Wisconsin Groundwater Coordinating Council

Fiscal Year 2010

REPORT TO THE LEGISLATURE

August, 2010

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Department of Agriculture, Trade, and Consumer Protection – **Kathy F. Pielsticker**
Department of Commerce - **Berni Mattsson**
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**
University of Wisconsin System – **Anders Andren**

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U. S. Geological Survey - **Randy Hunt**

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Department of Commerce - **Jon Heberer**
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Wisconsin County Code Administrators - **Ray Schmidt**
Dane County Conservation and Planning – **Mike Kakuska**
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Wisconsin Water Association - **Nancy Quirk**
Department of Transportation - **Bob Pearson**
University of Wisconsin System **- Steve Born**
U. S. Geological Survey **–** vacant

State of Wisconsin \ GROUNDWATER COORDINATING COUNCIL

Jim Doyle, Governor

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August, 2010

To: The Citizens of Wisconsin
The Honorable Governor Jim Doyle
Senate Committee on Environment and Natural Resources
Assembly Committee on Natural Resources
Secretary Frank Busalacchi - Department of Transportation
Secretary Aaron Olver - Department of Commerce
Acting Secretary - Department of Agriculture, Trade & Consumer Protection
Secretary Karen Timberlake - Department of Health Services
Secretary Matthew J. Frank - 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 2010 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 26 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 10 (July 1, 2009 to June 30, 2010). 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.*

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

- Research and monitoring on virus occurrence, arsenic treatment, nitrate effects, mercury methylation, extreme precipitation events and developing new tools for looking at hydrostratigraphy and investigating fecal contamination.
- Continued implementation of the Great Lakes Compact (2008 Wisconsin Act 227) and the Groundwater Quantity Law (2003 Wisconsin Act 310).
- Groundwater education continued with the tenth year of the groundwater teacher workshops and the first full year of a new outreach program at the Wisconsin Geological and Natural History Survey.

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

Sincerely,

Bruce Baker, Chair
Groundwater Coordinating Council

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PURPOSE OF THE GCC AND THIS REPORT

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."

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 2010 (FY 10). Please note that this year's report format has been changed from previous years. This report has been greatly condensed with supporting information referenced by numerous Internet links.

Membership of the GCC includes the Secretaries of the Departments of Natural Resources (DNR); Commerce; 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 four GCC subcommittees are listed on the inside of the front cover.

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.

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 GCCs 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 10 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. After a multi-agency effort spear-headed by the UW Water Resources Institute, the GCC approved the FY 11 Joint Solicitation for Proposals in August of 2009. A total of 12 project proposals were received. A comprehensive review process including the GRAC, the GCC's Monitoring & Data Management and Research Subcommittees 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 11. The process resulted in the selection of seven new projects for funding for FY 11, five by UWS and two 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

All Wisconsin state-funded groundwater research and monitoring projects:
https://dnr.wisconsin.gov/topic/Groundwater/GCC/research.html

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

In 2010 considerable progress was made by WRI and DNR in locating older final reports and summaries for digitization and availability on the Internet.

Information and Outreach Activities
For the tenth 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 UW Stevens Point. In January and February, educators from 28 schools and nature centers took part in the workshops held at Mount Horeb, Spooner, and Green Bay. 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 240 groundwater models have been given to schools and nature centers since 2001 and nearly 500 educators have received hands-on training in using the model effectively.

A survey was completed of participating educators covering the program's past 10 years. Of the 72 educators who responded to the survey:

- 92% of the models are in use at varying levels.
- 93% indicated using the model to demonstrate and discuss groundwater with more than 100 students per year.
- 100% believe the sand-tank model increased their students understanding of groundwater.

The WRI again contributed to several news releases for the annual "Groundwater Awareness Week" in March 2010 that were distributed via the UW media mailing lists. The WRI and UW-Extension also arranged for DNR and UW-Stevens Point staff to discuss groundwater and drinking water concerns on Wisconsin Public Radio's Larry Meiller show during the week.

The WRI collaborated with the GCC Education Subcommittee to continue work on a series of four fact sheets on Wisconsin's most important groundwater resource issues: nitrate, arsenic, groundwater quantity, and pathogens. These fact sheets complement the 2008 publication Protecting Wisconsin's Buried Treasure. The nitrate and arsenic fact sheets and the booklet are available online.

The Education Subcommittee also provided input for the UWEX Water reuse and conservation fact sheet and a WGNHS karst handout revision.

Other Coordination Activities
The GCC continued to promote communication, coordination and cooperation between the state agencies through its quarterly meetings. In FY 10, the GCC received briefings, heard presentations, and discussed:

- Activities of the Legislative Groundwater Work Group
- Methylmercury production in a groundwater-dominated wetland
- The FY 11 Joint Solicitation
- Groundwater drawdown in the Northeast Groundwater Management Area (Brown, Outagamie, and Calumet Counties)
- Impacts of State budget cuts on groundwater programs including the DNR Water Division work reduction policy
- DNR Water Division leadership change
- The occurrence and generation of nitrite in ground and surface waters in an agricultural watershed
- Many small informational items presented by the agencies.

More information on the coordinating efforts of the GCC can be found in the FY 10 GCC meeting minutes. 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 10. Detailed discussions of the groundwater activities of each agency can be found in this report and on the GCC webpages:

Department of Natural Resources Groundwater Activities

Department of Agriculture, Trade, and Consumer Protection Groundwater Activities

Department of Commerce Groundwater Activities

Department of Transportation Groundwater Activities

Department of Health Services Groundwater Activities

Wisconsin Geological and Natural History Survey Groundwater Activities

University of Wisconsin System Groundwater Activities

United States Geological Survey – Wisconsin Division Groundwater Activities

United States Department of Agriculture – Natural Resources Conservation Service Groundwater Activities

CONDITION OF THE GROUNDWATER RESOURCE

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 online and in this report.

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 were the herbicide metabolites metolachlor ESA and alachlor ESA which each had a proportion estimate of 21.6%. More information on pesticides in Wisconsin groundwater can be found in this report.

Nitrate: Nitrate-nitrogen is the most common contaminant found in Wisconsin's groundwater. Nitrate can enter groundwater and surface water from a variety of sources including farm fields, animal feedlots, septic tanks, and decaying vegetation. Concentrations of nitrate in private water supplies frequently 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. This combined dataset from DNR's Groundwater Retrieval Network (GRN) database, the Center for Watershed Science and Education database, and DATCP's groundwater database, included only the most recent nitrate result for each sampled private well. Out of the 48,818 samples, 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 in this report.

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% 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. (Borchardt, 1998, 2000, 2003a, 2004b). Other studies showed virus presence in four La Crosse municipal wells (Hunt and Borchardt, 2003, Borchardt et al. 2004); in the municipal wells and wastewater system in Madison (Borchardt, et.al, 2007); and in five shallow municipal wells serving smaller communities (Hunt and Borchardt, in review).

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 in this report

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 35 public water systems exceed the drinking water standard of 15 pCi/L for gross alpha activity (Nelson). 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 in this report.

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 in this report.

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 in this report.

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 $15.5 million has been spent by DNR, UWS, DATCP, and Commerce through FY 10 on 376 different projects dealing with groundwater or related topics. A list of all these projects is available on the GCC webpage.

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 webpages 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.

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 2010 statewide groundwater protection priorities in the areas of research, monitoring, policy, planning, and coordination. In addition, the following list of priorities sets forth the GCC's recommendations for future groundwater protection and management needs to state agencies, the Governor, the Legislature, and the citizens of Wisconsin.

Research & Monitoring Priorities

1. **Evaluate the scope of manure pollution of groundwater.:** Groundwater contamination associated with manure handling and disposal is an ongoing problem in many parts of Wisconsin Rural home owners sometimes report brown, discolored, or smelly well water, and some of these cases have been directly linked to manure contamination. Concern about this problem is increasing as Wisconsin farming methods have evolved toward larger farms with thousands of animal units and proportionally higher waste loads. Manure handling has also evolved toward producing material with higher liquid content, which is easier to transport and store but has a higher probability of moving to groundwater than the higher-solid manure produced by traditional Wisconsin farms. A statewide assessment of manure-groundwater issues is needed to understand the scope and magnitude of the problem. Mechanisms, pathways, and timing of movement into groundwater, the influence of landscape settings and climatic factors, the applicability of new analytical tools and methods of vulnerability assessment and best management practices (BMPs) and the threat of associated contaminants (bacteria, nitrate, pharmaceuticals, viruses, other pathogens, etc) all need to be better understood. Several manure management research and monitoring projects started in FY 08. The GCC and its subcommittees need to help evaluate the findings and guide follow-up projects on this topic.

2. **Evaluate occurrence of recently discovered groundwater contaminants:** Recent research conducted in Europe and the U.S. indicates that traces of pharmaceuticals (including antibiotics and hormones) and pesticide breakdown products are common contaminants found in groundwater and surface water. Recent sampling funded by the WDNR and USGS documented wastewater byproducts in some drinking water wells in Wisconsin. In addition, studies have found evidence of viruses and other microbial agents in both municipal water supplies and domestic wells. More research is needed to evaluate the human health threats these substances pose and the level of occurrence in Wisconsin's groundwater resource,.

3. **Define the impacts of groundwater withdrawals:** Recent headlines about lakes, streams and springs drying up in various parts of the state, and severe groundwater level drawdowns in southeastern Wisconsin have generated many questions about the effects of groundwater withdrawals on surface waters and long-term groundwater availability. Aside from a few cases, the picture of groundwater withdrawals and associated impacts on surface water is ill-defined at the state-scale. There is a need to further quantify hydrologic relationships between surface water and groundwater, as well as to develop tools to evaluate the impacts of withdrawals on surface waters. The GCC should continue to encourage research efforts that will address this issue.

4. **Understand the links between land use and groundwater quantity and quality:** Intelligent decision-making requires an understanding of how land use change (such as a change from rural to urban land use) impacts groundwater. For example, Juckem et al. (2008) show that land management mitigates or magnifies stresses such as climate change. Also, agricultural nonpoint source rules require nutrient management plans that are intended to reduce nutrient inputs. The effects of land and nutrient management practices on surface water and groundwater quality need to be better understood. Another example is the impact of storm water infiltration on groundwater. Storm water infiltration rules require storm water infiltration trenches in many commercial and multi-family residential settings in Wisconsin. This will help reduce runoff in urban areas, but the impacts of trenches on groundwater quality and quantity are not fully understood. Research is needed to determine the impact of infiltration devices on local groundwater, and to assess the need for signage or abandonment criteria to protect the groundwater resource.

5. **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. Additionally, recent groundwater/surface-water modeling by USGS suggests that climate change will affect timing of groundwater recharge, amount of baseflow in streams, the relative contribution of groundwater to lakes, and the distribution of wetlands on our landscape. More work is needed on 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 management strategies for Wisconsin's groundwater supply.

6. **Investigate extent and origins of naturally occurring substances in groundwater:** Continued problems of elevated arsenic, low pH, and other water quality problems in

domestic wells exist over large areas of northeast Wisconsin. Additionally elevated sulfate, total dissolved solids (TDS), and radium have been found in some new deep municipal wells in the Lower Fox River Valley. In some other existing deep wells as far south as Milwaukee, TDS has been steadily increasing over several years. Elevated levels of radium, sulfate and TDS pose a problem for local water managers, and the origin of these constituents is not well-understood. The State needs more information about the extent and naturally occurring contaminants in order to give advice to homeowners, municipalities, and well drilling contractors. The GCC should continue to encourage research efforts that will provide information useful in addressing these issues.

7. **Continue to evaluate and catalog Wisconsin's groundwater resources.** Water supply problems are typically not statewide problems but rather local supply problems. That is, the flow of water in the natural system cannot always keep up with the local demands placed upon it; our ability to extract water locally exceeds the natural replenishment. Although we have ample amounts of water in our state, we can still experience water shortages locally. The groundwater resource needs to be further defined in terms of its quality, quantity, and availability.

Policy & Planning Priorities

8. **Continue to fund groundwater monitoring and research**: Numerous years of state budget cuts and increased costs have reduced the number of groundwater research and monitoring projects that are funded each year (see http://dnr.wi.gov/org/water/dwg/gcc/rtl/2010/FY1999-2010Projects.doc). Continued cuts will hamper the State's ability to address critical groundwater monitoring and research needs in the future. Research and monitoring are necessary to identify and test cost-effective groundwater protection strategies that can prevent groundwater problems rather than try to remediate them later at a much greater cost. The GCC encourages its member agencies and the Legislature to restore adequate resources for groundwater monitoring and research and to seek partnerships to leverage additional funds.

9. **Find solutions to groundwater nonpoint pollution problems**: A 2008 DATCP report indicated that 33.5% of wells contain a detectable level of at least one pesticide or pesticide metabolite and 11.7% of Wisconsin's wells still contain detectable atrazine residues. In addition, 9% exceed the nitrate standard. These rates are substantially higher in agricultural areas. More work is needed to determine if Wisconsin groundwater will continue to deteriorate without a substantial change in farming practices, and what practices will sustain both agriculture and groundwater quality. An evaluation of Chapter 160 of the Wisconsin Statutes (Groundwater Protection Standards) is also needed to determine if it is adequate to protect groundwater quality in Wisconsin. The GCC will support the agencies and the UWS in obtaining information pertinent to the human health implications of consuming nitrate and pesticide contaminated groundwater and the effect of discharge of this groundwater on surface waters and their ecosystems.

10. **Address groundwater quantity management issues at both statewide and regional levels:** Groundwater quantity issues came to the forefront of public discussion in FY 04, with the development and passage of landmark groundwater quantity legislation, 2003 Wisconsin Act 310. Since passage of the new law the DNR has begun implementing the new law and the Groundwater Advisory Committee has addressed specific policy issues related to groundwater management planning and the overall of effectiveness of the law. There is a need for proactive regional groundwater planning in certain areas of the state

11. **Meet funding needs for nutrient management practice research to evaluate resource protection effectiveness.** From 2005 to 2007, nitrogen fertilizer sales increased 25% resulting in the application of approximately 400 million pounds of N in excess of UW recommendations. A recent DATCP survey of private well water quality shows increasing probability of nitrogen contamination of drinking water as the percentage of nearby agricultural land use increases. A USGS study further finds that nitrate contamination of groundwater is increasing (Saad). The implementation of nutrient management plans by farmers should reduce nitrogen loading to groundwater. Nutrient management planning has increased dramatically in recent years. With a tight agricultural economy, farmers are embracing nutrient management because it is beneficial economically as well as environmentally. While nutrient management planning is a necessary first step, the plans must be implemented and maintained over time. Additionally, the individual practices that make up nutrient management plans need to be evaluated to ensure both practicality for farmers and effectiveness for groundwater and surface water protection. No funds for this needed research are currently budgeted.

12. **Develop methods to assess and protect against health hazards posed by exposure to 'orphan' contaminants as well as multiple contaminants in a water supply.** Data collected by DNR and DATCP indicate that many groundwater aquifers are contaminated with 'orphan' chemicals, such as pesticide degradates, chlorinated organics and petroleum derivatives, for which toxicity information is inadequate to support risk assessment. Solutions are needed to effectively address scenarios where multiple contaminants are present in a well. Frequently wells are found to have one or more pesticide degradates present, perhaps in combination with a parent compound or other unrelated compounds. The GCC will support the agencies in their attempt to develop uniform methods that can be used to establish contaminant-specific advisories for owners of impacted water supplies.

Coordination Priorities

13. **Support implementation of a 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.). In FY 04, several agencies worked together to develop and refine a Statewide Groundwater Monitoring Strategy to guide agency monitoring efforts for the next eight to ten years. The strategy has been incorporated into the DNR Water Monitoring Strategy.
In FY 07 a multiagency groundwater monitoring workgroup developed a process and priorities for taking the first step of enhancing the Wisconsin Observation Well Network. The GAC, in its 2006 and 2007 reports, stressed the value of an enhanced monitoring network and included recommendations urging sufficient funding. However, at this time funding has not been found to support any significant improvement of the monitoring well network. The GCC encourages agencies, the university, and federal and local partners to implement this and

other components of the strategy and to seek funding to support its implementation.

14. **Support Implementation of the Great Lakes Compact:** The Great Lakes Compact establishes a consistent framework for oversight of groundwater and surface water in the Great Lakes basin. Implementing legislation (2007 Wisconsin Act 227) includes a water use permitting system for review and approval of water withdrawals and diversion applications, direction to develop a statewide water conservation and efficiency program, and a statewide requirement for water supply service area planning. Effective implementation will rely on sound data and research and development of innovative approaches to water use and management. The GCC will play an important role in supporting these research and management initiatives.

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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 new provisions under 2003 Wisconsin Act 310 and much of the Great Lakes Compact are also being implemented by DG. The program also coordinates the state's Wellhead Protection and Source Water Protection programs.

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.

Remediation and Redevelopment (RR) – Oversees response actions at spills, hazardous substance release sites, abandoned containers, drycleaners, brownfields (including the Site Assessment Grant program), "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.

Watershed Management (WT) – Regulates the discharge of municipal and industrial wastewater, by-product solids and sludge disposal from wastewater treatment systems and wastewater land treatment/disposal systems. WT also issues permits for discharges associated with clean-up sites regulated by WT for the RR program. WT also has primary responsibility for regulating stormwater and agricultural runoff as well as managing waste from large animal feeding operations.

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

Drinking Water and Groundwater Program

Groundwater 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, establishes these groundwater standards and creates a framework for their implementation. There are currently groundwater quality standards for 123 substances of public health concern, 8 substances of public welfare concern and 15 indicator parameter substances in NR 140.

Revisions to NR 140 groundwater quality standards were last adopted by the Legislature in 2007. These revisions established new state NR 140 groundwater standards for alachlor-ESA, a degradation product of the corn herbicide alachlor.

The DNR is currently going through the rulemaking process to adopt proposed new and revised ch. NR 140 groundwater quality standards. These proposed amendments to ch. NR 140 standards are based on recommendations received from the DHS. Public hearings have been held and the DNR is now requesting that the Natural Resources Board consider adoption of these proposed rule amendments.

The DG program maintains a table listing NR 140 health and welfare based enforcement standards, NR 809 state drinking water standards, and established health advisory levels (HALs) for substances in water. 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 table substances.

DG staff work with RR program staff to identify policy issues, develop guidance, and provide training related to the implementation of chs. NR 720, NR 722, NR 724 and NR 726, Wis. Adm. Code. 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 closes soil and 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. Prior to 2004, the DNR reviewed proposed high capacity wells to determine whether the well would be constructed in compliance with applicable rules and whether the well would impair the water supply of a public utility well. The DNR is authorized to deny approval or to 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 by operation of the proposed well. In May of 2004, the statutes regarding high capacity wells were expanded through 2003 Wisconsin Act 310 to give the DNR additional limited authority to consider environmental impacts of proposed wells on critical surface water resources and springs (see Chapter 1 for more information on the Act). 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 new programs created by Act 310. Since then, these staff have handled work associated with updating the high-capacity well inventory, collecting annual pumping information, application review, data management, inspections, providing staff support for the Groundwater Advisory Committee (GAC), and development of a new administrative rule (NR 820) authorized by Act 310 to implement the statutory requirements.

The new rule – 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. Since late 2007, when Ch. NR 820 went into effect, the DNR has approved fewer than 25 wells in groundwater protection areas. In most cases, the application involved a

proposed well with a pumping capacity that was very small relative to the size of the potentially affected water body, or the well was intended to be used on a short-term or sporadic basis. For each well that was approved within a groundwater protection area, the DNR determined that the well would not result in significant adverse environmental impact and in some cases imposed conditions on the operation of the well to ensure that significant impacts did not occur. In addition, a small number of wells with potential to affect a spring were also subjected to additional review. In each case the wells were found to have little potential of resulting in significant adverse environmental impact to the spring and were subsequently approved or approved with conditions placed on the operation of the well.

Act 310 and Chapter NR 820 also require that all owners of high capacity wells submit annual reports documenting the monthly volume of water pumped from their wells. To facilitate this reporting, DG staff has been updating the inventory of high capacity wells in the state. Starting in late 2006 and continuing through 2010, substantial progress was made in verifying ownership and collecting basic well information for the roughly 10,000 existing high capacity wells in the state. Pumpage data have been collected for calendar years 2007, 2008 and 2009 and the level of compliance, in terms of percentage of wells for which pumping was reported, has improved in each successive year. High capacity well pumpage data is available on the DNR website. Information received from well owners using these pumpage reports, in combination with pumpage data already collected for municipal and certain other public water supplies, will help to establish baseline information regarding groundwater use in the state.

Great Lakes Compact and Implementation of 2007 Act 227 - Congress' unexpectedly swift consent to the Great Lakes – Saint Lawrence River Basin Water Resources Compact (Compact) in 2008 greatly accelerated the timetable for implementing the Compact in Wisconsin.

Implementation of the Compact and related water use legislation continues at a rapid pace. The 2009-11 biennial budget included position authority and funding for two full time positions starting in fiscal year 2010; and an additional two full time positions in fiscal year 2011. Two Water Supply Specialists joined the Water Use Section in late 2009, and the DNR has sought approval to fill the additional two positions in fiscal year 2011.

In December 2009, the DNR submitted Wisconsin's list of "baseline" water withdrawals from the Great Lakes basin to the Great Lakes – Saint Lawrence River Basin Water Resources Council (Council). The baseline list included approved water withdrawals above the 100,000 gallons-per-day threshold in the Great Lakes basin that existed as of December 8, 2008—the Compact's effective date. The DNR also submitted to the Council in December 2009 two reports summarizing the status of Wisconsin's implementation of the water management and water conservation and efficiency programs required by the Compact. The baseline withdrawal list, along with the required reports for Wisconsin and the other Great Lakes states, can be found online.

The DNR is in the process of promulgating seven administrative rules to implement the Compact and associated statewide water use legislation. At its August 2010 meeting, the Natural Resources Board approved the following three rules: Water Use Registration and Reporting; Water Use Fees; and Water Conservation and Water Use Efficiency. Additionally, the Natural Resources Board authorized public hearings on the Water Use Permitting rule. Three additional rules are being drafted in 2010, with a goal of requesting public hearing authorization from the Natural Resources Board in the fall of 2010. These rules include Water Supply Service Area Planning, Water Loss and Consumptive Use, and Water Use Public Participation.

Well construction and abandonment. DG sets and enforces minimum standards for well construction, pump installation and well abandonment 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.

Representatives of the Private Water Supply Program worked with the Wisconsin Water Well Association and members of the Wisconsin legislature to develop revisions to Ch. 280, Wis. Stats. that will result in increased protection of groundwater (as well as increased public health protection.) The changes went into effect in June, 2008. The significant changes include:

- Well abandonment must be performed by a licensed well driller or pump installer, or someone employed by a licensed well driller or pump installer—homeowners may not abandon their own wells. There is an exemption for wells under the authority of municipal abandonment ordinances.

- Well and pressure system inspections conducted as part of real estate transactions must be done by an individually-licensed well driller or pump installer (not an employee of a licensed person.) Inspection details will be specified in department rules and will require a diligent search for any wells that need to be abandoned.

- Drill rig operators must register with the department and will be required to complete additional training and/or testing requirements prior to becoming eligible to receive a well driller license. Each rig must have a licensed well driller or registered rig operator present onsite to supervise during all drilling activities.

- The department has authority to issue citations for some violations that don't rise to the level of referral to the Department of Justice, e.g., work done without a license; work on substantially non-complying existing pump installations (pits, short-cased wells); improper well abandonment; or repeated failure to collect water samples and/or submit well construction reports.

The Private Water Supply Program is currently working with the Well Driller and Pump Installer Advisory Council to draft administrative rules to implement the revisions to Ch. 280, Wis Stats.

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 have included falsification of water samples, failing to notify well owners of repeated unsafe water test results, failing to grout, short casing wells, and unlicensed contractors. Falsification of water samples involves collecting a water sample from a known safe source and claiming it was collected from the newly constructed well. Failure to notify involves well water owners who were not told about the unsafe results for the water they were consuming. Failure to grout or failure to properly grout is a threat to groundwater because the empty space around the well casing pipe provides an easy conduit for contamination to enter the groundwater and contaminate lower aquifers. Short casing well involves installing less than the code minimum amount of casing, and then reporting and billing for casing that was not installed.

Another activity involved the designation and enforcement of special well construction requirements in areas where arsenic is known to exist. These requirements, if not followed, could trigger the release of naturally occurring arsenic into groundwater at higher levels. The DNR has

designated a special casing area that covers all of Outagamie and Winnebago Counties. In these areas wells must be constructed to avoid the arsenic rich St. Peter and Prairie du Chien formations. Wells can be constructed to draw water from the overlying Galena/Platteville dolomite or they must be cased and grouted into the Cambrian sandstone. The Department is working with the WGNHS to update and refine the geologic mapping and improve the accuracy of the special casing requirement depths.

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 (see the "Microbial Agents" section in Chapter 4, and the "Detection and Monitoring of Microbiological Contaminants" section of Chapter 5 of this report for more information on the development and use of microbial source tracking methods). These new tools have proven useful in granting Well Compensation awards to private well owners with well contamination from manure. Since 2006 when the Well Compensation statute was revised to allow use of funds for replacement of water supplies due to manure contamination, over 40 well compensation grants totaling over $530,000 have been awarded for that purpose. Additional costs have been incurred by well owners to cover related expenses not covered by the grants.

Private water staff continue to maintain the popular web page titled "What's Wrong with My Water?" 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 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 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 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 technique that involves the direct injection of water into an aquifer for storage and later recovery. The technique is promoted as a solution to problems that water utilities may face in managing peak seasonal water demands. ASR may prove to be a lower cost alternative to more traditional water supply management approaches involving the construction of water storage facilities, expansion of water treatment facilities or the drilling of additional wells if the injected water does not need to be conditioned (deoxygenated, pH adjusted, dechlorinated, etc.) to prevent the mobilization of minerals from the rock matrix of the receiving aquifer. Mobilization of metals such as arsenic and manganese and the in-situ formation of chlorinated compounds which are by-products of water disinfection practices appear to be some of the more frequently encountered problems when unconditioned drinking water or surface water is reinjected directly into a groundwater aquifer.

State administrative rules (Chapter NR 811, Wis. Admin. Code) regulate the use of ASR in Wisconsin. Only municipal water systems are allowed to operate an ASR system and only

treated drinking water may be injected. Demonstration testing is required before routine operation of an ASR system may be approved by the DNR. These restrictions help to ensure that this type of underground injection practice complies with both federal regulatory requirements and Wisconsin's Groundwater Law.

To date, only the municipalities of Oak Creek and Green Bay have sought approval to develop ASR wells. Work at the Green Bay ASR well was terminated after significant concentrations of arsenic and other contaminants were mobilized during the injection and storage phases of the ASR demonstration test.

Oak Creek completed the required ASR demonstration test and received a conditional approval to operate its ASR well; however, after performing two additional ASR cycles, the concentrations of manganese and iron in groundwater were observed to have increased to levels that are above their respective enforcement standards. As a result of the exceedances, the utility is required to make changes to its ASR operations plan. If ASR operations cannot be modified in a manner that will return the ASR facility to compliance with Wisconsin's groundwater protection regulations, the DNR is required to rescind its approval for Oak Creek Water and Sewer Utility to operate an ASR system. ASR activities have been temporarily suspended while the water utility considers its options. A final decision on future ASR operations will be made in 2010.

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Public water systems. DG oversees monitoring and operation 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. Also, through ch. NR 811 (Requirements for the Operation and Design of Community Water Systems), DG regulates the general operation, 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. 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).

This fiscal year, DG has been working updating existing rules dealing with lead and copper, groundwater disinfection, water system design and operation, and disinfection byproducts.

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 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 2010, 20 communities submitted wellhead protection plans to the DNR. There are now 362 communities who have a WHP plan for at least one of their wells. The list is online.

For the tenth 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 28 schools centers took part in the workshops held at Mount Horeb, Spooner, and Green Bay 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 200 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. DG staff worked with U.S. EPA Region V and the other Region V states to increase the acreage eligible for CRP in WHP areas in 2009. The new CRP Rule (7 CFR part 1410) defines WHP areas as including land located within a 10-year time of travel surrounding a public well.

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 from Projects (http://devlwww.dnr.state.wi.us/org/water/dwg/gcc/rtl/gccreport2010.htm) for more information on the DNR's monitoring studies.

Due to the State budget shortfall only one project, a continuing project from FY 2009, was supported in FY 2010. The cost was $12,000. Two new projects were selected for funding in FY 11. More details on the DNR's groundwater monitoring and research activities can be found online.

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 10, 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 online. 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 10, 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 10. 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 well construction reports (see WGNHS section) 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 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 NR 700 rule series, Wis. Adm. Code, Investigation and Remediation of Environmental Contamination, and 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.

Cleanup Of Groundwater Contamination. In FY 2010, the program spent approximately $240,000 in Environmental Fund dollars, and approximately $880,000 in bonding to initiate or continue environmental cleanup actions at over 30 locations where groundwater contamination is known or suspected. The Environmental Fund is used when contamination is significant but no identifiable private party has legal responsibility for the contamination, the person(s) legally responsible do not have the financial ability to proceed, or the responsible person simply refuses to proceed. Private contractors conduct these 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 is the Brownfields Site Assessment Grant (SAG) program. The SAG program benefits 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 provides grants to local governmental units to conduct environmental site assessments and other eligible activities at contaminated properties. Eligible activities include site assessment and investigation, demolition, asbestos abatement, removal of petroleum and hazardous substance storage tanks and removal of abandoned containers. Although the SAG program does not fund remediation activities, it funds preliminary activities to determine whether remediation is necessary. Sites are 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 is 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 will 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. In FY 10-11, the RR program will not award funds for any projects. The RR Program was unable to award additional funds due to a forced lapse of funds as a result of the Wisconsin state budget shortfall.

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. The WDNR, through a partnership with the Redevelopment Authority of the City of Milwaukee (RACM) was awarded two $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. The first $400,000 assessment grant, awarded in 2004, was closed out early in 2009 with all funds being exhausted. Assessment activities are continuing under the 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.

In FY 10 the partnership continued with significant progress by:
- completing Phase I environmental site assessments at 10 properties;
- completing or continuing Phase II work at 14 properties; and
- identifying additional sites for Phase I or II assessment work.

Completion of the first grant occurred in the fall of 2008. However, the partners were awarded a completive grant of an additional $400,000 EPA site assessment grant in May 2007. The DNR has an Urban Reinvestment Initiative and 30th Street web page.

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. The RR program provided 52 redevelopment assistant reviews – which can include liability clarification letters, off-site exemption letters, cleanup agreements for tax delinquent properties, etc. – at brownfield properties throughout the state in FY 10.

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 10, DNR issued a Certificate of Completion at 9 properties for completed cleanups and 21 new sites began the voluntary cleanup process.

Drycleaner Environmental Response Fund (DERF) Program. The DERF program reimburses drycleaner 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 NR 700 rule series. The DERF program closed to new applicants in August of 2008. There are 230 sites in the program, with 178 at various stages of investigation and cleanup and 52 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, NR 746 – and its Department of Commerce counterpart, Comm 46 – was promulgated in February 2001. The bulk of 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 Commerce 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 NR 140 enforcement standards are placed on the GIS Registry. 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.

In 2001, revisions to 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 NR 140 enforcement standards and sites closed with soil contamination above 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.

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. 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 Commerce 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 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 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 only accepts electronic submittal (via diskette or CD) 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 has been concerned that staff might not be aware of some old, closed landfills that may be impacting groundwater. Program staff used several reports from the Groundwater and Environmental Monitoring System to do a rough screening of old, closed town, city and village landfills with monitoring wells. In July 2003 we sent the screening reports, identifying landfills that need further attention to each of the regions for follow-up evaluations. Program staff have since reviewed most of the identified sites. 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 by February 2009.

In FY 01, WMM studied 31 landfills that accept municipal solid waste, to try to determine whether VOC contamination in groundwater at these landfills is 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 done 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) 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.

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.

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 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 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.

Wastewater Discharges. WT 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 NR 206, Wis. Adm. Code (domestic wastewater) and 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 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.

WT 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.

WT 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 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 WT issued a general permit to regulate the operation of these types of systems in a more streamlined manner.

Septage And Sludge Management. WT implements the regulations in chapters NR 113, NR 204 and NR 214, Wis. Adm. Code. NR 113 relates to septage management and NR 204 governs the treatment quality, use, and disposition of municipal wastewater treatment plant sludge. NR 113 and NR 204 incorporate federal septage and sludge standards. WT regulates the land application of industrial sludge, liquid wastes and by-product solids through 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 NR 114 will now require minimum compliance training of all certified septage operators in their continuing education requirements cycles to ensure a compliance focus.

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.

Efforts are proposed to modify the multiple land application codes (NR 113, NR 204, NR 214) for numerous reasons which are not limited to: 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.

WT 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 award from U.S. EPA will provide WT 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, 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 the Act provides explicit pre-emptive authority to the state by disallowing restrictive local ordinances if they are not identical to state regulations.

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. DNR has been implementing revisions to ch. NR 243, Wis. Adm. Code, promulgated in July of 2007 to address revisions to federal rules that govern the operation and permitting of large concentrated animal feeding operations (CAFO). The revisions to NR 243 improve groundwater protection associated with CAFO land application practices by increasing setback requirements from community and non-community 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 NR 243, and response to acute manure related groundwater impacts (e.g., well contaminations).

There are currently 194 WPDES permits issued for livestock operations (87% dairy; 5% 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 Chapter 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 NR 216 require nearly 200 municipal separate storm sewer systems to obtain permit coverage and require construction sites down to one acre of land disturbance to have permit coverage to control erosion during construction. Permit holders are also required to install post-construction practices to limit pollutant discharge after construction is completed (storm water management). The DNR has developed performance standards (i.e. 80% sediment control, infiltration, peak flow, buffer requirements, etc.) that became effective in 2002. Provisions to implement NR 216 changes were included in two revised general permits. The general permit for municipal stormwater discharges was reissued on January 19, 2006 (expires on December 31, 2010) and the general permit to regulate stormwater discharges from construction sites was reissued on September 29, 2006 (expires on September 30, 2011).

Nutrient Management Plans: Sections 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 that must be met. The performance standard itself became effective January 1, 2005 for high priority areas in the State

(source water areas, impaired waters and outstanding/exceptional resource waters) and became effective for the remainder of the state on January 1, 2008. On an ongoing basis, federal, state and local agencies have built the necessary technical resources and expertise to implement NRCS Standard 590, including development and dissemination in cooperation with the University of Wisconsin of the field-based Soil Nutrient Application (computer) Program. Implementation of this performance standard can not be required without cost sharing in certain situations. A multi-partner conservation consortium was effective in securing cost share resources from the legislature to help farmers meet the requirements. The 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.

For more information, visit the following website (https://dnr.wi.gov/) or contact Bruce Baker at 608-266-1902 (Bruce.Baker@wisconsin.gov) or Mike Lemcke at 608-266-2104 (Michael.Lemcke@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 Wisconsin's Comprehensive Groundwater Protection Act (1983 Wisconsin Act 410), 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. Standards for additional pesticides have been proposed. DATCP applies these standards and the Groundwater Law when addressing nonpoint and point sources of pesticide contamination in groundwater.

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 on April 1, 2009. 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. 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 related triazine herbicide, in a small area of the Lower Wisconsin River Valley near Spring Green. DATCP is conducting additional sampling of private wells 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 crop and livestock producers that apply manure or other nutrients directly or through contract to agricultural fields. DATCP has adopted the USDA NRCS 590 nutrient management standard via administrative rule, ATCP50, 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 the Farmland Preservation Program or Working Lands Initiative 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 rate, timing, and nutrient sources to mitigate movement of nutrients and manure when applying 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. Recent 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 to 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 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, less than 20% of agricultural land in Wisconsin follows an approved nutrient management plan. DATCP contends that the current nutrient management standard, while not 100% protective under all conditions, would dramatically 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 have been directed to provide support for nutrient management implementation, including farmer outreach and education, Snap-Plus Nutrient Management Planning Software, farmer training and program evaluation activities. DATCP elected to phase in nutrient management cost-sharing over two years, allocating about $3.0 million in 2008. Due to budget shortfalls, cost-share funding was reduced to about $740,000 for 2009. Despite budget cuts, DATCP continued to maintain funding for implementation support, ensuring access to farmer training and other support activities.

DATCP nutrient management program staff has 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 also allocated funds to DATCP for the creation of a Manure Management Advisory System. This system is currently focused on helping farmers

develop a good 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, two new tools in development include web-accessible WI "590" Nutrient and Manure Application Restriction Maps and a model based website for predicting the likelihood for runoff events to take place on a given day. The 590 Restriction maps will be available on a statewide basis at the section level to assist farmers in making sound decisions about manure and nutrient applications to their cropland.

Through these combined efforts, DATCP increased the number of acres covered by nutrient management plans statewide in 2008 to over 1.6 million acres, an increase of about 600,000 acres from 2007.

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, out-dated 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 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 program. In the Fall of 2007, prescription drug collection authority was given to the Department and the annual program budget expanded to $1 million. In 2007, nearly 2.3 million pounds of chemical wastes were collected by municipalities and counties with grants from the Department. In 2009 the program budget was reduced to $750,000 annually and program management reduced to one 75% FTE. Over 2,280,000 pounds of wastes were collected, including over 22,000 pounds of pharmaceutical waste. Total Clean Sweep collection costs exceeded $1.5 million.

DATCP's rules for minimizing environmental damage from agrichemical storage and handling were put in place in 1988. Thirteen 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, about 500 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 also cleaned up over 900 acute spills of agrichemicals. The ACCP staff have received 997 reimbursement applications and provided over $ 33.3 million in reimbursement payments.

The Pollution Prevention for Agrichemical Dealerships program began in 2000 and has evolved and been renamed the Environmental Partners program. Its purpose is to reduce the amount of agrichemicals that escape into the environment during routine transfer and handling of agricultural chemicals and fertilizers at agrichemical storage and dealership sites. The program

helps protect soil and groundwater by encouraging better management practices. Participation in the program is voluntary, with the agrichemical industry and the Department working together to identify problems and brainstorm ideas to reduce pollution. The ideas used to solve problems at each facility can be shared so that everyone can learn and benefit from the program. To date, about 45 agrichemical dealerships have volunteered for assessments at their dealership sites. Participation has dropped significantly since 2007 due to decreased industry interest in the program and a lack of promotional efforts by the department, as a result of budget reductions and hiring limitations. More information about this program can be obtained at ***https://www.datcp.state.wi.us*** (keyword search "Environmental Partners").

In 2007, DATCP received authority to manage a pollution prevention grant program. DATCP began preparing rules to govern how this grant program would be implemented, but with budget reductions and hiring limitations, has had to place a hold on further rule development.

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 online.

Research Funding
Due to budget constraints, DATCP did not have funding for new pesticide research projects in FY 2010. DATCP funds fertilizer research at approximately $130,000 per year.

Groundwater Data Management
DATCP maintains two groundwater sample databases: the Drinking Water Well System and the Monitoring Well System. The Drinking Water Well System contains contact and location information, well characteristics, and pesticide and nitrate sample results for private and public drinking water wells. The Monitoring Well System contains similar information for monitoring wells. These data represent samples analyzed by DATCP, Wisconsin State Lab of Hygiene (WSLH), and other public and private laboratories. DATCP's Drinking Water Well System currently contains information for over 56,000 wells and nearly 361,000 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 (GPS) 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 (https://www.datcp.state.wi.us/) or contact Kathy Pielsticker or Stan Senger, DATCP, 2811 Agriculture Drive, PO Box 8911, Madison, Wisconsin, 53708-8911; phone: 608-224-4500; e-mail:kathy.pielsticker@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.

Summary of Agency Activities in FY 2010

The 9th cycle of revisions to NR 140 groundwater quality standards were presented to the Natural Resources Board in April 2010. These proposals, developed by DHS toxicologists, include new standards for 16 chemicals including minor dinitrotoluene isomers, acetochlor and acetochlor metabolites, and revisions for 16 existing enforcement standards. These proposals are expected to be sent to the Legislature in the late summer or fall of 2010 for adoption.

DHS has developed environmental public health tracking (EPHT) modules to create data systems that link health outcome information with relevant information on hazards and exposures. As part of this cooperative agreement, DHS has identified and developed environmental public health indicators of priority drinking water contaminants such as total trihalomethanes (THMs) and arsenic in community water supplies, and county-level indicators of nitrate contamination of private wells. Additional county-level indicators describing the proportion of the total population served by private or public wells, and surface or groundwater drinking water sources have also been developed. All indicators serve as tools to assist in developing future targeted environmental health analyses. Other partners in this initiative include DATCP, the Wisconsin State Laboratory of Hygiene, and the UW's Division of Information Technology (DoIT) and School of Medicine and Public Health.

In order to make data and information about private well water quality available in ways that facilitate work in Wisconsin's local health departments, Wisconsin's EPHT program is undertaking an effort to create a widely-accessible web-based portal on private well water quality. Local health partners have consistently indicated a need for more complete and detailed data related to private well drinking water quality. Wisconsin's EPHT program requested and received

supplemental grant funds to better characterize this need and how it can be met. Two full-day workshops were hosted in the spring of 2010 with attendees that included local health department partners from across the state and representatives from a number of agencies with private well water testing data (e.g., DNR, DATCP, State Laboratory of Hygiene, UW-Stevens Point Water and Environmental Analysis Laboratory, county laboratories and private testing laboratories). The first workshop included structured, interactive exercises to delineate the specific data that would be useful and how those data might be utilized by local health personnel. Participants agreed that data would be used in activities aimed at: educating the public about drinking water quality issues, increasing the number of people that test their wells and identifying specific contaminants as priorities for certain geographic areas. The second workshop further delineated the types of datasets that would be useful and the potential for data stewards to collaborate and deliver such a dataset. As a result of this project, representatives from DATCP and UW Stevens Point agreed to meet and determine the feasibility of integrating their respective datasets and making those data available to public health partners. EPHT program partners are assessing the feasibility of using the EPHT portals as one way to make the data available. The group is also investigating potential funding sources to support this initial effort. It is anticipated that some early results from the project will be available by the end of 2010.

For over fifteen years, DHS and DNR have provided local health departments with fee exempt well water testing. Local health departments offer this service to low-income families. In addition to testing for coliform bacteria, nitrates, fluoride, and arsenic, a panel of 14 metals has been added to the analysis. Since July of 2007, more than 4,000 private wells have been tested through this program. DHS provided a summary of test results from these wells to county health departments in the spring of 2010.

For more information, visit https://DHS.wisconsin.gov/eh/Water/, or contact Henry Anderson (608-266-1253*; Henry.Anderson@wi.gov *), Lynda Knobeloch (608-266-0923; Lynda.Knobeloch@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. Highlights of the WGNHS groundwater activities for FY 10 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 https://wi.water.usgs.gov/public/gw/.

County Groundwater Studies.

Geologic and groundwater studies at the county scale continue to be an important part of WGNHS programs. During FY 10, the Survey initiated or carried out geologic and/or groundwater studies in the following counties: Brown, Dane, Calumet, Columbia, Fond du Lac, Iowa, Marquette, Outagamie, Sheboygan, Walworth, Waukesha, and Winnebago. Local-scale hydrogeologic studies developed from these projects in FY10 include Geneva Lake (Walworth County) and the Town of Byron (Fond du Lac County). 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://www.uwex.edu/wgnhs/watertable1.htm.

Regional Groundwater Studies

Regional geologic and groundwater studies usually span multiple counties. During FY 10 the WGNHS was involved in several regional projects, including the following:

a. Geologic and hydrogeologic analyses in southeastern Wisconsin. The WGNHS conducted regional groundwater modeling and analyses in the SEWRPC (Southeastern Wisconsin Regional Planning Commission) region, spanning seven counties in SE Wisconsin. During FY 10 this work included evaluation of new groundwater flow models for the Troy Valley area in southern Waukesha and northern Walworth Counties.

b. 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, and Waupaca Counties. Many of these new maps are now available digitally and have been released as open-file reports (see *http://www.uwex.edu/wgnhs/wofrs.htm*). Lists of current projects are maintained at

http://www.uwex.edu/wgnhs/proj_water.htm and
http://www.uwex.edu/wgnhs/proj_geol.htm .

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 FY10 included the following:

a. Hydrogeology of a*quitards and multi-aquifer wells.* Aquitards, low-permeability geologic materials such as clay or shale, 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 multiple aquifers. During FY2010, 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. WGNHS hydrogeologists also directed graduate student research, funded through the Wisconsin Joint Solicitation Program, in distributed temperature sensing (DTS) technology to identify flow within multi-aquifer wells. DTS employs fiber optic cable to collect simultaneous temperature measurements along the full length of a deep well. The method is useful to identify areas and rates of preferential flow in bedrock wells.

b. *Viruses in groundwater*. During 2005 WGNHS hydrogeologists, working with researchers at the Marshfield Clinic, detected human enteric viruses in water from three deep municipal wells in Madison, WI (see Borchardt and others, 2007). Detection of infective viruses in such deep bedrock wells was unexpected and has important implications for protection of groundwater quality and human health. The virus presence suggests that the deep wells may be more vulnerable to contamination than previously believed. In FY10 the WGNHS completed a second follow-up study which confirmed that viruses are present in many wells and that transport times from the surface to the wells can be rapid (see Http://www.uwex.edu/wgnhs/news.htm). This work is continuing in FY11 with installation of two monitoring wells near a virus-positive water supply well thought to be impacted by leaky municipal sewers. WGNHS investigators are seeking federal grants in support of this research on impacts to groundwater quality from leaky sewers.

c. *Flooding*. Severe flooding occurred across a large portion of southern Wisconsin following intense rainfalls in June, 2008. In several areas, long-lasting flooding occurred far from streams and rivers where the water table rose above the land surface. In FY10, the WGNHS continued to provide technical assistance and education programs to affected communities and to state and federal agencies charged with mitigating the impacts of high water table elevations, including Spring Green (Sauk County), Mukwanago (Waukesha County), and Fish Lake (Dane County) (see http://www.uwex.edu/wgnhs/news.htm) . In FY11, the WGNHS will complete a study, funded through the Wisconsin Joint Solicitation Program, of the potential for groundwater inundation of low-lying areas under wetter-than-normal climate patterns forecast for late in this century.

d. *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 FY10, recharge delineations were used in groundwater vulnerability assessments for Iowa County and the Town of Byron (Fond du Lac County). This technique will be used in FY11 to complete a similar assessment for Columbia County.

e. *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 velocities in such rocks can be unusually high, and the rocks usually have very low ability to attenuate contaminants. Work by the WGNHS on carbonate aquifers in eastern Wisconsin suggests that detailed stratigraphic analysis, coupled with geophysical and hydrogeologic data, may help predict the hydraulic properties of these complex and vulnerable aquifers. During FY 10, WGNHS staff used surface geophysical techniques to determine the depth to bedrock in areas covered by dense, fine-grained glacial sediment. WGNHS projects in FY10 and FY11 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, including a variety of sinkholes, cavities, and solution openings, commonly are found in carbonate rock (limestone and dolomite). 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, as well as providing technical expertise in site-specific hydrogeologic investigations (for example, Borchardt et al, 2010).

f. *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.

g. *Water-level recovery in the Lower Fox Valley*. In late 2007, suburban communities in the Lower Fox Valley reduced consumption of groundwater by switching to surface water supplied by pipeline from Lake Michigan. Water levels in the deep sandstone aquifer near Green Bay rebounded following this decrease in pumping. The Survey has monitored the water level recovery in the deep sandstone aquifer since mid-2007, to document water level recovery and to improve understanding of the deep hydrogeologic system in this region of the state. The Survey completed county-wide bedrock mapping and stratigraphic interpretation of Brown County with support from the USGS STATEMAP program. The Survey conducted borehole geophysics and packer testing in several boreholes during this mapping effort, extending our hydrostratigraphic data set in this region.

Groundwater Data Management

During FY 10 the WGNHS continued to collect geologic and groundwater data and provide this data to a variety of users. Significant efforts include the following:

a. *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 state-wide database. See http://www.uwex.edu/wgnhs/wisclith.htm. A new area of development in WGNHS hydrogeologic databases in FY10 was the collection and management of data related to porosity and permeability of Wisconsin's aquifers and aquitards.

b. *Well construction reports.* The WGNHS serves as the repository for Well Constructor's Reports 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. See http://www.uwex.edu/wgnhs/wcrs.htm

c. *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 Geology and Geophysics, University of Wisconsin-Madison. During 2008 the WGNHS updated this database to include hydrogeologic properties of materials. The data are available for public distribution on CD-ROM. See http://www.uwex.edu/wgnhs/wisclith.htm

d. *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://www.uwex.edu/wgnhs/core.pdf

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 routinely attends many regional and state-wide meetings to promote the use of WGNHS data sets and publications.

In FY 11 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, flooding, karst and shallow bedrock, 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 11. In FY10, staff members contributed to professional short courses and webinars that educate consultants, regulators, and officials. Topics included technical

aspects of well hydraulics, wellhead protection, aquitards, arsenic in groundwater, and other hydrogeologic topics.

Groundwater education efforts in FY10 included the contribution of WGNHS staff scientists to discussions of the Groundwater Work Group, organized by Senator Miller and Representative Black. This effort resulted in draft legislation referred to as the "Groundwater Quantity Bill" (2009 Assembly Bill 844 and Senate Bill 620).

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 11. We also provide a collection of representative Wisconsin rocks for teachers to use, which include samples of our major aquifers.

Recent WGNHS Publications Relevant to Wisconsin's Groundwater Resources

Batten, W. G. and J. W. Attig, 2010. Preliminary geology of Iowa County, Wisconsin. Wisconsin Geological and Natural History Survey Open-File Report 2010-01.

Borchardt, M., A. , K. Bradbury, R. , E. C. J. Alexander, R. J. Kolberg, S. C. Alexander, J. R. Archer, L. A. Braatz, B. M. Forest, J. A. Green, and S. K. Spencer, 2010, Norovirus Outbreak Caused by a New Septic System in a Dolomite Aquifer: Ground Water, v. 10.1111/j.1745-6584.2010.00686.x.

Bradbury, K.R. and W. G. Batten, 2010. Groundwater susceptibility maps, diagrams, and report for the Town of Byron, Fond du Lac County, Wisconsin. CD-ROM contains GIS data, metadata, and PDFs. [9MB]. Wisconsin Geological and Natural History Survey Open-File Report 2010-02.

Brown, B.A., Hunt, T.C., Johnson, D.M., and Reid, D.D., 2009, The Upper Mississippi Valley lead-zinc district revisited: Mining history, geology, reclamation, and environmental issues 30 years after the last mine closed: Geological Society of America (North-Central Section), 42nd annual meeting, Illinois State Geological Survey Guidebook 38, 19 p.

Brown, B.A., Madison, F.W., Czechanski, M.L., and Schoephoester, P.R., 2009, Identification of areas suitable for surface application of waste in carbonate bedrock settings [abstract]: Proceedings of Wisconsin Land Information Association 2009 Annual Conference, p. 19.

Carter, J.T., M.B. Gotkowitz, and M.P. Anderson, *In Press*. Field verification of stable perched groundwater in layered bedrock uplands. Ground Water.

Cooley, E.T., Lowery, B., Kelling, K.A., Speth, P.E., Madison, F.W., Bland, W.L., and Tapsieva, A., 2009, Surfactant use to improve soil water distribution and reduce nitrate leaching in potatoes: Soil Science, vol. 174, no. 6, 11 p.

Gotkowitz, M.B., 2009, Groundwater pumping near Geneva Lake: Evaluating its effect on the lake: Wisconsin Geological and Natural History Survey Educational Series 49, 6 p.

Gotkowitz, M., 2010, Water-table Elevation, Groundwater Recharge and Groundwater Susceptibility Maps of Iowa County, Wisconsin. Wisconsin Geological and Natural History Survey Educational Series 50-1, 50-2 and 50-3.

Gotkowitz, M.B., and Attig, J.W., 2009, Groundwater-induced flooding at Spring Green, Wisconsin: Program and Abstracts for the 33rd Annual Meeting of the American Water Resources Association—Wisconsin Section, p. 14.

Gotkowitz, M.B., and Carter, J.T., 2009, Groundwater flow model of the Geneva Lake Area, Walworth County, Wisconsin: Wisconsin Geological and Natural History Survey Open-File Report 2009-02, 36 p, 1 plate.

Gotkowitz, M.B., 2010. Preliminary hydrogeology of Iowa County, Wisconsin. Wisconsin Geological and Natural History Survey Open-File Report 2010-03.

Hart, D.J., Schoephoester, P.R., and Bradbury, K.R., 2009, Groundwater recharge in Dane County, Wisconsin, estimated by a GIS-based water-balance model: Wisconsin Geological and Natural History Survey Open-File Report 2009-01, 16 p.

2009-03. wiscLITH: A digital lithologic and stratigraphic database of Wisconsin geology, version 3. 2009. 1 CD-ROM.

Root, T.L., M. B. Gotkowitz, J.M. Bahr, J.W. Attig. 2009. Hydrostratigraphic influences on arsenic in glacial aquifers. Ground Water. doi: 10.1111/j.1745-6584.2009.00637.x

Schaetzl, R.J., Stanley, K., Scull, P., Attig, J.W., Bigsby, M., and Hobbs, T., 2009, An overview of loess distribution in Wisconsin: Possible source areas and paleoenvironments: Geological Society of America Abstract with Programs, vol. 41, no. 4, p. 22.

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

Wilcox, J.D., Bahr, J.M., Hedman, C.J., Hemming, J.D.C., Barman, M.A.E., and Bradbury, K.R., 2009, Removal of organic wastewater contaminants in septic systems using advanced treatment technologies: Journal of Environmental Quality, vol. 38(1), p. 149–156.

Wilcox, J.D., M. B. Gotkowitz, K.R. Bradbury, and J. M. Bahr, *In press.* Using ground-water models to evaluate strategies for drinking-water protection in rural subdivisions, Journal of the American Planning Association.

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://www.uwex.edu/wgnhs/.

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 24 rest areas and 64 waysides. 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 Operations
- 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 1,026 salt storage sites listed in the database and 1,281 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 Operations 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 58 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 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. Approximately 5 sites are currently monitored, and new sites are added periodically. 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 (https://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.

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, 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 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 FY 09 included research focused on various groundwater contaminants, including pathogenic bacteria, endocrine disrupting chemicals, phosphorus, nitrate/nitrite, methylmercury and arsenic.

During FY 10, the WRI directed a wide-ranging program of priority groundwater research consisting of 6 projects (see Table 1). 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:

- Use of the 2009 Behavioral Risk Factor Surveillance Survey to Assess the Safety of Private Drinking Water Supplies
- Fecal Source Tracking Using Human and Bovine Adenovirus and Polyomaviruses
- Predicting Mercury Methylation: Testing the Neutral Sulfide Speciation Model in a Groundwater-Dominated Wetland
- Assessing the Effect of Pleistocene Glaciation on the Water Supply of Eastern Wisconsin
- Forecasting Impacts of Extreme Precipitation Events on Wisconsin’s Groundwater Levels
- DTS as a Hydrostratigraphic Characterization Tool

These six 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-Stevens Point, UW-Green Bay, UW-Parkside and UW-Oshkosh.

The UWS selected five new groundwater research projects from proposals submitted in response to this year’s Solicitation for Proposals for support during FY 11 (July 1, 2010–June 30, 2011),

and two projects, selected from the previous year's solicitation, will receive continuation support during FY 10 (see Table 2). The new projects are based at UW-Madison and UW-Milwaukee.

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. The UW-Madison Water Resources Library 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 FY 07 WRI staff members developed a Web site (iPROPOSE) that enabled online submission and review of the Joint Solicitation for Groundwater Research and Monitoring proposals. 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 Web site 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 and fairly. In FY 08, 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 FY 09 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 UW-Madison Water Resources Institute Web site (*www.wri.wisc.edu*) makes it fast and easy for visitors to find information about WRI research projects and publications. The site is integrated with the UW Aquatic Sciences Center's interactive Project Reporting Online (iPRO) system, an online tool that allows principal investigators to report on the progress of their projects. In 2009, the WRI website received 10,69 visitors in 16,728 visits. They viewed 39,890 web pages.

Water Resources Publications

In 2007, the UW Water Resources Institute published a 20-page illustrated pamphlet and two-page executive summary describing the activities of Groundwater Coordinating Council (GCC) since its creation 20 years ago. The pamphlet, entitled *Protecting Wisconsin's Buried Treasure*, documents the accomplishments, impacts and benefits of the Groundwater Research & Monitoring Program. Coordinated by the GCC Education Subcommittee, this project represents a truly collaborative effort involving all GCC members. More than half of the printed copies of the pamphlet have been distributed to date, and a free electronic copy of the pamphlet in the ASC's online Publications Store has been downloaded 1,100 times.

Drawing on some of the most important issues identified in the pamphlet, two fact sheets were published in 2009: *Nitrate in Groundwat*er and *Arsenic in Groundwater*. These fact sheets were never printed for distribution but are instead available as downloadable publications. The arsenic

fact sheet has been downloaded 312 times and the nitrate fact sheet has been downloaded 50 times since they were placed on the website.

Two more fact sheets are in preparation on *Water Quantity and Groundwater Drawdown* and *Pathogens in Groundwater*. These publications will provide a complementary packet of information with long-term usefulness to all GCC member agencies.

In February 2006, WRI and the UW-Madison Department of Civil & Environmental Engineering published *Design Guidelines for Stormwater Bioretention Facilities* by Dustin Atchison, Ken Potter and Linda Severson. This manual provides design guidelines and a numerical model (RECARGA) that can be used for creating bioretention facilities for small-scale stormwater management that promotes infiltration of storm water in order to reduce its volume, improve its quality and increase groundwater recharge. This document continues to be extremely popular at the ASC Publications Store. Since its publication, a total of 490 print copies have been distributed and over 167 copies of the pdf file have been downloaded..

"Water Matters" Lecture Series

The WRI cosponsored "Water Matters: A Lecture Series" as part of the public programming accompanying the October 2008–January 2009 "Mami Wata: Arts for Water Spirits in Africa and its Diasporas" exhibition at the UW-Madison Chazen Museum of Art. Besides the Chazen and WRI, other major partners in this project were the UW Sea Grant Institute and the UW-Madison Department of Art History. Designed to enhance public awareness and understanding of water resources issues in the context of a changing climate, the series of five lectures featured presentations by the WRI director (Anders Andren) and faculty members from the UW-Madison American Indian Studies Program, Center for Limnology, Zoology Department and Life Sciences Communications; Northland College Department of Biology, and UC-Berkeley.

The series attracted a total of 295 attendees, and evaluations were submitted by 116 (39%). Evaluation data indicate 52% of the lecture attendees were adult campus visitors (the primary target audience), 48% were students (the secondary target audience), and 48% had no prior awareness of the WRI. Seventy one percent reported that they gained new insights as a result of the lecture they attended, and on a scale of 1 to 5 (5 = excellent), 89% gave the presentations a rating of 4 or 5. In addition, the "Water Matters" Web site, which featured audio of the American Indian "MadTown Singers" group, attracted 514 visits and 827 page views over a one-month period. One of the presenters, UW-Madison Center for Limnology Director James Kitchell, was a featured on the October 19, 2008, "University of the Air," a Wisconsin Public Radio program that typically attracts more than 300,000 listeners.

Regional Climate Change Seminar Series

The WRI helped support "Climate Change in the Great Lakes Region: Starting a Public Discussion," a seminar series sponsored by the UW Sea Grant Institute and Wisconsin Coastal Management Program. From March through September 2007, eight climate-effects experts spoke at seven sites around Wisconsin to discuss what is known, what is predicted and what can be done to adapt to a changing climate. To continue and expand public discussion of what climate change means for the Great Lakes region, an 80-page summary report and a DVD featuring video and the PowerPoint® presentations from all eight seminars were published in 2008, either of which may be purchased or downloaded free of charge from the UW Aquatic Science Center's online Publications Store (*aqua.wisc.edu/publications*). To date, 902 copies of the printed summary report and 50 copies of the DVD have been distributed, and the online PDF of the report has been downloaded 2,494 times. A written summary and video of each seminar PowerPoint®

presentation are also available for free download from the "The Seminars" section of the project Web site (*www.seagrant.wisc.edu/ ClimateChange*).

Groundwater Awareness Week

The WRI again contributed to a series of seven news releases for the annual "Groundwater Awareness Week" in March 2010 that were distributed via the UW-Madison WRI's statewide media mailing list and the UW-Extension network. The WRI and UW-Extension also arranged for Stephen Ales, drinking and groundwater team supervisor for the Wisconsin Department of Natural Resources, and Kevin Masarik, outreach specialist for the UW-Stevens Point Center for Watershed Science and Education, to be guests on the March 10th broadcast of Wisconsin Public Radio's popular "Larry Meiller Show," a 45-minute live call-in talk show. Aired on WPR stations statewide, the program attracted callers from throughout the state, mainly with questions related to well water contaminants and testing issues. Program producers have said the number of calls show strong enough statewide interest in the topic to merit additional programs on groundwater topics in the future.

AWRA Annual Conference

The WRI once again cosponsored the American Water Resources Association-Wisconsin Section's annual conference, "Wisconsin's Changing Water Resources," held March 4-5, in Middleton. Other sponsors included the UW-Stevens Point Center for Watershed Science and Education, Wisconsin Department of Natural Resources, Wisconsin Geological and Natural History Survey, and the U.S. Geological Survey's Wisconsin Water Science Center. About 200 water managers and scientists from throughout Wisconsin attended the conference, which featured more than 60 oral and poster presentations on a wide range of water resources topics. Plenary session topics included groundwater-borne viruses and illnesses risk, Wisconsin's water laws and the implications of climate change on Wisconsin's water resources.

The Wisconsin Initiative on Climate Change Impacts (WICCI) hosted a special afternoon workshop at this year's conference to help identify the potential effects of climate change on the state's water resources and to develop possible adaptation strategies. About 20 people attended the workshop to answer the following question:

> *Based on the latest climate projections for Wisconsin, and your professional experience in the field of expertise, what are the possible (or most likely) impacts to water resources and/or hydrologic processes on the landscape that would be important to communicate to the people of Wisconsin at this time?*

Results from the workshop were instrumental in developing preliminary adaptation strategies to climate change in Wisconsin. These results are being incorporated into the Water Resources Chapter of a climate change assessment report that will be delivered to the Natural Resources Board in October, 2010.

Wisconsin's Water Library Outreach Activities

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 effects of the chemical bisphenol A on water quality, making an inventory of the literature related to citizen monitoring of water quality for the Bad River Watershed group, advising and locating a local journalist on how to find historical materials relating to hidden streams in Dane County, researching the locations of natural springs near Stevens Point for a professor at University of Wisconsin-Stevens Point, researching tertiary

wastewater treatment techniques for a student taking the wastewater operator's exam, and researching the intersection of groundwater regulations and land-use regulations for a University of Wisconsin-Madison professor in support of her research.

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.

The library applied for and won a Friends of the UW Madison Libraries grant to purchase materials relating to water and climate change in order to expand the titles the library owns on this important topic and to create a substantial collection for use by researchers working on the Wisconsin Initiative on Climate Change Impacts.

Library staff also continued to be involved in the Allied Drive Story Hours project. Allied Drive is a Madison neighborhood with the highest concentration of children of any urban neighborhood in Dane County and many families that live in poverty. The program is a partnership with eight special UW-Madison campus libraries, the UW-Madison School of Library and Information Studies, and the Madison School and Community Recreation Safe Haven Childcare Program. Each month, a different campus library hosts a reading hour with themes relating to their specialized subject area.

Library Web Sites

The library maintains several information transfer tools to reach library patrons and the most frequently accessed is the library's recently redesigned website (*aqua.wisc.edu/waterlibrary*). The library's site serves as an outreach site for those who want to know more about our state's water resources. The site's overhaul was designed to make books and other materials in the library easily accessible to any Wisconsin resident. There are three areas of the Web site, each designed to address the needs of the library user groups: There is an area for 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.

During the past 12 months, the library site has 43,148 visitors with 58,431 page views. The average time spent on the site is almost six minutes, a sign that Web surfers are finding items of interest and are drilling deeper into the information on the site after their initial entry.

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 500 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 their question and receive a response in a timely manner.

During the reporting period, the library also introduced several Web 2.0 tools to reach new library users and to raise visibility of the library. The library has a blog, AquaLog (*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 30 hits per days, 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 (www.facebook.com/pages/Madison-WI/UW-Wisconsins-Water-Library/92090121028?ref=nf) is used often to announce events and display interesting links to its "fans". Twitter (*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 Web Sites

WRI maintains several other Web sites in addition those described above. The UW Water Resources Institute Web Site (*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 Web site are updated annually.

The ASC Publications Store (*www.aqua.wisc.edu/publications*) features publications from both the Water Resources and Sea Grant Institutes. In the reporting period on July 1, 2009 to June 30, 2010, WRI distributed 129 copies of groundwater-related materials to the public. However, the majority of our publications are downloaded directly by users as PDF documents. The most popular publication was Groundwater Drawdown which was downloaded 573 times. There were also 201 downloads of Wisconsin's Buried Treasure, 69 copies of the nitrate fact sheet, and 78 copies of the arsenic fact sheet.

UWS FY 10 Publications Resulting from Groundwater Research & Monitoring Program Projects

Water Resources Institute Reports

Bahr, J.M. and E.E. Roden. 2009. Influence of Wetland Hydrodynamics on Subsurface Microbial Redox Transformations of Nitrate and Iron. Water Resources Institute, University of Wisconsin, Madison. 15p. Final_WR07R007.pdf

Creswell, J. E., Babiarz, C. L., Shafer, M. M., Armstrong, D. E., Roden, E. E. 2009. Controls on Methylation of Groundwater Hg(II) in Hyporheic Zones of Wetlands. Water Resources Institute, University of Wisconsin, Madison. 15p. Final_WR07R008.pdf

Deitchman R.S. and S.P. Loheide II. 2009. A thermal remote sensing tool for mapping spring and diffuse groundwater discharge to streams. Water Resources Institute, University of Wisconsin, Madison. 16p. Final_WR07R005.pdf

Li, J. and C.H. Yang. 2009. Transport and Survival of Pathogenic Bacteria Associated With Dairy Manure in Soil and Groundwater. Water Resources Institute, University of Wisconsin, Madison. 17p. Final_WR07R001.pdf

Theses

Arrington, K. 2009. Mapping Infiltration Rates in Dane County, WI. Ph.D. Soil Science, University of Wisconsin-Madison.

Deitchman, R.S. 2009. Thermal remote sensing of stream temperature and groundwater discharge: Applications to hydrogeology and water resources policy in the state of WI, M.S. Thesis, UW-Madison.

Jablonski, M. 2009. Comparison of the Role of Ionic Strength and Surface Charge Heterogeneity on the Initial Adhesion, Distribution, and Detachment of Two Escherichia coli Strains. Master's thesis, Department of Civil Engineering and Mechanics, University of Wisconsin-Milwaukee.

Miller, C.A. 2009. Influence of Wetland Dynamics on Microbial Redox Transformations of Nitrate and Iron. Master of Science (Geology). University of Wisconsin-Madison.

Rigo, M.V. 2009. Plasmonic Optical Fiber Sensor for Oxygen Measurement. Ph.D. thesis, Department of Chemistry & Biochemistry, University of Wisconsin-Milwaukee.

Other Publications

Deitchman R.S. and S.P. Loheide II. 2009. Ground-based thermal imaging of groundwater flow processesat the seepage face. Geophysical Research Letters, Vol. 36, L14401, doi:10.1029/2009GL038103

Engle, M.A., Tate, M.T., Krabbenhoft, D.P., Schauer, J.J., Kolker, A., Shanley, J.B., Bothner, M.H. 2010, Comparison of Atmospheric 1 Mercury Speciation and Deposition at Nine Sites across Central and Eastern North America, Geophysical Research (in press).

Gao, J., Pedersen, J.A. 2009. Sorption of sulfonamide antimicrobial agents to humic-clay complexes. J. Environ. Qual. J Environ Qual 39:228-235 (2009)
DOI: 10.2134/jeq2008.0274

Kolker, A., Olson, M., Krabbenhoft, D.P., Tate, M.T., and Engle. M.A., 2010, Patterns of mercury dispersion from local and regional emission sources, rural Central Wisconsin, USA, Atmos. Chem. Phys., 10, 1–10, 2010.

Lepore, B.J. and Barak, P. 2009. A Colorimetric Microplate Method for Determining Bromide Concentrations. Soil Sci Soc Am J, 73: 1130-1136.

Lepore, B.J., Morgan, C.L.S., Norman, J.M. and Molling, C.C. 2009. A Mesopore and Matrix Infiltration Model Based on Soil Structure. Geoderma. 152(3/4): 301-313

Lepore, B. J., A.M. Thompson and A. Petersen. 2009. Impact of polyacrylamide delivery method with lime or gypsum for soil and nutrient stabilization. Journal of Soil and Water Conservation 64: 223-231.

Li, Z., Hong, H. 2009. Retardation of Chromate through Packed Columns of Surfactant-Modified Zeolite. J. Hazard. Mater, **162**, 1487-1493.
http://dx.doi.org/10.1016/j.jhazmat.2008.06.061

Liu, Z., Li, Y., Li, Z. 2009. Relationship between land use and surface water quality in Wisconsin - a GIS approach. J. Integr. Environ. Sci., **6**, 69-89.

Luczaj, J.A., McIntire, M.J., Steffel, A.M., and Duca, A.L. 2009. Geochemical Characterization of Sulfide Mineralization in Eastern Wisconsin Carbonate Rocks. 33rd American Association of Water Resources Wisconsin Section Meeting, Stevens Point, Wisconsin, March 5-6, 2009. Program and Abstracts, p. 38.

Pedersen, J.A.; Karthikeyan, K.G.; Bialk, H.M. 2009. Sorption of human and veterinary antibiotics to soils. Natural Organic Matter and Its Significance in the Environment. Wu, F.; Xing, B. (eds); Science Press: Beijing, China, pp. 276-299.

Stelzer, R.S. and B.L. Joachim. 2010. Effects of elevated nitrate concentration on mortality, growth, and egestion rates of Gammarus pseudolimnaeus amphipods. Archives of Environmental Contamination and Toxicology. 58:694-699.

Summitt, A., Hart, D. J., Masarik, K., and Fratta, D. 2009. Imaging the Fate of Septic Tank Effluent using Multiple Geophysical Techniques. Journal of Environmental and Engineering Geophysics (in preparation for publication - draft completed).

Wilcox, J.D., J.M. Bahr, C.J. Hedman, J. D. C. Hemming, M.A.E.Barman and K. R. Bradbury. 2009. Removal of organic wastewater contaminants in septic systems using advanced treatment technologies. J. Env. Quality 38:149-156.

Zhang, X., Hong, H., Li, Z., Guan, J. 2009. Removal of Azobenzene from Water by Kaolinite. J. Hazard. Mater. Oct 30;170(2-3):1064-9.

For More Information on the WRI

Visit the WRI Web site (*wri.wisc.edu*) or contact Dr. Anders W. Andren, director, UW-Madison Water Resources Institute, 1975 Willow Drive, Madison, WI 53706; phone (608) 262-0905, fax (608) 262-0591, or email *awandren@seagrant.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/watersheds/*.

Drinking Water Programs. In 2009, the Center assisted over 2,979 households in having their water tested in conjunction with county Extension offices and the Watershed Center's Water and Environmental Analysis Laboratory. Of these, 10% exceeded drinking water standards for nitrate-nitrogen. Fifteen percent of samples were unsafe because of coliform bacteria. Sixteen Drinking Water Education Programs helped nearly 1,113 well users in 13 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 565,754 individual test results for approximately 72,136samples covering the state; including 20 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 and Dodge Counties.

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.

Ongoing Research

- Understanding the effects of groundwater pumping on lake levels and streamflows in central Wisconsin

Recent Publications and Reports

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.

Kraft, G.J., B.A. Browne, W.D. DeVita, and D.J. Mechenich. 2008. Agricultural Pollutant Penetration and Steady-State in Thick Aquifers. Ground Water Journal 46(1):41-50.

Browne, B.A., G.J. Kraft, W.D. DeVita, and D.J. Mechenich. 2008. Collateral Geochemical Impacts of Agricultural N Enrichment from 1963 to 1985: A Southern Wisconsin Groundwater Depth Profile. J. of Env. Quality.

Lowery, B., G. J. Kraft, W. L. Bland, A.M. Weisenberger, and Phillip E. Speth. 2008. Trends in Groundwater Levels in Central Wisconsin. In Proceedings of Wisconsin's annual potato meetings. University of Wisconsin - Madison College of Life Sciences and UW-Extension. Madison WI.

Lowery, B., W.L. Bland, G.J. Kraft, A.M. Weisenberger, M.L. Flores, and P.E. Speth. 2008.

Local groundwater levels in Wisconsin. In Proceedings of the Wisconsin Fertilizer, Aglime & Pest Management Conference. University of Wisconsin - Madison College of Life Sciences and UW-Extension. Madison WI.

Clancy, K., G.J. Kraft, and D.M. Mechenich. 2008. Knowledge development for groundwater withdrawal management around the Little Plover River, Portage County Wisconsin. Report to the Wisconsin Department of Natural Resources, Project NMG00000253. University of Wisconsin – Stevens Point.

Kraft, G.J., K. Clancy, and D.M. Mechenich. 2008. A survey of baseflow discharges in the western Fox-Wolf watershed. University of Wisconsin – Stevens Point.

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.

Other UW-Extension Water Programs

UW Environmental Resources Center (ERC). The UW Environmental Resources Center (ERC) hosts UWEX state specialists addressing water resources, land and water conservation, and forestry. 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 Cooperative States Research Education and Extension Service (CSREES), 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 manure management and fractured bedrock geology including:

- Presentation and tour to the WI Land and Water Conservation Board
- Training for manure applicators on manure application in Karst areas
- Half day workshop on Karst incorporated into the Conservation Planning Training sessions
- Karst manure and fertilizer management incorporated into farmer training in 3 counties.

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.

Recently completed 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 more than 170 nutrient management education projects since its inception in 1997. These projects have resulted in awards of over $2.5 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 1,600 farmers since 1997. More information can be found at http://clean-water.uwex.edu/malweg/.

Basin Education Initiative. 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's 22 major river basins. Fifteen locally situated Basin Educators develop and conduct programs throughout each basin, 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 at http://basineducation.uwex.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 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 UW Extension 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

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 in addition to the public.

The chemical and microbial groundwater contaminants routinely tested include all contaminants regulated by the federal Safe Drinking Water Act as well as many emerging contaminants that appear on the USEPA Contaminant Candidate List. Examples include: fecal indicators (total coliform, *E. coli*, coliphage, *Bacteroides spp., Rhodococcus coprophilus,*Sorbitol-Fermenting *Bifidobacteria*), *Helicobacter pylori*, *E. coli* O157:H7, Salmonella, waterborne viruses (Norovirus), parasites (Cryptosporidium, Giardia, and microsporidia), radioactivity, inorganic compounds (mercury, nitrate, arsenic) and organic compounds (atrazine, PCBs, PBDEs).

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. In FY 07 WSLH updated their well water activity sheet, "*Test your well water annually"* brochure, and other well water testing promotional materials for National Public Health Week. Staff members attend and present papers at a variety of conferences and symposia and publish research findings in professional journals.

Brief summary of groundwater-related research in FY 2009:

- Assessing occurrence, persistence and biological effects of hormones released from livestock waste. Jocelyn Hemming, PhD, Wisconsin State Laboratory of Hygiene. (Funded by the U.S. EPA, project ongoing).
- Toxicological Relevance of Endocrine Disruptors and Pharmaceuticals in Drinking Water. Jocelyn Hemming, PhD, Wisconsin State Laboratory of Hygiene. (Funded by the American Water Works Association Research Foundation – AWWARF, project completed).
- Assessment of the potential of hormones from agricultural waste to contaminate groundwater. Jocelyn Hemming, PhD, Wisconsin State Laboratory of Hygiene. (Funded by the DNR through the GCC's joint solicitation, project ongoing).
- Development of a PCR method for Adenoviruses as a means of distinguishing human from bovine contamination. Sam Sibley, University of Wisconsin State Laboratory of Hygiene. (Funded by the DNR through the GCC's joint solicitation, project completed).
- Assessment of the Efficacy of the First Water System for Emergency Hospital Use. Sharon C. Long, PhD, Jeremy Olstadt ,Wisconsin State Laboratory of Hygiene and Dennis Tomcyzk, Hospital Emergency Preparedness, Wisconsin Division of Public Health. (Funded by the Wisconsin Division of Health, publication pending with the Journal of Disaster Medicine and Public Health Preparedness).
- Madison Metropolitan Sewerage District: Biosolids Research 2009-2010 and Madison Metropolitan Sewerage District: PFRP Equivalency Project**,** Sharon C. Long, PhD and Jamie R. Stietz, Wisconsin State Lab of Hygiene. (Project ongoing).
- Evaluation of PCR-based methods for *Rhodococcus coprophilus*. Sharon C. Long, PhD and Jamie R. Stietz, Wisconsin State Laboratory of Hygiene. (Funded by the DNR through the GCC's joint solicitation, publication pending).

Summary of groundwater-related research and activities in FY 2010:

Aquatic Toxicology Section

- **Removal of Organic Wastewater Contaminants in Septic Systems Using Advanced Treatment Technologies**. Wilcox, J.D, Bahr, J.M., Hedman C.J.,Hemming, J.D.C, Barman, M.A.E., and Bradbury, K.R. 2009. J. of Environ. Qual. 38:149-156.
- **Assessing the Potential of Hormones from Agricultural Waste to Contaminate Groundwater**. GCC study (funded by the Wisconsin Department of Natural Resource Bureau of Drinking and Groundwater)

- **Assessing occurrence, persistence and biological effects of hormones released from livestock waste**. USEPA Star Grant R833421(Ongoing research).

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, the sterol coprostanol, makes up a significant portion of the human excreted sterol content, and is not normally found in surface waters. Therefore, 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. It is important to note that few studies have been reported in the scientific literature to date, and sterol source tracking data should correlated to orthogonal methodologies, such as the microbial source tracking protocols in making a final determination.
- **Analysis of PPCP 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**. Jeanine D. Plummer, Worcester Polytechnic Institute, Sharon C. Long, Wisconsin State Laboratory of Hygiene and University of Wisconsin. - The objective of this research is 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. Communication pieces for application of this indicator system by source water and water utility managers will be developed based on the research results.
- **Fecal Source Tracking Using Human and Bovine Adenovirus and Polyomaviruses**. Pederson, J.A., McMahon, K.D., Long, S.C., Sibley, S. Wisconsin State Laboratory of

Hygiene and University of Wisconsin. This is an ongoing project funded by the Groundwater Coordinating Council, WI DNR.

- The WSLH Water Microbiology Section is conducting "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.

Flow Cytometry Section

- DiGiovanni, G., N. Garcia, R. Hoffman and G. Sturbaum. "Getting the Most From LT2 Monitoring: **Genotyping Cryptosporidium On Method 1622/1623 Slides.** 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, visit the following website (http://www.slh.wisc.edu/) or contact William Sonzogni, Wisconsin State Laboratory of Hygiene, 2601 Agriculture Drive, Madison, WI 53718, phone (608) 224-6200, or email sonzogni@facstaff.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 through the conservation practices and many federal conservation programs which provide technical and financial assistance to landowners. Summaries and highlights of Wisconsin NRCS conservation accomplishments, by program, are available in the Wisconsin NRCS State Report for 2009 *ftp://ftp-fc.sc.egov.usda.gov/WI/Pubs/annualreport09.pdf*

Highlights of federal FY 2009 (Oct. 1, 2008 - Sept. 30, 2009) conservation accomplishments include:

- Conservation plans written on 316,621 acres
- Wetlands created, restored or enhanced on 2,206 acres
- Comprehensive Nutrient Management plans written = 114
- Comprehensive Nutrient Management Plans applied = 127
- Watershed or area-wide conservation plans developed = 32
- Land with conservation applied to improve water quality = 454,013 acres
- Cropland with conservation applied to improve soil quality = 415,117 acres
- Land with conservation applied to improve irrigation efficiencies = 5,501 acres
- Grazing and forest land with conservation applied to improve the resource base = 39,894 acres
- Non-federal land with conservation applied to improve fish and wildlife habitat quality = 16,953 acres

The agency also provides leadership with its Standards Oversight Council – an Interagency Committee to revise and maintain Conservation Practice Standards. Practice standards benefit the public by helping to protect groundwater. For example NRCS Practice Standards for Feed Storage Leachate and Runoff Control, and for Milking Center Wastewater Treatment System are were finalized in 2008-9.

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.

U.S. Geological Survey - Water Resources Discipline: Wisconsin Water Science Center

The mission of the U.S. Geological Survey - Water Resources Discipline (USGS-WRD) is to provide hydrologic information and understanding needed for the optimum 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 computerized 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] and Center for Land Use Education [CLUE], Southeast Wisconsin Regional Planning Commission (SEWRPC), the, Mole Lake 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).
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 two tribal areas (with the Mole Lake and Lac du Flambeau Tribes).
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).

Wisconsin projects funded entirely by USGS:

1. Availability and use of fresh water in the United States: Lake Michigan Pilot Study *http://water.usgs.gov/ogw/gwrp/activities/wateravail_pilot.html*.
2. Relation between groundwater flow and beach health (water quality) at Horseshoe Bay in Door County
3. Hydrologic and biogeochemical budgets in temperate lakes and their watersheds, northern Wisconsin Long Term Ecological Research site, http://infotrek.er.usgs.gov/doc/webb/index.html.
4. Western Lake Michigan Drainages National Water-Quality Assessment http://wi.water.usgs.gov/wmic/index.html.
5. Spatial and temporal shallow groundwater recharge rates in Wisconsin.
6. Great Lakes Restoration Initiative work on forecasting effects of future climate and land use change.

Compilation of Wisconsin 2005 Water-Use Data. Every 5 years, the USGS Wisconsin Water Science Center is responsible for presenting data collected and/or estimated for water diversions and withdrawals to the USGS National Water-Use Information Program. 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. 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.

In the last three years, there were 14 investigations of the USGS Wisconsin Water Science Center that incorporated a 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.

The USGS Wisconsin Water Use 2005 report (Buchwald, 2009) has been released and can be accessed through the USGS Publication Warehouse at *http://pubs.er.usgs.gov/* . Additionally, information about this study 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*.

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 newly developed USGS code GSFLOW (Markstrom et al. 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.

There have been three phases of recent study of the Black Earth Creek watershed cooperatively funded by communities in the watershed, WDNR, and USGS. The first phase of the project involved modeling surface and groundwater flow using existing data for the area. Results of the modeling effort provided direction for additional fieldwork needed to enhance the model in Phase 2 of the study. In Phase 3 the model was used to assess the effects of climate change and possible land-use development scenarios and mitigation strategies, including basinwide conversion of fallow lands to biofuel production.

Rock River Basin Groundwater-Flow model

A study of the shallow groundwater-flow system in the Rock River Basin was undertaken from 2007 to 2009 by the U.S. Geological Survey in cooperation with the Rock River Coalition (RRC). The primary objectives of the study are to improve understanding of the hydrogeology of the Rock River Basin, evaluate groundwater/surface-water interaction and base flow contribution to the Rock River and its tributaries, estimate amounts and rates of groundwater flow, and highlight areas that would benefit from additional data collection. These objectives have been achieved through the development of a numerical screening model to simulate the groundwater-flow system of the basin. The screening model describes the regional characteristics of the groundwater-flow system, and is a tool that can be used to test alternative plans to manage the resource (for example, effects of pumping well locations and rates on stream base flows). Additionally, the screening model provides a framework from which local or site-specific models can be developed with little additional data collection. Two public meetings have been held to present the results of the study, and work was published in a USGS Scientific Investigations Report (Juckem, 2009a).

Groundwater-flow Model of Pierce, Polk, and St. Croix Counties

Groundwater is the sole source of residential water supply in Pierce, Polk, and St. Croix Counties, Wisconsin. In cooperation with the three county governments, a regional three-dimensional groundwater-flow model and three associated demonstration inset models were developed to simulate the groundwater-flow systems of the counties. The objectives of the regional model of Pierce, Polk, and St. Croix Counties were to improve understanding of the groundwater-flow system and to develop a tool suitable for evaluating the effects of potential water-management programs. Three inset models were extracted from the regional model to simulate groundwater-surface water interaction, contributing areas to streams, and transient response of surface water resources to seasonal precipitation, recharge variability, and groundwater withdrawal. A number of stakeholder meetings have been held, and a USGS Scientific Investigations Report was published (Juckem 2009b).

Great Lakes Basin Pilot study to improve fundamental knowledge of the water balance of the basin, including the flows, storage, and water use by humans. At the request of Congress, the USGS is assessing the availability and use of the Nation's water resources to gain a clearer understanding of the status of our water resources and the land-use, water-use, and natural

climatic trends that affect them. The goal of the National Assessment of Water Availability and Use Program is to characterize how much water we have now, how water availability is changing, and how much water we can expect to have in the future.

Water availability is a function of many factors, including the quantity and quality of water and the laws, regulations, economics, and environmental factors that control its use. The focus of the Great Lakes Basin Pilot study is on improving fundamental knowledge of the water balance of the basin, including the flows, storage, and water use by humans. An improved quantitative understanding of the basin's water balance not only provides key information about water quantity but also is a fundamental basis for many analyses of water quality and ecosystem health.

For Wisconsin this Pilot study is providing important hydrologic data sets, an assessment of historical water use (Buchwald and others, 2010), detailed recharge maps developed with the Soil Water Balance model (Dripps 2003; Dripps and Bradbury 2007; Westenbroek and others, 2009), and a calibrated groundwater-flow model (Feinstein and others, 2010) providing information critical to water management and implementation of the Great Lakes Compact.

Agriculture-Related Trends in Groundwater Quality of the Glacial Deposits Aquifer, Central Wisconsin

Measuring and understanding trends in groundwater quality is necessary for determining whether changes in land management practices have an effect on groundwater quality. A recent USGS publication (Saad, 2008) describes an approach that was used to measure and understand trends using data from two groundwater studies conducted in central Wisconsin as part of the USGS NAWQA program. One of the key components of this approach, determining the age of sampled groundwater, gave a temporal component to the snapshots of water quality that were obtained through synoptic-sampling efforts. Results of these studies indicate measured concentrations of nitrate and atrazine plus deethylatrazine were correlated to historical patterns of fertilizer and atrazine use. Concentrations of nitrate in groundwater have increased over time; concentrations of atrazine plus deethylatrazine increased and then decreased.

Development and use of the USGS Coupled surface-water groundwater model code at the Northern Wisconsin Long Term Ecological Research site

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 et al., 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 et al. 2008). The first evaluated a uniform 4.4^{o} C increase in air temperature that represented one projected year 2100 condition. The second evaluated the same uniform increase in air temperature, but added the effects of extreme precipitation events by combining weekly precipitation into a single day in each week (changing precipitation timing, but not total annual amounts). Expected decreases in lake stage and stream flow were observed; more interestingly, results suggested that climate change may result in changes in the sources of water to ecosystems, as illustrated by a rain-dominated soft-water lake changing to a groundwater influenced flow-through lake. Inclusion of extreme precipitation events was somewhat mitigated

when combined with the increase in temperature because the soil zone had more storage available. The effect on the biotic system was evaluated using simulated changes in hydrograph shape metrics. Both climate scenarios resulted in decreases in expected macroinvertebrate abundance and richness, with the lowest expected quality at a stream site that periodically went dry during the simulations. Even though the simulations could be improved with more sophisticated climate processes and scenarios, these results demonstrate a potential utility for GSFLOW modeling for today's resource management actions.

Web Site – Protecting Wisconsin's Groundwater Through Comprehensive Planning. In cooperation with the UW-Extension Center of Land Use Education and the Wisconsin DNR a web site has been developed to make Wisconsin groundwater information and data accessible and usable, thereby encouraging government officials and planners to incorporate groundwater into their comprehensive-planning processes (http://wi.water.usgs.gov/gwcomp/index.html). This web site provides summaries of, and access to, data and information on geology, general hydrology, and groundwater quantity and quality generated by state, local, federal, and independent sources. The data and information take the form of maps, reports, data bases, and web resources. All data are from publicly accessible sources. This web site also provides guidance for incorporating groundwater information into comprehensive plans, and presents case studies of municipalities that have worked hard to understand their groundwater resources and develop groundwater goals, objectives, and policies.

From January 1 through June 9, 2010, the website has been accessed over 11,400 times, and is averaging over 400 successful requests for information per day, and over 60 successful requests for pages per day. Nearly 1,000 distinct files have been requested and more than 700 different individuals or organizations from dozens of countries have visited the site over that period. The complete Web Server Statistics are available at:
http://wi.water.usgs.gov/server_stats/2009/usgs/wi.water_gwcomp_i.html#req

Through the Local Government and Planning 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 this web site is undetermined; other than correcting identified errors this site is currently static. Funding for development of this web site came from the Wisconsin Department of Natural Resources through the GCC's Joint Solicitation for Groundwater Research & Monitoring. Additional funds were provided by the US Geological Survey Cooperative Water Program.

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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).

DEPARTMENT OF COMMERCE

Three of the seven Divisions of the Department of Commerce 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) and private onsite wastewater treatment systems 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 Comm 10, Wis. Admin. Code). The Bureau of PECFA reimburses owners and operators of leaking petroleum storage tanks (Chapter Comm 47, Wis. Admin. Code) and has regulatory jurisdiction of petroleum sites determined to be a low or medium risk to the environment (Chapter Comm 46, Wis. Admin. Code).

Within the Division of Housing and Community Development, one program provides financial assistance for the cleanup and redevelopment of contaminated properties (Chapter Comm 110, Wis. Admin. Code). The Blight Elimination and Brownfield Redevelopment (BEBR) Program provides grants of up to $1.25 million to assist local governments, businesses and individuals with the assessment and remediation of the environmental contamination at abandoned, idle or underused industrial or commercial facilities or sites.

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 Commerce.

General Plumbing – Reuse and Stormwater Use. The Department plumbing code includes standards for reuse of wastewater and stormwater. Currently, the Chapter 82 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 communicates 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 and water well regulations. The Department also communicates with the USEPA Region 5 office regarding POWTS related matters. Department staff continues to participate in efforts to develop 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 Comm 10, 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 Comm 10, 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 Commerce 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 Commerce 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 will 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. This past year the department partnered with trade associations working with the regulated community to provide training related to the revised Comm 10 and the pending operator training.

Wisconsin has over 6,600 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, and provided Commerce 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 Commerce authorization to access the property and remove the UST(s), Commerce 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. 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 Commerce 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.

Petroleum Environmental Cleanup Fund Act (PECFA)
Since 1989, the PECFA program has reimbursed approximately $1.51 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, conducts a competitive public bid process 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 was $10.1 million for FY10 and in 2011 is $9.1 million. In FY09, the PECFA program reimbursed $10.41 million to 672 claimants. The Program currently reimburses claimants within two months of receiving a claim. The Program's current bond obligation is $236 million.

In addition to administering the PECFA fund, the Department of Commerce 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.

Blight Elimination and Brownfield Redevelopment (BEBR) Grants
The BEBR program typically awards approximately $6 million annually that will be utilized for redevelopment awards of up to $1.25 million. Funds may be used for the environmental activities including investigation, remediation or groundwater monitoring. Expenditures for site acquisition, demolition, building rehabilitation or infrastructure improvements may also be eligible for reimbursement.

The BEBR program has awarded $69,950,000 in grants since the inception of the initiative in 1998. Funds have been used to remediate 178 properties with soil or groundwater contamination which has resulted in the creation of over 6,900 full-time jobs.

Data Management
Commerce is continuing its data integration information technology (IT) initiative. With regard to groundwater protection, Commerce 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

For more information, visit the website or contact Berni Mattsson, ERS Division Administrator, P. O. Box 7839, Madison, Wisconsin 53707-7839, phone: 608-266-9403, fax: 608-267-1381; e-mail Berni.Mattsson@Wisconsin.gov.

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, Stoll, 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). 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), 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 has required Wisconsin towns, cities, villages and counties to develop comprehensive plans by 2010 in order to undertake common land use activities such as zoning and land division regulation. As of March 16, 2010 the Wisconsin Department of Administration estimated that 90% of local governments that exercise land use regulations have adopted or are in the process of developing comprehensive plans.[i]

Communities that rely on ground water as their sole source of water need to assess the magnitude and limits of their water source as part of their comprehensive development 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, Wis.) to determine what kinds of groundwater supply information was most relevant and usable for land use planning from a community's perspective (Cherkauer, 2005). This study determined that the most important information needed by such a community is a good basic understanding of the geology, sources, sinks and water balance of its aquifer system 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 a long-term land use plan 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 WRI 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). 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 (Comprehensive Planning in Wisconsin: Are Communities Planning to Protect Their Groundwater Water Resources IMPACT 7(6):19-21).

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 in their comprehensive ("Smart Growth") 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 the citizen plan commissioners. The same interagency team prepared a centralized website that provides a suggested process for integrating groundwater information into comprehensive plans and 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, 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 2002-2006 for water quality and 2005 for water quantity.

Through the Local Government and Planning 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 Wisconsin Department of Natural Resources through the Joint Solicitation for Groundwater Research & Monitoring of Wisconsin's Groundwater Coordinating Council. Additional funds were provided by the US Geological Survey Cooperative Water Program.

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[i] ESTIMATED Wisconsin Local Government Comprehensive Planning Status. www.doa.state.wi.us/docview.asp?docid=8078

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 (Sonzogni, 2002a). 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 (Sonzogni, 2002b). 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)

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, 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.

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 3 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 is currently underway. 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 and 2010). 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 (the precursor to radon) 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, 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 southeastern 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 SE 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. Hart and others searched state records and discovered that approximately 170 such wells exist in SE 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 investigating the sources of high salinity and radium in the deep sandstone aquifer that supplies water to residents of eastern Wisconsin (Grundl, 2000). This project is examining in detail the chemistry of the groundwater and the rock formations of this complex aquifer and determining whether high pumping rates are raising salinity and radium levels. This will 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.

In late 2007, 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 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, 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. The rate of recovery has significantly slowed showing that nearly all of the recovery

has occurred. 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. 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. The water levels there were not affected by the decreased pumping to the north and have remained relatively steady since 2005. The water use has also remained steady.

These projects illustrate the importance of monitoring the resource. We now know that if the pumping around Little Chute, Kaukauna, and Kimberly continues to remain steady, the cone of depression will also remain steady. We also know that a further decrease in pumping will cause more wells to flow along the western edge of the main cone of depression and that if pumping stays below 4-7 mgd in the main cone of depression 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 the Bureau 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

Methyl mercury (MeHg) is one of the most toxic and persistent substances in the environment. Current 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, 2002). Recent results show that MeHg concentrations in these hyporeic (shallow zone) pore waters co-vary with the mercury methylation rate at depth (Armstrong, 2004). This suggests that the measured MeHg concentrations are likely produced in situ, and are not from legacy sources. Methylation rates in the hyporeic 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, 2006). Current results also show that methylation rates are not controlled by the total mercury concentration in pore waters (Shafer, 2010). Instead, high concentrations of strong mercury-binding ligands have been observed and are believed to influence methylation rates by one of several possible mechanisms. 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 hyporeic zone. For example, due to the lack of correlation between total mercury and methylation rate in pore water, the mitigation of atmospheric mercury inputs to the watershed, may not immediately affect MeHg export. In addition, any impact on 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, 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, 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 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 (McMahon, 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 State Lab of Hygiene developed breast cancer cell line assay (E-screen assay) technique 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, 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) assessed groundwater movement and contaminant transport through carbonate bedrock areas in four counties in northeastern Wisconsin. The carbonate bedrock areas chosen for study have shallow soil depths and karst features, and are considered to be very vulnerable to contamination leaching from the ground surface. The research specifically evaluated the fate and transport of endocrine disrupting chemicals in groundwater associated with the land application of dairy waste on soils above the vulnerable bedrock aquifer.

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 provides 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 online under Monitoring and Research):

- New and enhanced physicochemical or biological methods to renovate waters contaminated by pesticides and volatile organic carbon compounds (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.(Metz and Benson, 2007),(Li et. al. 2007), (Shafer et. al. 2007), (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 (Bahr, 1994-95),. (Evans & Li, 2002-03);
- Innovative agricultural practices designed to reduce groundwater contamination by pesticides and nitrate (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); and
- Development of new technologies for evaluating the integrity of water supply well and exploration borehole seals (Edil, 1996, 1998-99), (Edil and Benson, 1997-98);
- Multi-parameter sensors for monitoring groundwater quality (Krabbenhoft et. al, 2007), (Geissinger, 2006-08), (Anderson & Glanchandani, 2002-03).

Rain Garden Design & Evaluation

In February 2006, WRI and the UW-Madison Department of Civil & 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 that promotes infiltration of storm water 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 storm water 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 and is available free of charge on the DNR website. The manual continues to be extremely popular at our ASC Publications Store. From FY 07 through, FY 09, over 900 printed copies and over 40,000 downloads were recorded.

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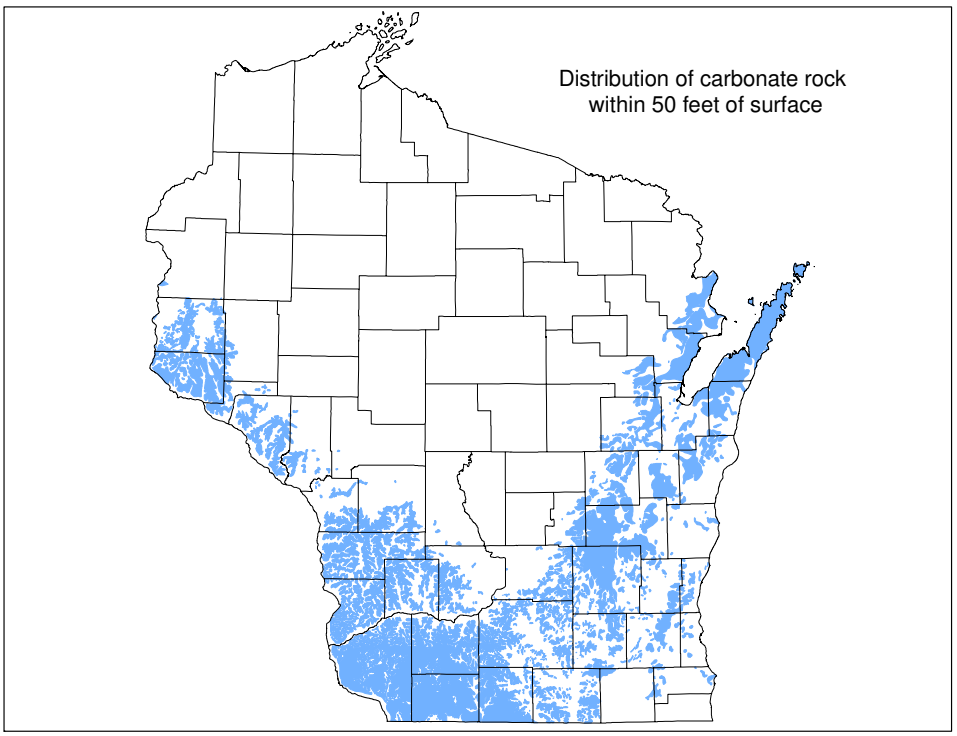
Groundwater Movement in Shallow Carbonate Rocks

Shallow carbonate bedrock (dolomite and limestone) underlies much of Northeastern Northwestern, and Southwestern Wisconsin (see map below). During the 1980's and 1990's Door County was the site of five research projects by the WGNHS to develop a framework for studying the complex groundwater flow regime in fractured rock found in many parts of the state (see 2007 Report to the Legislature). This research in Door County laid groundwork for a recent non-joint solicitation project that delineated the areas contributing water to springs providing critical habitat to the endangered Hine's emerald dragonfly (Cobb and Bradbury, 2008). Results of this project are being used to protect the spring contribution areas from contamination and development that might harm the dragonfly (see *http://www.fws.gov/Midwest/endangered/insects/hed/DoorCtyHEDgrndwtrRptMay2008.html*).



Location of shallow carbonate bedrock in Wisconsin

As a follow-up to this work, 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 study began in July, 2010.

The techniques developed in the Door County research are being applied to carbonate rocks in other parts of Wisconsin to help address the question "how much soil is enough?" when making management decisions in carbonate rock areas. In 2008, researchers (Muldoon and Bradbury, 2009) completed a project monitoring shallow groundwater adjacent to agricultural fields in areas

of moderately thick soil (10-20 feet) over carbonate rock in Brown, Calumet, Manitowoc, and Kewaunee Counties, with the goal of assessing water quality variations in areas of significant soil cover. All four wells showed rapid rises in water levels within 24 to 48 hours of significant recharge events. Electrical conductivity data indicate that the water-level rise is due to dilute recharge water entering the saturated zone rather than the drainage of vadose zone water. All wells exhibit elevated nitrate and chloride values and periodically exceeded the nitrate standard of 10 mg/l NO3-N. This work shows that even in areas of moderately thick soil in the areas studied wells respond rapidly to recharge events following snowmelt or heavy thunderstorms.

The Door County work also laid the groundwork for a follow-up project supported without state funds where shallow carbonate rock is being studied at a contaminated site in Pierce County (Cobb, 2007). Groundwater remediation activities at the Town of Warren TCE site provided an opportunity to conduct a multi-well tracer test in dolomite below over 20 feet of soil cover. The tracer revealed that very rapid (10's of feet per day) groundwater movement is occurring at the site, and that most movement is along bedding-plane conduits. These results show the necessity of conduit monitoring in such environments and demonstrate the potential rapid movement of groundwater.

A third recent study complementing the Door County work occurred on the Platteville Pioneer farm, located a few miles southeast of Platteville in Lafayette County (Kraft, 2008). Work at this has shown that groundwater movement in the southwest has some similarities and dissimilarities to those in the northeast part of the state. In common with northeastern Wisconsin, recharge reaches the shallow aquifer quickly and penetrates the upper part of the aquifer in a karst-like fashion. However, it appears that transmission to the deeper part of the aquifer is not as strongly dominated by conduit-type flow as in the northeast.

Groundwater quality problems associated with nitrate, bacteria, and foul-smelling water in domestic wells in parts of Brown, Door, Calumet, Kewaunee, and Manitowoc Counties led the the formation of a Northeastern Wisconsin Karst Task Force, which issued a report (the "Karst Report") in early 2007 (see *http://learningstore.uwex.edu/Assets/pdfs/G3836.pdf*). This report summarized issues in the affected areas and made suggestions for future research and regulation. Motivated in part by this report, studies of karst features and shallow fractured rock have been undertaken in other areas. In Calumet County, the UW Discovery Farms program has been evaluating methods for rapidly assessing bedrock depth in agricultural fields. In Fond du Lac County the Town of Byron funded an investigation of groundwater vulnerability over the Town region. This work was carried out by the WGNHS and is available here: http://www.uwex.edu/wgnhs/wofrs/WOFR2010_02.pdf

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Developing New Tools for Groundwater Protection

Continuing cooperation between state and federal agencies and the University System, with funding provided through the Joint Solicitation Program, has fostered development of several new tools and methods for groundwater protection that are now becoming commonly used in Wisconsin. One such success story is the development of a rapid method for estimating groundwater recharge based on a soil-water balance method. Information on groundwater recharge rates is critical for building reliable groundwater flow models, but recharge rates are notoriously difficult to measure. Through a series of projects (Dripps and Bradbury, 2007; Hart et al., 2008, 2009; Westenbroek et al., 2009) Wisconsin investigators have developed, tested, and applied a computerized technique for rapid estimation of spatially and temporally distributed recharge rates using widely-available data on land use, topography, soils, and climate. Application of this model has become routine for many new groundwater studies in Wisconsin, and the technique has seen use in other states, notably Minnesota and Nebraska.

In addition to improvements in site and county scale characterization of groundwater recharge, a recent estimate of the larger-scale distribution of statewide recharge (Figure 1) was developed using 1970-1999 stream baseflow data and GIS watershed delineation (Gebert et al., 2009a, 2009b). This type of tool was intended to help develop more realistic initial estimates of groundwater recharge, which in turn facilitate better and more efficient groundwater model development, resource and water availability evaluations, and protection plans. The statewide map also has value in that it encompasses areas where groundwater system is not the dominant component to hydrologic flows, thus are areas that likely have not yet had extensive hydrogeologic study. Groundwater resources may still be important in such areas, especially given potential future land use and climate change. Therefore, initial estimates of groundwater recharge will likely have value in future hydrogeological studies in these understudied portions of the state.

Groundwater models are one of the primary tools for groundwater protection, but be expected to be only as good as their representation of real world characteristics important for groundwater flow. Recent work has shown how including processes in the unsaturated zone can influence groundwater recharge estimates and groundwater-surface water interaction in northern Wisconsin (Hunt et al., 2008). In addition to including relevant processes important to groundwater flow, groundwater modeling is improved by evaluating the degree to which a model represents the real world. New methods for constructing groundwater models were developed to help optimally simulate the natural world (Fienen et al., 2009a; Doherty and Hunt, 2010; Doherty et al., 2010). These developments are timely, given the recent access to higher-levels of computing power such Cloud Computing (Hunt et al., 2010). Moreover, because this is assessed by comparing how well simulated results compared to data measured in the field, these mathematical frameworks can be extended to evaluate the efficiency of funds spent for monitoring. Collection of field data to constrain and calibrate models is expensive, and insight on how best to extract the most information from existing field data have been investigated (e.g., Hunt et al., 2007; Fienen et al. 2009b). Such tools have additional utility for groundwater protection because they are designed to quantitatively evaluate the efficacy of current and future monitoring network designs. Such information is critical for evaluating the “bang for the buck” of alternative networks, and ensures that decision makers are maximizing the funding resources available for monitoring.

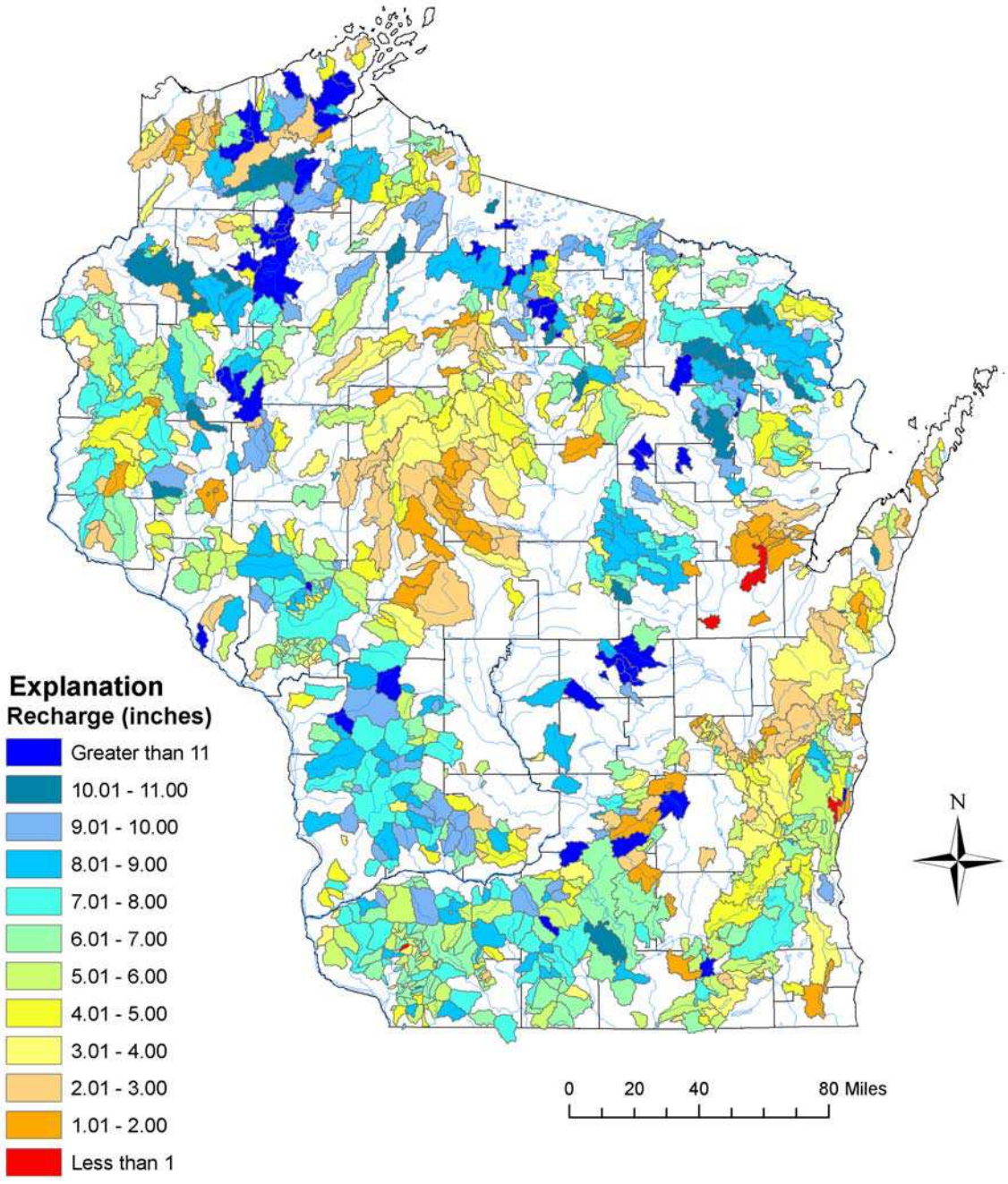

Figure 1: Spatial distribution of average annual recharge at partial record stations in Wisconsin (from Gebert et al., 2009b).

Other innovative work done at UW Madison includes use of Unmanned Aerial Vehicles (UAVs) to collect thermal remote sensing data for mapping of groundwater discharge. Thermal imagery was collected at the stream reach scale (several kms), at four times during the day – dawn, noon, 4pm, and dusk. Groundwater discharge, visible in this imagery is intended to allow 1) a better understanding of stream-aquifer interactions; 2) insight into the underlying groundwater flow

system; 3) identification of reaches where groundwater discharge may threaten surface water quality through discharge of contaminated groundwater; 4) developing a water quality monitoring program that can account for areas of known discharge; and 5) targeting reaches for conservation or restoration where stream-aquifer interactions are favorable for supporting aquatic ecosystems (Deitchman, 2009).

Another new technique is distributed temperature sensing (DTS). In this technique a fiber optic cable has pulsed laser light shown down it. Some of that light is reflected and scattered backward. The back scattered light can be used to measure temperature along the entire cable. The UW-Madison and WGNHS are using this technique to measure simultaneous temperatures in wells as warm water is circulated in the well. The temperature record can then show preferential flow zones in the well.

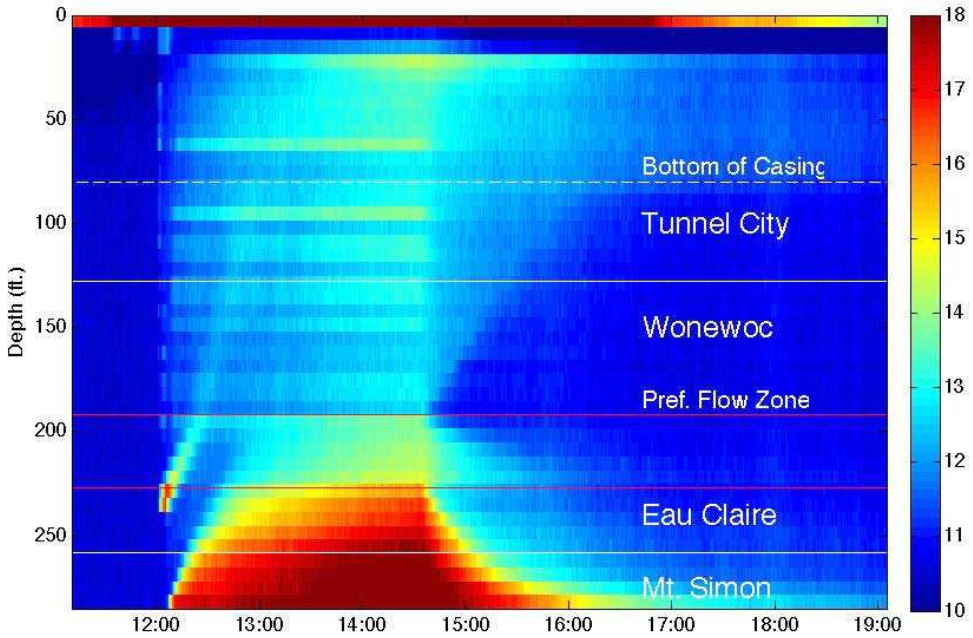

Figure 2 Record of temperature in the well with depth and time. Warm water circulation began at 12:00 and stopped at 14:40. The preferential flow zone is marked by the cooler (blue), at 195 feet depth.

Modern borehole logging and imaging represent additional new tools coming into wider use in Wisconsin. Borehole geophysical logging refers to a series of field techniques in which various electronic sensors are lowered down wells or boreholes to record physical properties of the subsurface rocks and water. Typical sensors include temperature, electrical conductivity, natural radiation, borehole diameter, fluid flow, and borehole imaging (see Figure 3). While these techniques are by no means new, and have long been used in the petroleum industry, they have only recently been applied routinely to shallow environmental and water-supply problems. Modern computers and electronics make these instruments portable and much less expensive and easier to use than in the past. The WGNHS routinely uses such instruments to collect subsurface data from wells across the State, and this information is invaluable for understanding Wisconsin's hydrogeology. . For example, using a spinner flow meter, the WGNHS was able to identify flows of around 60 gallons per minute in a multiaquifer well located in Madison, WI. This well was

allowing flows of lower quality water from the upper aquifer through the well into the lower aquifer. The City of Madison, after learning of the issue, abandoned the well preventing further transport of water between the aquifers. During 2010 the WGNHS received an Equipment Grant from the National Science Foundation to purchase additional downhole imaging equipment and related software. Having this state-of-the-art equipment available in Wisconsin will foster wider use of these techniques.

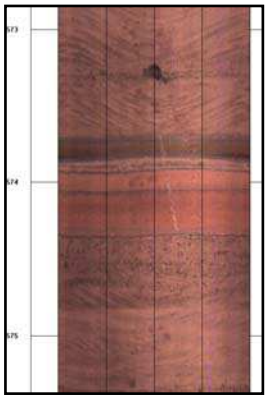

Figure 3 Optical borehole image from a WGNHS test well drilled in Pierce County. This image shows the borehole wall between 573 and 575 feet below the surface.

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Nitrate

Based on data collected by the DNR, DATCP and UW-Extension's Central Wisconsin Groundwater Center, nitrate is currently our most widespread groundwater contaminant. Nitrate contamination is increasing in extent and severity (Kraft 2002, 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. Background nitrate levels in groundwater are below 1 milligram per liter (mg/L). Higher levels indicate a source of contamination such as agricultural or turf fertilizers, animal wastes, septic tanks, municipal sewage treatment systems, and decaying plant debris.

Approximately 80 per cent of nitrate inputs into our groundwater originate from manure spreading, agricultural fertilizers, and legume cropping systems (Shaw, 1994). Nitrate contaminated wells are more prevalent in agricultural districts. Studies have repeatedly shown that agricultural counties in southern and west-central Wisconsin have a higher percentage of nitrate-contaminated water supplies.

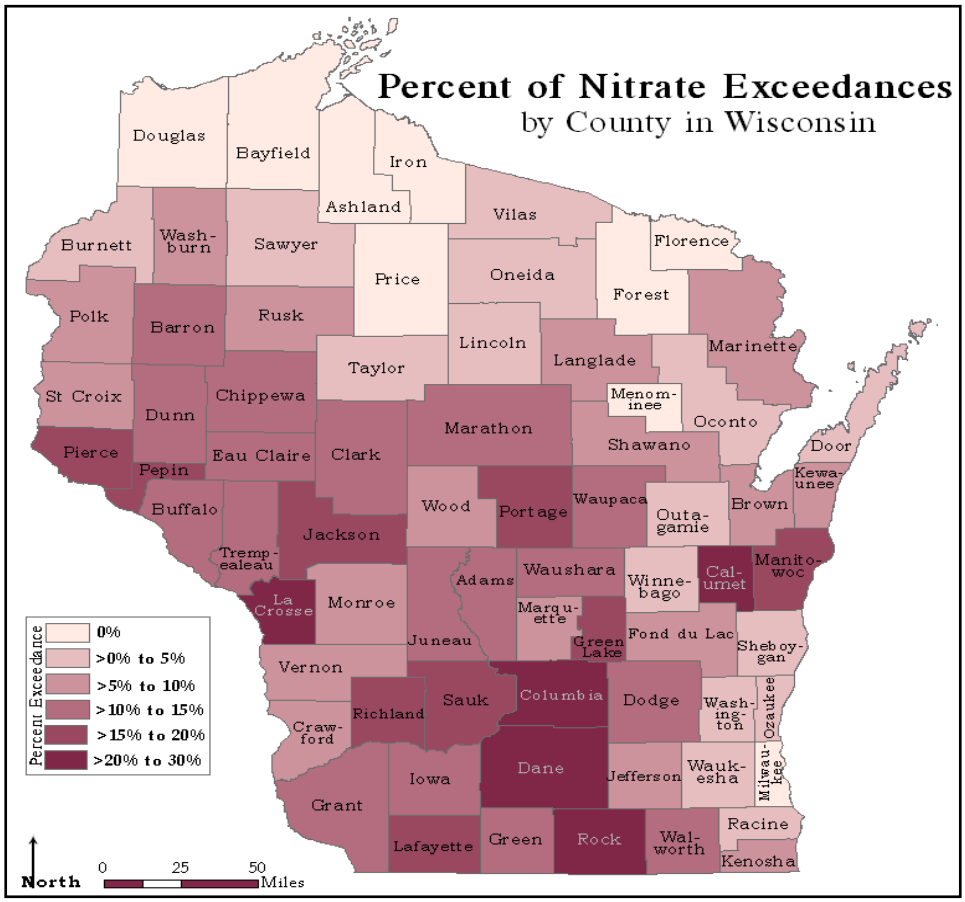
A 2007 random survey of private wells conducted by DATCP estimated that 9% of wells statewide exceeded the nitrate enforcement standard (ES) of 10 mg/L. The highest percent of wells exceeding the ES occurs in highly cultivated areas south-central Wisconsin where an estimated 21% of the wells had unsafe nitrate levels.

In 2005 and 2007, DNR aggregated and analyzed data from three groundwater databases: DNR's Groundwater Retrieval Network (GRN) database (25,894 samples), the Center for Watershed Science and Education database (21,525 samples) and DATCP's groundwater database (1,399 samples). The dataset included only the most recent nitrate sample analytical result for each private well sampled. Of 48,818 wells sampled, 5,686 (11.6 %) equaled or exceeded the ES of 10 mg/L. As seen in the map below, the percent of wells exceeding the ES varied across the state. Calumet, Columbia, Dane, La Crosse and Rock counties had exceedance rates of 20% to 30%.

DHS obtained research funding from the WRI to add a module to the 2008 and 2009 Behavioral Risk Factor Surveys on the testing of private drinking water supplies. Based on responses to this survey, 36 percent of Wisconsin's families obtain their water from a privately-owned well and one-third of 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." Some owners indicated that they didn't know how to find a lab or didn't know what tests to request. Only 13% listed cost as a reason for not testing their water.

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 to 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.



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.

Once nitrate converts to nitrite in the human body it can then convert into a carcinogen called N-nitroso compounds (NOC's). NOC's are some of the strongest know 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. Currently 25 (up from just 14 in 1999) of Wisconsin's municipal water systems have exceeded the nitrate ES and have collectively spent over $24 million on remedies. Excessive nitrate levels have also forced the replacement of hundreds of other smaller public wells.

The 10 mg/L ES is the advisory level for privately owned wells that supply drinking water; however, the individual owners carry the responsibility of making sure their wells are tested. The

DNR and DHS recommend that new private wells be tested for nitrate at least every five years during their use. Testing is strongly recommended for wells used by pregnant women and infants less than 6 months of age. 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 1500 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.

A modeling study on contaminant transport in Central Sands wellhead protection areas (Mechenich and Kraft, 1997) predicted eventual nitrate-N concentrations of 38 mg/L for the Whiting municipal wells recharge area, and 26 mg/L for Plover municipal wells. Full farmer adoption of University of Wisconsin recommendations would decrease the predictions to 26 mg/L for Whiting and 19 mg/L for Plover. These concentrations are about 1.5-2 times higher than present values. In this study area agriculture was responsible for 89% of the nitrate inputs to groundwater whereas septic systems contributed about 7%. The investigators concluded that in some hydrogeologic settings current recommended fertilizer application practices are not capable of keeping groundwater nitrate concentrations below the enforcement standard.

A study on nitrate inputs to a Central Wisconsin groundwater aquifer (Kraft, 2003) concluded that nitrate concentrations will continue to increase if current nitrogen input rates continue. Nitrate-N concentrations under potato and vegetable fields averaged about 20 mg/L when grower inputs of nitrogen fertilizer were made according to University recommendations, but some applications are made at higher than recommended rates.

A later similar study (Kraft 2004) investigated nitrate penetration into the sandstone aquifer in south central Wisconsin. The sandstone lies beneath 30 meters of glacial till deposits resulting in a transport time from the ground surface to the sandstone of about 18 years. In this study, Kraft found a steady increase in nitrate concentrations. Modeling suggests that under modern land use practices, in 20-40 years the groundwater in this aquifer will reach a state where the average concentration will be over 10 ppm.

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.

- 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.

Another paper (Saad, 2008) describes the analysis of data from the USGS National Water-Quality Assessment (NAWQA) Program study area in the Western Lake Michigan Basin in Central Wisconsin. Samples from 1994 were compared to 2002 for one set of wells. Median nitrate values increased by 4.5 mg/l from 1994 to 2002. Of the 26 wells re-sampled, 13 showed an increase in concentration, seven remained virtually the same and six showed a decrease. Age-dating of the water allowed for a comparison of nitrate concentrations over time with historic agricultural chemical use. Here a clear trend of increasing nitrate with increasing fertilizer use was seen.

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. Several studies have suggested that nitrate concentrations as high as 30 mg and exceeding 100 mg NO3-N/L do not cause substantial mortaility in aquatic animals (Scott and Crunkilton 2000, Camargo et al. 2005). However, 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).

Sublethal 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).

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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 (the 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 under special casing areas. (See more under interagency coordination).

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. 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).

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.
- A study funded through the joint solicitation completed in 2007 involving researchers from WGNHS, DNR and West Virginia added new data to the geologic model for the SWCDA and refined the mapping project.
- Educational outreach to the well drillers continues.

More information related to arsenic can be found on the DNR Arsenic Web Page.

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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 can not 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).

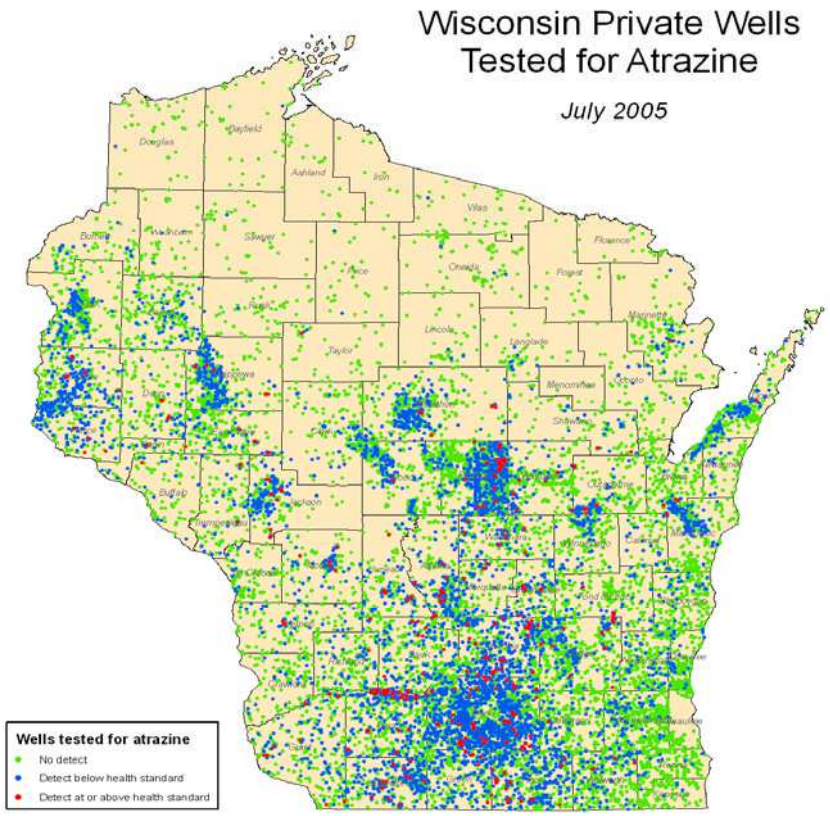
Serious concerns about pesticide contamination in Wisconsin were first raised in 1980 when aldicarb, a pesticide used on potatoes, was detected in groundwater near Stevens Point. The DNR, DATCP, and other agencies responded to these concerns by implementing monitoring programs and conducting groundwater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

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% 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% of private wells tested have atrazine detections, while about 1% 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% of the time and levels over the enforcement standard in about 5% 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)

- 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

Triazine screen. In 1991, the Wisconsin State Laboratory of Hygiene (WSLH) began a public testing program using an immunoassay screening test for triazine-based compounds such as atrazine. The triazine immunoassay screen uses specific antibodies designed to selectively bind to target compounds that are present at low concentrations. While there is no enforcement standard (ES) for the triazine screen, comparing the triazine results to the ES and preventive action limit (PAL) for atrazine provides a reference point for the severity of contamination. In a recent survey of DNR groundwater databases, more than 14,000 triazine screen results have been recorded. Forty-two percent of the samples had a detection of a triazine compound; 13% exceeded the 0.3 ug/l PAL for atrazine and 1.6% exceeded the 3.0 ug/l ES for atrazine.

One problem with the triazine screen is that it does not detect all the atrazine metabolites and therefore underestimates the total atrazine concentration. The WSLH advises homeowners that the triazine screen results should be used for initial screening purposes only. Higher triazine detects often receive a follow-up gas chromatography test. In 2002, the DNR funded a study with the WSLH to evaluate a new immunoassay test for the metabolite diamino atrazine. Results were delivered in late 2003 and it appears that a combination of the new and existing tests can better predict the level of atrazine plus metabolites in groundwater samples.

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.

2000 Groundwater Survey - Beginning in October 2000 and ending in May 2001, DATCP collected 336 samples from private drinking water supplies to determine the statewide impact of pesticides on groundwater resources (DATCP 2002). DATCP analyzed the samples for commonly used herbicides including the chloroacetanilide herbicides and their metabolites. The results from this study were also compared to previous surveys to attempt to understand trends in groundwater quality over time. A total of seven common herbicides, ten metabolites and nitrate were included in this survey. Highlights from this overall study show:

- The proportion of wells that contain a detectable level of an herbicide or herbicide metabolite was 37.7%.
- Alachlor ESA and metolachlor ESA were the most commonly detected herbicide compounds with proportion estimates of 27.8 and 25.2%, respectively.

- A statistically significant decline in parent atrazine concentrations between 1994 and 2001 but no corresponding decline in total chlorinated residues of atrazine.

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% had declined in concentration and 16% had increased. About 50% of well owners continued to use their contaminated well and about 25% had installed new wells at an average cost of $6,300. This well survey has been repeated annually through 2009, with samples collected from 150 different wells at least once during this time period. As of 2009, atrazine levels had gone down in over 80% of the wells. Six wells remain above the enforcement standard.

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 2009, this study entered its 23rd program year. In 2009 samples from monitoring wells near 22 agricultural fields were sampled. A total of 14 compounds were detected in groundwater. Three of these (nitrate, alachlor ESA and atrazine + metabolites) were found at levels 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% 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%. 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%.

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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. 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.

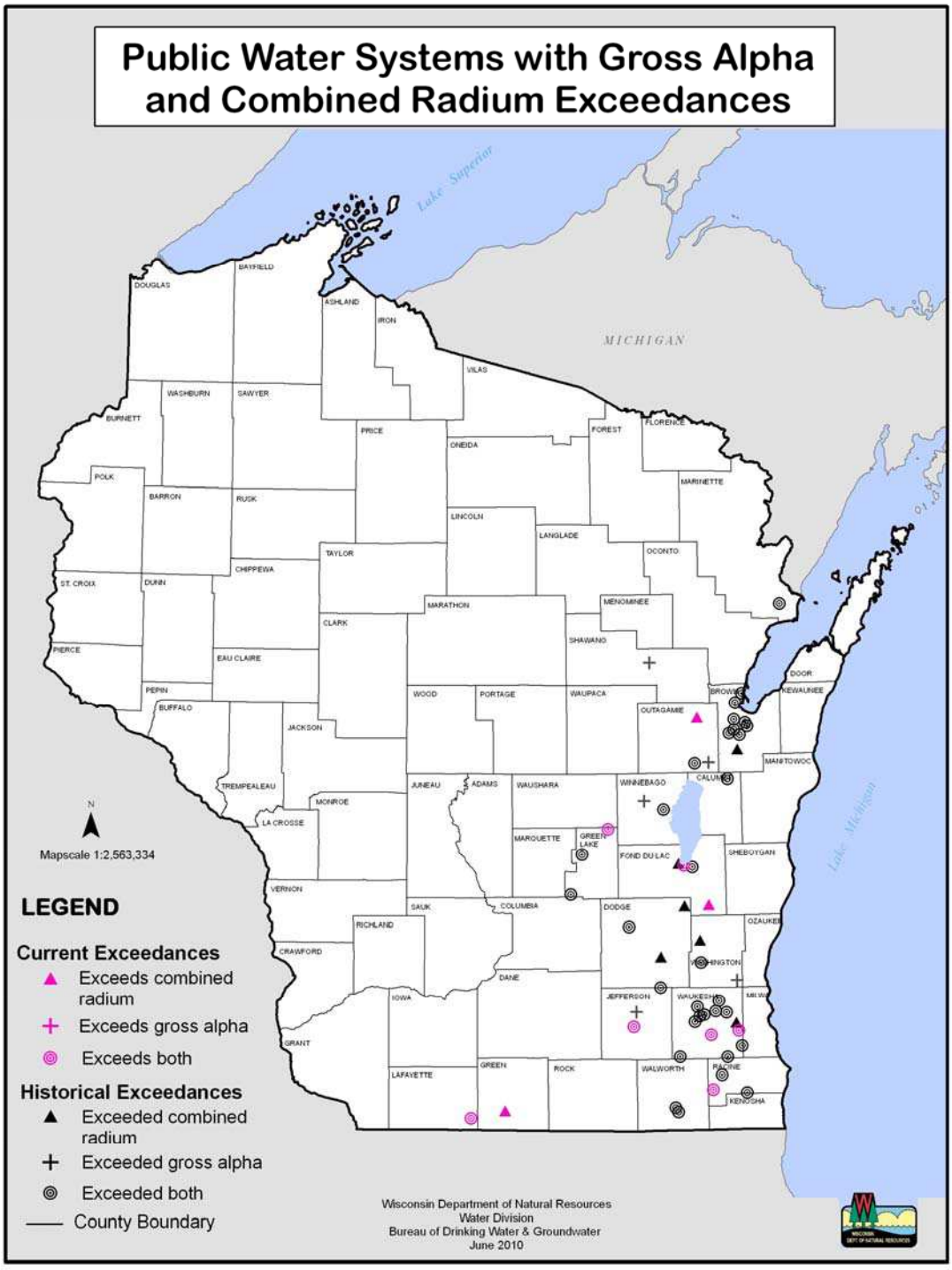
Drinking water monitoring completed since 2009 has shown a few more systems that have exceeded a radionuclide standard. Currently, there are less than 10 systems that are serving water that exceeds a radium or gross alpha standard. The DNR has formal agreements with these systems to gain compliance with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

Determining which process(es) control the release of solid- phase radioactivity in the Cambro-Ordovician 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 June 2010 or have exceeded radionuclide standards in the past. Source: DNR

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.

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.

A second study "Factors Affecting the Determination of Radon in Groundwater" 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 2008, 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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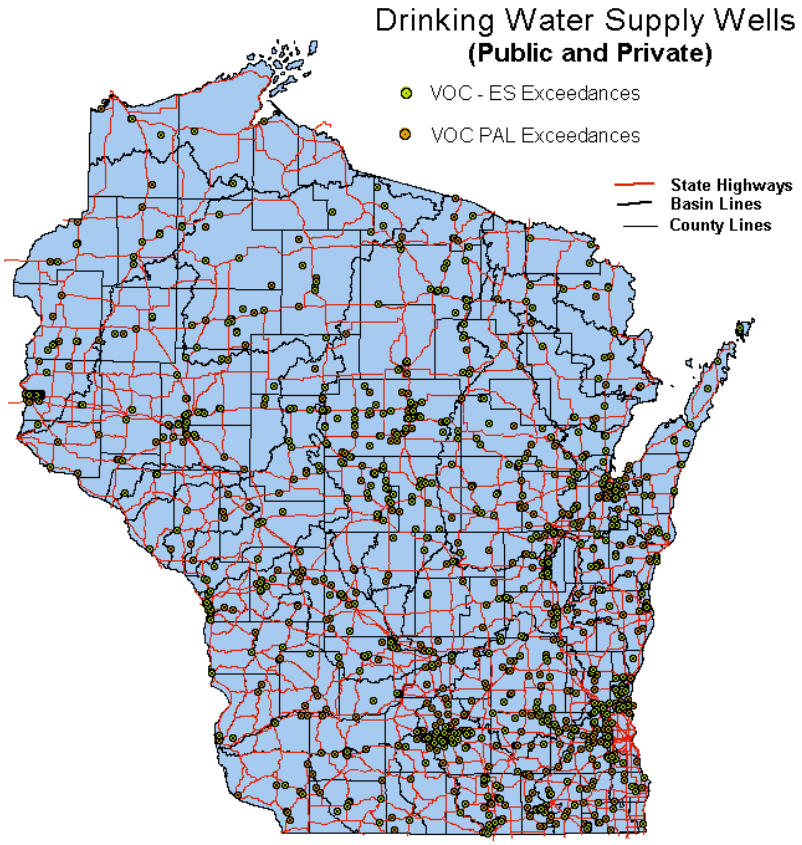
Summaries of the gross alpha and radon studies are available on the WSLH web site at *http://www.slh.wisc.edu/radiochem/research.html*.

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 ES and PAL exceedances based on data from 6,399 unique wells recorded in the 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 68 active, licensed solid waste landfills, all of which are required to monitor groundwater. In addition, the DNR currently tracks about 20,000 leaking underground storage

tanks (LUSTs) and about 7,600 reported releases at a variety of facilities. Many of these sites have been identified as sources of VOCs. Facilities include gas stations, bulk petroleum and pipeline facilities, plating, dry cleaning, industrial facilities, and abandoned non-approved unlicensed landfills. The DNR also tracks approximately 31,000 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 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 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 may be more closed landfills with problems that have not yet been 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 have been given health advisories not to 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 has taken 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 2009, approximately 1,100 hazardous substance discharges were reported to the DNR. Approximately 850 were spills, and 300 required greater follow up. Of the 300 sites, 135 were from USTs, and 7 were agrichemical discharges transferred to DATCP.

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 can be found online.

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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% of private well water samples tested positive for total coliform bacteria, an indicator species of other biological agents (Warzecha, and others 1995). Approximately 3% 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.

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 20% 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). 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 make 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.

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 8% 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% 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 flowpaths 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). 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 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% 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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GROUNDWATER QUANTITY

Adequate groundwater is present throughout most of Wisconsin to support municipal, industrial, agricultural, and domestic demands, yet important challenges have been identified. In some areas of the State groundwater is being withdrawn at unsustainable rates, jeopardizing water supplies for increasing populations as well as baseflow for streams, lakes and wetlands.. The GCC has long supported stronger management of groundwater pumping in Wisconsin (DNR, 1997). 2003 Wisconsin Act 310 took some first steps. The Groundwater Advisory Committee and its technical advisory committees expended significant effort attempting to recommend additional public policy related to groundwater quantity during 2006 and 2007. The extensive recommendations were captured in two separate reports to the Legislature, but the Legislature has not acted on those recommendations. Policy development is needed to address issues related to regional management of groundwater resources in areas experiencing water quantity issues and possible expansion of the review of high capacity wells to include consideration of additional water resources.

Water Use

As part of the National Water-Use Information Program, the U.S. Geological Survey (USGS) 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 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.

Also, as a result of 2003 Act 310, groundwater pumping reports are required of high capacity well users. Pumpage date for calendar year 2009 collected by DNR and the Public Service Commission includes data for over 10,000 high capacity wells. Just over 200 billion gallons of water were pumped from these wells.

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 102 wells, and the data are publicly available on the Internet: http://wi.water.usgs.gov/data/groundwater.html.
Funding levels for this program have steadily declined since 1995. The current funding level is inadequate to maintain the existing network; resulting in compromised data as wells go out of

service due to age, equipment failure, or ownership issues.

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 were 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 begun to recover. The WGNHS determined that so far, water levels have risen more than 100 feet in certain places (Luczaj, 2009). Although the water levels are approaching a new stable level, a smaller additional rise is expected.

Quantity and Quality
An example of how regional drawdown can bring about 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 will be precedent-setting and could be challenging in terms of and demonstrating compliance with the Great Lake Compact and securing concurrence by other jurisdictions. 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. Fortunately, several communities voluntarily went beyond what state law requires, to protect surface waters and other water users in siting their wells and managing their water use.

Another example of regional drawdown causing groundwater quality problems is 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.

Alternative Sources
Other developments also highlight the importance of groundwater quantity. The cities of Oak Creek and Green Bay sought approval to use aquifer storage recovery (ASR) wells to address water shortages during peak demand periods. 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.

In Green Bay it was determined that ASR, as pilot tested without modification, would not be allowed because significant concentrations of arsenic and other contaminants were mobilized from the rock matrix of the aquifer during the demonstration test. The Green Bay Water Utility elected not to pursue developing 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.

Pilot testing of ASR at Oak Creek demonstrated that the technique is possible; however, concentrations of manganese and iron were found to increase with each successive cycle. DNR conditionally approved routine ASR operations as long as groundwater monitoring continued to show that concentrations of mobilized substances do not exceed state groundwater quality standards. However, groundwater quality data submitted to the DNR in 2007 indicated that the concentrations of manganese and iron in the groundwater around the ASR well continued to be above state groundwater quality standards. As a result of the exceedances, the utility is required to make changes to its ASR operations plan. If ASR operations cannot be modified in a manner that will return the ASR facility to compliance with Wisconsin's groundwater protection regulations, the DNR is required to rescind its approval for Oak Creek Water and Sewer Utility to operate an ASR system. ASR activities have been temporarily suspended while the water utility considers its options. A final decision on future ASR operations will be made in 2010.

Surface Water Impacts

In addition to the large regional areas experiencing adverse effects from groundwater withdrawals such as in the northeast and southeast portions of the state, there are also cases of smaller more localized areas of impact. Situations exist where wells, springs, and wetlands have gone dry; lake levels have dropped; and streamflow has been reduced, apparently in response to groundwater pumping.

In the central sands region, streamflows and lake levels appear to be depressed in a way not entirely attributable to recent climatic conditions. One case in particular, the Little Plover River, a Class I trout stream and Exceptional Resource Water in Portage County, has demonstrated the strong connection between groundwater and surface water. The central sands area has a high concentration of high capacity wells and counties within the region are routinely among the highest in the state in regard to the amount of annual groundwater pumpage. . As a result of high rates of groundwater withdrawal within its watershed, the Little Plover has experienced dramatically reduced flows in the last few years to the point of completely drying up in stretches every year since 2005. Statistical approaches and groundwater flow modeling indicate that the Little Plover River would have continuous year-round flow in the absence of groundwater pumping in the area. The Little Plover River is just one example of diminished surface water resources in the Central Sands Region – other headwaters streams are also exhibiting reduced flows and a number of seepage lakes have experienced severely depressed lake levels over the past several years. (Kraft, 2008)

2003 Act 310

The outcome of several years of work on groundwater pumping policy was 2003 Wisconsin Act 310. The Act has been touted it as a "good first step", but it is also recognized that further efforts would be needed to adequately manage groundwater resources in Wisconsin. As discussed above, the Groundwater Advisory Committee considered possible enhancements to the Act and presented those to the Legislature.

In the fall of 2009, State Senator Mark Miller and State Representative Spencer Black convened a Legislative Work Group to consider the adequacy of the State's groundwater quantity law. The

Work Group's goal was to *"Establish a statewide water management policy that protects Wisconsin's water quantity and quality on a sustainable basis for the benefit of Wisconsin's residents and economy. The policy would establish a vision and priorities for the long-term management of the state's groundwater and surface water resources. This policy should:*

- *Balance competing water uses, including environmental protection, economic stability and societal health*
- *Rely on sound science and the principles of adaptive management*
- *Encourage efficient water use while discouraging waste*
- *Provide for coordination among state and local government agencies*
- *Seek to ensure clean and adequate water supplies for future generations"*

The Work Group met regularly through December 2009 soliciting information from a variety of groundwater experts in the state. Information from the Work Group's meetings is posted on the group's web site: *http://www.legis.wi.gov/senate/sen16/news/Issues/GroundwaterWorkgroup.asp*

Subsequently, Sen. Miller and Rep. Black co-authored legislation (SB620 and AB844) that would substantially modify the existing statutes pertaining protecting groundwater quantity by:

- Creating a framework for implementing the existing groundwater management area concept.
- Establishing criteria and a process for designating new groundwater management areas.
- Creating a petition process under which citizens could request environmental review of proposed high capacity wells if they demonstrated the proposed well could pose a significant threat to nearby surface water resources.
- Directing the DNR to conduct a statewide inventory of large springs and changing the criteria for determining which springs qualify for protection under the high capacity well law.

A summary of the proposed legislation, prepared by Legislative Council staff, is available at the following web site:
http://www.legis.wi.gov/senate/sen16/news/Issues/Groundwater/030410_GH2O%20Leg%20Council%20memo.pdf

Public hearings were held before the Senate Committee on the Environment and the Assembly Committee on Natural Resources and extensive public testimony, both in support and in opposition, was received. The legislative session expired before the bills were voted on by either the Senate or Assembly. It is anticipated that similar bills will be considered in future legislative sessions.

Great Lakes Compact

In 2008, Wisconsin ratified the Great Lakes – Saint Lawrence River Basin Water Resources Compact (Compact) and enacted legislation to implement it. The Compact addresses water quantity management in the Great Lakes – Saint Lawrence River Basin (Basin). It sets out requirements for Basin water uses in the areas of registration, reporting, management, and water conservation and efficiency. It also prohibits diversions of Basin water with limited exceptions for straddling communities, communities in straddling counties and intrabasin transfers (transfers of water from one Great Lake basin to another).

Wisconsin's legislation implementing the Compact—2007 Wisconsin Act 227—is extensive and includes the following components that affect groundwater quantity management:

- Requires statewide registration of existing and new water withdrawals with the capacity to withdraw more than 100,000 gallons per day averaged over 30 days.

- Withdrawals over 100,000 gallons per day averaged over 30 days must be reported annually.

- An initial withdrawal amount must be determined and will be the basis for considering requests for an increased withdrawal.

- Great Lakes Basin withdrawals averaging 100,000 gallons per day or more in any 30-day period require a permit. General permits with a 25-year term are required for withdrawals averaging 100,000 gallons per day or more in any 30-day period but less than 1 million gallons per day for any 30 consecutive days. Individual permits with a 10-year term are required for withdrawals exceeding 1 million gallons per day for any 30 consecutive days. Both types of water use permits establish the authorized withdrawal amount, as well as requirements for reporting and water conservation.

- The Department must develop and implement a water conservation and efficiency program with voluntary measures to apply across the state, additional mandatory elements that apply in the Great Lakes Basin, and the most stringent requirements for communities applying for diversions or water uses with high rates of water loss.

- Public notice, comment and hearing processes are a part of the review of all new water use permits and applications for diversions.

- All public water supply systems serving 10,000 or more people must have an approved water supply service area plan by 2026. This planning process uses a cost-effectiveness analysis that assesses the environmental and economic impacts of alternatives.

- The DNR must develop a statewide water resources inventory and publish a state water use report every five years.

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. 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 rise in the water table elevation and the related long-term increase in lake stage.

Several communities are affected by elevated groundwater levels. Examples include Clear Lake, in Rock County, where the lake stage has increased by about 7 feet over the past year. In Spring Green, 4,378 acres outside of areas currently designated as floodplain by the Federal Emergency Management Agency (FEMA) were flooded for over five months. 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 (described above), 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 recently devastated by groundwater conditions.

Although the hydrogeologic setting varies among affected areas in southern Wisconsin, the widespread occurrences of groundwater flooding and the regional nature of intense precipitation events in 2007 and 2008 show that it is a regional issue. Researchers at the WGNHS and the UW Madison are completing a one-year study of these affected hydrologic systems and climate change, funded by the UW System.

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