Wisconsin Groundwater Coordinating Council

Fiscal Year 2012

REPORT TO THE LEGISLATURE

August, 2012

GROUNDWATER COORDINATING COUNCIL MEMBERS

Department of Natural Resources – **Ken Johnson (Chair)**
Department of Agriculture, Trade, and Consumer Protection – **John Petty**
Department of Safety and Professional Services – **Eric Scott**
Department of Health Services - **Henry Anderson, MD**
Department of Transportation - **Dan Scudder**
Geological and Natural History Survey (State Geologist) - **James Robertson**
Governor's Representative – **George Kraft**
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Research & Monitoring

Geological and Natural History Survey - **Ken Bradbury** (Co-Chair) *, **Madeline Gotkowitz* and Bill Bristoll**
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Center for Watershed Science and Education - **George Kraft* and Dave Mechenich**
Natural Resources Conservation Service - **Tim Weissbrod**
* Member of Standing Joint Solicitation Work Group

Outreach & Partnership

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U. S. Geological Survey **– Marie Peppler**
Natural Resources Conservation Service - **Tim Weissbrod**
Association of Wisconsin Regional Planning Commissions – **Eric Fowle**
Wisconsin Alliance of Cities – vacant
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Wisconsin Rural Water Association – **Andrew Aslesen**
Wisconsin Water Association - **Nancy Quirk**

State of Wisconsin \ GROUNDWATER COORDINATING COUNCIL

Scott Walker, Governor

101 South Webster Street
Box 7921
Madison, Wisconsin 53707
FAX 608-267-7650
TDD 608-267-6897

Ken Johnson,
Council Chair
DNR

James Robertson
WGNHS

John Petty
DATCP

Henry Anderson, MD
DHS

James Hurley
UWS

Eric Scott
DSPS

Dan Scudder
DOT

George Kraft
GOVERNOR'S REP.

August, 2012

To: The Citizens of Wisconsin
The Honorable Governor Scott Walker
Senate Committee on Environment and Natural Resources
Assembly Committee on Natural Resources
Secretary Mark Gottlieb - Department of Transportation
Secretary Dave Ross - Department of Safety and Professional Services
Secretary Ben Brancel - Department of Agriculture, Trade & Consumer Protection
Secretary Dennis Smith - Department of Health Services
Secretary Cathy Stepp - Department of Natural Resources
President Kevin P. Reilly - University of Wisconsin System
State Geologist James Robertson - Geological and Natural History Survey

The Groundwater Coordinating Council (GCC) is pleased to release its 2012 Report to the Legislature. The GCC was formed in 1984 to help state agencies coordinate non-regulatory activities and exchange information on groundwater. For the past 28 years, the GCC has served as a model for interagency coordination and cooperation among state agencies, the Governor, local and federal government, and the university. It is one of the few groups in the nation to effectively coordinate groundwater activities in its state from an advisory position.

This report summarizes and provides links to information on GCC and agency activities related to groundwater protection and management in FY 12 (July 1, 2011 to June 30, 2012). The links also provide information on the condition of the groundwater resource. At the end of this report are the GCC's recommendations titled *Directions for Future Groundwater Protection.* (*http://dnr.wi.gov/topic/groundwater/documents/GCC/Report/Recommendations.pdf*). The report and supporting materials are available online at *http://dnr.wi.gov/topic/Groundwater/GCC/report.html*.

Highlights of the State's groundwater protection activities this past year include:

- Research and monitoring contributing to our understanding of many groundwater issues including the impacts of agricultural practices, antibiotics, climate change, water use, and fecal contamination.
- Progress on integrating and increasing access to groundwater data by DATCP, WGNHS and UWS.
- Continued progress by the Water Resources Library in providing full-text reports of UWS and DNR groundwater monitoring and research projects through the UW Ecology and Natural Resources Digital Collection at http://digital.library.wisc.edu/1711.dl/EcoNatRes.Groundwater.

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

Sincerely,

Ken Johnson, Chair
Groundwater Coordinating Council

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PURPOSE OF THE GCC AND THIS REPORT

In 1984, the Legislature enacted 1983 Wisconsin Act 410, 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." For a summary of statutory language relating to the GCC see: http://dnr.wi.gov/topic/groundwater/documents/GCC/Report/StatLanguage.pdf

The GCC is required by s. 15.347, Wis. Stats., to prepare a report which "summarizes the operations and activities of the council…, describes the state of the groundwater resource and its management and sets forth the recommendations of the council. The annual report shall include a description of the current groundwater quality of the state, an assessment of groundwater management programs, information on the implementation of ch. 160, Wis. Stats., and a list and description of current and anticipated groundwater problems." This report is due each August. The purpose of this report is to fulfill this requirement for fiscal year 2012 (FY 12). Please note that this report has been prepared in the style of an executive summary with supporting information referenced by numerous Internet links.

Membership of the GCC includes the Secretaries of the Departments of Natural Resources (DNR); Safety and Professional Services, Agriculture, Trade & Consumer Protection (DATCP); Health Services (DHS); Transportation (DOT); the President of the University of Wisconsin System (UWS); the State Geologist; and a representative of the Governor. Agency designees and members of the two GCC subcommittees are listed on the inside of the front cover and at (http://dnr.wi.gov/topic/groundwater/documents/GCC/Report/Members.pdf). More information about the GCC and its activities can be found on the GCC web pages: http://dnr.wi.gov/topic/Groundwater/GCC/ .

The GCC's role in facilitating inter-agency coordination includes the exchange of information regarding 1983 Wisconsin Act 410, Wisconsin's Comprehensive Groundwater Protection Act, 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 Protection and Source Water Protection provisions and many other regulations. For a summary of Wisconsin's groundwater law see http://dnr.wi.gov/topic/groundwater/documents/GCC/Report/WIgroundwaterLaw.pdf .

GROUNDWATER COORDINATION ACTIVITIES

To complete coordination activities, the GCC is authorized to create subcommittees on "the subjects within the scope of its general duties…and other subjects deemed appropriate by the Council." See a list of GCC subcommittee members on the inside cover of this report.

The GCC and its subcommittees regularly bring together staff from over 15 different agencies, institutions and organizations to communicate and work together on a variety of research, monitoring and data management, educational, local government and planning issues. In addition, numerous contacts and informal conversations are generated both at meetings and through email communications among GCC and subcommittee members, leading to better communication across agency lines on a variety of

groundwater-related issues. These activities regularly create efficiencies and provide numerous benefits to Wisconsin's taxpayers.

Coordination of Groundwater Research and Monitoring Program

The GCC is directed to "advise the Secretary of Administration on the allocation of funds appropriated to the Board of Regents of the University of Wisconsin under s. 20.285(1)(a) for groundwater research." In 1990 this directive lead to the collaborative formation of a joint solicitation process by the UWS, DNR, DATCP, and Commerce and to the Wisconsin Groundwater Research and Monitoring Program (WGRMP). The joint solicitation was first carried out for projects funded in FY 92.

In FY 12 the GCC, the UWS, DNR and the Groundwater Research Advisory Council (GRAC) again collaborated on the annual solicitation for groundwater research and monitoring proposals as specified in a November 2002 Memorandum of Understanding *http://dnr.wi.gov/topic/groundwater/documents/GCC/MonitoringResearch/MOU2002.pdf* . After a multi-agency effort spear-headed by the UW Water Resources Institute, the GCC approved the FY 13 Joint Solicitation for Proposals in August of 2011: *http://dnr.wi.gov/topic/groundwater/documents/GCC/MonitoringResearch/FY13JointSolicitation.pdf* . A total of 22 project proposals were received. A comprehensive review process including the GRAC, the GCC's Monitoring & Research Subcommittee and outside technical experts resulted in recommendations that were used by the UWS and DNR in deciding which groundwater-related proposals to fund in FY 13. The process resulted in the selection of ten new projects for funding for FY 13, five by UWS and five by DNR. The GCC approved the proposed UWS groundwater research plan as required by s. 160.50(1m), Wis. Stats., and a letter to this effect was sent to the UWS President and the Department of Administration.

Links to WGRMP project lists

Projects funded in FY 12:
http://dnr.wi.gov/topic/groundwater/documents/GCC/MonitoringResearch/FY12Projects.pdf
Projects selected for funding in FY 13:
http://dnr.wi.gov/org/water/dwg/gcc/rtl/2012/MonitoringResearch/FY13projects.pdf

All Wisconsin state-funded groundwater research and monitoring projects:
http://dnr.wi.gov/topic/groundwater/documents/GCC/MonitoringResearch/FY13projects.pdf

The UW Water Resources Institute (WRI) provides access to summaries and reports of GCC-facilitated groundwater research (*http://wri.wisc.edu/Default.aspx?tabid=69*) as well as cataloging all WRI research reports into WorldCat and MadCat, two library indexing tools that provide both worldwide and statewide access to this research. The Water Resources Library has partnered with UW Libraries' Digital Collections Center to digitize and post UWS and DNR final project reports. As a result of this partnership, full-text reports are also available through the UW Ecology and Natural Resources Digital Collection at http://digital.library.wisc.edu/1711.dl/EcoNatRes.Groundwater. In 2012 progress continued in locating older final reports and summaries for digitization and availability on the Internet.

Information and Outreach Activities

For the twelfth year in a row, three groundwater workshops for teachers were taught jointly by GCC Education Subcommittee members from the DNR, WGNHS and the Center for Watershed Science and Education (CWSE) at Stevens Point. In January and February, educators from 26 schools and nature centers took part in the workshops held at Mount Horeb, La Crosse, and Amherst Junction. The workshop leaders instructed teachers on using a groundwater sand-tank model and provided additional resources to incorporate groundwater concepts into their classroom. Educators who attended the

workshops received a free model. With funding from a U.S. Environmental Protection Agency (EPA) wellhead protection grant, over 250 groundwater models have been given to schools and nature centers since 2001 and about 500 educators have received hands-on training in using the model effectively.

Education Subcommittee members representing The UW-Stevens Point Center for Watershed Science and Education and the WRI again contributed to four news releases for the annual "Groundwater Awareness Week" in March 2012 that were distributed via the UW media mailing lists.

Other Coordination Activities

The GCC continued to promote communication, coordination and cooperation between the state agencies through its quarterly meetings. In FY 12, the GCC received briefings, heard presentations, and discussed:

- Denitrification in the region beneath and alongside a stream bed,
- The groundwater impacts of sand mining for hydrofrac sand used in shale gas mining.
- The FY 13 Joint Solicitation
- DNR's implementation of the administrative rules on water use registration and reporting (NR 856), fee (NR 850), water use permits for existing withdrawals in the Great Lakes basin (NR 860), and mandatory water conservation measures (NR 852).
- Waukesha's Great Lakes Diversion Application
- The State Supreme Court decision to affirm the DNR's broad authority and duty to manage, protect, and maintain waters of the state and the Court's recognition of the connection between surface water and groundwater in the DNR's evaluation of high-capacity well applications.
- Improving inter-agency collaboration on groundwater issues through the new GCC Priorities and Operations Plan
- Use of the 2009 behavioral risk factor surveillance survey to assess the safety of private drinking water supplies
- DATCP's Intranet Groundwater Results Mapping Application.
- The effects of nutrient management practices on groundwater quality
- DNR's work to investigate strategies needed to reduce nitrate contamination of drinking water and evaluate the potential for changing practices to reduce nitrate leaching to groundwater.
- Combination of co-precipitation with zeolite filtration to remove arsenic from contaminated water
- Social media tools used by the Aquatic Sciences Center to deliver water science information.
- Distributed temperature sensing (DTS), an improved method of borehole dilution testing, that can help to measure subsurface heterogeneity in hydraulic properties and processes.
- Preparation of the FY 12 GCC Report to the Legislature.
- Many other informational items presented by the agencies.

More information on the coordinating efforts of the GCC can be found in the FY 12 GCC meeting minutes at: *http://dnr.wi.gov/topic/Groundwater/GCC/minutes.html* . Through these activities, the GCC continues to play an important role in ensuring agency coordination, increasing efficiency, and facilitating the effective functioning of state agencies in activities related to groundwater protection and management. Ultimately groundwater is better protected, which benefits public health and preserves Wisconsin's natural resources for future generations.

SUMMARY OF AGENCY GROUNDWATER ACTIVITIES

State agencies and the University of Wisconsin System addressed numerous issues related to groundwater protection and management in FY 12. Detailed discussions of the groundwater activities of each agency can be found on the following GCC web pages:

Department of Natural Resources groundwater activities:
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DNRactivities.pdf

Department of Agriculture, Trade, and Consumer Protection groundwater activities
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DATCPactivities.pdf

Department of Safety and Professional Services groundwater activities:
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DSPSactivities.pdf

Department of Transportation groundwater activities
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DOTactivities.pdf

Department of Health Services groundwater activities
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DHSactivities.pdf

Wisconsin Geological and Natural History Survey groundwater activities:
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/WGNHSactivities.pdf

University of Wisconsin System groundwater activities
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/UWSactivities.pdf

United States Geological Survey – Wisconsin Division groundwater activities
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/USGSactivities.pdf

United States Department of Agriculture – Natural Resources Conservation Service groundwater activities: *http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/NRCSactivities.pdf*

CONDITION OF THE RESOURCE: Groundwater Quality

Major groundwater quality and quantity concerns in Wisconsin include:

Volatile Organic Compounds (VOCs)
Sources of VOCs in Wisconsin's groundwater include landfills, underground storage tanks, and hazardous substance spills. Thousands of wells have been sampled for VOCs and about 60 different VOCs have been found in Wisconsin groundwater. Trichloroethylene is the VOC found most often in Wisconsin's groundwater. More information on VOCs in Wisconsin groundwater can be found here:
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/VOCs.pdf

Pesticides
Pesticide contamination in groundwater results from field applications, pesticide spills, misuse, or improper storage and disposal. Pesticide metabolites are related chemical compounds that form when the parent pesticide compounds break down in the soil and groundwater. The most commonly detected pesticide compounds in Wisconsin groundwater are: metabolites of alachlor (Lasso) and metolachlor (Dual), and atrazine and its metabolites. A 2007 DATCP private well survey estimated that the proportion of wells in Wisconsin that contained a pesticide or pesticide metabolite was 33.5%. Areas of the state with a higher intensity of agriculture generally had higher frequencies of detections of pesticides. The two most commonly-detected pesticide compounds, metolachlor ESA and alachlor ESA, each had a proportion estimate of 21.6%. In October 2011 DATCP reported on the results of its 2010 Survey of Weed Management Practices in Wisconsin's Atrazine Prohibition Areas

(*http://datcp.wi.gov/uploads/Environment/pdf/WeedMgtAtrazinePAs.pdf)*. The main purpose of this survey was to identify differences in herbicide use and other weed control practices inside and outside of Wisconsin's atrazine prohibition areas. Survey results suggest that although many corn growers would like the option to use atrazine in a prohibition area, they have adapted well to growing corn without it. Half of the respondents indicated that they do not find it more difficult to control weeds in a PA without atrazine. More information on pesticides in Wisconsin groundwater can be found here: *http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Pesticides.pdf*

Nitrate

Nitrate is Wisconsin's most widespread groundwater contaminant and is increasing in extent and severity. Nitrate levels (as nitrate-N) in groundwater are below 1 milligram per liter (mg/L) where pollution sources are absent. Higher levels indicate a source of contamination such as agricultural or turf fertilizers, animal waste, septic systems, and wastewater. At least 90% of nitrate inputs into our groundwater originate from manure spreading, agricultural fertilizers, and legume cropping systems. Concentrations of nitrate in private water supplies have been found to exceed the state drinking water standard of 10 mg/L. In 2005 and 2007, DNR aggregated and analyzed data from three extensive statewide groundwater databases. Most recent samples from 48,818 private wells showed 5,686 (11.6 %) equaled or exceeded the 10 mg/L standard. A 2007 DATCP survey estimated the proportion of private wells that exceeded the 10 mg/l enforcement standard for nitrate-nitrogen at 9.0%. More information on nitrate in Wisconsin groundwater can be found here:
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Nitrate.pdf

Microbial agents

Microbiological contamination often occurs in areas where the depth to groundwater is shallow, in areas where soils are thin, or in areas of fractured bedrock. Microbial agents include bacteria, viruses, and parasites. These agents can cause acute illness and result in life-threatening conditions for young children, the elderly and those with chronic illnesses. In one assessment (Warzecha et.al., 1994), approximately 23% of private well water samples statewide tested positive for total coliform bacteria, an indicator species of other biological agents. Approximately 3% of these wells tested positive for *E. coli*, an indicator of water borne disease that originates in the mammalian intestinal tract. The DNR has recently begun tracking total coliform detects in the raw water samples through its Drinking Water System database.

Viruses in groundwater are increasingly a concern as new analytical techniques have detected viral material in private wells and public water supplies. Research conducted at the Marshfield Clinic indicates that 4-12% of private wells contain detectible viruses. Other studies showed virus presence in four La Crosse municipal wells, in the municipal wells and wastewater system in Madison, and in five shallow municipal wells serving smaller communities.

Public and private water samples are not regularly analyzed for viruses due to the high cost of the tests. The presence of coliform bacteria has historically been used to indicate the water supply is not safe for human consumption. However, recent findings show that coliform bacteria do not always correlate with the presence of enteric viruses. More information on microbial agents in Wisconsin groundwater can be found here: *http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/MicrobialAgents.pdf*

Radionuclides

Naturally-occurring radionuclides, including uranium, radium, and radon are an increasing concern for groundwater quality, particularly in the Cambro-Ordovician aquifer system in eastern Wisconsin. The water produced from this aquifer often contains combined radium activities in excess of 5 pCi/L and in some cases in excess of 30 pCi/L. Approximately 40 public water systems exceed the drinking water standard of 15 pCi/L for gross alpha activity. Federal standards are causing many communities to search

for alternative water supplies or treatment options. More information on radionuclides in Wisconsin groundwater can be found here:
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Radionuclides.pdf

Arsenic
Naturally occurring arsenic has been detected in wells throughout Wisconsin. DNR historical data show that 3,830 public wells and 3,013 private wells have detectable levels of arsenic. About 10% of these wells exceed the federal drinking water standard of 10 µg/L. Although arsenic has been detected in well water samples in every county in Wisconsin, the problem is especially prevalent in northeastern Wisconsin where increased water use has likely released arsenic from rocks and unconsolidated material into the groundwater. The State continues to proactively address arsenic concerns through well drilling advisories, health studies, well testing campaigns, and studies aimed at improving geological understanding and developing practical treatment technologies. More information on arsenic in Wisconsin groundwater can be found here:
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Arsenic.pdf

CONDITION OF THE RESOURCE: Groundwater Quantity

Despite a general abundance of groundwater in Wisconsin, there is a concern about the overall availability of good quality groundwater for municipal, industrial, agricultural, and domestic use and for adequate baseflow to our lakes, streams, and wetlands. Groundwater use grew from 570 to 804 million gallons per day (Mgal/d) from 1985 to 2000. Groundwater use was estimated to be 983 Mgal/d in 2005, but much of the increase between 2000 and 2005 was due to a shift in how irrigation water use was estimated.

Groundwater quantity problems have occurred both naturally and from human activities, and often affect groundwater quality. Regional effects of groundwater withdrawals are well documented in the Lower Fox River Valley, southeastern Wisconsin, and Dane County. Localized effects of groundwater pumping on trout streams, springs, and wetlands have been noted throughout the state. Groundwater quantity legislation enacted in 2004 was the first step towards managing groundwater quantity on a comprehensive basis. The DNR began implementing a new rule, NR 820, regulating high-capacity wells in FY 08. The Great Lakes Compact, signed by Governor Doyle in 2008, requires Wisconsin to have water conservation goals within the Great Lakes Basin. Implementing legislation (2007 Wisconsin Act 227) is currently being implemented. More information on groundwater quantity issues in Wisconsin can be found at the following links:

Issues and Problems
- Water Use: *http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/WaterUse.pdf*
- Surface Water Impacts*:*
  http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/SurfaceWaterImpacts.pdf
- Regional Drawdowns*:*
  http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/RegionalDrawdowns.pdf
- Impact of Reduced Quantity on Groundwater Quality
  http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/QuantityQuality.pdf
- Land use and high groundwater conflicts*:*
  http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/LandUseHighGW.pdf
- Alternative Sources – Aquifer Storage and Recovery*:*
  http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/AlternativeSources.pdf

Management Solutions

- Statewide Groundwater Level Network*:* *http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/GroundwateLevelNetwork.pdf*
- Wisconsin Stream Model: *http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/WIstreamModel.pdf*

BENEFITS OF MONITORING AND RESEARCH PROJECTS

The GCC provides consistency and coordination among state agencies in funding Wisconsin's Groundwater Research and Monitoring Program to meet state agency needs. Approximately $15.7 million has been spent by DNR, UWS, DATCP, and Commerce through FY 12 on 382 different projects dealing with groundwater or related topics. A list of all these projects is available on the GCC webpage (*http://dnr.wi.gov/topic/groundwater/documents/GCC/MonitoringResearch/AllProjects.pdf*). Projects funded have provided valuable information regarding the Wisconsin's groundwater resources, helped evaluate existing regulatory programs, increased the knowledge of the movement of contaminants in the subsurface, and developed new methods for groundwater evaluation and protection. While the application of the results is broad, some areas where the results of state-funded groundwater research and monitoring projects have been successfully applied to groundwater problems in Wisconsin include:

- Pharmaceuticals, personal care products, and endocrine disrupting compounds
- The Atrazine Rule
- Groundwater monitoring at solid waste disposal sites
- Arsenic monitoring and research in Northeastern Wisconsin
- Groundwater movement in shallow carbonate rocks
- Developing new tools for groundwater protection
- Prevention and remediation of groundwater contamination
- Detection and monitoring of microbiological contaminants
- Groundwater drawdowns
- Comprehensive planning
- Rain garden design and evaluation
- Methylmercury formed in groundwater

See the GCC webpage (*http://dnr.wi.gov/topic/Groundwater/GCC/report.html*) under the “Benefits from Projects” tab for more information on some of these projects and how agencies have used the project results to improve the management of the state's groundwater resources.

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 needs to state agencies, the Governor, the Legislature, and the citizens of Wisconsin. These recommendations include top priorities of immediate concern, on-going efforts that require continued support, and emerging issues that will need to be addressed in the near future.

Priority Recommendations

Evaluate the occurrence of viruses and other pathogens in groundwater and groundwater-sourced water supplies, and develop appropriate response tools. Recently, viruses and other microbial pathogens have been found in municipal and domestic wells, challenging previous assumptions about their occurrence. The legislature and agencies should support research to refine our understanding of pathogens in groundwater and their threat to human health. Agencies should also work with partners to increase awareness of waste disposal choices, their risks and costs. Background on the issue and the rationale for the recommendation are found at:
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/MicrobialAgents.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/Benefits/DetectMonMicrobes.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DHSactivities.pdf

Implement practices that protect groundwater from nitrate and associated contaminants (pesticides, pharmaceuticals, and their degradates). Nitrate contamination that approaches unsafe levels in drinking water is pervasive in Wisconsin – posing an acute risk to infants and a chronic risk of serious disease in adults. Agencies should validate and promote practices that lead to efficient use of agricultural nitrogen and produce safer drinking water. The legislature should support the implementation of these practices with appropriate funding mechanisms. Background on the issue and the rationale for the recommendation are found at:
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DNRactivities.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DATCPactivities.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Nitrate.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Pesticides.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/Benefits/PharmPCPedc.pdf

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

- supporting an inventory of information on the location, quantity, and uses of the state's groundwater;
- supporting targeted research and modeling of the impact of groundwater withdrawals on other waters of the state; and
- supporting proactive regional groundwater planning in areas with limited groundwater resources where increased groundwater use and development/population growth pressures are leading to water availability and sustainability issues related to groundwater and surface water resources.

Background on the issue and the rationale for the recommendation are found at:
http://dnr.wi.gov/topic/groundwater/documents/GCC/Report/WIgroundwaterLaw.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DNRactivities.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/WaterUse.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/RegionalDrawdowns.pdf

Ongoing Recommendations

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

Support implementation of the Statewide Groundwater Monitoring Strategy. Chapter 160 of the Wisconsin Statutes requires the DNR to work with other agencies and the GCC to develop and operate a system for monitoring and sampling groundwater to determine whether harmful substances are present (s. 160.27, Wis. Stats.). The strategy has been incorporated into the DNR Water Monitoring Strategy (*http://dnr.wi.gov/org/water/monitoring/strategy.htm*), but needs are constantly evolving as new problems emerge. For example, food processors, homeowners, municipalities, and well drilling contractors need more information about the origin and extent of naturally occurring contaminants such as arsenic and other heavy metals, acidic conditions, sulfate, total dissolved solids, radium and uranium. Wisconsin should continue to encourage research efforts that will provide information for addressing these issues. State agencies, the university, and federal and local partners should continue to implement and modify this strategy to efficiently meet monitoring objectives. Background on the issue and the rationale for the recommendation are found at:
http://dnr.wi.gov/org/water/dwg/gcc/rtl/2012/Benefits/Drawdowns.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/GroundwateLevelNetwork.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuantity/QuantityQuality.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Arsenic.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/GwQuality/Radionuclides.pdf

Continue to catalog Wisconsin's groundwater resources. Management and protection of Wisconsin's groundwater resources requires publically-accessible and up-to-date data in order to foster informed decisions, not only on state policy matters but also for sound business decisions on siting or technology investments. State agencies and the University should continue to collect, catalog, share, and interpret new data about Wisconsin's groundwater so that it can be used by health care providers, people seeking business locations, as well as homeowners and local governments.

Continue to support applied groundwater research. Numerous years of state budget cuts and increased costs have reduced the number of groundwater research projects that are funded each year (see *http://dnr.wi.gov/org/water/dwg/gcc/rtl/2012/MonitoringResearch/AllProjects.doc*). Continued cuts will hamper the State's ability to address critical groundwater monitoring and research needs in the future. Research is necessary to identify and test cost-effective groundwater protection strategies that can prevent groundwater problems before they need to be remediated at a much greater cost. State agencies and the Legislature should work to restore adequate funding to answer the key groundwater questions facing Wisconsin water suppliers and to seek partnerships to leverage additional research support.

Emerging Issues

Frac sand mining. In the past two years unprecedented growth of the frac sand mining and processing industry has occurred in west-central Wisconsin; growth is expected for another decade. The potential impact of this industry on groundwater resources has not been comprehensively evaluated to avoid problems and plan for restoration. Wisconsin agencies and the legislature should support research and field investigations to understand how this industry might impact groundwater, and should partner with industry to rapidly develop and adapt best-management practices for mining and long-term site restoration.

Metallic mining. During 2011 a proposed iron mine in northern Wisconsin generated significant public discussion. Several lead, zinc, and copper mines have also been proposed around the state. These proposed mines are located in sparsely-populated regions where background information on groundwater resources is often incomplete. Workers, residents, and mining operators will require substantial supplies of water for drinking and processing ore. The state should support background

data collection and groundwater assessments to inform both public debate and technical discussions about potential mining.

Dairy industry expansion and concentration. During 2011 and 2012 several animal feeding operations that house thousands of animals have been sited or proposed in Wisconsin. These operations require large quantities of groundwater and must also dispose of large volumes of animal waste. Wisconsin should support policies and research that allows for effective siting and efficient operation of these facilities while protecting groundwater quality and quantity. Background on the issue and the rationale for the recommendation are found at:
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DNRactivities.pdf
http://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DATCPactivities.pdf

Evaluate potential impacts of climate change on Wisconsin's groundwater. Climate change will likely increase the frequency and severity of weather patterns that may produce unprecedented flooding or drought conditions. As a result, land and water use patterns may also change and affect the groundwater supply. These may include biological or chemical contamination issues or increased demand for groundwater by agricultural, municipal, and commercial users. More work is needed to determine the range of possible climates in Wisconsin's future. Work is also needed on feedback mechanisms between climate and groundwater to fully characterize possible changes to Wisconsin's groundwater resource. This research will help identify drought response and long-term management strategies for Wisconsin's groundwater supply.

DEPARTMENT OF NATURAL RESOURCES

The Department of Natural Resources (DNR) has statutory authority as the central unit of state government to protect, maintain and improve the quality and management of the waters of the state, ground and surface, public and private (s. 281.11 Wis. Stats.). The DNR establishes the groundwater quality standards for the state under authority of ch. 160, Wis. Stats. DNR regulatory activities to protect groundwater are the responsibility of four programs:

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

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

Remediation and Redevelopment (RR) – Oversees response actions at spills, hazardous substance release sites, abandoned containers, drycleaners, brownfields (including the Site Assessment Grant program through 2010), "high priority" leaking underground storage tanks, closed wastewater and solid waste facilities, hazardous waste corrective action and generator closures, and sediment cleanup actions. A significant amount of the RR's work relates to groundwater contamination. See *http://dnr.wi.gov/topic/Brownfields/* and *http://dnr.wi.gov/topic/Brownfields/Cleanup.html*.

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

Watershed Management (WT) –WT has primary responsibility for regulating stormwater and agricultural runoff as well as managing waste from large animal feeding operations. See *http://dnr.wi.gov/topic/Watersheds/*, *http://dnr.wi.gov/topic/SurfaceWater/*, and *http://dnr.wi.gov/topic/Waterways/*.

More information about the groundwater programs and activities of the DNR is detailed below.

Drinking Water and Groundwater Program

Groundwater Quality Standards.

Chapter 160, Wis. Stats., requires the DNR to develop numerical groundwater quality standards, consisting of enforcement standards and preventive action limits, for substances detected in, or

having a reasonable probability of entering, the groundwater resources of the state. Chapter NR 140, Wis. Adm. Code (http://legis.wisconsin.gov/rsb/code/nr/nr140.pdf), establishes these groundwater standards and creates a framework for their implementation. There are currently groundwater quality standards for 138 substances of public health concern, 8 substances of public welfare concern and 15 indicator parameter substances in ch. NR 140.

Revisions to ch. NR 140 groundwater quality standards were last adopted by the Legislature in 2010. These revisions established new state ch. NR 140 groundwater standards for 15 substances of public health concern: Acetochlor, Acetochlor ethane sulfonic acid + oxanilic acid (Acetochlor-ESA+OXA), Aluminum, Ammonia (as N), Chlorodifluoromethane (HCFC-22), Chlorpyrifos, Dimethenamid/Dimethenamid-P, Dinitrotoluene (Total Residues), 1,4-Dioxane, Ethyl Ether, Manganese, Metolachlor ethane sulfonic acid + oxanilic acid (Metolachlor-ESA+OXA), Perchlorate, Propazine and Tertiary Butyl Alcohol (TBA).

The ch. NR 140 revisions adopted by the Legislature in 2010 also included revised standards for 15 substances of public health concern: Acetone, Boron, Carbaryl, Chloromethane, Dibutyl Phthalate, 1,3-Dichlorobenzene, 1,3-Dichloropropene, Ethylene Glycol, Methyl Ethyl Ketone (MEK), Metolachlor/s-Metolachlor, Metribuzin, Phenol, Prometon, Toluene and Xylene.

The DG program maintains a table listing ch. NR 140 health and welfare based enforcement standards, ch. NR 809 state public drinking water standards, and established health advisory levels (HALs) for substances in water (*http://dnr.wi.gov/topic/DrinkingWater/HealthAdvisoryLevels.html*). This table of regulatory standards and advisory levels provides a useful source of information to members of the public concerned about the safety of their drinking water and it is also a valuable resource for DNR staff involved with groundwater contamination and remediation cases. Links to resource web sites listed in the table allow users to obtain additional toxicological and health related information on many of the substances listed on the table.

DG staff work with other DNR groundwater regulatory staff to identify policy issues, develop guidance, and provide training related to the implementation of ch. NR 140. DG staff provide advice and assistance on site investigations, soil and groundwater remediation, and case closure decisions. This coordination is critical in obtaining statewide consistency on how the DNR evaluates, addresses and remediates groundwater contamination sites.

Groundwater Protection Act Implementation

The DNR is authorized under statute to regulate wells on any property where the combined capacity of all wells on the property, pumped or flowing, exceeds 70 gallons per minute (100,000 gallons per day). Such wells are defined as high capacity wells. Since 1945, the DNR has reviewed proposed high capacity wells for compliance with applicable well construction rules and to determine whether the well would impair the water supply of a public utility well. The DNR is authorized to deny approval or limit the operation of a proposed high capacity well in order to ensure that the water supply for a public utility well is not impaired. In May of 2004, the statutes regarding high capacity wells were expanded through 2003 Wisconsin Act 310 to give the DNR additional authority to consider environmental impacts of proposed wells on critical surface water resources and springs. DNR may deny or limit an approval to assure that proposed high capacity wells do not cause significant adverse environmental impacts to these valuable water resources.

In FY 07, five groundwater quantity staff began implementing the programs created by Act 310. Since then, these staff have handled work associated with updating the high-capacity well inventory, collecting annual pumping information, reviewing applications, managing data, conducting inspections, providing staff support for the Groundwater Advisory Committee (GAC),

and developing an administrative rule (ch. NR 820) authorized by Act 310 to implement the statutory requirements.

Chapter NR820 went into effect on September 1, 2007. The rule provides a mechanism for evaluating proposed high capacity wells to determine whether the well will have a significant adverse environmental impact on springs, trout streams or outstanding and exceptional resource waters.

The Lake Beulah Decision

The Wisconsin Supreme Court's July 2011 decision in Lake Beulah Management District v. State, *2011 WI 54 (2011*) has further modified DNR high capacity well application reviews. The *Lake Beulah* case involved approval of a high capacity well for the Village of East Troy and the extent of possible impacts to nearby Lake Beulah. The Court concluded that "the DNR has the authority and a general duty to consider whether a proposed high capacity well may harm waters of the state."

Given the Wisconsin Supreme Court's affirmation of DNR authority in the *Lake Beulah* decision, the DNR has broadened the scope of its high capacity well application review beyond the specific considerations of Wis. Stat. s. 281.34 and Ch. NR 820. DNR's scope of review for high capacity well applications now includes potential impacts to all waters of the state, including all surface waters, wetlands, and public and private wells.

Great Lakes Compact and Implementation of 2007 Act 227

The Great Lakes—St. Lawrence River Basin Water Resources Compact (Compact) took effect on December 8, 2008 following ratification in each of the eight Great Lakes States and Congress' consent. The 2009-11 biennial budget included position authority and funding for a total of four full time positions, which were filled in late 2009 and early 2011.

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

Water Use Reporting and Registration - All owners of high capacity wells and all surface water withdrawers who withdraw more than 100,000 gallons per day (gpd) averaged over 30 days must submit annual reports documenting the monthly volumes of water pumped from their wells. These data have been collected since 2007 for high capacity wells. The compliance with reporting for these wells has improved each successive year. Starting in 2010 surface water withdrawal data was also collected. High capacity well pumpage data is available on from the DNR website at *http://prodoasext.dnr.wi.gov/inter1/hicap$.startup*. Surface water withdrawal data will also be available in the future.

Information received from well owners and surface water withdrawers using these pumpage reports, in combination with pumpage data already collected for municipal and certain other public water supplies, establishes baseline and trends information regarding groundwater and surface water use in the state.

Water Conservation and Water Use Efficiency

Administrative rule, ch. NR 852, went into effect in January 2011 and establishes a mandatory water conservation and water use efficiency program for new or increased Great Lakes Basin surface water and groundwater withdrawals.. In addition, mandatory conservation is required for

any new or increased diversions of Great Lakes water and any water withdrawals statewide that would result in a water loss of 2 million gallons per day or more. The rule identifies conservation and efficiency measures that withdrawals subject to the mandatory program must meet.

The rule also helps guide a statewide voluntary water conservation and efficiency program. The voluntary program will focus on providing information and education, identifying and disseminating information on new conservation and efficiency measures, and identifying water conservation and efficiency research needs. The program is coordinated with the Public Service Commission and the Division of Safety and Buildings.

Water Use Permits

Act 227 requires Water Use Permits in the Great Lakes Basin effective December 8, 2011. General permits with a 25-year term are required for withdrawals of 100,000 gallons per day averaged over 30 days up to 1 million gallons of water for 30 consecutive days. Individual permits with a 10-year term are required for withdrawals of 1 million gallons or more per day for any 30 consecutive days. Existing withdrawals will be issued automatic permits in 2011 prior to the December deadline. New or increased withdrawals will be required to apply for a permit. Administrative rule ch. NR 860 prescribes a review process for the individual permits requires and additional environmental review.

Water Use Fees

The 2009-11 biennial budget bill (2009 Wisconsin Act 28) contained statutory language directing the DNR to collect water use fees to fund Great Lakes Compact implementation and water use program development in Wisconsin. The statute directs that all persons with water supply systems with the capacity to withdraw 100,000 gallons per day or more must pay an annual $125 fee per property. Act 28 also directed the DNR to promulgate a rule imposing an additional fee on Great Lakes Basin water users withdrawing more than 50 million gallons per year. That rule, ch. NR 850, went into effect in January 2011, and prescribes a tiered system for additional Great Lakes Basin fees on withdrawals exceeding 50 million gallons per year. Water use fee revenue will be used to: document and monitor water use through the new registration and reporting (http://dnr.wi.gov/topic/WaterUse/registration.html) requirements; implement the Great Lakes Compact through water use permitting (*http://dnr.wi.gov/topic/WaterUse/permits.html*) and regulating diversion of Great Lakes Basin waters; help communities plan water supply needs; build a statewide water conservation and efficiency program; and to develop and maintain a statewide water resources inventory. The DNR began assessing water use fees in 2011.

Well Construction and Private Wells

DG sets and enforces minimum standards for well construction, pump installation and well filling and sealing through ch. NR 812, Wis. Adm. Code. The standards are intended not only to provide health protection but also to protect groundwater. DG also licenses and educates well drillers under ch. NR 146, Wis. Adm. Code, so that they are qualified to construct wells in a way that won't contaminate groundwater. Drillers submit reports to the DNR describing the construction of each well drilled. Field staff in the program conduct surveillance and inspections to enforce the minimum well construction standards.

The Private Water Supply Program continued its surveillance, investigation, and referral of well drilling and pump installation violators to the Department of Justice for prosecution. During the past year violations committed by contractors have included failing to notify well owners of unsafe water test results, unlicensed contractors, failure to obtain water samples, false well construction reports, and identity theft of a licensed pump installer.

The Private Water Section also responds to numerous complaints regarding the contamination of

private wells. Contamination by manure has been an increasing problem in recent years. Using the results of newly developed analytical tools for tracking the source of microbial contamination, staff are able to determine whether fecal contamination is from grazing animal manure or human sources. These new tools have proven useful in granting Well Compensation awards to private well owners with well contamination from manure.

Private Water staff continue to maintain the popular web page titled "What's Wrong with My Water?" (*http://dnr.wi.gov/topic/DrinkingWater/QualityProblems.html*) The website answers some commonly asked questions about private well water quantity, helps well owners diagnose their aesthetic water quality problems and captures and preserves DNR water supply institutional knowledge.

DG continues to promote electronic management of well construction, well abandonment and other information through its website at *http://dnr.wi.gov/topic/Wells/formsSoftware/* and through semiannual releases of a Water Well Data CD with well construction reports and many other related files.

Groundwater monitoring well requirements, as specified under ch. NR 141, are administered by DG staff. Activities include consultation on well construction with Remediation and Redevelopment, Waste Management & Materials, Watershed Management and Department of Commerce staff, consultants and drillers. Random inspections of environmental drilling operations provide an opportunity for DNR hydrogeologists to update drillers and consultants about ch. NR 141 requirements and enhance compliance with the code. Review of new technologies and their application also continue to be a priority.

Aquifer Storage and Recovery (ASR)

Aquifer storage and recovery (ASR) is a water management technique that uses an injection well to temporarily place surface water or treated drinking water directly into an aquifer for storage. The injected water is then recovered from the aquifer, most often by means of the same well, as it is needed. In some settings, ASR may be an effective way to manage the seasonal peaks in water demand that confront many drinking water utilities. Use of ASR can prove to be a lower cost alternative to the other more traditional engineering approaches that would involve constructing more above ground water storage facilities or surface water reservoirs, drilling additional water supply wells, or expanding the output capacity of a utility's water treatment plant.

Water systems using ASR must be carefully evaluated and designed. The water to be injected must often be conditioned (dechlorinated, deoxygenated, pH adjusted, etc.) prior to its placement underground in order to avoid adverse chemical interactions with the mineralogy of the bedrock of the receiving aquifer. Mobilization of metals such as arsenic and manganese has been observed at a number of ASR sites in the United States. In-situ formation of trihalomethanes (chlorinated compounds such as chloroform, bromoform, etc.) has also been reported at ASR sites where drinking water containing a chlorine residual from water disinfection practices has been injected. A number of these elements and compounds have been determined to be carcinogenic.

Administrative rules in Chapter ch. NR 811, Wis. Admin. Code, regulate the use of ASR wells in Wisconsin. The rules were promulgated to ensure that the quality of public drinking water supplies is maintained and to protect the state's groundwater and surface water resources from any harm that may result from ASR activities. Only municipal water systems are allowed to construct ASR wells and only water piped directly from a municipal water distribution system may be injected into an ASR well. Demonstration testing is also required before routine operation of an ASR well or ASR system may be approved by the DNR.

To date, only the municipal water utilities serving Oak Creek and Green Bay have sought approval to construct ASR wells. The Green Bay utility suspended ASR-related activities after arsenic and other metals were mobilized during the initial stages of the required ASR demonstration test.

The Oak Creek utility completed the required demonstration testing and received conditional approval to operate its ASR well in 2004. However, after several operational ASR cycles, the concentrations of iron and manganese in groundwater at the ASR well site increased to levels that exceeded the respective groundwater quality enforcement standards for those elements. The utility has subsequently discontinued use of the ASR system.

Public water systems

DG oversees monitoring of public water systems through ch. NR 809 (Safe Drinking Water), Wis. Adm. Code, to ensure all public water systems are safe to drink and use. Working in cooperation with owners and operators of water systems DG ensures that samples are collected and analyses completed to determine if the water meets federal Safe Drinking Water Act (SDWA) standards. Through ch. NR 810 DG regulates the operation of public water systems. Through ch. NR 811 DG regulates the general design and construction of community water systems. DG also works to educate water system owners and operators concerning proper operation and maintenance of water systems to ensure safe drinking water for Wisconsin consumers.

DG developed and continues to maintain data about Wisconsin's drinking water and groundwater quality through the Drinking Water System database (*http://dnr.wi.gov/topic/DrinkingWater/QualityData.html*). The Drinking Water System is an important tool used to efficiently enforce SDWA regulations for public water systems. It contains the monitoring and reporting requirements for each public water system and their drinking water sampling results. It also includes violations for any missing requirements and exceedances of the maximum contaminant levels (MCLs).

Wellhead protection

The goal of Wisconsin's Wellhead Protection (WHP) program is to reduce the risk of groundwater contamination in areas contributing groundwater recharge to public water supply wells, consistent with the state's overall goal of groundwater protection. A WHP plan is required for new municipal wells and must be approved by the DNR before the new well can be used. A WHP plan is voluntary for any public water supply well approved prior to May 1, 1992; the DNR promotes and encourages but does not require wellhead protection planning for these older wells.

The DNR coordinates a statewide public information effort aimed at encouraging water utilities to protect their water supplies from potential sources of contamination through WHP planning. A video and several publications are available to assist communities in their WHP efforts. The DNR also maintains a web page (*http://dnr.wi.gov/topic/DrinkingWater/WellheadProtection/*) with a variety of relevant information.

In addition, the DNR has developed a tracking system for wellhead protection activities in the DNR's Drinking Water System database. The DNR uses this information to report annually to U.S. EPA on WHP progress.

In FY 2012, approximately 20 communities submitted wellhead protection plans to the DNR. There are now approximately 400 communities who have a WHP plan for at least one of their wells. The list is online at *http://dnr.wi.gov/topic/DrinkingWater/documents/WHP/communities.pdf.*

For the twelfth year in a row, DNR staff worked with the Groundwater Center at the Center for Watershed Science and Education (CWSE) and the Wisconsin Geological and Natural History Survey (WGNHS) to sponsor three groundwater workshops for teachers in January and February. Educators from 26 schools centers took part in the workshops held at La Crosse, Mount Horeb, and Amherst Junction and were able to take a free groundwater model back to their school. Besides learning how to use the groundwater model, the educators received groundwater resources to incorporate groundwater concepts into their classroom. The intent of the workshops is to provide information for teachers to educate students – and their parents – on the importance of protecting groundwater in their own communities. With funding from an EPA WHP grant, groundwater models have been given to over 270 schools or nature centers since 2001.

The DNR continues to work with the Wisconsin Rural Water Association (WRWA) staff in providing assistance to local communities in their protection efforts. WRWA staff work on both plans for individual communities and area wide plans for multiple water supply systems. The DNR and WRWA staff share information and meet as needed to discuss progress and priorities. WRWA staff also helped with the teacher workshops noted above.

The DNR provided WHP information to Wisconsin communities, other states and EPA through its website. Staff sent publications and reviewed draft plans and ordinances. The DNR updated the WHP website to keep current information available to communities interested in wellhead protection and made copies of the WHP video available.

The DNR continued to work with the federal Farm Service Agency to identify cropland in WHP areas. Farmers that own cropland in WHP areas could be eligible for cost-sharing and annual rental payments as part of the federal Conservation Reserve Program (CRP). The CRP program is designed to protect the environment by taking agricultural cropland out of production and installing conservation practices.

Groundwater Information and Education

As noted in the WHP discussion above, staff from the DNR and other agencies led three groundwater workshops for educators to provide training in the use of the groundwater sand tank model and provide the model and additional resources to the educators.

The DNR continued to have significant demand for the *Groundwater: Wisconsin's Buried Treasur*e publication and the *Groundwater Study Guide* folder.

Groundwater Monitoring and Research

Chapter 160 of the Wisconsin Statues requires the DNR to work with other agencies and the Groundwater Coordinating Council (GCC), to develop and operate a program for monitoring and sampling groundwater to determine whether harmful substances are present (s. 160.27, Wis. Stats.). The DNR has also supported groundwater monitoring studies evaluating existing design and/or management practices associated with potential sources of groundwater contamination. The intent of these studies is to reduce the impacts of potential sources of contamination by changing the way land activities that may impact groundwater are conducted. See the "Benefits" tab on the GCC website (http://www.dnr.state.wi.us/org/water/dwg/gcc/rtl/gccreport2012.htm) for more information on the benefits from DNR's monitoring studies.

Four projects were funded in FY 12 for a total cost of $126,151. Five new projects were selected for funding in FY 13. More details on the DNR's groundwater monitoring and research activities can be found at

http://dnr.wi.gov/topic/groundwater/documents/GCC/MonitoringResearch/FY12Projects.pdf and *http://dnr.wi.gov/topic/groundwater/documents/GCC/MonitoringResearch/FY12Projects.pdf*. Final reports and 2-page research summaries are available for many projects from the Water Resources Institute website: *http://www.wri.wisc.edu*

In FY 12, the DNR continued to seek funding to implement the statewide groundwater monitoring strategy. The objective of the strategy is to coordinate groundwater monitoring between all agencies that assess groundwater quality and quantity in the state. Key components of the strategy include:

- A fixed network of groundwater level monitoring locations
- A statewide assessment of groundwater quality
- A fixed network of groundwater quality monitoring sites
- Surface water monitoring stations, and
- Water use reporting

These components of the strategy have been integrated into DNR's overall water monitoring plan (http://dnr.wi.gov/org/water/monitoring/strategy.htm). Other agencies will also continue to make improvements in their monitoring efforts based on the comprehensive strategy. The components of the strategy may change over time according to needs of the different agencies. The requirements of Chapter 160, Wis. Stats., will continue to be met under the strategy.

Groundwater Data Management

Groundwater data from the DNR's consolidated Groundwater Retrieval Network (GRN) system is available on the following website: *http://prodoasext.dnr.wi.gov/inter1/grn$.startup*. GRN accesses groundwater data from database systems in the Waste & Materials Management, Drinking Water & Groundwater and Watershed Management programs including information on approximately 300,000 wells. These wells represent public and private water supply wells, piezometers, monitoring wells, non-potable wells, and groundwater extraction wells. In FY 12, DG staff continued to improve the locational data associated with GRN's wells and the ease with which the data can be accessed.

The DNR continued to make progress on several other groundwater-related data initiatives in FY 12. DG continued to improve its public water supply well data and coordinated efforts with the RR, WMM, and WT programs to improve the DNR's data on significant potential sources of contamination that may threaten these wells. Additionally the WGNHS and DNR continue to improve their searchable index of scanned images of more than 350,000 pre-1989 well construction reports for numerous program uses. Work continued to refine and update DG's Mapping Application which is a geographic information system that maps locations of high-capacity wells, trout streams, springs, outstanding water resources, and exceptional water resources, public wells, source water areas, and potential contaminant sources within source water areas in a format consistent with high-capacity well approval, vulnerability assessment program, WHP, and other DNR needs. Another application, the Assessment Form, uses the mapped potential contaminant sources along with well construction, monitoring, and geologic information to help DNR staff determine the susceptibility of public wells to contamination. These applications are at the leading edge of DNR's efforts in integrating spatial and tabular data toward the goal of public health and resource protection.

Remediation and Redevelopment Program

The Bureau for Remediation and Redevelopment (RR) has primary responsibility for implementing and aiding cleanups under the Spill Law, the Environmental Repair Law, federal programs (Superfund, Hazardous Waste Corrective Action, Leaking Underground Storage Tanks

(LUST), and Brownfields), the Land Recycling Law and State Brownfield Initiatives, the Drycleaner Environmental Response Fund and at closed landfills. The RR program provides technical assistance, helps to clarify legal liability, provides financial assistance primarily to local governmental units and provides technical project oversight of cleanup projects.

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

Cleanup Of Groundwater Contamination

As of mid-June, in FY 2012, the program spent approximately $395,045 in Environmental Fund dollars, and approximately $324,371 in bonding to initiate or continue environmental cleanup actions at over 28 locations where groundwater contamination is known or suspected. The Environmental Fund is used when contamination is significant but no identifiable private party has legal responsibility for the contamination, the person(s) legally responsible do not have the financial ability to proceed, or the responsible person simply refuses to proceed. Private contractors conduct these cleanups with oversight by DNR staff. Whenever feasible, the RR program and legal staff attempt to recover costs from responsible persons after the cleanups are undertaken.

Investigation, Cleanup and Redevelopment of Brownfields

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

One of the financial assistance programs implemented by the DNR was the Brownfields Site Assessment Grant (SAG) program. The SAG program benefited groundwater by serving as a funding source for (1) the removal of potential sources of groundwater contamination, and (2) site investigations to determine whether groundwater and soil are contaminated, including the determination of the extent and degree of contamination.

This program provided grants to local governmental units to conduct environmental site assessments and other eligible activities at contaminated properties. Eligible activities included site assessment and investigation, demolition, asbestos abatement, removal of petroleum and hazardous substance storage tanks and removal of abandoned containers. Although the SAG program did not fund remediation activities, it funded preliminary activities to determine whether remediation is necessary. Sites were eligible for funding only if the persons responsible for the contamination are unknown, cannot be located, or cannot pay for the activities for which grant funding was requested.

In FY 10, DNR awarded 34 Site Assessment Grants totaling approximately $1.6 million to 27 communities across the state. Small grants up to $30,000 make up 24 of the awards, while 10 are large grants between $30,000 and $100,000. Local governments have also pledged more than

$704,000 in additional funds for the projects, well beyond the 20 percent match required through the application process ($319,000). The grants provide funds for environmental activities on 127 acres of land. Activities include 41 site assessments and investigations, the demolition of 37 buildings or structures and the removal of 218 tanks, drums and other abandoned containers. Since site assessment grants began 10 years ago, the state has awarded more than $15 million to 199 communities to begin investigation and cleanup on more than 1,500 acres.

In addition to the Site Assessment Grants, the RR Program granted funds to local governments through the Brownfields Green Space and Public Facilities Grant program to pay for the remediation of contaminated soil and groundwater at properties that will be reused as parks and public facilities.

Due to fiscal challenges facing the state of Wisconsin, there were no DNR Brownfield Site Assessment Grants awarded in FY 2011. Also, the 2011-2013 State Biennial Budget bill changed the state brownfields grant programs so that the new Wisconsin Economic Development Corporation (WEDC) will be administering state funds for brownfield activities. The Remediation and Redevelopment (RR) Program's commitment to brownfields redevelopment remains strong and the tradition of working with communities and private parties to achieve economic and environmental success will continue. The DNR will also continue to offer technical assistance and possibly some limited federal brownfields funds to assist in the assessment and cleanup of contaminated properties.

The RR Program also provides redevelopment assistance at brownfield sites with groundwater contamination. Program staff assist local governments and private businesses with the cleanup and redevelopment of brownfields by providing technical assistance. In many cases, these properties have groundwater contamination, or soil contamination that poses a threat to groundwater. In 2004, the DNR, through a partnership with the Redevelopment Authority of the City of Milwaukee (RACM) was awarded a $400,000 U.S. EPA Brownfields Site Assessment Grants for assessment activities in Milwaukee's 30th Street Industrial Corridor. Through this partnership, the RR Program initiated work on redevelopment of this economically and environmentally distressed area of the state. Assessment activities are continuing under a second $400,000 assessment grant which was awarded in 2007. Over 60 properties in the Corridor have had an environmental assessment or a site investigation conducted since 2004. The DNR Urban Reinvestment Initiative and 30th Street web page is located at: *http://dnr.wi.gov/topic/Brownfields/Corridor.html* .

The RR program also provides a number of different assurance, comfort or general liability clarification letters related to properties with groundwater contamination. Collectively, these letters facilitate the reuse and development of properties. In FY 12, the RR program provided 154 redevelopment assistant reviews – which can include liability clarification letters, off-site exemption letters, cleanup agreements for tax delinquent properties, building on abandoned landfill approvals, etc. – at Brownfield properties throughout the state.

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

After a person has conducted an environmental investigation of the property, and cleaned up soil and groundwater contamination, the DNR will issue a "Certificate of Completion" which provides a release from future liability for any contamination that occurred on the property prior

to issuance of the certificate. In FY 12 DNR issued 13 certificates of completion, and 21 new sites began the voluntary cleanup process.

Dry Cleaner Environmental Response Fund (DERF) Program

The DERF program reimburses dry cleaner owners and operators for eligible costs associated with the cleanup of soil and groundwater at sites contaminated by dry-cleaning solvents. Fees paid by the dry-cleaning industry provide program funding. Environmental cleanups at dry cleaner sites are conducted following the ch. NR 700 rule series. The DERF program closed to new applicants in August of 2008. There are 230 sites in the program, with 163 at various stages of investigation and cleanup and 67 sites closed. The program is implemented through ch. NR 169, Wis. Adm. Code.

Site closure rules for petroleum contaminated sites

Under the Petroleum Environmental Cleanup Fund Award (PECFA) Program, ch. NR 746 – and its Department of Safety and Professional Services counterpart, ch. SPS 46 – was promulgated in February 2001. The bulk of ch. NR 746 establishes risk and closure criteria to determine whether petroleum contaminated sites can be closed using natural attenuation as a final remedy for groundwater contamination. The rule also defines which petroleum-contaminated sites DNR and Department of Safety and Professional Services have authority to administer; summarizes site investigation requirements, and delineates other administrative requirements such as when remediation and remediation funding is terminated, tracking and transfer of sites, staff training and dispute resolution.

The rule provides that sites with contamination in low permeability (clay) materials can close after a site investigation if all risk criteria are met and the groundwater contamination is stable or receding. For contamination in permeable materials, sites must meet all risk criteria and demonstrate through monitoring that groundwater contaminants are declining. Sites requesting closure with groundwater contamination above ch. NR 140 enforcement standards are placed on the GIS Registry. Ch. NR 726 provides closure requirements for all other sites.

Tracking System and GIS Applications

The program's main database on the status of sites undergoing investigation and/or cleanup is the Bureau of Remediation and Redevelopment Tracking System (BRRTS). In 2000, the program created BRRTS on the Web, making the DNR's main database for contaminated properties accessible via the Internet at *http://dnr.wi.gov/topic/brownfields/botw.html* .

In 2001, revisions to ch. NR 726, 716, 749, and 811/812 implemented a Geographic Information System (GIS) Registry of Closed Remediation Sites to replace the requirement to record groundwater use restrictions at the County Register of Deeds Office. In 2002, additional rule revisions required the inclusion of sites with residual soil contamination on the GIS Registry. The GIS Registry currently includes locational information on sites closed with residual groundwater contamination above the ch. NR 140 enforcement standards and sites closed with soil contamination above ch. NR 720 soil standards, as well as site specific information pertaining to where the contamination is on the property in question and at what concentration it was found at the time the closure decision was made. In 2006, new legislation in WI Act 418 replaced the use of deed restrictions for certain sites with residual contamination with conditions of closure and placement on the GIS Registry.

Inclusion on the GIS Registry on the Internet provides a means of notifying future owners or users of the property of the existence of soil and/or groundwater contamination, as well as any responsibilities of the property owner (or occupant in some cases) to comply with any conditions

of closure. The site specific information is attached to each site by a link to a .pdf. The GIS Registry can be accessed on the Internet at *http://dnr.wi.gov/topic/Brownfields/rrsm.html* .

The GIS Registry is to be used with well construction requirements for private wells, and with a setback distance for new municipal wells. Beginning in July 2004, the DNR made the GIS Registry information available to well drillers through a Well Construction CD that is updated twice a year. Before drilling, well drillers are asked to consult the CD to determine if a well is proposed for a property listed on the Registry. If the proposed well is located on a closed remediation site, then the driller must contact regional Drinking Water and Groundwater staff prior to any well construction activities to determine if additional casing or other construction techniques may be required.

In 2005, an expanded GIS application was made available, called the RR Sites Map. This application shows the locations of the majority of sites available on BRRTS (open and closed), or provides an address for those sites for which geolocational coordinates have not yet been obtained. The RR Sites Map can also be accessed on the Internet at *http://dnr.wi.gov/topic/Brownfields/rrsm.html* . In 2008, additional layers regarding financial tools and liability clarification actions were added, so RR Sites Map now provides even more information on redevelopment and cleanup activities.

The GIS applications are linked to BRRTS on the Web and are all useful for locating potential contamination sites when evaluating new municipal well placement or for property transactions. These databases make site specific information on open and closed remediation sites much more available and accessible to the public and specific interested groups, particularly those wanting to install or replace a potable well on an affected property, as well as those buying properties. Sites regulated by the Departments of Safety and Professional Services and Agriculture, Trade and Consumer Protection are also included in BRRTS on the Web, the GIS Registry and RR Sites Map.

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

Waste and Materials Management Program

The Bureau of Waste and Materials Management (WMM) implements the DNR's Groundwater Standards Program in several ways during the life of a landfill. When staff review an applicant's "Feasibility Report," which proposes to site a landfill in a particular location, they review baseline data submitted by the applicant to determine whether exemptions and alternative concentration limits are needed for the public health and welfare parameters listed under ch. NR 140. In addition, reviewers establish preventive action limits for indicator parameters based on calculations submitted by the applicant. During the active life of a landfill and after closure, staff evaluate groundwater conditions at the landfill site to determine compliance with ch. NR 140 standards. Should conditions warrant, staff require groundwater investigation reports that include proposals for further evaluations and recommendations for remediation at landfills that exceed groundwater standards. Staff review results of site investigations triggered by the exceedances of groundwater standards and evaluate the effectiveness of remedial actions at active solid waste facilities and closed landfills, by comparing results to groundwater standards over time.

WMM accepts only electronic submittal of environmental monitoring data from landfill owners, labs and consultants. As of January 2006, WMM provides facilities and the public access to the environmental monitoring data contained in its Groundwater and Environmental Monitoring System (GEMS) database. In the future, a web interface, possibly using the Department's Data

Portal and/or Web Access Management System, will allow facilities to upload environmental monitoring data into GEMS. Currently, funding is not available to do the necessary programming.

WMM was concerned that staff might not be aware of some old, closed landfills that might be impacting groundwater. Program staff used several reports from the GEMS to do a rough screening of old, closed town, city and village landfills with monitoring wells. In July 2003, screening reports identifying landfills that needed further attention were sent to regional staff for follow-up evaluations. A more in-depth screening of all closed landfills occurred in November 2006. Review of all the sites identified in the screening as possibly impacting the environment was completed in February 2009.

In FY 01, WMM studied 31 closed landfills that previously accepted municipal solid waste, to try to determine whether VOC contamination in groundwater at these landfills was increasing, decreasing or remaining stable. One purpose of this study was to determine whether natural attenuation is occurring in groundwater near leaking landfills. The study showed a large number of stable or decreasing concentration trends. However, the concentrations took longer to stabilize and stabilized at higher levels than at other types of VOC contamination sites described in the literature.

Another study in FY 00-01 was carried out to evaluate the effectiveness of chemical oxygen demand (COD) as an indicator parameter at landfills. Mercury waste is generated when COD is analyzed in the laboratory so the overall goal was to reduce that amount of mercury. Findings from the first year of the study indicated that there was potential to eliminate COD monitoring at some types of landfills. The second year of the study evaluated possible alternatives to sampling for COD. Dissolved organic carbon (DOC) appeared to be an acceptable alternative in certain circumstances. WMM staff incorporated the recommendations of this study into code changes that went into effect in February 2006.

A study was done in FY 03 to review groundwater quality at solid waste landfills to determine whether they are a source of pesticide contamination. Eleven sites were sampled and analyzed for 14 common Wisconsin pesticides. Findings indicated that leaking landfills may be contributing alachlor, aldicarb, atrazine and 2,4-D to groundwater. The study researchers believed a follow-up study was needed to provide more evidence to help make concrete recommendations about which pesticides to sample for. However, staff and funding have not been available for this.

Water Quality Program

The Bureau of Water Quality (WQ) is responsible for statewide implementation of DNR's groundwater standards primarily through the issuance of discharge permits to facilities, operations and activities that discharge treated wastewater and residuals to groundwater. Field staff that work on integrated basin teams carry out compliance and enforcement activities using policies, codes and guidelines developed by the WQ program. Integrated basin planning carried out in the field under guidelines developed by WQ assess and evaluate groundwater (and surface water) and provide general and specific recommendations for the protection and enhancement of the basin's groundwater.

<u>Wastewater Discharges</u>

WQ issues Wisconsin Pollutant Discharge Elimination System (WPDES) permits to all communities, industrial facilities, and large privately owned wastewater systems which discharge treated domestic or industrial wastewater to groundwater through land treatment/disposal systems. These systems are primarily spray irrigation, seepage cell, subsurface absorption

systems, and ridge & furrow treatment systems regulated under ch. NR 206, Wis. Adm. Code (domestic wastewater) and ch. NR 214, Wis. Adm. Code (industrial wastewater). WPDES permits issued to these facilities contain groundwater monitoring and data submittal requirements that are used to evaluate facility compliance with ch. NR 140, Wis. Adm. Code, groundwater quality standards. Groundwater monitoring systems at existing facilities are evaluated and upgraded as necessary at permit re-issuance. DNR has issued specific permits for 360 municipal and industrial facilities that discharge directly to land disposal (groundwater) systems.

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

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

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

In 2000, the Department of Commerce (now called the Department of Safety and Professional Services) and DNR completed revision of an interagency memorandum of understanding after Commerce issued rules for private onsite wastewater treatment systems under ch. Comm 83, Wis. Adm. Code. The DNR completed refined procedures, guidance, and rules for the review and permitting of large private onsite wastewater treatment systems (POWTS). In general, large POWTS are defined as those with a capacity of greater than 12,000 gallons per day (gpd). The DNR started issuing permits to large POWTS in early 2000. On February 1, 2005 WQ issued a general permit to regulate the operation of these types of systems in a more streamlined manner.

DNR reissued the Nondomestic Wastewater to a Subsurface Soil Absorption System general permit in 2011. The requirements for requesting a permit, and for renewing permit coverage, revisit the setback requirements for changes due to new water supply wells during the previous permit period. The general permit is renewed every five years. The renewal process provides for identifying land use changes that may have occurred. This will serve as a check on groundwater and public health protection, and could also identify future concerns and permit needs.

Septage And Sludge Management

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

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

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

Proposed efforts to modify the multiple land application codes (NR 113, NR 204, NR 214) have been stalled for the time being to focus on streamlining issues. However, these code changes are only temporarily stalled as the following need to be addressed: creating consistency within these land application codes and between other related codes such as runoff management; providing a clearer understanding of code requirements; implementing best management practices consistent with total maximum daily loadings (TMDLs) of phosphorus; and modifying code language to be consistent with current practices employed by industry and contractors.

WQ continues to implement a new statewide computer system that records and monitors treatment and disposal of municipal sludge, septage, and industrial land-applied wastes. This system includes an inventory and a history of all sites used for land application. A recent grant awarded by U.S. EPA providing WQ funds to implement additional tasks to increase efficiency in information transfer between the regulated community and the agency. Wisconsin became the fourth state delegated authority by U.S. EPA to implement municipal sludge regulations, through its delegated NPDES (WPDES) permit program, in July of 2000.

Wisconsin Act 347 became effective April 29, 2006 and provides incentives for more wastewater treatment plants to accept and treat septage. This is accomplished through the offer of a zero percent Clean Water Fund loan for the planning and construction of receiving facilities, and additional capacity provided for septage. Facilities which are upgrading capacity by more than 20% must evaluate septage generation and available disposal options in their planning area during facility planning. Although they are not mandated to provide such capacity, they are offered the zero percent loan if they do so. Structures are provided by which publicly owned treatment works establish costs for receipt of septage and a process is laid out for dispute resolution when such costs are questioned. Land application also remains a viable option when appropriate and

Act 347 provides explicit pre-emptive authority to the state by disallowing restrictive local ordinances if they are not identical to state regulations.

Watershed Management Program

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

Agricultural runoff

Chapter NR 243 Wis. Adm. Code, covers Wisconsin Pollutant Discharge Elimination System (WPDES) permit requirements for livestock operations and contains provisions to protect surface water, groundwater and wetlands in Wisconsin. Revisions to ch. NR 243 promulgated in July of 2007 improve groundwater protection associated with CAFO land application practices by increasing setback requirements from community and non-community public wells and karst features and further restricting winter applications of manure. Implementation of the revisions has been facilitated by the hiring of a full-time staff person dedicated to nutrient management plan-related issues. Nutrient management plans submitted as part of the issuance of WPDES permits to CAFOs address how, when, where and in what amounts CAFOs apply manure, process wastewater and associated nutrients to cropped fields. The staff person is responsible for training DNR staff, permittees and consultants on nutrient management planning requirements for CAFOs to ensure proper application of manure and process wastewater in order to protect surface waters and groundwater in Wisconsin. The DNR also promotes groundwater protection through the implementation of agricultural performance standards in ch. NR 151, Wis. Adm. Code, the issuance of Notices of Discharge under ch. NR 243, and response to acute manure related groundwater impacts (e.g., well contaminations).

There are currently 218 WPDES permits issued for livestock operations (86% dairy; 6% poultry; 4% swine; 4% beef). Regional and central office staff have successfully maintained the permit backlog at less than 15%. The trend of growing numbers of permit applications for larger-scale livestock operations is expected to continue.

Storm Water

Final revisions to ch. NR 216, Wis. Adm. Code were promulgated on August 1, 2004. The revisions were completed primarily to comply with federal storm water regulations that took effect on March 10, 2003. The revisions to ch. NR 216 require nearly 220 municipal separate storm sewer systems (MS4s) to obtain permit coverage and require construction sites down to one acre of land disturbance to have permit coverage to control erosion during construction. Construction site permittees are also required to install post-construction practices to limit pollutant discharge after construction is completed (long-term storm water management). In addition, under Chapter NR 151, Wis. Adm. Code, the DNR has developed MS4 performance standards (e.g., 40% total suspended solids control within existing urban areas) and construction site performance standards (e.g. 80% sediment control, infiltration, peak flow, buffer requirements, etc.) that became effective in 2002. Provisions to implement ch. NR 216 and the performance standards in ch. NR 151 are included in two general permits. The MS4 general permit for municipal storm water discharges was reissued on January 19, 2006 (expired on December 31, 2010) and the general permit to regulate storm water discharges from construction sites was reissued on September 29, 2006 (expired on September 30, 2011).

Nutrient Management Plans

Sections ch. NR 151.07 and ATCP 50.04(3) require all crop and livestock producers to develop and implement nutrient management plans. Technical Standard NRCS 590 contains planning and implementation requirements for all nutrient management plans. The ch. NR 151 performance standard itself became effective January 1, 2005 for high priority areas (source water areas, impaired waters and outstanding/exceptional resource waters) and became effective for the remainder of the state on January 1, 2008. Federal, state and local agencies maintain technical resources and expertise to implement NRCS Standard 590, including development and dissemination of the field-based Soil Nutrient Application Program (www.snapplus.net) in cooperation with the University of Wisconsin. Implementation of the ch. NR 151 performance standard cannot be required without cost sharing in many situations. A multi-partner conservation consortium was effective in securing cost share resources from the Legislature to help farmers meet nutrient management plan requirements. DATCP administers these funds through its Soil and Water Resource Management Program. In addition, the NRCS provides cost sharing for development and implementation of comprehensive nutrient management plans including 590 compliant planning and implementation. In other situations, cost sharing does not have to be provided to require compliance. This includes compliance for farms operating under a WPDES Animal Feeding Operation Permit, farms receiving state farmland preservation tax credits under the state's Working Lands Program, livestock operations obtaining local permits under the state Livestock Siting Law and livestock operations that voluntarily apply for new or altered manure storage facilities when the local regulation requires development and implementation of a nutrient management plan. DNR promulgated a revised ch. NR 151 performance standard as of January 2011. The new performance standard may require DATCP to amend ATCP 50 and 51, via rulemaking. Changes included in the ch. NR 151 revisions may impact nutrient management plan development and implementation. These changes include: TMDL's, soil erosion and pastures, tillage setback, phosphorus index, process-wastewater discharge prohibitions and nutrient management plan clarifications re: municipal sludge, industrial waste or septage; explanation on how these sources may impact nutrient management plans.

For more information, visit the following website (http://dnr.wi.gov/) or contact Ken Johnson at 608-264-6278, (kenneth.johnson@wisconsin.gov) or Mel Vollbrecht at 608-266-2104 (mary.vollbrecht@wisconsin.gov), DNR, P O Box 7921, Madison, WI 53707-7921.

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 assure 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, and 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 incentive components.

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

Nonpoint Source Activities

Pesticides. DATCP's primary effort related to nonpoint contamination of groundwater from pesticides continues to involve the herbicide atrazine. In response to concerns about atrazine contamination, DATCP amended administrative rule ch. ATCP 30 in 1992 to manage the use of atrazine in an effort to reduce or eliminate the potential for further groundwater impacts. Rule revisions have been made in several subsequent years in response to additional detections of atrazine in groundwater with the latest revision being effective as recent as April 2011. In 2012, a rule revision will be completed to update the maps. No additional prohibitions will be added. A set of maps for 101 prohibition areas is available from the Environmental Quality Section covering 1.2 million acres that have been incorporated into the rule. The maps were updated with new base mapping software in 2012 to update roadway names and other manmade features that have changed over the years, and to 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 and is now holding roughly constant. The decline in use may have been a result of the atrazine management rule and concern about groundwater contamination.

In 2008 DATCP prohibited the use of a simazine, a triazine herbicide related to atrazine, in a small area of the Lower Wisconsin River Valley near Spring Green. A recent report by DATCP on alternatives to atrazine use for weed control within atrazine prohibition areas was unable to determine if simazine is relied on more heavily inside of atrazine prohibition areas due to its similarities to atrazine. The findings and a link to the alternate weed control practices report is available in the “pesticides” section of this report. DATCP continues to perform routine testing of private wells for simazine both inside and outside of atrazine prohibition areas to determine if additional actions are needed to protect groundwater from simazine.

Nutrients. Through its Land and Water Resource Management program, DATCP assists in the protection of water resources through nutrient management. The DNR rules on runoff management to protect both groundwater and surface water, NR 151, Wisconsin Administrative Code, lay out the procedures for implementing and enforcing compliance with agricultural performance standards including nutrient management. The nutrient management rules apply to all Wisconsin farmers who engage in agriculture and mechanically apply nitrogen, phosphorus or potassium nutrients from manures or fertilizers to cropped fields. DATCP has adopted the

USDA- NRCS 590 nutrient management standard via administrative rule, ATCP 50, to meet DNR's performance standards. Under Wisconsin Statutes, cost-share funds must be made available to producers to compel compliance. However, as many as half of Wisconsin farms may be compelled to comply with nutrient management standards and other performance standards without cost-sharing because they are either: Concentrated Animal Feeding Operations (operations with 1,000 animal units or greater); or, farms regulated by local manure storage or livestock siting ordinances; or, participants in Wisconsin's Farmland Preservation Program.

DATCP's nutrient management standard includes a number of practices to protect groundwater from the impacts of nutrient applications including:

- nutrient and manure application setbacks from karst features and other conduits to groundwater.
- combinations of reduced nutrient application rates, timing, and nutrient sources to mitigate movement of nutrients and manure when they are applied to highly permeable or thin soils.
- nitrogen applications must meet University of Wisconsin recommendations for crop production.

Like other agricultural performance standards, the nutrient management standard is "designed to achieve water quality standards by limiting nonpoint source water pollution" (Chapter 281.16 (3) 'Nonpoint sources that are agricultural'). Requiring applications of nitrogen to meet University of Wisconsin recommendations for crop production, in conjunction with the other practices listed above, is meant to "limit" non-point pollution of groundwater. Statewide estimates by DATCP indicate that in 2007, over 200 million pounds of nitrogen (from all sources) were applied *in excess* of UW recommendations. Clearly, if Wisconsin's agricultural lands are to meet University recommendations for crop production, and comply with the other required nutrient management practices, significant reductions in nitrogen loading to groundwater would be realized.

Research conducted by John Norman on silt loam soils at Arlington indicates that applications of nitrogen consistent with UW recommendations on continuous corn would, on average, roughly comply with the nitrate water quality standard of 10 parts per million. Other research cited later in this report, on other soils and cropping systems, indicate that applications consistent with UW recommendations for nitrogen would result in leaching of nitrogen to groundwater that would exceed the nitrate standard. Additional research, and importantly, monitoring of actual in-field practices are needed to illuminate the effectiveness of the nutrient management standard to protect groundwater under various conditions. DATCP has advocated that approach through its priority recommendations to the GCC.

Currently, 21 percent of agricultural land in Wisconsin follows an approved nutrient management plan. DATCP contends that the current nutrient management standard, while not 100 percent protective under all conditions, would significantly improve water quality if it were implemented widely throughout the state.

Increasing attention on the role of land use practices in achieving water quality goals was recognized in the 2008-2009 state budget. Funding for the land and water resource management program's cost-share allocation increased from $520,000 to $6.5 million in the second year of the 2008-2009 biennium. A portion of those funds were directed to provide support for nutrient management implementation, including farmer training, outreach and education, Snap-Plus Nutrient Management Planning Software support and program evaluation activities. For the 2008

allocation, DATCP elected to use part of this increased appropriation to allocate $2,996,483 in cost-sharing grants for nutrient management plans and $403,000 in implementation support grants. However, during the years since 2008, lapses and other spending reductions have significantly reduced the funds available for DATCP to allocate for cost-sharing and implementation support. Beginning in 2009, budget shortfalls forced DATCP to reduce its allocation of cost-share funding to $735,544, and reduce its allocation of implementation support grants to $518,745. The most recent 2011-13 Biennial Budget contained an annual appropriation of $5.36 million in SEG funds for nutrient management cost-sharing and for activities to support nutrient management. However, as a result of shortfalls in the Wisconsin Environmental Fund, DATCP was directed not to spend $3.5 million of these funds, and as a result, it allocated $1,317,333 for cost-sharing and $591,399 for contracts to support nutrient management implementation in FY 2012.

DATCP nutrient management program staff have worked to 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. The 2008-2009 state budget first allocated funds to DATCP for the creation of a Manure Management Advisory System. This system is currently focused on helping 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. In order to accomplish this goal, new tools are web-accessible and include WI "590" Nutrient and Manure Application Restriction Maps, a map service for GIS users, and a model based website for predicting the likelihood for runoff events to take place on a given day. The 590 Restriction maps are available on a statewide basis at the section level to assist farmers in making sound decisions about nutrient applications to their cropland.

Through these combined efforts, the total number of acres covered by nutrient management plans statewide in the 2011 crop year rose to over 1.8 million acres. In just five years, since the 2006 crop season, this is an increase of 1 million acres.

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.

Since 1990, the Agricultural Clean Sweep grant program has helped farmers dispose of unwanted pesticides, farm chemicals, and empty pesticide containers. Beginning in 1996, the program extended collection services to small agricultural businesses. In 2004, DATCP began operating and managing the state's household hazardous waste grant program. 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 2011, 64 grants were issued: 19 for agricultural waste, 27 for household hazardous waste and 18 for collection of unwanted pharmaceutical wastes. There were 477 farmers and 577 agricultural businesses that brought in 146,646 pounds of agricultural wastes. Farm participation seems to be declining as more farmers are using custom application and products are becoming

more concentrated. Many counties report they are considering ag waste collections every other year or every two years. The amount of household hazardous waste collected continues to increase. More than 2 million pounds were collected in 2011 from nearly 40,000 residents. Drug collections netted nearly 32,000 pounds of unwanted pharmaceuticals. Collections occurred through collection events or through permanent drop boxes.

DATCP's rules for minimizing environmental damage from agrichemical storage and handling were put in place in 1988. Fourteen local DATCP specialists work with facilities across the state to keep them in compliance with the ATCP rules designed to protect the environment. DATCP staff also educate facility managers and employees about how routine practices may affect the environment.

In August 1993, section 94.73 of the Wis. Stats. was created and established the Agricultural Chemical Cleanup Program (ACCP) to address point sources of contamination and reimburse responsible parties for cleanup costs related to pesticide and fertilizer contamination. To date, more than 520 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 has assisted clean ups at over 970 acute agrichemical spill locations. The ACCP staff has received 1160 reimbursement applications for more than $39.6 million in reimbursement payments.

Groundwater Sampling Surveys
DATCP conducts a number of annual surveys to investigate the occurrence of pesticides in groundwater resulting from nonpoint sources. Results of these surveys are at: *http://dnr.wi.gov/org/water/dwg/gcc/rtl/2010/Pesticides.doc*

Research Funding
Due to budget constraints, DATCP did not have funding for new pesticide research projects in FY 2011. DATCP currently funds fertilizer research at approximately $130,000 per year.

Groundwater Data Management
In 2011, DATCP received a grant from Department of Health Services (DHS) to merge two groundwater sample databases into one database. The new system combines data from the former drinking water well and monitoring well databases. DATCP also created a GIS web-mapping application that allows the user to search the database and plot maps that show data located within a user-defined geographic area. The new database was placed on-line in early 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), and other public and private laboratories. DATCP's groundwater database currently contains information for over 62,000 wells and nearly 792,000 pesticide and nitrate-N sample analytical results.

DATCP uses geographic information system (GIS) tools to analyze groundwater data and prepare maps for public hearings, DATCP board meetings, presentations, and other uses. DATCP prepares and maintains GIS layers of well locations, atrazine concentrations, atrazine prohibition areas, and other pesticide and nitrate-N data. These GIS layers and associated database information are 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). For example, see the map of "Private Wells Tested for Atrazine in Wisconsin" in the Pesticide part of this report (*http://dnr.wi.gov/org/water/dwg/gcc/rtl/2010/Pesticides.doc*). Other GIS analyses

involve identifying groundwater wells that may be impacted by point sources of pesticide and nitrate-N contamination. DATCP also uses global positioning system receivers to locate and map wells and other features, such as agrichemical facilities and spill sites that may affect groundwater quality.

For further information, visit the following web site (http://www.datcp.state.wi.us/) or contact John Petty or Stan Senger, DATCP, 2811 Agriculture Drive, PO Box 8911, Madison, Wisconsin, 53708-8911; phone: 608-224-4500; e-mail:john.petty@wisconsin.gov or stan.senger@wisconsin.gov.

DEPARTMENT OF HEALTH SERVICES

Chapter 160, Wis. Stats., directs the Department of Health Services (DHS) to recommend health-based enforcement standards for substances found in groundwater and specifies the protocol for developing the recommended standards. Recommended standards are sent to the DNR and are submitted through the rule-making process as amendments to ch. NR 140, Wis. Adm. Code. When requested, DHS staff develop health-based drinking water advisories for substances that do not have an enforcement standard. 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 water-borne illness. Toxicologists, public health educators, and epidemiologists employed in the Department's Division of Public Health present water quality information to the public at town meetings and conferences, and provide direct assistance to families via home visits, letters to well owners, and telephone consultations. DHS staff also review correspondence sent to well owners by DNR representatives. The agency frequently provides supplemental advice and assistance to families whose drinking water is highly contaminated with volatile substances such as benzene and vinyl chloride, especially in cases where the contaminants may pose concerns from inhalation of indoor air. Follow-up letters sent by DHS explain the health effects of specific contaminants and suggest strategies for reducing exposure until a safe water supply can be established. DHS staff are called upon to review the toxicity of constituents of well construction and rehabilitation products to ensure that products approved for use in Wisconsin can be used safely without risk of chemical overexposure. DHS prepares and distributes a wide variety of informational materials on groundwater and drinking water issues related to human health.

For more information, visit http://DHS.wisconsin.gov/eh/Water/, or contact Henry Anderson (608-266-1253; Henry.Anderson@wi.gov) or Mark Werner (608-266-7480; Mark.Werner@wi.gov), 1 W. Wilson St., Rm. 150, Madison, Wisconsin, 53701.

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

The Wisconsin Geological and Natural History Survey (WGNHS), University of Wisconsin-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 geology and soils programs, which provide maps and research-based information essential to the understanding of groundwater recharge, occurrence, quality, movement, and protection.

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. A summary of current projects at WGNHS in various counties and legislative districts can be accessed at *http://WisconsinGeologicalSurvey.org/projects/search.htm*.

Highlights of the WGNHS groundwater activities for FY 12 include the following:

Groundwater-Level Monitoring Network

Wisconsin's statewide groundwater-level monitoring network has been operated jointly with the U.S. Geological Survey (USGS) since 1946. Currently, the network consists of approximately 140 wells in 66 counties and it provides a consistent, long-term record of fluctuations in water levels in deep and shallow aquifers. Such information is critical to track the effects of high capacity well pumping, the response of groundwater levels to droughts, the effects of land-use changes on groundwater systems, and the impacts of climate change. The long-term data are also used for calibration of regional groundwater models. The WGNHS will continue to support the maintenance of these wells and to supply the information to public and private clients and aid in data interpretation. For available data, see *http://wi.water.usgs.gov/data/groundwater.html*.

The WGNHS, in consultation with DNR and USGS, has identified several projects necessary to improve the monitoring network in the Great Lakes Basin in areas of intense groundwater pumping (southeast and northeast Wisconsin). We anticipate completing three to four such tasks in 2011–2012 to retrofit and repair several older monitoring wells in these areas of interest.

County Groundwater Studies

Geologic and groundwater studies at the county scale continue to be an important part of WGNHS programs. During FY 12, the Survey initiated or carried out geologic and/or groundwater studies in the following counties: Brown, Dane, Door, Calumet, Columbia, Fond du Lac, Grant, Green Lake, Iowa, Kewaunee, Marquette, Menominee, Ozaukee, Shawano, Waupaca, Waushara, Outagamie, Price, and Sheboygan. Many of these studies will generate or have generated water-table maps. For a current list of available county-scale water-table maps see http://WisconsinGeologicalSurvey.org/watertable1.htm.

Regional Groundwater Studies

Regional geologic and groundwater studies usually span multiple counties. During FY 12 the WGNHS was involved in several regional projects, including the following:

a. Geologic mapping and groundwater investigations. With funding from the federal STATEMAP program, WGNHS scientists are preparing new geologic maps and acquiring new groundwater data for Brown, Iowa, Grant, Waupaca, Manitowoc, and Sheboygan Counties. Many of these new maps are now available digitally and have been

released as open-file reports (see *http://WisconsinGeologicalSurvey.org/wofrs.htm*). Lists of current projects are maintained at *http://WisconsinGeologicalSurvey.org/proj_water.htm* and *http://WisconsinGeologicalSurvey.org/proj_geol.htm*.

b. Hydrogeology of the Chequamegon-Nicolet National Forest. In cooperation with the USGS, and with finding from the US Forest Service, the WGNHS is conducting a multi-year study of the hydrogeology of the state's National Forests. Initial focus has been on the Park Falls Unit in Price County. The study will move into the Washburn-Great Divide Unit (Bayfield, Ashland, and Sawyer Counties), and Medford Unit (Taylor County) during 2012.

c. Hydrogeology of the frac-sand mining district in western Chippewa County. Beginning in 2012, the WGNHS, in cooperation with the USGS and the Chippewa County Department of Land Conservation and Forest Management, will launch a 5-year study to evaluate the impact of land use and water use changes associated with frac-sand mining and irrigated agriculture. In parallel to a groundwater modeling effort, a series of informational outreach meetings will be held within Chippewa County to update the general public about the study and provide an additional point of contact regarding water resources within this part of the State.

d. Geothermal resources. In anticipation of increased interest in geothermal heating and cooling in Wisconsin, the Survey is participating in a DOE-funded effort to evaluate geothermal resources of the state. We have begun measuring the thermal conductivity of Wisconsin's bedrock units and are measuring geothermal gradients in deep test wells at sites across Wisconsin. The information gained from this work will help engineers and heat pump installers design better groundsource heat pump systems.

Groundwater Research Activities

The WGNHS carries out specific groundwater research projects focused on understanding topics important to groundwater use and management in Wisconsin and elsewhere. Active research areas during FY 12 included the following:

a. *Hydrogeology of aquitards and multi-aquifer wells.* Aquitards are low-permeability geologic materials such as clay or shale. They are critical resources for protecting water-supply wells from contamination, yet are often difficult to characterize. Multi-aquifer wells are wells that are open across an aquitard, providing a pathway for groundwater flow between aquifers. During FY2012, the WGNHS continued research in these areas with study of groundwater movement through sand lenses and clayey sediment of the regionally extensive glacial Lake Oshkosh basin.

b. *Viruses in groundwater*. WGNHS hydrogeologists, working with researchers at the Marshfield Clinic, completed a project analyzing the presence of human viruses in deep municipal wells in Madison, WI (see http://wisconsingeologicalsurvey.org/wofrs/WOFR2010-04a.pdf). Detection of infective viruses in such deep bedrock wells was unexpected and has important implications for protection of groundwater quality and human health. The presence of viruses suggests that the deep wells may be more vulnerable to contamination than previously believed. This work continued in FY 12 as WGNHS investigators received a major grant from the US EPA to continue this research on impacts to groundwater quality from leaky sewers

(see http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/9454/report/0) .

c. *Groundwater recharge*. Groundwater recharge is critical to maintaining the supply of Wisconsin's groundwater, but mapping and quantifying recharge areas and rates can be a difficult process. The WGNHS has developed a computerized technique for rapidly delineating recharge areas for use in regional groundwater models. Currently, the WGNHS is incorporating the recharge delineation methodology into new projects and is cooperating with the USGS in using it in other areas of Wisconsin. In FY 12, recharge delineations were used in groundwater vulnerability assessments in Columbia County and in National Forest Units in Price County and in the East central Regional Planning Commission area (Menominee, Shawano, Waupaca, and Waushara Counties), see http://wisconsingeologicalsurvey.org/wofrs/WOFR2011-05.pdf).

d. *Fluid flow in fractured rocks.* Fractured rocks (limestone, dolomite and crystalline rocks) underlie much of Wisconsin and form important aquifers over large parts of the state. Groundwater in carbonate rocks can move through fractures and solution features. Groundwater movement in such rocks can be quite rapid, and the rocks usually have very low ability to attenuate contaminants. WGNHS projects in FY 11 and FY12 in this carbonate terrain include development of a groundwater budget for Dunes Lake (Door County) and a study of springs in the Mink River Estuary (Door County).

   Karst features, such as sinkholes, cavities, and solution openings, cracks, and fractures, commonly are found in carbonate rock. WGNHS staff continually responds to questions about karst; and prepared a statewide fact sheet on karst (*http://wisconsingeologicalsurvey.org/pdfs/karst.pdf*). WGNHS researchers began investigations into the properties of clayey residuum covering parts of southwestern Wisconsin in mid-2011. This residuum, called the Rountree Formation, might provide protection for the underlying carbonate aquifers where it occurs.

e. *Investigation of unsewered rural subdivisions*. Population growth and urban expansion in many areas has resulted in residential development on formerly agricultural land, but there have been few studies of the impacts of such developments on groundwater quality. To document the effects of this land-use conversion on groundwater quality, the WGNHS initiated a monitoring program to collect water-quality data before, during, and after construction of a new, unsewered subdivision located on agricultural land several miles outside of Madison, Wisconsin.

Groundwater Data Management

During FY 12 the WGNHS continued to collect geologic and groundwater data and provide this data to a variety of users. Significant databases and data efforts include:

a. *Data viewer construction.* With support from WDNR, the WGNHS has begun development of a map-based application to access a catalog of hydrogeologic data. The application will provide DNR staff and eventually the public with efficient and timely access to statewide hydrogeologic data, and will include several methods to search by area for data of interest, such as geologic and geophysical logs or well construction reports
b. *wiscLITH database*. The Survey recently updated a digital database, called *wisc*LITH, which contains lithologic and stratigraphic descriptions of geologic samples collected

from across the state. Current work efforts focus on including more data for areas of the state where there are active geologic and hydrogeologic projects, and improving the quality and consistency of information in the statewide database. See http://WisconsinGeologicalSurvey.org/wisclith.htm.

c. *Well construction reports.* The WGNHS serves as the repository for well constructor's reports (WCRs) from wells installed between 1936 and 1995. These reports were usually submitted to the DNR by a well driller within a few months of a well's completion. The database and scanned images are now available to state agencies, consulting firms, and private well owners on CD-ROM and paper copies. See http://WisconsinGeologicalSurvey.org/wcrs.htm

d. *Tillpro Database*. TILLPRO is primarily a database of grain-size analyses performed on unlithified sediment samples collected from Wisconsin and analyzed in the Quaternary Laboratory at the Department of Geoscience, University of Wisconsin-Madison. The data are available for public distribution on CD-ROM. See http://WisconsinGeologicalSurvey.org/wisclith.htm

e. *WGNHS Research Collections and Education Center (RCEC).* The WGNHS archives geologic records, rock samples, core samples, and other materials in Mt. Horeb, Wisconsin. Currently the RCEC contains over 2.5 million feet worth of drillhole cuttings, more than 600,000 feet of drill core, and more than 51,000 individual hand samples of rock from across the State. Examination tables and basic laboratory facilities at the RCEC allow convenient analysis and study of these materials. See http://WisconsinGeologicalSurvey.org/core.pdf

f. *Physical properties of Wisconsin's bedrock aquifers and aquitards.* The WGNHS has created a database of the porosity and density of core samples collected from drill holes around the state. The database includes high-resolution images of the core taken from different depths along with a summary table. This information is available at *http://WisconsinGeologicalSurvey.org/porosity_density/porosity_density_intro.htm*

Groundwater Education

WGNHS groundwater education programs for the general public are usually coordinated with the UW-Extension network of county-based faculty, the DNR, the Central Wisconsin Groundwater Center, or the UW-Extension Environmental Resources Center. The WGNHS also produces and serves as a distributor of many groundwater educational publications and visual aids. Some of these materials are primarily DNR products, but it has proven to be convenient and effective to use our map and publication sales and distribution system. The Survey's education and outreach programs have been energized by the hiring of an Outreach Manager in 2009, who attends many regional and statewide meetings to promote awareness of our services, data sets, and publications.

WGNHS presents groundwater educational activities at the State Fair, at children's museums and schools and at afterschool programs on campus: the target audience is the general public.

In FY 2012, WGNHS staff members plan to participate in groundwater educational meetings in counties where county mapping and/or other hydrogeologic studies are in progress. Arsenic in groundwater, the potential groundwater implications of proposed quarries, gravel pits, and high-capacity wells, and groundwater issues relevant to comprehensive planning have been popular topics recently and probably will continue to provide educational opportunities in FY 2012.

Several staff members will contribute to professional short courses that educate professionals (such as consultants, regulators, and officials) on technical aspects of well hydraulics, wellhead protection, waste disposal, etc. Staff members will continue to participate with the DNR and the Central Wisconsin Groundwater Center in the teacher-education programs connected to the distribution of the groundwater sand tank models. WGNHS maintains a long commitment to 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 for DNR water staff and new DNR employees have been held in the past and will continue as requested in FY 2012. We also provide a collection of representative Wisconsin rocks for teachers to use, which includes samples of our major aquifers.

Efforts to reach teachers will increase in FY 2012 by distributing groundwater information materials (such as the Buried Treasure booklet) and making presentations at teacher training outlets such as the Wisconsin Society of Science Teachers annual conference. Additionally, survey staff will focus on collaborating with teachers in preparing educational materials for the classroom and will prepare "fact sheets" based on our technical publications with information for the general public. Our Research Collections and Education Center is providing a locale for various groups to carry on their related education programs. In particular, the Wisconsin Rural Water Association will use the Education Center for their Operator Training in 2012. We hope to expand this capability throughout the year for this and other groups with educational missions that are similar to ours.

For more information, contact Ken Bradbury, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin, 53705-5100; phone: 608-263-7389; email: **krbradbu@wisc.edu;** ***Web site:*** ***http://WisconsinGeologicalSurvey.org/.***

DEPARTMENT OF TRANSPORTATION

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 80 rest area wells. Other DOT groundwater related activities include: road salt research; hazardous material and waste investigation or remediation; wetland compensation and research; and storm water management and research. Various divisions and sections in DOT are responsible for these activities:

- Salt Use and Storage - Bureau of Highway Maintenance
- Salt Research - Bureau of Highway Construction (Geotechnical Section)
- Hazardous Materials (petroleum) - Environmental Services Section
- Hazardous Waste - Environmental Services Section
- Wetlands - Environmental Services Section
- Erosion Control and Storm Water Management - Environmental Services Section
- Rest Area Potable Well Sampling - Bureau of Highway Operations

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 insure that 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 1,255 salt storage sites listed in the database and 2,468 sub-sites. Each county keeps detailed inventories of salt which are updated monthly. 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 300 pounds per lane mile for subsequent applications. Electronic controls for salt spreader trucks are continually tested 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 in-situ weather monitoring system. Pavement temperature sensors recorded at 59 locations along major highway routes are used to determine application methods. Annual training for snowplowing and salt spreading techniques is provided for county snowplow operators.

Salt Usage Tracking
The DOT Bureau of Highway Maintenance is currently in the process of having all of the county trucks that work on the state system equipped with AVL/GPS equipment. This technology will allow the bureau to better track the application of salt usage across the state. It will also help in the optimization of plow routes to make plowing most efficient. In conjunction with the AVL/GPS equipment the bureau is testing out new software called the Maintenance Decision Support System or MDSS. MDSS combines the science of snow removal with weather forecasting. The goal is to only apply the minimum amount of salt necessary given the current weather conditions and forecasts. Many other state who have implemented these technologies are seeing cost savings and salt reductions across their highways.

Salt Monitoring and Research
Since 1970, DOT has investigated potential road salt impacts on the environment adjacent to highways. Early investigations (1970s to early 80s) were focused on evaluating road salt impacts to surface water runoff, vegetation, and soils. In the last several years DOT has conducted limited investigations evaluating road salt impacts to groundwater. Approximately 20 sites throughout the state have been studied. In general, 1 or 2 shallow monitoring wells at each site were monitored quarterly for a period of 5 years. The monitoring consists of analyzing soil, water, or vegetation samples for calcium, sodium, chloride, and electrical conductivity. Results from the studies are discussed in 5 separate DOT progress reports entitled: Investigation of Road Salt Content of Soil, Water and Vegetation Adjacent to Highways in Wisconsin (1972, 1975, 1979, 1989 and 1996).

Well Access
For the past several decades, DOT has provided access to wells used in the Wisconsin Groundwater Observation Network maintained by USGS and WGNHS. Currently there are 24 wells in the network that are on DOT property.

For more information, visit the following web site (http://www.dot.state.wi.us) or contact Bob Pearson, Environmental Services Section, Room 451, 4802 Sheboygan Ave., P. O. Box 7965, Madison, Wisconsin 53707-7965; phone: 608-266-7980, or e-mail robert.pearson@wisconsin.gov.

DEPARTMENT OF SAFETY AND PROFESSIONAL SERVICES

Effective July 3, 2011, the Safety and Buildings and Environmental and Regulatory Services Divisions were merged with the Department of Regulation and License creating the new Department of Safety and Professional Services (DSPS). These two of the six Divisions of DSPS regulate activities, protect or remediate Wisconsin's groundwater resources.

Within the Division of Safety and Buildings, two plumbing programs have the responsibility of safeguarding public health and the waters of the State. Graywater reuse and stormwater is regulated by the General Plumbing Program (Chapter Comm 82, Wis. Admin. Code). Private onsite wastewater treatment systems are regulated by the Private Onsite Wastewater Treatment Systems Program (Chapter Comm 83, Wis. Admin. Code).

Also within the Safety and Buildings Division the Soil Erosion and Sediment Control Program has statutory jurisdiction over stormwater runoff on building sites that are regulated under Chapter 101 of the statutes.

Within the Division of Environmental and Regulatory Services (ERS), two Bureaus regulate petroleum tanks and petroleum cleanups. The Bureau of Petroleum Products and Tanks regulates flammable and combustible liquids and hazardous substance liquids (Chapter SPS 310, Wis. Admin. Code). The Bureau of PECFA reimburses owners and operators of leaking petroleum storage tanks (Chapter SPS 347, Wis. Admin. Code) and has regulatory jurisdiction of petroleum sites determined to be a low or medium risk to the environment (Chapter SPS 346, Wis. Admin. Code).

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. Currently in Wisconsin there are over 65 approved stormwater use or wastewater reuse plumbing systems.

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 USEPA Region 5 office regarding POWTS related matters. Department staff participates when requested in the development of a regional and national model code related to onsite sewage systems.

Soil Erosion and Sediment Control

The Department works with the Department of Natural Resources in regulating the erosion and sediment control issues on building sites under the authority of s. 101, Stats.

Petroleum Product and Hazardous Substance Storage Tanks
The ERS Division continues to maintain regulatory oversight of aboveground and underground petroleum and CERCLA hazardous substance storage tanks in the Chapter SPS 310, Wis. Admin. Code. Underground storage tank regulations include the Federal EPA Underground Storage Tank (UST) requirements, as well as heating fuels, tanks supplying stationary combustion engines such as emergency generators, and other tanks storing regulated liquid products. Chapter SPS 310, Wis. Admin. Code, was revised with an effective date of July 2009, which included the Federal Energy Policy Act of 2005 operator training requirements.

In order to maintain a federally regulated tank in use (i.e. tanks used for vehicle fueling), the tank must have a valid "permit-to-operate." Permit renewal administrative review includes compliance assessment of the owner's financial responsibility. Federally regulated and large fuel oil USTs are subject to periodic inspections involve verification of leak detection, spill and overfill protection, and record keeping. Annual inspections have been performed by Department of Safety and Professional Services (DSPS) employees and private contractors. Due to budget reduction initiatives many of the private contractor inspections have been eliminated with the objective to move these inspections to DSPS inspectors, but extending the time between inspections to no more than two years.

Program tank permit initiatives have resulted in approximately 93% of the tanks required to have financial responsibility being in compliance with the rule. The remaining tanks will not be permitted and will be shut-down if financial responsibility coverage is not verified. The closure of federally regulated tanks will continue, but at a slower pace than experienced over the past few years. Closure of out-of-service residential heating fuel tanks is continuing as realtors and lenders recognize the potential problems and liability.

Proactive educational outreach efforts and annual inspections by the Department and its agents have resulted in a high level of regulatory compliance, and a reduction of system failures and environmental contamination. Mandates required in the Federal Energy Bill of 2005 that must be implemented in Wisconsin by August 2012 are expected to have a significant positive impact on release reduction as the requirement for secondary containment and owner/operator training is implemented with revisions to the administrative code. The ongoing regulatory challenges are owner operational compliance with leak detection. The department has partnered with trade associations working with the regulated community to provide training related to the revised SPS 310 and the pending operator training.

Wisconsin has over 6,300 abandon underground storage tanks (USTs). Many of the tanks are on property of indigent owners. The 2009 Wisconsin Act 28 modified ss.101.143 (3), Stats, with the creation of ss. 101.1435, Stats, and provided DSPS with $100,000 per year from the petroleum inspection fund to contract for the closure of abandon USTs. Internally this program is referred to as the "PIF tank closure" program. The owner must give DSPS authorization to access the property and remove the UST(s), DSPS will procure the contractor via low bid, and subsequently place a lien against the property for the amount of the tank closure. The PIF closure covers the excavation and backfill, removing the islands, scrapping the tank(s) and piping, soil assessment when required, and removal of existing canopy. In some situations, canopies are taken down to eliminate the risk that the footing zone may weaken as a result of excavation and consequently the structural integrity susceptible to wind.

The closure program comes with challenges, such as: locating and communicating with the property owner and the owner agreeing to a lien against the property. On the positive side is the cooperation of the Department of Justice (DOJ) to include authorization for DSPS to remove

tanks under the PIF program in judgments served for non compliance with tank closure requirements. Some owners found the financial means to remove tanks when approached with the possibility of DOJ referral. To date the funding program has provided for the closure of seventy-six underground tanks at twenty-six facilities.

Petroleum Environmental Cleanup Fund Act (PECFA)
Since 1989, the PECFA program has reimbursed approximately $1.52 billion to petroleum storage tank system owners for costs associated with the investigation and remediation of petroleum contaminated sites. The program, in addition to auditing owner invoices and authorizing payments, performs technical reviews of site investigations, evaluates the feasibility of remedial options, approves funding for scopes of work, and makes decisions regarding closures for the majority of the State's leaking underground storage tank (LUST) sites.

The Petroleum Inspection Fee supports PECFA's spending authority. The spending authority for 2012/2013 is $9.1 million. In FY 12, the PECFA program reimbursed $6.97 million to 726 claimants. The Program currently reimburses claimants within two months of receiving a claim. The Program's current bond obligation amount is $188 million.

In addition to administering the PECFA fund, the DSPS PECFA Bureau has the administrative authority for low and medium risk petroleum contaminated sites (which includes both soil and groundwater sites). The Bureau closes approximately 150 sites per year.

Data Management
DSPS is continuing its data integration information technology (IT) initiative. With regard to groundwater protection, DSPS maintains databases of underground petroleum storage tank systems and properties with petroleum contamination either in the past or currently. 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. The revised rule requires that counties conduct an inventory to identify all POWTS within their jurisdictional areas. Counties must also initiate new or enhance existing reporting programs related to inspection, maintenance and servicing events. This is expected to be a multi-year effort with code specified deadlines.

UNIVERSITY OF WISCONSIN SYSTEM

The University of Wisconsin System (UWS) has research, teaching and outreach responsibilities. These three missions are integrated through cooperation and joint appointments of teaching, research and Extension personnel who work on groundwater issues. UWS staff members work with state and federal agencies and other partners to solve groundwater resource issues. Citizen outreach is accomplished through publications, video and audio podcasts, social media, media relations, public meetings, teleconferences, and water testing and satellite programs. Activities of several specific programs are described below.

The UW Water Resources Institute (WRI)

The UW Water Resources Institute (WRI) is one of 54 water resources institutes located at Land Grant universities across the nation. It promotes research, training and information dissemination focused on Wisconsin's and the nation's water resources problems.

Research

The WRI research portfolio includes interdisciplinary projects in four broad areas: groundwater, surface water, groundwater-surface water interactions and drinking water. Groundwater is a top priority and an area of particular strength at the WRI. Key areas of emphasis in FY12 included hydrology and research focused on various groundwater contaminants, including pathogenic bacteria, antibiotics, and nitrate/nitrite.

During FY12, the WRI directed a wide-ranging program of priority groundwater research consisting of eight projects (see http://dnr.wi.gov/org/water/dwg/gcc/rtl/2012/FY12Projects.pdf). 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. Groundwater issues investigated during the past year include:

- Groundwater Recharge Characteristics and Subsurface Nutrient Dynamics Under Alternate Biofuel Cropping Systems in Wisconsin
- Reducing Nitrate in Groundwater with Slow-Release Fertilizer
- Influence of Adsorbed Antibiotics on Water Quality and Soil Microbes
- Transport of Manure-Derived, Tetracycline Resistant Escherichia coli in Unsaturated Soil
- Silage leachate: Waste quality assessment and treatment
- Establishing paleoclimate records from spring tufa deposits in the driftless area of Wisconsin
- Preferential flow paths in heterogeneous glacially-deposited aquitards
- The effects of particulate organic carbon quantity and quality on denitrification of groundwater nitrate

These seven projects, funded by the UWS, provided training in several disciplines for post-doctoral research associates, graduate student research assistants and undergraduate students at UW-Madison, UW-Milwaukee, UW-Extension, UW-Parkside, and UW-Oshkosh.

For FY13 (July 1, 2012–June 30, 2013), the UWS selected five new groundwater research projects from proposals submitted in response to the Joint Solicitation, and five projects, selected

from the previous year's solicitation, will receive continuation (see *http://dnr.wi.gov/org/water/dwg/gcc/rtl/2012/FY13Projects.pdf*). The new projects are based at UW-Extension, UW-Madison, UW-Milwaukee, and UW-Green Bay.

Beginning with FY11, the WRI's annual 104(B) allocation was used to expand the scope of the Joint Solicitation to include research on the effects of climate change on Wisconsin's water resources. Priorities for climate change research were established through a partnership with the Wisconsin Initiative on Climate Change Impacts (WICCI). Established in 2007, WICCI is a university-state partnership created to:(a) assess and anticipate the effects of climate change on specific Wisconsin natural resources, ecosystems and regions; (b) evaluate potential effects on industry, agriculture, tourism and other human activities; and (c) develop and recommend adaptation strategies that can be implemented by businesses, farmers, public health officials, municipalities, resource managers and other stakeholders. Three climate change proposals were funded during FY12 (see *http://dnr.wi.gov/org/water/dwg/gcc/rtl/2012/FY12Projects.pdf*) and all three will receive continuation in FY13 (see *http://dnr.wi.gov/org/water/dwg/gcc/rtl/2012/FY13Projects.pdf*).

Teaching

Institutions within the UWS continue to offer undergraduate- and graduate-level courses and programs focusing on diverse issues regarding groundwater resources. Additionally, several campuses offer for-credit, field-oriented water curriculum courses for middle and high school teachers during summer sessions. The WRI views continuing education for K-12 teachers as an important component of its outreach and training effort. Wisconsin' Water Library, housed on the UW-Madison campus and a service of the WRI, maintains an extensive curriculum collection of guides with innovative approaches and other educational materials for teaching water-related science in K-12 classrooms. The curricula are available for checkout by all teachers and residents in Wisconsin.

Grants Administration

In FY07, WRI staff members developed a website called iPROPOSE (see *https://aqua.wisc.edu/ipropose*) that enabled online submission and review of the Joint Solicitation for Groundwater Research and Monitoring 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 iPROPOSE by answering a series of questions online. Once all of the reviews are completed, the UW Groundwater Research Advisory Council is given access to anonymous reviews and original proposals to help decide which proposals to recommend for funding. The website provides a framework for consistently capturing the same information from all of the prospective investigators and reviewers, thus helping to ensure that each proposal is treated equally. In FY08, the site was refined to increase the efficiency of the review process, including updates to the reviewer database, keywords and generating reports. iPROPOSE received several administrative enhancements during FY09 to simplify and streamline the reviewer assignment process. New tools allow easier tracking of assigned reviewers and global management of their reviews. New features also allow fast and easy database record comparisons and merging.

Information and Outreach Activities

The University of Wisconsin Water Resources Institute website (see *http://wri.wisc.edu*) is a portal to information about WRI research projects and publications. The site is integrated with the UW Aquatic Sciences Center's interactive Project Reporting Online system (see https://aqua.wisc.edu/ipro), an online tool that allows principal investigators to report on the progress of their projects. In this reporting period, the WRI website received 22,514 visitors,

which is 955 more visitors than in the previous year. Additionally, WRI has a presence on Twitter, Facebook, Tumblr and Flickr. The program's You Tube channel, youtube.com/asc, was redone during this reporting period to better group and display its videos specific to water research. In this reporting period, a new video was produced and added to the channel. It details the work of a researchers looking into the role streams may play in neutralizing nitrates in groundwater. One of the most popular videos on the channel is "Testing Well Water for Microorganisms." It has nearly 4,000 views, a large number for such a scientific topic. Furthermore, the video garnered a national communications award, an APEX, in 2011.

The program is also reaching audiences through an informative and entertaining seven-part audio podcast about mercury in aquatic environments. The series is offered through the WRI site, as well as through the University of Wisconsin-Madison iTunes University site.

Water Resources Publications

The program offers an online, easily accessible publications store with free information or information available for a nominal cost. In this reporting period, the most popular publication was a fact sheet on groundwater drawdown and its implications for various regions in Wisconsin. More than 2,000 people accessed the material online. No hard copies of this were mailed out since the download is fast, easy and free. This was also the No. 1 item in the store, outpacing downloads and interest over more than 100 other items.

The program also produces the "Aquatic Sciences Chronicle" on a quarterly basis. It circulates to roughly 3,000 subscribers with an interest in WRI projects and related topics. Archived issues can be found at *http://aqua.wisc.edu/chronicle*.

News Releases and A Guest Editorial

The WRI again contributed to a series of news releases for the annual Groundwater Awareness Week in March 2012. It distributed a news release regarding the AWRA conference and attracted a reporter to cover the plenary talk, and prepared and distributed a guest editorial highlighting Groundwater Awareness Week.

AWRA Annual Conference

The WRI was once again integral to the planning and staging of the American Water Resources Association-Wisconsin Section's annual conference. There was unprecedented interest with more than 200 attendees and more conference abstract and poster submissions than in the previous 35 years of this conference. The conference was titled Science-Based Policy for Wisconsin's Water Resources. General areas covered included groundwater, surface water, wetlands, hydrochemistry, and nutrients and contaminants. The Wisconsin Section is also dedicated to mentoring future leaders in water resources and offers a student workshop, and an opportunity for students to showcase their academic work. The meeting was supported by other academic and governmental partners, including the American Water Resources Association, Wisconsin Section; Center for Watershed Science and Education; UW–Stevens Point Wisconsin Department of Natural Resources; U.S. Geological Survey; Wisconsin Water Science Center; and Wisconsin Geological and Natural History Survey. The Water Resources Institute also provided materials for distribution from a booth at the conference.

Wisconsin's Water Library Outreach Activities

Wisconsin's Water Library is a unique resource for Wisconsin citizens. It contains more than 30,000 volumes of water-related information about the Great Lakes and the waters of Wisconsin. The library includes a curriculum collection, dozens of educational videos, a children's collection, and more than 20 journals and 100 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. Some examples of reference queries answered in this reporting period include: researching the use of nanotechnology in the treatment of wastewater according to TMDL (total maximum daily load) limits at wastewater treatment plants; crating a bibliography of materials for use by a brand new elementary school teacher teaching her first third grade unit on the water cycle; assisting a student in the Nelson Institute learn about global water supply issues and how this is reflected in Wisconsin; and helping a homeowner find lake level data from a lake in northern Wisconsin.

During the reporting period, in partnership with the Wisconsin Department of Natural Resources and the Wisconsin Wastewater Operator's Association (WWOA), the library continued its outreach to current and future wastewater operators of Wisconsin. The library cataloged the essential technical manuals into the library catalog and provided loans to WWOA members around the state in support of their required state license examinations as well as in support of the educational needs of their daily work.

Wisconsin's Water Library continues to catalog all groundwater research reports from projects funded by the Water Resources Institute 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.

During this reporting period, the library completed a project to create a digital archive of the entire collection of DNR Groundwater Research and Monitoring Program reports (see *http://wri.wisc.edu/Default.aspx?tabid=87*) The UW Digital Collections Center completed the archival process in October of 2011, ensuring a permanent and accessible electronic record of Wisconsin groundwater-related activities since 1984. Paper copies of the reports will continue to be a part of the Wisconsin Water Library. The Water Library's role in the project was to provide metadata that ensures discoverability of reports by anyone looking for information on a particular project.

To build water literacy library staff also conducted story hours at public libraries in southern Wisconsin and at other events through the state. Over 350 children of all ages enjoyed hearing stories, making crafts and singing songs on water-related themes. In addition, the library has forged a positive and ongoing relationship with the Ho-Chunk Nation of Wisconsin, which included six different presentations at their Head Start program for children ages three to six.

Library Websites

The library maintains several information transfer tools to reach library patrons and the most frequently accessed is the library's robust website (see *http://aqua.wisc.edu/waterlibrary*). The library's site serves as an outreach tool for those who want to know more about the state's water resources. The site's design ensures books and other materials in the library are easily accessible to any Wisconsin resident. There are three areas of the Web site, each set up to address the needs of distinct library user groups: UW system faculty, staff and students; a section just for Wisconsin residents; and an area dedicated to just children, and their guardians and parents. Library staff continually update the site with new topical reading lists, new links to useful water-related Web sites, and pages with the library's new books. These frequent updates encourage users to return to the site often. The overall goal is to build water literacy among target audiences.

During the past 12 months, the library site had 81,753 visitors with 155,924 page views. While this is slightly down from 2010, it can be attributed to the library's increased emphasis on social media tools (see below) that grew exponentially from the previous year.

In addition to its website, Wisconsin's Water Library uses other technology tools to reach library patrons. Using email, the library sends out a bimonthly *Recent Acquisitions List* to close to 600 contacts, an increase over 100 contacts. The message also includes recent updates to the library website and contact information for users to ask any water-related question. The library also supports an e-mail at askwater@aqua.wisc.edu, which is monitored daily. Anyone with a water-related query can pose a question and receive a response in a timely manner.

The library is using Web 2.0 (also known as "social media) tools to reach new library users and to raise visibility of the library. The library has a blog, AquaLog (see *http://aqualog2.blogspot.com*), where library staff reports on news, publications, and resources about water and the Great Lakes. The blog has seen increased usage over the time it has been active. It now sees approximately 60 visitors per day, on average.

The library is also using social media tools, Facebook and Twitter. Users of both technologies can become followers of both and get the latest on water-related information instantly. Facebook (see http://www.facebook.com/WiscWaterLib?ref=nf) is used often to announce events and display interesting links to its "fans". Twitter (see *http://twitter.com/WiscWaterLib*) is an excellent way to communicate in a timely manner. Both tools have seen increased use by library patrons and both have loyal and increasing numbers of followers.

Other Websites

WRI maintains several other Websites in addition those described above. The UW Water Resources Institute Website (see http://wri.wisc.edu) introduces users to the Wisconsin program and includes a variety of information for those interested in water-related issues and research. The project listing, project reports, groundwater research database, funding opportunities and conference information sections of the website are updated annually.
All issues of the UW Aquatic Sciences Chronicle are available online (see http://aqua.wisc.edu/chronicle). This quarterly publication circulates to an audience of nearly 6,000 that includes local and state water management agencies, and water-related non-governmental organizations. Readers are found in Wisconsin and across the country.

WRI material is also featured on two external and highly trafficked sites – iTunes University and You Tube. At iTunes University (see http://itunes.apple.com/WebObjects/MZStore.woa/wa/viewPodcast?id=430421609), visitors can download a WRI-sponsored seven-part audio podcast series. "Water, Wisconsin and the Mercury Cycle" details mankind's historic uses of mercury, Wisconsin's water resources and mercury in Wisconsin waters. A major part of the series also focuses on WRI-funded research on mercury. On You Tube (see http://www.youtube.com/UWASC), visitors can download short, informative videos on WRI-funded research. Three videos are posted and explain new testing protocols to determine the presence and levels of microorganisms in well water (*http://www.youtube.com/uwasc#p/u/1/ey-xqU0i9PI*), using thermal remote sensing to map groundwater flow (*http://www.youtube.com/uwasc#p/u/2/gOBCnZGpSiU*) and discharge and groundwater nitrate processing in deep-stream sediments (*http://www.youtube.com/uwasc#p/u/7/KQVguo4_pMU*).

UWS FY 12 Publications Resulting from
Groundwater Research & Monitoring Program Projects

Water Resources Institute Reports

Bauer-Dantoin A, K Fermanich, J Zorn, and S Wingert 2011. Assessing levels of potential health effects of endocrine disrupting chemicals in groundwater associated with Karst areas in Northeast Wisconsin. Water Resources Institute, University of Wisconsin, Madison. 20p. Final_WR08R004.pdf

Grundl, T, N Magnusson, and J Krall 2011. Assessing the Effect of Pleistocene Glaciation on the Water Supply of Eastern Wisconsin. Water Resources Institute, University of Wisconsin, Madison. 31p. Final_WR09R004.pdf

Joachim DR, MB Gotkowitz, KW Potter, KR Bradbury, SJ Vavrus, and SP Loheide 2011. Forecasting impacts of extreme precipitation events on Wisconsin's groundwater levels. Water Resources Institute, University of Wisconsin, Madison. 22p. Final_WR09R005.pdf

Li, Z. 2011 Combination of Co-Precipitation with Zeolite Filtration to Remove Arsenic from Contaminated Water. Water Resources Institute, University of Wisconsin, Madison. 19p. Final WR08R002.pdf

Loheide SP, and DR Joachim 2012. Development and Application of a User-Friendly Interface for Predicting Climate Change Induced Changes in Evapotranspiration. Water Resources Institute, University of Wisconsin, Madison. 15p. Final_WR10R001.pdf

Pedersen JA, KD McMahon, S Long, and SD Sibley 2011. Fecal Source Tracking Using Human and Bovine Adenovirus and Polyomaviruses. Water Resources Institute, University of Wisconsin, Madison. 16p. Final_WR09R002.pdf

Stanley, E 2011. Occurrence and Generation of Nitrite in Ground and Surface Waters in an Agricultural Watershed. Water Resources Institute, University of Wisconsin, Madison. 16p. Final_WR07R003.pdf

Stelzer, RS, and L Bartsch 2011. Groundwater Nitrate Processing in Deep Stream Sediments. Water Resources Institute, University of Wisconsin, Madison. 14p. Final_WR10R005.pdf

Theses

Bartkowiak, B. 2007. Geochemical and flow characteristics of two contact springs in Iowa County, Wisconsin. B.S. Thesis, Department of Geology, Beloit College, Beloit Wisconsin.

Jaochim, Douglas R. 2011. Modeling the impacts of future climate change on groundwater recharge and evapotranspiration in Wisconsin. MS Thesis, Water Resources Engineering, University of Wisconsin, Madison, WI 102p

Powers, S.M. 2012. River nutrient uptake and transport across extremes in channel form and drainage characteristics. Ph.D. Thesis, Limnology and Marine Science, University of Wisconsin, Madison. 135p.

Summitt, A. 2009. Geophysical Mapping of Septic Effluent and the Evaluation of Performance of Mounded Septic Leach Fields. MS Thesis, Geological Engineering, University of Wisconsin-Madison.

Other Publications

Craig, L., J. Bahr and E. Roden, 2010. Localized zones of denitrification in a floodplain aquifer in southern Wisconsin, Hydrogeology Journal, 18(8): 1867-1879

Henning, P.E., M. Veronica Rigo, and Peter Geissinger. 2012. Fabrication of a Porous Fiber Cladding Material Using Microsphere Templating for Improved Response Time with Fiber Optic Sensor Arrays. The Scientific World Journal – Analytical Chemistry. 876106 (7 pp)

Leaf, A.T., D.J. Hart and J.M. Bahr, 2012. Active thermal tracer tests for improved hydrostratigraphic characterization, Ground Water. In Press. doi: 10.1111/j.1745-6584.2012.00913.x

Li, Z., Jean, J.-S., Jiang, W.-T., Chang, P.-H., Chen, C.-J., Liao, L. (2011) Removal of arsenic from water using Fe-exchanged zeolite, J. Hazard. Mater., 187, 318-323. DOI:10.1016/j.jhazmat.2011.01.030

Li, Z., Hong, H., Jean, J.-S., Koski*, A. J., Liu, C.-C., Reza, S., Randolph*, J. J., Kurdas*, S. R., Friend*, J. H., Antinucci*, S. J. (2011) Characterization on arsenic sorption and mobility of the sediments of Chia-Nan plain, where black foot disease occurred, Environ. Earth Sci., 64, 823-831. DOI:10.1007/s12665-011-0938-7

Li, Z., Jiang, W.-T., Jean, J.-S., Hong, H., Liao, L., Lv, G. (2011) Combination of hydrous iron oxide precipitation with zeolite filtration to remove arsenic from contaminated water, Desalination, 280, 203-207. DOI:10.1016/j.desal.2011.07.009

Namdar G. R., and H.R. Bravo. 2011. Evaluation of Correlations between Precipitation, Groundwater Fluctuations, and Lake Level Fluctuations Using Spectral Methods (Wisconsin, USA), Hydrogeology Journal, 19(4):801-810. DOI:10.1007/s10040-011-0718-1

Namdar G. R., and H.R. Bravo. 2011. Coherence among Climate Signals, Precipitation, and Groundwater, Ground Water Journal. 49(4):455-615. DOI:10.1111/j.1745-6584.2010.00772.x

Powers, S.M., R.A. Johnson, and E.H. Stanley. 2012. Nutrient retention and the problem of hydrologic disconnection in streams and wetlands. Ecosystems 15:435-449.

Rigo, M. V., and Peter Geissinger. 2012. Crossed-Optical Fiber Sensor Arrays for High-Spatial-Resolution Sensing: Application to Dissolved-Oxygen-Concentration Measurements. Journal of Sensors. 464092 (10 pp)

Stelzer, R.S., and L.A. Bartsch. 2012. Nitrate removal in deep sediments of a nitrogen-rich river network: a test of a conceptual model. Journal of Geophysical Research- Biogeosciences, In Press.

Swanson, S.K., Bradbury, K.R., and Hart, D.J., 2009. Assessing the vulnerability of spring systems to groundwater withdrawals in southern Wisconsin, Geoscience Wisconsin 20 (1).

For more information on the WRI visit the WRI website (*wri.wisc.edu*) or contact Dr. James P. Hurley, director, UW-Madison Water Resources Institute, 1975 Willow Drive, Madison, WI 53706; phone (608) 262-0905, fax (608) 262-0591, or email *hurley@aqua.wisc.edu*.

UW-Extension's Central Wisconsin Groundwater Center

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. Recent policy work focuses on groundwater pumping and impacts on surface waters. The center is part of the Center for Watershed Science and Education, an office of UW-Extension Cooperative Extension Service and the UW-Stevens Point College of Natural Resources. More information can be found at http://www.uwsp.edu/cnr-ap/watershed/.

Well Water Testing

In calendar year 2011, the Center assisted nearly 3,307 households in having their water tested in conjunction with county Extension offices and the Watershed Center's Water and Environmental Analysis Laboratory. Of these, 11% exceeded drinking water standards for nitrate-nitrogen. Eighteen percent of samples were unsafe because of coliform bacteria. Sixteen Drinking Water Education Programs helped nearly 1,181 well users in 14 counties to understand potential remedies for these problems and the relationship of land use practices to groundwater quality.

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 Drinking Water Education Programs conducted through the Center. There are currently 632,203 individual test results for approximately 80,227 samples covering the state; including 23 counties with 100 to 500 samples and 33 counties with 500 or more samples. Chemistry data includes pH, conductivity, alkalinity, total hardness, nitrate-nitrogen, chloride, saturation index, and coliform bacteria. In 1998, a new sampling program for iron, sodium, potassium, copper, lead, calcium, magnesium, manganese, zinc, and triazine was also initiated. Arsenic and sulfate were added late in 1999. The database primarily covers the period 1985 to the present. The database is PC-based and can be easily queried to be a significant source of information for local communities and groundwater managers. Reports that summarize county-wide results have been generated for Iowa, St. Croix, Dodge and Fond du Lac Counties.

Interactive Well Water Quality Mapping Tool

The Groundwater Center recently made available on publically available online mapping tool that allows people to search for groundwater quality information. The tool incorporates private well water data from the Groundwater Center's database, the WI Dept. of Natural Resources Groundwater Retrieval Network, and the Dept. of Ag., Trade and Consumer Protection. Summary maps are available for 14 different water quality parameters and can be viewed at a county, town, or section level detail. Summary tables can be generated for a specific county, town or any user defined area. The mapping tool can be accessed at: www.uwsp.edu/cnr-ap/watershed/Pages/wellwaterviewer.aspx.

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 for the Center.

Partnerships
Center staff works with agencies and private organizations, including the Wisconsin Agricultural Stewardship Initiative, Wisconsin Potato and Vegetable Growers Association Nonpoint Pollution subgroup, DATCP Atrazine Technical Advisory Committee, and Extension Nutrient Management Self-Directed Team. The Center continues to work closely with local governments, Land Conservation Departments, UW-Extension County Faculty and Basin Educators, Groundwater Guardian groups, and many local watershed based groups.

Recent Publications and Reports
Kraft, G.J., D.J. Mechenich, K. Clancy, and J. Haucke. 2012. Irrigation effects in the northern lake states – Wisconsin central sands revisited. Ground Water Journal. V. 50: 308-318.

Bussan, A.J., G. Kraft, and J.D. Isherwood, eds. 2011. Walking on water: essays for the central sands. Publication A3961, University of Wisconsin – Extension, Madison WI

Kraft, G.J., D.J. Mechenich. 2010. Groundwater Pumping Effects on Groundwater Levels, Lake Levels, and Streamflows in the Wisconsin Central Sands. Report to the Wisconsin Dept. of Natural Resources, Project NMI00000247. University of Wisconsin – Stevens Point.

Masarik, K., D. Tscheschlok, D. Mechnich. 2010. Fond du Lac County Groundwater: A community resource. Groundwater Series #4. University of Wisconsin – Stevens Point, Center for Watershed Science and Education.

For more information on UW-Extension's Central Wisconsin Groundwater Center contact George Kraft, Center for Watershed Science and Education, College of Natural Resources, UW-Stevens Point, Stevens Point, WI 54481; phone (715) 346-4270; email: *gndwater@uwsp.edu*.

UW Environmental Resources Center (ERC)

The UW Environmental Resources Center (ERC) hosts UWEX state specialists addressing water resources, land and water conservation, forestry, conservation professional training, citizen engagement, and volunteer monitoring. ERC also coordinates a number of regional and national programs addressing water resources and national youth water education initiatives related to groundwater.

ERC Regional Water Programs and Conservation Professional Development
Through a federal partnership with USDA National Institutes for Food & Agriculture (NIFA), ERC hosts the Great Lakes Regional Water Program, a 6-state program involving collaboration among Land Grant Universities, state agencies, and federal agencies across the region (http://www.uwex.edu/ces/regionalwaterquality/). One of the programs emerging from this collaboration is a partnership providing multi-state professional development to conservation professionals(http://conservation-training.wisc.edu/). Wisconsin programs have included issues of

conservation lands management, including manure management and fractured bedrock geology including:

- Presentations and tour to the WI Land and Water Conservation Board
- Training for manure applicators on manure application in Karst areas
- Karst issues incorporated into the Conservation Planning Training sessions and into farmer training

ERC Youth Education

The ERC provides national coordination for two youth water education programs, Educating Young People about Water (EYPAW) and Give Water a Hand (GWAH).
EYPAW offers four guides and a water curricula database to provide assistance for developing a community-based, youth water education program. The EYPAW Web site, http://www.uwex.edu/erc/eypaw, provides access to a database of more than 190 water-related curricula that may be searched by grade level or water topic. Goals of the GWAH curriculum are to protect and improve local water quality by encouraging youth to investigate local issues, and to plan and complete a service project. Youth then address a problem they identify with the assistance of a local natural resource expert. Program materials may be downloaded from the Give Water a Hand Web site, http://www.uwex.edu/erc/gwah.

Other ERC youth water education initiatives include:

- Agua Pura – a leader institute planning manual and guide for Latino water education
- Evaluating USGS Water Education Resources – an assessment of USGS materials to assist with USGS education program development decisions
- Source Water Education – a gap analyses of youth water curricula for source water education and riparian education resources.
- Water Action Volunteers (WAV) – a program for both kids and adults who want to learn about and improve the quality of Wisconsin's waterways through projects and hands-on activities.

Other projects include a national youth riparian curriculum, and the National Extension Water Outreach Education project to develop and promote best education practices for water education and to improve access to education resources and strategies. Find links to these programs on the ERC Web site at http://www.uwex.edu/erc.

Multi-Agency Land and Water Education Grant Program (MALWEG)

UW-Extension coordinates the Multi-Agency Land and Water Education Grant Program (MALWEG), which has funded approximately 200 nutrient management education projects since its inception in 1997. These projects have resulted in awards approaching $3 million in educational assistance funds to county-based conservation professionals in Wisconsin who in turn deliver research-based best management practices and expertise into the hands of farmers on an individual basis.

MALWEG partners, such as USDA-NIFA; Natural Resource Conservation Service; UW-Extension; Wisconsin DNR; Wisconsin DATCP, and UW Discovery Farms, have contributed funding and time to this effort. The counties have also matched a considerable amount of resources to reach more than 1,800 farmers since 1997. More information can be found at http://clean-water.uwex.edu/malweg/.

UW Extension’s Regional Natural Resources Program (RNRP)

The UWS cooperates on community-focused educational programs with other state agencies involved with water resources and natural resource issues. Since 1998, UW-Extension has

worked in partnership to support state, county and local efforts to protect and improve surface and ground water quality and quantity across the state. Twelve locally situated Natural Resource Educators develop and conduct programs that reach local and statewide audiences, 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, and a variety of other water quality issues. More information can be found http://naturalresources.uwex.edu.

For more information on UW ERC programs related to groundwater, contact Ken Genskow, UW Environmental Resources Center, UW-Madison, 445 Henry Mall, Room 202 Madison, WI 53706, phone (608) 262-0020, fax (608) 262-2031, or email kgenskow@wisc.edu

UW Nutrient and Pest Management (NPM) program.

In 1990 a broad coalition of agricultural organizations, environmentalists, and the University sought funding for a water quality program for farmers and the agricultural community. The NPM outreach program has conducted on-farm demonstrations and education throughout Wisconsin to address groundwater and surface water contamination from agriculture and the profitability of recommended practices.

A major portion of the program's focus has been nutrient management – the careful, profitable use of fertilizers and animal manures in crop production. NPM recently revised and distributed the Nutrient Management Farmer Education Curriculum that includes a discussion of nitrates in groundwater. The curriculum has been taught throughout the state to hundreds of producers. NPM also coordinates training workshops for Nutrient Management Planners that teach agricultural and conservation professionals how to write nutrient management plans. To prevent pesticide contamination of groundwater resulting from field applications, program staff provided integrated pest management education and coordinated Wisconsin extension's WeedSoft development and delivery. WeedSoft is a computer program that helps growers make cost effective, environmentally sound weed management decisions. One module includes leaching ratings to assist growers in herbicide selection. NPM has recently developed several mobile "apps" to support farmer nutrient management information through smart phones.

NPM continues to work with Wisconsin farmers to ensure they are not over-applying nitrogen and other inputs so as to minimize potential losses to groundwater. The NPM field staff completed on-farm demonstrations, manure spreader calibration, and taught many farmers how to write and update their nutrient management plans. More information on these efforts and many publications are available at the NPM web site (http://ipcm.wisc.edu).

For more information on the NPM program, visit the following website (http://ipcm.wisc.edu) or contact Scott Sturgul, Wisconsin NPM Program, 445 Henry Mall, Room 314, Madison, WI 53706, phone (608) 262-7486, or email ssturgul@wisc.edu.

Wisconsin State Laboratory of Hygiene

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 and, collectively, their efforts make up the
WSLH Drinking Water Quality Program
The mission of the WSLH Drinking Water Quality Program is to protect the health of drinking water consumers by providing analytical expertise, research and educational services to the scientific and regulatory communities and the public.

The chemical and microbial groundwater contaminants routinely tested include all contaminants regulated by the federal Safe Drinking Water Act as well as many emerging contaminants that appear on the USEPA Contaminant Candidate List. Examples include: fecal indicators (total coliform, *E. coli*, coliphage, *Bacteroides spp.*, *Rhodococcuscoprophilus*, Sorbitol-Fermenting *Bifidobacteria*), *Helicobacter pylori*, *E. coli* O157:H7, Salmonella, waterborne viruses (Norovirus), human-adenovirus, parasites (Cryptosporidium, Giardia, and microsporidia), radioactivity, inorganic compounds (mercury, nitrate, arsenic) and organic compounds (atrazine, PCBs, PBDEs). The Water Microbiology section is currently working on a molecular method for detection of bovine adenovirus in groundwater for microbial source tracking applications.

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 is then used for making management decisions regarding fecal pollution control of groundwater.

Another important focus of the WSLH Drinking Water Quality Program is emergency response to incidents involving groundwater. For example, WSLH works with DHS and DNR to investigate outbreaks of illnesses of unknown (possibly food or water) origin. Staff provides background information on the outbreaks for local public health officials, local media, and the general public. WSLH also responds to spills and incidents and supports state agencies in remediation and emergency clean-up activities. Most recently, WSLH has focused its efforts on enhancing and expanding terrorism response programs.

WSLH also provides educational and outreach activities related to groundwater and drinking water including, (1) instructional consultations for well owners and well drillers, (2) on-site training of municipal water supply operators, and (3) tours for a variety of international, educational, regulatory, and other governmental groups. Staff members have developed an interactive study guide dealing with safety, sampling, and chemistry for drinking water operators and publications related to drinking water including a well water activity sheet, "*Test your well water annually*" brochure, and other well water testing promotional materials. Staff members attend and 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

- Interpretation of GC-MS analysis of sterols as a chemical source tracking indicator. Sterols are the excreted metabolites of hormones (i.e. - plant and animal) that are ingested by animals or metabolized from endogenous sources (i.e. - human synthesis and

metabolism of cholesterol). Depending upon the sterol detected, and in what quantity, determinations may be inferred as to the type of source responsible. For example, a high level of coprostanol, relative to background, indicates anthropogenic contamination of a surface water sample. Detection of cholesterol along with plant sterols, such as beta-sitosterol and stigmasterol, would be indicative of fecal contamination by animals utilizing a mixed diet. Detection of the plant sterols alone would possibly occur with herbivore fecal contamination. Sterol source tracking data should correlated to orthogonal methodologies, such as the microbial source tracking protocols, in making a final determination.

- Analysis of pharmaceuticals and personal care products and antibiotics as tools to indicate pollution from humans and animals. This analysis in conjunction with our Microbial Source Tracking "Toolbox" is used to support the 2005 Wisconsin Act 123 (2005 Senate Bill 646) WI Well Compensation Act Amendment (Compensation for Bacterial Contamination of Wells.

Chemical Terrorism and Preparedness 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 threat agents, provides sampling materials and guidance for first responders including hazardous material, drinking water, and natural resource entities, and performs any needed testing of environmental samples related to chemical incidents. One facet of this support has been the development of a drinking water collection kit, tailored to allow appropriate collection for assessing a wide range of chemical and microbiological contaminants in drinking water. These kits have been provided to all drinking water utilities serving over 3000, as well as to public health and other appropriate agencies.

Water Microbiology Section

- "Assessment of Torque Teno Virus as a Candidate Viral Pathogen Indicator in Drinking Waters" seeks to determine the value of Torque Teno (TT) virus as an indicator for viral pathogen risk. This research will include three primary foci: assessment of the density and occurrence of TT virus in sources and raw waters; evaluation of TT virus behavior through drinking water treatment unit processes (coagulation, clarification, filtration and disinfection); and comparison of these data to those for coliforms, coliphages, and enteroviruses.
- The fecal source tracking toolbox available to WSLH has been expanded to with the conception and optimization of novel species-specific PCR assays for distinguishing human from bovine adenoviruses in groundwater samples. These viruses are widespread in human and bovine populations, and have already proven useful for indicating the presence and source of wastes in groundwater.
- Follow-up total coliform and *E. coli* testing of private wells previously affected by past flooding. This is made possible through a Wisconsin Division of Health Grant which will provide fee exempt testing to homeowners who have experienced a previous unsafe bacterial test result of their well.
- Another study is investigating whether substituting manure for chemical fertilizers in the Central Sands area of Wisconsin would improve the level of contamination of nitrates in groundwater. The trade-off between slow-released nitrogen vs. potential pathogen loading from manure is being assessed.
- Indicator organisms have been used for over a century to assess risk of transmission of waterborne diseases. Currently, culture-based methods are used to enumerate indicators,

which are relatively time intensive, at least 24 hours to obtain results, and can lead to false-negatives when viable but non-culturable organisms are present. Molecular methods have seen increased use in many fields, and their application to the water community is timely. A current project seeks to optimize a quantitative PCR (qPCR) method for measuring *E. coli* in recreational and drinking waters that will provide rapid (potentially same day), unbiased results.

- As a part of a larger laboratory-wide preparedness program WSLH is prepared to offer appropriate microbial water quality testing when disaster strikes. WSLH is a member of the Environmental Response Laboratory Network (ERLN) and the Water Laboratory Alliance (WLA) for both chemical and biological response. This involves participation in nationwide preparedness drills coordinated by the Centers for Disease Control and Prevention in conjunction with the U.S. Environmental Protection Agency. Coming up later in the year, WSLH will be participating in a disaster exercise that has been designed on the scale of the Katrina disaster.

Inorganic Chemistry Section

- Detectable concentrations of hexavalent chromium (Cr(VI)) have been measured in drinking water sourced from Wisconsin groundwater. A current project seeks to determine if there are potential human health concerns within certain aquifers of Wisconsin. The hypothesis that mineralized edges of three major geological basins of Wisconsin provide the conditions favorable to the formation of Cr(VI) is being tested with the goal of characterizing the major aquifers of Wisconsin as to their natural background concentrations and release rates of total Cr and Cr(VI).

Flow Cytometry Section

- Many Cryptosporidium species identified using current methods are not human pathogens and their presence in drinking water may cause undue alarm. The WSLH is working with Texas A&M University to develop methods which distinguish human pathogenic species from those that pose no threat to humans. This is a multi-national study with laboratories in seven different countries participating in the method validation portion of the project.
- The Flow Cytometry Unit at the WSLH continues to provide support for USEPA Office of Water. One such activity includes the provision of precisely-enumerated Cryptosporidium and Giardia standards for use in method improvement studies.

For more information on the WSLH, visit the following website (http://www.slh.wisc.edu/) or contact David Webb, Wisconsin State Laboratory of Hygiene, 2601 Agriculture Drive, Madison, WI 53718, phone (608) 224-6200, or email David.Webb@slh.wisc.edu.

USDA Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) is a federal agency within the US Department of Agriculture. The NRCS works with private landowners to promote conservation of natural resources.

The agency protects groundwater by providing technical assistance to landowners for conservation practices and many federal conservation programs which provide financial assistance to landowners. Summaries and highlights of Wisconsin NRCS conservation accomplishments, by program, are available on the Wisconsin NRCS website at *www.wi.nrcs.usda.gov*

As of July 17, 2012 NRCS accomplishments included:

- Conservation plans written on 199,711 acres and applied on 258,737
- Wetlands created, restored or enhanced on 363 acres
- Comprehensive Nutrient Management Plans written = 47

NRCS also provides leadership on the Standards Oversight Council (SOC), a partnership between state/federal conservation agencies, county Land Conservation Department staff and the Wisconsin Land and Water Conservation Association (WLWCA) to provide a cooperative process to create and revise conservation practice standards. The major conservation practice standards currently in progress using Standards Oversight Council work teams are:

- Manure Storage (313): This practice standard controls the siting and design for manure storage facilities and temporary manure stacks. One of the primary issues being addressed by the team is updating the liner requirements and the definition of groundwater that is used in siting of manure storage facilities.
- Waste Transfer (634): This practice is used to transfer manure and waste water from the livestock production area to the manure storage. The definition of groundwater for design purposes and testing methods to ensure proper sealing of the joints of the transfer pipe are major issues that are being addressed.
- Waste Treatment (629): This practice is used to treat dilute runoff from livestock production sites utilizing vegetated treatment areas (filter strips) or other biological methods. Sizing the treatment areas and how to deal with flushes of concentrated wastes are the primary technical issues being addressed.

To find out more information about NRCS, go to the home page at http://www.wi.nrcs.usda.gov, contact Renae Anderson at 608-662-4422 ext. 227 or renae.anderson@wi.usda.gov.

U.S. Geological Survey: Wisconsin Water Science Center

The mission of the U.S. Geological Survey - Water Mission Area is to provide hydrologic information and understanding needed for the optimal utilization and management of the Nation's water resources for the overall benefit of the people of the United States. The Wisconsin Water Science Center accomplishes this mission in large part through cooperation with other Federal, State and local agencies, by:

- Systematic data collection for long-term determination and evaluation of the quantity, quality, and use of Wisconsin's water resources.
- Conducting analytical and interpretive water-resource appraisals describing the occurrence, availability, and physical, chemical, and biological characteristics of surface water and groundwater.
- Conducting supportive basic and problem-oriented research in hydraulics, hydrology, and related scientific fields to improve investigation and measurement techniques, and to understand hydrologic systems in order to quantitatively predict their response to stress.
- Disseminating data and the results of investigations and research through reports, maps, Internet distribution and other computer information services.
- Coordinating the activities of Federal agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and groundwater.
- Providing scientific and technical assistance to other Federal, State, and local agencies, to licensees of the Federal Energy Regulatory Commission, and to international agencies on behalf of the U.S. Department of State.

The Wisconsin Water Science Center is currently conducting groundwater-related cooperative projects with the Wisconsin Department of Natural Resources (WDNR), UW Systems, UW-Extension through the Wisconsin Geological and Natural History Survey [WGNHS], Southeast Wisconsin Regional Planning Commission (SEWRPC), the Mole Lake, Forest County Potawatomi, Red Cliff, Bad River, and Lac Du Flambeau Tribes of Wisconsin, the US Forest Service, and numerous county and city governments. The federal funds that support these projects come from the Cooperative Water Program, an ongoing partnership between the USGS and non-Federal agencies (http://water.usgs.gov/coop/). In addition, the Wisconsin Water Science Center conducts projects that are funded entirely by USGS Federal programs. All recent and current projects that have a significant groundwater component are listed below.

<u>Projects funded cooperatively with state and local agencies:</u>

1. Operation and maintenance of the Wisconsin Observation Well Network; data collection, processing, archiving, and presentation (with WGNHS).
2. Development of the Water Use in Wisconsin summary report (produced at a 5-year interval); data collection and estimation, development of water-use coefficients and default values; evaluation compiled by aquifer, geographic, and political criteria (with WDNR).
3. Simulation of groundwater/surface-water systems in the vicinity of Chenequa, Wisconsin using Local Grid Refinement of the SEWRPC southeast Wisconsin groundwater-flow model (with Village of Chenequa and SEWRPC; Feinstein and others, 2010).
4. Evaluating land use and climate change effects on a southern Wisconsin trout stream - results of the Black Earth Creek modeling study (with WDNR and local communities and augmented by USGS Federal funds).
5. Assess the breeding range contraction of Great Lakes area Common Loons resulting from the alteration of habitat characteristics sensitive to climate change (with WDNR).

6. Simulation of groundwater/surface-water systems and wellhead protection in three tribal areas (with the Mole Lake, Forest County Potawatomi, and Lac du Flambeau Tribes, Fienen and others, 2011).
7. Simulation of the effects of water diversion from Shell Lake, Washburn County, on the shallow groundwater – lake system (with the City of Shell Lake and the WDNR).
8. Groundwater/surface water interactions in the Upper Fox River Valley of southeastern Wisconsin.

Wisconsin projects funded entirely by USGS:

1. Availability and use of fresh water in the United States: Glacial Aquifer System – Upper Midwest.
2. Hydrologic and biogeochemical budgets in temperate lakes and their watersheds, northern Wisconsin Long Term Ecological Research site, http://wi.water.usgs.gov/webb/.
3. Western Lake Michigan Drainages National Water-Quality Assessment http://wi.water.usgs.gov/wmic/index.html.
4. Great Lakes Restoration Initiative work on forecasting effects of future climate and land use change.

Compilation of Wisconsin Water-Use Data. Every 5 years, the USGS Wisconsin Water Science Center is responsible for presenting data collected and/or estimated for withdrawals and water diversions to the USGS National Water-Use Information Program. The 2010 water-use dataset is still in development. Accompanying this dataset, a report, detailing water use in Wisconsin, is published that serves many purposes such as quantifying how much, where, and for what purpose water is used, tracking and documenting water-use trends and changes, and facilitating cooperation with other agencies to support hydrologic projects. Presently, the USGS Wisconsin Water Use 2005 report (Buchwald, 2009) is available and can be accessed through the USGS Publication Warehouse at *http://pubs.er.usgs.gov/*.

Over the past year, there were four USGS investigations that incorporated a Wisconsin water-use component. The majority of these investigations integrate water-use data into hydrologic models that evaluate the impact of water use on water resources, including calculation of water budgets, groundwater-flow paths, and baseflow contribution to surface-water features. Water-use data and the periodic report are becoming increasingly critical in understanding water use, supporting Groundwater Management Areas around the state, and supporting implementation of the Great Lakes Compact.

Later this year, the USGS is planning to make its summarized water-use data, used in the compilation, stored in Aggregate Water-Use Database System (AWUDS) available through NWIS Web at *http://waterdata.usgs.gov/nwis*. Persons will have the option to retrieve data for water use by compilation year, category, area (e.g., county, watershed), and status (e.g., originally published versus later updated).

The Water-Use Information Program is evolving from being a data-collection and database management program to a water-use science program, emphasizing applied research and development of techniques for statistical estimation of water use, as well as analysis of water using behaviors (National Research Council, 2002). The USGS Wisconsin Water Science Center will continue to develop new and strengthen existing partnerships to broaden the understanding of water use in Wisconsin.

Additional information about these studies and other USGS water-use products, along with summaries of data and information on Wisconsin water use can be found at the following web site: http://wi.water.usgs.gov/data/wateruse.html.

Groundwater assistance to Wisconsin Tribes: Several bands of the Lake Superior Chippewa Tribes have been planning expansions to their drinking water infrastructure and, as part of that work, have needed simulations of the shallow groundwater system to understand the spatial pattern of water pumped by the proposed wells. Results for the first study for Mole Lake were published in Fienen and others (2011). Similar results for Forest County Potawatomi are forthcoming. The Bad River and Red Cliff Tribes also obtained funding from the Bureau of Indian Affairs to fund USGS to provide modeling and analysis of groundwater research on their respective reservations. This will include monitoring network design, field measurements, and state-of-the-art modeling.

Water Resources Impacts of Frac-Sand Mining: New advances in deep horizontal drilling and hydraulic fracturing ("fracking") technologies have unlocked massive natural gas reserves in shale formations in several areas around the United States. While little potential for such gas extraction is present in Wisconsin, several ancient sand formations provide ideal material for "frac-sand" which is a critical element for fracking. The sand, uniform in size and composition, is pumped into fractures that are created in the fracking process to keep them open, allowing gas to flow. The sand resources in Wisconsin are a major commodity now and sand mining has increased dramatically in the past two years. USGS, in cooperation with WGNHS and Chippewa County is undertaking a regional study in Chippewa County to characterize water resources impacts by frac sand mines and agriculture in the area. The 5-year project is currently in the last part of the planning stage and will launch in early 2013.

Background Water Resources Conditions in the Penokee/Gogebic Iron Range: Proposed taconite mining in the Bad River Watershed in northern Wisconsin has initiated increased interest in potential water resources impacts of the major land-use change. USGS Midwest Area Mining Initiative funds were provided to perform background screening level modeling of groundwater in the area around the ore body. This screening model will then be available for assisting in designing a monitoring network focused on particular impacts of concern to stakeholders. The Bad River Tribe also obtained funds through the Bureau of Indian Affairs which will expand the scope of this effort to include the Reservation in the downstream area of the Bad River watershed.

Evaluating land use and climate change effects on a southern Wisconsin trout stream: Results of the Black Earth Creek modeling study: A well-known trout stream and Outstanding and Exceptional Resource Water – the Black Earth Creek (BEC) watershed in northwest Dane County – is undergoing land use conversions from agricultural to residential and commercial. Currently the long-term impacts of urbanization on the base flow and stormflow (flood peaks) is not well characterized. Urbanization may increase both stormflow (Steuer and Hunt, 2001) and non-point source loads of nutrients, pesticides, and sediments. Because increased surface flows divert water that normally recharges to the groundwater system; urbanization can result in less groundwater being discharged as base flow to streams. By understanding the interactions between surface water and groundwater systems, the effectiveness of water management alternatives used to mitigate the effects of urbanization can be evaluated. A coupled groundwater/surface-water computer model of the basin has been constructed using the USGS code GSFLOW (Markstrom and others, 2008). This approach includes all elements of the hydrologic cycle including rainfall, snowmelt, evapotranspiration, interflow, streamflow, baseflow, and groundwater flow resulting in a quantitative characterization of the entire hydrologic system.

Expansions to the Groundwater Monitoring Network: In compliance with requirements of the Great Lakes Compact monitoring mandates, the USGS, WGNHS, and WDNR are cooperatively expanding existing groundwater monitoring resources. Of particular interest are areas of substantial past and present groundwater withdrawals in southeastern Wisconsin and the Green Bay area. These improvements represent excellent progress toward more informed management of groundwater resources, particularly where pumping stresses are important.

Dane County Groundwater-Flow Model: In cooperation with the WGNHS, the Dane County Groundwater-Flow model is being comprehensively revised. This model, originally published in 2000 (Krohelski and others, 2000) has been used for planning by county and local governments throughout the county. The 1999 model was developed using the state-of-the-art modeling and calibration tools at the time, techniques, software, and data continue to evolve. As a result, updating the Dane County model using current capabilities will enhance the value of the model for planning. Improvements include better representation of surface water features and their interactions with the groundwater system, a finer grid resolution, more representative treatment of recharge, new findings related to the stratigraphy of the county simulation of transient conditions (both historical and predictive), and improved calibration and uncertainty calculation techniques.

Groundwater and Surface Water Interactions in the Upper Fox River Valley of southeastern Wisconsin (Feinstein and others, 2012): The Fox River Valley, including Waukesha County, is experiencing rapid urbanization and consequently increasing demands on deep groundwater pumping for domestic supply needs. These demands are stressing the availability of groundwater and, in some cases, water-quality considerations (such as radium in Waukesha County) are making it difficult to meet the increased needs through traditional sources. One alternative is to increase shallow pumping from the shallow aquifer that is more closely connected with the surface water system. To better understand both potential surface water impacts due to increased shallow pumping and to characterize exchange between the shallow groundwater and surface water, a model is an important tool for resource management. USGS has been involved in creating a model using the newly developed MODFLOW-NWT code (Niswonger and others, 2011) for this purpose.

Great Lakes Restoration Initiative: The USEPA Great Lakes Restoration Initiative (GLRI) has a substantial footprint in Wisconsin. This large, multi-year initiative is aimed at improving water and ecological conditions throughout the Great Lakes Basin (http://www.epa.gov/glnpo/glri/). Most of the projects are not directly connected to groundwater. However, the surface water modeling using the Precipitation Runoff Modeling System (PRMS) throughout the Basin provides important information on groundwater/surface water interactions and recharge. PRMS modeling combined with proposed background work at several sites in the Lake Superior basin will be vital for responsible management and evaluation of proposed mining activities.

Development and use of the USGS Coupled surface-water groundwater model code at the Northern Wisconsin Long Term Ecological Research site: Modeling has focused on the local isthmus scale (Fienen and others, 2009) as well as larger watershed-scale (Hunt and others, 2008). Simulations of climate-change effects on groundwater systems have often been simplified, using estimates to characterize changes in the hydrologic cycle. The recently developed USGS groundwater/surface-water code, GSFLOW (Markstrom and others, 2008), combines two widely used models: PRMS and MODFLOW. Using this approach, the effect of projected rainfall and temperature changes, due to climate change, on stream flow and groundwater recharge can be predicted.

Two relatively simple climate scenarios were examined using a GSFLOW model of the USGS Trout Lake Water, Energy and Biogeochemical Budgets (WEBB) study site in northern Wisconsin, USA (Hunt and others, 2008; Walker and others, 2009). This work was followed up a more encompassing set of analyses using 3 IPCC emission scenarios from 4 GCMs (Markstrom and others, 2012; Hunt and others, 2012; Walker and others, 2012). Even though the simulations could be improved by inclusion of more sophisticated processes and scenarios, these results demonstrate a utility for hydrologic modeling for today's resource management actions.

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For more information please contact Randy Hunt (608-821-3847),* rjhunt@usgs.gov*, Mike Fienen (608-821-3894),* mnfienen@usgs.gov*; Paul Juckem (608-821-3845),* pfjuckem@usgs.gov*, Cheryl Buchwald (608-821-3873),* cabuchwa@usgs.gov*, USGS, 8505 Research Way, Middleton, Wisconsin, 53562-3581 or visit the USGS Wisconsin Water Science Center Groundwater Team web page (http://wi.water.usgs.gov/ground-water/index.html).

Arsenic Monitoring and Research in Northeastern Wisconsin

Wisconsin is also a leader in groundwater monitoring for naturally occurring compounds. Two projects in the DNR Lake Michigan District (Stoll, 1992; 1994) identified the existence of arsenic contamination in groundwater. Homeowners were alerted through direct mailings, public meetings and mass media news releases. Continuing educational efforts and studies were done to alert 72,000 people of their potential exposure to the substance in their drinking water.

In one of the studies the DNR coordinated with the DHS to conduct health surveys on individuals consuming locally contaminated water supplies and made appropriate health recommendations. Local County Health Departments in affected areas are also actively monitoring groundwater quality and are providing assistance to homeowners. In 2001 and 2002, DHS staff received additional funding to conduct a follow-up investigation on the relationship between exposure to inorganic arsenic in water and health outcomes (Knobeloch, 2002). As part of this research effort, local health departments, DNR staff, town clerks and others have conducted well sampling campaigns in townships in the affected counties.

More than 2200 households submitted samples and returned health surveys, providing health and exposure information for 6669 individuals. Approximately 20% of the water supplies contained arsenic levels above 10 µg/L. Slightly more than 10% of the families consumed water that had an arsenic level greater than 20 µg/L. People over the age of 50 were more likely to report a diagnosis of skin cancer if they had consumed water that had an arsenic concentration greater than 5 µg/L for 10 years or more. Cigarette use was also associated with higher skin cancer rates: residents who both smoked and consumed arsenic-contaminated water reported the highest skin cancer prevalence rate. No association was seen between exposure to arsenic-contaminated water and the incidence of other types of cancer. However, findings from this study were consistent with previously reported associations between arsenic exposure and the prevalence of adult onset diabetes and cardiovascular disease.

As part of this study, DHS conducted a survey of households in selected areas of northeastern Wisconsin affected by arsenic in groundwater. The goal of this survey was to assess residents' understanding of their laboratory results, learn what actions people have taken in response to their results, and to identify barriers to increased participation in well sampling campaigns. The survey revealed that more than 80% of those who perceived their well water to be unsafe had taken action to reduce their exposure to arsenic, usually by installing a treatment system or by drinking bottled water. Among those who had not sampled their wells for arsenic, confidence in the safety of their well and lack of information about how to have their water tested were the most commonly cited reasons. Many of those who had not had their wells tested had reported that they had only recently moved into their homes or into the area.

Studies conducted by DNR of the extent of the arsenic contaminated area led to the establishment of an "Arsenic Advisory Area" (AAA) in the early 1990s (Stoll, 1992; 1994). This area included the strip of land five miles either side of the bedrock subcrop of the St. Peter Sandstone, extending in a northeasterly trend, from a location just southwest of Oshkosh, to a location just west of Green Bay. For this area, DNR developed special well construction specifications, more stringent than the minimum Private Well Code requirements. DNR guidance recommends the installation of 80 feet of casing through the sandstone contact for drinking water wells in the AAA (Weissbach, 1998). These specifications were recommended, but not required, for new wells constructed within the "Arsenic Advisory Area". The specifications, when followed, increased the likelihood of installing a well with low arsenic levels. A special well casing depth area (SWCDA) was established for the Town of Algoma in Winnebago County in 2001. In this area, all wells must be drilled with mud/wash rotary methods, Bradenhead grout methods and cased to the Cambrian sandstone aquifer.

In 2002 the WGNHS completed field experiments in the Fox River Valley that evaluated mechanisms of arsenic release to groundwater from domestic wells completed in the St. Peter sandstone aquifer, including studies of arsenic exposure to residents in the area and the effects of well chlorination on arsenic levels (Gotkowitz 2002). Findings support the hypothesis that high levels of arsenic in groundwater occur where mineralization is oxidized in well boreholes. However, two distinct geochemical mechanisms appear to contribute low to moderate arsenic concentrations to well water in this aquifer. 1) Oxidation of sulfide minerals may release arsenic to groundwater in confined portions of the aquifer; oxidation may have occurred at some time in the geologic past, or current levels of oxygen dissolved in the groundwater may be sufficient to permit slow oxidation to occur. 2) Reductive dissolution of arsenic-bearing iron oxides also seems to contribute low to moderate levels of arsenic to groundwater when the geochemical environment becomes sufficiently reducing. This occurs under some domestic water use patterns, because increasing groundwater residence time in wells correlates to the onset of strongly reducing conditions and higher arsenic concentrations. The well borehole is a microbiologically active environment, and biogeochemical reactions likely contribute to the observed increase in arsenic concentrations. Reducing the volume of well bore storage relative to water use may help to limit arsenic concentrations in well water. Results of this study were presented to DNR Drinking Water and Groundwater Program staff and used by the DNR to develop well construction guidelines for Outagamie and Winnebago Counties.

Other projects addressed related aspects of arsenic in groundwater. One such study refined analytical methods for arsenic detection (Aldstadt 2002) and another developed prediction tools using multivariate analysis of geochemical data (Shafer et al, 2007). Two projects investigated the role of chlorination in arsenic release (Sonzogni 2003; Gotkowitz, 2007), three projects investigating treatment methodologies for both private and public water supplies (Anderson 2003; Park 2003; McGinley 2003; Li 2011), and one study addressed arsenic in southeastern Wisconsin aquifers (Bahr and Gotkowitz 2004). This body of work provides information about the occurrence, health risks, and remediation of arsenic in Wisconsin's drinking water supplies. On-going efforts include compilation of private well sampling results. The goal of this effort is to continue identification of areas in Wisconsin with relatively high numbers of wells impacted by naturally occurring arsenic.

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The Atrazine Rule

The development of the Atrazine Rule (ATCP 30, Wis. Adm. Code) illustrates how the benefits of state-funded research and monitoring can build on one another. In the mid-1980s the corn herbicide atrazine was first detected in monitoring wells and private drinking water wells in Wisconsin. The first systematic well sampling program to characterize atrazine contamination on a statewide basis was the 1988 DATCP Grade A Dairy Farm Well Water Quality Survey (LeMasters, 1989). This state-funded well survey estimated that atrazine was present in 12% of the Grade A Dairy Farm Wells in the State.

This study left unanswered many questions regarding the sources, groundwater susceptibility, and the presence of pesticides other than atrazine. Without better information on these and other questions, it was challenging for DATCP, the agency charged with groundwater protection related to agricultural chemicals, to develop a plan of action. It was obvious that a concerted information gathering program was needed. Over the next several years, before and during the development of the DATCP atrazine rule, the Wisconsin Groundwater and Pesticide Research Program played an essential role in providing the needed information. Research and monitoring were conducted on several topics that played a direct role in the evolution of the atrazine rule.

The state research and monitoring program funded several key projects to better understand the sources of atrazine contamination. When atrazine was first found in groundwater, an argument had been made that this was the result of point sources such as spills and mishandling. One of the most important findings that allowed DATCP to begin developing the atrazine rule was that normal agricultural applications of atrazine could lead to groundwater contamination. The DATCP groundwater monitoring project for pesticides (Postle, 1986-96) used monitoring wells located next to agricultural fields to study groundwater contamination by atrazine and other pesticides. This study showed that atrazine from field use on sandy soils could cause contamination, often above the 3 µg/L ES. The UW Water Resources Center conducted a detailed hydrogeologic study (Chesters, 1990-91) at a farm in Dane County and showed conclusively that atrazine contamination could result from both field applications and mixing/loading practices. With the knowledge that nonpoint contamination of groundwater by atrazine was indeed occurring, DATCP could develop ways to reduce this contamination.

State-funded research was essential in showing that atrazine contamination did not follow simplistic notions of groundwater contamination susceptibility. One of the most important findings was that the Central Sands and the Lower Wisconsin River Valley (LWRV), two areas that appear similar in soils and agricultural practices, had significantly different susceptibility to contamination. These differences were pointed out in several research projects conducted by the UW Soil Science Department (Daniel, 1991; Lowery, 1991; McSweeney, 1991; Lowery, 1992-3). This information had a direct influence on the atrazine rule in that there is now a use prohibition in the LWRV and managed use in the Central Sands.

Another key finding related to the susceptibility of groundwater to atrazine contamination was that many of the areas with high frequency of detections had medium textured (loamy) soils. It had previously been thought that these areas were less susceptible to leaching and groundwater contamination than areas with sandy soils. State-funded research and monitoring efforts, however, showed that the intensity of atrazine use, in addition to soil and geologic conditions, played an important role in the contamination. This finding helped to explain why many areas in south central Wisconsin, with medium textured soil and high corn production, had many wells contaminated with atrazine. This knowledge allowed DATCP to adopt management strategies for reducing atrazine contamination in these areas.

When atrazine was first discovered in Wisconsin's groundwater in the mid-1980s, DATCP was interested in managing its use based on predictive modeling of contamination processes. Modeling activities funded

by the state research program, however, indicated that the behavior of atrazine and other contaminants in the environment was complex and could not be reliably predicted by modeling. In response to this finding, DATCP adopted a more empirical approach to identifying management areas. Actual well results were plotted on maps and, together with an analysis of soils and geology, management areas were delineated.

When monitoring and rule making efforts for atrazine first started, parent atrazine was the only compound that was considered. As more research was conducted, however, it was discovered that three metabolites (breakdown products) of atrazine were present in groundwater and were of health concern (Chesters, 1990-91; LeMasters, 1990; Cowell, 1990; Cates, 1991). State-funded sampling programs showed that due to the presence of atrazine metabolites, the groundwater problems were more serious than previously considered. This knowledge allowed DNR to strengthen the groundwater standard for atrazine in 1992 and allowed DATCP to strengthen the atrazine rule in 1993 and extend required use reductions to the entire state.

It is interesting to try to envision how DATCP's atrazine rule would look if it did not have the benefit of the intensive research and monitoring efforts. It is safe to say that it would not have been developed on as good an understanding of the behavior of atrazine in the environment or the geographic patterns of contamination. It is possible that without the intensive monitoring efforts, the full extent of the problem would not have been discovered and atrazine use would not have been reduced. On the other hand, it is possible that with inadequate knowledge a "broad brush" approach would have been taken. This could have resulted in unfair regulations that were not tailored to the different geographic areas of the state.

Two important aspects of environmental regulation that promote its acceptance are that it is based on science and that it is fair. Good research is necessary to achieve these two characteristics. The Atrazine Rule has experienced a relatively high degree of acceptance due to the effort that was put into its development.

Comprehensive Planning

The State of Wisconsin requires Wisconsin cities, villages, towns and counties that adopt or amend zoning, land division or official mapping ordinances to do so consistent with a comprehensive plan beginning January 1, 2010. As of November 2010, the Wisconsin Department of Administration estimated that 84% of local governments had adopted or were in the process of developing a comprehensive plan. Of those communities that have not adopted a plan, many do not exercise land use regulations that require consistency with a plan (Herreid, 2011).

Communities that rely on groundwater as their sole source of water need to assess the magnitude and limits of their water source as part of their comprehensive plan, but most have little expertise in quantifying and protecting their water supply. A project funded by the UWS partnered with such a community (Richfield, WI) to determine what kinds of groundwater supply information are most relevant and usable for planning from a community's perspective (Cherkauer, 2005). This study determined that a good basic understanding of the geology, sources, sinks and water balance of its aquifer system are needed so that residents and community leaders know where their water comes from. Interaction with users at all levels is also crucial to developing the awareness needed to create long-term plans and supporting laws to ensure a sustainable water supply under foreseeable future conditions. The next step is to share this model with other communities to help them plan how best to actively manage and protect the recharge areas that supply their water.

A related UWS-funded project evaluated whether Wisconsin communities are addressing groundwater in their comprehensive plans, and what tools would make them more likely to do so (Markham, 2005(A)). This project provided multiple presentations to local and state groups involved in groundwater planning; a webpage of study results; articles in a Center for Land Use Education newsletter distributed to more than 160 community planners and educators; a presentation to about 100 people at the 2005 conference of the American Water Resources Association-Wisconsin Section; and publication of an article in a national journal (Markham, 2005(B)).

A DNR- and USGS-funded project provided support for centralizing access to groundwater information for use in comprehensive planning (Markham, 2008). The project utilized an interagency team of federal, state and local agencies to assist numerous Wisconsin communities with comprehensive planning by providing groundwater information and data in an accessible and user-friendly manner. Specifically, the interagency team provided personalized assistance for three pilot counties in the form of a 20-30 page report and a locally-tailored presentation for citizen plan commission members. The same interagency team prepared a centralized website that provides a suggested process for integrating groundwater information into comprehensive plans. The website also includes web pages for each of Wisconsin's 72 counties that include local data about groundwater susceptibility, sources of drinking water, groundwater quality, potential sources of contaminants, groundwater quantity, and money spent on cleanup and ground-water protection strategies. The website is available at *http://wi.water.usgs.gov/gwcomp/index.html*. From June 2009 through May 2010 the website averaged over 500 successful requests for information per day, and over 80 successful requests for pages per day. The comprehensive planning law states that comprehensive plans must be updated at least every 10 years. As communities update their plans, the most recent data on the website is from 2002-2006 for water quality and 2005 for water quantity.

Through its Outreach and Partnership Subcommittee, the GCC will seek ways to further assist local communities in their planning efforts to encourage groundwater protection. Long term hosting and maintenance of the site is undetermined; other than correcting identified errors this site is currently static. Funding for development of this web site came from the DNR through the GCC-coordinated Joint

Solicitation for Groundwater Research & Monitoring. Additional funds were provided by the USGS Cooperative Water Program.

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Detection and Monitoring of Microbiological Contaminants

Protecting groundwater from microbial contamination is a top public health priority. The United States and Canada experience significant levels of gastrointestinal disease from drinking water, more than 70 percent of which is associated with contaminated well water. The GCC has solicited research projects during the last several years that attempt to improve understanding of microbiological aspects of groundwater contamination.

Bacteria

Several projects have focused on developing new techniques for detecting, quantifying, and monitoring microorganisms in groundwater and soils. Researchers at the UW-Madison Soil Science Department developed a rapid molecular method using the polymerase chain reaction (PCR) to assay soils for the presence of specific sewage-borne pathogens (Hickey 1998). PCR-based methods eliminate the need to culture organisms for detection, and remedy shortcomings of traditional techniques by allowing rapid, sensitive, and specific identification of the pathogens of concern rather than indicator organisms. The PCR protocol Hickey developed was designed to detect DNA originating from *E. coli*, which is one of the major species of bacteria associated with human waste. This method is capable of distinguishing *E. coli* DNA from that of its closest relative, *Shigella* and detecting the DNA equivalent to about 20 cells.

Because they have the capacity to co-metabolize a wide variety of organic chemicals, including halogenated compounds, methanotrophic bacteria have significant potential for bioremediation. The UW-Milwaukee Department of Biological Sciences has developed methods for quantification of methanotrophs in groundwater (Collins 1998, 2000). These methods, that include competitive PCR and direct PCR, provide approaches to monitoring bioremediation and natural attenuation. In addition, this work has provided the basis of another study that applied direct PCR to the detection of pathogens in groundwater (Collins 2002).

A study by the Wisconsin State Laboratory of Hygiene (WSLH) investigated storage and handling requirements for water samples submitted for coliform and *E. coli* analysis (Degnan and others, 2003). Currently the USEPA has no guidelines for sample holding times and shipping temperatures for drinking water samples submitted for *E. coli* testing. The study provided evidence to expand the allowable storage time of water samples submitted for *E. coli* analysis beyond the current eight hour limit as well as supporting a single preservation protocol for both surface waters and drinking water samples. A change to a maximum holding time of chilled samples for up to 30 hours could easily be supported by the data presented in this study. The data also called into question the current practice of allowing up to 48 hours for submitting drinking water samples with no attempt to cool them. A reduction in the time period to 30 hours, or a requirement to ship the samples at less than 10 degrees C, could be supported by the data.

Another WSLH study developed a culture method for detecting *Helicobacter pylori* from a heterogeneous microbial population in water, and then use this method to establish a data base for its occurrence in Wisconsin groundwater (Degnan and others 2003). Prior to this study, there were no reliable methods for detecting viable *H. pylori* in environmental samples (water, manure, vegetables, etc.). *H. pylori* is recognized by the World Health Organization to be the primary cause of peptic ulcers, chronic gastritis and stomach cancer. About 50% of the U.S. population is thought to be symptomatic or asymptomatic carriers, even though the source of human infection is not well understood. The efforts of this study resulted in the development of a high quality plating media for selecting viable *H. pylori* from mixed microbial populations. Samples from over 400 private wells were *H. pylori*-absent, including wells used by infected residents. These results suggest that the route of *H. pylori* to humans in Wisconsin probably does not involve private well water.

WSLH researchers in the Water Microbiology Unit recently completed testing of a hollow fiber ultrafiltration method for concentrating low levels of microorganisms from large volumes (up to 100 L) of drinking water. Acceptable levels of organism recoveries were demonstrated for bacteria (*E. coli* and enterococci), viruses (MS2 coliphage) and parasites (*Cryptosporidium* and *Giardia*). Quantitative recoveries were recorded for concentrations as low as 0.3 organisms per 100 ml. Establishing testing with lower detection limits for pathogens and indicators adds an additional margin of safety in the protection of public health from waterborne diseases.

A study conducted at the WSLH (Long, 2009), and funded by the DNR, developed a Real-Time PCR assay for the molecular detection of *Rhodococcus coprophilus.* Detection of *Rhodococcus coprophilus* is an indicator of fecal pollution from grazing animals. This data is useful as part of the WSLH's "toolbox" of microbial source tracking methods to determine the source of fecal contamination of groundwater. Other assays performed as part of the microbial source tracking (MST) toolbox are; genotyping of male-specific coliphages, detection of sorbitol-fermenting *Bifidobacteria* and detection of *Bacteroides* using different primer and probe sets to distinguish between human and animal sources of fecal pollution. In the last 2 years there have been 49 groundwater samples collected for analysis. One sample was from a drain tile and the others were from 40 different private wells (with 8 wells sampled twice). Results indicate 28 of the 49 samples were positive for contamination from grazing animals, 3 samples tested positive for bacteria associated with human waste, 10 samples tested positive for recent but inconclusive fecal contamination, and 9 samples tested clean. The use of these analyses has proven valuable to DNR in granting Well Compensation awards for replacement wells for wells contaminated with livestock waste (manure)

Recently, a new "tool" for the WSLH's microbial source tracking program was developed by Sibley et.al that enables scientists to detect bovine adenovirus. This assay determines environmental fecal contamination from those animals. These viruses were detected from both stool and urine (Pedersen, 2008).

A UW Water Resources Institute project examined the strengths and weaknesses of 10 enzyme-based tests approved by the U.S. EPA for detecting total coliform and E. coli in drinking water (Olstadt and others, 2007). The results suggest these tests differ significantly in their ability to detect/enumerate total coliforms and E. coli and to suppress false positive results from *Aeromonas ssp*., a non-coliform organism. The most significant of these findings was the inability of some test method/sample matrix combinations to even detect E. coli in high concentrations.

The release of antibiotics into our water resources is driving efforts to characterize the occurrence, fate, and transport of resistant bacteria in the environment. In a recent WRI-sponsored project, onsite-wastewater treatment systems were evaluated as a potential source of genes that encode antibiotic resistance in bacteria (McMahon, 2006). The concentrations of resistance genes in the septic tanks were several orders of magnitude higher than those observed in treated municipal wastewater effluent. The investigators hypothesize that past agricultural activity may have contributed to the presence of resistance genes in subsurface bacteria, but long term sampling with higher spatial resolution is required to adequately confirm the hypothesis.

Drinking water quality is negatively impacted by the presence of biofilms (aggregate of microorganisms) inside distribution pipes and storage containers. The drinking water industry considers biofilms to be the major cause of problems with water quality, public health as related to water consumption, and infrastructure maintenance. WSLH and Process Research Solutions, LLC (private consulting company), funded by a 2010 Water Research Foundation grant, are partnering to study the relationship between water chemistry parameters and the proliferation of biofilms in distribution systems. The research model

is described the CRC Press publication *Water Distribution System Monitoring*, authored by Abigail Cantor who is also a research partner on the project. Abigail designed and fabricated a metal coupon module that can be installed within a municipal water utility distribution line, removed for testing, and transported within its own shipping container. The module is equipped with metal coupons (iron, copper, or lead) that mimic the pipe surface. Modules are shipped to WSLH for quantitative testing, using a process that was developed here at WSLH and published in the aforementioned book.

Eight such modules are due for testing in July of 2012 after installation up to two years within four Wisconsin utilities (Onalaska, Marshfield, Madison, and Kenosha). It is hoped that the data collected will help construct a method to prevent biofilm development rather than expend effort and budget to cure it.

Viruses

The Marshfield Clinic Research Foundation has investigated the association of pathogenic viruses and bacteria in private wells with incidences of infectious diarrhea and indicators of well water contamination (Borchardt 1998, 2000). In general, infectious diarrhea was not associated with drinking from private wells, nor was it associated with drinking from wells positive for total coliform. However, wells positive for enterococci were associated with children having diarrhea of unknown etiology, which was likely caused by Norwalk-like viruses. Final results indicate that the incidence of virus contamination in private wells may affect 4-12% of private wells. Of concern to drinking water regulators is the seasonal variability of the virus occurrences and lack of correspondence between viral presence and common microbial indicators.

In another study with the US Geological Survey, Marshfield researchers found that 50% of water samples collected from four La Crosse municipal wells were positive for enteric viruses, including enteroviruses, rotavirus, hepatitis A virus, and Norwalk-like virus (Hunt, 2003; Borchardt, 2004). As with the private well study, there was no correspondence to common indicators of sanitary quality. More surprising, there was no relationship between presence of surface water in the well water samples as determined by isotope analysis and virus occurrence. Recent work between Marshfield Clinic and USGS targeted the source and transport of viruses to drinking water wells. This work was funded by the WDNR and USGS, and involved field investigation using physical measurements, wastewater tracers, and virus analyses. Water sampling screening in 14 Wisconsin communities again documented virus occurrence in wells without surface water sources, and a second sanitary sewer source was supported by wastewater tracer presence. Using more intensive characterization at one municipal well in three Wisconsin communities, the relation between high wastewater tracer and virus occurrence was documented, and also demonstrated sufficiently short travel times such that viruses would be expected to remain infectious even in a 400 foot deep municipal well. Given the wide extent and age of infrastructure, these findings suggest that viruses may be more common than previously expected in Wisconsin drinking water. Recent work by Marshfield Clinic has begun to evaluate whether the viruses are inactivated through disinfection processes, or result in illness in the community. This type of research into the link between virus occurrence and human health will provide the overall context to this extensive Wisconsin research topic.

Very recently viruses have also been to found in deep bedrock wells that are thought to be protected by low permeability confining units. Studies funded by AWWARF and DNR examined virus occurrence in three deep (>400 feet) confined bedrock wells serving Madison. The surprising result was that infectious viruses were repeatedly present in two of three wells sampled. Examination of potential virus sources and pathways was inconclusive, but sampling results suggest that the deep groundwater is more vulnerable to virus contamination than previously thought (Borchardt, 2007). A follow-up study (Bradbury and others, 2010) funded through the Wisconsin Joint Solicitation found viruses in each of seven deep wells sampled over a period of two years, with many samples positive for infectivity. Correlation between viral serotypes found in sewage, lakes, and groundwater suggests very rapid transport, on the order of weeks, from the source(s) to wells. If such rapid transport exists, then deeply-cased municipal wells may be much

more vulnerable to shallow contamination than previously assumed (see http://wisconsingeologicalsurvey.org/wofrs/WOFR2010-04a.pdf). One outcome of the initial study was the use of increased disinfection by the Madison Water Utility in order to assure public health.

A combined microbial and chemical target toolbox is being tested, validated and applied at WSLH to conduct microbial source tracking. The toolbox uses microbial and chemical tracers that are specific or unique to waste sources to determine sources of contamination and allows for a weight-of-evidence approach for identifying sources of contamination. Current methodology discriminates between human sewage-related sources and animal fecal contamination and can identify grazing animal contamination. This suite of tests has been applied to contamination events in Dodge and Door Counties, among others. In one instance, an improperly installed septic system was the culprit. In another instance, farm field manure runoff during heavy rains was identified. By identifying the source of microbial contamination, remediation or correctional actions can be targeted and the spending limited funds on "false sources" can be avoided. Research to improve on the methods in this toolbox is being funded by the DNR and UWS.

After several years of development and validation, researchers at the Marshfield Clinic Research Foundation now possess the capacity for high-throughput testing of waterborne viruses. Virus tests include six common human enteric virus groups and six common bovine viruses. The number of tests that used to take three months to complete can now be accomplished in an afternoon. Recently, these researchers completed a study involving more than 20,000 virus analyses of the groundwater supplying drinking water in 14 Wisconsin communities. This level of laboratory capacity relies on three major advances: 1) Inexpensive and effective concentration of waterborne viruses using glass wool filtration, a method developed and fully validated at Marshfield Clinic (Lambertini, 2008); 2) Virus detection by real-time quantitative polymerase chain reaction (qPCR) using recently developed high-throughput platforms and highly specific fluorescent probes; and 3) Development at Marshfield Clinic of a unique Laboratory Information Management System (LIMS) for quality assurance, quality control, and data management of analyses for waterborne pathogens. Contingent on several more advances, the researchers believe it will be possible to screen a water sample for all common waterborne pathogens using an approach that is inexpensive, efficient, and reliable.

The sole use of bacterial fecal markers is not adequately protective of human health or indicative of the presence of other microorganisms, including viruses. Therefore, the fecal source tracking toolbox available to WSLH has been expanded to with the conception and optimization of novel species-specific PCR assays for distinguishing human from bovine adenoviruses in groundwater samples (Pedersen, 2008, 2010 and 2011). These viruses are widespread in human and bovine populations, and have already proven useful for indicating the presence and source of wastes in groundwater. Because the environmental fate and transport behaviors and prevalence of enteric viruses can differ, we are currently evaluating additional species-specific virus targets, polyomaviruses and Torque Teno Viruses. The additional of these viral targets will provide the WSLH with unique source tracking capacity and with a robust set of makers for describing the presence of fecal contamination. The interrogation of samples for multiple viral and bacterial targets is especially important for situations where contamination is suspected in private wells.

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Groundwater Drawdowns

Large-scale withdrawals of groundwater are adversely affecting the environment, economy and public health in large areas of Wisconsin. These drawdowns can cause the water level in wells, lakes, streams and wetlands to drop or cause them to dry up entirely. Drawdowns can also cause the levels of arsenic, radium, and salinity in drinking water to increase.

State-supported research is using groundwater information and groundwater flow models developed at a regional scale and adapting it for use at the local level. In Washington County, researchers worked with the city of Richfield to develop a protocol for quantifying its groundwater budget (Cherkauer and LaCosse, 2001). That information will be coupled with projected changes in land use and pumping demand to define the effects of several development scenarios on the community's water supply. This protocol is currently being applied to the entire 7-county SEWRPC region of Southeast Wisconsin.

Regional studies have identified central Waukesha County as an area where continued deep groundwater pumping might be causing the deep aquifers to become unconfined as water levels fall (Eaton, 2004). A 2004 project installed one deep piezometer near Pewaukee for use as a monitoring point to document water-level declines.

The Maquoketa shale forms an important aquitard, or low permeability geologic layer, in eastern Wisconsin. Restriction of recharge to the deep sandstone aquifer by the Maquoketa is the major reason that drawdowns in the deep sandstone aquifer in Southeast Wisconsin are so severe. Hart and others (2007) investigated groundwater flow across the Maquoketa and in particular studied how cross-connecting wells and fractures control flow across the shale. Cross connecting wells are generally older wells that are open to aquifers both above and below the shale. These wells form conduits from one aquifer to another and can cause drawdown in the upper aquifer while also causing water-quality degradation in the lower aquifer. The investigators searched state records and discovered that approximately 170 such wells exist in Southeast Wisconsin. They also investigated faults and fractures through the Maquoketa and discovered that such features, although sparse, also can have a major impact on the overall rate of flow across the shale. The implication is that naturally occurring low-permeability formations, such as the Maquoketa, may transmit more water than originally thought due to the presence of cross-connecting wells and fractures.

Another project investigated the sources of high salinity and radium in the deep sandstone aquifer that supplies water to residents of eastern Wisconsin (Grundl and Bradbury, 2000). This project examined the chemistry of the groundwater and the rock formations of this complex aquifer to determine the causes behind rising salinity and radium levels to help city planners and water utility directors better understand the relationship between well operations and water quality in this region, and evaluate effects of urban growth on water supplies. Results showed that radium in excess of the EPA drinking water limit occurred in a band located just inside the western edge of the Maquoketa Shale. As groundwater in the deep sandstone aquifer transitions from unconfined conditions to confined conditions beneath the Maquoketa Shale, geochemical interactions with aquifer minerals, primarily sulfate minerals, cause radium levels to rise. A more complete understanding of geochemical processes occurring in the deep sandstone aquifer is hindered by the paucity of data points, in particular the complete lack of vertically discrete data.

In late 2007, several suburban communities in the Lower Fox Valley reduced consumption of groundwater by switching to surface water supplied by pipeline from Lake Michigan. As a result, water levels in the deep sandstone aquifer near Green Bay in Central Brown County have begun

to recover. In mid-2007 the WGNHS began an effort to monitor the water level recovery in the deep sandstone aquifer near Green Bay with the objective of documenting the recovery and improving our understanding of the deep hydrogeologic system in this region of the state (Luczaj and Hart, 2009). Since 2007, as part of a regional study, water levels have been monitored and collected into a database. As of spring 2009, water levels had risen by 100 feet in much of the region and, in some wells, by more than 150 feet. In 2011, the rate of recovery has significantly slowed. The water levels are still rising but more slowly and are expected to level off in the next several years but its not clear exactly how soon or at what level (Luczaj, 2011, and Maas, 2010). Another result of the decrease in pumping and increasing water levels is that some wells in the northwestern part of the GMA near Howard and Suamico have begun flowing. The highest level since recording began in 1952 was recorded in a USGS monitoring well in April 2012. This well is located on the southern shore of Green Bay in the deep sandstone aquifer. In addition to water levels, the pumping rates of current groundwater users in the region have also been collected. The study also identified a smaller cone of depression near Little Chute, Kaukauna, and Kimberly where water use has remained steady. The water levels there were not affected by the decreased pumping to the north and have remained relatively steady since 2005.

These projects illustrate the importance of monitoring the resource. We now know that if the pumping around Little Chute, Kaukauna, and Kimberly does not impact the Central Brown County cone of depression. We also know that a further decrease in pumping will cause more wells to flow along the western edge of the Central Brown County cone of depression and that if pumping stays below 4-7 mgd that the St Peter sandstone will likely remain saturated and will pose less risk for release of arsenic.

Other State-supported research has investigated the viability of aquifer storage and recovery (ASR) for Wisconsin, where excess water is stored in aquifers when demand is low and withdrawn for use when demand increases (Anderson, 2004). Computer models of groundwater flow and transport in ASR systems have been developed for two representative groundwater systems in Wisconsin. A better understanding of pumping rates, storage times and other factors that affect recovery efficiency of ASR systems has helped guide decision-making about using these systems in Wisconsin.

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Groundwater Monitoring At Solid Waste Disposal Sites

The DNR's Waste and Materials Management (WMM) program received project funding ten times from 1985 to 2003 through the joint solicitation process. These projects have benefited the program in many ways, primarily impacting regulations and monitoring practices.

The first two studies (Friedman, 1985-87; Battista, 1988-89) revealed for the first time that groundwater around many Wisconsin landfills was contaminated by VOCs. The studies also showed that VOC contamination of groundwater was more common at unlined municipal solid waste landfills than at other types of landfills. A follow-up VOC study (Connelly 1993-94) showed that VOC levels have decreased at most of the unlined landfills, though at many of the sites VOC levels do not show continued decline. There was no VOC contamination definitely attributable to leachate migration at any of the older, engineered landfills confirming that these sites are performing as WMM program staff had hoped. The results of the three VOC studies were used to establish requirements for VOC sampling at new and existing landfills. These studies also indicated that inorganic compounds could be useful in predicting VOC contamination at landfills. Therefore, until EPA rules began requiring VOC monitoring in 1996, the WMM program allowed sites to sample for inorganic parameters as part of routine monitoring and not sample VOCs unless inorganics were elevated. The VOC studies provided valuable data that were used to convince EPA to reduce the number of VOCs required for monitoring at municipal solid waste landfills in Wisconsin. This reduction in monitoring (the use of inorganics and the reduced number of VOCs when they are required) allowed landfill owners considerable cost savings while maintaining equivalent environmental protection. Additionally, the VOC data were used to require responsible parties to define the degree and extent of contamination and remediate groundwater contamination at their landfills.

Research on methods of assessing groundwater quality data and data quality control completed in the third VOC study has been helpful to WMM program staff and consultants in interpreting groundwater quality data from landfills and other facilities. This study also showed the need to require laboratories to report data between the limit of detection and the limit of quantification.

An assessment of Wisconsin's Groundwater Monitoring Plan program (Pugh, 1992) for active non-approved landfills provided the documentation of a set procedure for selecting monitoring sites. This information was useful in meetings held to convince municipalities that they had not been singled out for further evaluation of groundwater contamination and to demonstrate that the process used for selecting landfills for monitoring was objective.

Three studies from 1991 to 1994 on the potential groundwater impacts at deer pits, yard waste sites, and construction and demolition landfills (Pugh, 1992-3; Pugh, 1994) were conducted because little or no data existed on the potential impact to groundwater from these sites. Research provided the information necessary to revise rules and establish policy regarding monitoring and siting of construction and demolition (C/D) landfills, deer pits, and yard waste sites in Wisconsin. The groundwater study of deer pits showed that impacts were minimal and helped the WMM program decide not to require liners and loosen some construction and reporting requirements. Similarly, the yard waste site study showed only minor groundwater impacts, which led the WMM program to encourage active management of these sites rather than stiffen regulations. The study of construction and demolition landfills showed some groundwater impacts at large sites but little or no impacts at smaller sites. These findings led to revisions of DNR regulations in 1996 allowing lined intermediate size C/D landfills, which can provide the economic benefits of a large site without the potential negative impacts of very large sites. Based on the research, the

regulations were written to require groundwater monitoring of inorganic parameters at small size C/D landfills but only require VOC sampling when establishing background. Since these studies have been conducted, many states and the EPA have contacted the WMM program about the information collected.

Another study undertaken by the WMM program (Connelly, 1994) was a comparison of groundwater sampling methods for collecting metals samples at monitoring wells. The study was in response to EPA's October 1991 ban on field filtering of groundwater samples that became effective in October 1994. The WMM program opposed this ban because many Wisconsin monitoring wells produce very turbid water which can lead to false positive results for metals if samples are not filtered. Additionally, the new EPA-recommended procedure, low-flow pumping, requires a significant amount of additional equipment. The study showed that the low-flow pumping method was appropriate in many circumstances but could not be used to sample slowly recovering wells. The results showed that turbidity was the best indicator that a well has been sufficiently purged. The results of the investigation were used to revise groundwater sampling procedures required by the WMM program. Additionally, the study helped establish Wisconsin as one of two leading states playing a major role in advising EPA on revisions to their groundwater sampling requirements at municipal solid waste landfills.

A follow-up study by the WMM program (Svavarsson, 1995) compared low flow pumping and bailing for VOC groundwater sampling at landfills. The study indicated that, in contrast to what some were claiming, there was very little difference in the results when using the two different methods. These findings were incorporated into the new groundwater sampling code and allowed the use of either method for sampling VOCs. This reduced the cost that landfill owners would otherwise have had to bear to purchase and operate low-flow pumping equipment.

A joint project between WMM and UW Stevens Point evaluated the effectiveness of chemical oxygen demand (COD) as an indicator parameter at landfills (Connelly and Stephens, 2000). One reason for evaluating COD is that mercury waste is generated when COD is analyzed in the laboratory. The DNR's overall goal was to reduce the amount of mercury that gets into the environment. Eliminating COD sampling at the 400+ landfills that currently sample for it would help the agency meet that goal. Findings from the first year of the study indicated that there is potential to eliminate COD monitoring at some types of landfills. The second year of the study evaluated possible alternatives to sampling for COD. Dissolved organic carbon (DOC) appears to be an acceptable alternative in certain circumstances. WMM staff incorporated the recommendations of this study into code changes that went into effect in February 2006.

Between July 2000 and July 2001 the Bureau studied 31 landfills accepting municipal solid waste, to try to determine whether VOC contamination in groundwater at these landfills is increasing, decreasing or remaining stable (Connelly 2001). Investigators chose sites with 10 years of data and summarized the trends over this period of time. One purpose of this study was to determine whether natural attenuation is occurring in groundwater near leaking landfills. The study showed that natural attenuation processes were occurring at most of the landfills as evidenced by the large number of stable or decreasing concentration trends. However, the concentrations took longer to stabilize and stabilized at higher levels than at other types of VOC contamination sites described in the literature.

WMM received funding for the period October 2002 to October 2003 to study groundwater quality at solid waste landfills to determine whether they are a source of pesticide contamination. Eleven sites were sampled in the spring and summer of 2003 and the findings summarized in a 2005 GEMS Newsletter article. Groundwater samples were analyzed for 14 common Wisconsin

pesticides using immunoassays and additional GC/MS methods. Preliminary findings indicated that leaking landfills may be contributing alachlor, aldicarb, atrazine and 2,4-D to groundwater. The study researchers believed a follow-up study was needed to provide more evidence to help make concrete recommendations about which pesticides to sample for. However, staff and funding have not become available to do the follow-up study.

Methylmercury Formed in Groundwater

Methylmercury (MeHg) is one of the most toxic and persistent substances in the environment. Research has focused on how MeHg forms from inorganic mercury deposited from atmospheric sources such as coal combustion. A UW study conducted at the Allequash Creek watershed in northern Wisconsin determined that anoxic zones in shallow groundwater are an important site of MeHg formation (Stoor, et al., 2002).

Further study showed that MeHg concentrations in these hyporheic (shallow zone) pore waters co-vary with the mercury methylation rate at depth (Meyer, et al., 2005). This suggests that the measured MeHg concentrations are likely produced in situ, and are not from legacy sources. Methylation rates in the hyporheic zone of the peat bog are generally higher than those of the headwater springs – which is consistent with previous observations of increased wetland export of MeHg (Armstrong, et al., 2006).

Additional work also showed that methylation rates were not controlled by the total mercury concentration in pore waters (Creswell, et al., 2008). Instead, high concentrations of strong mercury-binding ligands have been observed and are believed to influence methylation rates by one of several possible mechanisms (Creswell, et al., 2010). Current research examines the leading mechanism by determining the role of neutral sulfide complexes on methylation in Allequash groundwater (Shafer 2011).

This information advances our understanding of mercury transport and methylation in groundwater, and will help us interpret the watershed response to changing conditions in the hyporheic zone. For example, due to the lack of correlation between total mercury and the methylation rate in pore water, the mitigation of atmospheric mercury inputs to the watershed, may not immediately affect MeHg export. In addition, any variation in groundwater levels, whether due to climate change or conjunctive use of groundwater and surface waters, will likely influence MeHg production in both natural and engineered wetlands.

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Pharmaceuticals, Personal Care Products and Endocrine Disrupting Compounds in Groundwater

Pharmaceuticals, personal care products (PCPs) and endocrine disrupting compounds (EDCs) are a large group of substances present in human generated waste streams that potentially could contaminate groundwater resources. These substances are often classified, along with other chemicals, as contaminants of emerging concern (CECs), emerging contaminants (ECs) or trace organic contaminants (TOrCs).

Pharmaceuticals such as antibiotics, birth control pills and various prescription medicines may be present in wastewater effluents. PCPs, including shampoos, detergents and "over the counter" non prescription medications, are found in both treated wastewater discharges and the municipal solid waste stream. EDCs adversely affect the behavior of natural hormones in humans and other animals. They include both anthropogenic chemicals, such as pesticides and plasticizers, and naturally occurring compounds like steroids and plant produced estrogens. EDCs are found in domestic and industrial wastewaters and in agricultural run-off. Some pharmaceutical and PCP compounds act as endocrine disruptors. New analytical methods, allowing detection of very small quantities of a substance, have helped improve investigations into the occurrence of emerging contaminants such as pharmaceuticals, PCPs and EDCs in the environment.

Discharges of treated wastewater through land (soil) treatment systems, leachate leaking from solid waste landfills, sludge biosolids landspreading activities and infiltration of polluted surface waters can potentially contaminate groundwater aquifers. The mobility and fate of discharged/released substances in the subsurface is a function of a variety of factors including the substance's adsorption and biodegradability properties and the amount and characteristics of any soil through which the substance percolates before reaching groundwater. Recent studies in other states have shown that pharmaceuticals, PCPs and EDCs can be present at sites where treated wastewater is used to recharge groundwater. In Wisconsin, research has been done evaluating the occurrence and movement in the subsurface of some pharmaceuticals, PCPs and EDCs.

A DNR and DATCP-funded study (Karthikeyan and Bleam, 2003), investigated the presence of antibiotics in treated wastewater effluents, and their potential fate in the subsurface. A variety of antibiotics were detected in wastewaters analyzed for the study. Two antibiotics, tetracycline and sulfamethoxazole, were found in all of the treated wastewater effluents tested for the project. Very small concentrations of these two antibiotics were also detected in groundwater monitoring wells located directly adjacent to one of the study land treatment system seepage discharge sites.

A UW-funded study (Pedersen and Karthikeyan, 2005) investigated the soil adsorption properties of common antibiotics. This study found that under certain soil conditions some antibiotics, such as the sulfonamide antibiotics, have the potential to be mobile in the subsurface. A number of additional studies, focused on specific antibiotic compounds, have evaluated the factors that effect antibiotic mobility and fate in the subsurface environment (Gao and Pedersen, 2005) (Gao and Pedersen, 2010) (Gu and Karthikian, 2005a) (Gu and Karthikian, 2005b) (Gu and others, 2007) (Gu and Karthikian, 2008) (Sibley, 2008) (Pedersen and others, 2009).

A study of the use of a screening assay to evaluate the occurrence of estrogenic endocrine disrupting chemicals in groundwater was conducted by the Wisconsin State Lab of Hygiene (Sonzogni and others, 2006)). This study included testing of both high capacity water supply wells located in close proximity to surface waters into which treated wastewater effluent was being discharged, and water supply wells located in areas of home on-site wastewater treatment system discharge to groundwater. A breast cancer

cell line assay (E-screen assay) was used to test study samples for the presence of estrogenic endocrine disrupting compounds. Estrogenic EDCs were detected in surface waters tested but multiple groundwater samples from high capacity water supply wells located near those surface waters showed no estrogenic endocrine disruptor activity. Samples for estrogenic EDC analysis were collected from home on-site wastewater treatment systems and from groundwater monitoring wells located adjacent to two of the systems. Estrogenic activity was detected in wastewater treatment system effluent but was not detected in groundwater monitoring well samples.

A DNR project conducted in Dane County (Bradbury and Bahr, 2005) assessed groundwater impacts from on-site wastewater treatment system discharge. This project included an assessment of pharmaceuticals, PCPs and estrogenic EDCs in treatment system effluent, soil pore water and groundwater. Four compounds, acetaminophen (Tylenol), paraxanthine (caffeine metabolite) and the hormones estrone and β-estradiol, were detected in wastewater treatment system effluent samples. No pharmaceuticals, PCPs or estrogenic EDCs were detected in the groundwater or soil pore water samples collected for the study.

A UW study (Bauer-Dantoin, 2009) monitored the extent to which groundwater in northeastern Wisconsin is contaminated with endocrine disrupting chemicals (EDCs). The Silurian aquifer of northeastern Wisconsin may be particularly susceptible to nonpoint source contamination due to the existence of shallow soils, dolomite bedrock, and karst features, which combine to facilitate the transport of surface runoff to groundwater. Land application of manure containing synthetic and endogenous hormones may be a significant source of nonpoint source pollutants, including EDCs, to groundwater in the heavily farmed regions of northeast Wisconsin. This study used the MCF-7 breast cancer cell proliferation assay (E-screen) to determine if groundwater samples collected from four northeast Wisconsin counties, including Brown, Calumet, Fond du Lac, and Kewaunee, exhibited estrogenic behavior. Groundwater samples were collected four times between the summer of 2008 and the spring of 2009, and were analyzed for estrogenicity, 17β-estradiol concentrations, nitrate, conductivity, total coliform, enterococci, and *E. coli*. The wells chosen for this study were located in agricultural areas of northeast Wisconsin, were cased into the Silurian aquifer, and were chosen in light of past contamination with bacteria and/or nitrate. Estrogenic activity was detected in a portion of the groundwater samples during all four sampling periods, despite apparent toxicity and/or anti-estrogenic effects observed in the E-screen. The estradiol equivalents found in the study are below the range known to cause endocrine disruption in wildlife and are within the range of levels found in other studies that utilized the E-screen to analyze water samples. Unsafe levels of bacteria and nitrate occurred during all four sampling periods. Average bacterial contamination increased following snowmelt events in February and March 2009. Coliform, enterococci, and *E. coli* were positively correlated throughout the study, with the strongest correlations occurring in the March 2009 sampling period. Correlations were not found between nitrate and bacteria, or nitrate and estrogencity. One weak, positive correlation was found between *E. coli* and estrogenicity in the March 2009 sampling period.

A DNR project conducted by the Wisconsin State Laboratory of Hygiene explored the potential of hormones from livestock operations to contaminate groundwater. Water samples were collected during precipitation or snowmelt from agricultural fields and subsurface tiles and evaluated for hormones and hormone activity. Some samples did contain hormones (including estrogens, androgens and progesterone) in ng/L concentrations, and concentrations were usually lower in tile water samples than on the surface water samples. Additionally, groundwater samples were collected from monitoring wells at UW-Platteville Pioneer Farms. None of the groundwater samples had detectable levels of hormones or hormone activity, indicating that sorption by soil and degradation of hormones can occur and will protect groundwater at some sites.

The DNR is using the results of pharmaceutical, PCP and EDC research studies to evaluate whether current state groundwater protection regulations are adequate to address potential adverse impacts from the discharge of these substances. Studies comparing the levels of pharmaceuticals, PCPs and EDCs present in wastewater influent with treatment system effluent levels are providing information on the removal effectiveness of wastewater treatment processes. Research into the behavior of pharmaceutical, PCP and EDC substances in soil and groundwater is helping the DNR develop effective monitoring strategies. Studies evaluating new sampling techniques and analytical test methods have helped assure that the DNR is utilizing the best available tools to assess the occurrence of these substances in the environment.

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Prevention and Remediation of Groundwater Contamination

The State of Wisconsin (through the UWS Water Resources Institute) has supported many research projects emphasizing new technologies for prevention or remediation of groundwater contamination. Final reports and studies in progress provide information or products that will be important for future efforts aimed at controlling or attenuating groundwater contamination in Wisconsin. The findings cover a wide range of technologies (see list of projects at: http://dnr.wi.gov/org/water/dwg/gcc/rtl/GCCReport2012.htm under Monitoring and Research):

- New and enhanced physicochemical or biological methods to renovate waters contaminated by pesticides and volatile organic carbon compounds (Hickey, 2006-08), (Park and Benson, 2007), (DeVita and Dawson, 2005-06), (Li, 2004-05), (DeVita and Dawson, 2003-04), (Evangelista and Pelayo, 2003), (Collins, 1997-2002), (Li, 2000), (Benson and Eykholt, 2000), (Benson, 1997-2000), (Hoopes, 1997-99), (Park, 1997-98), (Bahr, 1996-98), (Hickey, 1994-96), (Anderson, 1994-95), (Chesters and Harkin, 1991), (Harris and Hickey, 1991-92);
- Enhancements in the ability to control, monitor, and predict the movement of landfill and mine waste contaminants to groundwater (Edil and Benson 2006-07), (Edil, Benson and Connelly, 2004-05), (Edil and Benson, 2000), (Edil 1997), (Benson, 1995-96), (Edil and Park, 1992-93);
- New technologies for the treatment and removal of Arsenic and heavy metals from groundwater. (Li 2009-11), (Metz and Benson, 2007),(Li et. al. 2007), (Shafer et. al. 2005-07), (Benson and Blowes, 2005-06), (Metz, 2006), (Metz & Benson, 2004-06), (Anderson, 2003), (Park, 2002-03), (McGinley, 2002-03);
- Improvements in the predictability of pump-and-treat or excavate-and-treat remediation applications to contaminated aquifers (Evans & Li, 2002-03), (Bahr, 1994-95);
- Innovative agricultural practices designed to reduce groundwater contamination by pesticides and nitrate (Larson, 2011-13), (Thompson 2010-12), (Stelzer and Joachim, 2010), (Miller, 2009), (Bahr and Roden, 2009), (Kraft and Mechenich, 2007), (Kraft and Browne, 2006-07), (DeVita and Dawson, 2001-04), (Norman, 2000-03), (Bundy, 1993-94, 1997-98), (Shinners, 1995-96), (Newenhouse, 1995), (Harrison, 1992-93), (Bahr, 1991-92);
- Development of new technologies for evaluating the integrity of water supply well and exploration borehole seals (Edil,1998-99), (Edil and Benson, 1997-98), (Edil, 1996);
- Multi-parameter sensors for monitoring groundwater quality and quantity (Bahr and Hart, 2009-10), (Loheide 2007-09), (Krabbenhoft et. al, 2007), (Geissinger, 2006-08), (Anderson & Glanchandani, 2002-03); and
- Assessment of emerging biological pathogens and pharmaceutical compounds (Li and McWilliams 2010-12), (Xu 2010-12), (Li & Yang, 2007-09), (McMahon 2005-07), (Sonzogni et al., 2004-06).

Rain Garden Design & Evaluation

In February 2006, WRI and the UW-Madison Department of Civil and Environmental Engineering published "Design Guidelines for Stormwater Bioretention Facilities" (Atchison and others). This manual provides design guidelines and a numerical model (RECARGA) that can be used for creating bioretention facilities for small-scale stormwater management. The system promotes infiltration of stormwater in order to reduce its volume, improve its quality and increase groundwater recharge. A basic bioretention facility is commonly referred to as a rain garden. It is a landscaped garden in a shallow depression that receives stormwater from nearby impervious surfaces. The model, which was based on WRI supported research (Potter, 2002), is now recommended by the Wisconsin Department of Resources (DNR) for use in meeting its new stormwater infiltration regulations. The manual is available free of charge on the DNR website (http://dnr.wi.gov/runoff/rg/). The manual continues to be extremely popular at the UW Aquatic Sciences Center Publications Store. The entire run of 502 printed copies was distributed between FY07 and FY10. The document continues to be popular with 1,362 electronic downloads in FY12 bringing the total number of electronic downloads to 25,441 since FY07.

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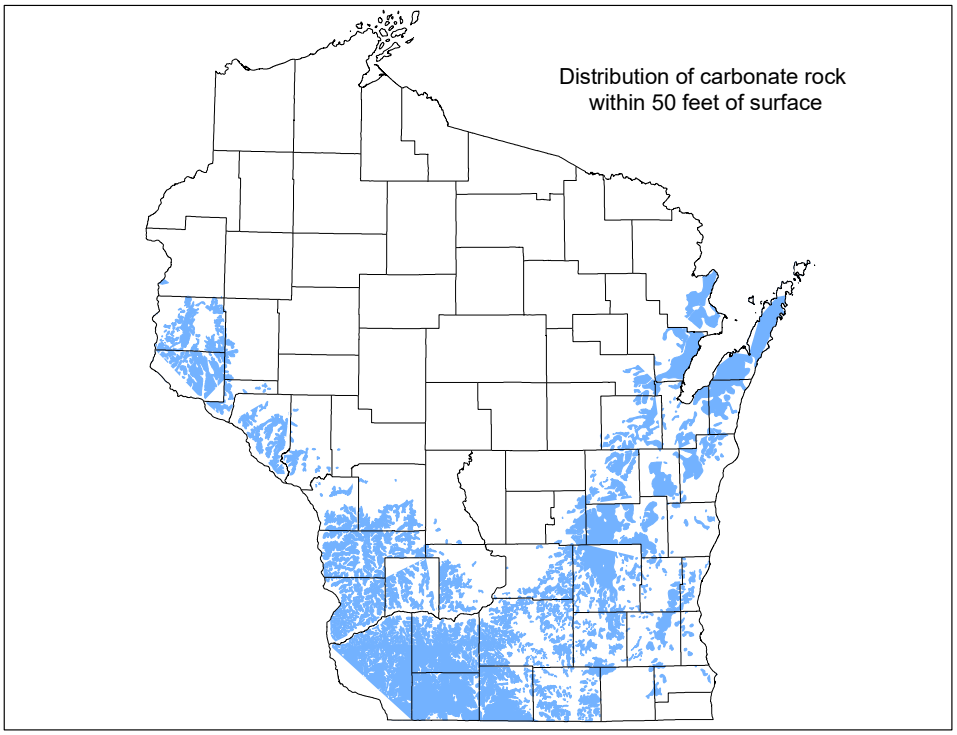
Groundwater Movement in Shallow Carbonate Rocks

Shallow carbonate bedrock (dolomite and limestone) underlies much of Northeastern Northwestern, and Southwestern Wisconsin (see map below).



Location of shallow carbonate bedrock in Wisconsin

The WGNHS has conducted a series of projects to examine the hydrogeology of fractured carbonate rock in Wisconsin. Recently, the WGNHS and UW-Oshkosh received a Wisconsin Coastal Management Grant to develop a groundwater monitoring network around the Mink River Estuary in Door County. This pristine estuary is fed by carbonate springs originating in the fractured dolomite. The instrumentation phase of this project was completed in 2012, and a second WCM grant is funding construction of a groundwater flow model for the estuary, scheduled for completion in 2013.

Over the past few years, the WGNHS has developed a program of research and public education on groundwater movement in fractured rocks and has provided assistance to various agencies facing carbonate-rock problems. During FY 2013, the WGNHS will continue such activities. WGNHS staff members are also involved in presenting professional short courses on fractured-rock hydrogeology.

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

The WGNHS is serving as a clearinghouse for karst information and has begun assembling a karst database for the state. WGNHS scientists have conducted geophysical surveys near some of these features in order to characterize their depth and extent. The results of those studies have been used by municipalities for planning purposes and selecting options for sinkhole remediation. The WGNHS will continue to refine these geophysical techniques so that karst can be more effectively characterized across Wisconsin.

During FY 2013, the WGNHS will continue to provide data and consultation on karst issues as requested by various units of government and the public.

Nitrate

Nitrate is Wisconsin's most widespread groundwater contaminant (data from DNR, DATCP and UW-Extension's Central Wisconsin Groundwater Center) and is increasing in extent and severity (Kraft et al. 2008, Kraft 2003, Kraft 2004, Saad 2008). Nitrate (NO_3) is a water-soluble molecule that forms when ammonia or other nitrogen rich sources combine with oxygenated water. Nitrate levels (as nitrate-N) in groundwater are below 1 milligram per liter (mg/L) where pollution sources are absent. Higher levels indicate a source of contamination such as agricultural or turf fertilizers, animal waste, septic systems, and wastewater. At least 90% of nitrate inputs into our groundwater originate from manure spreading, agricultural fertilizers, and legume cropping systems (Shaw, 1994).

DATCP (2007) and DNR (2005, 2007) surveys and meta-analysis of state databases indicate 9 to 11% wells statewide exceeded the nitrate enforcement standard (ES) of 10 mg/L. Exceedence rates are greater in agricultural districts, with rates in highly cultivated areas in south-central Wisconsin estimated at 21% of wells. As seen in Figure 1 below, 20-30% of the privately owned wells in Calumet, Columbia, Dane, La Crosse and Trempealeau counties exceed the 10 mg/L nitrate standard. A nationwide USGS study compared nitrate concentrations in 495 wells between 1992 and 2004 and showed that the proportion of wells with concentrations of greater than 10 mg/L increased from 16 to 21 percent (Dubrovsky etal., 2010).

Human health concerns are the primary reason high levels of nitrate in drinking water are of concern. Nitrate can cause a condition called methemoglobenemia or "blue-baby syndrome" in infants under six months of age. Nitrate in drinking water used to make baby formula is converted to nitrite in the child's stomach. The nitrite then changes hemoglobin in blood (that part of the blood that carries oxygen to the body) to methemoglobin which deprives the infant of oxygen and in extreme cases can cause death. The Wisconsin DHS has investigated several cases of suspected blue-baby syndrome and associated at least three with nitrate contaminated drinking water. Non-fatal cases were reported in Trempealeau County (June, 1992), Columbia County (July 1998) and Grant County (April 1999). The Grant County case required an emergency MedFlight to a regional medical center and 17 day hospitalization to stabilize the 3 week old infant (Knobeloch, 2000). Currently, concerns are also being raised regarding the effect of nitrate on thyroid function, diabetes and cancer. More research is needed in this area. To ensure protection of health, people of all ages are encouraged to drink water that meets the safe drinking water standard for nitrate of 10 mg/L.

Once nitrate converts to nitrite in the human body it can then convert into N-nitroso compounds (NOC's). NOC's are some of the strongest known carcinogens and have been found to induce cancer in a variety of organs. As a result, additional human health concerns linked to nitrate contaminated drinking water include increased risk of: non-Hodgkin's lymphoma (Ward et al., 1996); gastric cancer (Xu et al., 1992; Yang et al., 1998); and bladder and ovarian cancer in older women (Weyer et al., 2001). There is also growing evidence of a correlation between nitrate and diabetes in children (Parslow et al., 1997; Moltchanova et al., 2004).

Because of these health concerns, city and village water supplies that exceed the 10 mg/L ES are required to treat drinking water to the federal drinking water standard of 10 mg/L. Common solutions include drilling of a new non-contaminated well or the removal of excess nitrate through water treatment processes. A 2012 survey of Wisconsin municipal systems found that 47 systems have had raw water samples that exceeded the nitrate ES (up from just 14 systems in 1999). A 2012 survey of Wisconsin municipal systems showed that respondents had collectively

spent over $32.5 million on remedies, up from $24 million as of 2004. Excessive nitrate levels have also forced the installation of treatment systems or the replacement of wells at hundreds of other smaller public systems.

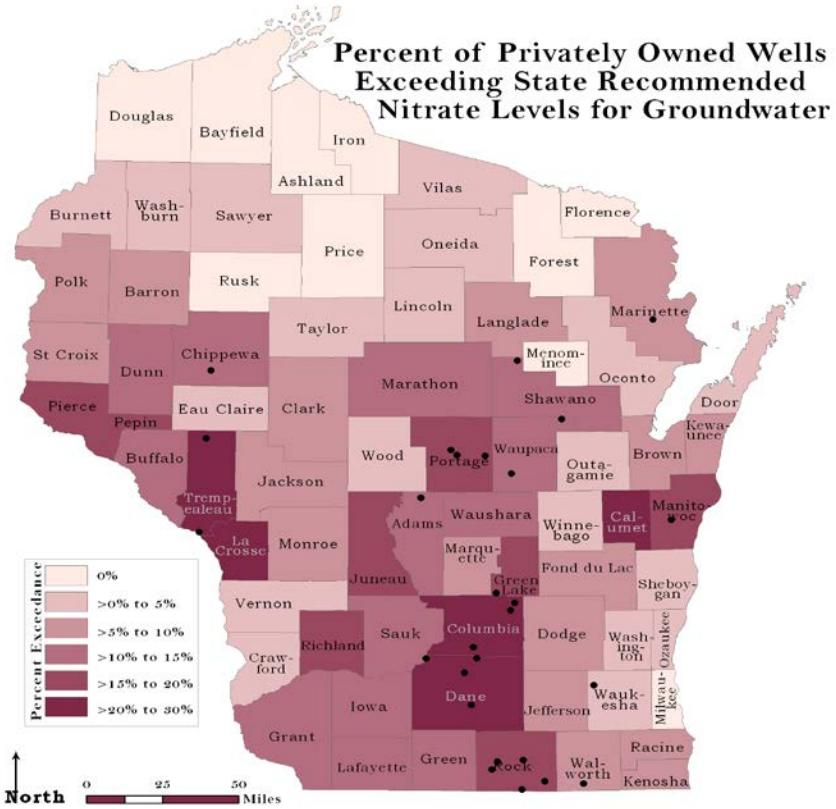


Figure 1: Municipal water systems with raw water samples exceeding 10 mg/L, and percentage of nitrate samples from private wells exceeding 10 mg/L by county. Data sources: DNR, Center for Watershed Science and Education, and DATCP groundwater databases.

About one third of Wisconsin's families obtain their water from privately owned wells and hence are at risk of excessive nitrate exposure. A 2008-9 DHS survey determined that one-third of private well owners have never had their water tested for nitrate. The most common reasons cited by well owners who had not tested their water was that their water "tasted and looked fine." Thirteen percent listed cost as a reason for not testing their water.

Owners of nitrate-contaminated private wells do not qualify for well compensation funding unless the nitrate level in their well exceeds 40 mg/L and the water is used for livestock. In order to establish a safe water supply, they may opt to replace an existing well with a deeper, better cased well or to connect to a nearby public water supply. Alternatively, they may choose to install a water treatment system or use bottled water. A study published by DHS examined this issue

(Schubert et al., 1999). Their survey of 1,500 families found that few took any action to reduce nitrate exposure. Of those who did, most purchased bottled water for use by an infant or pregnant woman.

In addition to the effects of elevated nitrate concentration on human health, a number of studies have shown that nitrate can have lethal and sublethal effects on a variety of species of fishes, amphibians, and aquatic invertebrates. This is significant in that many baseflow-dominated streams in agricultural watersheds can exhibit elevated nitrate concentrations, with levels in some Wisconsin streams at times exceeding 30 mg/L NO_3-N. Stream nitrate concentrations and nitrogen exports are expected to increase on average as older water within the aquifer is replaced by modern water that is reflective of current land-use (Masarik, et.al, 2007). \

Ex-situ studies of trout species have observed effects on mortality in developing embryos and reduced growth in fry at concentrations as low as 6 mg/L NO_3-N (Crunkilton and Johnson 2000). Other studies have shown that a variety of aquatic animal species experience lethal effects of nitrate concentrations as low as 8 to 30 mg NO3-N/L (Camargo and Ward 1995, Marco et al. 1999, Smith et al. 2005).

Sub-lethal effects of exposure to elevated nitrate concentration can occur at even lower nitrate concentrations (e.g. McGurk et al. 2006). A recent laboratory study of the lethal and sublethal effects of elevated nitrate concentration on amphipods from a Central Wisconsin stream did not show any evidence of lethal effects but did show some evidence of lower growth rates as nitrate concentration increased (Stelzer and Joachim 2010). In Wisconsin, exposure of animals to potentially lethal nitrate concentrations would be most likely to occur in springs and in groundwater-fed low-order streams in agricultural or urban areas, and in nitrate-rich water bodies on farms (ditches, ponds).

Various studies indicate nitrate is increasing and that current management activities to limit nitrate pollution have questionable effectiveness (Mechenich and Kraft 1997, Kraft 2003, Saad 2008). For instance, nitrate concentrations in Central Wisconsin groundwater will continue to increase even using University recommendations for fertilizer application. Nitrate concentrations will increase as nitrate pollution penetrates deeper into thick aquifers (Kraft et al. 2008). Nationally there is also evidence that nitrate contamination in deeper aquifers is likely to increase during the next decade as shallow groundwater with elevated concentrations moves downward (Dubrowsky et.al, 2010).

Several studies funded through the joint solicitation and done at the UW Arlington Agricultural Research Station have looked at nitrogen inputs on fields in continuous corn (Brye, 2001; Masarik, 2003; and Norman, 2003). Important findings include:

- Nitrate concentrations are highly variable throughout the year, and from year to year. Highest concentrations are measured in wet years, particularly when wet years follow dry years. Highest concentration measured in leachate (for two week period) on optimally fertilized fields – around 45 mg/L. Highest annual flow-weighted mean concentration – 24 mg/L. During the dry years the nitrate concentrations were actually quite low.

- Over the long-term (7 years), flow-weighted mean nitrate leaching values on continuous corn rotations fertilized at economic optimum rates were around 10 mg/L. Nearly 20% of nitrogen fertilizer applied at economic optimum rates is lost to leaching over the long-term. These studies show that even in the best managed agricultural systems, groundwater concentrations at or above the health standard for nitrate-nitrogen are likely.

- When manure was applied to a field in addition to the optimal rate of nitrogen fertilizer, the flow-weighted mean concentration was two to three times greater than the flow-weighted mean concentration from fields that just received the optimum amount of fertilizer.

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Arsenic

Naturally-occurring arsenic was discovered in Wisconsin's groundwater in 1989 during a routine investigation conducted by the DNR. Investigations done in the early 1990s found that approximately 4% of the private wells located in Winnebago and Outagamie Counties had arsenic levels that exceeded 50 µg/L which was the federal drinking water standard at that time. The most seriously contaminated water supply had an arsenic level of 15,000 µg/L. The DNR issued an advisory for the area recommending drilling and casing 80 feet beyond the top of the St Peter sandstone which is the primary source of the arsenic. Increasing the casing length was successful in bringing arsenic concentrations below 50 µg/L in about 85% of the wells studied. Over the years the department has continued to work with drillers to improve well drilling and construction techniques to minimize arsenic levels in potable wells.

Arsenic is released from aquifer materials by several mechanisms. The primary mechanism in NE Wisconsin is oxidation of sulfide minerals when groundwater is drawn down and the rock is exposed to air, or air is introduced to the rock formations during well drilling. Other metals (such as nickel, cobalt, cadmium, chromium, lead and iron) associated with the sulfide minerals can also be released to groundwater and may increase health risks. In areas of SE Wisconsin and in some glaciated areas of Northern Wisconsin, arsenic is bound to iron oxide minerals in the aquifer sediments. In these settings, groundwater at depth is susceptible to elevated arsenic due to a lack of oxygen in the groundwater system.

Prior to implementation of a new, lower federal standard for arsenic in 2006, the department coordinated with DHS and local health departments to sample private wells in several towns in Outagamie and Winnebago Counties. Nearly 4,000 wells were sampled between 2000 and 2002. Test results indicated that approximately 20% of the wells had concentrations over the proposed standard of 10 µg/L (same as the earlier sampling). In some areas, over 40% of the wells exceeded 10 µg/L. A high density development in the Town of Algoma became the first special well casing depth area (SWCDA) in 2002. Three other smaller areas followed soon after.

Between 2002 and 2004 the DNR required more stringent specifications within four small areas where arsenic contamination problems were severe. To avoid creating a 'hodge-podge' of small SWCDAs scattered over a two-county region, DNR decided to seek a more comprehensive regional approach. Based on the success of the SWCDA and the large number of wells involved, the DNR expanded the SWCDAs to include all of Winnebago County and Outagamie County. Information on the specifics of the SWCDAs requirements can be found at: http://dnr.wi.gov/topic/Groundwater/arsenic/casingRequirements.html.

Understanding the occurrence of arsenic in Wisconsin's groundwater has been a good example of interagency cooperation. Initial work with DHS and local health departments and town boards effectively defined the problem and raised awareness. Research supported by the joint solicitation helped define the extent and mechanisms of release. DNR and Commerce worked jointly with water treatment companies on developing treatment systems for arsenic removal. Well drillers assisted in identifying drilling methods that reduce arsenic.

Sixteen studies through the joint solicitation have explored arsenic related topics from detection to geologic controls to well construction and treatment (See *http://dnr.wi.gov/topic/Groundwater/arsenic/*). Recently completed research focused on release mechanisms, triggers and reaction kinetics that affect well construction, disinfection, and

rehabilitation. A second focus of recent work is identifying other areas of the state with impacted groundwater.

A DHS Health Consultation study on arsenic in private wells in the Wind Lake, Racine County area showed arsenic is present in both the deep glacial and Silurian bedrock aquifers (http://www.atsdr.cdc.gov/HAC/pha/WindLakePrivateWells/WindLakeHC04-28-2009.pdf) Of 25 wells tested, 12 contained arsenic levels above the ES of 10 µg/L. Free test kits were made available to any interested resident in the area and resulted in 92 samples from 70 different private wells. The results showed 22 of 70 (31%) wells with arsenic levels at or above the ES. Test results ranged from 10 to 27 µg/L. In addition to arsenic, water from 10 wells had lead at levels above the ES of 15 µg/L.

The DNR, DHS, Commerce and others continue to work on arsenic problems around the state. Arsenic has been found at levels above the ES in every county. DHS has conducted two separate studies on the health effects of arsenic on Wisconsin citizens. DHS researchers have observed higher rates of skin cancer, heart disease and depression among consumers of water that contains traces of arsenic (Knobeloch et al, 2002; Zierold et al, 2004).

A 2007 study funded by the joint solicitation examined the relationship between arsenic contamination and common well disinfection practices such as shock chlorination. Results indicate the complex cycling of iron and arsenic in well bores and aquifers. Microbiological activity in the aquifer and the amount of pumping from a well affect arsenic release related to shock chlorination (Gotkowitz et al, 2008; West et al. 2012). This work suggests that managing the quality of water in domestic wells in arsenic-impacted areas of Wisconsin may be beyond the ability of homeowners. Effective well construction requirements implemented in SWCDAs in Winnebago and Outagamie Counties are being applied in other areas of the state. In addition, extending public water supplies or promoting use of household treatment systems are alternatives for providing a reliable source of potable water.

Ongoing efforts to address arsenic in groundwater include:

- Ongoing testing of private wells for arsenic through the fee-exempt testing offered to low-income families by local health departments.
- Refinement of the geology in the Outagamie and Winnebago county area and updating casing requirements,
- DHS and DNR sampling of transient non-community wells
- Commerce and DNR evaluating and pilot testing arsenic treatment systems for public and private systems that do not have an alternative aquifer option. One point-of-use treatment system was recently approved.
- DNR and local governments are working with several Blue Cross/Blue Shield grants for a healthier Wisconsin to explore impediments to private wells sampling and promote well sampling programs
- DNR efforts to improve well construction for school and community wells
- DHS, DNR and the WGNHS are working together to gather information from drillers and pump installers on areas with high iron and corrosive water, which may be indications of an arsenic problem. Sampling of these areas is being lead by DHS.
- DHS and DNR targeting of wells for sampling in the southern and SW potions of the state.
- Requiring arsenic sampling for all new and reconstructed wells in Florence County.
- Educational outreach to the well drillers continues.

More information related to arsenic can be found on the DNR Arsenic Web Page: http://dnr.wi.gov/org/water/dwg/arsenic/index.htm

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Pesticides

Pesticide contamination in groundwater results from field applications, pesticide spills, misuse, or improper storage and disposal. The health effects of pesticide exposure vary by pesticide. For example, atrazine, a common corn herbicide, has been linked to weight loss, cardiovascular damage, retinal and some muscle degeneration, and cancer when consumed at levels over the drinking water limit for long periods of time (http://www.epa.gov/safewater/contaminants/ basicinformation/atrazine.html). Long-term exposure to alachlor, another herbicide, is associated with damage to the liver, kidney, spleen, and the lining of the nose and eyelids, and cancer (http://www.epa.gov/safewater/pdfs/ factsheets/soc/alachlor.pdf). In Wisconsin about 30 pesticides currently have health-based drinking water limits and groundwater standards in ch. NR 140, Wis. Adm. Code. Occasionally, pesticides and pesticide metabolites that do not have groundwater standards are detected in drinking water in which case the health effects cannot be properly evaluated.

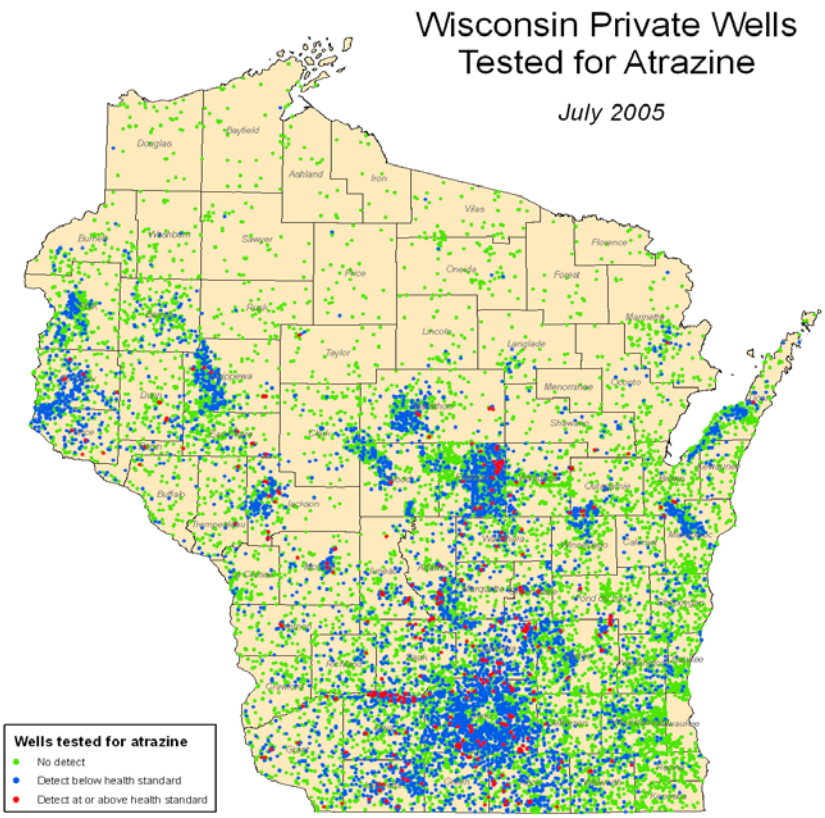
The health effects of multiple pesticides in drinking water are not well understood. Some studies have found that pesticide mixtures at equal or less than the EPA drinking water standard can produce effects that are not found upon exposure to a single pesticide at the same concentrations. Tests of mixtures of the insecticide aldicarb, the herbicide atrazine, and nitrate in rats show endocrine, immune and behavioral effects including decrease in speed of learning, change in aggression intensity and frequency, change and reduction in memory and motor coordination in the brain, change in growth hormone, and reduction in antibodies formation capability (Porter, 1999). Frogs exposed to pesticide mixtures used on a corn field (with each pesticide at 0.1 ppb) had retarded larval growth and development and induced damage to the thymus, resulting in immunosuppression (Hayes, 2006).

Serious concerns about pesticide contamination in Wisconsin were first raised in 1980 when aldicarb, a pesticide used on potatoes, was detected in groundwater near Stevens Point. The DNR, DATCP, and other agencies responded to these concerns by implementing monitoring programs and conducting groundwater surveys. In 1983 the DNR and DATCP expanded their sampling programs to include analysis of pesticides commonly used in Wisconsin. These programs now include sampling for pesticide metabolites which are chemical compounds that form when pesticides break down in the soil and groundwater. The most commonly detected pesticides compounds in Wisconsin groundwater are metabolites of alachlor (Lasso), metolachlor (Dual) and Atrazine and its metabolites.

<u>Atrazine</u>
Atrazine, an herbicide used on corn, is one of the pesticides most often found in private drinking water wells in Wisconsin. There are significant health concerns for humans and wildlife associated with atrazine. Studies have found that male frogs develop both male and female sex organs when exposed to concentrations of atrazine at $1/30^{th}$ of the current drinking water standard (Hayes et. al. 2002 and Hayes et. al. 2003)

The first systematic well sampling program to characterize atrazine contamination on a statewide basis was the 1988 DATCP Grade A Dairy Farm Well Water Quality Survey. This state-funded well survey estimated that atrazine was present in 12 percent of the Grade A Dairy Farm Wells in the State. Since that initial study, DATCP has collected data from many private and monitoring wells in the state as part of statewide surveys and focused monitoring projects (summarized below).

In July 2005, DATCP produced a map showing locations of private drinking water wells tested for atrazine in the state (see below). The DATCP pesticide database contains test results from nearly 16,000 wells tested with the immunoassay screen for atrazine and over 7,000 wells tested by the full gas chromatography method. The immunoassay screen results showed that about 40 percent of private wells tested have atrazine detections, while about 1 percent of wells contained atrazine over the groundwater enforcement standard of 3 µg/L. The 7,000 wells tested by full gas chromatography showed detectable levels of atrazine 25 percent of the time and levels over the enforcement standard in about 5 percent of the wells. The enforcement standard for atrazine includes parent atrazine and three of its breakdown products (metabolites).



Private wells tested for atrazine in Wisconsin as of July 2005 (source: DATCP)

Some pesticides, like atrazine, get into groundwater mostly through general use, while others are only found in groundwater if they have been spilled or mishandled. A combination of factors is most likely responsible for the widespread atrazine contamination shown on this map:

- Atrazine was the most widely used herbicide in Wisconsin for more than 40 years because it is effective and inexpensive (glyphosate use has now passed atrazine use in Wisconsin due to

Roundup-ready soy beans and corn, but fortunately glyphosate is not a groundwater threat because it is tightly bound to the soil)
- Atrazine was commonly used at much higher rates and applied more often before DATCP's Atrazine rule (ch. ATCP 30, Wis. Adm. Code) began in 1991
- Atrazine leaches through the soil into groundwater more readily than many other herbicides

Weed Management Survey in Atrazine Prohibition Areas

In 2011 DATCP completed a report entitled Final Report on the 2010 Survey of Weed Management Practices in Wisconsin's Atrazine Prohibition Areas. The main purpose of this survey was to evaluate differences in herbicide use and other weed control practices inside and outside of Wisconsin's atrazine prohibition areas. A specific objective was to determine whether simazine, a triazine herbicide that is similar to atrazine, is used more extensively inside prohibition areas since atrazine is prohibited and if this could become a bigger water quality problem. Information was also collected on how prohibiting the use of atrazine affects the ability to grow corn.

The results of this survey suggest that although many corn growers would like the option to use atrazine in a prohibition area, they have adapted well to growing corn without it. Half of the respondents indicated that they do not find it more difficult to control weeds in a PA without atrazine. Only about eight percent of respondents indicated that it is much more difficult to control weeds in a prohibition area and another 32 percent said it is somewhat more difficult.

Corn growers appear to be split on the question of whether it costs more to control weeds in a prohibition area with 39 percent responding "yes" and 39 percent "no". The 39 percent that said it costs more reported an average cost increase of $13.60 per acre. Only 5 percent of the corn growers surveyed indicated that they had experienced a yield reduction in a prohibition area.

By far the most common alternative to atrazine in prohibition areas was glyphosate-containing products such as Roundup. A comparison of the use of six commonly-used herbicides inside versus outside of prohibition areas showed only minor differences. It was not possible to determine if simazine is used more inside prohibition areas due to low reported use both inside and outside of prohibition areas. A full report on this survey can be found at *http://datcp.wi.gov/uploads/Environment/pdf/WeedMgtAtrazinePAs.pdf*.

Chloroacetanilide herbicide metabolites

In a study completed in 2000, 27 monitoring wells, 22 private drinking water wells, and 23 municipal wells in Wisconsin were sampled for alachlor, metolachlor, acetochlor, and their ethane sulfonic acid (ESA) and oxanillic acid (OA) metabolites. Wells were selected based on previous detections of pesticides or proximity to agricultural fields. Alachlor, metolachlor, and acetochlor are chloroacetanilide herbicides that are commonly used on corn and other crops in Wisconsin. With the exception of alachlor ESA, no historical data exists for these metabolites in Wisconsin groundwater because laboratory methods were not previously available. Over 80 percent of the monitoring wells and drinking water wells included in the survey contained the ESA and OA metabolites of alachlor and metolachlor. The metabolites of acetochlor showed a lower frequency of detection. Metabolite concentrations ranged from near the level of detection to 42 µg/L. Monitoring wells and private drinking water wells showed higher detection frequencies and concentrations than the deeper municipal wells, but the municipal wells did show significant impacts. Fifty-two percent of the municipal wells had at least one detection. No municipal well had pesticide levels that exceeded an enforcement standard.

The following are other DATCP pesticide related studies conducted recently or as part of ongoing

research.

Exceedance Survey

In 1995, DATCP completed a re-sampling of 122 Wisconsin wells that previously exceeded a pesticide enforcement standard. Most of the wells in the survey had exceeded standards for atrazine. Most were also within an atrazine prohibition area. Of wells exceeding standards for atrazine, 84 percent had declined in concentration and 16 percent had increased. About 50 percent of well owners continued to use their contaminated well and about 25 percent had installed new wells at an average cost of $6,300. This well survey has been repeated annually through 2010, with samples collected from 150 different wells at least once during this time period. As of 2010, atrazine levels had gone down in over 80 percent of the wells. Five wells remain above the enforcement standard. A full report on this program can be found at *http://datcp.wi.gov/uploads/Environment/pdf/FifteenYearsoftheDATCPExceedenceSurvey.pdf*.

Pesticide and Groundwater Impacts Study

In 1985, DATCP and DNR began a study to evaluate the potential impact of agriculture on groundwater quality. The study focused on areas of the state with high groundwater contamination potential. In 2010, this study entered its 24th year. In 2010 samples from monitoring wells near 22 agricultural fields were sampled. A total of 14 compounds were detected in groundwater, but only nitrate-N was found at a level above an existing water quality standard. Other compounds detected include alachlor, acetochlor ESA, metribuzin, thiamethoxam, and metolachlor and its ESA and OA metabolites.

Monitoring Reuse of Atrazine in Prohibition Areas

In FY 98 through FY 05, DATCP monitored the limited reuse of the herbicide atrazine in selected areas where atrazine use has been prohibited. DATCP gathered the data to see if renewed atrazine use at current restricted use rates will cause groundwater contamination. DATCP monitored groundwater quarterly at 17 fields, 10-40 acres in size, for 5 to 7 years. The data showed that all of the sites that followed study protocols exceeded the ES for atrazine at some point during the study. The nitrate enforcement standard was exceeded at 100 percent of these sites over the same sampling period. A technical advisory committee reviewed the study results and recommended that the atrazine prohibition areas remain in place and the DATCP Board concurred.

2007 Survey of Agricultural Chemicals in Wisconsin Groundwater

In 2007 DATCP conducted a statewide statistically designed survey of agricultural chemicals in Wisconsin groundwater. The purpose of the survey was to obtain a current picture of agricultural chemicals in groundwater, relate findings to land use, and compare results to previous surveys conducted in 1994, 1996, and 2001. Three hundred and ninety-eight private drinking water wells were sampled as part of this survey. Each well sample was analyzed for 32 compounds including 17 pesticide parent compounds, 14 pesticide metabolites and nitrate-nitrogen. Health standards have been established for 11 of the parent compounds and 4 of the metabolites. Based on the statistical analysis, it was estimated that the proportion of wells in Wisconsin that contained a pesticide or pesticide metabolite was 33.5 percent. The average number of pesticide or pesticide metabolite detects for wells with detects was 2.3. Areas of the state with a higher intensity of agriculture generally had higher frequencies of detections of pesticides and nitrate. The two most commonly-detected pesticide compounds were the herbicide metabolites metolachlor ESA and alachlor ESA which each had a proportion estimate of 21.6 percent. The final report for this project can be found at *http://datcp.wi.gov/uploads/Environment/pdf/ARMPub180.pdf*.

Organic Farming

Wisconsin has seen dramatic growth in certified organic farms (which do not use synthetic pesticides), from 422 in 2002 to 1,202 in 2007, an increase of 285%. Similarly, from 2002 to 2011, organic acreage in Wisconsin has increased from 81,026 acres to 195,603 acres, a 241% increase. Though the percentage of farms and farm acreage in Wisconsin that are organic remains below 2% of the total, organic markets continue to expand due to increased consumer interest in organic food, and reports of increased profits by organic producers (DATCP, 2011). Another benefit of organic farming is the significantly decreased potential for pesticides in groundwater (drinking water in rural areas) where organic practices are followed.

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Naturally-Occurring Radionuclides

Naturally-occurring radionuclides, including uranium, radium, and radon are becoming an increasing concern for groundwater quality, particularly in the Cambro-Ordovician aquifer system in eastern Wisconsin. The water produced from this aquifer often contains combined radium activities in excess of 5 pCi/L (picocuries/liter) and in some cases in excess of 30 pCi/L. For municipal supplies, this aquifer is the main area where water contains radionuclides in excess of DNR standards. Historically, about 80 public water systems have exceeded a radionuclide drinking water standard. Over 50 public water systems exceeded both the drinking water standards of 15 pCi/L for gross alpha activity, and 5 pCi/L for combined radium, (see map below). The DNR is enforcing the radionuclide standard adopted into NR 809. The DNR has been working with these systems since 2003 to ensure that they develop a compliance strategy and take corrective actions. The vast majority of these systems are now serving water that meets the radium and gross alpha standards.

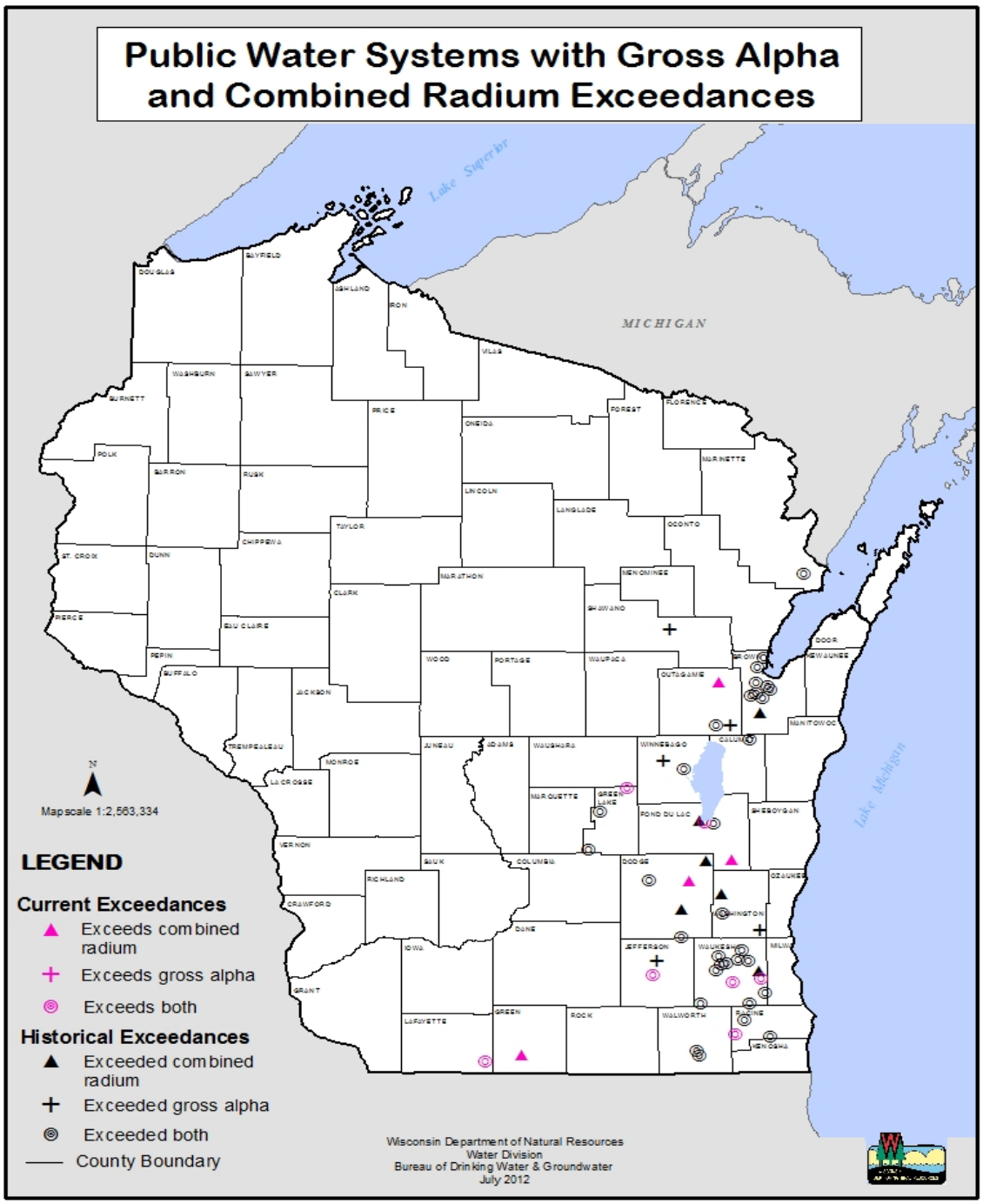
Drinking water monitoring completed since 2009 has shown a few more systems that have exceeded a radionuclide standard. Currently, there are less than 10 systems that are serving water that exceeds a radium or gross alpha standard. The DNR has formal agreements with these systems to gain compliance with the drinking water standards for radionuclides.

Previous studies have shown that radium concentrations in excess of 5 pCi/L cannot be explained solely by the presence of parent isotopes in the aquifer solids but rather is controlled by co-precipitation into the sulfate minerals barite and celestite (Grundl, et al. 2006). These minerals occur naturally in the aquifer. High radium activity occurs in the Cambro-Ordovician aquifer in a band coincident with the westward edge of the Maquoketa shale (Grundl and Cape 2006). This band extends across the entire eastern portion of the state from Brown County in the north to Racine County in the south. Radium activities have remained relatively constant from the middle 1970s to the present. High gross alpha activity also occurs in a band roughly coincident within the Maquoketa shale that extends along the entire eastern portion of the state.

Although sulfate minerals control the observed radium concentrations, determining which process(es) control the original release of radioactivity from aquifer solids into the groundwater will require a more thorough understanding of the system

In 2000 and 2001, DNR staff collected samples from about 100 community and non-transient non-community public water wells. The WSLH analyzed each sample for several alpha-emitting radiochemicals (total Uranium (U-238, U-234, U-235), total Thorium (Th-228, Th-230, Th-232), Radium 226, and Polonium 210) in an attempt to identify and quantify the relative contribution of each chemical to the total gross alpha activity in the samples (Arndt and West, 2004).

Results indicate that radium and its progeny (uranium is a major contributor in relatively few systems, 2 or 3) is the major contributor to high gross alpha activities. Small quantities of polonium and thorium have also been detected but they do not appear to be major contributors to the total gross alpha activity in public water system wells. Another important finding was that total gross alpha measurements are an overestimate of the activities of all of the alpha emitters. The WSLH has developed models to account for the discrepancy between the total gross alpha activity and measurements of individual radionuclides.



Public water systems that exceed radionuclide standards as of August 2012 or have exceeded radionuclide standards in the past. Source: DNR

The same study showed that the gross alpha activity depends appreciably on the radionuclide used as the calibration standard, the time between sample collection and sample preparation, the time between sample preparation and sample analysis, and whether a radiochemical or a gravimetric method is used to determine the total uranium activity. This is important since

according to EPA regulations an adjusted gross alpha activity exceeding 15 pCi/L is considered to be a gross alpha violation. Using the model, it is shown that for some water samples the value obtained for the adjusted gross alpha activity can range from being well within compliance to being well out of compliance. Thus the use of the model developed in this work should be of assistance in helping a water utility with a gross alpha violation determine the reason for the violation, and, therefore, how to correct it (http://www.slh.wisc.edu/ehd/radiochem/dnr_reports/dnrfinal.pdf).

A second study "Factors Affecting the Determination of Radon in Groundwater" (http://www.slh.wisc.edu/ehd/radiochem/dnr_reports/factors.pdf) will help determine the impact of expected new EPA standards for radon in drinking water. Staff from the DNR will sample about 340 non-community, non-transient and other-than-municipal water systems per year. To date, approximately 250 samples have been collected from non-transient, non-community wells. Preliminary results tend to support findings from earlier community water system monitoring which indicated that approximately 50% of the public water systems monitored in Wisconsin exceed the proposed radon standard of 300 pCi/L. As of July 2012, EPA has not finalized the drinking water standard for radon. The standard will likely be set at 3,000 pCi/L.

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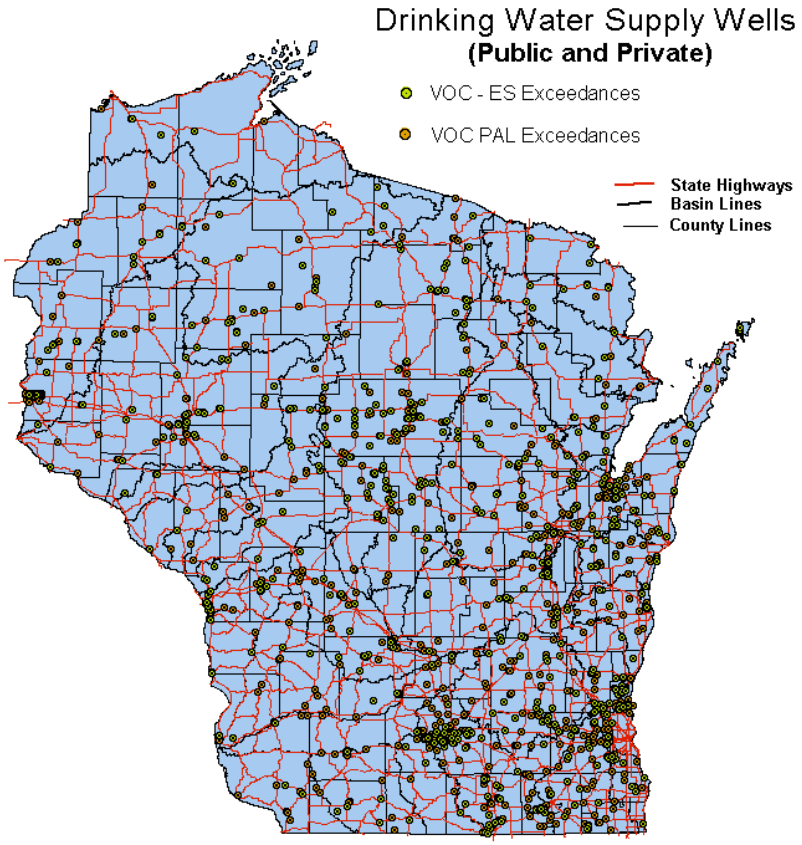
Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are a group of common industrial and household chemicals that evaporate, or volatilize, when exposed to air. Examples of VOCs include gasoline and industrial solvents, paints, paint thinners, drain cleaners, air fresheners, and household products (such as spot and stain removers). Short-term exposure to high concentrations of many VOCs can cause nausea, dizziness, tremors or other health problems. Long term exposure to some VOCs may cause cancer. Sources of VOCs in Wisconsin's groundwater include landfills, underground storage tanks (USTs), and hazardous substance spills.

Thousands of wells have been sampled for VOC analysis. Fifty-nine different VOCs have been found in Wisconsin groundwater, though only 34 of those have health based standards. Trichloroethylene is the VOC found most often in Wisconsin's groundwater. The figure below shows the location of drinking water wells with past enforcement standards (ES) and preventive actions limits (PAL) exceedances based on data from 6,399 unique wells recorded in the DNR's Groundwater Retrieval Network (GRN) database.



Volatile Organic Compounds (VOCs) past enforcement standard (ES) and preventive action limit (PAL) exceedances for public and private drinking water supply wells. Source DNR

Wisconsin has 66 active as well as 600 closed, licensed solid waste landfills which are required to monitor groundwater. In addition, the DNR currently tracks about 20,000 leaking underground storage tanks (LUSTs) and about 8,000 reported releases at a variety of facilities including gas stations, bulk petroleum and pipeline facilities, plating, dry cleaning, industrial facilities, and abandoned non-approved unlicensed landfills. Many of these sites have been identified as sources of VOCs. The DNR also tracks approximately 33,000 spills, some of which were also sources of VOCs.

Landfills

Two studies conducted over four years revealed that VOCs were significant contributors to groundwater contamination at unlined Wisconsin landfills (DNR 1988, 1989). Out of a total of 45 unlined municipal and industrial landfills tested, 27 (60%) had VOC contamination in groundwater. All of these landfills are currently closed. Of 26 unlined municipal solid waste landfills tested, VOCs contaminated groundwater at 21 (81%). No VOCs were confirmed present at any of the six engineered (liner and leachate collection) landfills included in the studies. While 20 different VOCs were detected overall, 1,1 – Dichloroethane was the most commonly occurring VOC at all of the solid waste landfills.

In a follow-up VOC study conducted from July 1992 through July 1994, the DNR reviewed historical data and sampled groundwater at 11 closed, unlined landfills and at six lined landfills. VOC levels had decreased after closure at all but two of the unlined landfills, though at many sites VOC levels did not show continued improvement. Also, the level of contamination, while below initial concentrations, remained high at many closed sites. No VOC contamination attributable to leachate migration was found at any of the six lined landfills investigated.

Increasing numbers of residential developments are located close to old, closed landfills. In 1998 and 1999 the Department of Health Services (DHS) sampled private wells down-gradient of 17 small, closed landfills in Ozaukee County. Eight of the private wells had VOC results above maximum contaminant levels. The results of this sampling showed that there might have been more closed landfills with problems than had been previously identified.

The DNR Bureaus of Waste & Materials Management, Remediation & Redevelopment, and Drinking Water & Groundwater in cooperation with the DHS, responded to this issue in early 1999 by evaluating 16 old, closed landfills – at least three from each of the five DNR regions across the state. Private wells around each of the landfills were sampled in 1999 and significant levels of contamination found. Of the 113 wells that were tested, 31 had detects of VOCs. Fourteen of the homes had levels exceeding drinking water standards and were given health advisories to not drink their water. The DNR evaluated all of the landfills where the private wells had detects to determine whether more sampling or further action was required and took follow-up measures at all of the landfills where levels exceeded drinking water standards.

Underground storage tanks

Wisconsin requires underground storage tanks (USTs) with a capacity of 60 gallons or greater to be registered with the Department of Commerce. Since 1991, this registration program has identified over 180,946 USTs of which 81,421 are federally regulated. About 12300 federally regulated tanks are in use, with a total of nearly 53,000 USTs in use total (federally regulated and state regulated). A federally regulated tank is any tank, excluding exempt tanks that is over 1,100 gallons in size, has at least 10 percent of its volume underground, and is used to store a regulated substance. Wisconsin regulates USTs down to 60 gallon capacity. Exempt tanks include: farm or residential tanks of 1,100 gallons or less; tanks storing heating oil for consumptive use on the

premises where stored; septic tanks; and storage tanks situated on or above the floor of underground areas, such as basements and cellars.

Hazardous waste

Hazardous waste treatment storage and disposal facilities are another VOC source. There are approximately 140 sites statewide subject to corrective action authorities, and DNR's Bureau for Remediation and Redevelopment is overseeing investigation or remediation at approximately half of these sites. Generators improperly managing hazardous waste are another source of VOC contamination. The majority of hazardous waste projects are being addressed in accordance with the NR 700 Wis. Adm. Code series.

Hazardous Substance Spills

The Hazardous Substance Spill Law, ch. NR 292.11 Wis. Stats., requires immediate notification when hazardous substances are discharged, as well as taking actions necessary to restore the environment to the extent practicable. In FY 12 approximately 900 hazardous substance discharges were reported to DNR. Approximately 550 were spills, 310 were Environmental Repair Program sites or LUSTs, and 11 were agrichemical discharges reported to DNR.

The NR 700 Wis. Adm. Code series, specifically ch. NR 706, contains the requirements for notification when a discharge or spill occurs. Chapter NR 708 contains requirements for taking immediate and/or interim actions when releases occur. Groundwater monitoring is performed when necessary to delineate the extent of contamination. The spills program 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.

Summaries of hazardous substance release and cleanup information may be found at http://dnr.wi.gov/topic/Brownfields/RRProgram.html.

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Microbial agents

The United States produces some of the cleanest drinking water in the world and yet there are still reports of waterborne disease outbreaks. These outbreaks are produced by microbial agents including bacteria, viruses and parasites. These agents can cause acute and chronic illnesses and result in life-threatening conditions for individuals with weakened immune systems. Of the approximately 20 outbreaks reported nationally per year, more than half are related to groundwater consumption (Lee, and others 2002; Yoder and others 2008). Many waterborne outbreaks are not reported or detected.

In Wisconsin, a statewide assessment showed approximately 23 percent of private well water samples tested positive for total coliform bacteria, an indicator species of other biological agents (Warzecha, and others 1995). Approximately 3 percent of private well water samples tested positive for *E. coli*, an indicator of potential water borne disease that originates in the mammalian intestinal tract.

The DNR recommends that private well owners test their water for total coliform bacteria annually or when there is a change in taste, color, or odor of the water. Public drinking water systems that disinfect their water supplies are required to sample, on a quarterly basis, for bacteria from the raw water (before treatment) in each well. These raw water samples are representative of the source from which the wells draw groundwater. The DNR has recently begun tracking total coliform detects in the raw water samples through its Drinking Water System database. Approximately

Manure spreading can contaminate groundwater with bacteria and/or viruses in karst areas and/or where soils are thin. Contamination is more likely when landspreading of manure occurs prior to, or during runoff events. Runoff events occur when precipitation exceeds soil infiltration rates, or snowpack melts during the spring thaw. Runoff risks can be substantially reduced if manure spreading is done according to an approved nutrient management plan which includes a number of restrictions on manure applications to thin soils and locally identified karst features. Currently, however, less than 21 percent of state farmland is covered by a state-approved nutrient management plan. Scores of private wells have had to be replaced due to manure contamination at a cost to the state of over $500,000

DNR private water staff respond to homeowner complaints regarding private well contamination events, many of which correspond to manure spreading. Until 2007 there were no readily available methods for testing for manure in these wells. Standard methods for testing for bacteria do not show whether the bacteria are derived from human or animal sources. Recently developed laboratory techniques have made it possible to discern whether bacteria are from human, animal or other sources. These microbial source tracking (MST) tools include tests for *Rhodococcus coprophilus* (indicative of grazing animal manure), *Bifidobacteria* (indicative of human waste) and *Bacteriodes* (indicative of recent fecal contamination by either humans and/or grazing animals). Recently, an analysis was developed by Sibley et al. that can successfully detect bovine adenoviruses to indicate bovine fecal contamination of groundwater thus increasing the size of the molecular “toolbox” for better understanding of the origin of fecal contamination. The DNR has been using these tools since 2007 to determine the source of fecal contamination in private wells. Since 2007, in response to private well water quality complaints over 60 groundwater samples have been analyzed. Results indicate that the majority of well water samples were contaminated with grazing animal waste. Less than ten percent of samples collected indicate microbial contamination from human sources. Even more rare were wells contaminated with

both grazing animal and human fecal bacteria. Approximately twenty percent of the well samples had no indication of microbial contamination. DNR's Drinking Water & Groundwater and Runoff Management programs are working with the DATCP nutrient management program to find ways of controlling this significant threat to health.

Some parts of the state are particularly vulnerable to microbial contamination. Microbiological contamination often occurs in areas where the depth to groundwater or depth of soil cover is shallow or in areas of fractured bedrock. In these areas, there is little natural attenuation potential. Door County is one such location where bedrock is fractured and wells are often shallow. Many other parts of Wisconsin contain areas of shallow, fractured bedrock or minor karst features making them very vulnerable to microbial contamination from the land surface.

In a recent survey of 25 private wells in Door County, 18 had detections of total coliform in at least one monthly sample over a 1-year period (Braatz, 2004). Forty percent had detections of a fecal indicator (*E. coli* or enterococci). Significant seasonal trends were also apparent, with higher percentages of wells with fecal indicators in the summer months. There were also waterborne illness outbreaks at two Door County restaurants, one in December 2004 and another in May 2007 (Borchardt, M. A., 2010). The cause of the May 2007 outbreak was a genogroup 1 norovirus, quantified in the restaurant's well water at more than 50 viruses per liter, well above the infectious dose necessary for a widespread outbreak. More than 250 people became ill and 6 people were hospitalized. The nucleic acid sequences of the viruses from the well and stool specimens from ill patrons were identical, providing definitive evidence for the waterborne transmission route. Moreover, a state-of-the-art dye tracer study conducted by the University of Minnesota demonstrated unequivocally a rapid transport route from the restaurant's new septic system to its well. Transport was from both: 1) untreated effluent discovered leaking from a broken pipe fitting near a septic tank; and 2) discharge from the septic drainfield. Groundwater and public health experts believe another outbreak in Door County may be imminent due to the widespread shallow soils and karst bedrock found in the county, which makes it difficult to find an appropriate place for locating septic systems.

There is overwhelming evidence in the state of Wisconsin and nationwide that karst areas have highly vulnerable groundwater requiring special consideration and protection. These findings lead to the conclusion that current requirements for septic systems and associated leach fields are inadequate to protect public health and the environment in areas of Wisconsin where water wells are completed in shallow carbonate aquifers. A way to mitigate this problem would be to refine requirements for construction of private water wells to include well construction practices that will most likely provide safe, potable groundwater in these settings.

Researchers at the Marshfield Clinic Research Foundation have investigated the association between pathogenic viruses and bacteria in private wells with incidences of infectious diarrhea as indicators of well water contamination (Borchardt, and others 2003b). In general, infectious diarrhea did not correlate with drinking from private wells or drinking from wells that had positive analytical results for total coliform. However, wells which tested positive for enterococci were associated with children having diarrhea of unknown etiology likely caused by noroviruses. A subsequent study of 50 private wells throughout the state indicates that 8percent of private wells may be subject to virus contamination (Borchardt and others 2003a). Wells positive for viruses did not show seasonal trends nor were they associated with commonly used indicators of microbial contamination such as total coliform or fecal enterococci. These studies suggest that increased monitoring and detection methods for viruses are needed to assess the risk of drinking water with potential microbial contamination.

In another study in collaboration with the US Geological Survey, Marshfield researchers found that 50 percent of water samples collected from four La Crosse municipal wells were positive for enteric viruses, including enteroviruses, rotavirus, hepatitis A virus, and norovirus (Borchardt and others 2004). As with the above described private well study, there was no correlation to common indicators of sanitary quality, nor was there a consistent seasonal trend. More surprising, viruses were common even in those wells without any Mississippi River water infiltration (Borchardt and others 2004, Hunt and others 2005), suggesting fecal sources other than those associated with surface waters were contaminating the wells. The most likely source is leaking sanitary sewers. The study did not address whether the viruses are inactivated through disinfection processes, or result in illness in the community.

Leaking sanitary sewers were shown to be a source of infectious viruses to drinking water wells in subsequent work funded by WDNR and the USGS (Hunt and others, in review). Marshfield Clinic and USGS researchers performed a synoptic sampling of over 30 unconfined municipal wells in 14 Wisconsin communities. Groundwater collected was evaluated for surface water contributions and presence of waste-water tracers and human enteric viruses. From this survey 8 wells had surface water contributions, 4 had unambiguous waste-water tracers, and 5 were positive for viruses. These analyses were used to identify 3 well sites used for intensive instrumentation of the shallow groundwater system between the wellhead and suspected sanitary sewer sources. Viruses and waste-water tracers were found in the groundwater at all three instrumented sites. The work showed that concurrent sampling at any one time may not show simultaneous virus and trace presence due to differences in analytical precision and seasonality of the sources in the waste stream. However, given sufficient sampling over time, a good relation between unambiguous waste-water tracers and virus occurrence was identified such that locations that were characterized by recurring unambiguous tracer occurrence also were found to have enteric viruses present. Moreover, nearby groundwater velocities and presence of infectious viruses at the wellhead demonstrate that high-capacity pumping can induce travel times that are sufficiently short such that viruses are not inactivated during their time in the subsurface. Because sanitary sewers are commonly located near municipal wells and can carry very high numbers of infectious viruses, and very small numbers of infectious viruses in water can constitute a health risk, drinking water wells can be considered vulnerable to fast groundwater flow paths that only contribute a very small amount of virus-laden water to a well. Thus, these results suggest that evaluations of drinking well vulnerability should include low yield-fast transport pathways in addition to traditional high yield-slower transport plume contaminants currently included in wellhead protection. Such evaluations are thought to be important in communities such as the 14 included in the study, as they were chosen because they did not routinely employ chlorination or other disinfection procedures at the time of the study.

Microbial contamination of groundwater is not restricted to aquifers typically regarded as vulnerable or shallow aquifers. In a novel study, researchers at the Marshfield Clinic, Wisconsin Geological and Natural History Survey, and the University of Waterloo, discovered human viruses in the confined aquifer supply Madison's drinking water (Borchardt et al 2007). This finding was completely unexpected because it was believed the 3 to 9 meter shale confining layer protected the aquifer from microbial contamination. Additional research by Marshfield Clinic, WGNHS, and USGS, on the Madison wells has shown virus transport from leaking sanitary sewers to the wells is very rapid, on the order of weeks to months instead of years (Bradbury and others, 2008; Bradbury et al 2010). The virus transport and contamination levels were particularly high after extreme rainfall events or rapid snowmelt. From a public health perspective, the lesson learned is that all aquifers are potentially vulnerable to microbial contamination and require a similar level of disinfection for drinking water purposes. Public water systems that supply

groundwater in Wisconsin are not required to disinfect their drinking water. Approximately sixty communities in the state do not disinfect the groundwater supplied for drinking water.

Public and private water samples are not regularly analyzed for viruses. Viral testing is expensive and very few labs are capable of conducting the test. The presence of coliform bacteria has historically been used to indicate the water supply is not safe for human consumption. However, virus data complicates this interpretation since the presence of coliform (and other indicators as well) do not always correlate with the presence of enteric viruses. For example, municipal water sampled by Borchardt and others (2004) showed that, even though 50 percent of the samples were positive for viruses, none of the same samples tested positive for coliform or other indicators. Recently, water samples from private residences in Door County found low levels of some viruses but water samples did not contain coliform (Wisconsin DNR). Indicators have a high positive predictive value but a low negative predictive value for pathogen occurrence. In other words, when an indicator is present in drinking water there is a high probability that particular water source will be contaminated with a pathogen at some point in time. However, if an indicator is absent, no inferences can be made about pathogen occurrence. Additional study is needed to determine what virus results mean to human health.

Data from the U.S. EPA shows that the highest percentage of microbial unsafe water is found in small water systems, like transient non-community (TN) systems such as restaurants and convenience stores (Peterson, 2001). There are approximately 9,500 active TN systems in Wisconsin. The mobility of people consuming water at small water systems and general lack of knowledge of illness symptoms hinder waterborne illness outbreak identification.

Nationally, the Center for Disease Control tracks and identifies failures in water systems that lead to illness outbreaks. Because of the increasing evidence for widespread occurrence of microbial contaminants, additional monitoring requirements for vulnerable public water systems are on the horizon.

The U.S. EPA promulgated the Groundwater Rule, on November 8, 2006 which modified Safe Drinking Water Act requirements to increase monitoring for fecal contamination in groundwater and reduce the occurrence of illness from drinking water borne microbial pathogens. The first strategy of the Groundwater Rule includes sanitary surveys of public systems to identify deficiencies. The second strategy is an improvement on Safe Drinking Water Act requirements which have focused on sampling for microbial indicators in the distribution system. The Groundwater Rule will require source water monitoring when total coliform is detected in the distribution system. Third, the Rule requires corrective action for non-complying features found in the water system and eliminating fecal contamination with treatment or providing an alternative permanent source of water. The forth strategy of the Rule is monitoring requirements to ensure that treatment equipment is maintained. The Groundwater Rule includes preventative strategies that prior EPA drinking water legislation did not adequately address. Implementation of the deficiency and monitoring requirements of Groundwater Rule began on December 1, 2009.

Wisconsin conducts inspections and requires correction of non-complying features. Therefore, the major changes resulting from the Rule are additional monitoring of source water and installation of approved treatment devices or a new water source for the wells found to contain fecal contamination.

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Water Use

Chapter 281 of the Wisconsin Statutes requires annual reporting to the Wisconsin Department of Natural Resources (WDNR) 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. Reporting data is spatially located such that inquiries can be customized to specific locations, withdrawal types and water uses. The annual collection of these reports will facilitate better understanding of how groundwater withdrawals are affected by meteorological, hydrological, and socio-economic variability.

Results from 2010 reporting show that the largest category of groundwater withdrawals was public water supply accounting for 47% of the total statewide groundwater withdrawals (WDNR 2011). The second largest category of groundwater withdrawal in the state was agricultural irrigation accounting for 26% of statewide groundwater withdrawals. Precipitation in 2010 was notably higher than average and likely represents the lower range of withdrawals for agricultural irrigation.

As part of the National Water-Use Information Program, the U.S. Geological Survey (USGS) also collects, compiles, and disseminates information about water use. Every 5 years, since 1950, the USGS has collected Wisconsin water use data and published it in a National circular. Since 1978, these data were aggregated every 5 years at the county level, and sometimes by watershed and aquifer, to be published in a state summary. Currently there are six reports that summarize water use in Wisconsin.

The USGS estimated total groundwater use in Wisconsin during 2005 to be 986 million gallons per day (Mgal/d) (Buchwald, 2009). This estimate is 380 Mgal/d greater than withdrawals estimated for 1979, and 146 Mgal/d greater than those estimated for 2000 (Ellefson and others, 2002; Lawrence and Ellefson, 1982). Total groundwater use in 2005 can be divided into public-supply water use, as in water for various community uses delivered by a water-supply system (305 Mgal/d), and self-supplied water use, as in water withdrawn by a user and not obtained from a public supply (681 Mgal/d). Irrigation water use was the largest category of self-supplied use (387 Mgal/d), although the reported 2005 estimate was believed to be at the higher end of the range of possible irrigation water use.

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Surface Water Impacts

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.

The problem has been well documented in the central sands region of the state (parts of Portage, Waushara, Waupaca, Adams, and Marquette Counties), where 20% of the state's groundwater is pumped from over 3000 high capacity wells, dominantly for irrigation (Buchwald 2009). Dozens of lakes and potentially hundreds of stream miles may be affected. Some lakes have completely dried, most notably Long Lake near Plainfield. Others have suffered varying degrees of ecological impacts. Recreation has been impaired, for instance, in Portage County where the county swimming beach at Wolf Lake has been closed for about 8 years. The Little Plover River, a Class I trout stream and Exceptional Resource Water in Portage County, dried in parts during 2005-2009.

Statistical approaches and groundwater flow modeling indicate that area streams and lakes would have had continuous and healthy flows and water levels in the absence of groundwater pumping in the area.

Several of the GCC agencies are participating in a Wisconsin Institute on Sustainable Agriculture (WISA) consortium (http://wisa.cals.wisc.edu/current-projects) to help understand the potential impacts of irrigation pumping on lake levels in Wisconsin's Central sands region.

References:

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Regional Drawdowns

The effects of groundwater withdrawals are well documented on a regional scale in the Lower Fox River Valley, southeastern Wisconsin, and Dane County. There have been substantial declines in groundwater levels in these three areas. In August of 2007, six suburban communities in the Lower Fox Valley reduced consumption of groundwater by about 8.2 million gallons per day by switching to surface water supplied by pipeline from Lake Michigan. As a result, water levels in the deep sandstone aquifer near Green Bay have risen. The WGNHS determined that so far, water levels have risen more than 150 feet in certain places (Luczaj, 2009). Although the water levels are approaching a new stable level, a smaller additional rise is expected. The USGS and the WGNHS maintain a water level network of wells across the state. In April 2012, the water levels in one such well, located in the deep sandstone just north of the City of Green Bay, reached their highest point since measurements began in 1952.

See also http://dnr.wi.gov/topic/groundwater/documents/GCC/Benefits/Drawdowns.pdf for a discussion of how GCC-coordinated research and monitoring has addressed drawdowns.

Reference:

Luczaj, J.A. and Hart, D.J., 2009, Drawdown in the Northeast Groundwater Management Area (Brown, Outagamie, and Calumet Counties, WI). Final Project Report submitted to the Wisconsin Department of Natural Resources on July 3, 2009; 59 pages.

Impact of Reduced Quantity on Groundwater Quality

An example of how regional drawdown can bring about groundwater quality concerns is seen in Southeastern Wisconsin. As prolonged heavy water withdrawals from wells in the deep sandstone aquifer have drawn water levels down hundreds of feet and in recent years, the concentrations of radionuclides and other elements have increased in many of these wells. Radionuclides are carcinogenic and very costly to remove. Several communities facing a regulatory deadline for reducing the level of a specific radionuclide, radium, in their drinking water have been forced to look for alternative sources. Alternatives have included switching from a groundwater source to a surface water source, namely Lake Michigan, extensive treatment of water from deep wells to remove the contaminants, and expanded use of wells in shallow aquifers. Each of these options presents significant obstacles or concerns. Continued use of the deep aquifer with extensive treatment will be quite expensive, will add to the existing drawdown problems and may not be sustainable in the long term. Use of Lake Michigan water outside of the basin would be precedent-setting and could be challenging in terms of demonstrating compliance with the Great Lake Compact and securing concurrence by other Great Lakes states. The DNR is reviewing the City of Waukesha's application for a diversion of Lake Michigan water. Expanded use of shallow wells could also be problematic because it may impact surface waters or other shallow wells. In addition, shallow wells are generally more susceptible than deeper wells to contamination from near-surface sources such as nitrate and pesticides.

Another example of regional drawdown causing groundwater quality problems occurs in the Lower Fox River Valley, where detections of arsenic in private well water have increased in recent years (also described in the Groundwater Quality Section of this report). Investigations in the affected area indicate that most of the arsenic is coming from a highly mineralized zone at the top of the St. Peter Sandstone. Increased groundwater use in the Lower Fox River Valley has lowered water levels in the bedrock aquifer. In some locations, this has exposed the mineralized zone to the atmosphere leading to oxidation and subsequent release of arsenic to the groundwater. In 2006 a new (lower) standard of 10 µg/L for arsenic in drinking water took effect, leading to many wells being in substantive violation of this standard.

Land use and high groundwater conflicts

In contrast to the groundwater issues above that relate to a lack of sufficient groundwater quantity, too much groundwater can also be a problem. A dramatic example was when Southern Wisconsin experienced record amounts of precipitation from August 2007 through July 2008. Severe flooding occurred across this region, resulting in significant property loss, human displacement, and disruption of transportation. While most of the initial flooding occurred as surface water overflow, longer-term groundwater flooding remained for many weeks or months following the rain events. Groundwater flooding occurs when the water table rises above the land surface, and can be long-lasting because water-table decline requires drainage of an entire aquifer. Seepage lakes may also experience flooding of shoreline beaches and developments due to a rise in the water table elevation and the related long-term increase in lake stage.

Several communities recently affected by elevated groundwater levels experienced a return to drier conditions in the first half of 2012. Examples include Clear Lake, in Rock County, where the lake stage increased by about 7 feet in 2009, but returned to previous conditions in May 2012. In Spring Green, 4,378 acres outside of areas currently designated as floodplain by the Federal Emergency Management Agency (FEMA) flooded for over five months in 2008. Modeling and field investigation indicate this flooding was caused by water table rise above ground surface. Mitigation of high groundwater elevations in Spring Green included a $5.4 million FEMA grant in 2009 to acquire and demolish 28 flood damaged homes. Due to insufficient funding for the Statewide Groundwater Level Observation Network, the addition of a Spring Green monitoring well to the long term network has not been possible. This is a missed opportunity for the State to aid citizens and local government in a community hit hard by both drought and deluge over just a few years.

Although the hydrogeologic setting varies among affected areas, the widespread occurrences of groundwater flooding and the regional nature of intense precipitation events in 2007 and 2008 suggest this is a regional issue. A recently completed study of affected hydrologic systems and climate change, funded by the UW System., suggests that years of extremely high water table conditions may still occur but will remain relatively rare in this century (Joachim et al, 2011). Water resource managers should expect to see some years of high recharge amongst overall less recharge on average. The study concluded that warmer climate conditions will increase evapotranspiration and result in a reduction of groundwater recharge under certain crop types or land cover. Specifically related to the Spring Green region, the study indicated that water table fluctuations up to 3 meters should be expected in planning basement and foundation depths, road construction, or design of on-site wastewater treatment systems.

Reference:
Joachim DR, Gotkowitz MB, Vavrus SJ, Loheide SPI, Bradbury KR. 2011. Forecasting Impacts of Extreme Precipitation Events on Wisconsin's Groundwater Levels, Wisconsin Geological and Natural History Survey, Open File Report 2011-03

Statewide Groundwater Level Network

Wisconsin's statewide groundwater level monitoring network, jointly operated by the University of Wisconsin Extension - Wisconsin Geological and Natural History Survey and the U.S. Geological Survey, provides data crucial to understanding the state's groundwater quantity issues. This network currently consists of 181 real-time, continuous and periodic monitoring wells, and the data are publicly available on the Internet: http://wi.water.usgs.gov/data/groundwater.html.

Steadily declining funding since 1995 has led to the removal of many wells from the monitoring network. To fill in some of the resulting data gaps, USGS and WGNHS have identified several existing wells for addition to the current groundwater observation network. In 20131-2012, the DNR, WGNHS and USGS will use water use fee revenue to begin refitting and instrumenting these wells. A deep well located in Milwaukee County and a well in Waukesha County will be refitted to allow observation of groundwater in multiple aquifers. New, shallower wells will also be installed at each of these sites to monitor the upper aquifer. These monitoring points will provide a picture of groundwater movement, quantity and quality in the major aquifers of southeast Wisconsin and within the Maquoketa Shale confining unit. Two spring complexes in Waukesha County will also be instrumented to monitor groundwater discharge and assist with understanding shallow groundwater conditions. As part of this same effort, the USGS will assess the condition of at least six monitoring wells in eastern Wisconsin, which were formerly in the monitoring network but removed due to insufficient funding. If the wells are in working condition and demonstrate a good connection to the groundwater system, they will be reincorporated into the groundwater level network.

Wisconsin Stream Model

During the 2013 and 2014 fiscal years, DNR researchers will develop a detailed model that predicts streamflow in ungaged streams, identify factors (such as land use, groundwater recharge, or climatic elements) that may be closely linked to stream ecology, and relate those factors to the abundance of fish species in Wisconsin's streams. This project will help determine what hydrologic changes are likely to cause significant environmental impacts to Wisconsin streams.

Alternative Sources – Aquifer Storage and Recovery

Aquifer Storage and Recovery (ASR) is a water management tool that involves injecting treated municipal drinking water back into the aquifer during times of less water use and pumping this water back out when demand is high, typically during the summer. The cities of Oak Creek and Green Bay sought approval to use ASR wells to address water shortages during peak demand periods.

In Green Bay ASR was pilot-tested , but yielded water with significant concentrations of arsenic and other contaminants, mobilized from the rock matrix of the aquifer. The Green Bay Water Utility stopped pursuing an ASR well after learning that the Central Brown County Water Authority would construct a pipeline and purchase drinking water from the Manitowoc Water Utility rather than buy additional drinking water from the Green Bay utility.

Similarly, pilot testing of ASR at Oak Creek found increasing concentrations of manganese and iron in each successive cycle. Concentrations of mobilized substances eventually exceeded state groundwater quality standards. In 2011 the utility discontinued ASR operations and, instead, expanded its surface water treatment capability.

See the Department of Natural Resources Agency Activities section of this report for more information.