Groundwater Series #4

Fond du Lac County Groundwater

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Center for Watershed Science and Education

UW Extension

Fond du Lac County Groundwater:
A community resource

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Clean and dependable supplies of water are critical to ensure a high quality of life and maintain a strong economy. Groundwater is of particular importance since it is the primary source of water for many Fond du Lac County residents and industries.

While municipal water supplies are subject to strict guidelines and water quality testing to ensure that water meets the criteria for safe drinking water; the thousands of household wells which serve as the primary water supply for rural residents are not routinely tested. These private well owners often no little about the quality of their well water and little information is available to assist them in identifying concerns.

If not carefully monitored, managed and protected, high-quality groundwater can be depleted or significantly degraded. When our clean water is degraded, it is often a time consuming and expensive process to determine where to locate the next well or how to obtain a safe supply of water.

Locally we are increasingly faced with the question of how to manage this vital resource. Here in Fond du Lac County, there are areas where land-use practices have resulted in elevated concentrations of human-induced pollutants such as nitrate and pesticides in groundwater.

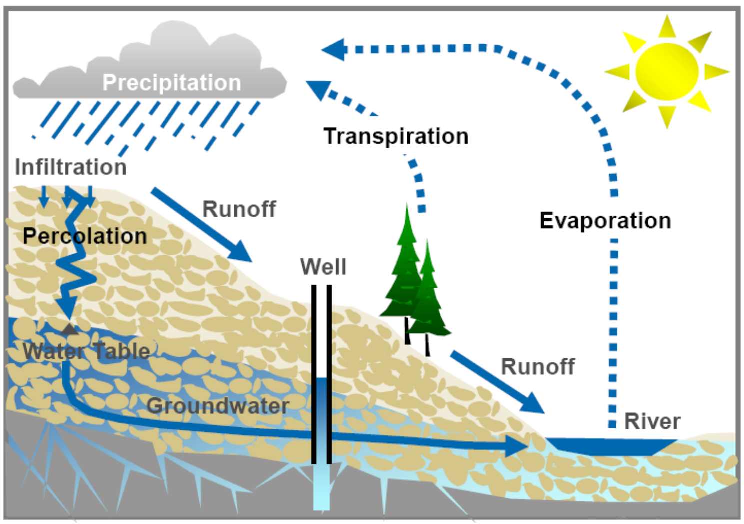
Taking necessary precautions to limit groundwater impacts should be a high-priority for all communities, but is particularly relevant for those areas where groundwater degradation has already been observed because of current land-use or is likely to occur because of local geologic conditions.

The results from over 1,500 voluntarily submitted well tests have been used to generate this summary. While the results are not part of a scientific study, they do provide insight into the overall quality of groundwater in Fond du Lac County. This report is intended to educate residents and local leaders on important groundwater issues. The dissemination of this information helps to highlight groundwater concerns and can be useful for informing future groundwater management decisions.

The residents of Fond du Lac County that participated in these well testing programs deserve special thanks; without them this report would not have been possible.

What is Groundwater?

Groundwater is water contained in the empty spaces between soil particles and rock materials below the surface of the earth. If you dig a hole and find the **saturated zone**, the point at which all of the empty spaces between the soil and rock are filled with water, you have hit the **water table**. The saturated areas below the water table make up our groundwater resources.

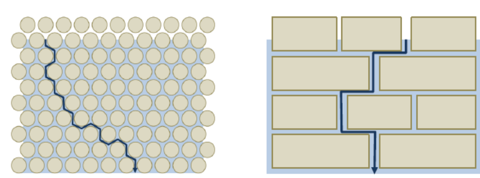


The hydrologic cycle.

Groundwater is not the mysterious subject that some people believe it to be. Wisconsin's groundwater is related to all other water on earth through a process called the **hydrologic cycle**, or the water cycle. In the water cycle, water is transported from the earth by the processes of **evaporation** and **transpiration** to form clouds. The water in the atmosphere eventually falls back to the earth as precipitation. Some precipitation runs off into surface water. Some soaks into the ground to be used by plants. Water that soaks past the roots of plants to the saturation zone becomes groundwater. Some of this water will be pumped out by wells and used in our everyday activities.

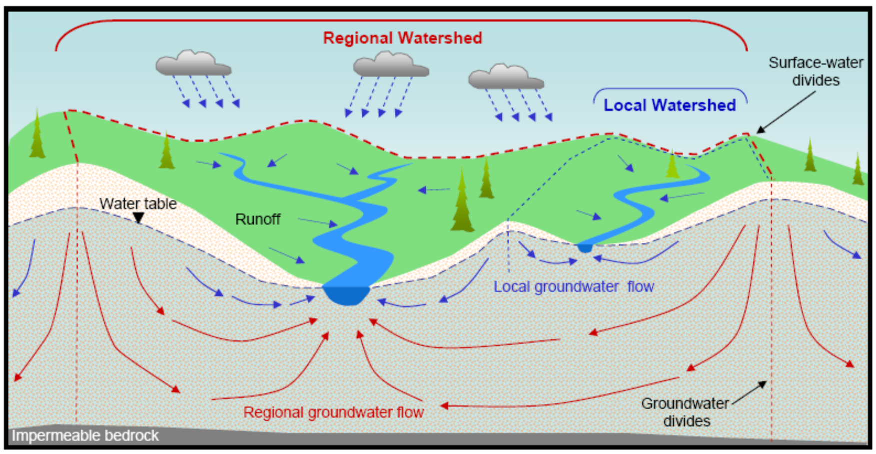
Groundwater that supplies Wisconsin's **wells** does not flow in underground rivers. Rather, the **aquifers**, water bearing geological formations that transmit and store water, are more appropriately thought of as underground "sponges". Major aquifers in Fond du Lac County include unconsolidated deposits (mostly glacial deposits) and dolomite and sandstone bedrock.

What many people do not realize is that groundwater is always moving. It moves very slowly through the small pores or cracks found in the soil and bedrock. Two factors that affect the rate at which groundwater moves are: 1) the size of the pore spaces and 2) how well the pores or cracks within an aquifer are connected. The larger the spaces and the better connected those spaces are, the faster water will move. Typically groundwater may only move a few feet per day, although in areas where there is fractured carbonate bedrock, groundwater may move much quicker – hundreds or thousands of feet per day particularly following large rain or snowmelt events.



The size of void spaces in between soil particles or cracks in rocks and how well those spaces are connected determines how quickly water moves through an aquifer.

In Wisconsin's shallow aquifers, groundwater flows only short distances, a few thousand feet to a few miles, from **recharge areas,** areas where water infiltrates into the ground, to **discharge areas** lower points on the landscape where groundwater intersects the land surface and water exits the ground. Examples of discharge areas include streams, rivers, lakes and wetlands.

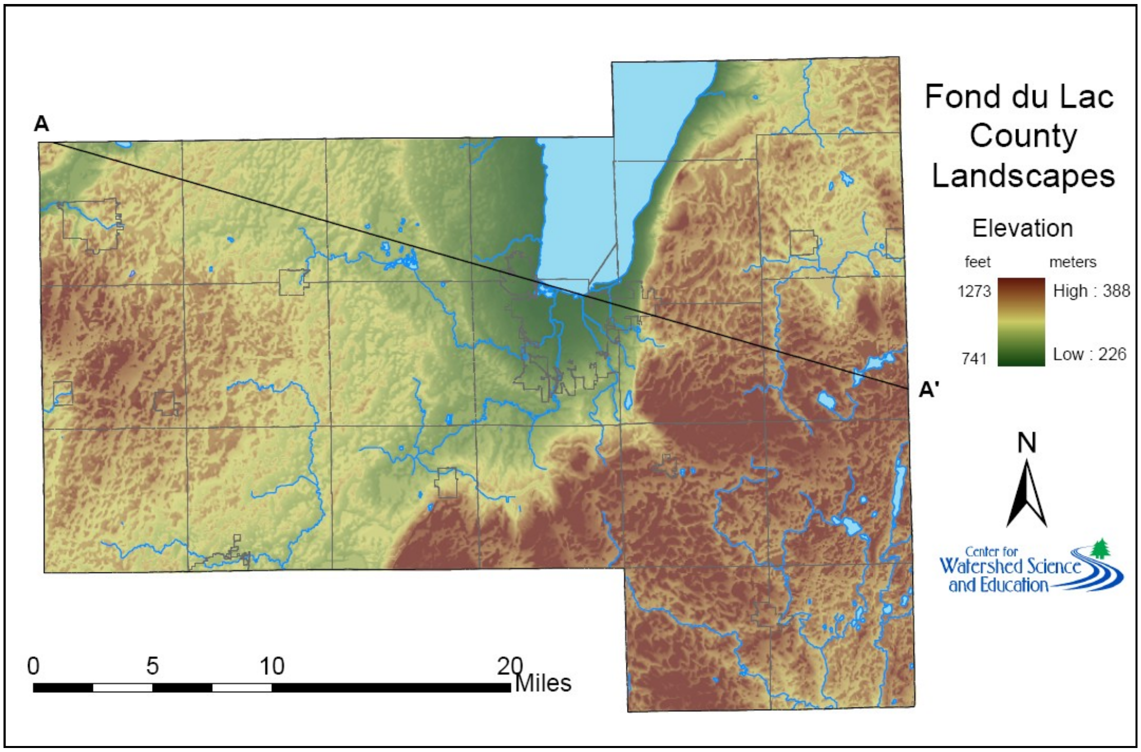


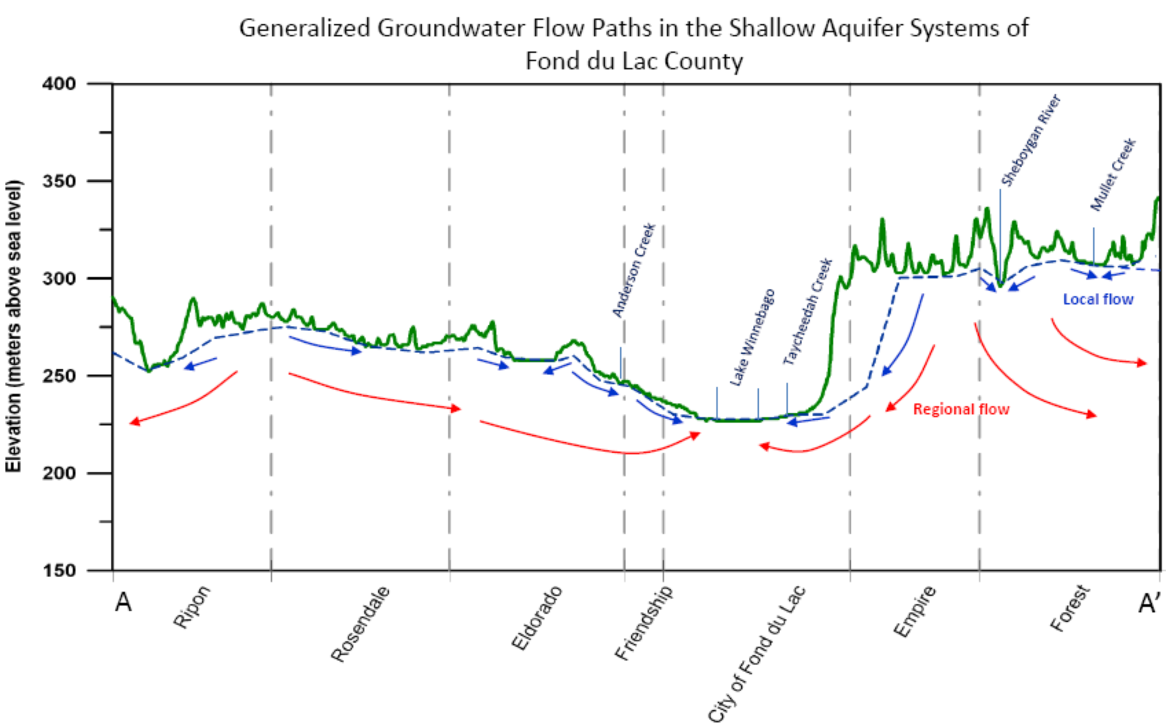
Local groundwater flows shorter distances to nearby streams. Deeper in the aquifer groundwater generally flows longer distances to more regional discharge areas.

Groundwater traveling in shallow flowpaths has been in the groundwater system only a few years or decades; most of the groundwater that we use is supplied by these shallow flowpaths. Deeper in the aquifer where the groundwater flowpaths are much longer, water may be in the groundwater system decades or longer as it works its way to a regional discharge location. Even though water may be very old, it is important to understand that our groundwater is a local resource which originated as precipitation and does not travel down from Canada or Lake Superior.

Since groundwater generally discharges to the landscape at surface water bodies, we use the concept of a **watershed** to determine the area of recharge for groundwater, lakes and rivers. A watershed is the land area where water originates for lakes, streams or groundwater aquifers. Any water that ends up in a lake or river originated or fell somewhere within that lake or river's watershed. Most precipitation that isn't taken up by plants or doesn't evaporate will eventually find its way to a lake or river within the watershed, some through direct runoff over the land surface and much of it through infiltration and groundwater flow. Large rivers, such as the Rock River, will have a regional watershed that can be divided up into smaller local watersheds, all of which eventually flow to a common discharge point.

Water is often referred to as the universal solvent because it can dissolve many different materials, some which may be harmful, and may be found in groundwater. Because the groundwater used by most Fond du Lac County residents is locally recharged, it is greatly affected by local geological conditions and local land use. People may be surprised that groundwater quality problems do exist in Fond du Lac County. Some of the problems occur naturally from the contact of water with soil and rock; others are introduced by human activity.





Top: Landscape map showing elevations and major watershed boundaries for Fond du Lac County. Bottom: Generalized cross section (from A to A' on top map) showing inferred water table elevation and likely direction of localized groundwater flow direction in the shallow aquifer system.

It is important to keep in mind that what we do on the land and how carefully those activities are conducted will determine whether or not groundwater becomes polluted. Many everyday activities have the potential to affect the quality of the groundwater below.

Geology of Fond du Lac County

In order to understand some of the key factors affecting groundwater, it is important to know about the **geology** and soils of Fond du Lac County. Geologic materials and soils both influence groundwater. Different geological formations have different chemical and physical properties that greatly affect groundwater chemistry as well as the storage and transport of groundwater. All of these properties are important when we describe the susceptibility of groundwater to contamination in particular parts of Fond du Lac County.

The geology of Fond du Lac County is very similar to a layered cake. Each layer of the cake was formed during different geologic periods and each has unique physical and geochemical properties that influence groundwater. Some geologic materials are metamorphic, formed billions of years ago, when Wisconsin was experiencing volcanic activity. Many of the layers however are sedimentary in nature, these layers were deposited when ancient seas rose and fell over Wisconsin hundreds of millions of years ago. The most recent layers are the result of glacial activity in the region.

In order to learn more about the different aquifers, let's work our way forward through time in the order that these layers were formed starting with the oldest and lowermost geologic material.

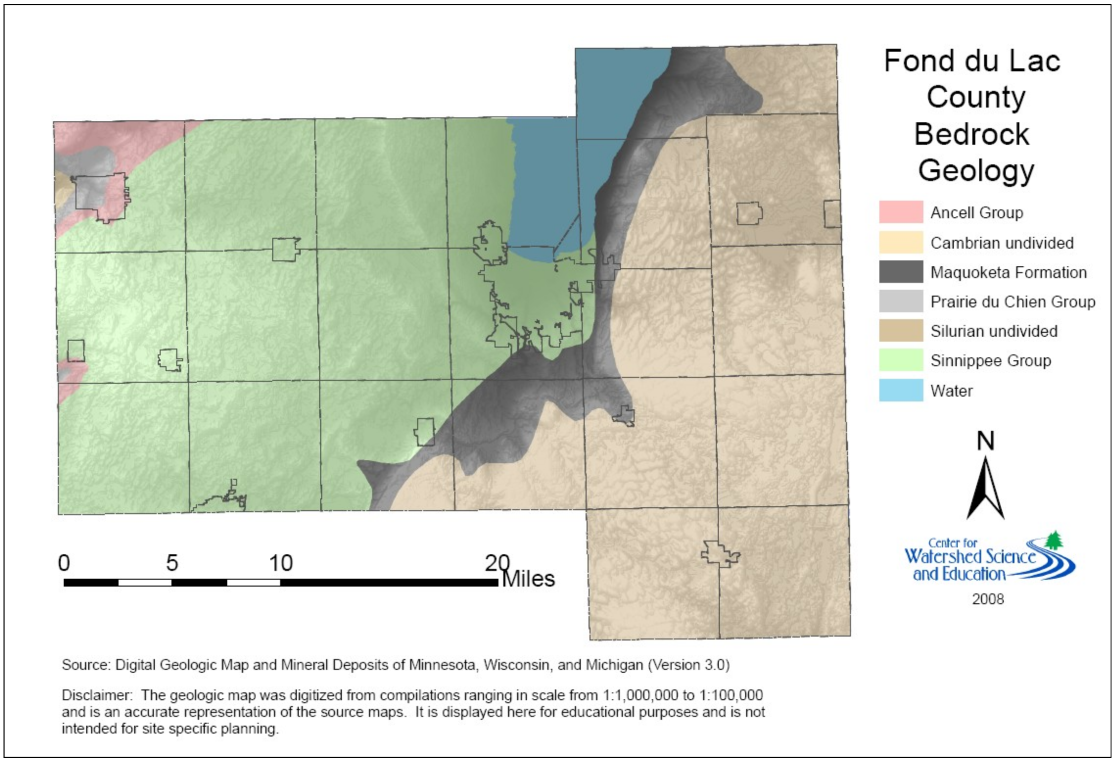
Precambrian Rocks

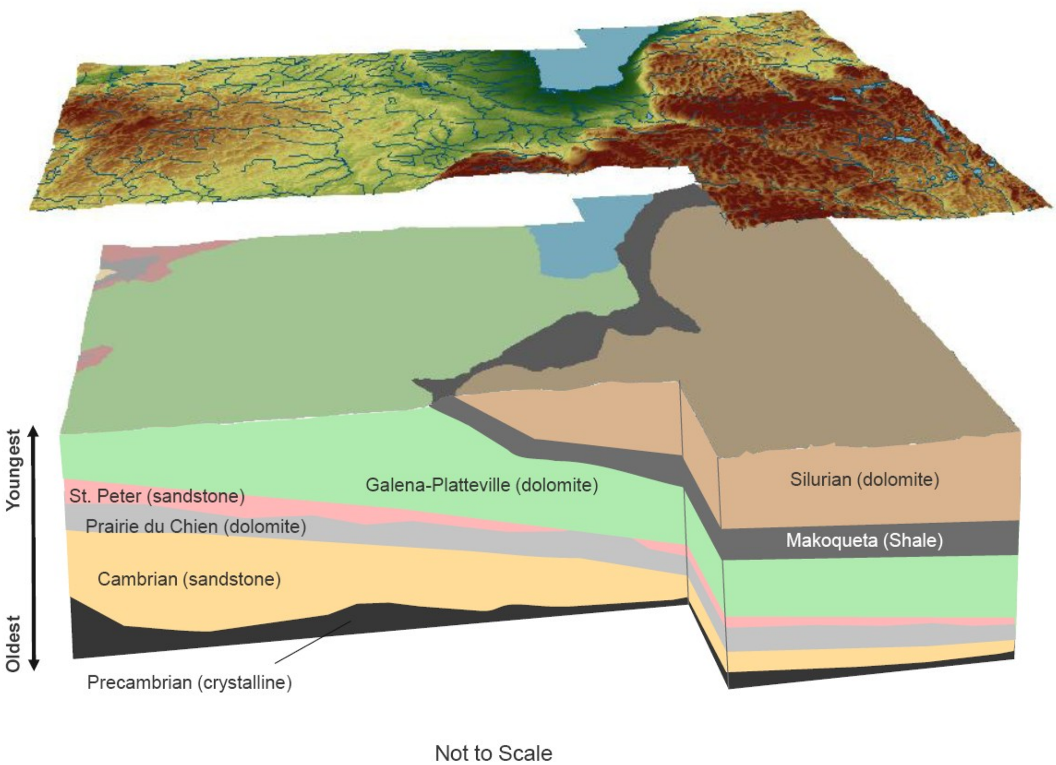
The Precambrian layer is the bottommost layer of bedrock. While this layer underlies the entire county, it is often buried deep below the other layers of geologic material. Precambrian rocks consist of some very old sedimentary rocks, as well as igneous and metamorphic rock types such as basalts, ryolites, and granites formed from volcanic activity and igneous intrusions. These are some of the oldest rocks in the world and were formed approximately 2.8 billion years ago. In general most Precambrian rock types store very little water and do not transmit water readily. These properties make for a very poor aquifer; as a result it is not practical for most wells in Fond du Lac County to extend into this geologic formation to obtain their water.

Cambrian Undivided

Located on top of the Precambrian rocks are the Cambrian sandstones. Cambrian sandstones are sedimentary rocks that were formed during the Cambrian period from about 550 to 490 million years ago. As upland areas eroded, weathered materials were deposited onto the landscape by wind and rivers. This landscape was later submerged as sea levels rose. The ocean waves and currents redeposited the sand over the ocean floor, and over time this layer of sand was loosely cemented together to form sandstone rock.

Sandstone is quite porous and allows a substantial amount of water to be stored and transmitted through the small interconnected pore spaces between the cemented sand grains. Pouring water into sandstone is much like pouring water into a very rigid sponge. This material when pumped is capable of producing hundreds of gallons per minute, which makes sandstone an excellent aquifer for obtaining





Generalized three-dimensional map of Fond du Lac County bedrock geology. Only intended to show order and approximate location of different geologic layers. Thicknesses and extent of geologic formations varies within the county.

water. It is generally the principal source of water for municipal and industrial wells in the county. Where this formation is close to the surface, private wells may extend down into this layer to obtain their water.

While this layer underlies most of the county it is the uppermost bedrock layer in only about 1% of the county.

Prairie du Chien Group

Overlying the Cambrian sandstone layer we find a formation of the Prairie du Chien dolomite. Dolomite is another sedimentary carbonate rock formed when ancient seas deposited limestone on the ocean floor. Over time the magnesium enriched sea water helped convert the limestone into dolomite rock.

Dolomite is a dense rock that does not hold much water. Rather, groundwater is carried in the many cracks and fissures present in this formation. Dolomite is also soluble in slightly acidic water, and over time solution fractures will continue to enlarge as water travels through the cracks and slowly dissolves the carbonate rock. The properties of carbonate aquifers make them susceptible to groundwater contamination, particularly when they are the uppermost bedrock layer (see also karst topography).

This is the uppermost bedrock layer in about 1% of the county.

Ancell Group (St. Peter Sandstone)

In some parts of the county the Prairie du Chien layer is overlain by the St. Peter Sandstone; formed during a period when sea levels lowered and the area was exposed to weathering. Rivers and streams exhumed some of the underlying Cambrian Sandstone from upland areas, while wind and water redeposited the sand on top of the more recently formed dolomite layers. St. Peter sandstone is very finely sorted quartz sand that has been cemented together over time. This formation is the uppermost bedrock layer in about 2% of the county.

Karst Landscapes - The enlarging of fractures by the weathering of dolomitic rock has created the potential for what is known as **karst topography** in areas of the county where dolomite is the uppermost layer of bedrock. Karst topography is generally located in areas characterized by thin soils or shallow unconsolidated deposits overlying fractured dolomite or limestone bedrock. Areas where karst topography is found may also have sinkholes, sinking streams and fracture traces on the landsurface. Silurian dolomite accounts for 41% of the uppermost bedrock layer in Fond du Lac County. This bedrock layer is often a productive aquifer and many residential wells in the eastern portion of the county tap into this bedrock layer for their water supply. Because water moves through fractured bedrock very quickly, the potential for pollutants to move quickly to groundwater and sometimes into our wells can represent a significant problem in areas of the county where karst topography occurs.

Area of Silurian dolomite such as this where the soil layer is thin to absent are very prone to groundwater contamination.

Sinnippee Group (Galena-Platteville Formation)

The Galena-Platteville formation consists mostly of dolomite; its formation characteristics are similar to the Prairie du Chien formation. This formation underlies nearly 95% of Fond du Lac County and constitutes approximately 48% of the uppermost bedrock layer. It is an aquifer that is heavily accessed by private wells in Fond du Lac County.

Maquoketa Formation

This layer consists of shale that separates the Galena-Platteville Formation from the Silurian Formation. It is another sedimentary rock composed of fine clays. Shale has very limited permeability; as a result this layer does not transmit very much water. This layer is often referred to as an **aquitard**, because of its ability to restrict water movement. This formation is generally not considered an aquifer and very few wells rely on this formation to obtain water.

Silurian Undivided

The Silurian Dolomite is only present in the eastern portion of Fond du Lac County, but is the uppermost bedrock layer in 41% of the county. It consists mainly of dolomite deposits formed approximately 430 to 415 million years ago when Silurian seas covered Wisconsin. This particular layer of dolomite tends to be highly fractured because of fluctuations in sea levels which allowed the tidal flats that form this rock to occasionally dry out and crack.

Because of its physical properties, water and contaminants can move quickly through this formation. Over time these fractures have been enlarged by water moving through fractures creating dissolution cavities.

The Niagara Escarpment is an elevated ridge that runs along the eastern shore of Lake Winnebago and extends south through the county. The Escarpment is a result of a resistant layer of Silurian dolomite that has been able to withstand millions of years of weathering as surrounding layers of more easily eroded rock have been worn away.

Portions of the Silurian dolomite where the overlying soil is thin or absent are highly susceptible to groundwater contamination (See karst topography).

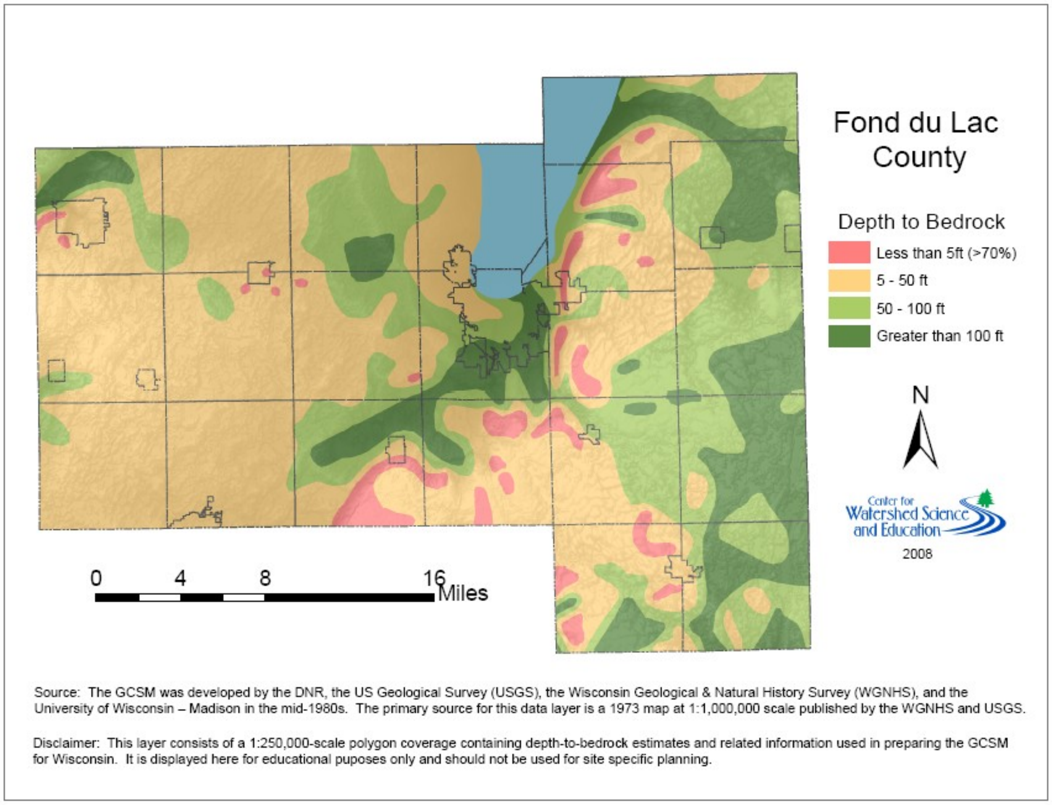
Unconsolidated Materials

The unconsolidated materials overlying bedrock in Fond du Lac County are largely sediments deposited by the glaciers that occupied this part of Wisconsin between 26,000 and 10,000 years ago, but also include some alluvium, lacustrine and marsh deposits. These materials can range in size from small particles of clay to boulders.

In 57% of the county this material is less than 50 ft thick. In many parts of the county this layer does not extend below the water table and therefore does not provide water. In areas where a substantial amount of the unconsolidated materials are saturated, obtaining water from these materials is highly variable depending on the type of material.

For more information on the geology of Fond du Lac County look for the following resources which were useful in obtaining information for this section:

Dott, R.H., and J.W. Attig. 2004. Roadside Geology of Wisconsin. Missoula: Mountain Press Publishing Company.



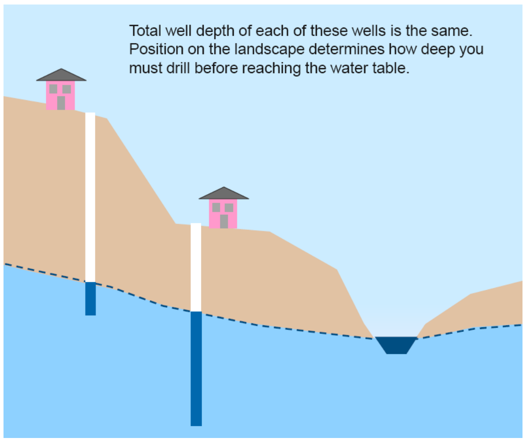
Map showing depth to bedrock which is also the depth of unconsolidated deposits.

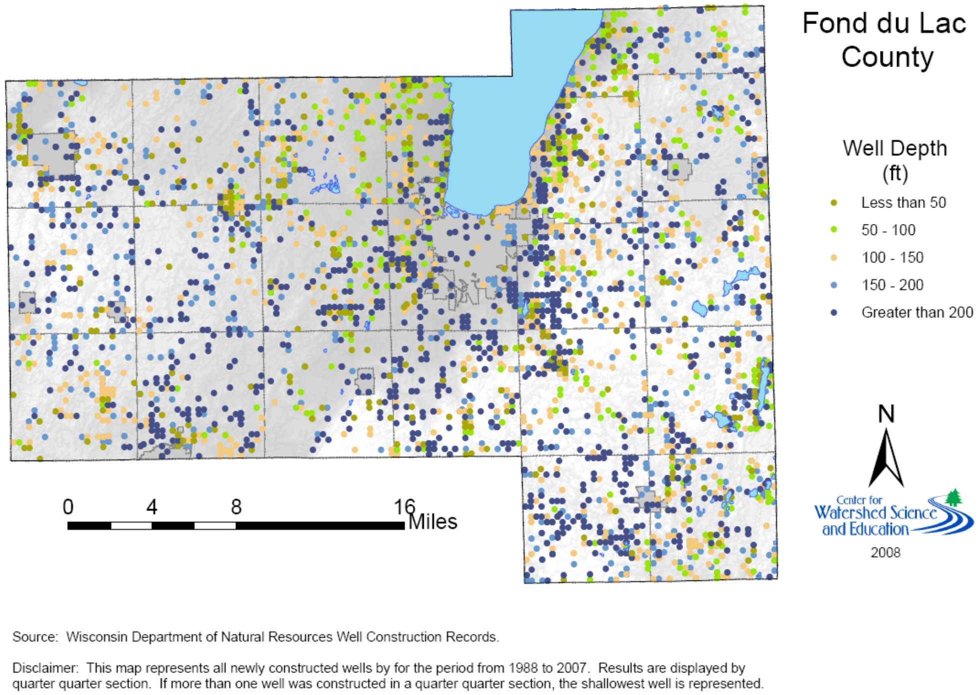
Where Does Our Drinking Water Come From?

Wells are what we use to extract water from the ground. There are private wells which typically serve one home, and there are large **municipal water systems** which often consist of multiple wells that provide water for whole cities or villages.

Wells aren't much more than a vertical hole drilled into the soil and rock below. Wells must be drilled deep enough to extend past the water table into the groundwater aquifer. If you are located close to a lake, river or stream; the water table may be very close to the land surface. If you are located on the top of a hill or ridge however, the water table is often located much deeper and wells in these regions must often be drilled much deeper as a result.

As water is pumped or removed from the well, water contained in the void space of adjacent rock or unconsolidated material replaces the water that was removed from the well. A recent study found that typical Wisconsin residential

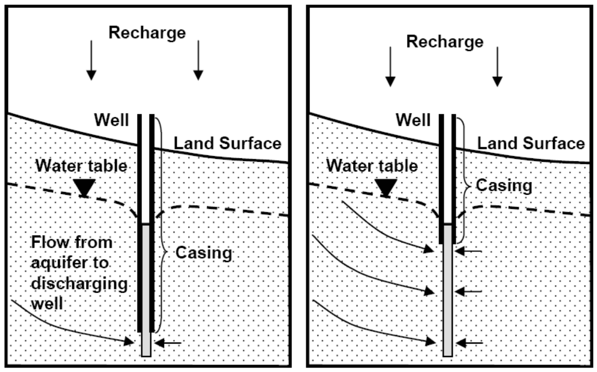




Well depths reported from Well Construction Reports for wells drilled during the period from 1988-2008.

wells obtain water that recharged within about a ¼ - ½ mile of the well (Gotkowitz, 2007).

Well casing is the metal lining that helps to seal the well off from the surface and prevents unconsolidated material from falling into the well. A properly installed casing is important in maintaining the physical and sanitary conditions necessary to provide a dependable and safe supply of drinking water. Casing also plays an important role in determining which section of the aquifer a well receives its water from. Wells cased above or just below the water table access water that recharged recently; groundwater quality near the top of the water table is much more likely to be influenced by local land-use activities than a well in which the casing extends



Casing plays an important role in maintaining the sanitary conditions of a well and determining which area of an aquifer a well draws water from.

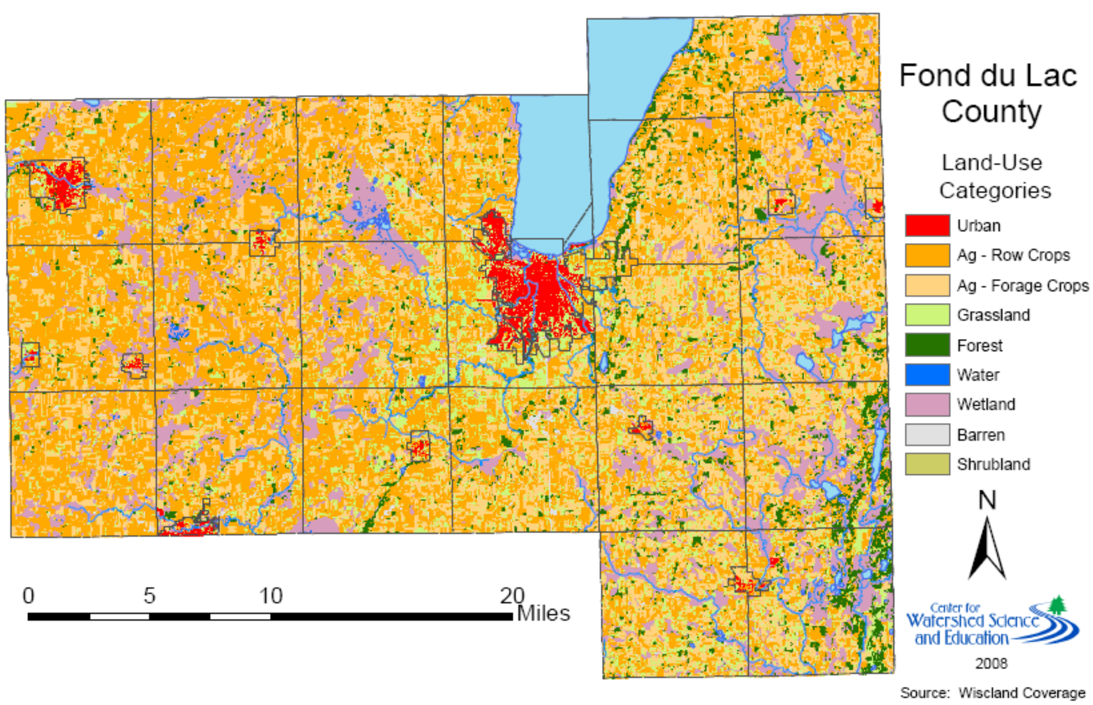
deeper into the groundwater aquifer. When groundwater quality issues are confined to certain sections of the aquifer or may be the result of certain geologic formations, casing can play an important role in obtaining quality groundwater.

Human impacts on groundwater

Quality

Water under natural conditions is never just H_2O or pure hydrogen and oxygen atoms. Water is often referred to as the universal solvent because it has the ability to dissolve many different types of materials. Just because water is not pure water does not necessarily mean that it is contaminated or unsafe to drink. Groundwater will naturally contain certain solutes depending on the type of soils and minerals the water has contacted along its way. Minerals or elements such as calcium and magnesium, which are readily found in groundwater, are necessary for good health. On the other hand, naturally occurring arsenic in groundwater is a contaminant since it can negatively affect human health.

Generally, the deeper the water is found below the water table, the older the water tends to be. In areas where groundwater has been affected by human activities, groundwater deeper in the aquifer often shows less signs of being impacted by local land-uses. Part of this is due to the age of the water; it may also be attributed to a larger recharge area attributed to deeper wells. If the recharge area contains a mixture of land uses (ex. Corn field (*high impact*), hay field (*medium impact*) and natural prairie (*no impact*)) the effects on groundwater often are muted since recharge from low groundwater impact land-uses may offset part of the high impact uses.



General land-use map of Fond du Lac County.

However, all groundwater originates as precipitation infiltrating into the ground. Eventually even very deep groundwater that does not show signs of being impacted today may show signs of degradation in water quality over time as newer water replaces older water within the aquifer.

While many people know that a leaking landfill or a chemical spill are sources of contamination, everyday activities such as fertilizing your lawn or salting roads and sidewalks can also contaminate groundwater supplies. Depending on what activities are taking place in a community and how carefully those activities are performed, many chemicals will eventually find their way into our groundwater. Because groundwater travels very slowly, we may not realize that our water resources have been contaminated until it is too late. Once groundwater becomes contaminated, it is very difficult to clean up. Since the water being withdrawn from wells is often years or even decades old, eliminating the contamination source today may not improve quality for years to come.

Quantity

Wells that pump large amounts of water from an aquifer will lower the water table surrounding the well. This is referred to as a **cone of depression**. Depending on how much water is being pumped and the well location, under certain circumstances wells have the potential to impact nearby rivers and streams. Residential wells that serve individual homes remove relatively small amounts of water and generally do not affect groundwater flow patterns. High capacity wells can pump significant amounts of water that would normally flow to a nearby river or stream. If located in close proximity to the headwaters of a small stream, this may significantly reduce the amount of groundwater discharge to the stream. Sometimes this can result in damaging effects to the stream's aquatic ecosystem. Conversely, high capacity wells installed next to large rivers such as the Wisconsin River have very little effect on flow reduction as a percentage of overall discharge. It is important when siting new high capacity wells to understand what effect they will have on nearby surface waters and whether there are better locations to install a well.

Drinking Water and Health

While the majority of wells in Wisconsin provide a clean and dependable supply of drinking water, there are a number of contaminants found in private and municipal wells that can negatively impact health. Contaminants in drinking water are a cause for concern. Health effects related to contaminants in drinking water can be divided into two categories; those that cause acute effects and those that cause chronic effects.

Acute effects are usually seen within a short time after exposure to a substance. Bacterial contamination or other harmful pathogens are responsible for many acute related illnesses due to consumption of water. People who consume water contaminated with harmful bacteria or other pathogens usually develop symptoms within a relatively short period of time after ingesting the water. Copper is another example of a chemical contaminant that can cause acute health effects. While small amounts of copper are beneficial, too much in drinking water can cause abdominal pains.

Chronic effects result from exposure to a substance over a long period of time; this may result if you are using contaminated water as your principal water supply for a long or extended period of time (generally years or decades). Even very small amounts of contaminants like pesticides, arsenic or lead in your primary water supply may increase the likelihood of developing certain types of long-term health effects such as cancer.

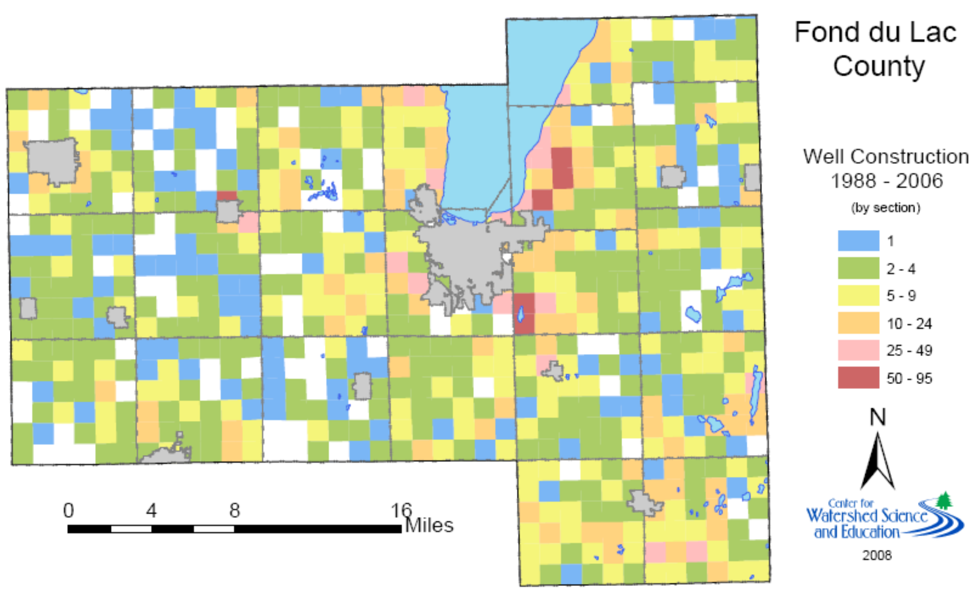
Developing safe drinking water standards

When dealing with substances that cause chronic health effects, it can be difficult to determine how much of a substance is too much. For those contaminants that cause chronic health effects such as cancer, it is assumed that at any dose some adverse health effects may be possible. Drinking water standards are developed to provide a reasonably low risk of developing any adverse health effects; risk levels usually range from one additional case of cancer in ten thousand people to one in a million. As with other health related issues, certain individuals or groups of individuals may be more at risk than others.

While drinking water standards have been established for some of the more common chemicals found in groundwater, there are many others for which standards have not yet been developed. To complicate matters further, little is known regarding multiple contaminants in water and the combined effect that they may have on people's health.

Public vs. Private Water Systems

Any water supply system that provides drinking water to the public and has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year is considered a "public water system". As of 2009 there were 215 public water systems in Fond du Lac County, 11 of which are municipal



Source: Wisconsin Department of Natural Resources Well Construction Records.

Disclaimer: This map represents all newly constructed wells by section for the period of 1988 to 2007. It does not distinguish between well types and does not account for wells that were drilled to replace existing wells.

Newly constructed wells (by section) for the period from 1988-2006. **(see p. 30 for breakdown by town and annual year)**

systems and provide water to whole cities or villages. Public water systems are regulated by the WI Department of Natural Resources, meaning that they are regularly tested and must notify the public if water exceeds certain drinking water standards. In the case of municipal wells, if water does exceed drinking water standards additional steps must eventually be taken to ensure that the standards are met before the water is distributed to the individual homes in the community. Municipal systems provide reasonable assurance that drinking the water will not result in any acute or chronic health effects. If you would like to find out more about the water quality from your municipal water supply contact your local water utility or visit the WI Department of Natural Resources online database of public water supply systems.

Private water supply systems, which is the term used to describe rural residential wells, are not required to be regularly tested. The majority of the county's nearly 12,000 wells fall under the category of private water supply. It is up to the individual homeowner to determine what tests to perform and how often. If water quality problems are detected, the homeowner is not required to treat the water; it is often left up to each individual to determine what the risks are and whether those risks are great enough to correct the problem or find an alternative source of drinking water. The following information will help individuals on private wells to understand what water quality tests are important and how to interpret the test results.

Interpreting water quality information can often be difficult,. Well owners are often unable to understand what water test results mean in terms of drinking water safety, aesthetics and effects on household plumbing. The following information was collected from over 1,500 private well samples collected from 1994 to 2008 and is summarized for educational purposes (See Appendix A for summary of all results). Interpretation information has also been included for common water quality tests to help people determine if their water is safe to drink and help to characterize groundwater quality in Fond du Lac County.

Tests Important to Health

Coliform Bacteria

A coliform bacteria test is the most important test to perform on your well. Testing for coliform bacteria helps to determine if a private well is providing bacteriologically safe water and should be performed annually —think of it as sort of a check-up like going to the doctor or dentist. You should also test for bacteria any time there is a sudden change in the taste or odor and/or following a flooding event in your area.

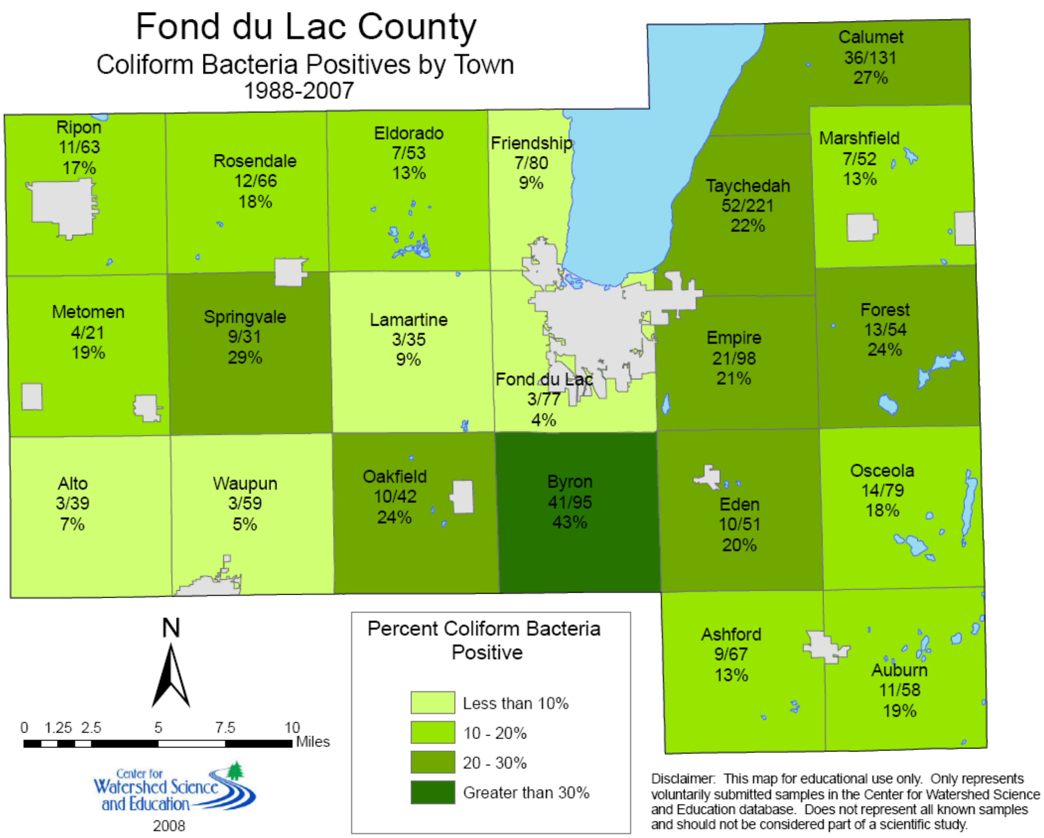
A cracked or loose well cap represents a pathway for bacteria or other undesirable organisms such as insects into a well.

Coliform bacteria are common microorganisms found in surface waters and soils but are also found in human and animal waste. Wells that supply drinking water should not contain any coliform bacteria. Their presence is an indicator of unsanitary conditions within the well or water supply.

Coliform bacteria do not usually cause disease themselves, however; their presence indicates a potential pathway for fecal coliform and other pathogenic (waterborne disease-causing) organisms such as *E. coli (a specific type of coliform bacteria)* to enter the well. The presence of coliform bacteria should be taken

Important Reminders for Keeping Bacteria Out of Wells

- One of the most common sanitary defects is related to the well cap. Wells should have a vermin proof cap which covers the top of the well. If the well cap is loose or cracked, insects or small animals can enter and contaminate the well with bacteria. Loose connections to the well may also allow bacteria an opportunity to enter the water supply.
- Other sanitary defects may have to do with the well casing. Over time the casing may corrode or crack, allowing water to enter into the well close to the surface before bacteria can be filtered out. A casing that does not extend sufficiently into the water table may also encourage bacteria contamination of a well, especially in areas of fractured dolomite groundwater flow.
- Water should not be allowed to pond in areas around the well casing. Ideally the soil should gently slope away from the casing to avoid standing water in the area immediately adjacent to the well.
- Avoid planting trees, shrubs or other unnecessary vegetative cover next to the casing. Roots from trees and shrubs can extend deep into the soil and sometimes sacrifice the integrity of the well system. These plants also make it difficult to perform maintenance or repairs to the water system. In addition, tall grasses or flowers can provide cover for insects and small animals which is something that should be avoided. Keeping the area directly surrounding the casing relatively open and undisturbed is desirable.
- Grouting is also a component of a properly constructed well and should fill any gaps between the casing and the surrounding soil or material. A poorly grouted casing may allow water to carry bacteria from the surface down into the groundwater.
- Wells that are no longer in use can also represent a source of bacteria contamination. Wells that have not been properly filled and sealed represent a direct conduit to the groundwater. Left open, these wells are a pathway for water and pollutants to reach the current well. Properly filling and sealing wells should be considered by everyone with an unused well on their property. *The Fond du Lac County Land Conservation Department can help answer questions related to properly filling and sealing an unused well and may even have cost sharing opportunities available to help abandon the well properly.*



Percent of samples (by town) that tested positive for coliform bacteria based on data collected through the well testing programs.

seriously and steps should be taken to correct the problem. If E. coli bacteria are also detected, this is confirmation that human or animal wastes are contaminating the water supply and is a much more serious concern. Contamination from human or animal wastes can cause gastrointestinal diseases, hepatitis, or other serious waterborne diseases.

Regulations concerning well construction (NR 812) are based on the premise that a properly constructed well should provide bacteriologically safe water continuously without the need for treatment. In most cases a properly constructed well will prevent bacteria and other disease causing organisms from entering a well.

Soils are usually able to filter bacteria out of water before it reaches the saturated zone. Unfortunately, in areas with fractured carbonate bedrock, bacteria can more easily contaminate the groundwater aquifer (for more information see Karst Landscapes). Under these conditions even a properly constructed well may become contaminated with bacteria. Installing wells according to required distances from septic systems, animal feedlots and manure pits should help in avoiding contamination from fecal bacteria and other disease causing organisms. Ensuring that pets or livestock are not allowed to graze or inhabit the area directly surrounding the well is a good precaution.

If bacterial contamination is detected, any

Interpreting Nitrate-Nitrogen Levels

The natural level of nitrate in Wisconsin's groundwater is typically less than 1.0 mg/L (parts per million). Concentrations greater than 1.0 mg/L are an indication that groundwater is likely being impacted by surrounding land-use activities. Because nitrate is very mobile in groundwater, it is considered a good indication that the groundwater is also susceptible to other forms of pollutants. Wells that have elevated levels of nitrate should also consider testing for pesticides if agricultural activities are likely to be the source of nitrate in groundwater.

There are health implications related to drinking water with high nitrate. **Concentrations less than 10 mg/L of nitrate-nitrogen meet US EPA safe drinking water standards for this contaminant.** Studies suggest that infants less than six months of age that drink water (or formula made with water) containing more than 10 mg/L of nitrate-nitrogen are susceptible to methemoglobinemia, also known as "blue baby syndrome". This condition interferes with the blood's ability to carry oxygen. Studies also suggest that high nitrate water may be linked to birth defects and miscarriages. Pregnant women and infants less than 6 months of age should avoid drinking water that is over 10 mg/L for nitrate-nitrogen. All individuals should avoid long-term consumption of water with concentrations of nitrate-nitrogen exceeding 10 mg/L nitrate-nitrogen.

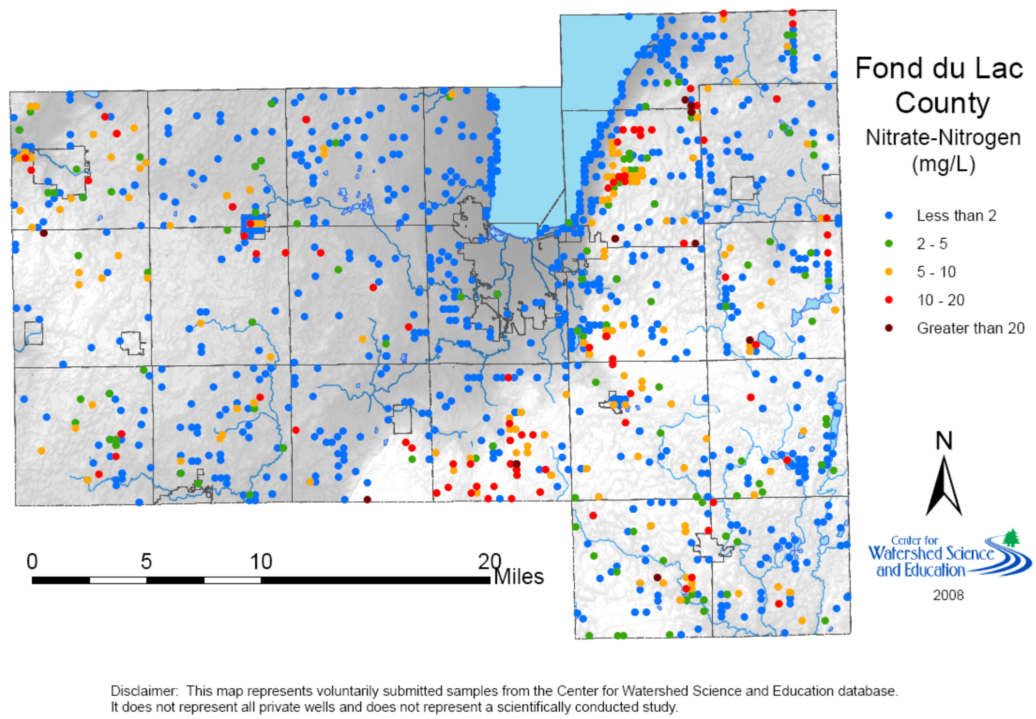
sanitary defects must be identified and corrected. The well will also need to be sanitized to ensure that any bacteria present in the well are destroyed and the water is safe to drink in the future (See DNR Publication *Bacteriological Contamination of Private Wells* for more information on the procedure for disinfecting a well). Sometimes the source of the bacteria is never identified but the problem is able to be corrected by disinfecting the well.

Coliform bacteria is a common problem that many wells may experience during the life of the well. As wells get older they are often more likely to develop sanitary defects that would allow bacteria into a well water system. In Fond du Lac County approximately 19% of all wells tested through this program have detected problems with coliform bacteria. The numbers are slightly higher or lower depending on which town you are located. The Town of Byron shows nearly 43% of wells detecting coliform bacteria. Geologic conditions here likely contribute to a larger percentage reporting problems with bacteria than the county average.

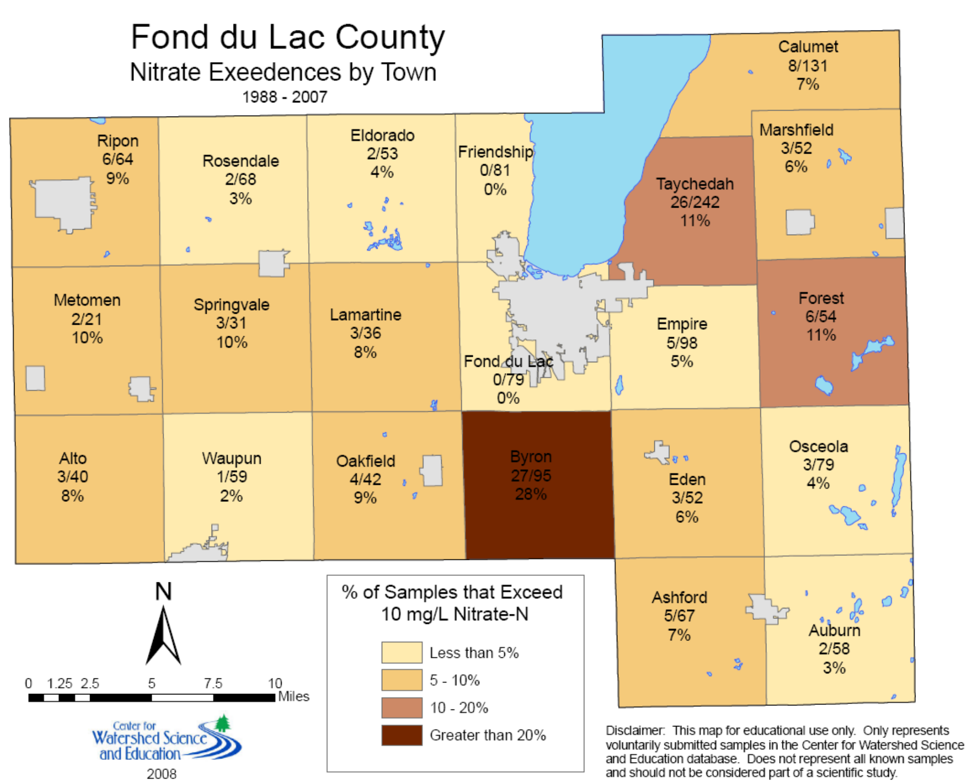
Nitrate-Nitrogen

Nitrate is the most widespread contaminant found in Wisconsin's groundwater. All wells should be tested for nitrate to determine initial levels. Routine testing is recommended if initial testing shows elevated levels in your well; and since nitrate is a good indicator of land-use impacts test results can be used to track changes in water quality over time. Elevated nitrate levels in groundwater commonly result from the use of agricultural and lawn fertilizers, animal waste/bio-solid application to fields or septic systems.

Applying more nitrogen fertilizer than a plant needs often leads to nutrient leaching into groundwater as nitrate, sometimes resulting in concentrations that are considered unsafe for drinking water. Even when applying just the right amount, nitrate often leaches to groundwater under wet conditions during spring recharge or when water carries nitrate past the root zone of plants quicker than the plants are able to take it up.



Nitrate-nitrogen concentrations from private well testing programs. (1988-2007 data)



Percent of samples (by town) that exceed the 10 mg/L safe drinking water standard for nitrate-nitrogen. Numbers indicate the number of exceedences and the total number of samples per town. (1988-2007) (1988-2007 data)

Elevated levels of nitrate in groundwater may also result from nearby septic systems. When designed and installed carefully, septic systems are generally effective at preventing bacteria from entering groundwater but do not effectively remove nitrate. Nitrate plumes from septic systems are often very discrete and have been known to travel beyond minimum separation distances required for well construction. Wells that are installed downgradient and in the contamination plume of a septic system can show very high levels of nitrate. Along with nitrate there are other contaminants in septic effluent that may be a concern (e.g. pharmaceuticals, solvents, viruses). Septic systems are not likely to cause widespread groundwater contamination unless density of septic systems is sufficiently great (some studies suggest densities of 0.4—0.7 dwellings per acre is the cutoff to protect groundwater quality, Shaw et al., 1993); however the concentration within an individual well may be substantial if the well is located down gradient of a drain field and in-line with the septic plume.

While nitrate is a groundwater pollutant, it also represents an economic loss for those farmers who continue to apply fertilizer in excess of what crops can take up in any given year. This is especially true for farmers who don't properly apply nitrogen credits from manure applications. Any nitrate that is detected in groundwater below an agricultural field represents nitrogen that has not been utilized by crops. As the price of nitrogen fertilizers and energy continue to increase, practicing nutrient management will become extremely important. Tailoring nutrient inputs to meet the needs of the crop and reduce leaching losses will become increasingly important as a way to improve profitability and protect groundwater at the same time.

According to the water test data for Fond du Lac County, 8% of the wells tested exceeded the safe drinking water standard for nitrate-nitrogen. Overall, nitrate concentrations across much of Fond du Lac County are generally low, although some areas of elevated nitrate concentrations were found. Wells that reported the highest concentrations tended to be located primarily in and around the town of Byron; these are also areas where there is a high potential for karst landscape concerns (see p. 6 for details on karst landscapes). Concentrations of nitrate-nitrogen ranged from undetectable levels to 30.7 mg/L. The county-wide average nitrate-nitrogen concentration was 2.6 mg/L.

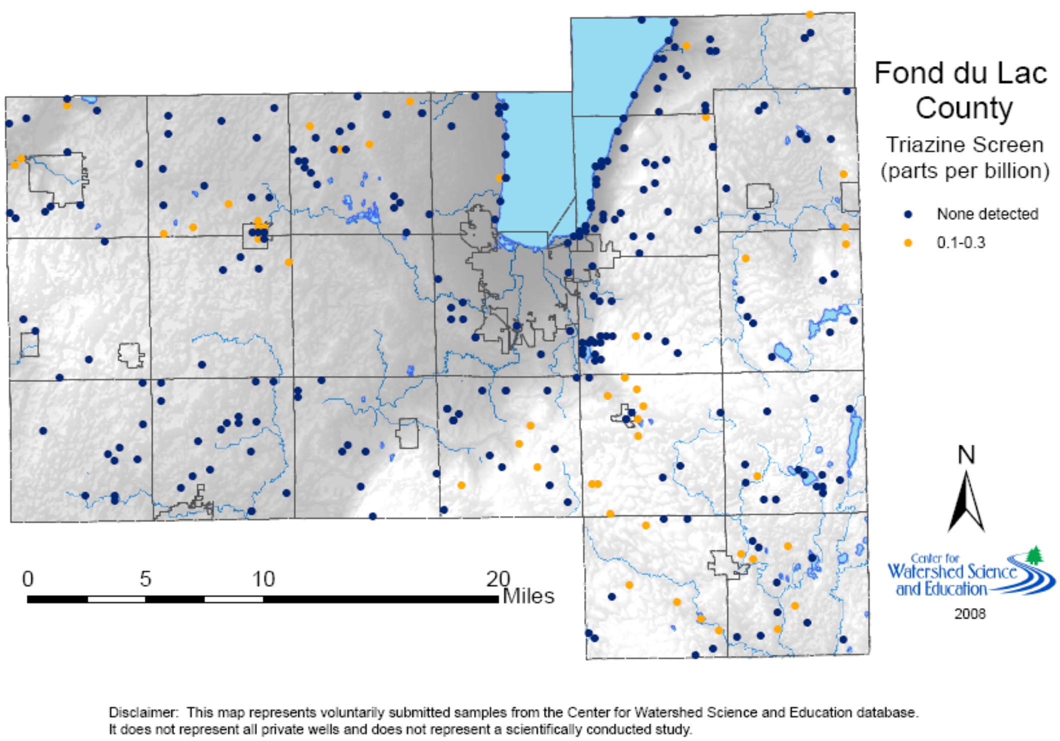
Pesticides

A pesticide is any substance used to control or repel a pest or prevent the damage that pests may cause. The term pesticide includes insecticides, herbicides, fungicides and other substances used to control pests. When pesticides are spilled, disposed of, or applied on the soil, some amount can be carried into the surrounding surface water or groundwater. These products move with water and can eventually enter groundwater and nearby drinking water wells. The occurrence of pesticides in groundwater is more common in agricultural regions, although it can occur anywhere where pesticides are used.

While the long-term or chronic health effects of drinking water that contain pesticides are not completely understood, certain pesticides may cause an increased risk of developing certain diseases, including cancer. Because of the large number of pesticides on the market, health standards for safe amounts in drinking water have not been established for all pesticides. This is further complicated by the fact that pesticides can break down into many other chemicals which may also adversely impact health. Little is known about the health effects of drinking water containing a combination of smaller amounts of multiple pesticides and pesticide breakdown products. As a result, limiting the amount of pesticides that end up in groundwater is the best way to ensure safe drinking water for the future.

Based on a Department of Agriculture, Trade and Consumer Protection survey, the most frequently detected pesticides in Wisconsin groundwater are alachlor, metolachlor, and atrazine (DATCP, 2007). While these are the most commonly detected, there are often others depending on the types of pesticides that have been applied in the area. The safe drinking water standard for alachlor is 2 ppb (parts per billion) while atrazine is 3 ppb. The groundwater standard for metolachlor is 15 ppb.

Results from a limited number of triazine samples from Fond du Lac County revealed that 17% of the wells that were tested contained measurable amounts of this pesticide in the groundwater. These results are based on the triazine screen tests performed during the water testing programs. While none of the tests were over the 3 ppb standard for total atrazine, this test is only a screening tool and often underestimates the total amount of parent atrazine and its breakdown components. While this is only one of many pesticides that are used in Fond du Lac County, it does show areas where pesticides have been found in groundwater.



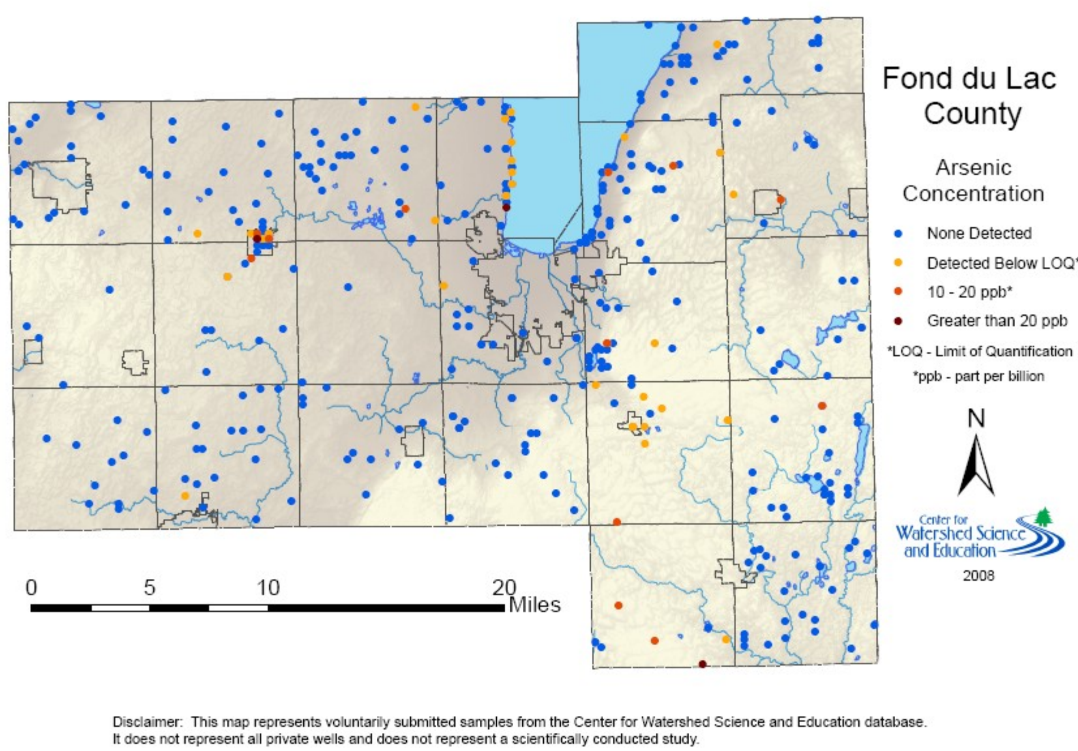
Triazine screen concentrations from well testing programs (data through 2008).

Care should be taken by individuals when deciding on the types and application rates of pesticides, and strategies should be developed to minimize the potential adverse health effects and environmental impacts that result from pesticide use particularly in areas adjacent to your well.

Arsenic

Arsenic is often naturally occurring at low levels in the soil and bedrock, but has been found at levels above the drinking water standard in some Wisconsin wells. Studies show that prolonged exposure to low levels of arsenic can increase the chances of developing cancer of the skin, liver, kidney or bladder.

The drinking water standard for arsenic is 0.010 mg/L (may also be reported as 10 parts per billion). Arsenic has been detected in approximately 14% of wells tested in Fond du Lac County; 4% contained levels exceeding the drinking water standard for arsenic. An arsenic advisory area has been established in Outagamie and Winnebago Counties where an arsenic rich hydrogen sulfide layer exists. The geologic conditions associated with the arsenic advisory area extend down into portions of Fond du Lac County. Wells with high concentrations of iron may be more likely to contain arsenic bearing minerals. Because little is known about the extent of arsenic in groundwater throughout Fond du Lac County, all residents are encouraged to test for arsenic at least once. If arsenic is detected in initial sampling, routine testing for arsenic is encouraged to see if arsenic levels are increasing over time.



Arsenic concentrations from well water testing programs (data through 2008).

Lead

Lead is a toxic metal which until 1985 was commonly used in the construction of most copper plumbing systems in Wisconsin. Water that sits in lead pipes or pipes containing lead solder however, has the potential to dissolve lead and increase the concentration of lead in drinking water to unsafe levels. Brass fixtures also contain lead and may increase levels in drinking water. Corrosive water increases the likelihood of experiencing elevated lead levels. Groundwater in Wisconsin generally has little to no naturally occurring lead.

The safe drinking water standard for lead is less than 0.015 mg/L (or 15 parts per billion) of lead. Lead can be especially harmful to young children. Drinking water that contains elevated lead levels has been shown to cause brain and nerve damage as well as kidney damage. One way to reduce lead levels in drinking water is to run the faucet for a couple of minutes to flush out water that has sat in pipes for extended periods of time. Treatment systems can also be purchased which reduce the amount of lead in the water or reduce corrosivity and the ability of the water to dissolve lead.

Dangerously high levels of lead have also been found in water that sits in garden hoses for an extended period of time. Many hoses contain polyvinyl chloride which uses lead as a stabilizer. Overtime lead can leach from the hose into the water, increasing the concentration of lead significantly. As a result, garden hoses should never be used to obtain water for consumption; this is especially true for young children.

Copper

Copper is a reddish metal that occurs naturally in rock, soil, water, and air; however the source of copper in drinking water is most often due to plumbing. Copper pipes are commonly used in household plumbing. Much like lead, when water sits in copper pipes for extended periods of time it has the potential to dissolve copper pipes and increase copper levels in water. Corrosive water increases the likelihood that you will experience elevated copper levels in drinking water. Blue-green staining in sinks and bathtubs is a good indicator that copper corrosion is taking place.

Small amounts of copper should not cause problems; however too much copper in our diets can be potentially harmful. The safe drinking water standard for copper is 1.3 mg/L of copper. Immediate effects from drinking water with high levels of copper may include vomiting, diarrhea, stomach cramps, and nausea. Long-term exposure of high levels of copper may cause kidney and liver damage. To reduce copper levels in drinking water run the faucet to flush out water that has sat in pipes for extended periods of time. Treatment systems are also available that will reduce the amount of copper in drinking water or reduce the corrosivity and the ability of the water to dissolve copper.

Volatile Organic Compounds (VOCs)

VOCs are a group of common industrial and household chemicals that evaporate, or volatilize, when exposed to the air. Sources of VOCs include a variety of everyday products such as gasoline, fuel oil, solvents, degreasers, polishes, cosmetics, and dry cleaning solutions. VOCs are most commonly used at airports, automobile service stations, machine and paint shops, electronics and chemical plants, dry cleaning establishments, and most residential homes. When chemicals containing VOCs are spilled or disposed of on or below the land surface some of the chemicals can be carried down into the groundwater where they may pose a threat to nearby wells. Counties often have Clean Sweep programs that collect old and unwanted household chemicals. These programs ensure that chemicals are properly disposed of in ways that don't negatively affect groundwater.

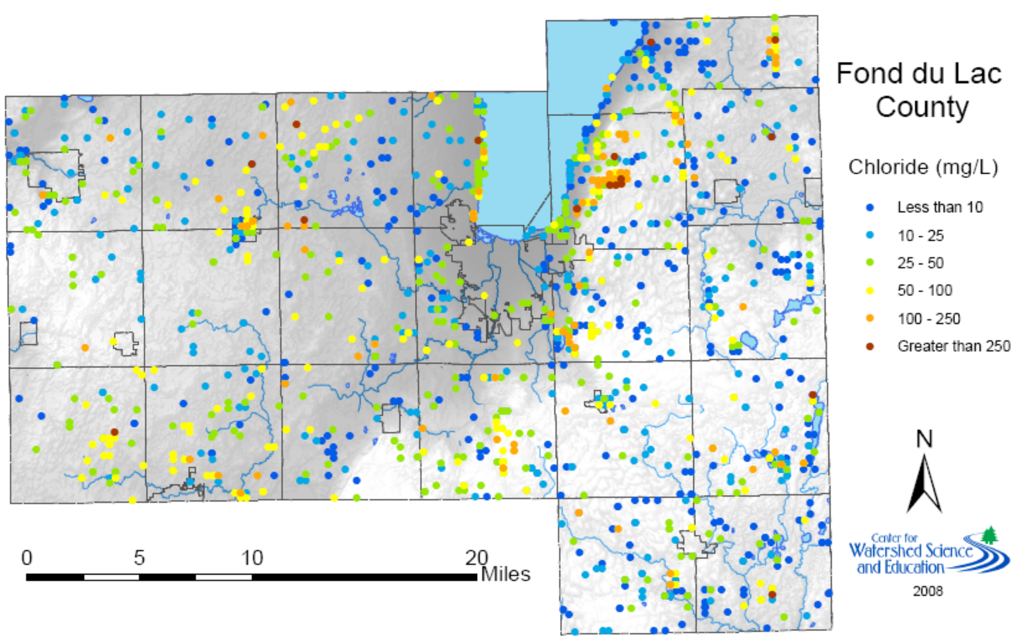
Some VOCs are quite toxic while others pose little risk. Health risks vary depending on the type of VOC, but effects of long-term exposure can include cancer, liver damage, spasms, and impaired speech, hearing and vision.

Limited well data exists to show the extent of VOC testing performed in Fond du Lac County. VOCs are generally not widespread contaminants in groundwater. If there has been a chemical spill or you have other reasons to suspect contamination you may want to consider a VOC test.

Other Water Quality Indicator Tests

Chloride

In most areas of Wisconsin, chloride in groundwater is naturally less than 10 mg/L. Higher concentrations usually indicate contamination by septic systems, road salt, fertilizers, animal waste or other wastes. Some wells in Fond du Lac County may have naturally high chloride levels related to local geologic conditions. Chloride is not toxic in concentrations typically found in groundwater, but some people can detect a salty taste at 250 mg/L. High chloride may also speed up corrosion in plumbing (just as road salt does to your car).



Disclaimer: This map represents voluntarily submitted samples from the Center for Watershed Science and Education database. It does not represent all private wells and does not represent a scientifically conducted study.

Chloride concentrations from well water testing programs (data through 2008).

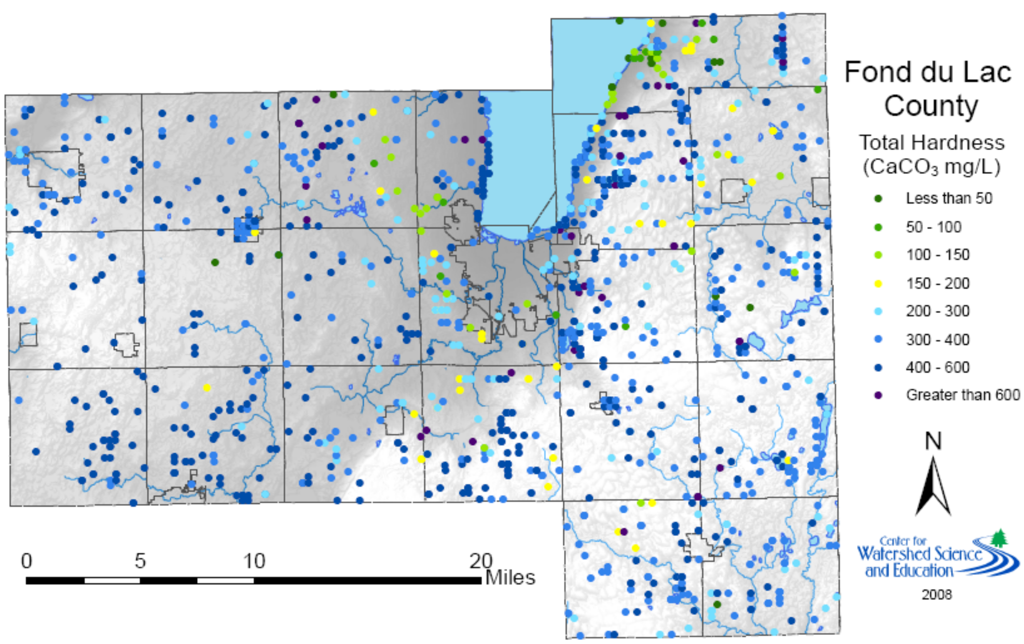
Because of its mobility in groundwater, chloride is also considered an indicator of other potential surface related contaminants. Levels of chloride that are above what is typical under natural conditions indicate that groundwater is being affected, and extra care should be taken to ensure that land-use activities do not further degrade water quality.

In Fond du Lac County 25% of the well tests showed low levels of chloride in groundwater while 25% were only slightly elevated. The remaining 50% of wells which tested above 25 mg/L of chloride likely indicate human influence or areas of naturally high chloride.

Total Hardness

Water hardness results when minerals, generally calcium and magnesium, dissolve naturally into groundwater from soil or limestone and dolomite rocks. There are no drinking water standards for hardness; however, high hardness is usually undesirable because it can cause lime buildup (scaling) in pipes and also in water heaters. Over time hard water will decrease water heater efficiency. In addition, calcium and magnesium react with soap to form a "scum", decreasing the cleaning ability of the soap and increasing bathtub rings and graying of white laundry.

The ideal range for total hardness is typically between 150 and 200 mg/L or ppm of hardness as $CaCO_3$. Water that is naturally low in calcium and magnesium (often referred to as soft water)



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Total hardness concentrations from well water testing programs (data through 2008).

may be corrosive. Soft water contains less than 150 mg/L of total hardness as $CaCO_3$.

Water that contains more than 200 mg/L $CaCO_3$ is considered hard. Water softeners are commonly used to reduce problems associated with hard water. The water softening industry measures hardness in grains per gallon. 1 grain/gallon = 17.1 mg/L $CaCO_3$.

Groundwater in Fond du Lac County is generally hard with about 86% of all samples reporting hardness values above 200 mg/L $CaCO_3$. Hard water is typical of wells that are located in areas with dolomite bedrock.

pH

The pH is a measure of the hydrogen ion (acid) concentration in water. A pH of 7 is neutral. Values above 7 are alkaline or basic; those below 7 are acidic. In Wisconsin pH is commonly found between 6.0 and 9.0.

Low values are most often caused by the lack of carbonate minerals such as limestone and dolomite in the aquifer. Some contaminant sources such as landfills or mine drainage may also lower pH.

A change of 1 pH unit is a 10-fold change in acid level. Acidic water is often corrosive and can react with plumbing. The lower the pH value the more corrosive the water will be. It may be important to note that pH values are often slightly higher in the laboratory than at your well, because carbon dioxide gas (CO_2) leaves water when it is exposed to air. If corrosion is a problem, neutralizing filters can often be installed to counteract the effects of acidic water.

The pH of groundwater in Fond du Lac County tends to be basic mainly as a result of the carbonate bedrock in the area. Ninety-nine percent of all well tests were above 7.0, while 23% were above 8.0. This is normal for eastern Wisconsin groundwater.

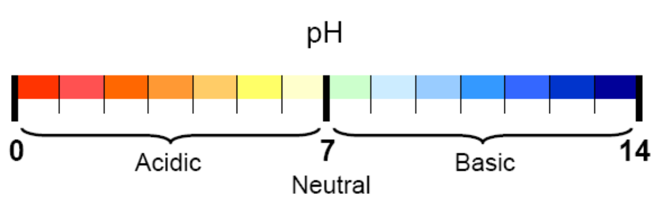
Alkalinity

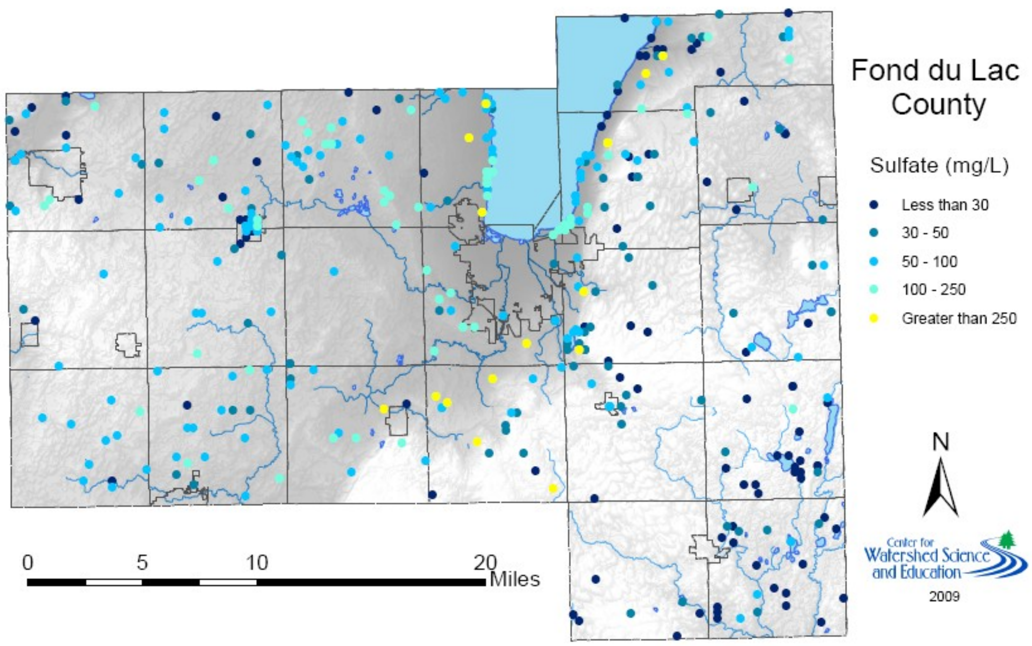
Alkalinity is the measure of water's ability to neutralize acid, and is related to pH. Like total hardness, it results from the dissolution of carbonate minerals such as limestone and dolomite. Water that is low in alkalinity is more likely to be corrosive. Because it results from the dissolution of carbonate minerals, it is generally close to the hardness value. A lower alkalinity value could indicate significant amounts of other anions such as chloride or sulfate.

Conductivity

Conductivity (specific conductance) is a measure of the ability of water to conduct an electrical current. Conductivity is a test of overall water quality and is not a health concern. It is related to the amount of dissolved ions in water, the more dissolved ions in the water the greater the conductivity.

The pH scale is used to indicate water acidity. pH of 7 is neutral. Most natural groundwater in Wisconsin is between 6 and 9. Water with a pH less than 7 is acidic and more likely to cause corrosion.





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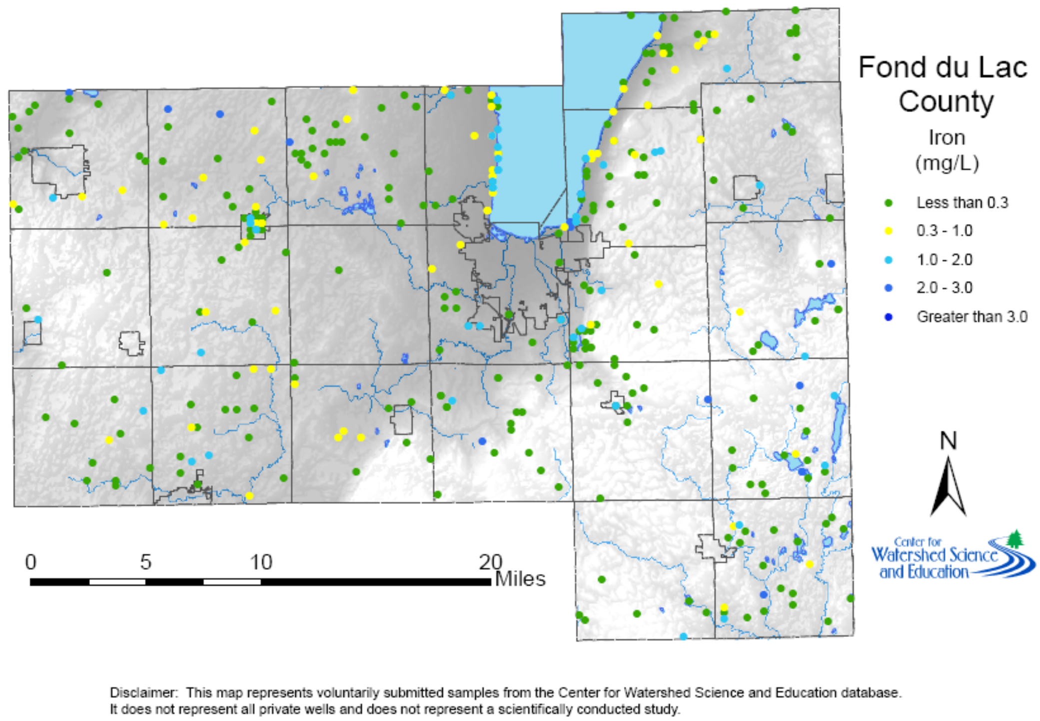
Sulfate concentrations of wells tested during private well testing programs (data through 2008).

Typically calcium and magnesium represent the majority of dissolved ions in solution. As a result, conductivity (measured in μmhos/cm at 25^{o} C) is about twice the hardness (mg/L $CaCO_3$) in most uncontaminated waters in Wisconsin. If the conductivity is much greater than twice the hardness, it may indicate the presence of contaminants such as sodium, chloride, nitrate, or sulfate, which may be human-influenced or natural. Changes in conductivity may indicate changes in water quality. Water softeners prevent scale buildup, but also decrease any protection from corrosion the unsoftened water may have provided.

Sulfate

Sulfate is naturally occurring in groundwater,; geologic materials such as metallic sulfides or gypsum are likely sources. Typically concentrations are less than 30 mg/L throughout much of the state; however higher values do occur in various locations including Fond du Lac County. There is a secondary drinking water standard of 250 mg/L of sulfate. Excessive levels of sulfate can cause a temporary laxative effect in some people. Elevated sulfate may also be a concern for livestock; decreased milk production has been associated with high levels of sulfate provided to dairy cows. About 19% of the wells tested in Fond du Lac exceed 100 mg/L, while about 4% exceed the secondary standard of 250 mg/L.



Manganese concentrations of wells tested during private well testing programs (data through 2008).

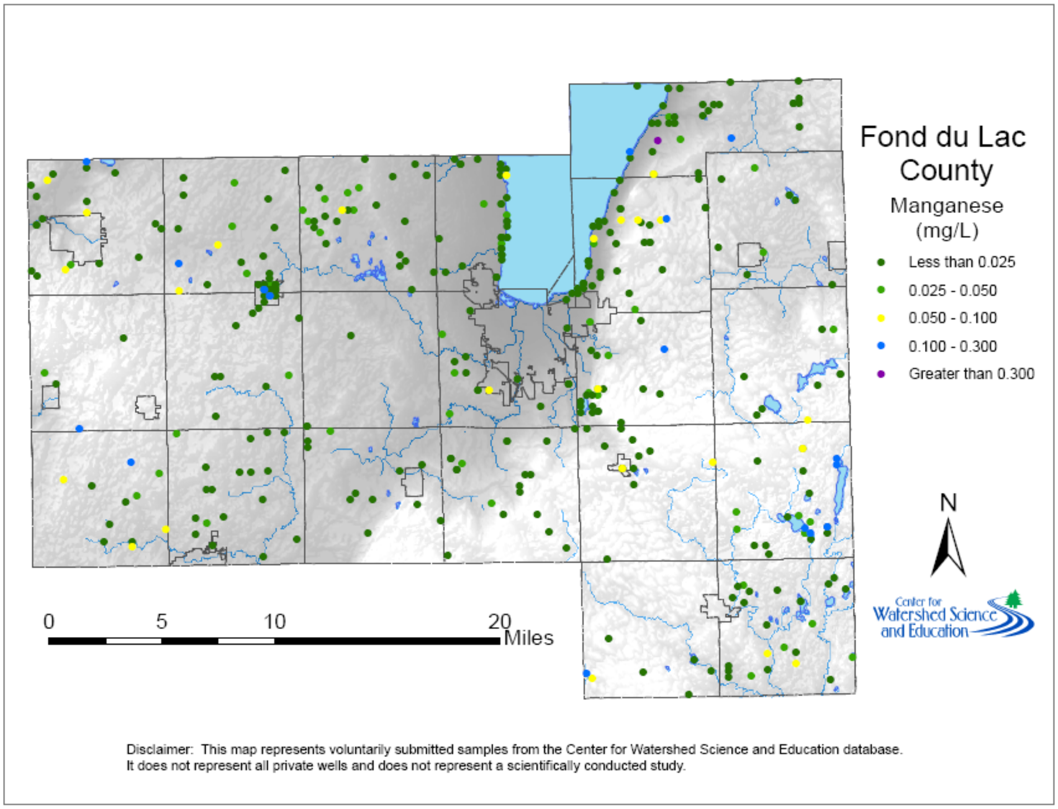
Iron

Iron is a naturally occurring mineral that is commonly found in groundwater. Increased iron concentrations are typically found in areas with water that is low in oxygen. While there are no known health effects caused by drinking water that contains iron, concentrations greater than 0.3 mg/L are associated with aesthetic problems relating to taste, odor and color.

Reddish-orange staining of bathroom fixtures and laundry can often be attributed to high levels of iron in the water. Low levels of iron can often be treated with a household water softener, which also eliminates problems associated with hard water, although using a water softener to remove iron is not recommended if your water is naturally soft. Iron removal can also be accomplished using aeration techniques or a permanganate water treatment system.

Taste and odor problems can be magnified by the presence of iron bacteria, which thrive in wells that have a high concentration of iron. Homes that have iron bacteria often first notice that the water smells like raw sewage or rotten eggs. People also report slimy water or report an oily sheen on water that is allowed to sit. While the presence of iron bacteria is not considered to be a health issue, it is often a nuisance and is difficult to eliminate. Periodic disinfection of the well is often used to control the problems associated with iron bacteria (*For more information obtain a copy of a DNR brochure entitled Iron Bacteria Problems in Private Wells*).

Thirty-six percent of samples tested in Fond du Lac County showed levels of iron exceeding the aesthetic limit.



Manganese concentrations of wells tested during private well testing programs (data through 2008).

Manganese

Similar to iron in groundwater, manganese is naturally occurring and is found in areas where water is low in oxygen such as areas of wet or organic soils. Manganese found in groundwater can be a nuisance for aesthetic reasons.

While there is no primary drinking water standard for manganese, there is a health advisory level of 0.3 mg/L, concentrations exceeding this level should not be consumed. There is a secondary drinking water standard for manganese in water which is set at 0.05 mg/L. Above this level there is a tendency for manganese to form black precipitates that can cause staining of plumbing fixtures. Oxidation treatment methods similar to those used for iron removal systems can often be used to control problems associated with elevated levels of manganese.

Eleven percent of the well tests reported levels of manganese above 0.05 mg/L.

Emerging Contaminants

Pharmaceuticals

The increase in prescription drug medications over the years has led to increased concerns of their fate in the environment. Little is known about the extent of pharmaceuticals in our groundwater, but as you can imagine anything that we send down our drains and to our septic system could potentially end up in our groundwater. Some of these compounds have been detected in wastewater and other environmental water testing. Routine testing of private wells is generally cost prohibitive at this time.

It is important that we do what we can to minimize these contaminants showing up in our groundwater and surface waters. Disposing of unused pharmaceuticals by flushing them down your toilet is not encouraged because of the potential for these chemicals to reach our surface and groundwater. *Contact your local health department for drop-off facilities, collection events or other recommendations on proper disposal of unused pharmaceuticals.*

Viruses

Viruses are pathogens that can sometimes cause acute illnesses when ingested. Viruses are another contaminant that we know little about and there is no routine test available for private well owners at this time. How persistent they are in groundwater is still not well understood, but recent studies do suggest that viruses can reach groundwater if there is a source of fecal waste such as septic systems or leaking sewer lines. Geology and soils likely affect the ability of viruses to contaminate groundwater although there is much to learn regarding their mobility and prevalence in groundwater.

Improving Water Quality

It may be surprising to hear that private well owners with water quality concerns are allowed to use their wells, even if the water does not meet safe drinking water standards. Even though private well owners are not required to correct water quality problems, many people do choose water treatment or find alternative sources of water to avoid drinking water with contaminants or aesthetic concerns. What options a person chooses will depend on a variety of factors including feasibility, initial cost, as well as any ongoing operating and maintenance costs. The ideal solution is to eliminate the source of the problem, but this may not be a realistic possibility in many situations. The following are available when deciding on a solution to water quality problems—

Protect the Source

For water quality problems caused by human activity protecting the recharge area for your well and eliminating the contamination source is the ideal solution. In cases where the source of contamination is obvious, such as a failing septic system or a leaking underground storage tank, it may be easy to eliminate the source. However, identifying contamination sources can often be difficult or challenging, especially when dealing with non-point pollutants like nitrate from widespread application of fertilizers. In addition, eliminating the contamination source may not result in a change in water quality for a long time since it may take years for newer uncontaminated water to replace the contaminated groundwater within the aquifer. While improving land management practices or taking additional steps to eliminate groundwater contamination should be a goal of everyone in the community, it is important to realize that temporary solutions also often have to be implemented to avoid drinking unsafe drinking water in the short-term.

Drilling a New Well

In situations where problems are ongoing or can be attributed to well construction faults, drilling a new well or correcting the fault is the preferred solution. Replacing the well may also be an option for water quality problems caused by land -use activity such as high nitrate or pesticides.

Unless a well can be relocated upgradient of a known source of contamination, changing the well depth is often more critical than the location of the new well on a particular piece of property. However, it is important to note that drilling a new well does *not* guarantee better water quality. While deeper wells often tap into older water that is less impacted by surface activities, other problems such as high iron or increased levels of hardness may be more likely. In addition, water quality changes over time, and while nitrate and pesticide concentrations may be low initially, there is no guarantee that they will not increase as newer water replaces older groundwater in the aquifer.

When drilling a new well, always consult with neighbors who have private wells. Look for similarities in well construction among those individuals who are satisfied with their water quality. Also, local well drillers may have recommendations based on knowledge of local conditions and may be able to provide guidance.

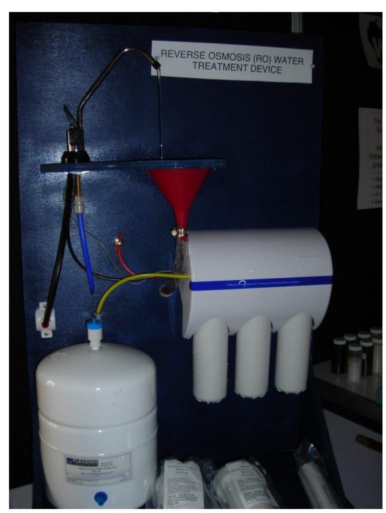
Water Treatment

Water treatment can be successful at removing health related contaminant as well as reducing aesthetic concerns associated with water quality. When deciding if water treatment is the best option, always consider the cost of the device, annual maintenance, as well as energy costs to operate the device. It is also important to remember that routine maintenance is necessary to ensure that the water treatment device is working properly.

No single water treatment device designed today is capable of solving all water quality problems. The type that you purchase depends on the particular concern and the amount of contaminant in your water. Before purchasing a water treatment device, always test water at a certified laboratory. Know the types and amounts of contaminants that you are looking to remove. Check before you buy anything to make sure the device is capable of removing the particular contaminant of concern as well as the amount that is in your water. The Department of Commerce maintains a list of approved treatment devices for the state of Wisconsin and can be found at the following web address:

http://commerce.wi.gov/php/sb-ppalopp/contam_alpha_list.php

Water treatment systems can be divided into two categories; point-of-entry systems and point-of-use. **Point-of-entry** systems are able to treat water throughout the entire house and are typically used to treat aesthetic concerns associated with water quality. Water softeners are a common example of a point-of-entry system. **Point-of-use** systems only treat water at the faucet where you get your drinking water from and are usually used to remove health related contaminants from drinking water.



Example of point-of-use reverse osmosis unit that can be installed under the kitchen sink.

Reverse-osmosis and distillation units are examples of point-of-use systems commonly used to reduce levels of nitrate and arsenic and some other common health related contaminants.

Bottled Water

To avoid drinking unsafe drinking water some people will often buy bottled water from a store or water supply business. Some people incorrectly assume that bottled water is always purer or better than the water that is coming from their private well. The well tests from Fond du Lac County reveal that the many private wells provide water that is similar, or depending on the brand, better water quality than bottled water that is sold in stores. However, for those people who have water quality problems, bottled water may be an option to avoid drinking unsafe drinking water. When purchasing bottled water choose a company that is able to provide details regarding the source of the water, how the water was treated, as well as the water quality information for important health related contaminants. Many types of bottled water are simply tap water that is treated using reverse osmosis or distillation units like those available for residential homes. When considering bottled water or water treatment, it is important to consider the cost of buying bottled water versus the cost and long-term maintenance of a water treatment system when making your decision.

Raingardens are depressions generally planted with native plant species that collect stormwater and allow it to infiltrate into the soil and replenish groundwater.

Information about the quality of water from Wisconsin bottling companies can be found online at:

http://datcp.state.wi.us/fs/consumerinfo/food/health/bottled-water/index.jsp

Groundwater Use in Fond du Lac County

While Wisconsin has an abundant supply of groundwater, water quantity is increasingly becoming a concern as populations increase. While completely running out of groundwater is not a realistic possibility in Fond du Lac County, groundwater withdrawals can still have adverse impacts to surface waters or nearby wells. These impacts are important to consider when planning

Water Conservation Tips

- Install low flow toilets and fixtures; purchase water efficient appliances.
- Fix leaky faucets or plumbing.
- Plant flower, plant and lawn varieties that require less water.
- Raise the lawn mower blade to at least three inches or to its highest level. A higher cut encourages deeper roots, shades the root system, and holds soil moisture.
- Collect rainwater in a rain barrel and use it to water the lawn or plants.
- Direct stormwater away from impervious areas or preferably install raingardens to collect stormwater. This not only decreases pollutant runoff into surface waters but also replenishes groundwater supplies.

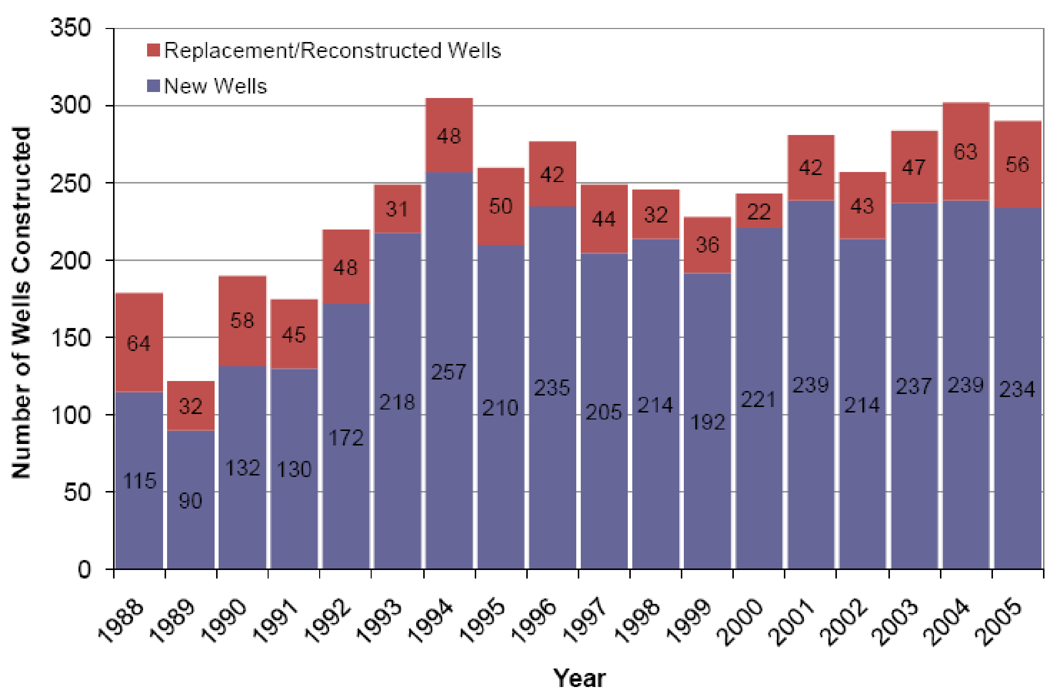
for new growth or installing high capacity wells. It is important that municipalities identify areas where they would like to install new wells in advance so they can begin to plan for wellhead protection and avoid other potential conflicts.

High capacity wells can sometimes have negative effects on surface waters or surrounding wells if they are going to draw the water table down significantly. Proper care should be taken to avoid installing high capacity wells near surface waters such as headwater streams or springs that are particularly vulnerable.

Water conservation can be an important tool to reduce environmental impacts and save money at the same time. For municipal water utilities conserving water may mean prolonging the need for expanding existing infrastructure. Installing new wells can be expensive for communities. Finding ways to reduce water-use has saved some communities millions of dollars when their conservation efforts were able to account for increases in demands and the need for additional wells.

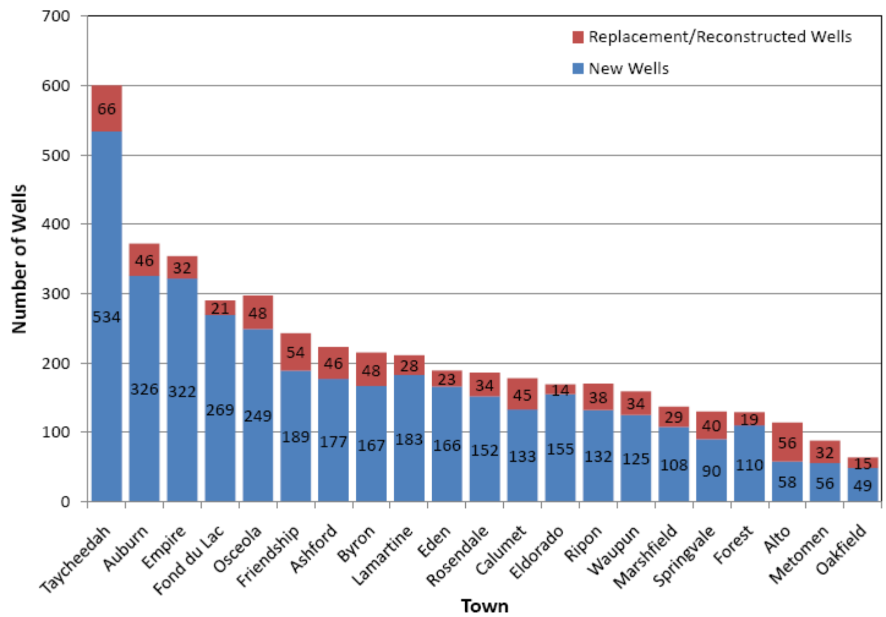
Groundwater Management

Well construction report data from 1988 to 2004 indicates that the installation of private wells has also been increasing. It is important to remember that private wells do not have wellhead protection plans and are not required to be regularly tested or treated. We must realize that there are currently areas where groundwater may not meet recommended drinking water standards. Planning can be a useful tool to ensure that large numbers of new private wells are not being installed in areas where the groundwater quality is degraded, where septic system density may be affecting neighboring



Number of wells constructed in Fond du Lac County by year.

Number of wells constructed in Fond du Lac County by Town for the period between 1988—2006.



wells, or where existing land-uses may be incompatible with providing quality groundwater for residential wells.

The ultimate goal of groundwater management is to protect, maintain, and improve the quality and quantity of groundwater. The responsibility of regulating pollution sources is often handled by state agencies. In situations where the state has not preempted local authority, local regulations that control the location of land-uses, the types of permitted activities, and regulate densities can be important tools for managing groundwater and reducing conflict between non-compatible land-uses (Born et al., 1987). Because groundwater is influenced by local geology and human activities, it is important that local governments realize the role they have in managing this resource for the future. The emphasis of groundwater management should be placed on conservation and prevention, not remediation after groundwater becomes degraded.

Ensuring success requires local communities to clearly identify goals that protect groundwater. While not a comprehensive list, an effective local groundwater management strategy will include similar goals to the following:

- Include groundwater protection in smart growth comprehensive plans.
- Encourage wise land-use decisions that will minimize impacts to groundwater.
- Utilize technology such as groundwater flow models for groundwater planning purposes.
- Protect municipal and/or private water supplies from contamination by adopting wellhead protection ordinances and developing source water protection plans.
- Encourage farmers to adopt nutrient management plans and less nutrient intensive cropping systems, particularly in areas that show impacts from fertilizers.
- Develop water conservation strategies and to minimize the impacts of expected increases in water use from population growth.
- Educate community members about the local groundwater resource, its use, current and potential problems, as well as solutions.
- Establish and maintain a data collection, monitoring and analysis program.
- Coordination and cooperation between state agencies, local government, non-profit organizations, and citizens.

Summary

Even though it's often buried deep underground, and we can't see it, groundwater is one of Fond du Lac County's most valuable natural resources. A clean and dependable supply of groundwater provides safe drinking water, supports a healthy economy, and maintains our lakes, rivers and streams. Unless people are willing to sacrifice any of these qualities, the community must be committed to managing groundwater resources in a way that preserves the quality and quantity.

Groundwater is a local resource and is replenished by the rain and snow that infiltrate the soil. Many everyday activities that we do on the land surface have the potential to impact the quality and quantity of our groundwater resources below. While there are some naturally occurring contaminants, most of the unwanted chemicals in groundwater are a direct result of human activity. These activities can also affect lakes, rivers and wetlands, which are intimately connected to groundwater.

The more than 1,500 homeowners who had their private wells tested between 1994 and 2006 helped to create a better picture of current groundwater quality in Fond du Lac County. Fond du Lac County groundwater is generally characterized by having high hardness, a pH greater than 7.0, and high alkalinity. While the testing showed many private wells provide drinking water that meets or exceeds drinking water standards, test results revealed that groundwater quality has been impacted to some degree by local land-use.

Results indicate that nearly 32% of all wells tested had concentrations of nitrate-nitrogen above 2 mg/L, an indication of local land-use impacts. Eight percent of all wells tested greater than the safe drinking water standard for nitrate-nitrogen. In addition, 19% of the wells tested positive for coliform bacteria and 17% of the wells that were tested for triazine reported detectable levels of common corn herbicides.

Once groundwater becomes contaminated it is very difficult and costly to clean up, therefore minimizing the extent to which we contaminate groundwater should be the goal of everyone. As a result, communities will need to make difficult choices when it comes to managing groundwater and making future land-use decisions. Local governments can only do so much however; everyone in Fond du Lac County will need to make personal decisions when it comes to their individual actions that involve using water or conducting activities on their property that can affect this underground resource. Groundwater is truly a community resource and every one of us has a critical part to play in protecting groundwater for future generations.

Controlled burns are an important tool used by land management professionals to manage ecosystems such as grasslands. Setting aside conservation areas can help to protect groundwater quality and quantity.

References

Born, S.M., D.A. Yanggen, and A. Zaporozec. 1987. A Guide to Groundwater Quality Planning and Management for Local Governments. Wisconsin Geological and Natural History Survey. Special Report No. 9, 48 p.

DATCP. 2007. Agricultural Chemicals in Wisconsin Groundwater. Wisconsin Department of Agriculture, Trade and Consumer Protection-Agricultural Resource Management Division publication 98c. Madison, Wisconsin.

Devaul, R.W., C.A. Harr, and J.J. Schiller. 1983. Ground-Water Resources and Geology of Fond du Lac County, Wisconsin. Information Circular Number 44. U.S. Geological Survey and Wisconsin Geological and Natural History Survey.

DNR. 2006. Water Well Data. WI Department of Natural Resources; Bureau of Drinking Water and Groundwater.

Dott, R.H., and J.W. Attig. 2004. Roadside Geology of Wisconsin. Missoula: Mountain Press Publishing Company.

Yanggen, D.A., and B. Webendorfer. 1991. Groundwater Protection through Local Land-Use Controls. Wisconsin Geological and Natural History Survey. Special Report No. 11, 91 p.

Zaporozec, A. and R.D. Cotter. 1985. Major Ground-Water Units of Wisconsin. Wisconsin Geological and Natural History Survey.

Glossary

alluvium - Sediment deposited by flowing water, as in riverbeds, or floodplains.

aquifer - Water bearing geological formations that transmit and store water.

aquitard - A layer or section of the aquifer that impedes water movement.

cone of depression - When pumping water from a well, the water level adjacent to the well is lowered creating a cone where water has been pulled from the aquifer.

discharge area - Area where groundwater is discharged or returned to the earth's surface through springs, seeps, or baseflow.

evaporation - Process by which water changes from a liquid to a gas.

geology - The scientific study of the origin, history, and structure of the earth.

groundwater - Water contained in the empty spaces between soil particles and rock materials below the surface of the earth.

high capacity well - A well that is capable of pumping 70 gallons per min. or 100,000 gallons of water per day.

hydrologic cycle - Also referred to as the water cycle, explains how water is constantly in a state of movement through the environment.

irrigation well - A well that pumps water for the sole purpose of watering crops.

karst topography - An area where bedrock is easily dissolved by water. Generally characterized by connecting cracks and layers between rocks that easily transport water and pollutants to groundwater.

municipal water system - water system owned by a city, village, county, town, federal or state institution; town sanitary district, utility district, public inland lake/rehabilitation district, municipal water district for care or correction, or a privately owned utility serving the foregoing.

point-of-entry - A whole house water treatment system; treats water as it enters the house.

point-of-use - A water treatment system that treats a small amount of water at a particular faucet, typically supplies enough water only for drinking and cooking.

pollutant - A waste material that contaminates soil, air, or water.

recharge area - Area on the land surface where precipitation is able to infiltrate into the soil and percolate down to the saturated zone of an aquifer.

transpiration - The emission of water vapor through the leaves of plants.

water table - Level below the surface of the earth where groundwater exists; separates the saturated zone from the unsaturated zone.

watershed - Area of land that contributes water to a water body through surface water runoff or groundwater.

well - A vertical excavation that extends into a liquid bearing formation. In Wisconsin, wells are drilled to obtain water, monitor water quality, and monitor water levels.

well abandonment – Process of sealing a well that is no longer in use. Unused wells represent a direct conduit to groundwater.

well casing - Metal lining along the inside of a well that prevents unconsolidated material from falling into the well; also controls the part of the aquifer a well receives water from.

Additional Groundwater Resources

- For copies of **WI Department of Natural Resources (DNR)** publications please call (**608)266-0821** or visit http://www.dnr.state.wi.us/org/water/dwg/pubbro.ht.
- For copies of **UW-Extension (UWEX)** publications please call (**877)947-7827** or visit http://www.uwex.edu/ces/
- The **Wisconsin Geological and Natural History Survey (WGNHS)** has many excellent geology and groundwater resources including maps available from their office. If interested call (**608)263-7389** or for a complete listing visit their website at http://www.uwex.edu/wgnhs/pubs.ht.

Teaching Resources

- **Wisconsin's Groundwater Study Guide.** A curriculum development guide primarily for 6th to 9th grade earth science teachers. Adaptable to older and younger students and informal education settings. For a copy call (**877)268-WELL** or visit http://dnr.wi.gov/org/water/dwg/gw/educate.htm
- **Groundwater Flow Demonstration Model**. Over the years this two-dimensional model has effectively demonstrated basic groundwater concepts to both children and adult audiences. Offering a glimpse underground, concepts such as groundwater flowpaths, leaking landfills, cones of depression, and groundwater surface water connections are brought to life. For information on ordering a model call (**715)346-4613** or to borrow a model call (**715)346-4276** for a list of available models.

Groundwater Publications

- **Groundwater: Protecting Wisconsin's Buried Treasure.** DNR. PUB-DG-055-06. An easy to read full-color magazine designed to help people learn more about their groundwater resources, what it is used for, common threats, and groundwater protection.
- **Answers to Your Questions about Groundwater**. DNR. PUB DG-049 2003. Answers to many of the common concerns and misconceptions that the average person has about groundwater.
- **Better Homes and Groundwater**. DNR. PUB-DG-070 2004. Easy to do activities to perform in our own backyards to improve and protect the quality of our groundwater resources.
- **Answers to Your Questions on Well Abandonment**. DNR. PUBL-DG-016 2004. This brochure explains the importance of abandoning unused wells to protect groundwater quality and covers procedures for abandoning wells properly.
- **Wellhead Protection: An ounce of prevention…** DNR. PUB-DG-0039 99REV. Brief description of the importance of wellhead protection and initial steps for protecting community water supplies.
- **A Growing Thirst for Groundwater**. DNR. 2004. This article in WI Natural Resources Magazine looks at the rising issue of groundwater quantity in Wisconsin. It also identifies steps which have recently been taken to ensure that there is enough groundwater for our homes and businesses, as well as our state's lakes, rivers, and wetlands. http://www.wnrmag.com/stories/2004/jun04/ground.ht
- **GCC Directory of Groundwater Databases**. DNR. PUB-DG-048 1998. This document from the Wisconsin Groundwater Coordinating Council provides a listing of groundwater related information maintained in computerized and non-computerized databases.

Groundwater Policy

- **Wisconsin Groundwater Coordinating Council Report to the Legislature.** GCC. The Groundwater Coordinating Council 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. Download at http://www.dnr.state.wi.us/org/water/dwg/gcc/Pubdwnld.htm
- **Well Water for Rural Residential Subdivisions: Using groundwater flow models to evaluate options for water supply.** UWEX. 2007. Explores the use of computer groundwater flow models to help communities make informed decisions regarding well construction and placement for rural residential subdivision design.
- GCC Comprehensive Planning and Groundwater Fact Sheets.
  - Download at http://www.dnr.state.wi.us/org/water/dwg/gcc/Pubdwnld.htm
  - **Groundwater and its Role in Comprehensive Planning.** GCC. Fact Sheet 1. 2002. This informational sheet provides a basic explanation of what groundwater is and why it is an important consideration when preparing comprehensive plans for local governments.
  - **Resources to Help You Protect Your Drinking Water Supply.** GCC. Fact Sheet 2. 2002. This informational sheet identifies state resources available to help communities protect drinking water supplies.
  - **Residential Development and Groundwater Resources.** GCC. Fact Sheet 3. 2002. This informational sheet identifies potential considerations of the effects of residential development on groundwater resources and also offers suggestions on how to minimize those impacts.

Drinking Water Publications

- **You and Your Well**. DNR. PUB-DG-002 2003. Information and requirements for a properly constructed well.
- **Do Deeper Wells Mean Better Water?** UWEX. G3652. This brochure explores different well construction terminology and explains how well depth can affect water quality.
- **Tests for Drinking Water from Private Wells**. DNR. PUBL-DG-023-04REV. Advises private well owners on the tests and frequency that should be performed on their well to ensure safe drinking water.
- **Choosing a Water Treatment Device**. UWEX. G3558-5. Describes the most common water treatment devices for home use and lists contaminants that each is capable of removing.
- **Bacteriological Contamination of Drinking Water**. DNR. PUB-DG-003-2000. Explains how wells become contaminated with bacteria, how to test for it, and how eliminate bacteria in your well.
- **Improving Your Private Well Water Quality**. UWEX. G3826. This brochure explores ways to improve your private well water quality. Lists common water quality problems or contaminants and describes common approaches to improve water quality, including common water treatment technologies.
- **Lead in Drinking Water**. DNR. PUB-DG-015 2003
- **Copper in Drinking Water**. DNR. PUB-DG-027 2003
- **Arsenic in Drinking Water**. DNR. PUB-DG-062 2006
- **Pesticides in Drinking Water**. DNR. PUB-DG-007 2002
- **Radium in Drinking Water**. DNR. PUB-DG-008 2002
- **Nitrate in Drinking Water**. DNR. PUB-DG-001 2004
- **Volatile Organics in Drinking Water**. DNR. PUB-DG-009 00
- **Iron in Drinking Water**. DNR. PUB-DG-035 01REV
- **Radon in Private Well Water**. DNR. PUB-DG-036 2004
- **Iron Bacteria Problems in Wells**. DNR. PUBL DG-004 2005
- **Sulfur Bacteria Problems in Wells**. DNR. PUBL-DG-005 99 Rev

Useful Websites

Fond du Lac County. Government information source for Fond du Lac County listing services offered through county government and contact information for Land Information, Land and Water Conservation Department, Health Department, UW-Extension, and Code Enforcement. http://www.fdlco.wi.gov

Fond du Lac County Land and Water Conservation Department. Under the direction of the Fond du Lac County Land and Water Conservation Committee of the Fond du Lac County Board of Supervisors, the Land and Water Department works to promote sustainable land use management for long-term conservation of land, water and other natural resources. http://www.fdlco.wi.gov/Index.aspx?page=70

Center for Watershed Science and Education, UW-Extension/UW-Stevens Point. Helping citizens and governments manage the groundwater in Wisconsin wisely, through education, public information, applied research, and technical assistance. http://www.uwsp.edu/cnr/watersheds

Wisconsin Geological and Natural History Survey. Provide objective scientific information about the geology, mineral resources, water resources, soil, and biology of Wisconsin. Communicate the results of our activities through publications, technical talks, and responses to inquiries from the public. http://www.uwex.edu/wgnhs/index.htm

Wisconsin Department of Natural Resources

- **What's Wrong With My Water.** Assists well owners in diagnosing and finding solutions to common aesthetic related well water quality problems. http://www.dnr.state.wi.us/org/water/dwg/private/waterproblems.htm
- **Drinking and Groundwater Section.** Working to safeguard Wisconsin drinking water and groundwater now and in the future. http://www.dnr.state.wi.us/org/water/dwg
- **Bureau for Remediation and Redevelopment Tracking System.** Allows you to find information on incidents that contaminated soil or groundwater in your area. http://botw.dnr.state.wi.us/botw/Welcome.d

Wisconsin Department of Commerce Product Approval List. Helps user to search for approved water treatment devices specific to individual contaminants of concern. http://commerce.wi.gov/php/sb-ppalopp/contam_alpha_list.php

Appendix A

Fond du Lac County Well Testing Summary (1988 - 2009)

Nitrate-Nitrogen (mg/L)		
Range	**n**	**%**
None Detected	807	54
0.1 - 2.0	236	16
2.0 - 5.0	145	10
5.0 - 10.0	204	14
10.0 - 20.0	102	7
> 20.0	14	1

Total Hardness (mg/L $CaCO_3$)		
Range	**n**	**%**
None Detected	51	3
2.0 - 25.0	30	2
25 - 50	18	1
50 - 150	53	4
150 - 200	53	4
200 - 300	167	11
300 - 400	519	35
400 - 500	450	30
> 500	141	10

Conductivity (umhos/cm)		
Range	**n**	**%**
< 50	3	0
50 - 100	2	0
100 - 200	1	0
200 - 500	146	10
500 - 800	760	51
800 - 1000	378	25
> 1000	211	14

pH		
Range	**n**	**%**
< 5.0	0	0
5.0 - 5.5	0	0
5.5 - 6.0	1	0
6.0 - 6.5	1	0
6.5 - 7.0	8	1
7.0 - 7.5	138	9
7.5 - 8.0	1005	67
8.0 - 8.5	335	22
> 8.5	13	1

Saturation Index		
Range	**n**	**%**
< (-3.0)	6	0
(-3) - (-2)	0	0
(-2) - (-1)	34	2
(-1) - 0	44	3
0 - 1	1232	83
>1	163	11

Chloride (mg/L)		
Range	**n**	**%**
None Detected	5	0
0.5 - 10.0	378	25
10.0 - 25.0	372	25
25.0 - 50.0	383	26
50.0 - 100	232	15
100 - 200	95	6
> 200	36	2

Alkalinity (mg/L $CaCO_3$)		
Range	**n**	**%**
None Detected	0	0
2.0 - 25.0	3	0
25 - 50	5	0
50 - 150	52	3
150 - 200	71	5
200 - 300	446	30
300 - 400	834	56
400 - 500	71	5
> 500	7	0

Triazine (ug/L)		
Range	**n**	**%**
None Detected	270	83
0.1 - 0.3	52	16
0.3 - 1.0	2	1
1.0 - 3.0	0	0
> 3.0	0	0

Coliform Bacteria		
Range	**n**	**%**
Positive	287	19
Negative	1223	81

Calcium (mg/L)		
Range	n	%
None Detected	0	0
0.1 - 25	90	22
25 - 50	54	13
50 - 200	257	63
> 200	4	1

Magnesium (mg/L)		
Range	n	%
None Detected	19	5
0.1 - 10	61	15
10.0 - 40.0	88	22
40.0 - 100	230	57
> 100	7	2

Iron (mg/L)		
Range	n	%
None Detected	18	4
0.002 - 0.3	244	60
0.3 - 1.0	68	17
> 1.0	76	19

Copper (mg/L)		
Range	n	%
None Detected	33	8
0.001 - 0.13	277	68
0.13 - 1.3	87	21
> 1.3	9	2

Sodium (mg/L)		
Range	n	%
None Detected	0	0
0.1 - 10.0	117	29
10.0 - 30.0	132	33
30.0 - 100	75	19
> 100	81	20

Potassium (mg/L)		
Range	n	%
None Detected	18	4
0.3 - 5.0	341	84
5.0 - 10.0	27	7
10.0 - 50.0	17	4
> 50.0	2	0

Zinc (mg/L)		
Range	n	%
None Detected	11	3
0.001 - 0.1	292	72
0.1 - 1.0	86	21
1.0 - 5.0	16	4
> 5.0	1	0

Manganese (mg/L)		
Range	n	%
None Detected	86	21
0.001 - 0.05	275	68
0.05 - 0.2	42	10
0.2 - 1.0	3	1
> 1.0	0	0

Lead (mg/L)		
Range	n	%
None Detected	252	61
0.002 - 0.015	134	33
0.015 - 0.05	14	3
0.05 - 0.1	7	2
> 0.1	4	1

Arsenic (mg/L)		
Range	n	%
None Detected	350	86
0.005 - 0.012	41	10
0.012 - 0.05	17	4
0.05 - 0.1	0	0
> 0.1	0	0

Sulfate (mg/L)		
Range	n	%
None Detected	3	1
0.1 - 20	60	15
20 - 100	264	65
100 - 250	62	15
> 250	16	4