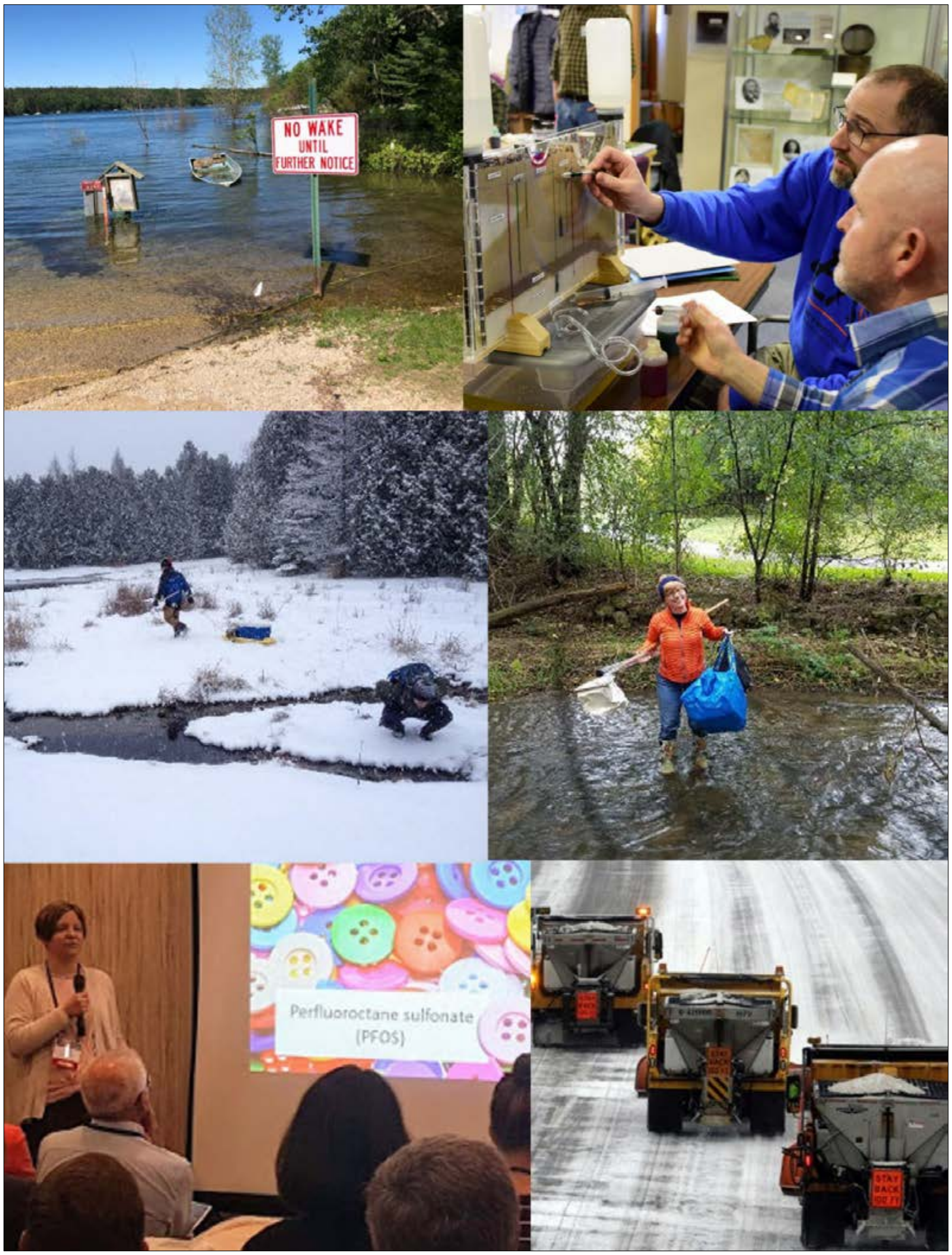
Wisconsin Groundwater Coordinating Council

Report to the Legislature

Fiscal Year 2020



2020 GROUNDWATER COORDINATING COUNCIL MEMBERS

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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 – **Patricia Trainer**
Geological and Natural History Survey (State Geologist) – **Ken Bradbury**
Governor's Representative – **Steve Diercks**
University of Wisconsin System – **James Hurley**

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UWSP Center for Watershed Science and Education - **George Kraft***

** Member of Standing Joint Solicitation Work Group*

Outreach & Partnership

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Center for Watershed Science and Education – **Kevin Masarik**
State Laboratory of Hygiene – **Jocelyn Hemming**
Wisconsin Rural Water Association – **Andrew Aslesen**

State of Wisconsin \ GROUNDWATER COORDINATING COUNCIL

Tony Evers, Governor

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August 31, 2020

To: The Citizens of Wisconsin
The Honorable Governor Tony Evers
Senate Chief Clerk
Assembly Chief Clerk
Secretary-designee Craig Thompson - Department of Transportation
Secretary-designee Dawn B. Crim - Department of Safety and Professional Services
Secretary-designee Randy Romanski - Department of Agriculture, Trade & Consumer Protection
Secretary-designee Andrea Palm - Department of Health Services
Secretary Preston D. Cole - Department of Natural Resources
Interim President Tommy G. Thompson - University of Wisconsin System
State Geologist Kenneth Bradbury - Geological and Natural History Survey

The Groundwater Coordinating Council (GCC) is pleased to provide its 2020 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 *on-line report* summarizes and links to information on the GCC and agency activities related to groundwater protection and management in FY20 (July 1, 2019 to June 30, 2020). 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,

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 2020 (FY20). 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.

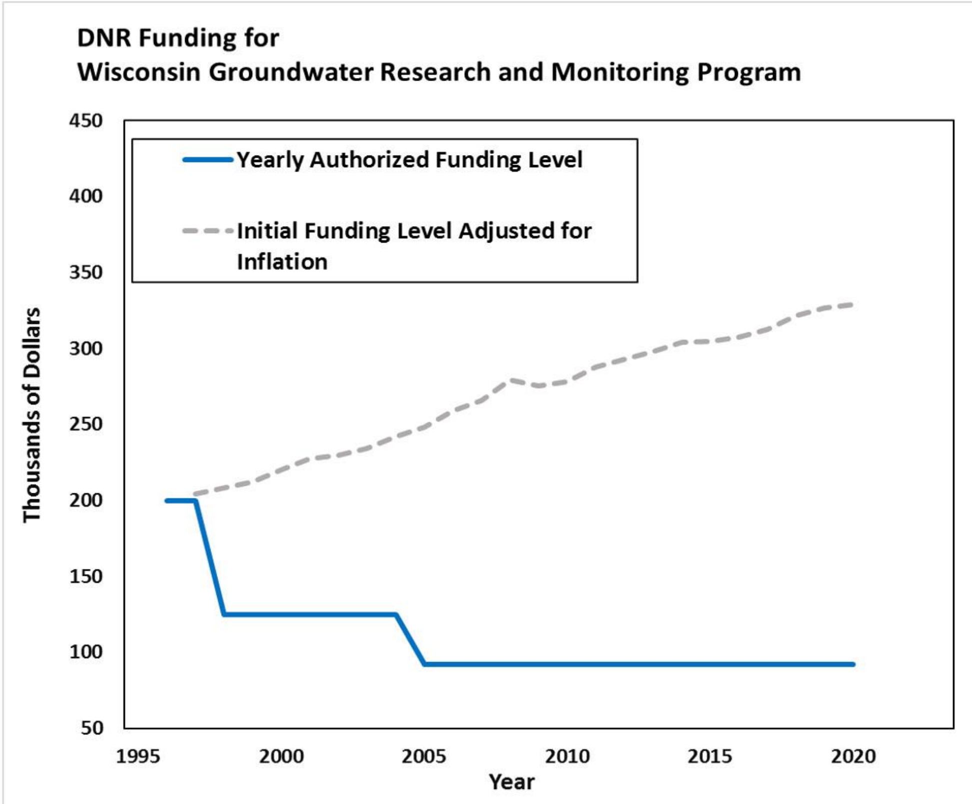
GROUNDWATER COORDINATION ACTIVITIES

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.


DNR Funding for
Wisconsin Groundwater Research and Monitoring Program
Yearly Authorized Funding Level
Initial Funding Level Adjusted for Inflation
Thousands of Dollars
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2020
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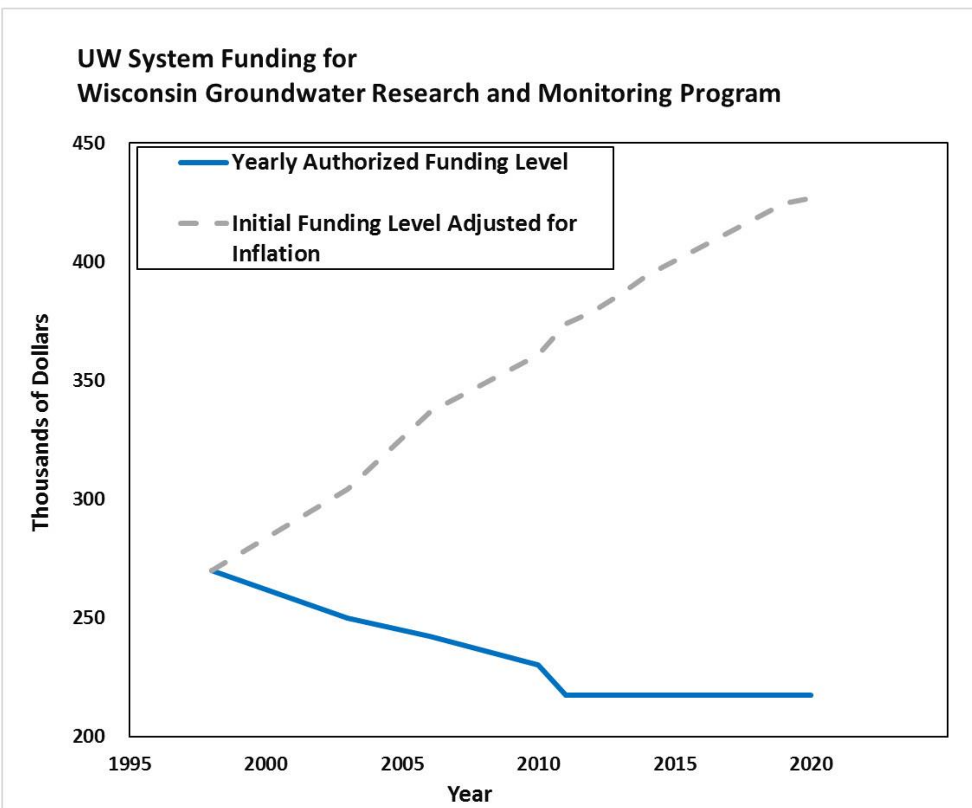
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The GCC, the UWS, DNR and the Groundwater Research Advisory Council (GRAC) again collaborated on the annual solicitation for groundwater research and monitoring proposals as specified in the Memorandum of Understanding. After a multi-agency effort spearheaded by the UW Water Resources Institute, 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 Monitoring & Research 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 FY20 - five by UWS, one by DNR, one by DATCP and one co-funded 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 (WRI) 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 on-line.

Information and Outreach Activities
Since 1994 groundwater workshops for teachers have been taught jointly by GCC Outreach and Partnership Subcommittee members from the DNR, WGNHS and the Center for Watershed Science and Education (CWSE) at 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 460 groundwater models have been given to schools and nature centers since 2001 and over 850 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 FY20 meetings:

- DNR, Per and Polyfluoroalkyl substances (PFAS) investigation and treatment
- DHS, Understanding the Health Risk of PFAS in Drinking Water
- UWSP, Public Water Supply Nitrate Trend Tool

More information on these topics and the coordinating efforts of the GCC can be found in the FY20 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 FY20. Detailed discussions of the groundwater activities of each agency can be found at the agency activities tab in the on-line report*.*

CONDITION OF THE RESOURCE: Groundwater Quality

Major groundwater quality concerns in Wisconsin are summarized below and detailed in the on-line 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 WDHS, 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 20 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 also requested that DHS review toxicologic information on an additional 34 PFAS compounds and, if appropriate, provide recommendations for ch. NR 140 groundwater standards.

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 detectible 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, 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 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 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, and 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 *on-line 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 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 on-going 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 on-line 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 on-line 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.

For example:

- 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 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.

DEPARTMENT OF NATURAL RESOURCES


Ozone generator inspection at a public water supply system.

DNR establishes groundwater quality standards for the state and coordinates their implementation by diverse agencies and programs (ch. 160, Wis. Stats.). DNR works with operators of landfills, entities land spreading waste, and those overseeing remediation and redevelopment of contaminated sites, to ensure standards are met that 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 on an annual groundwater work plan.

FY 2020 Highlights

- DNR is formulating a strategy to address PFAS in the State. This will include a request for voluntary sampling of influent and effluent by WPDES permitted municipal wastewater treatment plants. PFAS may be present in municipal wastewater treatment facilities' biosolids that have been regularly applied to agricultural lands throughout the state. Wisconsin will be drawing on the examples and experiences of other states to guide future PFAS efforts at State agencies that protect groundwater resources within the State.

- DNR received approval and began rulemaking for the NR 140 Cycle 10 list of 27 substances (including PFOS and PFOA) and began holding stakeholder meetings to gather input. DNR continues to monitor DHS progress on the Cycle 11 list. The Cycle 11 list is being reviewed by DHS to possibly recommend NR 140 health-based groundwater standards which contains 34 PFAS compounds and six pesticides.

- DNR received approval and began rulemaking for the NR 809 to set MCLs for PFOS and PFOA and began holding stakeholder meetings to gather input.

- Revisions to chapter NR 812, Wis. Adm. Code went into effect July 1, 2020. The revisions update well construction standards based on modern equipment and techniques, streamline approval procedures and reflect recent statutory changes.

- DNR committed $112,600 in FY20 to continue to operate and maintain the Wisconsin Groundwater Level Monitoring Core Network in collaboration with USGS and WGNHS. This 'Core Network' includes 94 long-term monitoring groundwater wells and 2 spring flow gages and is operated and maintained by the USGS and the WGNHS.

- DG and Community Financial Assistance staff issued 65 grants to low-income private well owners, providing over $139,000 to help replace contaminated wells or fill and seal unused wells.

- *Central Sands Lakes Study* – 2017 Wisconsin Act 10 requires DG to complete a study to model and evaluate Plainfield Lake, Pleasant Lake and Long Lake in Waushara County. Lake levels have been of keen interest to stakeholders in Central Wisconsin, particularly in the last decade. The department is taking the necessary steps to identify the components of the water budget driving the fluctuation in each of the three named lakes. Results are expected no later than June 2021.

- *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 agriculture 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 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 needed to protect groundwater quality in these areas.

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 Chapter 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* and *https://dnr.wi.gov/topic/Groundwater*.

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.wi.gov/topic/Brownfields/Cleanup.html*.

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 numerical groundwater quality standards which consists 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 (*https://docs.legis.wisconsin.gov/code/admin_code/nr/100/140*), establishes these groundwater standards and creates a framework for their implementation. Groundwater quality standards are set for 138 substances of public health concern, 8 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 recommendations to DNR in June 2019. DNR will propose rulemaking to incorporate the 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 [exit DNR]*. 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 has 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.

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, and it is also a valuable resource for agency staff and consultants involved with groundwater contamination and remediation actions. Links to resource web sites allows users to obtain additional toxicological and health related information on many of the substances listed in the table.

DNR continued to provide training to new staff in runoff management and drinking water programs on implementation of groundwater quality standards, including training for landspreading discharge permit writing and animal waste drinking water well contamination response. Groundwater and runoff program staffs 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 participated on the NRCS Source Water Protection Subcommittee. This subcommittee will provide 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 fire protection well, that, together with all other wells on the same property, except for residential wells and fire protection wells, have 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 and 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. To improve efficiency and consistency of review, DNR implemented a 'lean' project in 2013. The project increased efficiency by streamlining high capacity application and approval forms and eliminated duplication within the review process.

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 percent 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 (*link*) 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 will no longer rely 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 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 implements Compact-related programs including authorizing permits, 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 7 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 WDNR prior to withdrawing groundwater or surface water. This is typically done in conjunction with other approval or permitting procedures.

WDNR 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 percent in 2008 to 79 percent in 2010. These improvements continued so that the reporting response rate for 2013 – 2018 is 96 percent 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.

DNR developed a statewide set of conservation standards for agricultural irrigation with partners including the University of Wisconsin, environmental non-profit organizations and the Wisconsin Potato and Vegetable Growers. Participation in the Conservation Standards Program requires growers to report specific data such as cropping rotations, acreages and irrigation practices. Some growers will also develop conservation plans to target conservation practices in a manner that best suits their operation. In addition, analysis will be undertaken of economic factors so that the savings and efficiencies from water conservation can be calculated. DNR will continue to support UW researchers working to identify methods to improve irrigation efficiency through development of improved irrigation scheduling software.

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. Chapter NR 860, Wis. Adm. Code prescribes a review process for the individual permits requires and 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 contained 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 directed 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. Nearly three years of rulemaking incorporating public comment and well industry involvement led to changes to chapter NR 812, Wisconsin Administrative Code (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 8000 new or replacement wells were constructed in Wisconsin in 2019. 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. During 2019, staff conducted 940 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.

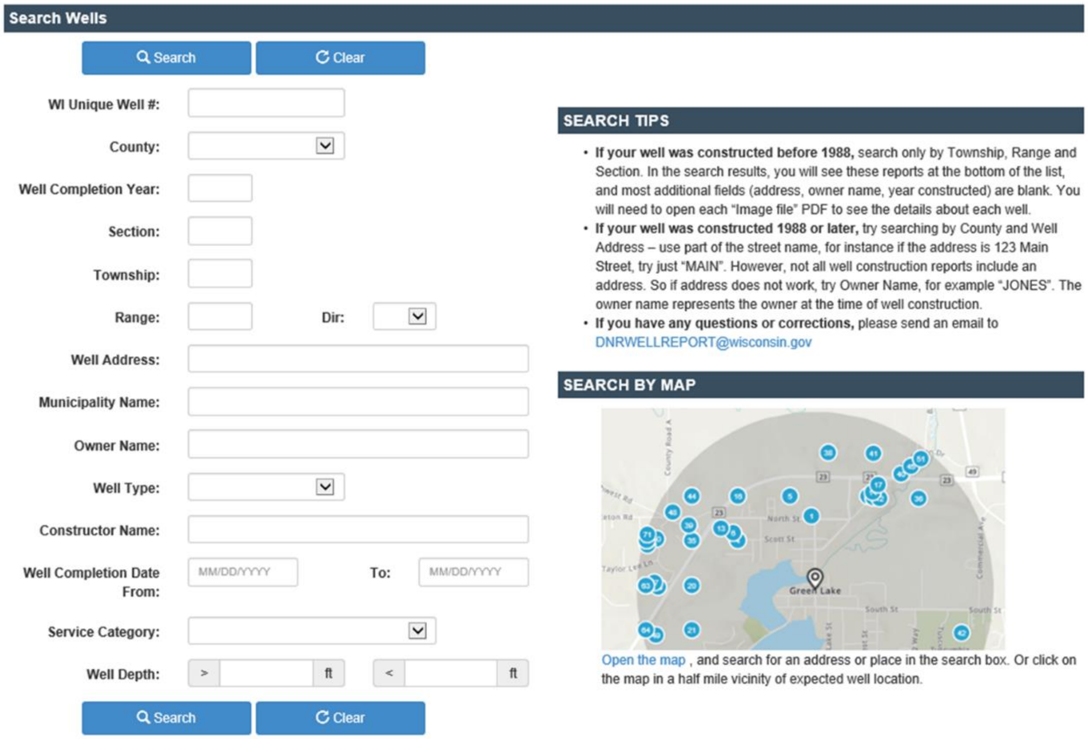
Private Water Supply staff are often the first-responders to reports of private well contamination. Well contamination by livestock waste has been an increasing problem in recent years. DG staff use field investigation and analytical tools to investigate the source of microbial contamination – known as MST 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, and 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 1200 individuals hold an active Water Well Driller, Heat Exchange Driller and/or Pump Installer license in Wisconsin.

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, help well owners diagnose their aesthetic water quality problems and provide suggested options. DG and Community Financial Assistance staff awarded a combined total of over $144,000 in well abandonment and well compensation grants in 2019. Well compensation grants provided cost-sharing funds to help nine owners replace wells due to Arsenic (3), Metals (3), and Manganese (1) contamination. Additionally, 65 well abandonment grants were issued around the state to help fund filling and sealing of unused wells.

DG continues to develop new or enhanced 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 "*[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, providing screen views and easy navigation customized for mobile devices.

The Well Driller Viewer was launched in 2018.

"*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 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 data system (EMOR) 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), 7 communities completed WHP plans this year (3 required and 4 voluntarily, with a total of 13 wells).

DNR and WRWA are working together on pro-active 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. The village of Luck, WI, in response to contaminant plumes that have the potential to affect the village's two municipal wells, 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 EPA on the percent of public water systems that are protected by substantial implementation of wellhead protection. In 2018, 35% 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 50.5% of the municipally served population is covered by source water protection plans with accompanying implementation ordinances.

DNR maintains a *web page* 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.

Since 1994, DNR staff have worked with the Groundwater Center at the Center for Watershed Science and Education (CWSE) and the Wisconsin Geological and Natural History Survey (WGNHS) to sponsor two groundwater workshops for teachers every year. Educators from 20 schools and nature centers were 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 460 schools or nature centers since 2001 and nearly 850 educators have received hands-on training in using the model effectively.

DNR and WRWA staff continues 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 reviewed draft plans and ordinances and provided technical advice to local officials responsible for carrying out wellhead protection.

Groundwater Information and Education

In 2014, the Groundwater Coordinating Council Report to the Legislature went on-line in interactive format. Web visits and time spent at the site increased substantially. Phone inquiries about the subject matter in the report were received for the first time in over five years.

Well drillers and pump installers, water testing providers, local health and conservation departments, health care providers and many individuals requested and received hundreds of thousands printed publications on groundwater. Among the most-frequently requested items were: 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 that may impact groundwater are conducted.

Based on measured stream flow and groundwater levels, the Little Plover River groundwater flow model published in 2017 was developed to help people understand the groundwater system and inform management decisions.

Eight *new projects* were selected through the Joint Solicitation process for funding in FY21. Final reports and 2-page research summaries are available for many projects from the *Water Resources Institute website*.

DNR committed $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 92 long-term monitoring groundwater wells and 2 spring flow gages. The long-term monitoring provides data that build the history of water levels in an area or aquifer. Uses of the data include 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 FY20, DNR continued monitoring reference springs, on a project begun by WGNHS, began 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

DNR's consolidated Groundwater Retrieval Network (*GRN*) accesses groundwater data from database systems in the Waste & Materials Management and Drinking Water & Groundwater 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 continued 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.

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, Petroleum Environmental Cleanup Fund Act, 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 FY19, the program spent almost $500,000 in Environmental Fund dollars to initiate or continue environmental cleanup actions at 25 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 $100,000 in Environmental Fund dollars in FY19 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 near the Johnson Controls International (JCI)/Tyco facility (Marinette), former Mirro plants (Manitowoc and Chilton) and Department of Defense sites (i.e. Wisconsin Air National Guard facilities at Truax Field and Volk Field) in Wisconsin.

The DNR is formulating a strategy to address PFAS in the State. At present, the DNR is in the initial stages of identifying PFAS sources and their potential impacts to municipal and private water supplies, groundwater and other environmental media in Wisconsin. This will include a request for voluntary sampling of influent and effluent by WPDES permitted municipal wastewater treatment plants. PFAS may be present in municipal wastewater treatment facilities' biosolids that have been regularly applied to agricultural lands throughout the state. The DNR intends to investigate the fate and transport of PFAS in biosolids. Additional statewide PFAS biosolids and sludge testing may be requested in the coming years.

Wisconsin will be drawing on the examples and experiences of other states to guide future PFAS efforts at State agencies that protect groundwater resources within the State. The DNR has hired two new PFAS research scientists to assist the state in this effort. The DNR received funding in the state budget to conduct a survey of fire departments and airports to evaluate the potential for PFAS contamination from firefighting foam (known as aqueous film forming foam or AFFF) and to develop best management practices for handling and disposing of AFFF. The DNR is also putting together a PFAS GIS screening tool to prioritize sites for potential sampling based on the likelihood of those substances being used and the susceptibility of nearby receptors (e.g., drinking water wells, wildlife, etc.).

<u>Investigation, Cleanup and Redevelopment of Brownfields</u>

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 195 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 220 sites in the program, with 108 at various stages of investigation and cleanup and 112 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.

The database is to be used with 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.

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 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.

WMM continues to be a participant in the Interagency Pharmaceutical Waste Working Group, with the Department of Agriculture, Trade and Consumer Protections 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.

<u>Monitoring Groundwater Quality Around Metallic Mines</u>

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 (Chapter 293, Wis. Stats.) and ferrous mining projects

(Chapter 295, Wis. Stats.). The regulatory framework for ferrous mining projects was recently created through enactment of 2013 Wisconsin Act 1 in March of 2013. The law created a process by which iron mining projects are evaluated and 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/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 provides for identifying 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.

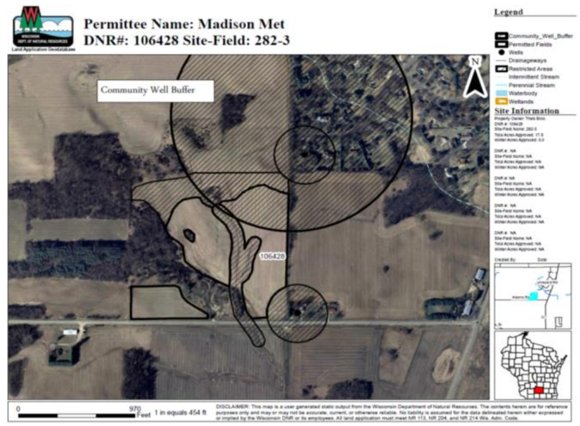
<u>Septage and Sludge Management</u>

WQ implements the regulations in chapters NR 113, NR 204, and NR 214, Wis. Adm. Code. 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 industry continues to explore more economical 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 proposed 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 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.



Clearer, more easily-produced maps in permits to land-apply wastes now help protect community and school water supply wells.

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 carries 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.

<u>Agricultural runoff and groundwater quality</u>

Chapter NR 243 Wis. Adm. Code covers Wisconsin Pollutant Discharge Elimination System (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 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).

As of December 31, 2019, 314 livestock operations were covered under discharge permits issued (87% dairy; 4% poultry; 5% swine; 4% beef). Regional and central office staff have successfully maintained the permit backlog at less than 25%. 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 Chapter 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 Chapter NR 151, Wis. Adm. Code, the DNR has developed runoff performance standards for MS4s and construction sites that are implement 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. The general permit to regulate storm water discharges from construction sites was reissued on September 30, 2011. There are 5 general permits that cover industrial activity, including heavy manufacturing, light manufacturing, scrap recycling, vehicle dismantling, and non-metallic mining.

For more information

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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 2020 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 270 groundwater and 105 surface water samples for more than 100 pesticide compounds plus nitrate.
- Provided cost-sharing for the installation and implementation of 1,189 conservation practices in 2019. These practices provided soil erosion control and helped manage manure and nutrients.
- Drafted a new technical standard currently out for public review and comment 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.
- Awarded grants to 26 producer-led groups for FY 2020 funding; 14 grants were fully funded and 12 grants were partially funded.
- Awarded $182,524 in Nutrient Management Farmer Education grants in 2019. Thirteen 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. Three 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. In 2018, DATCP adopted an updated USDA-NRCS 590 Nutrient Management Standard (2015) via administrative rule, ATCP 50, to meet DNR’s nutrient management performance standard.

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.

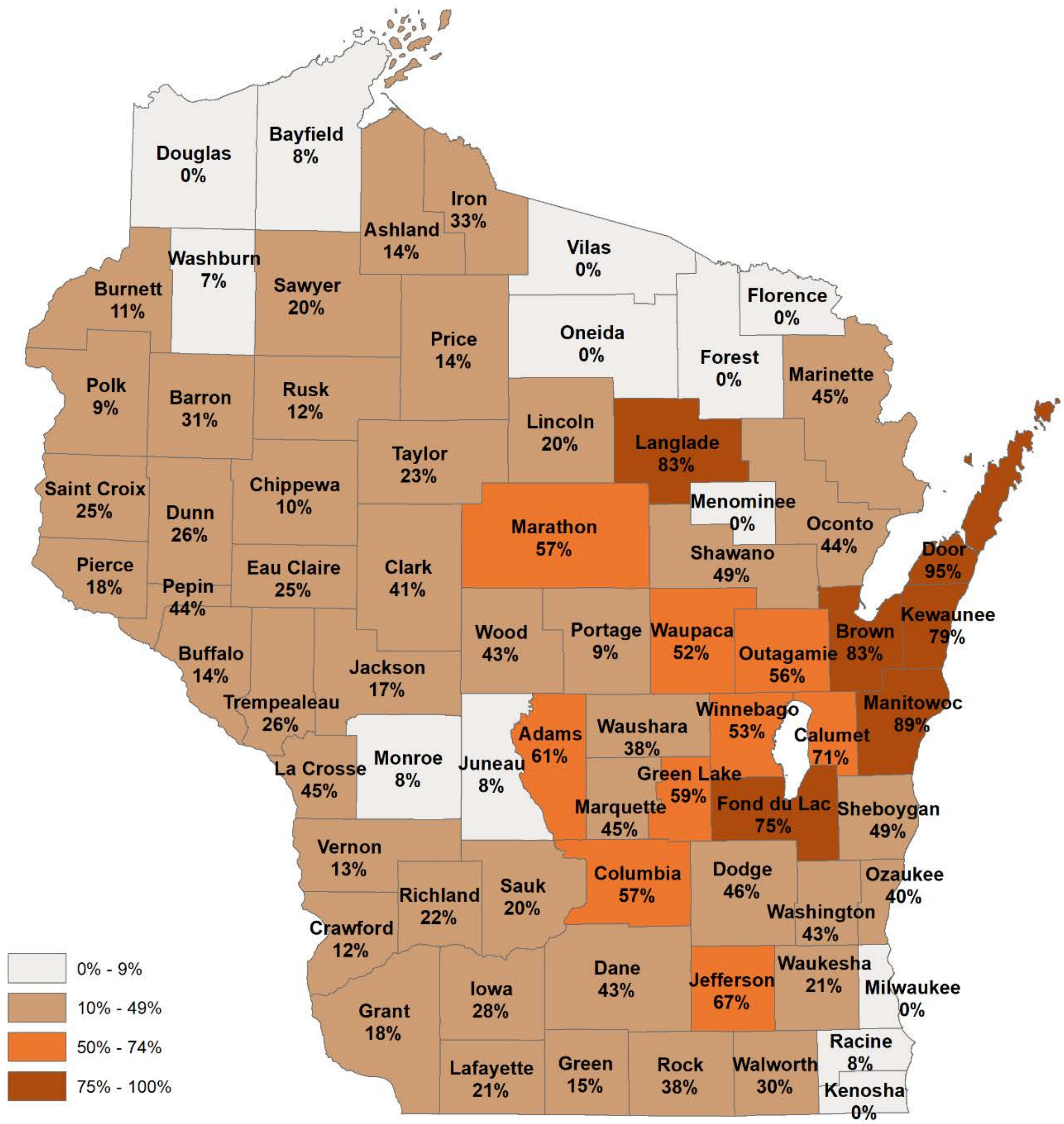
A Wisconsin nutrient management (NM) plan is an annually updated record that follows NRCS's 590 Nutrient Management Standard. A NM plan manages nutrient applications to ensure that crops receive the right amount of nutrients at the right time while minimizing degradation of both surface water and groundwater. 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.

The NRCS 590 Nutrient Management Standard was updated in 2015 to improve management of nitrogen, protect groundwater quality, require winter spreading plans, prohibit applications on areas that provide a direct conduit to groundwater and wells, limiting how and when to surface apply manure in certain areas and certain soils, including frozen or snow-covered soils. 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*.

Like other agricultural performance standards, the nutrient management standard is "designed to achieve water quality standards by limiting nonpoint source water pollution." Limiting applications of nitrogen to the University of Wisconsin fertilizer recommendation rates, in conjunction with other practices, is meant to limit nonpoint pollution of groundwater. Currently, 36.9% of agricultural land in Wisconsin is covered by an approved nutrient management plan (Figure 1).

Percent of County Cropland with 2019 Nutrient Management Plans



Harvested cropland acres are derived from National Agricultural Statistics Service, Census of Agriculture, 2017. The 2012 census reported 9,148,876 harvested cropland acres; the 2017 census reported 9,234,611 harvested cropland acres.

Figure 1. Cropland acres derived from National Agricultural Statistics Service. Census of Agriculture, 2012. Pasture land not included.

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 2019, 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 $182,524 in grants for farmer training (Nutrient Management Farmer Education grant program), and $618,000 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 $5,936,900 in SEG funds provides “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, resp. DATCP’s 2019 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 2019.

Funding Category	Total Requests	Unmet Requests	Final Allocations
County Staff/Support	$16,901,136	$7,937,036	$8,964,100
County LWRM Cost-Share (Bond)	$7,631,750	$4,176,750	$3,455,000
Bond Cost-Share Reserve (Bond)	$300,000	$0	$300,000
LWRM Cost-Share (SEG)	$3,082,116	$847,640	$2,234,476
Project Contracts (SEG)	$664,194	$46,194	$618,000
NMFE Training Grants (SEG)	$182,524	$0	$182,524
Total	**$28,761,720**	**$13,007,620**	**$15,754,100**

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. In 2015, the restriction maps were integrated directly into the SnapPlus program allowing the software to automatically identify and import field information from the maps. All of these tools can be accessed at *http://www.manureadvisorysystem.wi.gov/*.

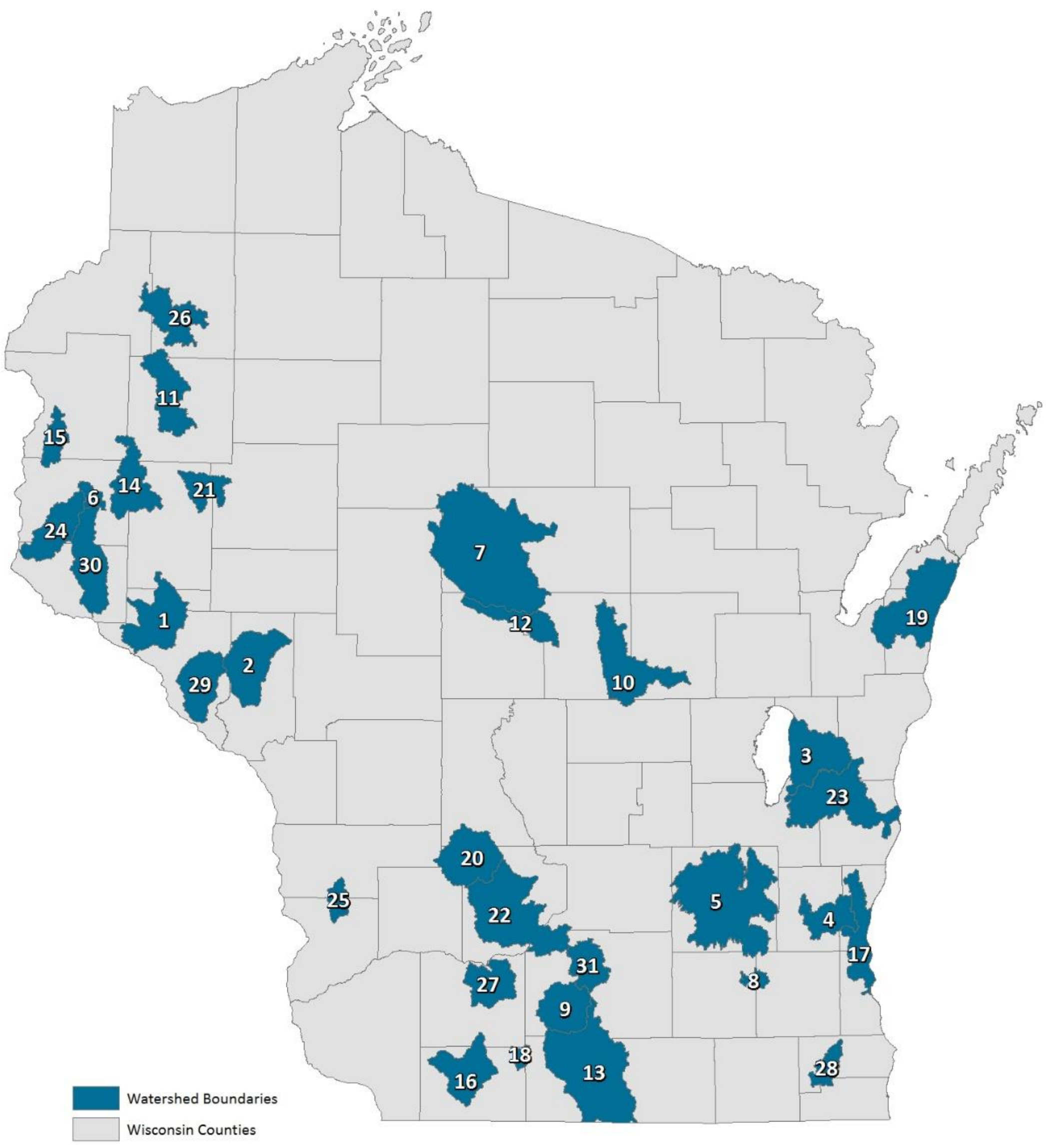
In 2017, DNR adopted a new targeted performance standard to reduce the risk of pathogen contamination to groundwater (NR 151.075). This new standard restricts manure application in designated areas where the bedrock consists of Silurian dolomite with a depth to bedrock of 20 feet or less. DATCP is responsible 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 began to meet in February 2019 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 draft of the technical standard is out for review and comment until June 22, 2020 and can be viewed at this website: *https://socwisconsin.org/current-work/full-process/01-verification-of-land-features/*.

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. Groups can now receive up to $40,000 in grant funding, double the available award from when the program started. For fiscal years 2017-19, the legislature increased the total program funding to $750,000 per fiscal year, triple the funding from the onset of the program.

Since inception, the program participation has nearly doubled and program funding has tripled. The acreage covered by the program since 2016 has increased over 200% and we expect acreage of conservation practices implemented by the groups to continue to grow. Producer-Led groups focus on nonpoint source abatement activities which benefit both surface and groundwater quality.

Producer-Led Grant Recipients 2016 - 2020



Map ID	Producer-Led Group	Map ID	Producer-Led Group
1	★**Bear Creek/Chippewa Farmer Groundwater Group**	17	**Milwaukee River Watershed Clean Farm Families (CFF)**
2	**Buffalo-Trempealeau Farmer Network**	18	Pecatonica Pride
3	★**Calumet County Agricultural Stewardship Alliance**	19	**Peninsula Pride Farms (PPF)**
4	**Cedar Creek Farmers - Improving Land for Cleaner Waters**	20	**Producers of Lake Redstone**
5	**Dodge County Farmers for Healthy Soil & Healthy Water**	21	**Red Cedar Conservation Farmers**
6	Dry Run Creek Farmer-Led Council	22	★**Sauk Soil and Water Improvement Group (SSWIG)**
7	Eau Pleine Partnership for Integrated Conservation (EPPIC)	23	**Sheboygan River Progressive Farmers**
8	**Farmers for Lake Country**	24	**South Kinni Farmer-Led Watershed Council**
9	**Farmers for the Upper Sugar River**	25	**Tainter Creek Farmer-Led Watershed Council**
10	**Farmers for Tomorrow**	26	**The Shell Lake - Yellow River Farmer-Led Watershed Council**
11	**Farmers of Barron County**	27	**Uplands Watershed Group**
12	**Farmers of Mill Creek**	28	**Watershed Protection Committee of Racine County**
13	**Farmers of the Sugar River**	29	Waumandee Watershed
14	**Hay River Farmer-Led Watershed Council**	30	**Western Wisconsin Conservation Council**
15	**Horse Creek Farmer-Led Watershed Council**	31	**Yahara Pride Farms**
16	**Lafayette Ag Stewardship Alliance (LASA)**		Bolded Producer-Led Groups received grant funding for 2020, Stars indicate new groups

Date: 11/13/2019 N

Figure 2. The location of the producer-led watershed initiatives awarded a DATCP grant.

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 2019, 91 grants were issued: 25 for agricultural waste, 36 for household hazardous waste and 30 for the collection of unwanted prescription drugs. There were nearly 630 farmers and 11 agricultural businesses that brought in slightly more than 120,000 pounds of agricultural waste, 6 percent less than 2018. 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 appears to be holding steady overall, ranging 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 amount of household hazardous waste collected declined slightly from 2018 but the number of households increased by 1,500 participants. About 2.1 million pounds were collected in 2019 from approximately 63,500 residents. Lead and oil-based paints are the most common waste collected from households. Nearly 759,000 pounds were taken in for disposal. The next category is solvents and thinners with 396,000 pounds collected. Pesticides are the third-most collected waste with almost 345,000 pounds brought in for disposal. Wisconsin residents 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 41,000 pounds of unwanted pharmaceuticals, an increase of about 3,000 pounds from the previous year. Drug collections supported by clean sweep grants are only a portion of the drug drop boxes and take back events in the state. In 2019, the Wisconsin Department of Justice coordinated and paid for the collection and disposal of 118,880 pounds of drugs. The pharmaceuticals collected through clean sweep projects are included in this total.

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 clean ups at more than 1,300 acute agrichemical spill locations. The ACCP has received nearly 1,600 reimbursement applications totaling about $46.8 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. In 2018, DATCP began funding a two-year research project to evaluate lawn care pesticides in groundwater in the Milwaukee metropolitan area. The project will be completed in July of 2020. Three additional research projects were funded starting in June 2019: two are assessing different aspects of neonicotinoid insecticides found in groundwater and shallow streams in the Central Sands Region, while the third is assessing the feasibility of using heat sensing and aerial mapping technologies to map springs and thin soils over karst features in Kewaunee County, features often associated with the movement of surface contaminants to groundwater. And in July 2020, DATCP will begin funding two projects: one expanding on the evaluation of the extent of neonicotinoids in groundwater and streams in the Central Sands; and one that explores the financial cost and feasibility of using various remote sensing tools to define soil thickness in Silurian bedrock areas. The latter study is hoped to aide farmers in better management of manure applications under new technical standards developed under ch. NR 151, Wis. Admin. Code.

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 the following web site (https://datcp.wi.gov/)
Contact Lori Bowman, Lacey Cochart or Stan Senger, DATCP
2811 Agriculture Drive, PO Box 8911
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DEPARTMENT OF HEALTH SERVICES (DHS)

FY2020 Highlights

- DHS toxicologists and public health educators started reviewing technical information of 40 substances on request from the DNR as part of the 11th cycle of recommended NR 140 groundwater quality standards. DHS also supported 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, including one in which per- and polyfluoroalkyl substances (PFAS) were the major contaminants in Marinette County. 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 been providing technical assistance by reviewing private well water testing results and recommending proper actions to reduce or halt exposure to PFAS.

- The Wisconsin Environmental Public Health Tracking (Tracking) Program awards mini-grants to local public and tribal health agencies (LPTHAs) to increase environmental public health improvement initiatives throughout Wisconsin. In 2019-2020, three local public health agencies are wrapping up projects that address well water quality. In addition to providing funding, Tracking staff connected each mini-grantee with subject matter experts and provided technical assistance related to epidemiology, communications, and evaluation as requested.

- The Climate and Health Program is currently working on three flood-related tools – Flood Resilience Scorecard, Wisconsin Flood Toolkit updates, and Wisconsin Flood Risk Mapping Application updates – to help LPTHAs, local and tribal government, and emergency managers better understand flood-related health impacts in Wisconsin. These 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.

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 rule-making process as amendments to Wis. Admin. Code ch. NR 140.

In FY2018, DNR requested that DHS review the health information for 27 substances as part of the 10th cycle of NR 140 groundwater quality standards. DHS provided recommendations to the DNR in June 2019. In FY2020, DHS supported DNR's rulemaking efforts for these standards including presenting at several public meetings. For more information on DHS' cycle recommendations, please visit the DHS website.

In FY2019, DNR requested that DHS review the health information for an additional 40 substances as part of the 11th cycle of standards (see table below for a list of substances). In FY2020, DHS worked on developing these recommendations. DHS estimates the recommendations for cycle 11 will be finished in Fall 2020.

Cycle 11 Substances

- Metalaxyl
- Chlorantraniliprole
- Flumetsulam
- Fomesafen
- Hexazinone
- Saflufenacil
- Perfluorotridecanoic acid
- Perfluorotetradecanoic acid
- Perfluorobutanoic acid
- Perfluoropentanoic acid
- Perfluorohexanoic acid
- Perfluoroheptanoic acid
- Perfluorononanoic acid
- Perfluorodecanoic acid
- Perfluoroundecanoic acid
- Perfluorobutane sulfonic acid
- Perfluorohexane sulfonic acid
- Perfluoroheptanesulfonic acid
- Perfluorooctane sulfonamide
- Perfluorododecanoic acid
- 6:2 Fluorotelomer sulfonic acid
- 8:2 Fluorotelomer sulfonic acid
- Perfluorodecane sulfonic acid
- Perfluoropentane sulfonic acid
- Perfluoro-2-methyl-3-oxahexanoic acid
- 4:2 Fluorotelomer sulfonic acid
- 10:2 Fluorotelomer sulfonic acid
- Perfluorohexadecanoic acid
- Perfluorooctadecanoic acid
- Dodecafluoro-3H-4,8-dioxanonanoate
- 9-chlorohexadecafluoro-3-oxanonane-1-sulfonate
- Perfluorododecanesulfonic acid
- Perfluorononane sulfonic acid
- N-Methyl perfluorooctane sulfonamide
- N-Ethyl Perfluorooctane sulfamide
- N-Methyl perfluorooctane sulfonamido acetic acid
- N-Ethyl perfluorooctane sulfonamidoacetic acid
- N-Methyl perfluorooctane sulfonamidoethanol
- N-Ethyl perfluorooctane sulfonamidoethanol
- GenX

Working with Partners to Address Drinking Water Concerns

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, LPTHAs, 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 FY2020, 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 LPTHAs and state partners (for example, DNR and DATCP).

Occasionally, DHS provides well water testing capacity through the Basic Agreement with the Wisconsin State Laboratory of Hygiene for LPTHAs conducting public health investigations in affected communities. For example, in FY2020, the Groundwater Program worked with the Dunn County Health Department and DNR to investigate uranium levels in wells in Ridgeland, Wisconsin. In December 2019, DNR learned that a public water system in the area had high levels of uranium in their water. Uranium is a naturally radioactive element that can be found in groundwater from certain types of rocks underground. At high levels, uranium may cause kidney problems. DNR hypothesized that this uranium was caused by fissures in bedrock. Due to limited knowledge of depth of other wells in the community, DHS provided fee-exempt testing at a number of private residences in this area. DHS also assisted the local health department in developing a press release and participated in a public meeting to inform residents about the testing program.

DHS' Groundwater Program consistently works to increase public awareness of groundwater and drinking water health issues. In FY2020, DHS created an infographic detailing the health effects of nitrate in drinking water and an infographic describing steps that homeowners can take to reduce their risk to lead from drinking water. Additionally, we updated several drinking-water-related websites to improve clarity and access to resources and presented at public meetings and scientific conferences on the health effects of nitrate, PFAS, and lead.

DHS continues to build relationships with state, local, and community partners. For instance, in FY2020, the Groundwater Program worked closely with Wisconsin Land+Water to design and lead a roundtable on nitrate health effects at a County Conservation meeting. We also surveyed attendees about their knowledge on nitrate and shared this information with Wisconsin Land+Water. Our goal is to use this information to develop future trainings and target appropriate audiences.

Participating in Water Quality Task Force Hearings

As a part of our work addressing water quality issues in Wisconsin, the Speaker's Task Force on Water Quality was created in 2019 to gather information and make policy recommendations to better assess and improve the quality of both surface water and ground water in Wisconsin. This task force held a series of hearings in both Madison and across the state. DHS presented a list of recommendations for legislative action that focused on enhancing community and statewide capacity to protect and promote public health by addressing water quality issues. DHS recommended:

- Enhancing our collective ability to develop timely and relevant guidelines, standards, and policies that inform public health advice and assure water quality-related policies protect public health.
- Building public awareness and knowledge of water quality issues to empower individuals and communities to make informed decisions.
- Promoting better understanding of the occurrence of water-quality-related human health hazards.
- Taking action to address water quality issues for which there are known solutions.

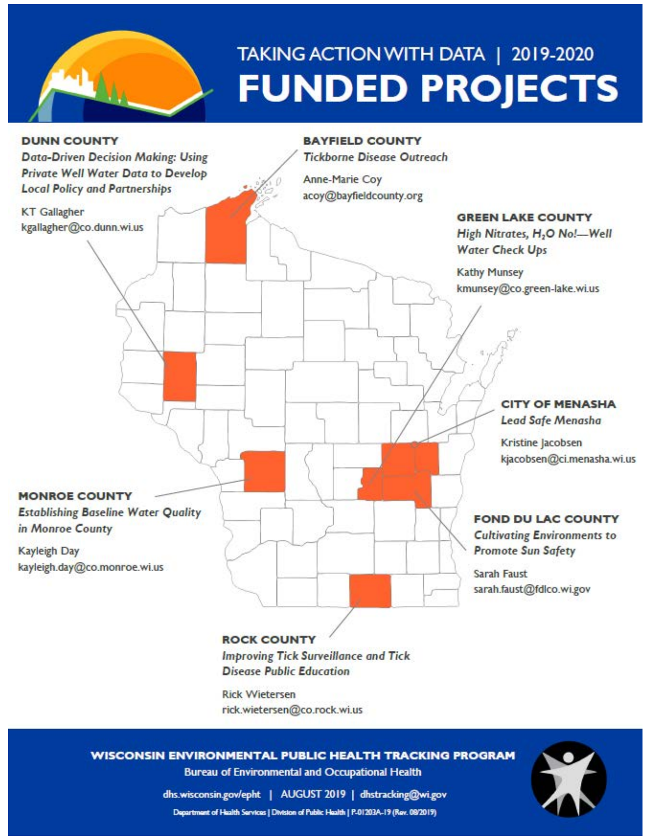
These recommendations reflect the need for multidisciplinary approaches to make meaningful progress toward improving water quality. For more information on DHS recommendations please visit the Speaker's Task Force on Water Quality website.

Environmental Cleanups

DHS receives hundreds of inquiries each year regarding various environmental health concerns. Many of these inquiries are specifically related to groundwater and drinking water concerns. The spectrum of inquiries various from issues in individual households to large community-level concern related to chemical discharge or historical contamination. For contaminated areas, the Site Evaluation Program at DHS assists with the site investigation process by reviewing environmental data and determines the health risk to residents and visitors by conducting risk assessments. For sites where groundwater contamination is a concern, the Site Evaluation Program works closely with the Groundwater Program to ensure that proper recommendations are provided to the community to reduce their exposure to harmful substances, and to support LPTHAs with outreach. One example of this effort is the ongoing investigation at Starkweather Creek, Truax Field, 4000 International Lane, Madison, WI (BRRTS Activity No. 02-13-584369), where PFAS were detected in surface waters and a nearby municipal well.

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 local public and tribal health agencies (LPTHA) to assist them in making positive public health improvements in their communities. The Wisconsin Tracking Program continued its successful mini-grant program and issued a request for applications for LPTHAs in 2019 for the fifth round of funding. Funds are used by grantees to explore data from the County Environmental Health Profiles and the Tracking data portal to identify an environmental health concern in their jurisdiction. LPTHAs developed and implemented environmental health initiatives within their communities, based on these data. Out of the seven LPTHAs funded in the current round (2019-2020), three addressed private well water quality. In the previous round of funding (2018-2019), three of eight LPTHAs addressed private well water quality.



The Wisconsin Tracking Program and other DHS staff provide ongoing support, technical assistance, and guidance to LPTHAs on epidemiology, communications, and evaluation throughout the project period. LPTHAs 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 LPTHAs 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.

While the current mini-grantees are still wrapping up their projects from this year, an example of a previous project that a local public health agency carried out in this area involved specifically addressing nitrate contamination in private wells. Results from this project were shared at the 2019 Wisconsin Public Health Association Conference.

Clark County: Increasing Well Water Testing and Identifying Contamination Sources

Clark County noticed that nitrate contamination in private well water had increased over time. In 2010, about 6% of wells had unsafe nitrate levels, which increased to 20% by 2017. Clark County staff worked with partners to aggregate well testing data from four sources into one cohesive database. Using geospatial analysis on the database, higher risk areas were identified on the database and the county targeted outreach and education in these areas. Furthermore, staff encouraged well testing through five community events. Over 120 well water tests were collected and over a quarter of them were either unsafe to drink because of nitrate contamination (≥ 10 mg/L) or were at-risk of becoming unsafe in near future (between 8.0-9.9 mg/L). Health department staff worked with partners to correct issues associated with possible contamination sources and referrals were made to eliminate other groundwater hazards. Seven homeowners installed reverse osmosis systems to correct nitrate issues and two other homeowners were connected with grant resources to eliminate public health hazards on their properties.

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 flood events.

Gaps identified previously by the Wisconsin Climate and Health Profile Report have led to the development of several flood-related projects, with the goal of enhancing understanding of flood risk 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 LPHAs and tribal health centers. The findings from these flood-related projects have helped inform LPTHAs and local emergency management planning processes.

CHP is currently working on two flood-related tools to help LPTHAs, 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 Wisconsin Flood Risk Mapping Application (WFRMA) 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.
- During FY2018 additional environmental monitoring occurred around the decommissioning of La Crosse Boiling Water Reactor due to tritium concentrations detected in site groundwater. No elevated levels were detected in off-site samples taken by the DHS EM program.

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.

For more information
Visit the DHS Water Quality webpage.
Contact:
Jonathan Meiman, 608-266-1253
Sarah Yang, 608-266-9337
Department of Health Services
Bureau of Environmental and Occupational Health
1 W. Wilson St., Rm. 150
Madison, Wisconsin 53701

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.

Measuring the water level in a monitoring well.
Photo: Mike Parsen

FY 2020 Highlights

(see *https://wgnhs.wisc.edu/2019-year-in-review/*; also see this story map describing the projects in more detail: *https://arcg.is/1aCrXG*)

- Investigating groundwater quality in southwestern Wisconsin
- Completion of the first comprehensive catalog of Wisconsin's springs in 60 years and the release of a web application that lets users explore the springs data
- Building background hydrogeology for the central sands lakes study
- Using drones to locates shallow bedrock, seepage faces, and underwater springs
- Conducting new geologic mapping in Bayfield, Dodge, Jefferson, and Waushara Counties
- Conducting new geologic mapping in Wisconsin's Driftless Area
- Initiating new hydrogeologic research in southwest Wisconsin
- Investigating groundwater-surface water relationships in Wisconsin streams, lakes, and wetlands
- Upgrading Wisconsin's statewide groundwater monitoring network

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. 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 2019 in eight 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/)

- ***Bayfield County groundwater atlas.*** In FY 2016, the Bayfield County Board requested WGNHS assistance to complete characterization of their groundwater resources, including a water well database, recharge analysis, depth to bedrock and groundwater contamination potential. The project was completed in 2019; final products are available here: https://wgnhs.wisc.edu/pubs/000967/.

- ***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 is 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 is scheduled for release in 2020.

Sampling springs in Door County wetlands. Photo: Dave Hart

- ***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 is scheduled for release in 2020.

Regional Groundwater Studies

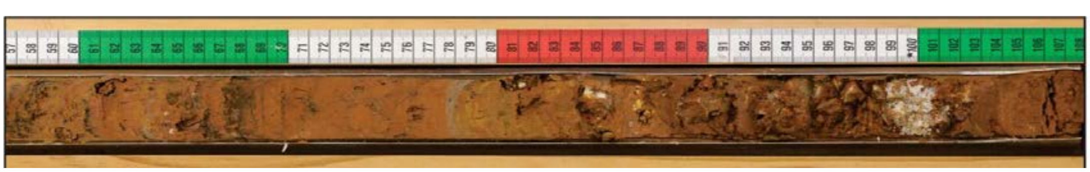
Regional groundwater studies usually span multiple counties. During 2019 the WGNHS was involved in several regional projects, including the following:

- ***Groundwater flow in the Mukwonago Basin.*** In cooperation with the USGS, and with funding from The Nature Conservancy, the WGNHS built and calibrated a groundwater flow model. This model will be used to understand the impacts of possible land use changes and groundwater pumping to groundwater dominated wetlands in the Mukwonago Basin. The model has been used to estimate potential impacts to selected wetlands, streams and lakes in the basin from increased pumping. The results will be part of a decision support tool for land use planning in the basin. That tool will be web based and directly provide users with an understanding of how a proposed well will affect stream flow and water levels of surface waters and wetlands in the basin. . A journal article describing the results is available here: https://ngwa.onlinelibrary.wiley.com/doi/pdf/10.1111/gwat.12931

- ***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.



Core of material from the Rountree Formation 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 areas during 2019 included the following:

- ***Nitrate study***. In 2019, WGNHS continued to assist the DNR with source water protection at public supply wells impacted by elevated nitrate. The WGNHS operates monitoring systems at two sites. The WGNHS is continuing this research in partnership with cooperating land managers to quantify nitrate loading to the underlying aquifer under an irrigated corn crop. In addition, the WGNHS supported field research and modeling to determine nitrate sources and movement near municipal wells at Waupaca, Wisconsin.

- ***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.


Collecting water-quality data in the Marengo River as part of a study to help the U.S. Forest Service manage trout habitat in response to climate change. *Photo: Dave Hart, WGNHS*

- ***Mapping the base of the Cambrian aquifer through geophysical modeling of Precambrian topography, southern Wisconsin.*** The Survey's bedrock geologists are using geophysical techniques combined with field mapping to determine the base of the Cambrian sandstone aquifer in parts of Columbia and Sauk Counties. This project, funded through the Wisconsin Joint Solicitation, is critical for determining aquifer thickness for use in hydrogeologic analyses.

- ***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.]

Groundwater Data Management and Support

In 2019 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:

- ***An updated springs inventory for the state of Wisconsin.*** The WGNHS completed a 3-year effort to inventory the springs of Wisconsin. This inventory resulted in a comprehensive database with information on flow rate, water quality and other physical attributes relevant to the classification of springs. The database (*https://dnrmaps.wi.gov/H5/?viewer=Water_Use_Viewer*) is used by the DNR for approving high-capacity well permits. In addition to developing this database, WGNHS staff began a long-term monitoring program of eight reference springs. These springs were selected in representative hydrogeological and ecological settings to provide a more robust understanding of springs and potential impacts from land use and groundwater withdrawals The analysis includes quarterly measurements of spring flow and water chemistry and surveys of aquatic plants and animals. In 2019 the WGNHS published a report on the statewide survey, guidelines for surveying springs (*https://wgnhs.wisc.edu/pubs/000968/*), and an interactive story map giving access to the site photos, detailed descriptions, and full datasets for 415 of Wisconsin's springs (*https://wgnhs.wisc.edu/springs-web-app/*).

One of the many springs inventoried as part of our multiyear project inventorying the springs of Wisconsin. *Photo: Grace Graham, WGNHS.*

- ***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 Departement of Transportation. In 2019 the WGNHS released a publiclly-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 UW-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 2019, 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 1983 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 about 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 2020 Highlights

- 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 providing ongoing training to County winter maintenance crews regarding Direct Liquid Application (DLA).
- Nineteen Counties used DLA last season including one Mosltly Liquid Route (MLR) on an Interstate.
- 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 (204 million pounds) yielding cost savings ($8.2 Million).
- 11.4 million gallons of brine solution was used last season, most in Wisconsin history.
- Forty-four Counties are now using route optimization technology.
- New DOT Podcast (Feb 25, 2020 – Transportation Connects): Clear Roads, Less Salt *https://wisdot.libsyn.com/clear-roads-less-salt-wisconsin-winter-road-maintenance-0*.

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 1,308 salt storage site locations listed in the database with a total of over 2,678 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. Last winter, several counties implemented route optimization where trucks are strategically routed based on shop location, salt supply and fuel location. These changes resulted in fuel and time efficiencies. Forty-four Counties have been supplied route optimization (route changes based on a uniquely designed map for each of those counties).

The newest DOT initiatives over the last 2 winter seasons in winter maintenance is called “Mostly Liquid Routes” (MLRs). Nineteen 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 pilot projects resulted in a reduction of about 50% road salt application while still achieving the “time to bare/wet” goals. Next winter the UW Traffic and Safety Laboratory (TOPS) will study MLRs for an additional 10-15 Counties.

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 in the New WisDOT podcast (Feb 25, 2020 – Transportation Connects – Clear Roads, Less Salt – Winter Road Maintenance) and refer to the following YouTube Links and links to WisDOT's Twitter account and Facebook:

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

https://www.youtube.com/watch?v=7Z_AnRlpSQ8
https://www.youtube.com/watch?v=4cTmhl_nN8c

https://twitter.com/WisconsinDOT/status/1214966252726210560
https://twitter.com/WisconsinDOT/status/1216778603637010434
https://twitter.com/WisconsinDOT/status/1224698887375654912
https://twitter.com/WisconsinDOT/status/1227684631383769088

https://www.facebook.com/WisDOT/photos/a.244273872263782/3036959442995197/?type=3&theater

For more information

Visit the following web site (https://wisconsindot.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 who work on groundwater issues. UWS staff members work with state and federal agencies and with other partners to solve groundwater resource issues. Research is coordinated through the University of Wisconsin Water Resources Institute, which conducts annual calls for proposals followed by rigorous peer 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 the University of Wisconsin-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 2020 Highlights


The Central Sands region irrigates its fields using high-capacity wells. Researchers check the effect on groundwater. Photo: Bonnie Willison

- In support of the Wisconsin Groundwater Research and Monitoring Program, provided UWS funding to six research projects focused on groundwater contaminants, including arsenic and nitrate; water quantity challenges in the Central Sands; geochemistry and microbiology; groundwater-surface water interactions; and new monitoring techniques, and supported graduate and undergraduate students at UW-Milwaukee, UW-Madison, and UW-Eau Claire.
- Coordinated the Request for Proposals and the review process for the FY21 Joint Solicitation for the Wisconsin Groundwater Research and Monitoring Program.
- Supported three 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 the state's lake level study and PFAS standards development and began recruitment for two more

fellows. Leveraged Aquatic Sciences Center funding to support two additional postdoctoral fellows working on aquatic toxicology and PFAS.

- Supported the annual Wisconsin Chapter of the American Water Resources Association meeting by leading and funding the writing, editing, graphic design, printing, and mailing of a conference registration brochure and the writing, editing, and graphic design, of the conference program. Due to the new coronavirus pandemic, the meeting was cancelled. However, the meeting materials had been created and distributed so at least resource managers, researchers, industry representatives and consultants, and students could connect on their own in an ad hoc fashion on topics that would have been covered during an in-person gathering.
- Maintained the *Wisconsin Water Library*, providing access to more than 30,000 volumes of water-related information. Library staff also reached 8,102 K-12 students.
- Maintained the *WRI website* as an information portal for research requests for proposals, news, and past research. Website traffic was roughly 5,390 sessions, involving about 5,100 visitors in this year.
- 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 also posted online. At *aqua.wisc.edu/chronicle*, all issues of the publication are archived and searchable.
- Supported the production of 26 final project reports, 14 theses, and 48 peer-reviewed publications over the past five years.
- Curated an art exhibit that was placed in two communities. The art focused on the healing power of water. *Under the Surface-A Photographic Journey of Hope and Healing* featured images captured by youth enrolled in a residential treatment program based in Webster and called Northwest Passage.

The Wisconsin Water Library's Senior Special Librarian Anne Moser curated an art installation that reached more than 19,000. Young people captured water images as a form of their treatment at a mental health residential facility. The artistic explorations are paired with instruction in biology. Photo: Lydia

- Created all-inclusive kits for children in pre-K to fourth grade to teach age-appropriate STEM concepts with a water theme. The kits are booked out for months into the future for use in classroom or story-time settings.

Research

One way to broadly share the science supported by the Wisconsin Groundwater Research and Monitoring Program and other funders is a poster session. Pictured is Carolyn Voter, one of WRI's Wisconsin Water Resources Science-Policy Postdoctoral Fellows, who is integral to the Central Sands Lake Study, as directed by the legislature.

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 FY20 included research focused on groundwater microbiology and geochemistry, groundwater-surface water interactions, new monitoring techniques, groundwater quantity challenges, and various groundwater contaminants, including arsenic.

During FY20, the WRI directed a wide-ranging program of priority groundwater research consisting of three new projects and three 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 six projects, funded by the UWS, provided training in several disciplines for several graduate student research assistants and undergraduate students at UW-Milwaukee, UW-Madison, 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. (new)
- Assessment of the source and mobility of phosphorus in the hydrologic system in western Wisconsin. Sarah Vitale and Brian Mahoney, UW-Eau Claire. (new)
- Microbially-mediated oxidation of trace element-bearing sulfide minerals in sandstones of Trempealeau County, WI. Eric Roden and Matthew Ginder-Vogel, UW-Madison. (new)
- The impact of dissolved organic matter composition on the formation of disinfection byproducts in groundwater. Christina Remucal, UW-Madison. (continuing)
- Improving water and nitrogen use efficiency under changing weather variability in the Central Sands. Christopher Kucharik, Matthew Ruark, UW-Madison. (continuing)
- Dynamics of arsenic concentration and speciation in Wisconsin private drinking water wells. Shangping Xu, Yin Wang, UW-Milwaukee. (continuing)

For FY21 (July 1, 2020 - June 30, 2021), the UWS selected five 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-Stevens Point, UW-Milwaukee, UW-Eau Claire, and UW-Madison and include:

- 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 and J. Brian Mahoney, UW-Eau Claire. (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 and Patrick Gorski, UW-Madison. (new)
- 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)


Changing amounts of snow cover may be affecting the amount of groundwater across the state. A University of Wisconsin-Madison researcher is leading the study. Photo Pixabay

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 FY20, this allocation supported:

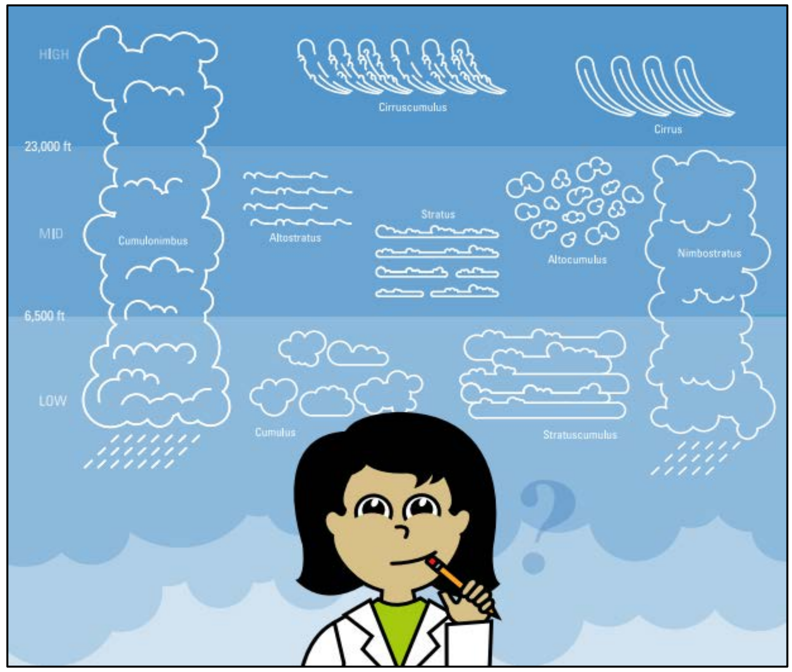
- Improving water and nitrogen use efficiency under changing weather variability in the central sands. Chris Kucharik, UW-Madison. (continuing)
- Fate of groundwater phosphorus from septic systems near lakes. Paul McGinley, UW-Stevens Point. (new)
- Impact of changing snow cover and frozen ground regimes 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 DNR's Drinking Water and Groundwater Program to work on the Central Sands Lakes Study (study requested by the legislature). (Dr. Carolyn Voter, 2019-2021).
- 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, 2020-2021).
- Recruit 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. (Dr. Bryan Maitland and tbd, 2020-2021).
- Support a Water Resources Science-Policy postdoctoral fellow in partnership with the DNR's Water Quality Program to work on stream water quality modeling and prediction. (Dr. Francisco Guerrero-Bolaño, 2019-2020).

Lastly, the Aquatic Sciences Center (home to WRI) successfully secured a grant from the U.S. Environmental Protection Agency to support a U.S. Environmental Protection Agency Human Health and the Environment Postdoctoral Research Fellow. (Dr. Ryan Lepak, 2019-2021). The Aquatic Sciences Center also provided a grant to UW-Madison to support a postdoctoral research fellow to address PFAS contamination of surface waters.

Teaching



The Water Resources Institute offers resources to teachers in the form of STEM curriculum kits on water-related topics geared toward children up to 4th grade. This illustration is included in a brand-new teaching tool for 2020. Children learn about clouds and the water cycle using this resource. Illustration: Kristen Rost.

Institutions within the UWS continue to offer undergraduate- and graduate-level courses and programs focusing on diverse issues 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 FY20, 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.

Eric Booth is a member of the board of directors for the Wisconsin Chapter of the American Water Resources Association, which brings together water professionals—and researchers such as himself—for an annual meeting. It is also a crucial training forum for students. Hopes are high that the meeting can happen in 2021 because it had to be cancelled due to COVID-19. The UW Water Resources Institute supports this meeting. Photo: Sara Stathas.

New to this year's WRI video catalog is "Wisconsin's Groundwater Coordinating Council. 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 nearly 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 content-population of *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.

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.

AWRA Annual Conference

The WRI was once again integral to the planning of the American Water Resources Association (AWRA)-Wisconsin Section's annual conference. The meeting is sponsored by numerous academic and governmental partners, including the Center for Watershed Science and Education, UW-Stevens Point Wisconsin; DNR; Wisconsin Water Science Center, U.S. Geological Survey; and WGNHS. Such collaboration forges stronger ties among these critical water research and monitoring entities. The 2020 conference did not take place due to COVID-19, but plans are developing for the 2021 conference.

Wisconsin's Water Library Outreach Activities

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.

> In mid-March, the physical library closed due to concerns related to the new coronavirus. However, the online feature Ask a Librarian chat remained a resource. Over a two-month period, Senior Special Librarian Anne Moser answered 11 in-depth reference questions. In an average year, there are two questions through that portal. These types of reference questions can take an hour or more of time to resolve.

Library Websites

The library maintains several information transfer tools to reach library patrons. The most frequently accessed is the *library's website*, which had about 3,500 visitors this year.

In addition to its website, Wisconsin's Water Library uses other technology tools to reach library patrons. Using email, the library sends out a bimonthly *Recent Acquisitions List* to about 600 contacts. The message includes recent updates to the library website and contact information for users to ask any water-related question. The library also supports an email at askwater@aqua.wisc.edu, which is monitored daily. Anyone with a water-related query can pose a question and receive a response in a timely manner.

The library has been using social media tools to reach new library users and to raise visibility of the library. *Facebook* is used often to announce events and display interesting links to its followers. The library's Facebook page currently has more than 580 likes. The library's *Twitter* tool has been in use since June of 2009 and now has more than 2,000 followers. Both tools have seen increased use by library patrons and both have loyal and increasing numbers of followers.

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.

Gorski, P., M. Shafer, J. Hurley, S. Zana, and J. Swarthout. 2015. Hexavalent chromium (Cr(VI)) in WI groundwater: identifying factors controlling the natural concentration and geochemical cycling in a diverse set of aquifers. Final report, Water Resources Institute, University of Wisconsin-Madison. WR12R005.

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.

Larson, E.R., and S.A. Allen. Establishing the long-term range of variability in drought conditions for southwest Wisconsin. Final report, Water Resources Institute, University of Wisconsin-Madison. WR13R003.

Larson, R., and M. Holly. 2015. Silage storage runoff water quality assessment and design recommendations to limit environmental impacts Final report, Water Resources Institute, University of Wisconsin-Madison. WR11R007.

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.

Loheide, S., and C.B. Voter. 2015. Effects of nuanced changes in lot layout and impervious area connectivity on urban recharge. Final report, Water Resources Institute, University of Wisconsin-Madison. WR12R002.

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.

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.

Potter, K. 2015. Quantifying and communicating uncertainty in products of the USGS National Water Census. Final report, Water Resources Institute, University of Wisconsin-Madison. WR14R005.

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.

Sellwood, S.M., D.J. Hart, M.B. Gotkowitz, and J.M. Bahr. 2015. Identifying the controls on flow and contaminant distribution in siliciclastic bedrock aquifer systems. Final report, Water Resources Institute, University of Wisconsin-Madison. WR12R001.

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.

Thompson, A., K.G. Karthikeyan, R. Stenjem, D. Hyndman, A. Kendall, and A. Parish. 2015. Implications of climate change and biofuel development for Great Lakes regional water quality and quantity. Final report, Water Resources Institute, University of Wisconsin-Madison. WR10R008.

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.

Wu, C. 2016. Uncertainty and variability of Wisconsin lakes in response to climate change. Final report, Water Resources Institute, University of Wisconsin-Madison. WR11R003.

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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.

Gerdts, N. 2015. Seasonal evaporation of polymictic and dimictic lakes under changing climate. M.S. Thesis. University of Wisconsin-Madison.

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. 2019. The Dynamics and Speciation of Arsenic in Drinking Water Wells in Eastern Wisconsin. M.S. Thesis. Geosciences. University of Wisconsin - Milwaukee. *https://dc.uwm.edu/etd/2328*. WR18R002.

Polich, Michael. 2015. Surface runoff, soil, and nutrient fluxes of cellulosic biofuel cropping systems. M.S. Thesis, University of Wisconsin-Madison.

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.

Sellwood, Stephen M. 2015. Characterization of groundwater flow in sandstone aquifers using heat as an in-well tracer. Ph.D. Thesis. Geoscience, University of Wisconsin-Madison.

Stefani, Nick. 2016. Field and Laboratory Measurement of Radon Flux and Diffusion for Uranium Mill Tailings Cover Systems. M.S. Thesis. Geological Engineering, UW-Madison.

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Cardiff, S.G., and R. F. Lepak. 2015. Summary of the Workshop on Trace Metals Monitoring in the Lake Superior Basin. *http://www.lic.wisc.edu/glifwc/workshops/tracemetals.html*.

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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* is an affiliate of the Center for Watershed Science and Education. It is part of UW-Madison's Division of Extension and is a partnership with the College of Natural Resources at UW-Stevens Point. 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 2019, 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. Twenty-five organized programs were conducted in the following counties: St. Croix, Chippewa, Crawford, Calumet, Douglas, Columbia, Shawano, Dodge, Sauk, Trempealeau, Pierce, Wood, Taylor, Iowa, Grant, Lafayette, Dunn, Waushara, Kewaunee, Sheboygan, and Pepin. Educational events organized by participating communities were attended by 816 participants. Of those surveyed, 42% indicated that their knowledge about the safety of their well water had "greatly improved"; another 38% indicated "some improvement". When asked questions about what actions they intend to undertake after participating in the program, responses ranged from "test my water more often" to "install a water treatment device".

In addition, nitrate screening and information on well water testing was provided at the Midwest Renewable Energy Fair Nearly 100 well owners brought samples to be screened for nitrate.

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 850,000 individual test results for approximately 112,283 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 WDNR 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 10,242 people.

Nitrate in Groundwater

The Center is investigating the impact of various cropping practices on groundwater quality in the Central Sands. 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 fertility or leaching studies often only focus 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. The work is a collaboration with Dr. Chris Kucharik and students of his Lab at UW-Madison Department of Agronomy.

Central Wisconsin county-based volunteer streamflow monitoring

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

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 Central Sands region.

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 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 has begun multi-year projects with Chippewa, Green, and Sauk Counties to organize citizen-based groundwater monitoring networks in each county. We will be recruiting 200-300 rural landowners were recruited in each county to test their wells for parameters such as nitrate, chloride, alkalinity, pH, hardness, and conductivity. The goal is to test the same wells for 5-years in a row for the purposes of understanding trends in rural groundwater quality over time. By testing the same wells annually, we 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. The projects are similar to *trend analysis/testing* that we have been conducting in partnership with the Kewaunee County Land Conservation Department in the Town of Lincoln.

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 currently participate 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. 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.

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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.
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 the 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.
- 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.

Northland College Professor Tom Fitz teaching Master Naturalist volunteers about artesian wells found in northern Wisconsin.

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 a total of over 120,000 volunteer hours providing nearly $3.1 million 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. Nearly 100% of survey respondents consistently report that their knowledge of Wisconsin's natural resources increases after taking the course. 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.

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 2019, the NPM program staff collectively educated 9,170 people, at 156 events, giving 111 unique (original, first-time) presentations. In addition, they provided 4,795 individual consultations via email, phone, and in-person contacts. Educational products developed in 2019 include 32 videos, 36 print publications, 1 mobile app, and 425 nutrient management training manuals. 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, 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 2019 show that as a result of local delivery of the curriculum, more than 8,239 producers farming approximately 2,360,553 acres in 55 counties have received in-depth education on nutrient management planning. In 2019, approximately 630 farmers operating about 178,800 acres in more than 23 Wisconsin counties added to this accomplishment list. Data are currently being collected for 2020 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 (50 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 425 copies requested and delivered in December of 2019. In addition to creating SnapPlus educational products, NPM staff actively train farmers, agronomists, and others to use SnapPlus. In 2019, NPM staff members assisted 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, manure spreader calibrations, cover crop and soil health education. NPM staff delivered educational programs in 13 WDATCP-sponsored *Producer-led Watershed Projects* across the state, a significant expansion from previous years. These programs included: combine cleaning clinics, soil health workshops, and cover crop (establishment, management, and termination) demonstrations. A combined total of 1,033 contacts were reached in 2019.
- *On-farm demonstrations, field plot research and subsequent educational programs* on various topics including: corn nitrogen rates, cover crops, conservation tillage, manure applications, etc. occurred in nine counties in 2019.
- *Land-spreading milk webinar*. In April 2020, the NPM Program produced a webinar on the topic of emergency land-spreading of milk. In Wisconsin, and elsewhere, many producers were forced to dump milk as a result of dairy processors being unable to accept raw milk due to COVID-19 staff illnesses and a sudden drastic drop in milk demand. Raw milk is very high in nutrients that can degrade water quality if introduced to ground or surface water. If milk enters surface water, fish kills can be expected due to its high biological oxygen demand (BOD). The webinar featured discussions on management practices for reducing the impact of land-applied milk on water quality. It also included discussions on dairy economics, applicable state regulations, and tips for managing manure storage systems that receive milk. The live webinar was viewed by over 600 people in 18 states and Canada. Since its debut on April 7, 2020, the webinar has been viewed over 1,500 times as of early June 2020. The webinar is achieved here: https://www.youtube.com/watch?v=Gk2aeVl4EoU&feature=youtu.be. In addition, the publication *Considerations when Landspreading Milk or Manure/milk Mixtures* was created: https://ipcm.wisc.edu/download/pubsNM/UW-LandspreadingMilkConsiderations2020.pdf.

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 2019 NPM conducted on-farm research waterhemp trials in Grant County.
- *Waterhemp Management Challenge Field Days.* In 2019 NPM staff in conjunction with Dr. Rodigo Werle of the UW-Madison Dept. of Agronomy hosted two field days at the Lancaster Ag Research Station and assisted with a third at a Brooklyn, Wisconsin farm. Over 300 farmers and agronomists learned about herbicide resistant waterhemp, its spread across Wisconsin, and control strategies in soybean and corn.
- *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.
- *Combine Cleaning Clinics*. The NPM Program along with UW-Madison faculty and local county partners organized four combine cleaning clinics to educate over 150 farmers and agronomists in 2019 about the need to prevent the spread of herbicide resistant weeds.
- *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.

Food Systems

- *Cover Crops Research, Education and Outreach.* NPM partnered with UWEX county agents, USDA-NRCS, county Land Conservation Departments, non-governmental organizations, and CALS specialists to deliver cover crop education in 40 Wisconsin counties. Activities include on-farm field days, on-farm research and demonstration, development of educational videos, and training farmers and agronomists.
- *Soil Health Education.* Soil health is a critical component to sustainable cropping systems. Over 3,500 adults (farmers, agency personnel, agricultural professionals, community members) and 1,600 youth were trained in across Wisconsin by NPM program staff in 2019. Many educational events were outdoor field days and included exploration of soil properties via soil pits and/or field tools.
- *Healthy Grown / Healthy Farms.* The Healthy Grown Program, which was expanded to the Healthy Farm Program, has been a national model of sustainable production systems, exemplifying integrated pest management and reduced pesticide systems for potato, onion, and carrot production. There is also an innovative ecosystem conservation component to restore privately owned landscaped in Wisconsin. In 2019, the Healthy Grown program enhanced its Innovative educational approach, expanded certification, and developed a new water quality/quantity education module which resulted in direct farmer engagement and on-farm best management practice (BMP) adoption. Ten operations with over 11,000 cropland cares were certified as "Healthy Grown" during 2019. NPM staff are involved in similar efforts for pea, sweet corn and soybean crops.
- *Water Stewardship Program and Wis. Potato and Vegetable Growers Association Water Task Force.* The NPM Program is a partner with many stakeholders in both the Water Task Force and Water Stewardship Program with the goal of promoting research and education on water quality and

quantity in the Central Sands, as well as recognition of famers who have adopted crop management practices to improve water stewardship. In 2019, NPM staff developed a self-paced, on-line training course to teach agricultural professionals about practices and programs they can utilize to when working with individual growers to develop water stewardship and conservation plans. The class was released in early 2020.

- *First Nation Sustainable Food Production and Food Sovereignty Initiatives*. NPM provided educational and technical support in soil fertility, soil health, and traditional agricultural practices to sustainable food production and food sovereignty initiatives lead by the College of Menominee Nation, La Courte Oreilles Ojibwa Community College, Menominee Indian Tribe of Wisconsin, Oneida Nation, and Stockbridge-Munsee Community.

Outreach and Communication

- *Mobile Applications*. The NPM Program is creating mobile applications (apps) for hand-held devices (Apple and Android). In 2019 one new app was created (*Tarspotter* – which is used to forecast corn disease) and our nine previously released apps were updated. Currently available mobile apps include: *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 126,300 users from across the world. All apps are created in collaboration with UW-Madison faculty and are promoting agricultural best management practices.
- *YouTube Videos*. Nearly 270 YouTube educational videos featuring UW-Madison-CALS specialists have been prepared and released by the NPM Program over the past seven 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. (Over 1.5 million total views as of October 2019.) Twenty-eight new videos were created in 2019.
- *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 1,200 recipients, with 20,000 PDF downloads in 2019. 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 2019, 32 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/.
- *Farm Technology Days 2019.* NPM was part of a team that organized and staffed a very popular and interactive photo booth demonstrating mobile technology use for agriculture.

For more information on the NPM program:
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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 Department of Health Services 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.

<u>Summary of Groundwater-Related Work at WSLH</u>

Organic Chemistry Section

- The State Laboratory is developing and validating methods for measurement of "PFAS" chemicals in various matrices, including groundwater/drinking water. As interest increased and the science and toxicology of PFAS is better characterized, this work is likely to continue and accelerate. The State Laboratory would be happy to partner with others and share information as appropriate to collectively advance these issues.

- Interpretation of GC-MS and LC-MS analysis of sterols as a chemical source tracking indicator. Sterols are the excreted metabolites of hormones (plant and animal) that are ingested by animals or metabolized from endogenous sources (e.g., human synthesis and metabolism of cholesterol). Depending upon the sterol detected, and in what quantity, the source may be inferred. For example, a high level of coprostanol, relative to background, indicates anthropogenic contamination of a surface water sample. Detection of cholesterol along with plant sterols, such as beta-sitosterol and stigmasterol, would be indicative of fecal contamination by animals utilizing a mixed diet. Detection of the plant sterols alone would possibly occur with herbivore fecal contamination. Sterol source tracking data should correlate to orthogonal methodologies, such as the microbial source tracking protocols, in making a final determination.
- 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

- 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 has been acquired and capability has been developed to use 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.
- 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 have become important in monitoring because they have been associated with specific geological formations and conditions in northeastern Wisconsin. For further study, the lab also has separated arsenic into its oxidation states and measured their relative concentrations. Detectable concentrations of arsenic have been more routinely measured in drinking water sourced from Wisconsin groundwater. Recent updates to Wisconsin regulations have increased monitoring requirements under certain scenarios. Arsenic in groundwater and drinking water has received increased attention in general.
- 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 contaminates 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/*)
Contact David Webb, Deputy Director, Wisconsin State Laboratory of Hygiene
2601 Agriculture Drive
Madison, WI 53718
Phone (608) 224-6200, email *David.Webb@slh.wisc.edu*

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 2020 Highlights

- The statewide private on-site wastewater treatment systems (POWTS) inventory was completed and all counties are operating a maintenance program for all POWTS in their jurisdiction.
- The Department developed and began implementing a training program to train county inspection staff basic and advanced level POWTS plan review and inspector training. That program continued in 2020.
- The Department partnered with a technical college to offer and provide instruction for a 2.5-day class developed for prospective and current soil testers to properly identify and evaluate soil and site conditions for the placement of POWTS systems. The class was postponed in 2020 due to COVID-19.

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. Counties must also initiate new or enhance existing reporting programs related to inspection, maintenance and servicing events by October 1, 2019.

For further information:
Visit the following web site (https://dsps.wi.gov/pages/Home.aspx)
Contact: Bradley Johnson
Phone: 920-492-5605
E-mail: mailto:Bradley.Johnson@Wisconsin.gov

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.
- 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 data collection and posting from the monitoring wells in the Plainfield and Coloma areas are part of the lakes study component of 2017 Wisconsin Act 10, related to the potential impacts of groundwater withdrawals in the Central Sands. If the DNR determines that the potential for significant impacts exists, several steps will be taken including a public hearing, economic impact analysis and providing recommendations to the Legislature for special measures to mitigate those impacts on the Long Lake, Plainfield Lake and Pleasant Lake watersheds.
- 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 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. 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.
- 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 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.
- 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.
- 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.

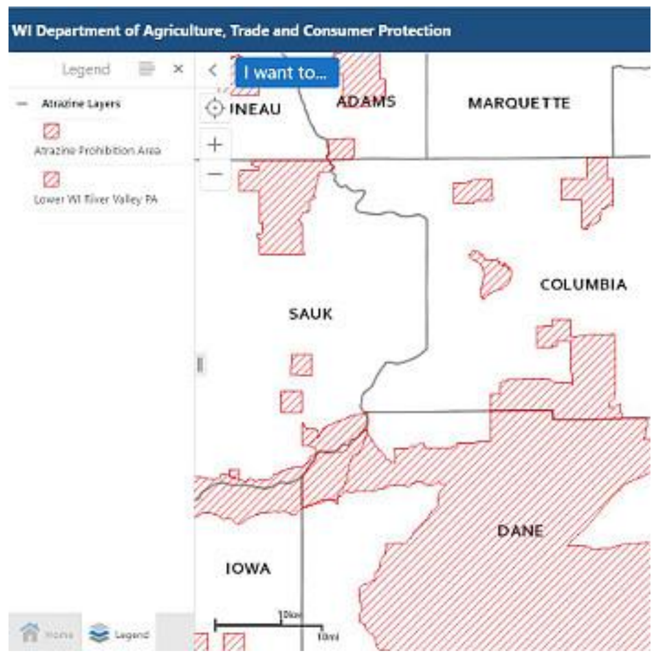
HIGHLIGHTS OF OVER 30 YEARS OF GCC-FUNDED RESEARCH

Projects funded have provided valuable information regarding the Wisconsin's groundwater resources, helped evaluate existing programs, increased the knowledge of the movement of contaminants in the subsurface and developed new methods for groundwater evaluation and protection. A complete compilation of all GCC funded projects can be found at UW Water Resources Institute searchable repository [exit DNR]. While the application of the results is broad, some areas where the results of state-funded groundwater research and monitoring projects have been successfully applied to groundwater problems in Wisconsin include:

Pesticides

Background

- Serious concerns about pesticide contamination were first raised in 1980 when aldicarb, a pesticide used on potatoes, was detected in groundwater near Stevens Point.
- Occurrences of the commonly used corn herbicide atrazine were also found in monitoring and private drinking water wells. A subsequent study found that atrazine was present in 12% of Grade A Dairy Farm wells.
- In total GCC has funded 30 studies on pesticides - including 14 on atrazine - on the sources, groundwater susceptibility and presence of pesticides in our groundwater.



Map showing the approximate boundaries of Atrazine Prohibition Areas in Wisconsin [exit DNR]. © DATCP.

Outcomes

- Aldicarb was withdrawn from use in Wisconsin.
- Low cost screening methodologies for detecting the presence of atrazine and its break-down products in drinking water were developed.
- Knowledge from the intensive research and monitoring efforts allowed DATCP to adopt management strategies for reducing atrazine contamination and create the Atrazine Rule [PDF].
- Follow-up studies demonstrated that where atrazine use has been prohibited by the Atrazine Rule, there is a clear reduction in atrazine levels, which generally drop below the groundwater standard in 2 - 7 years.

Learn more:

- Pesticides [PDF].
- DATCP - Atrazine [exit DNR]

Arsenic and other naturally occurring elements

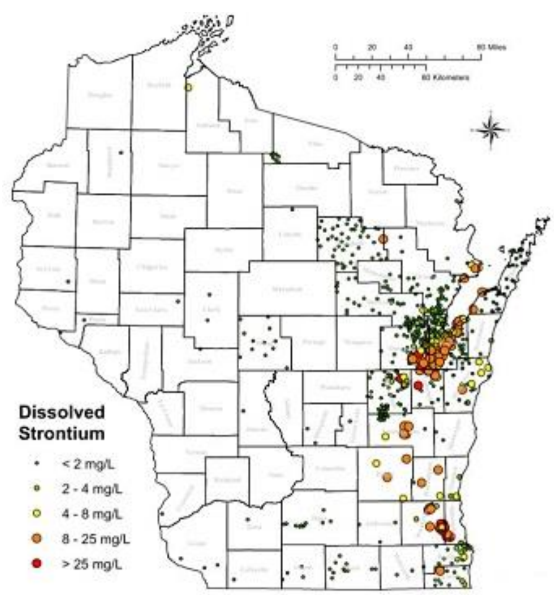
Background

- Naturally-occurring arsenic was discovered in Winnebago & Outagamie Counties groundwater in 1989 during a routine investigation conducted by the DNR.
- Sampling of thousands of private wells found approximately 4% of private wells exceeded the federal drinking water standard.
- Strontium is emerging as a trace element of concern in eastern Wisconsin, particularly in the Brown and Outagamie county areas. A study detected strontium above the US EPA's health advisory limit in about 63% of well samples from this area, but the full extent of groundwater with high strontium levels is not well documented, nor are the potential health effects.

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

Outcomes

- More than 15 GCC funded studies documented arsenic above the enforcement standard (ES) in the groundwater in every Wisconsin county.
- Innovative and inexpensive arsenic removal technology for public & private water supplies were created.
- Detection methods for arsenic were improved, including the development of an on-site measurement apparatus which reduced costs.
- Revised well-disinfection techniques were developed to ensure that arsenic levels are kept below the safe drinking water standard when treating a well for bacteria.
- Residents were informed of health risks of arsenic in drinking water and educational materials to help homeowners with reducing arsenic levels in their drinking water were developed.
- Educational outreach to well drillers continues to improve well drilling and construction techniques to minimize arsenic levels in private wells.



Statewide distribution of dissolved strontium in Wisconsin's aquifers. © Luczaj et al., 2013.

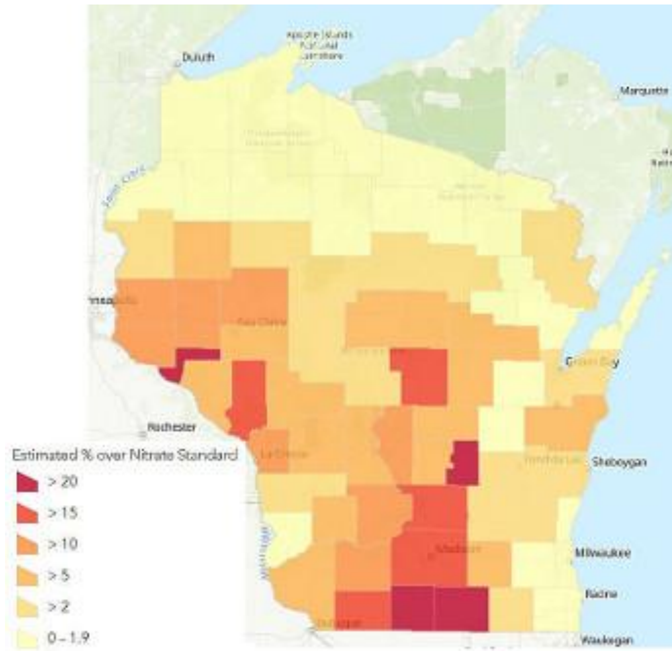
Learn more:

- Arsenic [PDF].
- Arsenic Research [PDF].

Nitrate

Background

- Nitrate is the most widespread groundwater contaminant in Wisconsin.
- Statewide, about 10% of private well samples exceed the maximum contaminant level (MCL) for nitrate.
- Around 90% of nitrogen inputs to groundwater in Wisconsin can be traced to agricultural sources.
- An estimated 42,000 private wells exceed the nitrate health standard; well replacement costs likely exceed $446 million dollars to provide safe water .



Map of Estimated Percentage of Private Wells over Nitrate Standard by County. © DNR.

Outcomes

- DHS expanded their health recommendation from pregnant women and children under 6 months, to include everyone drinking water with nitrate above the standard.
- In 2014, the private well code was changed to require sampling for nitrate in newly constructed wells and wells with pump work.
- Since 1985, GCC through the Joint Solicitation process has funded more than 35 studies on Nitrate. Numerous studies show that nutrient management plans do not meet the health-based standard for Nitrate.
- A new tool for viewing nitrate trends in Wisconsin's Public Water Systems has been developed by the UW – Stevens Point Center for Watershed Science and Education in partnership with the Wisconsin Department of Natural Resources. The tool will allow users to view summary statistics for public water system wells in addition to easily see which systems may be changing over time and if so whether those changes indicate whether nitrate-nitrogen concentrations are increasing or decreasing. The tool is expected to become available online in the coming months.

Learn more:

- Nitrate [PDF].

Viruses

Background

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

- Protecting groundwater from microbial contamination is a top public health priority.
- Limited statewide groundwater virus occurrence data exists because testing is expensive, not routinely performed, and levels cannot be reliably inferred from total coliform results.
- Viruses were found in deep bedrock wells that were thought to be protected, suggesting that deep groundwater is more vulnerable to virus contamination than previously thought.
- Public water systems are increasingly contaminated by viruses and other microbial agents.
- The incidence of virus contamination in private wells may affect 4-12% of private wells in the state.
- GCC has funded 10 research projects on viruses because of concern of presence of viruses in drinking water wells.

Outcomes

- Because of research funded by GCC, virus testing that used to take three months to complete can now be accomplished in an afternoon.
- Evidence indicating that disinfection with chlorine or ultraviolet light reduces the risk of illness from viruses and other microbial sources led DNR to amend a rule to require disinfection of municipal drinking water, but rule change 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 to gather information to support future drinking water protection.

Learn more:

- Pathogens [PDF].
- Detection and Monitoring of Microbiological Contaminants [PDF].

Radium

Background

- In eastern Wisconsin wells that draw from a very deep sandstone aquifer often have levels of radium above the MCL.
- These high levels of radium primarily affect public wells, since drilling deep enough to reach this aquifer is usually prohibitively expensive for smaller private systems.

- About 80 public water systems have exceeded a radionuclide drinking water standard at some point in time.
- Seven studies have been funded by the GCC on Naturally Occurring Radioactive Elements, including Radium, since 1987.
- Water level drawdown due to pumping in southeastern Wisconsin have shown some of the largest decreases in Wisconsin. These decreases have raised concerns about increases of radium in wells above drinking water standards and leading to increased costs to supply safe water meeting standards.

Outcomes

- DNR has been working with public water systems since 2003 to ensure that they develop a compliance strategy and take corrective action, currently less than 10 systems remain that are providing water in exceedance of the radium standards.
- Leveraging new models and knowledge about groundwater flow patterns in the Waukesha area, researchers found the relationship between radium and sulfate minerals in the area, collecting much needed information on the geochemical makeup of the region.
- 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 a diversion of Lake Michigan water with return flow.

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.

Learn more:

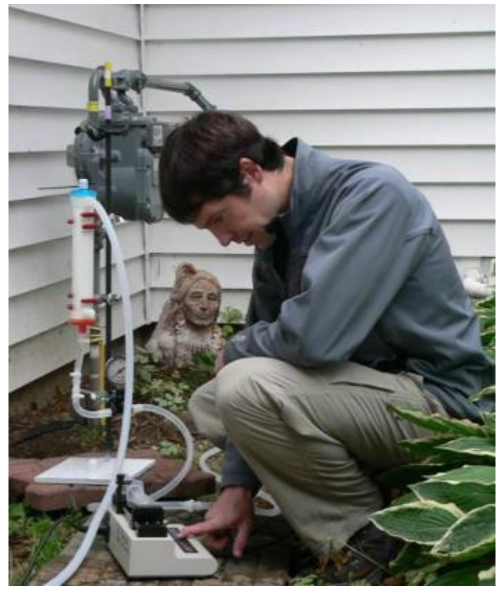
- Groundwater Drawdowns [PDF].
- Radionuclides [PDF].

Innovative lab methods

Background

- Groundwater quality testing can be expensive and limited analytical methods can be available.
- Projects funded by GCC have led to the development of new methods for groundwater evaluation and protection that take less time and are more cost efficient.

Outcomes



Dr. Sam Sibley, UW-Madison Department of Soil Science, collects a well water sample from a residential home to analyze using new MST tools. © Carolyn Betz, UW ASC.

- Research funded by GCC documented that holding times and higher temperatures do not affect the quality of E-coli samples. This finding led to a decrease in the number of samples rejected by laboratories and saved water systems a significant amount of time and money. The Department estimates that water systems are saving $300,000 to $600,000 per year in shipping costs alone.
- Laboratory techniques that have made it possible to discern whether bacteria are from human, animal or other sources have been developed. 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).
- Developed an analysis that can successfully detect bovine adenoviruses to indicate bovine fecal contamination of groundwater. The DNR has been using these tools as they become available to determine the source of fecal contamination in private wells. DNR and DATCP are working to find ways of controlling this major source of contamination and working on revised performance standards and prohibitions related to manure land application in areas of the state with carbonate bedrock and shallow soils.
- Virus testing that used to take three months to complete can now be accomplished in an afternoon.
- Improved detection techniques for arsenic have been developed, including the development of on-site measurement apparatus to reduce laboratory costs.
- Low cost screening methodologies for detecting the presence of atrazine and its break-down products in drinking water have been developed.

Methylmercury

Background

- Methylmercury (MeHg) is one of the most toxic and persistent substances in the environment.
- Funded research has focused on how MeHg forms from inorganic mercury deposited from atmospheric sources such as coal combustion.
- Measured MeHg concentrations are likely produced in situ and are not from legacy sources.
- GCC has funded five studies on Methylmercury in groundwater.

Outcomes

- Information advancing our understanding of mercury transport and methylation in groundwater that will help us interpret the watershed response to changing conditions in the hyporheic zone.
- Any variation in groundwater levels, whether due to climate change or conjunctive use of groundwater and surface waters, will likely influence MeHg production in both natural and engineered wetlands.

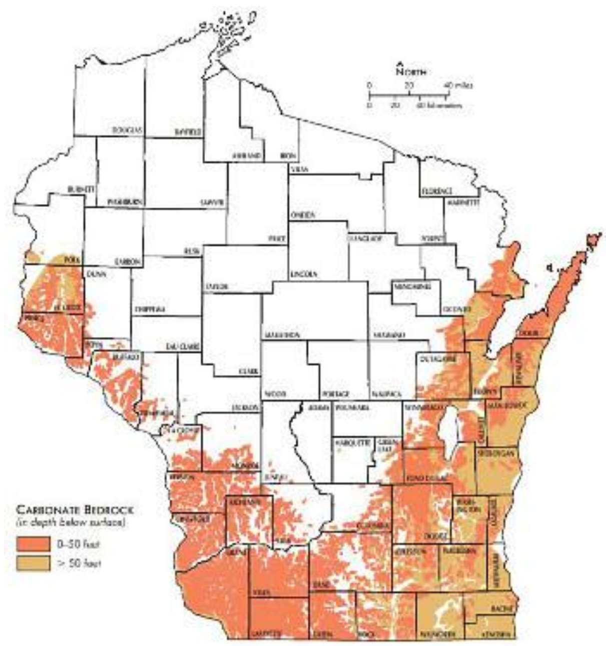
Learn more:

- Methylmercury Formed in Groundwater [PDF].

Fracture flow and karst

Background

- Karst features, including a variety of sinkholes, cavities and solution openings, commonly occur in carbonate rock (limestone and dolomite).
- Environmental problems associated with karst features include rapid groundwater contamination, unpredictable groundwater flow, difficulty in groundwater monitoring and unexpected failure or collapse of surface structures such as roads and foundations.
- There has been increased concern about the hazards and effects of karst features in many parts of Wisconsin, but little published information has been available.
- Fourteen studies have been funded through GCC regarding fracture flow and karst.



Areas with carbonate bedrock within 50 feet of the land surface are particularly vulnerable to groundwater contamination. © WGNHS.

Outcomes

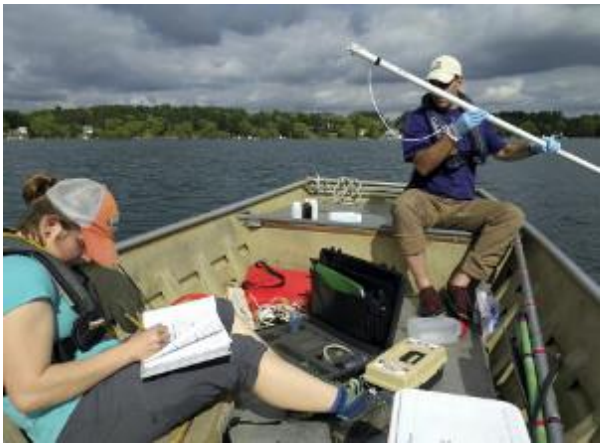
- A karst database for the state has been created. This includes geophysical surveys near some of these features in order to characterize their depth and extent.
- The results of studies have been used by municipalities for planning purposes and selecting options for sinkhole remediation.
- A program of research and public education on groundwater movement in fractured rocks was developed and has provided assistance to various agencies facing carbonate-rock problems.
- Funded project led to the development of a professional short courses on fractured-rock hydrogeology.

Learn more:

- Karst and Shallow Carbonate Bedrock in Wisconsin [exit DNR]

Groundwater/surface water interactions

Background



Water chemistry samples are collected from the study lakes and from nearby monitoring wells to understand groundwater-surface water interactions. DNR staff collecting water quality on Pleasant Lake © DNR

- 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 groundwater 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, and disconnect from, surface water resources that rely on the water from the aquifer. The result of the disconnection can impact the ecosystems of groundwater dependent surface water features such as springs, streams, wetlands and seepage lakes.
- The opposite can also occur, resulting in a higher than normal water table. Groundwater flooding occurs when frequent, sustained rainfall leads to excessive recharge of local groundwater levels and the water table rises above the land surface.

Outcomes

- The inventory and evaluation of groundwater levels (e.g. wells) and groundwater dependent surface water features (springs, lakes, and headwater streams). The inventory of those features and data associated with each feature is displayed on the DNR's Water Quantity Data Viewer.
- To understand the role of groundwater withdrawals on headwater streams, a groundwater flow model for the Little Plover River watershed in Portage County was completed. 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.
- To understand the lake level variation and the extent groundwater withdrawals have on lakes, a study of three lakes in Waushara County (Central Sands Lakes Study) is being conducted.

Learn more:

- Groundwater/Surface Water Interactions [PDF].

Emerging groundwater contaminants

Background

- Emerging contaminants are compounds that are increasingly being detected in groundwater and may have harmful human health or environmental impacts.
- Emerging contaminants often enter groundwater from wastewater from municipal, industrial or agricultural sources.
- Examples include: perfluoroalkyl and polyfluoroalkyl substances (PFAS); pharmaceuticals and personal care products, such as antibiotics, birth control pills, shampoos, and detergents; and other broad classes of emerging contaminants including viruses and agricultural pesticides, as well as their environmental break-down products (metabolites).
- 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. In response to this need, over 20 studies have been funded by GCC.
- A FY 2021 GCC-funded study will investigate the patterns of sorption of PFAS in aquifer materials from five areas in Wisconsin. Sorption is when substances dissolved in water attach to solid aquifer material. This is usually temporary and thus has the effect of slowing the speed at which contaminants migrate through an aquifer. Existing research has shown that sorption behavior among PFAS varies greatly. The results of this study will be useful toward predicting how fast different PFAS migrate through aquifers, with potential implications for protection of drinking water supplies.
- The PFAS problem is complex and widespread, so additional studies may be needed. One area for further research is strategies to reduce the levels of PFAS infiltrated to groundwater following land spreading of biosolids.

Outcomes

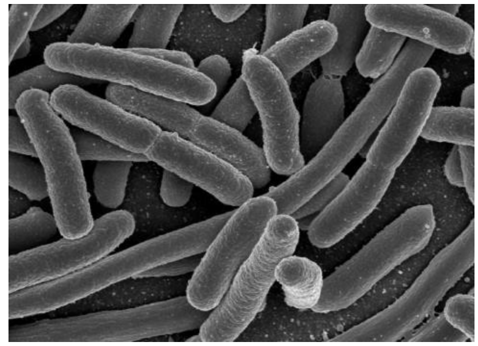
- In Wisconsin law, there is an established process that facilitates regular review of groundwater monitoring data and identification of contaminants of emerging concern (WI 160.27). A fundamental component of this process is the long-term groundwater monitoring data, so maintenance and expansion of current networks is an ongoing priority for the GCC.
- 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.

Learn more:

- Emerging Contaminants [PDF].
- Emerging contaminants, including PFAs.
- Pharmaceuticals, Personal Care Products and Endocrine Disrupting Compounds in Groundwater [PDF].

Microbial Pathogens

What are they?



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

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.

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.

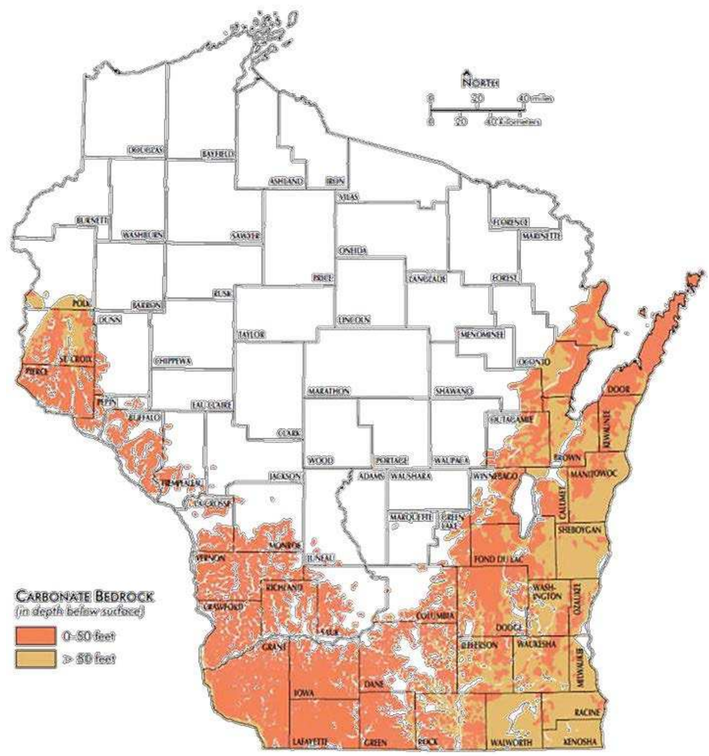
Coliforms are a broad class of bacteria that are naturally present in the environment and are used as an indicator that other potentially harmful microorganisms may be present. Fecal indicators, such as *E. coli*, enterococci and coliphages, are microbes whose presence more specifically indicates that 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.



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

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 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 perform, 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.

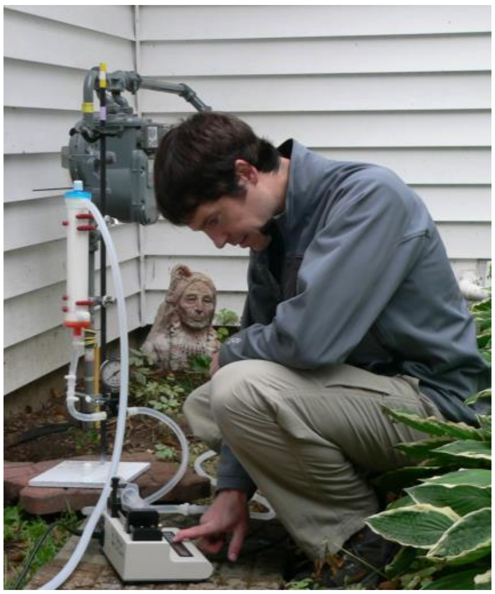
The risk of finding pathogens in groundwater is seasonably variable but typically highest following spring snowmelt or large rainstorms that generate runoff, since these events can create large pulses of water that move quickly through the ground, potentially carrying microbes from septic systems, sewer 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.

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*

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 [link]

DNR overview of cryptosporidium in drinking water [link]

DHS fact sheet on manure contamination of private wells [link]

WGNHS overview of karst landscapes [link]

WGNHS report on municipal drinking water safety [link]

DNR list of municipal drinking water systems that disinfect [link]

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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 methemoglobenemia 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).

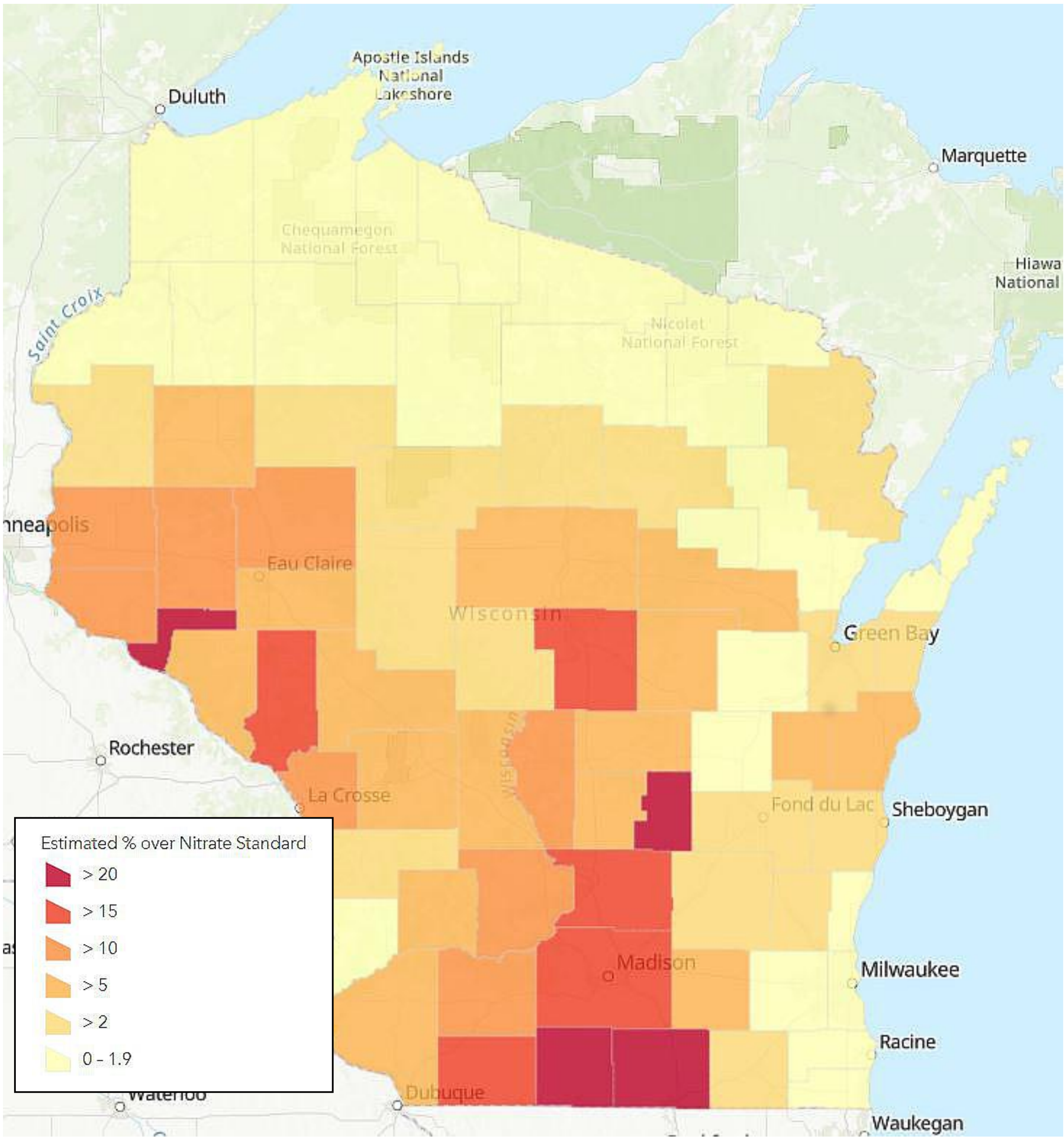
Nitrate is Wisconsin's most widespread contaminant, yet 33% of private well owners have never had their water tested for it. Photo: DNR

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 the standard by anyone poses a significant health risk. The nitrate sampling was also strongly supported by the Private Water Advisory Council.

Since October of 2014 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).

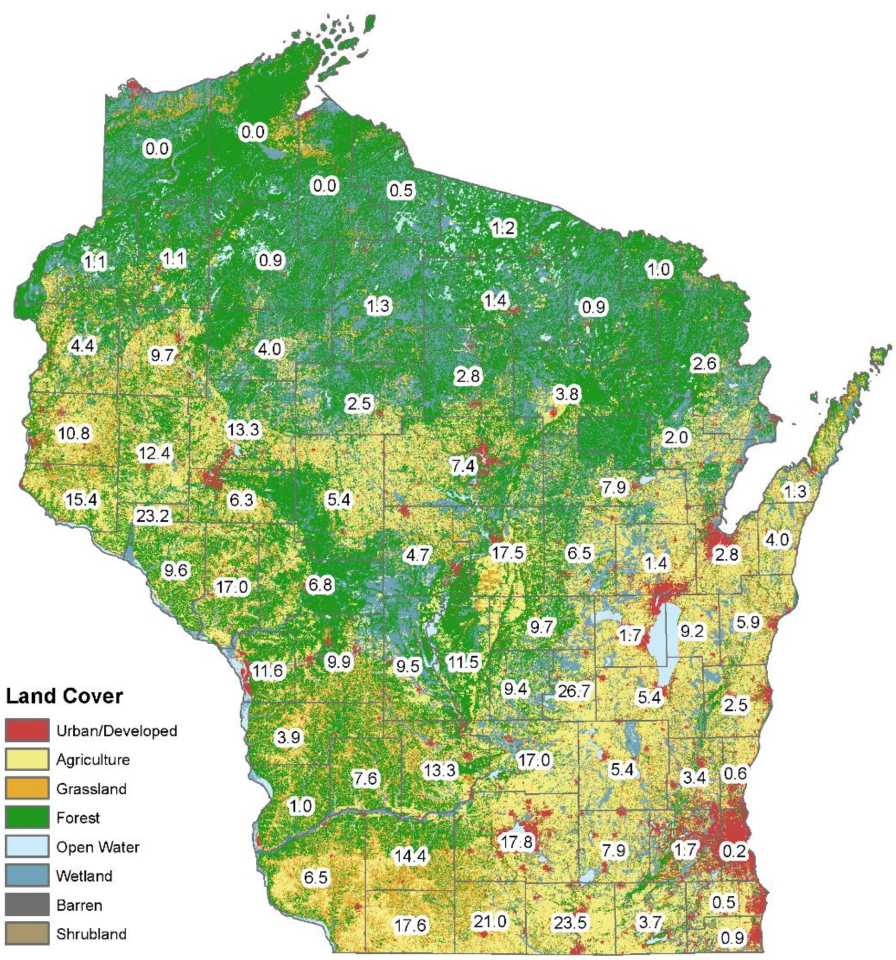


Map of Estimated Percentage of Private Wells over Nitrate Standard by County.

What makes an area vulnerable to nitrate contamination?

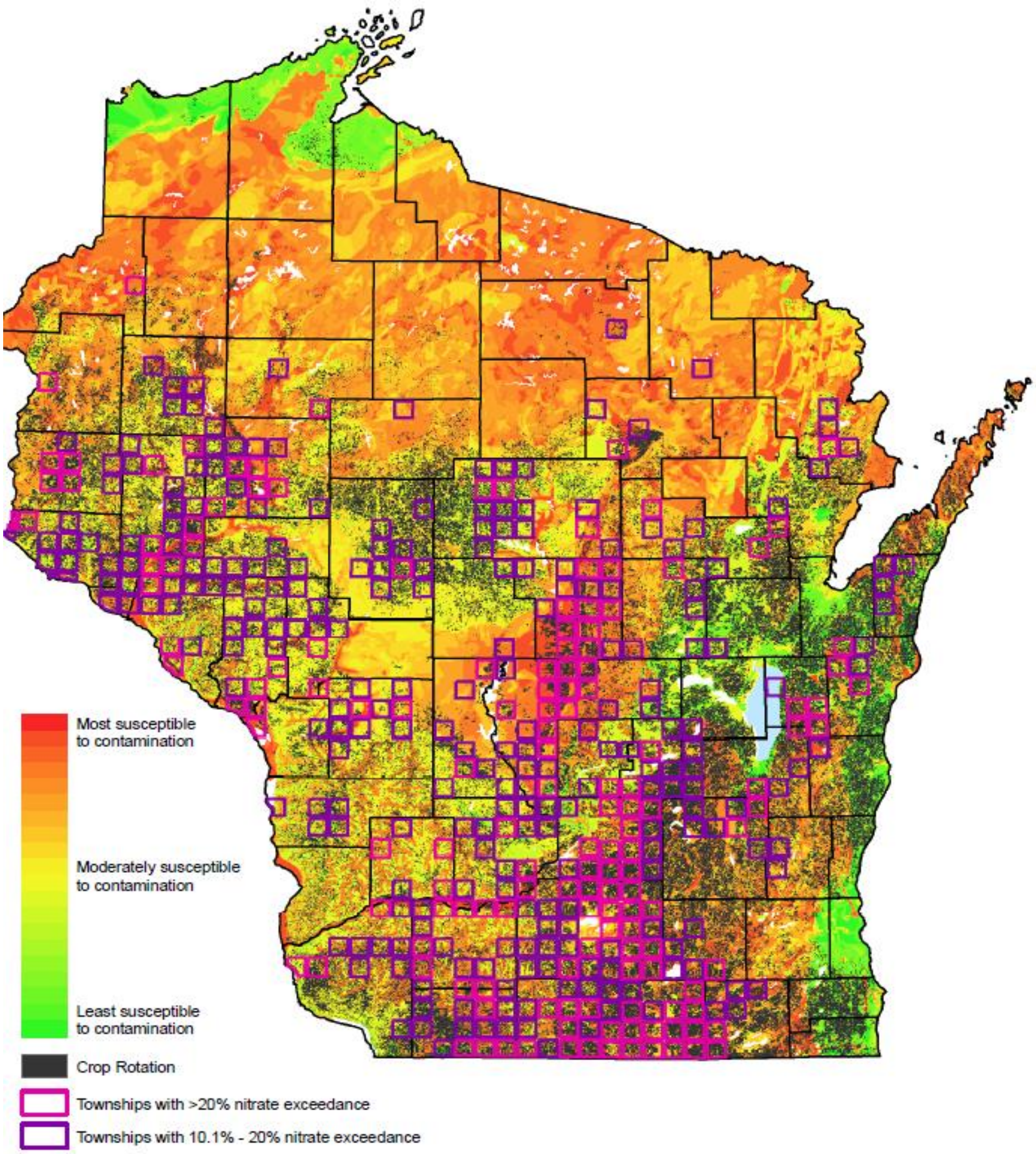
The sensitivity of an aquifer to contamination, sometimes called "intrinsic susceptibility", is a measure of the ease with which water enters and moves through an aquifer; it is a characteristic of the aquifer and overlying material and hydrologic conditions. The vulnerability of a groundwater resource 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 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.



Map of Estimated Percentage of Private Wells over Nitrate Standard by County with Land Cover.

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 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.



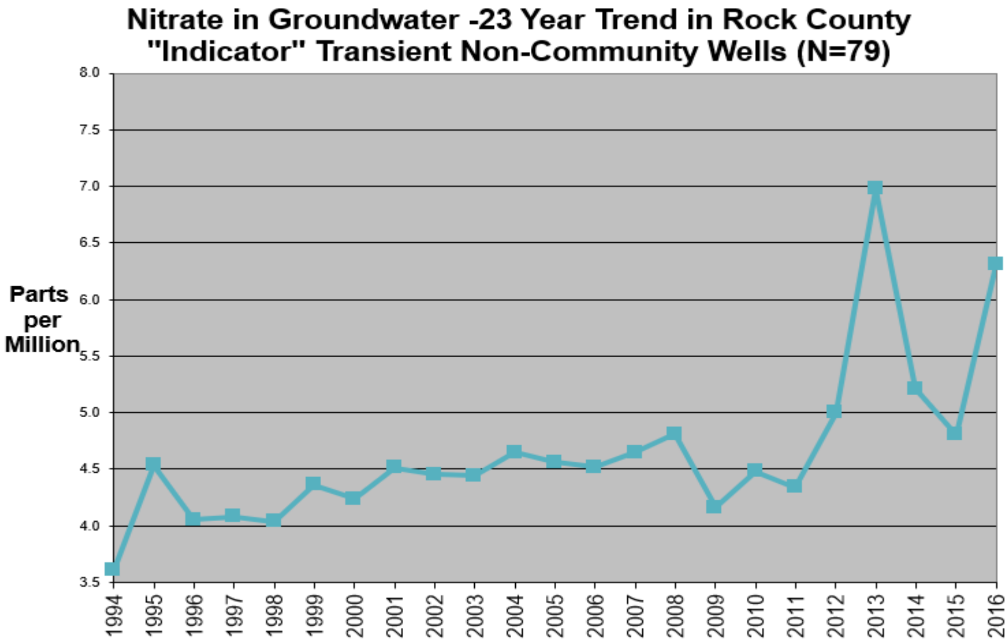
Sensitivity of Wisconsin's groundwater versus agricultural land use and nitrate impacts to private wells

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.

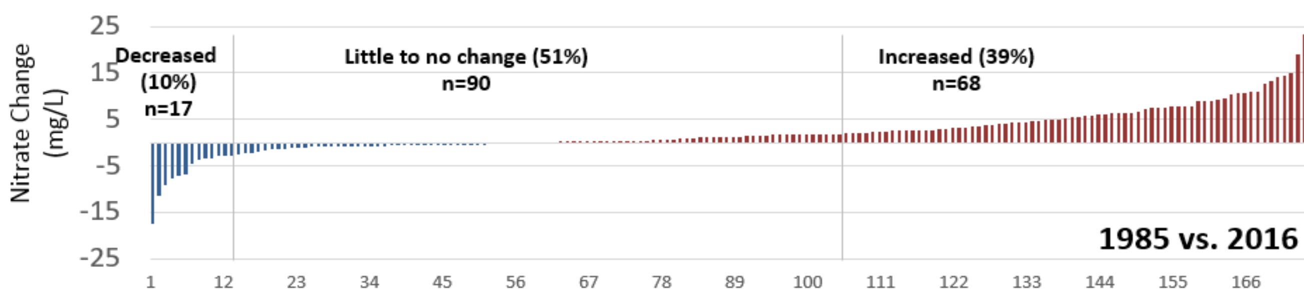
One available data set with a large number of wells distributed across the state is the Safe Drinking Water Act compliance data set for non-community public wells (e.g. small businesses, schools, and churches). There are approximately 11,0000 wells of this type active at any given time, and they are 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.

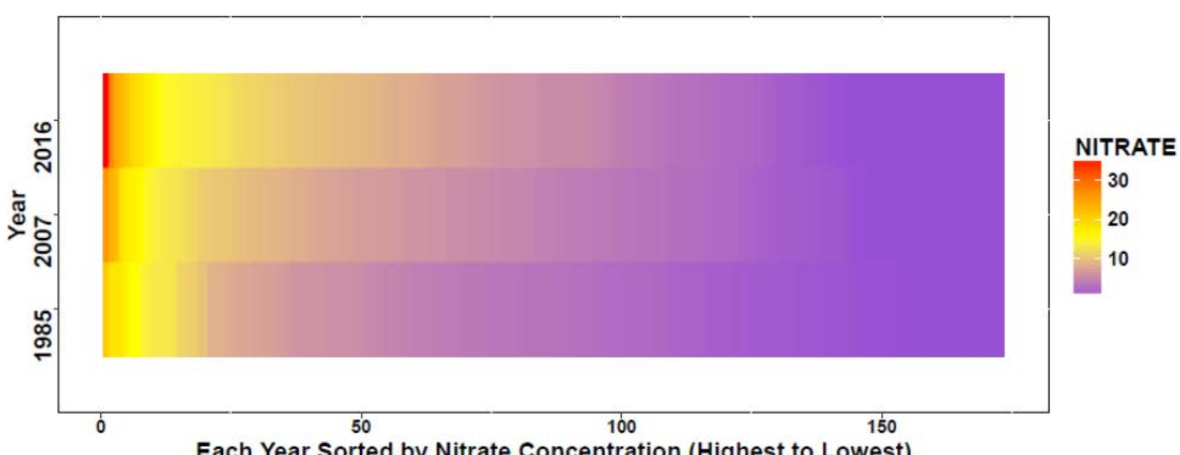
Upward nitrate trends over time are frequently observed when reviewing regional or local trends in well water quality, particularly where wells are vulnerable to nitrate contamination. For example, the Rock County Health department has been sampling and maintaining a dataset based on a consistent set 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

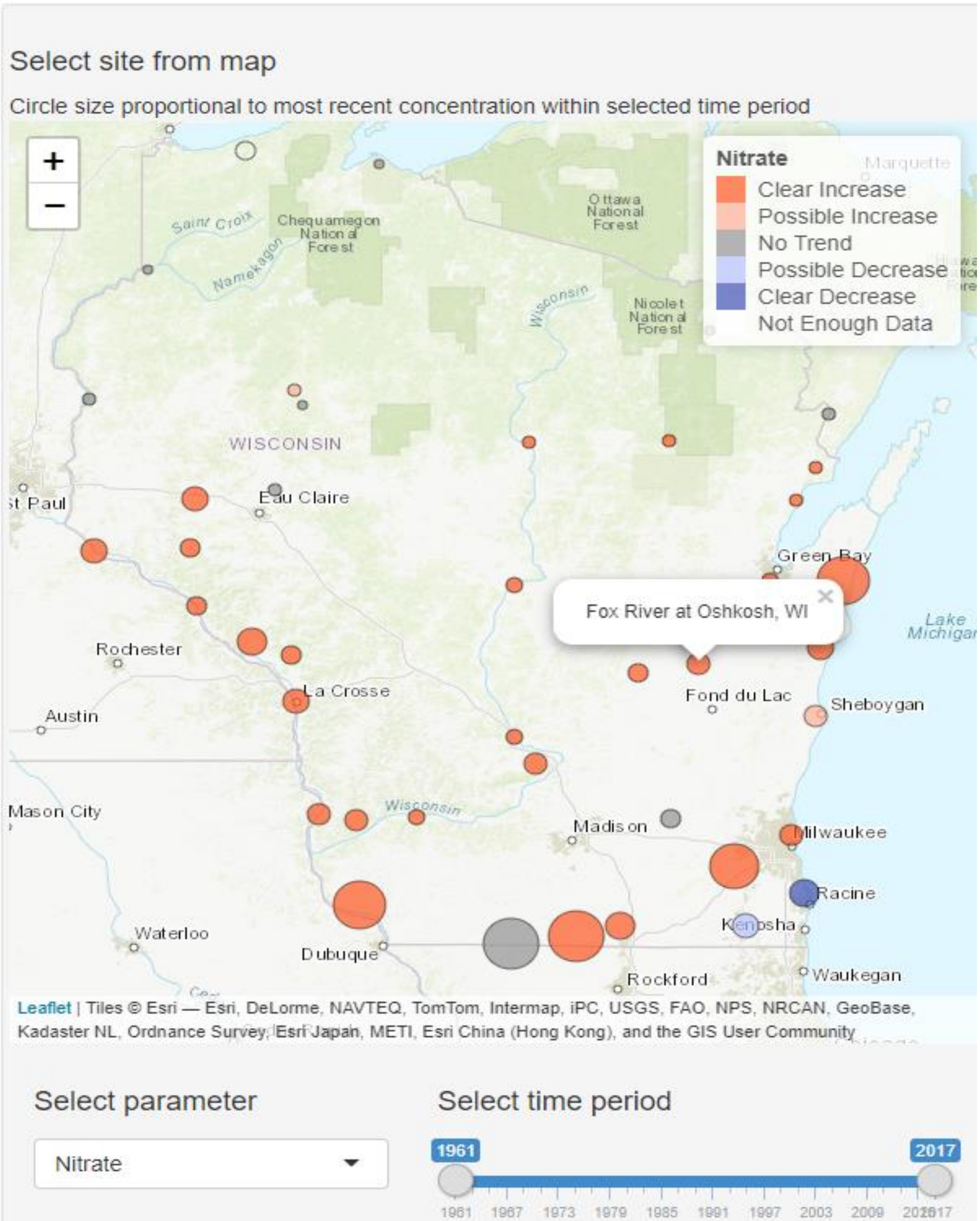
Chippewa County provides another example where a consistent set of private wells (175) were sampled multiple times over thirty years. This data set shows the importance of location: most wells saw little or no change over the 30 years (51%) and some wells showed a decrease (10%), while 39% showed an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



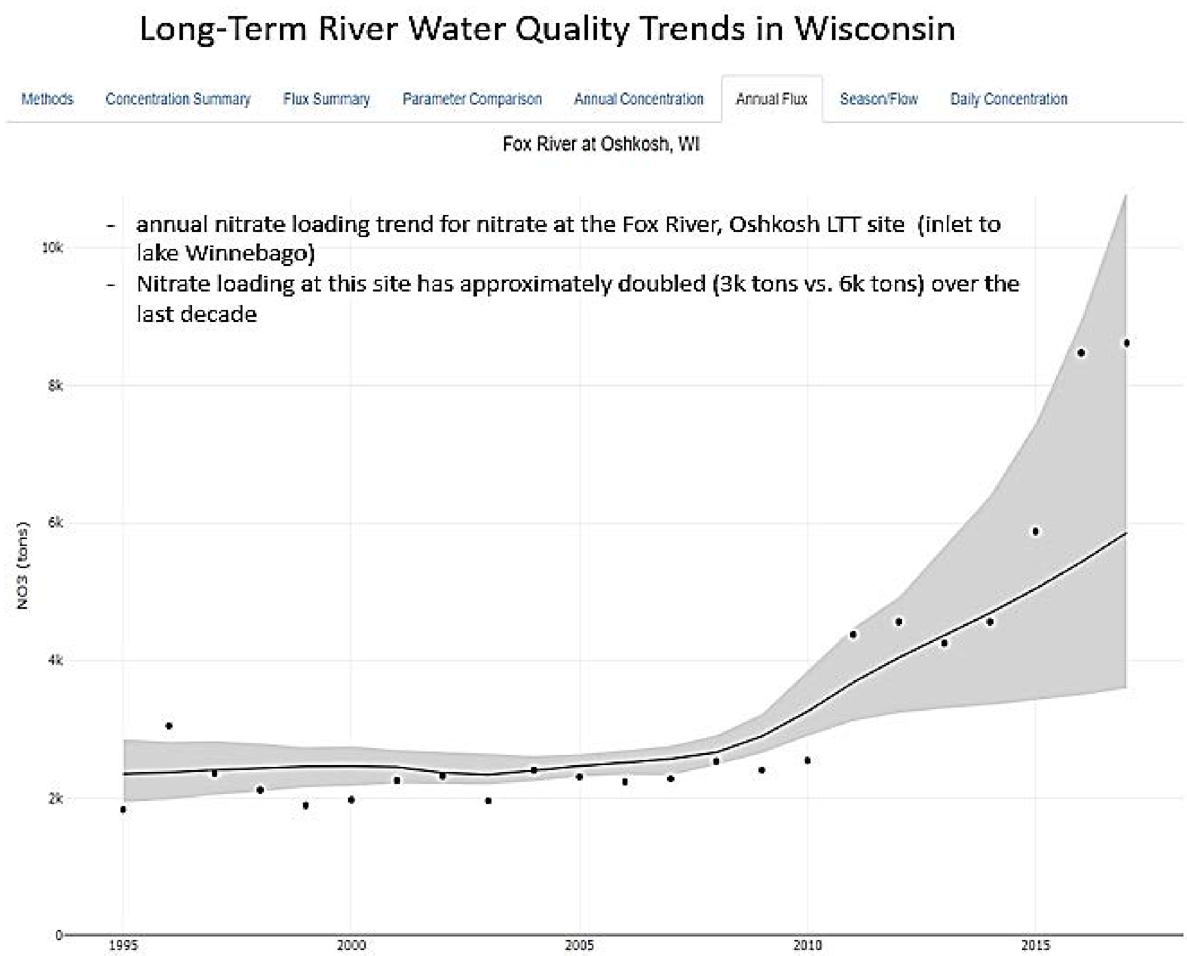


Source: Masarik et al., 2016 In preparation.

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 WDNR 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/



Estimated costs in Wisconsin to mitigate Nitrate

The data from new wells and pump work since 2014 was also 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
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. Theses 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 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.

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

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 though 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 DTSs 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 [link].

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 [link]

DNR overview of nutrient management planning [link]

DATCP overview of nutrient management [link]

DHS overview of nitrate health effects [link]

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.

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

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.

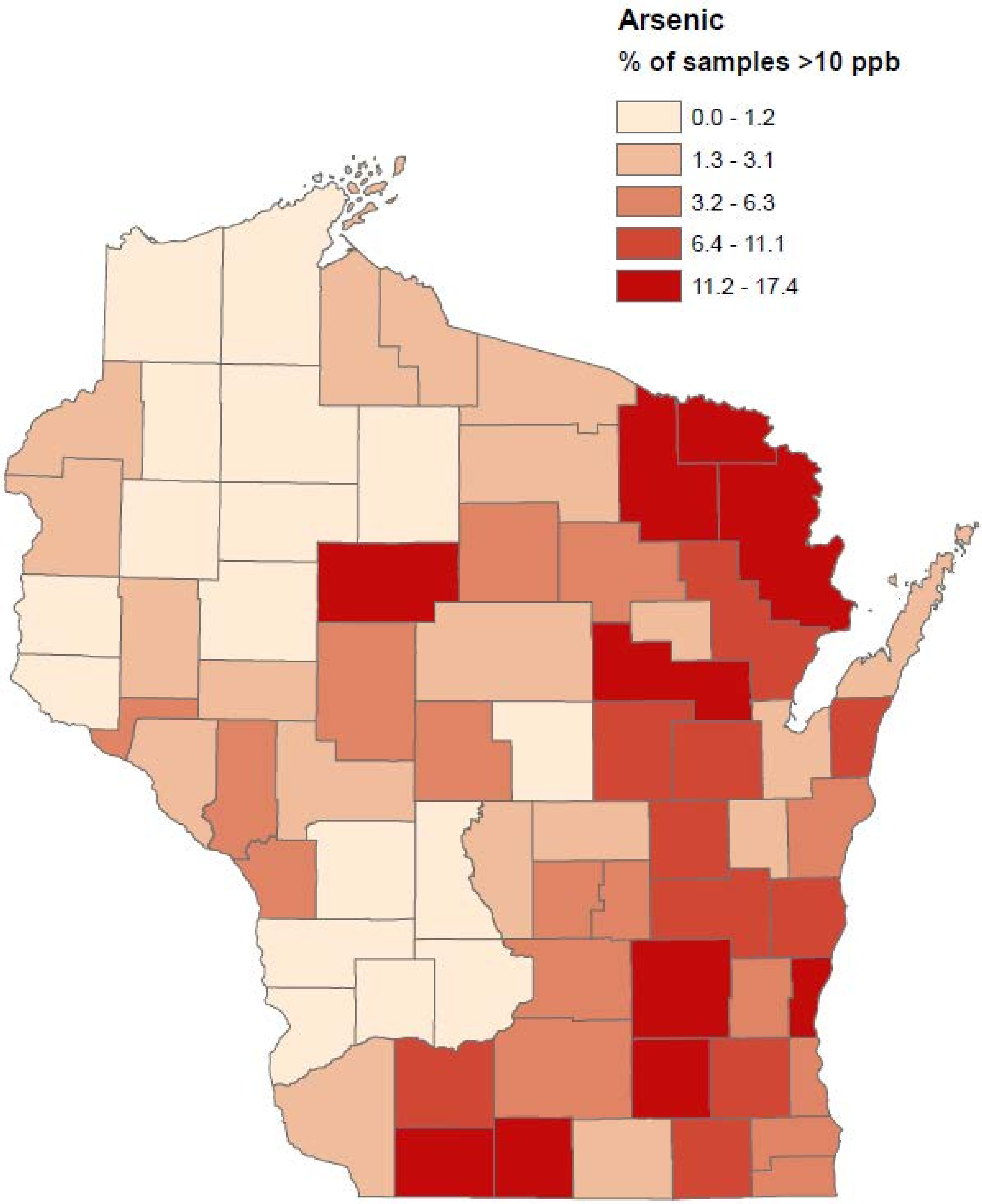
GCC Agency Actions

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 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.

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.

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.

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

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 (see attached) and the presence of heavy metals in geologic formations near La Crosse, among others (see attached).

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.

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 lll), 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 (µg/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

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

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).

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 set or 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.

Further Reading

DNR overview of arsenic in drinking water wells [link]

DNR special well casing depth areas for arsenic [link]

DHS overview of arsenic health effects [link]

WGNHS report on arsenic release due to well disinfection [link]

WGNHS report on preliminary investigation near Lake Geneva, Wisconsin [link]

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

Wisconsin Natural Resource magazine article on arsenic in private wells [link]

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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 a list of substances, designated "Cycle 10", that included pesticides and pesticide metabolites, was sent to DHS for review. Pesticides and metabolites included on the Cycle 10 list were eight herbicides and herbicide metabolites: Isoxaflutole, Isoxaflutole DKN, Isoxaflutole BA, Glyphosate, Glyphosate AMPA, Thiencarbazone-methyl, Sulfentrazone and Dacthal TPA & MTP degradates, and three neonicotinoid insecticides: Thiamethoxam, Imidacloprid and Clothianidin. The DNR received recommendations from DHS on June 21, 2019 for 21 new or revised groundwater quality standards, including recommendations for 10 new pesticide/pesticide metabolite standards (see https://www.dhs.wisconsin.gov/water/gws.htm). The DNR is in the process of formal rulemaking to potentially adopt the DHS recommended groundwater standards in ch. NR 140 (see https://dnr.wi.gov/topic/Groundwater/NR140.html).

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

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.

On April 10, 2019 the DNR transmitted a list of substances, designated "Cycle 11", to DHS (see https://dnr.wi.gov/topic/Contaminants/documents/pfas/DHSLetter20190410.pdf). The DNR has requested that DHS review available toxicologic information and, if appropriate, provide recommendations for state NR 140 groundwater quality standards for substances on the list. The Cycle 11 list includes six pesticides, including four herbicides: Flumetsulam, Fomesafen, Hexazinone and Saflufenacil, one insecticide, Chlorantraniliprole, and one fungicide: Metalaxyl.

Further Reading

DHS resources for contaminants in drinking water [link]

DNR overview of pesticides in drinking water wells [link]

DATCP water quality reports [link]

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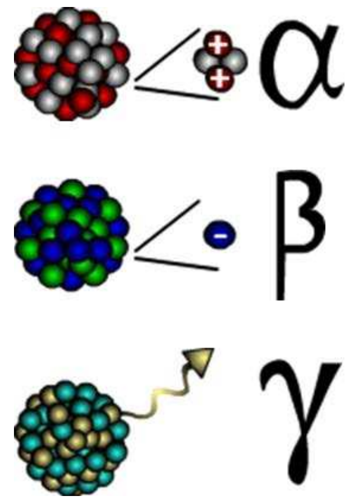
Naturally-Occurring Radionuclides

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.



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

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).

Occurrence in Wisconsin

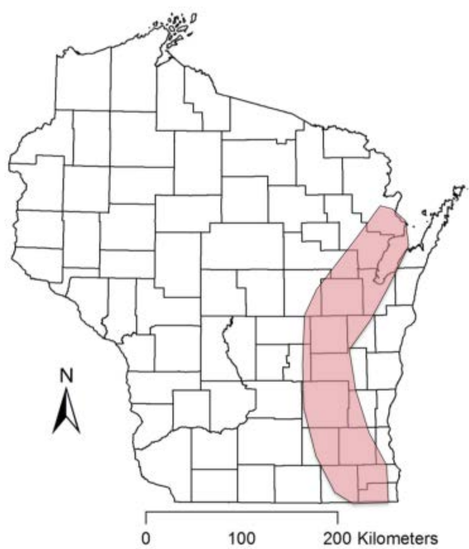
Since radionuclides occur naturally in rock formations, every well in Wisconsin contains some level of dissolved radionuclides. In many places these levels are not concerning, but some areas of the state tend to have notably high concentrations of radium, radon, and/or gross alpha activity.

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 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 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 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 [link]

DNR overview of radium in drinking water wells [link]

DNR overview of radon in drinking water wells [link]

WGNHS report on distribution of radionuclides in groundwater [link]

WGNHS report on radon in private wells in SE Wisconsin [link]

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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 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

Installation of a compacted clay and geotextile liner at a landfill site in Wisconsin. *Photo*: *DNR* 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 (Battista 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 (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 [link]

DNR overview of VOCs in private drinking water wells [link]

DNR map of open and closed contaminated sites [link]

DNR database of contaminated soil and groundwater [link]

DHS overview of vapor intrusion [link]

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

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Emerging Contaminants

What are they?

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

An emerging contaminant is a substance that has not historically been considered a contaminant, but for which there is increasing evidence that it is present in the environment and may cause adverse human and 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 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.

Emerging contaminants 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 was carbon dioxide (CO_2), water (H_2O), and dinitrogen gas (N_2).

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. In those cases, 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 works by comparing the measured information on the combinations of split fragments with a library of possible molecules. MS/MS is used for the measurement of PFAS, in important category of emerging contaminants, under U.S. EPA methods.

Availability of a laboratory analytical standard of a substance is helpful when using MS/MS, but not necessary if the goal is to screen a water sample for the variety of contaminants present. When emerging contaminants are known or suspected to degrade, use of MS/MS is particularly useful for finding the metabolites. MS/MS 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.

The following sections give information on categories of emerging contaminants that are 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 after their lifetime in 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 PPCPs discharge into the environment include wastewater treatment plants, which may remove some but not all of these compounds from wastewater, 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 consumer products including non-stick cookware, stain- and water-repellent clothing and carpeting, grease-resistant liners to food packaging including microwave popcorn, some spray paints, and certain types of industrial and aviation fire-fighting foams.

PFAS are not known to degrade in groundwater or elsewhere in the environment and therefore tend to 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.

Although PFAS have been used extensively since the mid-20th century, scientists are just recently understanding their potential impacts to human health. This understanding continues to develop based on ongoing research. The specific substances perfluorooctane sulfonate (PFOS), perfluorooctanoate (PFOA), perfluorohexane sulfonate (PFHxS), and perfluorononanoic acid (PFNA) are 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.

The two most widely studied PFAS are PFOS and PFOA, both of which present health risks and are commonly found in groundwater. While manufacturers of common PFAS such as PFOS, PFOA and precursor substances that degrade to these two compounds began phasing out their production in 2000, new “replacement” compounds have increased in production since then. The replacement PFAS are an example of the second category of emerging contaminants—emerging due to a recent change in practices, in this case production of the substances. Replacement PFAS include perfluorobutane sulfonate (PFBS)—often a replacement for PFOS—and Hexafluoropropylene Oxide Dimer Acid (HFPO-DA), which is used in food packaging and paints, among other products. These two compounds are currently under evaluation by the Wisconsin Department of Health Services for the possibility of recommending groundwater enforcement standards.

The acronym PFC has been used to describe PFAS in the past. This acronym is no longer used to describe per- and poly- fluoroalkyl substances (PFAS) because it is used to describe perfluorocarbons (i.e., refrigerants), which are a different family of chemicals. 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 often 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 20^{th} century, new pesticides continue to come into use. One such pesticide is the herbicide isoxaflutole, which is used for weed control in crops of corn. 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 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 oxic 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 main sources of microbial contaminants are manure from livestock and human sanitary sewage. Pathogenic microbes from these sources can 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 that itself is harmless, but 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, in which case the infected bacterial cell 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 pathogens in groundwater, please 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 in Illinois 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, which do not provide any such filtering. 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.

Bioavailable Anthropogenic Organic Matter

Bioavailable anthropogenic organic matter includes liquid and solid wastes from agriculture, wastes from paper mills, and biosolids from wastewater treatment. These wastes often contain a variety of compounds, many or most of which themselves are not considered contaminants. However, they can have effects on other contaminants. *Bioavailable* means that microorganisms (e.g. bacteria) can use the wastes as an energy source. This can have several effects on the soil and groundwater environment. Microbially-mediated chemical reactions often lower the pH of groundwater, which can under some groundwater conditions dissolve naturally occurring metals from the soil or aquifer material (see the Arsenic and Other Naturally Occurring Elements section of the report). Microbial populations can change. In a study in Spain in which river water containing a high proportion of treated wastewater was infiltrated to groundwater, subsurface microbial populations were found to become increasingly similar to the populations of bacteria that exist in the infiltrated water (Barba et al., 2019). Additionally, use of bioavailable compounds by microbes leads to decreasing oxygen concentration, or even oxygen being completely removed from water.

If oxygen is removed from the water, *reducing conditions* exist. Reducing conditions can have benefits for degradation of nitrate and certain emerging contaminants, but can also result in harmful metals—such as manganese, iron, and arsenic—being released from the sediment or rock in which groundwater occurs. Both can have health impacts at higher concentrations, and both are also heat-trapping (greenhouse) gases. For these reasons, impacts of bioavailable anthropogenic organic matter on water quality in Wisconsin is an issue that deserves further attention.

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. 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 near the Johnson Controls International/Tyco facility (Marinette), former Mirro plants (Manitowoc and Chilton) and Department of Defense sites (i.e. Wisconsin Air National Guard facilities at Truax Field and Volk Field) in Wisconsin. PFAS are present in some consumer products, industrial processes, and types of firefighting foams. Therefore, PFAS are potentially present at municipal fire departments, industrial facilities, and in waste streams entering municipal landfills and treatment works. PFAS have been identified in municipal wastewater treatment facilities' influent, effluent and biosolids due to the diverse waste streams accepted (i.e. industrial and municipal parties). There is some concern that biosolids may cause groundwater contamination when beneficially reused via spreading of biosolids on agricultural lands.

Municipal and industrial landfills and hazardous waste clean-up sites are always sources of concern for both known and emerging contaminants. One example of emerging contaminants suspected to originate at these sites are PFAS compounds. These compounds were detected in three public water supply wells during monitoring for unregulated contaminants required by the US EPA from 2013-2015. Since the EPA unregulated contaminant sampling effort, testing for a more comprehensive list of PFAS compounds has been conducted in Wisconsin, and the chemicals have been detected in private water supply wells, and at some municipal water supply systems. PFAS groundwater sampling is also being conducted at Department of Defense sites in Wisconsin. It is suspected that the compounds may be present in groundwater at other locations near firefighting training sites and facilities that manufacture products containing PFAS.

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 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 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 domestic 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 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.

Due to the expense of testing and the limited analytical methods available, only a fraction of the pesticides applied to agricultural fields and their metabolites have been tested for in groundwater. However, DATCP's most recent statewide statistical survey of agricultural chemicals in groundwater found that approximately 42% of private wells in Wisconsin contained at least one of the 101 pesticides and pesticide metabolites analyzed (DATCP, 2017). The most commonly detected compounds do have health-based groundwater standards, but the potential health effects of others are less understood.

Hormones from livestock operations were detected in runoff and tile drain water from one agricultural field in a study funded by the Wisconsin Groundwater Research and Monitoring Program (WGRMP), but they were not found in nearby groundwater monitoring wells (Hemming et al., 2013). A different study evaluated “shallow” water supply wells in karst bedrock areas in northeastern Wisconsin that were suspected of being impacted by agricultural activities due to nearby land use and contamination with bacteria and/or nitrate (Bauer-Dantoin, 2013). In this study, researchers identified estrogenic activity in some well samples, suggesting that agricultural activity may be a source of EDCs in groundwater in karst areas.

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.

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

Health effects of emerging contaminants vary and are not always well understood. Some emerging contaminants, including some pesticides, pharmaceuticals and PCPs, 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 these compounds may cause developmental, reproductive, neurologic and immune problems, as well as cancer (NIH, 2010), but more research is needed on many of them.

Ongoing 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 good 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 that facilitates regular review of groundwater monitoring data and identification of 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 representative sample of small (serving < 10,000 people), public water systems. The Third UCMR (UCMR3) monitoring period was completed in 2015 and monitoring for the Fourth UCMR (UCMR4) is occurring from 2018 - 2020. Data collected at Wisconsin public water supply systems during UCMR monitoring supplements data from other GCC-supported monitoring and occurrence studies.

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, the DNR formally requested that DHS provide recommendations for groundwater quality standards for two PFAS, PFOA and PFOS, in accordance with State law. In June of 2019, based on a review of thousands of peer-reviewed studies, the DHS recommended a groundwater enforcement standard of 20 parts per trillion (ppt) for combined levels of PFOA and PFOS. Upon receiving recommendations, the DNR has begun the formal rulemaking process to promulgate amendments to NR 140 groundwater quality standards. The rulemaking process may take up to 30 months to complete.

The DNR is formulating a strategy to address PFAS in the State. This will include a request for voluntary sampling of influent and effluent by WPDES permitted municipal wastewater treatment plants. PFAS may be present in municipal wastewater treatment facilities' biosolids that have been regularly applied to agricultural lands throughout the state. The DNR intends to investigate the fate and transport of PFAS in biosolids. Additional statewide PFAS biosolids and sludge testing may be requested in the coming years. Wisconsin will be drawing on the examples and experiences of other states to guide future PFAS efforts at State agencies that protect groundwater resources within the State.

Further Reading

DNR overview of pharmaceuticals and PCPs in the environment [link]

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

Wisconsin Remediation and Redevelopment Database (WRRD) [link]

DATCP Groundwater Quality Reports [link]

NIH factsheet on endocrine disruptors [link]

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

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

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

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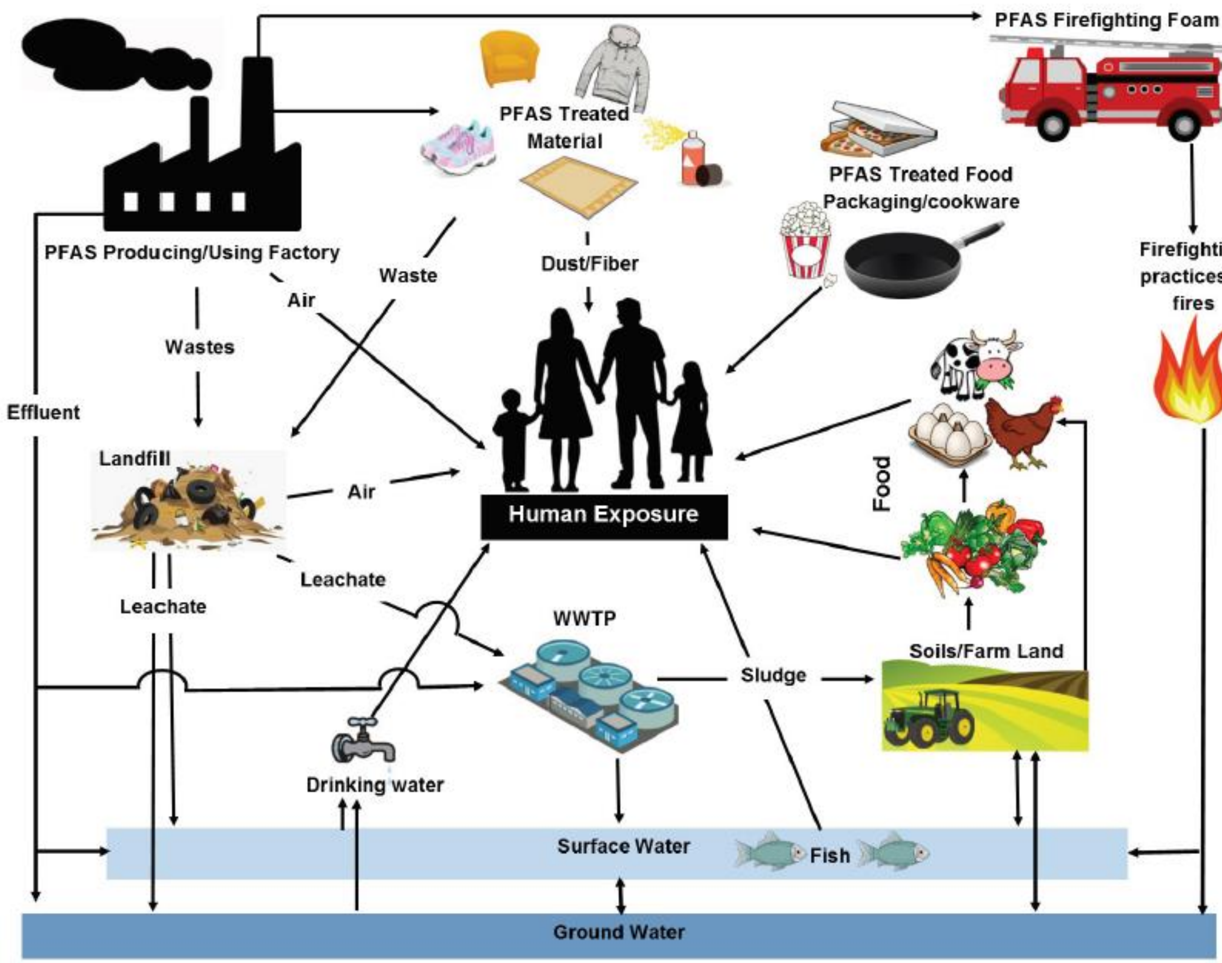
Per- and Polyfluorinated Alkyl Substances

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 fish caught from water contaminated by PFAS, accidentally swallowing soil or dust contaminated by PFAS, eating food that was packaged in material that contains PFAS, and using consumer products that contain PFAS. 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, experts are just recently understanding their potential impacts to human health. This understanding continues to evolve based on ongoing research. The specific PFAS perfluorooctane sulfonate (PFOS), perfluorooctanoate (PFOA), perfluorohexane sulfonate (PFHxS), and perfluorononanoic acid (PFNA) are 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, however, studies linking the two have been inconsistent and require further research.

Firefighters spraying foam on structures. Image credit: NPS

Currently, there is limited regulatory authority of 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, 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. With respect to groundwater, in June of 2019 the Wisconsin Department of Health Services (DHS) recommended a groundwater enforcement standard of 20 parts per trillion (ppt), as a combined standard for PFOS and PFOA, as part of the 10th Cycle of Groundwater Standards Proposals. To become enforceable, the recommended standard needs to go through the State's formal rulemaking process and be incorporated into ch. NR 140, Wis. Adm. Code. Until that time, persons undertaking groundwater cleanups of PFAS contamination are required to work with DNR and DHS to establish a site-specific cleanup standard.

Occurrence in Wisconsin

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, Madison, and Rhinelander.

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 also can 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.

GCC Agency Actions

Currently, there are no state or federal groundwater protection standards for PFAS. To address this regulatory gap, the DNR formally requested that DHS provide recommendations for groundwater enforcement standards for two PFAS, PFOA and PFOS, in accordance with State law. In June of 2019, based on a review of thousands of peer-reviewed studies, the DHS recommended a groundwater enforcement standard of 20 parts per trillion (ppt) for combined levels of PFOA and PFOS. Upon receiving recommendations, the DNR has begun the formal rulemaking process to promulgate amendments to NR 140. The formal process may take up to 30 months.

The DNR, in April of 2019, also requested that DHS review toxicologic information on 34 PFAS compounds and, if appropriate, provide recommendations for ch. NR 140 groundwater standards. This request was designated the "Cycle 11" review of substances for possible groundwater standards development. DHS is currently in the process of reviewing toxicologic information available for substances on the Cycle 11 list.

The DNR is formulating a strategy to address PFAS in the State. This will include voluntary sampling by WPDES discharge permit holders, municipal fire departments, and municipal wastewater treatment plants. Additional statewide PFAS biosolids and sludge testing will occur in the coming years and, given the ubiquitous nature of PFAS, it is expected that the detection of more widespread PFAS impacts will occur. To effectively protect human health and the environment from potential risks associated with the land application of PFAS containing biosolids, a PFAS land application numerical value should be developed in order to appropriately regulate and authorize land spreading proposals where PFAS has been detected. Wisconsin will be drawing on the examples and experiences of other states to guide future PFAS efforts at State agencies that protect groundwater resources within the State.

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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https://doi.org/10.1007/s11356-012-1275-4

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, accounting for 91 billion gallons in 2018, down from 92 billion in 2017 (DNR 2019). The second largest category of groundwater withdrawal in the state was agricultural irrigation, totaling 82 billion gallons in 2018, increasing from 64.6 billion gallons in 2017. Agricultural irrigation water use varies from year to year depending on the timing of rainfall during the growing season.

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 department is taking the necessary steps to identify the components of the water budget driving the fluctuation in each of the three named lakes. The study will move us forward in developing methodologies for determining "how much is too much?" for a lake. 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-terming monitoring. Accessible to scientists, water resources managers and the general public the springs inventory is available on the DNR Wisconsin Water Quantity Data Viewer.

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.

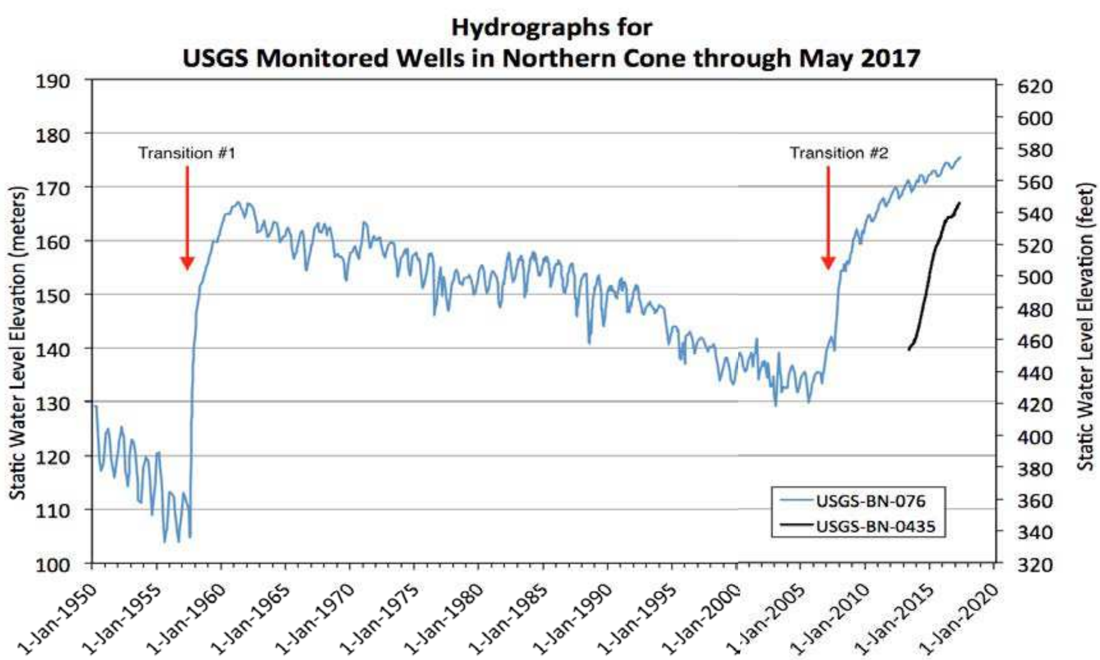

Figure 1: Changes in groundwater levels in a groundwater level monitoring well in Green Bay, Wisconsin. Transition 1 is City of Green Bay Switch to surface water. Transition 2 is Green Bay suburbs switch to surface water (Luczaj).

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.

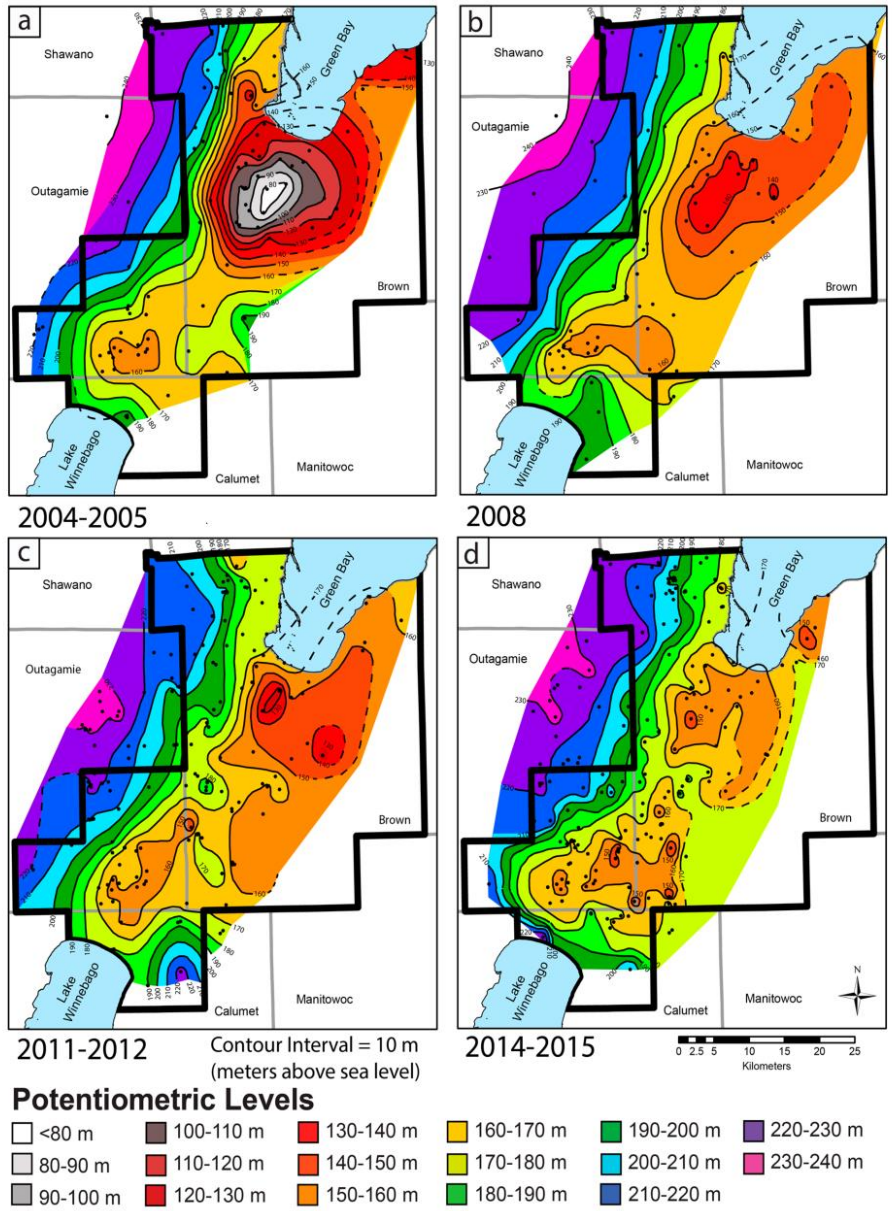

Figure 2: Water table elevations in Brown County (WGNHS).

Southeastern Wisconsin

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 2013 water levels to be approximately 100 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 pC/l. Treatment of that water can be costly, leading some communities to look at other water sources.

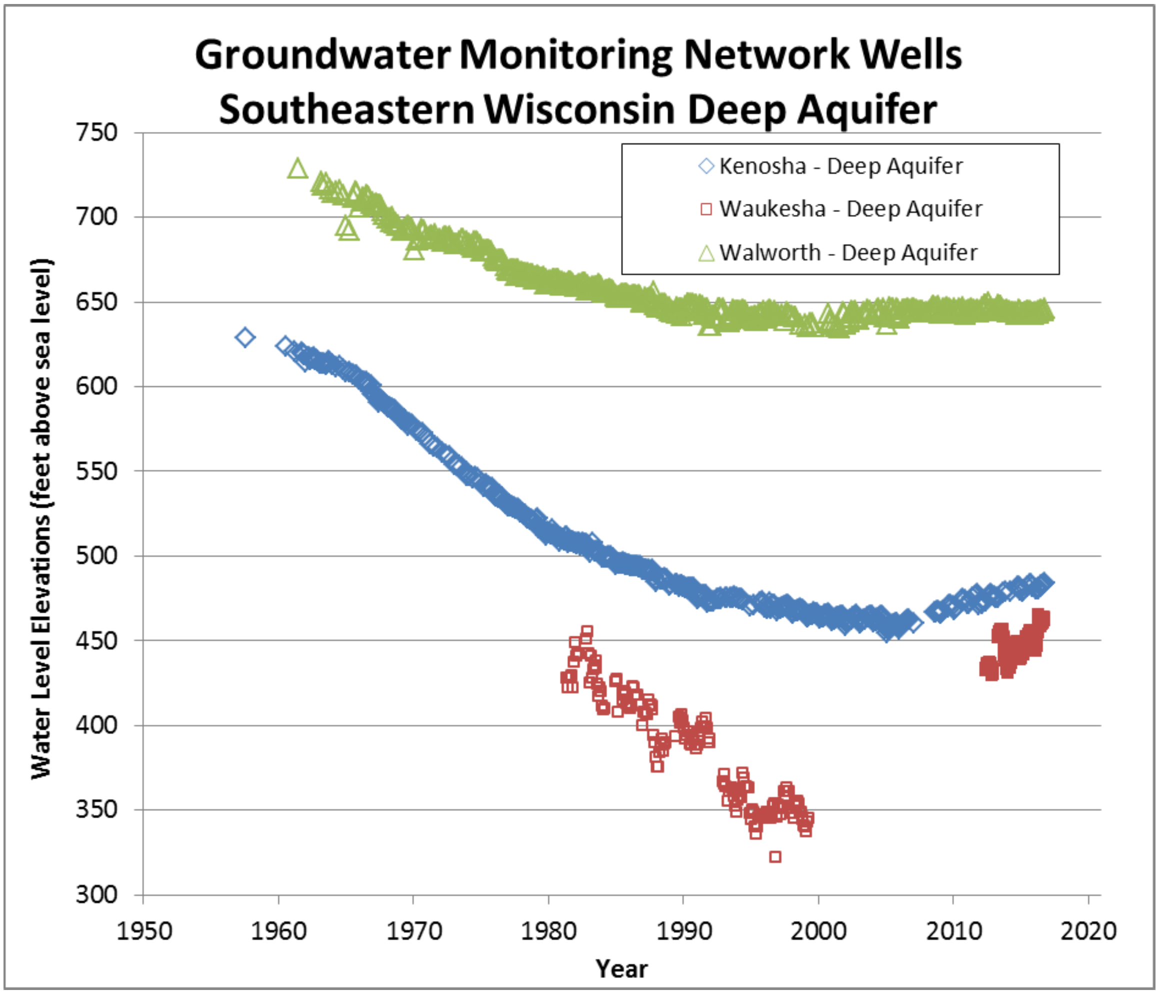

Figure 3: Water levels in a groundwater level monitoring wells in Waukesha, Kenosha and Walworth counties (DNR).

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%).

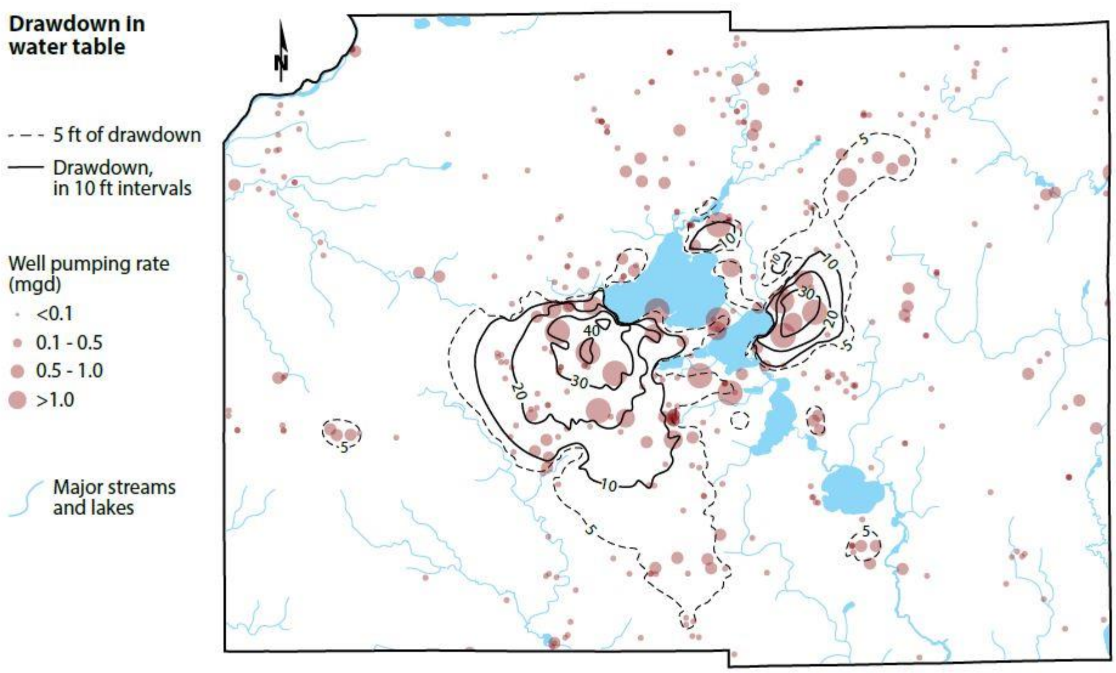

Figure 4: Simulated drawdown (feet) in the Mount Simon Sandstone; predevelopment to 2010. The Mount Simon Sandstone, located several hundred feet below land surface and up to 800 feet thick, is the lowermost aquifer unit within Dane County. This porous sandstone is a highly productive aquifer which provides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

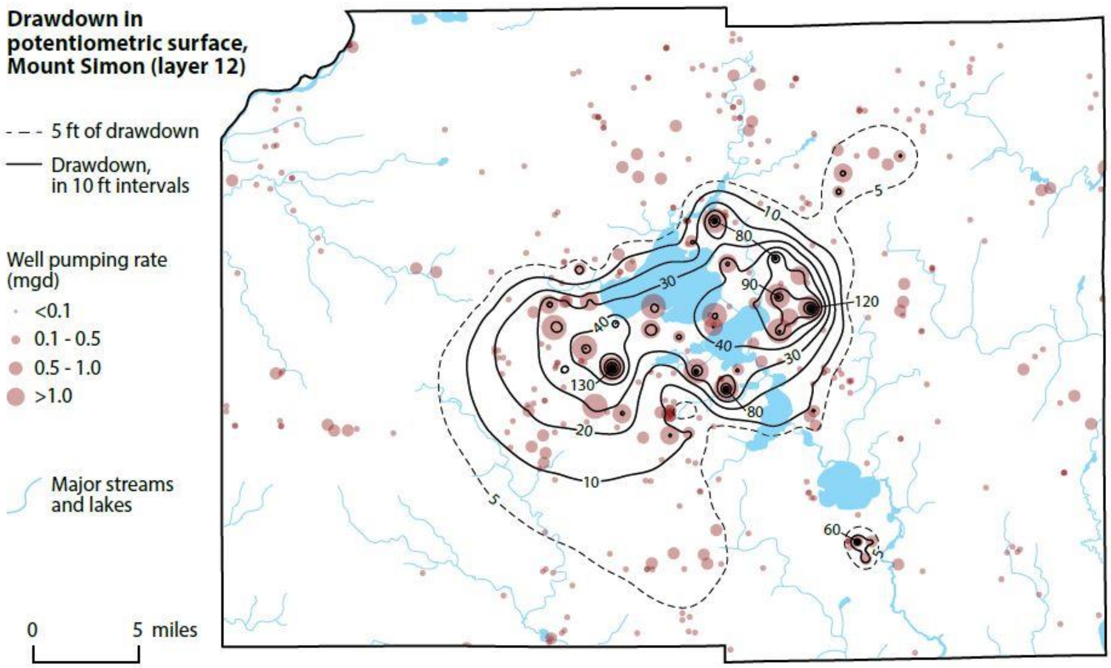

Figure 5: Simulated drawdown (feet) at the water table; predevelopment to 2010. Drawdowns from the lower Mount Simon aquifer system propagate upwards to the shallow sand and gravel and upper bedrock aquifer systems to create drawdowns at the water table (WGNHS).

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 will evaluate and model 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 includes 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 involves data collection and compilation across the region.

The department will determine if there is the potential for significant impacts to the lake's average seasonal levels as a result of groundwater withdrawals. If the department determines that the potential for significant impacts exists, several steps will be taken including a public hearing, economic impact analysis and providing recommendations to the Legislature for special measures to mitigate those impacts.

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Pfeiffer, S.M. personal communication, 2013.

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 2020, this network consists of 94 long-term monitoring wells, two spring gaging stations and project-specific, limited-term monitoring wells. The long-term 94 permanent wells and two spring gaging stations, or "Core Network" are located in 45 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 2020, DNR committed $112,600 and provided additional funding of $70,000 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.

In FY 2019 WGNHS received a 2-year grant from the USGS National Ground-Water Monitoring Network (NGWMN) program in the amount of $198,089. This grant, which continues through July 2020, seeks to repair 16 monitoring wells, replace three damaged wells, and install a new well in Langlade County. Improvement efforts also include compilation of historical well records, well borehole evaluations, and well integrity testing as needed to complement existing information for each well.

Central Sands Lakes Study

Under 2017 Wisconsin Act 10, the department will evaluate and model 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.

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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.

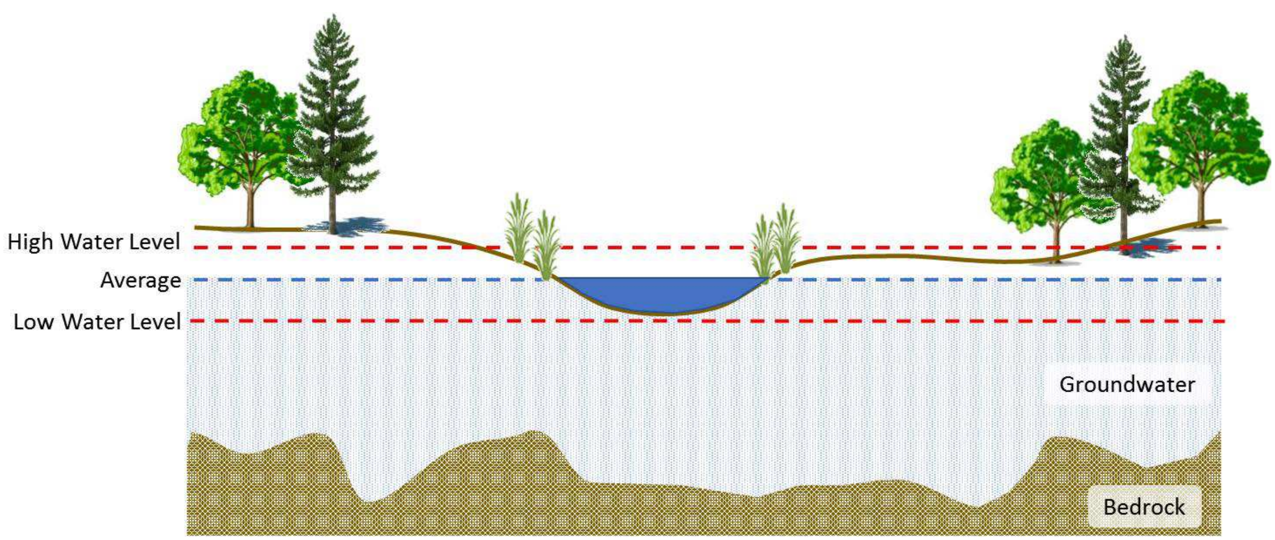
Groundwater level monitoring

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).



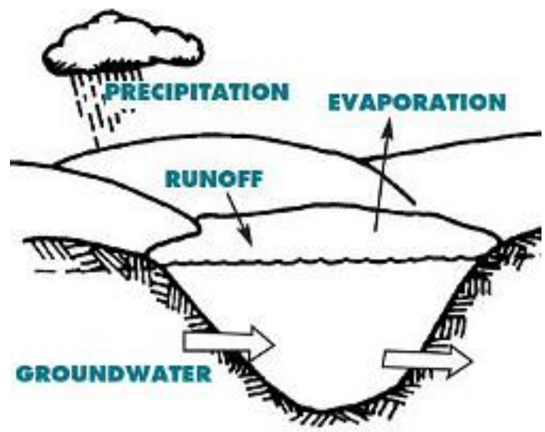
Water level variation diagram. Image credit: DNR.

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 outlet. Image credit: UW Stevens Point.

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 2020, water level statistics from the statewide monitoring network indicate groundwater levels that 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