Wisconsin Groundwater Coordinating Council

Report to the Legislature

Fiscal Year 2023

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

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State of Wisconsin \GROUNDWATER COORDINATING COUNCIL

Tony Evers, Governor

101 South Webster Street
Box 7921
Madison, Wisconsin 53707

August 31, 2023

To: The Citizens of Wisconsin
The Honorable Governor Tony Evers
Senate Chief Clerk
Assembly Chief Clerk
Secretary Craig Thompson - Department of Transportation
Secretary-designee Dan Hereth - Department of Safety & Professional Services Secretary Randy Romanski - Department of Agriculture, Trade & Consumer Protection
Secretary-designee Kirsten Johnson - Department of Health Services
Secretary Adam Payne - Department of Natural Resources
President Jay O. Rothman - University of Wisconsin System
Interim State Geologist Eric C. Carson - Geological and Natural History Survey

The Groundwater Coordinating Council (GCC) is pleased to provide its 2023 Report to the Legislature. The Report is intended to alert Wisconsin leaders to the state of our groundwater resource and its management and to provide recommendations for its protection. Our groundwater is an invaluable resource, and its proper management and protection requires the coordinated efforts of our leaders.

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 ideas continue to warrant the collaborative approach.

This online report summarizes and links to information on the GCC and agency activities related to groundwater protection and management in FY23 (July 1, 2022 - June 30, 2023). 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,
Chair Groundwater Coordinating Council

SECTIONS IN THIS DOCUMENT

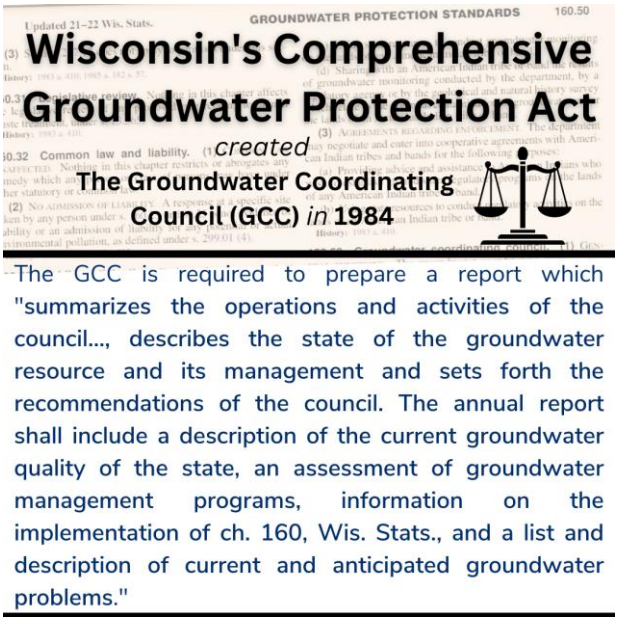
PURPOSE OF THE ANNUAL REPORT

The Groundwater Coordinating Council (GCC) was created in 1984 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 GCC is required by s. 15.347, Wis. Stats., to prepare an annual report due each August 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.*"

This report fulfills the requirement for fiscal year 2023 (FY23).

The report includes links to extensive supporting information.



For the online version of this report: dnr.wi.gov/topic/Groundwater/GCC.

SUMMARY OF GROUNDWATER MANAGEMENT PROGRAMS

State agencies and the University of Wisconsin System (UWS) addressed numerous issues related to groundwater management in FY23. Detailed discussions of the activities of the GCC, each state agency and the University of Wisconsin System can be found on the groundwater management programs webpage.

The GCC, state agencies and the University of Wisconsin System address numerous issues related to groundwater protection and management.

- Department of Natural Resources (DNR)
- Department of Trade and Consumer Protection (DATCP)
- Department of Health Services (DHS)
- Department of Transportation (DOT)
- Department of Safety and Professional Services (DSPS)
- University of Wisconsin System (UWS)
- Wisconsin Geological and Natural History Survey (WGNHS)

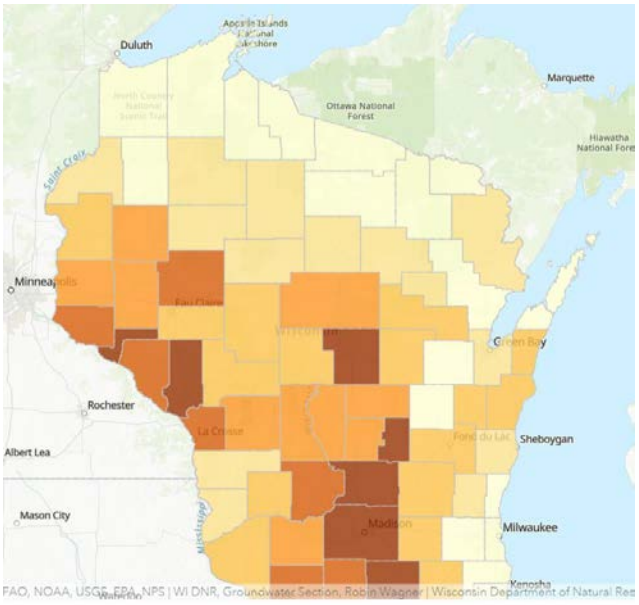
Highlights of groundwater management activities:

- **DNR**: Began a project to sample for PFAS and other water quality parameters in 450 private wells
- **DATCP**: Analyzed more than 200 groundwater and 150 surface water samples for over 100 pesticide compounds and nitrate plus nitrite as nitrogen.
- **DHS**: Addressed PFAS health concerns at several locations within the state (e.g., Marinette, La Crosse, Eau Claire, Wausau, Peshtigo, French Island, Madison, Rhinelander, Town of Stella).
- **DOT**: 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.
- **DSPS**: Counties are operating a maintenance program for all POWTS in their jurisdiction.
- **UWS**: In support of the Wisconsin Groundwater Research and Monitoring Program, provided UWS funding to six research projects focused on groundwater contaminants, including nitrate and road salt; water quantity challenges in the Central Sands; geochemistry and microbiology; and understanding public perspectives and values, and supported graduate and undergraduate students.
- **WGNHS**: Conducting new bedrock geologic mapping in Dodge, Jefferson, Lafayette, and Grant Counties.

STATE OF THE RESOURCE: GROUNDWATER QUALITY

Groundwater pollution from human activities and natural sources happens across Wisconsin. This is of particular concern for the 70% of Wisconsinites who get their drinking water from groundwater.

Other groups concerned about groundwater quality include farmers who rely on safe groundwater for crop and livestock production, and business owners who rely on groundwater for manufacturing and commerce. Lakes, rivers and streams are fed by groundwater. Fish and wildlife can't thrive when groundwater contaminants impact the surface water they are dependent upon.



Estimated No. Wells Over Nitrate Standard Map - 2022

The GCC continues to address major groundwater quality concerns in Wisconsin.

Nitrate contamination continues to increase. GCC member agencies continue to work on multiple initiatives related to reducing the risk of high nitrate levels in groundwater.

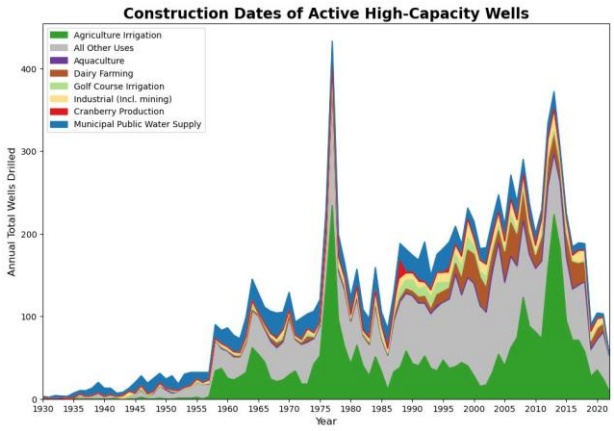
Details about each of the following groundwater contaminants, including what they are, their human and environmental health concerns, how widespread they are in Wisconsin and how they are trending over time can be found on the groundwater quality webpage.

- Nitrate
- Per- and Polyfluorinated Alkyl Substances (PFAS)
- Bacteria, Viruses and Other Pathogens
- Pesticides
- Arsenic
- Volatile Organic Compounds (VOCs)
- Naturally Occurring Elements, including Chromium, Manganese, Radionuclides & Strontium
- Emerging Contaminants

STATE OF THE RESOURCE: GROUNDWATER QUANTITY

Groundwater is not distributed equally in the aquifers of Wisconsin. Across most of the state sufficient volumes of groundwater exist to support the required municipal, industrial, agricultural and domestic uses. However, in some instances the aquifers either do not yield a lot of water or relatively small changes in the upper aquifer can harm the surface water resources that rely on groundwater.

There is geographic and temporal variation in groundwater withdrawals largely due to precipitation. While year to year withdrawals can vary, overall, the total volume of groundwater withdrawn has remained relatively constant in the last several years. Statewide the number of high capacity wells continues to grow with approximately 200 new wells approved last year bringing the total to over 14,000 active high capacity wells.



High capacity well construction has increased over time but fluctuates based on need and economic factors.

The impact of groundwater pumping continues to be a site-specific issue given the variability of Wisconsin's aquifers. 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. Increased water demand is overlapping with a low yield aquifer in northcentral 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 but are influenced by climate cycles between wet years and drought years.

The GCC continues to address groundwater quantity concerns in Wisconsin.

Details about each of the following groundwater quantity measures are detailed on the groundwater quantity webpage.

- Water Use
- Groundwater/Surface Water Interactions
- Regional Drawdowns
- Groundwater Levels and Aquifer Response
- Groundwater Level Monitoring Network
- Little Plover River Model and Watershed Enhancement Project
- Central Sands Lakes Study

RECOMMENDATIONS: DIRECTIONS FOR FUTURE GROUNDWATER PROTECTION

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

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

Priority Recommendations

- Set new and revised health-based groundwater standard recommendations that are imperative for protecting public health and the environment.
- Implement practices that protect groundwater from nitrate, pesticides and other agricultural contaminants.
- Address public health and environmental concerns regarding PFAS.

Ongoing Recommendations

- Evaluate the occurrence of viruses and other pathogens in groundwater and develop appropriate response tools.
- Support the sustainable management of groundwater quantity.
- Continue to catalog Wisconsin's groundwater resources.
- Evaluate the impacts of climate change on Wisconsin's groundwater.
- Support applied groundwater research in Wisconsin.

To learn more about each of these recommendations and for actions to take to address them, go to the recommendations section.

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These recommendations include top priorities of immediate concern and ongoing efforts that require continued support. For supporting groundwater management activities, see the groundwater management section of the report. For supporting information about groundwater quality, including contaminants, see the groundwater quality section of the report.

Priority Recommendations

- Set new and revised health-based groundwater standard recommendations that are imperative for protecting public health and the environment from PFAS, nitrate and other contamination
- Implement practices that protect groundwater from nitrate, pesticides and other contaminants.
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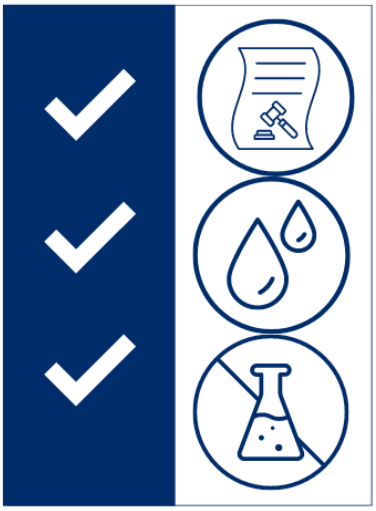

Ongoing Recommendations

- Evaluate the occurrence of viruses and other pathogens in groundwater and develop appropriate response tools.
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Priority Recommendations

Set new and revised health-based groundwater standard recommendations that are imperative for protecting public health and the environment from PFAS, nitrate and other contamination.

Wisconsin has a long and proud history of groundwater protection. Wisconsin's groundwater law adopted in 1983 is held up as one of the nation's model environmental laws in part because of its robust, science-based process for protecting the quality of our groundwater and public health. For 40 years, the groundwater law has guided the rule-making process that DNR and DHS follow, ensuring a scientifically rigorous review of available technical information and clarity on how recommended groundwater standards are selected.

The last time DNR and DHS were allowed to make revisions or additions to groundwater standards was 2009. Since 2019, DHS has provided DNR with two sets of recommendations (Cycle 10 and Cycle 11) based on state regulatory program needs for 47 new or revised groundwater standards. These include standards for pesticides, per- and polyfluoroalkyl substances (PFAS), metals, volatile organic compounds (VOCs) and bacteria. However, in 2022 the Natural Resources Board (NRB) ended rulemaking before sending the rule package to the legislature which would have set standards for the 26 Cycle 10 recommendations. As a result rulemaking was paused on the Cycle 11 PFAS and pesticides. While a NR 140 rule change setting new standard for e. coli and a revision in how total coliform is handled were successfully concluded in 2023, the backlog of needed standards and revisions continues to grow.

Did you know?

Groundwater standards are imperative for protecting public health and the environment from PFAS, nitrate and other contamination. Once established, the standards must legally be met by all regulated activities.

The GCC recommends the following action:

- **Allow DNR and DHS to finish rule-making that protects groundwater.**

  Forty-six NR 140 groundwater standards, first identified in 2019 and 2020, remain unaddressed. A total 36 new numerical standards remain to be addressed, 18 PFAS, 16 pesticides and two metals. Additionally, a total of 10 metals and VOCs have updated human-health information requiring a review of their existing standards. Without these needed new and revised numerical health-based standards, groundwater regulatory programs remain unable to protect the public health of Wisconsin residents.

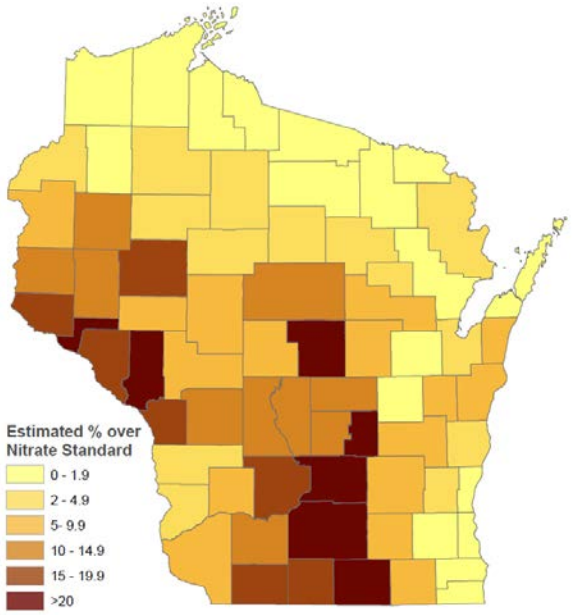
Implement practices that protect groundwater from nitrate, pesticides and other agricultural contaminants.

Nitrate that approaches and exceeds unsafe levels in drinking water is one of the top drinking water contaminants in Wisconsin and poses known health risks. In addition, pesticides are estimated to be present in over 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 implement the strategies that lead to efficient use of nitrogen and careful or reduced use of pesticides in order to protect groundwater and drinking water sources.

GCC member agencies have been and continue to work on multiple initiatives related to reducing the risk of high nitrate and pesticides levels in groundwater (see groundwater management sections – DNR, DATCP, UWS, WGNHS) but the problem still persists.

Where is nitrate contamination highest in Wisconsin?

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



The GCC recommends the following actions:

- **Make safe drinking water and protection of public health the top implementation priority for the state's interagency Nutrient Reduction Strategy.**
- **Create an online mapping tool to optimize targeting conservation practices where elevated nitrate in wells is present.**
- **Assess soil type specific nitrogen crop application rates and cropping best management practices to minimize nitrogen losses to groundwater and encourage their use.**
- **Develop educational materials and a broad outreach plan for farmers, nutrient management planners and agricultural industry stakeholders that identifies and encourages specific alternate cropping and nutrient management practices to minimize nitrogen losses to groundwater.**

- **Create and staff a source water protection program (modeled on surrounding states) to better prevent drinking water contamination from occurring and provide support in areas impacted by groundwater contamination.**
- **Develop surface water nitrogen numerical criteria to address nitrate alongside phosphorus within existing watershed based nonpoint pollution mitigation infrastructure.**
- **Incorporate nitrogen budgeting and nitrate leaching potential into nutrient management practice standards and existing nutrient management tools.**
- **Support collaborative interagency and producer involved development of Groundwater & Nitrogen Fertilizer Decision Support Tools.**
    - To advance this complex technical and social challenge and make progress in reducing ongoing nitrate impacts to groundwater, the current project development partnership seeks to expand, as there is a need to incorporate additional multi-disciplinary contributions from researchers, agricultural producers, and software developers.
- **Revamp, fund and enforce nutrient management planning.**
- **Continue groundwater monitoring to continue assessing known problem areas and identify new emerging areas of concern.**
- **Expand the well compensation program.**
    - GCC would like to see long-term funding secured for well owners to fix their wells. The short-term repurposing of federal dollars to well compensation was a welcome step. The funding provided $10 million in financial assistance to well owners to address contamination in their wells by awarding grants for the replacement, reconstruction, treatment or abandonment of their well. This program should be made permanent utilizing state funding.
- **Provide permanent funding to test private wells.**
    - Only one third of private well owners have ever had their water tested for nitrate, the state's most common contaminant exceeding human health standards (an estimated 10% or more, of private wells exceed the standard for nitrate-N).

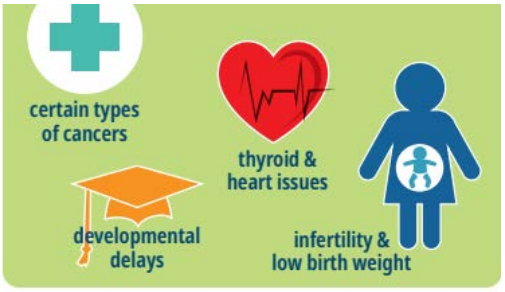
- **Expand regulation of nitrogen losses to groundwater to all farms, not just CAFOS.**
- **Further develop health standards and laboratory methods to keep pace with the evolving use of agricultural chemicals to ensure continued agricultural success that is so crucial for our state's economy is balanced with the protection of groundwater and human health.**

Address public health and environmental concerns regarding PFAS.

PFAS have been detected in both municipal and private drinking water sources in Wisconsin. Exposure to PFAS has been shown to have detrimental health effects, including the potential to cause cancer.

Should you worry about PFAS?

PFAS have been shown to have detrimental health effects, including the potential to cause cancer.



The GCC recommends the following actions:

- **Implement groundwater enforcement standards for two PFAS, PFOA and PFOS.**
- **Pursue development of additional groundwater enforcement standards for 19 additional PFAS compounds detected in Wisconsin for which human health impacts have been identified.**
- **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.**

Ongoing Recommendations

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

Evaluate the occurrence of viruses and other pathogens in groundwater and develop appropriate response tools.

Viruses and other microbial pathogens have been found in municipal and private wells, challenging previous assumptions about their persistence and transport.

The GCC recommends the following actions:

- **Continue to monitor and assess our understanding of pathogens in groundwater, in particular, where and when they pose threats to human health.**
- **Work with partners to increase awareness of waste disposal choices, their risks and costs.**
- **Improve best practices for well construction to minimize exposure to contaminated groundwater. Both agricultural manure sources and poorly constructed and maintained septic systems are potential threats to public health.**

Why do we care about viruses and other pathogens in groundwater?

Pathogenic microorganisms in drinking water can make people very sick and can result in death.

Support the sustainable management of groundwater quantity.

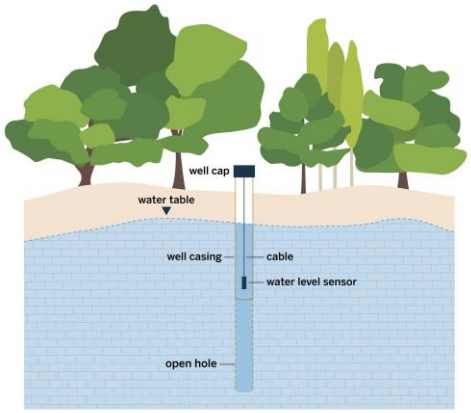
We must ensure that water is available to be used in Wisconsin. This will protect and improve our health, economy and environment now and into the future.

The GCC recommends the following actions:

- **Continue to inventory information on the location, quantity and uses of the state's groundwater.**
- **Support targeted monitoring and modeling of the impact of groundwater withdrawals on other waters of the state.**
- **Identify and evaluate options for areas with limited groundwater resources.**
- **Advance research relating to changes in land-use development patterns and the resulting increase in groundwater use and changes to recharge.**

Why do water levels matter?

GCC agencies monitor water levels in the state to ensure sustainable water supply for human consumption, healthy ecosystems and economic growth; and to support sound resource management decisions.



Continue to catalog Wisconsin's groundwater resources.

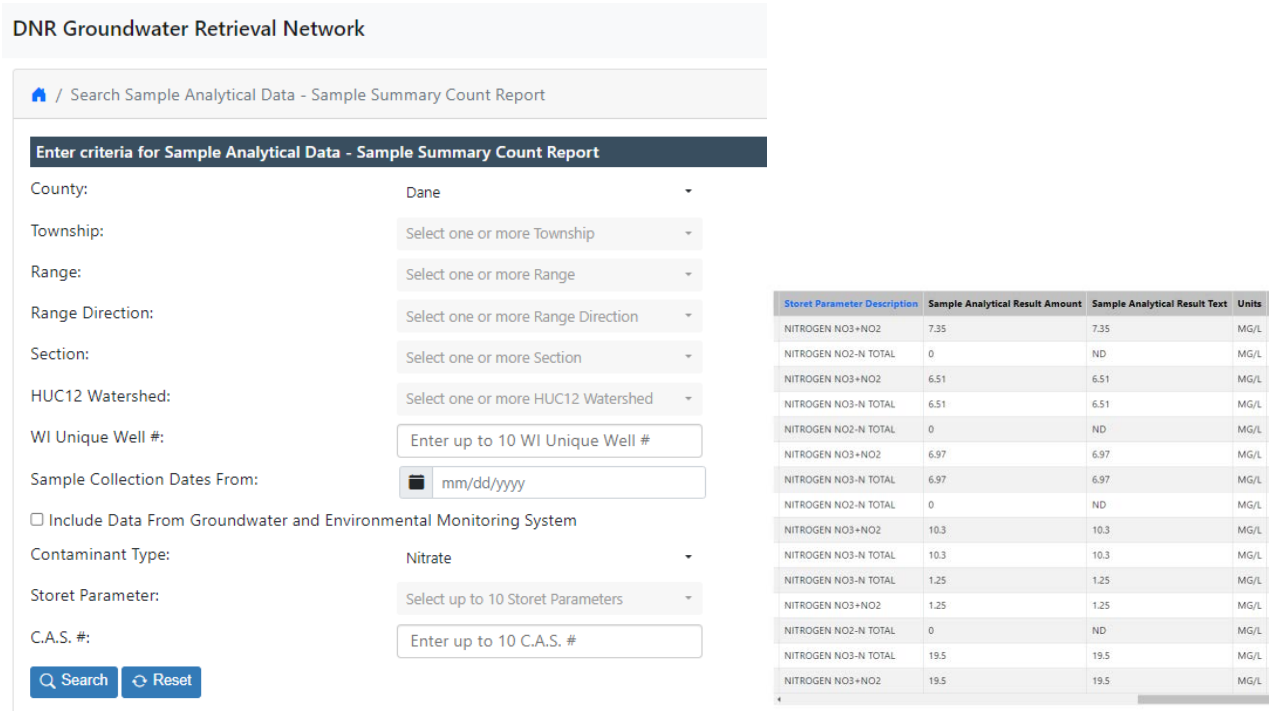
Management and protection of Wisconsin's groundwater resources requires publicly accessible, up-to-date data in order to foster informed decisions, not only on state policy matters but also for sound business decisions on siting or technology investments.

The GCC recommends the following actions:

- **Continue to collect, catalog, share and interpret new data about Wisconsin's groundwater so that it can be used by health care providers, people seeking business locations, homeowners and local governments.**
- **Share data about groundwater and groundwater vulnerabilities in accessible formats.**

Does the DNR have a lot of groundwater data?

Yes, the DNR maintains The Groundwater Retrieval Network (GRN) – GRN reports well information and well sample result data from several DNR databases. GRN can help you find information about an individual well or analyze regional or statewide groundwater conditions.



For example, GRN users can search for Nitrate contamination data by County.

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

Climate change is increasing the frequency and severity of weather patterns that produce unprecedented flooding or drought conditions. Severe flooding can affect groundwater quality, wells and water system operations. 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.

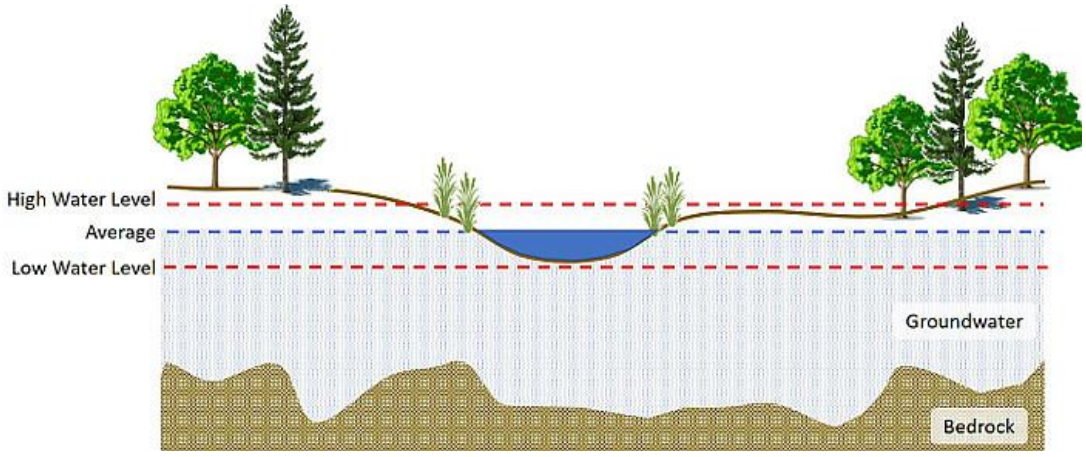
Public drinking water supplies as well as water-dependent industries need reliable estimates of these impacts in order to develop practical emergency response and adaptation strategies.

The GCC recommends the following actions:

- **Continue work to determine the range of possible climates in Wisconsin's future.**
- **Research to help identify the 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.**

How is climate change affecting groundwater?

Climate change has affected rainfall events by increasing the likelihood that they will occur with much more intensity and frequency. The accumulation of above-average precipitation resulted in many areas of Wisconsin experiencing high water and flooding issues.



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. And, 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.

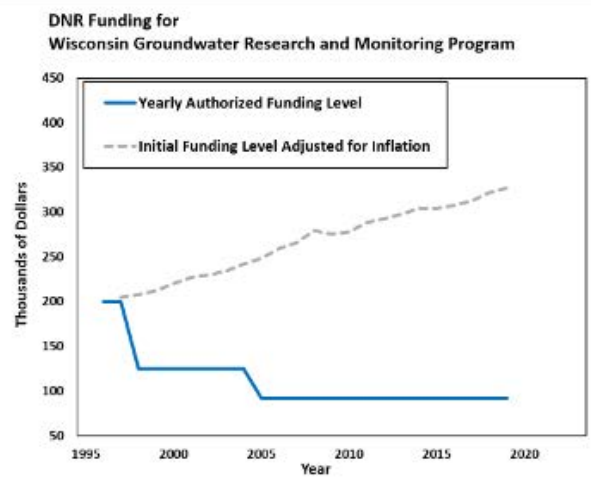
Collectively, since its inception this annual joint solicitation has funded 501 groundwater research and monitoring projects and has helped establish Wisconsin as an international leader in groundwater research.

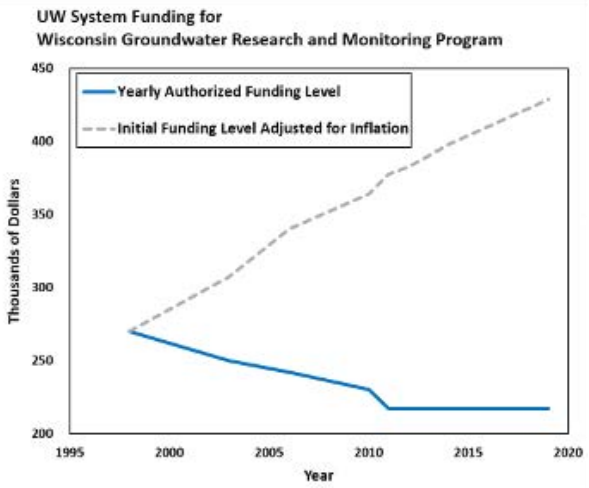
The GCC recommends the following action:

- **Restore the original authorized amounts of DNR and UW groundwater research funding.**

Did you know that funding for groundwater research in Wisconsin used to be much higher?

The history of DNR and UW System state legislative groundwater research funding levels (funding source created in 1996) are shown below. The solid blue line shows the actual authorized funding level through time, the dashed gray line shows the inflation adjusted value of the initial funding level in today's dollars.





THE GROUNDWATER COORDINATING COUNCIL

The Groundwater Coordinating Council (GCC) is an interagency group that is directed by law to assist state agencies and the University of Wisconsin System in the coordination and exchange of information related to groundwater.

To learn more about groundwater quality and quantity, see the State of the Resource Section of this report. For actions to address groundwater quality and quantity issues, see the Recommendations Section.

Sections in this document

Fiscal Year 2023 Highlights

Highlights include what was new or updated in the last year.

- From 10 groundwater-related proposals, seven new projects were selected for funding in FY23 - two by UWS, two by DNR and one by Department of Agriculture, Trade & Consumer Protection (DATCP).
- Two groundwater teacher workshops were held in FY 23. DNR staff worked with the Groundwater Center at the Center for Watershed Science and Education (CWSE) and WGNHS to provide training to educators from 20 schools and nature centers. Each attendee received a free groundwater model for their school. The GCC met four times in FY23 and discussed a variety of topics at its FY23 meetings including:

The GCC brings together staff from over 15 different agencies, institutions and organizations to communicate and work together on a variety of groundwater research, monitoring and data management, educational, and planning issues.

- WGNHS: Southwest Wisconsin Groundwater and Geology (SWIGG) study
- DNR: Marinette (JCI/Tyco) PFAS contamination
- DNR: Geospatial Data Management
- UW Milwaukee: Investigation of PFAS adsorption by selected Wisconsin aquifer sediments
- DNR: Prevalence and source tracing of PFAS in shallow groundwater used for drinking water in Wisconsin

Ongoing coordination activities

Ongoing coordination activities include what the GCC does to manage and protect groundwater on a regular basis.

- Brings together staff from over 15 different agencies, institutions and organizations to communicate and work together on a variety of groundwater research, monitoring and data management, educational, and planning issues. (*A list of GCC members and subcommittees is included below*).
- Provides consistency and coordination among state agencies in funding Wisconsin's Groundwater Research and Monitoring Program to meet state agency needs.
- Fosters communication, coordination and cooperation between the state agencies through quarterly meetings (more information can be found in the GCC meeting minutes).
- Identifies collaboration opportunities.
- Organizes across agency lines on a variety of groundwater-related issues.
- Works with representatives of federal and local agencies to promote communication and coordination with state groundwater activities.
- Promotes efforts to enhance the utility of groundwater monitoring and research funded by the state.
- Has funded approximately $20 million in projects over the last 30 years (through DNR, UWS, DATCP and DSPS (formerly Commerce)) on more than 460 projects selected to answer essential management questions and advance understanding of groundwater in Wisconsin.
- Avoids duplication and creates efficiencies providing numerous benefits to Wisconsin's taxpayers.
- Sponsors and participates in forums and other outreach events to promote discussion of groundwater issues.

- Ensures consistency in groundwater education, data management and mapping efforts.
- Runs the Groundwater Research & Monitoring Subcommittee.
- Coordinates the Education and Outreach Activities Subcommittee.
- Teaches annual groundwater workshops for teachers (jointly taught since 1994 by the GCC Outreach and Partnership Subcommittee members from the DNR, Wisconsin Geological and Natural History Survey (WGNHS) and the Center for Watershed Science and Education (CWSE) at U.W. Stevens Point).
    - Instructs teachers on using a groundwater sand-tank model and provides additional resources to incorporate groundwater concepts into their classroom.
    - Gives out groundwater models to schools and nature centers (since 2001 over 500 groundwater models have been given out and over 950 educators have received hands-on training in using the model effectively).
- Prepares an annual Report to the Legislature each August.

History and Purpose of the GCC

- 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'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 & Source Water Protection provisions, and many other programs.

FY 2023 Groundwater Coordinating Council Members

- Department of Natural Resources – Jim Zellmer, Chair
- Department of Agriculture, Trade & Consumer Protection – Mark McColloch
- Department of Safety & Professional Services – Bradley Johnson
- Department of Health Services – Mark Werner
- Department of Transportation – Barry Paye
- Geological and Natural History Survey (State Geologist) – Eric C. Carson (acting)
- Governor's Representative – Steve Diercks
- University of Wisconsin System – James Hurley

Subcommittees

Research & Monitoring

- Geological and Natural History Survey – Dave Hart*(Co-Chair) & Mike Parsen*
- Department of Natural Resources – Bill Phelps*(Co-Chair), Aaron Pruitt*
- Department of Agriculture, Trade and Consumer Protection – Ken Potrykus*
- Department of Safety and Professional Services – Tim Vander Leest*
- Department of Health Services – Sarah Yang* & Curtis Hedman*
- University of Wisconsin System – Maureen Muldoon*, Tim Grundl & Jennifer Brand*
- U. S. Geological Survey – Andy Leaf* & Cheryl Buchwald*
- UWSP Center for Watershed Science and Education – George Kraft*

** Member of Standing Joint Solicitation Work Group*

Outreach & Partnership

- Department of Health Services – Sarah Yang (Chair)
- Department of Natural Resources – Bruce Rheineck
- University of Wisconsin System – Moira Harrington
- Department of Agriculture, Trade and Consumer Protection – Mark McColloch
- Department of Safety and Professional Services – Travis Wagner
- Geological and Natural History Survey – Dave Hart
- Department of Transportation – Alyssa Barrette
- Center for Watershed Science and Education – Kevin Masarik
- State Laboratory of Hygiene – Jocelyn Hemming
- Wisconsin Rural Water Association – Andrew Aslesen

Wisconsin Department of Natural Resources

The Wisconsin Department of Natural Resources (DNR) establishes groundwater quality standards for the state, manages groundwater quantity and coordinates the implementation of the groundwater law in order to protect Wisconsin's groundwater and public health.

There are six programs within DNR that manage groundwater. Each program plays an important role in protecting Wisconsin's groundwater quality and quantity. Learn more about each program's work below.

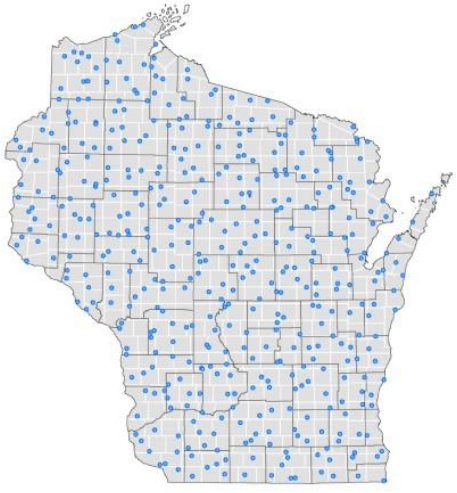
To learn more about groundwater quality and quantity, see the State of the Resource Section of this report. For actions to address groundwater quality and quantity issues, see the Recommendations Section of the report.

Sections in this document

Fiscal Year 2023 Highlights

Highlights include what was new or updated in the last year.

- In June 2022, the DNR began a project to sample for PFAS and other water quality parameters in 450 private wells, spaced apart geographically across the entire state. The main objective of the research study was to determine concentrations of PFAS present in ambient groundwater, that is, groundwater in locations that are not near a known high concentration release of PFAS. Another objective was to evaluate the usefulness of several potential source indicator chemicals, chemicals that might be used to pinpoint what source(s) of PFAS to groundwater may be present in an area. The project was a partnership between the



Wisconsin divided by 450 equal area cells – each cell includes a well tested for PFAS.

DNR, Wisconsin State Laboratory of Hygiene and the Center for Watershed Science and Education at the University of Wisconsin-Stevens Point.

- 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 March 2018, the DNR submitted a list of substances designated "Cycle 10" to DHS. DHS responded with recommendations to DNR in June 2019. Based on comments received during the rule public comment period, DHS has revised their recommendations for Cycle 10 groundwater standards. A plain language summary of each of the compounds in Cycle 10 is available at DHS's Recommended Groundwater Enforcement Standards. The DATCP website contains additional information on the Cycle 10 pesticide compounds. On Feb. 23, 2022, the Natural Resources Board (NRB) considered and did not approve this rule. The scope statement expired on March 3, 2022.
  - The DNR submitted a list of substances designated "Cycle 11" to DHS in April 2019. DHS responded with recommendations to DNR in November 2020. A plain language summary of each of the compounds in Cycle 11 is available at DHS's Groundwater Standards. After the NRB halted work on Cycle 10, DNR paused work on the Cycle 11 NR 140 Groundwater Pollutant Standards.
  - In March of 2022 the DNR proposed a rule to replace the existing total coliform bacteria standards with new state groundwater quality standards for Escherichia coli (E. coli) bacteria. The proposed rule also transitions total coliform bacteria from a public health groundwater quality standard to an indicator parameter. This rule will be published in August 2023.
  - In August 2022 the DNR proposed a to add public health groundwater standards for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Following the EPA's June 15, 2022 issuing of interim HAs for four PFAS the DNR drafted a Statement of Scope proposing rulemaking for these four PFAS. Based on its review of current proposed EPA draft MCLs for PFAS, the department has decided to continue rulemaking for two of the four PFAS listed in the Statement of Scope, PFOA and PFOS.
- In March 2023, DNR updated residents in the Town of Hudson and Warren in St. Croix County about changes in the status of the remediation of TCE in groundwater and provided information on water treatment technology and maintenance.
- In 2022, DNR started accepting applications for the new American Rescue Plan Act (ARPA) Well Compensation and Well Abandonment Grant Programs. The two-year programs will provide $10 million in financial assistance to well owners

to address contamination in their wells by awarding grants for the replacement, reconstruction, treatment or abandonment of their well. The eligibility criteria for both programs have been expanded beyond the previous Well Compensation Grant Program, and many previously ineligible individuals will now be eligible to apply. The expanded eligibility criteria include these changes to the contamination requirements: Any well contaminated with nitrate concentrations at or above the state's public health standard of 10 parts per million (ppm) is now eligible. Previously, only nitrate-contaminated wells with concentrations above 40 ppm that were used as a water supply for livestock were eligible. The program also allows the owners of non-community public wells to apply for grants and for well owners with bacteria that is harmful to human health to get grants to pay for new wells or treatment. In the first six months of the new programs, over $1.5 Million in grants had been awarded to replace over 100 contaminated wells and fill and seal over 40 wells.

- In 2022 over 120 municipal systems voluntarily sampled using EPA Method 537.1 for PFAS in Drinking Water, which detects 18 different PFAS compounds. A report of findings will be created following completion of the program. In addition, effluent at select Wisconsin Pollutant Discharge Elimination System (WPDES) permitted facilities was sampled and the department is also drawing on the examples and experiences of other states as it develops an interim plan to address PFAS that may be present in municipal wastewater treatment facilities' biosolids that are regularly applied to agricultural lands throughout the state. MCLs for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) were published in NR 809 in 2022. The MCL for PFOA and PFOS is 0.000070 mg/L (70 ppt). This level is set for the combined concentration of PFOA and PFOS. Under the Safe Drinking Water Act's fifth Unregulated Contaminants Monitoring Rule (UCMR5) select water systems will be asked to sample for 29 PFAS compounds and lithium. This will begin in 2023.
- Since 2019, DNR has provided technical support to 4 counties to develop DNR and EPA-approved 9 Key Element Watershed Plans that focus, in part, on reducing nitrogen leaching to groundwater from agricultural lands to meet groundwater quality standards and protect drinking water sources. Three counties (i.e., Kewaunee, Door and Adams) have approved plans and two counties (Rock and Kewaunee) are working to develop groundwater focused plans. These watershed plans provide a framework for improving water quality in a holistic manner over a ten-year period. They assess the contributing causes and sources of nonpoint source pollution, involve key stakeholders, and prioritize restoration and protection strategies in critical areas to address water quality problems.

- Certain parts of NR 216 were updated, including specific efforts to finalize concerns raised by the EPA including issues related to legislative authority, to respond to the federal "remand rule" and propose a realignment of the fee structure for construction site erosion control permits. The updated rule was formally promulgated in April 2022.

Ongoing management activities

Ongoing management activities include what each DNR program does to manage and protect groundwater on a regular basis.

Drinking Water and Groundwater (DG) program

- Implement groundwater quality standards to minimize the concentration of polluting substances in groundwater in order to protect public health; this includes adding new and/or revised standards as required by Wisconsin's groundwater law (ch. 160, Wis. Stats).
- Set and enforce minimum standards for well construction, pump installation and well filling and sealing in order to protect groundwater and safe drinking water in private drinking water wells as set forth in ch. NR 812.
- Respond to reports of private well contamination and encourage private well owners to test their wells annually for bacteria, nitrate and other contaminants of concern.
- Develop partnerships and collaborate to reduce nitrate contamination in private wells; including using The Nitrate Initiative and Groundwater & Nitrogen Fertilizer Decision Support Tools.
- Award well compensation and abandonment grants to private well owners to address contamination in their wells.
- Sampling and testing private wells for understanding and managing arsenic contamination in Wisconsin.
- Outlined a Special Well Casing Depth Area and developed well construction guidelines to protect drinking water wells in Winnebago and Outagamie County from arsenic contamination.

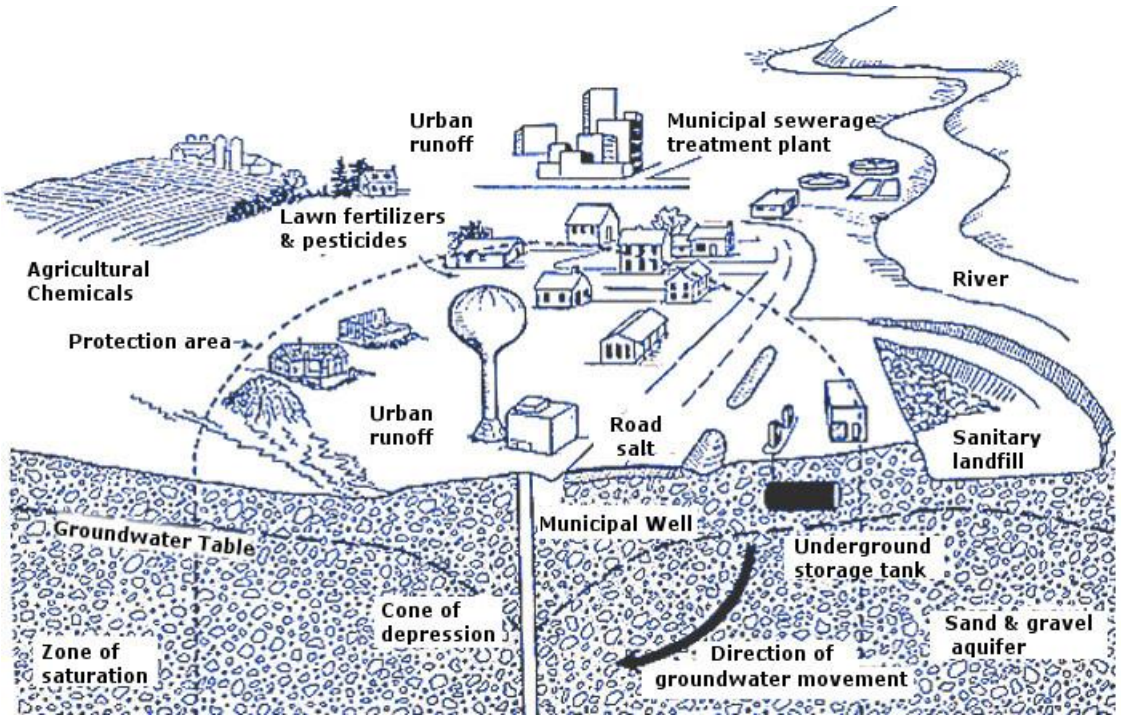
How does the DNR help protect private water supplies?

DG sets and enforces minimum standards for well construction, pump installation and well filling & sealing to help prevent contamination of groundwater. This means licensed contractors are qualified to do their work in a way that meets standards and won't contaminate groundwater, so well owners can feel more confident drinking their water.

- Work with public water system owners and operators across the state to meet groundwater quality and quantity regulations that help provide safe and reliable drinking water supplies as required by ch. NR 809 (Safe Drinking Water), Wis. Adm. Code.
- Regulate 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.
- Educate water system owners and operators to properly operate and maintain the water systems to ensure safe drinking water for Wisconsin consumers.
- Maintain drinking water and groundwater quality data in the Drinking Water System (DWS) database, an important tool used to efficiently enforce the Safe Drinking Water Act (SDWA).
- Work with public water systems on nitrate contamination issues and implementing the PFAS Action Plan.

What is source water and why should we protect it?

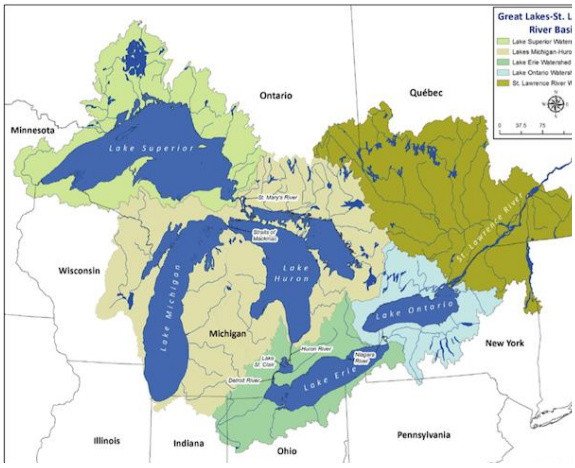
Source water comes from rain and snow that seeps into or flows over the ground before moving into water supply wells or intakes. Activities and facilities on the ground can contribute substances or contaminants that are carried by water flowing to the well. Identifying local priority areas to protect source water prevents contaminants from leaching into groundwater.



- Aid public water systems in implementing the revised total coliform rule (RTCR) so that when bacterial contamination potential is detected by the presence of total coliform, the DNR and water system operators investigate to find the cause, take action to fix it, and monitor to ensure public health protection.
- Coordinate the state's wellhead protection program to safeguard public water supplies at the source to reduce the risk of groundwater contamination in areas contributing groundwater recharge to public water supply wells; 43% of Wisconsin municipal public water systems are protected by a Wellhead Protection Plan (WHP); over 400 communities have a WHP plan for at least one of their wells; and approximately 57% of the groundwater sourced municipally served population is covered by source water protection plans with accompanying implementation ordinances.
- Participate in the state's source water protection program in order to identify and protect local sources of water, such as rivers, streams, lakes, reservoirs, springs and groundwater, that provide water to public drinking water supplies and private wells.
- Regulate high capacity wells under ch. 281, Wis. Stats.
- Analyze high capacity wells applications on a case-by-case basis; the analysis considers both the needs of the property and the environmental effects that the proposed high capacity well, when combined with existing environmental impacts, may have on waters of the state.
- Work with neighboring states to protect and manage the water of the Great Lakes through the Great Lakes Compact.
- Implement Compact-related programs including authorizing permits and approvals, implementing the water conservation and efficiency program, reviewing diversion applications and working in conjunction with groundwater quantity staff to collect annual water withdrawal reports.

What is the Great Lakes Compact?

The Compact is a formal agreement between the Great Lakes states which details how the states will work together to manage and protect the Great Lakes-St. Lawrence River Basin - the world's largest source of surface fresh water. This is one of North America's most important natural resources and must be protected. As part of the Compact, DNR registers water withdrawals, receives and analyzes water use reports, requires water use permits, implements a conservation program and manages Great Lakes diversions.



- Manage the Groundwater Retrieval Network (GRN), an application that consolidates and delivers well information and groundwater quality data from over 800,000 wells, including public and private water supply wells, piezometers, monitoring wells, non-potable wells and groundwater extraction wells.
- Commits $100,000 annually to help operate and maintain the Wisconsin Groundwater Level Monitoring Core Network (with USGS and WGNHS since 1946), monitoring wells that provide data about the history of water levels in an area or aquifer.
- Support groundwater monitoring studies evaluating existing design and/or management practices associated with potential sources of groundwater contamination.
- Educate teachers and students on the importance of protecting groundwater in their own communities, including working with the Groundwater Center at the Center for Watershed Science and Education (CWSE) and WGNHS to sponsor two groundwater workshops for teachers every year since 1994.

Did you know?

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

- Provide hydrogeologic advice to DNR programs, contractors and the public including: training new staff in runoff management and drinking water programs on the implementation of groundwater quality standards; training for land spreading discharge permit writing and animal waste drinking water well contamination response; consulting 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.
- Staffs the Groundwater Coordinating Council.

Office of Emerging Contaminants (OEC) program

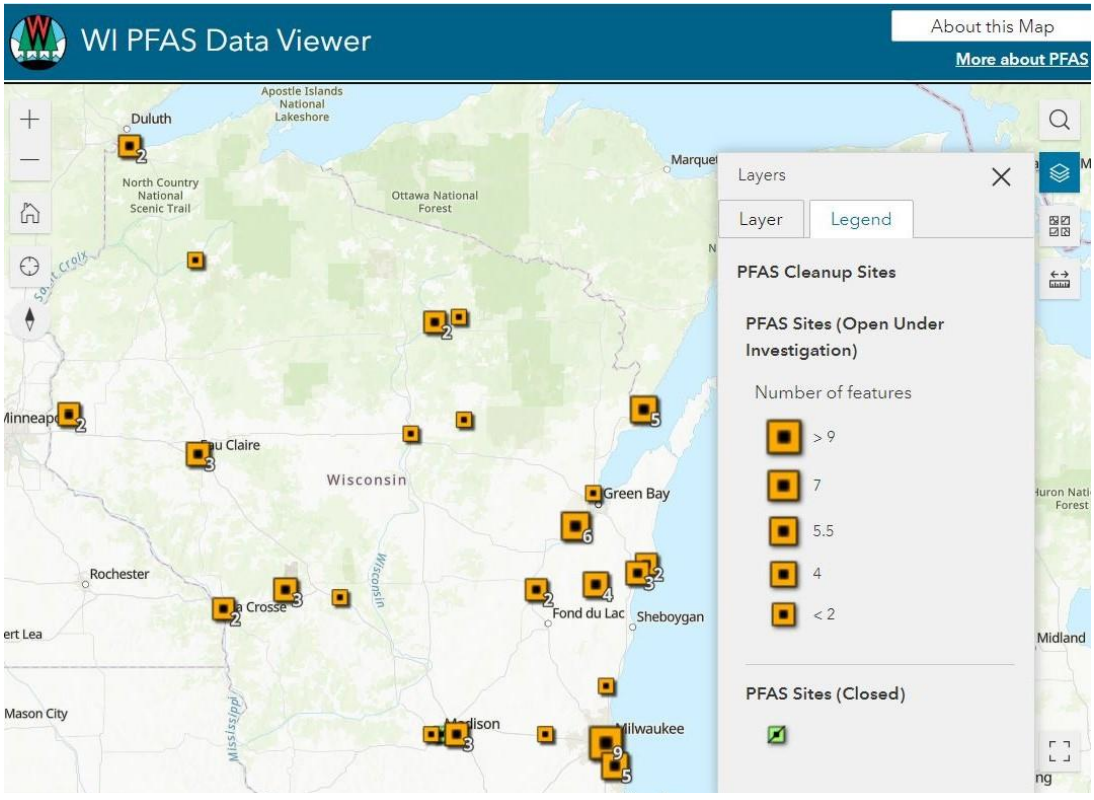
- Coordinate cross-program, division, and agency work around environmental contaminants and emerging topics, including PFAS.
- Staff the Wisconsin PFAS Action Council (WisPAC), a group of ~ 20 state agencies working to address PFAS contamination in the state; and staff

additional advisory bodies such as the PFAS External Advisory Group and the PFAS Technical Group to help foster ongoing discussion and collaboration with stakeholders.

- Monitors and advises on the implementation of the PFAS Action Plan, including sampling and ongoing monitoring, development of new methods and science-based standards and enhanced risk communication infrastructure and resources.
- Coordinates with and provides technical assistance to stakeholders across the state, including the firefighting community, through the development of best management practices, FAQs, and other resources related to Wis. Stat. 299.48 and ch. NR 159 regarding the prohibition of use to help prevent future contamination of Wisconsin's groundwater.

Where are PFAS impacting Wisconsin?

The PFAS Interactive Data Viewer allows users to see data about where PFAS impact Wisconsin.



Remediation and Redevelopment (RR) program

- Implements and aids cleanups under the Spill Law, the Environmental Repair Law, federal programs (Superfund, Hazardous Waste Corrective Action, Leaking Underground Storage Tanks (LUST)), brownfields properties, the Drycleaner

Environmental Response Program, contaminated sediments and at closed landfills.

- Provides technical assistance, financial assistance, technical project oversight of cleanup projects, and helps clarify legal liability.
- Helps with spill response and works with other agencies for conducting major spill response actions and removal of hazardous substances.
- Assists the EPA with the remediation of contaminated sediments in the Great Lakes areas of concern through execution of cooperative funding agreements. In 2022, the RR Program oversaw projects with a state cost share of $1.8 million and a total value of $42.3 million.
- Uses Environmental Fund dollars to initiate or continue environmental assessment and cleanup actions at sites with groundwater contamination across the state, including several closed landfills and manufacturing facilities.
- Provides temporary, emergency water to private well users affected by groundwater contamination. In 2022, the RR Program assisted almost 1500 affected residences at a total cost of $556,000.

Where are the Great Lakes areas of concern?

- Coordinates several efforts to encourage local governments and private businesses to cleanup and redevelop brownfield properties (properties where the release of hazardous substances threatens groundwater quality). This includes securing federal funding to assist local governments with assessment and cleanup. In 2022, the RR Program was awarded $2 million in U.S. EPA brownfields assessment funding to assist local governments with projects and to address high-risk VOC sites in environmental justice areas.
- Manages the Dry Cleaner Environmental Response Fund (DERF) Program to reimburse dry cleaner owners/operators for eligible costs associated with the cleanup of soil, groundwater and indoor air contaminated by dry-cleaning solvents.

- Manages the Bureau of Remediation and Redevelopment Tracking System (BRRTS), a database that includes: information on open remediation sites; sites closed with no residual contamination; sites closed with residual groundwater contamination above the ch. NR 140 enforcement standards; sites closed with soil contamination above ch. NR 720 soil standards; sites closed with other engineering or institutional controls; legacy sediment sites; and brownfields properties.
- Maintains BRRTS on the Web (BOTW), a web-based version of BRRTS that provides information to future owners or users of the property; well drillers; community members; and other interested parties of the existence of contamination, as well as any responsibilities the property owner (or occupant in some cases) is required to comply with as a condition of closure.
- Manages RR Sites Map, a web-based mapping system that is linked to BRRTS on the Web and is useful for locating potential contaminated sites when evaluating new municipal or private well placement.

Waste and Materials Management (WA) program

- Regulates and monitors groundwater quality at proposed, active, and inactive solid waste facilities and landfills.
- Reviews baseline groundwater data submitted by landfill applicants to determine whether exemptions and alternative concentration limits (ACLs) to established ch. NR 140 groundwater standards are needed to meet public health and welfare parameters.
- Checks required landfill groundwater detection monitoring data, collected and submitted by the landfill owner at sites (both active and closed) to determine compliance with ch. NR 140 standards and site specific ACLs and PALs.
- Audits results of site investigations triggered by exceedances of groundwater standards and evaluates the effectiveness of remedial actions at active solid waste facilities and closed landfills.

Is the groundwater near landfills contaminated?

WA staff check required landfill groundwater monitoring data to determine if the water is meeting standards. Pictured: Dane Co. Landfill

- Provides public access to environmental monitoring data contained in the Groundwater and Environmental Monitoring System (GEMS) through GEMS on the Web. Places landfill locations on a GIS mapping program called the WA Sites Viewer, which includes delineating waste boundaries and locating monitoring wells where known. This information is shared with the DG Program and licensed well drillers to aid well drillers in siting a water supply well. This GIS program has been an important tool for increasing compliance with the 1,200-foot setback requirement to a landfill and for the NR 812 well variance application requirement if the setback cannot be met.

Water Quality (WQ) program

- Issues discharge permits to facilities, operations and activities that discharge treated wastewater and residuals to groundwater when groundwater standards are met.
- Administers 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).
- Evaluates WPDES permits for groundwater monitoring and data submittal requirements to ensure compliance with groundwater quality standards.
- Maintains the System for Wastewater Applications, Monitoring, and Permits (SWAMP), for holders of specific WPDES and general permits that stores facility-specific information, permit requirements, monitoring results and violations of permit requirements for private and municipal wastewater treatment facilities.
- Manages current information on groundwater, wastewater and biosolids treatment and management, as well as historical sampling data from groundwater monitoring wells through SWAMP. Sampling results and site loading information are also available for land application of municipal biosolids, septage and industrial sludge, by-product solids and wastewater.
- 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.
- Issues WPDES general permits to a group of facilities with similar low-flow nondomestic wastewater, domestic wastewater, or mixed wastewater discharges to a subsurface soil absorption system pursuant to s. NR 205.08, Wis. Adm.

Code (except that DSPS permits subsurface soil absorption systems receiving domestic wastewater flows < 12,000 gal/day design flow).

- Review facility operating conditions (e.g. flow volume and pollutants), site restrictions and setback distance requirements of the systems to determine if the facility is applicable to be covered under the general permit; reviews and approves proposed new or modifications to these systems pursuant to s. 281.41, Wis. Stats.
- Reevaluates renewals every 5 years to determine if the facilities are still eligible for coverage under the permit and reviews land use changes that may have occurred. These review processes and permit required monitoring allow for tracking protection of groundwater quality and public health and could also identify future concerns and permit needs.
- Regulates the land application of organic industrial wastes, municipal biosolids and septage (chapters. NR 214, 204, and 113) through:
- Implementing 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.
- Reviews and approves land spreading sites and requirements on locations, loading rates, nutrient levels and time of year. Uses SWAMP and LAG databases to manage recording and monitoring 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. The site evaluation and approval process includes providing maps to the land application entities land applying septage, sewage sludge and industrial land applied wastes that show clear boundaries for approved areas to further protect surface and groundwaters.
- NR 113: Licenses septage businesses and provide compliance inspection of these businesses relating to servicing and disposing which includes additional treatment at wastewater treatment facilities or landspreading for beneficial use of nutrients and carbon replenishment in soils.
- NR 204: Governs treatment quality, use and disposition of municipal wastewater treatment plant sludge including additional treatment at other wastewater treatment facilities or beneficial reuse to capture nutrients and other soil amendments including liming and carbon replenishment in soils.
- NR 214: Regulates the land application of industrial sludge, liquid wastes and by-product solids. Reviews the beneficial use and disposition of industrial wastewater residuals such as liquid wastes, by-product solids and sludges for

beneficial reuse to reuse nutrients and other soil amendments including lime and carbon replenishment in soils.

- Encourages land spreading entities to provide for more storage capacity to minimize winter and spring runoff to surface water. Affirmed code requirements to ensure older structures meet the standards needed to assure storage is environmentally sound and protective of both groundwater and surface water.
- Helps create better training tools and compliance training in the area of septage management. Septage operator certification code changes (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 offered through associations, county updates and stand-alone classes.
- Inter-division work with the Bureau of Law Enforcement continues to increase as the industry continues to explore more options for waste disposal and re-use; unfortunately, many of these options for waste disposal can cause significant harm to waters of the state so continued enforcement efforts are necessary to deter further significant environmental harm.
- Offers a zero percent Clean Water Fund loan for the planning and construction of receiving facilities and additional capacity provided for septage to provide an incentive for more wastewater treatment plants to accept and treat septage (Wisconsin Act 347).

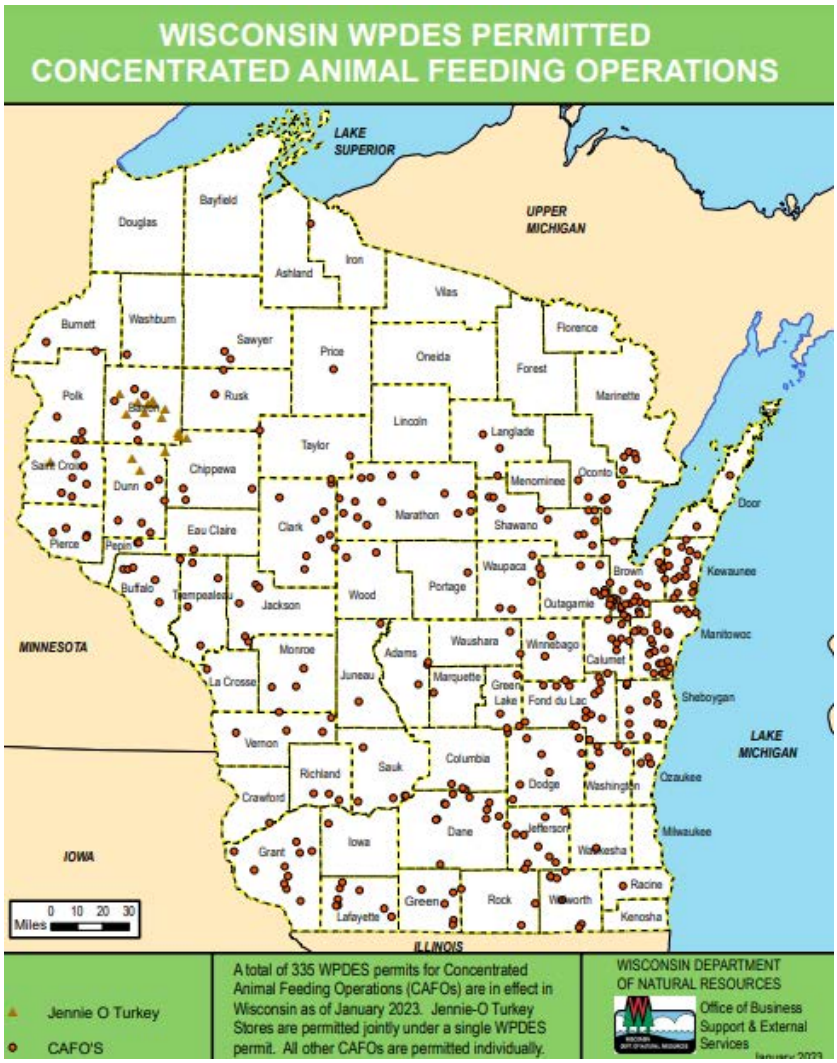
Watershed Management (WT) program

- Manages waste from large animal feeding operations (CAFOS) by issuing discharge permits (ch. NR 243). WPDES permit requirements protect surface water, groundwater and wetlands.
- Reviews nutrient management plans submitted as part of the issuance of WPDES permits for CAFOs that 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 protections include setback requirements from community/non-community public wells and karst features, and winter restrictions of manure applications.
- Carries out compliance and enforcement activities at CAFOs using policies, codes, and guidelines intended to meet groundwater and surface water quality standards. At the end of 2022, there were 334 permitted CAFOs; the trend of growing numbers of permit applications for large-scale livestock operations is expected to continue.

- Promotes groundwater protection through the implementation of agricultural performance standards and prohibitions in ch. NR 151; the issuance of Notices of Discharge under ch. NR 243; and response to acute manure related groundwater impacts (e.g., well contaminations).
- Implements requirements for all crop and livestock producers to create and implement nutrient management plans through NR 151.07 and ATCP 50.04(3), which requires cost sharing in many situations.

Do CAFOs have to have permits in Wisconsin?

Yes, CAFOs with 1,000 animal units or more must have a DNR-issued Wisconsin Pollutant Discharge Elimination System (WPDES) permit to operate. Below is a map of WPDES permitted CAFOs. As of January 2023, there were 334 WPDES permits for CAFOs in effect in Wisconsin.



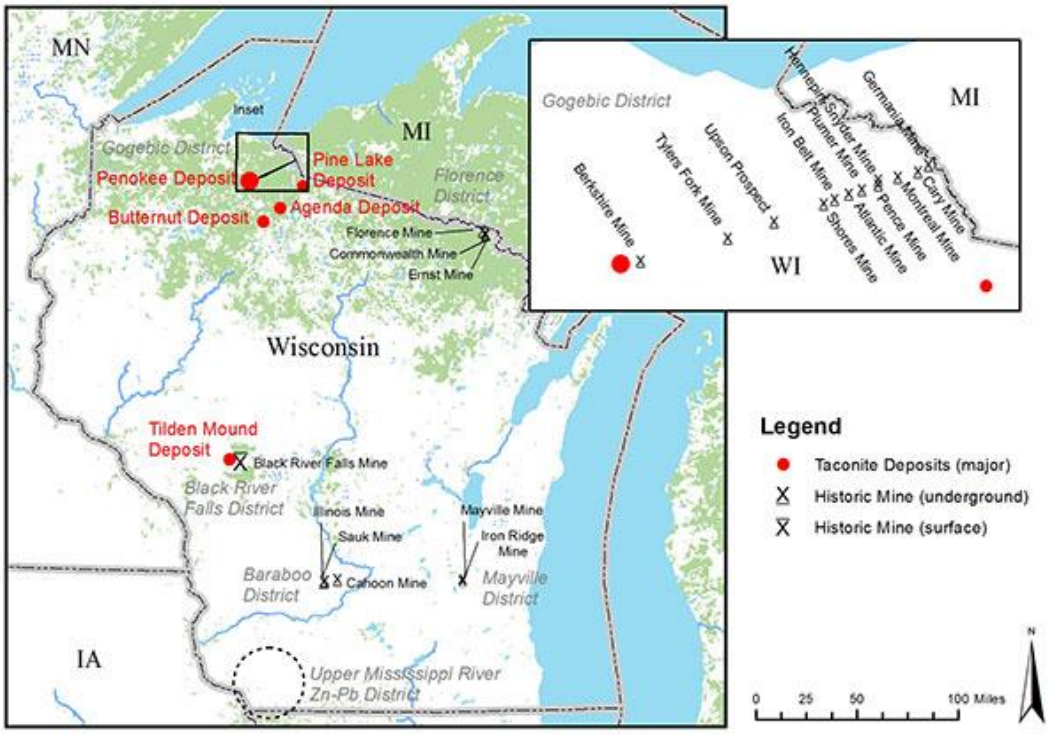
- Supports maintenance of technical resources and expertise to implement nutrient management plans (NRCS Standard 590), including development and dissemination of the field-based Soil Nutrient Application Planner software (snapplus.wisc.edu) in cooperation with the University of Wisconsin, DATCP and Wisconsin NRCS.
- Administers Nonpoint Source grants, such as Targeted Runoff Management and Notice of Discharge grants, that provide financial assistance to agricultural and urban landowners in targeted watersheds that are critical to addressing groundwater and surface water quality issues.
- Avoid increasing pollutants in groundwater from contaminated storm water. Issues permits to dischargers of contaminated storm water.
- Regulates storm water discharges as required under the federal Clean Water Act (ch. NR 216, Wis. Adm. Code); including: permits for about 245 municipalities in Wisconsin to control polluted runoff that may enter their municipal separate storm sewer systems (MS4s); 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 permits for certain industrial facilities to address potential contamination of storm water from outside activities and outdoor storage of materials.
- Developed runoff performance standards for MS4s and construction sites that are implemented through the storm water permit program.
- Issued the first MS4 general permit for municipal storm water discharges in 2006. The permit was reissued in 2014. In 2020, six general storm water permits expired requiring revisions and reissuance.
- The urban runoff team worked extensively with internal staff, external stakeholders and the EPA to develop general permits that meet the standards of the Clean Water Act and Wisconsin Statues in compliance with the department's Environmental Analysis and Sustainability (EAS) program delegated Wisconsin Pollutant Discharge Elimination System (WPDES) authority.
- Regulates metallic mining activity in the state, including monitoring groundwater quality around these mines.
- Determines whether a proposed mining project receives necessary approvals; issues related to groundwater quantity and quality are critical in making this determination.
- Approves ferrous mining projects according to ch. 295, Wis. Stats. The regulatory framework for ferrous mining projects includes provisions related to

groundwater withdrawals, mining waste site design and operation and protection of groundwater quality.

- Checks for compliance with existing groundwater quality standards according to the non-ferrous mining projects statute, ch. 293, Wis. Stats. which establishes point of standards application and evaluation processes and criteria that are unique to ferrous mining projects.

Where are mining projects in Wisconsin?

Iron deposits in Wisconsin that are currently being explored for mining or were the sites of historical mines.



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 2023 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 223 groundwater and 150 surface water samples for more than 100 pesticide compounds and nitrate plus nitrite as nitrogen in 2022.
- Created a Commercial Nitrogen Optimization Pilot Program (NOPP) designed to encourage agricultural producers to develop innovative approaches to optimize the application of commercial nitrogen for a duration of at least two growing seasons, helping to protect vital soil and water resources. Awards totaled $1.6 million and were granted to 20 producers who will collaborate with a University of Wisconsin (UW) System institution conduct commercial nitrogen optimization field studies.
- Provided cost-sharing for the installation and implementation of 1,016 conservation practices in 2021. These practices provided soil erosion control and helped manage manure and nutrients.
- Continued the ATCP 50 rule revision to incorporate DATCP 01 Technical Standard Verification of Depth to Bedrock into rule. The technical standard outlines the process for 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.
- In partnership with Wisconsin Geological and Natural History Survey, began using the 2022 airborne electromagnetic (AEM) survey of karst bedrock features to

develop updated maps that identify the 5 foot and 20 foot depth to bedrock in the Silurian dolomite area of northeast Wisconsin.

- Awarded grants to 43 producer-led groups for FY 2023, totaling $1,000,000.
- Continued a project to track estimated water quality outcomes and analyze benefits of conservation adoption in 13 of the 33 Producer-Led groups.
- Awarded $200,690 to 19 participants in the Nutrient Management Farmer Education grants for 2022. These grants go 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.

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, fungicides, 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 Resources Bureau's programs, DATCP assists in the protection of water resources through nutrient management and related conservation practice implementation. The DNR's NR 151 rule on runoff management establishes

agricultural performance standards intended to protect both groundwater and surface water. DATCP identifies the practices and procedures to implement and enforce compliance with these standards, including nutrient management. The nutrient management rules apply to all Wisconsin farmers who engage in agriculture and mechanically apply nitrogen, phosphorus, or potassium (N-P-K) nutrients from manures or commercial 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 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 N-P-K applied, and planned to be applied, to each field over the crop rotation, and identifies all crop management practices for each field.

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

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

2022 NMP Numbers	
NM Plans Reported	7,599
NM Acres Reported	3.45 million
Percent of WI Cropland Covered by NMP	37%
Farmer-Written Plans	1,708

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 2022, 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 supported several projects through the innovation grant program. This funding provides small amounts of financial assistance to support a new concept within a county. The allocation also provided $200,690 in grants for farmer training (Nutrient Management Farmer Education grant program), and just over $880,000 to support partners, including the University of Wisconsin System institutions, 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 $3.7 in GPR funds and $7.3 in SEG funds "for support of local land conservation personnel under the soil and water resource management program." DATCP's 2022 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 2022.

Funding Category	**Total Requests**	**Unmet Requests**	**Final Allocations**
County Staff/Support	$18,286,738	$7,256,738	$11,030,000
County LWRM Cost-Share (Bond)	$7,374,500	$3,934,726	$3,439,774
Bond Cost-Share Reserve (Bond)	$300,000	$0	$300,000
LWRM Cost-Share (SEG)	$2,846,439	$656,000	$2,190,439
Project Contracts (SEG)	$1,137,055	$251,716	$885,339
NMFE Training Grants (SEG)	$206,340	$0	$206,340
Innovation Grants (SEG)	$494,282	$226,400	$267,882
Total	**$30,645,354**	**$12,325.580**	**$18,319,774**

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

The RRAF provides Wisconsin's farmers with an innovative decision support tool which communicates the threat of undesirable conditions for manure and nutrient spreading for up to 10 days in advance. The system uses data outputs from the National Weather Service including snow accumulation and melt, soil moisture content and temperature and

forecast precipitation to create and display maps that provide the runoff risk for a 72-hour period. The 590 Restriction maps are available statewide to assist farmers in making sound decisions about how and where to apply nutrients on their cropland. The mapped data used to create the restriction maps are also available for GIS-users to download into their own mapping applications. All of these tools can be accessed at http://www.manureadvisorysystem.wi.gov.

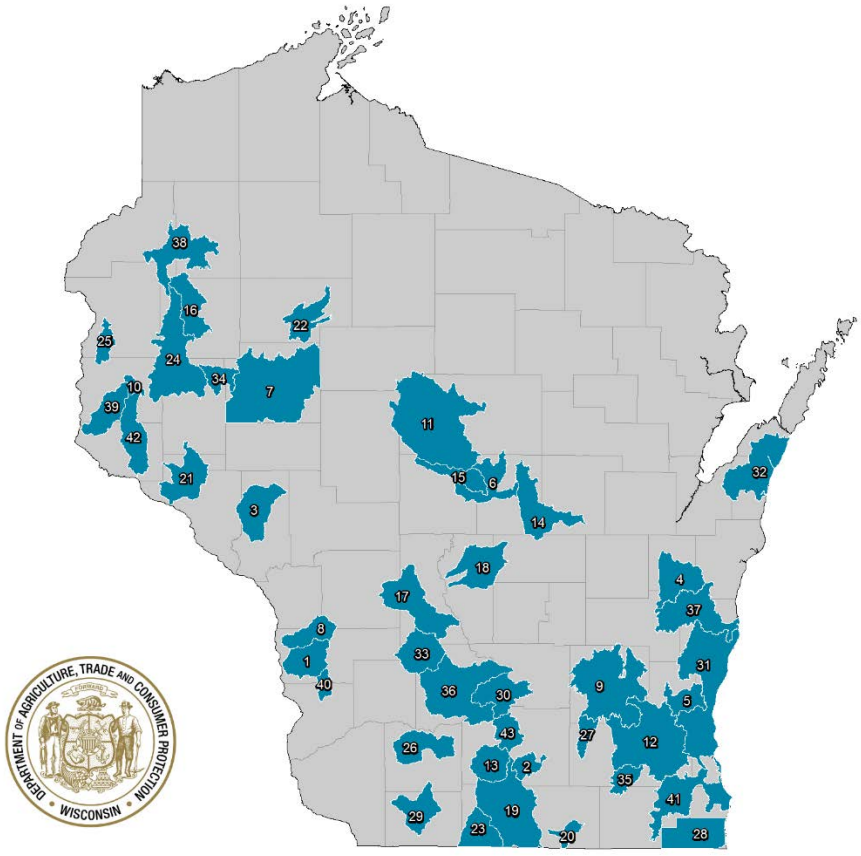
In 2018, DNR adopted a new targeted performance standard to reduce the risk of pathogen contamination to groundwater (NR 151.075). This new standard restricts manure application in designated areas where the bedrock consists of Silurian dolomite with a depth to bedrock of 20 feet or less. DATCP is responsible for the implementation of performance standards in NR 151 and in July 2021 adopted a technical standard to support the implementation of the performance standard called the Wisconsin DATCP Technical Standard 01 Verification of Depth to Bedrock. ATCP 50 is currently under revision to adopt the technical standard into administrative code so that it can be used.

In 2020, DATCP contracted with the U.S. Geological Survey (USGS) to update depth to bedrock maps of the Silurian/Karst bedrock region of northeastern Wisconsin. Current depth to bedrock maps are based on limited data and professional judgement, often from over 40 years ago. This project collected airborne geophysical data that encompasses selected areas of interest in Northeastern Wisconsin and focuses on the 5 and 20ft depths identified in the targeted Silurian bedrock performance standard. The data was collected using airborne electromagnetics, or AEM, which is a geophysical technology originally developed for use in the mining industry to locate and map ore bodies but more recently used to map groundwater resources. This work provided accurate, belowground properties that are otherwise difficult to assess and made public vital information for local water users and managers, farmers, conservation staff and agronomic professionals to better understand their groundwater resources and aquifer systems. The Wisconsin Geologic and Natural History Survey is using the data collected as part of the AEM Survey to update existing maps in 2023.

Program to Address Agricultural Nonpoint Contributions (ATCP 52)

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

Producer-Led groups focus on nonpoint source abatement activities which benefit both surface and groundwater quality. The program-wide 2022 Cover Crop and No-Till Analysis shows that farmers in the program planted 112,936 acres using no-till technology, a 35% increase from 2021, and 127,324 acres of cover crops, a 27% increase from 2021. Combined, these practices resulted in an estimated reduction of 218,480 tons of soil loss from occurring, 154,367 pounds of phosphorus from leaving farm fields, and 61,214 tons of carbon dioxide equivalents of soil greenhouse gas emissions. More information about this project can be viewed at our website: DATCP Home Producer-Led Tracking Project (wi.gov).



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 2022, 82 grants were issued: 28 for agricultural waste, 41 for household hazardous waste and 20 for the collection of unwanted prescription drugs. Farmer and agricultural participation in collection events brought in just under 75,000 pounds of agricultural waste

in total. Farm participation can vary greatly depending on the weather or the frequency of collections within a county. Some counties hold a farm collection every other year or every few years. Farm participation for 2022 appears to be lower than the long-term average agricultural waste collected, which has historically ranged between 100,000 and 150,000 pounds collected annually. Many counties report declining collections as more farmers are using custom application and pesticides are becoming more concentrated. Much of the old stockpiled pesticides were collected during the early years of the program. However, Clean Sweeps still see old, banned or cancelled pesticides, disposing of nearly 2600 pounds of chemicals like DDT and chlordane. The canceled events due to safety concerns from COVID-19 during 2021 contributed to the slight increase in the amount of waste counties took in, as residents had to stock pile their waste for an extended period of time.

The amount of household hazardous waste collected in 2022 was about 3.2 million pounds, compared to 2 million pounds collected in 2021. This increase in the amount of household hazardous waste is likely attributed to the canceled events stretching back to 2020 leading residents to stockpile waste until their next Clean Sweep event. The "Safer From Home" initiative implemented due to COVID-19 in 2020 gave residents the opportunity to remove hazardous waste from their homes and already disposed of the hazardous waste via 2020 Clean Sweep, resulting in less waste product to be collected in 2021. Latex paints remain the most common waste collected from households, followed by solvents/thinners, lead/oil paint, and pesticides/poisons as the fourth most collected waste brought in for disposal.

Wisconsin residents also turned over unwanted prescription drugs at various collection events or through permanent drug drop boxes located in law enforcement offices throughout the state Drug collections netted just under 23,000 pounds of unwanted pharmaceuticals, a decrease of about 12,000 pounds from the previous year. Again, the increase may be due to cancelled collection events or limited disposal opportunities as a result of health and safety concerns with COVID-19. Drug collections supported by clean sweep grants are only a portion of the drug drop boxes and take back events in the state. The Wisconsin Department of Justice also coordinates and pays for the collection and disposal of unwanted drugs. The pharmaceuticals collected through Clean Sweep projects are included in this program.

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

Since 1993, the Agricultural Chemical Cleanup Program (ACCP) addresses point sources of contamination and reimburses responsible parties for a portion of cleanup costs related to pesticide and fertilizer contamination. To date, 790 cases involving soil and/or groundwater remediation related to improper storage and handling of pesticides and fertilizers have been initiated at storage facilities. Over this same time period DATCP assisted cleanups at more than 1,700 acute agrichemical spill locations. The ACCP has

received 1,702 reimbursement applications totaling over $50.3 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. Starting in March 2023, DATCP initiated an additional statistically random sampling survey of private wells across the state. This survey is currently in progress and is expected to be completed by September 2023. The results of the survey are anticipated to be published in early 2024. The final report will also provide a comparison of pesticide and nitrate results to the 2016 statewide random survey. Publications of DATCP surveys are available on the web at: https://datcp.wi.gov/Pages/Programs_Services/GroundwaterReports.aspx.

Research Funding

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

Recently completed research projects funded by DATCP include:

- Assessment of Pesticide Contamination in Suburban Drinking Water Wells in Southeastern Wisconsin
- Aerial Thermal Imaging Applied to Wisconsin's Groundwater, Springs, Thin Soils, and Slopes
- Integrative Monitoring of Neonicotinoid Insecticides in Baseflow-Dominated Streams on the Central Sand
- Sublethal Effects of Chronic Exposure to Neonicotinoid Pesticides on Aquatic Organisms
- Advancing the Use of Nitrate Findings to Inform Groundwater Protection and Improvement Strategies
- Neonicotinoid Contaminants in WI Groundwater: Relationships to Landscape Cropping Systems

Titles of ongoing projects funded by DATCP include:

- **Geophysics-informed Transport & Shallow Bedrock Topography in Northeast and Southcentral WI Counties**. Report anticipated July 2023.
- **Neonicotinoid Groundwater Leaching Potential from Potato and Management Impacts at Field Scale.** Report anticipated September 2024.

- **On-farm Research and Local Partnership to Reduce Nitrate Loading From Agriculture in Pepin County**. Report anticipated February 2025.

In June 2023, DATCP will begin funding one new two year project to further improve our understanding on neonicotinoid and nitrate transport behavior. The project, titled *Understanding the quality and rate of recharge on uncultivated landscapes under natural and enhanced conditions,* will investigate the effects of natural and enhance recharge on the leaching of nitrate and neonicotinoids into groundwater.

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 69,000 wells and over 1,000,000 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.

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Wisconsin Department of Health (DHS)

FY2023 Highlights

- The Groundwater program assisted the Department of Natural Resources (DNR) in FY2023 in a project to sample public water systems and private wells across the state for per and polyfluoroalkyl substances (PFAS).
- Multiple DHS programs, including the Groundwater program and the Site Evaluation program, provided technical assistance and health education related to more than a dozen groundwater contamination sites in Wisconsin. In FY2023, these programs addressed PFAS contaminants at several locations within the state (e.g., Marinette, La Crosse, Eau Claire, Wausau, Peshtigo, French Island, Madison, Rhinelander, Town of Stella). The Site Evaluation program also assessed groundwater contamination at other sites for polycyclic aromatic hydrocarbons; benzene, toluene, ethylbenzene, and xylene (BTEX) compounds; and several chlorinated volatile organic compounds (VOCs).
- Wisconsin's Environmental Public Health Tracking program released a request for applications in FY2023 for local and tribal health departments (LTHDs). 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. Five LTHDs were funded and two of these projects focused on water quality, specifically testing of nitrates in private well water and improving access to private well testing. In addition, Wisconsin Tracking will be working with the DNR and two LTHDs to streamline data flow of private well water results to the DNR.
- The Climate and Health program (CHP) and Wisconsin Sea Grant piloted the Flood Resilience Scorecard (FRS) during the pandemic in summer 2020 to evaluate the City of Washburn's flood vulnerabilities. FRS is a comprehensive tool designed to help communities identify what makes them most vulnerable to flooding and what actions they can take to increase their resilience. FRS has been published online and is available for use. CHP will continue to evaluate flood vulnerability using FRS in 2023 to improve local flood resilience and health equity in Wisconsin communities. CHP also continued to promote its Risk Assessment Flood Tool (RAFT), an interactive flood planning and response map, to LTHDs and flood and emergency management professionals. DHS flood planning and response tools can help identify flood-prone areas of the state and identify populations at greatest 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 information on water quality and human health implications of groundwater and drinking water contamination 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 who have 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 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

Working with Partners to Address Drinking Water Concerns

DHS' Groundwater and Drinking Water program works with other DHS programs to support state, local, and community partners in response to groundwater contamination issues.

In FY2023, DHS' Groundwater and Drinking Water program assisted the DNR Groundwater Section in a project to sample private wells across the state for per and polyfluoroalkyl substances (PFAS) by drafting joint results letters and sharing these letters with the appropriate health department as results for PFAS and non-PFAS analytes became available. In total, we shared 934 letters with our local health partners.

The DHS' Groundwater and Drinking water section worked with other DHS programs and the DNR Groundwater section to respond to a PFAS Plume around the Town of Stella in Oneida County. The DHS worked to provide health guidance to residents and helped raise awareness for the ARPA Well Grant for the DNR.

Additionally, DHS' Groundwater and Drinking Water program worked with DNR's public water program on a project to voluntarily sample public water systems across the state for PFAS. The program worked to develop public notice language for systems with high levels of PFAS. In total, 140 systems were sampled and PFAS detections were observed in 33% of them, with five systems having exceedances. The DHS worked with the DNR to respond to the exceedances.

The Groundwater program also interacts directly with members of the public to address issues affecting their drinking water and increase public awareness of groundwater and drinking water health issues. In FY2022, the Groundwater program provided advisory letters to residents with concerns about their water quality on hazards including copper, manganese, and sodium.

Environmental Cleanups

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

In FY2023, PFAS was a major focus of our work within these programs. DHS supported DNR in a voluntary municipal PFAS testing program that took place through spring and summer 2022 as well as a statewide private well survey in fall of 2022 and continues to play a supporting role in the interpretation and response and serves as a liaison to local public health for the ongoing PFAS regulatory testing. The team routinely provided technical assistance to concerned citizens, impacted water systems, and contamination sites through the assessment of multiple interconnected exposure pathways, including groundwater, surface water, and biota (such as fish or deer consumption), providing appropriate recommendations to reduce or halt exposure to reduce PFAS levels in the body.

The Site Evaluation program has worked on multiple emergency responses that had potential impact to drinking water or groundwater, including the Menominee, Michigan Warehouse Fire and a wildfire in Necedah that impacted an abandoned junk yard. In both cases, rapid assessments of groundwater and drinking water were necessary to determine whether there were impacts to drinking water.

Beyond PFAS, the Site Evaluation program has also worked to assess groundwater contamination at several other sites across the state. These assessments included evaluating exposure pathways; performing hazard assessments; and mitigating risk for PAHs, BTEX compounds, and chlorinated VOCs such as TCE, PCE, and 1,2-DCA through risk communication. For example, in St. Croix, DHS staff attended a public listening session in a large special well casing area due to TCE concerns, where appropriate filtration and filter maintenance practices were discussed.

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

DHS continuously seeks to provide data and resources to LTHDs to assist them in making public health improvements in their communities. In FY2023, Wisconsin Tracking released a request for applications (RFA) to LTHDs for the seventh round of funding for the *Taking Action with Data* mini-grants project. Five LTHDs were funded through this mini-grant opportunity and two projects focused on water quality. LTHDs often select private well water quality as a topic they wish to address within their jurisdictions, as this is a significant concern in Wisconsin. Columbia County's project aims to increase education and testing for nitrates in private well water, while Eau Claire is working on improving rural access to well water testing through courier pick up. To learn more about prior mini-grant LTHD success stories, please see our *Environmental Public Health Tracking webpage*. We will release the RFA for our eighth round of funding in June 2023.

Wisconsin Tracking and other DHS staff provide ongoing support, technical assistance, and guidance to LTHDs on epidemiology, communications, and evaluation throughout the project period. LTHDs carry out their projects with support and assistance from the Tracking program as needed. Some examples of technical assistance we provide to LTHDs include sharing summaries of past projects focused on water topics completed by grantees; reviewing and providing feedback on surveys and data visualization; and assisting in their writing of project success stories.

One of the requirements to apply for mini-grant funding is for LTHDs to use data we have on our Environmental Public Health Tracking program's *public data portal* or in our County Environmental Health Profiles. The *2023 Profiles* were recently released and provide a county-specific sampling of data available on our portal in a PDF document. Private well water quality (arsenic and nitrate) is included in the Profiles. In spring 2022, Wisconsin Tracking successfully applied for a competitive grant to the Centers for Disease Control and Prevention (CDC). We were awarded funding for the next five years to continue the work our program started in 2002. The CDC is currently focused on data modernization as an essential component in the improvement of public health and our program is incorporating that into our workplan.

Climate and Extreme Weather Vulnerability Assessment

The DHS Climate and Health program (CHP), funded by the CDC, works to enhance statewide capacity to prepare for and respond to the public health impacts of climate change, including impacts to private wells from heavy rainfall and flooding events.

Gaps identified previously by the Wisconsin Climate and Health Profile Report have led to the development of several flood-related resources and tools over the past grant cycles. Projects have been developed with the goal of enhancing

understanding of flood risks in watersheds, populations vulnerable to flooding events, and identifying how to increase community resilience in flood prone areas. Flooding events can have negative effects on groundwater quality and public health. These effects can include well contamination and impacts to aquifers due to 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, and several LTHDs. The findings from these flood-related projects have helped inform LTHDs and local emergency management planning processes.

The CHP is continuing to promote and evaluate flood-related tools to help LTHDs, local emergency management, tribal emergency management, and municipal government officials and planners better understand flood vulnerability in Wisconsin:

- A Flood Resilience Scorecard has been published as a document online and is currently available in an interactive format. The tool has been created to aid communities at the municipal and county level 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 ultimately reduce the negative health impacts from flooding events. CHP hopes to continue to conduct outreach and evaluate the scorecard.
- The Wisconsin Flood Toolkit has been recently 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 has also been translated into Spanish.
- A third flood-related tool was launched in March 2019 and is undergoing continuous updates. The Risk Assessment Flood Tool (RAFT) provides an online customizable graphic interface for assessing a community's higher risk areas during flood events by overlaying critical infrastructure and vulnerability data with live river gage data from National Oceanic and Atmospheric Administration (NOAA). RAFT assists local emergency management, local emergency preparedness, tribal health centers, and local public health agencies in planning and preparing 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 operating and decommissioning 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. In addition, the EM program will monitor the decommissioning of Kewaunee Power Station for possible radioactive contaminants related to decommissioning.

DHS' ongoing EM program will provide assurances to the citizens of Wisconsin that the environment surrounding nuclear power facilities and other monitoring areas will continue to be evaluated.

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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.

WGNHS geoscientists investigating a quarry in Dodge County. (Photo by Carsyn Ames)

FY 2023 Highlights

(See the WGNHS 2022 Year In Review; also see this interactive project map describing the projects in more detail.)

- Reported the results of groundwater quality studies in southwestern Wisconsin
- Compiled depth to bedrock data in Wisconsin
- Acquired airborne electromagnetic (AEM) geophysical data over large parts of northeast and southwest Wisconsin
- Investigated groundwater and water-level fluctuations in the Bayfield Peninsula and the Chequamegon-Nicolet National Forest
- Evaluated the efficacy of NR151 regulations
- Investigated PFAS in groundwater
- Investigated Neonicotinoids in groundwater and surface water in Central Wisconsin
- Worked on understanding relationships between bedrock structure and folding and arsenic and other contaminants in groundwater
- Conducted new bedrock geologic mapping in Dodge, Jefferson, Lafayette, and Grant Counties
- Conducted new Quaternary geologic mapping in Wisconsin's Driftless Area and in Jefferson, Bayfield, Lafayette, and La Crosse Counties
- Prepared a new statewide Quaternary map of Wisconsin for publication
- Investigated groundwater-surface water relationships in Wisconsin streams, lakes, and wetlands
- Upgraded Wisconsin's statewide groundwater monitoring network

- Upgraded and enhanced geoscience information delivery

Details of Ongoing Activities

Groundwater-Level Monitoring Network

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

County and Local Groundwater Studies

Geologic and groundwater studies at county and local scales continue to be an important part of WGNHS programs. With funding from the federal STATEMAP program or local sources, WGNHS scientists initiated or carried out county or locally focused geologic and/or groundwater studies during 2021 in ten Wisconsin counties. New geologic mapping is the fundamental starting point for understanding groundwater resources in Wisconsin. Many of these studies will generate or have generated water-table maps or depth-to-bedrock maps. (Maps: https://wgnhs.wisc.edu/maps-data/maps/)

- *Southwest Wisconsin groundwater and geology (SWIGG) project*. The purpose of this project is to improve our understanding of groundwater quality in southwest Wisconsin (Iowa, Lafayette, and Grant Counties) and how groundwater quality is related to local hydrogeologic properties and well construction characteristics. Southwest Wisconsin is an area of shallow carbonate bedrock beneath generally thin soils. Due to the shallow fractured bedrock and the presence of minor karst features this area is considered very vulnerable to groundwater contamination, but prior to this study regional groundwater sampling has been sparse. Project objectives are to (1) evaluate private well contamination in three counties using indicator bacteria (total coliform and *E. coli*) and nitrate based on randomized synoptic sampling events; (2) assess well construction and geological characteristics (e.g., well age, depth to bedrock) that affect total coliform and nitrate contamination; and (3) identify the source of contamination in a subset of total coliform- and nitrate-positive wells using microbial tests that distinguish between human, bovine, and swine fecal sources. This project was completed in early 2022 and the administrative report is freely available. Additional information

about the project is at https://wgnhs.wisc.edu/southwest-wisconsin-groundwater-and-geology-study-swigg/.

- *Bayfield County Groundwater.* The thick sands in the central Bayfield uplands comprise an important groundwater recharge area, but the remote location and a water table more than 200 ft below land surface pose challenges to studying the local hydrogeology. In 2021, we continued to monitor two groundwater wells installed in the Bayfield County uplands in order to better understand regional groundwater flow there.
- *Nitrate in groundwater at Waupaca, Wisconsin.* The City of Waupaca, Wisconsin, uses groundwater pumped from a network of seven high-capacity wells as its municipal water supply. Recent increases in the concentration of nitrate in the municipal water supply raised questions about the source of this contamination and whether it might eventually exceed standards for drinking water. This study combined geologic, hydrologic, land-cover, water-use, and water-quality data from the area with a groundwater-flow model to simulate and predict the effects of different land and water use on the concentration of nitrate in groundwater pumped from two of the city's municipal wells. The resulting tool supports decision makers who are tasked with land-use management and demonstrates a study design that could be applied to well-head-protection efforts elsewhere in Wisconsin's Central Sands region. The WGNHS released a report on this work in early 2022.

Regional Groundwater Studies

Regional groundwater studies usually span multiple counties. During 2021 the WGNHS was involved in several regional projects, including the following:

- *Depth-to-Bedrock Mapping in Wisconsin.*
  Depth-to-bedrock maps show the thickness of unconsolidated materials overlying bedrock. These maps provide a key link between the underlying geology, groundwater flow, and land use and are important in guiding activities such as permitting, bridge construction, and the land application of waste products in sensitive areas. Given their role in guiding decision-making, the production of accurate depth-to-bedrock maps is critical. A new WGNHS report describes techniques for making the maps, identifies sources of data and evaluates their strengths and weaknesses, describes available tools and best practices for using them, and explains the concept of uncertainty—how it's measured, its importance in decision making, and ways of displaying it.

- *Hydrogeology of the Chequamegon-Nicolet National Forest (CNNF)***.** WGNHS continued several groundwater studies in the CNNF. These include characterizing groundwater-surface water interactions of recently flooded seepage lakes near Drummond, WI, and, as mentioned above, studying groundwater recharge in the sandy uplands portion of the Bayfield Peninsula. We also began a project along the North Fork of the Yellow River in Taylor County to improve understanding of the

local hydrogeology and to document baseline water chemistry. Over the course of the year, the project team made regular visits to this area to sample water, monitor water levels, and collect other varied hydrologic and geophysical measurements. In the fall, WGNHS sampled a combination of more than 150 lakes, streams, springs, and campground wells throughout the Chequamegon-Nicolet National Forest. This work contributes an updated reference point for establishing long-term records and for identifying trends of water quality conditions within the National Forest.

Collecting water samples in the CNNF. Photo by Anna Fehling.

- *Advancing the use of nitrate findings to inform groundwater protection and improvement strategies.* UW-Extension agents in Wood and Portage counties, Portage County staff, and the WGNHS developed this study based on input from the Central Sands County Groundwater Collaborative (CSGCC). The overarching goal is to advance the use of historical nitrate and neonicotinoid findings to inform groundwater protection initiatives and improvement strategies by counties within the Central Sands Region of Wisconsin – particularly, Adams, Juneau, Marquette, Portage, Waushara, and Wood.
- *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 evaluated the geographic distribution of this red clay layer across numerous counties in southwest Wisconsin and documented that the red clay layer provides fundamentally no buffering capacity to the groundwater system. The results of this investigation 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 projects during 2021 included the following:

- *Hydrogeology of Southwest Wisconsin.* The hydrogeology and hydrostratigraphy of the Driftless Region of southwestern Wisconsin are complex due to the presence of multiple bedrock aquifers, rugged topography, bedrock structures, and fractures and karst features. To begin to better understand this region the WGNHS has undertaken groundwater monitoring centered on the Platteville Pioneer Farm, an Experimental Farm in Grant County operated by UW-Platteville. The goal of the Pioneer Farm work is to develop better conceptual models of the groundwater flow systems in SW WI.
- *Mapping depth to bedrock.* WGNHS scientists worked with DNR, DATCP, NRCS, and UW–Green Bay officials to develop and release new guidance for depth–to–bedrock mapping in the state. An exciting offshoot of this project was the acquisition and interpretation of airborne electromagnetic (AEM) geophysical data over large parts of eastern Wisconsin. This work utilizes a helicopter-towed geophysical array to cover large land areas rapidly. Based on its success in eastern Wisconsin, WGNHS and partners are conducting a similar survey in parts of southwest and southeast Wisconsin in 2022.
- *NR151 monitoring project.* WGNHS staff have been working to identify and instrument several monitoring sites associated with NR151. This legislative code regulates the spreading of agricultural manure in locations such as eastern Wisconsin, where groundwater resources in thinly buried Silurian dolomite are particularly sensitive to surface contamination. In 2022, WGNHS hydrogeologists Maureen Muldoon, Grace Graham, and Pete Chase installed water quality monitoring equipment at one spring site in Calumet County and one farm (well) site in Door County.
- *Studying PFAS in groundwater.* WGNHS hydrogeologists Dave Hart and Pete Chase are collaborating with professors from the UW–Madison Geoscience and Geologic Engineering departments to understand how PFAS is transported through soils into the water table and then through groundwater. They have assisted with conducting field investigations and groundwater modeling of PFAS transport in Rhinelander. They are now

WGNHS hydrogeologists Grace Graham and Pete Chase installing monitoring equipment in Door County. (Photo by Maureen Muldoon).

using what they learned to assist the Town of Campbell in La Crosse County with their PFAS issue. Additionally, WGNHS is also collaborating with UW–Milwaukee's Shangping Xu to understand PFAS flux into Lake Michigan by examining present and historic contamination of Wisconsin's connected aquifers.

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

Groundwater Data Management and Support

In 2021 the WGNHS continued to collect geologic and groundwater data and provide this data to a variety of users. Significant databases and data efforts include the following:

- *Enhanced publications catalog*. The WGNHS maintains hundreds of reports, maps, and other records in digital form for free downloads to the public. During 2021 the Survey continued to upgrade the functionality of this service, allowing easier data searching, previewing and downloading of information related to Wisconsin's groundwater and geology.
- *Collection of downhole geophysical logs.* The WGNHS continually collects and compiles downhole geophysical logs from research wells and "wells of opportunity," such as municipal wells. The logs, including natural gamma radiation, temperature, caliper, fluid conductivity, borehole diameter and optical imaging, are important tools for understanding water-quality problems in individual wells, and for correlating geologic units in the subsurface. In addition to municipal wells, geophysical logging has been used to troubleshoot problems in private wells and wells owned by state agencies including Department of Corrections, Department of Natural Resources and Departement of Transportation. The WGNHS maintains 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 the UW-Madison Division of Extension. WGNHS produces and serves as a distributor of many groundwater educational publications through our website *(*https://wgnhs.wisc.edu*)*. We also distribute information about Wisconsin groundwater on our website at https://wgnhs.wisc.edu/water-environment. Our outreach efforts reach different and broader audiences through a variety of social media tools, including:

- *Facebook* - https://www.facebook.com/WGNHS
- *Twitter* - https://twitter.com/wgnhs
- *Pinterest* − http://www.pinterest.com/WGNHS/
- *YouTube* −https://www.youtube.com/channel/UCwwucf9-W1qocovGx-uzs7w

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

In 2021, 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/
Contact the Wisconsin Geological & Natural History Survey
3817 Mineral Point Road
Madison, Wisconsin 53705-5100
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DEPARTMENT OF TRANSPORTATION

Because of the 1984 Wisconsin Groundwater Law, the Department of Transportation (DOT) regulates the storage of highway salt (ss. 85.17 and 85.18, Wis. Stats.) to protect the waters of the state from harm due to contamination by dissolved chloride. DOT is also responsible for potable well sampling at 28 rest areas and some 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 2023 Highlights

- Maintains new social media partnership with WI Salt Wise:https://www.wisaltwise.com.
- Continues 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 provides ongoing training to County winter maintenance crews regarding Direct Liquid Application (DLA).
- Organized a Winter Tech Talk in October 2022 which was a large scale one-day in-person event held at Chippewa Valley Technical College's in Eau Claire. The event was for winter maintenance operators from the counties to meet, learn, discuss, and share information regarding winter maintenance practices, more specifically related to improvement in liquid use, including direct liquid application.

New fact sheet: Safe Highways – Less Salt

- 29 Counties used Direct Liquid Application (DLA) and some Mostly Liquid Route (MLR) last season.
- 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 (263 million pounds) yielding cost savings ($11.1 Million).
- 20.2 million gallons of brine solution was used last season, most in Wisconsin history.
- 44 Counties have been provided with route optimization technology to date.

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 1,323 salt storage site locations listed in the database with a total of over 2,410 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 75 weather stations along major highway routes are used to determine application rates and effectiveness. Annual training for snowplowing and salt spreading techniques is provided for county snowplow operators.

Salt Usage Tracking and Initiatives

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

The newest DOT initiatives over the last 5 winter seasons in winter maintenance is called "Mostly Liquid Routes" (MLRs). Multiple Counties used MLRs this past winter using brine or brine mixtures to keep the snow from sticking to the road between plow cycles, and rarely

put rock salt on the road. These projects can result in a reduction of about 50% road salt application while still achieving the "time to bare/wet" goals.

Research and Additional Information

In December 2021 two research projects were completed in coordination with the Department:

1. *Evaluation of Winter Maintenance with Salt Brine Applications in Wisconsin*
   - https://topslab.wisc.edu/research/tse/evaluation-of-winter-maintenance-with-salt-brine-applications-in-wisconsin/
2. *Expanding Application Rate Guidance for Salt Brine Blends for Direct Liquid Application and Anti-icing*
   - Expanding Application Rate Guidance for Salt Brine Blends for Direct Liquid Application and Anti-icing | Clear Roads

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

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

Explanations of liquid brine applications are provided on WisDOT podcast (Feb 25, 2020 – Transportation Connects – Clear Roads, Less Salt – Winter Road Maintenance) below and refer to the DOT social media for occasional postings and new information pertaining to Winter Maintenance and chloride reduction initiatives:

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

For more information

Visit https://wisconsindot.gov
Contact Barry Paye
Bureau of Technical Services
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UNIVERSITY OF WISCONSIN SYSTEM

The University of Wisconsin System (UWS) undertakes groundwater-related research, teaching, and outreach responsibilities. These three missions are integrated through cooperation and joint appointments of research, education, and outreach and extension personnel, along with postgraduate fellows, who address groundwater issues. UWS staff members work with state and federal agencies and other partners to solve groundwater resources issues. Research is coordinated through the University of Wisconsin Water Resources Institute, which conducts annual calls for proposals followed by rigorous peer and panel review of the proposed projects. Typically, four to seven projects are funded through the Institute each year. Citizen outreach is accomplished through publications, video and audio podcasts, social media, media relations, public meetings and presentations, teleconferences, and water testing and satellite programs. In the following sections, we describe the activities of several university programs, including the University of Wisconsin Water Resources Institute, the Central Wisconsin Groundwater Center *(affiliated with UW-Madison's Division of Extension and UW-Stevens Point)*, the Natural Resources Institute's Land and Water Programs at UW-Madison's Division of Extension, the University of Wisconsin Nutrient and Pest Management Program, and the Wisconsin State Laboratory of Hygiene.

Details of Ongoing Activities:

University of Wisconsin Water Resources Institute (WRI)

The University of Wisconsin Water Resources Institute (WRI) is one of 54 water resources institutes located on universities across the nation with core funding provided and administered by the U.S. Department of the Interior through the U.S. Geological Survey. The Institute 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 2023 Highlights

- In support of the Wisconsin Groundwater Research and Monitoring Program, provided UWS funding to six research projects focused on groundwater contaminants, including nitrate and road salt; water quantity challenges in the Central Sands; geochemistry and microbiology; and understanding public perspectives and values, and supported graduate and undergraduate students at UW-Milwaukee, UW-Madison, and UW-Platteville.
- Coordinated the Request for Proposals and the review process for the FY24 Joint Solicitation for the Wisconsin Groundwater Research and Monitoring Program.

Per- and polyfluoroalkyl substances (PFAS) are chemicals used in everyday items like clothing and cookware. They can accumulate in fish, wildlife and humans. Here, a WRI-funded researcher is in his lab. He is partnering with tribal communities to study PFAS in wild rice, maple sap and walleye. *Photo: Bonnie Willison*

- Supported five Water Resources Science-Policy post-graduate fellows in partnership with the Wisconsin Department of Natural Resources (DNR), Wisconsin Department of Health Services (DHS), and University of Wisconsin-Milwaukee Center for Water Policy to work on state priority groundwater and surface water challenges, including groundwater toxicology, statewide public health tracking for harmful algal bloom toxin exposure, and a statewide phosphorus conference. WRI also leveraged Aquatic Sciences Center funding to support 15 additional post- graduate fellows working on aquatic toxicology and PFAS, community flood resiliency, coastal hazards, coastal wetlands, Great Lakes fisheries, and aquaculture.
- Conducted a successful 2022 undergraduate research pilot experience for nine summer interns, resulting in several students applying for graduate water-related studies. The program expanded for summer 2023 and is offering opportunities for 31 students throughout the University of Wisconsin System. It is funded by the Freshwater Collaborative of Wisconsin, WRI, the Sea Grant College Program and Water@UW-Madison.

Several of the undergraduates participating in the 2023 summer research opportunity program. *Photo: Jim Hurley*

- Supported the annual Wisconsin Chapter of the American Water Resources Association meeting. The Wisconsin Water Library and the Wisconsin Geological and Natural History Survey continue to post digital copies of the meetings' proceedings from 1978 to the present on a University of Wisconsin-Madison library website to make the water science material widely available.
- Produced six episodes of a podcast called Wisconsin Water News that explores relevant water topics through this easily downloadable and informative tool.
- Supported the production of 14 final project reports, 10 theses, and 58 peer-reviewed publications over the past five years.

Research

The WRI research portfolio is supported by UW System funding for the Wisconsin Groundwater Research and Monitoring Program and includes interdisciplinary projects in four areas: groundwater, surface water, groundwater-surface water interactions, and drinking water. Groundwater is a top priority and an area of particular strength at the WRI.

During FY23, the WRI directed a wide-ranging program of priority groundwater research consisting of four 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. Key areas of emphasis in FY23 included research focused on groundwater contaminants, including nitrate and road salt; water quantity challenges in the Central Sands; geochemistry and microbiology; and understanding public perspectives and values and supported graduate and undergraduate students at UW-Milwaukee, UW-Madison, and UW-Platteville.

Groundwater issues investigated during the past year included:

- Measurement of bacterial transport and immobilization in variably saturated geologic materials of Wisconsin. Christopher Zahasky, Eric Roden, and Vy Le, UW-Madison. (continuing)
- Mass discharge of road salt via groundwater to surface waters in Southeastern Wisconsin. Charles Paradis, Laura Herrick, Cheryl Nenn, and Timothy Wahl, UW-Milwaukee, and Southeast Wisconsin Regional Planning Commission. (continuing)
- Data-driven groundwater depth and risk forecasting in the Central Sands region of Wisconsin for sustainable management. Jingji Huang and Ankur Desai, UW-Madison. (continuing)
- Assessment of biochar application to reduce nitrate leaching through agricultural vegetative treatment areas. Joseph Sanford, UW-Platteville. (continuing)
- Aligning the Wisconsin Idea on water: Interpreting public perspectives and values. Michael Cardiff, Ken Genskow, and Bret Shaw, UW-Madison. (new)
- Biomanipulation of groundwater flooding. Steven Loheide and Kenneth Potter, UW-Madison. (new)

A WRI research project is surveying rural residents about their perceptions related to groundwater quantity and quality. This first-of-its kind survey was earlier this year mailed to those who live in rural communities across Wisconsin.

For FY24, the UWS selected two new groundwater research projects from proposals submitted in response to the Joint Solicitation for Wisconsin Groundwater Research and Monitoring Program and will continue four projects selected from the previous years' solicitations. The projects are based at UW-Madison and include:

- Long-term threat of geogenic contaminants to water quality and quantity in the Midwestern Cambrian Ordovician Aquifer System. Matthew Ginder-Vogel, UW-Madison. (new)
- An experimental investigation on the leaching of per- and polyfluoroalkyl substances (PFAS) from contaminated soil. Shangping Xu and Yin Wang, UW-Milwaukee and Erin Berns-Herrboldt, UW-Green Bay. (new)
- Risk from pathogens and exposure to antibiotic resistance genes in private wells in southwest Wisconsin. Maureen Muldoon, UW-Madison. (new)

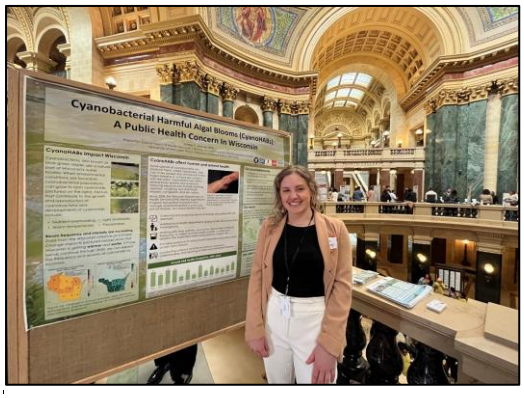
Additionally, the WRI receives an annual federal 104(B) allocation that can be used to advance groundwater and other water resources research and initiatives. This allocation is often used to fully support or augment a project selected through the state groundwater competition, freeing up state resources to invest in additional strong proposals submitted to the groundwater competition. In FY23, this allocation supported:

- Aligning the Wisconsin Idea on water: Interpreting public perspectives and values. Michael Cardiff, Ken Genskow, and Bret Shaw, UW-Madison. (continuing)
- Biomanipulation of groundwater flooding. Steven Loheide and Kenneth Potter, UW-Madison. (continuing)

In addition, this federal allocation was matched by state agency partners and used to:

- Support a Water Resources Science-Policy postdoctoral fellow in partnership with DNR's Fisheries Management Program to build understanding of habitat needs to support statewide fisheries in inland lakes (Dr. Ellen Albright, 2022-23).

- Support a Water Resources Science-Policy postdoctoral fellow in partnership with DNR's Fisheries Management Program to work on understanding habitat needs for the state (Dr. Bryan Maitland, 2020-22).
- Recruit and support a Water Resources Science-Policy fellow in partnership with DHS to work on public health aspects of harmful algal bloom toxin exposure (Jordan Murray, 2021-23).
- Recruit and support a Water Resources Science-Policy fellow in partnership with DHS to work on public health aspects of groundwater toxicology (AJ Jeninga, 2022-23).
- Recruit and partially support two Water Resources Science-Policy legal fellows placed at the UW-Milwaukee Center for Water Policy to work on water policy issues (Misbah Husain and Sarah Martinez, 2021-22).



Jordan Murray, a WRI-supported fellow researching harmful algal blooms at the Wisconsin Department of Health Services, shared her findings as part of the spring 2023 UW-Madison Day at the Capitol.

Lastly, the Aquatic Sciences Center (home to WRI) successfully secured a grant from the U.S. Environmental Protection Agency (EPA) to support two UW-U.S. EPA Human Health and the Environment Postdoctoral Research Fellows and two post-Masters Fellows (Drs. Prarthana Shankar and Sally Mayasich, 2019-23, and Emily Pavlovic and Alexandra Pesano, 2022-23). And, through a variety of partnerships, the Aquatic Sciences Center was also able to support post-graduate fellows to work on community flood resiliency (Jackson Parr, DHS, 2021-23), coastal hazards (Lydia Salus, Emily Rau, Sarah Brown, and Hannah Paulson, Wisconsin Department of Administration, 2019-23), coastal wetlands (Drs. Nicole Ward and Sophie Lafond-Hudson, DNR, 2021-22), aquaculture (Dr. Patrick Blaufuss, UW-Stevens Point and Milwaukee, 2020-22), and water policy (Anya Janssen and Andrian Lee, UW-Milwaukee Center for Water Policy, 2022-23).

Teaching

Institutions within the UWS continue to offer undergraduate- and graduate-level courses and opportunities 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 also 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. Through the librarian's outreach to teachers last year, 33,925 students were exposed to water-science learning. The library's curricula are available for checkout by all teachers and residents in Wisconsin. The librarian also has deep experience in working with children. She put that experience to use in developing kits based on field-tested science, technology, engineering, art, and math. New this year will be additional teaching materials about marine debris, along with a new play about marine debris written in collaboration with the respected regional theater group American Players Theatre. The play premiered in Door County in fall 2022 and a video about its creation can be found here

https://www.youtube.com/watch?v=wmN4BAxN31A&t=1s The other education 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.

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 FY23, WRI continued to use a 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 granted 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. 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. 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.

Video is a compelling way to share water-science information. The Institute's video catalog includes seven titles. The most popular one is "Testing well water for microorganisms." To date it has more than 13,000 views, which is a large number for a scientific topic.

The Pew Research Center, in a spring 2023 report, noted that about half of adults in this country have listened to a podcast in the past year. One in five of those responding to the Pew survey say they listen a few times a week. About 66% of survey respondents say podcasts appeal to them for learning, diversion, and entertainment. Satisfying this desire for learning through podcasts is an important reason why WRI offers podcasts. It provides five multi-part podcast series on topics such as groundwater, mercury in aquatic environments, and aquifers and watersheds.

During this reporting period, WRI staff were integral to the leadership and content-population of Water@UW-Madsion located here - https://water.wisc.edu/. The site is a portal to the breadth and depth of water-related work on the state's flagship campus, the UW-Madison, and serves as the first stop for anyone interested in water research. Graduate students can search for departments offering courses and degrees that fit their

interests. Prospective graduate students can use the site to investigate potential faculty advisors. Finally, staff and faculty can search for colleagues working on topics complementary to their own to facilitate greater interdisciplinary collaboration and efficiencies. This year, Institute Associate Director Dr. Jennifer Hauxwell advised the Water@UW-Madison executive committee, and Moira Harrington, the Institute's communications lead, and Natalie Chin, tourism outreach specialist, served on the committee. The group hosted a hybrid spring event that reached about 100 people in person and several dozen online. Additionally, WRI Director Jim Hurley serves on the Steering Committee for the Freshwater Collaborative of Wisconsin, another entity promoting collaboration, this time among University of Wisconsin System campuses.

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 in groundwater. The program also produces the Aquatic Sciences Chronicle on a quarterly basis. It circulates to roughly 5,800 electronic and print subscribers with an interest in WRI projects and related water topics. The newsletters are also posted online.

Wisconsin's Water Library

Wisconsin's Water Library is a unique resource for Wisconsin citizens. It contains more than 30,000 volumes of water-related information about the Great Lakes and the other 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 offers assistance 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 2022, the library started a brand-new book club to raise awareness of Ojibwe culture and teach children, parents, librarians, and educators about the water resources, with a focus on the Great Lakes. Each month, the virtual book club reached about a dozen

people. Participants expressed that the experience made them proud of their culture. Library staff also created a guide for librarians and information professionals about Traditional Ecological Knowledge, and added Ojibwe word keys to existing teaching kits about fish and freshwater ponds.

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

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. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 20p. WR17R001/2018WI372B.

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.

Kucharik, C.J., T. Campbell. 2020. Improving water and nitrogen use efficiency under changing weather variability in the Central Sands. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 18p. WR18R001.

Lark, T., and Y. Xie. 2020. Mapping annual irrigation extent at 30-m resolution across the United States, 1997-2017. (University of Wisconsin-Madison). Final Report, UW-USGS Irrigation Mapping Project. 60 pp. G19AC00080/2016WI354G.

Loheide, S. 2022. Impacts of Changing Frozen Ground Regimes on Groundwater Recharge. (University of Wisconsin-Madison). Final Report, University of Wisconsin Water Resources Institute. 17 pp. WR19R005/2020WI308B.

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McLellan, S. 2021. Detection of Sewage Contamination in Urban Areas of the Great Lakes. . (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 3 pp. WR16R005/2016WI354G.

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Price, J. 2022. Valuing groundwater quality: A cost function analysis of Wisconsin water utilities. (University of Wisconsin-Milwaukee). Final Report, University of Wisconsin Water Resources Institute. 16 pp. WR20R002.

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Stewart, E.D., W. Fitzpatrick, E.K. Stewart. 2021. Correlating bedrock folds and fractures to arsenic detection in drinking water, southeast Wisconsin. WR20R004

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. (University of Wisconsin-Extension). Final Report, University of Wisconsin Water Resources Institute. 15p. WR17R003.

Vitale, S., J.B. Mahoney, A. Baker. 2020. Assessment of the source and mobility of phosphorus in the hydrologic system in western Wisconsin. (University of Wisconsin-Eau Claire). Final Report, Final Report, University of Wisconsin Water Resources Institute. 19p. WR19R002.

Vitale, S., J.B. Mahoney, A. Baker. 2021. Source to sink evaluation of phosphorus in the hydrologic system in Wisconsin: Implications for lake eutrophication. Final Report, University of Wisconsin Water Resources Institute. 17 pp. WR20R003.

Theses

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Haas, Lisa. 2021. Microbially-Mediated Oxidation of Trace Element-Bearing Sulfide Minerals in Sandstones of Trempealeau County, WI. MS Thesis. Geosciences. University of Wisconsin-Madison. WR19R001.

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. WR12R004/2013WI329O.

Hyman-Rabeler, Katrina. 2021. Impacts of Changing Frozen Ground Regimes on Groundwater Recharge. MS Thesis. 160 pp. Geological Engineering, University of Wisconsin-Madison. WR19R005/2020WI308B.

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.

Michaud, 2018. Long term performance of radon barrier in limiting radon flux from four uranium mill tailings containment facilities. MS Thesis, Geological Engineering, University of Wisconsin-Madison. WR13R004/2013WI314B.

Peterson, Benjamin. 2021. Ecophysiology of mercury-methylating microorganisms in freshwater ecosystems. Ph.D. Thesis. 218 pp. Environmental Chemistry and Technology, University of Wisconsin-Madison. WR19R006/2019WI001G.

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.

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.

Voter, Carolyn. 2019. Hydroecologic Effects of Urban Development Decisions in Residential Areas. Doctoral dissertation. University of Wisconsin-Madison, Madison, WI. WR12R002/2013WI327O.

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Zambito, J., L. Haas, M.J. Parsen. 2022. Identifying the source of groundwater contaminants in West-Central Wisconsin, U.S.A.: Geochemical and mineralogical characterization of the Cambrian sandstone aquifer. Journal of Contaminant Hydrology. WR15R004.

For more information on the WRI:

Visit the WRI website *wri.wisc.edu*
Contact Jennifer Hauxwell, associate director, University of Wisconsin Water Resources Institute
1975 Willow Drive
Madison, WI 53706
Phone (608) 262-0905, email *jennifer.hauxwell@aqua.wisc.edu*

Central Wisconsin Groundwater Center

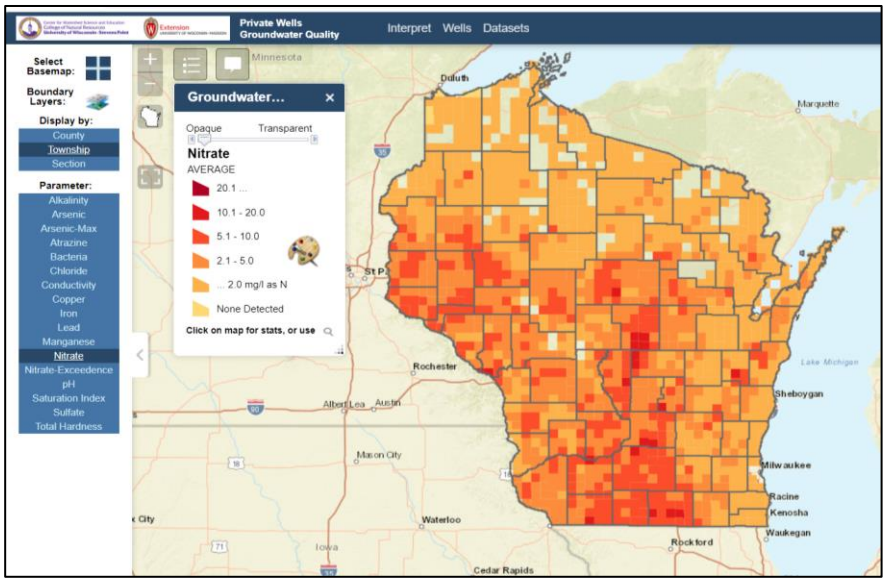
The Central Wisconsin Groundwater Center is an affiliate of the Center for Watershed Science and Education. It is a partnership between the College of Natural Resources at the University of Wisconsin–Stevens Point and the University of Wisconsin–Madison, Division of Extension. The Central Wisconsin Groundwater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

Well Water Testing and Outreach

In calendar year 2022, the center helped 6,669 households test their water in conjunction with the UW-Stevens Point Water and Environmental Analysis Laboratory (WEAL) along with partners in county Extension offices, county health departments, and county land conservation departments. Well water testing programs were conducted in the following counties: Adams, Ashland, Barron, Calumet, Chippewa, Crawford, Dodge, Douglas, Green, Kewaunee, Portage, Pepin, Pierce, Polk, Sauk, Sawyer, Sheboygan, St. Croix, Taylor, Vernon, and Waupaca. In-person educational programs have resumed for programs that have taken place in 2022.

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 1,048,575 individual test results for approximately 130,208 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.



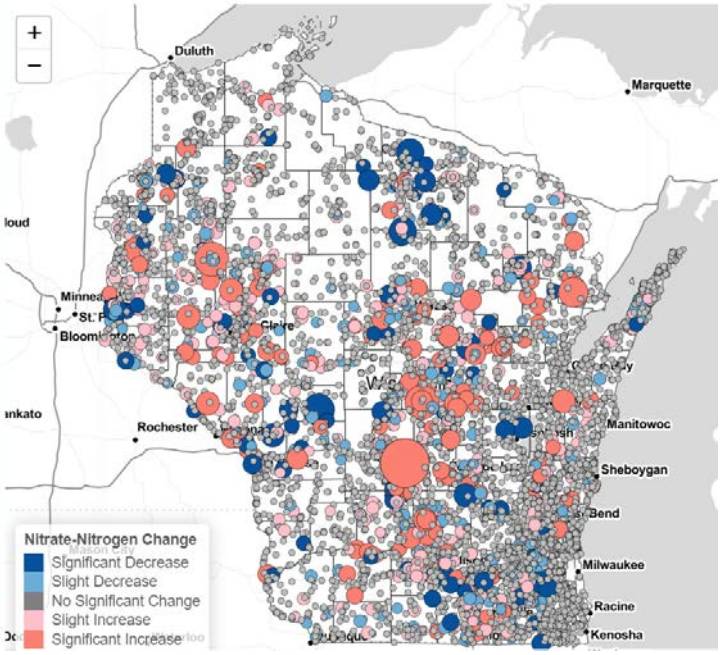
Screen capture of the Wisconsin Well Water Viewer showing average nitrate-nitrogen concentration by town-range. The viewer is accessible online and allows the public to better understand the variability of well water quality in Wisconsin. There is data on 14 different parameters.

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 health departments of Eau Claire and La Crosse counties was also integrated. Summary maps are available for 14 different water quality parameters and can be viewed or summarized into a table at a county, town or section level detail. Updated in 2019 to include nitrate/arsenic data from DNR well testing requirements for new wells and/or well pump work, it now includes data for over 200,000 samples: with 119,458 samples from Extension efforts. It allows users to see water quality in their community and other parts of Wisconsin. In 2022, the Viewer was accessed by 7,516 people. The viewer was recently updated to include data through December 31, 2021.

Nitrate in Groundwater

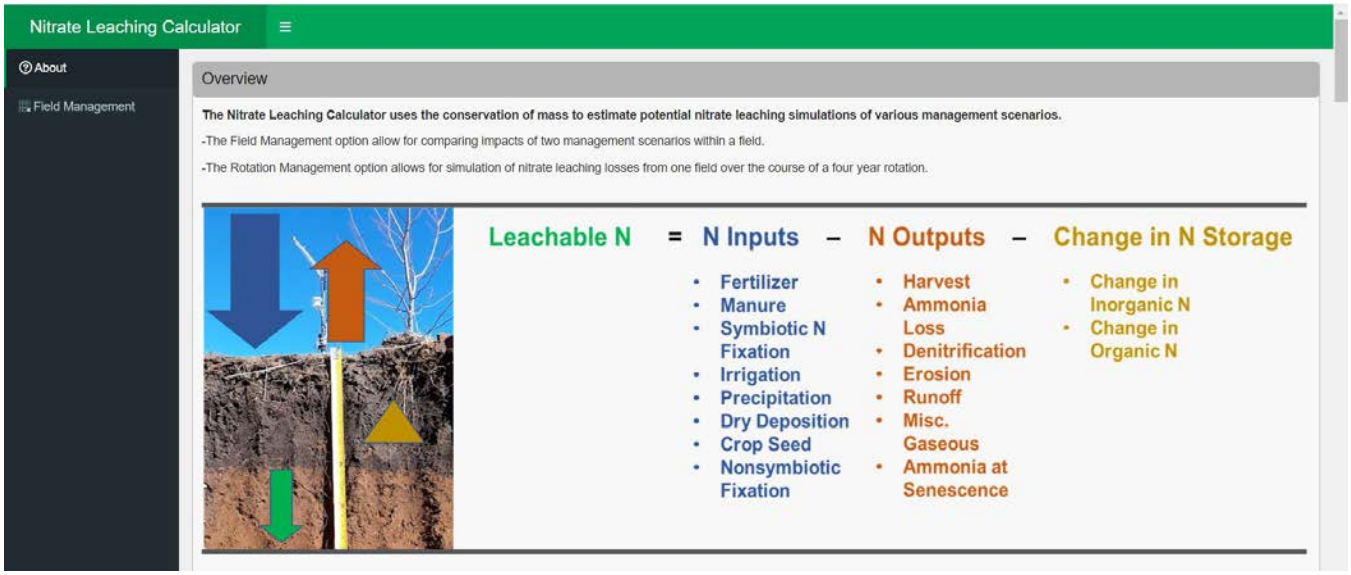
In April 2023, the Center updated a dashboard that investigates nitrate trends in public water supply systems. Using data from public water systems (i.e. municipal, other-than-municipal, transient, non-community, and non-transient, non-community), the app summarizes publicly available data that can be viewed spatially or by Wisconsin Unique Well Number. The data reveal that 90.7% of wells have no trend, 5.4% have an increasing trend, and 3.8% have a decreasing trend. The app can be found online at: https://www3.uwsp.edu/cnr-ap/watershed/Pages/nitrate_trends.aspx.



Nitrate trends in Wisconsin's public water supply systems are represented in this rendering. Red dots correspond to wells with increasing trends, while blue dots indicate decreasing trends. The size of the dots corresponds to the rate of change. Additional detail regarding individual wells can be found by visiting the online dashboard.

The Center is also investigating the impact of various cropping practices on groundwater quality in the Central Sands Region. Using a combination of lysimetry and wells, the study is collecting year-round data to better understand the timing of nitrate leaching losses from various crops. Because many leaching studies often focus only on the growing season, this data set will provide important insight into inter- and intra-annual variability of leaching that is necessary to calibrate and validate nitrate leaching models. As a result of this work, an online app was developed to estimate nitrate leaching potential using a simple mass balance approach. With minimal inputs (i.e. N fertilizer, yield, soil characteristics, etc.) the user can estimate the potential leachable nitrogen. A beta version of the calculator can be found here: http://68.183.123.75/wisconsinwater/BETA_VERSION_1.2/

The Nitrate Leaching Calculator based on work by Meisinger and Randall (1991) is a simple mass balance approach to estimating nitrate leaching losses under different management scenarios.



An additional project funded by the WRI from 2020-22 looking at the use of inter-planting to reduce nitrate leaching losses below commercial potato production is currently being summarized. The work was a collaboration with Dr. Chris Kucharik and students of his lab at UW-Madison Department of Agronomy.

Central Wisconsin Baseflow Stream Monitoring

For the past decade, the Center has collected monthly baseflow measurements on Central Wisconsin streams. This is part of an effort to better understand water conditions in the Central Sands Region affected by increased pumping. Currently, staff measuring baseflow at 70 sites throughout the Central Sands Region. Measurements are supplemented by measurements collected by county land conservation department staff. These measurements have been invaluable for calibrating groundwater flow models in the region and better understanding the impact of pumping and weather variability on Central Wisconsin streams.

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

PFAS in Private Wells

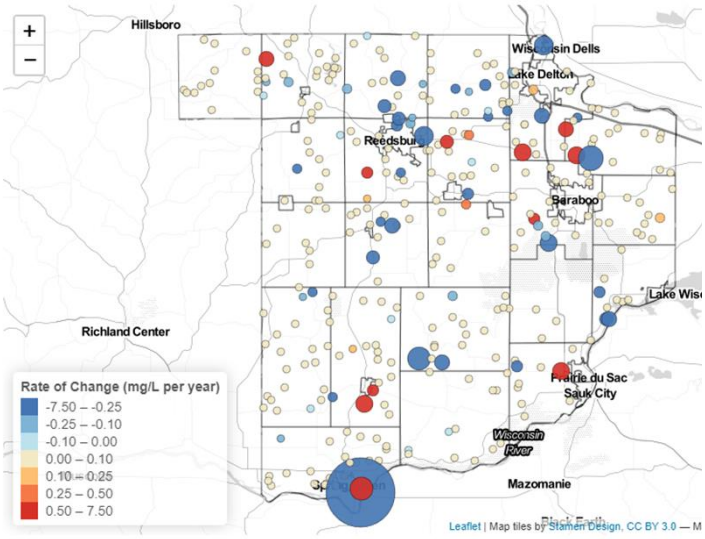
The Center partnered with the DNR and Wisconsin State Laboratory of Hygiene on a statewide testing project of private wells for Per- and polyfluoroalkyl substances. Center staff spent the summer/fall of 2022 collecting samples from 450 private wells selected by the DNR. WEAL performed analysis for inorganics as well as pesticides, artificial

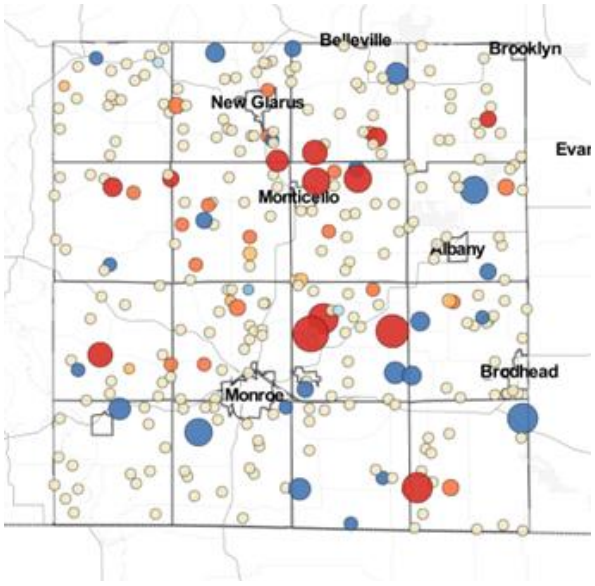
sweeteners, and personal care products. The data was written up for publication by DNR staff and is currently in review. The data will be useful for providing insight into factors that can be useful for predicting PFAS occurrence.

Five-Year County Well Water Quality Inventories

Starting in 2019, the Center began multi-year projects with Chippewa, Green, and Sauk counties to organize citizen-based groundwater monitoring networks in each county. Dodge County was added in 2020. Wells are tested annually for the following parameters: nitrate, chloride, alkalinity, pH, hardness, and conductivity. The goal is to test the same wells for five years in a row for the purposes of understanding trends in rural groundwater quality over time. By testing the same wells annually, Center staff are 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 following maps of Sauk County (left) and Green County (right) show wells with nitrate trends based on initial four years of data. Blue dots represent wells with decreasing trends, while red dots represent those with decreasing trends. The size of the dot corresponds to the rate of change. More detail can be found by visiting the dashboards that have been created for these projects.





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. In the past few years, staff recently participated in the Wisconsin DNR Central Sands Lake Study and the NR151 Nitrate Technical Advisory Committee.

Recent Publications and Reports (Past Five Years)

Masarik, K., McNelly, J., Johnson, A., & Lefebvre, L. (2023). Portage County Well Water Quality - 2012. Center for Watershed Science and Education, University of Wisconsin - Stevens Point & University of Wisconsin - Extension.

Nitka, A.L., DeVita, W., McGinley, P.M. 2019. Evaluating a Chemical Source-Tracing Suite for Septic System Nitrate in Household Wells. Water Research 148(1):438-445 *http://dx.doi.org/10.1016/j.watres.2018.10.019*

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

Luczaj, J., and K. Masarik. 2015. Groundwater quantity and quality issues in a water-rich region: Examples from Wisconsin, USA. *Resources* 2015 4:323-357. *doi*:*10.3390/resources4020323.*

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

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

For more information on the Central Wisconsin Groundwater Center:

Contact: Kevin Masarik and Abby Johnson
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Stevens Point, WI 54481
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University of Wisconsin-Madison Division of Extension: Natural Resources Institute's (NRI) Land and Water Programs

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

NRI Regional Water Programs and Conservation Professional Development

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

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

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

NRI Water Outreach and Education

The Water Action Volunteers stream monitoring program educates both children and adults about stream ecology and stream health. Volunteers continue to monitor more than 500 stream sites statewide for a variety of parameters, including stream flow, which is directly affected by groundwater. Volunteer-collected data helps 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 has resulted in over 227,000 volunteer hours providing nearly $6.8 million dollars in value to the state since the program began. Sixty host organizations have partnered with the program by having 187 individuals trained as instructors who have trained 1,395

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

volunteers statewide. There is a presence of Master Naturalists in all of Wisconsin's 72 counties. The course provides a broad overview of Wisconsin's natural resources and the processes that affect them. This program continues to grow in cooperation with partners across Wisconsin.

Regional Natural Resource Education Program

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

For more information on NRI/Land & Water programs related to groundwater:
Contact Chad Cook, NRI associate director of outreach
445 Henry Mall, Room 202
Madison, WI 53706
Phone (920) 232-1990, email *chad.cook@wisc.edu*

University of Wisconsin Nutrient and Pest Management (NPM) Program

Mission Statement

The University of Wisconsin's Nutrient and Pest Management (NPM) Program works with farmers, researchers, agricultural professionals, and citizens to provide research-based agricultural nutrient and pest management education on crop production practices that protect water quality, farm profitability, and resilient landscapes.

In 2022, the NPM Program completed its first strategic planning process. Briefly, the program worked with stakeholders to develop priority areas of work, conduct a SWOT (strengths, weaknesses, opportunities, threats) analysis, and map future direction. The areas of focus include nutrient management, pest management, and resilient agriculture. View the executive summary and/or the entire completed strategic plan here.

The NPM program staff collectively educated 17,000 people, at 225 events, giving 189 unique (original, first-time) presentations in 2022. In addition, they provided 16,000 individual consultations via email, phone, and in-person contacts. Nutrient management educational products developed in 2022 include 15 videos, seven print publications, and 122 (print) 38 (electronic) nutrient management training manuals and 49 additional flyers

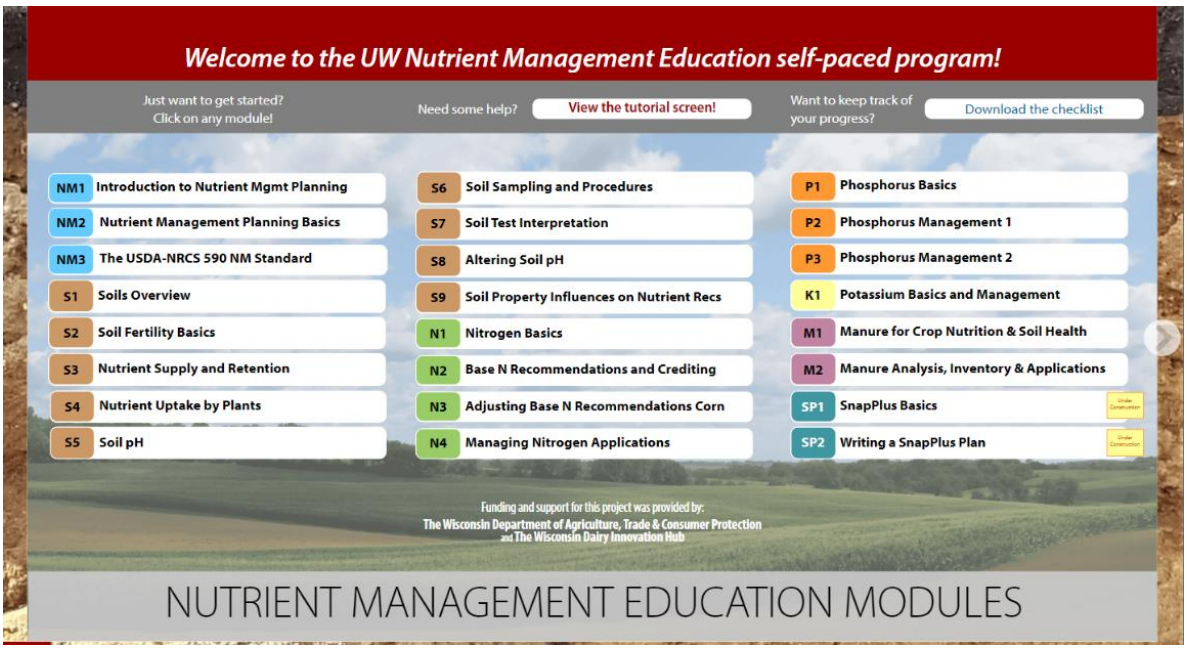
and factsheets were developed. 67 short videos were made and used for an online nutrient management training program.

NPM Program outreach products are available for viewing and downloading at: https://ipcm.wisc.edu/

Nutrient Management

The NPM Program is part of a team that develops, distributes, evaluates, and implements nutrient management education programs. Partners include University of Wisconsin-Madison College of Agriculture and Life Sciences (UW-CALS) faculty/staff; county-based UW-Extension staff; land and water conservation departments; Wisconsin technical colleges; the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP); 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, distribute, and implement 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.



- *Release of a new platform and updated content for the NMFE Curriculum*. An online, video-based instruction version was developed in 2021 and released in early 2022. The new NMFE allows for self-paced learning by users. The new curriculum is available at: https://nmfe.webhosting.cals.wisc.edu. (*Please allow a few minutes for the initial download*.) Content of the digital curriculum is displayed in a modular format. Each module deals with a specific component of a nutrient management plan and features multiple, short, instructive videos along with linked resources. This project was in response to challenges with the traditional delivery of the NMFE curriculum, including COVID-19 restrictions, as well as staff and budget reductions. So far, the website has been viewed 460+ times. This digital remote delivery method will: i) Eliminate or greatly reduce the need for physically close instructor-student contact, ii) Allow for self-paced, self-instruction, and iii) Increase the number of Wisconsin farms possessing and implementing NM plans. Support for this project is provided by DATCP and the UW-Madison Dairy Innovation Hub.

- *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 (15), 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 150 copies requested and delivered in fall of 2022. In addition to creating SnapPlus educational products, NPM staff actively train farmers, agronomists, and others to use SnapPlus. In 2022, NPM staff members continue to assist the SnapPlus team in the development of a new SnapPlus user interface as well as quality control reviews of the software program.

- *Educational support to Wisconsin watershed projects*. Activities include coordination and delivery of individual nutrient management plans, on-farm demonstrations (nutrient crediting, nitrogen rates for corn, soil health, cover crops, soil erosion control, etc.). Support activities include planning, advice, coordination, grant preparation, and reporting. In addition, NPM staff serve on the selection committee for DATCP-sponsored farmer-led watershed projects. NPM Program staff serve as key members of watershed projects (producer-led, federal NRCS, and other) in 26 watershed projects and seven demonstration farm networks.

- *On-farm demonstrations, field plot research and subsequent educational programs* on various topics including, adaptive nitrogen management for corn, cover crops, conservation tillage, manure applications, etc.

Pest Management

NPM, in conjunction with numerous partners including UW -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:

- *Waterhemp weed control project* involves statewide field trails evaluating control techniques for herbicide-resistant waterhemp. Waterhemp is a very aggressive weed

that is wreaking havoc across the nation's cropland fields. In 2022, NPM conducted on-farm research waterhemp trials in Dane, Grant, Chippewa, and Waupaca counties.

- *Soil conservation and weed management.* NPM working with the UW-Madison Department of Agronomy conducted on-farm research aimed at managing weeds while improving soil conservation. These trials look at using cover crops, no-till, residual herbicides, and system-based programs for the management of waterhemp and other troublesome weeds in Wisconsin.

- *Strategies for avoiding herbicide resistance in weeds.* The NPM program delivers educational outreach materials and trainings to Wisconsin producers and agri-businesses on strategies for avoiding the development of herbicide resistance in weeds. Strategies include awareness and diversification of herbicide modes of action used on a given farm/field, equipment sanitation to avoid transport of weed seeds, and identification of weed species likely to be resistant to popular herbicides.

- *White mold and waterhemp management using winter rye.* NPM conducted on-farm research aimed at managing white mold and waterhemp in soybean while improving soil conservation. These trials looked at using winter rye vs. conventional approaches to managing white mold on farms in Wisconsin.

- *On-farm roller crimper studies.* Three on-farm studies were conducted to investigate the on-farm utility of using the rye/roller-crimper system for white mold and waterhemp management while reducing pesticide inputs. Locations included Lafayette and Chippewa counties.

Cropping Systems

- *Cover crops research, education, and outreach.* NPM partnered with county Extension educators, USDA-NRCS, County Land Conservation Departments, non-governmental organizations, and UW-CALS specialists to deliver cover crop education programs in person and virtually across the state and Midwest. Activities included on-farm field days, on-farm research and demonstration, development of educational videos, fact sheets, publications, and training farmers and agronomists. NPM outreach specialists provided active leadership in the Wisconsin Cover Crops Conference and Cover Crops Research and Outreach Project (CCROP). Cover crop demonstration and research plots were continued at Peninsular, Lancaster, and Arlington agriculture research stations.

- *Soil Health Programm*ing: Nearly 100 soil health presentations were given in-person and virtually to approximately 5,800 farmers, lake and watershed groups, tribal communities, and youth throughout the state, region, and nation in 2022. NPM staff worked closely with community and farmer-led watershed groups to develop demonstration/research projects and field days to highlight the impact of agricultural practices on soil health and water quality. Additionally, NPM staff assisted the Wisconsin Natural Resources Conservation Service in delivering soil health education to new and existing agency staff, attendees at Farm Technology Days, and high school agriculture educators Six staff from NPM were involved. *Badger Crop Connect.* NPM

staff were part of a team of educators within the Crops and Soils Program of the Division of Extension that organized and delivered a new series of webinars containing timely Wisconsin crop management information from March through October 2022. These webinars were a successful alternative to in-person fields days. Three NPM staff delivered four unique presentations at four different sessions.

- *Healthy Grown / Healthy Farms.* NPM working cooperatively with the Wisconsin Potato and Vegetable Growers Association (WPVGA) has developed a national model of sustainable production systems, exemplifying integrated pest management. In addition, the program includes a nationally recognized ecosystem restoration effort. In 2022, 10growers were certified and over 12,800 acres of fresh market potatoes (about 40% of Wisconsin's fresh market acres) were verified as "Healthy Grown." NPM has worked with the WPVGA to expand "Healthy Grown" to carrots and onions.

- *Water quality and conservation expansion programs*. NPM staff have worked to expand water quality programs with state potato and vegetable growers. The inclusion of water modules into Healthy Grown was developed and the team is now looking at developing on-farm networks for water quality programs. NPM staff provide outreach coordination for the USDA-SCRI Potato Soil Health Project, work with the Central Wis. Farmer Cooperative Producer-Led Watershed, lead for the Central Wisconsin Water Quality Working Group, and continued work as a liaison with the Water Task Force.

- *First Nation sustainable food production and food sovereignty initiatives*. Through programming efforts of the College of Menominee Nation, Menominee Indian Tribe, the Stockbridge-Munsee Community, and Wisconsin Farm Bureau, NPM's Dr. Jamie Patton provided educational outreach on culturally relevant, sustainable food production practices to indigenous communities in the Great Lakes Region, as well as northeast Wisconsin non-native agricultural producers. Additionally, NPM supported youth STEM education by providing multiple presentations on environmental topics to the College of Menominee Nation-Sustainable Development Institute's Summer Sustainability Leadership Cohort, a program for Menominee High School youth.

- *UWEX Agricultural Institute Climate Change Team.* The NPM Program is part of a leadership group guiding the UWEX-Agriculture Institute Climate Change Education Team. The team's mission is to provide professional development and educational resources to enhance the ability of Extension agricultural educators to address current and expected challenges associated with climate change. In 2021, three professional development webinars were held, attended by 60 educators and specialists from three UWEX Institutes.

Outreach and Communication

- *Mobile applications*. The NPM Program creates mobile applications (apps) for hand-held devices (Apple and Android). Maintenance and updating of the NPM Program's apps occurred in 2022. Currently available mobile apps include: Tarspotter, Sporebuster, Manure Tracker, Sporecaster, Nitrogen (N) Price Calculator, Corn N Rate Calculator,

Potato Virus Predictor, Integrated Pest Management Toolkit, Corn Crop Calculator, Manure and Legume Nutrient Credit Calculator, and BeanCam (https://ipcm.wisc.edu/apps). Collectively, these apps have been downloaded by more than 180,000 users from across the world. All apps are created in collaboration with UW-Madison faculty and are promoting agricultural best management practices.

- *YouTube videos*. The NPM Program produced 35 new videos on a range of crop management topics in 2022. Over 370 YouTube educational videos featuring UWCALS specialists have been prepared and released by the NPM Program over the past 10 years. A complete listing can be found at https://www.youtube.com/user/uwipm. A conservative estimate of the number of views is greater than 1,200 worldwide per day with over 2.5 million total views as of November 2022.

- *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 1,250 recipients in 2022. Available online at: https://ipcm.wisc.edu/wcm.

- *NPM publications*. The NPM Program has a long history of collaborating with UW-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 2022, 50 new publications were produced. Formats range from simple pocket-sized cards to extensive manuals and workbooks. NPM staff roles include author, editor, and designer. A listing of NPM's print publications can be found at https://ipcm.wisc.edu/downloads.

- *NPM Resource Highlights.* An online, digital newsletter is sent monthly to the UWEX Agricultural Institute (AI) listserv. Its purpose is to inform AI affiliates of new and existing NPM Program resources that are seasonally pertinent. Publications, videos, mobile applications, etc. are featured. The original intent was to inform new county educators of NPM Program educational products; however, feedback from UW/UWEX faculty and staff indicate that they, also, find the information useful in their local programming efforts.

- The NPM Program won a Certificate of Excellence Award in 2022 from the American Society of Agronomy (ASA) Extension Education Materials Competition. The NPM Program has won a total of 25 awards from ASA in 10 years! The year 2022 award was for the *Nutrient Management Farmer Education Online Modules (*digital decision aids).

For more information on the NPM program:
Visit the website *https://ipcm.wisc.edu/*
Contact Damon Smith, Wisconsin NPM Program
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Madison, WI 53706
Email: *damon.smith@wisc.edu*

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 U.S. Environmental Protection Agency (EPA) 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). PFAS contamination has garnered significant attention and significant resources are being directed toward testing and outreach to support the many PFAS related efforts. 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 (DHS) and the Department of Natural Resources (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 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 present papers at a variety of conferences and symposia and publish research findings in professional journals.

Summary of Groundwater-Related Work at WSLH

Organic Chemistry Section

- The WSLH has developed and validated methods for measurement of PFAS chemicals in various matrices, including groundwater and drinking water. Significant coordination with state and federal partners occurs to ensure appropriate certifications are in place, which PFAS compounds to focus on, and matrix specific challenges such as limits of detection. As with many labs, capacity challenges exist so better and quicker ways to measure PFAS are continually being pursued. The WSLH is happy to partner with others and share information as appropriate to collectively advance understanding about these issues. State and federal efforts are ongoing to support drinking water and groundwater testing for PFAS compounds.
- Interpretation of data analyzed for petroleum compounds is performed to aid in fingerprinting possible sources of contamination.
- 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 an emergency response 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 continues to be deployed to assist in characterizing a possible contamination and the system worked as designed.

Water Microbiology Section

- 2021 and 2022 continues to see the WSLH performing significant work with SARS-CoV2 (Covid) in wastewater. Covid in wastewater has garnered significant attention and continues to be relevant and add value. This work was and continues to be a joint effort between the water microbiology and environmental toxicology sections. Covid in wastewater has been a useful tool to understand levels of the virus on a community level, thus indicating overall levels or trends of the virus on a broader scale.
- Source assessment requirement under the Revised Total Coliform Rule - WSLH continues to implement a scientifically based well assessment for wells testing positive for coliforms. This project is to develop and test a suite of microbial organisms that can determine the source of contamination by collecting a large volume sample using a hollow fiber ultra-filtration system.
- WSLH is researching changes to the fecal source tracking toolbox by implementing species-specific PCR assays for human, bovine, swine, and poultry Bifidobacteria;

improving the PCR primer sets for human and bovine Bacteroides spp.; and determining the feasibility of using pepper mild mottle virus to determine human contamination in groundwater. The research includes collecting fecal samples from animals throughout the state to determine sensitivity and cross reactivity for microbial sources of contamination.

- As a part of a larger laboratory-wide preparedness program, WSLH is prepared to offer appropriate microbial water quality testing when needed. WSLH is a member of the Environmental Response Laboratory Network and the Water Laboratory Alliance for both chemical and biological response. This involves participation in nationwide preparedness drills coordinated by the Centers for Disease Control and Prevention in conjunction with the U.S. EPA.
- The WSLH Flow Cytometry Unit coordinates and distributes samples for the only Cryptosporidium Proficiency Testing Program 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 is 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 that is designed to detect organisms that can be present in low concentrations.

Inorganic Chemistry Section

- Instrumentation is in place to measure isotopic ratios of certain metals (i.e. lead) to identify the source of the particular metal, be it the soil, paint, piping, etc. Each case is different, but it is possible to employ 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, are important in monitoring because they have been associated with specific geological formations and conditions in northeastern Wisconsin.
- Ancillary inorganic tests are routinely performed to measure chloride, sulfate, pH, alkalinity, and conductivity—properties that are important in controlling the chemical conditions for groundwater systems.
- As with other sections of the WSLH, the Inorganic Section responds to both spills that would affect surface water and groundwater. The lab has worked extensively with both DNR and DHS to identify contaminants in well water that may have had surficial origins. The WSLH has 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: Steve Strebel, interim associate director for non-clinical testing, Wisconsin State Laboratory of Hygiene
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Phone (608) 224-6216, email *steve.strebel@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 2023 Highlights

- Counties are operating a maintenance program for all POWTS in their jurisdiction.
- The Department continued offering training programs for the POWTS industry. This included monthly DSPS POWTS program updates provided virtually, technical training, and inspector training targeting new county inspection staff.
- The Department hired 2 project plan review positions authorized under WI Act 67. The positions are approved through June 2023.
- As allowed by law, the last Wisconsin Fund Grant application period was provided in January 2022. Unless the law is changed, this grant program will not be funded again.
- DSPS Announced Funding for UW-Stevens Point Study by Soil and Waste Resources Scientist to Update Septage Disposal Standards.

Details of Ongoing Activities

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

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

General Plumbing – Reuse and Stormwater Use

The Department plumbing code includes standards for reuse of wastewater and stormwater. Currently, the Chapter SPS 382 stormwater rules create the ability for plumbing to be integrally involved with the design and installation of storm systems complying with Chapter NR 151, Wis. Admin. Code. At this time, there are over 315 approved stormwater use or wastewater reuse plumbing systems in Wisconsin.

Private Onsite Wastewater Treatment Systems (POWTS)

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

Data Management

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

For further information:

Visit the following web site: https://dsps.wi.gov/pages/Home.aspx
Contact: Bradley Johnson
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REPORT OF THE GOVERNOR'S REPRESENTATIVE

Steve Diercks, Coloma, WI

As a potato and vegetable grower member of the Wisconsin Potato & Vegetable Growers Association (WPVGA) and the Governor's Representative on the Wisconsin Groundwater Coordinating Council, I am pleased to report that the 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:

- 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. These studies are being conducted on-farm as well as at the UW-Hancock Agricultural Research Station.

- 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), which is the term used for crop water use. This project is being led by Dr. Ankur Desai and uses the latest technology of an eddy covariance flux tower system to measure ET in an irrigated vegetable field as well as using another flux tower system to measure ET in a nearby forest. Research results are being shared with growers to assist them in their irrigation management and scheduling regimes. Four years of data show that the ET rates are higher (reflecting

greater water use) in the pine forest than the irrigated vegetable field. In 2022, the towers were moved to Plover into a potato production field owned by Worzella & Sons; along with one tower in the adjacent Boston School Forest. The in-field tower will be moved to another nearby potato field owned by the Worzellas in 2023.

- In 2023, the WPVGA was successful in receiving a third Producer-Led Watershed Protection Grant from the Wisconsin Dept. of Agriculture, Trade and Consumer Protection. Eight member farms are now participating in the project which is located in the Little Plover River/Wisconsin River watershed. Called the Central Wisconsin Farmers Collaborative, the group seeks to promote innovative conservation and stewardship practices that benefit the watershed, the landscape, and the land managers themselves through collaborative partnerships, farm-to-farm education programs and other strategic actions. Conservation practices employed by the group include the extensive use of cover crops, prairie and pollinator plantings, and no-till/minimum till practices. There are also extensive wetlands restoration practices employed in this watershed.

- An additional Producer-Led Watershed Protection group was formed in 2022 in the Central Sands and they are receiving second-year funding in 2023: Farmers of the Roche-A-Cri. Farmers of the Roche-A-Cri has WPVGA members representing Coloma Farms, Signature Farms, Heartland Farms, Nathan Bula Farms LLC, Sterling Farms and Flyte Family Farms. The WPVGA continues to encourage more member farms to participate in the Producer-Led Watershed Protection Grant program.

- Three WPVGA member farms are participating in the Nitrogen Optimization Pilot Program through WDATCP. Coloma Farms, Plover River Farms and Flyte Family Farms all received grant funding to conduct commercial nitrogen optimization research in 2023 and 2024.

- 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 has improved 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 ensure the project's success.

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

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

- The WPVGA 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. The Nature Conservancy is also contributing grant funds toward this project (seven years at $15,000/year).

- In cooperation with the DNR, the WPVGA continues to collect and post data from over 25 monitoring wells to continuously track fluctuations in groundwater at regular intervals across three areas designated as high risk for surface water impacts (Little Plover River/Plover area, Long Lake/Plainfield area, and Pleasant Lake/Coloma area). Groundwater elevations are posted at https://wisa.cals.wisc.edu every three weeks. The DNR received permission from the WPVGA to conduct the data collection and posting from the monitoring wells in the Plainfield and Coloma areas as part of the Central Sands Lakes Study component of 2017 Wisconsin Act 10, related to the potential impacts of groundwater withdrawals on three lakes in the Central Sands.

- WPVGA Executive Director Tamas Houlihan participated in the search and screen committee to select a UW Assistant Professor of Cropping Systems Water Quality position to work on potato and vegetable crops in the Central Sands. Dr. Steven Hall was hired and will officially begin work at UW-Madison on September 1, 2023. Plans are in place to have Dr. Hall work closely with the WPVGA Water Task Force as well as the WPVGA Research Committee on water quality research projects.

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.

BACTERIA, VIRUSES AND OTHER PATHOGENS

Key Takeaways

As you will read below, it is important to evaluate the occurrence of viruses and other pathogens in groundwater and groundwater-sourced water supplies and develop appropriate response tools in order to protect human health. Homeowner complaints about private well bacterial contamination events, which often correspond with manure spreading, are an ongoing concern for GCC agencies. The DNR and DATCP tried to update standards (NR 151) in order to address these issues, but they were not passed.

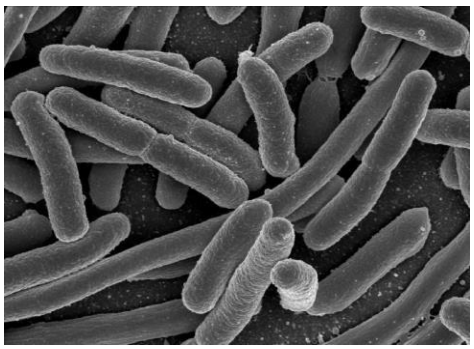
GCC member agencies continue to work on multiple initiatives related to reducing bacteria, viruses and other pathogens in groundwater (see groundwater management sections – DHS, DNR, DATCP, UWS, WGNHS).

For actions to address bacteria, viruses and other pathogens contamination in groundwater, see the Recommendations Section.

Sections in this document

What are bacteria, viruses and other pathogens?

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 pathogen "indicators", such as total coliform bacteria, fecal coliform bacteria, *Escherichia coli* (*E. coli*) bacteria, enterococci bacteria or coliphage viruses. These indicator microbes are not necessarily harmful themselves, but are a warning sign that other, potentially pathogenic, microorganisms may be present.



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

Microorganisms are prevalent and abundant in the subsurface and in groundwater.[1] The United States Geological Survey[2] 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[3]. While most microorganisms in the subsurface are harmless, pathogenic microbes from human and animal fecal waste sources can contaminate groundwater in areas where they can be readily transported through the subsurface to underground drinking water supplies.

There are no specific groundwater quality standards for pathogenic microorganisms in Wisconsin, but currently there are standards in ch. NR 140 for total coliform bacteria, an indicator of possible microbial pathogen contamination. The ch. NR 140 preventive action limit (PAL) and enforcement standard (ES) for total coliform bacteria are 0 coliform bacteria present in a tested sample. Public drinking water systems are regularly monitored for total coliform bacteria (WI NR 809.31-809.329), and these systems are tested for *E. coli*, and possibly other fecal indicators such as enterococci or coliphages, if coliform bacteria are found to be present.

In 2016 the Environmental Protection Agency (EPA) changed its rules related to the use of microbial pathogen indicators in the regulation of public drinking water systems. In 2016 the EPA's Revised Total Coliform Rule (RTCR) for public drinking water systems went into effect. Under the RTCR the existing total coliform bacteria drinking water maximum contaminant level (MCL) was removed and replaced with a total coliform treatment technique (TT). If total coliform bacteria are confirmed present in a public drinking water system the total coliform TT requires system assessment and corrective action. The EPA also established a drinking water MCL for *E. coli* bacteria under the RTCR. Detection of *E. coli* bacteria is considered a more specific indicator of fecal contamination, and the possible presence of harmful pathogens, than just detection of total coliform bacteria.

Total coliform bacteria include bacteria that naturally occur in the environment, and are, with a few exceptions, not harmful to humans. Under the RTCR, detection of total coliform bacteria is used as an indicator of possible microbial pathways into a public drinking water system. Under the RTCR, detection of *E. coli* bacteria in a public water supply system is an MCL violation. Public notification is required for a public drinking water system *E. coli* MCL violation. This notification instructs the public to either boil water from the public system before consuming, or to use bottled water.

Considering the changes that have been made to the public water system RTCR, the department has revised ch. NR 140 to establish groundwater quality standards for *E. coli* bacteria and to revise the current standards for total coliform bacteria. Rulemaking has now been completed to establish ch. NR 140 health based groundwater standards for *E. coli* bacteria and to transition total coliform bacteria

from a health based standard to an indicator parameter groundwater standard. These revisions to ch. NR 140 have been approved by the Natural Resources Board and state legislature. They will be effective August 1, 2023.

What are the human health concerns?

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 in 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[4].

Antibiotic resistance, associated with subsurface microorganisms, may also be a significant groundwater contaminant in some situations. Use of antibiotics at large animal feeding operations for growth promotion can result in antibiotic resistance (ineffectiveness of antibiotics in treating infections) spreading into the environment[5]. Groundwater monitoring around swine manure lagoons in Illinois found that antibiotic resistant genes, associated with leakage from the manure lagoons, were present in groundwater[6]. In a study of manure at a Wisconsin dairy farm, *E. coli* bacteria resistant to four different antibiotics were detected[7].

How widespread are bacteria, viruses and pathogens in Wisconsin?

Many factors influence microbial transport in the subsurface, both vertically through the unsaturated zone, and with groundwater flow through an aquifer. Processes such as filtration, adsorption and "die-off" can all affect the fate and transport of microbial pathogens[8]. These microbial removal and attenuation mechanisms can be complex, with a number of factors influencing how effective they may be at reducing the number of pathogens in groundwater. Factors such as soil depth, presence of preferential flow paths, soil saturation, microbial biofilms, temperature, pH, flow rate, soil microbial flora and soil organic matrix can all influence microbial pathogen transport and survival.

Fecal waste from humans, domesticated animals, wildlife, and insects can all be sources of pathogenic microorganisms in the environment. Discharges of human and domesticated animal fecal waste to the environment include wastewater effluent discharge and infiltration, and the land application of animal manure, septage and municipal wastewater biosolids. The land application discharge of human waste, and some animal waste, are regulated activities in Wisconsin. For these regulated activities, pathogen reduction, including soil treatment in the unsaturated zone, is required to remove and attenuate microbial pathogens that might be present in the waste. Soil treatment requirements in state administrative rules include minimum vertical separation distances between land disposal/application and groundwater. State rules also place limitations on waste discharge loading and application rates based on discharge site soil conditions.

Most bacteria entering the ground surface along with rainwater or snowmelt are filtered out or attenuated as water seeps downward through the unsaturated soil zone to groundwater, however, some strains of bacteria can survive a long time and may find their way into the groundwater by moving through coarse grained soils, shallow fractured bedrock, quarries, sinkholes, inadequately grouted wells or cracks in well casing. Water supply wells may also be contaminated by insects or small rodents that can carry microbial pathogens into wells with inadequate caps or seals.

In Wisconsin, it is well known that groundwater in areas with karst geology is vulnerable to microbial contamination and needs special consideration and protection. Karst geology includes areas with soluble carbonate bedrock that may have relatively large fractures through which water flows rapidly and where sometimes karst surficial features, such as sinkholes, caves and disappearing streams are present. 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 microbial pathogens. 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, including Door County, parts of Kewaunee County and in southwestern WI. Some of these areas are especially vulnerable since, in addition to karst geology, they have very thin soil cover.

How are bacteria, viruses and other pathogenic contamination trending over time?

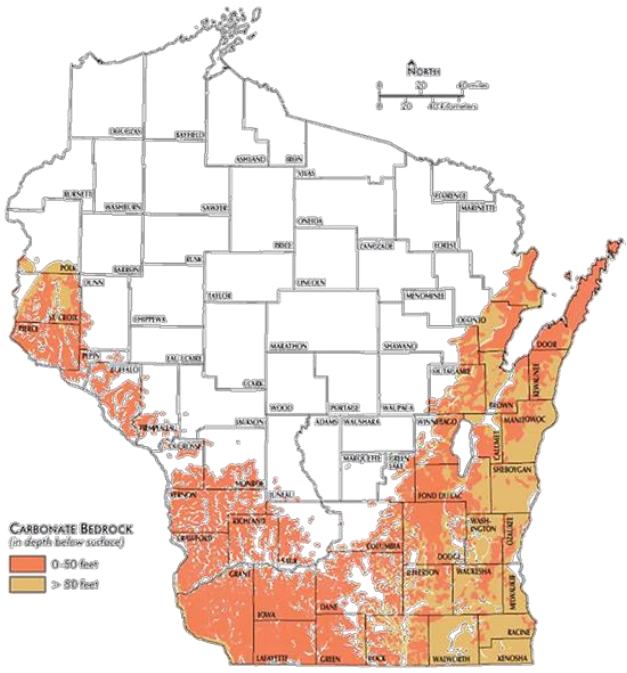
Analysis of statewide sampling results show that approximately 17% to 23% of private water supply wells in Wisconsin test positive for total coliform bacteria, and approximately 3% of private wells test positive for *E. coli* bacteria[9,10].

A study that sampled private water supply wells in Kewaunee County[11] showed that, county wide, private wells tested positive for total coliform bacteria at about the same percentage as statewide averages. Wells located in areas with shallower depths to bedrock, however, did test positive for total coliform and *E. coli* bacteria at percentages greater than state averages. Genetic markers, for microbial waste source indicators and pathogens, were detected, using polymerase chain reaction (PCR) molecular methods, in some of the study wells that were tested for those markers.

The Southwest Wisconsin Groundwater and Geology (SWIGG) study looked at the presence of total coliform bacteria and genetic markers for microbial waste source indicators and pathogens in private water supply wells in Grant, Iowa and Lafayette Counties[12]. The study area, in southwestern Wisconsin, has karst geology and relatively thin soil cover. Sampling found total coliform bacteria in private wells in the study counties at percentages greater than, or similar to, statewide averages. Waste source and pathogen genetic markers were detected, using PCR molecular methods, in some of the study wells that were tested for those markers. The study

also found possible correlations between a number of well construction, geologic and land use factors and potential sources of well contamination.

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[13]. 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. Since 2006, more than 60 private wells in Wisconsin have had to be replaced due to manure contamination, at a cost to the state of over $500,000[14].



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

An emerging concern is the potential presence of viruses in drinking water wells, including noroviruses, adenoviruses and enteroviruses. Virus contamination may not necessarily correlate well with total coliform bacteria detection in groundwater because viruses can have different transport properties than bacteria[15].

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 culturable enteroviruses, or enterovirus or norovirus genetic material, was reported detected in Wisconsin during the UCMR-3 sampling effort.

Homeowner complaints about private well bacterial contamination events, which often correspond with manure spreading, are an ongoing concern for GCC agencies. DNR's Drinking Water & Groundwater and Runoff Management programs has worked with DATCP's Nutrient Management program staff to find ways of controlling this major source of contamination. The DNR, in conjunction with DATCP, has

revised performance standards and prohibitions related to manure land application in areas of the state with carbonate bedrock and shallow soils.

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. More research is needed on the transport and survival times of various viruses in groundwater aquifers.

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. Recent findings, however, 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 related to this issue.

Further Reading

- DNR overview of bacteriological contamination in drinking water
- DNR overview of cryptosporidium in drinking water
- DHS fact sheet on manure contamination of private wells
- WGNHS overview of karst landscapes
- WGNHS report on municipal drinking water safety
- DNR list of municipal drinking water systems that disinfect

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NITRATE

Key Takeaways

Due to the pervasiveness of ongoing nitrate contamination in groundwater and the seriousness of its human health and environmental impacts, there is urgent need to address Wisconsin's nitrate contamination problem. Nitrate contamination has been negatively impacting Wisconsin waters for over 50 years and is still increasing. The GCC listed nitrate contamination of groundwater as a problem in the first annual report in 1985 and has emphasized nitrate in groundwater as a priority concern since 1994. GCC agencies continue to proactively address nitrate contamination but must be allowed to implement more effective practices in order to protect groundwater sources of drinking water.

GCC member agencies continue to work on multiple initiatives related to reducing the risk of high nitrate levels in groundwater and drinking water (see groundwater management sections – DNR, DATCP, UWS, WGNHS).

For actions to address nitrate contamination in groundwater, see the Recommendations Section.

Sections in this document

What is nitrate and what are the human health concerns?

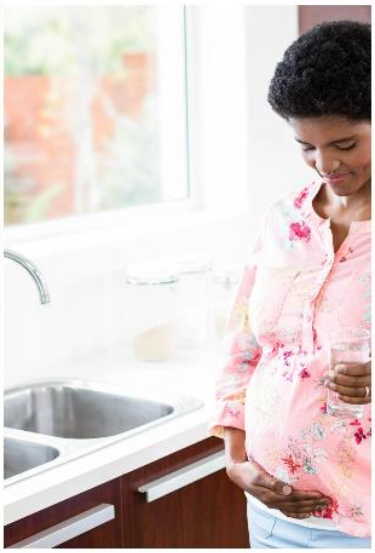
Nitrate (NO_3) is a water-soluble molecule that forms when ammonia or other nitrogen rich sources, including nitrogen fertilizers, combine with oxygen. Nitrate levels in groundwater are generally below 2 parts per million where pollution sources are absent. Higher levels indicate a human-caused source of groundwater contamination such as agricultural or turf fertilizers, animal waste, septic systems or wastewater. Nitrate dissolves easily in water and does not adsorb onto the soil. It can easily be carried into the groundwater by rainwater and melting snow as they percolate through the soil and bedrock into the underlying aquifer. While nitrogen fertilizer in agricultural use results in larger crop yields, high concentrations of nitrate in groundwater can harm public health. 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 mg/L or 10 ppm (WI NR 140.10, WI NR 809.11). Everyone should avoid long-term consumption of water containing nitrate above this level.

Nitrates are also found naturally in certain vegetables and are added as a preservative in cured meats. Is there a difference in health consequences based on how nitrate is consumed? Nitrate is reduced to nitrite in the body by bacteria in the mouth and gastrointestinal tract. In blood and tissues, nitrite is normally reduced to nitric oxide, which plays an important physiologic role in vascular and immune function. However, under certain conditions in the body, nitrite has the potential to be converted to harmful compounds, notably carcinogenic nitrosamines. The way nitrate is consumed, such as the type of food or in drinking water, may affect how nitrate is processed in the body[1]. While no negative health consequences are attributed to consuming nitrates from vegetables, the Wisconsin Department of Health Services (DHS) concludes, based on the weight of scientific data, that high levels of nitrate in drinking water pose a number of health risks.

Why do we care about nitrate in our groundwater?

Nearly 75% of Wisconsin's drinking water comes from our groundwater. Drinking water with high levels of nitrate is unsafe for everyone! It poses 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, such as thyroid disease and cancer.



Known public health risks:

- Infants below the age of 6 months who drink water containing nitrate in excess of the MCL are especially at risk, and could become seriously ill with a condition called methemoglobinemia or "blue-baby syndrome". This condition deprives the

infant of oxygen and in extreme cases can cause death. The DHS has associated at least three cases of suspected blue-baby syndrome in Wisconsin with nitrate contaminated drinking water2. In children, there is also growing evidence of a correlation between nitrate and diabetes[3,4].

- 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 defects5. 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. These studies collectively indicate an ongoing need for caution in addressing consumption of nitrate by pregnant women and support the continuation of private well testing programs.
- 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 potential associations with non-Hodgkin's lymphoma[6], gastric cancer[7,8], and bladder and ovarian cancer in older women[9].
- DHS also cites thyroid disease and colon cancer as 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."

What effect does nitrate contamination have on our wildlife?

Loss of biodiversity and serious health issues, including death in fish and amphibians have been shown to be caused by nitrate contamination.

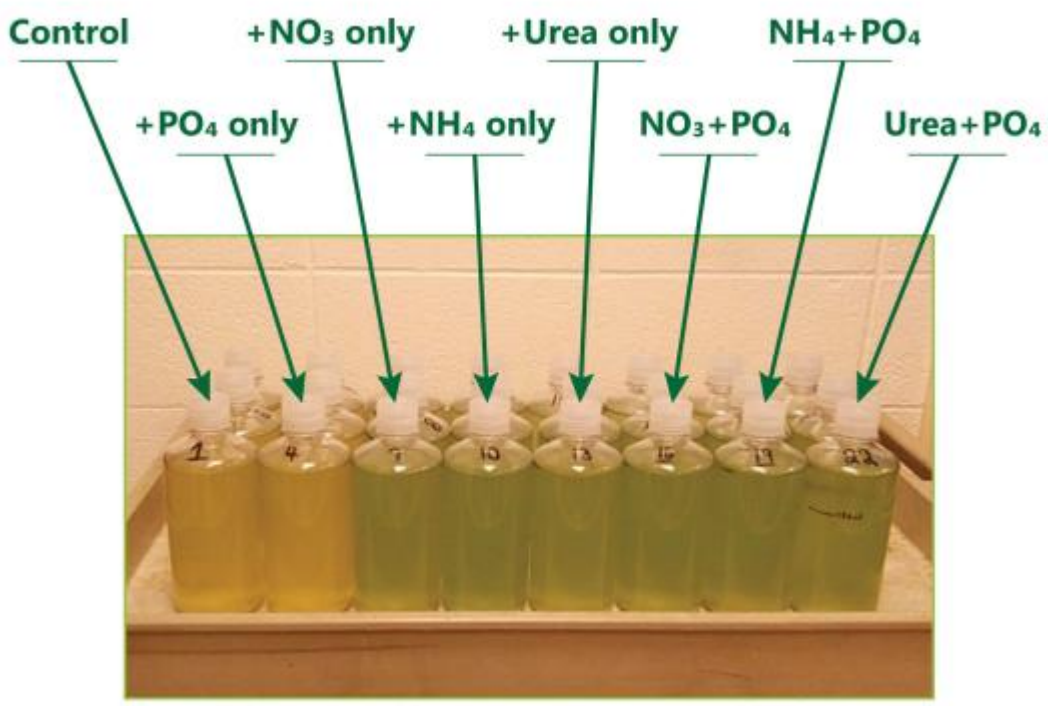
What are the environmental effects of nitrate contamination?

Adverse environmental effects from nitrate contamination are well documented.

- Loss of biodiversity in terrestrial and aquatic systems has been documented with increasing nitrate[10].
- A number of studies have shown that nitrate can cause harm or death in fishes, amphibians and aquatic invertebrates[11-17]. This is significant because many baseflow-dominated streams (springs, groundwater-fed low-order streams) in agricultural watersheds in Wisconsin exhibit elevated nitrate concentrations, at times exceeding 30 ppm.

- In addition to phosphorus, nitrogen contributes significantly to nutrient-related water quality degradation of lakes and streams in Wisconsin. Groundwater and drain tile transported nitrate, along with urea and ammonium play a significant role in the over-enrichment of water bodies, driving excessive algae and cyanobacteria growth, along with increasing the potential for harmful algal bloom toxin formation[18,19]

How Does Nitrogen Affect Harmful Algal Blooms?



Nutrient additions to Planktothrix bloom samples from Sandusky Bay show that nitrogen affects algae growth (Davis et al. 2015). Water samples that appear green indicate more algal growth than samples that appear yellow. The type of nutrient addition, if any, is shown above each column of water samples: the yellow bottle on the far left is the control (i.e., no nutrient addition), the second yellow bottle was spiked with phosphorus only, and the six green bottles on the right are spiked with either nitrogen or both nitrogen and phosphorus. Source: Great Lakes HABs Collaborative.

How widespread is elevated nitrate in Wisconsin's groundwater?

Nitrate is Wisconsin's most widespread groundwater contaminant and nitrate is increasing in extent and severity in the state[20-23].

Nitrate in public water systems

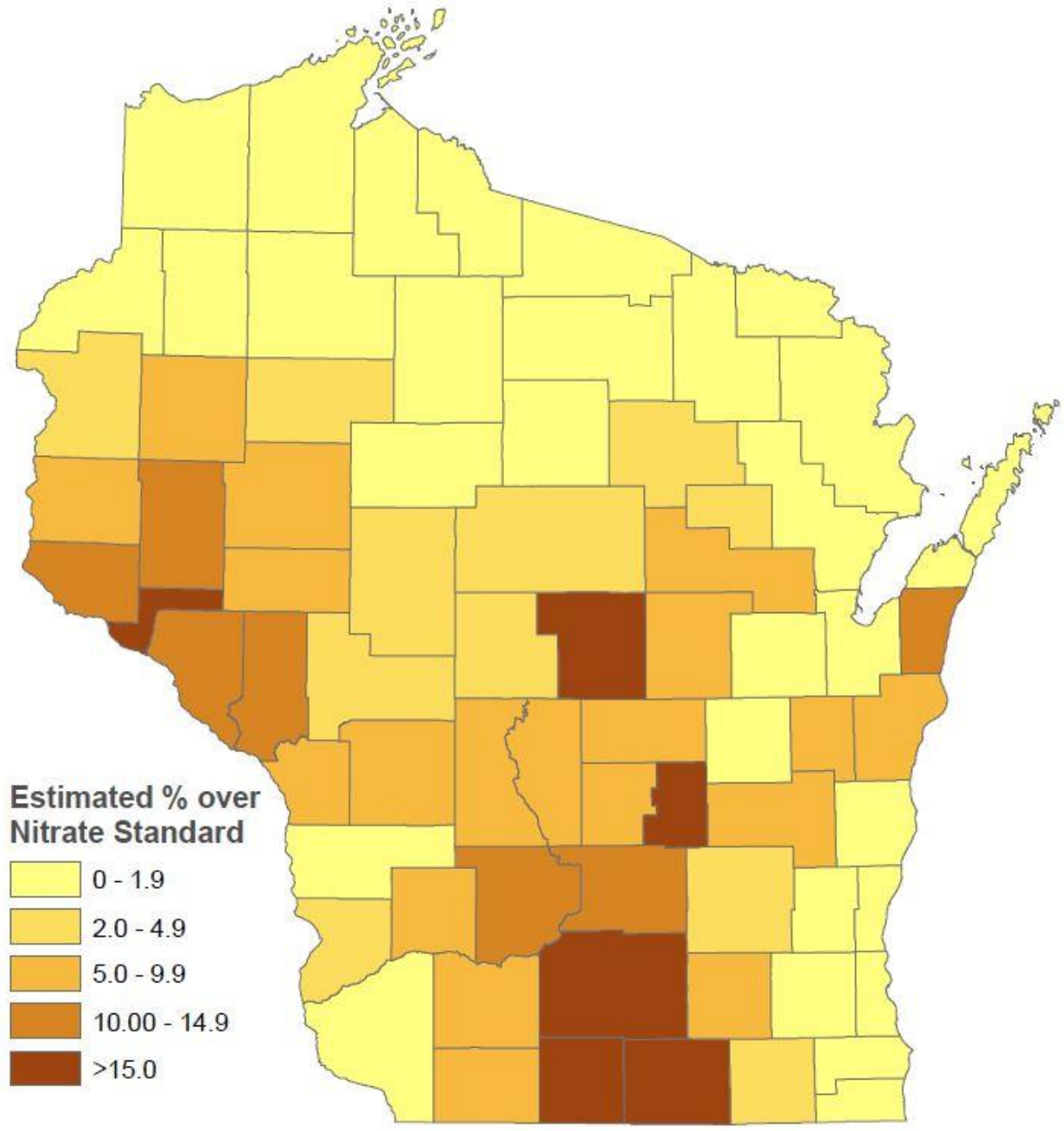
A 2012 survey of Wisconsin municipal water-supply systems found that 47 systems had raw water samples that exceeded the nitrate-N MCL, up from just 14 systems in 1999. Increasing nitrate levels have been observed in an additional 74 municipal systems. In FY 22, more than 200 public water supply systems (many of which were small businesses) exceeded the nitrate drinking water standard of 10 mg/L requiring them to post notices, provide bottled water, replace wells, install treatment or take other corrective actions.

Nitrate in private water systems

Private water wells, which serve about one third of Wisconsin families, are at continued risk of nitrate contamination. 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[24,25]. In agricultural areas, such as the highly cultivated regions in south-central Wisconsin, around 20%-30% of private well samples exceed the MCL[26]. Nitrate concentrations affect deeper wells over time as nitrate pollution penetrates aquifers and migrates farther from original source areas[21].

In 2014, in response to the DHS revised health recommendation that long-term use of water over the standard by anyone poses a significant health risk, ch. NR 812 Wis. Admin code (Well Construction and Pump Installation) was changed to require sampling for nitrate in both newly constructed wells and existing wells that had pump work done. To date, the pump work and new well dataset has over 200,000 samples, providing one of the least biased large data sets in Wisconsin.

Data from Jan. 2022 – June 2023 for new well and pump work showed that of the 23,126 samples taken, 1,379 or 6.0% were greater than 10 ppm and 7,299 or 31.5% were above the preventative action limit (PAL) of 2 ppm. Unfortunately, some counties have a much greater percentage of wells testing above the 10 ppm standard for nitrate. See map below for individual county results.



Map of Estimated Percentage of Private Wells over Nitrate Standard by County (Jan. 2022 through June 2023).

Land use and nitrate contamination

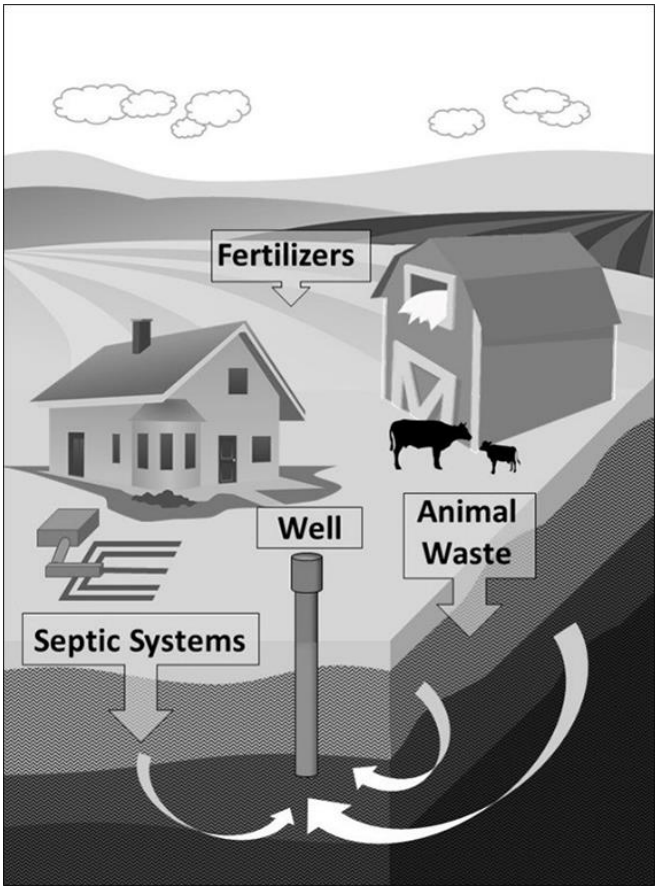
The vulnerability of groundwater to contamination depends on aquifer sensitivity in combination with a source of naturally occurring or human-caused contamination. An analysis completed in 1994 of relative source contributions concluded that about

90% of nitrogen inputs to groundwater in Wisconsin can be traced to agricultural sources including manure spreading and fertilizer application[27].

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.

How does nitrate get into our drinking water?

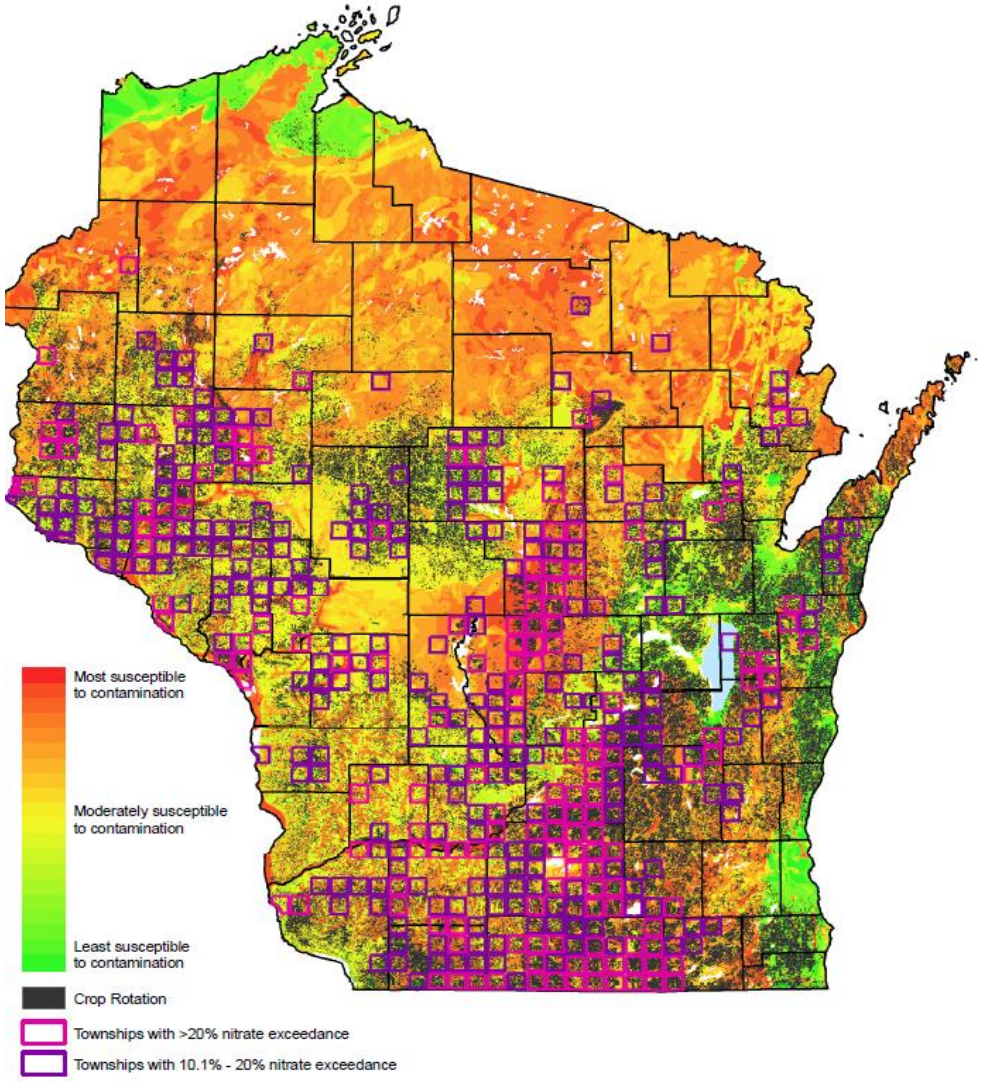
Nitrate can enter our groundwater (and then our drinking water) from fertilizer, animal and human waste runoff. *Graphic created by Minnesota Department of Health. Used with permission.*



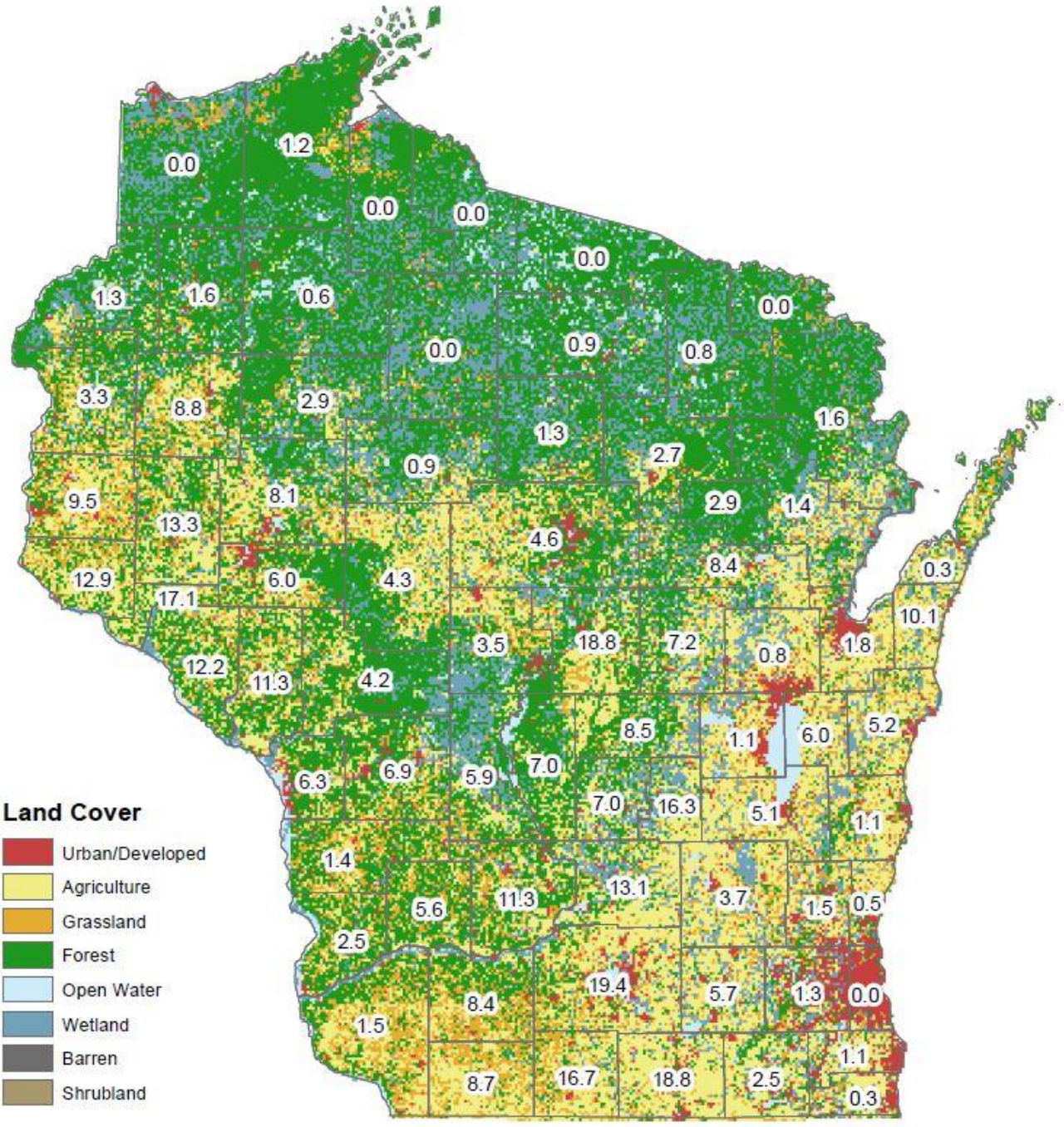
At a statewide scale, a mapping of broad land use categories overlayed with the estimated percentage of private wells exceeding the health-based standard by individual counties also illustrates that more wells are impacted in agriculturally intensive areas of the state.

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

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.



Map of Estimated Percentage of Private Wells over Nitrate Standard by County with Land Cover (Jan. 2022 - June 2023).

Is groundwater nitrate increasing or decreasing?

Evidence indicates that nitrate contamination of our groundwater resources has increased in more locations over time rather than decreased. 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.

At a statewide scale, evaluation of overall nitrate trends using existing private and public well data is challenging for several reasons. Private wells are not typically sampled consistently over time, and not all private well data is reported to DNR. Public water system sampling, on the other hand, is to ensure water is safe at the tap. Once a public well exceeds the nitrate MCL, the system is required to come back into compliance and the preferred action is to replace the well. Wells with increasing trends are thereby removed, biasing the public water data set towards wells without increasing nitrate concentrations.

Both new private and public wells tend to be sited, drilled and cased to avoid known water quality issues such as nitrate contaminated groundwater. To help evaluate aquifer depths where lower nitrate levels may be found, the DNR provides assessment tools to evaluate the depth of penetration of nitrate in the aquifer based on historical well sampling and well construction data within a Township. 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 data sets.

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

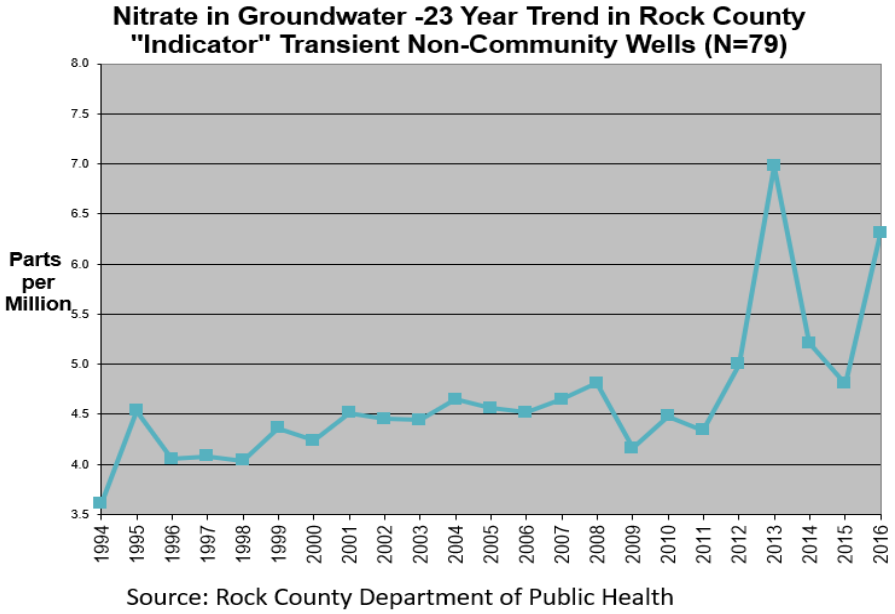
MCL violations for nitrate in recent years by public well type – Municipal Community (MC), Other than Municipal Community (OC), Non-Transient, Non-community (NN) and Transient, Non-community (TN). *Note: the numbers for TN systems do not include the approximately 200 wells on continuing operation (sampling between 10 ppm and 20 ppm).* DNR has initiated a work plan that will bring all TN public water systems back into compliance with the nitrate standard of 10 mg/L.

However, we do have a large number of public wells distributed across the state that are required to submit nitrate sample results to the DNR at least annually. On

average, there are approximately 11,0000 non-community public wells (e.g. small businesses, schools, churches) active at any given time. A review of the historical record of these well data since 1975, shows a relatively consistent number of wells exceed the 5 mg/L and 10 mg/L nitrate thresholds within any single 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 wells over the full period of record, there is a much larger set of wells represented (>20,000 individual 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 DNR 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 as corrective actions are implemented to meet drinking water standards. The table below lists MCL violations for nitrate in recent years by public well type – Municipal Community (MC), Other than Municipal Community (OC), Non-Transient, Non-community (NN) and Transient, Non-community (TN).

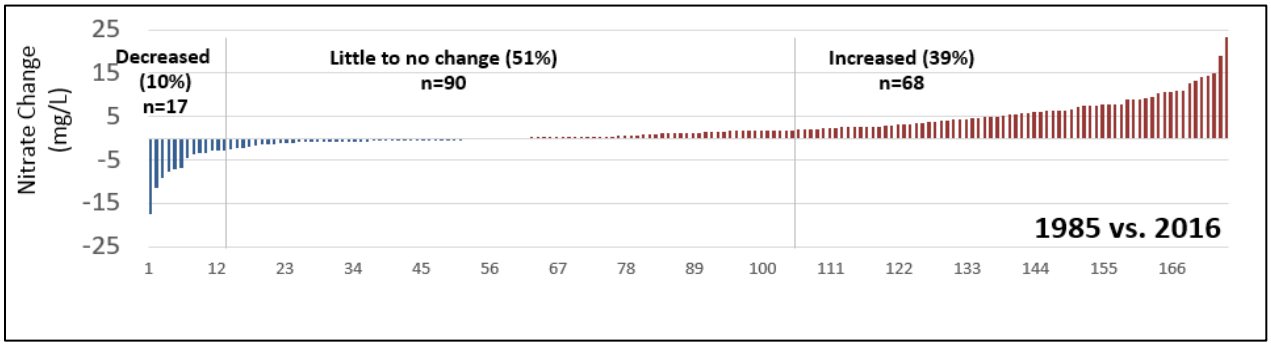
Regional and local nitrate trends

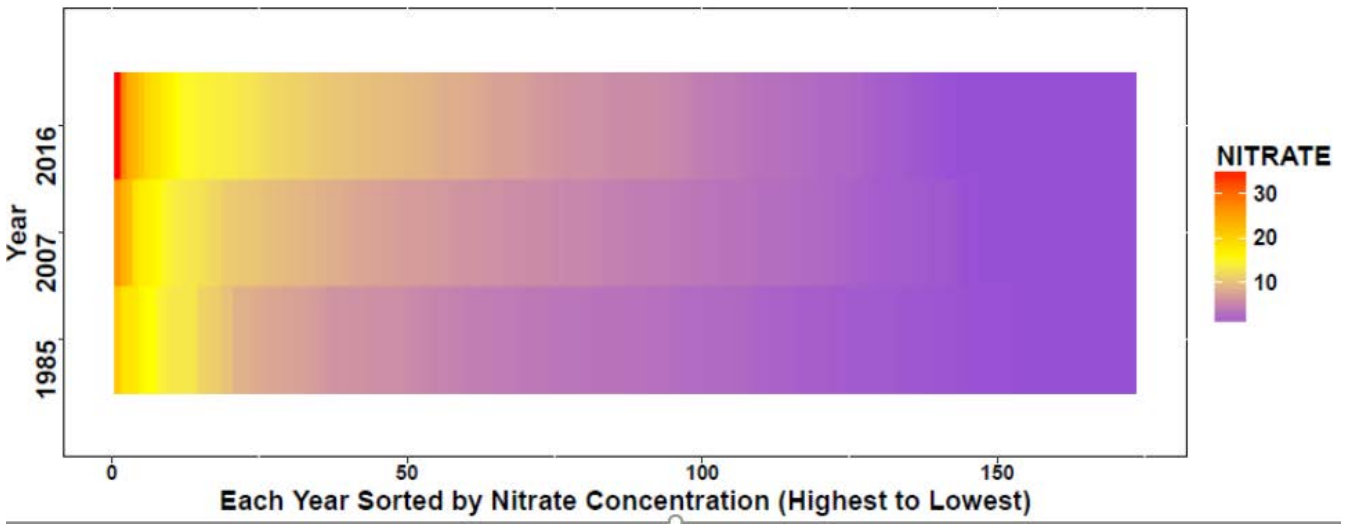
Wisconsin counties have conducted their own studies using consistent sets of well data that reveal local trends in aquifer nitrate levels. The Rock County Health department has been sampling and maintaining a data set based on a consistent set of transient non-community (TN) public wells over approximately 25 years. A group of 79 wells located throughout the county has shown an increasing average concentration since 1994, with a marked increase in the last decade (see figure below).



These consistently sampled TN wells show an increasing nitrate trend since 1994.

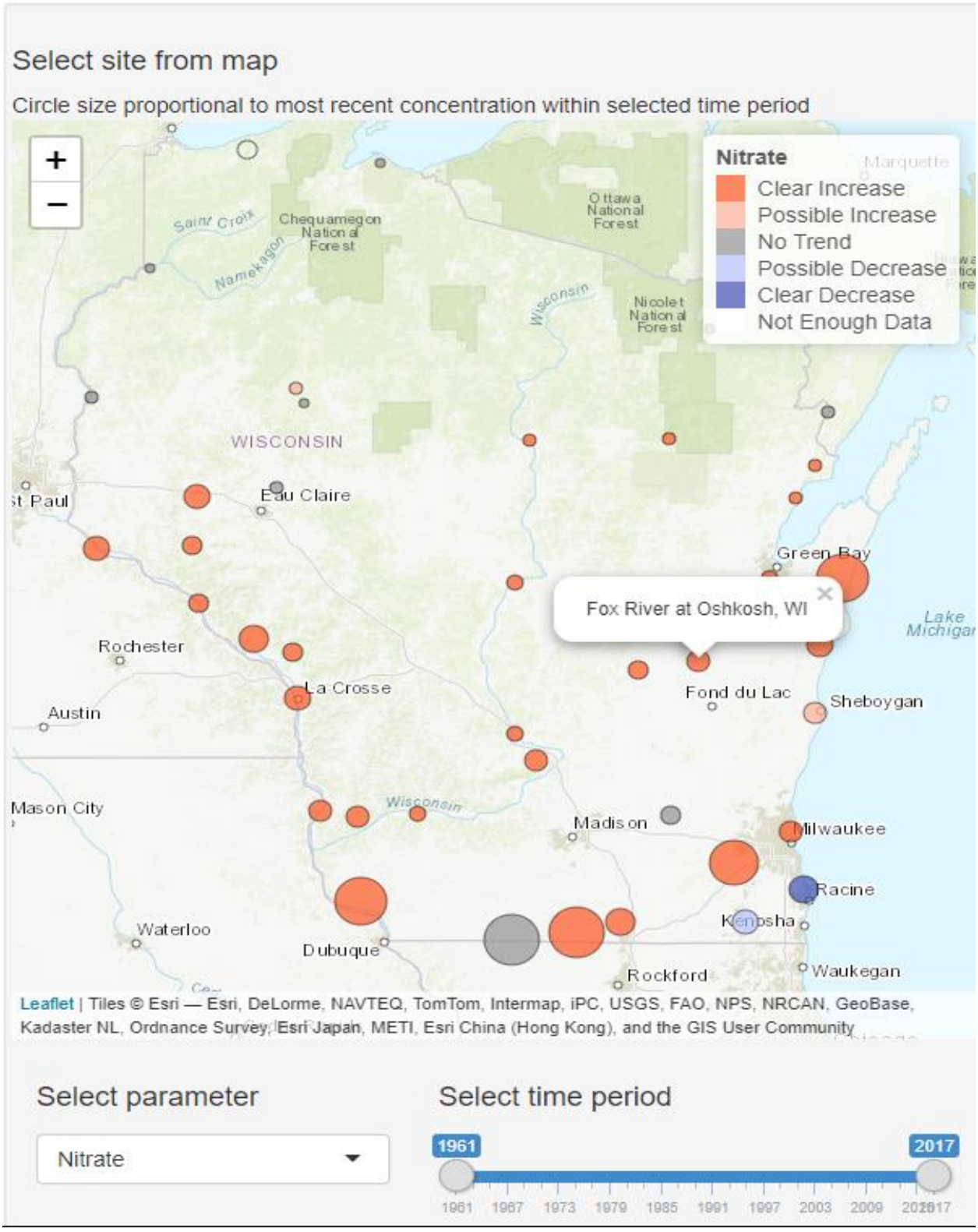
Chippewa County provides another example where a consistent set of private wells (175) were sampled multiple times over thirty years. This data set shows the importance of location: most wells saw little or no change over the 30 years (51%) and some wells showed a decrease (10%), while 39% showed an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



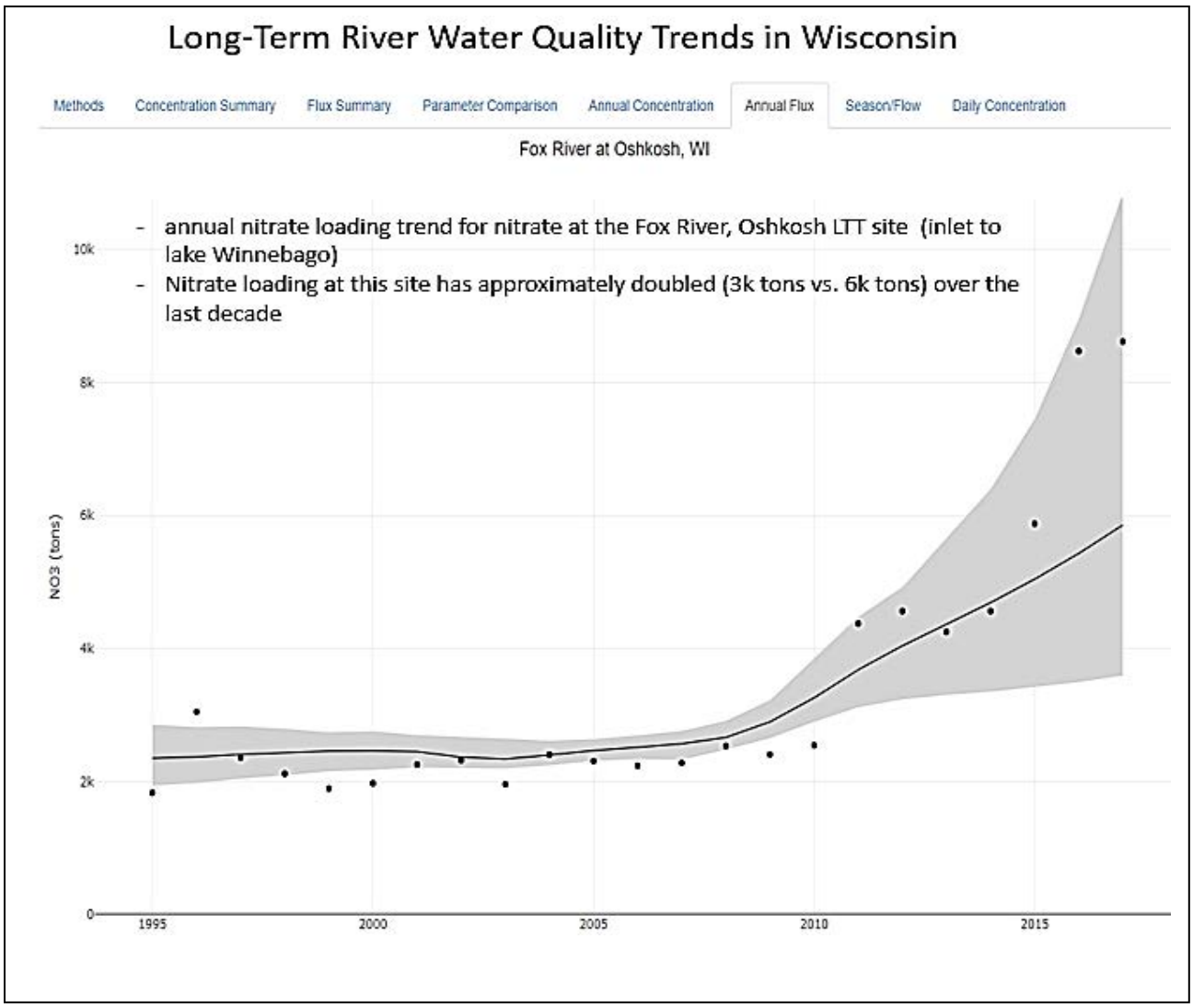


Chippewa study: old, mid and late era sample data. Masarik et al., 2016 In preparation.

Another useful method to assess long-term groundwater nitrate trends throughout the state is to evaluate data from groundwater baseflow dominated streams. A large portion of the state is covered by "groundwater dominated" watersheds (i.e. the ratio of groundwater baseflow to total streamflow is greater than 50%). Long term trend monitoring sites maintained by DNR and USGS in these watersheds 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 to be as high as 90%[28]. Data from DNR's Long Term Trend Network for streams shows increases in nitrate concentration for most locations throughout the state.



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



Estimated costs in Wisconsin to mitigate Nitrate

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 if the nitrate-N level in their well exceeds 10 ppm.

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[29]. Of the families who took actions, most purchased bottled water for use by an infant or pregnant woman. It appears that some private well owners in rural Wisconsin are installing reverse osmosis filter systems at considerable cost to obtain safe drinking water[23].

Private well owners cost analysis

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

The analysis 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 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 safe water at the source.

The data analysis from 2019 shows that 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 it with a new safe water supply exceeding 446 million dollars. Results by county are shown in the table below. These costs are now about double due to the increased cost of steel, cement and drilling being driven by supply chain issues during and after Covid-19.

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, because no reason was listed on the report. Using the same methodology, it is estimated that private well owners have spent more than 9 million dollars to replace wells with elevated nitrate levels.

Table 1: Estimated percent/number of private wells exceeding the health standard for nitrate and the total cost estimate to abandon the contaminated well and replace it with a new safe water supply by county.

County	Estimated # of private wells	Estimated % of wells over 10 ppm Nitrate Standard	Estimated # of private wells over Nitrate Standard	Estimated Replacement Cost (millions)
Adams	9959	12.4%	1232	$10.82
Ashland	2290	0.0%	0	$0.00
Barron	9336	9.3%	872	$8.69
Bayfield	5679	0.0%	0	$0.00
Brown	14077	2.9%	414	$4.93
Buffalo	3158	7.1%	224	$1.67
Burnett	6689	1.2%	82	$0.41
Calumet	3932	10.5%	413	$5.25

Table 1 continued:

County	Estimated # of private wells	Estimated % of wells over 10 ppm Nitrate Standard	Estimated # of private wells over Nitrate Standard	Estimated Replacement Cost (millions)
Chippewa	13242	13.5%	1788	$15.99
Clark	6581	5.4%	357	$1.80
Columbia	8762	17.9%	1564	$19.22
Crawford	2485	0.9%	24	$0.28
Dane	23506	18.3%	4313	$65.61
Dodge	11112	5.0%	553	$7.44
Door	11797	1.3%	153	$2.04
Douglas	5165	0.0%	0	$0.00
Dunn	7501	12.1%	906	$6.65
Eau Claire	9153	5.3%	483	$3.89
Florence	2423	1.6%	39	$0.18
Fond du Lac	12190	5.3%	649	$8.41
Forest	4073	1.3%	54	$0.19
Grant	5895	6.6%	389	$6.05
Green	5474	20.2%	1106	$15.22
Green Lake	4957	19.5%	968	$14.60
Iowa	3511	12.5%	438	$7.13
Iron	749	0.7%	6	$0.02
Jackson	4688	6.7%	312	$1.63
Jefferson	9491	8.3%	792	$8.16
Juneau	5166	11.6%	600	$3.85
Kenosha	15570	0.8%	132	$1.21
Kewaunee	3741	3.3%	122	$0.90
La Crosse	7216	13.4%	965	$8.99
Lafayette	2628	15.3%	402	$5.74
Langlade	6387	4.7%	298	$2.41
Lincoln	7396	3.7%	277	$1.55
Manitowoc	8693	6.2%	539	$6.87
Marathon	22195	7.1%	1578	$11.36
Marinette	10295	2.3%	239	$1.41
Marquette	5951	9.4%	559	$5.90
Menominee	1287	0.0%	0	$0.00
Milwaukee	23534	0.3%	80	$0.48
Monroe	6561	10.1%	662	$4.63
Oconto	13336	2.4%	321	$2.54
Oneida	15788	1.7%	274	$1.31
Outagamie	13997	0.8%	117	$1.91
Ozaukee	11940	0.7%	80	$0.69
Pepin	1593	20.1%	320	$2.48

Table 1 continued:

County	Estimated # of private wells	Estimated % of wells over 10 ppm Nitrate Standard	Estimated # of private wells over Nitrate Standard	Estimated Replacement Cost (millions)
Pierce	4678	14.7%	689	$9.98
Polk	8907	4.7%	422	$3.75
Portage	8658	17.7%	1536	$13.13
Price	4868	1.9%	94	$0.38
Racine	16892	0.6%	99	$0.84
Richland	3262	8.8%	286	$2.47
Rock	12275	24.4%	2999	$32.45
Rusk	4857	3.6%	175	$1.00
Saint Croix	13362	12.2%	1624	$15.97
Sauk	7775	13.4%	1042	$9.33
Sawyer	9796	1.0%	99	$0.48
Shawano	7604	8.0%	606	$5.14
Sheboygan	11561	3.0%	344	$3.03
Taylor	5255	2.7%	144	$0.91
Trempealeau	5044	18.2%	917	$10.05
Vernon	4350	3.3%	142	$2.11
Vilas	12718	1.6%	201	$0.95
Walworth	17916	4.0%	715	$6.31
Washburn	6395	0.8%	53	$0.34
Washington	19541	3.8%	735	$10.52
Waukesha	57361	1.8%	1041	$14.38
Waupaca	10389	7.1%	736	$6.15
Waushara	9254	10.4%	964	$9.08
Winnebago	14271	1.9%	266	$4.27
Wood	8099	4.9%	394	$2.75
Totals	**676,237**		**42,019**	**$446M**

Public water systems costs

Because nitrate is both an acute and chronic health issue, community Public Water Systems cannot serve water over the nitrate Enforcement Standard (ES), and therefore must either replace the well or install approved treatment if they exceed it. 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 costs, 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 the nitrate level warning is posted and bottled water is provided. TN systems include motels, restaurants, taverns, campgrounds, parks and gas stations. In recent years, there have been up to 300 TN systems in operation in this situation. WDNR has recently initiated a plan that will bring all TN public water systems back into compliance with the nitrate standard of 10 mg/L. Using the same process for developing costs as for the private well replacement, the total cost for TN well mitigation of the currently existing systems 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 (NN) (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.

Further Reading

- DNR overview of nitrate in drinking water
- DNR overview of nutrient management planning
- DATCP overview of nutrient management
- DHS overview of nitrate health effects
- DNR, DATCP, and DHS water quality recommendations
- NR 151 rule changes for nitrate

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ARSENIC

Key Takeaways

As you will learn below, given the seriousness of arsenic contamination in groundwater and its human health impacts, there is an urgent need to address Wisconsin's arsenic contamination problem. GCC member agencies and partners continue to proactively address arsenic concerns through well drilling advisories, health studies, well testing campaigns, studies aimed at improving geological understanding and developing practical treatment technologies.

GCC member agencies are working on multiple initiatives related to reducing arsenic contamination in groundwater (see groundwater management sections – DHS, DNR, UWS, WGNHS and the Regional Drawdowns and Research Highlights sections.)

For actions to address arsenic contamination in groundwater, see the Recommendations Section of the report.

Sections in this document

What is 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.

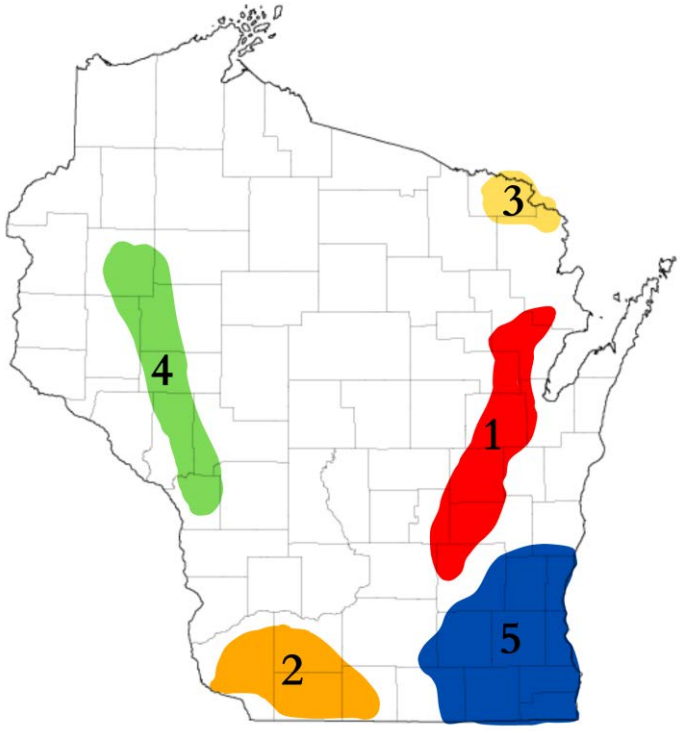
What are the human health concerns?

The Wisconsin health-based groundwater quality 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 10 micrograms per liter (ug/L) (WI NR 140.10, WI NR 809.11). People who drink water containing arsenic in excess of the 10 ppb MCL over many years could experience skin damage or problems with their circulatory system, nervous system, and have an increased risk of getting cancer.

How widespread is arsenic in Wisconsin?

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 10 ppb 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 effort and have designed portable field sampling kits, improved upon existing laboratory methods and are working on sensors that can immediately detect arsenic levels in groundwater. Researchers from the WGNHS funded by the WGRMP are 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.

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 counties and moderately high levels of arsenic (10 ppb – 30 ppb) are also common in some parts of southeastern Wisconsin.



Arsenic contamination is most common in northeastern Wisconsin (regions 1 & 3), but is also found in other areas throughout the state (regions 2, 4 & 5).

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.

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

In southeastern Wisconsin, most wells draw from glacial sand and gravel deposits or from Silurian dolomite bedrock 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.

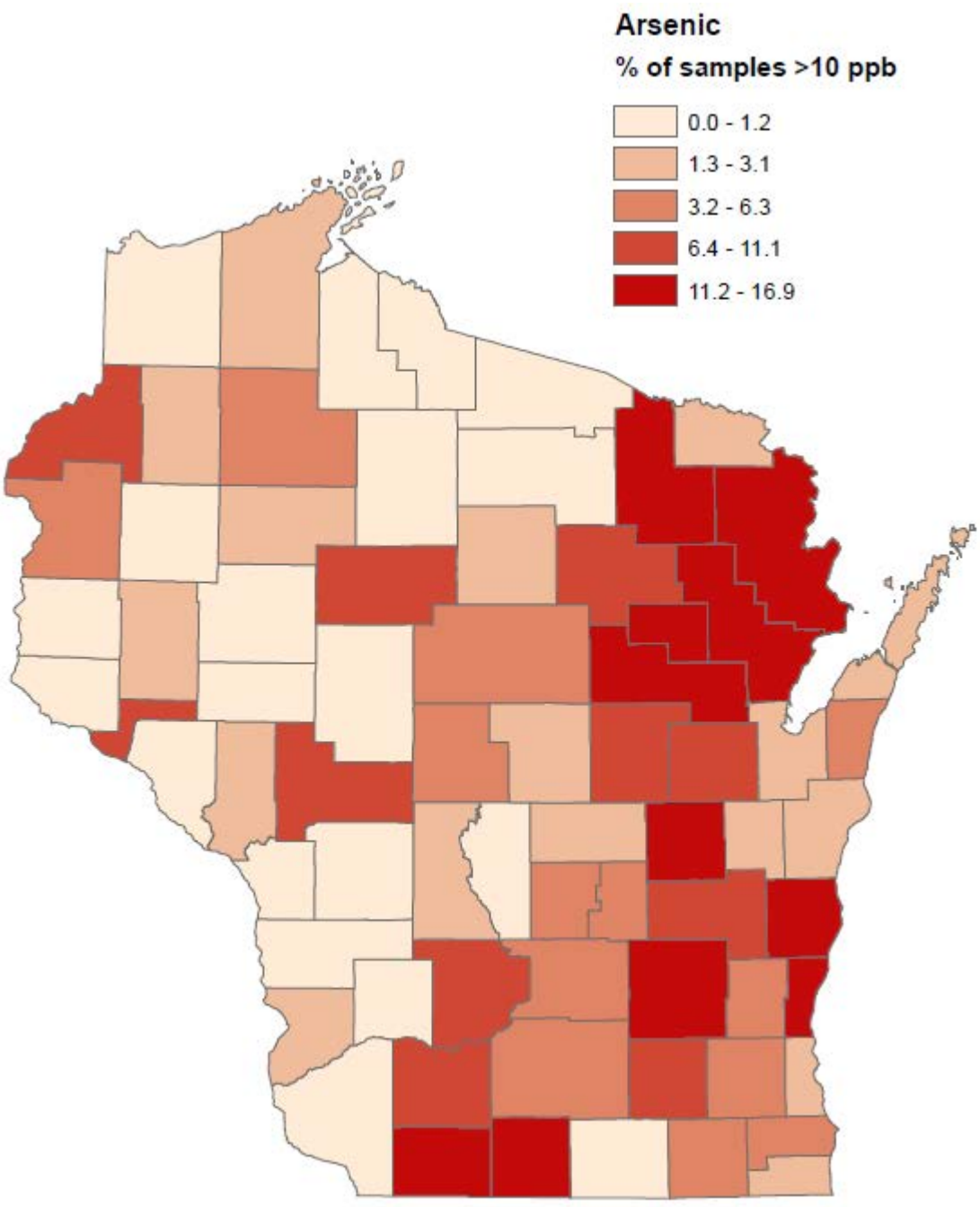
In northern Wisconsin sulfides and arsenopyrite can be found in the Precambrian granitic bedrock, and arsenic bearing iron oxides can be in the end moraine deposits of various glacial advances. Across the northern counties there are arsenopyrites in the Precambrian Bedrock associated with shear zones and other structures from Taylor to Florence County. Also arsenic released from iron oxides are common in the tills of moraines in the area.

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.[2] explains the occurrence of arsenic and metal bearing sulfides. Other metals commonly associated with arsenic are nickel, cobalt, copper, aluminum and vanadium.

How is arsenic contamination trending over time?

Arsenic continues to be an issue for Wisconsin well owners. Since 2014, the DNR has required testing for arsenic when pump work is done on existing wells. The data is analyzed to determine if additional Special Well Casing Depth Areas should be developed.

Data from Jan. 2022 – June 2023 for new well and pump work showed that of the 9,936 arsenic samples taken, 636 or 6.4% were over the enforcement standard (ES) of 10 ppb. The maximum level recorded was 907 ppb. About 39% or 3,814 samples were over the Preventive Action Limit (PAL) of 1 ppb.



Map 1. Map of Estimated Percent of Wells over Arsenic Standard (10 ppb) by County – January 2022 – June 2023. See tabular data by county below. This analysis shows that arsenic is more widespread than previously thought.

County	% > 10	County	% > 10
Adams	0.7	Marathon	4.5
Ashland	0.0	Marinette	14.4
Barron	0.0	Marquette	5.0
Bayfield	2.0	Menominee	12.8
Brown	2.9	Milwaukee	1.9
Buffalo	0.0	Monroe	1.2
Burnett	7.2	Oconto	12.4
Calumet	1.7	Oneida	0.0
Chippewa	0.8	Outagamie	10.9
Clark	0.0	Ozaukee	15.0
Columbia	3.4	Pepin	8.8
Crawford	2.2	Pierce	0.7
Dane	3.5	Polk	3.6
Dodge	16.9	Portage	1.4
Door	2.2	Price	0.0
Douglas	0.0	Racine	5.9
Dunn	2.9	Richland	0.0
Eau Claire	1.0	Rock	0.0
Florence	2.6	Rusk	2.9
Fond du Lac	10.3	Saint Croix	0.0
Forest	11.8	Sauk	10.7
Grant	0.9	Sawyer	3.7
Green	13.9	Shawano	15.5
Green Lake	5.0	Sheboygan	12.4
Iowa	7.2	Taylor	8.0
Iron	0.0	Trempealeau	3.0
Jackson	8.2	Vernon	0.0
Jefferson	8.2	Vilas	0.0
Juneau	3.0	Walworth	6.2
Kenosha	2.8	Washburn	2.1
Kewaunee	4.4	Washington	5.1
La Crosse	1.2	Waukesha	5.6
Lafayette	14.5	Waupaca	10.4
Langlade	7.1	Waushara	2.8
Lincoln	1.6	Winnebago	16.8
Manitowoc	1.3	Wood	3.8

Table 1. Percent of wells over 10 ppb arsenic by county (January 2022 – June 2023).

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. The DNR and some county governments are also working to both promote well sampling programs and explore impediments to private well sampling.

In areas of the state 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 moved homes from private wells to public supplies. This expansion has been effective in reducing exposure in towns like Algoma in Winnebago County.

Discovery triggers geochemical questions and 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. For example, ongoing investigations are exploring the occurrence of strontium near Green Bay and the presence of heavy metals in geologic formations near La Crosse, among others.

Further Reading

- DNR overview of arsenic in drinking water wells
- DNR special well casing depth areas for arsenic
- DHS overview of arsenic health effects
- WGNHS report on arsenic release due to well disinfection
- WGNHS report on preliminary investigation near Lake Geneva, Wisconsin
- DHS report on arsenic in Wind Lake Private Wells, Town of Norway, Racine County
- Wisconsin Natural Resource magazine article on arsenic in private wells
- Taylor, R.W. and G. Mursky. 1990. Mineralogical and geophysical monitoring of naturally occurring radioactive elements in selected Wisconsin aquifers. Wisconsin groundwater management practice monitoring project, DNR-051. Available at *http://digital.library.wisc.edu/1711.dl/EcoNatRes.TaylorMineral*

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PESTICIDES

Key Takeaways

As you will see below, monitoring groundwater for pesticides contamination is very important for human and environmental health. 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.

GCC member agencies continue to work on multiple initiatives related to reducing pesticides in groundwater (see groundwater management sections – DNR, DATCP, UWS).

For actions to address pesticides contamination in groundwater, see the Recommendations Section.

Sections in this document

What are 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. 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.

What are the human health concerns?

The health effects of exposure to pesticides or pesticide metabolites vary by substance. About 30 pesticides (and some pesticide metabolites) currently have 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[1] . 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[2,3].

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

Atrazine is an herbicide commonly used on corn. The groundwater quality ES for atrazine and its three chlorinated metabolites is 3 parts per billion (ppb). The drinking water MCL for atrazine (does not include metabolites) is 3 ppb. A number of epidemiological and animal studies have been conducted evaluating the potential health and environmental impacts from atrazine exposure[3-10] . 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.

Alachlor is an herbicide used on corn and soybeans. Use of alachlor in Wisconsin has been replaced by other herbicides in the same family[11,12] (e.g., metolachlor, acetochlor), however, its metabolites still linger in groundwater. Both the groundwater quality enforcement standard (ES) and public drinking water MCL for alachlor are 2 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, may 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 and potatoes. Both the parent, metolachlor, and metabolite forms, metolachlor-ESA and metolachlor-OXA, are routinely detected in groundwater. Health-based groundwater quality standards have been established for these compounds. 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 7 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[13]. Acetochlor has been classified by the EPA as a "suggestive human carcinogen".

How widespread are pesticides 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[14], up from 33% of private wells in a similar survey conducted in 2007[15]. The primary metabolites of metolachlor and alachlor, metolachlor ESA and alachlor ESA, were the two most commonly detected pesticide products in those surveys. 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 3 ppb. DATCP is currently in the process of conducting a new statewide survey of agricultural chemicals in groundwater.

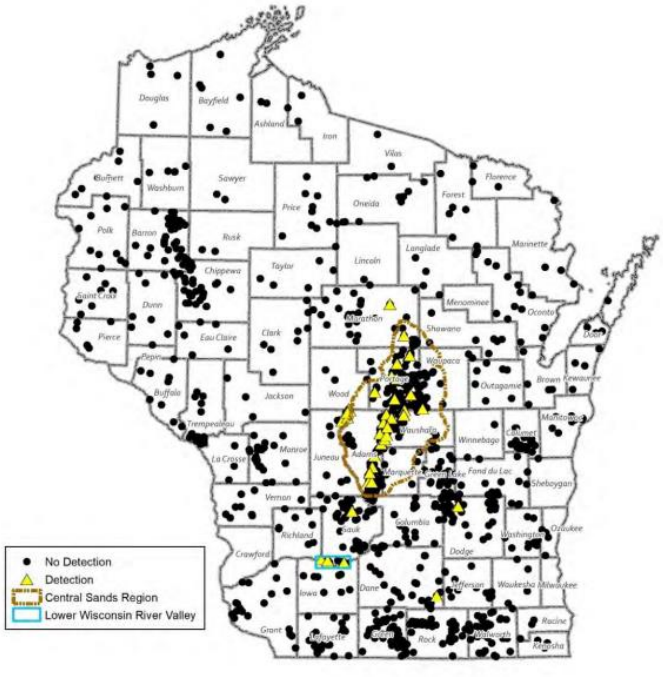
The past three decades have seen increased use of neonicotinoid insecticides. A FY20-FY21 project by UW-Stevens Point conducted sampling for neonicotinoid insecticides in groundwater-fed streams. Two sampling methods - traditional grab samples and time-integrative POCIS (polar organic compound integrative samplers) samples were collected, with findings that grab samples at baseflow conditions and POCIS samples provided similar results. The authors also constructed a linear regression model of the percentage of the entire groundwater contributing area that was agricultural land proximate to the sampled streams. It was found that this model explained about 60% of the variation in neonicotinoid concentrations. This suggests that neonicotinoid concentrations will continue to increase in groundwater-fed streams over the next several decades.

How is pesticides contamination trending over time?

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[16]. This 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.



Locations of neonicotinoid detections in all potable wells sampled - 2008 through 2016.

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[17]. 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[14]. Starting in March 2023, DATCP initiated a new statistically random sampling survey of agricultural chemicals in groundwater utilizing private well samples collected from homes across the state. This survey is currently in progress and is

expected to be completed by September 2023. Publications of DATCP agricultural chemical in groundwater surveys are available on the web at: *https://datcp.wi.gov/Pages/Programs_Services/GroundwaterReports.aspx*

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 into groundwater. The Stipulated Agreement allows for its 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 eight years that are intended to evaluate the potential for surface or groundwater impacts. In 2019 Bayer completed isoxaflutole and isoxaflutole metabolites monitoring at the surface water tile drainage sampling sites in areas that received isoxaflutole applications. BCS also concluded groundwater monitoring at three of the eight sites that received at least two applications of the pesticide over a multi-year study period. BCS is currently still sampling groundwater at the five remaining study sites. This monitoring is anticipated to be concluded in October 2023.

Further Reading

- DHS resources for contaminants in drinking water
- DNR overview of pesticides in drinking water wells
- DATCP water quality reports
- DATCP Home Groundwater Standards for Pesticides

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NATURALLY OCCURRING ELEMENTS

Key Takeaways

As you will read below, naturally occurring elements, including radionuclides, chromium, manganese and strontium occur in Wisconsin groundwater, sometimes at concentrations that exceed health guidance levels. Natural earth processes, such as rock weathering, soil erosion and mineral dissolution can cause trace elements to be released into groundwater. In areas where naturally occurring elements may be present in groundwater at levels close to, or above, health guidelines it is important to regularly test groundwater drinking water supplies to ensure that they are safe.

GCC member agencies continue to work on multiple initiatives related to ensuring that the public is aware of the possibility of high levels of naturally occurring elements including radionuclides, chromium, manganese and strontium in groundwater drinking water supplies (see groundwater management sections – DHS, DNR and UWS).

For actions to address naturally occurring elements contamination in groundwater, see the Recommendations Section.

Sections in this document

What are Naturally Occurring Elements and how widespread are they in Wisconsin?

Radionuclides occur naturally in rock formations, and every well in Wisconsin contains some level of dissolved radionuclides. Strontium and hexavalent chromium are metallic elements that may be naturally occurring in rock and soil. Manganese is a common, naturally occurring element found in rocks, soil, water, air and food. Under certain geochemical conditions, such as reducing redox conditions, these metals may be dissolved from rock or soil and mobilized in groundwater. Anthropogenic contamination may also be the source of these metals in groundwater.

Radionuclides

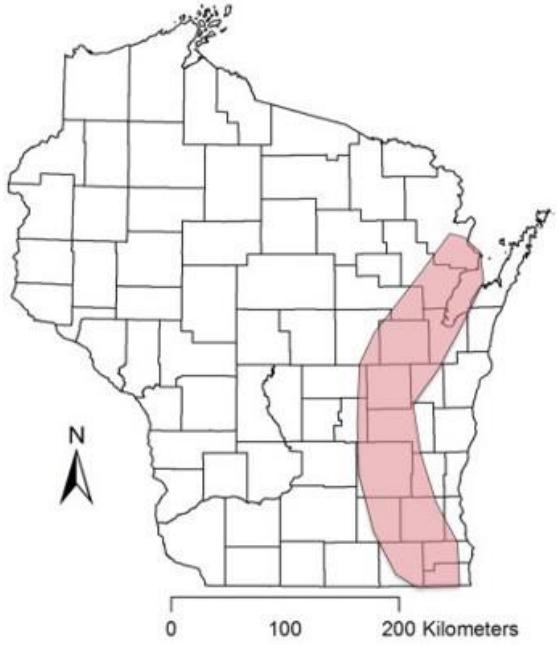
Radionuclides are radioactive atoms. It is possible for radionuclides to be manmade, as is the case with some materials from nuclear power reactors, but they also occur naturally in rock formations and are released to groundwater over

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.

Radionuclides occur naturally in rock formations, and every well in Wisconsin contains some level of dissolved radionuclides. In most 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 water from the Cambrian-Ordovician deep sandstone aquifer, where it underlies the Maquoketa shale geologic formation, often have levels of radium above the public drinking water maximum contaminant level (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, as high radium levels are present in groundwater drawn from deep bedrock aquifers and drilling wells deep enough to reach these deep aquifers is usually prohibitively expensive for homeowners using private water supply wells. High radium levels in the Cambrian-Ordovician deep sandstone aquifer is due to the fact that the solubility of radium is related to the solubility of sulfate minerals, and sulfate minerals in this part of the aquifer are more soluble than those to the west, where the sandstone aquifer is not "confined" beneath the Maquoketa shale formation.



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.

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 and gamma activity - now included in a broader group called photon emitters) and for specific radionuclides (uranium, radium). Public water system MCLs have been established for the radionuclides uranium and (total) radium, and for alpha and beta (plus photon) particle activity. These MCLs are: 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 (radium−226 plus radium−228), and 30 micrograms per liter (ug/L) for uranium (*WI NR 809.50-809.51*).

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.

Chromium

As water flows underground, metals such as chromium, may be dissolved from rock or soil and be mobilized, and therefore present in groundwater. Natural sources of chromium in groundwater include some types of igneous bedrock and soils derived from those bedrock sources. In groundwater, chromium can generally be found in one of two forms, as trivalent chromium (Cr III), or chromium-3, or as hexavalent chromium (Cr VI), or chromium-6. The US EPA has established a public water supply MCL for total chromium at 100 µg/L and, in Wisconsin, the NR 140 groundwater quality ES for total chromium is 100 µg/L. The DHS recently recommended a ch. NR 140 ES for hexavalent chromium of 70 nanograms per liter (ng/L). This standard was proposed by DNR in its "Cycle 10" revisions to ch. NR 140, however, the recommended Cycle 10 groundwater standards, including proposed hexavalent chromium standards, were not approved by the Natural Resources Board at their Feb. 2022 meeting.

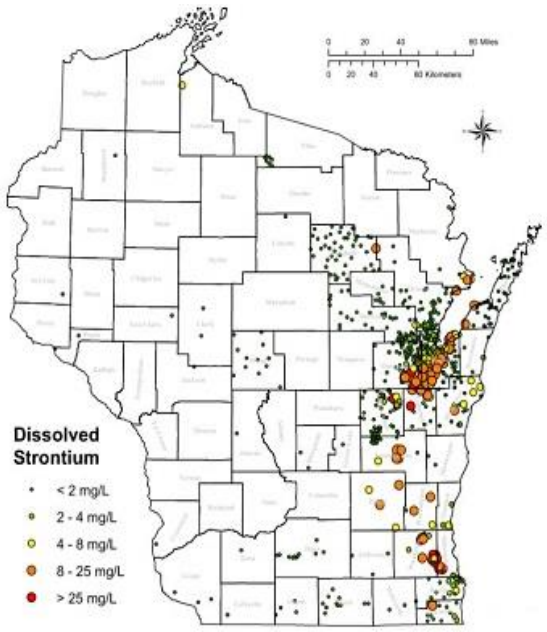
Manganese

Manganese is a common, naturally occurring element found in rocks, soil, water, air and food. Manganese is an essential element and is needed to form healthy bones, produce glucose and heal wounds. Small amounts of manganese are part of a healthy diet. Manganese is naturally found in breastmilk and included in infant formula to ensure proper development. Although the primary source of exposure to manganese is food, drinking water can increase the overall dietary intake of manganese. High levels of manganese can affect our health. Health based groundwater quality enforcement standards have been established in Wisconsin for manganese at 300 µg/L. The US EPA has also set a lifetime health advisory level of 300 µg/L for manganese in drinking water.

Strontium

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[1].

Strontium's chemical behavior is similar to calcium and strontium minerals have been found in carbonate bedrock deposits in Wisconsin. The weathering and dissolution of carbonate bedrock containing strontium minerals may be a source of elevated strontium in groundwater. Highly mineralized brines have also been shown to contain very high levels of dissolved strontium. No public water supply MCL has been established for strontium, but the US EPA has established a lifetime health advisory level for strontium in drinking water at 4,000 µg/L. The DHS recently recommended a ch. NR 140 ES for strontium of 1,500 µg/L. This standard was proposed by DNR in its "Cycle 10" revisions to ch. NR 140, however, the recommended Cycle 10 groundwater standards, including proposed strontium standards, were not approved by the Natural Resources Board at their Feb. 2022 meeting.



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

What are the human health concerns?

Strontium mimics calcium and is absorbed by growing bones. High levels of strontium have been linked to bone calcification effects and may cause bones to grow shorter and thicker than normal. Small amounts of strontium are not known to be harmful. People with calcium deficiencies, kidney conditions, and Paget's disease, a disease that causes your body to generate new bone faster than normal, may be more sensitive to the effects of high levels of strontium.

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.

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).

High levels of manganese can affect our health. According to the DHS, studies indicate that exposure to high levels of manganese can affect the nervous system. Studies on research animals suggest that high levels of manganese may also affect

reproduction and impact the kidneys. People over the age of 50 and infants less than six months old are the most sensitive to these effects. In older adults, high levels of manganese may cause a disorder similar to Parkinson's disease. In infants, exposure to high levels of manganese may affect brain development and impact learning and behavior. Some studies among people indicate that people with certain medical conditions (iron-deficiency anemia, liver disease) may also be more sensitive to the effects of manganese.

The groundwater enforcement standard and US EPA health advisory level of 300 µg/L are intended to protect against these effects. According to DHS, manganese above this level may pose an immediate health risk for sensitive groups. When manganese levels are above 300 µg/L, people over the age of 50 and infants less than six months old should stop using the water for drinking and preparing foods and beverages that use a lot of water. Manganese at these levels also pose a long-term health risk for everyone. There are also rare occasions when manganese concentrations in groundwater exceeds 1000 µg/L. The US EPA has determined that concentrations above this level pose an immediate health risk to all consumers.

In addition to the groundwater and health advisory standards, the US EPA has established a secondary water quality standard of 50 µg/L. Manganese concentrations greater than 50 µg/L in drinking water causes esthetic issues related to taste and color.

How is naturally occurring elements contamination trending over time?

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 radionuclide drinking water standards. The DNR continues to work with the remaining water systems to ensure that they develop a compliance strategy and take corrective actions.

Further Reading

- DHS resources for contaminants in drinking water
- DNR overview of radium in drinking water wells
- DNR overview of radon in drinking water wells
- WGNHS report on distribution of radionuclides in groundwater
- DNR Manganese and drinking water
- Origin and Distribution of Dissolved Strontium in the Cambrian-Ordovician Aquifer of Northeastern Wisconsin Grundl, T.J. 2000.
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- Hexavalent Chromium (Cr(VI)) in WI Groundwater: Identifying Factors Controlling the Natural Concentration and Geochemical Cycling in a Diverse Set of Aquifers

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VOLATILE ORGANIC COMPOUNDS (VOCs)

Key Takeaways

Continuing to identify and monitor known sources of VOCs is key to the protection of drinking water. Each year, several hundred contaminated sites, some of which involve VOCs, are reported to the DNR. Thousands of wells have been sampled for VOCs and about 60 different VOCs have been found in Wisconsin groundwater. Sources of VOCs in Wisconsin's groundwater include landfills, underground storage tanks and hazardous substance spills. A critical role of GCC agencies is identifying and monitoring all known sources of VOCs, not only landfills

GCC member agencies continue to work on multiple initiatives related to reducing Volatile Organic Compounds (VOCs) in groundwater (see groundwater management sections – DHS, DNR).

For actions to address Volatile Organic Compounds (VOCs) contamination in groundwater, see the Recommendations Section.

Sections in this document

What are 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.

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

What are the human health concerns?

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 Wisconsin Department of Health Services (DHS) website.

How widespread are VOCs in Wisconsin?

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. While about 60 different VOCs have been found in Wisconsin groundwater, only 34 currently have established health based groundwater quality standards in ch. NR 140 (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. DNR currently tracks about 700 current or former landfills, 21,000 LUSTs and 8,000 other facilities which are required to monitor groundwater. The DNR also tracks approximately 39,000 spills, some of which are also sources of VOCs. Given how common potential sources of VOCs are, these substances are more frequently found in groundwater near urban industrial and commercial areas. However, exceedances of groundwater standards for VOCs have been reported in every county in the state.

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

How is VOCs contamination trending over time?

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.

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[1],[2].

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[3].

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 limiting VOC contamination. Older landfills, however, continue to remain a concern[4].

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. 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.

Further Reading

- DHS resources for contaminants in drinking water
- DNR overview of VOCs in private drinking water wells
- DNR map of open and closed contaminated sites
- DNR database of contaminated soil and groundwater
- DHS overview of vapor intrusion
- USGS report on VOCs in the nation's groundwater and drinking water wells

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EMERGING CONTAMINANTS

Key Takeaways

Emerging contaminants are chemicals and substances characterized by a perceived, potential, or real threat to human health or the environment. Contaminants may be considered to be emerging because of the discovery of a new source or pathway that could impact human health. As you will read below, much is unknown about emerging contaminants in Wisconsin, so an important role of the GCC is to provide funding to support research studies that further scientific understanding of these substances and their occurrence, fate and transport in the groundwater environment.

GCC member agencies continue to work on multiple initiatives related to emerging contaminants in groundwater (see groundwater management sections – DNR, DATCP, UWS, WGNHS).

For actions to address emerging contaminants contamination in groundwater, see the Recommendations Section.

Sections in this document

What are emerging contaminants and how widespread are they in Wisconsin?

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

contaminants is important to characterize the nature of the risk and decide what actions may be required to protect human and environmental health.

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

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

Degradation processes, if they occur, can reduce the amount of contaminant that makes it to groundwater. Degradation can be abiotic or biotic, when 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. Incomplete degradation, also known as transformation, is when the parent compound transforms into one or more metabolites but not all the way to naturally occurring chemicals. Another process that can reduce the amount of a contaminant 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.

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.

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

Pharmaceuticals and Personal Care Products (PPCPs)

Pharmaceuticals enter the environment through disposal of unused pills as well as excretion of the compounds or their metabolites from the human body. A metabolite is a compound produced by the body's metabolism from the "parent" compound, i.e. the original pharmaceutical. Metabolites often, but not always, have similar chemical properties as the parent compound. Pharmaceuticals detected in groundwater worldwide include antibiotics, non-steroidal anti-inflammatory drugs, birth control medications, and many other prescription medicines. Many pharmaceuticals begin to degrade in subsurface soil and groundwater.

Pharmaceutical degradation products and metabolites in the subsurface environment are still being discovered. Stimulants such as caffeine and nicotine, as well as recreational drugs, may also be found in groundwater.

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

Antibiotics have been detected in treated wastewater effluent from facilities across the state, with very low concentrations of tetracycline and sulfamethoxazole detected in groundwater directly adjacent to a wastewater treatment facility groundwater discharge site[1]. 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[2], and estrogenic endocrine disrupting compounds (EDCs) were detected in POWTS effluent in a southeast Wisconsin study[3]. 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 domestic wastewater effluent, were found in the study in seven of ten monitoring wells and in two water supply wells.

Per- and Polyfluorinated Alkyl Substances (PFAS)

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

Many polyfluorinated substances that are part of the PFAS chemicals family transform in the environment to other PFAS, especially to perfluoroalkyl acids such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS). PFAS are not known, however, to degrade in groundwater or elsewhere in the environment into any non-toxic end products. They may therefore accumulate in environmental settings. PFAS can enter the environment in a number of ways, including placement of PFAS containing products in landfills, use of the PFAS

containing consumer products resulting in their presence in wastewater, land spreading of wastewater biosolids on cropland, and direct use and lack of containment of the PFAS chemicals at manufacturing and firefighting sites.

The two most widely studied PFAS are PFOA and PFOS, both of which present health risks and are commonly found in groundwater. While these two substances may have been manufactured directly during the mid-20th century, manufacturing shifted during the late 20th century to polyfluorinated substances (precursors) that may transform to end products, including but not limited to PFOA and PFOS. These compounds may transform slowly in soil and groundwater, representing ongoing sources of PFOA and PFOS to the environment.

Since the turn of the century, manufacturing has shifted to shorter chained PFAS compounds such as perfluorobutane sulfonate (PFBS) and its precursors, in applications where previously PFOS or its precursors were used. Manufacture of PFAS containing additional chemical structures (e.g. ethers) has also emerged, with this category of PFAS being known as "replacements". Examples of replacement PFAS are HFPO-DA (hexafluoropropylene oxide dimer acid, sometimes referred to by the trade name "GenX"), a replacement of PFOA, and PFBS, a replacement of PFOS. PFBS and HFPO-DA are among the compounds that were evaluated by the Wisconsin Department of Health Services and that agency has provided recommendations for groundwater quality standards for the two substances to the DNR.

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

Agricultural Contaminants, including Pesticides

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

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

Although pesticides have been in use since the middle of the 20th century, new pesticides continue to come into use. One such pesticide is the herbicide isoxaflutole, which has been approved in Wisconsin for limited use for weed control on corn crops. Field testing, to evaluate potential groundwater impacts from Isoxaflutole use, is underway.

Neonicotinoid insecticides are a relatively new group of neuro-active insecticides that are chemically similar to nicotine. Use of these insecticides has been increasing over the last 30 years. They are widely used in Wisconsin agriculture, with more than 500 pesticide products containing neonicotinoid active ingredients registered for use in the state. They're used on corn, soybeans, forage, small grains, vegetables and cranberries. Studies have shown that these pesticides are now found in groundwater-fed streams and DATCP monitoring data shows increased detections of them in samples collected around the state from monitoring wells, irrigation wells, private wells, and surface water.

Though functionally part of the PPCPs category of emerging contaminants, antibiotics and anti-parasitical drugs are also used in agriculture, to prevent infection outbreaks at large livestock rearing operations. 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 tends to sorb to soil and can be transformed under toxic conditions, but it may not be fully degraded to naturally occurring chemicals. Another type of contaminant from agriculture is hormones. Steroid hormones have been found in a study of dairy wastewater[4].

For more information on pesticides, see the pesticides section of the report.

Microbial Contaminants, including viruses and bacteria

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

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

Viruses in groundwater include norovirus, adenovirus and enterovirus. Viruses generally cannot reproduce without a host, but they can infect bacteria. A virus that infects, or replicates within bacteria is referred to as a "bacteriophage" (or simply

"phage"). This usage of bacteria as hosts may enable viruses to survive longer in groundwater.

Antibiotic resistance is considered by the World Health Organization to be a major threat to health, food security, and development. After usage of an antibiotic, there is a tendency for bacteria that survived previous applications of the substance to become a larger part of the overall bacterial population—this phenomenon results in antibiotic resistance.

While antibiotics are used in both human and veterinary medicine, a greater number of antibiotic compounds are thought to be used by 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[5]. 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[6]. In a study of groundwater impacted by dairies in California[7], antibiotic resistant *E. coli* bacteria were found in one sample, indicating potential for antibiotic resistant bacteria to be present in groundwater.

Human enteric virus indicators and pathogenic bacteria indicators have been found in groundwater supply wells in the Madison area[8]. Studies also suggest human enteric viruses from wastewater sources may be present in private and public drinking water wells across the state[9,10,11,12,13].

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

For more information on microbial pathogens, 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[14]. Microplastics have been found in marine environments for decades[15], but more recently are being discovered in terrestrial environments, including Lake Michigan[16].

A 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[17]. Microplastics appear to accumulate in soils, including ones used for agriculture[15]. Another study found microplastics—possibly leaked from septic systems—in karst groundwater in Illinois[18]. 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 flows through open fractures with minimal 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.

Other Emerging Contaminants

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

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

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

What are the human health concerns?

Health effects of emerging contaminants vary and are not always well understood. Some emerging contaminants, including some pesticides and PPCPs, act as endocrine disrupting compounds (EDCs), which adversely affect the behavior of natural hormones in animals and humans. EDCs include both anthropogenic chemicals, such as pesticides and plasticizers, and naturally occurring compounds like steroids and plant-produced estrogens. Scientific studies suggest toxic endpoints varying by compound, with possible health effects including developmental, reproductive, neurologic and immune problems, as well as cancer[19]. In many cases, more research is needed.

How are emerging contaminants trending over time?

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

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

The US Environmental Protection Agency (EPA) also has a process for regularly gathering data on emerging contaminants and assessing potential risks nationwide. The Unregulated Contaminant Monitoring Rule (UCMR) provides for monitoring of unregulated contaminants every five years, in all large (serving > 10,000 people) and a sample of small (serving < 10,000 people) public water systems. The Third UCMR (UCMR3) monitoring period was completed in 2015. Monitoring for the Fourth UCMR (UCMR4) began during 2018 and focused on select pesticides and several naturally occurring compounds. The Fifth UCMR (UCMR5) began in 2023 and focuses on PFAS, with an expanded analyte list and lower detection limits compared to UCMR3. Data collected at Wisconsin public water supply systems during UCMR monitoring along with GCC-supported monitoring and occurrence study results provide valuable information on the occurrence of emerging contaminants in Wisconsin's groundwater resources.

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

Further Reading

- DNR overview of pharmaceuticals and PCPs in the environment
- DNR overview of per- and polyfluoroalkyl substance (PFAS) contamination
- Wisconsin Remediation and Redevelopment Database (WRRD)
- DATCP Groundwater Quality Reports
- NIH factsheet on endocrine disruptors
- US EPA Third Unregulated Contaminant Monitoring Rule (2012-2016) fact sheets

- US EPA Third Unregulated Contaminant Monitoring Rule (2012-2016) data summary
- US EPA Fourth Unregulated Contaminant Monitoring Rule (2017-2021) information

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PER- AND POLYFLUORINATED ALKYL SUBSTANCES

Key Takeaways

PFAS chemicals have been found to be widespread in the environment. They have been detected in Wisconsin groundwater, in some areas at very high levels. As you will see below, given the severity of PFAS there is a real need to determine the extent of PFAS contamination of Wisconsin's groundwater, and to assure that, in areas of concern, individual residents and public utilities test water supplies to ensure they are safe.

GCC member agencies are working on multiple initiatives related to reducing PFAS levels in groundwater (see groundwater management sections – DHS, DNR, UWS)

For actions to address PFAS contamination in groundwater, see the Recommendations Section of the report.

Sections in this document

What are PFAS?

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.

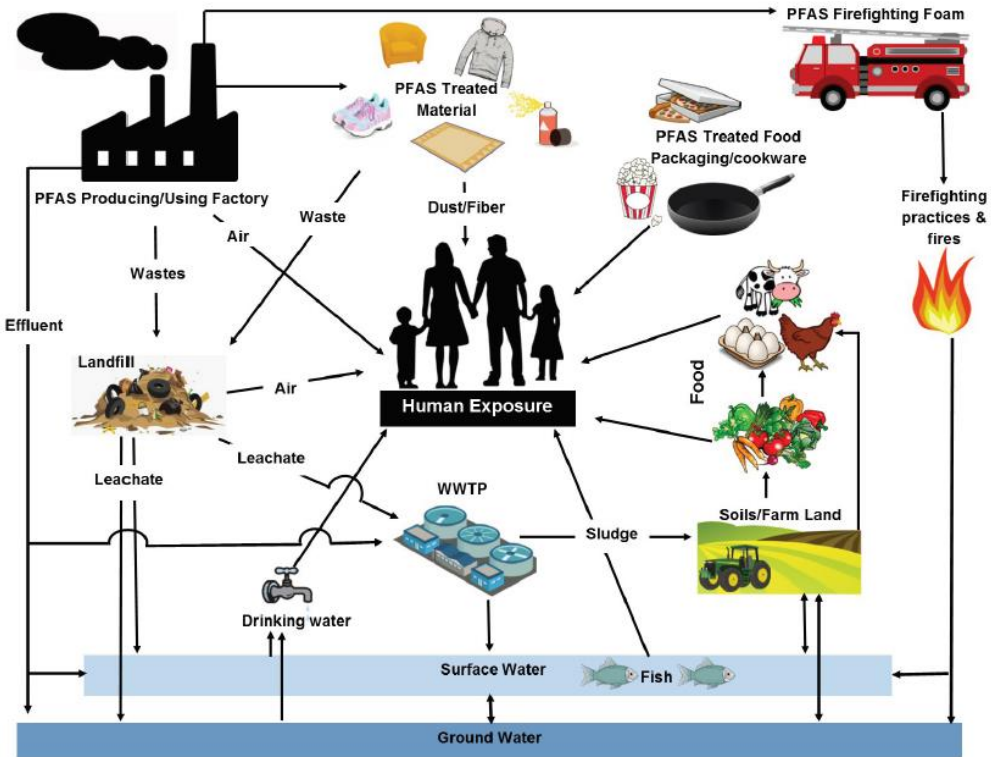
How might I come in contact with PFAS?

One of the main ways people come into contact with PFAS is by drinking contaminated water. Read the DNR PFAS brochure to learn more.

What are the sources of PFAS and how can I be exposed?

Sources of PFAS and modes of human exposure.

Image credit: Maine Drinking Water Program, Service Connection newsletter, Volume 25, Issue 4[1]



What are the human health concerns?

Although PFAS have been used extensively since the mid-20th century, in recent years the scientific health research community has made progress to better understand their potential impacts to human health. This understanding continues to evolve based on ongoing research. Perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) are the two most-studied individual PFAS chemicals. Current studies of these PFAS suggest exposure may:

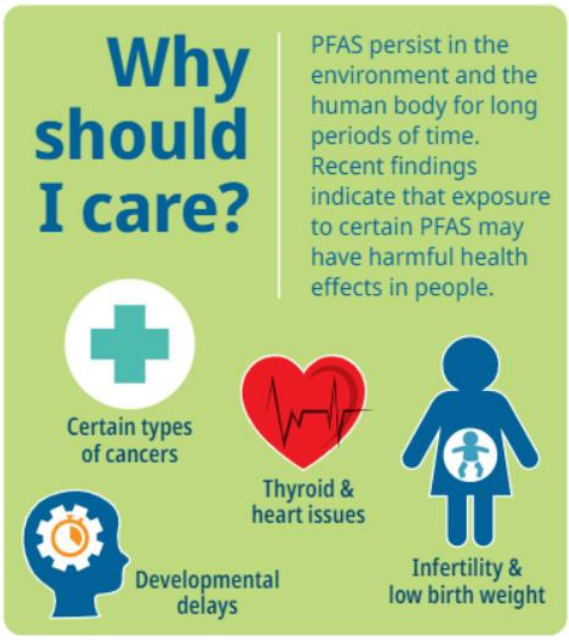
- affect childhood development,
- decrease female fertility,
- increase the risk of high blood pressure in pregnant women,
- increase cholesterol levels,
- increase the risk of thyroid disease,
- and decrease antibody response to vaccines.
- EPA research suggests that some PFAS may have the potential to cause cancer, but the topic requires further research.

Currently, there is limited regulatory authority regarding PFAS at the federal level. In 2016, the EPA issued a non-enforceable Lifetime Health Advisory level (HAL) for PFOA and PFOS of 70 parts per trillion (ppt) in drinking water. In June 2022, the EPA issued Interim updated lifetime HALs for PFOA and PFOS of 0.004 ppt and 0.02 ppt, respectively (four to five orders of magnitude lower than the previous HAL of 70 ppt). These health advisories are applicable to non-cancer health outcomes (the evaluation regarding cancer outcomes is still ongoing). Also in June 2022, EPA issued HALs for GenX chemicals, which refers to hexafluoropropylene oxide dimer acid (HFPO-DA) and its ammonium salt, and perfluorobutanesulfonic acid (PFBS) of 10 ppt and 2,000 ppt, respectively.

The EPA Interim updated lifetime HALs for PFOA and PFOS are lower than currently available laboratory technology can measure. The PFOS HAL is about 10x lower than what instruments typically in use today can detect. The PFOA HAL is about 30x lower than what instruments typically in use today can detect. If future technology advances occur to detect at these lower levels, it remains to be seen if it will be possible to perform the analysis without contamination at sub-ppt levels. Although the new EPA HALs for PFOA and PFOS are below current detection limits, toxicity studies suggest that negative health effects may occur even at concentrations of PFOA or PFOS in water that are not currently detectable. EPA has stated in an FAQ on the HALs that it is known that the lower the levels of PFOA and PFOS, the lower the risk.

Should you be concerned about PFAS?

There is a growing public health concern over PFAS which do not occur naturally and are widespread in the environment. They are found in people, wildlife and fish all over the world. Because PFAS do not break down easily in the environment, and some PFAS can stay in the body for a long time, they are referred to as "forever chemicals." Read the DNR PFAS brochure to learn more.



On March 14, 2023, EPA announced proposed draft National Primary Drinking Water Regulation Maximum Contaminant Levels (MCLs) for six PFAS: perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorohexane sulfonic acid (PFHxS), perfluorononanoic acid (PFNA), perfluorobutane sulfonic acid (PFBS) and hexafluoropropylene oxide dimer acid (HFPO-DA, commonly known as GenX Chemicals). Proposed is to regulate PFOA and PFOS as individual contaminants, at 4 ppt, and to regulate any mixture containing one or more of PFHxS, PFNA, PFBS,

and/or HFPO-DA (GenX Chemicals) using a hazard index approach to determine if the combined levels of these PFAS pose a potential health risk.

The WI Department of Health Services (DHS) has recommended state public health groundwater quality enforcement standards for 18 PFAS compounds. These recommended standards serve as state drinking water HALs. DHS has also recommended a cumulative risk assessment approach, called a hazard index (HI), for PFAS. The DHS PFAS HI takes into consideration all PFAS that have a recommended groundwater enforcement standard. The DHS PFAS HI is the summation of individual PFAS hazard quotients (HQs). The HQ is the ratio of the exposure dose (drinking water sample concentration) for: DONA, PFBS, PFHxS, PFNA, PFDA, PFTeA, PFUnA, PFDoA, PFODA, HFPO-DA , PFBA or PFHxA, or the combined concentration of NEtFOSE, NEtFOSAA, NEtFOSA, FOSA, PFOA, and PFOS, divided by their respective recommended public health enforcement standard. If the PFAS HI exceeds 1.0, DHS recommends that the water not be consumed.

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 in accordance with the federal Clean Water Act. New DNR administrative rules went into effect in 2022 to gradually phase in PFAS monitoring requirements for wastewater discharges. In some cases, these new regulations require some industrial sources to take action to reduce their PFAS discharge to municipal wastewater treatment facilities.

Following the EPA's June 15, 2022 issuing of interim HALs for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), and final HALs for perfluorobutane sulfonic acid and its potassium salt (PFBS) and hexafluoropropylene oxide (HFPO-DA) dimer acid and its ammonium salt ("GenX" chemicals), the DNR drafted a Statement of Scope proposing rulemaking to establish groundwater quality standards in ch. NR 140 for these four PFAS. Based on review of the current proposed EPA draft MCLs for PFAS, the department has decided to continue rulemaking for two of the four PFAS listed in the Statement of Scope, PFOA and PFOS. These proposed new groundwater quality standards for PFOA and PFOS are based on the existing recommendations developed by DHS.

How widespread are PFAS in Wisconsin?

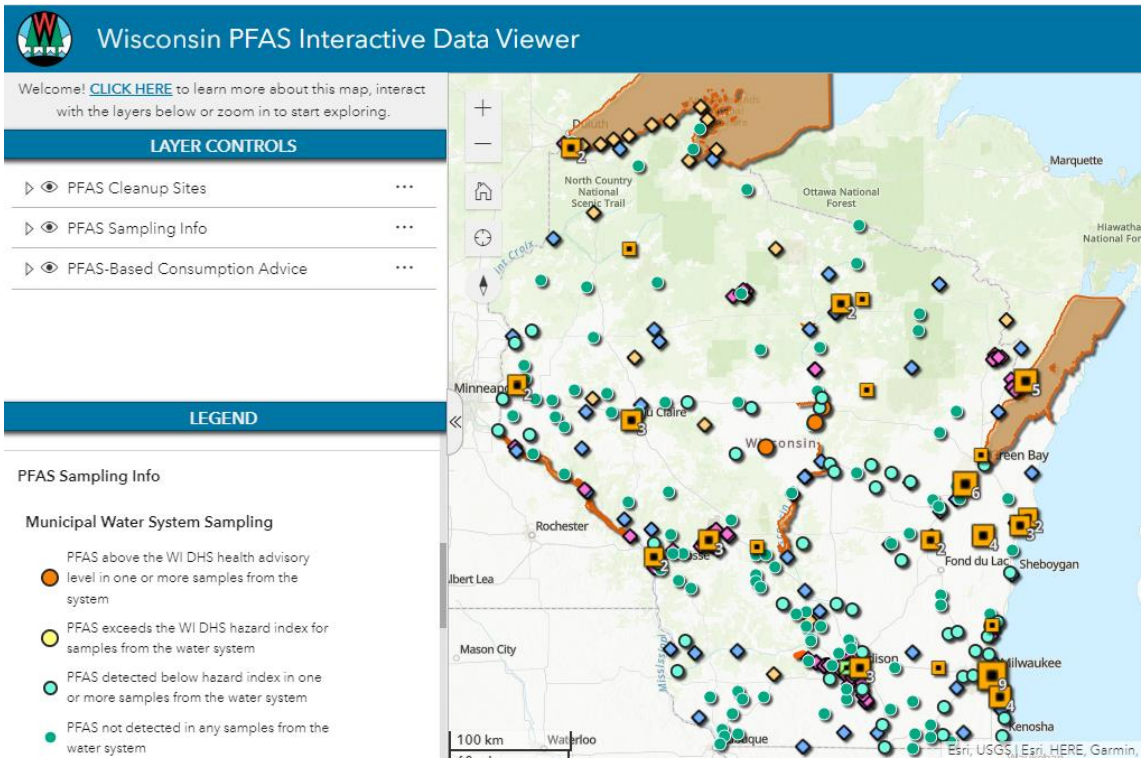
The DNR has conducted some sampling initiatives for PFAS in drinking water and ambient groundwater. These efforts included voluntary municipal drinking water sampling, open to all municipal systems, and a groundwater research study sampling private wells. Both projects were based on voluntary participation.

The municipal drinking water project sampled post-treatment water from about 130 municipal systems statewide. Laboratory analysis was done using EPA Method

537.1 for 18 PFAS, which includes 13 of the 18 PFAS that have established DHS drinking water HALs. Full results of the project will be available in 2024.

In June 2022, the DNR began a project to sample for PFAS and other water quality parameters in 450 private wells, spaced apart geographically across the entire state. The main objective of the research study was to determine concentrations of PFAS present in ambient groundwater, that is, groundwater in locations that are not near a known high concentration release of PFAS. Another objective was to evaluate the usefulness of several potential source indicator chemicals, chemicals that might be used to pinpoint what source(s) of PFAS to groundwater may be present in an area. Potential PFAS source indicators include some PFAS compounds that are environmental transformation products of fluorotelomer polymers, inorganic compounds such as nitrate and chloride, and some non-PFAS organic compounds. Those non-PFAS organics are the environmental transformation products of two herbicides (alachlor and metolachlor) that have been used extensively in Wisconsin, and a suite of human waste indicators that includes artificial sweeteners and pharmaceuticals. The project was a partnership between the DNR, Wisconsin State Laboratory of Hygiene and the Center for Watershed

The DNR maintains a Wisconsin PFAS Interactive Data Viewer a mapping tool that incorporates datasets from several DNR programs to show locations throughout Wisconsin that have been impacted by PFAS.



Science and Education at the University of Wisconsin-Stevens Point. The results of this study are currently under review and a project report is being drafted.

Prior to these two projects, limited information about the occurrence of PFAS in Wisconsin's groundwater resource had come mostly from the EPA's third Unregulated Contaminants Monitoring Rule (UCMR-3), conducted between 2013 and 2015, and from voluntary sampling by a few municipalities. In the UCMR-3 sampling, PFAS were detected in municipal water systems in La Crosse, West Bend, and Rhinelander. At the time, laboratory analysis was only done for six PFAS analytes, whereas since the beginning of 2020, laboratory analysis for Wisconsin samples has often been done for at least 33 PFAS analytes. Also, laboratory reporting limits were considerably higher in the UCMR-3 project than they are today. The data from UCMR-3 served as an initial indicator of the fact that both groundwater and drinking water supplies in Wisconsin have been impacted by PFAS. Voluntary sampling by a few municipalities (from 2019 through the first quarter of 2022) has shown additional impacts above Wisconsin DHS HALs in Madison, Eau Claire, Wausau and Rib Mountain. PFAS impacts in La Crosse and the Town of Campbell on French Island have also been documented during ongoing site investigations in those locations.

In the past several years, much work on PFAS in Wisconsin has focused on contaminated site investigations. As of July 2023, there are 95 open site investigations statewide (DNR Bureau for Remediation and Redevelopment BRRTS Tracking System at https://dnr.wisconsin.gov/topic/Brownfields/botw.html where one or more PFAS have been identified as a contaminant. Note that 33 PFAS investigation sites have now been closed (4 Environmental Repair Program cases and 29 NR 708 spill cases). PFAS related contaminated site investigations include former firefighting training areas (civilian, corporate and military), industrial facilities, landfills, and an area where biosolids were land applied.

The latter two types of sites are secondary sources, where PFAS were not produced or used directly but rather released to the environment due to their presence in consumer products or other waste streams. Among landfills, older unlined landfills may present a higher risk to groundwater. The environmental stability and lack of effective treatment of PFAS in municipal sewage plants may lead to their presence in biosolids, which might threaten the practice of biosolids land spreading as a beneficial reuse of municipal waste. In areas without municipal sewerage, PFAS may also be released to groundwater from septic systems due to their presence in numerous commercial products.

Where PFAS are discovered in groundwater and attributed to a responsible party, the site investigation and required remedial actions may result in a multi-year cleanup process, and for larger and more complex sites cleanup activities may take decades. This work includes all impacted media, not just groundwater. Despite the

fact that PFAS are exclusively created by industrial production and they do not occur naturally, PFAS have been found at relatively low levels in surface water (https://dnr.wisconsin.gov/topic/PFAS/SWFish.html), soil[2] and precipitation (in a study focused on Indiana and Ohio[3]; a Wisconsin-specific study of PFAS in precipitation was published in 2022[4]).

These studies indicate the potential that lower PFAS concentrations may also be found in ambient groundwater. The groundwater private well PFAS sampling project that finished up in the spring of 2023 should provide information about the chances of finding PFAS in private and small public (e.g., restaurants, schools, churches) drinking water systems. The project should also provide information to entities involved in PFAS site investigations that may help with determining if lower PFAS groundwater concentrations, more distal from the investigation site detections of PFAS, are from the site or may instead be coming from more disperse sources (e.g., consumer products).

Further Reading

- DNR PFAS page
- DHS Groundwater Contaminant recommendation process
- DHS Cycle 10 and Cycle 11 groundwater quality standard recommendations
- Interstate Technology and Regulatory Council fact sheets
- US Agency for Toxic Substances and Disease Registry PFAS page
- US Environmental Protection Agency PFAS page

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WATER USE

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

The Wisconsin Water Use StoryMap showed that the largest category of groundwater withdrawals was municipal public water supplies (DNR 2023). The second largest category of groundwater withdrawal in the state was agricultural irrigation. Agricultural irrigation water use varies from year to year depending on the timing of rainfall during the growing season.

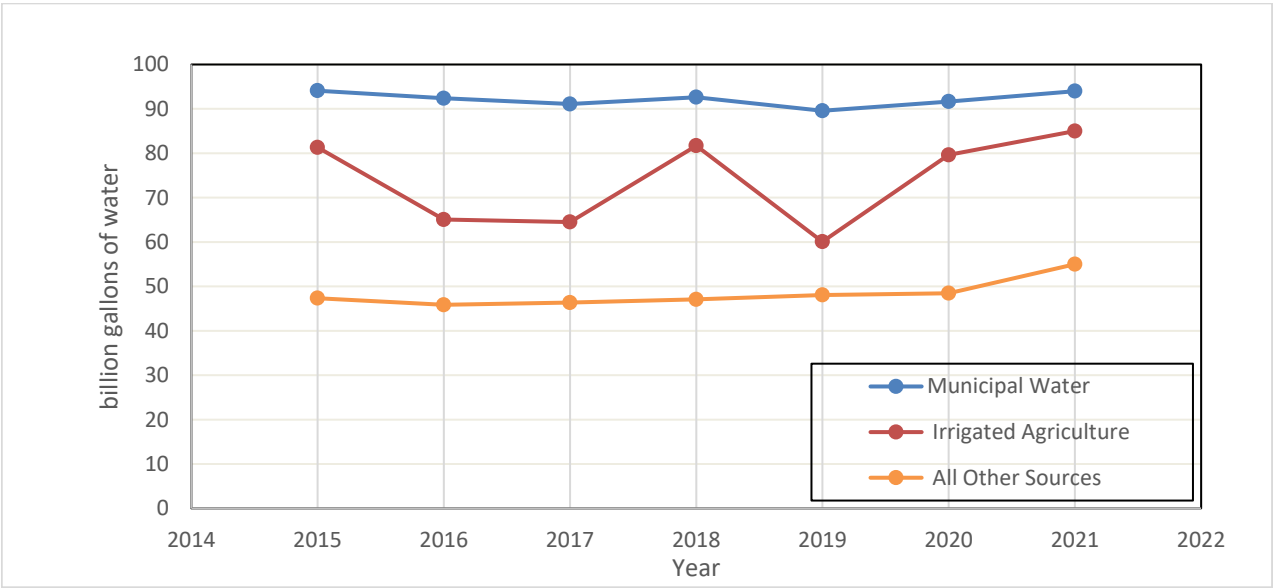


Figure 1. Wisconsin annual groundwater withdrawals, 2015 – 2021. (DNR)

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

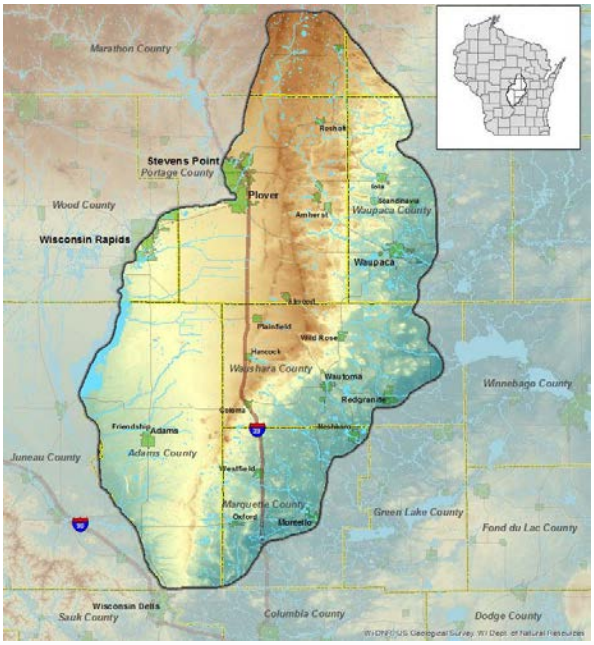
Reference:

Wisconsin Department of Natural Resources. 2023. Wisconsin Water Use – 2021 Reported Withdrawals. Technical Memo. 9p. Available at: https://dnr.wisconsin.gov/sites/default/files/topic/WaterUse/WithdrawalReport/2021.pdf.

CENTRAL SANDS LAKES STUDY

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

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



The Central Wisconsin Sand and Gravel Aquifer is defined as a contiguous area east of the Wisconsin River with sand and gravel surficial deposits greater than 50 feet deep.

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

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

Additional information on the study is available through the study reports, appendices and recorded presentations. The DNR held a public hearing and comment period in Spring 2021 and submitted their findings and recommendations to the Wisconsin Legislature on May 27, 2021.

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.

2017 Wisconsin Act 10, referred to by the DNR as the Central Sands Lakes Study, provides the basis for the DNR to define significant impacts on three Central Sands lakes (Plainfield, Long and Pleasant) in Waushara County and quantify the relationship between groundwater withdrawals, lake levels and significant impacts. The lakes have been of keen interest to stakeholders in Central Wisconsin, particularly in the last decade. The key findings from the three year study are that groundwater withdrawals cause reductions in Pleasant, Long, and Plainfield Lakes. The reductions are significant and impact the lakes' ecosystems in Long and Plainfield Lakes. The study findings show that the reduction caused by groundwater withdrawals to study lake levels are a result of the collective impact from many high-capacity wells rather than any specific high-capacity well. As a result, the DNR recommends a regional framework, such as a water use district, to implement measures to reduce significant impacts from groundwater withdrawals. Learn more at: https://dnr.wi.gov/topic/Wells/HighCap/CSLStudy.html.

Dane County

Although groundwater and surface water resources are plentiful in Dane County, there are several well documented cases of impacts to surface water due to groundwater withdrawals. Just as regional drawdowns have developed across Dane County in response to high-capacity pumping of groundwater for municipal and industrial supply (see Regional

Drawdowns section of the report), several smaller streams and spring systems have also been impacted over the past several decades resulting in reduced flow rates.

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

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

Springs Inventory

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

Because these special natural resources are vulnerable to groundwater pumping, the Department of Natural Resources (DNR) reviews high capacity well applications involving wells constructed near springs for adverse environmental impacts. Springs, for the purpose of a high capacity well review are defined in statute as "… an area of concentrated groundwater discharge occurring at the surface of the land that results in a flow of at least one cubic foot per second at least 80 percent of the time." There are over

10,000 known springs in Wisconsin, and it is not a simple task to determine, given a proposed high capacity well, which nearby springs need to be assessed. Correct information about the location and flow rate of each spring is critically important to have, and ongoing springs monitoring efforts have improved Wisconsin's spring's inventory. Springs can also be used as easy sampling points for indicators of groundwater quality.

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[1] 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[2]. 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. DNR continues the springs inventory monitoring project by identifying new springs, continue monitoring of reference spring sites, and revisiting previously identified springs in the springs inventory.

Wisconsin Stream Model

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

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REGIONAL DRAWDOWNS

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

Lower Fox River Valley

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

By 2005, increased pumping from the communities surrounding Green Bay caused water levels to decrease to the low levels seen in 1957. In response to that drawdown, six suburban communities in the Lower Fox Valley reduced consumption of groundwater by about 8.2 million gallons per day by switching to surface water supplied by pipeline from

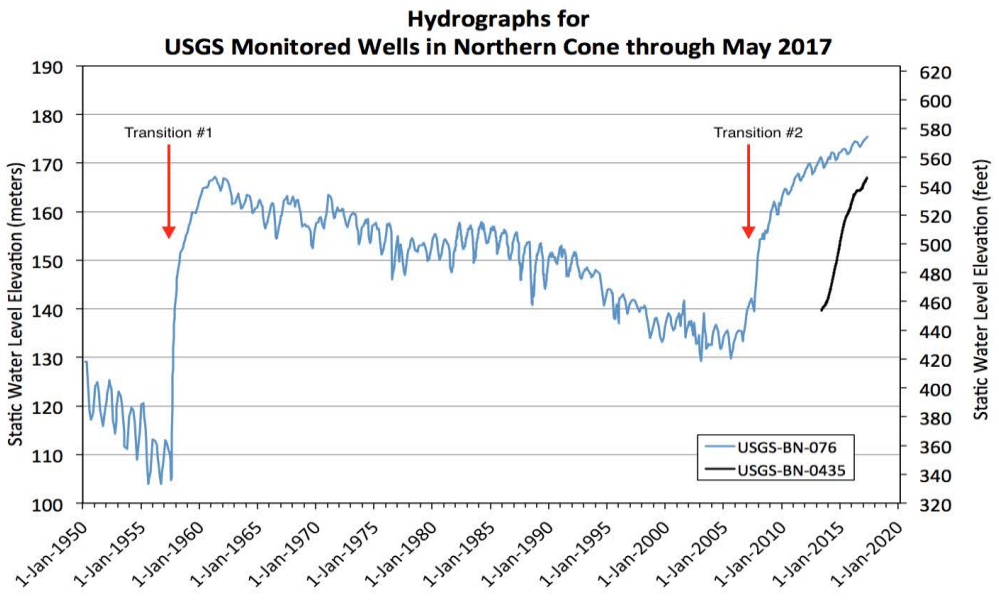


Figure 1: Changes in groundwater levels in a groundwater level monitoring well in Green Bay, Wisconsin. Transition 1 is City of Green Bay Switch to surface water. Transition 2 is Green Bay suburbs switch to surface water (Luczaj).

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.

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 six 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.

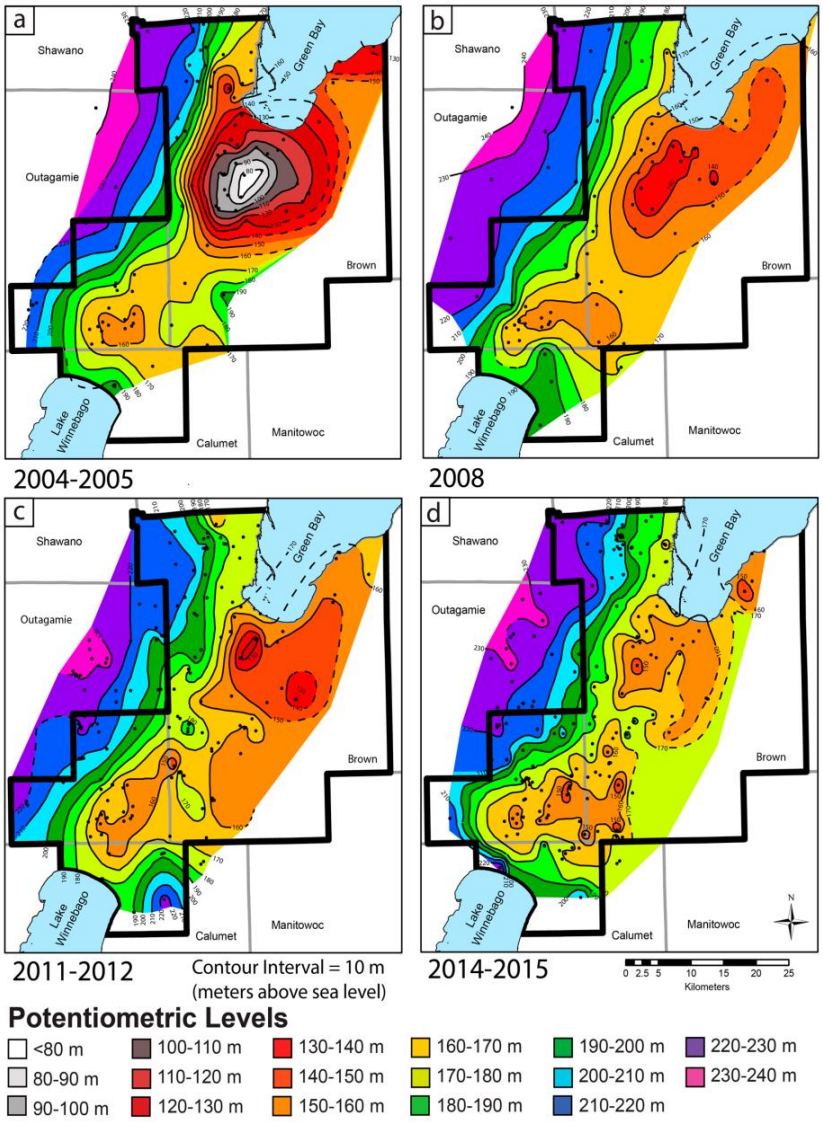


Figure 2: Water table elevations in Brown County (WGNHS).

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[1]. However, an added well in Waukesha County to the groundwater observation network

shows 2020 water levels to be approximately 150 feet higher than the levels observed in a nearby observation well in 1998[2]. 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.

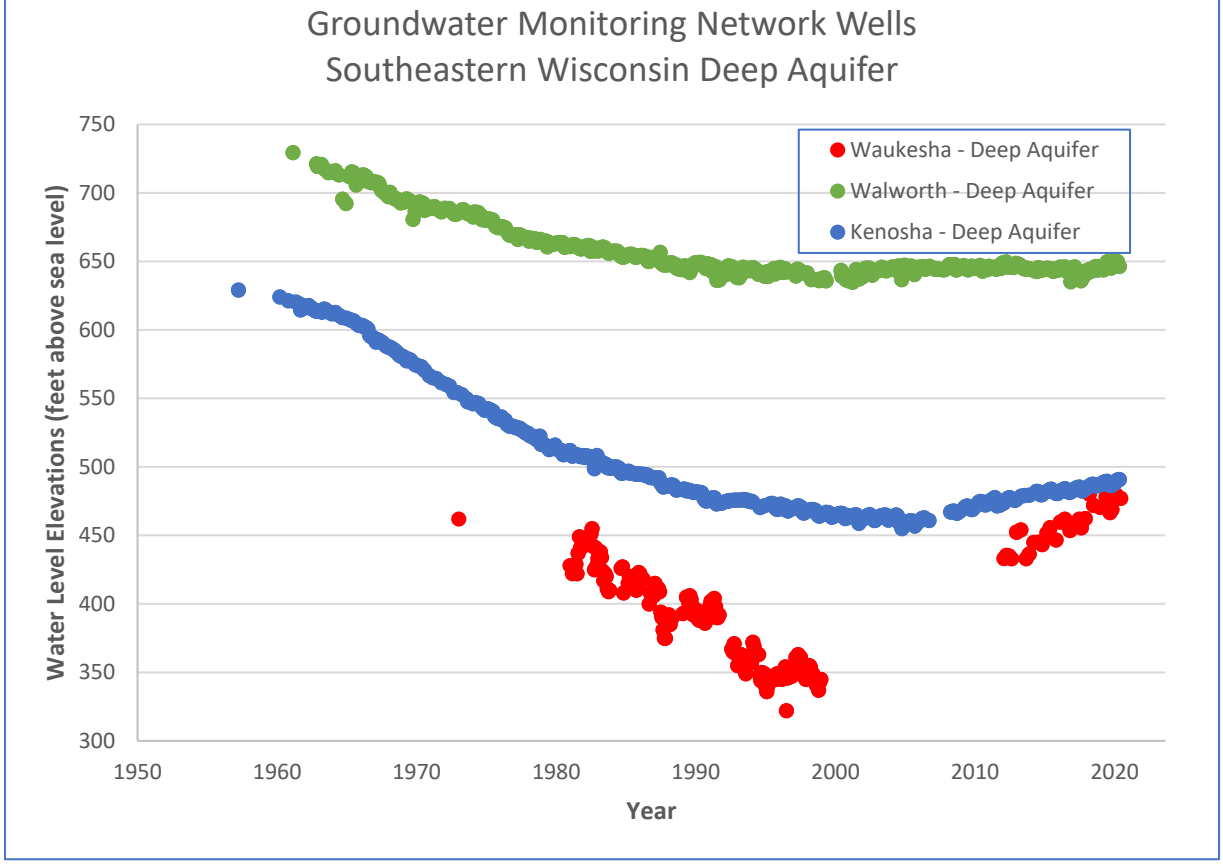


Figure 3: Water levels in a groundwater level monitoring wells in Waukesha, Kenosha and Walworth counties (DNR).

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[3] 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 85% of the total withdrawal rate of 50 million gallons per day. The next largest withdrawals are made by aquaculture (about 5 percent) and irrigation (under 5%).

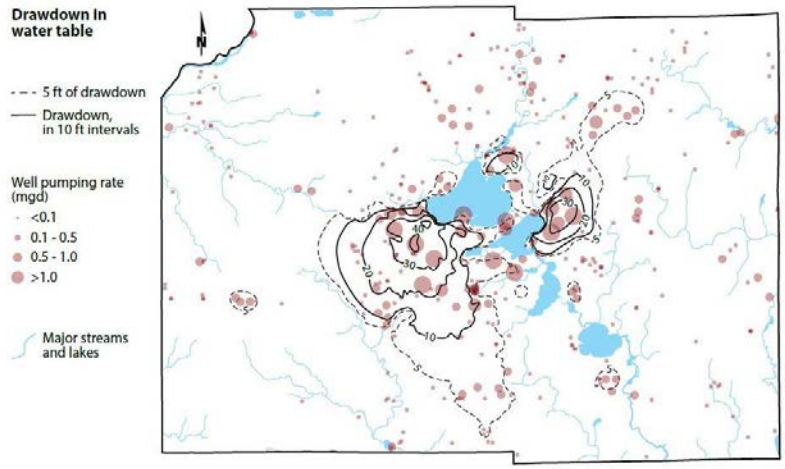


Figure 4: Simulated drawdown (feet) in the Mount Simon Sandstone; predevelopment to 2010. The Mount Simon Sandstone, located several hundred feet below land surface and up to 800 feet thick, is the lowermost aquifer unit within Dane County. This porous sandstone is a highly productive aquifer which provides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

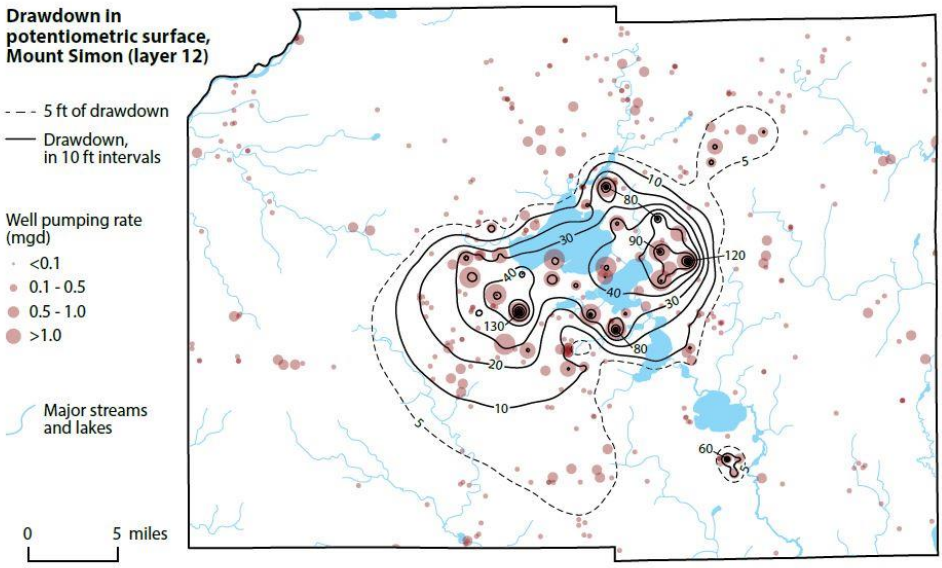


Figure 5: Simulated drawdown (feet) at the water table; predevelopment to 2010. Drawdowns from the lower Mount Simon aquifer system propagate upwards to the shallow sand and gravel and upper bedrock aquifer systems to create drawdowns at the water table (WGNHS).

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. This research, specific to the Little Plover River watershed[4] , confirms that the Little Plover River is closely connected to the groundwater system, making it vulnerable to impacts from nearby high capacity well groundwater withdrawals. Under 2017 Wisconsin Act 10, the department evaluated and modeled the potential impacts of groundwater withdrawals on three specific lakes in the Central Sands region through the Central Sands Lakes Study. The three lakes in the study are all in Waushara County – Long Lake and Plainfield Lake near Plainfield, and Pleasant Lake near Coloma.

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

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

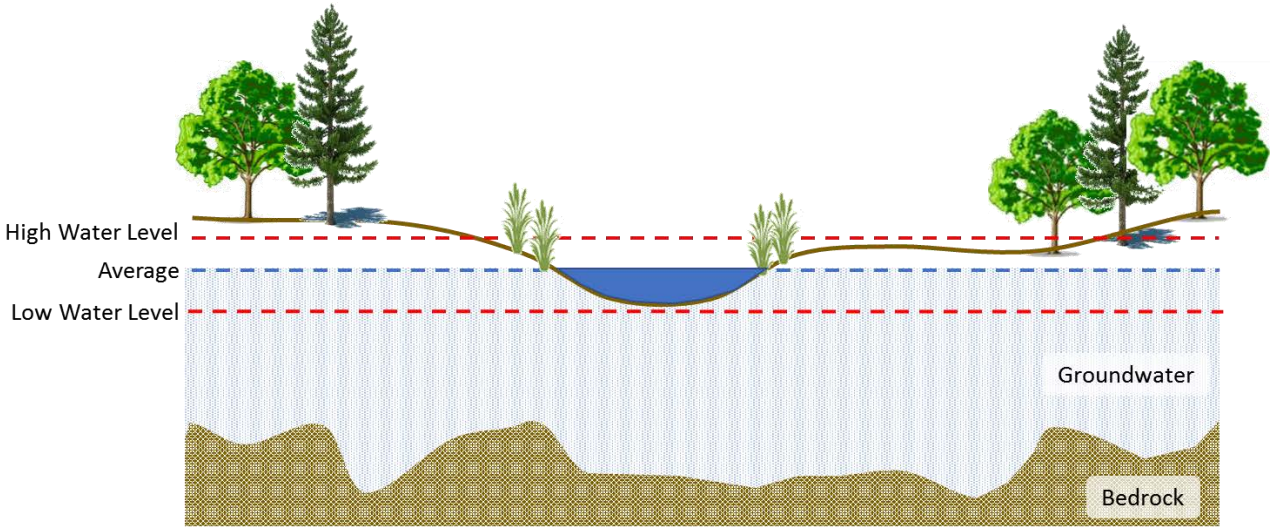
References:

1. Feinstein, D.T., D.J. Hart, T.T. Eaton, J.T. Krohelski, and K.R. Bradbury. Simulation of regional groundwater flow in southeastern Wisconsin. 2004.
2. Pfeiffer, S.M. personal communication, 2013.
3. Parsen, M.J., Bradbury, K.R., Hunt, R.J., and Feinstein, D.T., 2016, The 2016 groundwater flow model for Dane County, Wisconsin: Wisconsin Geological and Natural History Survey Bulletin 110, 56 p.
4. Bradbury, K.R., M.N. Fienen, M.L. Kniffin, J.J. Krause, S.M. Westenbroek, A.T. Leaf, and P.M. Barlow. 2017. A groundwater flow model for the Little Plover River in Wisconsin's Central Sands. Bulletin 111. Wisconsin Geological and Natural History Survey, 82 p. Available at http://wgnhs.uwex.edu/pubs/B111

GROUNDWATER LEVELS AND AQUIFER RESPONSE

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 below). 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.

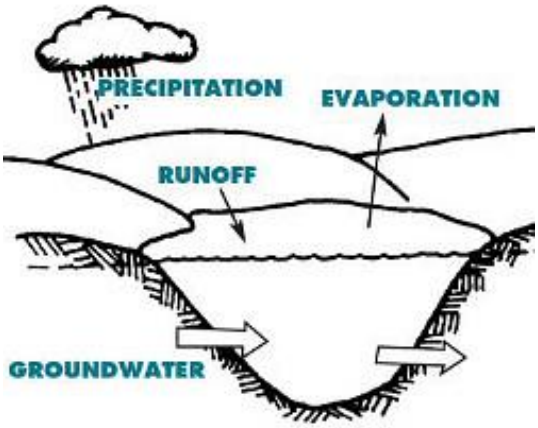
Floods and droughts are part of life in Wisconsin and elsewhere, but they come with significant economic, public health and environmental costs.

During years when Wisconsin receives a record-breaking amount of precipitation, many areas in Wisconsin experience high water and flooding issues. Information is available from the DNR to help residents cope with flooding. 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.

Status of groundwater levels
After a period of above-average precipitation amounts from 2017-2020, groundwater levels were at or near all-time highs in 2020 and 2021. After a period of more typical precipitation amounts (2022) to below-average precipitation amounts (2023), groundwater levels have begun declining.

Flooding resources

- Recommendations for private wells inundated by flooding
- Coping with flooding
- Flood insurance



Seepage lake: a natural lake fed by groundwater, precipitation and limited runoff. It does not have a stream outlet. Image credit: UW-Stevens Point.

GROUNDWATER-LEVEL MONITORING NETWORK

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 over 90 long-term monitoring wells that measure groundwater levels in aquifers across the state. Groundwater level monitoring wells are located in 47 of Wisconsin's 72 counties.

The DNR's water quantity data viewer shows the location and water levels associated with the statewide groundwater monitoring network.

In FY 2018, due to increasing reliance on network data to meet its Water Use program needs, DNR expanded its funding and management support of the groundwater level monitoring 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 2023, DNR committed $100,000 to the Wisconsin Groundwater Monitoring Network and provided additional funding of $75,950 to USGS to conduct additional monitoring on 5 stream gages, 1 lake gage, and 20 short-term project wells in central and northern Wisconsin. WGNHS received grants the USGS National Ground-Water Monitoring Network (NGWMN) program in FY 2021 and FY 2023 for $271,848 and $177,899 respectively. Once the work on both grants is completed, these two recent grants, together with FY2017 and FY2019 NGWMN grant, will result in repairs to 33 wells, twelve well replacements, seven new wells, and equipment upgrades to 17 wells. These improvements add three new counties to the Network (Barron, Buffalo, and St. Croix).

In 2022 the DNR released a StoryMap illustrating the collaboration between DNR, WGNHS, USGS, UW System and others to collect water quantity data to support our understanding on groundwater levels and interaction between surface water and groundwater. Visit https://storymaps.arcgis.com/stories/03c2609bb8bd470fafe2f4a83788f74d to learn more.

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. Learn more about the collaborative restoration effort at https://www.ploverwi.gov/328/Little-Plover-River-Watershed-Enhancemen.

The Village of Plover received a DNR grant in FY23 to continue improvements to the Little Plover River. Through this grant, the Village of Plover, NRCS, Portage Co. and other partners will fill a ditch and restore a wetland. This project will contribute to continuing efforts in the watershed to restore wetlands, thereby improving river baseflow, and reduce surface water runoff, decreasing the flashiness of the river. These efforts to restore the river hydrology are intended to improve habitat in the river.