowfall. A warmer climate will also likely impact the survival of pests and enable new pests to move into the state. Pesticides may need to be used to control these pests.

Overall, climate change is likely to make it more challenging to protect groundwater quality from extreme weather events. High intensity precipitation impacts the quality of water runoff — carrying more and different pollutants into our aquifers. In particular, high intensity precipitation or "mega-rain" events increase the likelihood of flooding.[87] Flood conditions are among the most adversely impactful to groundwater quality, especially in shallow aquifers.

Because floods result in water getting into places where it normally isn't, floodwaters often carry unusual pollutants. This can include household hazardous waste (like cleaning solutions or pesticides), industrial waste, or materials usually stored in above or underground storage tanks (like petroleum fuels). Flooding can also damage subsurface sewage treatment systems (SSTS/septic tanks) and result in wastewater treatment facilities overflowing. Both can result in significant bacterial contamination. It is of particular concern when floodwaters result in contaminated drinking water wells.

Marshall and Worthington Chloride Reduction

Consulting firm Bolton & Menk received a Chloride Reduction grant from the MPCA in 2021 to work with Marshall and Worthington officials to create a handful of incentives, including $500 to $700 rebates for replacing timer-based water softeners, $50 payments to contractors for every water softener optimization, and $500 payments for residents who got rid of their water softeners altogether. In Marshall, nearly 300 homeowners and businesses took part in the program, reducing salt use by up to 320,000 pounds per year. A similar rebate program for Worthington residents and businesses led to more than 200 replacement and retrofitted water softeners, reducing salt use by as much as 212,000 pounds per year.

Gaps and opportunities

Reducing chloride at the source is needed throughout the state of Minnesota, not only to restore already impacted waters but also to protect all water resources. There are multiple sources to consider, a variety of options to reduce chloride, and a large geographical area to address. Implementation of policies that support chloride reduction are needed to move beyond voluntary chloride reduction actions.

Geogenic contaminants

When thinking about groundwater contamination, we usually think about pollutants that are human-made. However, groundwater can also be subject to high levels of naturally occurring substances that are harmful. The term “geogenic contaminants” refers to chemicals that occur naturally in groundwater due to dissolution of minerals from the water-bearing rock or soil. We are learning just how common these substances are in Minnesota. Manganese, arsenic, sulfate, lithium, and radium are geogenic contaminants that have been commonly detected in Minnesota’s groundwater. As our understanding of the toxicology, occurrence, and magnitude of geogenic contaminants has increased, so has the concern for reducing Minnesotans’ exposure to these contaminants in drinking water. It is important to understand if these contaminants present a risk, and more data is becoming available that indicates potential levels of concern.

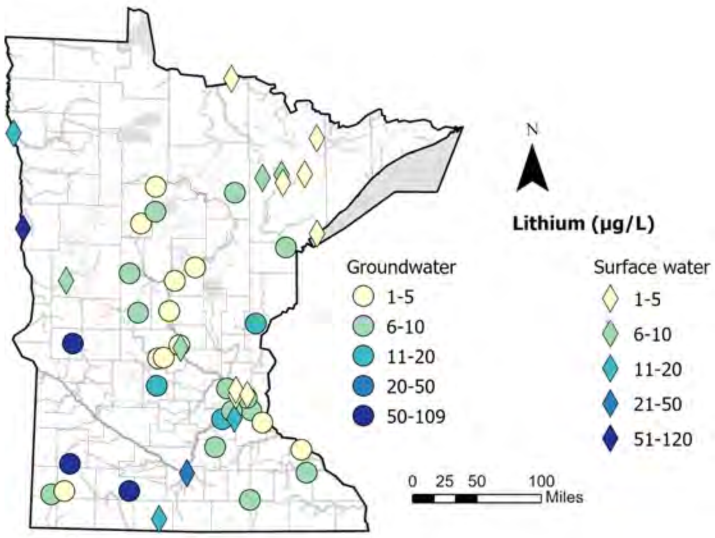
Monitoring and characterizing geogenic contaminants

While these contaminants are found across the state, they occur more commonly and at higher levels in some areas than others due to the geologic setting. For example, radium has been found at elevated levels in both the surficial and sandstone bedrock aquifers in Southeastern Minnesota. Manganese, arsenic, sulfate, and lithium are commonly found at elevated levels in the southwest and western portions of the state, which are characterized by clayey and water-poor surficial aquifers.

Many of these contaminants are of concern due to their known health effects. Arsenic and radium are carcinogens that can produce long-term health risk at relatively low concentrations in drinking water. Arsenic is detected in almost half the wells drilled in

Minnesota. Drinking water with elevated manganese levels over the short term is associated with developmental and nervous system effects, particularly in infants. Manganese is found at levels of concern for infants in half the wells constructed in Minnesota. Elevated levels of sulfate can cause dehydration and gastrointestinal issues, particularly in infants. Relatively little is known about the long-term health effects of lithium in drinking water, but its ubiquity in Minnesota drinking water sources warrants further study and MDH is currently reviewing scientific studies on health effects and lithium.

Figure 17. Statewide lithium distribution (from MDH's Unregulated Contaminant Monitoring Project, 2019)



Response to geogenic contamination

Geogenic contaminants pose unique challenges compared to point source pollutants due to their potential for widespread regional occurrence and their permanence. They may also present disproportionately high potential impacts to private well users, who are individually responsible for ensuring their drinking water meets safe levels and are not protected by federal regulations. Outreach and education for private well users are, therefore, of utmost importance. Unlike public water systems, there are few financial resources to assist private well owners. Social science indicates that when people feel that the cost of treatment may be prohibitive, they will avoid testing to learn what may be in their private well.

While the Safe Drinking Water Act requires public water systems to test and address arsenic and radium, gaps remain in testing for and addressing manganese, sulfate, and lithium in public water systems. Additionally, private wells are tested for arsenic when the well is first constructed; any additional testing is up to the well owner. (For more information, see MDH's web viewer of arsenic in private wells.)

To help bridge the gaps in information and protections for public water systems and private well water around these contaminants:

- MDH is working to develop a health risk assessment for lithium in drinking water that will provide context for the observed occurrence of lithium in groundwater.
- MDH works closely with water systems to test for manganese and provide guidance on how to address manganese if detected at high levels.
- MDH works with partners across the state to provide outreach and education about well testing, encouraging all private well households to test for two

geogenic contaminants: arsenic and manganese, as well as three non-geogenic contaminants: coliform bacteria, nitrate, and lead.

- MDH has launched a new initiative, the DWAMP, where one of the objectives is to monitor groundwater quality on a watershed scale throughout the state by sampling private drinking water wells.

Successes

- **Funding.** Since 2014, MDH has received Clean Water Fund dollars in most years to provide outreach and education to private well users about how to test their well, including for arsenic and manganese. This includes funding (through grants, starting in 2020) local well testing programs in 20 counties and one Tribal nation.
- **Monitoring.** All community water systems have been tested for manganese, which is not required under the SDWA. This testing effort has helped with mitigation responses to better protect vulnerable populations. Clean Water Funds also support the DWAMP, which launched in 2024 and helps in understanding ambient drinking water source conditions for public water systems and private wells.
- **Research.** Clean Water Funds have also enabled MDH to study the occurrence of arsenic and radium in private wells.

Gaps and opportunities

There are often gaps in dealing with geogenic contamination because these contaminants cannot be addressed with many of the typical approaches used for anthropogenic contaminants. While states like Minnesota have arsenic and manganese present in their groundwater, there is no resulting increase in funding to address these contaminants in public water systems. There is also no legal support or financial framework for addressing geogenic contaminants in private wells (unlike anthropogenic contaminants such as PFAS or nitrate in some areas). Recent efforts have focused on educating local government partners about private well challenges and building their capacity to interact with private well owners and users.

Given these gaps, there are substantial opportunities to establish equitable access to private well testing and mitigation, including:

- **Education, awareness, and partnerships.** Because these contaminants are ambient or naturally occurring, there is a need to share information about the importance of tackling them and to empower new partners to do more in this arena. Specific to private wells, there is a need to conduct outreach and provide educational resources and technical assistance to private well users for well testing and mitigation. This includes establishing a peer-to-peer learning network for private well owners.
- **Funding.** Increase funding to address geogenic contaminants in public water systems. Provide financial resources for private well users for well testing and expand income-based financial assistance for mitigation, which could take the form of treatment, well repairs, a new well, and making an old well viable again.
- **Analysis.** Establish easy access to laboratories that accept water samples from private well users. This includes increasing the number of accredited laboratories that accept samples from private well users and the number of laboratories that provide courier services.

Groundwater quantity

As Minnesota's population and economy grow, so does our use of water. Groundwater use has increased by 40% between 2000-2023, and that trajectory is largely projected to continue. Minnesota is considered to have abundant water resources; however, our groundwater supply is finite.

Across Minnesota there are increasing demands on our groundwater for multiple uses, making it more likely we might not have sufficient groundwater — at least in certain parts of the state — to meet the goal of Minnesotans having equitable access to and using groundwater sustainably to meet our common needs, while also leaving water for future generations. A lack of groundwater can impact access to drinking water, disrupt agricultural practices, hinder economic growth and development, and adversely impact the land surface and ecosystems.

This section of the report provides information on the general availability of groundwater across the state; how water is used in Minnesota and potential future uses of water; and then discusses the tools and programs that are used to manage and protect groundwater quantity. As noted in EQB's 2015 report, there continue to be warning signs of risk of groundwater depletion — particularly in certain areas of the state — and our groundwater use trends may not be sustainable.

Groundwater quantity and geography

Groundwater resources are not evenly distributed across the state. Groundwater availability depends upon the types of the sediments and rock layers beneath the land surface. Minnesota's geology includes shallow sediments (clay, sand and gravel) deposited by recent glaciers and streams and bedrock (limestone, sandstone, granite) deposited by ancient seas and even more ancient volcanism. The properties of the sediment and rock determine whether aquifers are present and whether an aquifer is only able to support limited uses or if it is capable of supporting larger withdrawals.

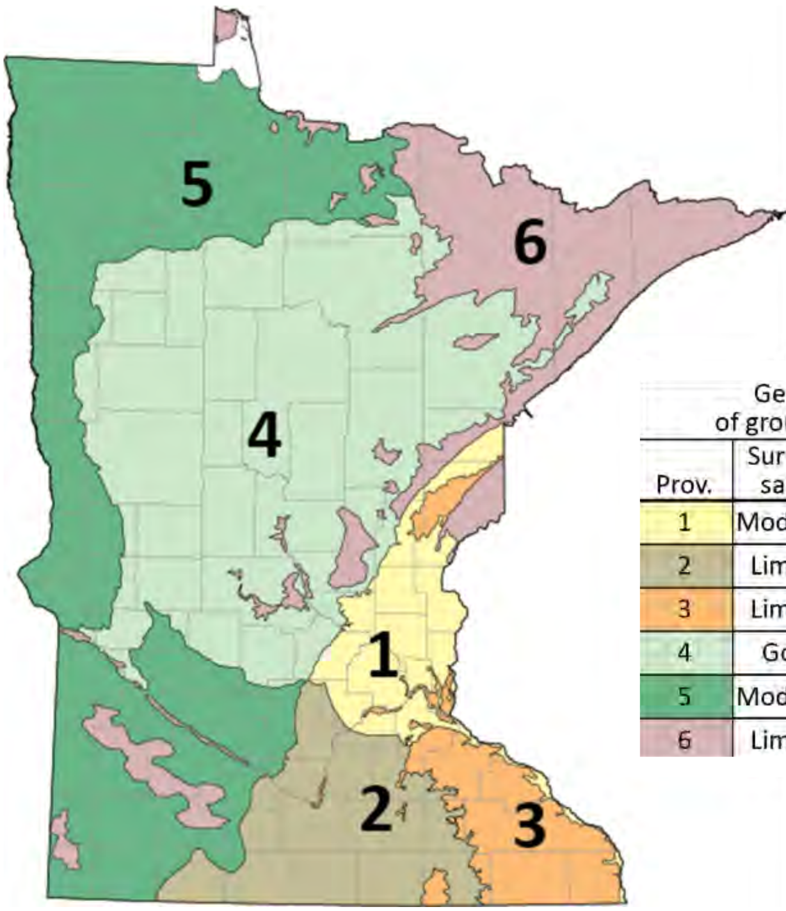
The Minnesota Groundwater Provinces map summarizes regional differences in aquifers and groundwater resources.

Introduced in 2001, the 2021 version incorporates updated geologic mapping completed by the Minnesota Geological Survey. The map combines the regional characteristics of two general types of aquifers: unconsolidated glacial sediments and bedrock comprising a wide range of rock types. This results in an illustration of the six groundwater provinces of the state distinguished by the combination of physical attributes of their underlying geology (thickness, lateral extent, permeability, and porosity type).

Each province has a unique combination of groundwater resources and management issues. It is important to note that local variability in geology can affect the availability of groundwater, therefore the map is not intended for site-specific applications.

Province 1 includes much of the Twin Cities metropolitan area. Plentiful and easily accessed bedrock groundwater supplies continue to provide a key resource for growth of the Twin Cities. Even with plentiful supplies, groundwater withdrawal from the bedrock has been shown to impact trout streams, calcareous fens and large recreational lakes.

Figure 18. Map of groundwater provinces and table of water availability



General availability of groundwater by source			
Prov.	Surficial sands	Buried sands	Bedrock
1	Moderate	Moderate	Good
2	Limited	Moderate	Good
3	Limited	Limited	Good
4	Good	Moderate	Limited
5	Moderate	Limited	Limited
6	Limited	Limited	Limited

Continued growth along the northern edge of the region has led to recent domestic well interferences, and treating PFAS contamination will require pumping large volumes of water in the east metro.

Province 2 has limited shallow sands; however, buried sands locally provide sufficient volumes for irrigation. Sandstone and carbonates (e.g., limestone) provide most of the high-volume groundwater utilized by municipalities and industries. Quarry dewatering for removal of sandstone and dolomite has impacted nearby calcareous fens and domestic water supplies. Groundwater from bedrock aquifers will support continued municipal and industrial growth.

Province 3 is dominated by karst landscapes. Surficial and buried sands are less than 50 feet thick in what is known as the "driftless area" of Minnesota. The lack of shallow sediments has allowed the development of karst topography, including features such as sinkholes, in the thick and extensive bedrock carbonates and sandstones. The large number of springs and cold-water trout streams found in the deeply incised valleys depend on groundwater discharge. Increased pumping by the City of Rochester from aquifers that discharge to local streams and calcareous fens presents unique challenges moving forward.

The Mississippi River and its tributaries receive groundwater discharge from the thick, laterally extensive surficial and buried sands and gravels as they meander through Province 4. These aquifers support the lakes and wetlands which are the economic drivers for local tourism. Agricultural irrigation relies on these water-rich sands and gravels. However, the many groundwater users can negatively impact streams and wetlands, and the shallow sand is susceptible to contamination.

Province 5 is covered by fine-grained sediments punctuated by surficial or buried sand aquifers of limited extent. Glacial Lake Agassiz sediments dominate the north. Thick lake clays occur along the Red River basin while former lake beach ridges support high volume appropriators. Rural water systems, sourcing groundwater from surficial or buried sands, deliver water through county-sized infrastructure to farmsteads throughout Province 5. The high demands placed on these limited aquifers has caused groundwater depletion problems in some locations - i.e., not leaving enough water for future generations. In other locations, groundwater pumping has caused negative impacts to groundwater-dependent ecosystems like calcareous fens. The underlying Cretaceous shales and sandstones are commonly buried deeply beneath glacial sediment and are provide limited water which is sometimes of poor quality.

Province 6 includes exposed or very shallow Precambrian bedrock. There are very limited surficial sediments, which typically are not considered an aquifer.

Groundwater uses

As noted in the introduction, groundwater has many uses; most, if not all, of these uses are "consumptive" uses. According to the DNR, consumptive use is water that is withdrawn and then not returned to its original source.[50]

Minn. Stat. 103G.261 sets out priorities for consumptive uses of water (from all sources, not just groundwater). The water use priorities are:

1. Domestic water supply; and as a contingency measure for power production
2. Uses less than 10,000 gallons per day (gpd)
3. Agricultural irrigation and processing of agricultural products that uses more than 10,000 gpd
4. Power production
5. Other consumption over 10,000 gpd
6. Nonessential uses

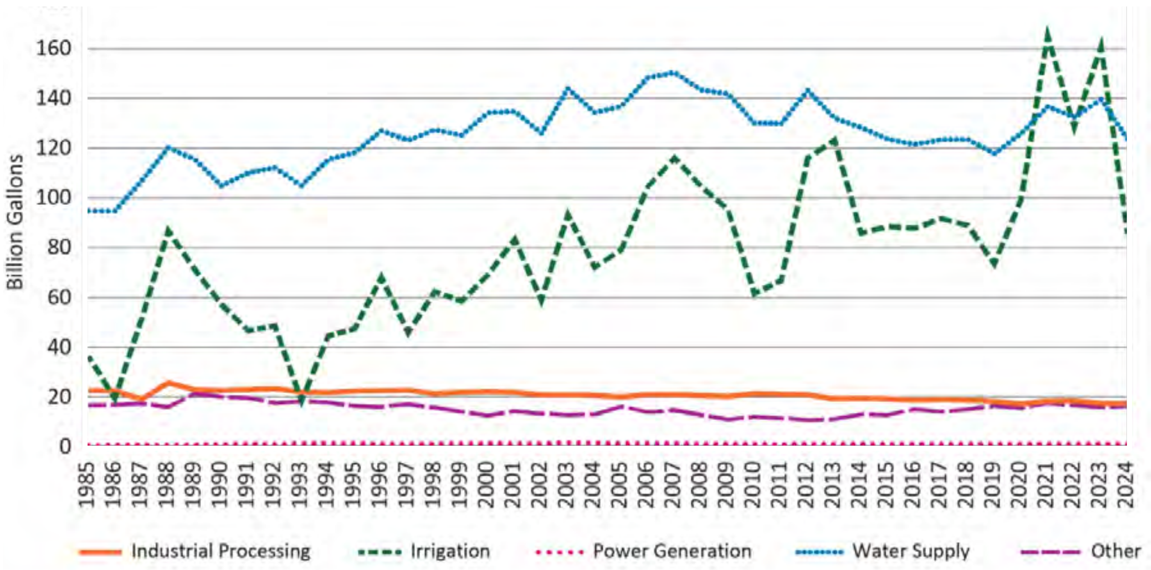
Categories of water use in Minnesota include:

- **Power generation.** When looking at all water consumption, this is the largest use; much of this water is used for cooling, is sourced from surface water, and is nonconsumptive because it is returned to the original sources.
- **Water supply.** Water for public, private, rural water, and institutional uses is the next largest use, and relies on both surface and groundwater sources.
- **Irrigation water.** Watering agricultural crops, golf courses and athletic fields, landscapes, etc. is the third largest use and comes from both surface and groundwater sources.
- **Industrial processing water.** Used in mining, paper mills, food processing and similar uses, this is the fourth largest use.
- **Other water use.** This is the smallest category, and includes uses like livestock watering, water level maintenance, and construction dewatering.[51]

Total 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 overall water use has decreased over the past twenty years by about 27%.

Of the categories of water use, groundwater provides the largest share of water for water supply and irrigation. From 2014 to 2020, total groundwater use remained steady. On average, **statewide groundwater use increased by one-third** during the 2021 to 2023 drought period, and 2021 was the first year that groundwater use for irrigation surpassed groundwater use for public water supply (Figure 19). 2024 groundwater use went back to the former 3-year average. Much more information on water use can be found in Appendix C.

Figure 19. Minnesota groundwater use by permit category



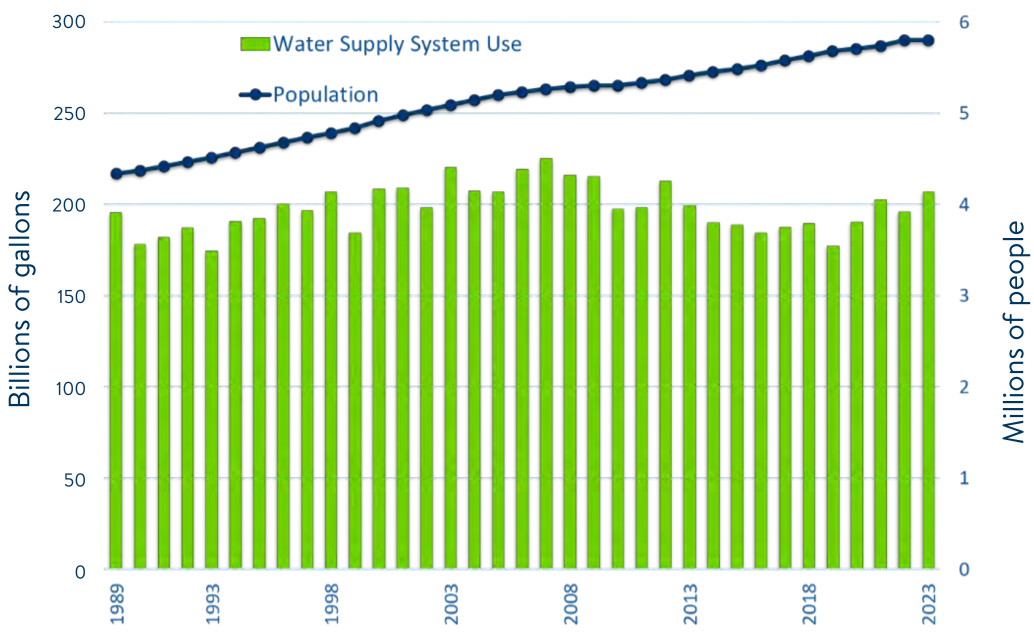
Water supply and consumer use

The most common way much of the public interacts with water on a daily basis is by using the water from the taps in their homes (or workplaces) for activities like drinking, cooking, washing, or watering our lawns and gardens. For many Minnesotans, this domestic water comes from a public water supplier — many of which pump groundwater to meet their community's needs.

As Minnesota's population has grown over time, water use generally has also grown with it. However, this trend might be changing. From 2010 to 2019, Minnesota saw a decrease in water use from water suppliers that serve communities and residents across the state.

There are likely a few reasons for this decline in water use. First, that decade was exceptionally wet, so there might have been less water spent on uses like watering lawns and gardens. Secondly, more use of water-efficient home appliances likely also contributed to the decrease in water use by water suppliers.

Figure 20. Water supply and Minnesota population



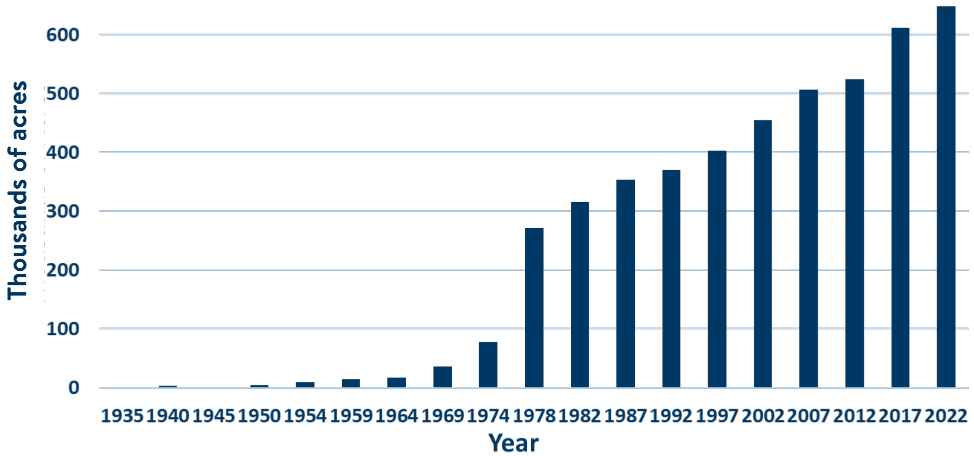
Note that consumer use of water varies by season. Summer water use within municipalities typically doubles due to lawn watering. In some communities, summer water use can increase by more than 3 — 4 times that of January water use totals. Unfortunately, drought conditions may further increase summer water use in the future, stressing groundwater aquifers that are shared among multiple communities.

Agricultural use

The largest use of water for agriculture purposes is for irrigation. Irrigation water comes from both groundwater and surface water sources, but the majority (about 90%) of agricultural irrigation water comes from groundwater.

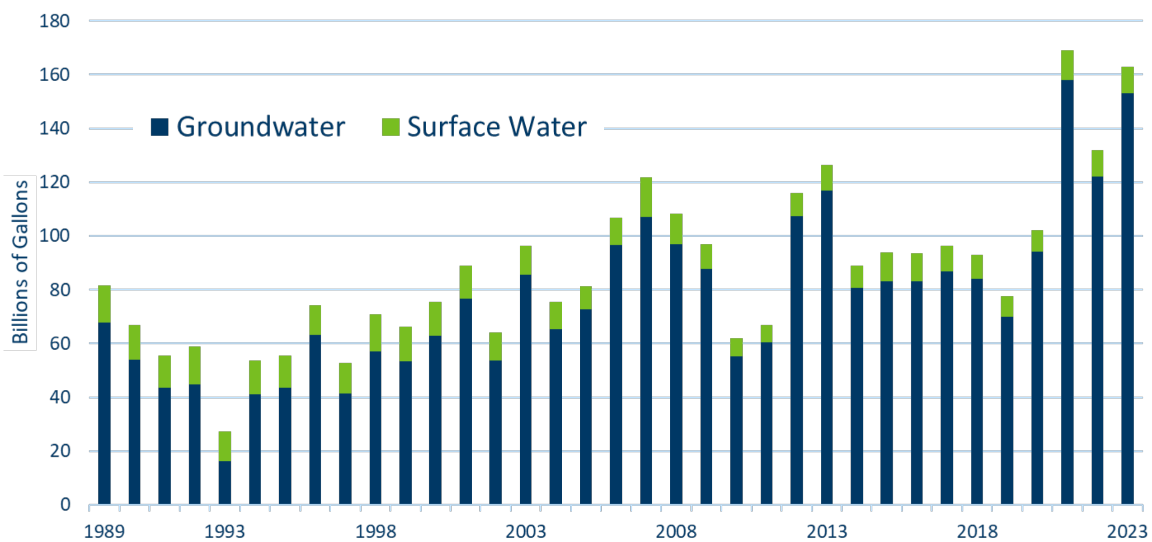
Irrigation usually occurs on sandy soils; dry conditions require extra water for crop production. As shown in the figure below, the majority of water use for irrigation is from groundwater aquifers and this has increased over time.

Figure 21. MN Irrigated Cropland (National Agricultural Statistical Service, USDA Irrigation info)



Since 1980, there has been increasing crop irrigation in Minnesota — both in terms of the acres of crops irrigated and the gallons of water that are used for irrigation. The DNR has also experienced a tremendous amount of additional permit applications for agricultural crop irrigation over this time period as growers (farmers, producers) understand the benefits irrigation can have on their farm, especially during dry periods and drought.

Figure 22. Agricultural crop irrigation - total annual water volume reported to DNR



There was significant increase in agricultural crop irrigation from the early to mid-1990s through the mid-2000s. A decade of increased precipitation from 2010 to 2019 somewhat dampened agricultural crop irrigation, but the period from 2021 to 2023 saw accelerated use of groundwater due to repeat dry growing seasons.

Industrial and other large water users

While industrial and other uses make up a smaller portion of Minnesota's overall water supply, individual large users of groundwater (or groups of larger users) can have an impact on local aquifers. This can especially be true in areas with more limited groundwater supply.

Many of these large water users are likely to have individual appropriation permits. Others may buy water from community water suppliers, potentially requiring additional withdrawals to support their operations.

For example, the ethanol production boom in the early 2000s created a demand for Minnesota's water that was unlike previous industrial water use development. Ethanol facilities were often sited to be near corn production but without consideration for water availability, which sometimes resulted in disappointed project proposers. More recently, large dairy facilities have been proposed in geographies with local community support and/or supply chain advantages but with very limited groundwater. In some places the rate of groundwater recharge is much lower than the proposed rate of groundwater extraction. In some places the available groundwater is not sufficient to meet the needs of both the proposed dairy and nearby crop irrigation. This has resulted in projects being downsized or relocated, but has also motivated more ingenuity in the use of storage ponds and rainwater catchment.

Planned data center in Rosemount, Minnesota. *Image: Meta*

New and expanding water-intensive (or potentially water-intensive) industries

While Minnesota has some existing large water users, there are also concerns about emerging or expanding water-intensive industries that might want to locate in Minnesota, and their potential impacts on our groundwater supply.

These industries are important to our economy, and it is essential to be sure that they are appropriately sited and planned, and that their potential effects on the environment, including local water quality and quantity, are evaluated.

The following section discusses new or growing industries that are likely to have a relatively high need for water in their processes and operations. Some of these industries — such as hydrogen production and carbon capture, utilization, and storage — will potentially be interconnected as they play a role in decarbonizing certain industrial sectors. Understanding water use across interconnected technologies will be important for decarbonizing industry while protecting groundwater.

Data centers

Data centers house IT infrastructure to run and deliver computing applications and services.[52] They can be very small in size, meeting the needs of a single company, or very large (sometimes known as hyperscale) to support intensive data storage and processing. As people and the economy increasingly rely on cloud-based data storage and computing, including artificial intelligence, there is more demand for the services provided by data centers. There are over 5,300 data center facilities nationwide.[53]

Until recently, data centers in Minnesota were smaller and generally more focused on the needs of a single or small group of companies. However, proposals for larger data centers have been growing over the last few years. Minnesota offers a sales- and use-tax exemption for qualified data centers to incentivize development, and many local governments are interested in the potential jobs, taxes, and other economic benefits provided by data centers.[54]

Data centers often require large volumes of water for cooling. It is difficult to project potential water use for possible future (but not yet formally proposed) individual data center, but studies indicate that "data centers rank in the top 10 of 'water-consuming industrial or commercial industries' in the U.S."[55] There are some indication that a "hyperscale" data centers can use up to 200 million gallons of water per year, while a smaller data center might use closer to 7 million gallons.[56]

With growing interest in Minnesota — there are up to 10 large to hyperscale sized data centers exploring potential locations[57] — data centers have the potential to have a large impact on groundwater quantity and availability. Some proposed data centers plan to buy water from community water suppliers, which means they are relying on the same aquifers and wellfields that are used for domestic water supply.

Data centers need cooling water of a certain quality to avoid corrosion, scaling, and bacteria growth. This can limit options or alternatives for cooling water. In addition, the cooling water might need to be treated prior to use, impacting water quality when it is discharged (either through a permitted direct discharge or, more likely, to a local wastewater utility).

Although cooling systems that use water are common, there are other options that require less water, such as closed loop liquid cooling using a heat exchanging fluid[58] or free-air cooling. Free-air cooling is a technique that uses cool external air — drawing it directly into the data center's server rooms.[59] Minnesota might be a good location for this type of cooling.

Hydrogen production

There is strong interest in the development and use of hydrogen as a potential clean energy source for Minnesota's economy that helps reduce climate pollution, particularly in sectors that are otherwise difficult to decarbonize. That hydrogen can then be used to support transportation; to make fertilizer, chemicals, and fuels; and potentially for long-duration energy storage in the power sector.

Systems work together to protect water quality and quantity

Although this report is focused on groundwater and presents threats to groundwater quality and quantity separately, we recognize the integrated nature of the water cycle.

This report uses the term "sustainable" to refer to both water quality and water quantity; we cannot meet either of these goals in isolation. Our concerns and the actions we need to take may be viewed at times through a single lens, but the big picture is much broader, and it is important that we also step back and take that larger view.

Because all water is connected, many (if not all) of the state's actions will produce multiple benefits to our waters — key actions will protect groundwater quantity and quality and have a beneficial impact for surface water.

These actions become even more important as climate change is increasing weather extremes. High intensity precipitation may increase the movement of pollutants from land into groundwater and can change how water infiltrates into the aquifer depending on soil type (sandy, coarse, etc.)

EQB's 2020 state water plan includes goals to manage natural landscapes to protect and improve water quality and to hold water and reduce runoff. A major strategy in the state water plan to meet these goals is to increase soil health. Healthy soil retains water, supporting plants and effective infiltration; reduces the speed and volume of runoff water, helping to reduce erosion; and reduces nutrient losses into groundwater and surface water. Similarly, work to manage the built environment to protect water is also important. Actions such as green infrastructure — rain gardens, swales, and pervious surfaces — slow down runoff and help hold water on the landscape in more urban areas. All the actions that we take on the landscape that work to hold and filter water prevent pollutant-containing runoff and support infiltration. This can work to protect the quality and quantity of water that recharges aquifers and the quality of water flowing over land into our lakes and streams.

Minnesota is part of the Heartland Hydrogen Hub, a regional initiative (covering Minnesota, Wisconsin, the Dakotas, and Montana) to produce commercial-scale low-carbon hydrogen.[60] The Heartland Hydrogen Hub is in the concept development phase, which is expected to last through early 2027. The Hub aims to eventually produce approximately 160 metric tons (176 short tons) per day of hydrogen.[61]

Hydrogen is generally made through two processes — steam methane reforming or electrolysis, a process where electricity splits hydrogen from water. Both require water. There is interest is in developing "green hydrogen," which means hydrogen produced via electrolysis using electricity generated by renewable sources (wind, solar, geothermal, hydro) or other non-CO_2 generating sources (such as nuclear).

RMI Estimates that producing green hydrogen takes about 20 — 30 liters of water per kilogram of hydrogen produced (equivalent to 2.4 to 3.6 gallons of water per pound of hydrogen produced).[62] In Minnesota, CenterPoint energy has been making up to 432 kg of hydrogen per day (about 952 lbs/day), using about two gallons of water per minute.[63]

At this level of consumption, meeting the target of the Heartland Hydrogen Hub would likely take around one million gallons of water per day. The Hydrogen Hub envisions a network of smaller projects, so water use in any given location is likely to be less. Water needs must be considered when siting hydrogen production facilities.

Sustainable aviation fuel

Sustainable aviation fuel (SAF) is a jet fuel replacement that can be made from crops, biomass, waste products, or clean electricity and hydrogen. The production and use of SAF is the highest-impact near-term strategy for reducing the aviation industry's contributions to climate change; most SAF production incentives require demonstrating a reduction in life cycle carbon emissions. For example, qualifying for Minnesota's SAF tax credit requires demonstrating a 50% reducing in life cycle emissions.

Minnesota can be a leader in SAF production, from growing the feedstocks to deploying the finished fuel. Minnesota is currently developing a framework to recruit, review, and regulate SAF producers to ensure SAF production will be done in a way that protects air quality, water quality and quantity, soil health, and the health of Minnesotans.

SAF can be made through multiple methods. There are at least 11 ASTM approved pathways and more are emerging all the time. The two most developed production pathways are:

- HEFA (hydroprocessed esters and fatty acids), which takes used oils or oilseed crops and processes them into SAF. Presently HEFA is the only commercially deployed pathway.

- AtJ or alcohol-to-jet, which converts ethanol or iso-butanol to SAF.

A third pathway being explored uses syngas and a Fischer-Tropsch process to create a liquid fuel. The syngas might be created by gasifying waste products (like municipal solid waste or woody biomass) or by using hydrogen created through electrolysis and carbon dioxide in what is called a power-to-liquid process or eSAF.

The amount of water required is highly variable depending on the specific process, but generally SAF production can require water in multiple stages of the process:

- Inputs (irrigation of crop feedstocks or creation of hydrogen)
- Production
- "Waste" (carbon capture, utilization, and storage)

It is difficult to estimate the overall water needs for SAF production, but meeting the U.S. government's grand challenge goal of 3 billion gallons of domestically produced SAF by 2030 and 35 billion gallons by 2050 could take a lot of water.[64]

For example, the National Renewable Energy Lab states that the "water footprint of drop-in fuels produced via HEFA from soybean oil has been estimated at between 2 and 309 gallons of water per gallon of fuel, depending on the irrigation method used and location."[65] Another analysis estimates that water demand for a production-sized facility could range from 44 to 85 million gallons of water per year, and notes that much of the water use comes from the production of hydrogen as an input to the SAF process.[66] Different projects considering locating in Minnesota have estimated their water needs from very small to up to tens or hundreds of thousands of gallons per day.

It is clear that a SAF production facility's water needs and the local availability of water should be a key factor in considering where to site SAF production facilities, and that water impacts should be part of project review and permitting.

The cultivation of crops for SAF feedstocks may also impact Minnesota's groundwater quality and quantity. If SAF relies on feedstocks that require significant inputs of water and nitrogen fertilizer, this could exacerbate concerns over groundwater quality and available quantity. However, if SAF production drives the cultivation of crops — such as oilseeds — that will help meet the state's goals around living cover and soil health, SAF production could have important co-benefits for Minnesota's water quality. Several crops in the portfolio of the state's Forever Green initiative, particularly winter camelina and pennycress, could be used to make SAF.

As the state works to build out a process to recruit, review, and regulate the production of SAF, a key goal is that the pursuit of low carbon fuel does not result in unintended environmental consequences. Potential adverse impacts to groundwater include: the worsening of water quality through the expansion of cropping systems that result in significant losses of nitrate to the groundwater and a decrease of groundwater availability for multiple uses due to high needs from SAF.

Carbon capture, utilization, and storage

In order to meet our climate goals, there is increasing interest in the use of carbon capture, utilization, and storage (CCUS) as a technology to decarbonize certain industrial sectors.[67] This technology involves capturing CO_2 generated at sources (largely through fossil fuel burning) and then storing it underground. According to Rosa, et al, these "technologies typically involve large water consumption during their energy-intensive capture process" and the "systems are energy- and water-intensive technologies that, if adopted, will commit humanity to additional water use."

Water is an important part of the carbon capture process. According to the Department of Energy National Energy Technology Laboratory's water working group, as of a decade ago "All currently available carbon capture technologies require additional water for exhaust gas processing, equipment cooling, and replacement power generation (large-scale capture and compression are expected to consume 30% or more of a facility's power output and associated water usage)."[68]

Although work has been done to reduce water use, it remains a challenge. Rosa, et al. evaluated four well known carbon capture and utilization technologies and estimated that their water footprint ranges from 0.74 to 575 cubic meters of water per metric ton (approximately 177 to 137,800 gallons per short ton) of CO_2 captured and stored.[69]

It will be important to consider the water impact of large-scale implementation of carbon capture, utilization, and storage.

Groundwater quantity management and protection

The state, primarily through the DNR, has multiple authorities, programs, and tools to manage water resources and water use. In addition, water supplies are managed at the local level and — particularly in the metro area — through regional collaboration. Water planning works to achieve multiple goals and support multiple water uses and users. These programs protect groundwater quantity by managing withdrawals and by promoting water efficiency.

Managing water appropriations

Water appropriation permitting

The DNR is responsible for regulating the use of water throughout the state by administering a permit program for the appropriation of high-volume water use and evaluating compliance with those permits and related laws, such as Minn. Stat., chapter 103G.

DNR requires an appropriation permit for anyone who uses, removes, or transfers more than 10,000 gallons per day or 1 million gallons per year of surface water or groundwater.

The DNR is required to evaluate the sustainability of each water appropriation permit application and proposal to ensure water is available for future generations, the use will not harm ecosystems, water will not be degraded, or water levels will not be reduced beyond the reach of public water supply and private domestic wells. In some cases, to understand the effects of issuing a permit for a specific volume and rate of water withdrawal, the DNR will require water level monitoring or an aquifer test. Projects must sometimes adapt their proposed operations to sustainably use limited groundwater.

The DNR currently manages over 10,000 active water appropriation permits. To improve compliance, the state legislature in 2022 provided additional compliance and enforcement tools for the DNR to use to ensure groundwater is used sustainably and as permitted.

The water appropriation permit is backstopped by the well interference program. A well interference is a situation where high-capacity groundwater pumping reduces water levels within an aquifer below the reach of a domestic or public water supply well, thereby *interfering* with the ability to access water from those wells. Domestic well owners and municipal water suppliers that lose access to water due to a high-capacity nearby appropriator can submit a well interference complaint to DNR, as described in [DNR's well interference process factsheet].

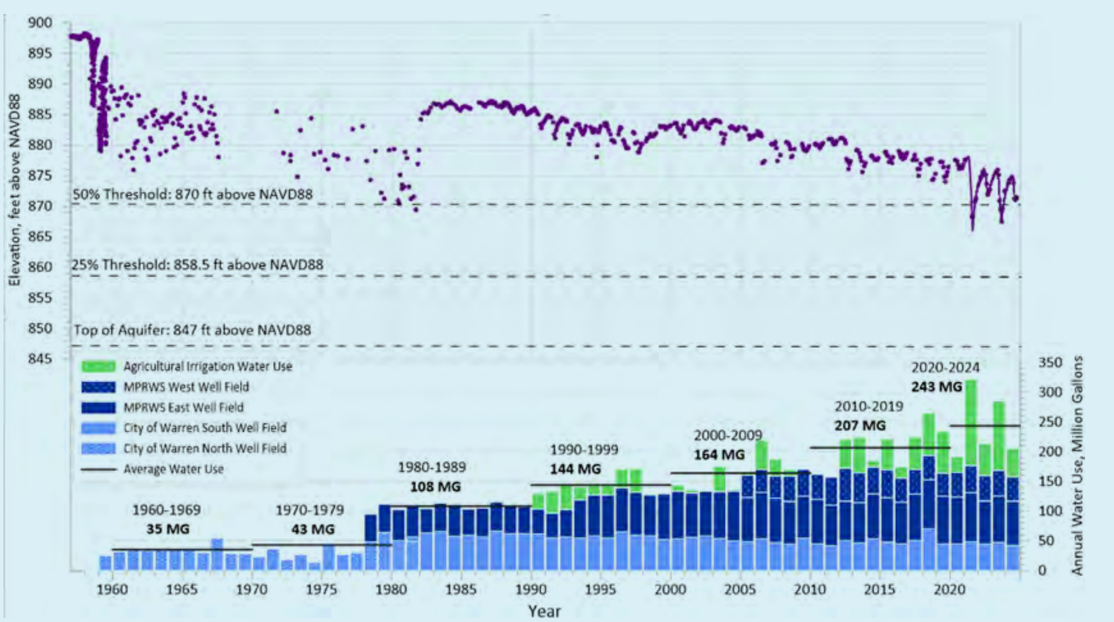
Climate and groundwater quantity

Climate change can exacerbate groundwater quantity challenges, particularly due to resulting changes in precipitation.

In some parts of Minnesota, groundwater levels are increasing. As described in Appendix C, groundwater quantity observation wells in the metro area show an upward or a stable trend over the past 20 years. Wet climatic conditions during the first 20 years of the century are one contributor to upward groundwater trends. Excess precipitation can lead to a groundwater surplus, which may result in new spring locations, larger base flows in streams and rivers, and even increases in surface water elevations. Higher groundwater elevations can negatively affect existing and proposed infrastructure, requiring modifications to site grading and drainage, foundation types, and increases the demand for pumping systems to mitigate so that the land surface can be used as intended.

Drought and longer growing seasons can increase the need for water for irrigation; make wells run dry; increase conflicts over water use; and lead to the need for restrictions on uses (like watering). Drought conditions can decrease recharge and therefore impact aquifer levels (dry wells, need to drill deeper and pay money); while fluctuating levels in the aquifer can impact land and soils (sinkholes).

Figure 19. Water elevations from DNR Observation Well 45000 vs Annual water use (million gallons/yr)



In the 2020 DNR Water Availability and Assessment Report (Appendix C to the 2020 EQB Water Plan), DNR staff highlighted a declining water level in an observation well near Warren, MN and indicated they were investigating the source of the problem. In the summer of 2021, the water level decline accelerated (Figure 19) due to increased pumping of the aquifer by municipal (City of Warren and the Marshall Polk Rural Water Supply) and agricultural irrigators. Drought conditions triggered an unprecedented pumping demand on the aquifer resulting in groundwater levels becoming critically low in the municipal water supply wells.

Minnesota Statute 103G.261 prioritizes water use in the state with drinking water supply as the highest priority water use. Therefore, DNR suspended four agricultural irrigation permits to protect the drinking water supply. The agricultural irrigators immediately stopped pumping, protecting drinking water supply in the area. Since 2021, groundwater levels have continued declining, which indicates that the aquifer system is likely over-allocated. DNR staff are studying the aquifer to determine what rate of use is sustainable.

Groundwater management areas

An additional tool under Minn. Stat. 103G for areas with increased water appropriation and limited groundwater availability is the option to designate groundwater management areas. Under Minn. Stat. 103G.287, subd. 4, "the commissioner may designate groundwater management areas and limit total annual water appropriations and uses within a designated area to ensure sustainable use of groundwater that protects ecosystems, water quality, and the ability of future generations to meet their own needs…"

The DNR has established three pilot groundwater management areas (GWMAs): the North and East Metro GWMA, the Straight River GWMA, and the Bonanza Valley GWMA. Plans are developed for each GWMA to guide DNR's efforts to sustainably manage groundwater appropriations in the area.

All groundwater management areas are implementing water conservation strategies and methods to ensure sustainable use of groundwater that protects ecosystems, water quality, and the ability of future generations to meet their own needs.

North and East Metro GWMA

The North and East Metro GWMA has completed an initial 5-year implementation plan. This plan stated certain goals for groundwater use, including that it does not harm aquifers and ecosystems; does not negatively impact surface waters; is reasonable, efficient and meets water conservation requirements; does not degrade water quality; and does not create unresolved well interferences or water use conflicts. The goals are similar for the Bonanza Valley and Straight River GWMAs.

Straight River GWMA

In the Straight River GWMA, planning began in early 2016 to ensure sustainable groundwater use. Following several meetings with area residents, permit holders, and local government leaders, the DNR embarked on a comprehensive review of stream flow data and pumping records by permit holders to understand the connection between the two.

In 2024, the DNR completed an analysis and report for the Straight River GWMA and concluded that in most places, groundwater use is having a minimal effect on streams in the area. The data demonstrate that aquifer water levels have been stable through the extensive period of record. Summer streamflow at the outlet of the Straight River GWMA has shown no downward trend. However, there are specific locations where pumping close to the stream and other groundwater streamflow areas limit the amount of baseflow reaching the stream. A groundwater flow model is likely needed to quantify the amount of streamflow diversion from high-capacity wells closest to the Straight River, determine where there is a need for diversion limits, and set any needed sustainable diversion limits.

Bonanza Valley GWMA

The Bonanza Valley GWMA, located in south-central Minnesota, was also designated as a groundwater management area in 2016. Groundwater use in the Bonanza Valley may be having a negative impact on aquifers, lakes, streams, or wetlands. The DNR has increased data collection in the area as described above and has begun work on a groundwater flow mode. The DNR is also working in this area to improve wetland water level monitoring over time. The DNR has initiated a long-term wetland monitoring project which is intended to provide information about how groundwater appropriations affect water levels in wetlands.

Groundwater use is vital to the people and economy in the Bonanza Valley and the DNR wants individuals, communities and businesses to continue to be able to use groundwater in the area. However, groundwater use in the Bonanza Valley might be having a negative impact on aquifers, lakes, streams or wetlands. The DNR has increased water level monitoring, prepared for groundwater flow analyses, and is implementing the plan to ensure sustainable use.

Successes

Communication – Landowners and project proposers are required to apply for a permit to appropriate groundwater in Minnesota. Through communication with landowners, industry groups, and farmer associations the DNR has improved compliance with our water laws. This relationship building and maintenance is a key to continue to improve compliance with water laws and protect water resources for future generations.

Data sharing –The watershed health assessment framework web-based tool now includes groundwater level monitoring data that anyone can access through a web browser. It can help inform water users of existing conditions in an aquifer and as conditions change over several years.

Well interference resolution –There were many well interferences reported during the drought years of 2021 to 2023. Groundwater pumping increased during these three years due to dry conditions. High rates of pumping lowered water levels in some aquifers, causing domestic wells to run out of water.

The City of Warren (described in the sidebar) was able to avoid well interference through communication between City staff and DNR staff, quick analysis by DNR staff, and quick decision-making by DNR to temporarily suspend non-essential uses. The DNR has continued to work with all appropriators in the Warren area to gather the data needed to determine a sustainable rate of groundwater use.

Water appropriation enforcement –The expanded enforcement authority, which allows issuance of administrative penalty orders, filled an important gap in DNR's enforcement program. This authority to compel compliance with water appropriation laws was further enhanced through changes in Minnesota Statute in 2023. The maximum penalty the DNR may levy on a landowner violating water appropriation laws increased from $20,000 to $40,000. Additional changes added more compliance and enforcement tools for the DNR to use to encourage permit compliance. The higher penalties are rarely used, but they have proven to be effective when they are employed.

Grants and Financing — Through MDA, there are opportunities for agricultural irrigators to obtain resources to help them implement conservation irrigation practices and other methods to promote efficiency in irrigation use. One example is Precision Irrigation Cost Share. With funds from the USDA Natural Resources Conservation Service Regional Conservation Partnership program, this cost share program administered by MDA provides technical and financial to agricultural irrigators for precision irrigation implementation. This includes partnering with a University of Minnesota Agricultural irrigation water quality specialist. As of 2024, this program has funded 39 projects and allocated all of the funds planned for a five-year program within the first two rounds of funding. The enthusiasm for this program shows that farmers recognize the value of water efficiency and that if we reduce barriers, people will embrace new, efficient technologies.

Weather Information — With Clean Water Fund resources, MDA is developing the Minnesota Ag Weather Network. MDA is deploying weather stations in strategic locations throughout Minnesota, in order to assist agricultural producers with scheduling of irrigation, chemical application, and other management practices.

Gaps and opportunities

Water Appropriation — There are additional opportunities to improve compliance throughout the water appropriation regulatory program including improved information, site inspections, permit reviews, and complaint response.

For example, the program relies on the self-reporting of pumping rate and annual volumes by appropriators. Often the rates or volume reported are based an indirect method of measurement, such as calculating the annual volume pumped by multiplying the number of hours a pump ran (often using the hours reported on an electric bill) multiplied by an estimated pumping rate (usually determined when the pump is first installed, however the rate often changes over time). Requiring flow meters or other methods of calibration would improve DNR's ability to accurately quantify water use.

DNR staff in the regulatory program review permit applications to determine whether the proposed water use will be sustainable and consistent with the rules and statutes related to appropriation of the waters of the state. Further enhancements could include adding staff to boost compliance and get to hard-to-reach places, or analysts to help determine trends in water use that might help in communication and planning. Improving compliance with our water appropriation laws will benefit the management of water resources for current and future generations, including the ecosystems that depend on those waters.

This program is sometimes expected to manage water quality along with appropriation permits, although permits are an imperfect tool for this work. There are opportunities for more intentional collaboration with the agencies that are more focused on water quality issues.

Water supply planning

Over five million people in Minnesota rely on water for their daily needs and to support the state's three million jobs and healthy economy. These needs range from drinking and bathing, to irrigation, to industrial and commercial operation, to power generation. Minnesota's water supplies also support the diverse natural resources used for recreation and other ecosystem services.

Groundwater is a critical source of water, providing about 75 percent of Minnesota's drinking water and 90 percent of agricultural irrigation. There are hundreds of thousands of privately-owned and public wells in Minnesota, although more than 75 percent of Minnesotans get their primary source of drinking water from a public supplier.

Our state faces several challenges in meeting current and future water needs, many of which are documented throughout this report. The state's population continues to grow. Industries and their water use continue to change. Groundwater pumping is increasing. Land use is changing. Naturally occurring and manmade contaminants impact water supplies. And variable weather like floods and droughts, as well as longer-term climate change, affect water supplies.

Private well owners and public water suppliers are ultimately responsible for providing water, but their decisions can have far-reaching effects. Since many water users share the same or connected aquifers, individual choices can add up and impact the broader groundwater system. Water suppliers need to undertake careful planning to ensure that their systems provide users with reliable water supply over time.

Minnesota has many agencies, like MDH, DNR, and the Met Council, that support water supply planning. They help suppliers create local plans to guide growth and ensure reliable, sustainable water for the future. Three key planning documents set long-term water supply goals and plan how to meet them:

1. **Local water supply plans** — Public water suppliers serving over 1,000 people, and all metro area communities with municipal systems, must submit a water supply plan to DNR every 10 years (Minn. Stat. 103G.291).
2. **Wellhead and intake protection plans** — Public water suppliers develop and regularly update wellhead protection plans following MDH guidance (Minn. R. 4720.5100 to 4720.5590).
3. **Local comprehensive plans (metro region)** — Communities in the Twin Cities metro region update their comprehensive plans every 10 years and submit them to the Met Council (Minn. Stat. 473.858). The local water supply plan is included as part of this comprehensive plan update.[70]

Each of these plans focuses in detail on different information, but they are also interconnected. For example, when looking across these three plans, they all must generally 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
- Allocation priorities consistent with 103G.261.

To complete these plans, communities tap into information, guidance, and implementation support from many agencies and partners. Strong water supply plans safeguard our current and future water supplies and provide important context and information for communities, individuals, and agencies making more specific decisions about their water.

Successes

The three water supply planning efforts have been successful as independent programs. For example:

- Since the program began in the 1990s, all 500 community water systems in the state with vulnerable groundwater wells have had Drinking Water Supply Management Areas delineated.[71] Source Water Protection plans have been completed for many community water supply systems, and resources are being committed to complete plans for the remaining 420 community water supply systems by 2025.[72]
- Since the program began in the 1990s, public water suppliers have completed three rounds of local water supply plan updates, creating a base of historical information that informs future planning.
- Water supply planning has become more consistently integrated into metro communities' local comprehensive plans. Originally, there was no recognition of water supply in Minnesota statutes addressing metro area comprehensive plan content; now it is included as well as direction for the Met Council to provide guidance (Minn. Stat. 473.859).

The three water supply planning efforts have also been successful in producing aligned, companion documents. For example:

- To better support the next round of local plan updates, DNR, the Met Council, and MDH have been collaborating to update local plan expectations and technical support. Starting in 2022, DNR, the Met Council, and MDH set a clear vision for what they can do together through their local planning responsibilities to secure a sustainable water supply for Minnesota. In addition to a shared vision, they also clarified roles and functions for each organization and established a structure to ensure coordinated local planning efforts going forward.
- This inter-agency collaboration is shaping efforts such as updated guidance for water supply content in metro area communities' local comprehensive plans, a pilot project for Minnesota's first multi-community Wellhead Protection Plan in Carver and Hennepin counties, and an updated interactive template and streamlined review process for local water supply plans.

Gaps and opportunities

The complexity of water supply planning in Minnesota has long been a recognized challenge. Water supply stakeholders have repeatedly requested more agency coordination and streamlined or consolidated planning processes. DNR, the Met Council, and MDH also recognize there are ongoing opportunities to better leverage one another's roles and resources to advance the shared goal of sustainable water supplies. For example, agencies should continue to work on better data sharing, including water planning information, to reduce the collection of duplicate information across agencies and to improve data consistency.

There is also an ongoing opportunity to better link water supply planning, drought response, and water conservation reporting to improve the understanding of whether city conservation and efficiency actions are working.

Emerging issues continue to challenge public water suppliers and private well owners. There are several areas where agencies and water suppliers can work together to identify needs and potential actions in local plans, so that communities are better able to negotiate those emerging issues. Some examples include new large water use industries, emerging contaminants, infrastructure investment needs, and extreme weather.

When compiled state-wide, the information provided through communities' water supply plans demonstrates that water supply challenges across Minnesota continue, and the costs to address them is high. Funding for water supply plan implementation is primarily the responsibility of public water suppliers and private well owners. Other funding sources for implementation of the three long-term water supply planning documents discussed here remain limited. For example, while a water supply plan is required to access Drinking Water Revolving Fund dollars and a wellhead protection plan opens up some limited grant resources, there are few other funding opportunities directly related to these plans.

Managing water demand

As discussed throughout this report, Minnesotans use water in many ways and for many reasons. A key part of ensuring that everyone has sustainable access to water — that they have enough to meet their needs — is to reduce the amount of water that is needed through a variety of strategies. These can include water conservation, improved efficiency (including ways to get more use out of each drop of water), or solutions such as water recycling and reuse.

Many strategies, particularly those related to water conservation, rely on education, incentives, and other mechanisms to change people's behavior and habits around how they use water. Other strategies — particularly those related to water reuse — require technology and infrastructure-based solutions.

Conservation and efficiency

The State works across agencies and with local partners and individuals to promote tools and actions that help people and communities use water wisely. Municipal and agricultural irrigation (Minnesota's second and third largest water uses) offer the greatest opportunities for water conservation through behavioral changes or efficiency improvements through technological means.[73]

Demand reduction through water conservation and efficiency reduces costs, protects water sources during droughts or emergencies, and helps ensure clean, reliable water for the future. Using water efficiently also lowers utility bills, reduces infrastructure needs, and supports long-term water system sustainability. Residents, businesses, and communities should benefit from smart water investments that protect our shared resources.

While water uses across the state vary greatly, the state agencies; the University of Minnesota; local governments; and water utilities offer a range of programs to address conservation and efficiency.

Some examples of these programs include:

- Metropolitan Council's Water Efficiency Grant Program, which uses Clean Water Fund dollars to provide grants to communities to support the purchase and installation of products that reduce water use.
- Minnesota Technical Assistance Program (MnTAP), which helps Minnesota businesses improve efficiency in energy and water use and reduce waste.

Conservation as a strategy is integrated into other state programs and tools for managing water. For example, the DNR builds conservation actions into water appropriations permitting and collects and analyzes water loss and conservation data to track progress and identify trends.

In addition, conservation is built into water planning. Minn. Stat. 103G.101 requires that the DNR 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. This statute works closely with the requirements of Minn. Stat. 103G.291 for municipal water accounting and demand reduction in municipal water supply planning.

While the DNR is responsible for setting statewide policy, local governments and water utilities are responsible for implementation at the regional and local level (see water supply planning section for more). For example, in the Twin Cities Metropolitan Area, the Metropolitan Council and regional partners work together to ensure that the region's water is conserved and used efficiently to optimize current water treatment infrastructure and treatment investments, safeguard the sustainability of water sources and ensure the utility service reliability.

Water circularity

Conversations about mechanisms to reduce water demand to support and maintain sufficient water supply are now moving beyond the long-standing tools of conservation and efficiency to consider a broader concept called *water circularity* or the *circular water economy*. While "water circularity" certainly includes water conservation and efficiency, it also moves beyond that to consider actions such as recycling and recovering water during the cycle of its use; recovering resources like energy from water; and recharging water.[74,75] It can also be thought of as keeping water in use for a longer duration or getting one more use out of each drop of water before it becomes wastewater.

The conversations about a circular water economy are largely driven by a recognition of increased water variability or water scarcity (exacerbated by climate change), and the need to meet or mitigate increasing demand for water for multiple uses. There is also interest in the connection between water and energy conservation.

Some examples of practices that would be considered part of a circular water economy include:

- Industries treating and reusing water within their processes
- Municipalities or others using graywater for irrigation or other non-drinking uses
- Agricultural irrigation using treated wastewater or graywater
- Other reuse of treated wastewater
- Recovering waste heat or energy from wastewater[76]

Implementing a circular water economy requires both technological solutions — such as advanced wastewater treatment — and increased public acceptance of reusing wastewater. There are also economic considerations; in general, the costs of using clean water are relatively low (some would say too low) and therefore may not appropriately incentivize the investment into the technology needed for water circularity. Innovation is likely to be needed to develop cost effective technologies. There are likely to be ongoing and increasing conversations around water circularity in the coming years.

Managed Aquifer Recharge

As part of a circular water economy, there is interest in managed aquifer recharge — the intentional movement of water into aquifers. According to the National Groundwater Association, categories of managed aquifer recharge include:

- Aquifer storage and recovery — injection of water into a well for storage in the aquifer and subsequent recovery from the same well
- Aquifer storage, transfer and recovery — injection of water into a well for storage in the aquifer and recovery from a different well, generally to provide additional water treatment
- Recharge pond or basin — a surface facility, often a large pond, used to increase the infiltration of surface water into a groundwater basin; basins require the presence of permeable soils or sediments at or near the land surface and an unconfined aquifer beneath

While there is a lot of interest in aquifer recharge as a potential to address groundwater quantity issues, there are also water quality impacts that need to be considered.

From 2019 to 2020, the University of Minnesota Water Resources Center and Freshwater led the Banking Groundwater: A study examining aquifer storage and recovery for groundwater sustainability in Minnesota, funded by the Environment and Natural Resources Trust Fund. Managed aquifer recharge is likely to be an ongoing area of study and research.

Water reuse

There is growing interest in the ability of water reuse (a key component of a circular water economy) to help meet our water needs and reduce demand on aquifers and other water sources. Although implementing water reuse strategies is an important opportunity, it needs to be done in a way that promotes benefits, reduces costs, and mitigates environmental and health risks.

In 2015, MDH was directed to study and report on approaches to water reuse to support the development of state policy related to reuse. MDH convened a Water Reuse Interagency Workgroup, and in 2018 produced a report on Advancing Safe and Sustainable Water Reuse in Minnesota.

That report noted that "Water reuse will be an increasingly important part of managing Minnesota's water resources as demands on our water supplies continue to grow due to population increases, urbanization, climate change, increased irrigation and industry growth... Despite increasing interest in water reuse, there is no comprehensive statewide guidance or policy on water reuse."

The workgroup's objectives were to: 1) Define successful implementation of water reuse in Minnesota; 2) Identify current conditions that support successful water reuse and identify barriers and solutions to barriers; and 3) Develop recommendations for safe and sustainable water reuse practices and policies.

The Workgroup developed eight Minnesota-specific recommendations in the report, including

- Create an expanded workgroup with practitioners, advisors and stakeholders to continue development of standards and programs.
- Prioritize research needs and integrate ongoing research to address questions about reuse.
- Define roles and responsibilities to oversee and monitor water reuse.
- Establish an information and collaboration hub on the web to share information and resources.
- Develop a risk-based management system to determine if regulation or guidance is needed.
- Develop water quality criteria for a variety of reuse systems based on the log reduction target approach for pathogens to manage human health risks.
- Resolve unique issues related to graywater reuse to determine the feasibility of expanding graywater reuse.
- Provide education and training to support water reuse.

Since then, there has been additional work focused on the potential to reuse rainwater and stormwater. In 2022, MDH drafted a white paper that evaluated the safety of reusing stormwater in Minnesota. Reusing stormwater (which includes capturing rainwater from roofs) can help decrease our reliance on groundwater. One concern is that stormwater may contain bacteria, viruses, or other pathogens that can cause illness. The MDH report made recommendations on how to reduce these risks through various options.

Following the release of the white paper, MDH worked with an external facilitator to convene stakeholders and to help address the need for consistent guidelines to streamline stormwater capture use design, implementation, and maintenance. The discussions identified, among other needs, the importance of having a centralized repository of information about stormwater reuse (including design, management, operation, and best practices) and the need for additional studies in several key areas to support water reuse, such as: system design, pathogen and exposure assessment, effectiveness of treatment methods, and stakeholder acceptance. The respective roles of the state agencies remain to be clearly delineated and design guidance that manages health and environmental risks is yet to be developed.

Successes

MetCouncil's Water Efficiency Grant program has saved over 200 million gallons of water since 2015.

Since 2014, MnTAP's internship program has included a track for water efficiency and MnTAP has continued expanding their capacity to assist industrial water users with water conservation and efficiency. The internship program has helped businesses save an estimated 233 million gallons of water between 2013-2023.

Gaps and opportunities

There are opportunities to expand successful water conservation and efficiency programs if and when resources are available. Many projects are funded with Clean Water Fund money, which is set to expire in 2034. Reauthorization of that funding will be critical; its loss would leave an enormous funding gap for these non-regulatory incentive programs.

The DNR's water conservation reporting tool has been active for almost ten years. The DNR is reviewing the data collected since 2017 and working to revise the reporting form to gather more streamlined and consistent data for improved analysis to provide a better year-over-year analysis and more impactful suggestions for water conservation.

Many conservation strategies focus on consumer water use and irrigation, and we have seen many successes where there is a financial incentive to save water in businesses and agriculture. However, residential outdoor water use continues to present a conservation challenge when the price of domestic water is relatively low and there is little financial incentive to conserve. Additional research on conservation behaviors is emerging, and there is space for Minnesota-specific research to help inform water conservation efforts specifically focused on outdoor domestic landscape irrigation.

Other challenges

Water infrastructure

Infrastructure for water distribution and management has impacts to groundwater quality and quantity and plays an important role in meeting our overall goals.

When residents are lucky enough to turn on the tap and have water arrive, it is easy not to think about how the water gets to their location or what happens to it along the way. Yet water distribution infrastructure is a key component of ensuring that residents of Minnesota have access to safe and sustainable groundwater to meet their needs. Without infrastructure — such as wells, pumps, pipes, and drinking water treatment systems — groundwater simply could not get out of the aquifers to where people use it. Strong infrastructure is needed to distribute water and make sure it is clean and usable when it gets to its final destination.

Infrastructure used for water management in agricultural settings is also important for meeting groundwater quality and quantity goals.

Drinking water infrastructure

Drinking water infrastructure is critical to delivering water and keeping it safe when it reaches the tap. Unfortunately, there are times when our infrastructure can present barriers to reaching that goal. For example, water service lines can corrode and leach lead and copper into drinking water, contaminating the water as it moves towards the tap. (More information is provided in the following section.) Older drinking water treatment systems may not deal with new contaminants of concern; degraded or broken well casings may allow contaminants to flow into water supply wells; and holes or breaks in sewer service lines can cause inflow and infiltration around wastewater systems.

Minnesota's water infrastructure is under strain. The 2022 American Society of Civil Engineers report card gave Minnesota's drinking water infrastructure a C- grade, citing as a key concern the fact that much of the state's drinking water infrastructure is over 50 years old; some is close to 100 years old, and much is reaching the end of its useful life.[77]

MDH recently released the Minnesota Drinking Water Action Plan, which sets out a key goal of establishing resilient drinking water infrastructure. The plan notes multiple concerns about drinking water infrastructure including:

- The need to update and upgrade infrastructure — whether treatment and distribution systems or private wells — to deal with aging, needed repairs, and emerging contaminants
- A shrinking workforce for public water systems and well construction
- Aging data systems and cyber threats

The state works to support water infrastructure construction, repair, and resiliency. Most water infrastructure is constructed and managed at the local level. All infrastructure is built to meet specific objectives. Over time, the useful life of the infrastructure diminishes due to age or changing design objectives (e.g., population growth leads to undersized system components, existing treatment and handling becomes insufficient to meet changing water quality, or when threshold values for PFAS drop by orders of magnitude). The state supports efforts to maintain safe, effective, and resilient infrastructure through funding and planning.

The Drinking Water State Revolving Fund (DWSRF) is the largest drinking water infrastructure funding source in the state of Minnesota. It provides below low-interest loans and grants for improvements to public water systems.

Currently the annual lending capacity of the base program is $56 million, without future appropriations after federal fiscal year 2026. The program is also able to provide principal forgiveness grants to water systems that are most in need, defined by certain affordability criteria, using both federal and state funding. The Infrastructure Investment and Jobs Act expanded funding to focus on emerging contaminants and lead service line replacement, though the future of federal funds is uncertain.

The current list of projects requesting support consists of 981 projects totaling approximately $1 billion. The DWSRF prioritizes funding for projects that protect public health and provide adequate water supply and those in communities with financial needs; there are additional points available for source water protection measures like well sealing.

The state also offers a Point Source Implementation Grant (PSIG) Program, which provides grants when wastewater systems receive more stringent discharge permit limits and need infrastructure projects to meet the new requirements. The program has recently been utilized to address high chloride concentrations at wastewater plants caused by home softener discharge. In these situations, it is more cost effective to soften the drinking water at a centralized drinking water treatment plant and eliminate the need for home softeners than trying to treat the wastewater. PSIG provides an 80% grant up to $7 million for components necessary to comply with the more stringent limit.

Successes

The availability of state funding has been critical to maintaining Minnesota's drinking water infrastructure, and there are notable success stories.

The city of Pipestone found itself faced with challenges affecting both public health and the environmental health of the community. In 2009, the city drinking water exceeded the Safe Drinking Water Act gross alpha (a measure of radioactivity) MCL. In 2014, the city wastewater plant was issued a chloride limit as part of their National Pollutant Discharge Elimination System (NPDES) permit. The chloride limit was well below their wastewater discharge concentration. The primary source of chlorides entering the wastewater system came from home softeners that residents used to address the hardness of the city's groundwater. Drastic changes were needed to the city's infrastructure to comply with both drinking water and wastewater standards. The city and their engineer collaborated with State staff to discuss potential solutions and possible funding options to address both issues. Lime softening the drinking water supply was selected because it would address multiple challenges for the city. Centrally softening the drinking water would improve the public health for the community by reducing the gross alpha concentrations while providing the added benefit of hardness reduction of the water so that home softeners could be eliminated. The project included construction of a new 1,200 gallon per minute drinking water treatment plant designed to remove gross alpha radioactivity and soften the water. Two new wells and the associated raw watermains were also included in the project. The $15.4 million project was funded with a $8.4 million DWSRF loan and $7.0 million State PSIG. The treatment plant went online in October of 2019.

Gaps and opportunities

With our aging infrastructure that will need repairs, replacement, and upgrades, and with the potential for population growth and spread to lead communities to build more and larger infrastructure, perhaps the largest threat or barrier to meeting our groundwater goal is the fact that infrastructure is expensive.

The ASCE report cites an EPA estimate that the public drinking water infrastructure need for Minnesota over the next twenty years is over $7.5 billion dollars. The Drinking Water Action Plan notes that funding to address CECs has increased, but funds to address legacy and geogenic contamination are limited.

There are also disparities in availability of funds for different types of infrastructure. Public water systems may be able to charge fees to support infrastructure upgrades, spreading their costs among their whole user base. However, about 90% of public water systems serve fewer than 10,000 customers, and therefore those ratepayers might be subject to disproportionate costs.[78] And, of course, private well owners have to bear the full cost of any well projects.

Public water systems have the potential to be eligible for loans and grants under the DWSRF. DWSRF dollars come from federal and state funds.[79] While the DWSRF is a great option for public water systems, there are more projects eligible than funds available. Additionally, the future of federal funding contributed to the DWSRF is questionable due to cuts proposed in early 2025.

Private wells are in a different situation, as there are very few options for public funding or assistance in improving, repairing, or building a new private well.

Tiling

Certain kinds of infrastructure may also have direct impacts on groundwater. Minnesota's agricultural economy is supported by systems of drainage that move water off fields, enabling numerous benefits such as stronger crop root systems and preventing inundation from large precipitation events. Subsurface drainage manages and removes excess water that has infiltrated into the soil. Subsurface drainage can be a quick pathway for nutrients from fields, such as nitrogen, to pollute local surface waters.[80] There are also concerns that subsurface drainage may adversely impact groundwater quantity by reducing evapotranspiration, changing the movement of water between aquifers, and decreasing infiltration by moving water more quickly into surface features. All of these could decrease groundwater recharge. There remains a need to further research this potential threat and gather data to determine its significance and the impact it could have on Minnesota's groundwater quantity and quality.[81]

As noted in the 2020 State Water Plan, climate change exacerbates water infrastructure challenges. Conditions worsened by climate change — such as high intensity precipitation and flooding - can degrade and destroy infrastructure, including washing out or overwhelming infrastructure like culverts, dams, and stormwater structures. Quick changes in temperatures that results in freeze/thaw cycles can cause pipes to burst. Across Minnesota much stormwater, drinking water and wastewater infrastructure needs rehabilitation or replacement to handle more extreme conditions. The State Water Plan and Minnesota's Climate Action Framework emphasize the need to develop infrastructure that is built to better handle these increases in extreme weather driven by climate change. Continuous improvement in data and information to assess vulnerabilities; planning, building policies, and design standards; and, most importantly, funding and resources are needed to support implementation of climate-resilient infrastructure.

Water equity

A key part of reaching the groundwater protection goal is to ensure that all people and communities have sustainable groundwater — regardless of their location, their income, how they access groundwater, or any other condition that tends to result in disparities.

Residents of Minnesota do have different experiences when it comes to sustainable groundwater, whether related to drinking water access, quality and information; how water is used for the economy; or groundwater impacts on ecosystems.

This section describes some critical equity challenges related specifically to different experiences in accessing and maintaining clean drinking water.

Private well users

Private well users are one group with a distinctly different experience in accessing sustainable drinking water. About 20% of Minnesotans (1.2 million people) get their drinking water from a private well. Private well owners are responsible for making sure their water is safe to drink for everyone in their household through regular voluntary testing, repairs, and mitigation. There are also many people who may rent or live on a property they do not own that gets drinking water from a private well. This report uses the term "private well users" to refer to anyone who gets their drinking water from a private well — regardless of whether they own or are responsible for the well providing their drinking water.

As discussed throughout this report, there are a combination of human-caused and geogenic contaminants in Minnesota groundwater and well water. Consuming water with these contaminants can cause both short- and long-term health effects.

The Minnesota Well Code is intended to protect health and groundwater by ensuring wells are properly constructed and maintained; it regulates well location, construction, repair, and sealing. Private well owners are supposed to make sure any repairs or changes to their well comply with the Well Code.

While customers of public water systems can rely on their water system and water operators to ensure drinking water meets all Safe Drinking Water Act standards, private well owners essentially must act as their own well operators; this is a high burden of cost, capacity, and knowledge. Private well owners also face challenges that are outside of their control or influence. For example, they have limited (if any) options to choose or change the geology in which their well is drilled, and they also have no control of how land is used in areas that may drain to the aquifer their well uses.

As noted in the section on infrastructure, there is limited financial assistance for private well users. A few state and federal grant and loan programs can be used for home water treatment, well construction, repairs, and sealing. However, these programs have specific eligibility requirements that limit availability and many households are ineligible. In addition, while there is some financial assistance and programming available to help address human-caused contaminants in private wells, there is no legal support for addressing geogenic contaminants, including arsenic and manganese, in private wells. This is despite the fact that 40% of private wells have arsenic, a known human carcinogen, in the water. MDH projects that about 50% of private wells have manganese at a concentration above what is safe for a baby to drink; consuming water with high levels of manganese can lead to problems with memory, attention, and motor skills.

An additional challenge is that we do not actually know how many private wells are in Minnesota. There are over 470,000 known private wells; we know there are many more that we are unaware of. Many of these unknown wells were constructed prior to the establishment of the Minnesota Well Code, which means they are at higher risk of being contaminated. Knowing how many private wells there are and where they are located will help ensure private wells are considered when implementing activities to protect sources of drinking water.

Small public water systems

Nearly 50% of Minnesota public water systems serve cities with populations below 500 people; over 80% serve cities with populations below 3,300. Implementing Safe Drinking Water Act requirements (from source to tap) is a particular challenge for small public water systems. They have limited financial resources to fund the work and limited technical resources and knowledge. They oftentimes lack authority outside of their municipal boundaries for land use activities that affect their drinking water source.

Lead in drinking water

A major equity issue in delivering sustainable water to communities is differing exposure to lead in drinking water. As noted by Nigra and Navas-Acien, "chronic lead exposure in public drinking water remains a persistent environmental injustice that disproportionately affects Black communities across the United States." They note further that, in a study of Black adults with kidney disease, "Black patients were served by water systems that reported both higher 90th percentile lead concentrations and smaller declines in 90th percentile lead concentrations over time compared with White patients."[82]

In 2019, in collaboration with UMN, MDH assessed the scope of the lead problem in drinking water systems. The resulting Lead in Minnesota report notes that lead is almost never found in source water, so the "two most significant sources of lead in Minnesota drinking water are lead service lines, which generally are controlled by cities, and plumbing fixtures, which generally are controlled by property owners" and estimated there are almost 100,000 lead service lines remaining in Minnesota. The report estimates costs for removing these two most significant sources of lead to be between $1.52 billion and $4.12 billion over 20 years. However, it also notes that — because lead is a neurotoxin that can cause cognitive damage — the economic benefit to society from the resulting increased learning ability and productivity is easily two times the cost of the lead removal.

Increased interest and monitoring of private wells is also making it clear that private well owners also face lead challenges. A 2020 study based on blood lead records from about 60,000 children in North Carolina showed that children in homes relying on private wells have a 25% increased odds of elevated blood lead, compared with children in houses served by a community water system regulated under the Safe Drinking Water Act.[83] Recent testing in southeast Minnesota showed that 42% of private wells had lead detections.

Successes

Funding - With the estimates of benefits from replacing lead service lines, the Lead in Minnesota report helped support $240 million in state funds to work toward the Minnesota Legislature's goal of replacing all lead service lines by 2033. MDH and others have been working to make sure that lead service line (LSL) replacement programs prioritize equity. The initial report indicated key steps, including:

- Recognizing that minority and low-income residents are more likely to be exposed to other sources of lead (e.g., lead-based paint), and that reducing further harm is a priority.
- Ensuring planning, implementation, and oversight includes affected low-income and minority consumers and gives serious consideration to their concerns.

- Taking steps to protect people with low incomes or limited access to capital so they do not opt out of LSL replacement.
- Making replacing LSLs serving rental property a priority because landlords may not otherwise see the value of the investment and tenants are often, depending on the area in question, more likely to be low income or minority.

Inventories - As of the end of 2024, 100% of public community water systems completed an inventory of water lines.

Replacements — Work is starting on the large task of replacing lead service lines. As of January 2025, 845 lead service lines have been replaced out of an estimated 100,000. The target is to replace 100% of water service lines that contain lead by 2033. Status updates can be found at MDH's Lead Service Line dashboard.

Gaps and opportunities

Much of Minnesota's work on equity and disproportionate impacts has focused on air quality, specifically how where people live and breathe impacts their exposure to pollutants. Less work has been done on issues related to groundwater and drinking water, and so there remain large gaps in our ability to characterize and communicate equity issues in this area. One particular challenge is that the source of drinking water can be close by or relatively distant from those drinking the water.

Conclusion

This report fulfills the requirements of Minn. Stat. 103A.204 — for EQB to report on policy issues related to coordination of state groundwater protection programs.

Overall, the state agencies and partners have achieved significant successes in our work towards groundwater protection. But challenges remain, and our collaborative work remains critical. The objective of the interagency workgroup was to identify those threats to groundwater in Minnesota that can only be mitigated by a coordinated response and therefore are most likely to drive our collective work over the next ten to fifty years.

We hope that the information in this report (and the related Appendices) supports informed funding and policy decisions on groundwater issues moving forward, and we look forward to continuing to work with all our partners to ensure that Minnesotans have equitable access to and use groundwater sustainably to meet our common needs.

Endnotes

1. MDH, Minnesota Public Health Data Access: Drinking water quality
2. "Contaminant" in this report refers to both natural and human-caused substances that may be of concern in water; "pollutant" is more specific and refers to human-caused substances.
3. DNR, Water conservation
4. Minnesota Humanities Center, Minnesota Indian Affairs Council, Smithsonian Museum of the American Indian.
5. Lower Minnesota River Watershed District.
6. Dalland.
7. National Park Service.
8. Minnesota Water Management Framework, 2023.
9. Minnesota Water Management Framework
10. DNR, MinnAqua image library.
11. University of Minnesota Extension, Groundwater and Aquifers in Minnesota
12. DNR, Groundwater provinces 2021.
13. USGS, Water Resources Mission Area.
14. Larson, K.
15. DNR, springs
16. Winter, et al.
17. MDH, About Using Surface Water Sources for Drinking Water and Winter, et al.
18. DNR, Frequently asked questions about lakes
19. DNR, Stream basics
20. MDH, About Using Surface Water Sources for Drinking Water
21. Norris.
22. 2020 State Water Plan, Appendix B.
23. In the context of drinking water monitoring, some pesticides are considered to be a CEC because of the lack of drinking water standards. Because Minnesota has a robust pesticide monitoring program, we have good information about pesticides in Minnesota's waters. MDA surveys groundwater wells that are susceptible to agricultural contamination for pesticide and collaborates with MDH to inform follow-up sampling at drinking water wells.
24. The MPCA also maintains the Groundwater Contamination Atlas, a map-based tool for learning about polluted sites that provides detailed narratives of the pollution issues as well as links to data.

25. MDH. Nitrate in Drinking Water.
26. The updated 2025 NRS provides the best and most complete recent information on these topics.
27. The Safe Drinking Water Act (SDWA) went into effect in 1974, with an interim MCL for nitrate in late 1975. The final MCL for nitrate-nitrogen went into effect July 1, 1992.
28. MGWA, 2022.
29. Lotthammer, 2010 and Trojan, 2006.
30. The reviewed information includes MPCA's ambient groundwater conditions report and several DNR county groundwater atlases.
31. MPCA, 2025. Condition of Minnesota's Groundwater Quality.
32. MPCA, 2025. Condition of Minnesota's Groundwater Quality.
33. Kuehner, et al. (2025).
34. MDH, 2024
35. MDH, May 2025.
36. For this program, more than 90,000 private well owners in 344 townships vulnerable to groundwater contamination were offered nitrate testing. Those who agreed were sent a nitrate test kit. "Initial results" refers to the results of that testing process.
37. Nitrate trends were calculated from 267 monitoring sites (253 wells and 14 springs).
38. This large-scale statewide effort has been revised and updated; the updated version is discussed later in the section on future response.
39. State of Minnesota, NRS 2014
40. State of Minnesota, NRS, 2025.
41. A DWSMA is a defined area around drinking water wells and intakes where contaminants are most likely to get into the drinking water.
42. For more information see the MPCA factsheet
43. BWSR, 2025.
44. BWSR, 2020.
45. BWSR, 2019.
46. MDA. 2023 Water Quality Monitoring Report.
47. Common detection is defined as the common detection of a pollutant in groundwater that is not due to misuse or unusual circumstances but is likely to be the result of normal use of a product or practice. The designation prompted actions to address the pollutant including the development and promotion of BMPs, additional monitoring, and increased data analysis.
48. MDA, BMPs.
49. MPCA, 2025 Groundwater Condition report.

50. Much of Minnesota's groundwater is pumped from underground, used, and not returned to the aquifer. If water is being pumped out faster than it is being recharged, this can result in aquifer drawdown and impact water availability. In addition, after use, much of this water moves to wastewater treatment and then into surface waters — especially rivers and streams. As groundwater use has increased, so has the volume of discharge.
51. DNR, Water use data
52. IBM, data centers.
53. Ahmad.
54. As of March 2025, DEED's list of qualified data centers in Minnesota (those over 25,000 square feet that have invested at least $30 million and are therefore eligible for the tax exemption) included 42 data centers. Certification as a qualified data center requires having completed the project and documented the minimum investment and facility square footage requirements.
55. Ahmad.
56. Zhang.
57. Orenstein
58. Marohn, K.
59. Zhang.
60. Commerce, 2024 Quad Report
61. Heartland Hydrogen Hub Fact Sheet
62. RMI
63. Commerce, 2024 Quad Report.
64. U.S. DOE, Synthetic Aviation Fuel Grand Challenge.
65. Rosales Calderon et al., page 28
66. Wu, M.
67. For instance, CCUS is a significant part of ethanol-to-jet SAF production.
68. National Energy Technology Laboratory.
69. 0.74 m3 = 740 liters or approximately 195 gallons; 575 m3 = 575,000 liters or approximately 311 gallons
70. A comprehensive plan is an expression of a community's vision for the future and a strategic map to reach that vision. Comprehensive planning is an important tool to guide future development of land to ensure a safe, pleasant, and economical environment for residential, commercial, industrial, and public activities. Minn. Stat. 473.858 requires all cities in the Twin Cities metropolitan area to develop a comprehensive plan, and specifies they submit those plans to the Met Council for review for compatibility and conformity with the Met Council's regional system plans. Comprehensive planning is not mandatory in communities outside the seven-county Twin Cities metropolitan region. Minn. Stat. 462.351 to 462.364 provide communities with the necessary powers and a uniform process for municipal planning.

71. State of Minnesota, 2024 Clean Water Fund Performance Report, pg 50 - 51.
72. MDH, Planning for source water protection
73. Some discussion on conservation in irrigation appears in the section on water appropriations.
74. Stockness
75. WEF.
76. WEF.
77. ASCE.
78. MDH, DWAP.
79. MDH, DWRF.
80. Fausey.
81. MGWA (2018)
82. Nigra and Navas-Acien (2021).
83. Gibson et. al (2020).
84. Westerlund.
85. BWSR, 2023.
86. Johnson, T., Butcher, J., Santell, S., Schwartz, S., Julius, S., LeDuc, S. (2022) A review of climate change effects on practices for mitigating water quality impacts. Journal of Water & Climate Change,13(4), pages 1684-1705. https://doi: 10.2166/wcc.2022.363
87. Mega-rain = more than 6" over 1000 square miles (2020 state water plan and https://climate.umn.edu/our-changing-climate/extreme-events
88. USGS, Water Resources Mission Area

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