



Wisconsin Groundwater Coordinating Council

Report to the Legislature

Fiscal Year 2021

The Groundwater Coordinating Council (GCC) prepares an annual report each year that summarizes the operations and activities of the council, describes the state of the groundwater resource and its management and makes recommendations.



2021 GROUNDWATER COORDINATING COUNCIL MEMBERS

- ▶ Department of Natural Resources – Jim Zellmer, Chair
- ▶ Department of Agriculture, Trade & Consumer Protection – Sara Walling
- ▶ Department of Safety & Professional Services – Bradley Johnson
- ▶ Department of Health Services – Jonathan Meiman, MD
- ▶ Department of Transportation – Robert Pearson
- ▶ Geological and Natural History Survey (State Geologist) – Ken Bradbury
- ▶ Governor's Representative – Steve Diercks
- ▶ University of Wisconsin System – James Hurley

SUBCOMMITTEES

Research & Monitoring

- ▶ Geological and Natural History Survey - Dave Hart*(Co-Chair) & Mike Parsen*
- ▶ Department of Natural Resources – Bill Phelps*(Co-Chair), Shaili Pfeiffer* & Matt Silver*
- ▶ Department of Agriculture, Trade and Consumer Protection – Stan Senger* & Ken Potrykus*
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- ▶ U. S. Geological Survey - Andy Leaf* & Cheryl Buchwald*
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- ▶ State Laboratory of Hygiene – Jocelyn Hemming
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State of Wisconsin \ GROUNDWATER COORDINATING COUNCIL

Tony Evers, Governor

101 South Webster Street
Box 7921
Madison, Wisconsin 53707

Jim Zellmer,
Council Chair
DNR

August 31, 2021

To: The Citizens of Wisconsin
The Honorable Governor Tony Evers
Senate Chief Clerk
Assembly Chief Clerk
Secretary-designee Craig Thompson - Department of Transportation
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Secretary-designee Randy Romanski - Department of Agriculture, Trade & Consumer Protection
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The Groundwater Coordinating Council (GCC) is pleased to provide its 2021 Report to the Legislature. The GCC was formed in 1984 to help state agencies coordinate non-regulatory activities and exchange information for efficient management of groundwater. For over 30 years, the GCC has been a model for interagency coordination and collaboration among state agencies, local and federal government, and the university. It is one of very few examples of effective statewide coordination of groundwater efforts from an advisory position.

The level of coordinating effort and investment in groundwater is particularly appropriate as Wisconsin depends so heavily on groundwater for its drinking water. Wisconsin also relies on groundwater to irrigate crops, water cattle, and process a wide variety of foods, as well as feed trout streams and spring-fed lakes - all of which are vital to our state economy. New challenges and new ideas continue to warrant the GCC's collaborative approach.

This [online report](#) summarizes and links to information on the GCC and agency activities related to groundwater protection and management in FY21 (July 1, 2020 to June 30, 2021). Search "GCC" on dnr.wi.gov to find the full report. Click on the picture tabs for chapters of the report, beginning with the GCC's recommendations. The Executive Summary is attached.

We hope you will find this report to be a useful reference in protecting Wisconsin's priceless groundwater supply.

Sincerely,

A handwritten signature in black ink that reads "James A. Zellmer".

James A. Zellmer, Chair
Groundwater Coordinating Council

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PURPOSE OF THE GCC AND ANNUAL REPORT

In 1984, the Legislature enacted Wisconsin's Comprehensive Groundwater Protection Act, to improve the management of the state's groundwater. The Groundwater Coordinating Council (GCC) was created and is directed by s. 160.50, Wis. Stats., to "serve as a means of increasing the efficiency and facilitating the effective functioning of state agencies in activities related to groundwater management. The Groundwater Coordinating Council shall advise and assist state agencies in the coordination of non-regulatory programs and the exchange of information related to groundwater, including, but not limited to, agency budgets for groundwater programs, groundwater monitoring, data management, public information and education, laboratory analysis and facilities, research activities and the appropriation and allocation of state funds for research."

The GCC is required by s. 15.347, Wis. Stats., to prepare a report which "summarizes the operations and activities of the council..., describes the state of the groundwater resource and its management and sets forth the recommendations of the council. The annual report shall include a description of the current groundwater quality of the state, an assessment of groundwater management programs, information on the implementation of ch. 160, Wis. Stats., and a list and description of current and anticipated groundwater problems." This report is due each August. The purpose of this report is to fulfill this requirement for fiscal year 2021 (FY21). The report is an interactive web page with links to extensive supporting information.

The GCC's role in facilitating inter-agency coordination includes the exchange of information regarding Wisconsin's Comprehensive Groundwater Protection (Act 1983 Wisconsin Act 410), Wisconsin's Groundwater Protection Act (2003 Wisconsin Act 310), the Great Lakes Compact (2007 Wisconsin Act 227), the federal Safe Drinking Water Act's Wellhead and Source Water Protection provisions, and many other programs.

GROUNDWATER COORDINATION ACTIVITIES

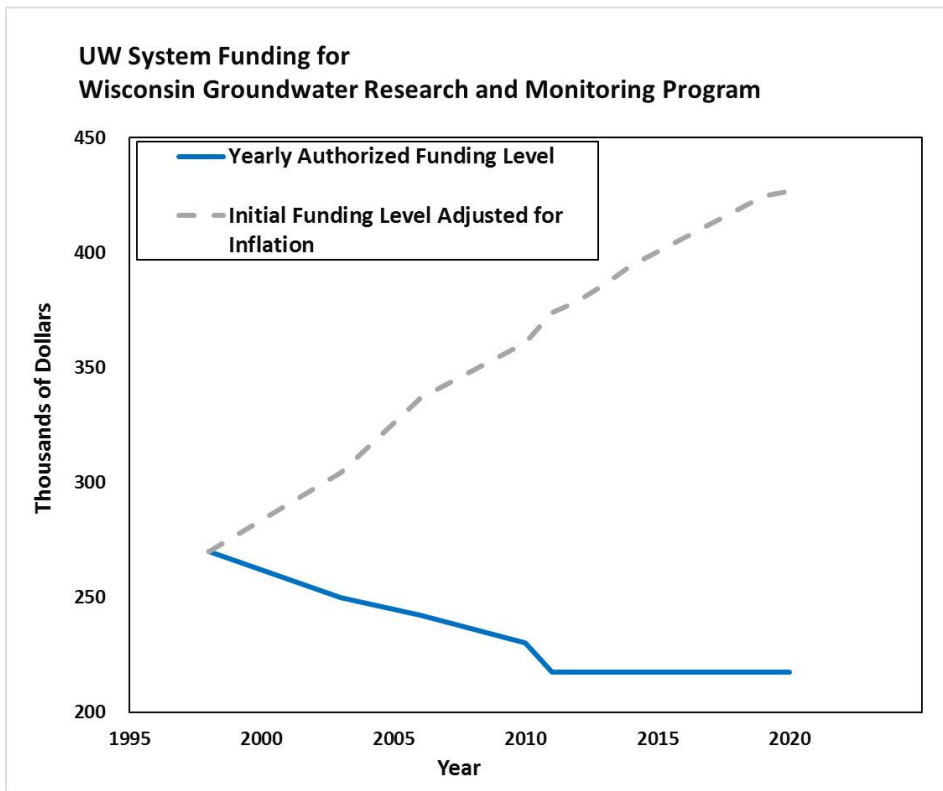
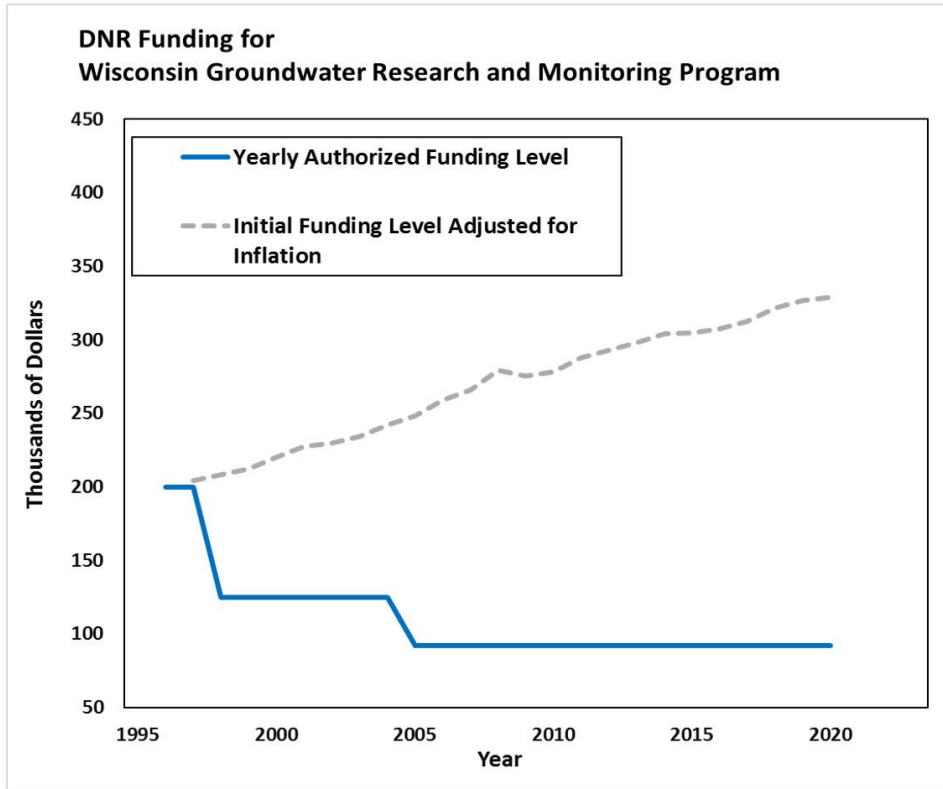
In addition to the council of agency leaders, the GCC is authorized to create subcommittees on "the subjects within the scope of its general duties...and other subjects deemed appropriate by the Council." See a list of GCC members and subcommittees on the inside cover of this executive summary.

The GCC and its subcommittees regularly bring together staff from over 15 different agencies, institutions and organizations to communicate and work together on a variety of research, monitoring and data management, educational, and planning issues. A strong network among GCC and subcommittee members leads to coordination across agency lines on a variety of groundwater-related issues. These activities regularly avoid duplication, create efficiencies, and provide numerous benefits to Wisconsin's taxpayers.

Coordination of Groundwater Research and Monitoring Program

The GCC is directed to "advise the Secretary of Administration on the allocation of funds appropriated to the Board of Regents of the University of Wisconsin under s. 20.285(1)(a) for groundwater research." Since 1992, a joint solicitation process has facilitated selection and funding of sound scientific research and monitoring to answer state priority needs. The history of DNR and UW System state legislative groundwater research funding levels (funding source created in 1996) are shown below. The solid blue line shows the actual

authorized funding level through time, the dashed gray line shows the inflation adjusted value of the initial funding level in today's dollars.



The GCC, the UWS, DNR and the Groundwater Research Advisory Council (GRAC) again collaborated on the annual solicitation for groundwater research and monitoring proposals as specified in the Memorandum of Understanding. After a multi-agency effort spearheaded by the UW Water Resources Institute (WRI), the GCC approved selected projects for the annual program of research to answer current groundwater management questions.

A comprehensive review process including the GRAC, the GCC's Research & Monitoring Subcommittee, and outside technical experts resulted in recommendations that were used by the UWS and DNR in deciding which groundwater-related proposals to fund. From 18 proposals, eight new projects were selected for funding in FY21 - five by UWS, one by DNR, one by Department of Agriculture, Trade & Consumer Protection (DATCP) and one jointly by DNR and DATCP. The GCC approved the proposed UWS groundwater research plan as required by s. 160.50(1m), Wis. Stats., and a letter to this effect was sent to the UWS President and the Department of Administration. Current groundwater research and monitoring projects are listed in the report as well as all Wisconsin Joint Solicitation groundwater research and monitoring projects.

The UW Water Resources Institute provides access to summaries and reports of GCC-facilitated groundwater research, as well as cataloging all WRI research reports into WorldCat and MadCat, two library indexing tools that provide both worldwide and statewide access to this research. The Water Resources Library has partnered with UW Libraries' Digital Collections Center to digitize and post UWS and DNR final project reports. As a result of this partnership, full-text reports are also available through the UW Ecology and Natural Resources Digital Collection. Progress continues in making older final reports and summaries accessible online.

Information and Outreach Activities

Since 1994 groundwater workshops for teachers have been taught jointly by GCC Outreach and Partnership Subcommittee members from the DNR, Wisconsin Geological and Natural History Survey (WGNHS) and the Center for Watershed Science and Education (CWSE) at U.W. Stevens Point. Teacher applications to participate continue to fill all available workshop space and equipment. The workshop leaders instructed teachers on using a groundwater sand-tank model and provided additional resources to incorporate groundwater concepts into their classroom. Educators who attended the workshops received a free model. With funding from a U.S. Environmental Protection Agency (EPA) wellhead protection grant, over 475 groundwater models have been given to schools and nature centers since 2001 and over 900 educators have received hands-on training in using the model effectively. Educators are regularly surveyed to promote continued use and evaluate educational benefits.

Other Coordination Activities

The GCC continued to promote communication, coordination, and cooperation between the state agencies through its quarterly meetings. In addition to identifying collaboration opportunities, making decisions about research, and guiding report development, the GCC received briefings and discussed a variety of current topics at its FY21 meetings:

- DNR: Linking groundwater and climate to understand long-term lake level fluctuations in Wisconsin

- UWS: Joint Solicitation groundwater research project repository
- DNR: Wisconsin Nitrate Initiative and Nitrogen Fertilizer Decision Support Tools
- DNR: WisPAC statewide PFAS Action Plan
- DNR: Central Sands Lake Study findings/recommendations
- UWSP: Integrative monitoring of neonicotinoid insecticides in baseflow-dominated streams on the Central Sand Plain

More information on these topics and the coordinating efforts of the GCC can be found in the FY21 GCC meeting minutes. Through these activities, the GCC plays an important role in ensuring agency coordination, increasing efficiency, avoiding duplication, and facilitating the effective functioning of state agencies in activities related to groundwater protection and management. As a result, groundwater is better protected, which benefits public health, sustains our economy, and preserves Wisconsin's natural resources for future generations.

SUMMARY OF AGENCY GROUNDWATER ACTIVITIES

State agencies and the University of Wisconsin System addressed numerous issues related to groundwater protection and management in FY21. Detailed discussions of the groundwater activities of each agency can be found at the [agency activities tab in the online report](#).

CONDITION OF THE RESOURCE: GROUNDWATER QUALITY

Major groundwater quality concerns in Wisconsin are summarized below and detailed in the [online report](#).

Nitrate

While nitrate in agricultural use has benefits such as larger crop yields, high concentrations in groundwater lead to public health concerns. Nitrate is Wisconsin's most widespread groundwater contaminant and is increasing in extent and severity. Statewide various studies show about 10% of private well samples exceed the 10 mg/L health-based standard for nitrate-N. Nitrate levels in groundwater above 2 milligrams per liter (mg/L) indicate a source of contamination such as agricultural or turf fertilizers, animal waste, septic systems, and wastewater. Approximately 90% of total nitrate inputs into our groundwater originate from agricultural sources.

According to the Wisconsin Department of Health Services (DHS), high levels (above 10 mg/l) of nitrate in drinking water can affect everyone. Nitrate can cause blue baby syndrome and may cause birth defects. Nitrate may cause thyroid disease and may increase the risk for certain kinds of cancer.

More than 200 public water supply systems (mostly systems like mobile home parks, restaurants and taverns) exceeded the nitrate drinking water standard of 10 mg/L in FY 21, requiring them to post notices, provide bottled water, replace wells, install treatment, or take other corrective actions. Concentrations of nitrate in private water wells have also been found to exceed the standard. A 2017 DATCP survey estimated that 8% of private wells exceeded the 10 mg/L enforcement standard for nitrate. GCC member agencies are working on multiple initiatives related to reducing the risk of high nitrate levels in groundwater and drinking water.

Per- and Polyfluorinated Alkyl Substances (PFAS)

(PFAS) are a large group of human-made chemicals that have been used in industry and consumer products worldwide since the 1940s. Their ability to repel water and oil and withstand high temperatures has made PFAS a particularly useful ingredient in industrial and commercial products, including non-stick products, stain- and water-repellent clothing, and aqueous film forming foams (AFFFs). These chemicals do not easily break down in the environment and have been known to accumulate in the environment and humans.

Under the Safe Drinking Water Act's third Unregulated Contaminants Monitoring Rule (UCMR-3), select municipal water systems were asked to test for PFOA and PFOS, between 2013 and 2015. PFAS were detected in public water systems in La Crosse, West Bend and Rhinelander. Testing has also been conducted voluntarily by several municipal water systems and included a more comprehensive list of PFAS (i.e. additional compounds such as those included as part of EPA's Method 537.1). These testing efforts identified PFAS in varying concentrations in municipal water systems in Marinette, Peshtigo and Madison.

PFAS have also been found in groundwater near Department of Defense sites in Wisconsin, such as Wisconsin Air National Guard facilities at Truax Field and Volk Field. PFAS are present in many consumer products and AFFFs and can also be released from industrial facilities that manufacture or use the compounds. Therefore, PFAS are potentially present at fire departments, industrial facilities, landfills and wastewater treatment plants due to the diverse waste streams accepted from industrial and municipal parties. PFAS have also been identified in municipal wastewater treatment plants' biosolids. As biosolids are put to beneficial reuse via agricultural landspreading, this may be an important pathway for the substances to enter groundwater.

At present, the DNR is continuing to identify PFAS sources and their potential impacts to groundwater and other environmental media in Wisconsin. Currently, there are no state or federal groundwater protection standards for PFAS. To address this regulatory gap, the DNR initiated rulemaking to implement DHS recommendations for groundwater enforcement standards for two PFAS, PFOA and PFOS, in accordance with State law. DNR has also begun rulemaking for an additional 16 PFAS compounds and six pesticides.

Bacteria, viruses and other pathogens

Bacteria, viruses and other pathogens often occur in areas where the depth to groundwater is shallow, in areas where soils are thin or in areas of fractured bedrock. These pathogens can cause acute illness and result in life-threatening conditions for young children, the elderly and those with chronic illnesses. An estimated 17% of private water supply wells statewide test positive for total coliform bacteria, an indicator species of other biological agents (Knobeloch et al., 2013). Approximately 3% of these wells tested positive for *E. coli*, an indicator of water borne disease that originates in the mammalian intestinal tract.

Viruses in groundwater are increasingly a concern as new analytical techniques have detected viral material in private wells and public water supplies. Research conducted at the Marshfield Clinic indicates that 4-12% of private wells contain detectable viruses.

Other studies showed virus presence in four La Crosse municipal wells, in the municipal wells in Madison and in five shallow municipal wells serving smaller communities.

Public and private water samples are not regularly analyzed for viruses due to the high cost of the tests. The presence of coliform bacteria has historically been used to indicate the water supply is not safe for human consumption. However, recent findings show that coliform bacteria do not always correlate with the presence of enteric viruses. GCC member agencies are involved with research and risk reduction measures as well as emergency response on this issue.

Pesticides

Pesticides are a broad class of substances designed to kill, repel or otherwise disrupt living things that are considered pests. They include insecticides, herbicides, fungicides and anti-microbials, among other types of biocides. In Wisconsin, the main source of pesticides in groundwater is agricultural herbicide and insecticide applications. For this reason, detection is more common in highly cultivated areas where agriculture is well established, notably in the south-central, central and west-central parts of the state.

In 2016, DATCP conducted a statewide statistical survey of agricultural chemicals in groundwater that found an estimated 41.7% of private wells in Wisconsin contained a pesticide or pesticide metabolite, up from 33% of private wells in a similar survey conducted in 2007 (DATCP, 2008; DATCP, 2017). The primary metabolites of metolachlor and alachlor, metolachlor ESA and alachlor ESA, were the two most commonly detected pesticide products. Atrazine and its metabolites, known collectively as the total chlorinated residues of atrazine (atrazine TCR), were also prevalent and occurred in about 23% of wells.

Many sampling programs initiated by DATCP, DNR and other agencies in the mid-1980s to early 1990s are still ongoing today. The longest running sampling program for pesticides began in 1985 and is designed to evaluate the potential impact of agriculture on groundwater quality by sampling monitoring wells near selected agricultural fields in areas with high groundwater contamination potential. Testing in this program confirms that the metabolites of metolachlor and alachlor are the two most common pesticides products detected in groundwater near the monitoring well sites. A DATCP review of data from samples it collected statewide from 2008 through 2016 revealed an increased occurrence of detections of neonicotinoid insecticides in samples collected from monitoring wells, irrigation wells, private wells and surface water samples.

DATCP has also conducted a statewide, statistically designed survey of agricultural chemicals in Wisconsin groundwater five times since the early 1990s (1994, 1996, 2001, 2007 and 2016). In 2016, nearly four hundred samples from private drinking water wells were analyzed for 101 pesticide compounds, including 70 herbicides, 26 insecticides, 4 fungicides and 1 pesticide safener. Health standards have been established for 27 of the compounds analyzed. In addition to capturing the current picture of agricultural chemicals in groundwater, this series of studies relates these findings to land use and compares results of the 2016 survey to those of previous surveys. The final report of the results of the 2016 survey was published in early 2017 (DATCP 2017).

Arsenic

Arsenic is an odorless and tasteless, naturally occurring element present in soil and rock. Under certain environmental conditions, arsenic can dissolve and be transported in groundwater. It can also be released as a by-product from agricultural and industrial activities. Everyone is exposed to small amounts of arsenic since it is a natural part of the environment, but under some geologic conditions elevated amounts of arsenic can be released to groundwater.

In Wisconsin, most arsenic found in groundwater is naturally occurring, released from minerals in bedrock and glacial deposits. Arsenic has been detected above the enforcement standard (ES) in the groundwater in every county in Wisconsin. Arsenic contamination of groundwater is common in northeastern Wisconsin in areas around Winnebago and Outagamie County and moderately high levels of arsenic (10 ppb – 30 ppb) are also common in some parts of southeastern Wisconsin.

GCC member agencies and partners continue to proactively address arsenic concerns through well drilling advisories, health studies, well testing campaigns, studies aimed at improving geological understanding and developing practical treatment technologies.

Volatile Organic Compounds (VOCs)

Volatile Organic Compounds (VOCs) are a group of common industrial and household chemicals that evaporate, or volatilize, when exposed to air. Examples of products containing VOCs include gasoline and industrial solvents, paints, paint thinners, air fresheners and household products such as spot and stain removers. Chemical names for the VOCs in these products include benzene, Trichloroethylene (TCE), toluene and vinyl chloride, among others. Improper handling or disposal of VOCs is often the reason why they occur in groundwater.

Sources of VOCs in Wisconsin's groundwater include landfills, underground storage tanks and hazardous substance spills. Thousands of wells have been sampled for VOCs and about 60 different VOCs have been found in Wisconsin groundwater. Trichloroethylene is the VOC found most often in Wisconsin's groundwater.

Radionuclides

Radionuclides are radioactive atoms. It is possible for radionuclides to be manmade, as is the case with some materials from nuclear power reactors, but they also occur naturally in rock formations and are released to groundwater over millions of years by geochemical reactions. Common naturally occurring radionuclides in groundwater include uranium, radium and thorium. Naturally occurring radionuclides are a concern for groundwater quality, particularly in the Cambrian-Ordovician aquifer system in eastern Wisconsin. The water produced from this aquifer often contains combined radium activity in excess of 5 pCi/L and in some cases in excess of 30 pCi/L. Historically, about 80 public water systems exceeded a radionuclide drinking water standard, causing these communities to search for alternative water supplies or treatment options. The vast majority of these systems are now serving water that meets the radium standard. The DNR continues to work with the remaining water systems to ensure that they develop a compliance strategy and take corrective actions.

CONDITION OF THE RESOURCE: GROUNDWATER QUANTITY

Groundwater quantity conditions are summarized below and detailed in the [online report](#).

Groundwater is available in sufficient amounts throughout most of Wisconsin to provide adequate water supplies for most municipal, industrial, agricultural and domestic uses. What is frequently missed is that groundwater pumping lowers water levels in aquifers and connected lakes, wetlands and streams; and diverts flow to surface waters where groundwater would have discharged naturally. The amount of water level lowering and flow diversion is a matter of degree. At certain amounts of pumping in an area, streams, lakes and wetlands can dry up and aquifers can be perilously lowered.

Groundwater pumping shows a continued long-term increase. Numbers of high capacity wells, especially in the Central Sands region of the state (parts of Portage, Waushara, Waupaca, Adams and Marquette Counties), indicates pumping amounts will continue to expand.

Groundwater pumping issues have arisen in multiple regions of Wisconsin. Large scale drawdowns of the confined aquifer have been documented in the Lower Fox River Valley and southeastern Wisconsin. Surface water impacts have been well-documented in the Wisconsin Central Sands and Dane County. These impacts have included the drying of lakes and streams.

BENEFITS OF MONITORING AND RESEARCH PROJECTS

The GCC provides consistency and coordination among state agencies in funding Wisconsin's Groundwater Research and Monitoring Program to meet state agency needs. Approximately \$20 million has been spent over 30 years by DNR, UWS, DATCP and DSPS (formerly Commerce) on more than 450 different projects selected to answer essential management questions and advance understanding of groundwater in Wisconsin.

Projects funded have helped evaluate existing programs, increased the knowledge of the movement of contaminants in the subsurface and developed new methods for groundwater protection. While the application of the results is broad, a few examples where the results of state-funded groundwater research and monitoring projects are successfully applied to groundwater problems in Wisconsin include:

- Detection and characterization of sources of microbial pathogens
- Extent of arsenic in Northeastern Wisconsin
- Evaluation of drawdown in Eastern Wisconsin
- Best practices for minimizing risk of groundwater contamination
- Methods for diagnosing causes of bacterial contamination in public water systems
- Understanding barriers to private well testing
- Statewide inventory and database of springs

RECOMMENDATIONS: DIRECTIONS FOR FUTURE GROUNDWATER PROTECTION

The GCC is directed by statute to include in its annual report a "list and description of current and anticipated groundwater problems" and to "set forth the recommendations of the Council" (s. 15.347(13)(g), Wis. Stats.). In this section, the GCC identifies its recommendations for future groundwater protection and management.

These recommendations include top priorities of immediate concern and ongoing efforts that require continued support.

Priority Recommendations

Implement practices that protect groundwater from nitrate and other agricultural contaminants (microbial agents, pesticides and their degradates).

Nitrate that approaches and exceeds unsafe levels in drinking water is one of the top drinking water contaminants in Wisconsin, posing an acute risk to infants and women who are pregnant, a possible risk to the developing fetus during very early stages of pregnancy, and a chronic risk of serious disease in adults. In addition, pesticides are estimated to be present in approximately 40% of private drinking water wells in Wisconsin. Areas of the state with a higher intensity of agriculture generally have higher frequencies of detections of pesticides and nitrate. Agencies should develop and evaluate a strategy to promote practices that lead to efficient use of nitrogen and careful or reduced use of pesticides in order to protect drinking water sources.

Implementation of these practices should be supported with appropriate technical tools and incentives such as:

- Identifying sensitive areas of the state based on geology where elevated nitrate is present and making information available through an online mapping tool
- Assessing soil type specific nitrogen crop application rates and cropping best management practices to further minimize nitrogen losses to groundwater and encourage their use, especially in highly sensitive areas of the state
- Developing a broad outreach plan and educational materials for farmers and nutrient management planners, and agricultural industry stakeholders that identify and encourage the use of specific alternate cropping and nutrient management practices to minimize agricultural nitrogen losses to groundwater
- Supporting research to assess the ability for alternative conservation practices, including saturated buffers and bioreactors, to minimize sources of nitrogen to surface and groundwater
- Developing strategies and outreach programs that encourage the full implementation of nutrient management plans

Address public health and environmental concerns regarding PFAS.

PFAS have been detected in both municipal and private drinking water sources in Wisconsin. PFAS have also been found in groundwater near Department of Defense sites in Wisconsin, such as Wisconsin Air National Guard facilities at Truax Field and Volk Field. PFAS are present in many consumer products and AFFFs. Current studies of these PFAS suggest exposure may affect childhood development, decrease female fertility, increase the risk of high blood pressure in pregnant women, increase cholesterol levels, increase the risk of thyroid disease and decrease antibody response to vaccines. EPA research suggests that some PFAS may have the potential to cause cancer.

The GCC recommends the following actions be supported to address PFAS concerns:

- Implement DHS recommendations for groundwater enforcement standards for two PFAS, PFOA and PFOS, in accordance with State law

- Pursue development of additional groundwater enforcement standards for PFAS compounds detected in Wisconsin
- Continue to identify PFAS sources and their potential impacts to groundwater and other environmental media
- Develop benchmarks for PFAS in other media such as surface water, biosolids and sludge to protect groundwater resources
- Support the Wisconsin PFAS Action Council (WisPAC) in developing and coordinating statewide initiatives around PFAS

Evaluate the occurrence of viruses and other pathogens in groundwater and groundwater-sourced water supplies and develop appropriate response tools.

Viruses and other microbial pathogens have been found in municipal and domestic wells, challenging previous assumptions about their persistence and transport. Monitoring and assessment should focus on refining our understanding of pathogens in groundwater, in particular, where and when they pose threats to human health. Agencies should also work with partners to increase awareness of waste disposal choices, their risks and costs.

Ongoing Recommendations

Without ongoing attention to the following needs, Wisconsin cannot address the priority recommendations (see above) or begin to understand emerging issues.

Support the sustainable management of groundwater quantity and quality in the state to ensure that water is available to be used, which will protect and improve our health, economy and environment now and into the future.

This includes:

- Supporting an inventory of information on the location, quantity and uses of the state's groundwater
- Supporting targeted monitoring and modeling of the impact of groundwater withdrawals on other waters of the state
- Supporting identification and evaluation of options for areas with limited groundwater resources
- Supporting research relating to changes in land-use development patterns and the resulting increase in groundwater use and changes to recharge

Continue to catalog Wisconsin's groundwater resources.

Management and protection of Wisconsin's groundwater resources requires publicly-accessible and up-to-date data in order to foster informed decisions, not only on state policy matters but also for sound business decisions on siting or technology investments. State agencies and the University should continue to collect, catalog, share and interpret new data about Wisconsin's groundwater so that it can be used by health care providers and people seeking business locations, as well as homeowners and local governments. Options for sharing data about groundwater and groundwater vulnerabilities should include accessible formats including online mapping tools. Wisconsin should improve the accessibility of current data and continue to encourage research efforts that will provide information.

Evaluate potential impacts of climate change on Wisconsin's groundwater.

Climate change will likely increase the frequency and severity of weather patterns that may produce unprecedented flooding or drought conditions. More severe flooding can affect groundwater quality, wells and water system operations. Public drinking water supplies as well as water-dependent industries need reliable estimates of these effects in order to develop practical emergency response and adaptation strategies. Additionally, land and water use patterns may also change and affect the groundwater supply. These may include biological or chemical contamination issues, or an increased demand for groundwater by agricultural, municipal and commercial users. More work is needed to determine the range of possible climates in Wisconsin's future. Work is also needed on feedback mechanisms between climate and groundwater to fully characterize possible changes to Wisconsin's groundwater resource. This research will help identify both flood and drought response and long-term management strategies for Wisconsin's groundwater supply.

Support applied groundwater research in Wisconsin.

Wisconsin is recognized as a national leader in [groundwater research](#), which is appropriate given how uniquely important this resource is for public health, the economy and the environment in this state.

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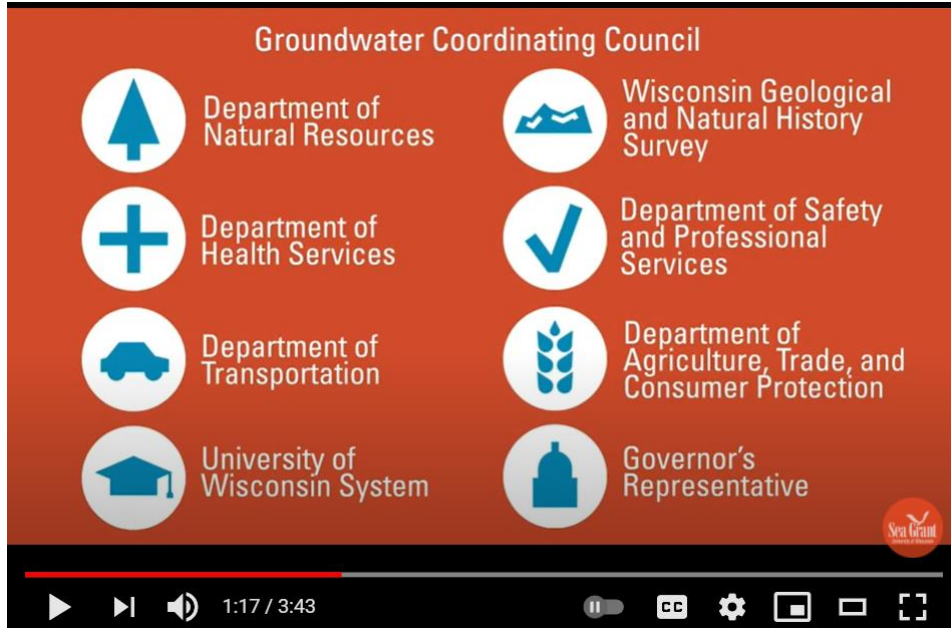
- Wisconsin leads the nation in the number of public water systems that rely on groundwater (more than 11,000).
- Over 97% of agricultural irrigation water and more than one third of the water used for commercial and industrial purposes come from groundwater supplies.
- Many ecosystems in Wisconsin are strongly dependent on groundwater availability and groundwater quality.

Wisconsin's reputation for groundwater research is largely due to the well-established joint solicitation process for groundwater research and monitoring projects coordinated by the GCC. This approach streamlines proposal writing and the review process and improves communication among agencies and researchers. The solicitation is a coordinated effort of the University of Wisconsin System and the Wisconsin Departments of Natural Resources; Agriculture, Trade and Consumer Protection; and Safety and Professional Services.

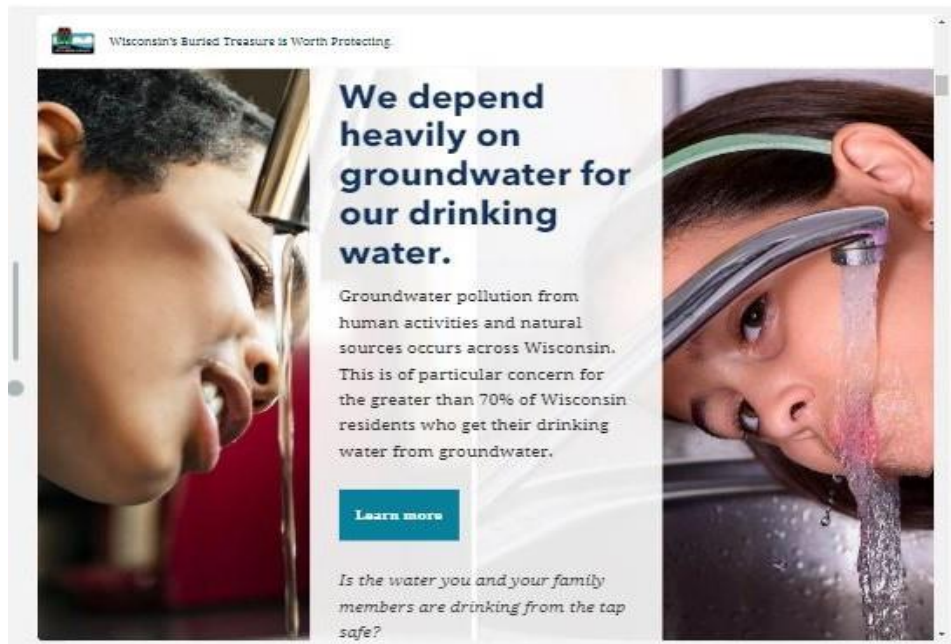
Collectively, since its inception this annual joint solicitation has funded 483 groundwater research and monitoring projects and has helped establish Wisconsin as an international leader in groundwater research. The GCC recommends the following actions be taken to support applied groundwater research in Wisconsin:

Restoring the original authorized amounts of DNR and UW groundwater research funding (adjusted for inflation using U.S. Bureau of Labor Statistics Consumer Price Index calculator) to DNR \$329,255 and UW \$426,790 annually. Restoring funds to this level would allow nearly half of the submitted proposals to be funded each year instead of 1/6 to 1/4 typically funded over the last ten years. Alternatively, increasing the funding to \$500,000 each for DNR and UW would allow the joint solicitation program to better attract qualified researchers to address concerns such as PFAS, which is more expensive to test for and research than most other groundwater issues facing Wisconsin.

Additional consideration could be given to create dedicated funding mechanisms for the departments of Agriculture, Trade and Consumer Protection; Health Services; and Safety and Professional Services to conduct groundwater research targeting the needs of each respective agency.



Watch the video online to learn more about the GCC.



This year's online GCC Report includes an interactive StoryMap.

DEPARTMENT OF NATURAL RESOURCES

The Wisconsin Department of Natural Resources (DNR) establishes groundwater quality standards for the state and coordinates the implementation of ch. 160, Wis. Stats. DNR works with operators of landfills, entities that land spread waste, and those that oversee remediation and redevelopment of contaminated sites, to ensure standards are met to avoid increasing the concentration of pollutants in groundwater. The DNR works with public water systems across the state to protect groundwater quality and quantity to provide safe and reliable drinking water supplies. DNR manages groundwater quantity (ss. 281.11, 281.12, 281.34, and 281.346, Wis. Stats.). DNR staffs the Groundwater Coordinating Council and collaborates with the UW-System on the joint solicitation for groundwater research and with the Wisconsin Geologic and Natural History Survey (WGNHS) on an annual groundwater work plan.



Ozone generator inspection at a public water supply system.

Fiscal Year 2021 Highlights

- DNR continues to implement elements of the Wisconsin PFAS Action Plan. This includes sampling effluent at select WPDES permitted facilities and the planned sampling of municipal public water systems. DNR is also drawing on the examples and experiences of other states as it develops an interim plan to address PFAS that may be present in municipal wastewater treatment facilities' biosolids that are regularly applied to agricultural lands throughout the state.
- DNR continues with rulemaking for the NR 140 Cycle 10 list of 27 substances (including PFOS and PFOA). DNR received approval and began rulemaking for the NR 140 Cycle 11. The Cycle 11 list contains DHS recommended standards for 16 PFAS compounds and six pesticides.
- DNR continues rulemaking for NR 809 to set MCLs for PFOS and PFOA.
- DNR committed \$100,000 in FY21 (fiscal year) to continue to operate and maintain the Wisconsin Groundwater Level Monitoring Core Network in collaboration with United States Geological Survey (USGS) and Wisconsin Geological and Natural History Survey (WGNHS). The 'Core Network' includes 97 long-term monitoring groundwater wells and is operated and maintained by the USGS and the WGNHS.
- The Drinking Water and Groundwater and Community Financial Assistance programs continue issuing grants to low-income private well owners. The grants provide funding to help replace contaminated wells or fill and seal unused wells.
- [Central Sands Lakes Study](#) – The number of high capacity wells in the Central Sands Region have increased over the past few decades, which has raised concerns about the impact of groundwater pumping on streamflow and lake levels. As required by 2017 Wisconsin Act 10, the DNR and partners evaluated and modeled

the impacts of groundwater withdrawals from high-capacity wells from Pleasant, Long and Plainfield Lakes in Waushara County. The key findings of the study are that groundwater withdrawals cause reductions in all three study lakes. The reductions are significant and impact the lakes' ecosystems in Long and Plainfield Lakes. The DNR recommends a regional framework, such as a water use district, for addressing impacts to water resources from high-capacity well pumping.

- [Nitrate Targeted Performance Standard](#) – As part of the effort to address groundwater issues and protect drinking water and public health across Wisconsin, the DNR is working with key public and agricultural industry stakeholders, state agencies, the State Legislature, the governor and the general public to update ch. NR 151, Wis. Admin. Code. The rule modification is intended to develop a targeted performance standard to abate agricultural nitrate pollution in areas of the state with highly permeable soils which are susceptible to groundwater contamination (sensitive areas) for the purpose of achieving compliance with the nitrate groundwater quality standard. Rule revisions will define sensitive areas in the state and agricultural performance standards and prohibitions needed to protect groundwater quality in these areas.
- [Wisconsin PFAS Action Council \(WisPAC\)](#) - WisPAC released the [Wisconsin PFAS Action Plan](#) in December 2020. The plan includes 25 action items with recommendations such as establishing science-based standards, developing risk communication infrastructure, streamlining the processes associated with the delivery of safe drinking water supplies, and supporting veterans and their families who may have a higher risk of exposure, among others.

Details of Ongoing Activities

The DNR programs that protect and manage groundwater are as follows:

Drinking Water and Groundwater (DG) – Regulates public water systems, private drinking water supply wells, well abandonment and high capacity wells. DG is responsible for adoption and implementation of groundwater quality standards contained in ch. NR 140, Wis. Adm. Code, and works closely with other programs and agencies to implement ch. 160, Wis. Stats., including groundwater monitoring, data management, hydrogeologic advice and staffing the Groundwater Coordinating Council. Groundwater quantity provisions (2003 Wisconsin Act 310, codified at s. 281.34, Wis. Stats. and ch. NR 820) and the Great Lakes Compact (2007 Wisconsin Act 227, codified at ss. 281.343 and 281.346, Wis. Stats.) are also implemented by DG. The program also coordinates the state's Wellhead Protection and Source Water Protection programs. See <https://dnr.wi.gov/topic/DrinkingWater>, <https://dnr.wisconsin.gov/topic/Wells>, <https://dnr.wi.gov/topic/Groundwater> and <https://dnr.wisconsin.gov/topic/WaterUse>.

Remediation and Redevelopment (RR) – Oversees response actions at spills, hazardous substance discharge sites, sites impacted by environmental pollution, abandoned containers, drycleaners, brownfields (including grant programs that provide assistance with environmental assessment and cleanup), leaking underground storage tanks, closed wastewater and solid waste facilities, hazardous waste corrective action and generator closures and sediment cleanup actions, all of which are closely related to groundwater issues. In addition, the RR program provides temporary emergency water in instances where hazardous substances or animal waste has adversely affected private

wells. See <https://dnr.wi.gov/topic/Brownfields/> and <https://dnr.wisconsin.gov/topic/Spills>.

Waste and Materials Management (WMM) – Regulates and monitors groundwater quality at proposed, active, and inactive solid waste facilities and landfills. WMM reviews investigations of groundwater contamination and implementation of remedial actions at active solid waste facilities and landfills. WMM also maintains a Groundwater and Environmental Monitoring System (GEMS) database of groundwater quality data from over 600 solid waste facilities and landfills and uses reports from GEMS to evaluate whether sites are adversely affecting groundwater quality. See <https://dnr.wi.gov/topic/Landfills/gems.html>.

Water Quality (WQ) - Regulates the discharge of municipal and industrial wastewater, by-product solids and sludge disposal from wastewater treatment systems and wastewater land treatment/disposal systems. WQ also issues permits for discharges associated with clean-up sites regulated by WQ for the RR program. See <https://dnr.wi.gov/topic/Wastewater> and <https://dnr.wi.gov/topic/TMDLs>.

Watershed Management (WT) – WT has primary responsibility for regulating stormwater and agricultural runoff, as well as managing waste from large animal feeding operations. See <https://dnr.wi.gov/topic/nonpoint/>, <https://dnr.wisconsin.gov/topic/cafo> and <https://dnr.wi.gov/topic/stormwater/>.

Drinking Water and Groundwater Program

Groundwater Quality Standards Implementation

Chapter 160, Wis. Stats., requires the DNR to develop numerous groundwater quality standards which consist of enforcement standards and preventive action limits for substances detected in, or having a reasonable probability of entering, the groundwater resources of the state. [Chapter NR 140, Wis. Adm. Code](#), establishes these groundwater standards and creates a framework for their implementation. Groundwater quality standards are set for 138 substances of public health concern, eight substances of public welfare concern and 15 indicator parameter substances in ch. NR 140.

In accordance with [state groundwater law](#), the DNR periodically submits a list of substances to the Department of Health Services (DHS) and requests that they review available toxicologic information and provide recommendations for new and/or revised groundwater standards. These lists submitted to DHS are designated as NR 140 "cycle" lists. DHS then prepares a Scientific Support Document back to DNR which describes the information and methodology used to develop each recommended standard.

The DNR submitted a list of 27 substances, designated "Cycle 10," to DHS in March 2018. DHS responded with recommended standards to DNR in June 2019. DNR is currently in the middle of rulemaking to incorporate the Cycle 10 recommendations into NR 140. A plain language summary of each of the compounds in Cycle 10 is available at [DHS's Recommended Groundwater Enforcement Standards](#). The DHS Cycle 10 recommendations include a recommended groundwater quality Enforcement Standard of 20 parts per trillion

(ppt) for the combined concentration of two PFAS compounds, PFOS and PFOA. The DNR also submitted a list of 40 substances, designated "Cycle 11", to DHS in April 2019. The Cycle 11 list of substances includes 34 PFAS compounds detected, or potentially present, in Wisconsin groundwater. Rulemaking for the Cycle 11 list is underway. The current status of NR 140 rulemaking for Cycle 10 and 11 can be found here: [NR 140 Groundwater Quality Standards Update](#).

To help ensure awareness of known health risks, DNR updated its [table](#) listing health and welfare based enforcement standards (ch. NR 140), state public drinking water standards (ch. NR 809) and established health advisory levels (HALs) for substances in water to reflect new or revised health advisory levels set this year. This table of regulatory standards and advisory levels provides a useful source of information to members of the public concerned about the safety of their drinking water. It is also a valuable resource for agency staff and consultants involved with groundwater contamination and remediation actions. Links to resource websites allows users to obtain additional toxicological and health related information on many of the substances listed in the table.

DNR continues to provide training to new staff in the runoff management and drinking water programs on the implementation of groundwater quality standards, including training for landspreading discharge permit writing and animal waste drinking water well contamination response. Groundwater and runoff program staff regularly consult on groundwater quality issues that arise in agricultural and urban runoff programs. Such coordination is critical in obtaining statewide consistency on how the DNR evaluates and reduces risk of groundwater contamination associated with regulated activities.

DNR staff actively participate on the NRCS Source Water Protection Subcommittee. This subcommittee provides guidance to State conservationists and directors on how to comply with source water protection activities contained in the 2018 Farm Bill, activities include identifying local priority areas for source water protection and practices to address water quality and quantity threats.

Groundwater Quantity Program Implementation

The DNR is authorized under ch. 281, Wis. Stats. to regulate wells, except for a residential well or a fire protection well that has a capacity of more than 100,000 gallons per day. Such wells are defined as high capacity wells. Any well, regardless of pump capacity, on a high capacity property is considered a high capacity well. 2015 Wis. Act 177 granted an exception for wells used for residential or fire protection purposes from being considered high capacity wells effective October 1, 2016. s. 281.34(1)(b) Wis. Stats.) Since 1945, the DNR has reviewed proposed high capacity wells for compliance with applicable well construction rules to determine whether the well would impair the water supply of a public utility well. The DNR review of high capacity wells has been evolving over the last decade as described in the paragraphs below.

In May of 2004, the statutes regarding high capacity wells were expanded through 2003 Wisconsin Act 310 to give the DNR additional authority to consider environmental impacts of proposed wells when the proposed well may significantly impact a large spring, results in 95% or greater water loss, or the well is located within 1,200-feet of a trout stream, exceptional resource water or outstanding resource waters. DNR may deny or limit an approval to assure that proposed high capacity wells do not cause significant adverse

environmental impacts to these valuable water resources. The Act 310 changes are implemented primarily through ch. NR 820, Wis. Adm. Code. DNR water use section staff implement the programs created by Act 310 including reviewing applications, managing data and collecting water withdrawal reports.

The DNR changed its procedures in July 2011 in response to a 2011 Wisconsin Supreme Court decision in *Lake Beulah v. Wisconsin Department of Natural Resources* to review each application for a new high capacity well to determine whether the well, along with other high capacity wells on the contiguous property, would result in significant adverse environmental impacts to waters of the state – which includes all streams, lakes, wetlands, public and private wells. Section NR 820.12(19), Wis. Adm. Code defines significant adverse environmental impact as:

Alteration of groundwater levels, groundwater discharge, surface water levels, surface water discharge, groundwater temperature, surface water temperature, groundwater chemistry, surface water chemistry, or other factors to the extent such alterations cause significant degradation of environmental quality including biological and ecological aspects of the affected water resource.

If the DNR determined the proposed well could directly result in significant adverse environmental impacts, the DNR would either deny the well application or request that an applicant modify their proposed construction or operation of the well to prevent such impacts. DNR based the need to modify or deny an application on the projected impacts to the affected water resource, e.g., estimated reductions in stream flow or lake level, and the resultant impacts to water temperature, the fishery and other ecological aspects of the stream or lake. In conducting these assessments, DNR considered site-specific hydrogeology, separation distance between the well(s) and the water resource, the hydrology and characteristics of potentially affected surface waters, construction details of nearby wells, characteristics of the proposed wells such as construction, pump capacity, and the water use and pumping schedule for the proposed well and any other existing wells on the property. This version of the technical review methodology was in place from July 2011 through May 2016.

In May 2016 Wisconsin Attorney General Schimmel issued a formal opinion (OAG-01-16) regarding the DNR's authority to consider environmental impacts when reviewing high capacity well applications. Attorney General Schimmel concluded that section 227.10(2m), Wis. Stats., prohibits the DNR from conducting an environmental review of a high capacity well unless it is in one of the specific categories identified in Wis. Stat. § 281.34, such as a well in a groundwater protection area; with a water loss of more than 95% of the amount of water withdrawn; or that may have a significant environmental impact on a spring (these categories are specified in Wis. Stat. § 281.34(4)); or if it may impair the water supply of a public utility (as described in Wis. Stat. § 281.34(5)). 2017 [Wisconsin Act 10](#) took effect on June 3, 2017. The Act amended and created several statutes pertaining to replacement, reconstruction and transfer of approved high capacity wells. The new law allows well owners to conduct these activities without DNR approval and without paying any additional fee, provided the statutory criteria are met. Please note that Act 10 does not affect any applications or approvals required for public or community water supply

systems, or school or wastewater treatment plant wells under Wis. Adm. Code Chapters [NR 810](#), [811](#), and [812](#) and this guidance does not address requirements under those chapters. Act 10 also includes a study of specific navigable water resources of the Central Sands area of Wisconsin. A report on this study is due to the legislature in June 2021.

In May 2020, Wisconsin's [Attorney General Josh Kaul issued a letter](#) to the DNR withdrawing a 2016 Attorney General Opinion concerning the DNR's review of high capacity well applications and the ruling of the Wisconsin Supreme Court in *Lake Beulah Management District v. Wisconsin Department of Natural Resources*. In response to a May 1, 2020 letter from the Wisconsin Attorney General, the DNR no longer relies on a 2016 Attorney General opinion in evaluating high capacity well applications but rather will act in accordance with the Supreme Court's decision in *Lake Beulah v. Wisconsin Department of Natural Resources* by considering environmental impacts on a case-by-case basis when presented with concrete, scientific evidence of potential harm. The Wisconsin Supreme Court heard a case related to high capacity well approvals in Spring 2021. The decision in this case may impact review of high capacity well applications. The DNR's High Capacity Well Application Review Process website (<https://dnr.wi.gov/topic/Wells/HighCap/Review.html>) describes the current technical approach.

Great Lakes Compact and Implementation of 2007 Act 227

The Great Lakes—St. Lawrence River Basin Water Resources Compact (Compact) took effect on December 8, 2008 following ratification in each of the eight Great Lakes States and Congress' consent. DNR water use section staff implement Compact-related programs including; authorizing permits and approvals, implementing the water conservation and efficiency program, reviewing diversion applications and working in conjunction with groundwater quantity staff to collect annual water withdrawal reports.

The DNR has promulgated four administrative rules to implement the Compact and associated statewide water use legislation. Three of these rules took effect January 1, 2011: Water Use Registration and Reporting (ch. NR 856); Water Use Fees (ch. NR 850); and Water Conservation and Water Use Efficiency (ch. NR 852). The Water Use Permitting rule (ch. NR 860) took effect in December 2011. Three additional rules are still in the drafting stage. These rules include Water Supply Service Area Planning, Water Loss and Consumptive Use, and Water Use Public Participation.

In January 2018, DNR receive an application to divert water from Lake Michigan to the Village of Mount Pleasant. The Village of Mount Pleasant is partly in the Great Lakes Basin and partly in the Mississippi River Basin. Under the Great Lakes Compact, the Village of Mount Pleasant is eligible to receive a diversion of Great Lakes water if the Compact criteria for a straddling community diversion are met. DNR approved the diversion on April 25, 2018 after holding a public comment period, public hearing and determining that the proposal met the Great Lakes Compact criteria. The diversion is approved to supply up to seven million gallons of water per day to the portion of the Village of Mount Pleasant in the Mississippi River Basin. The diversion area includes part of the area identified by Racine County as the future site of the Foxconn facility. The DNR's diversion approval was

challenged on May 25, 2018 and the DNR's approval was upheld by the administrative law judge.

Water Use Registration and Reporting

Following implementation of the Compact, all new or increased withdrawers that have the capacity on their property to withdraw 100,000 gallons per day (gpd) or more for 30 days must register with the DNR prior to withdrawing groundwater or surface water. This is typically done in conjunction with other approval or permitting procedures.

DNR continues to upgrade water use data management systems, improve existing registration data and expand data collection methods. These efforts resulted in an increase in withdrawal report response rates from below 50% in 2008 to 79% in 2010. These improvements continued so that the reporting response rate for 2013 – 2018 is 96% annually.

Water Withdrawal Registrations by Source Type and Major Basin (2020)

	Great Lakes Basin	Mississippi River Basin	Total
Groundwater	3,688	9,851	13,539
Surface Water	397	671	1,068
Total	4,085	10,522	14,607

Persons with registered withdrawals must measure or estimate their monthly withdrawal volumes and report the previous calendar years' monthly water use by March 1 of each year. These reports are collected and analyzed for errors and inconsistencies. The compilation of more than five years of water use reporting data has allowed DNR to assess trends in water use over time summary analysis is conducted on reported withdrawals and an annual water withdrawal reporting summary is made publicly available on the [DNR website](#). Individual reports are also provided upon request to governmental partners, researchers, businesses and private individuals.

Water Conservation and Water Use Efficiency

Ch. NR 852, Wis. Adm. Code, establishes a mandatory water conservation and water use efficiency program for new or increased Great Lakes Basin surface water and groundwater withdrawals. In addition, mandatory conservation is required for any new or increased diversions of Great Lakes water and water withdrawals statewide that would result in a water loss of two million gallons per day or more. The rule identifies conservation and efficiency measures that withdrawals subject to the mandatory program must meet.

The rule helps guide a statewide voluntary water conservation and efficiency program which focuses on providing information and education, identifying and disseminating information on new conservation and efficiency measures, and identifying water conservation and efficiency research needs. The program is coordinated with the Public Service Commission and the Department of Safety and Professional Services.

Water Use Permits

Water Use Permits are required for Great Lakes Basin groundwater or surface water withdrawals averaging 100,000 gallons per day or more in any 30-day period. General permits (valid until 2036) are required for withdrawals of 100,000 gallons per day averaged over 30 days up to 1,000,000 gallons of water for 30 consecutive days. Individual permits (valid for 10-years) are required for withdrawals of 1,000,000 gallons per day or more for 30 consecutive days. Ch. NR 860, Wis. Adm. Code prescribes a review process for the individual permits and requires additional environmental review. Since December 8, 2011, approximately 270 permits have been issued to new or increased withdrawals in the Great Lakes Basin.

Water Use Fees

Wisconsin Act 28 contains statutory language directing the DNR to collect water use fees to fund Great Lakes Compact implementation and water use program development in Wisconsin. The statute directs that all persons with water supply systems with the capacity to withdraw 100,000 gallons per day or more must pay an annual \$125 fee per property. Act 28 also directs the DNR to promulgate a rule imposing an additional fee on Great Lakes Basin water users withdrawing more than 50 million gallons per year. That rule, ch. NR 850, Wis. Adm. Code, prescribes a tiered system for additional Great Lakes Basin fees on withdrawals exceeding 50 million gallons per year. Water use fee revenue is used to; document and monitor water use through the new registration and reporting requirements, implement the Great Lakes Compact through water use permitting and regulate diversion of Great Lakes Basin waters, help communities plan water supply needs, build a statewide water conservation and efficiency program and to develop and maintain a statewide water resources inventory.

Well Construction and Private Wells

DG sets and enforces minimum standards for well construction, pump installation and well filling and sealing through ch. NR 812, Wis. Adm. Code. The standards are intended to protect groundwater and ensure safe drinking water. After three years of rulemaking to incorporate public comment and well industry involvement, NR 812 went into effect on July 1, 2020. The focus of revisions was to update well construction standards based on modern equipment and techniques, to correct and clarify rule language, to streamline approval procedures and to be consistent with changes in other statutes and codes. "Topic-of-the-Week" emails sent to drillers and pump installers in advance of July 1 provided specific details about changes to help the regulated community prepare. DG's web page on [NR 812 Changes](#) provide archives of outreach, publications and training modules about the rule revisions.

More than 9,500 new or replacement wells were constructed in Wisconsin in 2020. Advance notification to DNR is required for all well construction. After construction, drillers submit Well Construction Reports to the DNR describing the construction of each well drilled. Private Water Supply staff enforce minimum well construction standards by conducting compliance inspections with a focus on private wells under construction and reviewing well construction reports and associated sampling results. Despite some

restrictions due to COVID protocols, during 2020 staff conducted 713 compliance inspections of wells under construction, and additional inspections of pump installation and well filling/sealing work. DNR staff initiated enforcement action on multiple violations including failure to submit required reports and well drilling or pump installing without a license.

DG staff promote compliance through regular communication with drillers and pump installers, including in-person contacts, a Private Water Advisory Council with industry advisors, and a web page with industry-focused information and resources. The quarterly "NewsBits" e-newsletter provides program updates, annual data and compliance reminders to drillers, pump installers and other interested parties.

Private Water Supply staff are often the first responders to reports of private well contamination. Well contamination by livestock waste has been an increasing problem in recent years. DG staff use field investigation and analytical tools to investigate the source of microbial contamination – known as MST (Microbial Source Tracking) sampling – and determine whether fecal contamination is due to grazing animal manure rather than human sources. Agency news releases to both the agricultural community and general media emphasize ways to avoid contamination and encourage regular sampling and well inspection by private well owners.

DG handles license renewal for well drillers, heat exchange drillers and/or pump installers each year under ch. NR 146, Wis. Adm. Code. New applicants demonstrate experience and take a one-time examination to obtain a license. New License Exam Study Guides are now available to assist applicants to prepare for the exam. All license holders must attend training each year to earn required continuing education credits. DNR works with training providers to evaluate and approve all continuing education credits, ensuring that license holders are qualified to do their work in a way that meets standards and won't contaminate groundwater. More than 1,200 individuals hold an active Water Well Driller, Heat Exchange Driller and/or Pump Installer license in Wisconsin. During the pandemic, the DNR worked with continuing education providers to develop online training options and provided for the safe proctoring of in-person exams. The DNR is currently engaging with a third party to implement online examinations, which had not been an option before the pandemic.

DG encourages private well owners to test their wells annually for bacteria and other contaminants they may be concerned about. DG maintains the popular web page titled "What's Wrong with My Water?" to answer commonly-asked questions about private well water, to help well owners diagnose their aesthetic water quality problems and to provide suggested options. DG and Community Financial Assistance staff awarded a combined total of over \$110,000 in well abandonment and well compensation grants in 2020. Well compensation grants provided cost-sharing funds to help six owners replace wells due to metals and other contamination. Additionally, 49 well abandonment grants were issued around the state to help fund filling and sealing of unused wells.

DG continues to develop new and enhance existing electronic tools to help well drillers, well owners and others to find information and comply with well construction and well

filling and sealing requirements. DG launched a new place to search for Wisconsin well construction reports (WCRs) in late 2019. Starting at the [Search Well Records](#) web page, several new features are available:

- Users can search by text, or search by map and zoom into an address or place. Search Tips are available on the first screen.
- Pre-1988 WCRs are included. Wisconsin Unique Well Numbers are assigned to the pre-1988 wells, starting with the digit "8" – for example "8AB123".
- Public Well WCRs are included. For noncommunity wells, the complete WCR is available. For municipal and other-than municipal wells, the WCR is available with exact location information removed for security.
- The department has started to enter information from pre-1988 WCRs to make them more searchable. This effort will be ongoing and will make it easier to find WCRs in the future.

DG launched a new place to search for Wisconsin well construction reports (WCRs)

The "[Well Driller Viewer](#)" tool provides a searchable map view of landfill setbacks, special well casing depth areas, remediation sites and other data to assist well drillers in planning projects and meeting requirements of NR 812, Wis. Adm. Code. The Well Driller Viewer – Mobile-Friendly App was added in 2019. With a few easy steps, anyone can download an app and access the Well Driller Viewer on a smartphone. The app provides screen views and easy navigation customized for mobile devices.

"[Online WCR](#)" is the electronic system for submitting Well Construction Reports to DNR. Online WCR checks for common errors to make sure the report is



The Well Driller Viewer was launched in 2018.

complete and submits the data directly to DNR without the need to send in a paper report. A similar online [Well Filling and Sealing Report](#) system allows contractors to submit filling and sealing reports, which are required to be submitted electronically. Both systems reduce time and errors for both well professionals and DNR staff and result in more accurate data available more quickly.

Public water systems

DNR's Public Water Supply (PWS) program oversees the drinking water quality provided by public water systems (ch. NR 809 (Safe Drinking Water), Wis. Adm. Code). Working in cooperation with owners and operators of water systems, the PWS program ensures that samples are collected, and analyses completed to determine if the water meets federal Safe Drinking Water Act (SDWA) standards. The PWS program also regulates the operation of public water systems through ch. NR 810 and the general design and construction of community water systems through ch. NR 811 and NR 812 for non-community systems. Additionally, the PWS program works to educate water system owners and operators concerning proper operation and maintenance of water systems to ensure safe drinking water for Wisconsin consumers.

The PWS program maintains data about Wisconsin's drinking water and groundwater quality through the [Drinking Water System database](#). The Drinking Water System is an important tool used to efficiently enforce SDWA regulations for public water systems. It contains the monitoring and reporting requirements for each public water system and their drinking water sampling results. It also includes violations for any missing requirements and exceedances of the maximum contaminant levels (MCLs).

DNR maintains an electronic monthly operating report (EMOR) data system to accept and store monthly operating report data from public drinking water systems. EMOR contains required documentation of a system's operations such as monthly pumpage, chemical usage for treatment, chlorine residual, turbidity and temperature. EMOR generates data reports to monitor treatment operations and make efficient water quality and quantity management decisions.

Public water systems continue to face rising nitrate levels. Community and non-transient non-community water systems must take immediate action if a nitrate MCL of 10 mg/L is observed (e.g., take well off-line, blend, treat etc.). Transient non-community systems, which include taverns, restaurants, churches and campgrounds, are required to post notices warning customers of the exceedance and to provide bottled water to infants and pregnant women. Rising nitrate concentrations are a result of increasing concentrations in groundwater caused by land use activities and weather patterns. The public water supply program continues to work with other DNR programs and external partners to reduce nitrate in groundwater and surface water.

The PWS program is working with public water systems to implement the federal revised total coliform rule (RTCR). Wisconsin has adopted a "find-and-fix approach" so that when bacterial contamination potential is detected by the presence of total coliform, DNR and water system operators investigate to find the cause, take action to fix it, and monitor to ensure public health protection. Among many RTCR implementation activities, water

supply specialists tested new water supply sampling methods developed by the State Laboratory of Hygiene. The method will help public water systems distinguish whether the source of bacterial contamination is in the groundwater or due to a defect of the water system. For additional information about the Public Water Supply Program you can review the current [Annual Compliance Report](#).

Wellhead protection

The goal of Wisconsin's Wellhead Protection (WHP) program is to reduce the risk of groundwater contamination in areas contributing groundwater recharge to public water supply wells, consistent with the state's overall goal of groundwater protection. A WHP plan is required for new municipal wells and must be approved by the DNR before the new well can be used. A WHP plan is voluntary for any public water supply well approved prior to May 1, 1992. DNR promotes and encourages, but does not require, wellhead protection planning for all wells. With planning assistance from Wisconsin Rural Water Association (WRWA), 12 communities completed WHP plans this year (a total of 25 wells).

DNR and WRWA are working together on proactive strategic interventions to support wellhead protection actions in selected communities with wells susceptible to contamination. DNR, WGNHS, WRWA, and other partners are developing and using groundwater monitoring, modelling and related tools in Spring Green and Waupaca to demonstrate a voluntary community-based approach to rising nitrate levels. In response to contaminant plumes that have the potential to affect two municipal wells in the village of Luck, WI, the village has updated its WHP plan, participated in groundwater teacher workshops, and is evaluating new spill prevention and remediation and redevelopment opportunities with support from DNR and WRWA.

DNR continues to measure and report to US Environmental Protection Agency (EPA) on the percent of public water systems that are protected by substantial implementation of wellhead protection. In 2019, 40% of Wisconsin municipal public water systems were protected by implementation of a WHP plan. Over 400 communities now have a WHP plan for at least one of their wells and approximately 55% of the municipally served population is covered by source water protection plans with accompanying implementation ordinances.

DNR maintains a [webpage](#) with a variety of information aimed at encouraging and supporting water utilities in protecting their water supplies from potential sources of contamination.

DNR staff from a variety of water programs completed several collaborative projects to more effectively align management of both phosphorus and nitrogen losses to lakes, streams and groundwater. Different chemical behavior and separate Clean Water and Drinking Water federal laws make coordination somewhat challenging. Wisconsin's Nutrient Reduction Strategy and its newly-revised Nonpoint Source Program Plan now more thoroughly address both groundwater and surface water.

DNR and WRWA staff continue to coordinate their assistance to local protection efforts. WRWA staff work on plans for individual communities and area wide plans for multiple

water supply systems. DNR staff review draft plans and ordinances and provide technical advice to local officials responsible for carrying out wellhead protection.

Groundwater Information and Education

Since 1994, DNR staff have worked with the Groundwater Center at the Center for Watershed Science and Education (CWSE) and WGNHS to sponsor two groundwater workshops for teachers every year. Educators from 20 schools and nature centers are selected to attend the workshops and receive a free groundwater model for their school. Besides learning how to use the groundwater model, the educators received groundwater resources to incorporate groundwater concepts into their classroom. The intent of the workshops is to provide information for teachers to educate students – and their parents – on the importance of protecting groundwater in their own communities. With funding from an EPA WHP grant, groundwater models have been given to over 475 schools or nature centers since 2001 and nearly 900 educators have received hands-on training in using the model effectively.

Since the Groundwater Coordinating Council Report to the Legislature went online in an interactive format in 2014, web visits and time spent at the site have continued to increase. In FY19, the GCC report was accessed online over 5000 times; in FY20, it was accessed online over 6500 times.

Well drillers and pump installers, water testing providers, local health and conservation departments, health care providers and many individuals request and receive hundreds of thousands printed publications on groundwater. Among the most-frequently requested items are: Nitrate, Groundwater: Wisconsin's Buried Treasure publication, and the Groundwater Study Guide packet.

Groundwater Monitoring and Research

Chapter 160 of the Wisconsin Statutes requires the DNR to work with other agencies and the Groundwater Coordinating Council (GCC) to develop and operate a program for monitoring and sampling groundwater to determine whether harmful substances are present (s. 160.27, Wis. Stats.). The DNR has also supported groundwater monitoring studies evaluating existing design and/or management practices associated with potential sources of groundwater contamination. The intent of these studies is to reduce the impacts of potential sources of contamination by changing the way land activities may impact groundwater are conducted.

Seven [new projects](#) were selected through the Joint Solicitation process for funding in FY22. Final reports and 2-page research summaries are available for many projects on the [Water Resources Institute website](#).

DNR commits \$100,000 annually to operate and maintain the [Wisconsin Groundwater Level Monitoring Core Network](#) in collaboration with USGS and WGNHS. This 'Core Network' has been in existence since 1946 and currently includes 97 long-term monitoring groundwater wells and two spring flow gages. The long-term monitoring provides data that builds the history of water levels in an area or aquifer. Uses of the data includes: assessing aquifers in drought or wet conditions, assessing groundwater divides and surface water impacts, calibrating groundwater flow models and other decision-support

tools, determining the relationship between water resources and withdrawals and more. In addition to supporting the statewide groundwater level monitoring network, DNR also supports monitoring of streams, lakes and springs to understand groundwater influences on these surface water resources. In FY21, DNR continued monitoring reference springs, a project begun by WGNHS, continued revisiting springs in the Wisconsin Spring Inventory, and surveyed newly identified springs. As part of the Central Sands Lakes Study, DNR added 21 project groundwater level monitoring wells – or short-term monitoring wells – to the Central Sands region.

Groundwater Data Management

The DNR's consolidated Groundwater Retrieval Network ([GRN](#)) accesses groundwater data from database systems in the DG, Waste & Materials Management, and Watershed Management programs, including information on approximately 300,000 wells. These wells represent public and private water supply wells, piezometers, monitoring wells, non-potable wells and groundwater extraction wells. DG staff continue to improve the locational data associated with GRN's wells and the ease with which the data can be accessed.

The DNR's high capacity well and surface water intake data continues to improve. Since the database was developed in 2007, much of the previously existing locational and ownership information has been verified or updated to improve data quality. The improved data quality has helped increase response rates on annual water withdrawal reporting. Between 2008 and 2013, reporting response rates increased from 60% to over 95%. The online reporting system has increased reporting accessibility and improved communication with the user community.

Office of Emerging Contaminants

The Office of Emerging Contaminants (OEC) coordinates cross-program, division, and agency work around environmental contaminants and emerging topics such as PFAS. OEC staffs the Wisconsin PFAS Action Council (WisPAC), which consists of nearly 20 state agencies working to address PFAS contamination in the state. The office monitors and advises on the implementation of the PFAS Action Plan, including sampling and ongoing monitoring, development of new methods and science-based standards, and enhanced risk communication infrastructure and resources. In alignment with recommendations from the Action Plan, OEC staffs additional advisory bodies such as the PFAS External Advisory Group and the PFAS Technical Group to help foster ongoing discussion and collaboration with stakeholders.

OEC coordinates with and provides technical assistance to stakeholders across the state, including with the firefighting community around PFAS-containing firefighting foam through the development of best management practices, FAQs, and other resources related to Wis. Stat. 299.48 and ch. NR 159 regarding the prohibition of use to help prevent future contamination of Wisconsin's groundwater. OEC also staffs and coordinates work with sister agencies in the Great Lakes, and with partner organizations such as ECOS and ITRC, to share information, research, advisories, and other activities.

Remediation and Redevelopment Program

The Remediation and Redevelopment (RR) program has primary responsibility for implementing and aiding cleanups under the Spill Law, the Environmental Repair Law, the Land Recycling Law, federal programs (Superfund, Hazardous Waste Corrective Action and Closure, Leaking Underground Storage Tanks (LUST)), brownfields properties, the Drycleaner Environmental Response Fund, contaminated sediments and at closed landfills. The RR program provides technical assistance, helps to clarify legal liability, provides financial assistance and provides technical project oversight of cleanup projects.

All cleanups are conducted according to the ch. NR 700 rule series, Wis. Adm. Code, Investigation and Remediation of Environmental Contamination, and ch. NR 140, Groundwater Quality. The majority of cleanups are done by persons responsible under the law, or persons or groups involved in the redevelopment of potentially contaminated properties. Program staff provide technical assistance on cleanups conducted by consultants at the direction of responsible parties. In addition, RR staff contract and direct consultants on state- and federally-funded cleanups and assessments. The RR Program also provides assistance for spill response; and works with other agencies, particularly the U.S. EPA Removals Program, for conducting major spill response actions and removal of hazardous substances when the responsible party is unable or unwilling to do so and there is a risk to public health, welfare, or to the environment. The RR program is also responsible for assisting EPA with the remediation of contaminated sediments in the Great Lakes areas of concern.

Cleanup of Groundwater Contamination

As of June 30, 2019, in FY20, the program spent approximately \$1,500,000 in Environmental Fund dollars to initiate or continue environmental cleanup actions at over 30 locations where groundwater contamination is known or suspected. The Environmental Fund is used when contamination is significant, but no identifiable private party has legal responsibility for the contamination, the person(s) legally responsible do not have the financial ability to proceed, or the responsible person simply refuses to proceed. Private contractors conduct these investigations and cleanups with oversight by DNR staff. Whenever feasible, the RR program and legal staff attempt to recover costs from responsible persons after the cleanups are undertaken. In addition to these "state-lead" projects, the RR program spent approximately \$280,000 in Environmental Fund dollars in FY20 to cleanup emergency spills to prevent additional groundwater contamination.

Under the Safe Drinking Water Act's third Unregulated Contaminants Monitoring Rule (UCMR-3), select municipal water systems were asked to test for six PFAS (PFOA, PFOS, PFNA, PFHxS, PFHpA and PFBS) between 2013 and 2015. Levels were detected in public water systems in La Crosse, West Bend, and Rhinelander. Testing has also been conducted voluntarily by several municipal water systems and included a more comprehensive list of PFAS (i.e. additional compounds such as those included as part of EPA's Method 537.1). These testing efforts identified PFAS in varying concentrations in municipal water systems in Marinette, Peshtigo, and Madison, and PFAS has also been found in groundwater at several sites across the state, including near the Johnson

Controls International (JCI)/Tyco facility (Marinette), former Mirro plants (Manitowoc and Chilton), French Island in the town of Campbell and city of La Crosse, and Department of Defense sites (i.e. Wisconsin Air National Guard facilities at Truax Field and Volk Field) in Wisconsin.

Investigation, Cleanup and Redevelopment of Brownfields

Brownfields are abandoned, idle or underused industrial or commercial facilities or sites whose expansion or development is adversely affected by actual or perceived environmental contamination. The RR program coordinates several efforts to encourage local governments and private businesses to cleanup and redevelop brownfield properties. At many brownfields sites, the release of hazardous substances threatens groundwater quality.

Program staff assist local governments and private businesses with the cleanup and redevelopment of brownfields by providing technical assistance. The RR program provides a number of different types of assurance, comfort, or general liability clarification letters related to properties with groundwater contamination, as well as other contaminated media, depending on the site-specific circumstances. Collectively, these letters facilitate the reuse and development of properties. Since 1994, the RR program has provided thousands of redevelopment assistant reviews – which can include liability clarification letters, off-site exemption letters, cleanup agreements for tax delinquent properties, building on abandoned landfill approvals, etc. – at brownfield properties throughout the state.

The RR program also continues to assist parties with voluntary investigations and cleanups of brownfield properties through the Voluntary Party Liability Exemption (VPLE) process. Many sites that follow the VPLE process have contaminated groundwater.

In the VPLE program, after a person has conducted an environmental investigation of the property and cleaned up contamination, the DNR can issue a "Certificate of Completion" which provides a release from future liability for any discharge that occurred on the property prior to approval of the investigation and cleanup of that discharge. Since 1994, the DNR has issued over 200 certificates of completion with no reopeners.

Dry Cleaner Environmental Response Fund (DERF) Program

The DERF program reimburses dry cleaner owners and operators for eligible costs associated with the cleanup of soil and groundwater at sites contaminated by dry-cleaning solvents. Fees paid by the dry-cleaning industry provide program funding. Environmental cleanups at dry cleaner sites are conducted following the ch. NR 700 rule series. There are 219 sites in the program, with 102 at various stages of investigation and cleanup and 117 sites closed. The program is implemented through ch. NR 169, Wis. Adm. Code.

Tracking System and GIS Applications

The program's main database on the status of sites undergoing investigation and/or cleanup is the Bureau of Remediation and Redevelopment Tracking System ([BRRTS](#)).

In 2001, revisions to ch. NR 726, 716, 749, 811, and 812 implemented requirements to list sites with residual groundwater contamination on the database to replace the requirement to record groundwater use restrictions at the County Register of Deeds Office. In 2002, additional rule revisions required the inclusion of sites with residual soil contamination on the database. In 2006, the spill law was amended (see s. 292.12, Wis. Stats.) to expand the use of DNR's databases to track sites with residual contamination left in place at the time of case closure. The database currently includes locational information on open sites, sites closed with no residual contamination, sites closed with residual groundwater contamination above the ch. NR 140 enforcement standards and sites closed with soil contamination above ch. NR 720 soil standards, sites closed with other engineering or institutional controls, and brownfields properties, as well as site specific information pertaining to investigation and cleanup of each property.

Information in the database is available through BRRTS on the Web (BOTW). This internet-accessible application provides information to future owners or users of the property of the existence of soil and/or groundwater contamination, as well as any responsibilities of the property owner (or occupant in some cases) to comply with any conditions of closure. The site-specific information is attached to each site by a link to a pdf.

In 2005, an expanded GIS application was made available, called the [RR Sites Map](#). This application shows the locations of the majority of sites available on BRRTS (open and closed). In 2008, additional data regarding financial tools and liability clarification actions were added. In June of 2013, RR Sites Map was migrated to Geocortex where it obtained a new look but kept the same functionality.

RR Sites Map is linked to BRRTS on the Web and is useful for locating potential contamination sites when evaluating new municipal well placement or for property transactions. The database makes site specific information on open and closed remediation sites much more available and accessible to the public and specific interested groups, particularly those wanting to install or replace a potable well on an affected property, as well as those buying properties. Sites regulated by the Department of Agriculture and Trade and Consumer Protection (DATCP) are also included in BRRTS on the Web and RR Sites Map.

A well driller or well constructor shall consult with the department prior to drilling in areas where the driller has been notified or determines that there are contaminated formations or groundwater contamination levels in excess of the standards specified in s. NR 812.06, or prior to drilling a well on a property identified by the department as having residual contamination and continuing obligations requiring listing on the department's database to determine if additional casing or other construction techniques may be required.

The RR Program continues to make improvements to both BOTW and RR Sites Map. In addition to the ongoing programming efforts, work continues on quality assurance and quality control (QA/QC) of existing data.

Waste and Materials Management Program

Monitoring Groundwater Quality Around Landfills

The Waste and Materials Management Program (WMM) implements the DNR's Groundwater Standards Program in several ways during the life of a landfill. When staff review an applicant's "Feasibility Report," which proposes to site a landfill at a particular location, they review baseline groundwater data submitted by the applicant to determine whether exemptions and alternative concentration limits (ACLs) to the established ch. NR 140 groundwater standards are needed for the public health and welfare parameters, based on the concentrations of those substances present in the groundwater before landfill development. In addition, reviewers establish preventive action limits (PALs) for indicator parameters based on statistical calculations of the baseline concentrations.

During the active life of a landfill and after closure, staff review routine groundwater detection monitoring data, collected and submitted by the landfill owner at sites where monitoring is required to determine compliance with ch. NR 140 standards and site-specific ACLs and PALs. Ch. NR 140 provides a list of response actions that the DNR may require a facility to take after a groundwater standard exceedance is confirmed. When conditions warrant, staff require groundwater investigation reports that include proposals for further evaluations and recommendations for remediation at landfills that cause groundwater standards to be exceeded. Staff review results of site investigations triggered by the exceedances of groundwater standards and evaluate the effectiveness of remedial actions at active solid waste facilities and closed landfills by comparing results to groundwater standards and by looking at concentration trends over time.

WMM accepts only electronic submittal of environmental monitoring data from landfill owners, labs and consultants. The electronic data submittals are currently uploaded by DNR to the WMM Groundwater and Environmental Monitoring System (GEMS) database. WMM provides public access to the environmental monitoring data contained in GEMS through "GEMS on the Web." In addition to enhancing GEMS on the Web to allow more flexibility in choosing a specific date range and particular monitoring points, WMM is seeking resources to program a web interface, possibly using the department's Data Portal or Web Access Management System, so that facilities can upload environmental monitoring data into GEMS.

The WMM Program is placing stronger emphasis on having facilities collect water samples for VOC analysis, rather than for indicator parameters, in exchange for a reduced sampling frequency. VOCs are a key contaminant used to determine water supply well vulnerability to contamination and set monitoring requirements.



Bags of pharmaceuticals collected by Jefferson County as part of an effort to keep pharmaceutical waste out of the groundwater. *Photo credit: Barbara Bickford*

The WMM Program updated its guidance titled, *Reducing or Terminating Monitoring at Landfills*, in 2020 (Pub-WA-1013-2019). More closed landfills in the state are reaching the end of their owner financial responsibility period. Groundwater monitoring data has been collected for decades at these sites and for those sites which the groundwater data show little to no impact to groundwater quality from the landfill, owners often express an interest in reducing or terminating monitoring to reduce costs. This guidance provides information to landfill owners and consultants on how to evaluate whether the monitoring data collected from their landfill and site-specific conditions support reducing or terminating monitoring, and it discusses whether additional data should be collected. The guidance provides a consistent and object process and set of criteria for evaluating whether reducing or terminating monitoring is warranted so that it can be done in a manner protective to the groundwater.

The WMM has been placing landfill locations on a GIS mapping program called the *WMM Sites Viewer*, which includes delineating waste boundaries and locating monitoring wells where known. This information is shared with the DG Program and licensed well drillers to aid well drillers in siting a water supply well. At this time, almost all of the known landfills have been placed on the GIS mapping program. This GIS program has been an important tool to increasing compliance with the 1,200 foot set-back requirement to a landfill and for the NR 812 well variance application requirement, if the set-back cannot be met.

WMM continues to be a participant in the Interagency Pharmaceutical Waste Working Group, with the DATCP and other partners. Keeping pharmaceuticals out of household and industrial waste streams is the main way to reduce the risk that the substances will reach groundwater through landspreading or septic systems.

Environmental Analysis and Sustainability Program

Monitoring Groundwater Quality Around Metallic Mines

The Environmental Analysis and Sustainability Program regulates metallic mining activity in the state. Issues related to groundwater quantity and groundwater quality are critical in determining whether a proposed mining project receives necessary approvals. State statutes have created separate approval processes for non-ferrous mining projects (Ch. 293, Wis. Stats.) and ferrous mining projects (Ch. 295, Wis. Stats.). The regulatory framework for ferrous mining projects includes provisions related to groundwater withdrawals, mining waste site design and operation and protection of groundwater quality. The law requires compliance with existing groundwater quality standards but establishes point of standards application and evaluation processes and criteria that are unique to ferrous mining projects.

Water Quality Program

The Bureau of Water Quality (WQ) is responsible for statewide implementation of DNR's groundwater standards primarily through the issuance of discharge permits to facilities, operations and activities that discharge treated wastewater and residuals to groundwater.

Wastewater Discharges

WQ issues Wisconsin Pollutant Discharge Elimination System (WPDES) permits to all communities, industrial facilities and large privately-owned wastewater systems which discharge treated domestic or industrial wastewater to groundwater through land treatment/disposal systems. These systems are primarily spray irrigation, seepage cell, subsurface absorption systems and ridge & furrow treatment systems regulated under ch. NR 206, Wis. Adm. Code (domestic wastewater) and ch. NR 214, Wis. Adm. Code (industrial wastewater). WPDES permits issued to these facilities contain groundwater monitoring and data submittal requirements that are used to evaluate facility compliance with ch. NR 140, Wis. Adm. Code (groundwater quality standards). Groundwater monitoring systems at existing facilities are evaluated and upgraded as necessary at permit re-issuance. In 2015, DNR issued 10 new permits for municipal and industrial facilities that discharge directly to land disposal (groundwater), bringing the total number of such permits to 214.

DNR also regulates the land application of organic industrial wastes, municipal biosolids and septage (chapters NR 214, 113, and 206) through approval of land spreading sites and requirements on locations, loading rates, nutrient levels and time of year. In recent years, as the quantities of these materials and agricultural manure have increased, competition for acceptable land spreading sites has increased, particularly in some areas of the state. Some instances of unacceptable impacts to groundwater have occurred associated with these activities. In addition, DNR has pushed land spreading entities to provide for more storage capacity to minimize winter and spring runoff to surface water. As a result, wastewater generators and haulers have sought to utilize existing tanks and lagoons, and in some cases, substandard earthen manure pits or substandard storage tanks. The industrial wastewater program has affirmed code requirements to ensure older structures meet the standards needed to assure storage is environmentally sound, protective of both groundwater and surface water.

WQ maintains a database, designated the System for Wastewater Applications, Monitoring, and Permits (SWAMP), for holders of specific WPDES and general permits. This database system stores facility-specific information such as; address, contacts, location, permit requirements, monitoring results and violations of permit requirements for private and municipal wastewater treatment facilities. The system contains current information on groundwater, wastewater and biosolids treatment and management. Historical sampling data from groundwater monitoring wells is available through the system and current sample results are added on a monthly basis. Sampling results and site loading information are also available for land application of municipal biosolids, septage and industrial sludge, by-product solids and wastewater.

WQ assists and participates in local planning efforts for existing developed areas (served by onsite wastewater treatment systems) that are investigating the possibility of providing a public sewerage system.

DNR continues to monitor the Nondomestic Wastewater to a Subsurface Soil Absorption System general permit it reissued in 2011; the general permit is in use at 25 sites. The

requirements for requesting a permit, and for renewing permit coverage, revisit the setback requirements for changes due to new water supply wells during the previous permit period. The general permit is renewed every five years. The renewal process identifies land use changes that may have occurred. This will serve as a check on groundwater and public health protection and could also identify future concerns and permit needs.

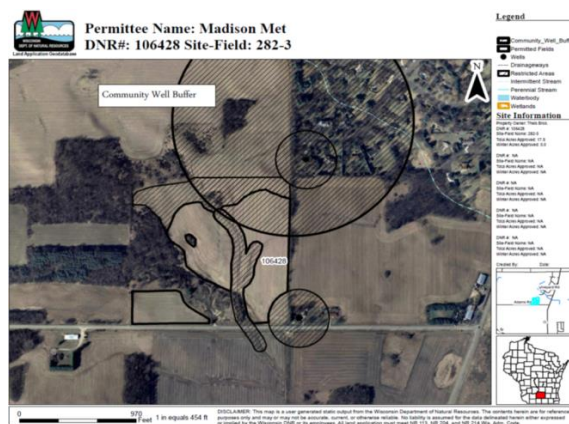
Septage and Sludge Management

WQ implements the regulations in chapters NR 113, NR 204, and NR 214, Wis. Adm. Code. Ch. NR 113 relates to septage management and ch. NR 204 governs the treatment quality, use and disposition of municipal wastewater treatment plant sludge. Ch. NR 113 and ch. NR 204 incorporate federal septage and sludge standards. WQ regulates the land application of industrial sludge, liquid wastes and by-product solids through ch. NR 214. Chapters NR 113, NR 204, and NR 214 contain treatment quality standards and land application site requirements and restrictions that are designed to prevent runoff to surface water or leaching of nutrients and pollutants to groundwater.

Results of federal and state septage audits identified the need for compliance training in the area of septage management. Cooperation with U.S. EPA led to the on-going creation of better training tools and implementation of numerous compliance classes. Recent septage operator certification code changes in ch. NR 114 now require minimum compliance training of all certified septage operators in their continuing education requirements cycles to ensure a compliance focus. New classes and training segments are currently offered through various associations, county updates and stand-alone classes.

Inter-division work with the Bureau of Law Enforcement will continue to be necessary and likely increase as the industry continues to explore more options for waste disposal and re-use during these difficult economic times and “green” transformation. Unfortunately, many of these options can cause significant harm to waters of the state. Continued enforcement efforts are necessary to deter further significant environmental harm. Increasing the number of audits is intended to preempt significant operations that create long-term harm of the environment. Also, efforts are underway to systemize audits to minimize the intrusion to the permitted community, but allow ample discussion to provide educational opportunities if needed.

Proposed efforts to modify the multiple land application codes (NR 113, NR 204, and NR 214) have been stalled for the time being to focus on streamlining issues. However, these code changes are only temporarily stalled as the following need to be addressed; creating consistency within these land application codes and between other related codes such as runoff management; providing a clearer



Clearer, more easily-produced maps in permits to land-apply wastes now help protect

understanding of code requirements; implementing best management practices consistent with total maximum daily loadings (TMDLs) of phosphorus; and modifying code language to be consistent with current practices employed by industry and contractors.

WQ continues to implement a statewide computer system that records and monitors treatment and disposal of municipal sludge, septage and industrial land-applied wastes. This system includes an inventory and a history of all sites used for land application. Wisconsin became the fourth state delegated authority by U.S. EPA to implement municipal sludge regulations, through its delegated NPDES (WPDES) permit program, in July of 2000.

Wisconsin Act 347 provides incentives for more wastewater treatment plants to accept and treat septage. This is accomplished through the offer of a zero percent Clean Water Fund loan for the planning and construction of receiving facilities and additional capacity provided for septage. Facilities which are upgrading capacity by more than 20% must evaluate septage generation and available disposal options in their planning area during facility planning. Although they are not mandated to provide such capacity, they are offered the zero percent loan if they do so. Structures are provided by which publicly owned treatment works establish costs for receipt of septage and a process is laid out for dispute resolution when such costs are questioned. Land application also remains a viable option when appropriate and Act 347 provides explicit pre-emptive authority to the state by disallowing restrictive local ordinances if they are not identical to state regulations.

Watershed Management Program

The Bureau of Watershed Management (WT) is responsible for statewide implementation of DNR's groundwater standards primarily through the issuance of discharge permits to concentrated animal feeding operations (CAFO) and dischargers of contaminated storm water. Field staff carry out compliance and enforcement activities using policies, codes, and guidelines intended to meet groundwater quality standards. Integrated basin planning, carried out in the field under guidelines developed by WT, assess and evaluate groundwater (as well as surface water) and provide general and specific recommendations for the protection and enhancement of the basin's groundwater.

Agricultural runoff and groundwater quality

Chapter NR 243 Wis. Adm. Code covers WPDES permit requirements for livestock operations and contains provisions to protect surface water, groundwater and wetlands in Wisconsin. Revisions made to ch. NR 243 have improved groundwater protection associated with CAFO land application practices by increasing setback requirements from community/non-community public wells and karst features and by further restricting winter applications of manure. Nutrient management plans submitted as part of the issuance of WPDES permits to CAFOs address how, when, where, and in what amounts CAFOs apply manure, process wastewater, and associated nutrients to cropped fields to protect surface waters and groundwater. Groundwater monitoring has been conducted voluntarily and as a requirement at selected sites. The DNR also promotes groundwater protection through the implementation of agricultural performance standards and prohibitions in ch. NR 151, Wis. Adm. Code, the issuance of Notices of Discharge under

ch. NR 243, and response to acute manure related groundwater impacts (e.g., well contaminations).

By the end of 2020, there were 318 permitted CAFOs – 307 large CAFOs, 9 medium CAFOs, and 2 proposed large CAFOs that have not been built. Over 90% of the permitted CAFOs are dairy operations. The trend of growing numbers of permit applications for larger-scale livestock operations is expected to continue.

Sections NR 151.07 and ATCP 50.04(3), Wis. Adm. Code, require all crop and livestock producers to develop and implement nutrient management plans. Technical Standard NRCS 590 contains planning and implementation requirements for all nutrient management plans. In 2015, DNR staff participated in a NRCS effort to update its technical standard for nutrient management plans to reflect new federal water quality protection criteria, including a nitrogen loss risk assessment.

Federal, state, and local agencies maintain technical resources and expertise to implement NRCS Standard 590, including development and dissemination of the field-based Soil Nutrient Application Program (snapplus.wisc.edu) in cooperation with the University of Wisconsin. Implementation of the Chapter NR 151 performance standard cannot be required without cost sharing in many situations. A multi-partner conservation consortium was effective in securing cost share resources from the Legislature to help farmers meet nutrient management plan requirements. DATCP administers these funds through its Soil and Water Resource Management Program. In addition, the NRCS provides cost sharing for development and implementation of comprehensive nutrient management plans, including 590 compliant planning and implementation. In other situations, cost sharing does not have to be provided to require compliance. This includes compliance for farms operating under a WPDES Animal Feeding Operation Permit, farms receiving state farmland preservation tax credits under the state's Farmland Preservation Program, livestock operations obtaining local permits under the state Livestock Siting Law, and livestock operations required by county regulation to develop and implement a nutrient management plan when voluntarily applying for a manure storage permit to cover new or altered manure storage facilities.

As part of the effort to protect drinking water and public health in areas of the state vulnerable to pathogen contamination of groundwater, the Department of Natural Resources worked with key public and agriculture industry stakeholders, state agencies, the State Legislature, the governor and the general public to update ch. NR 151, Wis. Adm. Code. The NR 151 rule modification developed targeted performance standards to address land spreading of manure on soils in sensitive areas of the state - i.e. where depth to bedrock is shallow and the bedrock is fractured (also described as karst topography).

Storm Water and groundwater quality

Storm water discharges are regulated as required under the federal Clean Water Act under ch. NR 216, Wis. Adm. Code. Chapter NR 216 requirements include: 1) permits for about 245 municipalities in Wisconsin to control polluted runoff that may enter their municipal separate storm sewer systems (MS4s); 2) permits for owners of construction

sites with one or more acre of land disturbance to control erosion during construction and to install practices to limit post-construction pollutant discharge after construction is completed; and 3) permits for certain industrial facilities to address potential contamination of storm water from outside activities and outdoor storage of materials.

In addition, under ch. NR 151, Wis. Adm. Code, the DNR has developed runoff performance standards for MS4s and construction sites that are implemented through the storm water permit program. Chapter NR 151 was updated and those changes became effective on January 1, 2011.

Provisions to implement Chapter NR 216 and the performance standards in Chapter NR 151 are included in several general permits. The MS4 general permit for municipal storm water discharges was first issued on in January 2006. The MS4 general permit was reissued in May 2014.

In 2020, six general storm water permits expired requiring revisions and reissuance. Five of the industrial general permits expire including the scrap metal and auto recycling permits at the end of March, the Tier 1 and Tier 2 industrial permits May 31, the non-metallic mining general permit August 31 and the construction site general permit August 31. The urban runoff team worked extensively with internal staff, external stakeholders and the US EPA to develop general permits that meet the standards of the Clean Water Act and Wisconsin Statutes in compliance with the department's delegated Wisconsin Pollutant Discharge Elimination System (WPDES) authority.

Chapter NR 216, Wis. Admin. Code establishes criteria defining those storm water discharges needing WPDES storm water permits, as required by s. 283.33, Stats., and to implement the appropriate performance standards of sub chapters. III and IV of ch. NR 151. Chapter NR 216 identifies which industrial facilities, construction sites and municipalities require WPDES storm water permits, application requirements, and storm water discharge permit criteria for each type of facility. In 2020, the department undertook an effort to re-write certain parts of NR 216. Specific efforts were made to finalize concerns raised by the US EPA in its 2011 75 issues letter related to legislative authority, to respond to the federal "remand rule" and proposes a realignment of the fee structure for construction site erosion control permits. The department is preparing the final rule package for review by the Natural Resources Board.

For more information

Visit the [DNR website](#)

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DEPARTMENT OF AGRICULTURE, TRADE AND CONSUMER PROTECTION

Protecting Wisconsin's groundwater is a priority for the Department of Agriculture, Trade and Consumer Protection (DATCP). DATCP's major activities in this area include management of pesticides and nutrients, research, and funding of local soil and water resource management projects.

In compliance with Chapter 160, Wisconsin Statutes, DATCP manages pesticides and pesticide practices to ensure that established groundwater standards for contaminants are not exceeded. This may include prohibition of certain activities, including pesticide use. DATCP regulates storage, handling, use, and disposal of pesticides, as well as the storage and handling of bulk quantities of fertilizer. DATCP has authority to develop a statewide nutrient management program through section 92.05 Wis. Stats. The program includes compliance, outreach and incentives.

Enforcement standards have been established in Wisconsin for many known and potential groundwater contaminants, including over 30 pesticides. DATCP helps landowners comply with these standards and the Groundwater Law.

FY 2021 Highlights

- Performed annual groundwater sampling of private wells in agricultural areas using a targeted sampling approach and annual sampling of field-edge monitoring wells located on or near agricultural fields.
- Analyzed about 209 groundwater and 69 surface water samples for more than 100 pesticide compounds plus nitrate.
- Provided cost-sharing for the installation and implementation of 1,064 conservation practices in 2020. These practices provided soil erosion control and helped manage manure and nutrients.
- Continued development and finalization of a technical standard for use in verifying and documenting land features, particularly the depth to bedrock of cropland, specifically for the purposes of applying manure as a crop nutrient to reduce the risk of pathogen contamination in areas with Silurian dolomite in eastern Wisconsin.
- Supported an airborne electromagnetic (AEM) survey of karst bedrock features to develop updated maps that identify the 5 foot and 20 foot depth to bedrock in the Silurian dolomite area of northeast Wisconsin.
- Awarded grants to 30 producer-led groups for FY 2021 funding, totaling \$750,000.
- Initiated a project to track estimated water quality outcomes and analyze benefits of conservation adoption in 13 of the 33 Producer-Led groups.
- Awarded \$350,117 in Nutrient Management Farmer Education grants in 2020. Twenty of these grants were Tier 1 awards to counties and technical colleges which provide nutrient management training to producers and plan writers for development of nutrient management plan in compliance with state standards. Four additional awards grants were awarded as Tier 2 awards to support nutrient management education.

Details of Ongoing Activities

Nonpoint Source Activities

Pesticides

DATCP's primary effort related to nonpoint contamination of groundwater from pesticides includes regular sampling of private wells and monitoring wells across the state for herbicides, insecticides and nitrate. The agency uses statistically random and targeted sampling designs to compare and contrast pesticide and nitrate occurrence in private wells statewide to that found in predominantly agricultural areas. DATCP shares sample data for pesticides with well owners, EPA, counties, DNR and others to improve knowledge and awareness of pesticide contaminants in drinking water, and uses the data to inform decisions involving new policy or regulations.

One example of how DATCP uses groundwater data to ensure compliance with Chapter 160, Wisconsin Statutes, involves the herbicide atrazine. Atrazine is a corn herbicide that has been found to cause nonpoint groundwater contamination. Several revisions to Ch. 30, Wisconsin Adm. Code have been made in response to detections of atrazine in groundwater, with the latest revision being put into effect in April 2011. Maps for 101 prohibition areas are available from the Agricultural Chemical Management Bureau covering about 1.2 million acres that have been incorporated into the rule. The maps were updated with new base mapping software in 2012 to 1) update roadway names and other manmade features that have changed over the years, and 2) provide a consistent look for maps that had been created using different map software since the early 1990s. Pesticide use surveys indicate that atrazine use has declined from peak levels in the late 1980's but remains one of the top corn herbicides used. Its decline in use may be in-part a result of the atrazine management rule and concerns about groundwater contamination. Prohibition areas total about 1.2 million acres, but DATCP estimates the actual area effected by use prohibitions is less than 300,000 acres per year when non-cropland (woodland, developed land, roads, water, etc.) and cropland not used for growing corn is removed from the 1.2 million-acre land total.

Nutrients

Through its Land and Water Resource Management program, DATCP assists in the protection of water resources through nutrient management and related conservation practice implementation. The DNR's NR 151 rule on runoff management establishes agricultural performance standards intended to protect both groundwater and surface water. DATCP identifies the practices and procedures to implement and enforce compliance with these standards, including nutrient management. The nutrient management rules apply to all Wisconsin farmers who engage in agriculture and mechanically apply N-P-K nutrients from manures or fertilizers to cropped fields or pastures. Under Wisconsin Statutes, cost-share funds must be made available to producers to compel compliance. However, as many as half of Wisconsin farms may be compelled to comply with nutrient management standards and other performance standards without cost-sharing because they fall into one of the following categories:

Concentrated Animal Feeding Operations (operations with 1,000 animal units or greater); Farms regulated by local manure storage or livestock siting ordinances; or Participants in Wisconsin’s Farmland Preservation Program.

A Wisconsin nutrient management (NM) plan is an annually updated record that follows NRCS’s 590 Nutrient Management Standard. A NM plan manages nutrient applications to ensure that crops receive the right amount of nutrients at the right time while minimizing degradation of both surface water and groundwater. A NM plan accounts for all nitrogen, phosphorus, or potassium (N-P-K) applied, and planned to be applied, to each field over the crop rotation, and identifies all crop management practices for each field.

The objective of the 590 NM Standard is to decrease the opportunity for nutrient losses to occur, decrease the total residual amount of nutrients in the soil and to keep those residual nutrients within the soil-crop system by limiting the processes (leaching, runoff, erosion and gaseous losses) that carry nutrients out of the system. The 590 NM Standard contains criteria for surface and groundwater protection that manages the amount and timing of all nutrient sources.

To learn more about DATCP’s nutrient management program, visit: https://datcp.wi.gov/Pages/Programs_Services/NutrientManagement.aspx. For a summary of the water quality protection features of the 590 standard, visit: <https://datcp.wi.gov/Documents/NM590Standard2015.pdf>.

2020 NMP Numbers	
NM Plans Reported	7,865
NM Acres Reported	3.3 million
Percent of WI Cropland Covered by NMP	36.3%
Farmer-Written Plans	1,843
Agronomist-Written Plans	6,022

The DATCP allocated its annual appropriation of funds to counties through its annual allocation process. This process provides “for cost-sharing grants and contracts under the soil and water resource management program under s 92.14.” In 2020, the allocation provided nearly \$6 million to counties for landowner cost-sharing. This cost-sharing includes bond funds and SEG funds and supports the implementation of diverse conservation practices from manure management systems, to erosion control and nutrient management planning. The allocation also provided \$350,000 in grants for farmer training (Nutrient Management Farmer Education grant program), and nearly \$900,000 to support partners, including UWEX/CALS, to enhance the statewide infrastructure fundamental to implementing state conservation activities, with an emphasis on development of the SnapPlus nutrient management planning software.

The DATCP also provided an annual appropriation of \$3,027,200 in GPR funds and \$6,400,000 in SEG funds “for support of local land conservation personnel under the soil and water resource management program.” DATCP would need an increase of over \$3 million in its annual appropriations to reach the statutory goal of funding 3 positions at 100, 70 and 50 percent, respectively. DATCP’s 2020 final allocation plan under the Soil

and Water Resource Management Grant Program is summarized in Table 1 below. In most cases, the available appropriations are not able to meet the total requests of the counties for cost-sharing and staffing support.

Table 1. Summary of Requests and Allocations for Grant Year 2020.

Funding Category	Total Requests	Unmet Requests	Final Allocations
County Staff/Support	\$17,626,768	\$8,187,668	\$9,439,100
County LWRM Cost-Share (Bond)	\$7,975,750	\$4,585,750	\$3,390,000
Bond Cost-Share Reserve (Bond)	\$300,000	\$0	\$300,000
LWRM Cost-Share (SEG)	\$3,081,616	\$994,884	\$2,086,732
Project Contracts (SEG)	\$1,046,250	\$158,099	\$888,151
NMFE Training Grants (SEG)	\$350,117	\$0	\$350,117
Total	\$30,380,501	\$13,926,401	\$16,454,100

DATCP nutrient management program staff train farmers, consultants and local agencies on the principles of sound nutrient management, how to comply with performance standards and how to use available tools to create and evaluate an ATCP 50-compliant nutrient management plan. DATCP also maintains a Manure Management Advisory System (MMAS), which helps farmers develop a clear understanding of field-specific soils and their ability to accept nutrients and manure for optimal crop production while protecting water quality. The system includes web-accessible tools, including: WI "590" Nutrient and Manure Application Restriction Maps, a map service for geographic information system (GIS) users, and the Runoff Risk Advisory Forecast (RRAF) model.

The RRAF provides Wisconsin's farmers with an innovative decision support tool which communicates the threat of undesirable conditions for manure and nutrient spreading for up to 10 days in advance. The system uses data outputs from the National Weather Service including snow accumulation and melt, soil moisture content and temperature and forecast precipitation to create and display maps that provide the runoff risk for a 72-hour period. The 590 Restriction maps are available statewide to assist farmers in making sound decisions about how and where to apply nutrients on their cropland. The mapped data used to create the restriction maps are also available for GIS-users to download into their own mapping applications. All of these tools can be accessed at <http://www.manureadvisorysystem.wi.gov>.

In 2017, DNR adopted a new targeted performance standard to reduce the risk of pathogen contamination to groundwater (NR 151.075). This new standard restricts manure application in designated areas where the bedrock consists of Silurian dolomite with a depth to bedrock of 20 feet or less. DATCP is responsible for the implementation of performance standards in NR 151 and assembled a team to develop a technical standard to support the implementation of the performance standard. The team met from February

2019 through August 2020 and drafted the Wisconsin DATCP Technical Standard 01 Verification of Depth to Bedrock. This standard is a new standard to define the criteria and procedures to verify and document the depth to bedrock when a landowner wishes to contest the current categorization of cropland specifically for the purposes of applying manure as a crop nutrient. The purpose of this standard is to provide appropriate methods for verification of depth to bedrock to support implementation of s. NR 151.075 in areas where the bedrock consists of Silurian dolomite with a depth to bedrock of 20 feet or less. A final version of the technical standard and associated guidance will be made available on the DATCP website and eventually incorporated into administrative code.

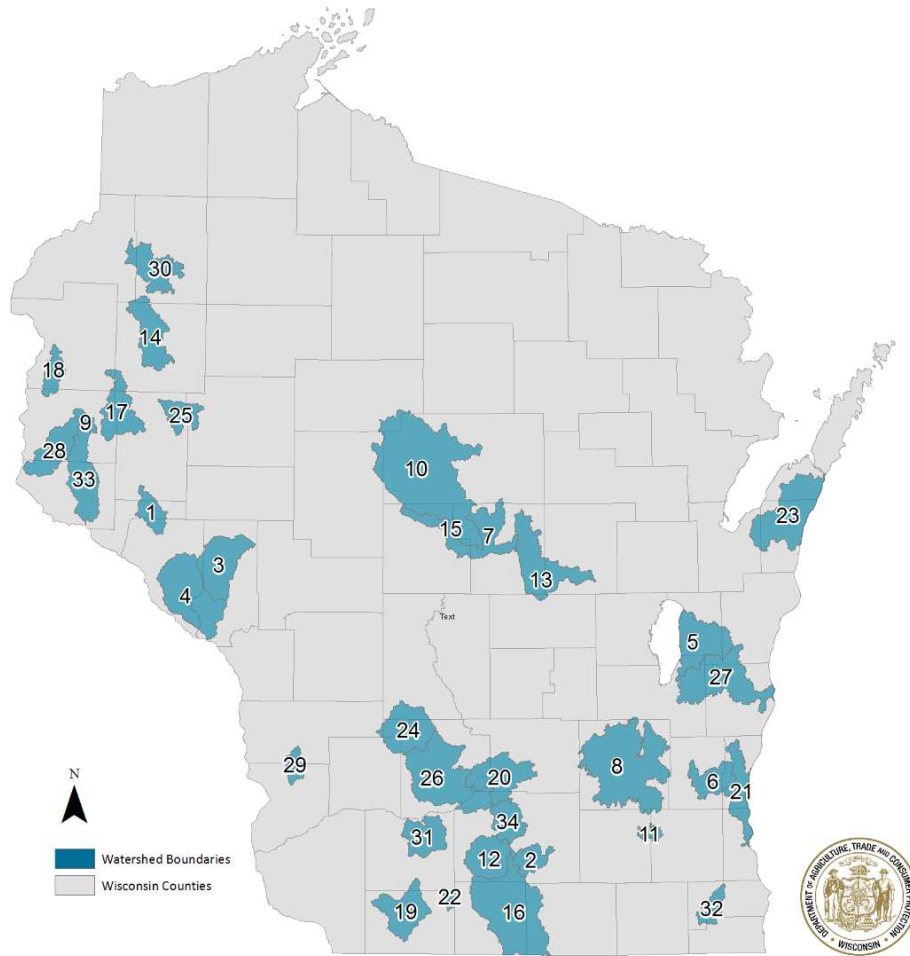
In 2020, DATCP contracted with the U.S. Geological Survey (USGS) to updated depth to bedrock maps of the Silurian/Karst bedrock region of northeastern Wisconsin. Current depth to bedrock maps are based on limited data and professional judgement, often from over 40 years ago. This project will collect airborne geophysical data that encompasses selected areas of interest in Northeastern Wisconsin and focuses on the 5 and 20ft depths identified in the targeted Silurian bedrock performance standard. The data will be collected using airborne electromagnetics, or AEM which is a geophysical technology originally developed for use in the mining industry to locate and map ore bodies but more recently used to map groundwater resources. This work will provide accurate, belowground properties that are otherwise difficult to assess and will make public vital information for local water users and managers, farmers, conservation staff and agronomic professionals to better understand their groundwater resources and aquifer systems.

Program to Address Agricultural Nonpoint Contributions (ATCP 52)

Producer-Led Watershed Protection Grants are awarded by the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) to help farmers address the unique soil and water quality challenges of their local landscapes with innovative and collaborative approaches.

Producer-Led groups focus on nonpoint source abatement activities which benefit both surface and groundwater quality. The program-wide 2020 Cover Crop and No-Till Analysis shows that 211 farmers in the program planted 62,587 acres using no-till technology — a 19% increase from 2019. This resulted in an estimated reduction of 84,860 tons of soil erosion and prevented 54,072 pounds of phosphorus loss. Cover crop implementation followed a similar trend, with 83,843 acres planted across 423 farms (a 19% increase from 2019). The estimated outcomes of these improvements are a reduction of 75,364 tons of erosion and 41,492 pounds of phosphorus from leaving farm fields. More information about this project can be viewed at our website: [DATCP Home Producer-Led Tracking Project \(wi.gov\)](https://www.datcp.wisconsin.gov/producer-led-tracking-project).

Producer-Led Groups 2021



ID	Group Name	ID	Group Name	ID	Group Name
1	Bear Creek/ Chippewa Farmer Groundwater Group	13	Farmers for Tomorrow	25	Red Cedar Conservation Farmers
2	Biological Farming Friends	14	Farmers of Barron County	26	Sauk Soil and Water Improvement Group (SSWIG)
3	Buffalo County Conservation Farmers (BCCF)	15	Farmers of Mill Creek	27	Sheboygan River Progressive Farmers
4	Buffalo-Trempealeau Farmer Network (BTFN)	16	Farmers of the Upper Sugar River	28	South Kinni Farmer-Led Watershed Council
5	Calumet County Agricultural Stewardship Alliance	17	Hay River Farmer-Led Watershed Council	29	Tainter Creek Farmer-Led Watershed Council
6	Cedar Creek Farmers - Improving Land for Cleaner Waters	18	Horse Creek Farmer-Led Watershed Council	30	The Shell Lake - Yellow River Farmer-Led Watershed Council
7	Central Wisconsin Farmers' Collaborative (CWFC)	19	Lafayette Ag Stewardship Alliance (LASA)	31	Upland Watershed Group
8	Dodge County Farmers for Healthy Soil & Healthy Water	20	Lake Wisconsin Farmer Watershed Council	32	Watershed Protection Committee of Racine County
9	Dry Run Creek Farmer-Led Council	21	Ozaukee County Clean Farm Families (CFF)	33	Western Wisconsin Conservation Council
10	Eau Pleine Partnership for Integrated Conservation (EPPIC)	22	Pecatonica Pride	34	Yahara Pride Farms
11	Farmers for Lake Country	23	Peninsula Pride Farms (PPF)		
12	Farmers for the Sugar River	24	Producers of Lake Redstone		

Point Source Activities

Previous work by DATCP identified pesticide and fertilizer operations as possible point sources of groundwater contamination. Past problems included improper disposal of unwanted agricultural chemicals, lack of containment for spills, outdated product handling methods, and poor understanding by workers in the industry of how small actions, when continued over time, lead to large problems. DATCP has worked to address these problems through point source prevention. In cases where environmental degradation

has already occurred, DATCP oversees environmental cleanup of contaminated soil and groundwater.

Beginning in 1990, the Agricultural Clean Sweep grant program helped farmers dispose of unwanted pesticides, farm chemicals and empty pesticide containers. In 2003, DATCP also began operating and managing the state's household hazardous waste grant program and Agricultural Clean Sweep became Wisconsin Clean Sweep. In fall 2007, prescription drug collection was added to the grant and the annual program budget expanded to \$1 million. In 2009 the program budget was reduced to \$750,000 annually and program management reduced to 75 percent FTE.

In 2020, 92 grants were issued: 28 for agricultural waste, 38 for household hazardous waste and 26 for the collection of unwanted prescription drugs. Farmer and agricultural participation in collection events brought in slightly more than 82,000 pounds of agricultural waste in total, an over 30 percent decline from the agricultural waste collected in 2019. Farm participation can vary greatly depending on the weather or the frequency of collections within a county. Some counties hold a farm collection every other year or every few years. Farm participation for 2020 appears to be lower than the long-term average agricultural waste collected, which has historically ranged between 100,000 and 150,000 pounds collected annually. Many counties report declining collections as more farmers are using custom application and pesticides are becoming more concentrated. Much of the old stockpiled pesticides were collected during the early years of the program. However, Clean Sweeps still see old, banned or cancelled pesticides like DDT and chlordane. The added difficulties of health and safety concerns due to COVID-19 during 2020 contributed further to the decrease in collected waste as some counties made decisions to cancel collection events scheduled for the early portions of the year, or entirely.

The amount of household hazardous waste collected in 2020 increased significantly over the total amount collected in 2019. About 3.2 million pounds were collected in 2020 compared to 2.1 million pounds collected in 2019, an over 50 percent increase. This large increase in amount of household hazardous waste collected may be attributed to a large proportion of the state's population participating in the "Safer From Home" initiative implemented due to COVID-19 in 2020, with residents taking the opportunity to remove hazardous waste from their homes and bringing it to Clean Sweep collections. Lead and oil-based paints remain the most common waste collected from households, followed by solvents and thinners and pesticides as the second- and third-most collected waste brought in for disposal. Wisconsin residents also turned over unwanted prescription drugs at various collection events or through permanent drug drop boxes located in law enforcement offices throughout the state. Drug collections netted just over 27,000 pounds of unwanted pharmaceuticals, a decrease of about 14,000 pounds from the previous year. Again, the decrease may be due to cancelled collection events or limited disposal opportunities as a result of health and safety concerns with COVID-19. Drug collections supported by clean sweep grants are only a portion of the drug drop boxes and take back events in the state. The Wisconsin Department of Justice also coordinates and pays for

the collection and disposal of unwanted drugs. The pharmaceuticals collected through Clean Sweep projects are included in this program.

Fourteen local DATCP specialists perform compliance inspections and work with facilities across the state to help keep them in compliance with the ATCP rules designed to protect the environment. Agency staff also educates facility managers and employees about how routine practices may affect the environment.

Since 1993, the Agricultural Chemical Cleanup Program (ACCP) addresses point sources of contamination and reimburses responsible parties for a portion of cleanup costs related to pesticide and fertilizer contamination. To date, nearly 750 cases involving soil and/or groundwater remediation related to improper storage and handling of pesticides and fertilizers have been initiated at storage facilities. Over this same time period DATCP assisted cleanups at more than 1,300 acute agrichemical spill locations. The ACCP has received nearly 1,600 reimbursement applications totaling about \$48 million in reimbursement payments.

Groundwater Sampling Surveys

DATCP manages a number of sampling programs to investigate the occurrence of pesticides in groundwater resulting from nonpoint sources. Three programs commonly used to assess drinking water quality are the annual targeted and exceedance sampling programs, and the less frequent statewide random sampling survey. DATCP also works with growers to assess water quality beneath agricultural fields by testing a network of field-edge monitoring wells at several locations across the state.

The most recent statistically random sampling survey of private wells statewide occurred in 2016. The results of the survey were published in early 2017, providing a comparison of pesticide and nitrate results to an earlier statewide random survey, published in 2008.

Publications of DATCP surveys are available on the web at:

https://datcp.wi.gov/Pages/Programs_Services/GroundwaterReports.aspx.

Research Funding

DATCP currently funds groundwater research at about \$150,000 and fertilizer research at approximately \$200,000 per year, respectively. The UW coordinates groundwater research project funding through the [Wisconsin Groundwater Research and Monitoring Program](#). Reports for past DATCP-funded research projects can be found in the [WGRMP Repository](#).

Recent titles include:

[Assessment of Pesticide Contamination in Suburban Drinking Water Wells in Southeastern Wisconsin](#)
[Aerial Thermal Imaging Applied to Wisconsin's Groundwater, Springs, Thin Soils, and Slopes](#)

Titles of ongoing projects funded by DATCP include:

- **Neonicotinoid Insecticides in Baseflow-Dominated Streams on the Central Sand Plain.** Report anticipated September 2021.
- **Sublethal Effects of Chronic Exposure to Neonicotinoid Pesticides on Aquatic Organisms.** Report anticipated December 2021.

- **Neonicotinoid Contaminants in WI Groundwater: Relationships to Landscape Cropping Systems.** Report anticipated September 2022.
- **Geophysics-informed Transport & Shallow Bedrock Topography in Northeast and Southcentral WI Counties.** Report anticipated September 2022.

In June 2021, DATCP will begin funding two new projects. One will conduct a literature review of prior research work performed in the Central Sands Region of the state to help identify knowledge gaps and management strategies for nitrate and neonicotinoid insecticides. A second project will conduct research on a Pepin County farm to evaluate nitrogen leaching using equilibrium tension lysimeters installed under fields where conventional agricultural cropping scenarios are employed versus where alternative nutrient application and tillage practices are employed. Both projects hope to identify practical management tools growers can use to reduce the potential for groundwater contamination resulting from fertilizer and pesticide applications.

Groundwater Data Management

DATCP maintains its groundwater data in a database that is linked to a geographic information system (GIS) web-mapping application. The system allows the user to search the database and plot maps that show data within a user-defined geographic area. The database was placed on-line in 2012. It contains contact and location information, well characteristics, and pesticide and nitrate sample results for private and public drinking water wells and combines that data with monitoring well data collected from hundreds of agricultural chemical cleanup cases. The database includes samples analyzed by DATCP, Wisconsin State Lab of Hygiene (WSLH), as well as other public and private laboratories. DATCP's groundwater database currently contains information for over 62,000 wells and nearly 800,000 pesticide and nitrate-N sample analytical results.

DATCP uses GIS tools to analyze groundwater data and prepare maps for public hearings, DATCP board meetings, presentations and other uses. DATCP prepares and maintains data in GIS of well locations, atrazine concentrations, atrazine prohibition areas and other pesticide and nitrate-N data. This database information is used to generate maps of statewide pesticide and nitrate-N detections in wells, as well as maps for chapter ATCP 30, Wis. Adm. Code (Pesticide Product Restrictions). Other GIS analyses involve identifying groundwater wells that may be impacted by point sources of pesticide and nitrate-N contamination by allowing comparisons of groundwater results with other features in GIS, such as locations of agrichemical dealership sites and spill sites that may affect groundwater quality.

For further information:

Visit <https://datcp.wi.gov>

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DEPARTMENT OF HEALTH SERVICES (DHS)

FY 2021 Highlights

- In November 2020, DHS provided DNR recommendations for 22 substances in the 11th cycle of groundwater standards. DHS also continued to support DNR's rulemaking efforts for the 10th cycle of groundwater standards.
- Multiple DHS programs, including the Groundwater Program and the Site Evaluation Program, provided technical assistance and health education related to several groundwater contamination sites in Wisconsin. In FY2021, these programs addressed PFAS contaminants at several locations within the state (e.g., Peshtigo, French Island, Madison, Rhinelander).
- Due to the COVID-19 response, Wisconsin Tracking did not issue mini-grants in FY2021. Instead, the program worked with FY2020 mini-grantees to finish their previously funded projects. Wisconsin Tracking will be releasing a new RFA to fund five projects for FY2022. In addition to providing funding, Wisconsin Tracking staff connect mini-grantees with subject matter experts and provide technical assistance related to epidemiology, communications, and evaluation as requested.
- The Climate and Health Program (CHP) and Wisconsin Sea Grant adapted a process to pilot the Flood Resilience Scorecard (FRS) during the pandemic in summer 2020 to evaluate the City of Washburn's flood vulnerabilities. FRS uses a whole-community approach to flood assessment based on environmental, institutional, and social criteria. They will continue to evaluate flood vulnerability using FRS in an estimated 30–40 communities in 2021 to improve local flood resilience and health equity in Wisconsin communities. CHP also continued to promote its Risk Assessment Flood Tool (RAFT), an interactive flood planning and response map, to local and tribal health departments (LTHDs) and flood and emergency management professionals. DHS flood planning and response tools can help identify flood-prone areas of the state and help focus on the populations who are most at risk to drinking water contamination resulting from flooded wells. In 2020, CHP participated in the Healthy Communities and Strong Economy work group of the Governor's Task Force on Climate Change.

Overview

DHS serves as a primary resource for information about the health risks posed by drinking water contaminants and is charged with investigating suspected cases of waterborne illness. Toxicologists, public health educators, epidemiologists, and environmental health specialists employed in the DHS Division of Public Health work together to:

- Develop recommendations for groundwater standards for the protection of public health upon request by the DNR.
- Present water quality information and human health implications of groundwater and drinking water issues to the public through town meetings and conferences, as well as a wide variety of informational materials.

- Provide direct assistance to families via home visits, letters to well owners, and telephone consultations.
- Educate residents with contaminated water supplies on the health effects of specific contaminants, and recommend strategies for reducing exposure until a safe water supply can be established.
- Provide advice and assistance in cases of vapor intrusion when shallow groundwater is contaminated with volatile organic chemicals, such as benzene and vinyl chloride, which are released as vapors from groundwater directly into buildings through foundations.
- Improve understanding of current and potential groundwater and drinking water issues related to human health in Wisconsin through exposure biomonitoring, disease surveillance, health assessment, and capacity and vulnerability assessment. Information from these activities assists project development, focuses area prioritization, and supports academic research. This information also aids local and state agency work on groundwater-related public health issues.

Detail

Reviewing Scientific Information to Develop Public Health Recommendations for Groundwater Contaminants

Wisconsin Stat. ch. 160 directs DHS to recommend health-based standards for substances found in groundwater and specifies the protocol for developing these recommendations. Recommended standards are sent to the DNR and are submitted through the rulemaking process as amendments to Wis. Admin. Code ch. NR 140.

In FY2021, DHS provided DNR with recommended groundwater standards for 22 substances—16 PFAS and 6 agricultural chemicals (see the table below for a summary of these recommendations). DHS was unable to recommend standards for 18 PFAS because of limited health information.¹ To learn more about these recommendations, please visit DHS' [Cycle 11 website](#).

Substance	Recommended Enforcement Standard(i)	Recommended Preventive Action Limit(i)
Metalaxyl	800 µg/L	160 µg/L
Chlorantraniliprole	16 mg/L	3.2 mg/L
Flumetsulam	10 mg/L	2 mg/L
Fomesafen	25 µg/L	5 µg/L
Hexazinone	400 µg/L	40 µg/L
Saflufenacil	460 µg/L	46 µg/L
Perfluorotetradecanoic acid (PFTeA)	10 µg/L	2 µg/L

¹This includes 9-chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9Cl-PF3ONS; also known as F-53B Major); 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS; also known as F-53B Minor); 4:2 Fluorotelomer sulfonic acid (4:2 FTSA); 6:2 fluorotelomer sulfonic acid (6:2 FTSA); 8:2 fluorotelomer sulfonic acid (8:2 FTSA); 10:2 Fluorotelomer sulfonic acid (10:2 FTSA); N-methyl perfluorooctane sulfonamide (NMeFOSA); N-methyl perfluorooctane sulfonamidoacetic acid (NMeFOSAA); N-methyl perfluorooctane sulfonamidoethanol (NMeFOSE); perfluorodecane sulfonic acid (PFDS); perfluoroheptanoic acid (PFHpA); perfluoropentanoic acid (PFPeA); perfluorotridecanoic acid (PFTriA); perfluoroheptanesulfonic acid (PFHpS); perfluoropentanesulfonic acid (PFPeS); perfluorododecanesulfonic acid (PFDoS); perfluorohexadecanoic acid (PFHxDA); and perfluorononane sulfonic acid (PFNS).

Perfluorobutanoic acid (PFBA)	10 µg/L	2 µg/L
Perfluorohexanoic acid (PFHxA)	150 µg/L	30 µg/L
Perfluorononanoic acid (PFNA)	30 ng/L	3 ng/L
Perfluorodecanoic acid (PFDA)	300 ng/L	60 ng/L
Perfluoroundecanoic acid (PFUnA)	3 µg/L	0.6 µg/L
Perfluorobutanesulfonic acid (PFBS)	450 µg/L	90 µg/L
Perfluorohexanesulfonic acid (PFHxS)	40 ng/L	4 ng/L
Perfluorooctane sulfonamide (FOSA)	20 ng/L*	2 ng/L*
N-Ethyl Perfluorooctane sulfonamide (NEtFOSA)		
N-Ethyl perfluorooctane sulfonamidoacetic acid (NEtFOSAA)		
N-Ethyl perfluorooctane sulfonamidoethanol (NEtFOSE)		
Perfluorododecanoic acid (PFDoA)	500 ng/L	100 ng/L
Hexafluoropropylene oxide dimer acid (HFPO-DA; GenX)(iv)	300 ng/L	30 ng/L
Perfluorooctadecanoic acid (PFODA)	400 µg/L	80 µg/L
4,8-Dioxa-3H-perfluorononanoic acid (DONA)	3 µg/L	0.6 µg/L

In FY2021, DHS continued to support DNR’s rulemaking efforts for Cycle 10 groundwater standards by presenting at several public meetings and providing technical support to stakeholder inquiries. To learn more about these recommendations, please visit DHS’ [Cycle 10 website](#).

Working with Partners to Address Drinking Water Concerns

The DHS Groundwater Program works with other DHS programs (e.g., On-Call Chemical and Natural Disasters Emergency Response Team; Site Evaluation Program) to support citizens, LTHDs, and other partners responding to a broad range of groundwater contamination issues (e.g., manure spills, nitrate, PFAS).

We work directly with members of the public to address issues affecting their drinking water. In FY2021, the Groundwater Program provided advisory letters to residents with concerns about their water quality. We also work closely with partners to respond to issues that affect groundwater and drinking water. This often involves facilitating communication between LTHDs and state partners (for example, DNR and DATCP).

The DHS Groundwater Program consistently works to increase public awareness of groundwater and drinking water health issues. In FY2021, DHS created infographics describing steps that homeowners should take if their [private well](#) or [public water](#) has high levels of manganese, and developed a protocol for homeowners to follow if they suspect their private well is contaminated with [manure](#). Additionally, we updated several websites related to drinking water to improve content clarity and access to resources.

DHS continues to build relationships with state, local, and community partners. In FY2021, DHS assisted DNR in outreach related to manganese in drinking water. DHS worked with DNR’s public water use program to develop public notice language for public water systems with high levels of manganese and served as a liaison between DNR and

LTHDs on these sites. DHS also worked with DNR's private water program to address concerns related to potentially high manganese levels in Jim Falls, Wisconsin. By connecting with county staff, we were able to gain valuable information about manganese levels in nearby private wells and the effectiveness of treatment in these homes.

Environmental Cleanups

Multiple DHS programs including the Groundwater Program and the Site Evaluation Program provided technical assistance and health education related to several groundwater contamination sites in Wisconsin.

In FY2021, these programs addressed PFAS contaminants at several locations within the state, including Peshtigo, French Island, Madison, and Rhinelander. For these sites, DHS toxicologists and health educators assessed the human health risk of PFAS exposure through multiple exposure pathways including groundwater, surface water, and biota such as fish consumption. The team has provided technical assistance by reviewing private well water testing results using a hazard index approach and recommending proper actions to reduce or halt exposure to PFAS. The hazard index approach is a way to assess the risk of exposure to compounds with similar health effects.

Taking Action with Data: Use of the Environmental Public Health Data to Improve Environmental Health in a Community

DHS continually seeks to provide data and resources to LTHDs to assist them in making positive public health improvements in their communities. Due to the COVID-19 pandemic, Wisconsin Tracking placed the mini-grant program on hold for a year to allow LTHDs to address competing priorities of the pandemic. In FY2022, Wisconsin Tracking will be releasing a request for applications (RFA) for LTHDs for the sixth round of funding with the intent of funding up to five projects. Funds are used by grantees to explore data from the Tracking data portal and the County Environmental Health Profiles to identify an environmental health concern in their jurisdiction. LTHDs will develop and implement environmental health initiatives within their communities based on these data. LTHDs frequently address private well water quality, as this is a significant concern in Wisconsin. In the previous round of funding (2019–2020, which led into 2021), three of seven LTHDs addressed private well water quality. To learn more visit the [DHS Environmental Public Health Tracking](#) webpage.

Wisconsin Tracking and other DHS staff provide ongoing support, technical assistance, and guidance to LTHDs on epidemiology, communications, and evaluation throughout the project period. LTHDs are empowered to carry out their projects with support and assistance from the Tracking Program as needed. Some examples of technical assistance the Tracking Program provided LTHDs include sharing examples of work completed by grantees working on water topics during past grant years; reviewing and providing feedback on surveys and data visualization; and assisting in writing up success stories.

Climate and Extreme Weather Vulnerability Assessment

The DHS Climate and Health Program (CHP), funded by the Centers for Disease Control and Prevention, works to enhance statewide capacity to prepare for and respond to the

public health impacts of climate change, including impacts to private wells from heavy rainfall and flooding events.

Gaps identified previously by the Wisconsin Climate and Health Profile Report have led to the development of several flood-related resources and tools, with the goal of enhancing understanding of flood risks in specific watersheds and populations vulnerable to flooding events. Flooding events can have negative effects on groundwater quality and public health, such as well contamination and impacts to aquifers from chemical releases and flood runoff that contains nutrients and other chemical pollutants from both urban and agricultural sources. These projects involve partnerships within DHS and with the University of Wisconsin Center for Climatic Research, Wisconsin Sea Grant, the Association of State Flood Plain Managers, Wisconsin Emergency Management (WEM), and a number of LTHDs. The findings from these flood-related projects have helped inform LTHDs and local emergency management planning processes.

CHP is currently working on two flood-related tools to help LTHDs, local emergency management, tribal emergency management, and municipal government officials and planners better understand flood vulnerability in Wisconsin:

- A [Flood Resilience Scorecard](#) is in the final stages of development and field testing before dissemination later this year. The tool has been created to aid communities in flood vulnerability assessment. The scorecard identifies institutional, social, environmental, and infrastructure vulnerabilities that could hinder a municipality's ability to prepare for and respond to flood events. The scorecard will provide recommendations for improvements that will reduce the negative health impacts from flooding events.
- The [Wisconsin Flood Toolkit](#) is currently being revised to include specific considerations for priority populations, those who are particularly susceptible or vulnerable to flooding events. This update will help municipalities better tailor their response and messaging to those most in need during a flooding event. This tool will eventually be translated into Spanish.
- A third flood-related tool was launched in March 2019 and is undergoing continuous updates. The [Risk Assessment Flood Tool \(RAFT\)](#) provides an online customizable graphic interface for assessing a community's risk and vulnerability during a flood event in real time. This tool helps local emergency management, local emergency preparedness, tribal health centers, and LPHAs plan and prepare for flooding events. It will also inform future outreach efforts targeted at private well owners in vulnerable areas.

Environmental Radiation Monitoring

Wisconsin Stat. ch. 254 directs the DHS Environmental Monitoring (EM) Program to collect various types of samples for environmental radiation monitoring, including surface and well water from selected locations at planned sampling intervals near nuclear power plants. The EM Program provides an ongoing baseline of radioactivity measurements to assess any Wisconsin health concerns from the operation of nuclear power generating

facilities in or near Wisconsin, or other radiological incidents that may occur within Wisconsin or worldwide. These monitoring programs show the following:

- Environmental radioactivity levels have been trending downward in the time period since the 1950s–1960s’ atmospheric nuclear testing and such radiological incidents as the Chernobyl nuclear reactor incident of 1986.
- Starting in mid to late FY2022, Kewaunee Power Station will start active decommissioning (demolition). As a result of the active decommissioning, the environmental monitoring program will collect a variety of samples including groundwater to ensure the health and safety of the Wisconsin’s residents and natural resources.
- DHS’s ongoing EM Program will provide assurances to the citizens of Wisconsin that the environment surrounding nuclear power facilities and other monitoring areas will continue to be evaluated.

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Bureau of Environmental and Occupational Health

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WISCONSIN GEOLOGICAL & NATURAL HISTORY SURVEY

The Wisconsin Geological & Natural History Survey (WGNHS), part of the University of Wisconsin-Madison’s Division of Extension, performs basic and applied groundwater research and provides technical assistance, maps, and other information and education to aid in the management of Wisconsin’s groundwater resources. The WGNHS groundwater program is complemented by the Survey’s geology programs, which provide maps and research-based information essential to the understanding of groundwater recharge, occurrence, quality, movement and protection. The Survey distributes maps, reports and data related to Wisconsin’s geology and groundwater. The Director of the WGNHS is a permanent member of the Wisconsin Groundwater Coordinating Council (GCC) and several WGNHS staff members serve on GCC subcommittees.



Installing a monitoring well in Bayfield County. *Photo: Pete Chase*

FY 2021 Highlights

- (See [the WGNHS 2020 Year In Review](#); also see this [story map](#) describing the projects in more detail.)
- Investigating groundwater quality in southwestern Wisconsin
- Building background hydrogeology for the [Central Sands Lakes Study](#)
- Investigating groundwater and water-level fluctuations in the Bayfield Peninsula
- Using drones to locate shallow bedrock, seepage faces, and underwater springs
- Investigating Neonicotinoids in stream water in Central Wisconsin
- Understanding relationships between bedrock structure and folding and arsenic and other contaminants in groundwater
- Conducting new bedrock geologic mapping in Dodge, Jefferson, and Grant Counties
- Conducting new Quaternary geologic mapping in Wisconsin's Driftless Area and in Jefferson and Bayfield Counties
- Conducting hydrogeologic research in southwest Wisconsin
- Investigating groundwater-surface water relationships in Wisconsin streams, lakes, and wetlands
- Upgrading Wisconsin's statewide groundwater monitoring network
- Upgrading and enhancing geoscience information delivery

Details of Ongoing Activities

Groundwater-Level Monitoring Network

The WGNHS continues to cooperate with the Department of Natural Resources and U.S. Geological Survey in the operation and maintenance of Wisconsin's statewide groundwater-level monitoring network. The WGNHS supports evaluation and maintenance of the monitoring network, aids in data collection, interpretation, and provides information to public and private clients. Recent grants from the U.S. Geological Survey's National Groundwater Monitoring Network program have injected over \$550,000 in new funding to repair and evaluate old wells, replace failing wells, and drill new wells in areas of the state lacking monitoring coverage. By 2022, these investments will have resulted in repairs or evaluations to 38 monitoring wells and the drilling of 17 new wells across 30 of Wisconsin's 72 counties. Of the roughly 100 wells in the long-term network, nearly half will have been evaluated, improved, or added thanks to this funding source, representing a generational upgrade to the monitoring network. The WGNHS' webpage dedicated to the monitoring network has also recently been updated and a new video documents the current activities and value of the network. Visit: <http://wgnhs.wisc.edu/water-environment/groundwater-monitoring-network>.

County and Local Groundwater Studies

Geologic and groundwater studies at county and local scales continue to be an important part of WGNHS programs. With funding from the federal STATEMAP program or local sources, WGNHS scientists initiated or carried out county or locally focused geologic and/or groundwater studies during 2020 in ten Wisconsin counties. New geologic mapping

is the fundamental starting point for understanding groundwater resources in Wisconsin. Many of these studies will generate or have generated water-table maps or depth-to-bedrock maps. (Maps: <https://wgnhs.wisc.edu/maps-data/maps/>)

Southwest Wisconsin groundwater and geology (SWIGG) project. The purpose of this project is to improve our understanding of groundwater quality in southwest Wisconsin (Iowa, Lafayette, and Grant Counties) and how groundwater quality is related to local hydrogeologic properties and well construction characteristics. Southwest Wisconsin is an area of shallow carbonate bedrock beneath generally thin soils. Due to the shallow fractured bedrock and the presence of minor karst features this area is considered very vulnerable to groundwater contamination, but prior to this study regional groundwater sampling has been sparse. Project objectives are to (1) evaluate private well contamination in three counties using indicator bacteria (total coliform and *E. coli*) and nitrate based on randomized synoptic sampling events; (2) assess well construction and geological characteristics (e.g., well age, depth to bedrock) that affect total coliform and nitrate contamination; and (3) identify the source of contamination in a subset of total coliform- and nitrate-positive wells using microbial tests that distinguish between human, bovine, and swine fecal sources. More information: <https://wgnhs.wisc.edu/southwest-wisconsin-groundwater-and-geology-study-swigg/>

Hydrogeology and groundwater flow model of Columbia County. This multi-year study is a cooperative effort between the WGNHS and USGS, sponsored by the Columbia County Department of Land Conservation and the Wisconsin DNR. The project involved characterization of the county's groundwater system and included development of a groundwater flow model. The model is used extensively at the request of county officials to evaluate potential sources of poor groundwater quality in many private and public groundwater supply systems. A technical report on the model and hydrogeology of the county is scheduled for release in 2021.

Bedrock controls over arsenic contamination in southeast Wisconsin. This project tests the hypothesis that the probability of detecting low to moderate arsenic in drinking water is related to proximity to Paleozoic folds and related fracture networks. It will provide a model for why certain areas are at higher risk. We are (1) mapping buried Paleozoic structures; (2) performing geochemical analysis of Paleozoic strata to evaluate stratigraphic intervals and mineral phases that host arsenic in the study area; (3) querying existing public and private well data. A better understanding of bedrock arsenic sources will be useful for potential casing regulations that could dramatically lower the percentages of wells that produce drinking water with low to moderate levels of arsenic within the southeast Wisconsin study area (Fond du Lac, Dodge and Jefferson Counties).

Water quality indicators of human impacts to the wetlands of Door County.

Door County is home to wetlands that are important habitat for endangered species such as the Hines Emerald dragonfly, as well as nesting and spawning areas for waterfowl and fish. Most of these wetlands depend on groundwater inputs to maintain water levels and quality. We collected groundwater discharging to the wetlands and tested it for human and agricultural indicators such as artificial sweeteners (indicators of septic waste) and pesticides. We are determining whether these indicators are linked to land use with the hope that they will serve as early detection for potential human and agricultural impacts to the water quality of these wetlands. A [technical report](#) on this project was released in 2020.



Bedrock geology of Dodge County. With cooperative funding from the USGS STATEMAP program, the WGNHS has completed new mapping of the bedrock geology and bedrock topography of Dodge County. A new map of depth to bedrock in the county was released in 2020.

Regional Groundwater Studies

Regional groundwater studies usually span multiple counties. During 2020 the WGNHS was involved in several regional projects, including the following:

Multi-instrument Stream Surveys. Improved modelling of groundwater and surface water interactions are needed now more than ever as we need to understand the complex interactions between societal, agricultural and natural systems. We have developed methodology to continuously measure water chemistry, depth and sediment type along with video of streams using instruments mounted in a canoe. We have begun collecting data on a series of five smaller streams located across Wisconsin. The data is expected to show locations of groundwater inflow and impacts. The goal is to provide data over miles of the streams that can be collected in less than a day that would otherwise not be available.

Central Sands lakes study. In early 2018, the Wisconsin Geological and Natural History Survey was contracted by the DNR to assist them in a 4-year study to evaluate and model the hydrology of Long and Plainfield Lakes in Waushara County, and Pleasant Lake along the border of Waushara and Marquette Counties. The WGNHS is coordinating efforts with DNR staff, as well as researchers at UW–Stevens Point, and USGS. The WGNHS' primary objectives are to improve the geologic and hydrogeologic characterization of the Central Sands, develop a hydrogeological framework for groundwater modeling and collect water-level measurements for use in model calibration.

Geology and hydrogeology of the Rountree Formation in southwest Wisconsin.

The uppermost bedrock formations across much of SW Wisconsin are carbonate rocks of the Sinnipee and Prairie du Chien Groups. As those rocks chemically weather over geologic time, they produce a dense red residual clay known as the Rountree Formation. However, because the Rountree Formation is covered by younger sediment, very little is known about it. This project will evaluate the geographic distribution of this red clay layer across numerous counties in southwest Wisconsin; investigate its geologic and geochemical properties; and assess what—if any—role it plays in buffering the bedrock groundwater system from surface contamination. The results of this investigation will merge with water quality data from the Southwest Wisconsin Groundwater and Geology (SWIGG) study to better understand the interaction between human land use, underlying geology, and groundwater contamination susceptibility in southwest Wisconsin.



Groundwater Research Activities

The WGNHS carries out specific groundwater research projects focused on understanding topics important to groundwater use and management in Wisconsin and elsewhere. Active research projects during 2020 included the following:

Hydrogeology of Southwest Wisconsin. The hydrogeology and hydrostratigraphy of the Driftless Region of southwestern Wisconsin are complex due to the presence of multiple bedrock aquifers, rugged topography, bedrock structures, and fractures and karst features. To begin to better understand this region the WGNHS has undertaken groundwater monitoring centered on the Platteville Pioneer Farm, an Experimental Farm in Grant County operated by UW-Platteville. The goal of the Pioneer Farm work is to develop better conceptual models of the groundwater flow systems in SW WI.

Groundwater/surface water interactions in the Marengo watershed in the Chequamegon National Forest. Water temperature is important to the health and habitat of streams. Groundwater discharge to the stream helps moderate and cool a stream. That cooler water provides improved habitat for trout. We are working with the U.S. Forest Service to collect data on temperatures, flows and water quality in the Marengo River in northern Wisconsin. These data have been used to construct a groundwater/temperature model of the river. The model will allow the U.S. Forest Service to understand how temperatures in the stream might change in the future and how managing stream conditions such as increasing shade or placing structures in the channel will affect the stream temperature. A [new report](#) on this project was released in 2020.

Using drones and thermal imaging to investigate depth to bedrock, seepage faces, and underwater springs. WGNHS scientists are investigating the use of thermal

cameras mounted on airborne drones in three specific applications related to groundwater. The drone techniques have shown promise for rapid mapping of shallow bedrock areas in eastern Wisconsin, for locating areas of groundwater seepage contribution to slope instability along the Lake Michigan shoreline, and for locating submerged springs discharging to lakes and streams. Details of this work are available in the Survey's [2020 Story Maps](#).

Neonicotinoid contaminants in Wisconsin groundwater: relationships to landscape cropping systems. WGNHS hydrogeologists are collaborating with researchers at the UW-Madison Department of Entomology to better constrain the temporal and spatial dynamics of neonicotinoids in stream water across the Central Sands Region and analyze potential linkages between land-use activity and neonicotinoid concentrations in streams. Neonicotinoid monitoring results in streams will be evaluated using a calibrated groundwater flow model for the Central Sands to delineate groundwater contributing areas to these streams. Agricultural land use patterns within the groundwater contributing areas will then be analyzed to develop statistical relationships between land-use type and neonicotinoid concentration in streams. These results will provide stakeholders an additional tool to assess risk to aquatic invertebrates, better protect sensitive taxa, and inform regulatory and land-use management decisions.

Groundwater Data Management and Support

In 2020 the WGNHS continued to collect geologic and groundwater data and provide this data to a variety of users. Significant databases and data efforts include the following:

Enhanced publications catalog. The WGNHS maintains hundreds of reports, maps, and other records in digital form for free downloads to the public. During 2020 the Survey significantly improved the functionality of this service, allowing easier data searching, previewing and downloading of information related to Wisconsin's groundwater and geology.

Collection of downhole geophysical logs. The WGNHS continually collects and compiles downhole geophysical logs from research wells and "wells of opportunity," such as municipal wells. The logs, including natural gamma radiation, temperature, caliper, fluid conductivity, borehole diameter and optical imaging, are important tools for understanding water-quality problems in individual wells, and for correlating geologic units in the subsurface. In addition to municipal wells, geophysical logging has been used to troubleshoot problems in private wells and wells owned by state agencies including Department of Corrections, Department of Natural Resources and Department of Transportation. The WGNHS maintains a publicly-accessible data viewer for geophysical logs and Quaternary core, see <https://data.wgnhs.wisc.edu/data-viewer/>

Hydrogeologic Data Viewer maintenance. The WGNHS continues to support the Hydrogeologic Data Viewer, a map-based application to access a statewide catalog of hydrogeologic data. The application provides DNR staff with online access to data and publications and includes several methods to search by area for data of interest, such as geologic and geophysical logs or well construction reports. Many of the geophysical logs are collected for the DNR in wells where water quality or lack of data is an issue.

wiscLITH database. When requested, the Survey provides updates of the digital database, wiscLITH, which contains lithologic and stratigraphic descriptions of geologic samples collected in Wisconsin. This is a publicly available database, and current work efforts focus on including more data for areas of the state with active geologic and hydrogeologic projects. Database: <https://wgnhs.wisc.edu/pubs/wofr200903/>.

Well construction reports. The WGNHS serves as the repository for well construction reports (WCRs) from wells installed between 1936 and 1989 and can provide digital or paper copies to those who request them. In addition, WGNHS serves as a point-of-contact for questions about WCRs and updates records when errors are found during project work.

High-capacity well approval tracking. WGNHS continues to track high-capacity well approvals in an internal database. This enables a more proactive approach for WGNHS researchers, in collaboration with the DNR, to work with well drillers, pump installers and consultants to collect samples and borehole geophysical logs from priority areas of the state.

WGNHS Research Collections and Education Center. The WGNHS archives geologic records, rock samples, core samples and other materials in Mount Horeb, Wisconsin. Our core repository contains over 2.5 million feet worth of drillhole cuttings, more than 650,000 feet of drill core and more than 15,000 individual hand samples of rock from across the state. Examination tables and basic laboratory facilities allow convenient analysis and study of these materials by qualified individuals. More about the repository: <https://wgnhs.wisc.edu/research/core-repository/>.

Groundwater Education

WGNHS groundwater education programs for the general public are usually coordinated with the DNR or the Central Wisconsin Groundwater Center at UW–Stevens Point or with the UW–Madison science outreach community as well as with the UW-Madison Division of Extension. WGNHS produces and serves as a distributor of many groundwater educational publications through our website (<https://wgnhs.wisc.edu>). We also distribute information about Wisconsin groundwater on our website at <https://wgnhs.wisc.edu/water-environment>. Our outreach efforts reach different and broader audiences through a variety of social media tools, including:

Facebook – <https://www.facebook.com/WGNHS>

Twitter – <https://twitter.com/wgnhs>

Pinterest – <http://www.pinterest.com/WGNHS/>

YouTube – <https://www.youtube.com/channel/Ucwwucf9-W1qocovGx-uzs7w>

WGNHS presents groundwater educational activities at various museums and schools and at UW-Madison outreach events (such as at Science Expeditions and at the Science Festival).

In 2020, WGNHS staff members participated in groundwater educational meetings in counties where mapping and/or hydrogeologic studies are in progress. Staff members will

continue to work with the DNR and the Central Wisconsin Groundwater Center on teacher-education programs connected to the distribution of groundwater sand-tank models.

The WGNHS maintains a long commitment to the continuing education of water well drillers, pump installers and plumbing contractors through participation in the programs of the DNR and the Wisconsin Water Well Association. Geologic and hydrogeologic field trips and presentations for DNR water staff and new DNR employees have been held in the past and will continue as requested.

The WGNHS Research Collections and Education Center is providing a locale for various groups to conduct related educational programs. Researchers and consultants also use our core holdings in that collection to better understand the subsurface and its aquifers. Staff of WGNHS organize and annually present papers at the Wisconsin Section of the American Water Resources Association reaching consultants, academics, and state and federal agency scientists with results of our research.

For more information:

Visit <https://wgnhs.wisc.edu/>

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DEPARTMENT OF TRANSPORTATION

As a result of the 1984 Wisconsin Groundwater Law, the Department of Transportation (DOT) regulates the storage of highway salt (ss. 85.17 and 85.18, Wis. Stats.) to protect the waters of the state from harm due to contamination by dissolved chloride. DOT is also responsible for potable well sampling at 28 rest areas and 55 seasonal waysides. Other DOT groundwater related activities include: groundwater investigation or remediation of contaminated properties; subsurface hydrogeologic investigations for infrastructure development; compensatory wetland restoration including hydrology performance monitoring (surface water/groundwater interaction); storm water management; and coordination with USGS and WGNHS for locational use and access for groundwater level monitoring points incorporated into the Wisconsin Groundwater-Level Monitoring Network.

FY 2021 Highlights

- Produced new fact sheet, Safe Highways-Less Salt (Efficiency for WI Winter Maintenance).
- Funded construction of 8 new salt storage facilities and 2 roof replacements.
- Began new social media partnership with WI Salt Wise: <https://www.wisaltwise.com>.
- Continue to research the effectiveness of brine chemicals and brine application rates for varying weather conditions in partnership with Clear Roads (National Research Consortium <https://clearroads.org>) and the UW Traffic and Safety Laboratory (TOPS Lab).
- Created the Brine Technical Advisory Committee (TAC) in 2018 and annually provide ongoing training to County winter maintenance crews regarding Direct Liquid Application (DLA).
- 30 Counties used DLA and some Mostly Liquid Route (MLR) last season.
- Preliminary results of new brine application techniques are showing significant reduction in overall salt use while maintaining clear roads and level of service for the traveling public.
- Less salt was used last winter season (76 million pounds) yielding cost savings (\$3.2 Million).
- 11.5 million gallons of brine solution was used last season, most in Wisconsin history.
- 44 Counties have been provided with route optimization technology to date



[New fact sheet: Safe Highways – Less Salt.](#)

Details of Ongoing Activities

Salt Storage

Highway salt is stored statewide by suppliers, counties, cities, villages and private companies. Annual inspections occur and reports are provided for salt storage sites to ensure storage practices are in accordance with ch. Trans 277, Wis. Adm. Code (Highway Salt Storage Requirements). The intent of the Code is to help prevent entry of highway salts into waters of the state from storage facilities. All salt must be covered and stored on an impermeable base. The base for stockpiles is required to function as a holding basin and to prevent runoff. The covers must consist of impermeable materials or structures to prevent contact with precipitation. State funded facilities are being added to the DOT salt storage program to provide greater capacity of indoor storage. This will improve groundwater protection and create greater flexibility for scheduling salt purchase at optimal prices.

The DOT annually updates salt storage facility records into a database and assists the DNR Wellhead and Source Water Protection program in locating salt storage facilities for GIS mapping applications. There are currently 1,333 salt storage site locations listed in the database with a total of over 3,150 buildings, brine tanks and stockpiles identified in the state. Facility inventories, inspections, repairs and improvements are included in the database.

Salt Use

The DOT Bureau of Highway Maintenance produces the Annual Winter Maintenance Report describing statewide salt use based on weekly reports from each county. Current policy in the State Highway Maintenance Manual restricts the spreading of deicer salts to a maximum of 400 pounds per lane mile per initial application, and up to 300 pounds per lane mile for subsequent applications. Electronic controls for salt spreader trucks are calibrated to record and verify application rates and coverage effectiveness. Other technology is used on county highway patrol trucks to keep salt on pavement surfaces (e.g., zero-velocity spreaders, ground speed controllers and onboard liquid pre-wetting units). Additional efforts to minimize and conserve salt applications include the use of an in-situ weather monitoring system. Pavement temperature sensors on most trucks and at 70 weather stations along major highway routes are used to determine application rates and effectiveness. Annual training for snowplowing and salt spreading techniques is provided for county snowplow operators.

Salt Usage Tracking and Initiatives

The DOT is working to ensure the right materials and resources are available and used before, during and after each storm event. The department continues to identify best practices based on national studies, pilot winter projects involving salt and brine use, plowing practices and snow plow route optimization.

The newest DOT initiatives over the last 3 winter seasons in winter maintenance is called "Mostly Liquid Routes" (MLRs). Multiple Counties tested MLRs this past winter using brine or brine mixtures to keep the snow from sticking to the road between plow cycles, and rarely put rock salt on the road. These projects can result in a reduction of about 50% road salt application while still achieving the "time to bare/wet" goals. This past winter the UW Traffic and Safety Laboratory (TOPS) worked on a study with 10+ Counties on the benefits of MLRs instead of traditional use of rock salt.

DOT winter maintenance and response performance measures can be found at these webpage links:

- <https://wisconsindot.gov/Pages/doing-bus/local-gov/hwy-mnt/winter-maintenance/default.aspx>
- <https://wisconsindot.gov/Pages/about-wisdot/performance/mapss/measures/mobility/winter.aspx>

Explanations of liquid brine applications are provided on WisDOT podcast (Feb 25, 2020 – Transportation Connects – Clear Roads, Less Salt – Winter Road Maintenance) and refer to the following social media links for additional information on Winter Maintenance:

- <https://wisdot.libsyn.com/clear-roads-less-salt-wisconsin-winter-road-maintenance-0>

YouTube

Using Less Salt & More Brine - https://www.youtube.com/watch?v=7Z_AnRlpSQ8
Liquid Only Roadway Treatments - https://www.youtube.com/watch?v=4cTmhl_nN8c

Twitter

Salt vs. Brine Graphic - <https://twitter.com/WisconsinDOT/status/1350096126813331456>
Living Snow Fence - <https://twitter.com/WisconsinDOT/status/1352262172819288066>
Throwback Thursday - <https://twitter.com/WisconsinDOT/status/1349725458640691200>
Inside a Snowplow - <https://twitter.com/WisconsinDOT/status/1346830876156432384>
Salt Awareness Week - <https://twitter.com/WisconsinDOT/status/1348691144838811648>
Corn Snow Fence - <https://twitter.com/WisconsinDOT/status/1364220971519905796>
WI plow drivers study winter maintenance techniques -
<https://twitter.com/WisconsinDOT/status/1214966252726210560>
Control salt distribution - <https://twitter.com/WisconsinDOT/status/1216778603637010434>
Part science, part art form - <https://twitter.com/WisconsinDOT/status/1227684631383769088>

Facebook

Salt Awareness Week - <https://www.facebook.com/WisDOT/posts/3934033823287750>
Salt vs. Brine Graphic - <https://www.facebook.com/WisDOT/posts/3942275765796889>
Corn Snow Fence - <https://www.facebook.com/WisDOT/posts/4056421804382284>
Liquid Salt Brine -
<https://www.facebook.com/WisDOT/photos/a.244273872263782/3036959442995197/?type=3&th eater>

For more information

Visit <https://wisconsin.gov>

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UNIVERSITY OF WISCONSIN SYSTEM

The University of Wisconsin System (UWS) has research, teaching, and outreach responsibilities. These three missions are integrated through cooperation and joint appointments of research, education, and outreach and extension personnel, along with postgraduate fellows, who address groundwater issues. UWS staff members work with state and federal agencies and other partners to solve groundwater resources issues. Research is coordinated through the University of Wisconsin Water Resources Institute, which conducts annual calls for proposals followed by rigorous peer and panel review of the proposed projects. Typically, four to seven projects are funded through the Institute each year. Citizen outreach is accomplished through publications, video and audio podcasts, social media, media relations, public meetings and presentations, teleconferences, and water testing and satellite programs. In the following sections, we describe the activities of several university programs, including the [University of Wisconsin Water Resources Institute](#), the [Central Wisconsin Groundwater Center](#) (affiliated

with UW-Madison's Division of Extension and UW-Stevens Point), the [Natural Resources Institute's Land and Water Programs](#) at UW-Madison's Division of Extension, the [University of Wisconsin Nutrient and Pest Management Program](#), and the [Wisconsin State Laboratory of Hygiene](#).

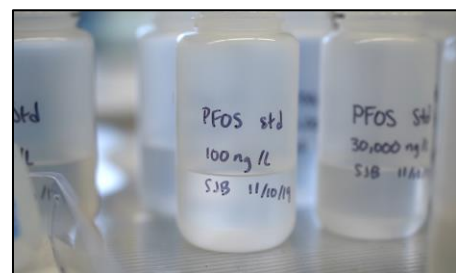
Details of Ongoing Activities:

University of Wisconsin Water Resources Institute (WRI)

The University of Wisconsin Water Resources Institute (WRI) is one of 54 water resources institutes located at Land Grant universities across the nation with core funding provided and administered by the U.S. Department of the Interior through the U.S. Geological Survey. It promotes research, training, and information dissemination focused on Wisconsin's and the nation's water resources problems. WRI is a UWS program administratively housed at UW-Madison's Aquatic Sciences Center, along with the University of Wisconsin Sea Grant College Program.

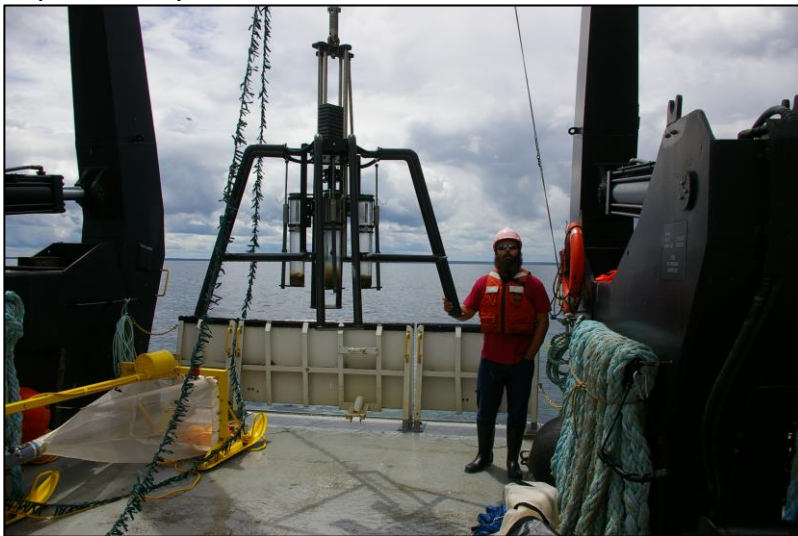
FY 2021 Highlights

- In support of the Wisconsin Groundwater Research and Monitoring Program, provided UWS funding to seven research projects focused on groundwater contaminants, including arsenic, nitrate, radium, and strontium; water quantity challenges in the Central Sands; geochemistry and microbiology; groundwater-surface water interactions; and economics of groundwater and water utilities and supported graduate and undergraduate students at UW-Milwaukee, UW-Madison, UW-Stevens Point, and UW-Eau Claire.
- Coordinated the Request for Proposals and the review process for the FY22 Joint Solicitation for the Wisconsin Groundwater Research and Monitoring Program.
- Supported five Water Resources Science-Policy postdoctoral fellows in partnership with the Wisconsin Department of Natural Resources (DNR) and Wisconsin Department of Health Services (DHS) to work on state priority groundwater and surface water challenges, including completion of a legislatively requested study on water in the Central Sands Region, development of decision-support tools for high-capacity wells, the effect of a changing climate on brook and brown trout, PFAS standards for drinking water, and statewide public health tracking for harmful algal bloom toxin exposure. It also leveraged Aquatic Sciences Center funding to support ten additional postdoctoral fellows working on aquatic toxicology and PFAS, community flood resiliency, coastal hazards, coastal wetlands, and aquaculture.
- Supported the annual Wisconsin Chapter of the American Water Resources Association meeting by leading and funding the writing, editing, graphic design and distribution of a conference registration brochure. Due to the new coronavirus pandemic, the meeting was held virtually.



Per- and polyfluoroalkyl substances (PFAS) are chemicals used in everyday items like clothing, cookware and even dental floss. Unfortunately, these chemicals also persist in the environment and cause numerous human health problems. Draft drinking water standards were developed this year. *Photo: Bonnie Willison.*

- Maintained the [Wisconsin Water Library](#), providing access to more than 30,000 volumes of water-related information. Library staff also reached 4,800 K-12 students.
- Produced and distributed four issues of the *Aquatic Sciences Chronicle* highlighting water research and the people who conduct water research and outreach. The *Chronicle's* dedicated readers consist of roughly 5,500 online and print subscribers, which include local and state water-management agencies and water-related non-governmental organizations. Readers are found in Wisconsin and across the country. The newsletters are available at aqua.wisc.edu/chronicle.
- Supported the production of 25 final project reports, 12 theses, and 46 peer-reviewed publications over the past five years.
- Saw recognition by external organizations, which is a mark of excellence. Post-doctoral fellow and UW-Madison graduate Ryan Lepak was the recipient of the prestigious Raymond L. Lindeman Award from the international Association for the Sciences of Limnology and Oceanography. UW-Madison's Matt Ginder-Vogel received a research award from the Wisconsin Section of the American Water Works Association.



Dr. Ryan Lepak has participated in numerous research cruises to assess the level of mercury in Wisconsin and Great Lakes waters. His findings drew the attention of the well-respected Association for the Sciences of Limnology and Oceanography, which awarded him a 2021 prize in the category of young scientist and outstanding peer-reviewed publication.

Research

- The WRI research portfolio is supported by UW System funding for the Wisconsin Groundwater Research and Monitoring Program and includes interdisciplinary projects in four areas: groundwater, surface water, groundwater-surface water interactions, and drinking water. Groundwater is a top priority and an area of particular strength at the WRI. Key areas of emphasis in FY21 included research focused on groundwater contaminants, including arsenic, nitrate, radium, and strontium; water quantity challenges in the Central Sands; geochemistry and microbiology; groundwater-surface water interactions; and economics of groundwater and water utilities and supported graduate and undergraduate students at UW-Milwaukee, UW-Madison, UW-Stevens Point, and UW-Eau Claire.

During FY21, the WRI directed a wide-ranging program of priority groundwater research consisting of five new projects and two continued projects. These included short- and long-term studies both applied and fundamental in nature. They provide a balanced program of laboratory, field, and computer-modeling studies and applications aimed at preserving or improving groundwater quality and quantity. These seven projects, funded

by the UWS, provided training in several disciplines for several graduate student research assistants and undergraduate students at UW-Milwaukee, UW-Madison, UW-Stevens Point, and UW-Eau Claire. Groundwater issues investigated during the past year included:

- Impact of changing snow cover and frozen ground regimes on groundwater recharge. Steven Loheide, UW-Madison. (continuing)
- Microbially-mediated oxidation of trace element-bearing sulfide minerals in sandstones of Trempealeau County, WI. Eric Roden and Matthew Ginder-Vogel, UW-Madison. (continuing)
- Investigating in-season cover crops for reducing nitrate loss to groundwater below potatoes. Kevin Masarik and Jacob Prater, UW-Stevens Point. (new)
- Valuing groundwater quality: A cost function analysis of Wisconsin water utilities. James Price, UW-Milwaukee. (new)
- Source to sink evaluation of phosphorus in the hydrologic system in Wisconsin: Implications for lake eutrophication. Sarah Vitale, Anna Baker, and J. Brian Mahoney, UW-Eau Claire and USGS Upper Midwest Water Science Center. (new)
- Correlating bedrock folds and fractures to arsenic detection in drinking water, southeast Wisconsin. Eric Stewart and Esther Stewart, UW-Madison. (new)
- Investigating sources of salinity associated with Ra and Sr in the Cambrian-Ordovician aquifer system of eastern WI. Matthew Ginder-Vogel, Patrick Gorski, and Sean Scott, UW-Madison and Wisconsin State Laboratory of Hygiene. (new)



Southeastern Wisconsin drinking water wells sited near ancient bedrock folds and fractures are more likely to contain a naturally occurring toxin—arsenic—according to recent findings by WRI researcher Eric Stewart. Photo collage: Yael Gen.

For FY22 (July 1, 2021 - June 30, 2022), the UWS selected four new groundwater research projects from proposals submitted in response to the Joint Solicitation for Wisconsin Groundwater Research and Monitoring Program and will continue two projects selected from the previous years' solicitations. The projects are based at UW-Milwaukee, UW-Madison, and UW-Platteville and include:

- Measurement of bacterial transport and immobilization in variably saturated geologic materials of WI. Christopher Zahasky, Eric Roden and Vy Le, UW-Madison. (new)
- Mass discharge of road salt via groundwater to surface waters in Southeastern Wisconsin. Charles Paradis, Laura Herrick, Cheryl Nenn, and Timothy Wahl, UW-Milwaukee and Southeast Wisconsin Regional Planning Commission. (new)
- Data-driven groundwater depth and risk forecasting in the Central Sands region of WI for sustainable management. Jingji Huang and Ankur Desai, UW-Madison. (new)
- Assessment of biochar application to reduce nitrate leaching through agricultural vegetative treatment areas. Joseph Sanford, UW-Platteville. (new)

Additionally, the WRI receives an annual federal 104(B) allocation that can be used to advance groundwater and other water resources research and initiatives. This allocation is often used to fully support or augment a project selected through the state groundwater competition, freeing up state resources to invest in additional strong proposals submitted to the groundwater competition. In FY21, this allocation supported:

- Fate of groundwater phosphorus from septic systems near lakes. Paul McGinley, UW-Stevens Point. (continuing)
- Impact of changing snow cover and frozen ground regimes on groundwater recharge. Steven Loheide, UW-Madison. (continuing)

In addition, this federal allocation was matched by state agency partners and used to: Recruit and support a Water Resources Science-Policy postdoctoral fellow in partnership with DHS's Environmental and Occupational Health Program to work on PFAS groundwater protection standards and drinking water health advisory levels. (Dr. Gavin Dehnert, 2020-21).

- Support a Water Resources Science-Policy postdoctoral fellow in partnership with DNR's Drinking Water and Groundwater Program to work on the Central Sands Lakes Study (study requested by the legislature). (Dr. Carolyn Voter, 2019-21).
- Recruit and support two new Water Resources Science-Policy postdoctoral fellows in partnership with DNR's Drinking Water and Groundwater Program and Fisheries Management Program to work on the state's streamflow model and effects of stream hydrology on fisheries. (Drs. Bryan Maitland and Dana Lapides, 2020-21).
- Recruit and support a Water Resources Science-Policy postdoctoral fellow in partnership with DHS to work on public health aspects of harmful algal bloom toxin exposure (Jordan Murray, 2021-22).



Pictured is Dr. Carolyn Voter, one of WRI's Wisconsin Water Resources Science-Policy Postdoctoral Fellows, who was integral to the 2021 Central Sands Lake Study Report, as directed by the legislature.

Lastly, the Aquatic Sciences Center (home to WRI) successfully secured a grant from the U.S. Environmental Protection Agency to support four UW-U.S. Environmental Protection Agency Human Health and the Environment Postdoctoral Research Fellows. (Drs. Ryan Lepak, Nathan Pollesch, Prarthana Shankar, and Sally Mayasich, 2019-22). The Aquatic Sciences Center also provided a grant to UW-Madison to support a postdoctoral research fellow to address PFAS contamination of surface waters (Dr. Sarah Balgooyen, 2019-22) and additional fellows to address community flood resiliency (Jackson Parr, DHS, 2021-22), coastal hazards (Adam Arend and Lydia Salus, Department of Administration, 2019-21), coastal wetlands (Dr. Nicole Ward, DNR, 2021-22), and aquaculture (Dr. Patrick Blaufuss, UW-Stevens Point, 2020-22).

Teaching

Institutions within the UWS continue to offer undergraduate- and graduate-level courses and programs focusing on diverse issues



The Water Resources Institute offers teaching resources for STEM learners of all ages on numerous water-related topics. Here, WRI's Wisconsin Water Library Senior Special Librarian is with youth of the Ho Chunk Nation. Photo: Narayan Mahon.

regarding groundwater resources. Additionally, several campuses offer for-credit, field-oriented water curriculum courses for middle- and high- school teachers during summer sessions. The WRI views continuing education for P-12 teachers as an important component of its outreach and training effort. The Wisconsin Water Library, housed on the UW-Madison campus and funded by the WRI, maintains an extensive collection of curricula with innovative approaches and other educational materials for teaching water-related science in P-12 classrooms. The curricula are available for checkout by all teachers and residents in Wisconsin. The librarian also has extensive experience in working with young children. She put that experience to use in developing kits based on field-tested science, technology, engineering, art, and math. The kits will eventually number 27 on topics such as the water cycle, art and water, and pond science. The kits contain several books, directions for a guided science experiment and other themed activities. Finally, the library provides checkout of an aquatic invasive species elementary and middle school curriculum collection known as an attack pack. The packs have been used to educate people about aquatic invasive species in the waters of Wisconsin and are being updated to include additional information about fish. A unique challenge associated with fully utilizing these kits in the past has been the difficulty in physically distributing them. Now, the WRI has devised an efficient distribution system through the public interlibrary loan system.

Grants Administration

The WRI conducts the annual outside peer review of all proposals submitted to the state of Wisconsin Joint Solicitation for Groundwater Research and Monitoring. In FY21, WRI continued to use a relatively new web-based proposal submission, review, and reporting system [eDrop](#). The website enables seamless online submission and review of proposals. At the site, prospective investigators submit a proposal by filling out a series of forms and uploading their full proposal and budget. Assigned reviewers then complete their reviews through eDrop by answering a series of questions online. Once all the reviews are completed, the UW Groundwater Research Advisory Council is given access to anonymous reviews and original proposals to help decide which proposals to recommend for funding. Agency partners also have access to the reviews to inform their selection processes as well. The website provides a framework for consistently capturing the same information from all the prospective investigators and reviewers, ensuring all proposals are treated equally.

Information-Sharing and Outreach Activities

The [University of Wisconsin Water Resources Institute website](#) offers research projects and publications. One of the site's main audiences is researchers. To that end, the site provides a clear navigational path to the WRI project listings, project reports, a groundwater research database, funding opportunities, and conference information sections. All of these areas are updated on a regular basis to ensure currency of information transfer. Additionally, WRI has a presence on Twitter, Facebook, and Flickr.

New to this year's WRI video catalog is "The Groundwater Level Monitoring Network," which details the 75-year history and value of this network that tracks the state's groundwater. The new video joins perennially popular ones such as "What is a spring?," "Streams neutralize nitrates in groundwater," "A new measure of groundwater flow," "Got oaks?," and one of the most popular videos on the WRI's [YouTube channel](#), "Testing well water for microorganisms." To date it has more than 13,000 views, which is a large number for a scientific topic.

The Pew Research Center, in a 2017 report, noted that the percentage of podcast listeners in America has substantially increased since 2006. At the time of the report, four in ten Americans ages 12 or older had listened to a podcast and 24 percent had listened to a podcast in the past month, up from just 9 percent in 2008. WRI capitalizes on this popular way of sharing water science information. It offers five multi-part series on topics such as groundwater, mercury in aquatic environments, and aquifers and watersheds.

During this reporting period, WRI staff were integral to the leadership and content-population of Water@UW-Madison located here - <https://water.wisc.edu/>. The site is a portal to the breadth and depth of water-related work on the state's flagship campus, the UW-Madison, and serves as the first stop for anyone interested in water research. Graduate students can search for departments offering courses and degrees that fit their interests. Prospective graduate students can use the site to investigate potential faculty advisors. Finally, staff and faculty can search for colleagues working on topics complementary to their own to facilitate greater interdisciplinary collaboration and exploration. This year, Dr. Jennifer Hauxwell chaired the Water@UW-Madison executive committee, and Moira Harrington served on the committee. The group hosted two events reaching hundreds of viewers, including co-hosting an event with the Freshwater Collaborative that featured speakers from each of the UW System schools. WRI director Jim Hurley serves on the Steering Committee for the Freshwater Collaborative.

Water Resources Publications

The program offers easily accessible publications through an online site, with free information or information available for a nominal cost. Topics include nitrates in groundwater, siting rain gardens, and arsenic. The program also produces the [*Aquatic Sciences Chronicle*](#) on a quarterly basis. It circulates to roughly 5,500 electronic and print subscribers with an interest in WRI projects and related topics. The newsletters are also posted online.

Wisconsin's Water Library

Wisconsin's Water Library is a unique resource for Wisconsin citizens. It contains more than 30,000 volumes of water-related information about the Great Lakes and the waters of Wisconsin. The library includes a curriculum collection, dozens of educational videos, a children's collection, and more than five journals and 30 newsletters.

In addition to archival benefits, the library provides outreach by answering many in-depth reference questions on a wide range of water-related topics. In partnership with the Wisconsin Department of Natural Resources and the Wisconsin Wastewater Operator's Association (WWOA), the library continued its outreach to current and future wastewater and drinking water operators of Wisconsin. The library catalogs the essential technical manuals and loans them to WWOA members around the state in support of required state license examinations.

Wisconsin's Water Library continues to catalog all groundwater research reports from projects funded by the WRI into WorldCat and MadCat, two library indexing tools that provide both worldwide and statewide access to WRI research. By having this information permanently indexed, the research results are easily available to other scientists throughout the University of Wisconsin System as well as across the nation and the world.

The library also maintains a digital archive of the entire collection [of Groundwater Research and Monitoring Program reports](#). The archive was created in partnership with the UW Digital Collections Center and ensures a permanent and accessible electronic record of Wisconsin groundwater-related activities since 1984. Paper copies of the reports continue to be a part of the Wisconsin Water Library.

Technical Research Publications Resulting From Recent WRI Groundwater Research and Monitoring Program-Sponsored and Other WRI-Supported Projects (Past Five Years):

Water Resources Institute Reports

- Bahr, J., M. Gotkowitz, and J. Olson. 2017. Long-term alterations in groundwater chemistry induced by municipal well pumping. Final report, Water Resources Institute, University of Wisconsin-Madison. WR15R002.
- Booth, E. G., S. P. Loheide II, D. Bart, P. A. Townsend, and A. C. Ryzak. 2019. Linking groundwater and nutrients to monitor fen ecosystems using airborne imaging spectroscopy. Final report, Water Resources Institute, University of Wisconsin-Madison. 15p. WR17R001.
- Choi, C.Y., D.J. Hart, J.M. Tinjum, and M.K. Harper. 2016. Assessment of environmental impacts of geothermal source heat exchange. Final report, Water Resources Institute, University of Wisconsin-Madison. WR14R002.
- Choi, W., and C. Wu. 2016. Impacts of climate and land use changes on streamflow and water quality in the Milwaukee River Basin. Final report, Water Resources Institute, University of Wisconsin-Madison. WR13R004.
- Ginder-Vogel, M., and C. Remucal. 2016. Effect of source chemistry on Mn-bearing solid dissolution and reactivity in municipal water systems. Final report, Water Resources Institute, University of Wisconsin-Madison. WR15R009 and WR14R004.
- Grundl, T., L. Fields-Sommers, and J. Graham. 2016. Groundwater-surface water interactions caused by pumping from a riverbank inducement well field. Final report, Water Resources Institute, University of Wisconsin-Madison. WR13R002.
- Grundl, T., R. Newton, N. Gayner, and M.J. Salo. 2020. Anthropogenically driven changes to shallow groundwater in southeastern Wisconsin and its effects on the aquifer microbial communities. (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 36p. WR16R001.
- Hauxwell, J. 2016. Wisconsin Water Resources Fellowship. Final report, Water Resources Institute, University of Wisconsin-Madison. WR15R006.
- Kucharik, C.J., T. Campbell. 2020. Improving water and nitrogen use efficiency under changing weather variability in the Central Sands. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 18p. WR18R001.
- Lark, T., and Y. Xie. 2020. Mapping annual irrigation extent at 30-m resolution across the United States, 1997-2017. (University of Wisconsin-Madison). Final Report, UW-USGS Irrigation Mapping Project. 60 pp. G19AC00080/2016WI354G.
- Larson, E.R., and S.A. Allen. 2016. Establishing the long-term range of variability in drought conditions for southwest Wisconsin. Final report, Water Resources Institute, University of Wisconsin-Madison. WR13R003.
- Loheide, S., and D. M. Ciruzzi. 2019. Historic changes in groundwater use by trees in Wisconsin due to high-capacity groundwater pumping and climate variability. Final report, Water Resources Institute, University of Wisconsin-Madison. WR17R002.

- McIntyre, P.B. 2016. Climate change impacts on stream temperature and flow: consequences for Great Lakes fish migrations. Final report, Water Resources Institute, University of Wisconsin-Madison. WR11R002.
- McLellan, S. 2021. Detection of Sewage Contamination in Urban Areas of the Great Lakes. . (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 3 pp. WR16R005/2016WI354G.
- Nitka, A., P. McGinley. 2017. Investigating the impact of nitrate contamination on uranium and other elements of emerging concern in Wisconsin groundwater. Final report, Water Resources Institute, University of Wisconsin-Madison. WR16R002.
- Noguera, D. M. Anderson, I. Tejedor, J. Wouters. 2017. Phosphorus and arsenic sensors for real time environmental monitoring. Final report, Water Resources Institute, University of Wisconsin-Madison. WR15R001.
- Plank, E., H. Yang, X. Min, Y. Wang, S. Xu. 2020. Dynamics of arsenic concentration and speciation in Wisconsin private drinking water wells. (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 32p. WR18R002.
- Remucal, C. 2020. The impact of dissolved organic matter composition on the formation of disinfection byproducts in groundwater. (University of Wisconsin-Madison). Final Report, Final Report, University of Wisconsin Water Resources Institute. 18p. WR18R003.
- Scherber, K.S., and S.P. Loheide. 2017. Hydraulic impacts of the loss of Wisconsin's winter on surface water – groundwater interactions. Final report, Water Resources Institute, University of Wisconsin-Madison. WR14R003.
- Stelzer, R., and T. Scott. 2017. Predicting the locations of nitrate removal hotspots at the groundwater-surface water interface in Wisconsin streams. Final report, Water Resources Institute, University of Wisconsin-Madison. WR15R003.
- Stewart, E.K., J. Rasmussen, J. Skalbeck, L. Brengman, M. Gotkowitz. 2018. Mapping the base of the Cambrian aquifer through geophysical modeling of Precambrian topography, southern Wisconsin. Final report, Water Resources Institute, University of Wisconsin-Madison. WR17R003.
- Ventura, S., and S. Cardiff. 2016. Advances in monitoring and analysis of trace metals: a workshop to address applications in the Upper Great Lakes. Final report, Water Resources Institute, University of Wisconsin-Madison. WR14R001.
- Vitale, S., J.B. Mahoney, A. Baker. 2020. Assessment of the source and mobility of phosphorus in the hydrologic system in western Wisconsin. (University of Wisconsin-Eau Claire). Final Report, Final Report, University of Wisconsin Water Resources Institute. 19p. WR19R002.
- Wu, C. 2016. Uncertainty and variability of Wisconsin lakes in response to climate change. Final report, Water Resources Institute, University of Wisconsin-Madison. WR11R003.
- Zambito IV, J.J., L.D. Haas, M.J. Parsen, and P.I. McLaughlin. 2016. The Wonewoc and Tunnel City: A potential natural source of groundwater contamination in west-central Wisconsin. Final report, Water Resources Institute, University of Wisconsin-Madison. WR15R004.

Theses

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- Fields-Sommers, Laura. 2016. Assessing the effects of riverbank inducement on a shallow aquifer in southeastern Wisconsin. M.S. Thesis. Freshwater Sciences and Technology, UW –Milwaukee, Milwaukee, WI. 211p.
- Gayner, Natalie June. 2018. River Bank Inducement Influence on a Shallow Groundwater Microbial Community and Its Effects on Aquifer Reactivity. M.S. Thesis. Freshwater Science. University of Wisconsin - Milwaukee. <https://dc.uwm.edu/etd/1990>. WR16R001.
- Hamby, A. 2018. The effects of faults and changing water levels on confined sandstone aquifer water chemistry in northeastern Wisconsin. MS Thesis. University of Wisconsin-Green Bay, Green Bay, WI.
- Lepak, R. 2018. Multidimensional Tracing of Mercury Sources and Bioaccumulation Pathways Using Stable Isotopic Analyses. PhD Thesis. Environmental Chemistry and Technology. University of Wisconsin - Madison. WR18R005.
- Li, Wenliang. 2016. Large-scale urban impervious surfaces estimation through incorporating temporal and spatial information into spectral mixture analysis. Ph.D. Thesis. Department of Geography, University of Wisconsin-Milwaukee, Milwaukee, WI. 110p.
- Magee, Madeline. 2016. Simulation of lake thermal structure, ice cover, and fish habitat in response to changing climate. Ph. D. Thesis. University of Wisconsin-Madison. 171p.
- Michaud, 2018. Long term performance of radon barrier in limiting radon flux from four uranium mill tailings containment facilities. MS Thesis, University of Wisconsin-Madison.
- Plank, Evvan. 2020. Dynamics of arsenic concentration and speciation in Wisconsin private drinking water wells. M.S. Thesis. Geosciences, University of Wisconsin-Milwaukee, Milwaukee, WI. WR18R002.
- Rabeler, Katrina Hyman. 2021. Impacts of Changing Frozen Ground Regimes on Groundwater Recharge. MS Thesis. Geological Engineering, University of Wisconsin-Madison. WR19R005.
- Salo, Madeline Jean. 2019. Anthropogenically Driven Changes to Shallow Groundwater in Southeastern Wisconsin and Its Effects on the Aquifer Microbial Communities. M.S. Thesis. Geosciences. University of Wisconsin - Milwaukee. <https://dc.uwm.edu/etd/2116>. WR16R001.
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Other Publications

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- Choi, W., F. Pan, and C. Wu. 2017. Impacts of climate change and urban growth on the streamflow of the Milwaukee River (Wisconsin, USA). *Regional Environmental Change* 17:889-899. doi:10.1007/s10113-016-1083-3.
- Deng, Y., and C. Wu. 2016. Development of a class-based multiple endmember spectral mixture analysis (CMESMA) approach for analyzing urban environments. *Remote Sensing*, in press.
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For more information on the WRI:

Visit the WRI website wri.wisc.edu

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Central Wisconsin Groundwater Center

The [Central Wisconsin Groundwater Center](http://www.uwsp.edu/cnr-ap/watershed/) is an affiliate of the Center for Watershed Science and Education. It is a partnership between the College of Natural Resources at the University of Wisconsin – Stevens Point and the University of Wisconsin – Madison, Division of Extension. The Central Wisconsin Groundwater Center provides groundwater education, research and technical assistance to the citizens and governments of Wisconsin. Assistance includes answering citizen questions, helping communities with groundwater protection, describing the extent and causes of groundwater pollution, assessing drinking water quality, and working on groundwater policy. More information can be found at <https://www.uwsp.edu/cnr-ap/watershed/>.

Well Water Testing & Outreach

In calendar year 2020, the center helped 5,968 households test their water in conjunction with the UW-Stevens Point Water and Environmental Analysis Laboratory along with partners in county Extension offices, county health departments, and county land conservation departments. Well water testing programs were conducted in the following counties: Sauk, Dunn, Green Lake, Monroe, Taylor, Trempealeau, Portage, Columbia, St. Croix, Vilas, Calumet, Vernon, Crawford, Richland, Pepin, Kewaunee, Douglas, Chippewa, and Dodge. Many of the programs that would have been held in spring, had to be rescheduled after July 1 due to the pandemic. In addition, had to be conducted via online webinars rather than in-person meetings.

Water Quality Database

The Groundwater Center maintains a database of private well testing data from the Water and Environmental Analysis Regional Laboratory at UW-Stevens Point and conducts drinking water education programs. There are currently more than 875,000 individual test results for approximately 116,396 samples throughout the state. Chemistry data include pH, conductivity, alkalinity, total hardness, nitrate-nitrogen, chloride, saturation index, coliform bacteria, an atrazine screen, various metals and minerals including arsenic, lead, and copper. The database primarily covers the period 1985 to the present. The database can be queried, making it an easily accessible source of information for local communities and groundwater managers.



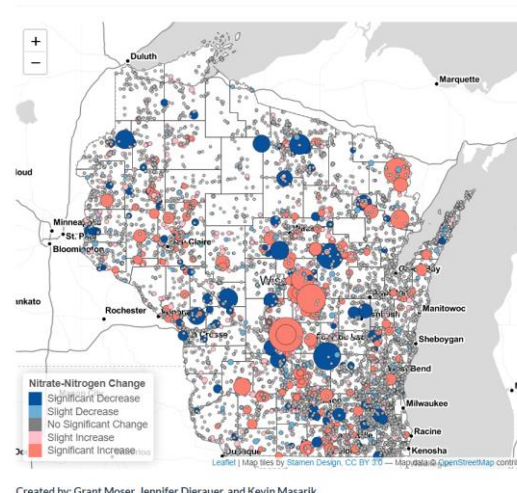
Interactive Wisconsin Well Water Quality Viewer

In July 2012, the Groundwater Center made publicly available an online mapping tool that allows people to search for groundwater quality information. The tool incorporates private well water data from the center's database, the Wisconsin Department of Natural Resources (DNR) Groundwater Retrieval Network and the Department of Agriculture, Trade and Consumer Protection. In 2014, data from the Eau Claire County Health Department were also integrated. [Summary maps](#) are available for 14 different water quality parameters and can be viewed or summarized into a table at a county, town or section level detail. Updated in 2019 to include nitrate/arsenic data from DNR well testing requirements for new wells and/or well pump work it now includes data for over 200,000 samples: with 105,381 samples from Extension efforts. It allows users to see water quality in their community and other parts of Wisconsin. In 2019, the Viewer was accessed by 8,052 people.

Nitrate in Groundwater

The Center launched a new app that investigates nitrate trends in Public Water Supply Systems. Using data from public water systems (i.e. Municipal, Other-than-Municipal, Transient, Non-community, and Non-transient, Non-community) the app summarizes publicly available data which can be viewed spatially or by Wisconsin Unique Well Number. The data reveal that 89.4% of wells have no trend, 6.8% have an increasing trend, and 3.9% have a decreasing trend. The app can be found online at: https://shiny.theopenwaterlog.com/nitrate_trends/.

The Center is also investigating the impact of various cropping practices on groundwater quality in the Central Sands Region. Using a combination of lysimetry and wells, the study is collecting year-round data to better understand the timing of nitrate leaching losses from various crops. Because many leaching studies often focus only on the growing season, this data set will provide important insight into inter- and intra-annual variability of leaching that is necessary to calibrate and validate nitrate leaching models. An additional project was started in 2020 looking at the use of inter-planting to reduce nitrate leaching losses below commercial potato production. The work is a collaboration with Dr. Chris Kucharik and students of his Lab at UW-Madison Department of Agronomy.



The Little Plover River, one of the many streams in the Central Sands region affected by increased pumping. Photo: UW WRI.

Central Wisconsin county-based volunteer streamflow monitoring

In a joint project with five county conservation offices and the DNR, the center launched a program that provides citizen volunteers with professional-grade streamflow monitoring equipment. This is part of an effort to better understand water conditions in the Central Sands Region affected by increased pumping. Staff members worked with county staff to recruit and train volunteers. Currently, staff are coordinating with 10 citizen volunteers to measure baseflow at 70 sites throughout the Central Sands Region. A quality control procedure is in place to independently verify a percentage of each citizen volunteer's measurements to ensure consistency and accuracy; results are extremely encouraging. These volunteers fill a large gap in baseline monitoring data of stream flow in the area.

Chemical Tracers for Identifying Sources of Groundwater Nitrate-Nitrogen

The center continues to refine chemical analysis methods for a suite of human wastewater tracers and agricultural pesticide metabolites to help trace the source of elevated groundwater nitrate concentrations in a well. This method study has resulted in a technique that has been applied to wells in Adams, Portage, St. Croix, Dunn, and Chippewa counties. Center staff worked with the DNR and the Wisconsin Department of Health Services to develop drinking water advisory levels for some of the compounds detected. Results from this study have been presented at the Wisconsin American Water Resources Association meeting and are available in a final report on the Groundwater Center's website.

Groundwater Phosphorus

Water samples collected through water education programs have been used to better understand the distribution, concentration, and sources of groundwater phosphorus in Wisconsin. This is one of the largest sources of groundwater phosphorus information available in the state, and it helps fill an important gap in understanding the sources of phosphorus to surface water resources. Results have been used by agencies and consultants studying Wisconsin surface waters, and they have also been summarized at several Wisconsin meetings and workshops.

Groundwater and Lakes

The center is working with several Wisconsin counties on lake management planning that incorporates groundwater flow modeling and groundwater in hydraulic and nutrient budgets. These studies are useful ways to communicate the connection between groundwater and surface water resources and highlight the need for protecting groundwater quality. Ongoing center research includes the movement of phosphorus from septic systems and the influence of nitrogen on lakes.

5-Year County Well Water Quality Inventories

Starting in 2019, the Center began multi-year projects with Chippewa, Green, and Sauk counties to organize citizen-based groundwater monitoring networks in each county. Dodge County was added in 2020. Wells will be tested for the following parameters: nitrate, chloride, alkalinity, pH, hardness, and conductivity. The goal is to test the same wells for five years in a row for the purposes of understanding trends in rural groundwater quality over time. By testing the same wells annually, Center staff will be better able to assess where/why groundwater quality changes and what characteristics and/factors can be used to predict changes in well water quality over time.

County	Year	n	Alkalinity	Chloride	Conductivity	Nitrate-Nitrogen	pH	Total Hardness	Total Hardness
			mg/L as CaCO ₃	mg/L	umhos/cm	mg/L		mg/L as CaCO ₃	n
Chippewa	2019	155	68.2	25.4	273	4.8	6.69	99.8	145
	2020	162	67.0	23.6	272	4.9	7.37	91.9	155
Dodge	2020	374	334.3	33.6	792	1.7	8.03	383.1	329
Green	2019	348	304.9	19.1	648	5.4	7.54	338.6	318
	2020	314	298.1	18.7	662	5.7	8.12	338.2	293
Sauk	2019	404	209.5	16.5	473	4.1	7.56	234.8	368
	2020	369	203.6	17.4	477	4.3	7.99	225.1	346

Policy

The center continues to play pivotal roles in a number of state groundwater issues. Working with partners in the private and public sectors on groundwater quantity policy and law has been a continuing priority. Center staff routinely present information on the science of groundwater quality and groundwater pumping and associated impacts to local and state government officials. Staff recently participated in the Wisconsin DNR Central Sands Lake Study and the NR151 Nitrate Technical Advisory Committee.

Recent Publications and Reports (past 5 years)

Nitka, A.L., DeVita, W., McGinley, P.M. 2019. Evaluating a Chemical Source-Tracing Suite for Septic System Nitrate in Household Wells. *Water Research* 148(1):438-445

<http://dx.doi.org/10.1016/j.watres.2018.10.019>

Nitka, A.L. and P.M. McGinley. 2017. Investigating the impact of nitrate contamination on uranium and other elements of emerging concern in Wisconsin groundwater. Report to the Water Resources Research Institute in partial fulfillment of UWS Project WR16R002.

Luczaj, J., and K. Masarik. 2015. Groundwater quantity and quality issues in a water-rich region: Examples from Wisconsin, USA. *Resources* 2015 4:323-357.

doi:[10.3390/resources4020323](https://doi.org/10.3390/resources4020323).

Masarik, K., M. Mechenich, A. Nitka and G. Kraft. 2018. Portage County Well Water Quality – 2017. Report in partial fulfillment of Portage County Project.

Masarik, K.C. 2016. Design of a field-scale approach for evaluating nitrogen management practices impacts to groundwater. Report in partial fulfillment of DNR Project #15_BMP_01.

McGinley, P., K. Masarik, M. Gotkowitz, and D. Mechenich. 2016. The impact of aquifer geology and anthropogenic acidification on groundwater phosphorus. *Applied Geochemistry*. 72:1-9.

<http://www.sciencedirect.com/science/article/pii/S088329271630097X>

McGinley, P.M., W. M. DeVita, and A.L. Nitka. 2016. Evaluating chemical tracers in suburban groundwater as indicators of nitrate-nitrogen sources. Final Report prepared for the Wisconsin Department of Natural Resources.

For more information on the Central Wisconsin Groundwater Center:

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University of Wisconsin-Madison Division of Extension: Natural Resources Institute's (NRI) Land & Water Programs

The Division of Extension Natural Resources Institute's (NRI) Land & Water Programs include state and local specialists addressing water resources, land and water conservation, forestry, conservation professional training, citizen engagement, and volunteer monitoring. NRI also coordinates a number of regional and national programs addressing water resources and water-education initiatives related to groundwater.

NRI Regional Water Programs and Conservation Professional Development

NRI coordinates the [North Central Region Water Network \(NCRWN\)](#), a 12-state collaboration among Land Grant universities, including partnerships with state and federal agencies across the Upper Midwest region. Through this network, Extension researchers and educators share programs and coordinate on an array of water resource issues, including groundwater quantity and quality. Currently, multi-state teams are active around soil health, watershed leadership, harmful algal blooms, drought, climate, and green infrastructure.

NRI also coordinates the [Conservation Professional Training Program](#), which develops and hosts multi-state professional development for conservation professionals. Wisconsin programs have included issues of conservation lands management such as manure management and fractured bedrock geology, including:

- Classroom and field training for local elected officials (town, county) both on the basic geology of local resources and localized research on groundwater quality and land use impacts in both the northeast and southwest regions of the state.
- Training public- and private-sector professionals to help farmers more effectively manage manure and commercial nitrogen fertilizers that can negatively impact groundwater.
- Training for manure applicators on manure application in karst areas.
- Providing conservation planning training and farmer training that includes karst issues.
- Offering projects that help water resource managers understand farmer awareness of, and capacity to adopt, conservation practices that are most likely to fit into farm management systems.

NRI Water Outreach and Education

The [Water Action Volunteers](#) stream monitoring program educates both children and adults about stream ecology and stream health. Volunteers continue to monitor more than 500 stream sites statewide for a variety of parameters, including stream flow, which is directly affected by groundwater. Volunteer-collected data is helping to characterize water quality and quantity across the state and to identify streams where impairments may exist. This program engages volunteer monitors in



partnership with schools, nature centers, and many others to provide educational experiences and important data regarding streams and hydrological systems.

The [Wisconsin Master Naturalist](#) program, active since 2012, follows a train-the-trainer approach to engage Wisconsin citizens in resource management. The course curriculum covers a variety of natural resources issues specific to Wisconsin, including groundwater quality and use. Certified volunteers are expected to provide 40 hours of natural-resource-related service annually to Wisconsin host organizations, such as nature centers, state parks, or museums. Areas of service include education/interpretation, stewardship, and citizen science. The Wisconsin Master Naturalist Program resulted in over 120,000 volunteer hours providing nearly \$3.1million dollars in value to the state since the program began. Fifty-three host organizations have partnered with the program by having 150 individuals trained as instructors who have trained 1,000 volunteers statewide. There is a presence of Master Naturalists in 65 of Wisconsin's 72 counties. The course provides a broad overview of Wisconsin's natural resources and the processes that affect them. This program continues to grow in cooperation with partners across Wisconsin.



Master Naturalist volunteer providing water quality monitoring on a stream in Rock County.

Regional Natural Resource Education Program

Extension's Natural Resources Institute cooperates on community-focused educational programs with other state agencies involved with water resources and natural resource issues. The [Regional Natural Resources Education Program](#) uses locally based natural resource educators to develop and conduct programs that reach local and statewide audiences by accessing state-level support for educational material development and program evaluation. The educational programs address a broad range of groundwater-related topics, including drinking water, threats to groundwater quality, impacts of land-use changes, and land management decisions on groundwater quantity, information about localized groundwater problems such as karst geology, water conservation, and efficiency, along with a variety of other issues associated with nutrients in surface water and groundwater. Educators have actively engaged with and facilitated the development and growth of farmer-led groups that learn about and implement conservation practices designed to address a host of water quality issues.

For more information on NRI/Land & Water programs related to groundwater:

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University of Wisconsin Nutrient and Pest Management (NPM) Program

Mission Statement

The University of Wisconsin's Nutrient and Pest Management (NPM) Program works with a wide range of partners to promote agricultural practices for protecting water quality while maintaining or improving farm profitability. The NPM Program serves Wisconsin farmers and the agricultural professionals who assist them. The program links farmers and researchers allowing for the exchange of knowledge on the profitability, practicality, and environmental impact of crop production practices and cropping systems.

Overall, in 2020, the NPM program staff collectively educated 5,037 people, at 282 events, giving 102 unique (original, first-time) presentations. In addition, they provided 15,347 individual consultations via email, phone, and in-person contacts. Educational products developed in 2020 include 30 videos, 34 print publications, and 125 nutrient management training manuals. *Please note that 2020 numbers were negatively impacted by COVID-19 travel and contact restrictions. Field activities including tours, field days, demonstrations, and other outreach activities were significantly reduced due to pandemic restrictions in 2020.*

NPM Program outreach products are available for viewing and downloading at:

<https://ipcm.wisc.edu/>

Nutrient Management

The NPM Program is part of a team that develops, distributes, evaluates, and implements nutrient management education programs. Partners include University of Wisconsin-Madison College of Agriculture and Life Sciences (UW-CALS) faculty/staff; county-based UW-Extension staff; land & water conservation departments; Wisconsin technical colleges; the Wisconsin Department of Agriculture, Trade and Consumer Protection; and the U.S. Department of Agriculture-Natural Resources Conservation Service, along with private-sector agri-businesses and Wisconsin farm producers. Activities include:

- *Nutrient Management Farmer Education Curriculum* (NMFEC) development and implementation. The NMFEC is an essential tool used throughout the state to teach farmers about crop nutrient management practices that improve profitability and reduce adverse impacts of nitrogen and phosphorus pollution. The NPM Program staff maintain, update, produce, and distribute the NMFEC. The curriculum combines classroom instruction, individual consultation, and on-farm field trials to deliver education on the preparation and understanding of farmer-written nutrient management plans. The curriculum is delivered statewide through collaborations with partners identified in the previous paragraph. Participation in a NMFEC project is the **only** mechanism for Wisconsin farmers to become certified to prepare their own nutrient management plans.
- Cumulative accomplishments numbers from 2000 to 2020 show that as a result of local delivery of the curriculum, more than 8,816 producers farming approximately 2,565,026 acres in 55 counties have received in-depth education on nutrient management planning. In 2020, approximately 580 farmers operating about 204,475 acres in more than 28 Wisconsin counties added to this accomplishment list. Data are currently being collected for 2021 accomplishments.
- *SnapPlus nutrient management planning software* assistance and refinement in conjunction with the SnapPlus team (UW-Madison Soil Science). NPM staff assist in

developing educational online videos (24 total), updating the SnapPlus online help system, refining output reports to meet the needs of end users and the creation of a SnapPlus training manual with more than 125 copies requested and delivered in December of 2020. In addition to creating SnapPlus educational products, NPM staff actively train farmers, agronomists, and others to use SnapPlus. In 2020, NPM staff members continue to assist the SnapPlus team in the development of a new SnapPlus user interface as well as quality control reviews of the software program. *Educational support to Wisconsin watershed projects.* Activities include coordination and delivery of individual nutrient management plans, on-farm demonstrations (nutrient crediting, nitrogen rates for corn, soil health, cover crops, soil erosion control, etc.). Support activities include planning, advice, coordination, grant preparation, and reporting. In addition, NPM staff serve on the selection committee for DATCP-sponsored farmer-led watershed projects. NPM Program staff serve as key members of watershed projects (producer-led, federal NRCS, and other) in 18 Wisconsin counties.

- *On-farm demonstrations, field plot research and subsequent educational programs* on various topics including: corn nitrogen rates, cover crops, phosphorus and potassium fertilizer trials for corn and soybean, conservation tillage, manure applications, etc. occurred in six counties in 2020.

Pest Management

NPM, in conjunction with numerous partners including UW-Madison-CALS faculty, county-based UW-Extension, the UW Integrated Pest Management (IPM) Program, and others, delivers timely educational programming on topics associated with pest management. Activities include:

- The *Waterhemp Weed Control Project* involves statewide field trails evaluating the effectiveness of various herbicides and herbicide application timings for the control of waterhemp. Waterhemp is a very aggressive weed that is wreaking havoc across the nation's cropland fields. The project goal is to develop control strategies for containing the spread of this weed that can severely impact farm profitability. In 2020 NPM conducted on-farm research waterhemp trials in Dane and Grant counties.
- *Soil conservation and weed management.* NPM working with the UW-Madison Dept. of Agronomy conducted on-farm research aimed at managing weeds while improving soil conservation. These trials look at using cover crops, no-till, residual herbicides, and system-based programs for the management of waterhemp and other troublesome weeds in Wisconsin.
- *Strategies for avoiding herbicide resistance in weeds.* The NPM program delivers educational outreach materials and trainings to Wisconsin producers and agri-businesses on strategies for avoiding the development of herbicide resistance in weeds. Strategies include awareness and diversification of herbicide modes of action used on a given farm/field, equipment sanitation to avoid transport of weed seeds, and identification of weed species likely to be resistant to popular herbicides.
- *Weed control in intermediate wheat grass (kernza).* A NPM staff member assisted the UW-Madison Dept. of Agronomy with a research project investigating the use of growth regulator herbicides for the control of management of winter annual and perennial broadleaf weeds in the perennial grass kernza.

Food Systems

- *Cover crops research, education and outreach.* NPM partnered with county Extension educators, USDA-NRCS, County Land Conservation Departments, non-governmental organizations, and CALS specialists to deliver cover crop education programs in person and virtually across the state and Midwest. Activities included on-farm field days, on-farm research and demonstration, development of educational videos, factsheets, publications, and training farmers and agronomists. NPM outreach specialists provided active leadership in the Wis. Cover Crops Conference and Cover Crops Research and Outreach Project (CCROP). Cover crop demonstration and research plots were continued at Peninsular Agriculture Research Station and Langlade ARS.
- *Soil health education.* Soil health presentations were given in person at two Wisconsin conferences (pre-COVID), several county Extension meetings, as well as through statewide online venues. NPM staff assisted tribal and Extension collaborators with the development of three grants in soil health and sustainable agriculture. Publications were authored and published in Hoards Dairyman, statewide newspapers, farmer-led watershed newsletters, Extension county newsletters and websites, and Extension's El Companero, bilingual dairy worker publication. A peer-reviewed article has been accepted and will be published in Tribal Colleges and University Research Journal in 2021. Collaboration with agencies and agronomists has resulted in the creation of two cropping system evaluator tools and a detailed soil health in-field scorecard, to be fully released in 2021.
- *Badger Crop Connect.* NPM staff were part of a team of educators within the Crops & Soils Program of the Division of Extension that organized and delivered a new series of webinars containing timely Wisconsin crop management information from May through September 2020. These webinars were a successful alternative to in-person fields days. Three NPM staff delivered six unique presentations at three different sessions. Collectively, there were 331 viewer logins for these discussions.
- *Healthy Grown / Healthy Farms.* NPM working cooperatively with the WI Potato and Vegetable Growers Association (WPVGA) has developed a national model of sustainable production systems, exemplifying integrated pest management. In addition, the program includes a nationally recognized ecosystem restoration effort. In 2020, ten growers were certified and over 12,500 acres of fresh market potatoes (about 40% of Wisconsin's fresh market acres) were verified as "Healthy Grown." NPM has worked with the WPVGA to expand "Healthy Grown" to carrots and onions.
- *Water stewardship online course development.* NPM staff developed the Wisconsin Water Stewards Course - a six-module, self-guided course focused mainly on water quantity issues. Water quality discussions are also included. The course is in CANVAS format and as a downloadable, non-credited, pdf option. Participants can view publications, videos, and all course materials. During 2020, 25 participants completed the class for formal credit (either certified crop advisor or other certification) while an additional 118 have taken the non-accredited version of the course.
- *First Nation sustainable food production and food sovereignty initiatives.* NPM has partnered with the College of Menominee Nation, Menominee Indian Tribe, and the Oneida Nation on several projects aimed at developing culturally relevant, sustainable food production practices and outreach to Indigenous communities. Research projects based upon traditional production techniques resulted in a peer-review publication and served as the foundational work leading to three successful

USDA-NIFA capacity building and research grant applications by the College of Menominee Nation – a 1994 tribal land-grant institution.

- *UWEX Agricultural Institute Climate Change Team.* The NPM Program is part of a leadership group guiding the UWEX-Agriculture Institute Climate Change Education Team. The team’s mission is to provide professional development and educational resources to enhance the ability of Extension agricultural educators to address current and expected challenges associated with climate change.

Outreach and Communication

- *Mobile applications.* The NPM Program creates mobile applications (apps) for hand-held devices (Apple and Android). Maintenance and updating of the NPM Program’s apps occurred in 2020. Currently available mobile apps include: *Tarspotter, Sporebuster, Manure Tracker, Sporecaster, Nitrogen (N) Price Calculator, Corn N Rate Calculator, Integrated Pest Management Toolkit, Corn Crop Calculator, Manure and Legume Nutrient Credit Calculator, and BeanCam.* Collectively, these apps have been downloaded by more than 130,000 users from across the world. All apps are created in collaboration with UW-Madison faculty and are promoting agricultural best management practices.
- *YouTube videos.* The NPM Program produced 31 new videos on a range of crop management topics in 2020. Over 300 YouTube educational videos featuring UW-Madison-CALS specialists have been prepared and released by the NPM Program over the past eight years. A complete listing can be found at <https://www.youtube.com/user/uwipm>. A conservative estimate of the number of views is greater than 1,200 worldwide per day with over 1.9 million total views as of November 2020.
- *Wisconsin Crop Manager newsletter and IPCM website.* The NPM and IPM Program website delivers the popular *Wisconsin Crop Manager* newsletter featuring contributions from faculty and staff across UW-CALS departments. *Wisconsin Crop Manager* is produced weekly during the growing season with semi-monthly and monthly releases during the winter months. The weekly e-mail distribution list contains 1,260 recipients, with 10,000 PDF downloads in 2020. Available online at: <https://ipcm.wisc.edu/wcm/>.
- *NPM publications.* The NPM Program has a long history of collaborating with CALS faculty specialists to create timely, pertinent, high-quality publications promoting the adoption of agricultural management practices to improve water quality and farm profitability. In 2020, 34 new publications were produced. Formats range from simple pocket-sized cards to extensive manuals and workbooks. NPM staff roles include author, editor, and designer. A listing of NPM’s print publications can be found at <https://ipcm.wisc.edu/downloads/>.
- *NPM resource highlights.* An online, digital newsletter created in 2020 is sent monthly to the UWEX Agricultural Institute (AI) list serve. Its purpose is to inform AI affiliates of new and existing NPM Program resources that are seasonally pertinent. Publications, videos, mobile applications, etc. are featured. The original intent was to inform new county educators of NPM Program educational products; however, feedback from established agents and UW/UWEX faculty indicates that they, also, find the information useful in their local programming efforts.
- The NPM Program won four Certificate of Excellence Awards in 2020 from the American Society of Agronomy (ASA) Extension Education Materials Competition. The NPM Program has won a total of 22 awards from ASA in 9 years! Year 2020 awards include: *Considerations when Landspreading Milk & Manure/Milk Mixtures*

(award category: pubs. <16 pages); *Visual Guide to Corn Development* (award category: pubs. >17 pages); *What's on Your Seed?* (award category: pubs. <16 pages); *Water Stewards online class*: (award category: audiovisuals).

For more information on the NPM program:

Visit the website <https://ipcm.wisc.edu/>

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Wisconsin State Laboratory of Hygiene (WSLH)

At the Wisconsin State Laboratory of Hygiene (WSLH), a great deal of effort is focused on identifying and monitoring chemical and microbial contaminants in groundwater through testing, emergency response, education and outreach, and specialized research. The activities related to groundwater span several departments at WSLH. The mission of the WSLH is to protect the health of drinking-water consumers by providing analytical expertise, research, and educational services to the scientific and regulatory communities and the public.

The chemical and microbial groundwater contaminants routinely tested include all contaminants regulated by the federal Safe Drinking Water Act, as well as many emerging contaminants that appear on the USEPA Contaminant Candidate List. Examples include: fecal indicators (total coliform, *E. coli*, coliphage, *Bacteroides* spp., *Rhodococcus coprophilus*, sorbitol-fermenting Bifidobacteria), *E. coli* O157:H7, toxigenic *E. coli*, Salmonella, waterborne viruses (norovirus), human-adenovirus, parasites (Cryptosporidium, Giardia, and microsporidia), radioactivity, inorganic compounds (mercury, nitrate, arsenic), and organic compounds (atrazine, PCBs, PBDEs). The water microbiology section of the WSLH currently has molecular capabilities to analyze for human adenovirus and distinguish between bovine and human *Bacteroides* spp. as part of the laboratory's toolbox approach to microbial source tracking in groundwater.

In addition to routine testing of fecal indicators and emerging contaminants, the WSLH now employs a "toolbox" of microbial and chemical source-tracking assays. Microbial and chemical source tracking is used to determine sources of fecal contamination in water, whether from human or animal sources, using multiple microbial and chemical agents. The data are then used for making management decisions regarding control of fecal pollution of groundwater.

Another important focus of the WSLH is emergency response to incidents involving groundwater. For example, WSLH works with the DHS and the DNR to investigate outbreaks of illnesses of unknown (possibly food or water) origin. Staff provides background information on the outbreaks for local public health officials, local media, and the general public. WSLH also responds to spills and incidents and supports state agencies in remediation and emergency cleanup activities.

WSLH also provides educational and outreach activities related to groundwater and drinking water including (1) instructional consultations for well owners and well drillers,

(2) assistance and consultation for municipal water supply operators, and (3) tours for a variety of international, educational, regulatory, and governmental groups. Staff members have developed publications related to drinking water, including a well water activity sheet, "Test your well water annually" brochure, and other well water testing promotional materials. Staff members present papers at a variety of conferences and symposia and publish research findings in professional journals.

Summary of Groundwater-Related Work at WSLH

Organic Chemistry Section

- The State Laboratory has developed and is validating methods for measurement of PFAS chemicals in various matrices, including groundwater/drinking water. Significant coordination with state and federal partners occurs to ensure appropriate certifications are in place, which PFAS compounds to focus on, and matrix specific challenges such as limits of detection. As with many labs, capacity challenges exist so better and quicker ways to measure PFAS are continually being pursued. The State Laboratory is happy to partner with others and share information as appropriate to collectively advance understanding about these issues.
- Interpretation of GC-MS and LC-MS analysis of petroleum compounds is done to aid in fingerprinting possible sources of contamination. Other source tracking tools and lists of compounds (human sources, animal sources) are also provided to assist in understanding source, fate, and transport of contaminants.
- Analysis of pharmaceuticals, personal care products, and antibiotics as tools to indicate pollution from humans and animals. This analysis in conjunction with the Microbial Source Tracking "Toolbox" is used to support various activities toward groundwater protection and management.

Chemical Emergency Response Section

- The WSLH serves as the only public health emergency preparedness-supported chemical response laboratory in Wisconsin. The lab has extensive capabilities for testing human exposures to priority chemical agents, provides sampling materials and guidance for first responders, including hazardous material, drinking water, and natural resource entities, and performs any needed testing of environmental samples related to chemical incidents. One facet of this support has been the development of a drinking water collection kit, tailored to allow appropriate collection for assessing a wide range of chemical and microbiological contaminants in drinking water. These kits have been provided to all drinking water utilities serving more than 3,000 people, as well as to public health and other appropriate agencies. The emergency kit was deployed in 2018 to assist in characterizing a possible contamination and the system worked as designed.

Water Microbiology Section

- 2020 and 2021 saw the WSLH performing significant work with Sars-CoV2 (COVID) in wastewater. This work was and continues to be a joint effort between the water microbiology section and environmental toxicology. COVID in wastewater has been a useful tool for communities to understand levels of the virus on a community level, thus indicating overall levels or trends of the virus on a broader scale.
- Source assessment requirement under the Revised Total Coliform Rule - WSLH continues to implement a scientifically based well assessment for wells testing positive for coliforms. This project is to develop and test a suite of microbial

organisms that can determine the source of contamination by collecting a large volume sample using a hollow fiber ultra-filtration system.

- WSLH is researching changes to the fecal source tracking toolbox by implementing species-specific PCR assays for human, bovine, swine, and poultry Bifidobacteria; improving the PCR primer sets for human and bovine Bacteroides spp.; and determining the feasibility of using pepper mild mottle virus to determine human contamination in groundwater. The research includes collecting fecal samples from animals throughout the state to determine sensitivity and cross reactivity for microbial sources of contamination.
- As a part of a larger laboratory-wide preparedness program, WSLH is prepared to offer appropriate microbial water quality testing when needed. WSLH is a member of the Environmental Response Laboratory Network and the Water Laboratory Alliance for both chemical and biological response. This involves participation in nationwide preparedness drills coordinated by the Centers for Disease Control and Prevention in conjunction with the U.S. Environmental Protection Agency.
- The WSLH Flow Cytometry Unit coordinates and distributes samples for the only Cryptosporidium Proficiency Testing Program (PT) available in the United States. This WSLH program supports environmental laboratories testing water samples for the presence of this parasitic protozoan under the Long Term 2 Enhanced Surface Water Treatment Rule. The program has been designed to provide water-testing laboratories and accreditation agencies with a means of assessing a laboratory's performance of U.S. EPA Method 1622/1623. The program is accredited under ISO 17043 "general requirements for proficiency testing" and distributes samples twice annually. The program operates with support from the WSLH Water Microbiology Department, which evaluates the robustness of the parasites suspensions prior to and following distribution to participant laboratories.
- The Water Microbiology Section of the WSLH Environmental Health Division has developed a suite of testing and sampling methods called Large Volume Sampling (LVS) that is designed to detect organisms that can be present in low concentrations.

Inorganic Chemistry Section

- Instrumentation is in place to measure isotopic ratios of certain metals (i.e. lead) to identify the source of the particular metal, be it the source, piping, etc. Each case is different, but it is possible to deploy this technology to better elucidate the source of a metal in drinking water or other matrices. Lead and mercury are good candidates for testing in these regards. Radium in groundwater is another candidate for the application of a potentially better tool.
- A variety of nutrients are routinely measured in drinking water, surface water, and groundwater. People with health concerns regarding their drinking water, such as nitrates, can submit samples for evaluation. Results are sent to the clients and the DNR for their database. The DHS has worked with WSLH at the county level to provide drinking water kits to families with newborns to monitor for nitrates in well water.
- Most types of metals are also measured. Those of health concern and public interest, such as arsenic and hexavalent chromium, are important in monitoring because they have been associated with specific geological formations and conditions in northeastern Wisconsin.
- Ancillary inorganic tests are routinely performed to measure chloride, sulfate, pH, alkalinity, and conductivity—properties that are important in controlling the chemical conditions for groundwater systems.

- As with other sections of the WSLH, the Inorganic Section responds to both spills that would affect surface water and groundwater. The lab has worked extensively with both DNR and DHS to identify contaminants in well water that may have had surficial origins. The WSLH recently has added multi-collector ICPMS instrumentation that can be used to measure isotopic fingerprints of metals to source-track their origin.
- The inorganic section has a dedicated trace-level clean lab that routinely measures metals or elements in water at the parts per trillion (ppt) ranges for unique applied low-level research questions and monitoring.
- The WSLH works with and receives samples from the U.S. Geological Survey, researchers at UW campuses, and the Wisconsin Geological and Natural History Survey on specialized groundwater projects. The lab also routinely measures samples from drinking water utilities that rely on groundwater.

For more information on the WSLH:

Visit the website <http://www.slh.wisc.edu/>

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DEPARTMENT OF SAFETY AND PROFESSIONAL SERVICES

Within the Division of Industry Services, two programs have the responsibility of safeguarding public health and the waters of the State. The General Plumbing Program regulates plumbing installations including graywater reuse, stormwater plumbing systems, cross-connection controls and household water treatment devices. Private on-site wastewater treatment systems that receive domestic wastewater and discharge to the subsurface are regulated by the Private On-site Wastewater Treatment Systems (POWTS) Program.

FY 2021 Highlights

- Counties are operating a maintenance program for all POWTS in their jurisdiction.
- The Department continued offering training programs for the POWTS industry despite not being able to meet in person. These programs were offered using virtual meeting platforms.

Details of Ongoing Activities

Plumbing – Reuse, Stormwater and Private Onsite Wastewater Treatment Systems (POWTS)

In addition to public health and safety, the water supply and quality issues facing Wisconsin are a focus of the General Plumbing and POWTS programs in the Department of Safety and Professional Services.

General Plumbing – Reuse and Stormwater Use

The Department plumbing code includes standards for reuse of wastewater and stormwater. Currently, the Chapter SPS 382 stormwater rules create the ability for

plumbing to be integrally involved with the design and installation of storm systems complying with Chapter NR 151, Wis. Admin. Code. At this time, there are over 315 approved stormwater use or wastewater reuse plumbing systems in Wisconsin.

Private Onsite Wastewater Treatment Systems (POWTS)

The Department maintains regular contact with the Department of Natural Resources regarding mutual issues of interest such as large onsite sewage systems, mixed wastewater treatment systems, Underground Injection Control (UIC) regulations, septage disposal and water well regulations. The Department also communicates with the US EPA Region 5 office regarding POWTS related matters. Department staff participate when requested in the development of a regional and national model code related to on-site sewage systems.

Data Management

DSPS is continuing its data integration information technology (IT) initiative called eSLA which stands for the Electronic Safety and Licensing Application. The POWTS program was involved with Phase 1 of the initiative which was rolled out in fall of 2018. The General Plumbing program was part of Phase 2 rolled out in June of 2019. The database also stores information on activities associated with on-site sewage system design, installation and maintenance. The Department is working with county code administrators and POWTS industry members to upgrade the reporting and recording of inspection, maintenance and servicing events for onsite sewage systems. The department promulgated a rule revision in late 2008 that implements POWTS program related provisions contained in 2005 Wisconsin Act 347 and further modified in 2011 by Wisconsin Act 134. The revised rule required that counties conduct an inventory by October 1, 2017, to identify all POWTS within their jurisdictional areas. With inventories maintained, Counties are required to further maintain a reporting program related to inspection, maintenance and servicing events for all POWTS in their jurisdiction.

For further information:

Visit the following web site: <https://dsps.wi.gov/pages/Home.aspx>

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REPORT OF THE GOVERNOR'S REPRESENTATIVE

Steve Diercks, Coloma, WI

As a potato and vegetable grower and the Governor's Representative on the Wisconsin Groundwater Coordinating Council, I am happy to report that the Wisconsin Potato & Vegetable Growers Association (WPVGA) continues to collaborate with multiple stakeholders to achieve sustainable groundwater quantity and quality.

Wisconsin's Central Sands region remains one of the most productive irrigated vegetable areas in the United States with top three rankings for potatoes, sweet corn, green beans,

peas, carrots, beets for canning and cabbage for kraut. This production, which is valued at nearly \$6 billion annually would not be possible without irrigation. At the same time, concerns have been raised over the potential impact of irrigated agriculture on the groundwater aquifer and surface waters of the Central Sands. In response, the WPVGA continues to bring together the people, organizations and expertise to foster the sustainable use of water resources. It is an example of collaboration involving GCC member agencies and the agriculture industry.

Voluntary conservation practices, groundwater monitoring, state-of-the-art technology and applied research are the focal points of the WPVGA's efforts. The Association continues to engage in activities that consolidate and build on the existing knowledge-base related to the hydrogeology of the Central Sands. Among these activities are the following:

Collaboration with the Village of Plover, the Wisconsin Wetlands Association, the Wisconsin Wildlife Federation, Wisconsin DNR, UW-Stevens Point, and others on the Little Plover River Watershed Enhancement Project (LPRWEP). This multi-party collaboration will improve the health and flow of the Little Plover River (LRP) and the quality of life of the surrounding community. The WPVGA recognizes that restoring the health of the river requires an array of on-the-ground practices and voluntary landowner participation, and is committed to utilizing a combination of protection, restoration and management practices that will ensure the project's success.

In cooperation with the DNR, the WPVGA continues to collect and post data from over 25 monitoring wells to continuously track fluctuations in groundwater at regular intervals across three areas designated as high risk for surface water impacts (Little Plover River/Plover area, Long Lake/Plainfield area, and Pleasant Lake/Coloma area). Groundwater elevations are posted at <https://wisa.cals.wisc.edu/> every three weeks. The DNR received permission from the WPVGA to conduct the data collection and posting from the monitoring wells in the Plainfield and Coloma areas as part of the Central Sands Lakes Study component of 2017 Wisconsin Act 10, related to the potential impacts of groundwater withdrawals on three lakes in the Central Sands. This spring, the DNR released their findings, which included a recommendation for the creation of a water management district throughout the entire Central Sands. They also identified precipitation as the primary factor affecting the fluctuation of lake levels. All three lakes included in the study, Long Lake, Plainfield Lake and Pleasant Lake, are presently several feet above their historic median levels.

Ongoing collaboration on a research project with the UW Atmospheric and Oceanic Sciences Department looking at newer, more accurate and advanced methods of measuring evapotranspiration (ET). This project is being led by Dr. Ankur Desai and uses the latest technology of an eddy covariance flux tower system to measure ET in an irrigated vegetable field as well as using another flux tower system to measure ET in a nearby forest. Research results are being shared with growers to assist them in their irrigation management and scheduling regimes. Three years of data show that the ET rates are higher (reflecting greater water use) in the pine forest than the irrigated vegetable field. The DNR is also using this information from the Desai lab to accomplish tasks related to the lakes study component of 2017 Wisconsin Act 10.

Funding software maintenance to keep the Wisconsin Irrigation Scheduling Program (WISP) and the Agricultural Weather Data Service operational. Work is being conducted at the direction of John Panuska at the UW Biological Systems Engineering Dept. The existing WISP software tracks a daily soil water balance to assist growers with irrigation

water management. The Desai lab is also working with the Biological Systems Dept. to fine tune the WISP ET calculations.

Maintaining and monitoring a network of privately-owned irrigation wells in the Central Sands to measure groundwater fluctuations. The network currently consists of over 50 wells across multiple Central Wisconsin counties sampled one to three times/year. The database is maintained by GZA GeoEnvironmental, Inc., and information is available on the WPVGA website (www.wisconsinpotatoes.com).

The WPVGA continues to collaborate with the University of Wisconsin and the DNR on a new initiative to recognize and reward water conservation. The Wisconsin Water Stewards Program establishes a baseline of water stewardship practices and assists growers in making continuous improvements in the area of water conservation. Growers have access to a broad range of expertise to help determine the best way to manage and conserve water resources on their individual farms. This has also become a component of the WPVGA's high-bar sustainability program known as Healthy Grown.

The WPVGA funds several applied research projects led by Dr. Yi Wang, UW Professor of Horticulture, and Dr. Matt Ruark, UW Professor of Soil Science, looking at nitrate concentrations in irrigation water as well as evaluating the performance of multiple potato varieties in low nitrogen environments. The research results will provide important information for growers to help them develop improved nutrient management programs that account for nitrogen being applied in the irrigation water, along with new varieties that use less nitrogen. This research also includes the study of slow release nitrogen products with a goal of reducing nitrate leaching into groundwater.

In 2021, four WPVGA farms will conduct on-farm research trials related to N use efficiency under the direction of Dr. Wang and Dr. Ruark. Each farm will use multiple N rates on three different potato varieties to identify varieties that perform well under low N rates.

Also in 2021, the WPVGA was successful in receiving a Producer-Led Watershed Protection Grant from the Wisconsin Dept. of Agriculture, Trade and Consumer Protection. Six member farms are participating in the project which is located in the Little Plover River/Wisconsin River watershed. Called the Central Wisconsin Farmers Collaborative, the group seeks to promote innovative conservation and stewardship practices that benefit the watershed, the landscape, and the land managers themselves through collaborative partnerships, farm-to-farm education programs and other strategic actions.

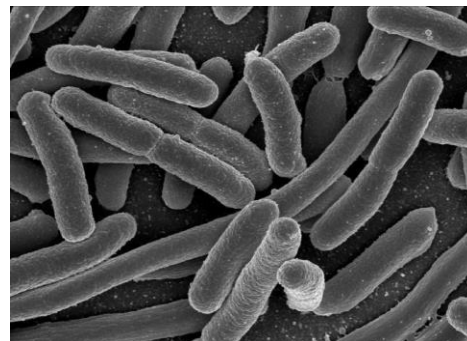
The WPVGA is partnering with Discovery Farms Wisconsin on a producer-led project in the Antigo Flats, an area of 70,000 acres in north central Wisconsin. The project is interested in documenting Phosphorus (P) loss from runoff events, learning about stream flow, reducing P loads to the Spring Brook and Eau Claire River watersheds and evaluating the impact of in-field actions on water quality. Two edge-of-field surface monitoring sites are located in Langlade County on seed potato operations.

All of these WPVGA initiatives are working toward sustainable groundwater quantity and quality through evaluating and implementing strategies to increase the efficiency of irrigation and crop production while conserving the amount of water used and maintaining or improving water quality.

MICROBIAL PATHOGENS

What are they?

Pathogens are organisms or other agents that can cause disease, including microorganisms such as bacteria, viruses and protozoa that can cause waterborne disease. Groundwater contamination by microbial pathogens can often be traced to human or livestock fecal wastes that seep into the ground from sources such as inappropriately constructed or failing septic systems, leaking sanitary sewers or improperly managed animal manure. Since it is difficult and expensive to test for all pathogenic microorganisms, water samples are usually tested for microbial “indicators” – microbes that are not necessarily harmful themselves, but are a warning sign that other, potentially pathogenic, microorganisms may be present.



E. coli, an indicator of fecal contamination. Photo: NIAID

Microorganisms are prevalent and abundant in the subsurface and in groundwater (Griebler and Lueders 2009). The United States Geological Survey (USGS Michigan Water Science Center) reports that “Most of the bacterial types found in soils and surface waters have also been found in shallow unconfined and confined aquifers”. Virus abundance in an alluvial aquifer in Colorado has been reported as ranging from 80,000 to 1,000,000 cell count per milliliter (Pan et al. 2017). A similar result of on average 71,700 of virus-like particles per milliliter was found for a shallow aquifer in Australia (Roudnew et al., 2013). In that study, in the underlying confined aquifer, with groundwater that entered the subsurface at least 1000 years ago, even higher virus-like particle concentrations were found, averaging from 48,200 virus-like particles per milliliter at 90 meters (295 feet) depth to 883,000 virus-like particles per milliliter at 60 meters (196 feet) depth. While most microorganisms in the subsurface are harmless, pathogenic microbes from human and animal waste sources can be significant sources of groundwater contamination in areas where they can be readily transported to underground drinking water supplies.

There are no groundwater standards for pathogenic microorganisms in Wisconsin, but standards have been established in ch. NR 140 for total coliform bacteria, a microbial pathogen indicator. Both the ch. NR 140 preventive action limit (PAL) and enforcement standard (ES) for total coliform bacteria are zero coliform bacteria present in a tested sample. Public drinking water systems are regularly monitored for total coliform bacteria ([WI NR 809.31-809.329](#)) these systems may also be tested for fecal indicators such as *E. coli*, enterococci or coliphages if coliform bacteria are found.

In 2016 the Environmental Protection Agency (EPA) changed its rules related to the use of microbial pathogen indicators in the regulation of public drinking water systems. In 2016 the EPA's Revised Total Coliform Rule (RTCR) for public drinking water systems went into effect. Prior to the RTCR, there was a drinking water maximum contaminant

level (MCL) for total coliform bacteria in public drinking water systems. Under the RTCR the total coliform bacteria MCL was removed and replaced with a total coliform treatment technique (TT). If total coliform bacteria are confirmed present in a public drinking water system the total coliform TT requires system assessment and corrective action.

The EPA also established a drinking water MCL for *E. coli* bacteria under the RTCR. Detection of *E. coli* bacteria is considered a more specific indicator of fecal contamination, and the possible presence of harmful pathogens, than just detection of total coliform bacteria. This is because coliform bacteria of both fecal and non-fecal origin exist, and total coliform testing detects any coliform, regardless of its origin. Under the RTCR there is no MCL violation for total coliform bacteria positive samples only, but if *E. coli* indicator bacteria are confirmed present in a public drinking water system there is an MCL violation.

The presence of *E. coli* bacteria in a drinking water supply indicates possible exposure to pathogens, potentially resulting in serious, acute health effects. Detection of *E. coli* bacteria in a public water supply system is considered an immediate public health issue and public notification is required. That notification informs the consumer of the public health threat, and instructs the consumer to either boil water from the public water supply before consuming, or to use bottled water. An assessment of the integrity of the water supply system is also required, with correction of any sanitary defects found.

Coliforms are a broad class of bacteria that are naturally present in the environment and are used as an indicator that other potentially harmful microorganisms may be present. Total coliforms, with a few exceptions, are not harmful to humans. Coliforms are abundant in the feces of warm-blooded animals, but can also be found in aquatic environments, soil, and on vegetation. *E. coli* bacteria are a type of coliform bacteria that serve as a fecal indicator in drinking water. Fecal indicators, such as *E. coli*, enterococci and coliphages, are microbes whose presence more specifically indicates that water may be contaminated with human or animal wastes. Pathogenic microorganisms in drinking water can make people very sick and can result in death. Common symptoms include diarrhea, cramps, nausea and headaches. Microbial contamination may pose a special health risk for infants, young children, the elderly and people with severely compromised immune systems.

Microbial pathogen contamination is of particular concern in public water systems, because a large number of people can be exposed to contamination in a short amount of time. In 1993, pathogen contamination at Milwaukee's surface water-sourced drinking water system resulted in 69 deaths and more than 403,000 cases of illness before the epidemic and its source were recognized. In 2007 an outbreak of norovirus, caused by contaminated well water, sickened 229 diners and staff at a Door County restaurant (Borchardt et al. 2011).

Antibiotic resistance, associated with subsurface microorganisms, may also be a significant groundwater contaminant in some situations. Use of antibiotics can result in

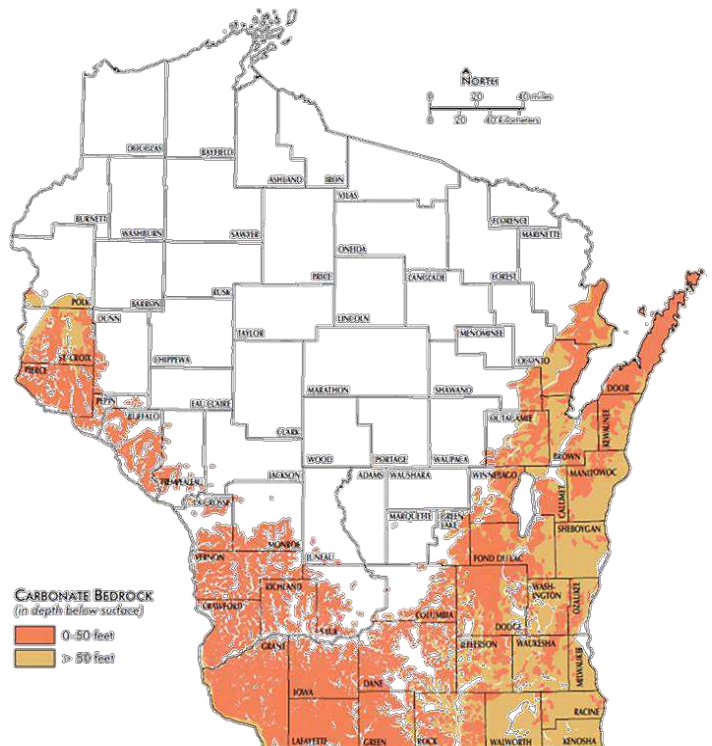
antibiotic resistance (ineffectiveness of antibiotics in treating infections) spreading into the environment. Groundwater monitoring around swine lagoons in Illinois found that antibiotic resistant genes, associated with lagoon leakage, were present in groundwater (Krapac et al. 2004). In a study of manure at a Wisconsin dairy farm, Walczak et al. (2011) isolated *E. Coli* bacteria that were resistant to four different antibiotics (cephalothin, ampicillin, tetracycline, and erythromycin). The *E. Coli* populations in the manure multiplied on average by about 15 after three days. *E. Coli* may be leached from manure and this might lead to spread of antibiotic resistance to groundwater.

Occurrence in Wisconsin

In Wisconsin, it is well known that groundwater in areas with karst geology – soluble carbonate bedrock, with many large fractures through which water flows rapidly, sometimes with karst surficial features, such as sinkholes, caves and disappearing streams present – is vulnerable to microbial contamination and needs special consideration and protection. In these areas, particularly where there is also thin soil cover and shallow groundwater levels, there is little opportunity for soil to slow and attenuate the transport of microbes. This results in a greater risk that viable pathogens may reach water supply wells. Soluble carbonate bedrock with karst potential can be found in some parts of the state. Door County and parts of Kewaunee County are especially vulnerable since these areas additionally have very thin soils. An estimated 17% of private water supply wells statewide test positive for total coliform bacteria (Knobeloch et al., 2013). Sampling of private water supply wells in Kewaunee County (Kewaunee Co., 2014) has suggested that, in some parts of the county, wells are testing positive for total coliform bacteria at percentages much higher than the statewide average.

A more recent, emerging concern is the potential presence of viruses in drinking water wells, including norovirus, adenovirus and enterovirus. Virus contamination may not necessarily correlate well with total coliform bacteria detection in groundwater (Borchardt et al., 2003b) because viruses have different transport properties than bacteria.

Viruses may be detected in water samples using cell culture methods that measure the



Karst potential in Wisconsin. Areas with carbonate bedrock within 50 feet of the land surface are particularly vulnerable to groundwater contamination.

Figure: [WGNHS](#)

cytopathic effect of viruses grown on various cell culture media. Not all types of viruses are culturable, but molecular nucleic acid based methods, such as polymerase chain reaction (PCR), can be used to detect viral genetic material, even from nonculturable viruses. Molecular nucleic acid based methods such as PCR, however, cannot distinguish between genetic material from viable, infectious viruses and genetic material from inactivated, nonviable viruses (Donia et al., 2009).

Research studies, utilizing PCR methods, have detected human enteric virus genomic material in both public and private wells in Wisconsin (Borchardt et al., 2003a, 2004, and 2007). There is limited statewide groundwater virus occurrence data since testing for viral genomic material is expensive, not routinely performed, and levels cannot be reliably inferred from total coliform results. In cities where such studies have been conducted, such as La Crosse and Madison, it has been suggested that transport of viruses from municipal sewer systems to groundwater supplies may be occurring and that this transport might be very rapid (Hunt et al., 2010; Bradbury et al., 2013). These studies suggest that viral contamination of groundwater could potentially occur at other municipal water systems because municipal wells are generally completed in areas with sanitary sewers.

The risk of finding pathogens in groundwater is seasonably variable but typically highest following spring snowmelt or large rainstorms that generate runoff, since these events can create large pulses of water that move quickly through the ground, potentially carrying microbes from septic systems, sewer mains and manure sources (Uejio et al., 2014). Nutrient management plans can help reduce the risk of contamination due to manure spreading, but even with the best manure management practices it is difficult to eliminate occurrences. Over 60 private wells have had to be replaced since 2006 due to manure contamination, at a cost to the state of over \$500,000 (Source: DNR Well Compensation Fund records).

There is evidence that disinfection with chlorine or ultraviolet light may reduce the risk of illness from viruses and other microbial sources (Borchardt et al., 2012; Lambertini et al., 2012; Uejio et al., 2014). Continuous disinfection is not dependent on indicator tests to protect human health. Disinfection, however, is not required by law for public water systems that source their drinking water from groundwater. About 60 municipalities in Wisconsin do not disinfect their public water supplies.

GCC Agency Actions

Homeowner complaints about private well *bacterial* contamination events, which often correspond with manure spreading, are an ongoing concern for GCC agencies.

Unfortunately, the standard methods for testing for bacteria do not show whether the bacteria are derived from human or animal sources and until 2007 there were no readily available methods for testing for manure.

Funding from the Wisconsin Groundwater Research and Monitoring Program (WGRMP) has supported the development of laboratory techniques that have made it possible to discern

whether bacteria are from human, animal or other sources (Pedersen et al., 2008; Long and Stietz, 2009). These microbial source tracking (MST) tools include tests for *Rhodococcus coprophilus* (indicative of grazing animal manure), *Bifidobacteria* (indicative of human waste) and *Bacteroides* (indicative of recent fecal contamination by either humans and/or grazing animals). An analysis can successfully detect bovine adenoviruses to indicate bovine fecal contamination of groundwater (Sibley et al., 2011).



Dr. Sam Sibley, UW-Madison Department of Soil Science, collects a well water sample from a residential home to analyze using new MST tools. Video story at: <https://youtu.be/dpE58Rd4i4E>. Photo: Carolyn Betz, [UW ASC](#)

The DNR has been using these tools as they become available to determine the source of fecal contamination in private wells. DNR's Drinking Water & Groundwater and Runoff Management programs are working with the DATCP nutrient management program to find ways of controlling this major source of contamination. The DNR, in conjunction with DATCP, are working on revised performance standards and prohibitions related to manure land application in areas of the state with carbonate bedrock and shallow soils.

The DNR developed a rule mandating disinfection of municipal drinking water but this was repealed by the state legislature in 2011. Nationally, the EPA included virus types found in Wisconsin studies on the list of 30 unregulated contaminants that were monitored from 2013 to 2015 in 6,000 public water systems across the United States to gather information to support future drinking water protection. In that

sampling, the Unregulated Contaminant Monitoring Rule 3 (UCMR-3) sampling effort, the presence of enterovirus was evaluated using microbial culture methods, and the presence of enterovirus and norovirus genetic material was evaluated using PCR methods. No enteroviruses, or enterovirus or norovirus genetic material, was reported detected in Wisconsin under the UCMR-3 sampling effort.

Future Work

Improving best practices for well construction in the vulnerable karst areas of the state is an ongoing topic of concern. In addition to the potential threat to health posed by manure sources, there are indications that inadequately constructed and maintained septic systems and leach fields could also be sources of microbial groundwater contamination and therefore detrimental to public health and the environment in areas where wells draw from shallow carbonate aquifers. This points to a need to revise the requirements for the construction of private water wells in these areas.

Most of the current data on bacterial contamination in Wisconsin is derived from private well samples. However, public drinking water systems that disinfect their water supplies are also required to sample quarterly for bacteria from the raw water (before treatment) in each well. The DNR began tracking total coliform detects in the raw water sample through its Drinking Water System database, so evaluation of this monitoring data from public wells may enhance understanding of statewide bacterial contamination. This understanding would be further enhanced by an analysis of the equivalence and positive predictive value of the laboratory methods (PCR kits, testing protocols) used to measure concentrations of bacteria and bacterial indicators in groundwater.

There are unanswered questions about viruses in drinking water as well. While previous work has suggested that municipal sanitary sewers may be potential sources of viruses in groundwater, the exact mechanism of entry in cities like Madison is unknown and cannot be explained by normal assumptions about hydrogeology. A study funded by the Wisconsin Groundwater Research and Monitoring Program investigated whether the rapid transport of viruses between the shallow and deep aquifers in Madison can be explained by vertical fractures in the shale layer that separates them. More research is needed on the transport and survival times of various viruses in groundwater aquifers.

Finally, additional public health studies where clinical samples and water samples are collected simultaneously, such as those conducted by GCC researchers in La Crosse, are needed to better describe the relationship between cause of illness and groundwater pathogens.

Further Reading

[DNR overview of bacteriological contamination in drinking water](#)

[DNR overview of cryptosporidium in drinking water](#)

[DHS fact sheet on manure contamination of private wells](#)

[WGNHS overview of karst landscapes](#)

[WGNHS report on municipal drinking water safety](#)

[DNR list of municipal drinking water systems that disinfect](#)

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Pumping test at one of Madison's municipal wells, part of a WGRMP-funded study to enhance understanding of fractures and virus transport. *Photo: Jean Bahr*

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NITRATE

What is it?

Nitrate (NO_3) is a water-soluble molecule that forms when ammonia or other nitrogen rich sources combine with oxygen. The concentration of nitrate in water is often reported as “nitrate-N” which reflects only the mass of nitrogen in the nitrate (ignores the mass of oxygen). Nitrate levels in groundwater are generally below 2 parts per million (as nitrate-N) where pollution sources are absent. Higher levels indicate an anthropogenic source of contamination such as agricultural or turf fertilizers, animal waste, septic systems or wastewater.



Flooded field after manure spreading. Nutrient application on agricultural fields accounts for 90% of nitrate in groundwater. Photo: Marty Nessman, DNR.

What are the human health concerns?

The health-based groundwater quality enforcement standard (ES) for nitrate-N in groundwater and the maximum contaminant level (MCL) for nitrate-N in public drinking water are both 10 ppm ([WI NR 140.10](#), [WI NR 809.11](#)). Everyone should avoid long-term consumption of water containing nitrate above this level.

Infants below the age of 6 months who drink water containing nitrate in excess of the MCL are especially at risk, and could become seriously ill with a condition called methemoglobinemia or “blue-baby syndrome”. This condition deprives the infant of oxygen and in extreme cases can cause death. The DHS has associated at least three cases of suspected blue-baby syndrome in Wisconsin with nitrate contaminated drinking water (Knobeloch et al., 2000). In children, there is also growing evidence of a correlation between nitrate and diabetes (Moltchanova et al., 2004; Parslow et al., 2007).

Birth defects have also been linked to nitrate exposure. Several epidemiological studies over the past decade have examined statistical links between nitrate exposure and neural tube birth defects (e.g., Brender et al., 2013). Some, but not all, of these studies have concluded there is a statistical correlation between maternal ingestion of nitrates in drinking water and birth defects. Further work, including a clear animal model, would be needed to conclusively demonstrate causation. Nonetheless, these studies collectively indicate an ongoing need for caution in addressing consumption of nitrates by pregnant women and support the continuation of private well testing programs for these women.

In the human body, nitrate can convert to nitrite (NO_2) and then to N-nitroso compounds (NOC's), which are some of the strongest known carcinogens. As a result, additional human health concerns related to nitrate contaminated drinking water include increased

risk of non-Hodgkin's lymphoma (Ward et al., 1996), gastric cancer (Xu et al., 1992; Yang et al., 1998), and bladder and ovarian cancer in older women (Weyer et al., 2001).

The Wisconsin Department of Health Services (DHS) also highlights thyroid disease and colon cancer as additional health concerns and states, "When nitrate levels are high, everyone should avoid long-term use of the water for drinking and preparing foods that use a lot of water."

Biotic effects

Adverse environmental effects are also well documented. Loss of biodiversity in terrestrial and aquatic systems has been documented with increasing nitrate. (Vitousek, P. M., et al. 1997) A number of studies have shown that nitrate can cause serious health issues and can lead to death in fishes, amphibians and aquatic invertebrates (Camargo et al., 1995; Marco et al., 1999; Crunkilton et al., 2000; Camargo et al., 2005; Smith et al., 2005; McGurk et al., 2006; Stelzer et al., 2010). This is significant because many baseflow-dominated streams (springs, groundwater-fed low-order streams) in agricultural watersheds in Wisconsin can exhibit elevated nitrate concentrations, at times exceeding 30 ppm. Groundwater and tile drain transported nitrate, along with urea and ammonium, also play a role in driving harmful algal bloom biomass trends and potential toxicity (Davis et al. 2015; Harke et al. 2016).

How widespread is elevated nitrate in groundwater?

Nitrate is Wisconsin's most widespread groundwater contaminant. Nitrate contamination of groundwater is increasing in extent and severity in the state (Kraft, 2003; Kraft, 2004; Kraft et al., 2008; Saad, 2008). A 2012 survey of Wisconsin municipal water-supply systems found that 47 systems have had raw water samples that exceeded the nitrate-N MCL, up from just 14 systems in 1999.

Increasing nitrate levels have been observed in an additional 74 municipal systems. Private water wells, which serve about one third of Wisconsin families, are at risk as well. Statewide, about 10% of private well samples exceed the MCL for nitrate-N, although one third of private well owners have never had their water tested for nitrate (Knobeloch et al., 2013; Schultz and Malecki, 2015). In agricultural areas, such as the highly cultivated regions in south-central Wisconsin, around 20%-30% of private well samples exceed the MCL (Mechenich, 2015). Nitrate concentrations are poised to further increase as nitrate pollution penetrates into deep aquifers and migrates farther from original source areas (Kraft et al., 2008).

In 2014 NR 812 code (Well Construction and Pump Installation) was changed to require sampling of newly constructed wells and wells with pump work for nitrates. This was in response to the DHS revised health recommendation that long-term use of water over



Nitrate is Wisconsin's most widespread contaminant, yet 33% of private well owners have never had their water tested for it. Photo: DNR

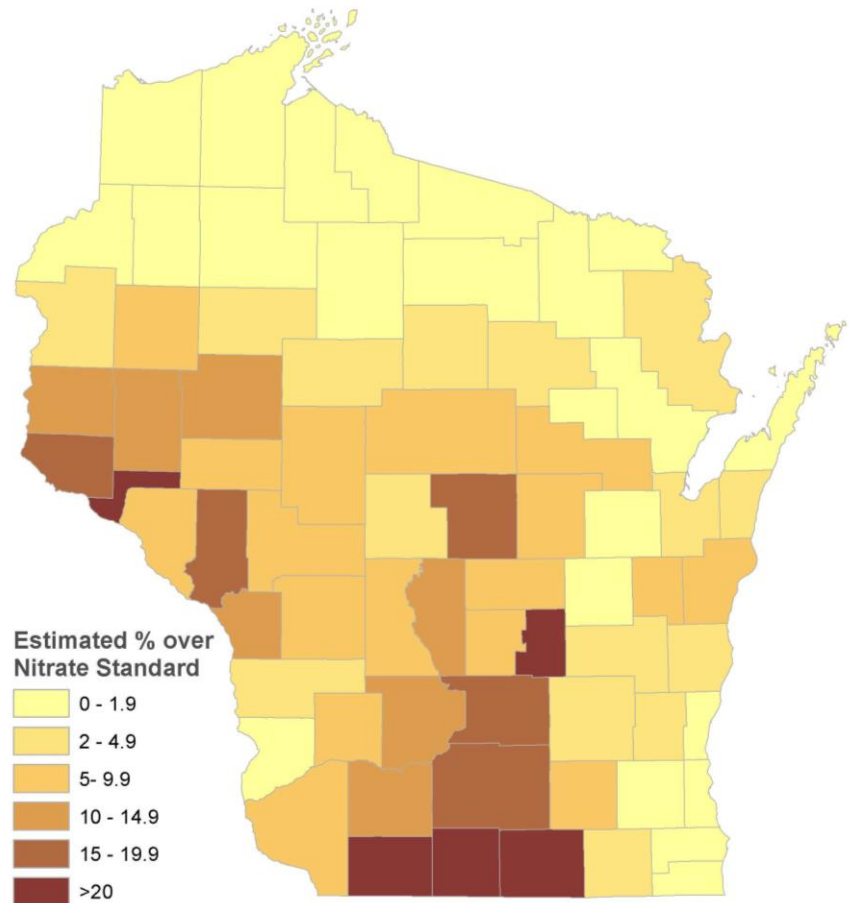
the standard by anyone poses a significant health risk. The nitrate sampling was also strongly supported by the Private Water Advisory Council. In 2020 for new well and pump work there were 17,029 samples taken. 1080 were greater than 10 ppm (6.3%).

Beginning in October of 2014 until late 2018 the department has received over 80,000 sample results. This last spring the department analyzed the data set. This is probably the least biased large data set available in Wisconsin. Overall 7% of sample results were greater than 10 ppm for nitrate. However, some counties have a much greater percentage of well testing above the 10 ppm standard. See map below for individual county results.

To obtain a safe water supply, private well owners may opt to replace an existing well with a deeper, better cased well or, if available, connect to a nearby public water supply. Owners of nitrate-contaminated private wells can qualify for the state well compensation grant program only if the nitrate-N level in their well exceeds 40 ppm and the water is also used to water livestock.

Alternatively, well owners may choose to install a water treatment system or use bottled water. In a survey of 1,500 families in 1999, the DHS found that few took any action to reduce nitrate exposure (Schubert et al., 1999). Of the families who took actions, most purchased bottled water for use by an infant or pregnant woman.

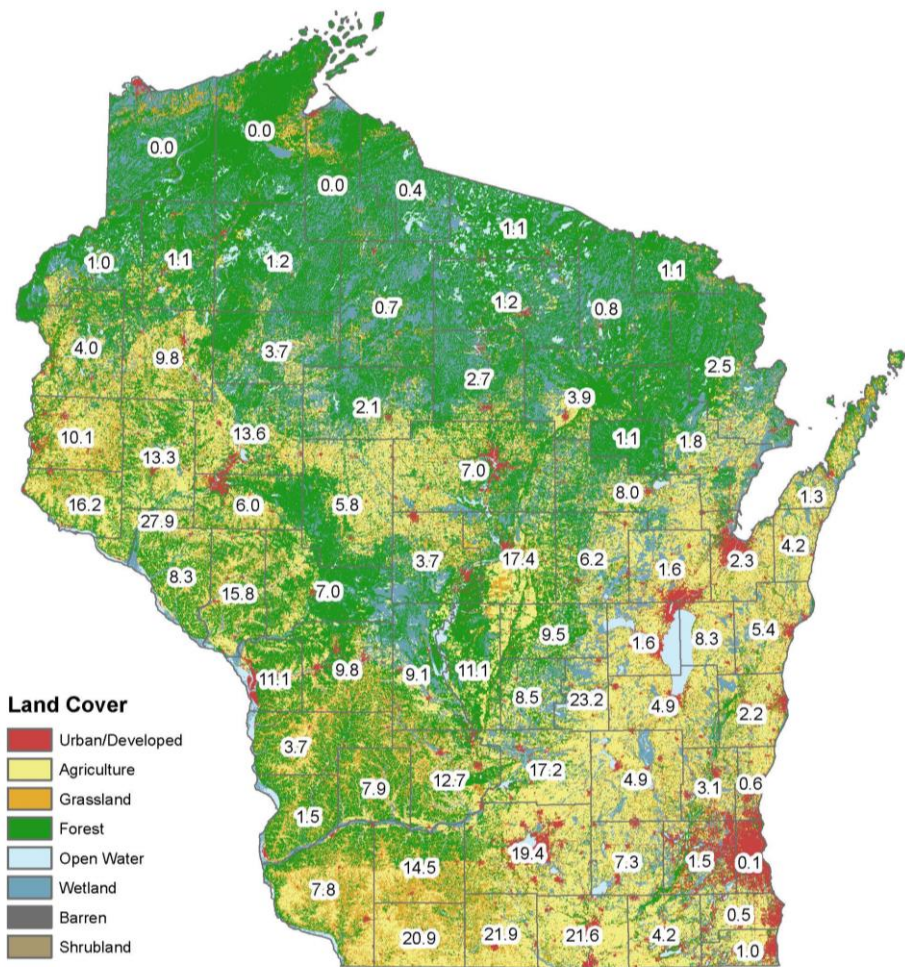
More recently, it appears that some private well owners in rural Wisconsin are installing reverse osmosis filter systems at considerable cost to obtain safe drinking water (Schultz and Malecki, 2015).



Map of Estimated Percentage of Private Wells over Nitrate Standard by County (October 2014 through April 2021).

What makes an area vulnerable to nitrate contamination?

The sensitivity of an aquifer to contamination, sometimes called “intrinsic susceptibility”, is a measure of the ease with which water enters and moves through an aquifer; it is a characteristic of the aquifer and overlying material and hydrologic conditions. The vulnerability of a groundwater resource to contamination depends on aquifer sensitivity in combination with a source of naturally occurring or anthropogenic contamination. Since the early 1990s, it has been well-accepted that around 90% of nitrogen inputs to groundwater in Wisconsin can be traced to agricultural sources including manure spreading and fertilizer application (Shaw, 1990). In a recently updated report, “Agricultural Chemicals in Wisconsin Groundwater, April 2017”, the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) and the Wisconsin Field Office of the National Agricultural Statistics Service (NASS) surveyed private wells and placed them into categories based on how intensively the surrounding land was cultivated for agricultural production. The survey found that overall, 8.2% of private wells in Wisconsin exceeded 10 mg/L for nitrate. However, marked differences in the

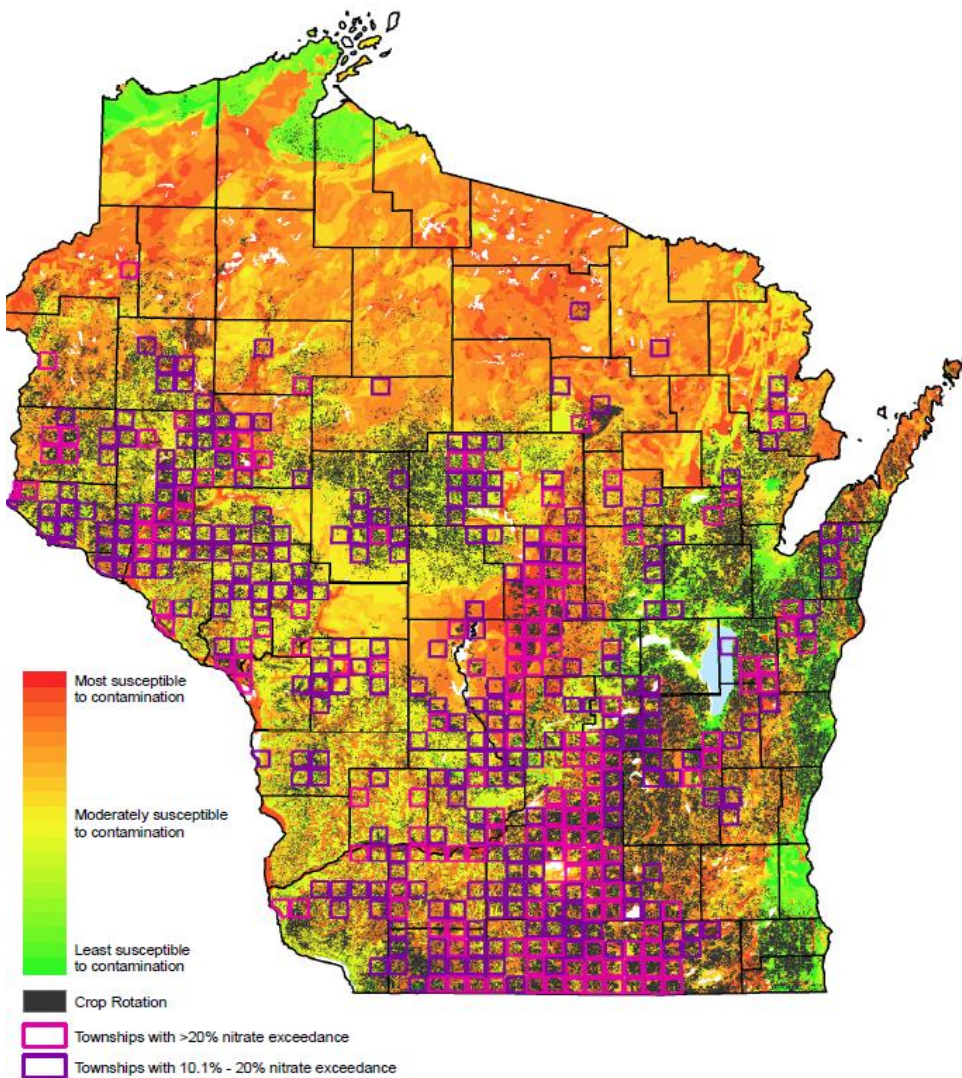


Map of Estimated Percentage of Private Wells over Nitrate Standard by County with Land Cover (October 2014 through April 2021).

percentage of wells over 10 mg/l were noted when grouping the data by surrounding agricultural intensity; the percentage increased from 1.7% when surrounding land was lightly cultivated to 20% of wells exceeding the health based standard when the surrounding land was greater than 75% cultivated (DATCP,2017).

Looking at a statewide scale, a simple plot of broad land use categories with the estimated percentage of private wells exceeding the health-based standard by individual counties also illustrates that more wells are impacted in agriculturally intensive areas of the state.

The dominant effect of land use in comparison to aquifer sensitivity is also illustrated when overlaying township level private well nitrate data and agricultural land use with the Groundwater Contamination Susceptibility Model (GCSM). The GCSM for Wisconsin was developed by WGNHS, WDNR, and the USGS and is intended to be used at broad scales. Five physical resource characteristics for which information was available were identified as important in determining how easily a contaminant can be carried through overlying materials to the groundwater. These factors are type of bedrock, depth to bedrock, depth



Sensitivity of Wisconsin's groundwater versus agricultural land use and nitrate impacts to private wells.

to water table, soil characteristics, and characteristics of surficial deposits (geologic materials lying between the soil and the top of the bedrock). Areas with sand and gravel are considered more sensitive to groundwater contamination; areas with silt and clay are considered less susceptible. When viewed at a statewide scale, many parts of the state with only moderate aquifer sensitivity have townships where greater than 10% and frequently greater than 20% of private wells exceed the health-based standard for nitrate in drinking water.

How is groundwater nitrate trending over time?

By analyzing a variety of data sources, evidence indicates that nitrate contamination of our groundwater resources has increased in more locations over time than have seen decreases.

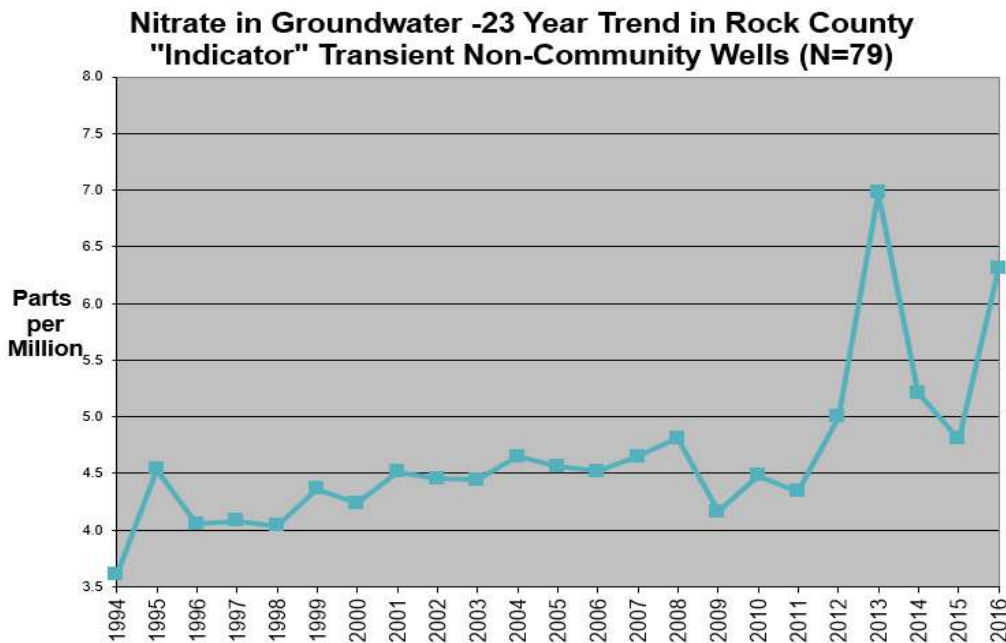
An assessment of overall statewide nitrate trends using existing private and public well data is challenging for several reasons. Fundamentally, public water data sampling is focused on the goal of providing water at the tap meeting required maximum contaminant levels (MCLs) and not to track changes in the groundwater resource over time. Private well sampling is conducted by a very low percentage of well owners in any given year and for those who do, their goal is getting information about the current condition of their water supply, not determining long-term changes in water quality of the resource itself. This leads to a large confidence interval in estimates of private wells above the nitrate standard and makes trends difficult to discern. What is needed is systematic repeated sampling of the same set of wells through time and this is rarely conducted in private wells. While public wells are required to regularly test and report results from a relatively stable set of wells, once they exceed the nitrate MCL the system is required by law to take action to come back into compliance with the MCL. The preferred action is to replace the well, thereby removing wells with increasing trends and biasing the public water dataset towards wells without increasing nitrate concentrations. In addition, both new private and public wells tend to be sited, drilled and cased to avoid known water quality issues such as nitrate contaminated groundwater. The result of these factors is that both private and public wells are not consistently sampling the "same" water or depths over time and are biased toward utilizing groundwater without contamination, making an analysis of the groundwater resource, comparisons over time and trend analysis difficult using these existing data sets.

One available data set with a large number of wells distributed across the state is the Safe Drinking Water Act compliance data set for non-community public wells (e.g. small businesses, schools, and churches). There are approximately 11,000 wells of this type active at any given time, and they are required to submit nitrate sample results to DNR at least annually. In review of the historical record of public supply well data since 1975, we find a relatively consistent number of wells exceed the 5 mg/L and 10 mg/L nitrate thresholds in any decade (i.e. about 18.3% of non-community water systems exceed 5 mg/L and about 6.5% exceed 10 mg/L). However, when looking at these public wells for the full period of record, there is a much larger set of wells represented (>20,000 wells) and the total number of wells exceeding these thresholds at any point in time is greater than in any discrete decade. Over the full record of the WDNR Public Water System database, approximately 21% of these wells exceeded 5 mg/L and approximately 8.3% exceeded 10 mg/L. Many of the nitrate impacted wells have dropped out of the data set over time. This is to be expected, as these are wells providing drinking water and subject to regulation to meet drinking water standards. The table below lists the MCL violation for nitrate over the last 5 years by well type.

Year	MC	OC	NN	TN
2015	3	6	12	18
2016	0	2	3	8
2017	3	4	15	27
2018	2	4	12	17
2019	3	2	8	22
2020	3	5	6	19

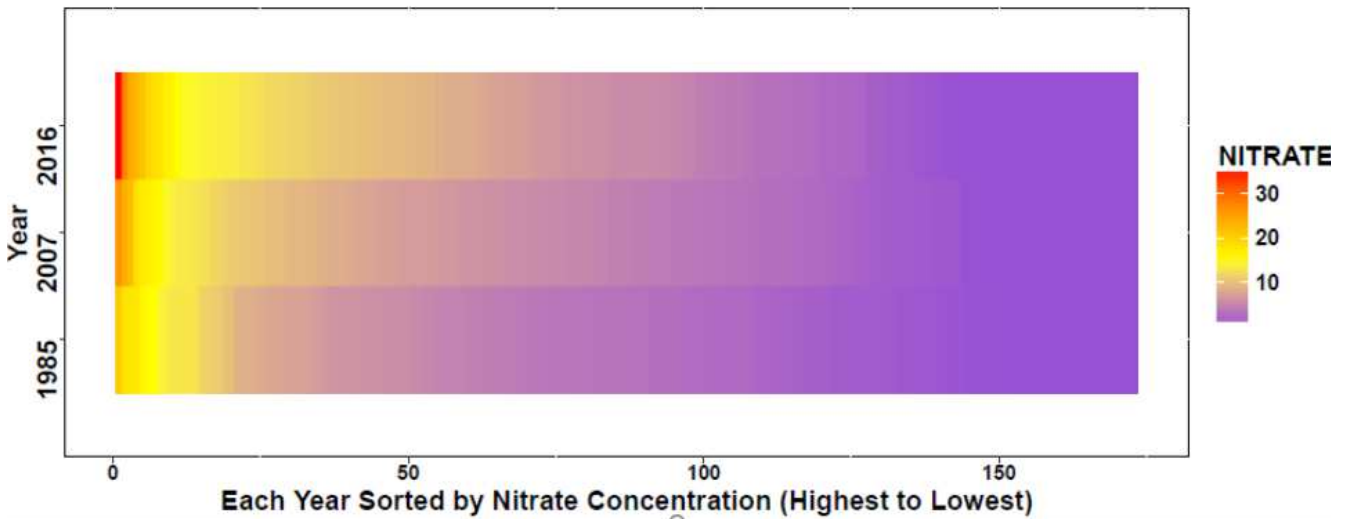
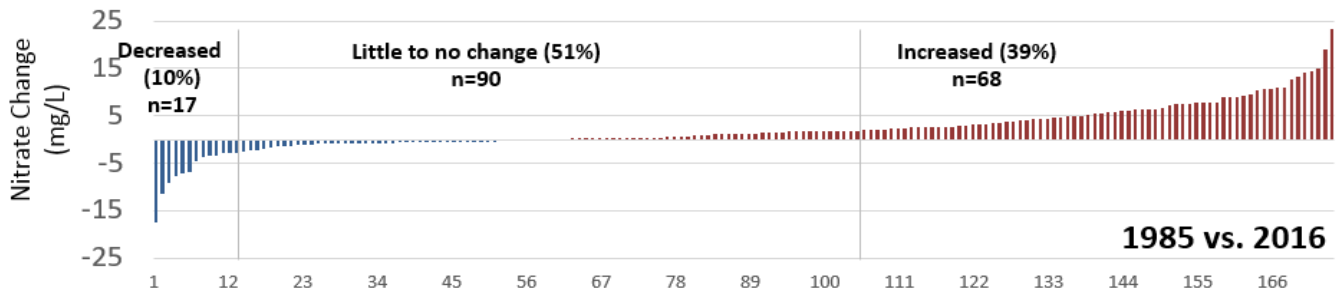
The numbers for TN systems do not include the wells on continuing operation between 10 ppm and 20 ppm.

Upward nitrate trends over time are frequently observed when reviewing regional or local trends in well water quality, particularly where wells are vulnerable to nitrate contamination. For example, the Rock County Health department has been sampling and maintaining a dataset based on a consistent set of transient non-community public wells over approximately 25 years. In aggregate, this consistent group of 79 wells have shown an increasing nitrate average concentration trend since 1994, with a marked increase in the last decade (see figure below).



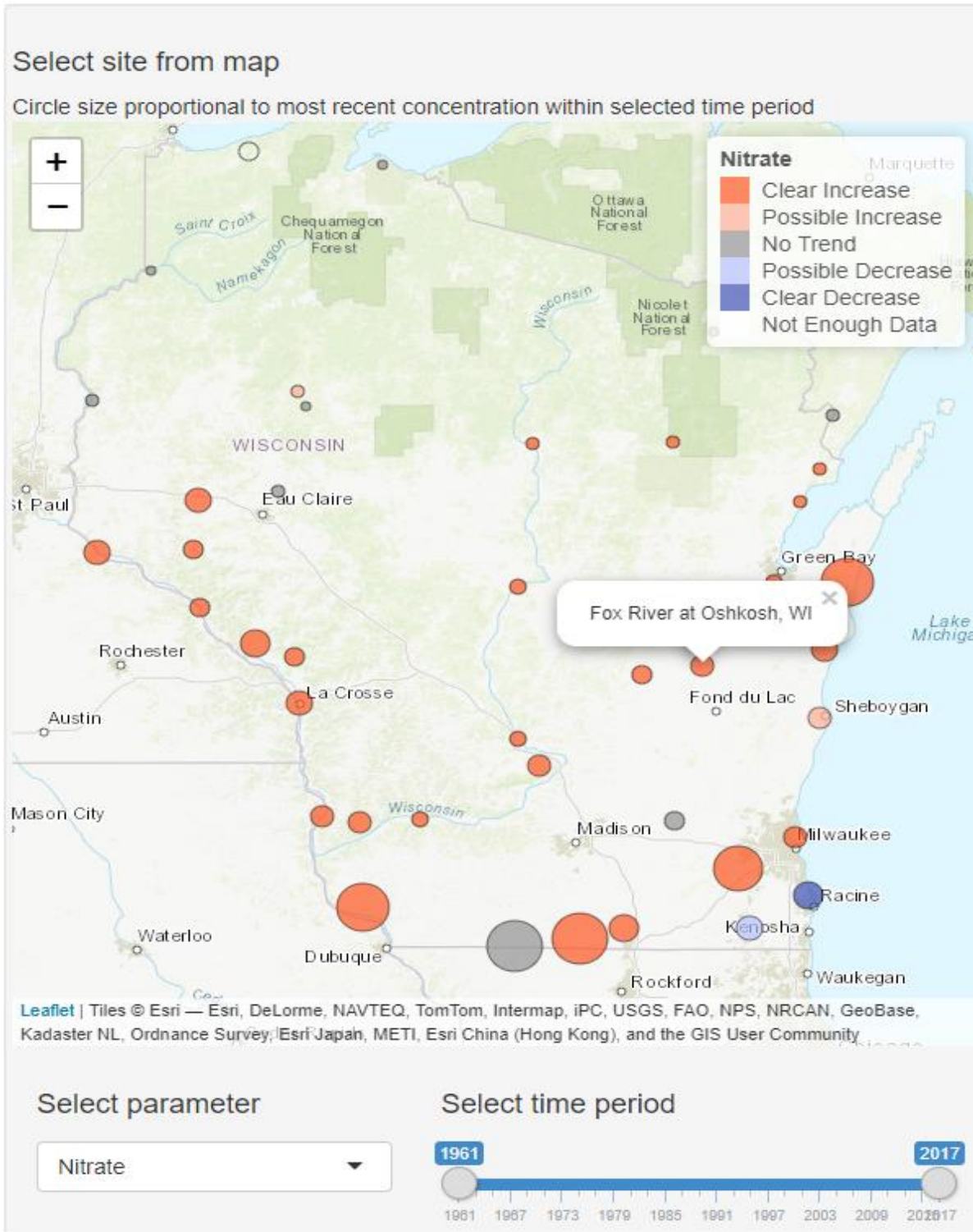
Source: Rock County Department of Public Health

Chippewa County provides another example where a consistent set of private wells (175) were sampled multiple times over thirty years. This data set shows the importance of location: most wells saw little or no change over the 30 years (51%) and some wells showed a decrease (10%), while 39% showed an increase in nitrate concentrations (see figure below).



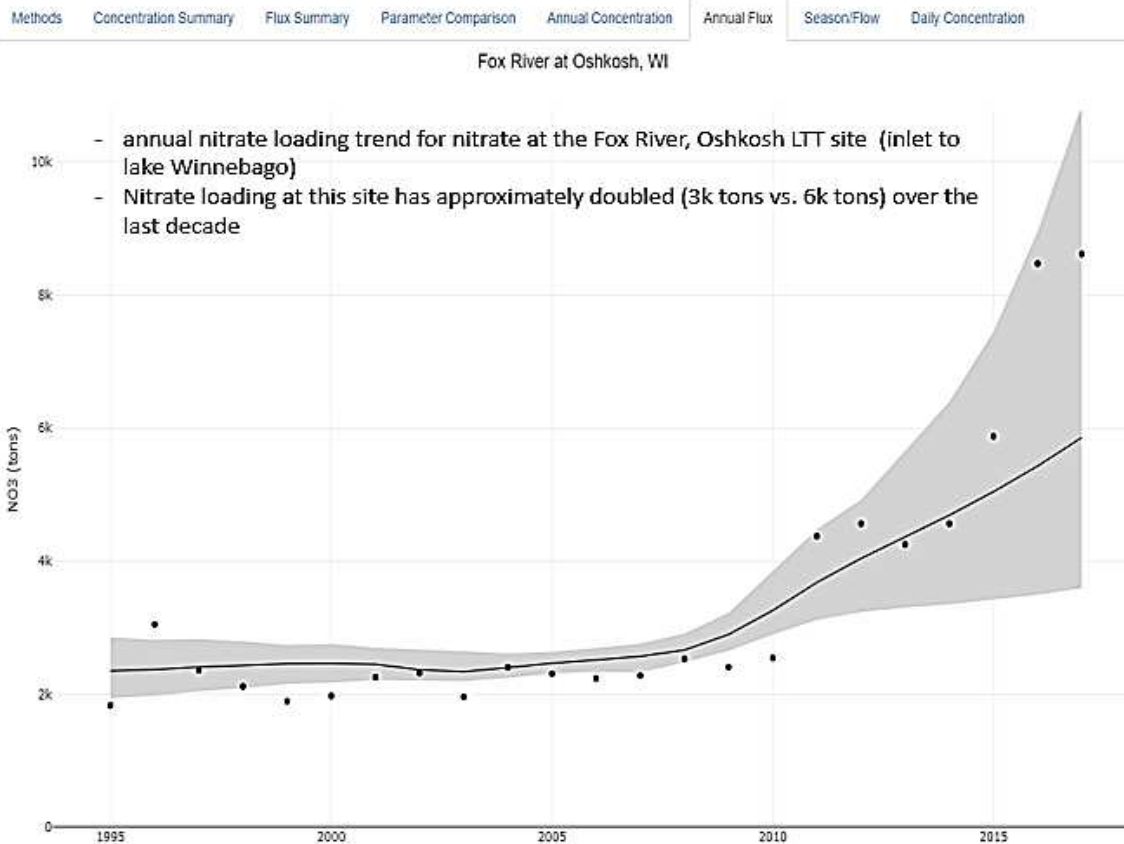
Source: Masarik et al., 2016 In preparation.

Another useful method to assess long term groundwater nitrate trends throughout the state is to evaluate data from groundwater baseflow dominated streams. A large portion of the state is covered by “groundwater dominated” watersheds (i.e. the ratio of groundwater baseflow to total streamflow is greater than 50%). Long term trend monitoring sites maintained by DNR and USGS in these watersheds can provide information about the aggregate water quality yielded by these watersheds over time for groundwater transported contaminants such as nitrate. Wisconsin has some large basins where the baseflow contribution at the monitoring station is estimated as high as 90% (USGS - Gerbert et al., 2011). Data from DNR’s Long Term Trend Network shows increases in nitrate concentration for most locations monitored throughout the state.



DNR Long Term Trend (LTT) Data Viewer: <https://wisconsindnr.shinyapps.io/riverwq/>

Long-Term River Water Quality Trends in Wisconsin



Estimated costs in Wisconsin to mitigate Nitrate

In 2019, the data from new wells and pump work from 2014 through 2018 was used in an analysis to develop a cost estimate for private wells to address nitrate over the health 10 ppm standard. The estimate is based on private well owners currently over the nitrate standard choosing the preferred safe at the source method of drilling to a depth where water below the standard can be obtained.

The process involved estimating the number of private wells in each county and multiplying that by the percentage of wells over 10 ppm for each county. A cost for individual well replacement was developed using the Groundwater Retrieval Network (GRN) nitrate data to determine the depth of penetration of nitrate into the aquifer. This depth was used as the estimated depth to construct a well reaching water safe at the source.

The estimated number of private wells exceeding the health standard for nitrate in Wisconsin is over 42,000, with a total cost estimate of abandoning the contaminated well and replacing with a new safe water supply exceeding 440 million dollars. Results by county are shown in the table below.

An estimate of the cost to well owners who have already replaced their well due to elevated nitrate was calculated by reviewing well construction reports submitted to the

department where nitrate was listed as the reason for the new well. This likely underestimates the number of wells replaced for nitrate, when no reason was listed on the report. Using the same methodology, it is estimated that private well owners have spent more the 9 million dollars to replace wells elevated nitrate to date.

	Estimated # of private wells	Estimated % of well over 10 ppm Nitrate Standard	Estimated # of private wells over Nitrate Standard	Estimated Replacement Cost (millions)
Adams County	9959	12.4%	1232	\$10.82
Ashland County	2290	0.0%	0	\$0.00
Barron County	9336	9.3%	872	\$8.69
Bayfield County	5679	0.0%	0	\$0.00
Brown County	14077	2.9%	414	\$4.93
Buffalo County	3158	7.1%	224	\$1.67
Burnett County	6689	1.2%	82	\$0.41
Calumet County	3932	10.5%	413	\$5.25
Chippewa County	13242	13.5%	1788	\$15.99
Clark County	6581	5.4%	357	\$1.80
Columbia County	8762	17.9%	1564	\$19.22
Crawford County	2485	0.9%	24	\$0.28
Dane County	23506	18.3%	4313	\$65.61
Dodge County	11112	5.0%	553	\$7.44
Door County	11797	1.3%	153	\$2.04
Douglas County	5165	0.0%	0	\$0.00
Dunn County	7501	12.1%	906	\$6.65
Eau Claire County	9153	5.3%	483	\$3.89
Florence County	2423	1.6%	39	\$0.18
Fond du Lac County	12190	5.3%	649	\$8.41
Forest County	4073	1.3%	54	\$0.19
Grant County	5895	6.6%	389	\$6.05
Green County	5474	20.2%	1106	\$15.22
Green Lake County	4957	19.5%	968	\$14.60
Iowa County	3511	12.5%	438	\$7.13
Iron County	749	0.7%	6	\$0.02
Jackson County	4688	6.7%	312	\$1.63
Jefferson County	9491	8.3%	792	\$8.16
Juneau County	5166	11.6%	600	\$3.85
Kenosha County	15570	0.8%	132	\$1.21
Kewaunee County	3741	3.3%	122	\$0.90
La Crosse County	7216	13.4%	965	\$8.99
Lafayette County	2628	15.3%	402	\$5.74
Langlade County	6387	4.7%	298	\$2.41
Lincoln County	7396	3.7%	277	\$1.55

	Estimated # of private wells	Estimated % of well over 10 ppm Nitrate Standard	Estimated # of private wells over Nitrate Standard	Estimated Replacement Cost (millions)
Manitowoc County	8693	6.2%	539	\$6.87
Marathon County	22195	7.1%	1578	\$11.36
Marinette County	10295	2.3%	239	\$1.41
Marquette County	5951	9.4%	559	\$5.90
Menominee County	1287	0.0%	0	\$0.00
Milwaukee County	23534	0.3%	80	\$0.48
Monroe County	6561	10.1%	662	\$4.63
Oconto County	13336	2.4%	321	\$2.54
Oneida County	15788	1.7%	274	\$1.31
Outagamie County	13997	0.8%	117	\$1.91
Ozaukee County	11940	0.7%	80	\$0.69
Pepin County	1593	20.1%	320	\$2.48
Pierce County	4678	14.7%	689	\$9.98
Polk County	8907	4.7%	422	\$3.75
Portage County	8658	17.7%	1536	\$13.13
Price County	4868	1.9%	94	\$0.38
Racine County	16892	0.6%	99	\$0.84
Richland County	3262	8.8%	286	\$2.47
Rock County	12275	24.4%	2999	\$32.45
Rusk County	4857	3.6%	175	\$1.00
Saint Croix County	13362	12.2%	1624	\$15.97
Sauk County	7775	13.4%	1042	\$9.33
Sawyer County	9796	1.0%	99	\$0.48
Shawano County	7604	8.0%	606	\$5.14
Sheboygan County	11561	3.0%	344	\$3.03
Taylor County	5255	2.7%	144	\$0.91
Trempealeau County	5044	18.2%	917	\$10.05
Vernon County	4350	3.3%	142	\$2.11
Vilas County	12718	1.6%	201	\$0.95
Walworth County	17916	4.0%	715	\$6.31
Washburn County	6395	0.8%	53	\$0.34
Washington County	19541	3.8%	735	\$10.52
Waukesha County	57361	1.8%	1041	\$14.38
Waupaca County	10389	7.1%	736	\$6.15
Waushara County	9254	10.4%	964	\$9.08
Winnebago County	14271	1.9%	266	\$4.27
Wood County	8099	4.9%	394	\$2.75
Totals	676,237		42,019	\$446M

Because nitrate is both an acute and chronic health issue, community Public Water Systems cannot serve water over the Enforcement Standard (ES), and therefore must either replace the well or install approved treatment if they exceed the ES. In 2019, the city of Colby in Marathon County spent \$769,000 to install a nitrate mitigation system. In 2018, the village of Junction City in Portage County replaced a public water supply well due to high nitrate concentrations at a cost of \$1,128,000. That same year, the village of Fall Creek spent \$1,074,000 to replace a well due to high nitrate. While complete information on the costs have not been confirmed, the current estimate is over 40 million dollars have been spent by municipal public systems to deal with nitrate. These cost estimates do not include increased sampling or investigative cost, nor operational costs to maintain treatment systems.

The Safe Drinking Water Act allows transient non-community (TN) systems to continue to operate with nitrate above the health standard of 10 mg/L but below 20 mg/L if nitrate level is posted. TN systems include motels, restaurants, taverns, campgrounds, parks and gas stations. Currently in Wisconsin there are nearly 300 TN systems in operation in this situation. Using the same process for developing costs as for the private well replacement, the total cost for TN well mitigation of the currently existing system over 10 ppm is 3.2 million dollars. Each year about 20 new TN systems go over the nitrate standard.

Over the past 10 years 61 Non-transient Non-community systems (such as wells serving schools, day care centers and factories) have gone over the standard. Using a similar cost estimate method as above, the cost to those systems is estimated at 747,000 dollars.

What is being done by GCC Agencies to address nitrate?

Nitrate has always been a core concern for GCC agencies. Over 40 projects or 10% of the total portfolio funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP), have investigated the occurrence, transport, removal or management of nitrogen in Wisconsin. In addition, multiple sampling programs have been carried out by the DNR, DATCP and the WGNHS to characterize the extent of contamination.

In addition to regular well sampling surveys performed by DATCP, DATCP supports the development of nutrient management plans (NMPs). These plans specify the amount and timing of nutrient sources applied to a field to optimize economic input. Approximately 31% of the agricultural land in Wisconsin is



Exploring best nitrogen management practices in on agricultural fields is a key research priority for the GCC. Photo: DNR

covered by an approved management plan (DATCP, 2015). Not all farms are required to have a nutrient management plan, but DATCP provides free resources and training for farmers to encourage total coverage across the state.

DATCP estimated that in 2007, over 200 million pounds of nitrogen were applied to agricultural lands in excess of UW recommendations, a number that could be substantially reduced with broader adoption of NMPs. However, NMPs do not presently contain mechanisms specifically designed to assess potential nitrate loading to groundwater.

Numerous studies indicate that NMPs are not always effective at reducing nitrate levels to below the MCL. Even in the best managed agricultural systems, over the long-term (7 years) nearly 20% of nitrogen fertilizer bypasses plants and is leached to groundwater, which makes it likely that groundwater concentrations of nitrate-N at or above the MCL will continue to be a concern for Wisconsin residents (Brye et al., 2001; Masarik, 2003; Norman, 2003). That said, there is still significant potential for improvement through increased adoption of NMPs.

The Nitrate Initiative was started by the WDNR Drinking Water and Groundwater Program in 2012 to develop partnerships and collaborate with the full spectrum of drinking water stakeholders, including the agricultural community, to evaluate strategies to reduce nitrate loading to groundwater from agricultural activities and enable protection of drinking water sources while maintaining farm profitability. Pilot projects were focused in locations where drinking water systems were approaching unsafe levels of nitrate contamination. Common themes and challenges (both technical and social) emerged during these projects. Because nitrate is an acute contaminant, water suppliers and consumers both need assurances that any land use mitigation efforts will be robust and reliable enough to result in a safe concentration of nitrate at the tap. Therefore, when water resource managers engage with landowners and agricultural producers in a groundwater management area, such as a wellhead protection area, these stakeholders need to know which conservation practices could achieve the desired water quality results, how intensively those practices need to be applied in a given setting and time period, and how much those practices will cost. Developing answers to these questions in the context of a nutrient management plan leads to the realization that data on the efficacy of conservation and nitrogen management practices for protecting groundwater is either lacking or involves significant degrees of variability in the expected results (owing to differences in physical setting and climatic drivers). Tools do not presently exist to allow for the formulation of a groundwater nutrient loading “goal” that will be protective of downgradient drinking water wells. Stakeholders also need to know the time period or “lag” between implementing practices in the field and the onset of water quality improvements at the tap. Traditional nutrient management planning and traditional wellhead protection planning are not designed or equipped to answer these questions.

This has led to the [recommendation](#) for the State, on a collaborative basis with all drinking water stakeholders, to engage in a multi-stage process to develop new technical tools that will enable the realization of the goal of protecting our sources of

drinking water while maintaining robust and profitable agricultural production. Such tools would assist local resource managers with creating landowner and producer partnerships to implement “groundwater protective” nutrient management plans in areas contributing recharge to potable wells.

Groundwater and nitrogen fertilizer decision support

In 2019 the WDNR developed “stage 1” workplans with technical partners to begin the development of a suite of Groundwater and Nitrogen Fertilizer Decision Support tools (GW & Nitrogen DSTs) for ultimate use by community water supplies, conservation departments, the agricultural community, and other drinking water stakeholders to help achieve groundwater protection in the context of nutrient management planning. Nitrogen fertilizer decision support tools will be developed and improved over time based on contributions from the full range of stakeholders. Guiding principles include creating tools that are complimentary and supplementary to the existing Nutrient Management Planning programming in the state. Starting with basic tools and progressing to more advanced applications over time, stakeholders will be engaged to develop collaborative solutions to existing data and research gaps, as well as barriers to adoption. Early products will focus on “the basics” such as nitrogen budgets and “mass balance” type analysis. More advanced products will utilize models in order to incorporate nitrogen cycle drivers and simulation of the effects of weather variability. The goal is pair with existing NMPs (e.g. a user might export a data file from SNAP+ and process separately with a Nitrogen DST to generate estimates of nitrate leaching potential and explore options to reduce losses). To protect our sources of drinking water, resource managers and the agricultural community need tools with the flexibility to scenario test potential nutrient management plans that incorporate various beneficial management practices. Because the nitrogen cycle is inherently “leaky”, we expect some nitrate leaching to occur under the best of circumstances. The goal is to provide reasonable expected ranges of the nitrate leaching below the root zone that would be expected to occur (based on the details of a nutrient management plan). This information is needed in order to devise groundwater management plans that assure that potable wells located hydraulically downgradient will remain below the health-based standard for nitrate. To achieve the dual goal of source water protection while maintaining farm profitability, we must also elucidate any tradeoffs in productivity. Where economic offsets are expected to occur, quantification of these costs could serve as the basis for utilizing existing state and federal conservation practice funding sources in new ways that protect drinking water sources and safeguard the public health.

This long-term project will provide a framework for the continued development and improvement of nitrogen fertilizer decision support products as more research and data is incorporated over time. To be successful, and develop the capacity in the state to protect our sources of drinking water even in agriculturally intensive settings, the full range of drinking water stakeholders in the state, including the agricultural community, will need to share “ownership” and responsibility for continuous development and improvement of these tools (analogous to the existing programming in the state that

develops and improves the science supporting nutrient management planning in general).

When fully realized, these tools would test alternative land management and nutrient management scenarios, predict the nitrate load reductions that can be expected from chosen conservation practices, inform economic tradeoffs, and address common questions, such as the estimated time delay between practice implementation and expected water quality improvements at a receptor of concern. Additionally, GW & Nitrogen DSTs will facilitate access to existing state and federal non-point pollution control programs that fund land conservation practices. The DSTs could be used, for example, to meet requirements of traditional watershed-based plans (such as “9 Key Element” Plans) by providing information on estimated nitrate pollutant load reductions based on proposed management practices and helping to describe achievable milestones (e.g. magnitude and timing of water quality improvements). Approved watershed-based plans, now expanded to include groundwater protection, would then meet the pre-requisites for agricultural practice cost share funding from existing non-point source pollution mitigation programs (which have traditionally focused primarily on improving surface water quality).

The Groundwater DSTs (and the underlying spatial datasets) will have many uses and applications beyond understanding nitrate transport from below the root zone and through the subsurface to a well or stream. To address potable well impacts from non-point pollution sources, we must facilitate identification of critical land areas where management actions will be most effective. Groundwater DSTs will leverage existing hydrogeologic research and modeling products and utilize advanced techniques to make essential hydrogeologic information more available to decision makers. Both the Groundwater and Nitrogen DSTs will be designed to communicate the sources of uncertainty associated with model predictions. Full realization of the DST products will quantitatively bracket model output ranges such that local planners can effectively incorporate these factors into the resource protection planning process.

Initial work began in early 2020 on the Groundwater and Nitrogen Decision Support Tool development. The development partnership is expected to expand over time, and incorporate multi-disciplinary technical contributions from researchers at the University of Wisconsin, and from other state agencies and organizations such as the Wisconsin Geologic and Natural History Survey (UW-Extension), the Wisconsin Department of Agriculture Trade and Consumer Protection, the Department of Health Services and the Wisconsin Rural Water Association. Key federal partners include USGS, USDA-NRCS, and EPA. The Wisconsin Land and Water Conservation Association is providing essential connections to county conservation and county health departments. Through these local connections, the range of participating agricultural stakeholders will expand, providing essential feedback and data for developing robust decision support and enable protection of drinking water supplies while sustaining profitable agricultural production.

Nitrate Targeted Performance Standard

In 2019, Governor Tony Evers directed DNR to pursue rulemaking through NR 151 to reduce nitrate contamination by establishing targeted nitrate performance standards for soils that are most likely to experience nitrogen contamination. The Wisconsin Natural Resources Board approved the DNR's Statement of Scope in December 2019. Which states that "The purpose of the proposed revisions to ch. NR 151, Wis. Adm. Code, and limited incorporation by reference of those proposed revisions to ch. 243, is to establish agricultural nonpoint source performance standards targeted to abate pollution of nitrate in areas of the state with highly permeable soils which are susceptible to groundwater contamination (sensitive areas) for the purpose of achieving compliance with the nitrate groundwater standards." The Scope further states that "The rule revisions will define sensitive areas in the state and the performance standards needed to protect surface and groundwater quality in these areas. Soil maps based, in part, on soil permeability in conjunction with groundwater quality information may be used to define sensitive areas." The promulgation of proposed rules generally takes about 31 months. Presently, the rule making committee has formed a Technical Advisory Committee (TAC) and is holding meetings open to the public. For further information, please see [NR 151 rule changes for nitrate](#).

Future Work

Given the pervasiveness of nitrate contamination in groundwater and the seriousness of suspected human health impacts, there is a need for a better understanding of the health effects of high nitrate in drinking water. DHS will continue to monitor and review the literature on this topic, particularly with regards to links with birth defects. Throughout all of this, continued groundwater monitoring is also needed to assess existing problem areas and identify emerging areas of concern. Development and communication of improved groundwater protection strategies, including technical tools and directing conservation incentives to promote efficient use of nitrogen and reduce losses to groundwater, are another top priority.

Further Reading

[DNR overview of nitrate in drinking water](#)

[DNR overview of nutrient management planning](#)

[DATCP overview of nutrient management](#)

[DHS overview of nitrate health effects](#)

[DNR, DATCP, and DHS water quality recommendations](#)

[NR 151 rule changes for nitrate](#)

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ARSENIC AND OTHER NATURALLY-OCCURRING ELEMENTS

ARSENIC - WHAT IS IT?

Arsenic is an odorless and tasteless, naturally occurring element present in soil and rock. Under certain environmental conditions, arsenic can dissolve and be transported in groundwater. It can also be released as a by-product from agricultural and industrial activities. Everyone is exposed to small amounts of arsenic since it is a natural part of the environment, but under some geologic conditions elevated amounts of arsenic can be released to groundwater.

The health-based enforcement standard (ES) for arsenic in groundwater and the maximum contaminant level (MCL) for arsenic in public drinking water are both 10 parts per billion (ppb) or micrograms per liter (ug/l) ([WI NR 140.10](#), [WI NR 809.11](#)). Some people who drink water containing arsenic in excess of the MCL over many years could experience skin damage or problems with their circulatory system, nervous system, and have an increased risk of getting cancer.

Occurrence in Wisconsin

In Wisconsin, most arsenic found in groundwater is naturally occurring, released from minerals in bedrock and glacial deposits. Arsenic has been detected above the ES in the groundwater in every county in Wisconsin. Arsenic contamination of groundwater is common in northeastern Wisconsin in areas around Winnebago and Outagamie County and moderately high levels of arsenic (10 ppb – 30 ppb) are also common in some parts of southeastern Wisconsin.

In *northeastern Wisconsin*, a geologic formation called the St. Peter Sandstone contains arsenic-rich minerals. When sulfide minerals common in this rock are exposed to oxygen in the air – either at the water table elevation or from drilling activity – chemical reactions solubilize these minerals and lead to very high levels of arsenic in water (exceeding 100 ppb, or 10 times the ES). In low-oxygen groundwater environments, arsenic can be released from the St. Peter Sandstone at lower concentrations which may still exceed the ES. This more moderate contamination may result from the same sulfide minerals or from arsenic that is bound to iron oxide minerals.

In *southeastern Wisconsin*, most wells draw from glacial sand and gravel deposits or Silurian dolomite formations. While oxidizing conditions tend to release arsenic from sulfide minerals in northeastern Wisconsin, reducing conditions (where dissolved oxygen is low) tend to release arsenic from iron compounds in the glacial deposits and dolomite of southeastern Wisconsin.

In *northern Wisconsin* sulfides and arsenopyrite can be found in the Precambrian granitic rock, while arsenic bearing iron oxides can be in the end moraines of the various glacial advances.

In *southwestern Wisconsin* sulfides associated with the lead-zinc district have contaminated a number of wells. Further north, sulfides in the Tunnel City formation have forced the replacement of at least a dozen wells from La Crosse to Barron counties. A report by Zambito, et. al. (2019) explains the occurrence of arsenic and metal bearing sulfides. Other metals commonly associated with arsenic are nickel, cobalt, copper, aluminum and vanadium.

GCC Agency Actions

Naturally-occurring arsenic was unexpectedly discovered in Wisconsin in 1987 during a feasibility study for a proposed landfill in Winnebago County. Follow up sampling by DNR and reports from nearby homeowners revealed a pressing need to determine the



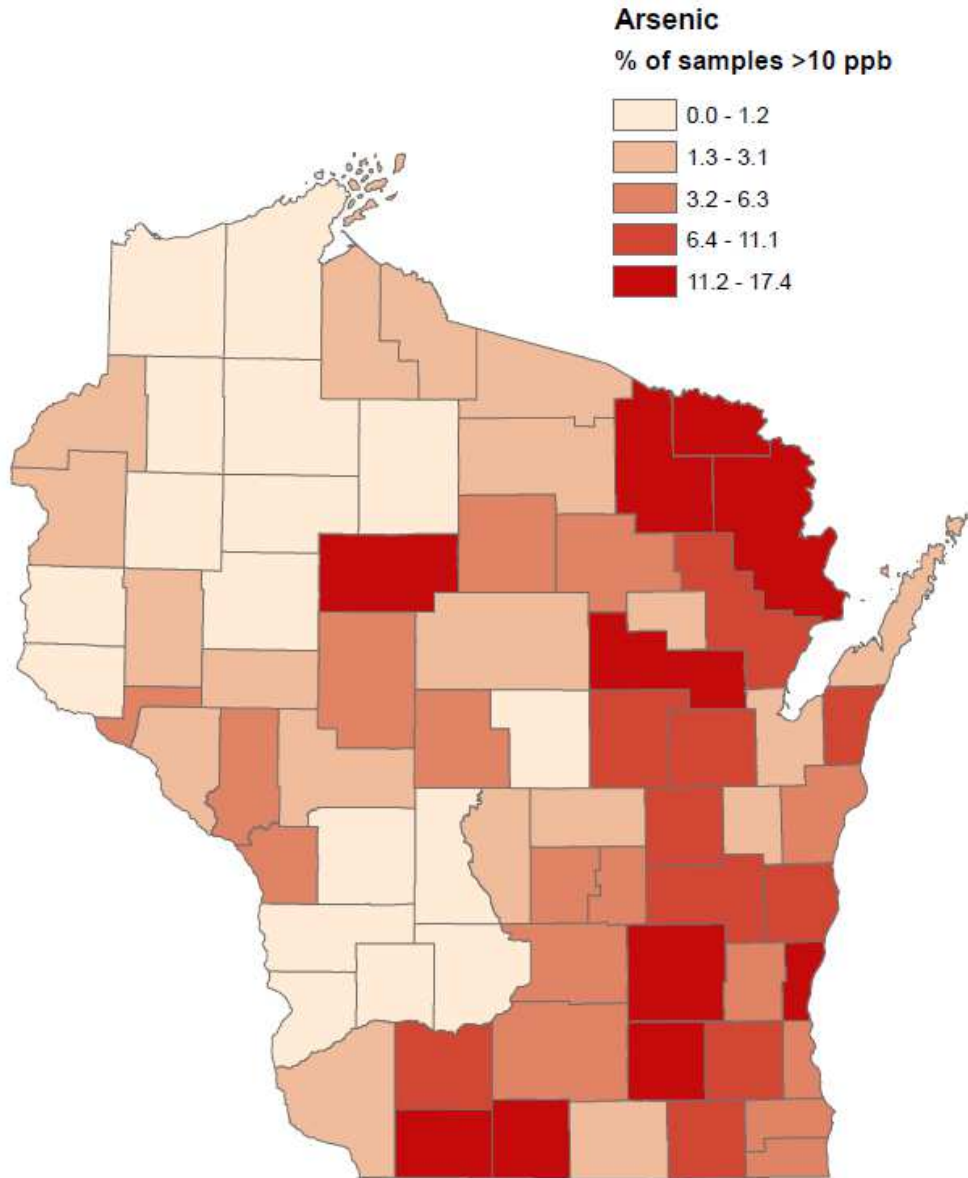
Arsenic is common in northeastern Wisconsin (regions 1 and 3) and southeastern Wisconsin. *Figure: Luczaj and Masarik, 2015.*

distribution and frequency of the problem. As a result, over the next several years DNR, the Department of Health Services (DHS) and local health officials teamed with researchers funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP) to sample thousands of private wells in the Winnebago and Outagamie County area and analyze where and why arsenic levels were elevated (Burkel, 1993; Burkel and Stoll, 1995). As researchers identified first the geologic formation, then the chemical reactions responsible for the situation (Pelczar, 1996; Simo, 1995 and 1997; Gotkowitz et al., 2003), DNR outlined a [Special Well Casing Depth Area](#) and developed well construction guidelines to protect drinking water wells in this area from contamination. Simultaneously, DHS worked with local health officials to inform residents of health risks, provide low-cost testing of private wells, and gather information about people with long-term exposure to arsenic in one of the largest epidemiological studies ever conducted in Wisconsin (Knobeloch et al, 2002; Zierold et al., 2004).

In the early 2000s, the US EPA lowered the MCL for arsenic from 50 ppb to 10 ppb (the current standard), which raised concerns for schools and residents in southeastern Wisconsin that had been observing arsenic levels in the 10-50 ppb range. Initial testing by DNR and the Wisconsin Geological and Natural History Survey (WGNHS) revealed that the geochemical explanations for arsenic contamination in northeastern Wisconsin could not explain the problem in southeastern Wisconsin (Gotkowitz, 2002), so the WGRMP funded further research to analyze the new situation and develop more appropriate guidelines (Sonzogni et al., 2003; Bahr et al., 2004; Root 2005; West et al., 2012). One of the important outcomes of these studies was improved understanding of how chlorine disinfection, which is often used to treat microbial biofilms (slime) in wells, can affect the release of arsenic (Gotkowitz et al, 2008). Shock chlorination of private wells should be limited in much of northeastern Wisconsin because it has a strongly oxidizing effect that encourages release of arsenic from sulfide minerals. Well chlorination does not similarly affect arsenic bound to iron compounds in groundwater environments such as southeastern Wisconsin. In these settings, well disinfection may in fact reduce arsenic levels by controlling microbes that contribute to iron dissolution.

The extensive research completed in Wisconsin over the past 20 years illustrates the highly variable nature of Wisconsin's geologic sources of arsenic to groundwater. A well with no detectable arsenic can be right across the street from a well that tests well above the MCL. Arsenic concentrations can vary over time, too. This makes regular testing – with efficient, accurate and affordable methods – critical. WGRMP-funded researchers have been important partners in this and have designed portable field sampling kits, improved upon existing laboratory methods and are currently working on sensors that can immediately detect arsenic levels in groundwater. Most recently a project has begun looking at the association of bedrock fold and faults with arsenic contamination.

In 2014, DNR began requiring testing for arsenic when pump work was being done on existing wells. The data is being analyzed to determine if additional Special Well Casing Depth Areas should be developed.



Map 1. Beginning in 2014 the department has required arsenic sampling when pump work is done on existing wells. The map above is from the 35,000+ samples collected over the first 4 and a half years. The map depicts the percent of wells over 10 ppb arsenic in each county (see tabular data below). This analysis shows that arsenic is more widespread than previously thought.

In 2020 there were 7779 samples taken during pump work on existing wells. 399 of those (5.1%) were over 10 ppb. There were 31 samples over 100 ppb.

County	% >10	% >50	% >100	County	% >10	% >50	% >100
Adams	1.6	0.5	0.3	Marathon	2.1	0.5	0.3
Ashland	2.2			Marinette	16.2	3.5	2.1
Barron	0.5	0.1		Marquette	4.6	0.8	0.4
Bayfield	1.1			Menominee	2.5		
Brown	1.9	0.4	0.1	Milwaukee	5.3		
Buffalo	1.6			Monroe	0.6		
Burnett	2.9			Oconto	11.1	2.1	1.3
Calumet	3.1			Oneida	2.2		
Chippewa	0.6			Outagamie	10.9	1.7	0.4
Clark	4.6	1.5	1.5	Ozaukee	17.4	2.7	1.0
Columbia	5.0	1.5	0.4	Pepin	3.8	0.6	
Crawford				Pierce			
Dane	4.6	1.1	0.4	Polk	1.9	0.2	
Dodge	12.5	4.9	3.6	Portage	1.2	0.2	0.2
Door	2.0	0.1	0.0	Price	1.0		
Douglas				Racine	4.8	0.1	
Dunn	2.5	0.4		Richland			
Eau Claire	1.4			Rock	1.8	0.4	0.2
Florence	12.6	2.0	1.2	Rusk	0.8		
Fond du Lac	10.1	4.5	2.3	Saint Croix	0.9		
Forest	15.5	1.4		Sauk	0.9		
Grant	3.1	0.4		Sawyer	0.5		
Green	12.7	3.9	1.6	Shawano	16.2	3.1	1.3
Green Lake	3.9	0.8	0.8	Sheboygan	9.6	0.2	0.1
Iowa	8.8	2.6	2.2	Taylor	13.4	1.5	
Iron	2.9			Trempealeau	3.9		
Jackson	1.7			Vernon			
Jefferson	12.6	3.7	1.1	Vilas	3.0		
Juneau	0.7			Walworth	6.8	1.1	0.5
Kenosha	4.0	0.5	0.2	Washburn	0.4		
Kewaunee	7.4	1.9		Washington	6.3	0.7	0.2
La Crosse	3.4	0.3		Waukesha	7.5	0.7	0.2
Lafayette	15.9	5.8	3.7	Waupaca	7.4	0.4	0.2
Langlade	6.2	2.5	1.2	Waushara	1.5		
Lincoln	3.4			Winnebago	7.3	1.0	
Manitowoc	3.8			Wood	4.0	0.4	0.4

Table 1. Percent of wells over 10 ppb, 50 ppb and 100 ppb arsenic by county.

Future Work

Sampling and testing private wells remain important priorities for understanding and managing arsenic contamination in Wisconsin. To encourage private well sampling, local health departments continue to offer fee-exempt testing to low income families. DNR and some county governments are also working to both promote well sampling programs and explore impediments to private well sampling.

In the areas of the state that are known to be vulnerable to arsenic contamination, there is a focus on reducing exposure. Several communities have expanded the service area for public water systems and moving homes from private wells to public supplies has been effective in reducing exposure in towns like Algoma in Winnebago County.

Areas outside the original region of concern in northeast Wisconsin and the more recent area of concern in southeast Wisconsin have not been as well described. Revisions to NR 812 now require wells to be tested for arsenic, in addition to bacteria and nitrate, during pump installation or when testing is requested during property transfers involving existing private wells. This may help to fill the data gap. In addition, researchers from the WGNHS funded by the WGRMP are currently working to understand the mineralogy of the Tunnel City rock formation in western Wisconsin, which may help define the risk of arsenic contamination in that region.

Discovery triggers geochemical questions, science improves understanding and helps GCC agencies better protect human health – this pattern is repeated by GCC agencies and researchers whenever natural contaminants are identified in groundwater in unexpected amounts in a new location. This continues today with ongoing investigations that are exploring the occurrence of strontium near Green Bay and the presence of heavy metals in geologic formations near La Crosse, among others.

OTHER NATURAL CONTAMINANTS IN WI GROUNDWATER

NATURALLY-OCCURRING RADIONUCLIDES

Radionuclides are radioactive atoms. It is possible for radionuclides to be manmade, as is the case with some materials from nuclear power reactors, but they also occur naturally in rock formations and are released to groundwater over millions of years by geochemical reactions. Common naturally-occurring radionuclides in groundwater include uranium and thorium, which both decay to different forms of radium, which in turn decays to radon. General indicators of high-energy radiation are monitored in water as alpha, beta, and gamma (now included in a broader group called photon emitters) activity.



Arsenic-rich minerals, such as arsenic-rich pyrite (pictured), are natural sources of arsenic in groundwater in Wisconsin.
Photo: JJ Harrison.

There are no ch. NR 140 groundwater quality standards for radionuclides in Wisconsin but maximum contaminant levels (MCLs) for public drinking water systems have been established for the radionuclides uranium and (total) radium, and for alpha and beta (plus photon) particle activity. No public water supply MCL has been established for radon but the United States Environmental Protection Agency (US EPA) has proposed that radon levels in water be no higher than 4,000 picocuries per liter (pCi/L), where indoor air radon abatement programs exist, and no higher than 300 pCi/L where indoor air radon abatement programs do not exist.

RADIUM IN SOUTHEASTERN WISCONSIN

A well-known example of natural contamination in Wisconsin is radium in southeastern Wisconsin. By the late 1990s, drawdown in this region due to decades of large-scale pumping was causing concerning increases in radium levels in drinking water. Initial links between radium and geologic formations in eastern Wisconsin had been drawn by GCC researchers in 1990 (Taylor and Mursky, 1990), but the source of radium was poorly understood, making it difficult to know how to manage drinking water sources. Research funded by the WGRMP in the late 1990s more clearly demonstrated that high radium is most common near the edge of the Maquoketa shale, which runs from Brown County in the north to Racine County in the south (Grundl, 2000).

A remaining puzzle was why radium levels were elevated to the east of the Maquoketa shale boundary but not to the west – conventional understanding of the sources of radium did not seem sufficient to explain observations. In the early 2000s, researchers at the University of Wisconsin and the Wisconsin Geological and Natural History Survey (WGNHS) leveraged new models and knowledge about groundwater flow patterns in the Waukesha area to elucidate the relationship between radium and sulfate minerals in the area, collecting much needed information on the geochemical backdrop of the region in the process (Grundl et al., 2003). Today, there are still unanswered questions about the precise geochemical processes that control radium activity, but our improved understanding of radium sources helps water managers in eastern Wisconsin define their options: treat water from deep aquifers, blend with water from shallow aquifers, or find alternate surface sources for drinking water.

NATURALLY-OCCURRING CHROMIUM IN GROUNDWATER

As water flows underground, metals such as chromium, may be dissolved from rock or soil and be mobilized, and therefore present in groundwater. Natural sources of chromium in groundwater include some types of igneous bedrock and soils derived from those bedrock sources. In groundwater, chromium can generally be found in one of two forms, as trivalent chromium (Cr III), or chromium-3, or as hexavalent chromium (Cr VI), or chromium-6. While trivalent chromium is an essential nutrient, hexavalent chromium is acutely toxic and has been classified as “likely to be carcinogenic to humans”. Water quality analysis for chromium is generally done for “total chromium” (trivalent chromium + hexavalent chromium). The US EPA has established a public water supply MCL for total chromium at 100 micrograms per liter ($\mu\text{g/L}$) and, in Wisconsin, the ch. NR 140

groundwater quality enforcement standard (ES) for total chromium is 100 µg/L. The DHS has recently recommended a ch. NR 140 ES for hexavalent chromium of 70 nanograms per liter (ng/L).

CHROMIUM IN DANE COUNTY

In Dane County, residents were surprised to learn in 2011 that hexavalent chromium (Cr [VI]) is present in Madison drinking water in very low concentrations. While trivalent chromium (Cr [III]) is an essential trace nutrient in low concentrations, Cr (VI) is a suspected carcinogen. As DHS responded to questions about the [health effects](#) of Cr (VI), WGNHS quickly embarked on a sampling study to determine whether there was a naturally occurring source of chromium in the local bedrock formations (Gotkowitz et al., 2012). Findings indicate that chromium naturally occurs in all formations, but only the upper aquifers seem to have the geochemical conditions to promote mobility of aqueous Cr (VI).



Sampling irrigation wells for Cr (VI). Photo: Patrick Gorski

WGRMP-funded researchers at UW-Madison and the Wisconsin State Laboratory of Hygiene followed up with a project to explore what geochemical environments create ideal conditions for Cr (VI) mobility in key geologic formations across the state (Gorski et al., 2015). Work like this helps Wisconsin communities prepare for a federal drinking water standard for Cr (VI), which does not currently exist but is expected to in the future.

NATURALLY-OCCURRING STRONTIUM IN GROUNDWATER

Naturally occurring, non-radioactive strontium is present in Wisconsin groundwater and has been found at very high concentrations in some parts of the State. Non-radioactive, or "stable strontium", naturally occurs in rock and soil and, under certain geochemical conditions, is dissolved from rock and soil sources and mobilized in groundwater. Very high levels of naturally occurring strontium have been documented in municipal water supply wells in eastern Wisconsin (USGS 1963). Strontium's chemical behavior is similar to calcium and strontium minerals have been found in carbonate bedrock deposits in Wisconsin. The weathering and dissolution of carbonate bedrock containing strontium minerals may be a source of elevated strontium in groundwater. Highly mineralized brines have also been shown to contain very high levels of dissolved strontium. No public water supply MCL has been established for strontium, but the US EPA has established a lifetime health advisory level for strontium in drinking water at 4,000 µg/L. The DHS has recently recommended a ch. NR 140 ES for strontium of 1,500 µg/L.

A research project, funded through WGRMP, was conducted to study the occurrence and sources of strontium in groundwater in northeastern Wisconsin (Luczaj 2013). Very high levels of strontium in wells drawing water from the Cambrian Ordovician bedrock aquifer in the northeast part of the state were documented in the study. The research found that groundwater chemistry in the Cambrian Ordovician aquifer was influenced by deep

regional bedrock faults, that created aquifer groundwater “zones” with differing major ion chemistry. Strontium minerals, precipitated from Michigan geologic basin hydrothermal brines, in carbonate bedrock and interstitial cement in sandstone formations were determined to be the likely source of elevated strontium in groundwater. The heterogenous nature of bedrock strontium mineral deposition, and the influence of major faults on groundwater chemistry, were suggested as reasons for the observed variability in strontium concentrations in well water across the study area.

UPDATE ON GROUNDWATER STANDARDS RELATED TO NATURALLY-OCCURRING ELEMENTS IN WI GROUNDWATER

Strontium, hexavalent chromium, aluminum, cobalt and molybdenum are all metallic elements that may be naturally occurring in rock and soil. Under certain geochemical conditions, such as reducing redox conditions, these metals may be dissolved from rock or soil and mobilized in groundwater. Anthropogenic contamination may also be the source of these metals in groundwater. The DNR is currently in rulemaking to add new, and revise existing, groundwater quality standards in ch. NR 140 for these substances. Under DNR rulemaking, Board Order DG-15-19 (see <https://dnr.wisconsin.gov/topic/Groundwater/NR140.html>), new state enforcement standard (ES) and preventive action limit (PAL) groundwater quality standards are being proposed for strontium and hexavalent chromium, and revised state groundwater quality PAL standards are being proposed for aluminum, cobalt and molybdenum.

Further Reading

[DNR overview of arsenic in drinking water wells](#)

[DNR special well casing depth areas for arsenic](#)

[DHS overview of arsenic health effects](#)

[WGNHS report on arsenic release due to well disinfection](#)

[WGNHS report on preliminary investigation near Lake Geneva, Wisconsin](#)

[DHS report on arsenic in Wind Lake Private Wells, Town of Norway, Racine County](#)

[Wisconsin Natural Resource magazine article on arsenic in private wells \(December 2000\)](#)

[Origin and Distribution of Dissolved Strontium in the Cambrian-Ordovician Aquifer of Northeastern Wisconsin](#)

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PESTICIDES

What are they?

Pesticides are a broad class of substances designed to kill, repel or otherwise disrupt living things that are considered pests. They include insecticides, herbicides, fungicides and anti-microbials, among other types of biocides. Normal field applications, spills, misuse or improper storage and disposal can all lead to pesticide contamination in groundwater. As pesticides breakdown in soil and groundwater or are absorbed and metabolized by the target pest, some are converted into related compounds called **metabolites**, which may also be harmful to the pest or other living things.



Pesticide application sign. Photo: DATCP.

The health effects of exposure to pesticides or pesticide metabolites vary by substance. About 30 pesticides (and some pesticide metabolites) currently have a ch. NR 140 groundwater quality standards ([WI NR 140.10](#)), and a smaller number have an established maximum contaminant level (MCL), applicable at public drinking water systems ([WI NR 809.20](#)). However, at least 90 different pesticides are used on major crops in Wisconsin (WASS, 2006). Occasionally, pesticides and pesticide metabolites that do not have a NR 140 groundwater quality enforcement standard (ES) or public

drinking water MCL are detected in drinking water supplies, and information on the health effects of these pesticide compounds is often very limited or difficult to evaluate. It is also difficult to predict the health effects of multiple pesticides in drinking water; several studies have indicated that pesticide mixtures can have different health effects than exposure to individual pesticides at the same concentrations (Porter, 1999; Hayes et al., 2006).

Periodically Department of Agriculture, Trade and Consumer Protection (DATCP) identifies pesticides that are newly approved, have a high rate of use, or have been detected ("parent" compound or metabolites) in groundwater. These pesticides may be candidates for state groundwater standards development. Identified candidate pesticides and metabolites may be included on a list of substances that the DNR transmits to the WI Department of Health Services (DHS) requesting that DHS review available toxicologic information and, if appropriate, provide recommendations for ch. NR 140 groundwater quality standards.

In March 2018 and April 2019, lists of substances designated "Cycle 10" and "Cycle 11", that included pesticides and pesticide metabolites, was sent to DHS for review. The pesticides and metabolites included on the Cycle 10 list were eight herbicides and herbicide metabolites: Isoxaflutole, Isoxaflutole DKN, Isoxaflutole BA, Glyphosate, Glyphosate AMPA, Thien carbazole-methyl, Sulfentrazone and Dacthal TPA & MTP degradates, and three neonicotinoid insecticides: Thiamethoxam, Imidacloprid and Clothianidin. The Cycle 11 list included five herbicides: Metalaxyl, Flumetsulam, Fomesafen, Hexazinone, Saflufenacil, and one insecticide, Chlorantraniliprole. DNR has received recommendations from DHS on all 16 pesticide/pesticide metabolite standards (see <https://www.dhs.wisconsin.gov/water/gws.htm>), and is currently in the process of formal rulemaking to potentially adopt the DHS recommended standards in ch. NR 140 (see <https://dnr.wi.gov/topic/Groundwater/NR140.html>).

Commonly detected pesticides and their metabolites which have established groundwater quality or drinking water standards in Wisconsin include atrazine, alachlor, metolachlor, and acetochlor.

Atrazine is an herbicide commonly used on corn. The groundwater quality ES for atrazine and its three chlorinated metabolites is three parts per billion (ppb). The drinking water MCL for atrazine (does not include metabolites) is three ppb. People who drink water containing atrazine in excess of health-based standards over many years could experience problems with their cardiovascular system or reproductive difficulties. A number of epidemiological and animal studies have been conducted evaluating the potential health and environmental impacts from atrazine exposure (Hayes et al., 2002; ATSDR, 2003; Hayes et al., 2003; Hayes et al., 2006; Hayes et al., 2011; Craigin et al., 2011; Agopian et al., 2012; Agopian et al., 2013).

Alachlor is an herbicide used on corn and soybeans. Use of alachlor in Wisconsin has been replaced by other herbicides in the same family (e.g., metolachlor, acetochlor) (NASS, 2015 and 2016), however, its metabolites still linger in groundwater. Both the

groundwater quality ES and public drinking water MCL for alachlor are two parts per billion (ppb), and the groundwater quality ES for one of its metabolites, *alachlor ESA*, is 20 ppb. People who drink water containing alachlor in excess of health-based standards over many years could have problems with their eyes, liver, kidneys or spleen, or experience anemia, and may have an increased risk of getting cancer.

Metolachlor is an herbicide used widely on corn and soybeans, and on vegetable crops including peas, snap beans, potatoes and some others. Both the parent and metabolite forms (metolachlor, metolachlor-ESA and metolachlor-OXA) are routinely detected in groundwater and have health-based groundwater quality standards established. The groundwater quality ES for metolachlor is 100 ppb, and the groundwater quality ES for metolachlor-ESA and OXA combined is 1,300 ppb. Although metolachlor and its metabolites are commonly detected in groundwater, the concentrations detected are typically well below their respective ESs.

Acetochlor is an herbicide used for pre-emergent control of weeds in corn. The state groundwater quality ES for acetochlor is seven ppb. A groundwater quality ES of 230 ppb has also been established for the combined acetochlor metabolites, acetochlor ESA and acetochlor OXA. No public water supply MCL has been established for acetochlor or its metabolites. Animal studies have shown that oral exposure to acetochlor can produce significant neurological effects (EPA, 2006). Acetochlor has been classified by the EPA as a “suggestive human carcinogen”.

Occurrence in Wisconsin

In Wisconsin, the main source of pesticides in groundwater is agricultural herbicide and insecticide applications. For this reason, detection is more common in highly cultivated areas where agriculture is well established, notably in the south central, central and west-central parts of the state.

In 2016, DATCP conducted a statewide statistical survey of agricultural chemicals in groundwater that found an estimated 41.7% of private wells in Wisconsin contained a pesticide or pesticide metabolite, up from 33% of private wells in a similar survey conducted in 2007 (DATCP, 2008) (DATCP, 2017). The primary metabolites of metolachlor and alachlor, metolachlor ESA and alachlor ESA, were the two most commonly detected pesticide products. Atrazine and its metabolites, known collectively as the total chlorinated residues of atrazine (atrazine TCR), were also prevalent and occurred in about 23% of wells. Less than 1% of well samples with atrazine TCR detections had atrazine TCR levels that exceeded the groundwater quality ES of three ppb.

GCC Agency Actions

Serious concerns about pesticide contamination in Wisconsin were first raised in 1980 when aldicarb, a pesticide used on potatoes, was detected in groundwater near Stevens Point. The DNR, DATCP and other agencies responded to concerns by implementing monitoring programs and conducting groundwater surveys, initially testing exclusively

for aldicarb, (Rothschild et al., 1982; Kraft 1990) but soon expanding to other pesticides and eventually pesticide metabolites as well (Postle and Brey, 1988). DATCP also developed rules to restrict aldicarb use in areas vulnerable to groundwater contamination.



A plane sprays pesticides on a field.
Photo: [DATCP](#).

When findings from these sampling surveys in the late 1980s and early 1990s showed that atrazine, a popular corn herbicide, was particularly prevalent in groundwater across the state (LeMasters and Doyle, 1989; Cowell and LeMasters, 1992), special projects were conducted to investigate how and why it reaches groundwater. Notably, researchers funded by the Wisconsin Groundwater Research and Monitoring Program discovered that normal field application of atrazine – not just point spills and misuse – was an important source of atrazine in groundwater (Chesters et al., 1990; Chesters et al. 1991). This

knowledge, combined with other findings regarding the roles of soil, geology and agricultural management (Daniel and Wietersen, 1989; Lowery and McSweeney, 1992; Levy and Chesters 1995; Levy et al. 1998), allowed DNR and DATCP to effectively and fairly design both groundwater standards and the atrazine rule, as detailed in this profile on the experience.

Where atrazine use has been prohibited by the atrazine rule, follow-up studies demonstrate there is a clear reduction in atrazine levels, which generally drop below the groundwater standard in 2 - 7 years (DATCP, 2010). Many farmers would like the option to use atrazine in these areas, but they have adapted well to growing corn without it. A 2010 DATCP survey found that the vast majority of farmers in atrazine prohibition areas have not observed a decrease in yield, most believe it is not more difficult to control weeds with other alternatives, and there is an even split in those who think weed control is more vs. less costly without atrazine (DATCP, 2011a). By far, the most popular alternatives to atrazine are glyphosate-containing products such as Roundup. From a groundwater perspective, this is fortunate since glyphosate binds very tightly to soil and thus is generally not considered a groundwater threat. There are concerns, however, that overuse of glyphosate may lead to glyphosate-resistant weeds.

Many sampling programs initiated by DATCP, the DNR and other agencies in the mid-1980s to early 1990s are still ongoing today. The longest running sampling program for pesticides began in 1985 and is designed to evaluate the potential impact of agriculture on groundwater quality by sampling monitoring wells near selected agricultural fields in areas with high groundwater contamination potential. Testing in this program confirms that the metabolites of metolachlor and alachlor are the two most common pesticides products detected in groundwater near the monitoring well sites.

A DATCP review of data from samples it collected statewide from 2008 through 2016 revealed an increased occurrence of detections of neonicotinoid insecticides in samples collected from monitoring wells, irrigation wells, private wells, and surface water samples. DATCP reported detections of the neonicotinoid insecticides clothianidin, imidacloprid and thiamethoxam in samples from monitoring wells, irrigation wells, and private wells tested, with most detections occurring in sandy irrigated vegetable growing areas in the Central Sands region and on terraces of the Wisconsin River Valley (DATCP, 2019). The review also reported that out of 34 streams sampled statewide, multiple detections of imidacloprid and thiamethoxam were reported year-round in two streams also located within the Central Sands region. Concentrations of total neonicotinoids detected in these streams pose significant concerns for aquatic invertebrates and other non-target aquatic species present in the streams. The report detailing the findings of DATCP's review was shared with U.S. EPA as they continue to evaluate the role that these compounds may have in declining pollinator populations nationwide.



Preparing to sample monitoring wells near an agricultural field. Photo: DATCP.

Another study that has been repeated annually since 1995 focuses on re-sampling wells that once previously exceeded a pesticide standard. Over 160 wells have been sampled multiple times in this program, and over time, atrazine levels have been shown to decline in about 80% of the wells (DATCP, 2010). Many of these wells are located in what are now atrazine prohibition areas and the declines are likely the direct result of restrictions placed on the use of this pesticide in these areas.

DATCP has also conducted a statewide, statistically designed survey of agricultural chemicals in Wisconsin groundwater five times since the early 1990s (1994, 1996, 2001, 2007 and 2016). In 2016, nearly four hundred samples from private drinking water wells were analyzed for 101 pesticide compounds, including 70 herbicides, 26 insecticides, 4 fungicides and 1 pesticide safener. Health standards have been established for 27 of the compounds analyzed. In addition to capturing the current picture of agricultural chemicals in groundwater, this series of studies relates these findings to land use and compares results of the 2016 survey to those of previous surveys. The final report of the results of the 2016 survey was published in early 2017 (DATCP 2017).

Future Work

DATCP began oversight of a Stipulated Agreement and Special Order between DATCP and Bayer CropScience (BCS) related to the limited use of the BCS pesticide isoxaflutole in Wisconsin. Isoxaflutole is a relatively new corn herbicide that has a high likelihood of leaching to groundwater. The agreement allows for use on corn grown in

just 12 counties (Columbia, Dane, Dodge, Fond du Lac, Grant, Green, Jefferson, Lafayette, Rock, Sauk, Walworth and Waukesha) while BCS performs specific studies over five years that are intended to clarify the potential for surface or groundwater impacts. Throughout the study, BCS will monitor surface water and tile drainage sites that receive isoxaflutole applications. They will also monitor groundwater at eight groundwater monitoring sites that receive three applications of the pesticide over the 5-year study period.

Further development of health standards and laboratory methods is of paramount importance for keeping pace with the evolving use of agricultural chemicals to ensure that the agricultural success that is so crucial for our state is fairly balanced with the protection of groundwater and human health.

Update on Groundwater Standards for Pesticides

The DNR is currently in rulemaking (DG-15-19) to potentially add new groundwater quality standards in ch. NR 140 for the "Cycle 10" pesticides and pesticide metabolites. Groundwater standards are being proposed for the eight Cycle 10 herbicides and herbicide metabolites: Isoxaflutole, Isoxaflutole DKN (Diketoneitrile) metabolite, Isoxaflutole BA (Benzoic Acid) metabolite, Glyphosate, Glyphosate AMPA (Aminomethylphosphonic Acid) metabolite, Thiencazabone-methyl, Sulfentrazone and Dacthal TPA (Tetrachloroterephthalic Acid) & MTP (Monomethyl Tetrachloroterephthalic Acid) degradates, and for 3 Cycle 10 neonicotinoid insecticides: Thiamethoxam, Imidacloprid and Clothianidin.

Rulemaking (DG-25-20) is also now underway to establish the DHS recommended groundwater quality standards for the "Cycle 11" pesticides in ch. NR 140. The Cycle 11 pesticides includes, four herbicides: Flumetsulam, Fomesafen, Hexazinone and Saflufenacil, one insecticide, Chlorantraniliprole, and one fungicide, Metalaxyl.

Further Reading

[DHS resources for contaminants in drinking water](#)

[DNR overview of pesticides in drinking water wells](#)

[DATCP water quality reports](#)

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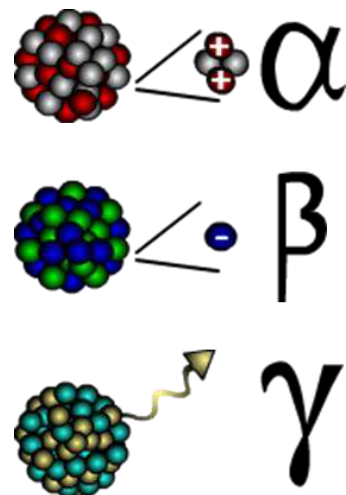
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NATURALLY-OCCURRING RADIONUCLIDES

What are they?

Radionuclides are radioactive atoms. It is possible for radionuclides to be manmade, as is the case with some materials from nuclear power reactors, but they also occur naturally in rock formations and are released to groundwater over millions of years by geochemical reactions. Common naturally-occurring radionuclides in groundwater include uranium and thorium, which both decay to different forms of radium, which in turn decays to radon.

There are no NR 140 groundwater quality standards for radionuclides in Wisconsin but drinking water at public water systems is monitored for general indicators of radioactivity (alpha, beta, gamma activity)—and for specific radionuclides (uranium, radium). Maximum contaminant levels (MCLs) in public drinking water systems have been established for radionuclides at 15 picocuries per liter (pCi/L) for alpha activity, 4 millirems per year (mrem/yr) for beta or gamma activity, 5 pCi/L for total radium, and 30 micrograms per liter (ug/L) for uranium ([WI NR 809.50-809.51](#)). People who drink water containing alpha, beta or gamma radiation, or radium or uranium in excess of established MCLs, over many years, may have an increased risk of getting cancer. In the case of uranium, an increased risk of kidney toxicity is possible as well. There is no public drinking water standard for radon, although the United States Environmental Protection Agency has proposed that radon levels be no higher than 4,000 pCi/L (where indoor air abatement programs for radon exist) or 300 pCi/L (where indoor air radon abatement programs do not exist).



Alpha, beta, and gamma types of radiation. *Figure: US EPA.*

Occurrence in Wisconsin

Since radionuclides occur naturally in rock formations, every well in Wisconsin contains some level of dissolved radionuclides. In many places these levels are not concerning, but some areas of the state tend to have notably high concentrations of radium, radon, and/or gross alpha activity.

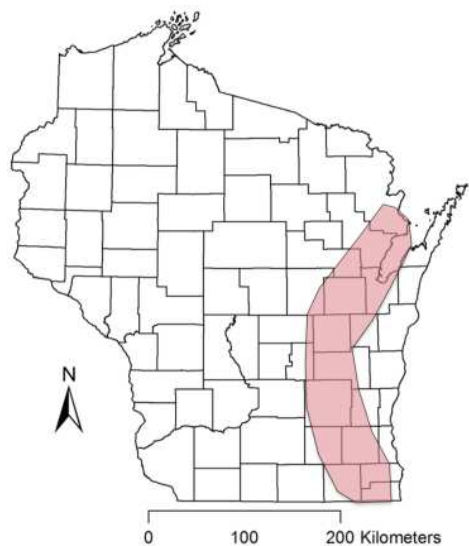
In *northern Wisconsin*, there are notably high levels of both radon and gross alpha activity. Here, the geologic source is usually granite bedrock or, in some cases, granitic sand and gravel deposits.

In *eastern Wisconsin*, wells that draw from a very deep sandstone aquifer, the Cambrian-Ordovician, to the east of where it underlies another geological formation, the Maquoketa shale, often have levels of radium above the MCL. This band of high radium activity stretches from Brown County in the north to Racine County in the south and primarily affects public wells, since drilling deep enough to reach this aquifer is usually prohibitively expensive for smaller private systems. The geochemical explanation for the high radium levels is that the solubility of radium is related to the solubility of sulfate minerals in this

aquifer, and the sulfate minerals that are common to the east of the Maquoketa shale are more soluble than those to the west of the Maquoketa due to the confined conditions and geochemical differences.

About 80 public water systems have exceeded a radionuclide drinking water standard at some point in time. The DNR has been working with these systems since 2003 to ensure that they develop a compliance strategy and take corrective action, so currently less than 10 remain that are providing water in excess of established radionuclide MCLs.

GCC Agency Actions



Area of Wisconsin where most of the wells that exceed the drinking water MCL for radium are located. This band coincides with where the Cambrian-Ordovician sandstone aquifer intersects the Maquoketa shale.

Figure: Luczaj and Masarik, 2015.

By the mid-1980s, regular monitoring of public water supplies in north central Wisconsin seemed to indicate that there was an increased risk of radionuclide contamination in wells drawing from the granite bedrock aquifer. This raised concern since, at the time, drilling to this deeper granite aquifer was viewed as the best alternative if wells in the shallow sand and gravel aquifer became contaminated by manmade sources. After collecting and analyzing nearly 500 samples from this area in the late 1980s, the DNR showed that the granite bedrock aquifer is indeed a significant source of radionuclides, especially *radon*, and the DNR began taking steps to educate well owners and expand the investigation. Follow up work in other regions of the state by the DNR, WGNHS, and DHS also showed that while nearly all aquifers in the state contain some amount of radon (at or above 300 pCi/L), exceedingly high levels (over 4,000 pCi/L) are only found in granite or in sand and gravel deposits derived from granite (Mudrey and Bradbury, 1993). A few studies by University of

Wisconsin researchers at this time also noted that unusually high levels of *radium* in eastern Wisconsin seemed to be related to the Maquoketa shale formation (Taylor and Mursky, 1990; Weaver and Bahr, 1991).

In the early 2000s, the flow patterns and geochemistry of groundwater in southeastern Wisconsin became of great interest as large-scale pumping driven by growing communities outside Milwaukee began to dramatically change groundwater conditions. One puzzle to scientists was why *radium* levels were elevated to the east of the Maquoketa shale in this region but not to the west – conventional understanding of the sources of radium did not seem sufficient to explain observations. Leveraging new models and knowledge about groundwater flow patterns in the Waukesha area, researchers at the University of Wisconsin and WGNHS, funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP), elucidated the relationship between radium and sulfate minerals in the area, collecting much needed information on the geochemical backdrop of the region in the process (Grundl and Cape, 2006; Grundl et al. 2006).

A study of radium in groundwater, in the Cambrian-Ordovician aquifer system, was conducted in the vicinity of Madison in 2016 - 2017 (Mathews et al. 2019). This study evaluated radium occurrence in groundwater relative to several geochemical parameters, as well as the presence of naturally occurring radium “parent elements”, uranium and thorium, in aquifer bedrock units. The Cambrian-Ordovician aquifer in central Wisconsin is composed of an unconfined bedrock aquifer unit and a confined bedrock aquifer unit, separated by the Eau Claire shale aquitard. Radium parent radionuclides (^{238}U and ^{232}Th) were found associated with both the Eau Claire shale aquitard and bedrock layers in both unconfined and confined Cambrian-Ordovician aquifer units. The study found an association in the upper, unconfined aquifer unit, between elevated levels of radium in groundwater and relatively high levels of total dissolved solids (TDS). High TDS in groundwater, creating competition between radium and other dissolved ions for sorption sites, is proposed as the explanation for the elevated groundwater radium found in the unconfined aquifer unit. Elevated groundwater radium in the lower, confined aquifer unit was found to be associated with very low groundwater dissolved oxygen (DO) levels. Dissolution of iron and manganese hydroxide radium adsorption sites occurs under low DO conditions and adsorbed radium can be mobilized into groundwater under those geochemical conditions.

The Wisconsin State Laboratory of Hygiene and other WGRMP-funded researchers have also made advances in sampling techniques and laboratory testing for radionuclide parameters, which tend to be very sensitive to collection and analysis methods. These studies have demonstrated how simple differences in approaches can cause one analysis to conclude a water sample is below the MCL while another can conclude the opposite about the same sample (Sonzogni et al., 1995; Arndt and West, 2004). Following these findings, researchers have developed corrections and guidelines to ensure reported test results are as accurate as possible.

Future Work

The DNR continues to work with public water systems that exceed drinking water standards for radionuclides to bring them into compliance. Options include blending water high in radionuclides with water from sources containing lower levels of radionuclides, finding an alternative water supply or constructing a new well in a low radionuclide aquifer, and softening or applying another effective radionuclide removal treatment technique to the water supply. The need for compliance with radium drinking water standards is the main reason the city of Waukesha sought, and received approval under the Great Lakes Compact, for diversion of Lake Michigan water.

Further Reading

[DHS resources for contaminants in drinking water](#)

[DNR overview of radium in drinking water wells](#)

[DNR overview of radon in drinking water wells](#)

[WGNHS report on distribution of radionuclides in groundwater](#)

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VOLATILE ORGANIC COMPOUNDS

What are they?

Volatile Organic Compounds (VOCs) are a group of common industrial and household chemicals that evaporate, or volatilize, when exposed to air. Examples of products containing VOCs include gasoline and industrial solvents, paints, paint thinners, air fresheners and household products such as spot and stain removers. Chemical names for the VOCs in these products include benzene, Trichloroethylene (TCE), toluene and vinyl chloride, among others. Improper handling or disposal of VOCs is often the reason why they occur in groundwater.



Collection of household products containing VOCs including paints, stains, and paint thinners. Photo: Tom Murphy VII

Health risks vary depending on the VOC. Short-term exposure to high concentrations of many VOCs can cause nausea, dizziness, anemia, fatigue or other health problems. Long-term exposure to some VOCs may cause cancer, liver damage, spasms, and impaired speech, hearing and vision. For more on the health effects of specific VOCs, see the resources listed by the Wisconsin Department of Health Services (DHS) at <https://www.dhs.wisconsin.gov/water/index.htm>.

Occurrence in Wisconsin

At least 59 different VOCs have been found in groundwater in Wisconsin, although only 34 of those have health based standards (groundwater [WI NR 140.10](#), drinking water [WI NR 809.24](#)). The main sources of VOCs in Wisconsin groundwater are landfills, leaking underground storage tanks (LUSTs), and a variety of facilities that use VOCs in their regular operations, including gas stations, bulk petroleum and pipeline facilities, plating



Installation of a compacted clay and geotextile liner at a landfill site in Wisconsin. Photo: DNR

facilities, dry cleaners and other industrial facilities. The Department of Natural Resources (DNR) currently tracks about 700 current or former landfills, 21,000 LUSTs and 8,000 other facilities which are required to monitor groundwater. The DNR also tracks approximately 39,000 spills, some of which are also sources of VOCs. Given how common potential sources of VOCs are, these substances are more frequently found in groundwater near urban industrial and

commercial areas. However, exceedances of groundwater standards for VOCs have been reported in every county in the state.

GCC Agency Actions

Early studies by the DNR and DHS in the late 1980s and early 1990s focused on VOC contamination from landfills, specifically from those without linings to protect groundwater from leachate. DNR scientists found that VOCs contaminated groundwater at 60% of unlined industrial landfills and 80% of unlined municipal solid waste landfills (Friedman, 1988; Batista and Connelly, 1989). Further review of monitoring data showed that while VOC levels typically decrease following the closure of unlined landfills, concentrations remain high and do not always show continued improvement within a reasonable period of time (Batista and Connelly, 1994). In the late 1990s, this knowledge raised concerns since increasing numbers of residential developments were located close to old, closed landfills. In 1999, the DNR and DHS designed targeted sampling of private wells near old, closed landfills to investigate and address the problem. For wells where VOCs were detected above drinking water standards, residents were given health advisories not to drink water and the DNR took follow-up measures at the nearby landfills. Much more stringent engineering standards have guided the design of modern landfills (those built after the 1980s), so these have a much better record in terms of VOC contamination, but older landfills continue to remain a concern (US DHHS, 2006).



Drilling to monitor for VOCs near a Wisconsin landfill. Photo: [DNR](#)

A critical role of GCC agencies is identifying and monitoring all known sources of VOCs, not only landfills. The Department of Agriculture and Consumer Protection (DATCP) keeps track of all underground storage tanks (USTs) with a capacity of 60 gallons or greater; this registry has identified over 180,000 USTs since 1991. Hazardous waste treatment, storage and disposal facilities must be licensed by the DNR and are subject to corrective action authorities in the event of spills or releases. The DNR's Bureau for Remediation and Redevelopment oversees investigation or remediation at 128 RCRA 2020 corrective action sites. More broadly, the Hazardous Substance Spill Law requires immediate notification to the DNR when any hazardous spills or discharges occur and requires that all necessary actions be pursued to restore the environment to the extent practicable. The spills program also develops outreach materials to help reduce the number and magnitude of spills and provide guidance for responding to spills. Topics addressed include spills from home fuel oil tanks, responses to illegal methamphetamine labs and mercury spills, all of which can lead to significant environmental impacts, if not properly addressed.

Future Work

Continuing to identify and monitor known sources of VOCs is key to continued protection of drinking water. Each year, several hundred contaminated sites, some of which involve VOCs, are reported to the DNR and each year, cleanup begins at another several hundred

sites. Continuing to track and respond to this ongoing issue remains an important objective for GCC agencies.

As part of a continuing commitment to protect public health, public welfare, and the environment, the DNR periodically updates groundwater quality standards in ch. NR 140, Wis. Adm. Code. In 2018 the DNR requested that DHS review new toxicological information available for five VOCs: Trichloroethylene (TCE), Tetrachloroethylene (PCE), 1,2,3-Trichloropropane (1,2,3-TCP), 1,1-Dichloroethane (1,1-DCA) and 1,4-Dioxane, to see if updated groundwater standards for these substances was warranted. Based on its review, DHS has recommended updated standards for four of the reviewed VOCs: TCE, PCE, 1,2,3-TCP and 1,4-Dioxane (see <https://www.dhs.wisconsin.gov/water/gws.htm>). The DNR is currently in formal rulemaking to potentially adopt the DHS recommended updated standards into ch. NR 140.

Further Reading

[DHS resources for contaminants in drinking water](#)

[DNR overview of VOCs in private drinking water wells](#)

[DNR map of open and closed contaminated sites](#)

[DNR database of contaminated soil and groundwater](#)

[DHS overview of vapor intrusion](#)

[USGS report on VOCs in the nation's groundwater and drinking water wells](#)

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EMERGING CONTAMINANTS

What are they?

An emerging contaminant is a substance for which there is increasing evidence of environmental occurrence and that the substance may cause adverse human and/or environmental health effects. The term is shorthand for “contaminants of emerging concern”. There are two general reasons why concern about a substance can be emerging. The first is technological improvements: some emerging contaminants may have been present in the environment for a long time but new measurement methods improve our ability to detect them. The second reason is emergence of a compound not previously common in the environment due to a new substance being manufactured, or recent changes in use or disposal practices of existing substances. Research on the occurrence and health effects of these contaminants is important to characterize the nature of the risk and decide what actions may be required to protect human and environmental health.



Pharmaceuticals, including antibiotics and birth control pills, and personal care products are one group of emerging contaminants. *Photo: US Department of Defense*

Emerging contaminants consist of a range of substances, many of which are produced synthetically, and may enter the environment in wastewater from municipal or industrial sources. Treatment of municipal wastewater typically lowers the concentrations of emerging contaminants, but considerable levels may remain after treatment. Groundwater is impacted if contaminants in treated wastewater infiltrate to groundwater. Emerging contaminants may also enter the environment from agricultural wastes, which may be solid or liquid. Agricultural wastes are often land-spread to make nutrients from the wastes available to crops, but if the wastes contain contaminants, they may migrate toward groundwater as irrigation water, rainwater or snowmelt infiltrate.

Degradation processes, if they occur, can reduce the amount of contaminant that makes it to groundwater. Degradation can be abiotic—for example, through reaction with water, known as hydrolysis—or biotic, meaning that a microbial organism starts a chemical reaction, in which the organism uses some of the original molecule but the rest—a *metabolite*—is left over. Degradation is normally only considered to be complete only if all of the parent compound is converted to other naturally occurring chemicals, such as carbon dioxide (CO₂), water (H₂O), and dinitrogen gas (N₂). Incomplete degradation, also known as transformation, is when the parent compound transforms into one or more metabolites but not all the way to naturally occurring chemicals.

Another process that can reduce the amount of a contaminant that arrives in groundwater is *sorption*. Sorption is a physical/chemical reaction in which substances,

dissolved or suspended in water, form a bond with minerals or soil organic matter, attaching them to the solid material. Sorption can be reversible, meaning that *desorption* can also occur later. Desorption can occur when the concentration of the same substance in infiltrating water decreases. This can happen, for example, during a large rain event. If a contaminant desorbs under commonly occurring conditions, sorption only increases the amount of time before contaminants make it to groundwater.

Emerging contaminants for which a laboratory analytical standard (i.e., the pure substance dissolved in water or another liquid at a known concentration) exists are often measured with *liquid chromatography with mass spectrometry detection* (LCMS). With this technique, a liquid sample is injected into the laboratory instrument, with or without procedures to “clean up” the sample by removing other compounds that may interfere with measurement. Substances within the sample are then ionized with an electrical charge, and ionized portions of the substances are detected with *mass spectrometry*. The results of mass spectrometry can then be used to determine the molecular weight of the substances in the sample under investigation and identification of specific compounds in the sample can be made.

Technologically advanced variations of this technique include the use of *tandem mass spectrometry detection* (MS/MS), in which two different methods of ionizing the chemicals dissolved in water are used, creating more fragments of the original substance. MS/MS is used for the measurement of Per- and Polyfluorinated Alkyl Substances (PFAS), in important category of emerging contaminants, under U.S. EPA and other methods.

Availability of a laboratory analytical standard of a substance is necessary for definitive detection and quantitation. However, emerging research laboratory techniques use high resolution mass spectrometry (HRMS) to obtain a more holistic picture of the variety of chemical compounds present in a sample, including ones for which an analytical standard does not exist. When emerging contaminants are known or suspected to transform, HRMS is particularly useful for finding the metabolites. HRMS is also useful for detecting compounds in the second category of emerging contaminants—newly manufactured substances—for which a laboratory analytical standard may not yet exist. The information on the combinations of split fragments can be compared to a library of possible molecules. From this comparison, inferences about possible chemicals (including metabolites) present can be made, even without a laboratory analytical standard for the substance. HRMS laboratory devices are more expensive and currently less commonly available than LCMS (including ones with MS/MS capability).

The following sections give information on categories of emerging contaminants that may be found in Wisconsin groundwater.

Pharmaceuticals and Personal Care Products

Pharmaceuticals enter the environment through disposal of unused pills as well as excretion of the compounds or their metabolites from the human body. A metabolite is a compound produced by the body's metabolism from the "parent" compound, i.e. the original pharmaceutical. Metabolites often, but not always, have similar chemical properties as the parent compound. Pharmaceuticals detected in groundwater worldwide include antibiotics, non-steroidal anti-inflammatory drugs, birth control medications, and many other prescription medicines. Many pharmaceuticals begin to degrade in soil passage or groundwater, but the presence and types of metabolites are, to a large extent, still being discovered. Stimulants such as caffeine and nicotine, as well as recreational drugs, may also be found in groundwater.

Together, pharmaceuticals and personal care products (PPCPs) - including shampoos, detergents and "over-the-counter" non-prescription medicines - make up a category of emerging contaminants that largely enter the environment from domestic wastewater and municipal sources. Point sources of PPCP discharge into the environment include wastewater treatment plants, which may remove some but not all of these compounds from wastewater, discharge from septic systems, land application of wastewater septage and leakage from older landfills.

Per- and Polyfluorinated Alkyl Substances (PFAS)

A group of emerging contaminants of much current concern are perfluoroalkyl and polyfluoroalkyl substances (PFAS). These molecules are comprised of organic carbon chains in which some (poly-) or all (per-) hydrogen atoms have been replaced with fluorine atoms. PFAS have been used in a variety of industry and consumer products since the 1940s and are now being detected in groundwater and drinking water supplies worldwide. PFAS gained widespread use in part due to their ability to repel water and oil and withstand high temperatures. They are found in numerous consumer products, such as non-stick cookware, stain- and water-repellent clothing and carpeting, grease-resistant liners to food packaging including microwave popcorn, some spray paints, and Class B fire-fighting foams (fires involving flammable liquids).

Many polyfluorinated substances that are part of the PFAS chemicals family transform in the environment to other PFAS, especially to perfluoroalkyl acids such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS). However, PFAS are not known to degrade in groundwater or elsewhere in the environment into any non-toxic end products. Therefore, they may accumulate in environmental settings. Ways PFAS can enter the environment include placement of PFAS-containing products in landfills, use of the products in combination with water resulting in their presence in wastewater, spreading of biosolids (a product of wastewater treatment) on cropland to replenish soil organic matter, and direct use and lack of containment of the chemicals at manufacturing and firefighting sites.

The two most widely studied PFAS are PFOA and PFOS, both of which present health risks and are commonly found in groundwater. While these two substances may have been manufactured directly during the mid-20th century, manufacturing shifted during the late 20th century to polyfluorinated substances (precursors) that may transform to end products, including but not limited to PFOA and PFOS. These compounds may transform slowly in soil and groundwater, representing ongoing sources of PFOA and PFOS to the environment. Since the turn of the century, manufacturing has shifted to shorter chained compounds such as perfluorobutane sulfonate (PFBS) and its precursors, in applications where previously PFOS or its precursors was used. Additionally, manufacture of PFAS containing additional chemical structures (e.g. ethers) has emerged, with this category of PFAS being known as “replacements”. An example of a replacement PFAS is hexafluoropropylene oxide dimer acid (HFPO-DA, sometimes referred to by the trade name "GenX"), which may be used in food packaging and paints, among other products. PFBS and HFPO-DA are among the compounds that were evaluated by the Wisconsin Department of Health Services and that agency has provided recommendations for groundwater quality standards for the two substances to the DNR.

For more information on PFAS, please see the PFAS section of the report.

Pesticides and other Agricultural Contaminants

In many agricultural practices, pesticides are applied to crops to kill or hinder the effects of “pests”, which can be insects, competing plants (weeds), fungi, and bacteria. On large areas of crops, application is done from small airplanes to distribute the chemicals over a large area. Due to crop irrigation and precipitation events, pesticides may leach into groundwater. Although about 30 pesticides are currently regulated in Wisconsin, over 90 are known to be used.

Most pesticides can sorb to soil and aquifer material, meaning they often travel to and through groundwater more slowly than the water itself. Some are also transformed into metabolites by bacteria. Active methods of destroying pesticides include photocatalytic techniques, which combine use of light and chemicals to “catalyze” pesticide-destruction reactions.

Although pesticides have been in use since the middle of the 20th century, new pesticides continue to come into use. One such pesticide is the herbicide isoxaflutole, which is used for weed control on corn crops. Isoxaflutole is currently being considered for regulation under NR 140 and is an example of a contaminant that is of emerging concern due to a recent increase in usage. For more information on pesticides, please see the pesticides section of the report.

Though functionally part of the PPCPs category of emerging contaminants, antibiotics and anti-parasitical drugs are also used in agriculture, to prevent infection outbreaks in mass raising of livestock. The overall amount of antibiotics used in such applications may be similar to or even greater than usage of antibiotics in human medicine, but generally fewer antibiotic substances are used in livestock applications. An example of a livestock antibiotic is sulfamethazine. Sulfamethazine has a tendency to sorb to soil and

can be transformed under toxic conditions, but it may not be fully degraded to naturally occurring chemicals. Another type of contaminant from agriculture is hormones. Steroid hormones have been found in a study of dairy wastewater (Zheng et al., 2008).

Microbial Contaminants

Microbial contaminants such as viruses and pathogenic bacteria can be contaminants in groundwater. In fact, most bacteria that exist in the natural environment are thought to present little if any human health risk. Some bacteria can also improve water quality by degrading other emerging contaminants (e.g. PPCPs). However, a few bacteria are pathogenic (disease causing) and can cause human health impacts. Areas where soil is thin and groundwater supplies are drawn from a carbonate (limestone/dolomite) bedrock aquifer may be especially susceptible to microbial contamination.

Two sources of microbial contaminants are manure from livestock and human sanitary sewage. Pathogenic microbes from these sources may cause gastrointestinal illnesses, sometimes severe. A common type of enteric bacteria (bacteria that reside in the gut of humans and other animals) is *Escherichia coli* (commonly referred to as *E. coli*). Most *E. coli* strains are harmless, but pathogenic strains exist, for example the Shiga toxin-producing strain *E. coli* O157:H7. Water tests for *E. coli* detect a strain of *E. coli* that itself is harmless, but which is a good indicator that pathogenic microbes may be present.

Viruses in groundwater include norovirus, adenovirus and enterovirus. Viruses generally cannot reproduce without a host, but they can infect bacteria. A virus that infects, or replicates within bacteria is referred to as a “bacteriophage” (or simply “phage”). This usage of bacteria as hosts may enable viruses to survive longer in groundwater.

Antibiotic resistance is considered by the World Health Organization to be a major threat to health, food security, and development. After usage of an antibiotic, there is a tendency for bacteria that survived previous applications of the substance to become a larger part of the overall bacterial population—this phenomenon is antibiotic resistance. While antibiotics are used in both human and veterinary medicine, a greater number of antibiotic compounds are thought to be used in humans. As a consequence of antibiotic use in human medicine, multi-resistant bacteria (i.e., bacteria resistant to more than one antibiotic) have been found in clinical settings. Antibiotic resistance has been found in municipal wastewater discharge in studies in Europe, with patterns indicating that the resistance developed in clinical settings is spreading into the environment (Pärnänen et al. 2019). In another study, a strain of *E. coli* resistant to multiple antibiotics was found in hospital wastewater, although community wastewater appeared to be a greater overall contributor of antibiotic resistance (Paulshus et al. 2019). In a study of groundwater impacted by dairies in California (Li et al. 2014), antibiotic resistant *E. coli* bacteria were found in one sample, indicating potential for antibiotic resistant bacteria to be present in groundwater.

For more information on microbial pathogen, see the Pathogens section of the report.

Microplastics

Microplastics are small pieces of plastic, often less than 1 millimeter in size. The name “micro” broadly refers to the size range of micrometers—a micrometer is one one-thousandth of a millimeter. Some microplastics are produced at this size for specific (industrial) purposes, while others are breakdown products of larger plastics (SAPEA, 2019). Microplastics have been found in marine environments for decades (Rochman, 2018), but more recently are being discovered in terrestrial environments, including Lake Michigan (Mason et al., 2016). A recent study published in the journal *Science* found atmospheric deposition of on average 132 plastics per square meter every day on western U.S. protected lands (Brahney et al., 2020). Microplastics appear to accumulate in soils, including ones used for agriculture (Rochman, 2018). A recent study found microplastics—possibly leaked from septic systems—in karst groundwater in Illinois (Panno et al., 2019). While infiltration of water through soils might slow, minimize, or prevent the spread of microplastics into groundwater due to the filtering effect of soils, karst groundwater is particularly susceptible to contamination because water often is present in open fractures. While Wisconsin also has near-surface karst groundwater in some parts of the state, no studies of microplastics in the State’s groundwaters are known.

Other Emerging Contaminants

Emerging contaminants not discussed above but which have been studied worldwide include flame retardants, phthalates and other plasticizers, and nanomaterials. Flame retardants are substances that are added to household, commercial building or other products to reduce flammability. A subset of flame retardants of particular concern are brominated compounds, such as polybrominated diphenyl ethers (often abbreviated “PBDEs”) and polybrominated biphenyls (often abbreviated “PBBs”).

Phthalates are used in bendable plastics as softening agents but are not chemically bound to the plastic and can leach out into water. Research indicates that they might not bioaccumulate (unlike many other synthetic organic compounds), but they have been found to be endocrine disrupting compounds, or substances that disrupt endocrine systems of humans and animals.

Nanomaterials are industrially produced physical particles that are between approximately 1 and 100 nanometers in size (there are one million nanometers in one millimeter). They have diverse uses in industry and commercial products, such as electronic components, paints and coatings, ultraviolet blockers in sunscreens, telecommunication, packaging materials and auto parts.

Occurrence in Wisconsin

The occurrence of emerging contaminants in Wisconsin is not easily generalized, but several studies supported by the GCC have investigated the potential for certain emerging contaminants to enter groundwater from specific sources.

PFAS.

For information on the occurrence of PFAS in Wisconsin's groundwater, please see the PFAS section.

Pharmaceuticals and Personal Care Products.

Antibiotics have been detected in treated wastewater effluent from facilities across the state, with very low concentrations of tetracycline and sulfamethoxazole detected in groundwater directly adjacent to a wastewater treatment facility groundwater discharge site (Karthikeyan and Bleam, 2003). Acetaminophen (Tylenol), paraxanthine (a caffeine metabolite) and the hormones estrone and β -estradiol have been detected in private on-site wastewater treatment system (POWTS) effluent in a Dane County study (Bradbury and Bahr, 2005), and estrogenic endocrine disrupting compounds (EDCs) were detected in POWTS effluent in a southeast Wisconsin study (Sonzogni et al., 2006). Neither study detected these compounds in groundwater. A follow up study at the Dane County site, ten years after subdivision development, however, found a number of contaminants that may have moved from POWTS discharge into groundwater. Artificial sweeteners—often used as an indicator of municipal wastewater effluent—were found in seven of ten monitoring wells and two water supply wells.



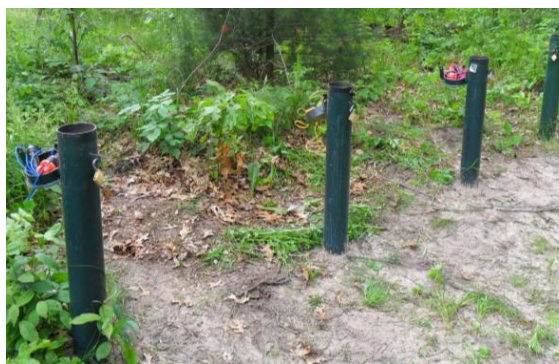
Pete Chase and Jacob Krause, WGNHS, install well casing during a WGRMP-funded experiment designed to improve understanding of virus transport from wastewater to drinking water wells. Photo: Blake Russo-Nixon.

Microbial pathogens.

Human enteric virus indicators and pathogenic bacteria indicators have been found in groundwater supply wells in the Madison area (Bradbury et al., 2015). Studies also suggest human enteric viruses from wastewater sources may be present in private and public drinking water wells across the state (Borchardt et al., 2003a, 2003b, 2004, 2007; Bradbury et al. 2013).

Pesticides.

For information on the occurrence of pesticides in Wisconsin's groundwater, see the pesticides section.



Nested piezometers installed for monitoring groundwater levels and sampling for groundwater contaminants near Spring Green. Photo: Blake Russo-Nixon.

GCC Agency Actions

By definition, much is unknown about emerging contaminants, so an important role of the GCC is supporting research studies that further scientific understanding of these substances. In addition to the many studies mentioned above that tested for occurrence of emerging contaminants, other WGRMP-funded projects have explored pathways of contaminant transport. One group of these studies investigated factors that affect the mobility and fate of antibiotics in the subsurface (Gao and Pedersen, 2005 and 2010; Gu and Karthikian, 2005a, 2005b, 2008; Gu et al., 2007; Sibley and Pedersen, 2008; Pedersen et al., 2009). This body of work has helped describe under what conditions specific antibiotic compounds bind to soil, which is important for assessing the risk to groundwater from antibiotics in wastewater sources.

Health effects of emerging contaminants vary and are not always well understood. Some emerging contaminants, including some pesticides and PPCPs, act as endocrine disrupting compounds (EDCs), which adversely affect the behavior of natural hormones in animals and humans. EDCs include both anthropogenic chemicals, such as pesticides and plasticizers, and naturally occurring compounds like steroids and plant-produced estrogens. Scientific studies suggest toxic endpoints varying by compound, with possible health effects including developmental, reproductive, neurologic and immune problems, as well as cancer (NIH, 2010). In many cases, more research is needed.

Periodic groundwater monitoring in areas known to be vulnerable to emerging contaminants is another way in which GCC agencies coordinate efforts to understand emerging contaminants. DATCP's regular statistical survey of agricultural chemicals and targeted monitoring programs in agricultural areas are examples of this. The DNR also regularly reviews groundwater data from near active and closed landfills, mining operations and hazardous waste remediation sites to gather information on potential sources of emerging contaminants.

Future Work

In Wisconsin law, there is an established process for regulated facilities to review groundwater monitoring data and identify contaminants of emerging concern ([WI 160.27](#)). A fundamental component of this process is the long-term groundwater monitoring data itself, so maintenance and expansion of current networks is an ongoing priority for the GCC.

The US Environmental Protection Agency (EPA) also has a process for regularly gathering data on emerging contaminants and assessing potential risks nationwide. The Unregulated Contaminant Monitoring Rule (UCMR) provides for monitoring of unregulated contaminants every five years, in all large (serving > 10,000 people) and a sample of small (serving < 10,000 people) public water systems. The Third UCMR (UCMR3) monitoring period was completed in 2015. Monitoring for the Fourth UCMR (UCMR4) began during 2018 and focused on select pesticides and several naturally occurring compounds. The Fifth UCMR (UCMR5) will begin in 2023 and will focus on PFAS, with an expanded analyte list and lower detection limits compared to

UCMR3. Data collected at Wisconsin public water supply systems during UCMR monitoring along with GCC-supported monitoring and occurrence study results provide valuable information on the occurrence of emerging contaminants in Wisconsin's groundwater resources.

The US EPA also maintains a [Contaminant Candidate List \(CCL\)](#) of physical, chemical, biological and radiological substances that might potentially be found in drinking water. Potential contaminants listed on the CCL are substances not currently subject to federal Safe Drinking Water Act (SDWA) regulation but are known, or anticipated to be present in public water supply systems. The US EPA evaluates occurrence data on these unregulated contaminants and this information assists with identification of potential emerging contaminants in Wisconsin groundwater.

Currently, there are no federal regulatory standards for PFAS associated with any environmental media. To address this regulatory gap, DNR is proceeding with NR 140 Cycle 10 rulemaking for a recommended standard of 20 ng/L for PFOA and PFOS, individually or combined. The DHS has provided recommendations for groundwater quality standards for sixteen other PFAS compounds as part of NR 140 Cycle 11. On June 23rd, 2021, the Natural Resources Board approved the NR 140 Cycle 11 statement of scope, allowing for rulemaking for those sixteen PFAS (and six pesticides) to proceed. Approved rulemaking may take up to 30 months to complete.

Further Reading

[DNR overview of pharmaceuticals and PCPs in the environment](#)

[DNR overview of per- and polyfluoroalkyl substance \(PFAS\) contamination](#)

[Wisconsin Remediation and Redevelopment Database \(WRRD\)](#)

[DATCP Groundwater Quality Reports](#)

[NIH factsheet on endocrine disruptors](#)

[US EPA Third Unregulated Contaminant Monitoring Rule \(2012-2016\) fact sheets](#)

[US EPA Third Unregulated Contaminant Monitoring Rule \(2012-2016\) data summary](#)

[US EPA Fourth Unregulated Contaminant Monitoring Rule \(2017-2021\) information](#)

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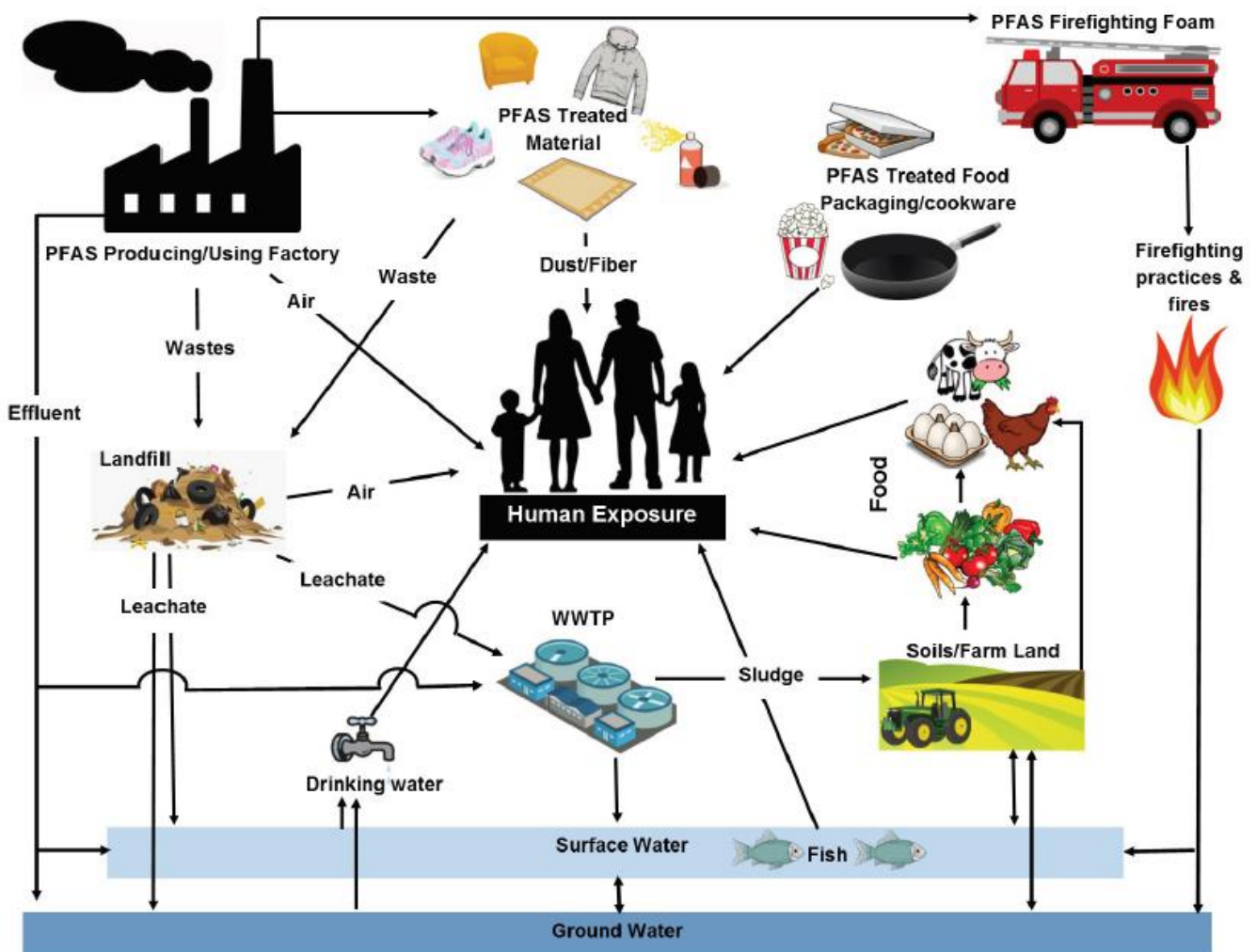
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PER- AND POLYFLUORINATED ALKYL SUBSTANCES

What are they?

Perfluoroalkyl and polyfluoroalkyl substances (PFAS) are a large group of human-made chemicals that have been used in industry and consumer products worldwide since the 1940s. Their ability to repel water and oil and withstand high temperatures has made PFAS a particularly useful ingredient in industrial and commercial products, including non-stick products, stain- and water-repellent clothing, and aqueous film forming foams (AFFFs). These chemicals do not easily break down in the environment and have been known to accumulate in the environment and humans. The acronym PFC has been used to describe PFAS in the past. This acronym is no longer used to describe per- and polyfluoroalkyl substances (PFAS) because it is used to describe perfluorocarbons (i.e., refrigerants), which are a different family of chemicals.



Sources of PFAS and modes of human exposure. Image credit: Maine Drinking Water Program, Service Connection newsletter, Volume 25, Issue 4. Image adapted from Oliaei et al., 2013.

Humans may be exposed to PFAS in several ways, including: drinking municipal or private well water contaminated by PFAS, eating wildlife (such as fish) in which PFAS have bioaccumulated, accidentally or unknowingly inhaling [dust](#) contaminated by PFAS (an original source could be couch or mattress coverings that were treated with PFAS), and eating food that was packaged in material that contains PFAS. Although numerous consumer products are thought to contain PFAS, direct exposure from consumer products may be more acute in certain cases in which a PFAS-containing product could be ingested (e.g., lipstick). In a nationwide study, low levels of PFAS were determined to be present in the blood of most Americans.

Although PFAS have been used extensively since the mid-20th century, in recent years the scientific health research community has made progress to better understand their potential impacts to human health. This understanding continues to evolve based on ongoing research. The four perfluoralkyl acids (PFAAs) perfluorooctane sulfonic acid (PFOS), perfluorooctanoic acid (PFOA), perfluorohexane sulfonic acid (PFHxS), and perfluorononanoic acid (PFNA) are among the most studied PFAS chemicals. Current studies of these PFAS suggest exposure may affect childhood development, decrease female fertility, increase the risk of high blood pressure in pregnant women, increase cholesterol levels, increase the risk of thyroid disease, and decrease antibody response to vaccines. EPA research suggests that some PFAS may have the potential to cause cancer, but the topic requires further research.

Currently, there is limited regulatory authority regarding PFAS at the federal level. In 2016, the EPA issued a non-enforceable [Lifetime Health Advisory level for PFOA and PFOS](#) of 70 parts per trillion (ppt) in drinking water and in February 2020 released an updated PFAS action plan titled [EPA PFAS Action Plan: Program Update](#), that, among other steps, pledges to work under the Safe Drinking Water Act (SDWA) to make a regulatory determination for PFOA and PFOS. Currently, the DNR, under [Chapter 292, Wisconsin Statutes](#), has authority to require parties that discharge PFAS to the air, land,



Firefighters training with firefighting foam. A specific type of firefighting foam, known as Aqueous Film Forming Foam, contains significant amounts of PFAS and is designed for use on fires involving flammable liquids (Class B).

and waters of the State to take action to restore the environment to a practicable level. DNR's Water Quality Program has authority to regulate discharges to surface water on a site-by-site basis in accordance with the federal Clean Water Act.

Occurrence in Wisconsin

Under the Safe Drinking Water Act's third Unregulated Contaminants Monitoring Rule (UCMR-3), about 90 municipal water systems statewide were sampled for PFOA and PFOS between 2013 and 2015. PFAS were detected in municipal water systems in La Crosse, West Bend, and Rhinelander. At the time, laboratory analysis was only done for six PFAS analytes, whereas since the beginning of 2020, laboratory analysis for Wisconsin samples has often been done for at least 33 PFAS analytes. Also, laboratory reporting limits were considerably higher in the UCMR-3 project than they are today. In the case of PFOA and PFOS, the UCMR-3 laboratory reporting limits were 20 ppt and 40 ppt, respectively. Currently, the Wisconsin Department of Health Services (DHS) recommended groundwater protection standard and drinking water health advisory level is 20 ppt for PFOA and PFOS individually or combined. The data from UCMR-3 served as an initial indicator of the fact that both groundwater and drinking water supplies in Wisconsin have been impacted by PFAS.

Since UCMR-3 was conducted, sampling has also been conducted voluntarily by several municipal water systems and in some cases laboratory analysis included a more comprehensive list of PFAS. These sampling efforts identified PFAS in varying concentrations in municipal water systems in Marinette (surface water source), Madison, and Rhinelander, as well as additional impacts in La Crosse and the Town of Campbell on French Island.

Other than UCMR-3 sampling, there has not yet been any statewide sampling of PFAS in groundwater in Wisconsin. However, DNR is currently planning a project to sample at least 90 of the state's 611 municipal water systems for PFAS in groundwater-sourced drinking water. Finished drinking water from all groundwater sources to each system will be sampled. These groundwater sources in the 90 selected systems represent about 30% of all groundwater sources of municipal drinking water statewide. The project is expected to begin during the summer/fall of 2021. The Wisconsin PFAS Action Council (WISPAC), a multi-agency PFAS task force created by Governor Evers' [Executive Order 40](#), recommends sampling of every municipal system and additional priority public water systems for PFAS, contingent upon availability of sufficient funding.

Much work on PFAS in Wisconsin has focused on contaminated site investigations. As of June 2021, there are approximately 60 open site investigations statewide in which one or more PFAS have been identified as a contaminant. Such contaminated site investigations include former firefighting training areas (civilian, corporate and military), industrial facilities, landfills, and an area where biosolids were land applied. The latter two types of sites are secondary sources, where PFAS were not produced or used directly but rather released to the environment due to their presence in consumer products or other waste streams. Among landfills, older unlined landfills

may present a higher risk to groundwater. The environmental stability and lack of effective treatment of PFAS in municipal sewage plants may lead to their presence in biosolids, which might threaten the practice of biosolids land spreading as a beneficial reuse of municipal waste. In areas without municipal sewerage, PFAS may also be released to groundwater from septic systems due to their presence in numerous commercial products.

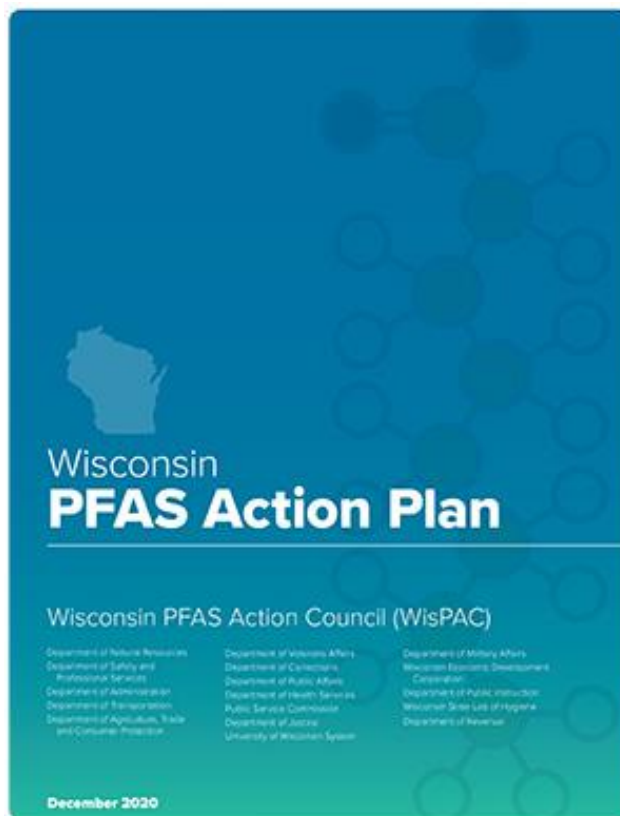
Where PFAS are discovered in groundwater and attributed to a responsible party, the resulting site investigation and remedial actions may be a multi-year process and for larger and more complex sites may take decades. This work includes all impacted media, not just groundwater. Meanwhile, DNR is reviewing scientific findings indicating that relatively low concentrations of PFAS may be common in groundwater, even at locations far away from known contaminated sites. Despite the fact that PFAS are exclusively created by industrial production and they do not occur naturally, the term 'background' is nevertheless sometimes used to refer to low concentrations of PFAS commonly found in groundwater and that may not be readily attributable to a specific industrial or commercial release to the environment. The paradox that PFAS are not naturally occurring but nevertheless may be widespread in the environment (potentially including groundwater), even at locations distant from known or suspected sources under investigation by responsible parties, makes PFAS especially challenging compared to many other contaminants.

GCC Agency Actions

Currently, there are no state or federal groundwater protection standards for PFAS. To address this regulatory gap, DNR requested DHS review of a total of 36 PFAS as potential updates to the NR 140 groundwater standards. As part of the Cycle 10 and Cycle 11 NR 140 updates, DHS searched for toxicity information for 36 individual PFAS. In June 2019, DHS recommended a groundwater enforcement standard of 20 parts per trillion (ppt) as a combined standard for PFOA and PFOS (part of the [Cycle 10](#) recommendations). DNR is currently in rulemaking to potentially establish PFOA and PFOS DHS-recommended groundwater standards in NR 140. In November of 2020, DHS recommended groundwater enforcement standards for 16 additional PFAS as part of DHS's [Cycle 11](#) groundwater standard recommendations. DHS recommended that four of those Cycle 11 PFAS be regulated as combined standards, along with PFOA and PFOS. For the remaining 12 PFAS, individual standards were recommended. On June 23rd, 2021, the Natural Resources Board approved the NR 140 Cycle 11 statement of scope, allowing for rulemaking for the 16 additional PFAS to proceed.

The DHS-recommended PFAS groundwater quality standards currently serve as guidance for safe drinking water levels. Until such time when rulemaking is completed, entities undertaking groundwater cleanups of PFAS contamination are required to work with DNR and DHS to establish site-specific cleanup standards. As additional guidance regarding cumulative health effects of PFAS mixtures, DHS recommends a [hazard index](#) be calculated for all PFAS drinking water samples. The hazard index effectively combines all of the recommended PFAS standards into a

single value. If the hazard index exceeds 1.0, DHS recommends that the water not be consumed. [Guidance for temporary water](#) for private well owners affected by PFAS is available.



The Wisconsin PFAS Action Plan was released in December 2020.

The [Wisconsin PFAS Action Plan](#) was released in December 2020. The plan was developed by the Wisconsin PFAS Action Council, or WISPAC, to serve as a roadmap for addressing PFAS contamination in diverse environmental media and settings in the state. The PFAS Action Plan presents several recommendations, including one specifically for drinking water (including groundwater sources). That recommendation is to conduct statewide drinking water testing, including all municipal systems as well as some other priority community and non-community public water systems. Work on sampling municipal systems is tentatively anticipated to begin during the summer/fall of 2021.

The PFAS Action Plan also presents several other recommendations that directly or indirectly relate to groundwater. The following table presents an overview of recommendations most directly related to groundwater (readers are referred to the PFAS Action Plan for more detail and other recommendations not listed here) and the status of implementation:

Recommendation number	Summary of recommendation (see the PFAS Action Plan for full text)	Status of groundwater-related implementation
1.1	Establish science-based environmental standards for PFAS	In progress with the DHS Cycle 10 and Cycle 11 (NR 140) recommended groundwater standards.
1.2	Safely manage PFAS in landfill leachate	DNR is reviewing scientific studies on PFAS in landfill leachate.
2.4	Test public water systems for PFAS	Sampling of drinking water from about 90 groundwater-sourced municipal systems tentatively expected to start during summer/fall 2021.
3.4	Identify PFAS sources and reduce discharges to wastewater facilities	DNR's Water Quality program has been conducting sampling of industrial wastewater treatment effluent. Any actions taken to reduce loading of PFAS to wastewater treatment plants are expected to have benefits for surface water as well as groundwater.
5.2	Monitor background ¹ levels of PFAS in the environment (includes groundwater and a variety of other environmental media).	DNR is reviewing studies relevant to background ¹ PFAS levels in groundwater and exploring what practical options might be feasible for sampling related to evaluation of background levels

Table footnote:

¹ Multimedia research has shown that PFAS can be transport long distances from a source. 'Background' is meant in the sense that some low concentrations of certain PFAS might be widespread and/or not readily attributable to a local source. However, PFAS do not occur naturally.

Further Reading

DNR PFAS page: <https://dnr.wi.gov/topic/Contaminants/PFAS.html>

DHS Groundwater Contaminant recommendation process: <https://www.dhs.wisconsin.gov/publications/p02432.pdf>

Interstate Technology and Regulatory Council fact sheets: <https://pfas-1.itrcweb.org/>

US Agency for Toxic Substances and Disease Registry PFAS page: <https://www.atsdr.cdc.gov/pfas/index.html>

US Environmental Protection Agency PFAS page: <https://www.epa.gov/pfas>

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WATER USE

Chapter 281 of the Wisconsin Statutes requires annual reporting to the Wisconsin Department of Natural Resources of monthly withdrawals from all wells and surface water withdrawal systems capable of supplying water at a rate of 100,000 gallons per day or more. This includes water uses such as public supply systems, energy production, paper manufacturing and agricultural irrigation. The reported water use data is spatially located, which allows for DNR to provide customized water use information to specific locations, withdrawal types and water uses. These annual water use reports improve our understanding of spatial and temporal trends in water withdrawals.

The [2018 Water Use StoryMap](#) showed that the largest category of groundwater withdrawals was municipal public water supplies (DNR 2019). The second largest category of groundwater withdrawal in the state was agricultural irrigation. Agricultural irrigation water use varies from year to year depending on the timing of rainfall during the growing season.

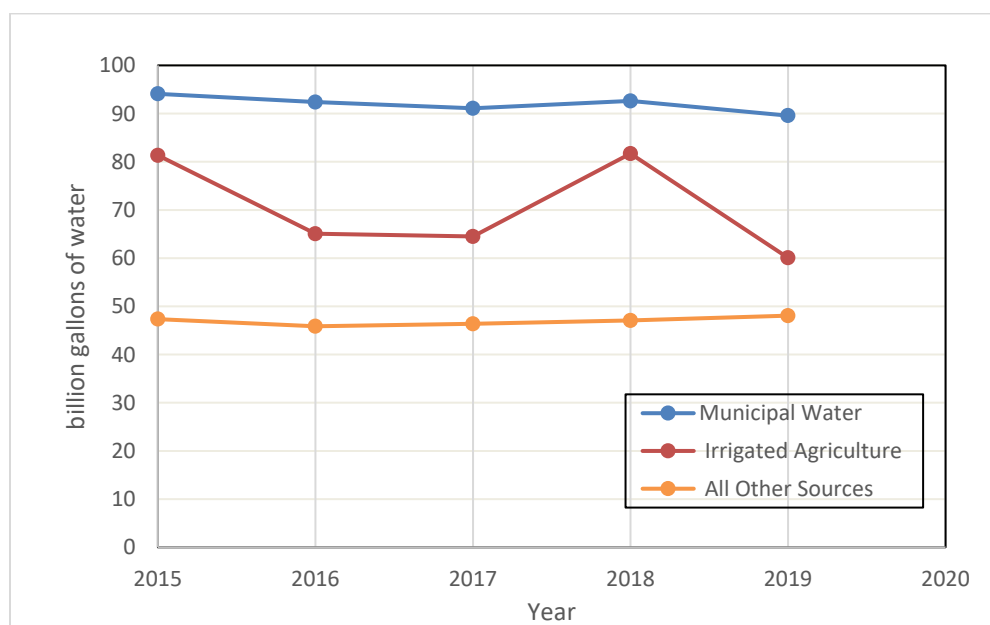


Figure 1. Wisconsin annual groundwater withdrawals, 2015 – 2019. (DNR)

New tools are available to view water use data spatially and to search and aggregate water use data at <https://dnr.wi.gov/topic/WaterUse/data.html>.

Reference:

Wisconsin Department of Natural Resources. 2019. Wisconsin Water Use – 2017 Reported Withdrawals. Technical Memo. 6p. Available at: <https://dnr.wi.gov/topic/WaterUse/documents/WithdrawalReportDetail2017.pdf>

GROUNDWATER/SURFACE WATER INTERACTIONS

Groundwater pumping is substantially impacting streamflows and water levels in lakes and wetlands in parts of Wisconsin. This issue differs from the large regional drawdown issues in the northeast and southeast, where water level declines are mainly in the confined or semi-confined systems not well connected to surface waters.

Central Sands

The Central Sands region lies east of the Wisconsin River and encompasses 1.75 million acres in parts of Adams, Marathon, Marquette, Portage, Shawano, Waupaca, Waushara and Wood counties. The 800 miles of trout stream and 300 lakes are generally well connected to the sand and gravel aquifer and provide recreation and tourism value including hunting, fishing, canoeing and kayaking. The productive sand and gravel aquifer also supports groundwater withdrawals from water use sectors including irrigated agriculture, municipalities and industry. Within this region 25% of the state's groundwater is pumped from several thousand high capacity wells, predominantly for irrigation. The number of high capacity wells and reduced water levels in some areas has caused concerns about the potential impacts of groundwater withdrawals on water resources. One example of the impact of groundwater withdrawals on water resources is the Little Plover River in Portage County. The Little Plover River, a Class I trout stream and Exceptional Resource Water in Portage County, has dried in parts during various years since 2005.

The Wisconsin Geological and Natural History Survey and United States Geological Survey constructed a groundwater flow model for the Little Plover River watershed in Portage County. This model is a scientific tool for understanding the complexities of geology, groundwater recharge and discharge, surface-water flow, well development and use and water balance. The model simulates the complex temporal and spatial interactions among streamflow, pumping and climate and provides users "what-if" evaluations of possible decisions involving management of water use or land-use changes. The Little Plover River Basin was chosen for this pilot study because the river has been the focus of recent management concern and because a great deal of hydrogeologic data already exists for this area (<https://fyi.uwex.edu/littleplovermodel/files/2014/08/Little-Plover-River-handout.pdf>).

Beginning in 2017 stakeholders including the Village of Plover and agricultural producers in conjunction with DNR, consultants and the Wisconsin Wetland Association, formed the Little Plover River Watershed Enhancement project with the goal of achieving sustained flow and aquatic health within the river. The stakeholders are utilizing the groundwater flow model as one tool to assist with establishing land and water best management practices.

In addition to examining the connection between groundwater withdrawals and streamflow in the Little Plover River area, [2017 Wisconsin Act 10](#), referred to by the DNR as the Central Sands Lakes Study, provides the basis for the DNR to define significant

impacts on three Central Sands lakes (Plainfield, Long and Pleasant) in Waushara County and quantify the relationship between groundwater withdrawals, lake levels and significant impacts. The lakes have been of keen interest to stakeholders in Central Wisconsin, particularly in the last decade. The key findings from the three year study are that groundwater withdrawals cause reductions in Pleasant, Long, and Plainfield Lakes. The reductions are significant and impact the lakes' ecosystems in Long and Plainfield Lakes. The study findings show that the reduction caused by groundwater withdrawals to study lake levels are a result of the collective impact from many high-capacity wells rather than any specific high-capacity well. As a result, the DNR recommends a regional framework, such as a water use district, to implement measures to reduce significant impacts from groundwater withdrawals. Learn more at:

<https://dnr.wi.gov/topic/Wells/HighCap/CSLStudy.html>.

Dane County

Although groundwater and surface water resources are plentiful in Dane County, there are several well documented cases of impacts to surface water due to groundwater withdrawals. Just as regional drawdowns have developed across Dane County in response to high-capacity pumping of groundwater for municipal and industrial supply ([see Regional Drawdowns section of the report](#)), several smaller streams and spring systems have also been impacted over the past several decades resulting in reduced flow rates.

Some of the most significant impacts have been to Starkweather Creek on the east side of Madison as well as springs along the south shore of Lake Mendota, north shore of Lake Wingra and around lake Monona. Baseflow in Starkweather Creek has decreased as stormwater is diverted from impervious areas to drainage ditches and high-capacity pumping lowers water levels. At Springhaven Pagoda, which was built in the late 1800's to house a spring near the shore of Lake Monona, the spring has stopped flowing entirely. At Merrill Springs, near Spring Harbor along the south shore of Lake Mendota, a spring pool that was built in the mid-1930s has decreased its flow by upwards of 90% (<http://www.springharboronline.com/where-are-the-springs-in-spring-harbor.html>). The reduction in these surface water flows is considered to be due to decreases in recharge from urbanization and, even more importantly, the result of regional drawdowns from pumping high-capacity wells.

The Dane County groundwater flow model, which is calibrated based on observed water levels in wells and lakes, as well as flow rates in streams and springs, has provided further evidence of impacts to surface water along the Yahara River corridor. Model simulations over the past decades have consistently shown a reversal in groundwater flow along the southern two-thirds of Lake Mendota and all of Lake Monona. The result is that lakes that historically gained groundwater now lose water to the groundwater system. This reversal, which is due primarily to the concentration of high-capacity wells in the greater Madison area, has effectively drawn groundwater levels down in wells and impacted flows in sensitive stream and spring systems which are replenished by shallow groundwater supplies.

Springs Inventory

[Groundwater springs \[video link\]](#) are special places where the water table reaches the land surface and overflows into streams and wetlands. Springs are critical natural resources since they supply cool, oxygen-rich water for trout and often harbor threatened and endangered species. Springs are also a window into the groundwater below the surface and they can provide a great deal of information about the chemical composition and flow of local groundwater. Springs are often well loved for their scenic beauty at public parks.

Because these special natural resources are vulnerable to groundwater pumping, the Department of Natural Resources (DNR) reviews high capacity well applications involving wells constructed near springs for adverse environmental impacts. Springs, for the purpose of a high capacity well review are defined in statute as "... an area of concentrated groundwater discharge occurring at the surface of the land that results in a flow of at least one cubic foot per second at least 80 percent of the time." There are over 10,000 known springs in Wisconsin and it is not a simple task to determine, given a proposed high capacity well, which nearby springs need to be assessed. Correct information about the location and flow rate of each spring is critically important to have, but existing data come from many sources – some as old as 1905 – with varying levels of quality and accuracy. Springs can also be used as easy sampling points for indicators of groundwater quality.



Pheasant Branch spring in Middleton, WI. Photo: WGNHS

In keeping with the stated mission of the GCC to assist in the efficient management and exchange of groundwater data, GCC agencies and researchers have worked together to gather data about Wisconsin's springs into a centralized inventory for Wisconsin. In 2007, the establishment of a statewide springs database (Macholl, 2007) was a major step forward in pulling together data from disparate sources. In 2017 researchers at Beloit College and WGNHS completed a three-year springs inventory for the State of Wisconsin. This inventory created a springs database by conducting field surveys of springs with historical flow rates of 0.25 cfs or more and established reference springs in representative hydrogeological and ecological settings for long-term monitoring. Accessible to scientists, water resources managers and the general public the springs inventory is available on the DNR [Wisconsin Water Quantity Data Viewer](#). DNR continues the springs inventory monitoring project by identifying new springs, continue monitoring of reference spring sites, and revisiting previously identified springs in the springs inventory.

Wisconsin Stream Model

DNR researchers have developed a [detailed model](#) that predicts streamflows in ungaged streams using identify factors (such as land use, groundwater recharge and climatic elements). The model also links these variables to the abundance of fish species in Wisconsin's streams. This project helps determine what hydrologic changes are likely to cause significant *environmental impacts* to Wisconsin streams.

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REGIONAL DRAWDOWNS

The effects of groundwater withdrawals on a regional scale are seen in the Lower Fox River Valley, southeastern Wisconsin, Dane County and the Central Sands. The Lower Fox River Valley and southeastern Wisconsin were designated Groundwater Management Areas based on water level drawdowns of more than 150 feet observed in those two regions. Drawdowns in parts of Dane County have been around 50 feet. Large groundwater drawdowns indicate changes in the flow systems. Around 1900, flowing wells were present in both the Lower Fox River Valley and southeastern Wisconsin. Pumping has caused drawdowns in those aquifers so that today the water levels are often hundreds of feet below the ground surface. Excessive drawdowns can cause reduced yields to wells, lower water quality and divert water from surface waters.

Lower Fox River Valley

Water levels in the Lower Fox River Valley have varied widely over time. Water levels in the deep aquifer of the Lower Fox River Valley were above the land surface before significant pumping from that aquifer in 1900. By 1957, increased pumping in the deep sandstone aquifer lowered water levels by hundreds of feet. In response, the City of Green Bay switched from groundwater supply to surface water supply and the water levels increased more than 200 feet in the aquifer.

By 2005, increased pumping from the communities surrounding Green Bay caused water levels to decrease to the low levels seen in 1957. In response to that drawdown, six suburban communities in the Lower Fox Valley reduced consumption of groundwater by about 8.2 million gallons per day by switching to surface water supplied by pipeline from Lake Michigan in 2007. As a result, water levels in the deep sandstone aquifer in and around Green Bay have risen. These changes at one well can be seen in Figure 1.

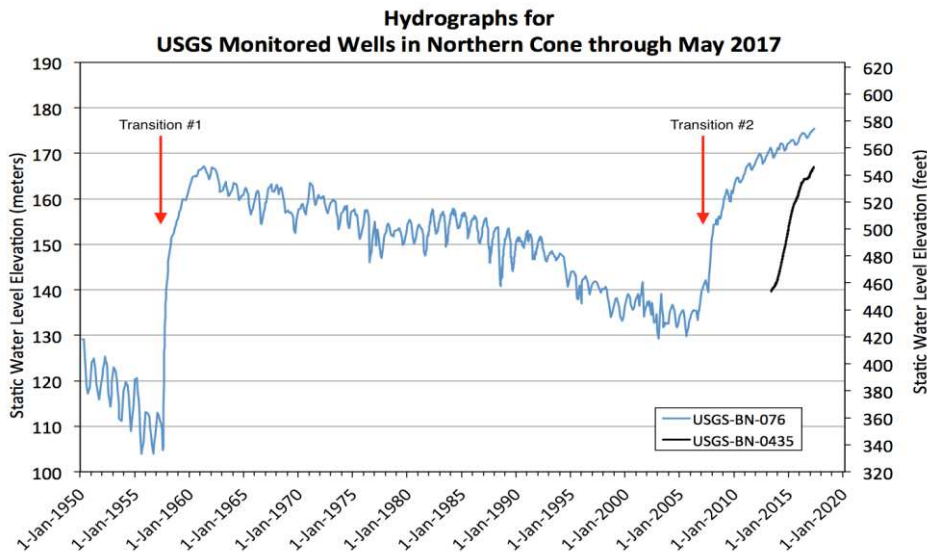


Figure 1: Changes in groundwater levels in a groundwater level monitoring well in Green Bay, Wisconsin. Transition 1 is City of Green Bay Switch to surface water. Transition 2 is Green Bay suburbs switch to surface water (Luczaj).

The water levels continue to rise, and some homeowners and the town of Howard have reported flowing wells. If water use continues to decrease, the number of flowing wells will increase over time as the water levels rise above the land surface. Contours of water levels before and after the reduction of pumping in 2007 are shown in Figure 2.

We know from previous drawdown and pumping records that when the pumping rate reaches around 6 million gallons per day that the deep aquifer has the potential to become dewatered, raising concerns about changes in the aquifer chemistry that might increase arsenic or radium concentrations. This provides good rationale for monitoring high-capacity pumping in this aquifer.

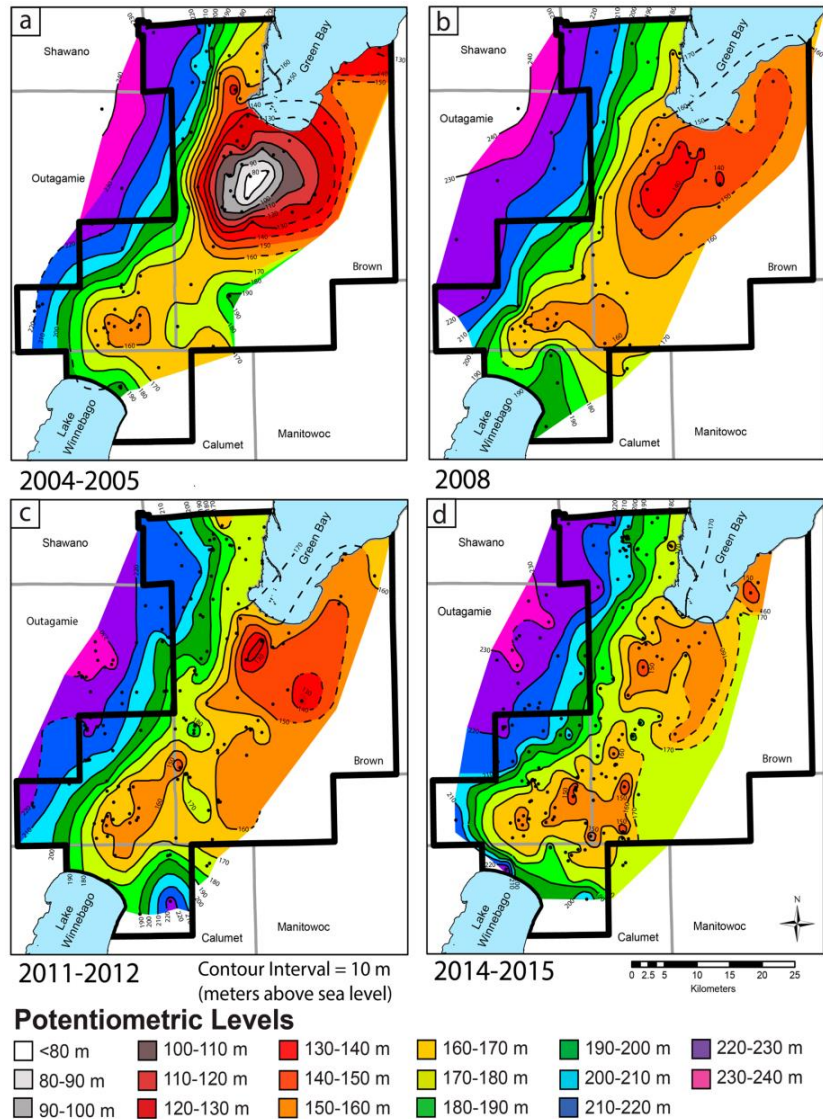


Figure 2: Water table elevations in Brown County

Water levels in southeastern Wisconsin have shown the largest decreases in Wisconsin. These decreases have raised concerns about increases of radium to wells above drinking water standards and increased pumping costs. As was the case for the Lower Fox River Valley, water levels in the deep sandstone aquifer were above the land surface before significant pumping in 1900. Pumping increased steadily from 1900 to 2000 and water levels in some wells steadily decreased by more than 500 feet. Figure 3 shows the water table decline until around 2000 to 2005. Research and monitoring from the late 1990's and early 2000's demonstrated an average of 7 feet per year decline in deep wells (Feinstein et al., 2004). However, an added well in Waukesha County to the groundwater observation network shows 2020 water levels to be approximately 150 feet higher than the levels observed in a nearby observation well in 1998 (Pfeiffer, 2013). The reduced drawdown is likely due to reduced pumping by communities from groundwater conservation efforts, reduced industrial water use and from seeking alternative sources of water to the deep sandstone. The deep sandstone aquifer sometimes has radium concentrations over the drinking water standard of 5 pCi/l. Treatment of that water can be

costly, leading some communities to look at other water sources.

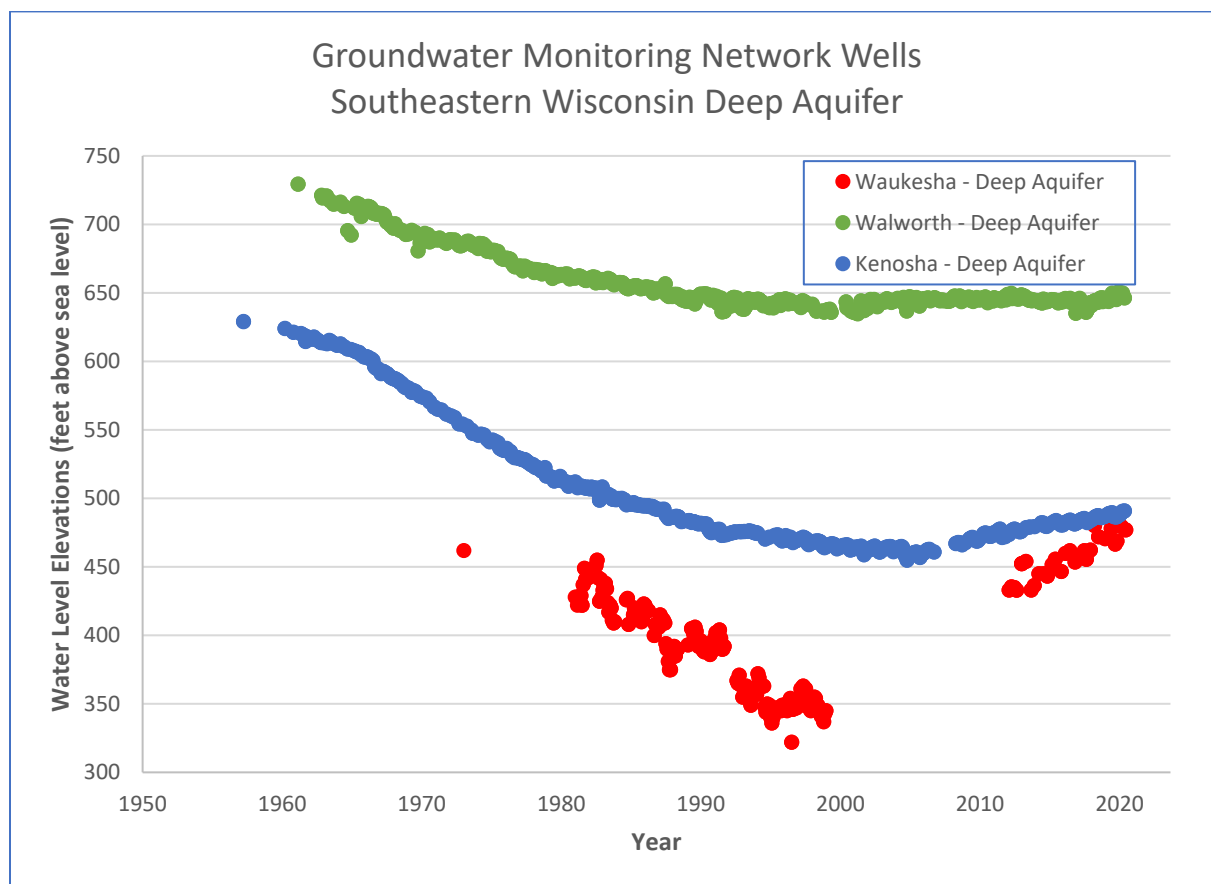


Figure 3: Water levels in a groundwater level monitoring wells in Waukesha, Kenosha and Walworth counties (DNR).

Dane County

Dane County presents another example of regional drawdowns which have been well documented through water level measurements and the development of multiple groundwater flow models, at a county-wide scale, over the past several decades. The 2016 Dane County model (Parsens, et al. 2016) has focused on increasing the spatial resolution of the model grid, better simulating surface water groundwater interactions, and introducing transient flow capabilities, all while upgrading the computer codes and calibration methods. Each of these model improvements provides new insights into the groundwater system within Dane County and a greater understanding of regional scale drawdowns.

The Dane County model was used to simulate drawdowns in both the Mount Simon Sandstone and at the water table. Figures 4 and 5 were generated by comparing predevelopment water levels to those measured in 2010 and document the presence of significant drawdowns in central Dane County, below the Yahara River corridor. In Dane County, municipal water supply is by far the primary groundwater user, representing roughly 80% of the total withdrawal rate of 50 million gallons per day. The next largest withdrawals are made by irrigation (under 10%) and aquaculture (under 5%).

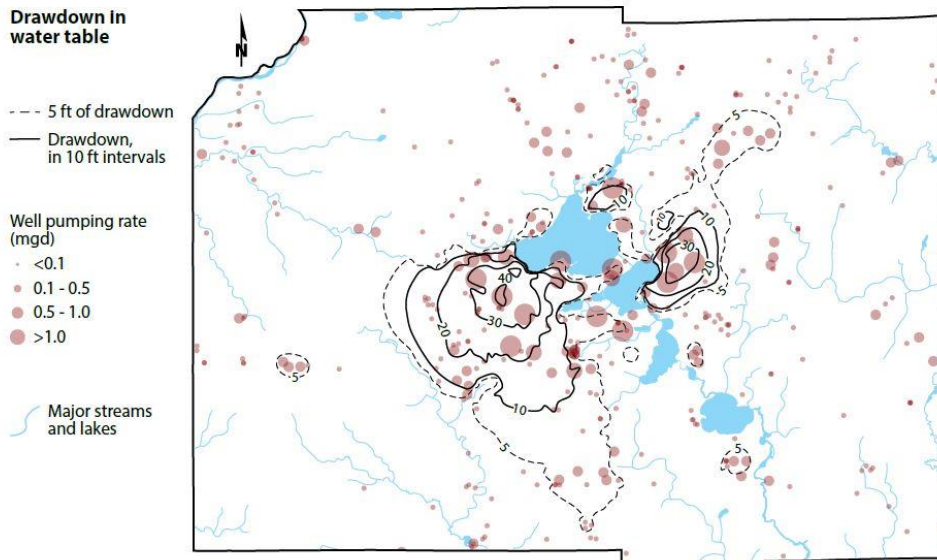


Figure 4: Simulated drawdown (feet) in the Mount Simon Sandstone; predevelopment to 2010. The Mount Simon Sandstone, located several hundred feet below land surface and up to 800 feet thick, is the lowermost aquifer unit within Dane County. This porous sandstone is a highly productive aquifer which provides the bulk of groundwater supplies to high-capacity municipal and industrial wells across Dane County (WGNHS).

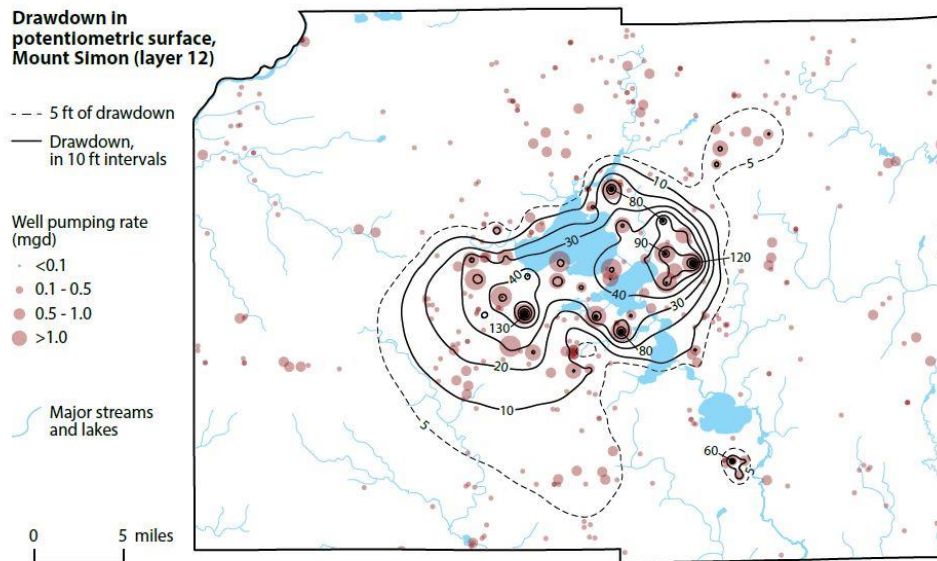


Figure 5: Simulated drawdown (feet) at the water table; predevelopment to 2010. Drawdowns from the lower Mount Simon aquifer system propagate upwards to the shallow sand and gravel and upper bedrock aquifer systems to create drawdowns at the water table (WGNHS).

Water use data collected for the updated 2016 model, indicate that groundwater withdrawals have declined by up to 15% over the past 10-15 years across Dane County. These reductions are believed to be primarily attributable to wet years, during which

water demand drops; and local groundwater conservation efforts. The 2016 model improves our understanding of regional drawdowns across Dane County and provide insights into groundwater systems across South Central Wisconsin.

Central Sands

In the *Central Sands*, the study of groundwater flow and its complex interactions with stream flows and lake levels dates back to [historical experiments](#) by USGS, WGNHS and the Wisconsin Conservation Department (precursor to the DNR) in the 1960s. Decades of continued study by GCC agencies and GCC-supported researchers, have further described the hydrogeology, climatology and impacts of groundwater pumping on lakes, rivers and wetlands in this region (Kniffen et al., 2014). This research, specific to the Little Plover River watershed (Bradbury and others, 2017), confirms that the Little Plover River is closely connected to the groundwater system, making it vulnerable to impacts from nearby high capacity well groundwater withdrawals. Under [2017 Wisconsin Act 10](#), the department evaluated and modeled the potential impacts of groundwater withdrawals on three specific lakes in the Central Sands region through the Central Sands Lakes Study. The three lakes in the study are all in Waushara County – Long Lake and Plainfield Lake near Plainfield, and Pleasant Lake near Coloma.

The study included the use of a groundwater flow model to evaluate cumulative impacts from existing and potential groundwater withdrawals on the three lakes. The groundwater flow model involved data collection and compilation across the region.

The key findings are that groundwater withdrawals cause reductions in Pleasant, Long, and Plainfield Lakes. The reductions are significant and impact the lakes' ecosystems in Long and Plainfield Lakes. The study findings show that the reduction caused by groundwater withdrawals to study lake levels are a result of the collective impact from many high-capacity wells rather than any specific high-capacity well. The DNR recommends a regional framework, such as a water use district, for addressing impacts to water resources from high-capacity well pumping.

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GROUNDWATER-LEVEL MONITORING NETWORK

Wisconsin's groundwater-level monitoring network has been operated jointly by the Wisconsin Geological and Natural History Survey (WGNHS) and the U.S. Geological Survey (USGS) since 1946, working in close cooperation with the Department of Natural Resources (DNR). As of June 2021, this network consists of 97 long-term monitoring wells and project-specific, limited-term monitoring wells. The long-term 97 permanent wells, or "Core Network," are in 47 of Wisconsin's 72 counties. This Core Network provides a consistent, long-term record of fluctuations in water levels in shallow and deep aquifers. The project-specific wells are supported with funding from various groundwater studies across the state and are generally only operational over the lifetime of an active groundwater study. These project wells provide valuable data and are often considered for addition to the Core Network if selection criteria are met.

Water levels collected from the network help scientists and managers evaluate effects of well pumping, the response of groundwater levels to drought or increased precipitation and effects of land-use change on groundwater resources. These data are also routinely used in the development of regional groundwater flow models, as long-term water-level measurements serve as reliable calibration targets.

In FY 2018, due to increasing reliance on network data to meet its Water Use program needs, DNR greatly expanded its funding and management support of the Core Network. On a day-to-day basis USGS and WGNHS continue to support the evaluation and maintenance of the monitoring network, aid in data collection, interpretation, and provide information to public and private clients through dedicated webpages. WGNHS provides a general overview of the monitoring network at <https://wgnhs.uwex.edu/water-environment/groundwater-monitoring-network>, and USGS maintains an interactive portal for viewing and downloading data at <https://waterdata.usgs.gov/wi/nwis/gw>.

In FY 2021, DNR committed \$100,000 and provided additional funding of \$90,200 to USGS to conduct additional monitoring on 3 stream gages, 3 lake gages, 2 precipitation buckets, and 27 short-term project wells as part of the Central Sands Lakes Study.

WGNHS received grants the USGS National Ground-Water Monitoring Network (NGWMN) program in FY 2019 and FY 2021 for \$198,089 and \$271,848 respectively. Once the work on both grants is completed, these two recent grants, together with a 2016 NGWMN grant will result in repairs to thirty wells, eight well replacements, and nine new wells, adding four new counties to the Network (Barron, Buffalo, Dunn, and St. Croix).

CENTRAL SANDS LAKES STUDY

The Central Sands Region spans portions of Adams, Marathon, Marquette, Portage, Shawano, Waupaca, Waushara and Wood Counties. The DNR defines the Central Sands as a contiguous area east of the Wisconsin River with sand and gravel deposits greater than 50 feet deep. These deposits create a productive aquifer that is used for irrigation, public and private water supplies, industry, and commercial uses. The Central Sands region also contains over 300 lakes and thousands of miles of streams.

Over the past 60 years, we have observed low water levels in lakes and streams in Wisconsin's Central Sands Region. Various researchers have studied the relationship between land use and impacts to water resources in the Central Sands Region. Their work has shown that the two main causes of water level changes are weather and the pumping of high capacity wells. Weather varies considerably from place to place and from year to year. The number of high capacity wells in the Central Sands Region have increased over the past few decades, which has raised concerns about pumping of groundwater and the impacts on water levels. In response to these concerns, the DNR evaluated and modeled Pleasant, Long, and Plainfield Lakes in Waushara County to determine whether groundwater withdrawals cause a significant reduction in lake levels below their average seasonal levels, as directed by the Wisconsin State Legislature, specifically Wis. Stat. § 281.34(7m)(2017 Wisconsin Act 10).

The DNR, in collaboration with the Wisconsin Geological and Natural History Survey (WGNHS), United States Geological Survey (USGS) and the University of Wisconsin System, completed the \$887,000 Central Sands Lakes Study using an approach that involved data collection and groundwater flow modeling.

The key findings are that groundwater withdrawals cause reductions in Pleasant, Long, and Plainfield Lakes. The reductions are significant and impact the lakes' ecosystems in Long and Plainfield Lakes. The study findings show that the reduction caused by groundwater withdrawals to study lake levels are a result of the collective impact from many high-capacity wells rather than any specific high-capacity well. The DNR recommends a regional framework, such as a water use district, for addressing impacts to water resources from high-capacity well pumping.

Additional information on the study is available through the [study reports, appendices and recorded presentations](#). The DNR held a public hearing and comment period in Spring 2021 and submitted their findings and recommendations to the Wisconsin Legislature on May 27, 2021.

CHIPPEWA COUNTY GROUNDWATER MODEL

Chippewa County worked with WGNHS and USGS to conduct a [5-year study of groundwater resources](#) in western Chippewa County. The goal of the study was to answer two questions, how does pumping of high-capacity wells affect water levels in nearby wells and flows in streams today and how might changes in pumping rates, placement of new high-capacity wells and changes to the landscape affect wells and streams in the future? The new model incorporates additional geological and water level data. Chippewa County now has a new tool to understand current groundwater conditions and to test hypothetical future scenarios. The [final report](#) was published in May 2019 and is available on the Wisconsin Geological and Natural History Survey website.

LITTLE PLOVER RIVER MODEL AND WATERSHED ENHANCEMENT PROJECT

With financial support from DNR, the Wisconsin Geological and Natural History Survey and the United States Geological Survey constructed a groundwater flow model for the Little Plover River watershed in Portage County. This model is a scientific tool for understanding the complexities of geology, groundwater recharge and discharge, surface-water flow, well development and use and water balance. The model simulates the complex temporal and spatial interactions among streamflow, pumping, and climate and provides users “what-if” evaluations of possible decisions involving management of water use or land-use changes. The Little Plover River Basin was chosen for this pilot study because the river has been the focus of recent management concern and because a great deal of hydrogeologic data already exists for this area. Learn more at:

<https://fyi.uwex.edu/littleplovermodel/files/2014/08/Little-Plover-River-handout.pdf>.

Beginning in 2017 stakeholders including the Village of Plover and agricultural producers in conjunction with DNR, consultants, and the Wisconsin Wetland Association, formed the Little Plover River Watershed Enhancement project with the goal of achieving sustained flow and aquatic health within the river. The stakeholders are utilizing the groundwater flow model as one tool to assist with establishing land and water best management practices.

GROUNDWATER LEVELS AND AQUIFER RESPONSE

Monitoring groundwater levels can be used for:

- understanding local water resources;
- assessing aquifers in drought or wet conditions;
- assessing groundwater divides and surface water impacts;
- calibrating groundwater flow models and other decision-support tools; and
- helping to determine the relationship between water resources and withdrawals.

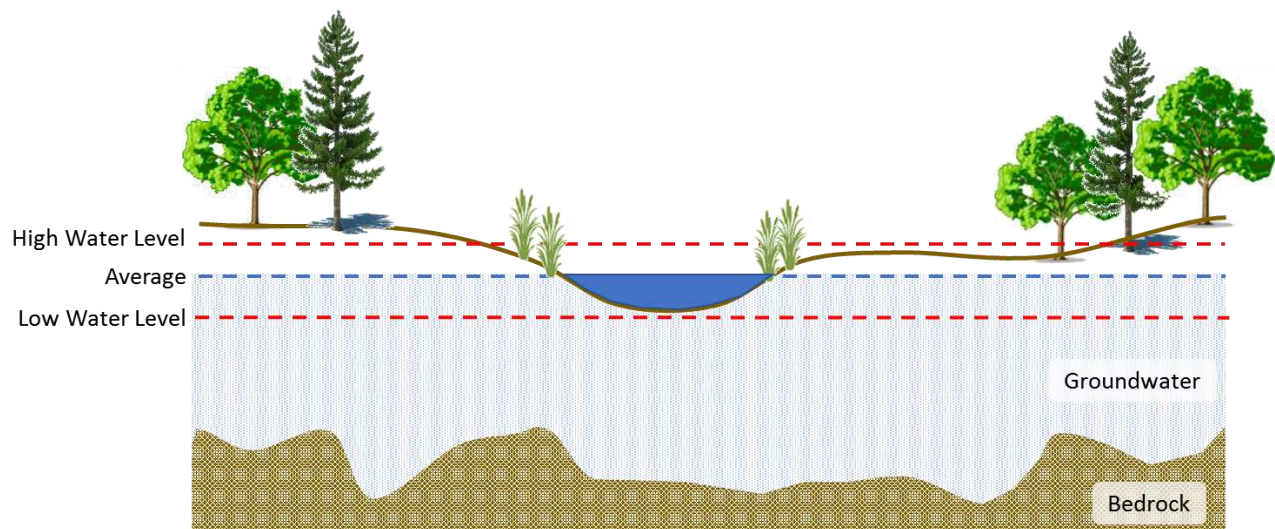
Groundwater level monitoring

The DNR and its partners at the [United States Geological Survey \(USGS\)](#) and the Wisconsin Geological and Natural History collectively operate and maintain a statewide network of monitoring wells that provide necessary long-term data for Wisconsin's statewide water resources inventory. The groundwater monitoring network, started in 1946, now consists of 92 long-term monitoring wells that measure groundwater levels in aquifers across the state.

The [DNR's water quantity data viewer](#) shows the location and water levels associated with the statewide groundwater monitoring network.

Groundwater level fluctuations

The upper surface of groundwater, referred to as the water table, can fluctuate in response to precipitation events and water withdrawals. During times of drought, local water tables can decline due to decreased recharge and increased water use (e.g. watering lawns, irrigating farm fields, municipal water supply). The result is that the water table can fall below surface water resources or from wells that withdraw water from the aquifer (see diagram below).



Water level variation diagram. Image credit: DNR.

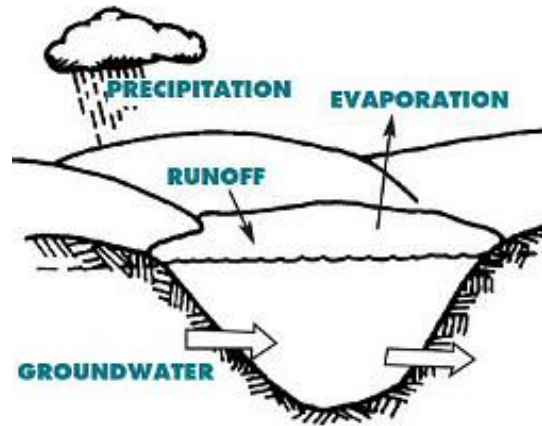
The opposite can also occur, resulting in a high water table (too much groundwater). Groundwater flooding occurs when frequent, sustained rainfall leads to excessively fast recharge of local groundwater levels and the water table rises above the land surface. This type of flood may be pronounced near seepage lakes (see diagram above). This type of flood can be long-lasting because water table decline requires drainage from the entire aquifer above the flood level. For the time that it takes for this drainage to occur, flood waters can cause significant property loss, human displacement and disruption of transportation.

Seepage lakes may also experience flooding of shoreline beaches and buildings due to a rise in the water table elevation and the related long-term increase in lake levels. Floods

and droughts are part of life in Wisconsin and elsewhere, but they come with significant economic, public health and environmental costs.

It may be difficult to determine if nearby flooding is due to surface water or groundwater flooding. For example, increased groundwater flow to nearby streams and rivers may cause the waterbodies to flood; or storm sewers that typically would drain to rivers don't work properly if too much inflow into the pipes from groundwater is occurring.

Over the past several years, Wisconsin has received a record-breaking amount of precipitation. The accumulation of above-average precipitation has resulted in many areas of Wisconsin experiencing high water and flooding issues. Information is available from the DNR to help residents [cope with flooding](#).



Seepage lake: a natural lake fed by precipitation, limited runoff and groundwater. It does not have a stream

Status of groundwater levels

Department staff track recent and historical precipitation and compare that data to long-term averages to characterize and identify trends. These precipitation patterns are compared to water level readings in monitoring wells statewide. As of June 2021, water level statistics from the statewide monitoring network indicate groundwater levels are at or near historic highs throughout the state, which is consistent with groundwater flooding reports received by the department in recent years.

Flooding resources

[Recommendations for private wells inundated by flooding](#)

[Coping with flooding](#)

[Flood insurance](#)