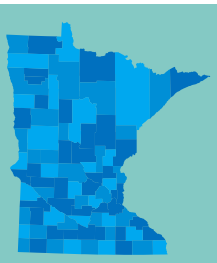
Groundwater monitoring

September 2025

Appendix B: 2025 Groundwater Monitoring Status Report

MINNESOTA POLLUTION CONTROL AGENCY



Prepared by:

Dave Tollefson, Kim Kaiser, Brennon Schafer, Jeff Berg (Minnesota Department of Agriculture, Pesticide and Fertilizer Management Division), Pooja Kanwar (Minnesota Department of Natural Resources), Steve Robertson (Minnesota Department of Health) and, Mark Ferrey, Sharon Kroening, Erik Smith (Minnesota Pollution Control Agency, Environmental Outcomes and Analysis Division) for the Minnesota Environmental Quality Board.

Minnesota Pollution Control Agency
520 Lafayette Rd N
St. Paul, MN 55155-4194
http://www.pca.state.mn.us
651-296-6300 or 800-657-3864

Minnesota Department of Agriculture
625 Robert St N
St. Paul, MN 55155-2538
http://www.mda.state.mn.us
651-201-6141 or 800-967-2474

MINNESOTA

Minnesota Pollution Control Agency | Minnesota Department of Agriculture

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

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

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Introduction

The 1989 Groundwater Protection Act (GWPA) (Minnesota Statutes, Chapter 103H.175) requires the Minnesota Pollution Control Agency (MPCA), in cooperation with other agencies participating in the monitoring of water resources, to provide a draft report on the status of groundwater monitoring to the Environmental Quality Board (EQB) for review every five years. This report is written to provide an update of groundwater monitoring activities in Minnesota to fulfill the MPCA's 2025 GWPA reporting requirements. For additional information on the background and history of groundwater monitoring in Minnesota, see *The Condition of Minnesota's Groundwater Quality, 2018-2023* (Kroening, 2024) available at: The Condition of Minnesota's Groundwater Quality, 2018-2023.

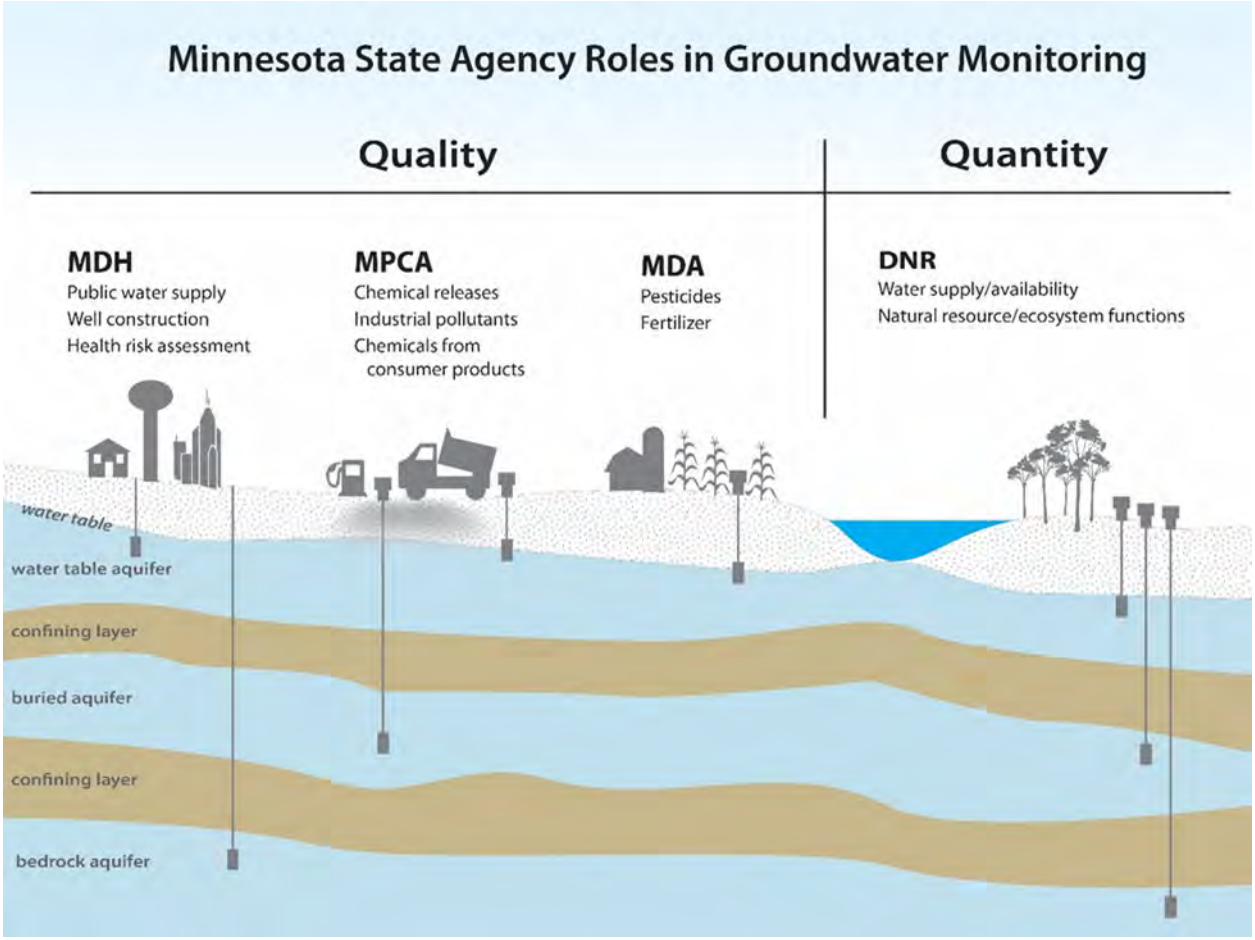
Agency roles in groundwater monitoring and assessment

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

Three state agencies, the MPCA; Minnesota Department of Agriculture (MDA); and Minnesota Department of Health (MDH), have important statutory roles and responsibilities in protecting the quality of Minnesota's groundwater as shown in Figure 1. The MPCA and MDA both conduct statewide ambient groundwater quality monitoring for non-agricultural chemicals and agricultural chemicals, respectively. These two agencies share many monitoring resources, including the computer database that stores the data that is collected, the technical staff that manage this information, and occasionally the sampling staff that collects the state's groundwater samples. For example, each year MPCA field staff collects pesticide samples from 20 wells in their network for the MDA. The MDH conducts monitoring to evaluate and address the human health risk of contaminants in the groundwater that is used for drinking. Beginning in 2025 the Drinking Water Protection Section at MDH developed a new monitoring program to test drinking water sources for CECs and other contaminants on an ongoing basis. This initiative is being referred to as the Drinking Water Ambient Monitoring Program (DWAMP). In addition to these agencies, the Minnesota Department of Natural Resources (DNR) monitors groundwater quantity conditions across the state through a network of groundwater monitoring wells, and the Metropolitan Council conducts regional water supply planning using the information collected by the MPCA, MDA, MDH, and DNR.

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

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



Water quality monitoring and assessment

Between 2020 and 2025, groundwater quality monitoring in Minnesota mainly was conducted by state agencies in partnership with local entities and the federal government. The following sections provide more detail about these monitoring activities.

National water quality monitoring

The National Groundwater Monitoring Network (NGWMN) was the primary national-scale groundwater monitoring program operated by the federal government from 2020-2025. The NGWMN is a collaborative effort between Federal, state, and local agencies, and the NGWMN compiles groundwater level and quality data from selected wells monitored by these governments according to a national monitoring network design. This network was authorized by the SECURE Water Act in 2009. The NGWMN provided information needed for planning, management, and development of groundwater supplies to meet current and future needs and ecosystem requirements. The NGWMN does not collect new information. Instead, the network typically used data that already was collected by the states, and other local units of government. The NGWMN initially was developed using data from five pilot studies, one of which was jointly conducted by the MPCA and DNR, available at National Groundwater Monitoring Network Report. As of 2025, the NGWMN continued to receive federal funding to encourage

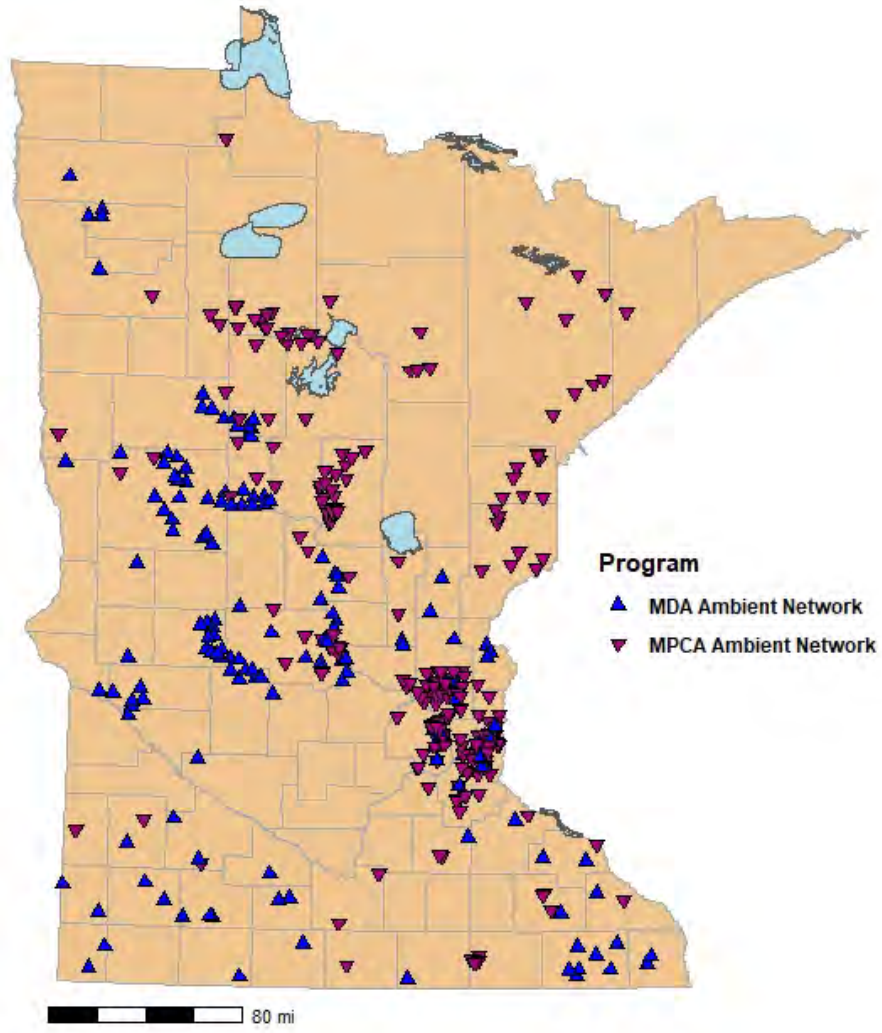
other partners, including those in Minnesota, to participate in the network and for the long-term operation and maintenance of the network.

Statewide water quality monitoring

The MPCA and MDA continued statewide ambient groundwater quality monitoring during 2020-2025. This monitoring continued to focus on aquifers that are vulnerable to anthropogenic (manmade) contamination from the land surface. Monitoring groundwater in vulnerable aquifers increases the likelihood that human impacts on groundwater quality will be detected within a reasonable time frame. The MPCA ambient monitoring efforts were conducted in non-agricultural areas of the state with a majority of samples collected in quaternary (glacial) sand and gravel aquifers. The MDA monitoring focused on agricultural regions in quaternary sand and gravel aquifers, with additional samples collected from springs and domestic wells in the southeastern part of the state where little or no quaternary deposits are present. The ambient monitoring targets pesticides and also collects nitrate samples. The locations for both MPCA and MDA monitoring programs are shown in Figure 2.

The MDH water-quality monitoring efforts through 2024 continued to focus on assessing public water supplies, which often utilize groundwater. The MDH facilitated the water quality sampling of the state's finished drinking water in cooperation with the public water supply systems to determine contaminant concentrations as part of the Safe Drinking Water Act regulations. The MDH also conducts additional groundwater monitoring in support of public water supply protection to evaluate potential threats in wellhead protection areas and where groundwater may be recharged by surface water.

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



Minnesota Pollution Control Agency

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

From about 2010-2015, the MPCA enhanced its early warning network. This network originally was developed in 2004 solely using existing wells to minimize costs. Most monitoring wells originally sampled by the MPCA's network were installed for the purposes of remedial investigations; the wells that were installed "upgradient" of the suspected contamination (usually a few hundred feet) were also used for ambient monitoring to minimize network installation costs. Using remediation wells resulted in a bias towards detecting gasoline-related volatile organic compounds in surficial aquifers and likely was

not representative of ambient groundwater conditions. The network enhancements focus on the groundwater quality underlying vulnerable, shallow sand and gravel aquifers to provide an early warning of groundwater contamination. The well installation associated with these network enhancements is complete, with almost 140 new monitoring wells added to the MPCA's network from about 2010-2015.

The MPCA staff test the groundwater contained in these wells each year for nitrate and other nutrients, and inorganic compounds such as arsenic, chloride, cadmium, and copper. A subset of these wells is typically tested each year for contaminants of emerging concern (CECs), such as prescription and non-prescription medicines and chemicals in commonly-used household products. Assessing CECs in the groundwater is part of the MPCA's larger efforts to determine the occurrence, distribution, sources, and fate of these contaminants in the hydrologic system.

The MPCA conducted two special projects by leveraging its Ambient Groundwater Monitoring Well Network to monitor for Per- and Polyfluoroalkylsubstances (PFAS) and organophosphate flame retardants (OPFRs). In 2019, the roughly 250 wells that comprised the network at that time were sampled for PFAS. Similarly, the MPCA monitored 116 ambient monitoring network wells for a suite of 13 OPFRs. The results from both of these studies were reported in *The Condition of Minnesota's Groundwater Quality, 2018-2023* (Kroening, 2024) available at: The Condition of Minnesota's Groundwater Quality, 2018-2023. Most recently, another full sampling of the network was conducted in 2024 with analytical results still pending.

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

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

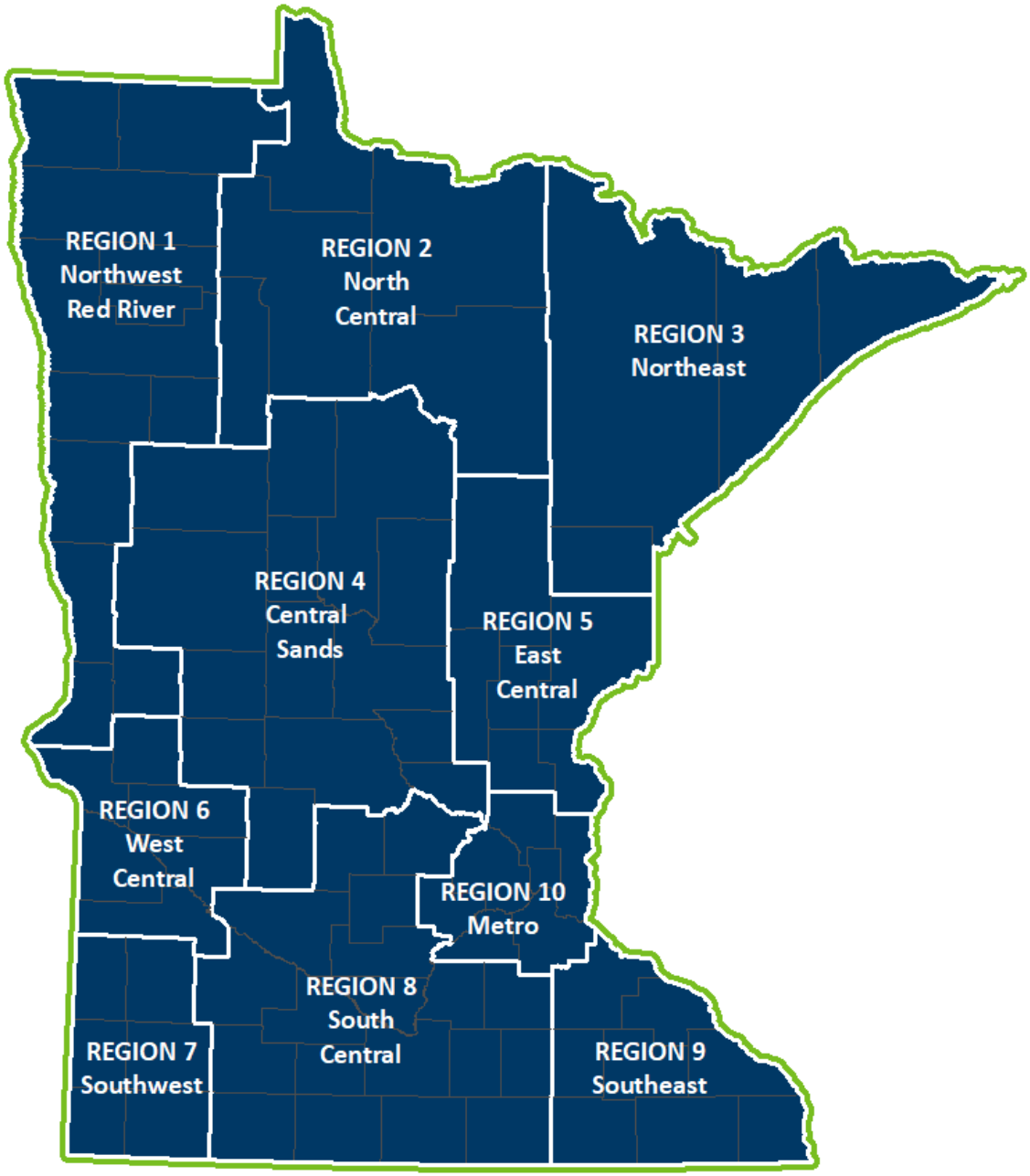
In addition to monitoring ambient groundwater conditions, the MPCA continued to collect groundwater quality information at contaminant spill and release sites, permitted landfills, and land treatment facilities. The MPCA remediation programs alone have investigated a cumulative total of 35,024 sites since 1990, with the main focus of protecting groundwater resources. Approximately 1,310 of these sites have ongoing corrective actions, many of which include groundwater monitoring. Petroleum product spill sites and voluntary investigation and cleanup sites (brownfields) make up the majority of these sites, followed by Superfund, RCRA, and closed landfills. The most common contaminants detected at remediation sites are volatile organic compounds and major and trace inorganic elements.

Minnesota Department of Agriculture

Ambient Monitoring Program

The MDA developed a regional water quality monitoring design based on Pesticide Monitoring Regions (PMRs). The PMRs established geographical areas for the purposes of collecting, analyzing, and reporting water quality monitoring data (Figure 3). Minnesota was divided into 10 Pesticide Monitoring Regions (PMRs) intended to represent areas of different agricultural land use as well as differing geologic and hydrologic regions in the state.

Figure 3. MDA Pesticide Monitoring Regions



The MDA began monitoring pesticides in groundwater in November 1985 and redesigned its network in 1998. New wells were installed in 1999, and the MDA began sampling these wells in 2000. Wells were first installed in the vulnerable aquifers located in the central sand plains Pesticide Monitoring Region (PMR 4) for the purpose of tracking pesticide trends over time. Pesticide monitoring of other PMRs of the state began in 2004, including sampling of naturally occurring springs in the southeast portion of the state (PMR 9). In 2009, natural spring monitoring was augmented with the sampling of domestic drinking water wells. Groundwater in the north central and northeastern part of the state is not currently monitored for pesticides due to very limited agricultural production in these heavily forested regions. The MDA collected pesticide samples from 168 wells and springs in 2023. Of the total sites, 142 were monitoring or observation wells, 13 were private drinking water wells, and 13 consisted of naturally occurring springs emerging from karst bedrock formations in southeastern Minnesota. All locations are considered sensitive to contamination from activities at the surface. These locations are considered the MDA's ambient groundwater network, shown as blue triangles on Figure 2. Pesticide concentrations in MDA's ambient groundwater network are generally detected well below drinking water standards, although some of the pesticide degradates do occur frequently in some areas.

Private Well Pesticide Sampling Program

The MDA began evaluating pesticide presence and magnitude in private drinking water wells in 2014 as part of the Private Well Pesticide Sampling (PWPS) Project. The PWPS Project is a companion project to the nitrate focused Township Testing Program (TTP), where sampling was targeted in townships with both vulnerable groundwater and row crop agriculture. Homeowners with a nitrate detection in their drinking water well as part of the TTP were offered pesticide sampling free of charge. A follow-up sample collected from their well, by the MDA, was analyzed again for nitrate and for a suite of pesticides similar to the list used in the MDA's ambient monitoring network.

Through 2023, the PWPS Project has sampled approximately 7,700 wells in 51 counties. With the exception of the degradates of the herbicide cyanazine (discussed below), concentrations of detected pesticides are generally well below drinking water standards but can occur frequently in certain regions.

Township Testing

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

Groundwater Protection Rule

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

The MDA also manages a remediation program which oversees the collection of a large volume of groundwater quality information from contaminant spill and release sites. Over 800 sites have been investigated and one of the main priorities of these investigations is to protect groundwater resources. Soil corrective actions are completed at most sites, and groundwater monitoring is completed at many of these sites. Typical sites include agricultural chemical storage and distribution cooperatives in rural Minnesota, agricultural chemical manufacturing facilities and wood treating facilities. Groundwater

monitoring also is conducted at sites managed by the MDA, including the former Kettle River Creosoting Company site in Sandstone, Minnesota. Common constituents that are monitored at MDA remediation sites include fertilizers, herbicides and insecticides and wood treatment compounds.

Minnesota Department of Health

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

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

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

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

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

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

Unregulated contaminants monitoring

From the standpoint of MDH and drinking water utilities, unregulated contaminants are those that lack specific water quality standards (e.g., Maximum Contaminant Levels or MCLs). The MCLs exist for approximately 100 compounds. The set of compounds that are known to exist in the environment is far larger and grows regularly because research into contaminants of emerging concern is active and on-going. Some of these contaminants have known health impacts to humans. Investigative monitoring to

assess the occurrence and distribution of contaminants of emerging concern is important to help understand the scope and scale of such contamination, to guide the development of health-based guidance, to inform other best management practices to avoid or limit occurrence in drinking water sources, and to provide solid information to maintain trust and confidence in public drinking water systems.

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

Federal unregulated contaminants monitoring rule sampling (UCMR)

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

Minnesota's unregulated contaminants monitoring project (UCMP)

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

Results from the MDH UCMP are illustrative of the widespread and varying nature of CECs in groundwater. Lithium, an unregulated metal, was detected in 100% of groundwater systems, with bromoform (a disinfection byproduct) and metalochlor SA (a pesticide) detected at a majority of the groundwater wells in which they were tested, and several pesticide and PFAS compounds 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, 8 benzotriazoles and 1 inorganic compound (lithium). Most of the compounds tested were not detected in groundwater at any system, illustrating the array of potential CECs in the ambient environment and variability in occurrence. Importantly, findings from UCMP indicated that groundwater in vulnerable geologic settings was more likely to contain detectable CECs than groundwater in nonvulnerable settings.

The Unregulated Contaminant Monitoring Project (UCMP) served as the basis for an inaugural program to survey CECs in groundwater on an annual basis, the Drinking Water Ambient Monitoring Program (DWAMP). Through DWAMP, MDH will continue to test for CECs in groundwater and drinking water sourced by groundwater in a more focused manner, with large-scale testing similar to UCMP performed every five years. In 2024, DWAMP focused on monitoring 1,4-Dioxane at public water systems and non-targeted analysis of PFAS and pesticides in public wells. We expect the nontargeted work to provide valuable information about the presence of unregulated PFAS and pesticide compounds that cannot be measured through conventional analytical techniques. In 2025, DWAMP will focus on neonicotinoids and select targeted unregulated pesticides in both public and private groundwater wells.

Pathogen (aka Virus) project

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

Pesticides (2010, 2015)

The MDH and MDA cooperated on two projects in 2010 and 2015 to evaluate occurrence and distribution of pesticides in selected public water system wells deemed to be most vulnerable to water quality impacts in vulnerable parts of the state. Sampling sites were selected statewide due to varying agricultural practices across the state. A summary of findings was published in October 2016, titled 2015 Reconnaissance Study of Pesticide Compounds in Community Public Water Supply Wells.

Per- and poly-fluorinated alkyl substances (PFAS)

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

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

Water quantity monitoring and assessment

The DNR continued statewide and regional groundwater quantity monitoring and assessments during 2020-2025. The DNR conducted statewide groundwater level monitoring and developed more county-scale groundwater sensitivity maps during this period.

Department of Natural Resources

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

The DNR maintains a groundwater level monitoring network across the state with approximately 1,250 actively measured wells, over 800 of which are instrumented to record level data hourly. Data collected from the network is used to assess groundwater resources, determine long-term trends in water levels, interpret impacts of pumping and climate, plan for water conservation, and evaluate water conflicts.

The DNR offers access to the observation well network for water quality studies. A recent example is partnering with MDH for their Pathogen Project using a well in Cottage Grove. The USGS has installed

real-time data equipment and MDH is using that data to determine when they need to sample the well for water quality.

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

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

Water level monitoring is also conducted at over 850 monitoring wells associated with groundwater appropriations permits. Information from these wells helps inform if pumping of groundwater is causing adverse impacts to surface water features or other water users. An ongoing water supply planning effort is guiding establishment or improvement of monitoring plans for all 650 public water suppliers.

Since 1995 the DNR, in collaboration with the Minnesota Geological Survey (MGS) has produced county geologic atlases. The DNR completes groundwater focused investigations as part of the atlas series. Atlases have recently been completed for Becker (2023), Cass (2023), Dodge (2024), Hennepin (2021), Hubbard (2024), Wadena (2024), and Winona (2021) counties. In addition to these completed groundwater atlases the Isanti and Houston County reports are expected to be published by Fall of 2025. As a part of all these projects, groundwater sampling is completed at selected wells to better understand groundwater movement and support groundwater sensitivity mapping. Approximately 80-100 wells are sampled in each investigated county to determine major ion and trace element concentrations. In addition, tritium values, and values of oxygen and hydrogen stable isotopes, are evaluated to help understand groundwater recharge rates and possible surface water body sources, respectively. Additional groundwater samples are collected from a few wells in each county for analysis of carbon-14 age dating at locations and in aquifers that likely have very old water in the range of thousands to tens of thousands of years.

Since 2016, the DNR, MPCA, and partners with the Olmsted County and Fillmore County Soil and Water Conservation Districts have collaborated on spring characterization throughout southeast Minnesota. The project measures spring level, temperature, nitrate concentration, and flow. Continuous or "time series" data is collected at these sites and coupled with collected water chemistry samples. These data capture hydraulic dynamics such as recharge response and lag time, helping to understand groundwater recharge and nitrate mobilization.

Current and emerging groundwater quality issues

Chloride

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

The most recent MPCA report on statewide groundwater quality (Kroening, 2024) found that high chloride concentrations result generally from the human use of this substance, such as pavement de-icing or water softening. The distribution of chloride concentrations in the state's various aquifers and the chemical signature of the water suggest a human-caused chloride source in most locations where chloride was found. Concentrations generally are stratified in the groundwater, with the highest concentrations near the water table and the lowest in the deepest aquifers. This distribution suggests the chloride was transported into the groundwater from a land surface source. The chemical signature also suggested that most chloride of the groundwater in the majority of the tested wells in urban areas resulted from sources such as salt used to de-ice pavement or soften water.

Concentrations are typically highest in the groundwater underlying urban areas that was naturally vulnerable to contamination. The MPCA's monitoring also found that chloride concentrations were highest in water table wells underlying urban parts of the state. The highest median concentration (106.0 mg/L) was found in wells underlying commercial/industrial areas, and the second highest median concentration was found in wells underlying sewered residential areas. The lowest median concentration (1.0 mg/L) was in wells underlying undeveloped forested parts of the state.

In the Prairie du Chien-Jordan aquifer, an important drinking water source in southeastern Minnesota, the highest chloride concentrations generally occur where the aquifer is close to the land surface and overlain by a thin layer of unconsolidated deposits. These areas include the eastern TCMA and the Prairie du Chien Plateau.

The MPCA also routinely examines whether chloride concentrations are changing in the groundwater. The last analysis focused on recent changes from 2013-2023. Overall, about 30% of the wells included in this trend analysis had a significant trend in chloride concentrations, and most of these trends were upward. The wells with upward trends were not just restricted to the water table; a substantial number of them were installed in bedrock aquifers.

The MPCA will continue to make chloride sampling a focus of its groundwater monitoring efforts, specifically evaluating the potential for downward migration from surficial sand and gravel aquifers to the sedimentary aquifers underlying the TCMA and southeast Minnesota.

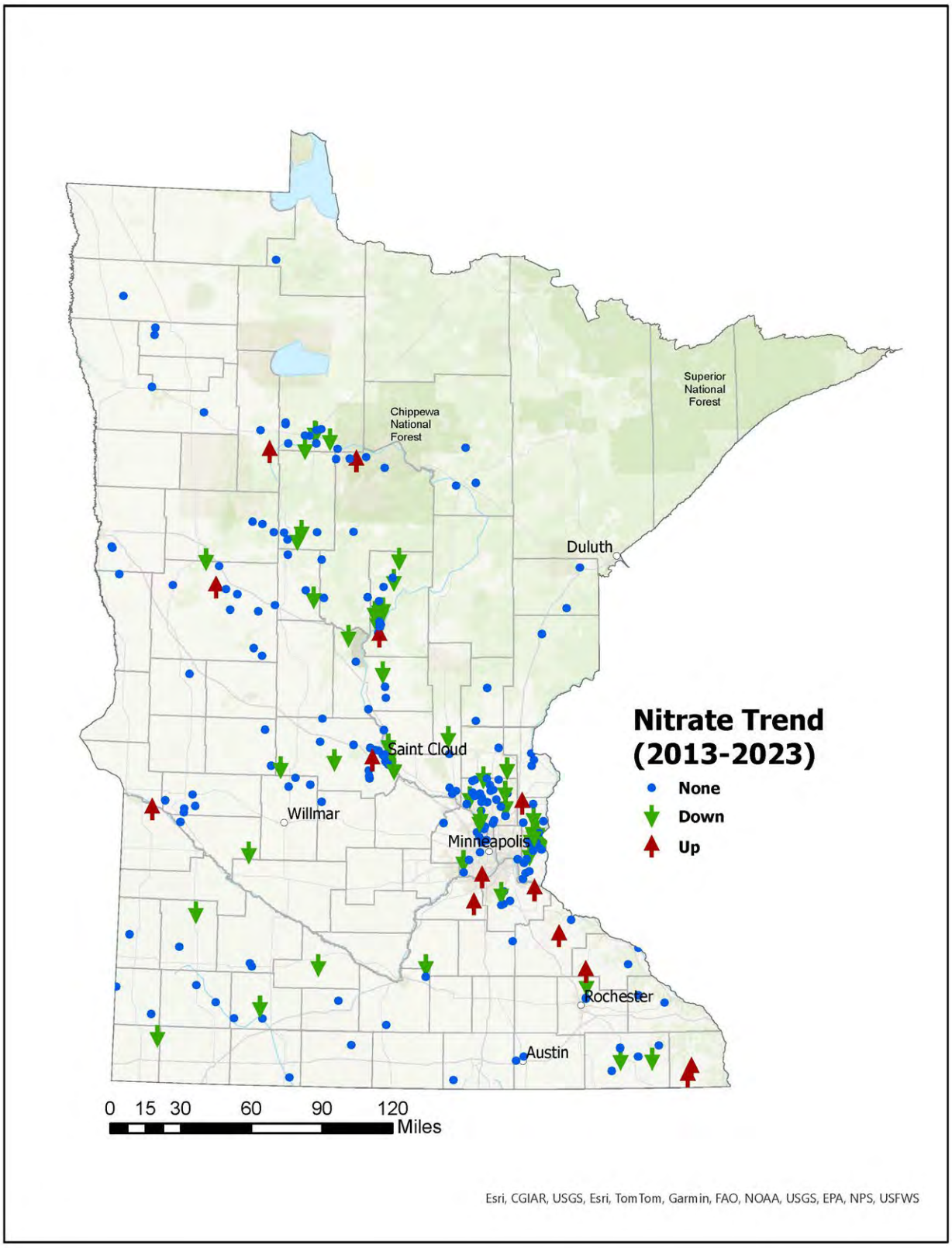
Nitrate

Nitrate continues to be one of the state's main groundwater quality issues, especially since a few communities have spent millions of dollars to ensure their water supplies do not contain excessive levels of this chemical. Most groundwater quality monitoring in the state includes a nitrate analysis, and these data were summarized in several recently published reports.

Assessments by the MPCA (Kroening and Ferrey 2013; Kroening and Vaughan 2019; Kroening, 2024) found that nitrate concentrations in the state's shallow groundwater still varied with land use. The most recently analyzed data found the median concentration in the groundwater near the water table in agricultural areas was 6.9 mg/L; whereas, the median concentration in the shallow groundwater underlying various urban land uses ranged from 0.9-1.5 mg/L.

The MPCA assessment also noted that the shallow sand and gravel aquifers, which usually are the uppermost aquifer in most parts of the state, contained the highest nitrate concentrations. About 40 % of the shallow sand and gravel aquifer wells that were tested, mainly in agricultural areas in Central Minnesota, contained nitrate concentrations that were greater than the Maximum Contaminant Level (MCL) of 10 mg/L set by the US Environmental Protection Agency for drinking water. Trends in nitrate concentrations in the groundwater also were quantified as part of the MPCA's groundwater quality assessments. The most recent study used data from over 250 wells and springs across the state, which primarily tapped the shallow sand and gravel aquifers to determine whether nitrate concentrations changed. The nitrate concentrations in most of these wells had no significant change from 2013-2023 (Figure 4).

Figure 4. Nitrate trends in Minnesota's groundwater, 2013-2023 [Data from the MPCA and MDA ambient groundwater monitoring networks].



The MDA maintains three different private well nitrate monitoring efforts; the Southeast Volunteer Nitrate Monitoring Network (VNMN), the Central Sands Private Well Network (CSPWN) and the Township Testing Program. The CSPWN and the Southeast VNMN are designed to be sampled annually long term, while the Township Testing was a short-term program and has been completed.

The Southeast Volunteer Nitrate Monitoring Network (VNMN)

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

Before data collection began, well network coordinators (county staff) enrolled volunteers (well owners) into the program by collecting detailed information about well location, well construction, and nearby nitrate sources. Between February 2008 and August 2023, 18 sampling events occurred representing approximately 7,287 samples. During this period, the percentage of wells exceeding the Health Risk Limit (HRL) for each sampling event ranged between 7.5 and 14.6%. As a regional network there is a downward trend in the 90th percentile for the time period of 2008 to 2023. However, there were no significant trends for the 10-year time period of 2014 to 2023.

More information can be found at: https://www.mda.state.mn.us/southeast-minnesota-volunteer-nitrate-monitoring-network

MDA Central Sands Private Well Monitoring Network (CSPWN)

The MDA's CSPWN testing indicated that only a small percentage of the tested domestic wells in Central Minnesota had nitrate concentrations that exceeded the HRL. Of the 1,555 wells tested in 2011, only 4.6% of the wells had a nitrate concentration that exceeded the HRL of 10 mg/L (Kaiser, 2012). Almost 89% of the wells had a concentration that was less than 3 mg/L. The measured concentrations varied by county. The highest percentage of wells with nitrate concentrations exceeding the HRL were in Morrison County. In contrast, no tested wells had nitrate concentrations exceeding the HRL in Cass, Crow Wing, and Douglas Counties. Not surprisingly, almost one-half of the wells with nitrate concentrations greater than the HRL were shallow, with depths less than 50 feet.

Approximately 550 homeowners from the first Central Sands sampling event (2011) volunteered to participate in long-term annual sampling of their private wells. These 550 homeowners were a subset of the original testing population of 1,555. Between 2011 and 2023, nine sampling events occurred with approximately 4,928 samples collected from the long-term volunteers. During this time, the percentage of wells exceeding the HRL for each sampling event ranged between 1.1% and 4.5%. As a regional network there is a downward trend in the 90th percentile for the 2008 to 2023 time period, as well as the 10-year time period of 2014 to 2023.

A report with the data from 2008-2018 from both networks can be found at MDA's Nitrate in Private Well Monitoring Networks webpage.

Township Testing Program (TTP)

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

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

As of March 2020, 344 vulnerable townships from 50 counties participated in the TTP from 2013 to 2019. In the 344 townships initially tested, 143 townships (41%) indicated 10% or more of the wells over the HRL for Nitrate-N.

Overall, 9.1% (2,925) of the 32,217 wells exceeded the HRL for Nitrate-N. These results reflect nitrate concentrations in private well drinking water regardless of nitrogen sources, or well construction. The final percentage of wells over the HRL can be different, by township, from the initial analysis based on follow-up sampling and site visits.

Once the follow-up sampling was completed, the MDA conducted an analysis of the results and prepared a final report for each county. 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. For the final dataset, it was determined that 44 (13%) townships had 10% or more of the wells over the HRL for Nitrate-N. In the final dataset of 28,932 wells, 1,359 (4.7%) exceeded the HRL for Nitrate-N Final results represent wells that are potentially impacted by a fertilizer source, while initial results represent private well drinking water regardless of source or the condition of the well. Detailed sampling results are available at MDA's Township Testing webpage. The MDA uses the results to prioritize future work to address nitrate concerns, as described in the Nitrogen Fertilizer Management Plan (NFMP).

Cyanazine

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

From 2019-2023, the MDA collected 3,929 private well pesticide samples across 50 counties in Minnesota). Samples were analyzed for nitrate and several pesticides including atrazine, cyanazine and their degradates. Total cyanazine, which is the summation of cyanazine parent plus its applicable degradates, was detected in approximately 30% of the targeted wells. During this period 174 private drinking water wells were identified with total cyanazine concentrations above the health risk limit of

1,000 ng/L, while 35 were above the acute health risk limit of 3,000 ng/L. Most of the detections identified to date occurred in Dakota, Goodhue, Scott and Washington Counties.

Additional information on cyanazine monitoring including an evaluation of reverse osmosis point-of-use water treatment systems can be found at the private well pesticide sampling webpage.

PFAS

PFAS is another one of the state's major water-quality issues. 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 East Metropolitan area of the Twin Cities. Since then, PFAS have been detected in water, sediment, soil, and fish all across Minnesota—from Duluth to Bde Maka Ska and Pine Island and places in between.

In 2021, the Minnesota state agencies developed the state's PFAS Blueprint to support a holistic and systematic approach to address PFAS contamination. This document provides in-depth discussions of concerns in 10 key issue areas. The MPCA and MDH continue to monitor for PFAS in the groundwater and utilize the agency's ambient groundwater monitoring network as an early warning system for PFAS migration into drinking water supplies in addition to monitoring the state's community water systems and private wells in known areas of PFAS contamination.

The MPCA continues to collect samples to assess PFAS in the ambient groundwater. From 2019-2023, the agency sampled over 250 wells from its ambient groundwater monitoring network for this suite of chemicals. Most of this monitoring was conducted in 2019, when the entire network was sampled for PFAS, with limited monitoring occurring from 2021-2023. Laboratory analytical methods have improved and now can test for more types of PFAS compared to past studies. The most recent assessment of PFAS in the ambient groundwater included 20 additional PFAS such as replacement chemicals for legacy PFAS (i.e., PFOA and PFOS) including HFPO-DA (used in the GenX technology platform) and ADONA.

These monitoring results continued to show that perfluoroalkyl acids, such as perfluorobutanoic acid (PFBA), perfluorooctanoic acid (PFOA), and perfluorooctane sulfonate (PFOS). The PFBA continued to be the most-frequently detected PFAS. PFOA was detected in 110 wells, which mostly were shallow monitoring well in the TCMA and other urban areas. All measured PFOA concentrations were greater than the health-based value of 0.24 ng/L set by MDH for drinking water in 2024, since the laboratory method reporting limit was greater than this value. Six shallow monitoring wells, ranging from 15-19 feet deep, had PFOS concentrations exceeding the human health criteria of 23 ng/L set by the MDH in 2023, and thirty-one wells had concentrations exceeding the USEPA's PFOS MCL of 4 ng/L. Five of the wells exceeding the USEPA's PFOS MCL supplied drinking water.

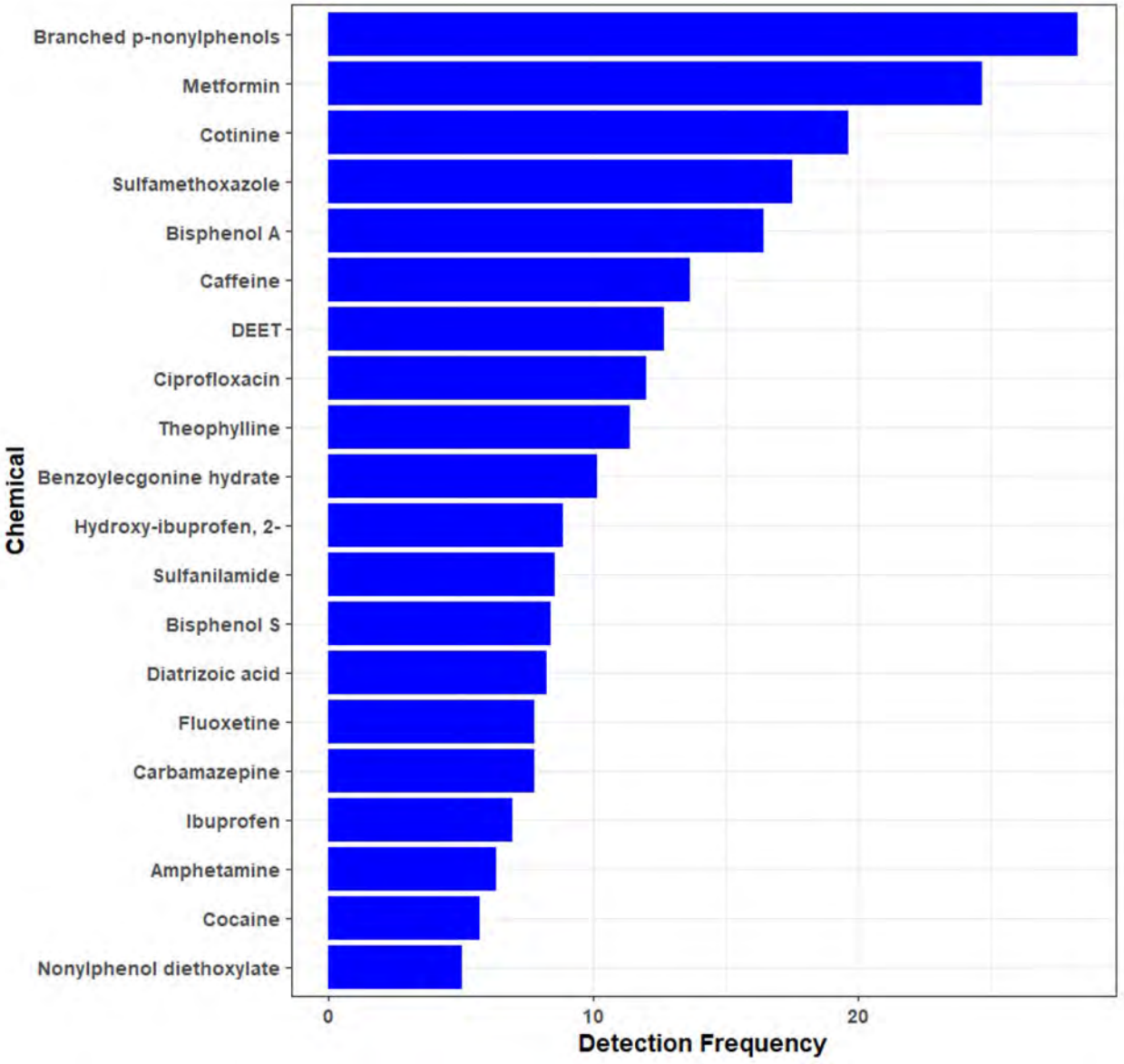
The MPCA will continue to measure PFAS in the ambient groundwater. In 2024, the agency monitored the ambient groundwater for these chemicals using MDH's recently-developed laboratory method.

Contaminants of emerging concern

The MPCA continued to monitor contaminants of emerging concern (CECs) in the groundwater, including pharmaceuticals, bisphenol A and its analogs, triclosan, and flame retardants. The MPCA has utilized its Ambient Groundwater Monitoring Network to monitor for CECs like these since 2009. To date, the agency has sampled over 250 wells in its monitoring network for over 200 CECs. The CEC data collected in the groundwater from 2018-2023 was interpreted in a report (Kroening, 2025). The CEC data collection from 2018-2023 focused on wells that CEC detections in them in past sampling campaigns. Most of the sampled wells were shallow monitoring wells that primarily were in urban areas. The average depth of these wells was 27 feet.

Sixty-eight different CECs were detected in the groundwater samples. Antibiotics were the type of CEC detected most often, which is consistent with this group of medications dominating the list of CECs that were analyzed in the groundwater samples. The twenty most-frequently detected CECs are shown in Figure 5, and all of the chemicals detected are listed in Kroening (2025).

Figure 5. CEC detection frequency in the ambient groundwater, 2018-2023 [Chart shows top 20 detected CECs].



The CECs detected in Minnesota's ambient groundwater typically had physical/chemical properties that permitted them to be present in the water. The most-frequently detected CECs in the ambient groundwater generally had high water solubilities and do not sorb to sediments or accumulate in human or animals. This result is consistent with the findings from other groundwater studies.

Many of the most-frequently detected CECs in the groundwater had a high water-solubility combined with a high use. Several of the most-frequently detected pharmaceuticals, such as the anti-diabetic

medication metformin and the antibiotics sulfamethoxazole and ciprofloxacin were among the most-prescribed medications in the U.S. Cotinine, which is present in tobacco products, was the third most-frequently detected substance, and these tobacco products were estimated to be used by almost 140 million people in the U.S. at least once a month in 2019. Caffeine, the sixth most-frequently detected CEC in the groundwater, is well-known to be a frequently consumed product in the U.S. The plasticizers bisphenol A and bisphenol S and the insect repellent DEET are all high production volume chemicals and are estimated to have a nationwide production volumes ranging from one million up to five billion pounds each year in 2019.

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

Organophosphate flame retardants

The MPCA leveraged its ambient groundwater monitoring network to assess the presence and distribution of organophosphate flame retardants (OPFRs) in the ambient groundwater in 2021. These are a class of chemicals that have been added or applied to materials since the 1960s to slow or prevent growth of a fire. These substances are commonly added to many products including home furnishings, electronics, building materials, and transportation products. The presence of OPFRs in the environment is a concern due to their toxicity and mobility in water, which can permit them to be transported long distances. The MDH has set human health guidance for drinking water for three chemicals in this class and eight of these chemicals were identified by MDH's Toxic Free Kids Program as chemicals of high concern. In 2021, groundwater samples were collected from 116 ambient monitoring network wells and analyzed for organophosphate flame retardants. Most of the sampled wells were in urban areas, including the TCMA, Brainerd, and St. Cloud.

Organophosphate flame retardants were detected in almost 95 percent of the sampled wells. The large percentage of detections likely is related to the fact that most of the analyzed substances were classified as high production chemicals and the sampled wells were installed in aquifers that had little natural geologic protection from contamination. In addition, the sampled wells were installed in urban areas where most OPFR use was expected to occur. The most frequently detected chemicals were tris(2-chloroethyl) phosphate, triphenyl phosphate, and triethyl phosphate, which were detected in over one-half of the sampled wells.

The detected concentrations generally were low. No concentrations exceeded the available human health guidance set by the MDH for drinking water.

Groundwater data access and management

Data from the MPCA's ambient groundwater monitoring network, previous monitoring efforts, and the open, closed, and demolition landfills are available on the MPCA's website through the Environmental Data Access (EDA) system. The MDA ambient groundwater data can also be accessed through the EDA system. The EDA system was developed to improve access to environmental data and is available at the MPCA Science and Data website. The MPCA's and MDA's ambient groundwater information is also available through the Water Quality Portal, which is a partnership of the USGS, EPA and National Water Quality Monitoring Council.

The MPCA ,MDA, and DNR now store the groundwater quality data that they each collect in the same database. The database is commercially available from EarthSoft Inc. and called the Environmental Quality Information System or EQuIS. The MDH is also in the process of transitioning the storage of

some of their groundwater quality data to this same database. The EQuIS database is managed as follows; a MnIT staff person serves as the EQuIS database administrator, and the MPCA, MDA, and DNR employ separate data coordinators to assist the data users in managing the information. The storage of these large sets of groundwater quality in the same database greatly simplifies regional or statewide analysis of groundwater quality conditions since the data are now stored in the same format. The MDH Environmental Laboratory, which analyzes a large number of the samples collected by the MPCA, and the MDA Laboratory have modified their systems and processes so the data generated by the laboratories can be easily uploaded to EQuIS.

Needs and conclusions

The ambient monitoring conducted by the MPCA, MDA, and more recently MDH, continues to provide valuable, long-term information on the water-quality conditions in aquifers vulnerable to contamination across Minnesota. As the demands for the state's groundwater come under increasing pressure (e.g. data centers) and variables such as climate change are introduced, this record of groundwater quality will become increasingly important for the proper use and management of this resource. A long-term commitment to the collection and analysis of groundwater data is necessary to identify changes in water quality and quantity over time and provide information needed to effectively manage and protect this critical resource. Groundwater movement is generally slow and often requires years of monitoring to assess the trends and direct and indirect impacts of human activities on this resource.

Recent groundwater quality assessments have reconfirmed that the chloride levels in the state's groundwater need to be watched. The high chloride concentrations present in some aquifers, especially in the shallow ones in the TCMA, either will be discharged into streams and lakes, or this chloride-laden groundwater will move downward into the deep aquifers that supply the state's drinking water. The inflow of groundwater containing chloride concentrations that exceed the chronic water-quality standard (230 mg/L) to streams may cause any chloride impairments to occur during baseflow conditions as well as during the usual winter period. Recent assessments have indicated that chloride concentrations have increased over time in the TCMA, in the shallow aquifers as well as parts of some bedrock aquifers. If these trends continue, more bedrock aquifer wells may be impacted by chloride in the future, and the water eventually may become unsuitable for drinking. Efforts are underway to fill identified, existing gaps in chloride monitoring. A large amount of the groundwater monitoring in the TCMA focuses on conditions at the water table. Additional deeper wells were recently installed by MPCA to track chloride moving into lower levels of the groundwater system.

Nitrate concentrations in the state's groundwater also should continue to be tracked, especially since some communities have had problems with high concentrations in their water supplies. The state's ambient monitoring networks should continue to monitor for nitrate in the groundwater, and MDA's nitrate-testing programs should continue to be funded to complete this important work. The newly implemented Groundwater Protection Rule should reduce the risk of nitrate from fertilizer impacting groundwater.

The presence of CECs, including PFAS, in the groundwater deserves continued watching. Although monitoring to date has found most CECs are low in concentration, it still is important to assess the presence of these chemicals because this monitoring identifies chemicals in the groundwater for which there are relatively few available human-health guidance values. The MDH's DWAMP program will focus on monitoring for these chemicals in groundwater that is actively being used as a drinking water source. This, in conjunction with efforts by the MDH to develop human-health guidance values for these chemicals are invaluable because it allows scientists to determine whether the presence of these chemicals makes water unsuitable for drinking.