DEPARTMENT OF NATURAL RESOURCES

Water Availability and Assessment Report

Appendix C to the 2020 EQB Water Plan

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Introduction

Minnesota's water resources are part of the very identity of our state: the land of 10,000 lakes. Our water resources provide habitat, recreational opportunity, drinking water supply and economic vitality. These resources are valued by Minnesotans and are part of our way of life.

This report is an exploration of water in relation to Minnesota's economy, communities, landscapes, and atmosphere. The report will describe how individuals, businesses and communities have been using water. The report will present data and information on the amount of water present and flowing through Minnesota over the recent past. The report will also present information on the Minnesota Department of Natural Resources' (DNR's) efforts to ensure the sustainable use of water in Minnesota.

The data and information on water resources in this report lead us to the following conclusions:

1. Climate: Minnesota's climate is changing. Our rainfall events are heavier and more intense and our winters are warmer. This trend fits with climate forecasts, which predict overall warmer and wetter conditions and more extreme weather such as damaging, intense rains. Although we are now in a wet cycle, droughts will return, and climate change models predict they will be longer and more severe than before.
2. Water Use: The total volume of water used has decreased over the last ten years, most notably in the energy sector due to the reduction of water use in power plants.
3. Streams: Streamflows have been high around the state, reflecting increased precipitation.
4. Lakes: Lake levels have been generally higher around the state, also reflecting increased precipitation.
5. Wetlands: There has been a slight increase in the acreage of wetlands around the state, and some wetlands are shifting toward wetter types. This is likely due to wetland restoration policies and programs, and increased precipitation.
6. Groundwater: Groundwater levels have been generally high around the state, although some locales will continue to have limited groundwater availability. Groundwater is limited in some places because the aquifers are poorly producing. In other areas, the aquifers recharge slowly and may not keep pace with the rate of use.
7. Programs: Sustainable water use continues to be supported through DNR programs by engaging with water users to support their water supply planning and water conservation efforts, collecting and using water resource and ecosystem data, and effectively applying Minnesota's water laws.

Section I: Assessment and Availability of Minnesota's Waters

Water availability in this report is described in terms of the elements we see on the landscape: climate and precipitation, streams, lakes, wetlands, and groundwater, and how we use water. Precipitation either soaks into the ground or runs off into lakes, rivers, and wetlands. Much of the water that soaks into the ground is stored in soil to be taken up by plants. Evaporation from plants and from the land and water surfaces returns moisture to the atmosphere, which perpetuates the hydrologic cycle. Each of these components is influenced to some degree by human actions at or near the land surface. Streamflow, storage in wetlands, and groundwater use can be controlled by human actions; however, natural variability of other components such as drought, flood, and geographic distribution of aquifers cannot be controlled. This variability presents challenges for the long-term sustainability of both human and ecological water needs. The following sections describe Minnesota's water availability from 2015 – 2019 through the trends of our climate, surface waters, groundwater systems and water use.

Climate Trends and Projections

Minnesotans are accustomed to cold and snowy winters, along with warm and humid summers, but also know that any season can be far warmer, colder, wetter or drier than normal. The high variability that we expect from Minnesota's climate can make it difficult to notice where, when, and how climatic conditions have changed in our state. **However, over 125 years of consistent climate data make it clear that widespread changes, outside the range of normal variations, are already underway in Minnesota.**

Indeed, Minnesota's climate is changing rapidly, and more changes are coming. In the past several decades, our state has seen increased rainfall, heavier downpours, and substantial warming, especially during winter and at night. These changes have already affected not just our water resources, but also how we interact with and use them. An overwhelming base of scientific evidence projects that Minnesota's climate will see additional, significant changes through the end of this century, with even warmer winters and nights, and even larger rainfalls—along with the likelihood of increased summer heat and the potential for longer dry spells. Planning for the future of Minnesota's water must include a thorough appraisal of the effects our changing climate will have on this vital resource.

Wetter and warmer conditions

Minnesota has experienced much wetter and warmer weather in the past several decades. All but two years since 1970 have been some combination of wetter and/or warmer than historic averages. **Compared to 20th century averages, all of the ten wettest and warmest years on record occurred after 1998** (Figure 1). Just last year, 2019, was the wettest year on record in Minnesota.

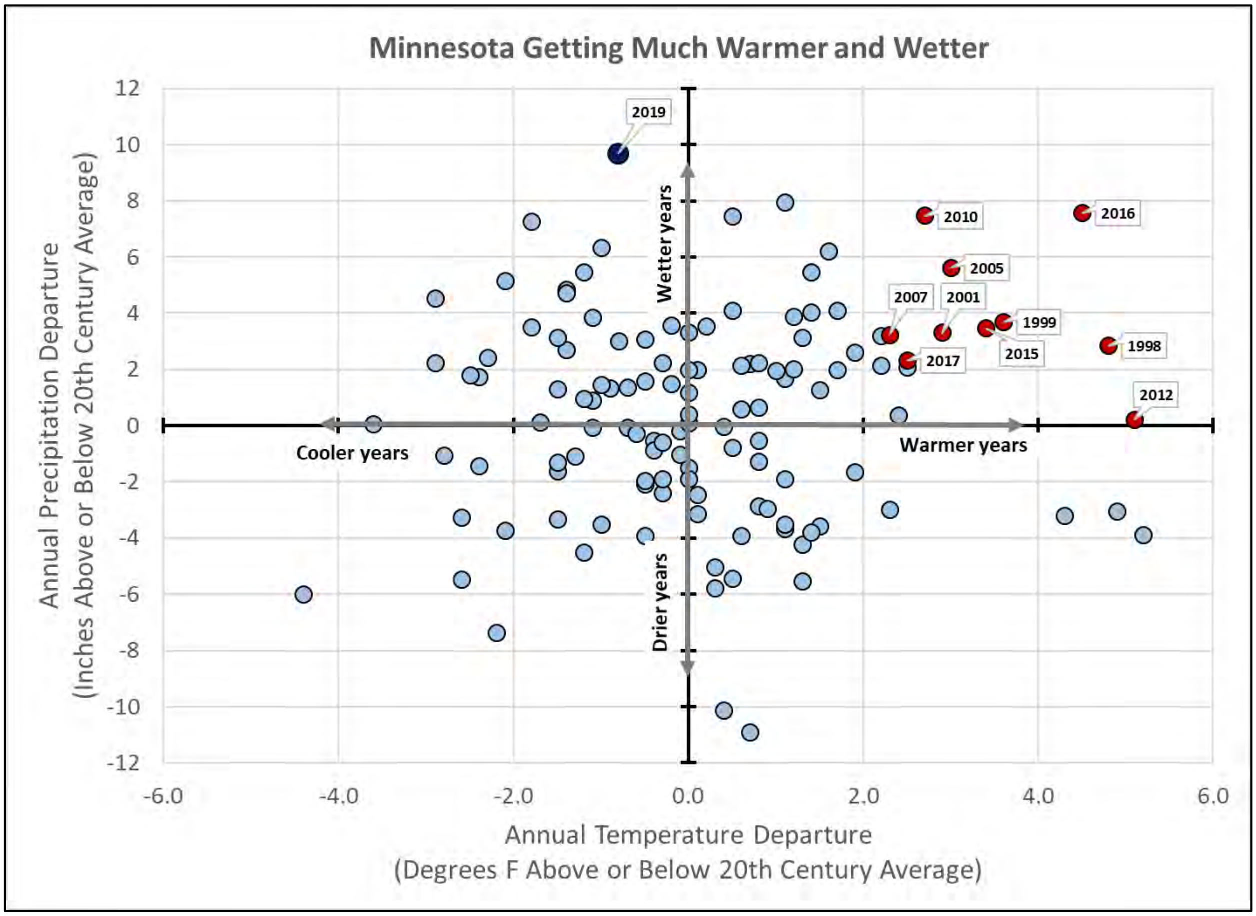


Figure 1. Plot of annual temperature and precipitation in Minnesota

Although the climate will vary from year to year, with occasional cool or dry years, climate scientists expect these increases to continue through the 21st century.

Unprecedented precipitation

Minnesota's climate swings naturally from relatively dry to relatively wet periods, but the wet conditions have dominated recent decades. Years with precipitation above historical averages have become increasingly frequent, and departures from those averages have grown as well, leading to sustained precipitation surpluses never before documented in the state (Figure 1, Figure 2).

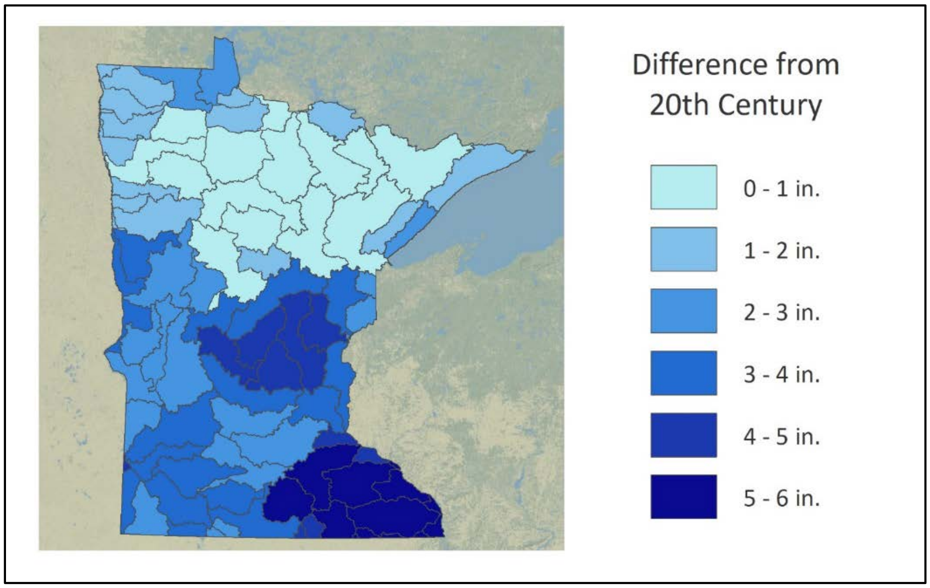


Figure 2. Annual precipitation increase since the 20th century

Modified map from DNR Watershed Health Assessment Framework.

June of 2014 was Minnesota's wettest month on record, with widespread severe flooding in many areas. In 2016, the town of Waseca broke Minnesota's annual precipitation record, only to have that record broken by both Harmony and Caledonia in 2018. During 2019, more precipitation fell across the state than any other year on record back to 1895, and the 2010s finished as Minnesota's wettest decade, by a wide margin. The precipitation increases have been most pronounced in southern Minnesota (Figure 2).

More damaging rains

Minnesota now sees more heavy precipitation than at any other time on record. At climate stations with over 100 years of observation, daily precipitation totals of 1, 2, and 3 inches have increased an average of 21%, 31%, and 62%, respectively. Measurements of the annual heaviest rainfall now average 20% greater than historical readings across the state. In August 2007, a catastrophic rainfall in southeastern Minnesota produced 15.1 inches of rainfall in just 24 hours in the town of Hokah. This is 39% more rainfall than ever had been recorded at any station in the state. Seasonal snowfall has been running near historical high marks also; in the 2010s, stations all over the state broke records for heavy snowfall.

Warmer but not hotter, yet

Minnesota is warming quickly but mostly during nights and winter. Annual temperatures have climbed 2.9 degrees since 1895, but 80% of that warming has been since 1970. During those five decades, winters have warmed by 5° F, winter nights have warmed by 6° F, but summers have warmed by just a half a degree F, and summer daytime high temperatures have decreased slightly in southern Minnesota (Figure 3).

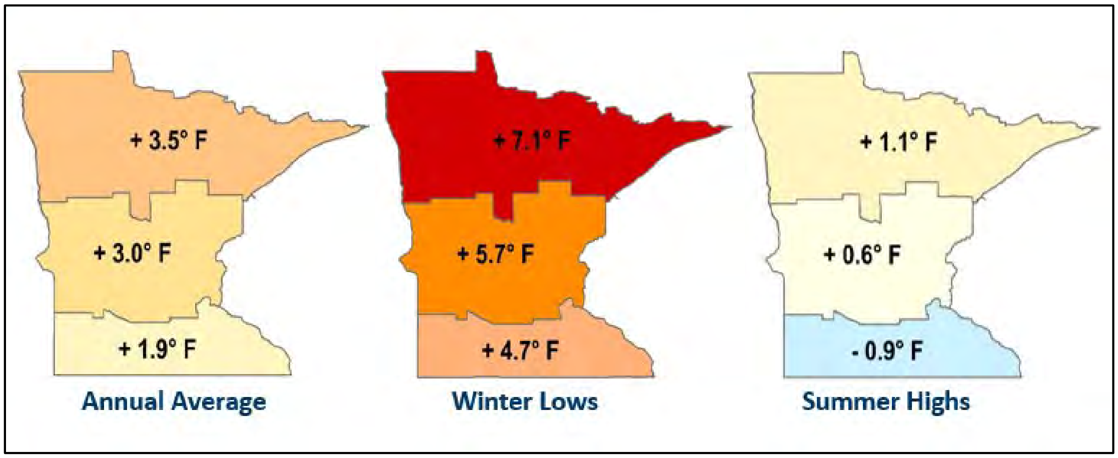


Figure 3. Temperature Change by Region

NOAA, National Center for Environmental Information

Winter cold extremes have become less frequent and less severe, while the state has observed no change in the frequency or severity of heat extremes. Climate models suggest, however, that summers will eventually get warmer, and that Minnesota will see increased heat extremes by the middle of this century, if not sooner.

Don't count drought out

Water is a defining resource for Minnesota, central to our economy, communities, and identity; so we always will be quite sensitive to dry conditions and drought. While Minnesota continues to experience periods of drought in specific regions, those periods have not increased in severity or length. Recent surges in precipitation have meant the state has not seen any increases in drought severity, duration, or areal coverage over the past few decades. **However, the extremely wet period from the 2010s will end eventually.** A shift towards a dry regime should be expected, as climate change will not eliminate wet and dry periods in Minnesota. Indeed, although climate projections depict that Minnesota will continue getting wetter in general, those same projections indicate that future dry spells may start to get longer too, especially once our summer heat intensifies. Even with a generally wetter climate, Minnesota should expect occasional episodes of severe drought, and these drought events could happen immediately following or may even occur in specific areas of the state *during* a wet period.

Water Use Trends

Whereas water use in Minnesota generally increased over the last decades of the 20th century, water use in the 21st century has been declining. In total, **Minnesota's water use has decreased over the past ten years from about 1400 billion gallons in the first decade of the century to about 1060 billion gallons at the end of the second decade** (Figure 4). This translates to approximately a 28% decline in water use while our population increased by approximately 7%.

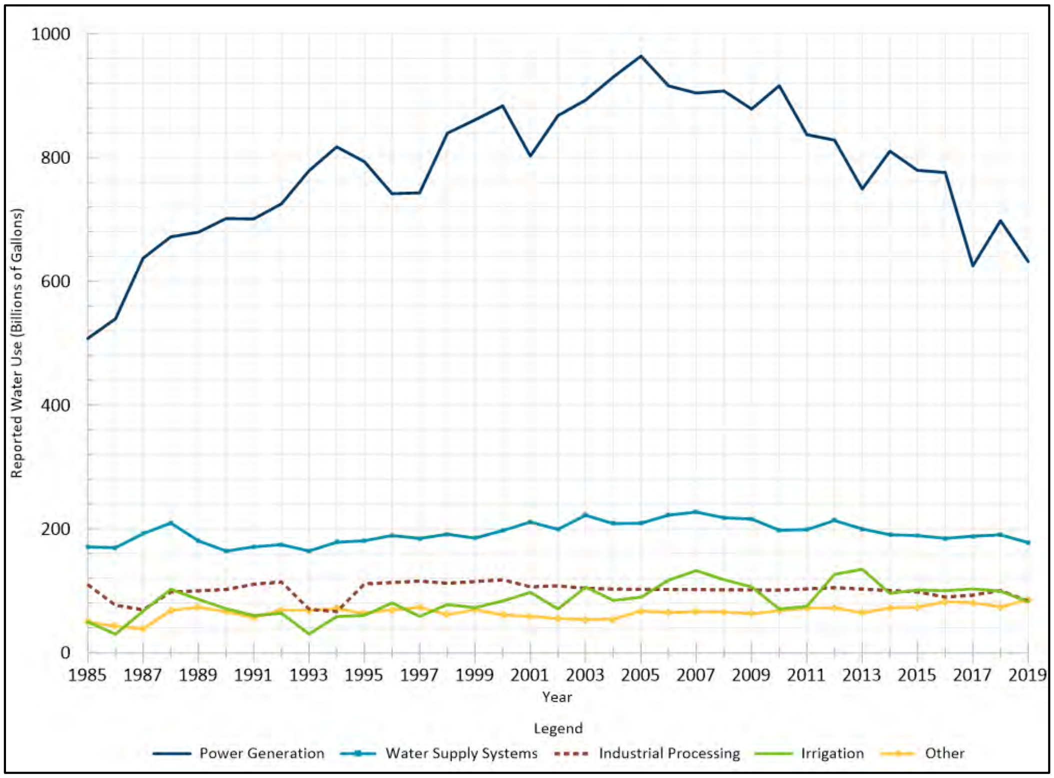


Figure 4. Reported water use by category of use

Decreasing water use for generating electricity

The largest portion of Minnesota's water use is from surface water for power generation. The majority of the decrease in the state's water use can be attributed to a decrease in water needed for power plant cooling – a use reduction of 33% from 2005 to 2019.

- This reduction occurred even as the overall demand for electricity remained constant.
- A number of large power plants converted from coal to natural gas. Natural gas plants require less cooling water. The share of the state's electricity produced by coal-fired electric plants declined from 53% to 31% over the period from 2011 to 2019.
- The amount of electrical power generated from wind and solar power has increased. These sources of electricity do not require cooling water. In 2019, the state's wind farms generated 19% of the state's total net electricity generation. Minnesota is a national leader in energy efficiency, and renewable energy has accounted for 84% of all new generation capacity since 2010.

Water use for non-power generation also declined from 2007 through 2019 (Figure 5). This decline is attributable to adopting water saving technologies, increased industrial water reuse, and implementation of irrigation best management practices. Additionally, recent wet years have likely contributed to the decline, as Minnesotans use less water for lawn and crop irrigation during times of ample precipitation.

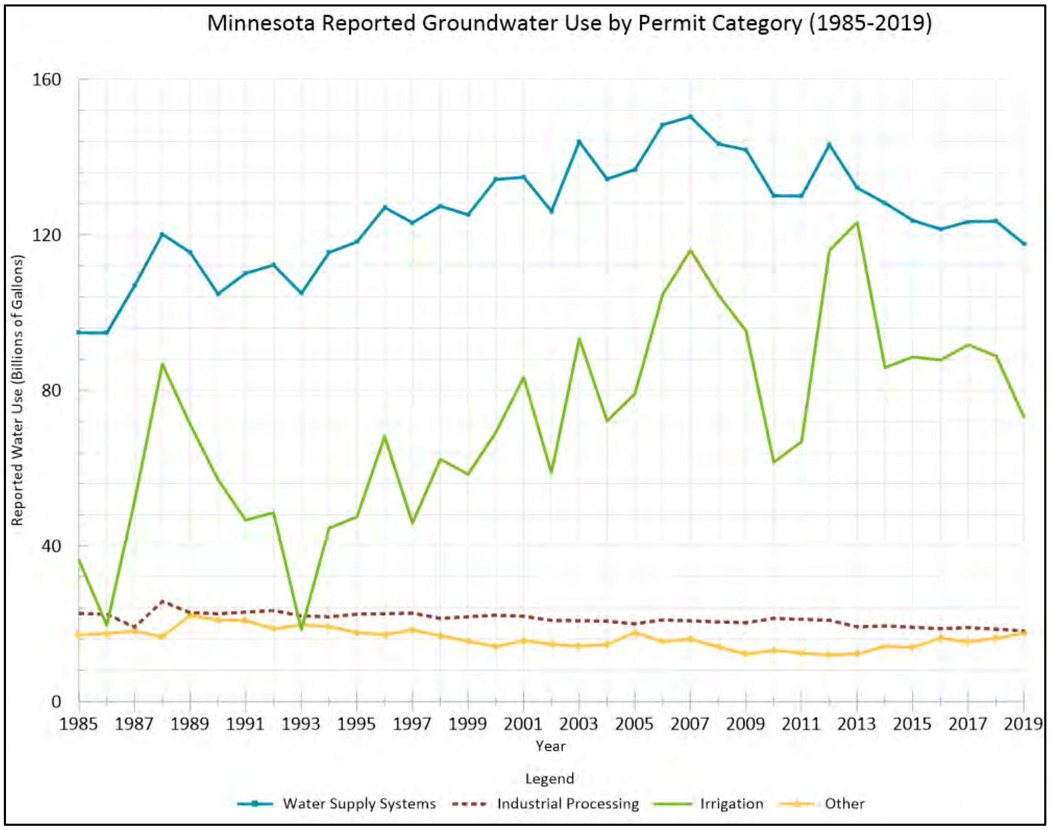


Figure 5. Reported water use by category of use, for non-power generation uses

Leadership in per capita water use

Minnesota has been making important strides in conservation, and individuals, businesses, and communities have all contributed to Minnesota's water conservation excellence. In 2018, 92% of water suppliers achieved the DNR residential water conservation goal of using less than 75 gallons per capita daily (GPCD). The statewide average residential GPCD is 52 (Figure 6).

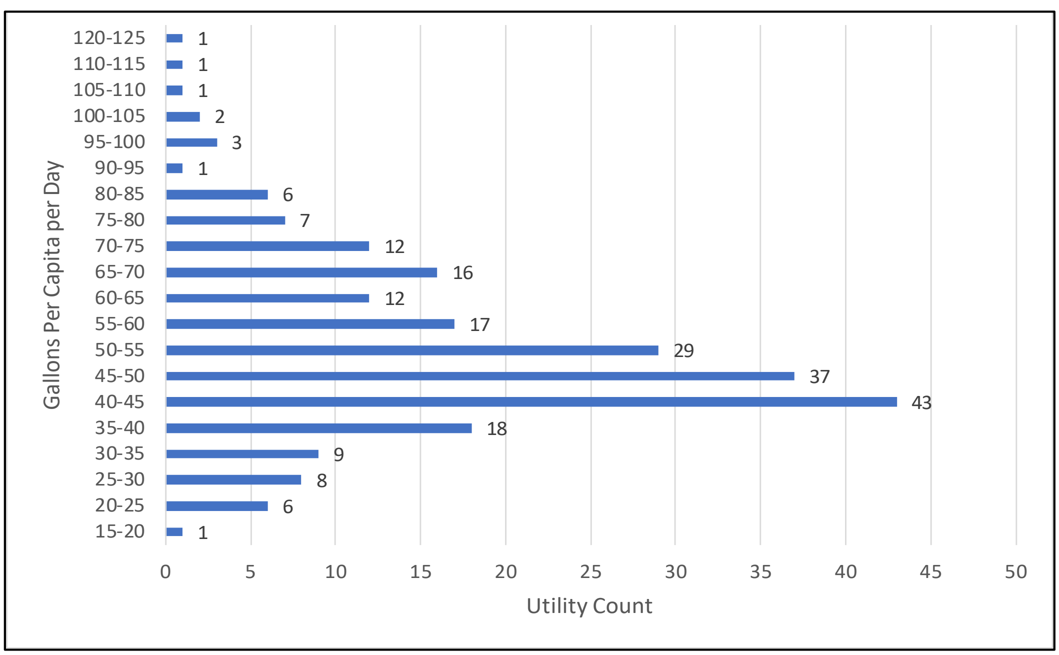


Figure 6. Residential gallons per capital per day (GPCD) of water supply use in 2018

Making waves in water efficiency

Many Minnesota companies lead the way in water and energy efficiency. For example, Chippewa Valley Ethanol Company in Benson has steadily reduced the amount of water used in its production. In 2007, the company used 3.7 gallons of water per gallon of ethanol produced. By 2019, that figure dropped to 2.8 gallons of water per gallon of ethanol, ahead of the industry water use benchmark. In 2019, Chippewa Valley constructed a water/wastewater treatment plant to treat and reuse boiler blowdown and cooling tower blowdown water that would otherwise be discharged. This will save 132,500 gal/day and help conserve the area's limited groundwater supply. Photo from the Chippewa Valley Ethanol Company.

Status of Minnesota's Streams

There is a direct correlation between a wetter Minnesota and changes to streamflow across most of the state. Compared to historical patterns, streams are now flowing higher in the spring, floods are bigger, bankfull flows last longer, and summer baseflow is increasing in some parts of the state. Climate models project increasingly intense, frequent floods, which are already manifested in our streams. These changes from climate are compounded by land use changes. The leading land use factors are those associated with a conversion to a primarily corn and soybean cropping system. As a result, drainage and tiling increase streamflows that subsequently cause stream channel erosion and instability, which degrades the instream habitat. Larger floods increase damage to infrastructure like roads, bridges, and buildings.

Streamflow in many watersheds across Minnesota has shifted over the past 20 years. **Comparing flow in streams to historic records reveals that our streamflow is higher than it used to be.** From water years 2000 through 2009, flow in 54% of watersheds ranked as *above normal* or *high* compared to historic records. From water year 2010 through water year 2019, flow in 75% of watersheds ranked as *above normal or high*. Of the 81 watersheds examined from 2010 through 2019, none had *below normal or low* flows (Figure 7).

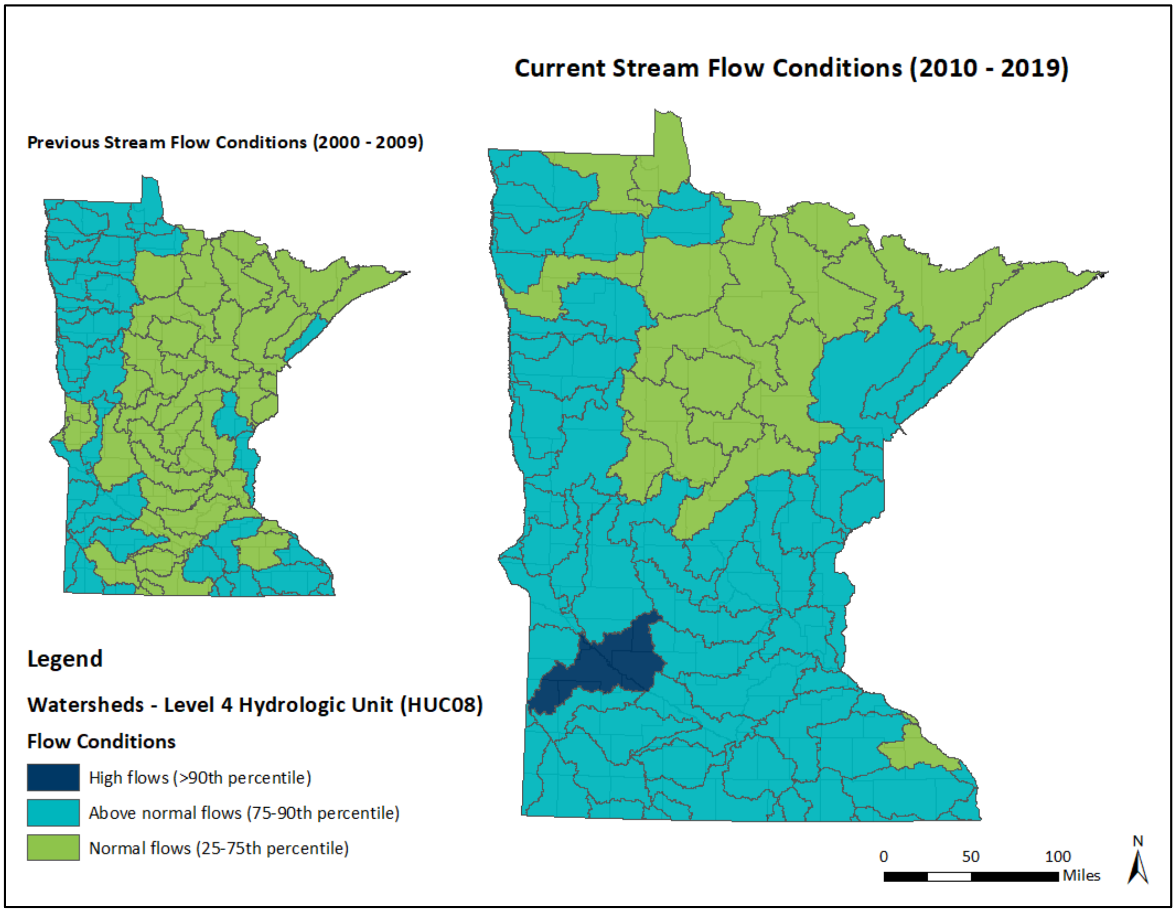


Figure 7. Overall stream flow data compared to historic records

In some watersheds, we are seeing both an unprecedented magnitude of annual precipitation and mean annual discharge in the years after 1991 (Figure 8). Coincident with the precipitation pattern is the change in land use land cover. While climate change has resulted in consistent increases in streamflow across the US, it does not reflect the complete change in streamflow measured as mean annual discharge. Primarily in the Midwest, additional increases in streamflow has come from human activities including land practices associated with conversion to row crop systems and urbanization. Several studies specific to the Midwest have examined the combined influence of climate change and land use change on streamflow. These found that land use change is responsible for a significant proportion of the increase, ranging from 32% to 40% to roughly equivalent with climate change.

These changes are illustrated at four streams where we conducted detailed case studies of streamflow conditions. We chose the case study sites to represent the breadth of Minnesota's variable geography: the Mississippi River (near Royalton), the Le Sueur River (in the Minnesota River watershed), the Buffalo River (in the Red River watershed), and the Rainy River. Five metrics of streamflow were evaluated for each site: flow magnitude, seasonality, flood flows, baseflows, and bankfull flow (Appendix A, found on the DNR web page "River Ecology Unit" under "Research").

Overall, each of the four streams is measurably wetter than in years past. Precipitation and mean annual flow have increased on all of the streams studied.

On the Le Sueur River, mean annual flow has increased. This change correlates with higher precipitation. Floods are also bigger and more variable, driven by both increased precipitation and land use changes. Flows are notably higher in the spring (April, May and June) than in previous years (Figure 8). Overall changes in flow on the Le Sueur River are showing impacts of climate change and land use change – specifically increased drainage and loss of perennial vegetation.

On the Mississippi River, flood flows have increased significantly since 1940, likely a result of increasing precipitation. Mean annual flow has increased markedly since 1940, which is also a result of increasing precipitation (Figure 9). August baseflow has increased. The patterns of precipitation and flows by season match closely, which indicates that changes in precipitation, rather than land use, are driving changes in streamflow on the Mississippi River.

On the Buffalo River, August baseflow has been consistently higher since 1990. Floods have also been slightly larger. Like the Le Sueur River, streamflow in the spring has also increased, which is likely the result of increased runoff from bare cropland at that time of year. Mean annual flow has increased, although that change preceded the increase in precipitation (Figure 10). Because the streamflow change preceded the precipitation change, land use changes may have affected this watershed prior to climate change impacts. The data suggest that land use changes may be adding to the hydrologic alteration due to climate change.

The Rainy River generally shows less change than other watersheds, but even there annual mean flow has increased coincident with increasing precipitation (Figure 11).

These findings align with climate change models, which project increasingly intense, frequent floods. Land use changes, including urban development and agriculture, can magnify the effects of climate change. Degraded stream channels caused by flooding make the ecosystems in our streams less diverse and less resilient. Damage to stream ecosystems can take time to accumulate and become apparent but will eventually effect our recreational use of streams. Our agricultural economy is especially vulnerable to more intense precipitation and larger floods. For example, climate change is resulting in significant increases in rainfall erosivity, therefore causing potential soil and nutrient loss. Additionally we are seeing an increase in frequency of higher flows responsible for flooding riparian areas potentially impacting crop production by waterlogging.

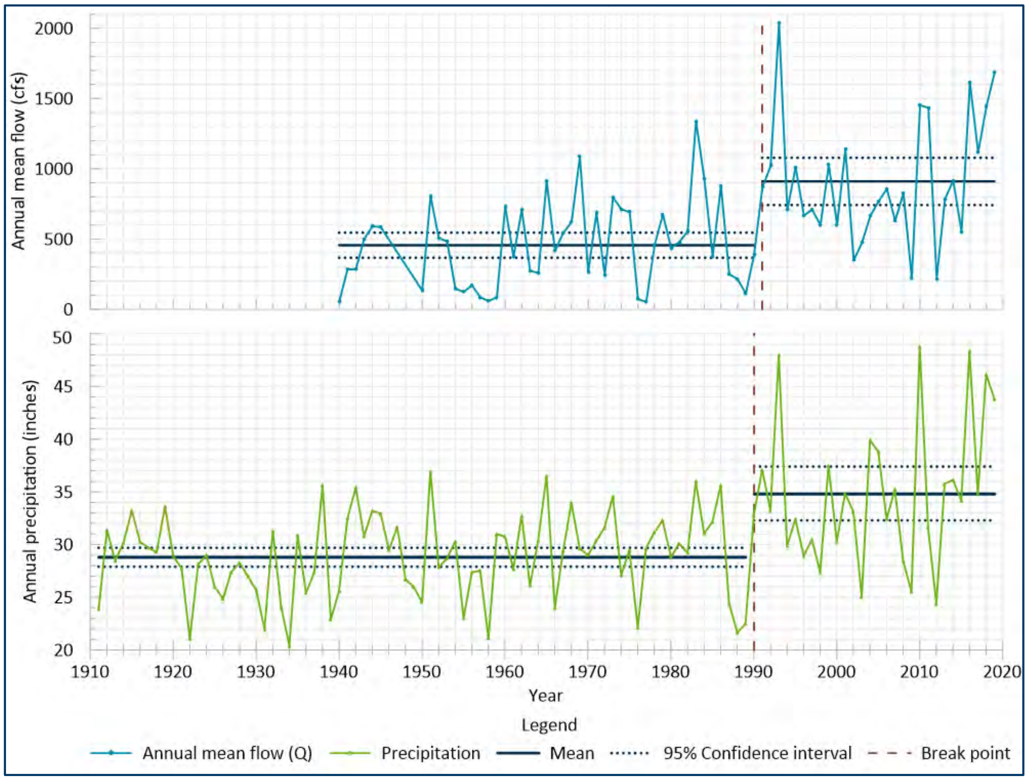


Figure 8. Mean annual flow on the Le Sueur River compared to precipitation

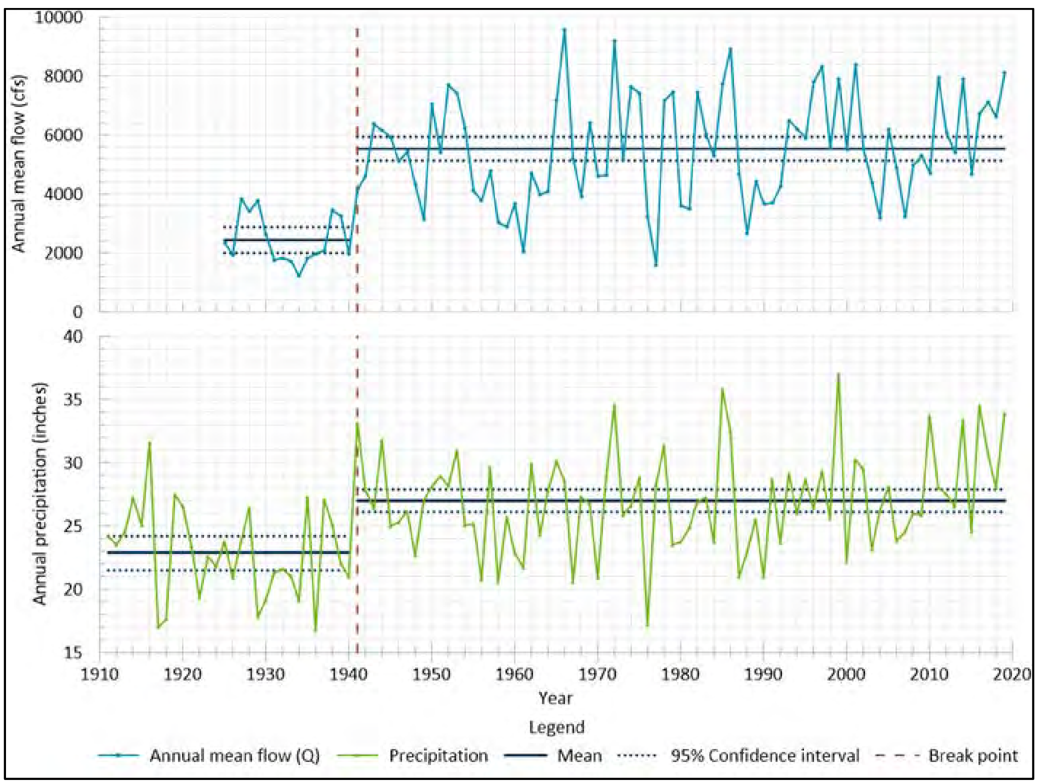


Figure 9. Mean annual flow on the Mississippi River compared to precipitation

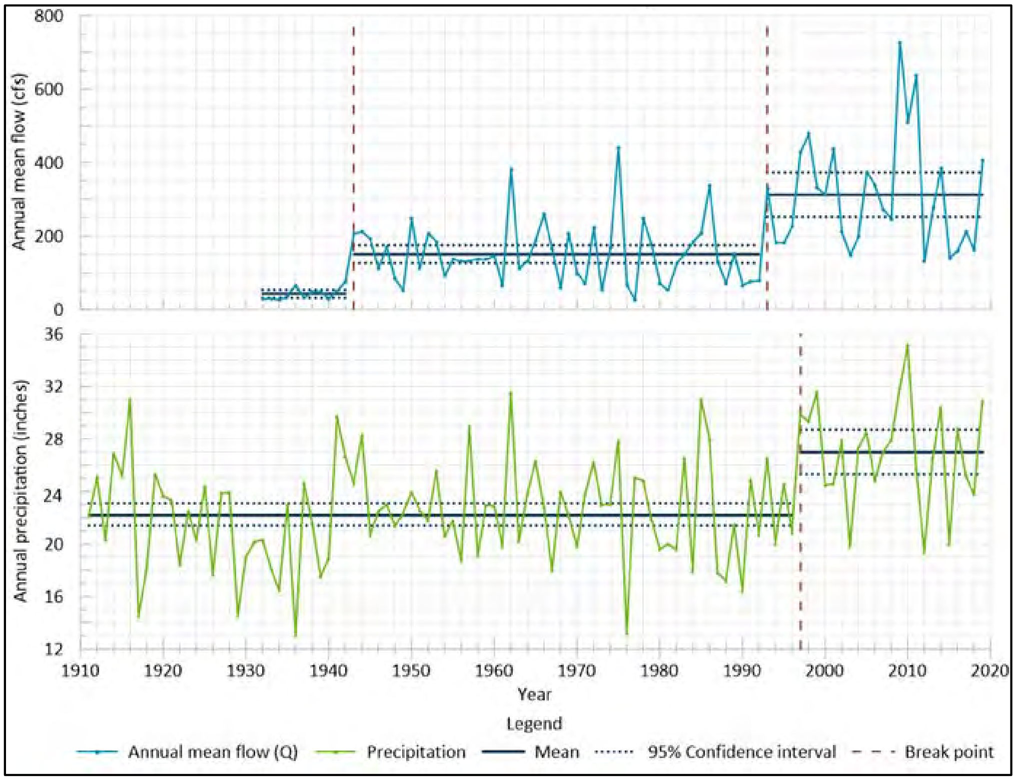


Figure 10. Mean annual flow on the Buffalo River compared to precipitation

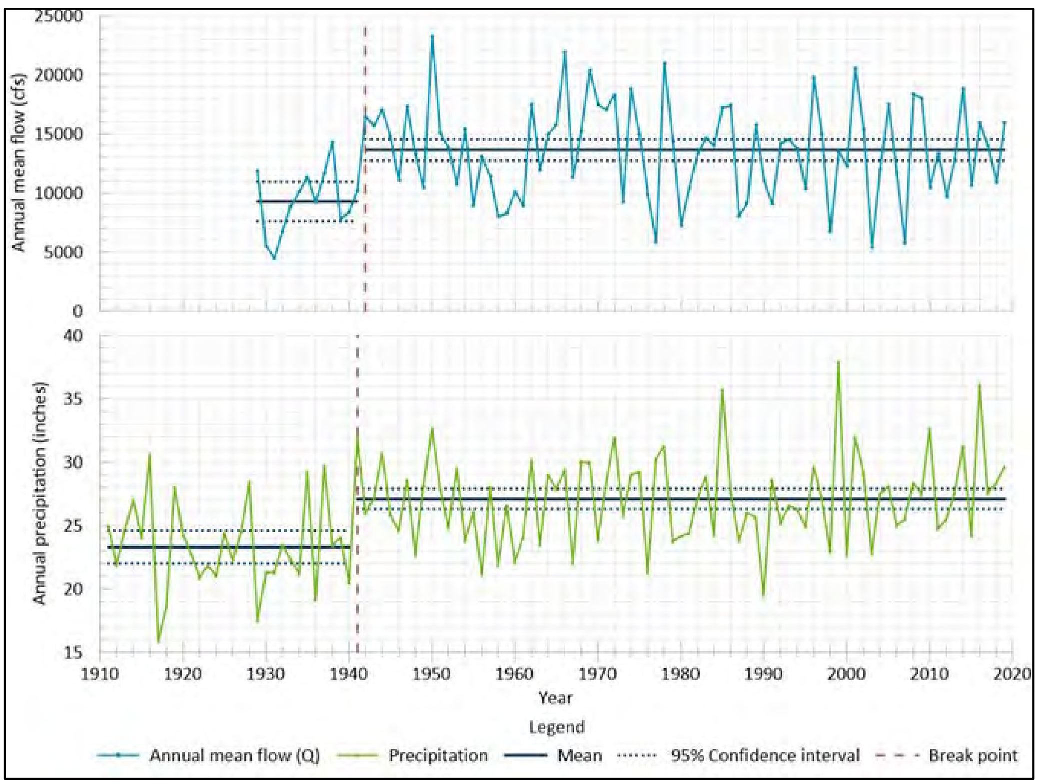


Figure 11. Mean annual streamflow on the Rainy River compared to precipitation

Status of Minnesota's Lakes

Lakes hold a special place in Minnesota's history, culture, and identity. They provide recreational opportunities, support a thriving tourism industry, help modulate the impacts of high and low precipitation, and enhance real estate values. Lakes are also important ecosystems that support fish and wildlife. They are one of the most visible and valued aspects of Minnesota's water resources.

One of the defining characteristics of lakes is their ability to slow down and store water. We benefit from lakes storing water, trapping sediment, and slowing runoff. Water levels in lakes are the difference between water coming in (such as precipitation or inflow from streams and groundwater) and water leaving (such as evaporation, human use or outflow to streams and groundwater). Most lakes naturally experience variability in water levels, but climate change, land use changes, and structures like weirs and dams can alter the normal range of water levels in lakes.

In 2019, most lakes that DNR monitors had higher-than-normal water levels (Figure 12)**.** Of Minnesota's 570 monitored lakes, 22 had water levels that ranked *very high* or *very low* compared to historic levels. Twenty-one of those 22 lakes had water levels more than two feet above the long-term median lake level, and only one lake was two feet below its long-term median. This broad shift toward higher lake levels is the result of increased precipitation and land use changes.

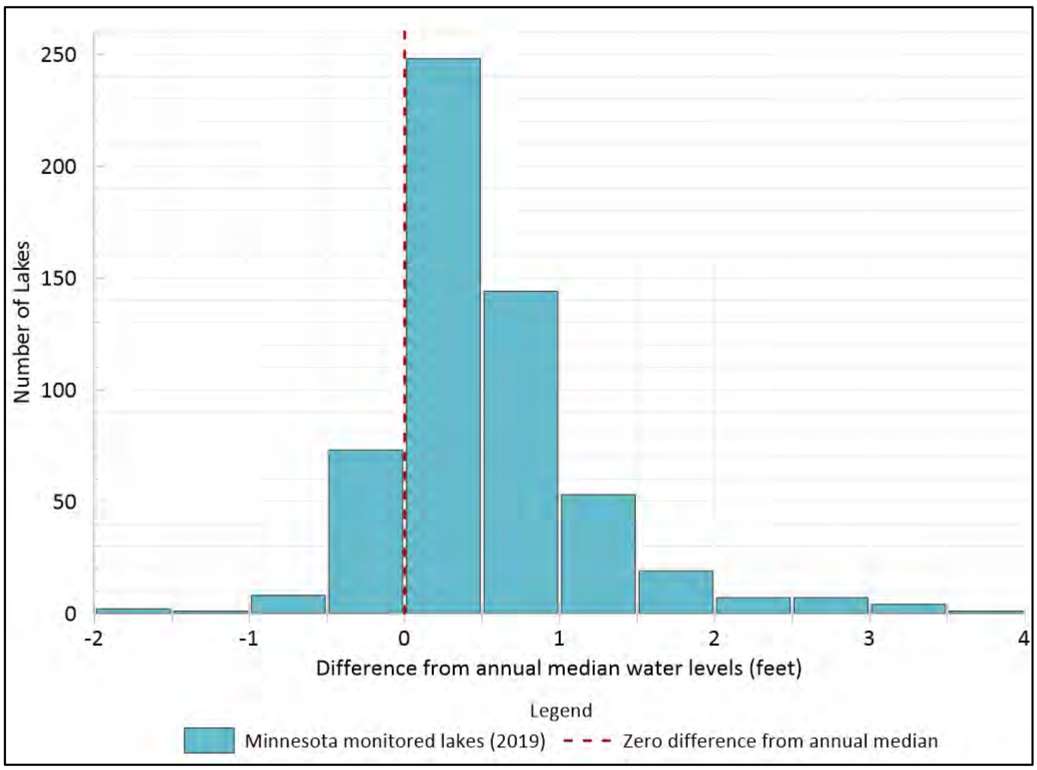


Figure 12. Departure from annual median water levels in 570 lakes

Human development along lakeshores leads to increased public expectations for managing lake levels to a very narrow range. In most cases, water resource managers have limited ability to control lake levels. As our climate becomes wetter overall, we will experience more problems due to high lake levels, unless we begin to plan and build for climate extremes. Although we have been in a historic wet period, drought will come and with it will come low lake levels.

Extremely high and low lake levels can cause property damage and temporarily impact recreational activities. However changing lake levels may be beneficial for lake ecosystems. Many lakes naturally have fluctuating water levels, and their aquatic plants have evolved with large water level fluctuations. For example, three-square bulrush protects shoreline from erosion by buffering waves and stabilizing sediments. It also provides important aquatic habitat for fish and wildlife. However, three-square bulrush requires periodic large water level fluctuations, i.e., long periods of wet and long periods of dry. Similarly, lowering the lake level of an impounded lake can improve water clarity and habitat for fish and migratory birds.

Property damage on Lake Superior

Following a period of low lake levels, Lake Superior has more recently reached near record high levels. High water levels are eroding the shoreline, damaging coastal infrastructure and property, flooding marinas, creating navigational hazards, shrinking recreational beaches, and harming coastal habitat.

Status of Minnesota's Wetlands

Minnesota's wetlands are critical our state's hydrology. Wetlands store water from snowmelt and spring rains, thereby preventing water from overwhelming floodways. The water stored in wetlands is a source of groundwater recharge as well as necessary wildlife habitat. Wetland plants take up nutrients, which improves water quality in downstream lakes and rivers. The plants also store carbon, provide habitat, and forage for wildlife.

Minnesota has 12.2 million acres of wetlands, second in total acreage among the 48 states coterminous states, behind only Florida. However, we have lost about half of our original wetlands. In southern and western Minnesota, millions of acres of our historic wetlands were lost to drainage and development, leaving most of those remaining in the north and east. This loss has resulted in a loss of water storage capacity, groundwater recharge, and other ecological benefits.

More recently, we have observed small, consistent net gains in wetland area (Figure 13). The DNR's wetland status and trends monitoring program shows that Minnesota had a net gain of 8,460 acres of wetland from 2006 through 2017. Wetland protection programs reduced wetland losses, including the passage of the Minnesota Wetland Conservation Act in the early 1990s. In addition, several state and federal programs are actively restoring wetlands.

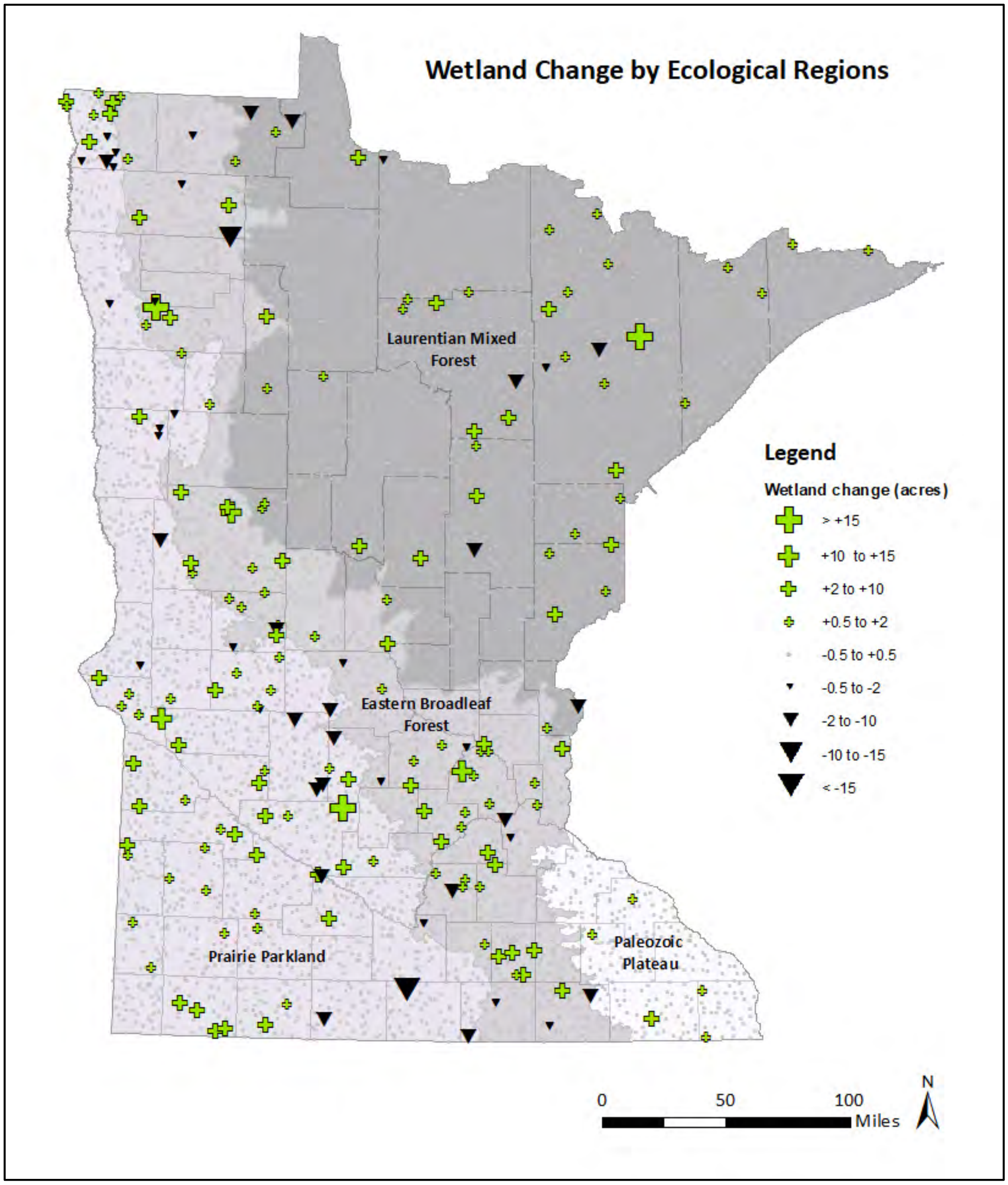


Figure 13. Wetland gains and losses from 2006 - 2017

A deeper look at the data shows that wetlands in Minnesota are changing. In addition to tracking total wetland acreage, the DNR wetland monitoring program tracks changes by wetland type. Although there have been small net gains in wetland acreage, the changes in wetland type suggest some potential areas of concern. Much of the observed gains were open-water-type wetlands (ponds), which typically have less wildlife habitat value than many other wetland types. Furthermore, the data also show conversions between wetland types, such as emergent wetlands converted to cultivated wetlands or ponds. Rather than a loss of wetland area, this is a loss of wetland function. Natural wetland vegetation is responsible for many of the important benefits of wetlands. Wetlands without significant vegetation, such as ponds, or those where the natural vegetation has been removed for growing cultivated crops, do not provide these benefits at the same level.

Historical wetland losses were due primarily to drainage for development, mostly agricultural production. Recent wetland changes are the result of climate, human activities, and groundwater use.

- Climate - A wetter climate in recent years may have allowed areas that were farmed during dry periods to revert to wetlands. It also has likely resulted in some wetlands shifting to wetter community types (e.g. wet meadows transitioning to shallow marsh).
- Human activity – Drainage and filling for urban or agricultural development are examples of direct impacts to wetlands, but wetlands may also be indirectly impacted. For example, development may lead to increased runoff and pollutant loading to wetlands.
- Groundwater appropriation – Many wetlands are directly connected to groundwater, and increased use of groundwater can cause wetlands to dry out. While water levels in wetlands often fluctuate naturally, groundwater appropriations can reduce water levels further and for longer periods of time. In turn, the wetland plant communities' change and ecological function is diminished. This has been observed in the Bonanza Valley and other areas where groundwater use in close proximity to wetlands has increased.

Status of Minnesota's Groundwater

Approximately three out of every four Minnesotans rely on groundwater for their drinking water. Minnesota's aquifers also support agriculture, industry and the natural resources that are vital to Minnesota's quality of life (streams, wetlands and lakes). Our aquifers are recharged by percolation of precipitation through soil. Some aquifers receive precipitation readily and can recharge quickly. Other aquifers are buried deep in the ground and can take years or decades to recharge. The DNR maintains a statewide network of approximately 1,100 observation wells to monitor our 'hidden' groundwater resource (Figure 14).

From 1993 to 2016, 37% of observation wells in Minnesota showed downward trends. **Now only 6% of wells statewide show downward trends**. These trend reversals are a direct result of increased precipitation and the implementation of robust conservation measures by local water users. Across Minnesota's varied geography, there are differences in groundwater trends:

- In the metro area, all observation wells show upward or stable trends over the past 20 years. This is a change from previous periods, when groundwater levels in the metro area were declining. The reversed trend in the metro area is likely due in part to the 1991 Groundwater Act, which banned the practice of Once-Through-Cooling with groundwater.
- In the central part of the state, 3% of observation wells are trending downward. In the western part of the state, 16% of wells are trending downward. Downward trends can result from a combination of factors, such as local drier conditions in the later years of the analysis period, increased groundwater use, or changes in land use and groundwater recharge. These wells may show where groundwater use is exceeding the rate of groundwater recharge.
- In the northeast and southeast portions of Minnesota, our observation well network is too sparse to draw conclusions about the overall state of the aquifers in those areas.

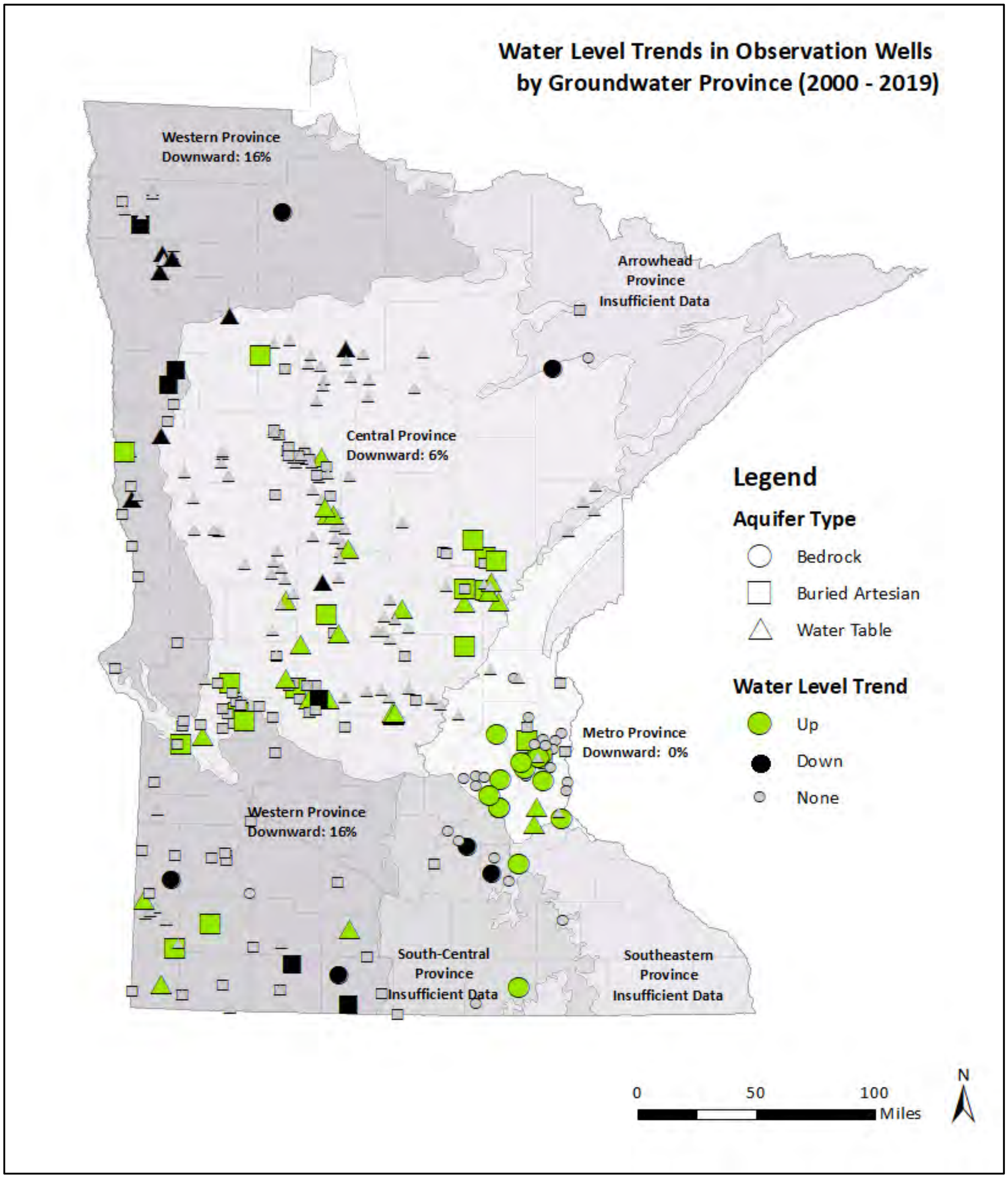
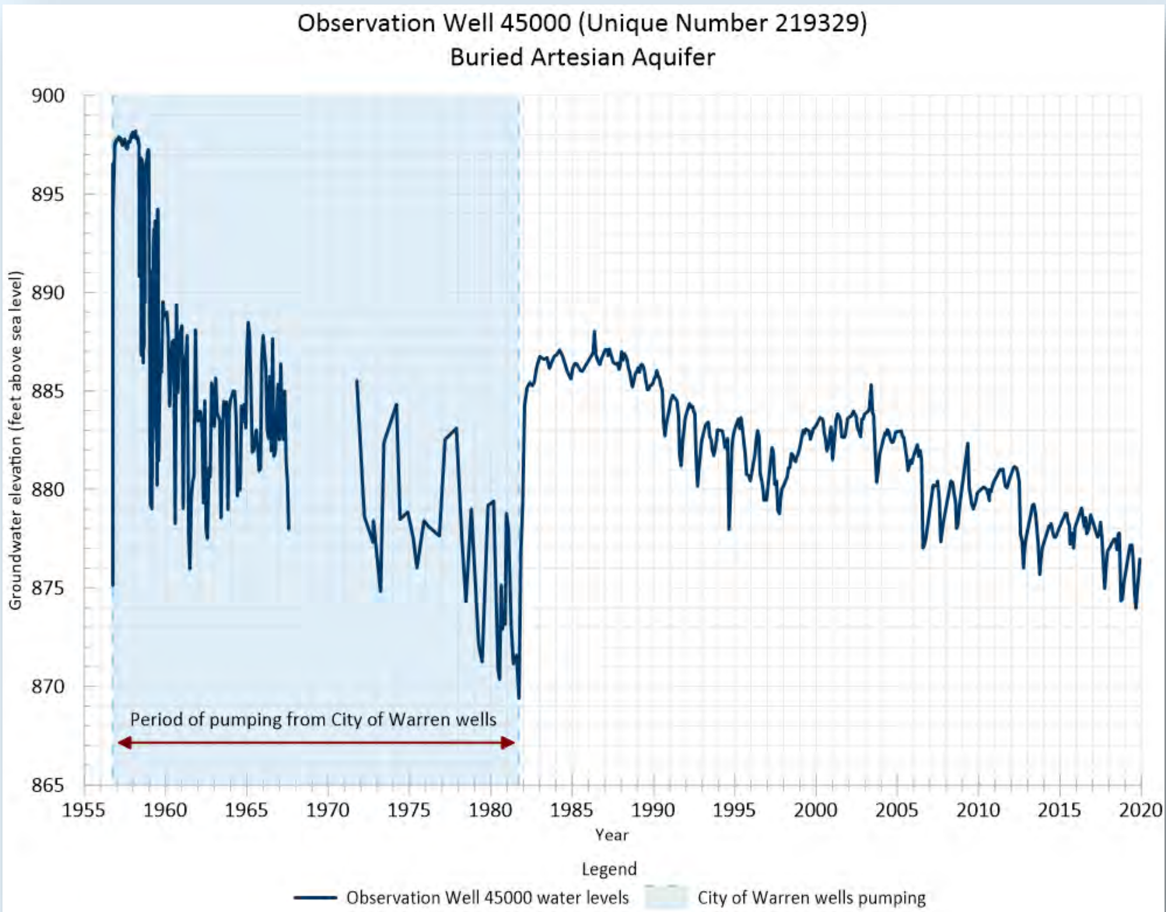


Figure 14. Water level trends in DNR observation wells, 2000 - 2019

Limited aquifers near Warren, Minnesota

Aquifers are scarce near Warren, Minnesota. In an observation well which monitors the primary aquifer, water levels have been slowly declining since 1991. Water levels also declined from 1956 to 1981 as a result of municipal pumping. When pumping was shifted to a different aquifer, water levels rose but did not return to pre-pumping levels. This partial recovery indicates the aquifer was pumped at a rate that exceeded its recharge rate. DNR hydrologists are investigating the source of the current water level decline and developing strategies to manage this aquifer.



Section II: The DNR's Role in Supporting Water Use

The Minnesota Department of Natural Resources plays an important role in supporting sustainable water use through its permit programs, data collection and analysis activities, law enforcement responsibilities, education, and technical assistance services. The DNR and other agencies in the executive branch have adopted a three-pronged approach to sustainable water resource management. This approach involves mapping, monitoring, and managing water resources adaptively over time. In the five years since the previous Water Availability and Assessment Report, the DNR's approach to water management has continued to evolve.

Implementation of Minnesota's water laws

Thus far, this report has provided data and information on water in relation to our economy, communities, landscapes, atmosphere and geology. This section of the report examines how the DNR continues to support the development of sustainable water use by individuals, businesses, and communities.

The DNR efforts are mandated under a variety of statutes. Here are highlights of some of the most important statutes and rules that govern DNR work, as well as how the DNR has applied those statutes into programs:

- **MN STATUTE: 103A.201 REGULATORY POLICY**
  - To conserve and use water resources of the state in the best interests of its people, and to promote the public health, safety, and welfare, it is the policy of the state to regulate Minnesota's public waters, subject to existing rights, and control the appropriation and use of waters of the state.
- **MN STATUTE: 103A.43: WATER ASSESSMENT AND REPORTS**
  - The DNR shall provide an assessment and analysis of the quantity of surface and groundwater and the availability of water to meet the state's needs.
- **MN STATUTE: 103G.101 WATER CONSERVATION PROGRAM**
  - The commissioner shall develop a water resources conservation program for the state
  - The program must include conservation, allocation, and development of waters of the state for the best interests of the people
  - The commissioner must be guided by the program in issuing permits for the use and appropriation of the waters of the state
- **MN STATUTE: 103G.255 ALLOCATING AND CONTROLLING WATERS OF THE STATE**
  - Directs the commissioner to administer the use, allocation and control of waters of the state; establish, maintain and control lake levels and water storage reservoirs; and determine ordinary high-water level of waters of the state.
- **MN STATUTE: 103G.261 WATER ALLOCATION PRIORITIES**
  - Directs the commissioner to adopt rules for allocation of water based on six priorities for the consumptive appropriation and use of water. Outlines where and when use of surface water should be encouraged or discouraged.
- **MN STATUTE: 103G.265 WATER SUPPLY MANAGEMENT**
  - Requires DNR to manage water resources to assure an adequate supply to meet long-range seasonal requirements for domestic, municipal, industrial, agricultural, fish and wildlife, recreational, power, navigation and quality control purposes. This law also requires DNR approval for large volume water diversions to places out of state and diversion from the Great Lakes.
- **MN STATUTE: 103G.285 SURFACE WATER APPROPRIATIONS**
  - Limits appropriation from watercourses during periods of low flow, requires protective elevations for lakes, restricts use of trout streams, and requires contingency plans.

- **MN STATUTE: 103G.287 GROUNDWATER APPROPRIATIONS.**
  - Identifies information needed an evaluation to be done for groundwater appropriation permits and allows for the designation of groundwater management areas. Also describes sustainability criteria: The commissioner may issue water-use permits for appropriation from groundwater only if the commissioner determines that the groundwater use is sustainable to supply the needs of future generations and the proposed use will not harm ecosystems, degrade water, or reduce water levels beyond the reach of public water supply and private domestic wells.
- **MN STATUTE: 103G.291 PUBLIC WATER SUPPLY PLANS; APPROPRIATIONS DURING DEFICIENCY**
  - Every public water supplier serving more than 1,000 people must submit a water supply plan to the commissioner that must address projected demands, adequacy of the water supply system and planned improvements, existing and future water sources, natural resource impacts or limitations, emergency preparedness, water conservation, supply and demand reduction measures, and allocation priorities. Plans must be updated every 10 years.
- **MN RULE: CHAPTER 6115, PUBLIC WATER RESOURCES and WATER APPROPRIATION AND USE**
  - These rules exist to provide for the orderly and consistent review of permit applications in order to conserve and utilize the water resources of the state in the best interest of its people.
  - These rules set forth minimum standards and criteria pertaining to the regulation, conservation, and allocation of the water resources of the state, including the review, issuance, and denial of public water work permit applications and water appropriation applications and the modification, suspension, or termination of existing permits.

Water Appropriation Permitting

The DNR is required to administer a permit system to manage the use of groundwater and surface water throughout the state and conserve these same waters for everyone to enjoy. In times of shortage, this may include restricting permitted water use, consistent with legislatively established priorities. A water appropriation (use) permit is required for anyone who uses more than 10,000 gallons of water per day or 1 million gallons of water per year. The number of water use permits for irrigation of agricultural crops represents 63% percent of all permits issued. Today the DNR manages more than 10,000 water use permits throughout the state. All of water users must submit annual reports of their monthly water use to the DNR. These reports assist DNR in managing the resource, especially during times of drought.

The DNR has established three groundwater management areas (GWMA) in locations with heavy use to ensure that groundwater resources remain sustainable: North and East Metro GWMA in 2015, Bonanza Valley GWMA in 2016, and Straight River GWMA in 2017. The DNR followed guidance contained in Minn. Stat. 103G.287 in creating these GWMA. DNR staff, in collaboration with local stakeholders in those areas, have developed implementation plans to improve the management of groundwater for all users and for the natural resources and fish and wildlife habitat that depend on that same water.

Over the past several years, the DNR has received a few requests for appropriating water in Minnesota and moving it across major watershed boundaries, and even out of the state. Minn. Stat. 103G.265 includes restrictions on moving water out of the state to ensure the remaining water in the area will be adequate to meet the needs of that area over the life of the diversion project. Minnesota is a member of the Great Lakes Compact and must follow the terms of the compact for any requests to divert water from the Great Lakes Basin. In addition, Minnesota and the signatory states of the Upper Mississippi River Basin, have agreed to give one another notice of any interbasin diversions that exceeds 5 million gallons per day average in any 30-day period.

MPARS: MNDNR Permitting and Reporting System

DNR uses the online MNDNR Permitting and Reporting System (MPARS) to manage a variety of water permits. This system allows the public to apply online for five DNR permit types (water appropriation, public waters work, dam safety, aquatic plant management and invasive aquatic plant management), as well as request changes to existing permits, pay permit-related fees, report water use, and communicate with DNR staff. DNR staff use the system to record the decision-making process for water permits. Over 10,000 customers, DNR water regulations staff, and interagency partners statewide use this system. Using MPARS, the DNR processes an average of 1100 water appropriation permits annually and receives 10,500 water use reports. This system helps streamline much of the administrative work that comes with water regulatory programs, allowing DNR employees to devote more time to assisting applicants, gathering the information needed to inform decisions, and related work. The DNR is currently working to expand MPARS to include aeration permits.

Regulatory Lake Protection

Minnesota's lakes are protected by a variety of laws and ordinances administered by various units of government. The DNR protects public waters, which include most lakes and many wetlands and watercourses, under the statutory authority of M.S. 103G.245. Alterations to public waters, such as fill placement, excavation, water level controls, restoration, culvert and structure placement, and mining, are regulated through the DNR public waters permitting program. Regulating activities on other public waters such as wetlands and watercourses upstream of lakes in the watershed has profound positive impacts to the lakes downstream. Activities that are categorically harmful or unreasonable are prohibited, while most other activities are conditionally allowed to some degree. This program seeks to balance protection and use of the water resource.

Shoreland Protection

With Minnesota experiencing more precipitation and fluctuating water levels, many lakes are experiencing high water resulting in shoreline erosion and flooding. In response, many property owners are seeking ways to protect their property, including hard armoring the shoreline and filling low areas. These actions can have negative impacts, including displacing natural vegetation that is important for fish and wildlife and reducing water storage capacity, increasing flood risk. The DNR administers the state shoreland program in cooperation with local governments that implement the state shoreland rules through local zoning. The DNR provides technical support and training services to local governments to help staff, planning commissions, and boards of adjustments make decisions consistent with the state's shoreland laws.

Engagement with water users

The DNR actively engages with water users to ensure thoughtful planning and water conservation efforts. Highlights of our engagement work are listed below.

Water Supply Planning

Planning for the future is a key tool to ensuring sustainable water supplies. Minnesota Statute 103G.291 requires all water suppliers serving more than 1,000 people to submit a water supply plan to the DNR every 10 years. These plans encourage communities to proactively consider how they will sustain water supplies to keep up with future growth and during times of shortage.

The DNR works with the Metropolitan Council to support the development of municipal water supply plans within the Twin Cities Metropolitan Area. We work directly with cities and towns throughout greater Minnesota to ensure their water supply plans emphasize water conservation and efficient use.

Local water utilities and communities are becoming leaders in water conservation strategies to ensure protection of their own local and regional supplies. We expect new water conservation efforts and innovations in the future. For example, as water utilities face mounting pressure to “do more with less,” smart water technologies will be more widely used, such as advanced metering infrastructure. Also, many cities are turning to green infrastructure and reuse projects to manage stormwater. There are several benefits of green infrastructure, including reduced costs over conventional stormwater infrastructure, water quality improvement, flood reduction, groundwater recharge, and water reuse opportunities.

Sustainability and resilience produce a good return on investment in the form of both economic and natural resource benefits. In working with water suppliers, the DNR will continue to encourage planning work to incorporate resilience and adaptability to climate change and extreme weather.

Water Conservation

Water conservation is any action that reduces the amount of water withdrawn from water supply sources, reduces consumptive uses, reduces the loss or waste of water, improves the efficiency of water uses, or increases recycling and reuse of water. Water conservation is integrated into all aspects of DNR water regulations and permitting through Minnesota Statute 103G.101, including statewide water conservation education and outreach.

Minnesota is the first state in the nation to have developed software that allows all of permitted high-capacity water users, which number 10,000 in Minnesota, to track and compare their water efficiency and conservation efforts and trends over time. The Minnesota Water Conservation Reporting System’s annual reports help various sectors to learn more efficient and cost-effective ways to conserve our water resources. The state benefits from MPARS collecting and aggregating the information from all cities and commercial, industrial, and institutional businesses, irrigation and other agricultural uses. The data will continue to guide water use decisions in the future. As our population grows and climate changes, we may experience increased use and seasonal intensity of use in some parts of the state. Our efforts to strive for water efficiency and conservation in all sectors will help protect Minnesota’s water supplies, industry, economies and natural resources well into the future.

Water resources science in decision making

The following sections describe the DNR efforts that contribute to better understanding the water availability in Minnesota through collecting, understanding, and applying water resource data to our decisions, and making that data available for others to use.

Climatology

The DNR State Climatology Office (SCO) collects, maintains, analyzes, and shares information about Minnesota’s climate with the state’s citizens, communities, organizations, and units of government at all scales[1]. From 2015 – 2019, the DNR improved the visibility of its climatology program by fostering collaboration, investing in new equipment, improving the ability to share data with the public, and prioritizing climate change as a major issue affecting natural resources. During this period, the DNR expanded real-time climate monitoring capabilities, developed new online climate analysis tools, enhanced its capacity to disseminate climate change information to Minnesotans, increased the scope of partnerships between climatology staff and those reliant on climate information, and committed to the update of the statewide drought plan.

The DNR will continue to maintain the monitoring networks, relationships, technologies, and delivery systems that enable it to provide important climate services to Minnesotans. The National Center for Environmental Information will release new climate averages or "normals" during 2021, and the SCO will need to update many of its materials and tools to reflect the changes. Additionally, the University of Minnesota will have completed intermediate and perhaps advanced climate modeling for Minnesota. New information from those projects will need to be integrated into the DNR's existing messages and products, along with relevant information from forthcoming global, national, and regional climate assessment reports. The SCO also faces the challenge of maintaining statewide precipitation observer numbers; this is always a challenge. The DNR relies heavily on a core group of volunteers but has struggled to expand that core and recruit replacement volunteers as others transition out of the program.

Water Resource Data Collection

The DNR collects hydrologic data across the state to facilitate resource management decisions related to our statutory responsibilities. These data are collected from a variety of networks and include data on lake levels, stream flow, groundwater levels, precipitation and climate. The DNR relies heavily on partners and volunteers in our data collection efforts. Soil and Water Conservation Districts are contracted to measure groundwater levels at observation wells and also record precipitation data for our volunteer precipitation observation program. MNgage is a volunteer driven program that monitors daily precipitation, it began in the 1960s and has consisted of approximately 1,500 volunteers for the past 4 decades. Similarly, the Lake Level Minnesota program consists of approximately 1,000 volunteers and cooperative organizations like lake associations that take readings throughout the summer at DNR-surveyed gages.

Since 2015, the DNR has continued to improve our hydrologic monitoring networks, hydrologic database, and websites. In 2018, streamflow and groundwater data were migrated into our new hydrologic database Water Information System KISTERS (WISKI), and our cooperative stream flow and groundwater websites were updated to allow users better access to more types of data. A new network of 40 climate stations was installed in 2015 to provide data to agricultural producers to inform irrigation schedules and to improve

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[1] Climatology staff maintain the nation's largest in-state precipitation monitoring network (in collaboration with Soil & Water Conservation Districts); oversee 40 automated hydro-climate stations around the state; partner with the National Weather Service and DNR hydrologists to quality-control real-time and archived precipitation data; develop and run databases, web pages, and applications offering users access to a wide variety of climate data; contribute to and produce weekly and monthly hydro-climatic conditions reports; co-lead Minnesota's drought planning efforts; educate Minnesotans about the state's changing climate; train DNR staff on climate change science; and engage users across the state with annual presentations, frequent website updates, and regular social media posts.

coverage of climate data across the state. Long term wetland monitoring was added in 2019 and consists of a network of reference quality wetlands that will provide information on the eco-hydraulic requirements of different wetland types in Minnesota. Stream flow monitoring stations were added to groundwater management areas and other areas of concern, and 253 new groundwater observation wells were added to the network.

As resources allow, the DNR will continue to maintain and improve its hydrologic monitoring networks, hydrologic databases and websites. Migration work will continue to move precipitation and lake level data into the WISKI database and web products will enhance users' access to data and analytical tools. Goals have been set to expand the observation well and wetland networks.

Stream Ecological Thresholds

The DNR has been collecting data on fish habitat associations on numerous streams across Minnesota since 1987, to be used in conjunction with models of stream hydraulics and discharge. The information generated will be used to establish the relationship between stream flow and ecological function. This data and information is fundamental to understanding the potential impact of cumulative water appropriations on the natural stream environment and ecology, a key to sustainable management of our water resources.

In 2017, the DNR began a stream modeling study to examine the impacts of groundwater withdrawals on Little Rock Creek and its aquatic community. Data were collected from the stream to examine the hydraulic changes that occur as water decreases and examine the impact on stream habitat for aquatic organisms. This study integrates with stream flow gaging work on Little Rock Creek and associated groundwater modeling, which help establish the amount of change in stream flow caused by groundwater pumping. Together, these studies have helped establish sustainable use limits (called sustainable diversion limits) for long-term water management at this site and serve as a demonstration of a viable approach for connecting all of the department's statutory responsibilities.

Further study and demonstration of the ecological thresholds approach for setting sustainable diversion limits will occur. This includes continuing statewide collection of aquatic habitat requirements for fish and mussel species. The information will be used to refine and expand our ability to manage water resources. During the next five years, the Little Rock Creek thresholds study will be completed, and the concepts and insights gained there will be used to inform our work in other watersheds where water use may be exceeding sustainability thresholds.

Wetland Science Program

The DNR wetland programs provide important information to help understand wetlands and their role in Minnesota's water protection and management efforts. Wetland science programs include maintaining a statewide wetland inventory, ongoing operation of a wetland status and trends program to track gains and losses, and developing a wetland hydrologic monitoring program. This information is being used to inform decisions about wetland policy as well as to guide wetland protection and restoration efforts.

In 2019, the DNR completed the first statewide update of the National Wetland Inventory for Minnesota in over 30 years. The DNR partnered with Minnesota Pollution Control Agency in this effort. In addition, in effort to address wetland impacts as well as ensure sustainable groundwater resources, the DNR has developed an online mapping tool that helps identify potential wetland restoration opportunities in the Bonanza Valley Groundwater Management Area. Unlike other restorable wetland prioritization tools, this tool focuses specifically on the potential for restored wetlands to promote groundwater recharge.

The DNR has begun to establish a wetland hydrology monitoring program. The purpose of this program is to define the normal water level range needed to support healthy wetlands. Monitoring sites are selected to be representative of healthy wetlands with native vegetation across a range of different wetland types. Since 2019, the DNR has established 20 long-term wetland water level monitoring stations in wetlands around the state. The DNR plans to expand this effort, contingent on funding, to include an additional 40 sites for water level monitoring in wetlands. These data will allow the DNR to develop science-based groundwater appropriation thresholds that protect wetlands and will be useful to other organizations for their own wetland management efforts.

Watershed Health Assessment Framework (WHAF)

With ongoing support from the Clean Water Fund, the DNR continues to develop and enhance the web-based tool WHAF for accessing data and information on watershed health and natural resource context. The WHAF includes information on water availability, wetland loss, stream alterations, and groundwater, as well as many other variables, for any user-selected location in Minnesota. The WHAF allows users to view a summary of health scores from five components (hydrology, geomorphology, water quality, connectivity, and biology) across watershed boundary scales.

In this way, users can note patterns and relationships between ecological context, health conditions, and the system's response. The WHAF is intended to provide information and guidance to natural resource managers, but also has been used by teachers**,** landowners**,** city planners, and other natural resource professionals.

The WHAF had several highlights from 2015 – 2019, including:

- *Watershed Context Reports* - These context reports, developed for all 81 major watersheds in Minnesota, provide an overview of ecological conditions and human influences in each watershed.
- *Climate Summary* - These reports, also available for all 81 major watersheds, provide an overview of climate conditions based on data collected from 1895 through 2018. The reports focus on conveying trends in seasonal and annual temperature and precipitation, summarize data using 30-year averages, and compare the averages to the entire climate record average.
- *WRAPS (Watershed Restoration and Protection Strategy)* – In conjunction with Minnesota Pollution Control Agency, the DNR developed protection strategies for streams during the last 5 years using the WHAF. This WHAF product establishes data-driven priorities for protection of stream reaches.

DNR's WHAF team is pursuing several enhancement efforts in the coming years:

- GRAPS *(Groundwater Restoration and Protection Strategies)* - In 2020, groundwater and drinking water information was added to the WHAF tool, allowing users to make informed land management decisions for groundwater protection.
- *Forecasting Climate Data* - Over the next 5 years, it is anticipated that climate data forecasts will be downscaled appropriately and the data made available for use. Once completed, efforts to incorporate forecasted climate change data into the WHAF will be undertaken.
- *Lake Health* - One area of expansion for the WHAF over the next 5 years will be to develop indices for assessing and tracking lake health. This includes developing on-demand hydrologic assessment tools capable of identifying the timing of significant hydrologic changes and trends.

Groundwater Modeling

Since 2015, the DNR has used groundwater flow models to examine the sustainability of groundwater use in several parts of the state, including the North and East Metro, the Little Rock Creek watershed in Benton and Morrison Counties, and the area around Cold Spring Creek in Stearns County. DNR groundwater modelers are working closely with managers at the City of Rochester and the City of Moorhead to guide their efforts to sustainably expand their water supply systems. DNR staff are starting to construct a groundwater model that will help quantify and understand how groundwater pumping affects aquifers and surface water in the Bonanza Valley.

Groundwater Atlas Mapping

The DNR is developing better maps to identify areas of groundwater availability. Since 1995 the DNR, in collaboration with the Minnesota Geological Survey (MGS) has produced a series of County Geologic Atlases. A completed county atlas consists of two parts. The MGS produces Part A, which describes the county geology, while the DNR produces Part B, which details the county's groundwater resources. These atlases help identify areas where groundwater resources may be available for future large volume users or to sustain existing high densities of users. Atlases are complete for most metro areas, southeast and central counties, and are in process for over 15 other counties, mainly in western and northern Minnesota. The GIS data sets and maps, which are available to the public, detail our current understanding of the aquifer systems, along with pollution sensitivity maps that show the interaction of groundwater and surface water.

The atlas is a critical tool for a broad range of resource managers. It provides comprehensive information for planners, managers, scientists, researchers and individuals statewide for a wide variety of projects such as water supply planning, land use decisions, resource development, resource protection, transportation planning, agricultural water supply, groundwater research/studies, and Environmental Impact Statements. Since 2015, the DNR has published 11 new and one revised Part B atlases. Atlases in nine previously un-mapped counties and revisions of two county atlases are underway.

Conclusion

Minnesota's climate is already changing, and that change is evident on our landscape. In the past several decades, we have seen increased precipitation, more extreme rainfall events, and substantial warming. In response, streamflow is increasing, floods are bigger, and our lakes are higher. Some wetlands are getting wetter. We also have more wetlands now than a decade ago – likely due to state and federal programs that protect and restore wetlands. Groundwater levels are generally stable; some areas with falling water levels in 2010 and 2015 have now stabilized – likely due to increased rainfall and improved water conservation. Nonetheless, we have areas where groundwater levels are falling, and the groundwater supply is limited. The energy sector and water suppliers have improved water conservation over the past decade, and consequently Minnesota's water use has declined, even as our population has grown.

We have been in a climatic wet regime recently. Although climate change forecasts predict an overall wetter climate, we will still experience droughts in the future, within the overall trends driven by climate change. DNR programs continue to support sustainable water now and prepare for the climate of the future by:

- engaging with water users to support planning resilient water supply systems and water conservation;
- collecting, understanding, and applying water resource data to our decisions, as well as making that data available for others to use;
- effectively implementing Minnesota's water laws.

The DNR is working with other regulators and water users to enhance resiliency and sustainability in face of these trends and anticipated future changes.

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