An Introduction to Groundwater in St. Croix County

UW Extension

Center for Watershed Science and Education

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INTRODUCTION

A clean and dependable supply of water is necessary to maintain a high quality of life and strong economy in Wisconsin. Groundwater is particularly important in St. Croix County since it serves as the primary source of water for its residents and many industries. Because we cannot see groundwater it is important that we pay extra attention to this resource if we are to ensure that the quantity and quality of groundwater is maintained for our future needs.

The luxury of quality drinking water is something that many of us commonly take for granted. Municipal and other public water supplies are subject to strict guidelines and water quality testing to ensure that the water meets current drinking water standards and is safe to drink. However, there are also thousands of private residential wells which serve as the primary water supply for a large number of people in rural areas of St. Croix County and are not required to be tested or treated.

Groundwater is vulnerable and if it is not carefully monitored, managed, and protected has the potential to be depleted or degraded. While much has been done to protect our groundwater supply we increasingly face the question of how to manage groundwater quality. Wide-spread land-use activities have resulted in elevated concentrations of pollutants such as nitrate and pesticides in groundwater. Contamination of groundwater by volatile organic compounds has resulted in a deep casing area and other additional measures designed to ensure public safety in parts of St. Croix County. Cleaning up groundwater after it is contaminated has proven difficult and expensive; therefore it is beneficial to prevent groundwater from becoming contaminated in the first place.

As a way to address the groundwater and drinking water concerns of St. Croix County residents, the St. Croix County UW-Extension office in cooperation with local town boards and the Center for Watershed Science and Education in Stevens Point conducted a number of drinking water testing programs throughout the county. These programs offered community members an opportunity to test their water and learn about their community's groundwater and drinking water quality.

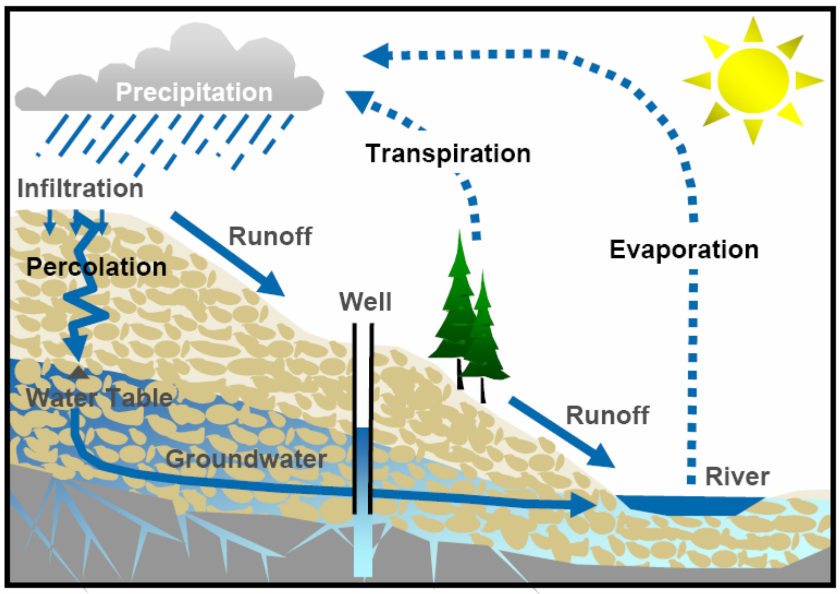
The results from over 2,000 voluntarily submitted residential well tests have been used to generate this report. While the water tests are not representative of a random sample and cannot be considered part of a scientific study, the results do give insight into the overall groundwater quality in St. Croix County. The information collected not only helps to highlight groundwater concerns in various parts of the county but has also helped residents of St. Croix to become better informed on local groundwater issues. This report is intended to summarize what was learned, to further educate residents and local leaders on important groundwater issues, and help them to manage groundwater resources for the future. The residents of St. Croix County who participated in the well water testing program 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.

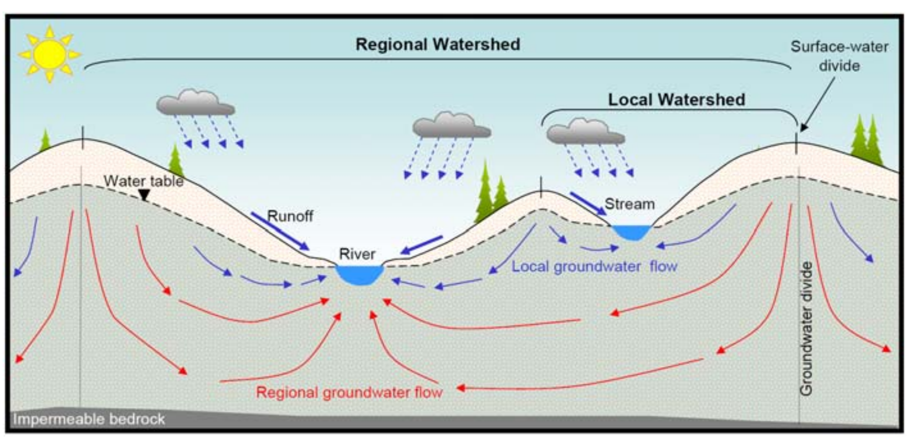
Groundwater is not the mysterious subject that some people believe it to be. Wisconsin's groundwater is related to all other water on earth through a process called the **hydrologic cycle**, or the water cycle. In the water cycle, water is transported from the earth by the processes of **evaporation** and **transpiration** to form clouds and 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 plant root zone to the saturation zone becomes groundwater. Some of this water is pumped out by pumping wells and used by humans in our everyday activities.

Figure 1
The hydrologic cycle.



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 St. Croix County include sand and gravel deposits and dolomite and sandstone bedrock.

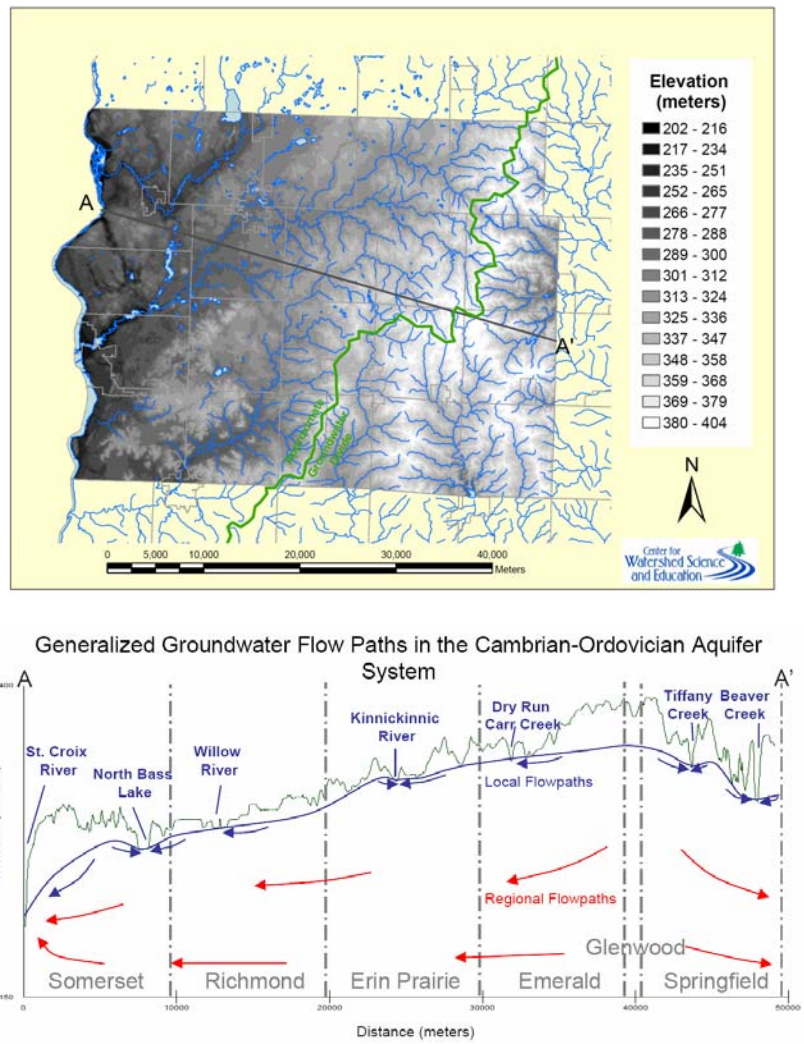
Figure 2
Local groundwater flows to nearby streams while regional groundwater flows longer distances to major discharge areas.



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 inches to a few feet per day, although in areas where there is fractured bedrock groundwater may move much quicker.

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 water exits the ground. Examples of discharge areas include streams, rivers, lakes and wetlands.

Figure 3
St. Croix County elevation map and generalized groundwater flow representing cross section from A to A'.



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 maybe even hundreds of years. Even though water may be very old, it is important to understand that our groundwater does not come from Canada, and few very deep wells tap water that has been underground since glacial times.

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 lakes and rivers. Any water that falls within the watershed has the potential to end up in that watersheds discharge area. 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. Tributary rivers like the Kinnickinnic River, will have a smaller watershed boundary than say the St. Croix River which it flows into.

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 St. Croix 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 St. Croix County. Some of the problems occur naturally from the contact of water with soil and rock; others are introduced by human activity.

While local geology plays an important role in determining how susceptible groundwater is to human contamination, it is important to keep in mind that what we do on top of the land and how carefully we do it often determines whether or not groundwater becomes polluted. Many everyday activities have the potential to impact our groundwater below.

In order to understand some of the key factors affecting groundwater, it is important to know about the **geology** and soils of St. Croix 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.

Geology of St. Croix County

The geology of Wisconsin is very similar to a layered cake, with each layer of the cake representing a different geological material and different geologic period. In order to learn about the different aquifers that are found in St. Croix County, we will work our way forward through time starting with the oldest and lowermost geologic material.

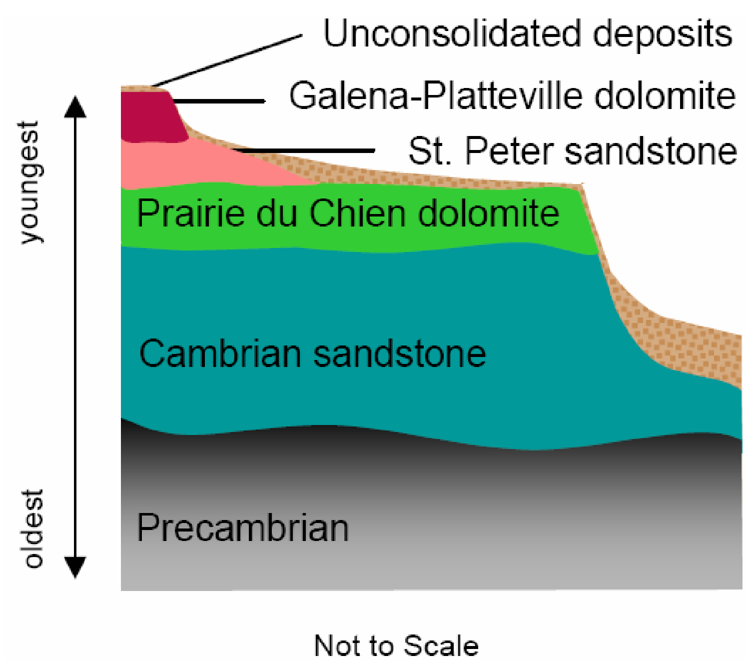
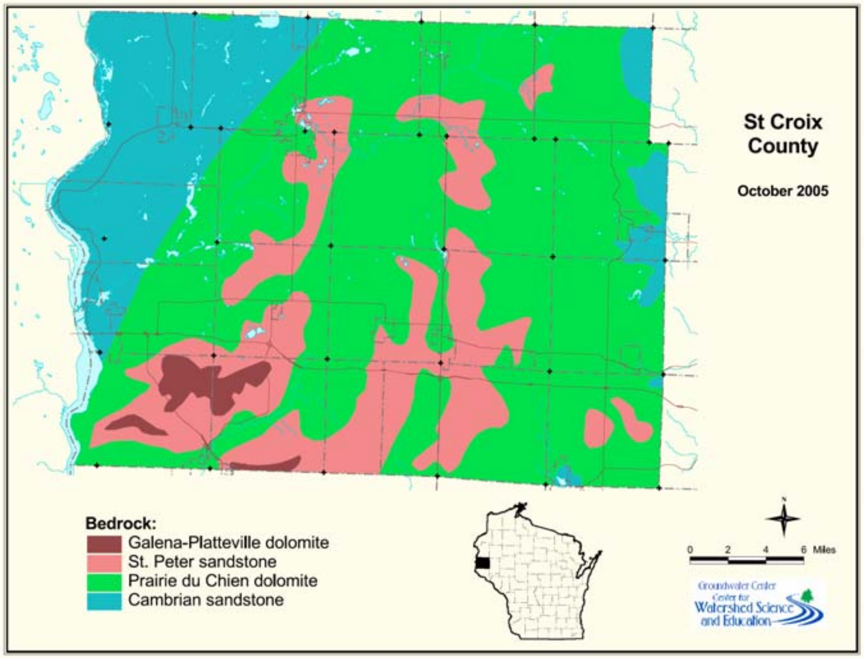


Figure 4 Generalized cross section of St. Croix County geology.

Figure 5
Map of uppermost bedrock layer in St. Croix County.



Precambrian Rocks
The Precambrian layer is the bottommost layer of bedrock in St. Croix County. 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 approximately 2.8 billion years ago. In general most Precambrian rock types store very little water and do not transmit water readily, making for a very poor aquifer; as a result it is not practical for wells in St. Croix County to extend into this geologic formation to obtain their water.

Cambrian Sandstones
Located above 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 a nearly flat 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. While this layer can be found underneath the entire county, it is the uppermost bedrock layer in only about one-fifth of the county. This material when pumped can generally produce between 100 and 1,000 gallons per minute, which makes sandstone an excellent aquifer for obtaining water. It is generally the principal source of water for municipal wells in the area.

Prairie du Chien Dolomite
Overlying the Cambrian sandstone layer we find a formation of the Prairie du Chien dolomite which is the uppermost bedrock layer in about one-half of the county. Dolomite is another sedimentary 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 soluble in slightly acidic water, and over time solution fractures have and continue to develop as water travels through the cracks in the dolomite.

The enlarging of fractures by the weathering of dolomitic rock has created the potential for what is known as **karst topography** in areas of St. Croix County where the Prairie du Chien layer is the uppermost layer of bedrock. Karst topography is generally located in areas characterized by thin soils or surficial deposits overlying fractured dolomite or limestone bedrock. Areas where karst topography is found may also have sinkholes, sinking streams and springs found nearby. This bedrock layer is often a very productive aquifer and many residential wells 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 St. Croix where karst topography is likely to occur.

St. Peter Sandstone

In some parts of St. Croix County the Prairie du Chien layer is overlain by the St. Peter Sandstone, which was formed during a period when sea levels lowered and St. Croix County was briefly exposed to weathering. Rivers and streams exhumed some of the underlying Cambrian Sandstone from upland areas, while wind and water helped redeposit the sand on top of the more recently formed dolomite layers. The St. Peter sandstone consists of very finely sorted quartz sand that has been cemented together over time. This geologic formation is the uppermost bedrock layer in only about one-fifth of the county and is largely unsaturated. It is not considered an important aquifer in the county.

Galena – Platteville Formation

The Galena-Platteville formation is the youngest bedrock layer in the county and is primarily dolomite that was formed in much the same way as the Prairie du Chien dolomite. Because this formation is only found in a small portion of southwestern St. Croix County and is mostly unsaturated, it is generally not considered an aquifer or source of water for wells.

Unconsolidated Materials

The unconsolidated materials overlying bedrock in St. Croix 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 and marsh deposits. These materials can range in size from clay to boulders. In most of the county this layer is not considered an aquifer, meaning that the material 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, such as the northwestern section of St. Croix county, obtaining water from these materials is highly variable, from 10 – 1,000 gallons per minute, depending on what type of material into which the well is drilled.

For more detailed information on the geology of St. Croix County look for the following resource which were useful in obtaining information in this section:

Borman, R.G. 1976. Ground-Water Resources and Geology of St. Croix County, Wisconsin. Information Circular Number 32. U.S. Geological Survey and Wisconsin Geological and Natural History Survey.

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

Where Does Our Drinking Water Come From?

More than likely if you drink water out of a faucet in St. Croix County you are drinking groundwater supplied by a well. 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.

Wells aren't much more than a hole drilled into the soil and rock below. Wells must be drilled deep enough to extend past the water table into the groundwater aquifer. As water is pumped or removed from the well, water contained in the adjacent rock or unconsolidated material replaces the water that was removed from the well.

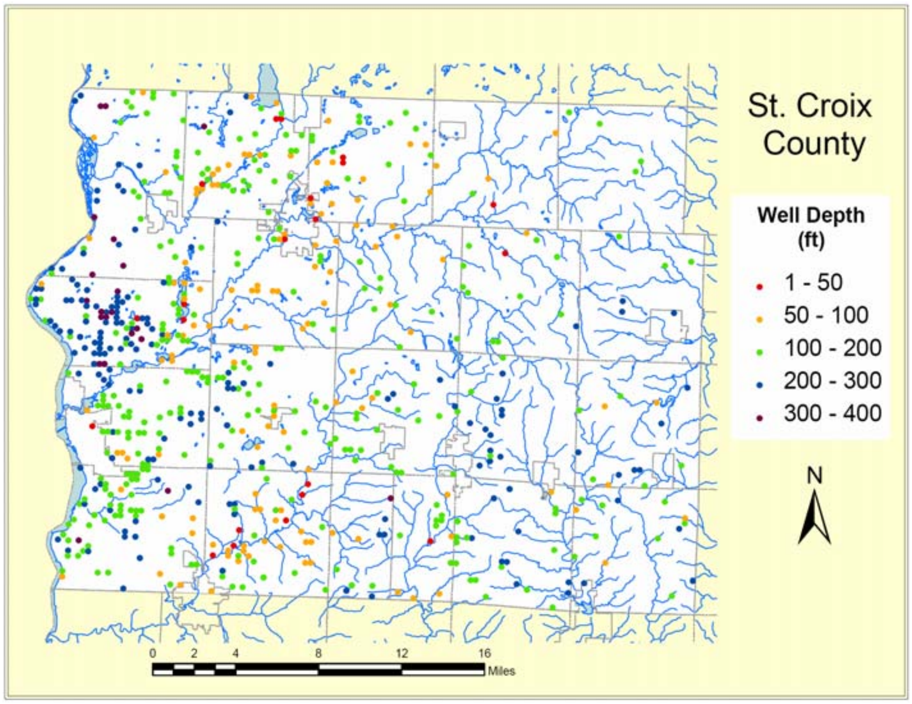


Figure 6
Self-reported well depths from water test participants.

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 where a well receives its water. Wells that are cased just below the water table receive water that recharged recently and generally can be affected by local land-use activities more quickly than are wells cased further below the water table.

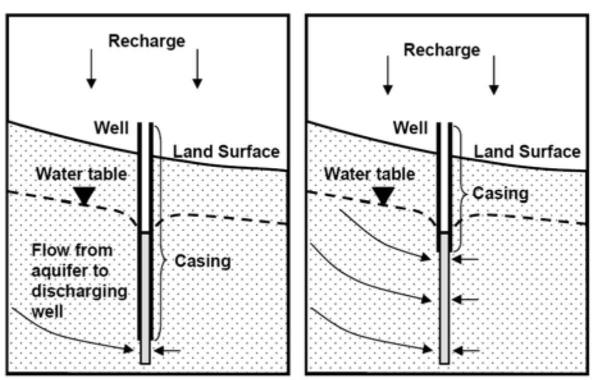


Figure 7
Casing plays an important role in maintaining sanitary conditions of a well and determining which area of an aquifer a well draws water from.

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, older groundwater tends to show less signs of being impacted. 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.

A well that pumps continuously often will lower the water table surrounding the well. This is referred to as a **cone of depression**. The cone of depression created by residential wells is minimal when compared to municipal or **high capacity wells**. Depending on how much water is being pumped and the well location, under certain circumstances wells have the potential to impact surface water bodies. A high capacity well located in close proximity to the headwaters of a small stream, for example, could reduce the amount of groundwater discharge to the stream. If the reduction in streamflow is significant, there can be potential impacts to the aquatic life in the stream. It is important when citing new high capacity wells that they will not negatively impact nearby surface waters.

What's in Groundwater?

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. Groundwater will naturally contain certain solutes depending on the type of soils and minerals the water has contacted. Minerals or elements such as calcium and magnesium, which are readily found in groundwater, can actually be beneficial to health. On the other hand, naturally occurring arsenic in groundwater is considered to be a contaminant since drinking water that contains arsenic can negatively impact people's health.

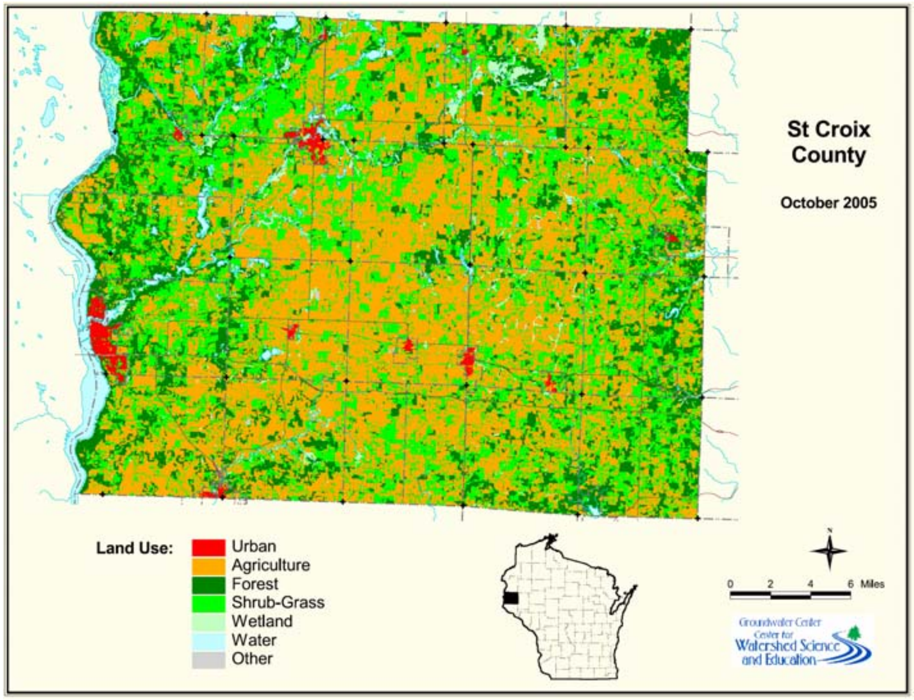
Table 1
Potential sources of groundwater contamination. (Born et al., 1987)

PLACE OF ORIGIN	POTENTIAL POLLUTION SOURCES			
	Municipal	Industrial	Agricultural	Other
	Waste Related			
At or near the land surface	Sludge and wastewater disposal (N)		Feedlots (P) Manure storage (P) and spreading (N) Whey spreading (N)	Septage disposal (N) Junkyards (P)
Below the land surface	Landfills (P) Wastewater impoundments (P) Seepage cells (P) Sanitary sewers (L)		Manure Pits (P)	Septic systems (P) Holding Tanks (P)
	Non-waste related			
At or near the land surface	Salt piles (P)	Above and on the ground storage of chemicals (P) Stockpiles (P) Tailing piles (P) Spills (P)	Irrigation (N) Fertilizers (N) Pesticides (N) Silage (P)	Highway deicing (L) Lawn fertilizers (N)
Below the land surface		Underground tanks (P) Pipelines (L)		Improperly constructed and abandoned wells (P) Overpumping (induced pollution) (P)

P=point source
N=nonpoint source
L=line source

WGNHS. 1987. A guide to groundwater quality planning and management for local governments.

Figure 8
St. Croix County land-use map.



Humans also have a significant impact on what is in our groundwater. 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 can also contaminate groundwater supplies. Depending on what land-uses are allowed to take place and how careful we are about carrying out these activities, some chemicals can eventually find their way into our groundwater. Because groundwater travels very slowly, we may not realize that we have contaminated it 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.

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 always 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 is an example of a contaminant that causes acute effects. People who consume water contaminated with harmful bacteria usually develop symptoms within a relatively short period of time after ingesting the water. Copper is another example of a contaminant that can cause acute health effects. While some copper is necessary, too much in drinking water can cause abdominal pains.

Chronic effects result from exposure to a substance over a long period of time; this could be months or many years. Drinking water that contains even very small amounts of contaminants like pesticides, arsenic or lead for a prolonged period of time increases the likelihood of developing certain types of cancer or other long-term health effects.

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. 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 may be more at risk than others. While standards exist 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 2005 there were 151 public water systems in St. Croix County, 11 of which are municipal 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.

Private water supply systems, which include most 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 the individual's responsibility 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.

Private Well Data from St. Croix County

Interpreting water quality information can often be difficult. While water testing by residential well owners is encouraged, individuals are often unable to understand what water test results mean in terms of drinking water safety, aesthetics and effects on household plumbing. In order to truly understand results people must be informed on what they are testing for and why; in addition people must have standards against which to compare their water test results. The following information was collected from over 2,000 private well samples collected from 1999 to 2005 and is summarized for educational purposes. (See Appendix A for summary of all results) Interpretation information has also been included to help people determine if their water is safe to drink and identify other potential problems.

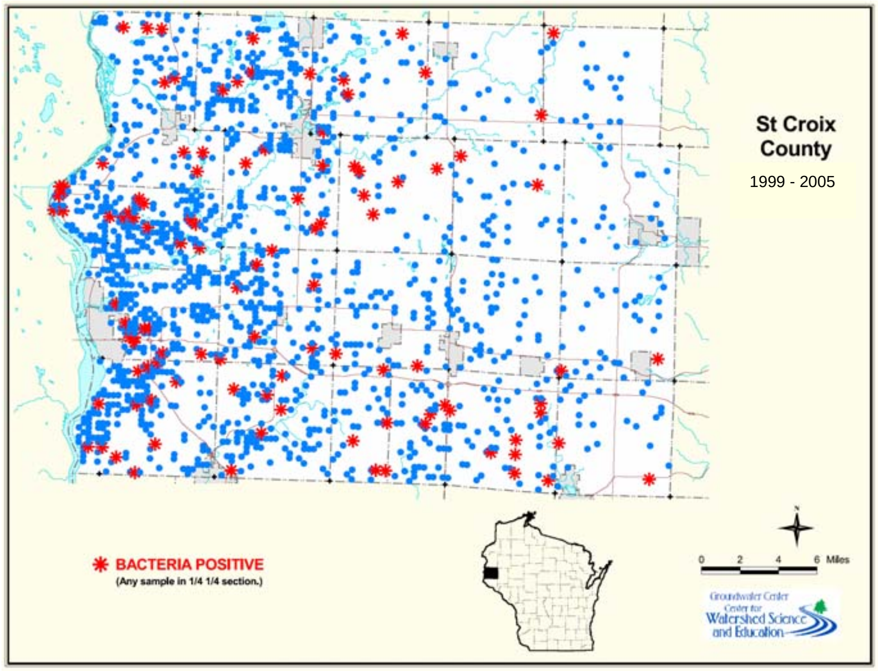
Tests Important to Health

Coliform Bacteria

Testing for coliform bacteria helps to determine if a private well is bacterialogically safe. There are many different types of bacteria. Coliform bacteria are very common microorganisms found in surface water, soil and in human and animal waste. All wells that supply drinking water should be absent of bacteria including coliform bacteria. 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* to enter the well.

If human or animal wastes are contaminating the water, gastrointestinal diseases, hepatitis, or other waterborne diseases may result.

Figure 9
Wells that tested positive for coliform bacteria.



In most cases a properly constructed well (Well Construction is regulated by NR 812) 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 thin soils or in karst regions, bacteria can more easily contaminate the groundwater aquifer. 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 potential bacteria problems. Also, ensuring that pets are not allowed in the area directly surrounding the well is a good precaution.

Bacteria can also enter wells through sanitary defects. 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 absent, insects or small animals can enter and can contaminate the well with bacteria. Bad or 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. 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. Similarly, improperly **abandoned wells** or wells that are no longer in use and have not been properly sealed may also represent a source of bacteria contamination. Improperly abandoned wells represent a direct conduit to the groundwater resource. Left opened, these wells are a pathway for water and pollutants to reach groundwater without being filtered by the soil. Anyone who knows of an abandoned well on their property should consider having it properly abandoned. *The St. Croix County Land and Water Conservation Department will be able to help answer questions related to well abandonment and may even have cost sharing opportunities available.*

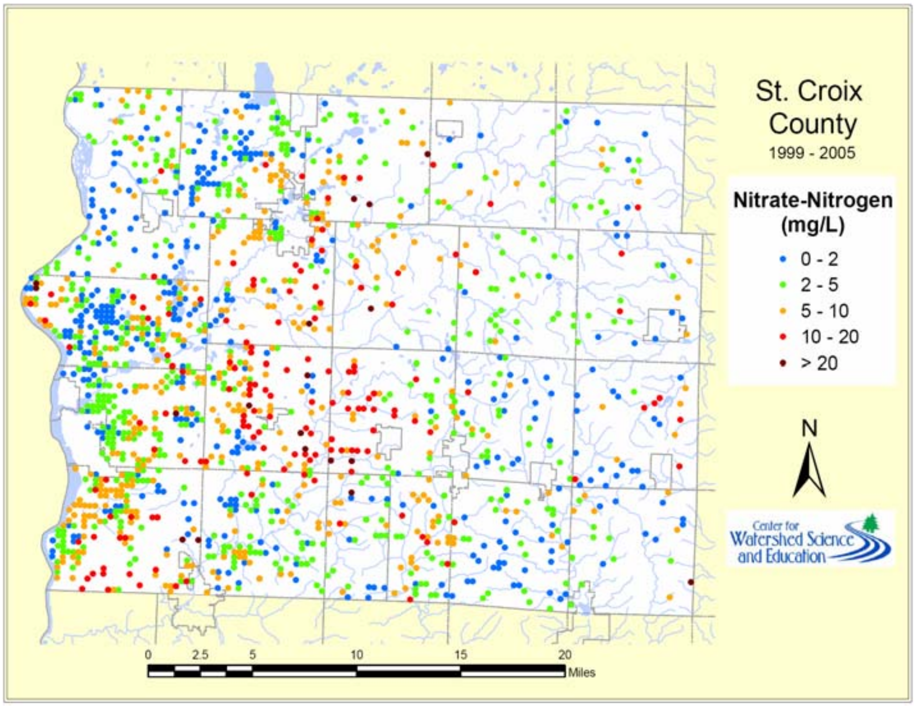
If bacterial contamination is identified any sanitary defects must be identified and corrected and the well must be sanitized to ensure that the water will be safe to drink in the future. A simple chlorination procedure sometimes called shocking the well is used to destroy the bacteria and sanitize the well. Sometimes the cause of bacterial contamination is never identified but the problem is able to be corrected by disinfecting the well. Private well owners are encouraged to perform a bacteria test on their well annually or if they notice a sudden change in the taste or odor of the water.

Nitrate-Nitrogen

Nitrate-nitrogen in groundwater commonly results from the use of agricultural and lawn fertilizer, animal waste, septic systems, or decomposing organic matter. It is a widespread groundwater contaminant in Wisconsin especially in agricultural regions where applying more nitrogen fertilizer than a plant needs often leads to nutrient leaching into groundwater as nitrate. Even when applying just the right amount, nitrate often leaches to groundwater under wet conditions when water carries nitrate past the root zone of plants quicker than the plants are able to take it up. Nitrate in groundwater can also be a problem in areas of high-density housing where homes rely on septic systems to treat wastewater. If designed properly most septic systems are effective at preventing bacteria from entering groundwater but are not generally able to remove much of the nitrate.

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. Any nitrate that is detected in groundwater below an agricultural field represents fertilizer that has not been utilized by crops. As the price of fertilizers and energy continue to increase, tailoring fertilizer applications to meet the needs of the crop and reduce leaching losses will become increasingly important as a way to improve profitability.

Figure 10
Concentration of nitrate-nitrogen in private wells.



The natural level of nitrate in Wisconsin's groundwater is typically less than 2.0 mg/L (parts per million). Concentrations greater than 2.0 mg/L suggest that groundwater is impacted by surrounding land-use activities. Because nitrate is very soluble in water, it is considered a good indication that groundwater is susceptible to other forms of pollutants as well. Areas that have elevated levels of nitrate may also consider testing the groundwater for pesticides if there is agriculture nearby.

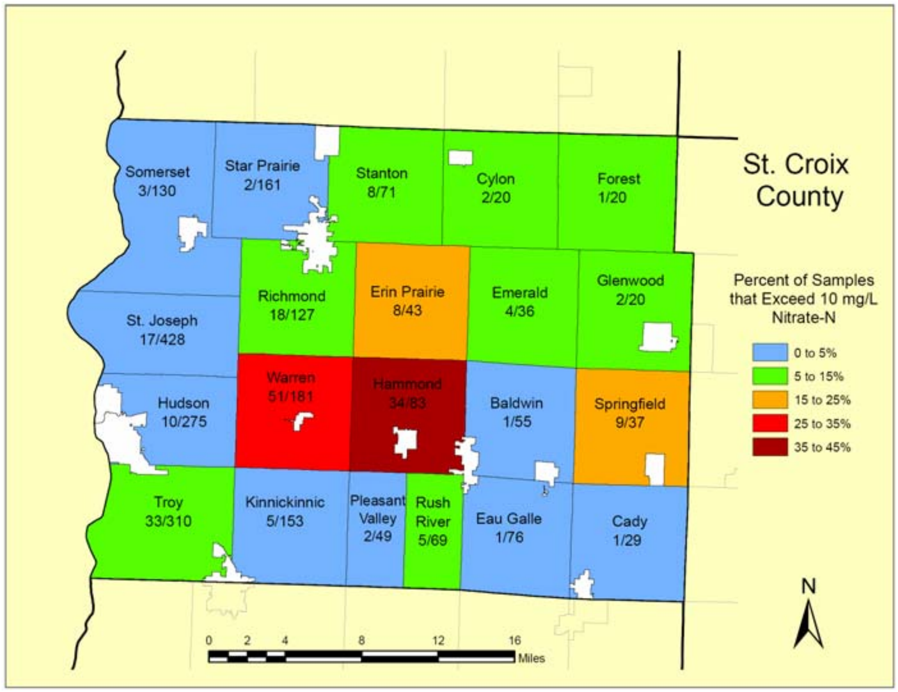


Figure 11
Map displaying percentage of samples that exceeded the nitrate-N standard by town. (Number of exceedences and total number of samples are listed below each Town name.)

There are certain health implications related to drinking water with high nitrate. The US EPA set the safe drinking water limit of nitrate-nitrogen in drinking water at 10 mg/L. According to the water test data for St. Croix County, 9% of the wells tested exceeded the safe drinking water standard for nitrate-nitrogen. Studies suggest that infants less than six months of age that drink water (or formula made with water) containing more than the standard for 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 high in nitrate.

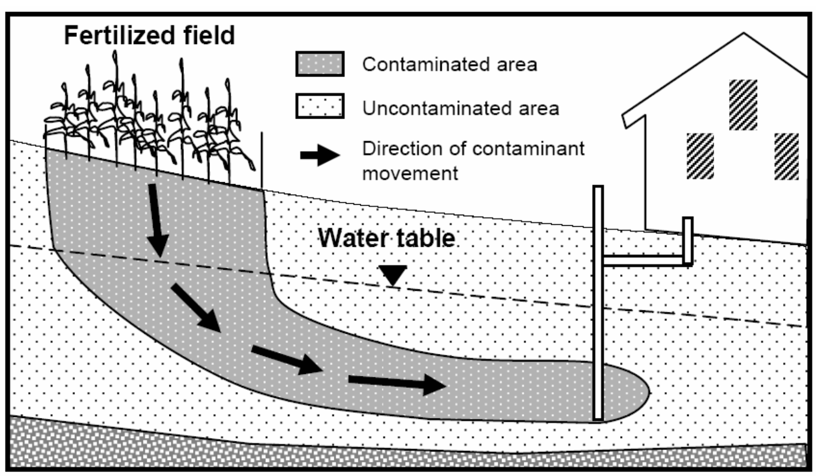
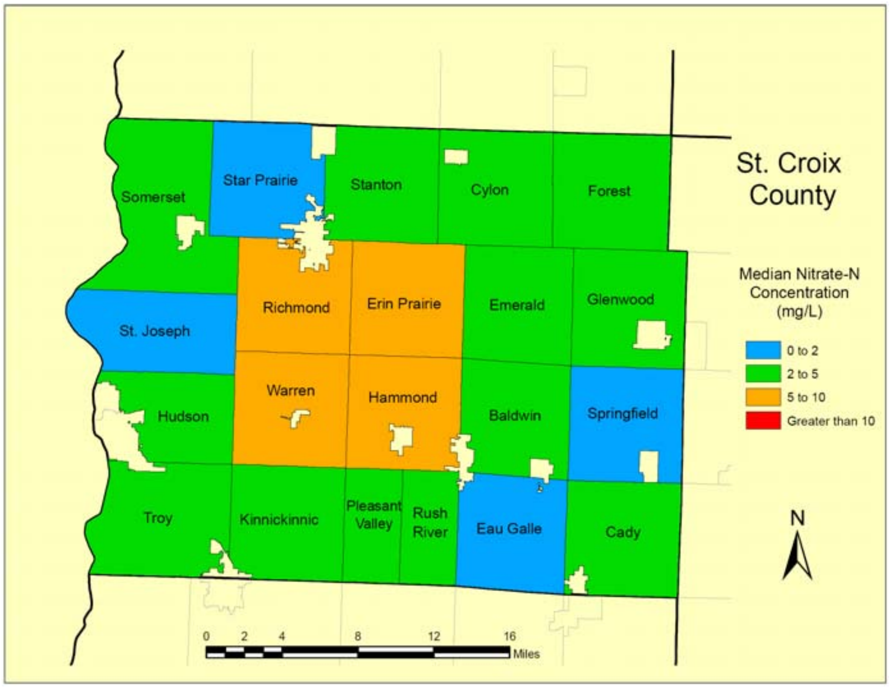


Figure 12
Diagram shows a common source of nitrate contamination to groundwater.

Figure 13
Map displaying the median nitrate-N concentration for each town based on all samples collected from 1999 to 2005.



In St. Croix County, the wells that reported the highest concentrations of nitrate-nitrogen tended to be located primarily in the towns of Hammond and Warren; these are also areas where karst topography can exacerbate the problem (see p. 6 for details on karst topography). Concentrations of nitrate-nitrogen ranged from 0 to 53.4 mg/L. The county-wide average nitrate-nitrogen concentration was 4.4 mg/L. While this average is below the drinking water standard, it does show that the groundwater is being impacted by local land uses in many places throughout the county.

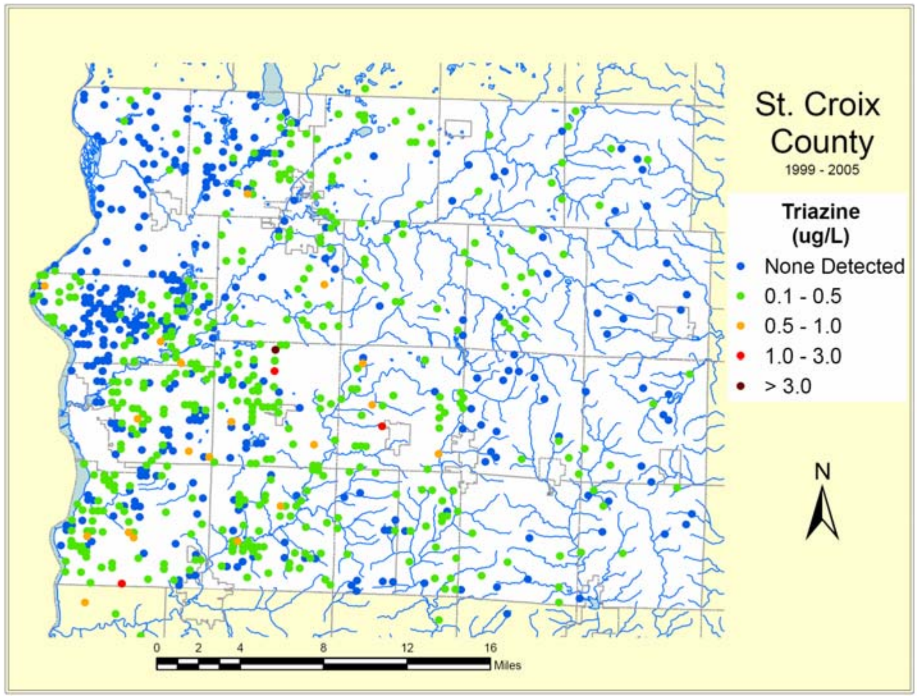
Pesticides

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 were 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 Department of Agriculture, Trade and Consumer Protection survey, the most frequently detected pesticides in Wisconsin groundwater are alachlor, metolachlor, and atrazine (DATCP, 2002). 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. There are currently no drinking water standards for metolachlor.

Figure 14
Triazine screen results from private well tests.



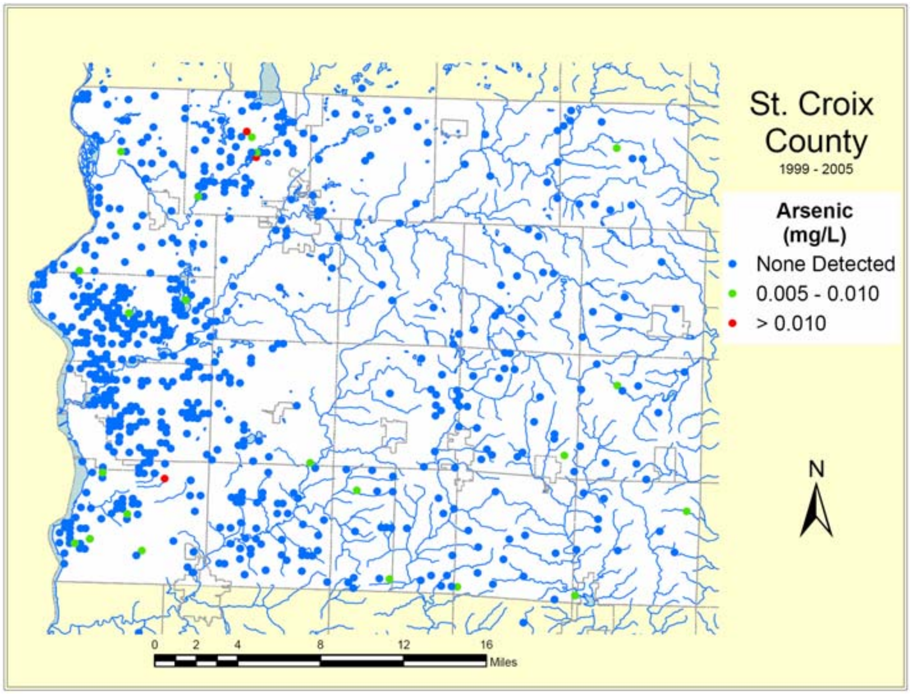
Results from St. Croix County revealed that 49% of the wells that were tested contained measurable amounts of triazine in the groundwater. These results are based on the triazine screen tests performed during the water testing programs. While none of the tests were over the 3 ppb standard for atrazine, this test is only a screening tool and often underestimates the amount of atrazine and its breakdown components. However, this is only one of many pesticides that are used in St. Croix County and does show that groundwater in St. Croix County is susceptible to contamination from localized pesticide use and is being affected by it. 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.

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). While the chance of finding elevated levels of arsenic appear to be greatest in northeastern Wisconsin, arsenic has been detected in other areas of the state as well, including St. Croix 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 the state, all residents are encouraged to test for arsenic at least once.

Figure 15
Arsenic concentration measured in private well samples.



Lead

Lead is a toxic metal which until 1985 was commonly used in the construction of most household plumbing systems in Wisconsin. Under natural conditions groundwater has little to no measurable lead. However, water that sits in lead pipes or pipes containing lead solder has the potential to dissolve lead and increase the concentration of lead in drinking water to unsafe levels. Corrosive water increases the likelihood of experiencing elevated lead levels.

The safe drinking water standard for lead is 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.

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. 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.

In St. Croix County there are four areas where known groundwater contamination from VOCs has resulted in the DNR implementing a "deep casing area" which regulates the drilling of wells. If VOCs are found in the well, it also mandates the installation and maintenance of a water-cleaning household filtration system to ensure public safety in these areas. There are four deep casing areas located in portions of the Towns of Hudson, Warren, and Star Prairie. Maps of affected areas can be found online at the following address:
http://www.wwraonline.com/st_27357.html

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, fertilizer, animal waste or other wastes. 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).

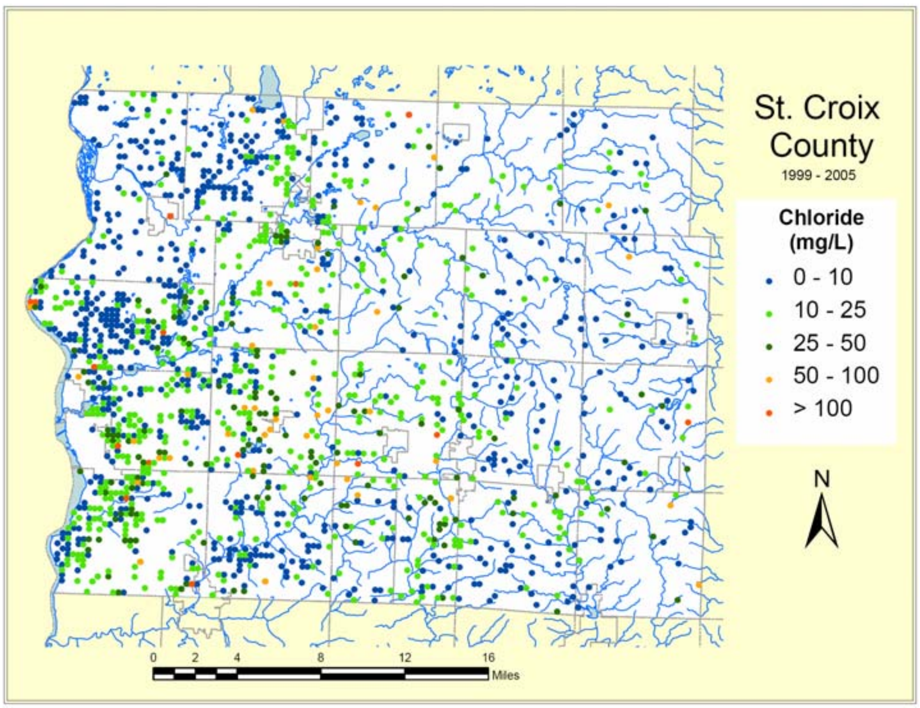


Figure 16
Chloride concentrations measured in private wells.

Chloride is also considered an indicator of other potential water quality problems. 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.

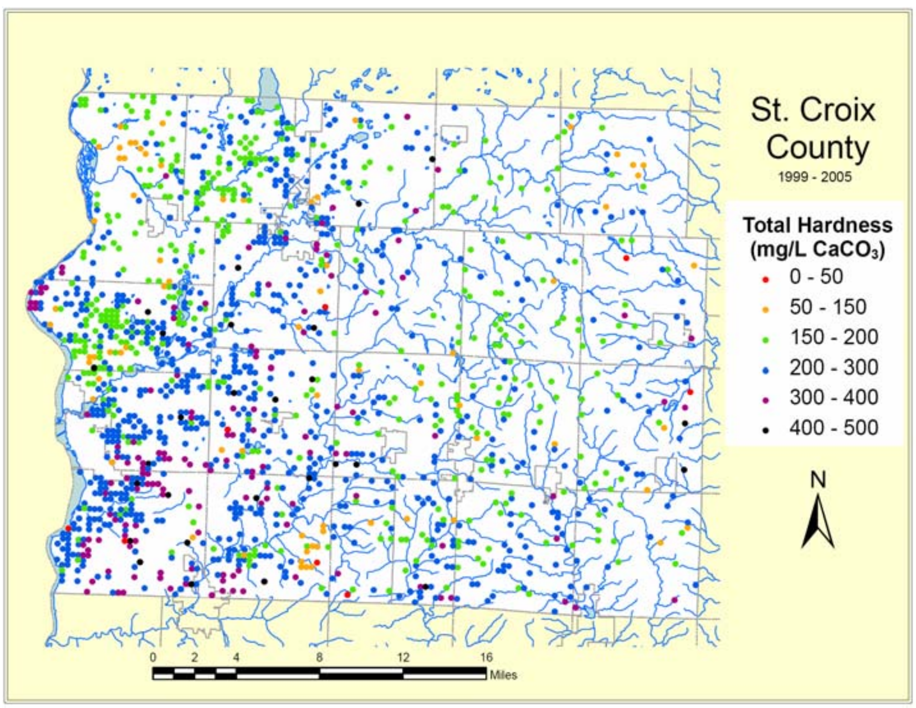
In St. Croix County 50% of the well tests showed natural levels of chloride in groundwater while another 37% were only slightly elevated. The remaining 13% of wells which tested above 25 mg/L (ppm) of chloride tended to be located near major roadways where road salt may be the source or in agricultural regions where fertilizer and animal wastes can often contribute to increased chloride levels. Residential septic systems can also be responsible for some of the elevated levels of chloride in groundwater particularly in areas with hard water where water softeners are commonly used.

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, which over time 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 $CaCO_3$. Water that is naturally low in calcium and magnesium (often referred to as soft water) 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 $CaCO_3$.

Figure 17
Concentration of total hardness measured in private well samples.

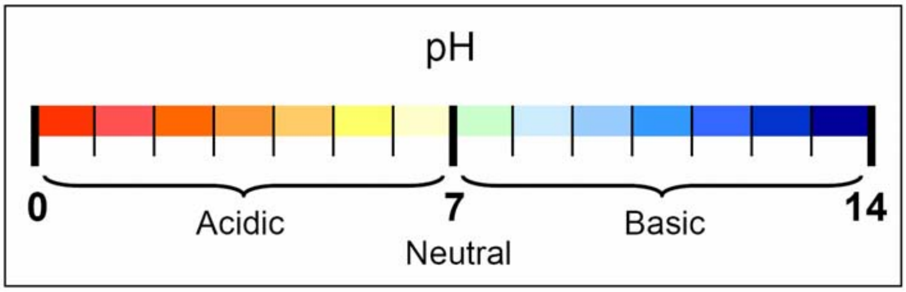


Groundwater in St. Croix County is generally hard with about 62% of all samples reporting hardness values above 200 mg/L $CaCO_3$. Hard water is typical of wells that are located in areas with dolomite bedrock. Many of the wells in the northwestern section of St. Croix County which are drilled into the unconsolidated deposits generally reported lower hardness values in the ideal range or slightly on the soft side.

pH

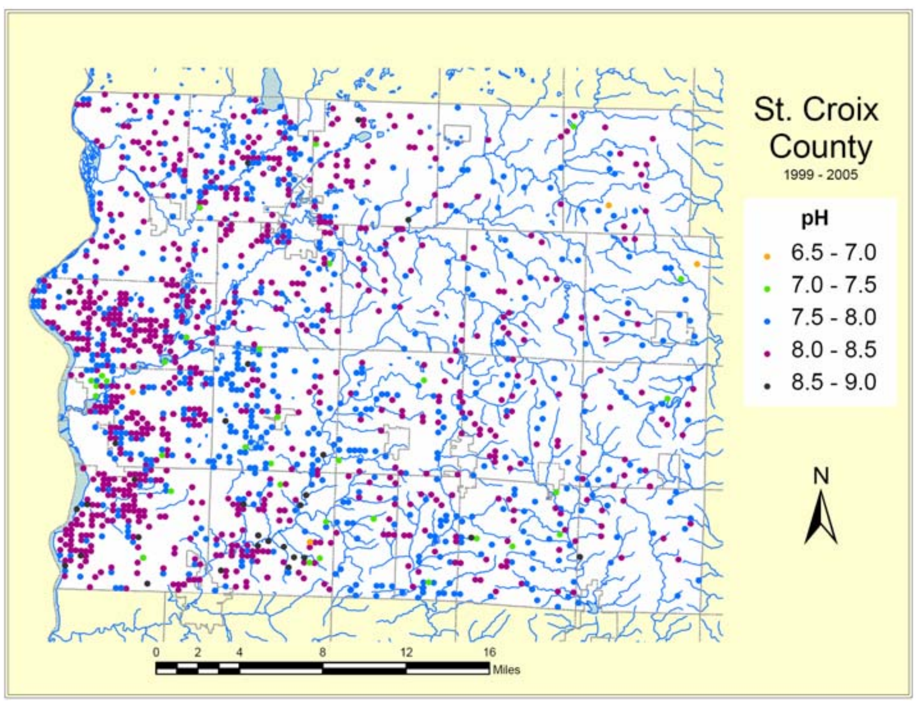
The pH is a measure of the hydrogen ion (acid) concentration in water. A pH of 7 is neutral. Values above 7 are alkaline or basic; those below 7 are acidic. In Wisconsin pH is commonly found between 6.0 and 9.0.

Figure 18
The pH scale.



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.

Figure 19
The pH values measured as a result of the private well testing program.

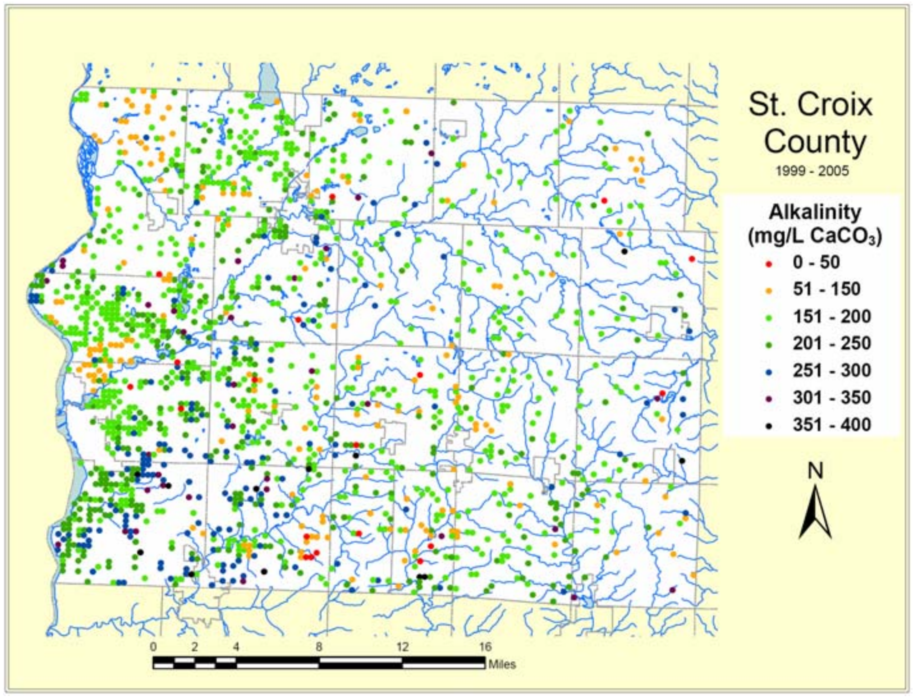


A change of 1 pH unit is a 10-fold change in acid level. Acidic water is often corrosive and can react with plumbing. The lower the pH value the more corrosive the water will be. It may be important to note that pH values are often slightly higher in the laboratory than at your well, because carbon dioxide 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.

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.

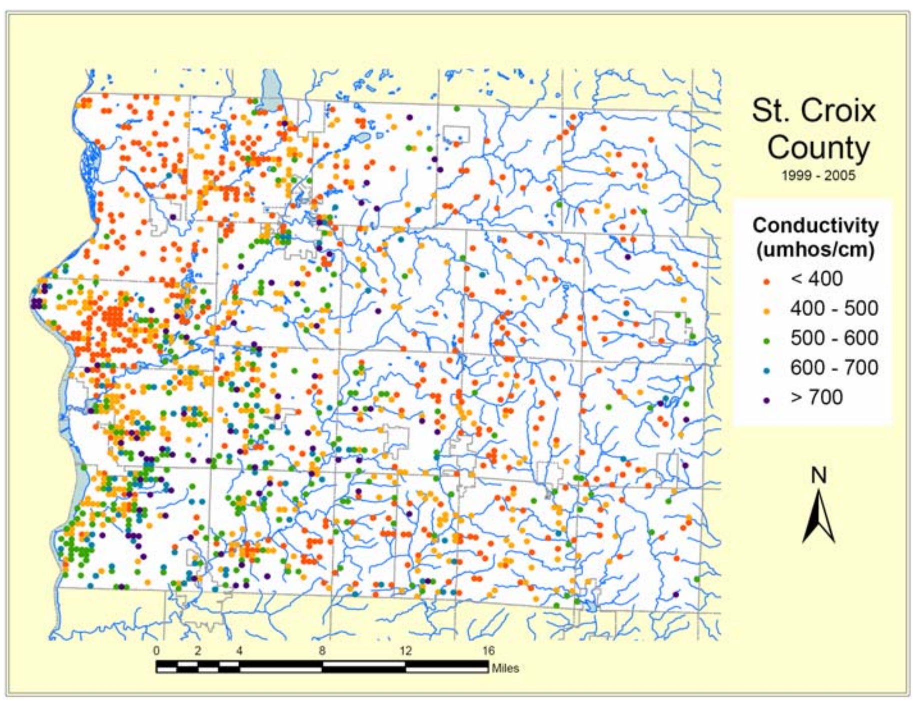
Figure 20
Alkalinity measurements from private well testing.



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.

Figure 21
Conductivity measurements of groundwater obtained during well testing programs.

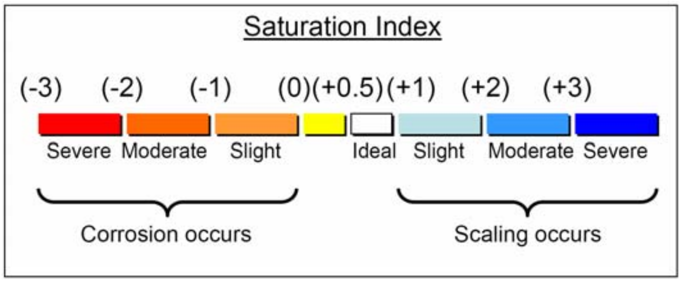


Typically calcium and magnesium represent the majority of dissolved ions in solution. As a result, conductivity (measured in μmhos/cm at 25^o C) is about twice the hardness (mg/L $CaCO_3$) in most uncontaminated waters in Wisconsin. If the conductivity is much greater than twice the hardness, it may indicate the presence of contaminants such as sodium, chloride, nitrate, or sulfate, which may be human-influenced or natural. Changes in conductivity over time may indicate changes in water quality.

Saturation Index

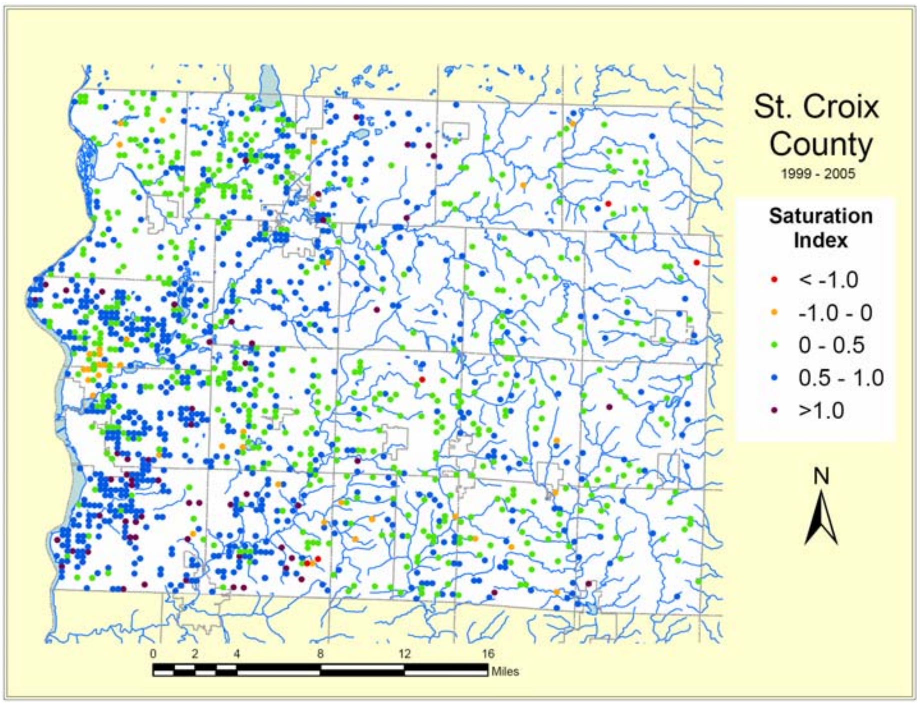
The saturation index is a measurement used to determine the tendency of lime (calcium carbonate) to precipitate (form a solid and settle out) from water or for the water to corrode household plumbing. It is calculated from pH, alkalinity, calcium hardness and conductivity data. Water with a low pH, low alkalinity, and low hardness value will result in corrosive water. Water that is high in pH, alkalinity and hardness will likely produce scale.

Figure 22
The saturation index helps determine whether water is corrosive or will likely form scale.



Water is a good solvent, and will attack unprotected metal plumbing. Lead, copper and zinc from pipes and solder joints may then leach (dissolve) into drinking water. Symptoms of corrosive water include pinhole leaks in copper pipes or green stains on plumbing fixtures. Lime precipitate (scale) is a natural protection against corrosion. Too much scale, however, will plug pipes and water heaters, decreasing their efficiency. Water softeners prevent scale buildup, but also decrease any protection from corrosion the unsoftened water may have provided.

Figure 23
Map showing saturation indices for St. Croix county calculated using data obtained through well testing program.



Values between 0 and 1 units are considered the most desirable because at this level the water is fairly balanced. Water with a value less than 0 will be more likely to corrode plumbing. Water with a saturation index greater than 1 will be more likely to form scale.

Iron

Iron is a naturally occurring mineral that is commonly found in groundwater. Increased iron concentrations are typically found in areas with acid waters or 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.

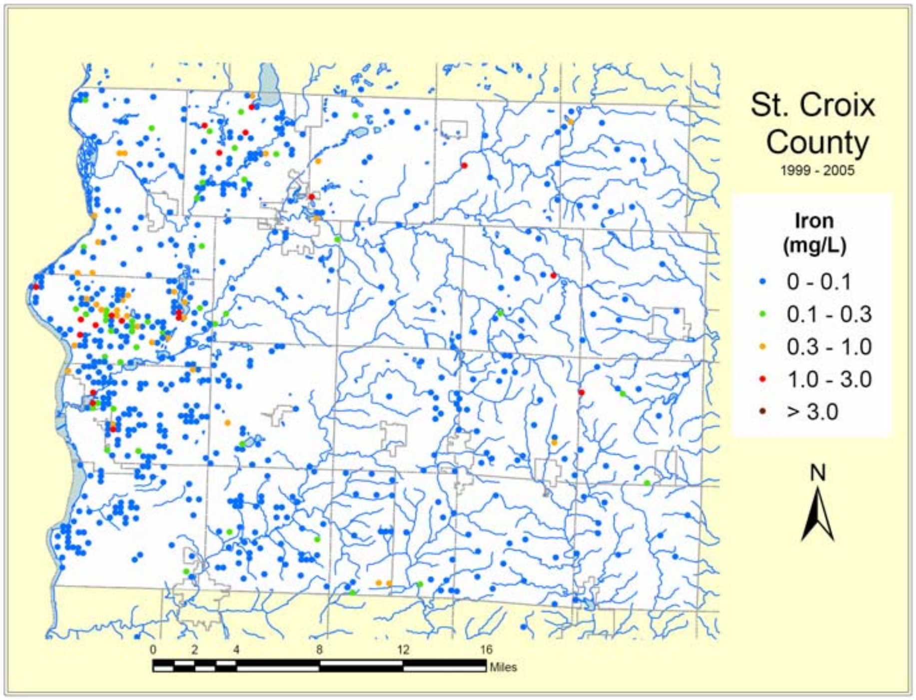


Figure 24 Results from well testing program showing iron concentrations.

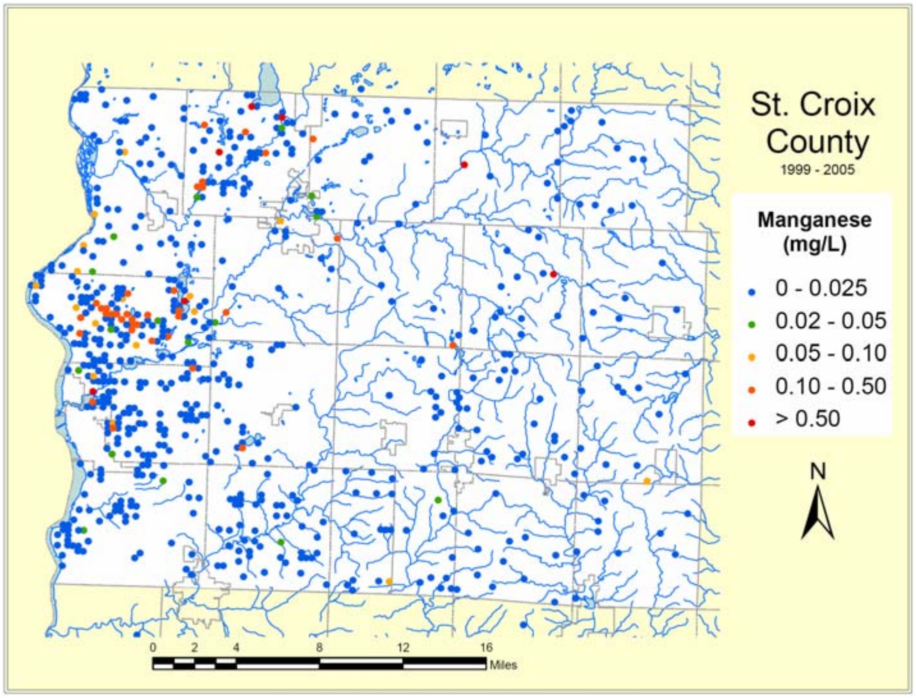
Reddish-orange staining of bathroom fixtures and laundry can often be attributed to high levels of iron in the water. Low levels of iron can often be treated with a household water softener, which also eliminates problems associated with hard water, although using a water softener to remove iron is not 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.

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. Although not considered to be a health issue at concentrations typically found in groundwater, manganese can be a nuisance for aesthetic reasons.

Figure 25
Results from well testing program showing manganese concentrations.



The aesthetic limit of manganese in water is set at 0.05 mg/L. This is because of the tendency for manganese to form black precipitates that can cause staining of plumbing fixtures. While it can be difficult to remove manganese using water treatment, iron treatment systems can often be used to control some of the problems associated with elevated levels of manganese.

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 unsafe water or correct aesthetic concerns with their water. What options a person chooses will depend on a variety of factors including feasibility, purchasing costs, as well as 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:

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.

When a change in water quality is desired, 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.

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. 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. People often assume that bottled water is always purer or better than the water that is coming from their private well. The well tests from over 2,000 private wells in St. Croix County reveal that the majority of private wells provide water that is similar or possibly even 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 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 deciding which option to choose.

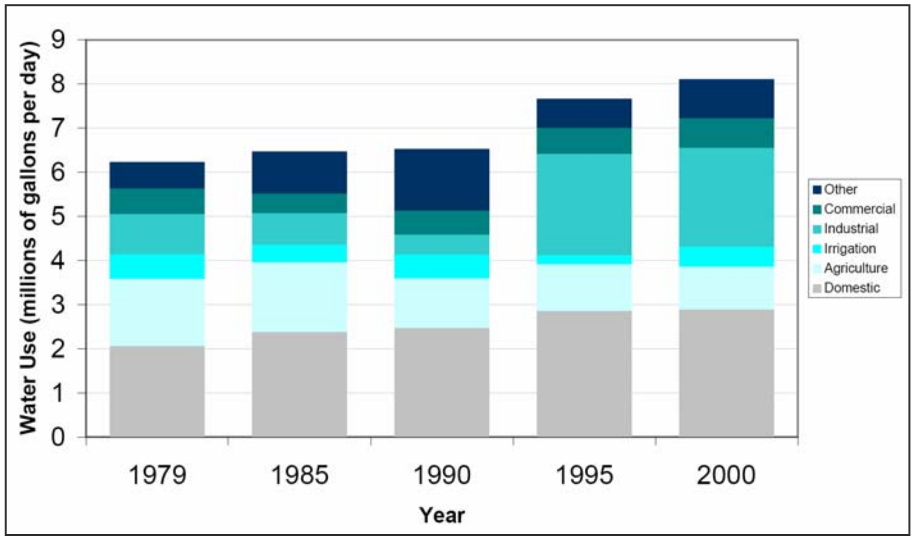
Eliminate the Contamination Source

The ideal solution to water quality problems caused by human activity is to eliminate the contamination source. 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. 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 to reduce contamination 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.

Groundwater Use in St. Croix County

While Wisconsin has an abundant supply of groundwater, water quantity has increasingly become a concern. While completely running out of groundwater may not be a realistic possibility in St. Croix County, groundwater withdrawals can still have adverse impacts that are important to consider when planning new growth or installing high capacity wells.

Figure 26
Water-use data for St. Croix County (Source: USGS).



Over the last twenty-five years, water-use data from the U.S. Geological Survey indicates that groundwater use in St. Croix County has been increasing. This trend is likely to increase given the fact that St. Croix is located in one of the fastest growing regions of the state. More growth translates into a greater demand for groundwater and more 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. In addition, high capacity wells can sometimes have negative effects on surface waters or surrounding wells. Proper care should be taken to avoid installing high capacity wells near surface waters such as headwater streams or springs that may be vulnerable to groundwater withdrawals.

Figure 27
Number of newly constructed wells in St. Croix County from 1988 – 2004 (Source: DNR)

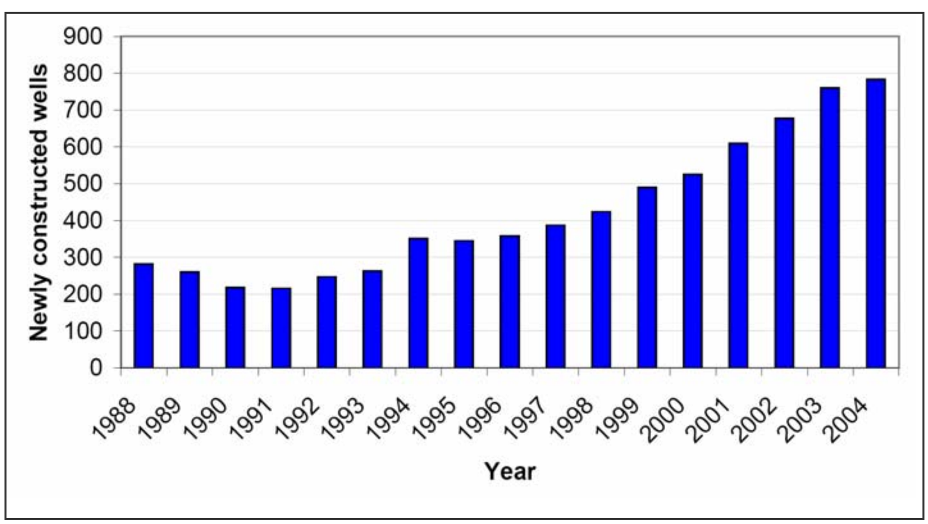
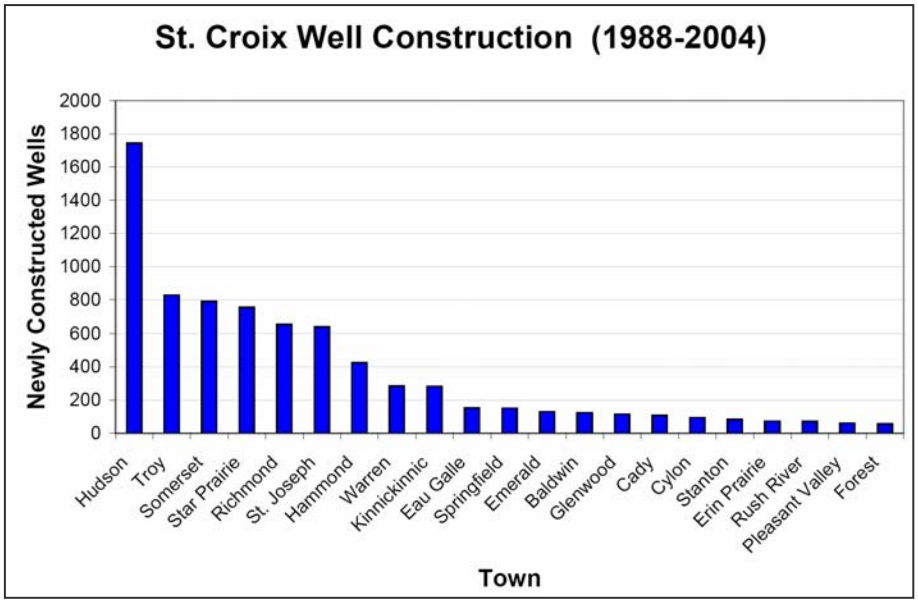


Figure 28
Number of new wells constructed in each town from 1988 to 2004.



Well construction report data from 1988 to 2004 indicates that the installation of private wells has also been increasing (DNR). It is important to remember that private wells do not have wellhead protection plans and are not required to be regularly tested or treated. 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.

Groundwater Management

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 (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 or contaminated.

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

- Encourage wise land-use decisions that will prevent adverse effects to groundwater quality or quantity.
- Protect municipal and/or private water supplies from contamination.
- Develop water conservation strategies and proper planning to minimize the impacts of expected changes in water use.
- Educate community members about the local groundwater resource, its use, the value, current and potential problems, as well as possible solutions.
- Establish and maintain a data collection, monitoring and analysis program.
- Coordination and cooperation between state agencies, local government, non-profit organizations, and citizens.

All of the previously stated goals will improve the chances of developing a successful comprehensive groundwater management strategy (Born et al. 1987). Because land-use activities can have a profound impact on groundwater quality, the making of sound land-use decisions by local governments is critical to protecting groundwater and drinking water supplies from contamination. Increased knowledge about the properties and importance of groundwater, will hopefully lead to wiser decision making by local governments and less opposition from within the community. Maintenance of a data monitoring program allows local governments to track changes in groundwater quality or quantity, and identify areas of concern. Lastly, because the authority for managing groundwater is not held by one agency, coordination and cooperation between state agencies, local governments, and citizens is vital to maximizing efficiency and achieving the ultimate goal of protecting groundwater.

Summary

Even though it's often buried deep underground, and we can't see it, groundwater is one of St. Croix 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 our groundwater resources wisely.

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 nearby surface waters as well, since groundwater flows to the rivers and lakes in St. Croix County.

The drinking water programs held between 1999 and 2005, in which over 2,000 households had their private wells tested, help us to create a better picture of current groundwater quality in St. Croix County. St. Croix County groundwater is generally characterized by having high hardness, a pH greater than 7.0, and high alkalinity. While the testing showed many private well provide drinking water that meets or exceeds drinking water standards, test results revealed that groundwater quality has been impacted by local land-use in parts of St. Croix County.

Private well testing indicated that nearly 69% of all wells tested had concentrations of nitrate-nitrogen above 2 mg/L, an indication of local land-use impacts. Nine percent of all wells tested greater than the safe drinking water standard for nitrate-nitrogen. In addition, 9% of the wells tested positive for coliform bacteria and 49% of wells reported detectable levels of triazine, the most commonly applied corn herbicide in Wisconsin. VOC contamination of groundwater has also resulted in deep well casing requirement areas in four parts of the county.

Once groundwater becomes contaminated it is very difficult and costly to clean up, therefore preventing groundwater contamination should be the goal of everyone. As a result, local governments will need to make wise choices when it comes to managing groundwater and making future land-use decisions. Local governments can only do so much however; everyone in St. Croix County will need to make wise personal decisions when it comes to their individual actions that involve using groundwater or making land-use decisions on their property that will potentially 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.

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Glossary

abandoned well - a well that is no longer being used; that if not properly sealed, represents a direct conduit for pollutants to enter the groundwater.

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 pumps more than 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 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

The following resources contain useful information designed for the general public to learn more about current groundwater issues and gain a better understanding of common drinking water concerns. Many resources are available in hardcopy form; some are also available online on the respective agency webpage.

- 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.htm.
- 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.htm.

Teaching Resources

- **Wisconsin's Groundwater Study Guide.** A curriculum development guide primarily for 6^{th} to 9^{th} 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-055-99. 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.htm
- **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
- 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 an 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. Basic 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.
- **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

St. Croix County. Government information source for St. Croix County listing services offered through county government and contact information. http://www.co.saint-croix.wi.us/

St. Croix County Land and Water Conservation Department. Under the direction of the St. Croix County Land and Water Conservation Committee of the St. Croix 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.co.saint-croix.wi.us/Departments/LandWater/default.htm

Groundwater Center. Helping citizens and governments manage the groundwater in Wisconsin wisely, through education, public information, applied research, and technical assistance. http://www.uwsp.edu/cnr/gndwater/

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.html

Wisconsin Department of Natural Resources

- **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.do

St. Croix County Well Testing Summary (1999 - 2005)

Nitrate-Nitrogen (mg/L)		
Range	n	%
None Detected	254	11
0.1 - 2.0	461	20
2.0 - 5.0	816	36
5.0 - 10.0	542	24
10.0 - 20.0	180	8
> 20.0	17	1

Total Hardness (mg/L $CaCO_3$)		
Range	n	%
None Detected	147	7
2.0 - 25.0	34	2
25 - 50	4	0
50 - 150	106	5
150 - 200	541	24
200 - 300	1146	51
300 - 400	240	11
400 - 500	31	1
> 500	3	0

Conductivity (umhos/cm)		
Range	n	%
< 50	147	7
50 - 100	34	2
100 - 200	4	0
200 - 500	106	5
500 - 800	541	24
800 - 1000	1146	51
> 1000	240	11

pH		
Range	n	%
< 5.0	0	0
5.0 - 5.5	0	0
5.5 - 6.0	1	0
6.0 - 6.5	2	0
6.5 - 7.0	10	0
7.0 - 7.5	47	2
7.5 - 8.0	750	33
8.0 - 8.5	1385	62
> 8.5	57	3

Saturation Index		
Range	n	%
< (-3.0)	9	0
(-3) - (-2)	7	0
(-2) - (-1)	72	3
(-1) - 0	115	5
0 - 1	1800	80
>1	249	11

Chloride (mg/L)		
Range	n	%
None Detected	32	1
0.5 - 10.0	1079	48
10.0 - 25.0	838	37
25.0 - 50.0	211	9
50.0 - 100	71	3
100 - 200	17	1
> 200	3	0

Alkalinity (mg/L $CaCO_3$)		
Range	n	%
None Detected	0	0
2.0 - 25.0	15	1
25 - 50	8	0
50 - 150	253	11
150 - 200	1032	46
200 - 300	878	39
300 - 400	66	3
400 - 500	0	0
> 500	0	0

Triazine (ug/L)		
Range	n	%
None Detected	520	51
0.1 - 0.3	368	36
0.3 - 1.0	131	13
1.0 - 3.0	5	0
> 3.0	1	0

Coliform Bacteria		
Range	n	%
Positive	207	9
Negative	2093	91

Calcium (mg/L)		
Range	n	%
None Detected	29	2
0.1 - 25	209	17
25 - 50	457	37
50 - 200	528	43
> 200	0	0

Magnesium (mg/L)		
Range	n	%
None Detected	97	8
0.1 - 10	140	11
10.0 - 40.0	966	79
40.0 - 100	20	2
> 100	0	0

Iron (mg/L)		
Range	n	%
None Detected	131	11
0.002 - 0.3	1008	82
0.3 - 1.0	47	4
> 1.0	39	3

Copper (mg/L)		
Range	n	%
None Detected	37	3
0.001 - 0.13	493	40
0.13 - 1.3	661	54
> 1.3	36	3

Sodium (mg/L)		
Range	n	%
None Detected	0	51
0.1 - 10.0	885	36
10.0 - 30.0	98	13
30.0 - 100	152	0
> 100	88	0

Potassium (mg/L)		
Range	n	%
None Detected	130	51
0.3 - 5.0	1039	36
5.0 - 10.0	20	13
10.0 - 50.0	15	0
> 50.0	19	0

Zinc (mg/L)		
Range	n	%
None Detected	9	1
0.001 - 0.1	332	27
0.1 - 1.0	759	62
1.0 - 5.0	119	10
> 5.0	3	0

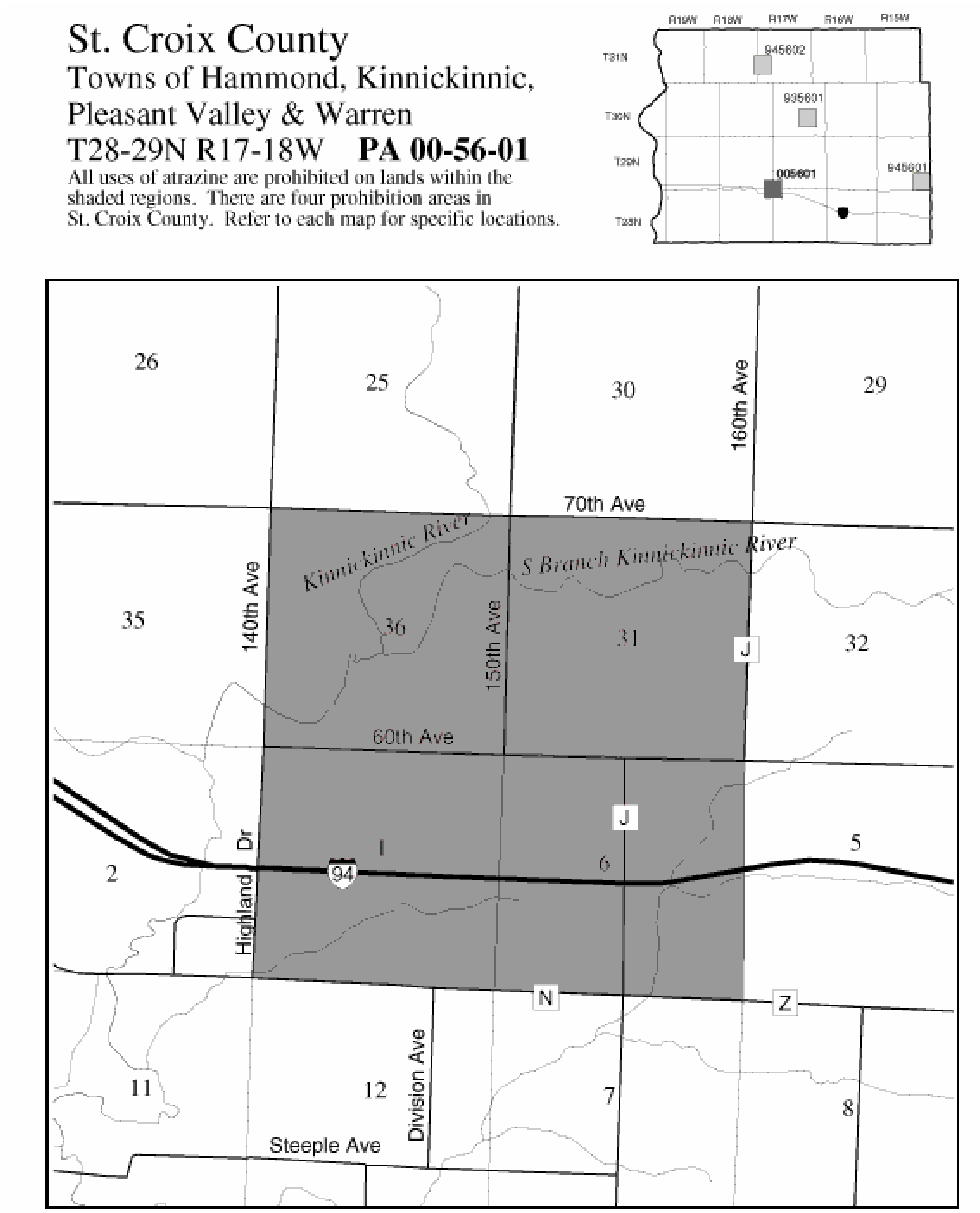
Manganese (mg/L)		
Range	n	%
None Detected	666	54
0.001 - 0.05	472	39
0.05 - 0.2	54	4
0.2 - 1.0	32	3
> 1.0	1	0

Lead (mg/L)		
Range	n	%
None Detected	608	49
0.002 - 0.015	525	43
0.015 - 0.05	76	6
0.05 - 0.1	14	1
> 0.1	9	1

Arsenic (mg/L)		
Range	n	%
None Detected	987	51
0.005 - 0.012	57	36
0.012 - 0.05	1	13
0.05 - 0.1	0	0
> 0.1	0	0

Sulfate (mg/L)		
Range	n	%
None Detected	9	1
0.1 - 20	861	82
20 - 100	171	16
100 - 250	3	0
> 250	0	0

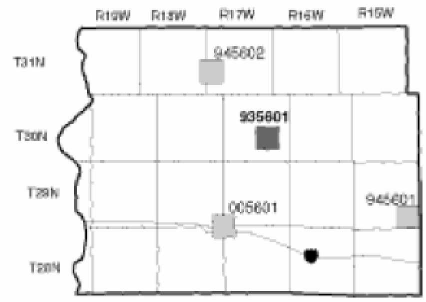
Appendix B – Atrazine Prohibition Areas

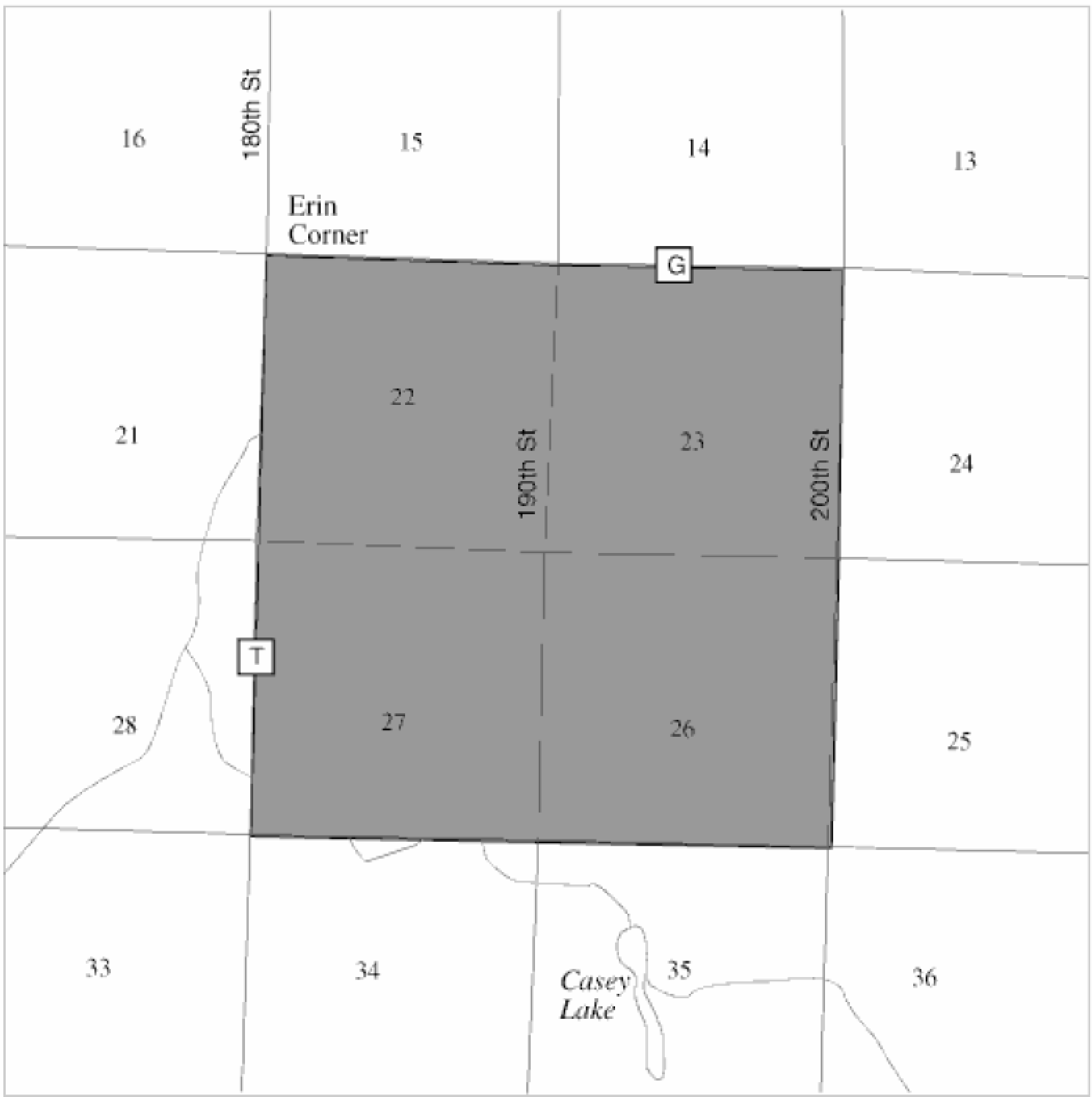


Accessed Online May 8, 2006
http://datcp.state.wi.us/arm/agriculture/pest-fert/pesticides/atrazine/county-maps/stcroix/index.jsp

St. Croix County
Town of Erin Prairie
T30N R17W **PA 93-56-01**

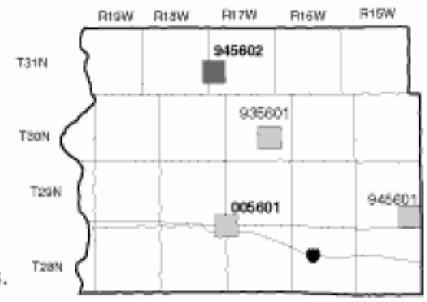
All uses of atrazine are prohibited on lands within the shaded regions. There are four prohibition areas in St. Croix County. Refer to each map for specific locations.



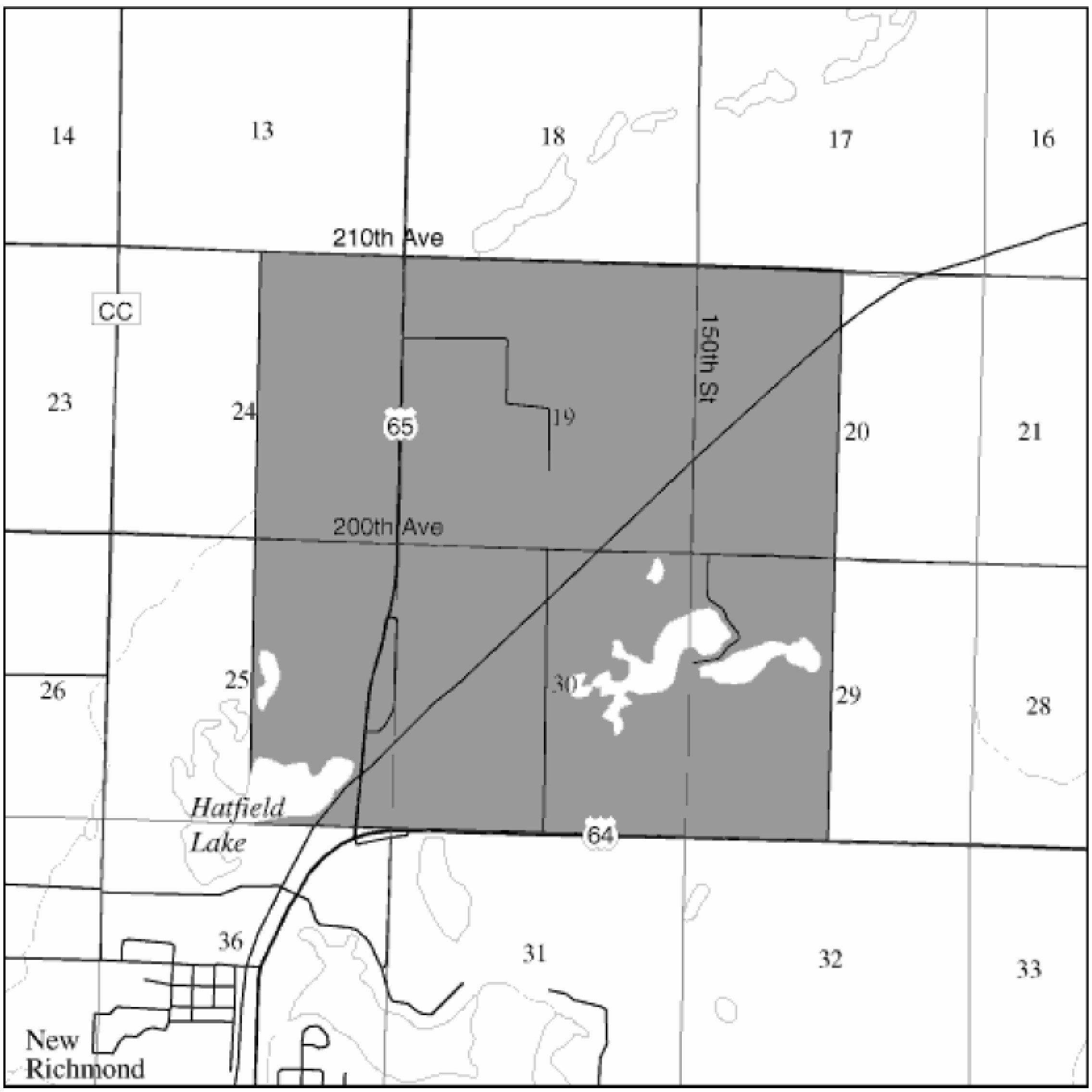


Accessed Online May 8, 2006
http://datcp.state.wi.us/arm/agriculture/pest-fert/pesticides/atrazine/county-maps/stcroix/index.jsp

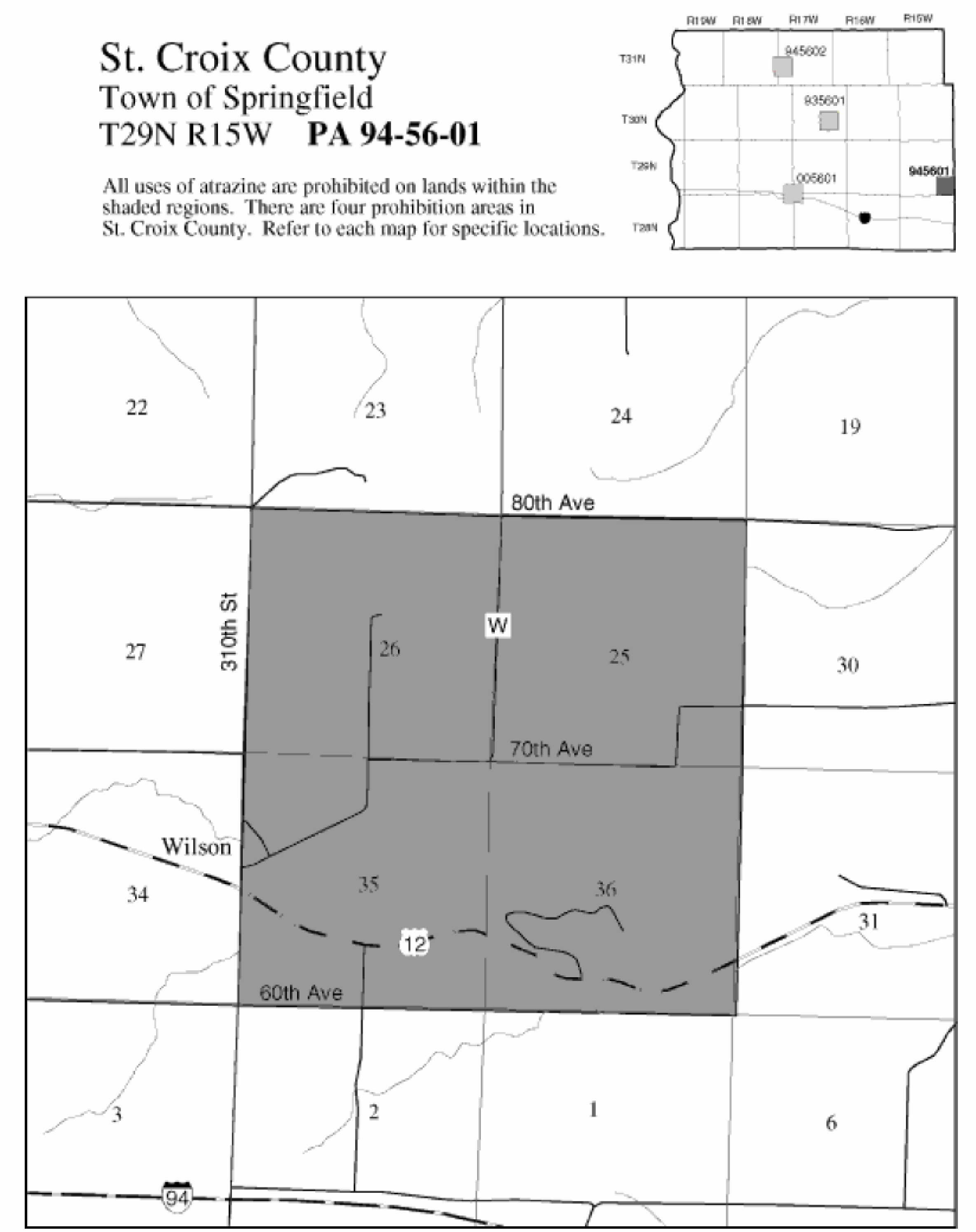
St. Croix County
Towns of Stanton & Star Prairie
T31N R17-18W **PA 94-56-02**



All uses of atrazine are prohibited on lands within the shaded regions. There are four prohibition areas in St. Croix County. Refer to each map for specific locations.



Accessed Online May 8, 2006
http://datcp.state.wi.us/arm/agriculture/pest-fert/pesticides/atrazine/county-maps/stcroix/index.jsp



Accessed Online May 8, 2006
http://datcp.state.wi.us/arm/agriculture/pest-fert/pesticides/atrazine/county-maps/stcroix/index.jsp