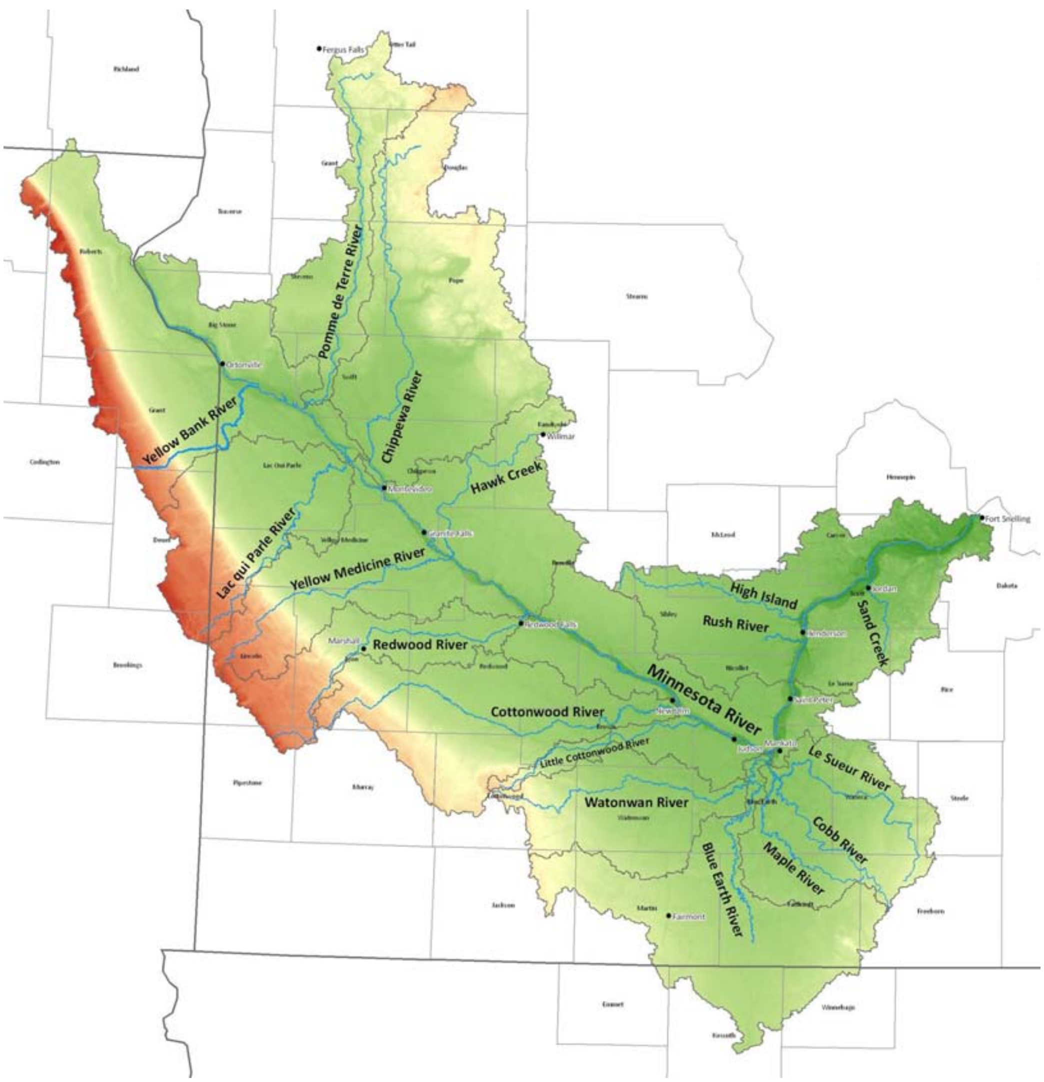
WATER QUALITY & QUANTITY

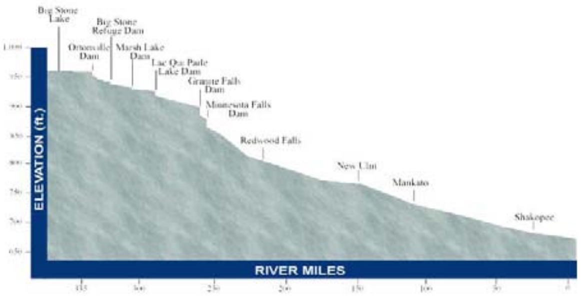
Rivers & Streams

The Minnesota River drains a basin of 14,840 square miles including all or parts of 37 counties; 1,610 square miles in South Dakota and the remaining area in North Dakota and Iowa. The Minnesota River meanders 335 miles from where it originates on the Minnesota-South Dakota boarder to its confluence with the Mississippi River near Fort Snelling. Surface water flow to the river comes from 1,208 minor watersheds. The Minnesota River Basin is divided into 12 hydrologic major watersheds and 13 management watersheds. The following section provides an overview of water quality trends in the basin. More detailed information about surface water quality monitoring can be found in the State of the Minnesota River reports:
http://mrbdc.mnsu.edu/mnbasin/state/index.html

On September 22, 1992, Governor Arne Carlson stood on the banks of the Minnesota River in Bloomington while holding a jar of dirty water and declared it was time to clean up this waterway. "Our goal is that within 10 years, our children will be swimming, fishing, picnicking and recreating at this river," Governor Carlson stated. After years of neglect, citizens, government agencies and nonprofit groups began to focus on restoring, improving and protecting the Minnesota River. In the span of a decade the river was listed as one of the most Endangered Rivers in the nation, the focus of a watershed-wide study – Minnesota River Assessment Project and saw the enrollment of over 100,000 critically sensitive acres into permanent easements.

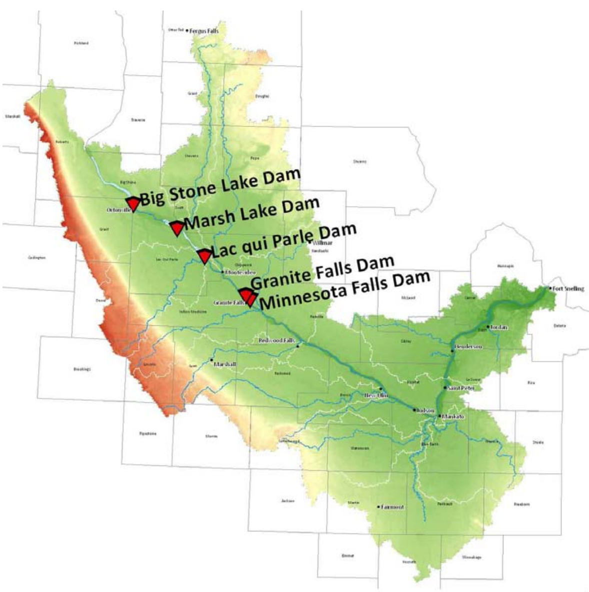


River Profile



The Minnesota River falls 274 feet from its headwaters at Big Stone Lake (964 feet) to the confluence with the Mississippi (690 feet). It drops approximately 0.8 feet per mile.

Dams on the Minnesota River



There are five major dams on the Minnesota River. Dams have been constructed at the outlets of Big Stone Lake, Marsh Lake, and Lac qui Parle to control lake levels and floodwaters. These dams create extensive lakes which are important wildlife management areas and hunting grounds. The other two dams are located in Granite Falls and a few miles downstream from Granite Falls called Minnesota Falls Dam.

Scott Kudelka

Granite Falls dam

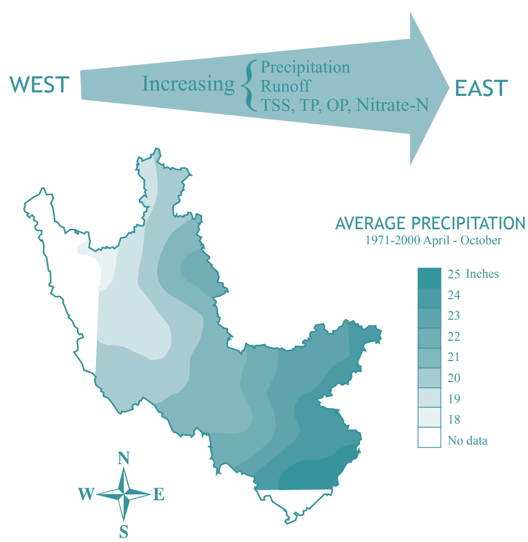
Climate Change & Precipitation

In the 1930s, many parts of the United States including Minnesota suffered through one of the driest periods in recorded history. Beginning around 1936, the average rainfall amount in Minnesota has steadily increased along with some extreme wet and dry years. According to the Minnesota Pollution Control Agency, precipitation in some areas of the state has increased by up to 20 percent, especially in the southern half.

Minnesota's location in the middle of the continent results in a variable climate due to the variety of air masses that flow across the state. Winters are typically dominated by cold, dry continental polar air and also occasionally replaced by somewhat milder maritime polar air (State Climatology Office, 2004). During the summer, Minnesota usually sees a clash between hot and dry continental tropical air masses from the desert southwest and the moist maritime tropical air coming up from the Gulf of Mexico.

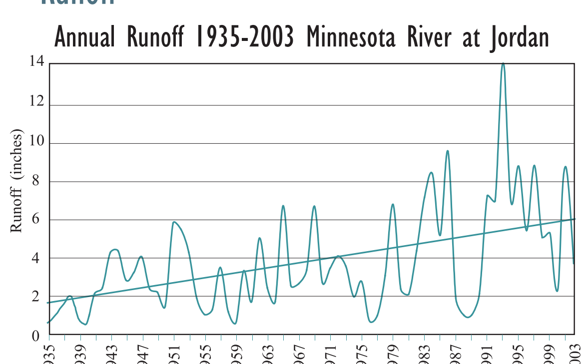
Precipitation is projected to increase by around 15 percent in the winter, summer and fall, with little change during the spring season according to MPCA. This state agency also projects a likely increase in the number of heavy rainfall events during the summer and the frequency of extremely hot days.

Precipitation



The Average Precipitation 1971-2000 map illustrates the west-to-east precipitation and runoff gradient. There is more rainfall as one moves eastwardly across the basin. Yields of key water quality pollutants (TSS, TP, OP and nitrate-N) follow this same general pattern of increasing in an easterly pattern.

Runoff

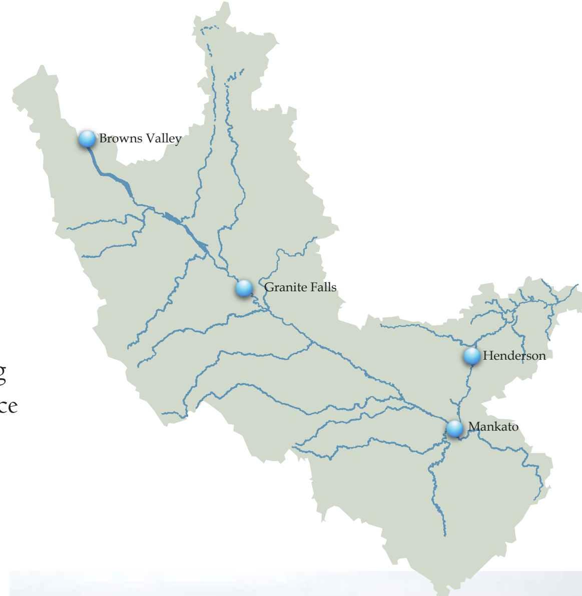


The annual runoff 1935-2003 graph illustrates the trend of increasing runoff volume over the past several decades. There is highly variable runoff from one year to another.

Rivers & Streams: Flooding

A natural and "man-made" phenomenon

Flooding is a natural occurrence of a river's riparian zone and provides many benefits including groundwater recharge, settling out sediment and supporting valuable wildlife habitat. A flood occurs when a waterbody like the Minnesota River receives a greater volume of water than it can handle, either at spring snowmelt or during a heavy rainstorm. Flooding only becomes a concern to humans when they impact the river's floodplain either by adding structures or planting crops. Humans have added to flooding problems primarily by intruding on the natural floodplain, but also by increasing the amount of impervious surface on the terrain and by displacing other natural storage on the landscape.



Browns Valley

Situated on a convex alluvial fan of the Little Minnesota River that drops rapidly some 780 vertical feet as it flows out of the Coteau des Prairies, the city of Browns Valley has dealt with major flooding issues since it was established in 1866. Most recently on March 4, 2007, the town was overwhelmed by intense and disasterous flooding when rapidly melting snow and ice jams forced the evacuation of about 100 people. The Little Minnesota River alluvial fan has partially filled the Glacial River Warren spillway in which it is located to form a very unique and dynamic quasi Continental Divide between the Red River and the Minnesota River basins. The convex form of the still actively forming alluvial fan and subsequent continental divide may distribute discharge from the Little Minnesota River north, east and south as different times or at the same time depending on the amount of discharge and the distributary nature of the stream channel at a particular point in time.

JOR Engineering

"Mother nature and humans have unwittingly concocted one of the most complex flood situations ever imagined at Browns Valley."– Dave Craigmile

Granite Falls

One of two cities with development on both sides of the Minnesota River, Granite Falls has been hit hard by flooding including 1997 (11.3 feet above flood stage) and 2001 (7.3 feet) with considerable damage to both residential and commercial buildings. To mitigate some of the flooding problems, the city has built a retaining wall and incorporated it with buildings located along the river, relocated other businesses and homes and put in additional flood prevention measures. In the near future, city officials hope to improve the levee, relocate City Hall and build a new water treatment plant out of the floodplain.

What Increases the Flooding Risk?

- Removal of stabilizing vegetation around stream banks and rivers
- Erecting structures that deflect or inhibit the flow of floodwaters
- Constructing bridges, culverts, buildings, and other structures that encroach on the floodplain.
- Drainage systems that funnel stormwater quickly into a receiving body of water like the MN River.
- Straightening meandering watercourses to hasten drainage.
- Filling and dumping of debris in floodplains.

Flooding continued

Mankato Free Press

Mankato Free Press

Scott Kudelka

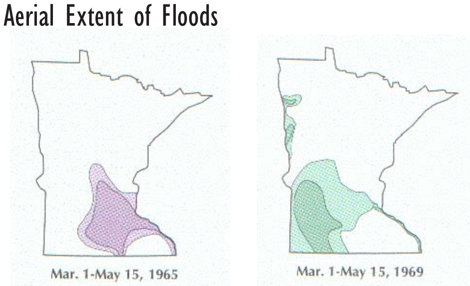
Mankato & North Mankato

Construction of a Flood Control System by the U.S. Corps of Engineers after the devastating 1965 flood has spared Mankato and North Mankato from any serious flooding since that time. Mankato is located at the confluence of the Blue Earth and Minnesota rivers. A doubling of water flow caused wide-spread flooding in 1881, 1908, 1916 and 1951 before the final major flood event in 1965. Today, both cities are protected by a flood wall levee system started in 1959 and finished thirty years later on each side of the Minnesota River along with sluice gates, additional gates and values, large pumps and pumping stations. Mankato and North Mankato have begun to make strides to make the Minnesota River a community asset.

Henderson

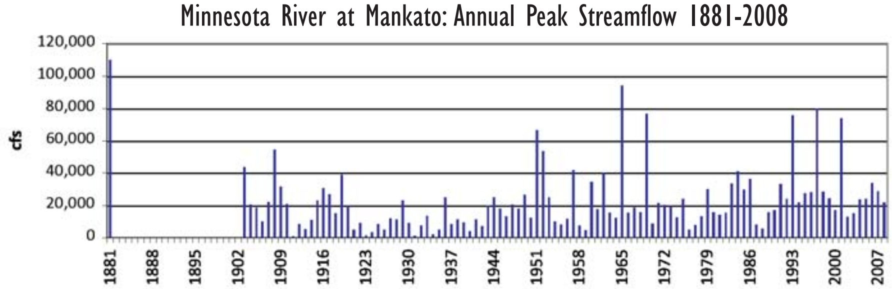
One of the historically significant towns along the Minnesota River, Henderson has been able to protect itself from flooding problems and still maintain some of its connection to the river. The 1965 flood hit this small community hard with a crest of 31.4 feet (highest in history). Approximately 285 people were evacuated from 95 homes. A $2.4 million levee system was completed by the U.S. Corps of Engineers in 1990 surrounding the city on three sides. This 1.5 mile permanent levee protected Henderson during the 1993, 1997, and 2001 floods along the Minnesota River. Today, residents enjoy a walking trail on top of the levee providing a close-up view of the Minnesota River floodplain.

Aerial Extent of Floods



Source: Minnesota Floods and Droughts

Minnesota River at Mankato: Annual Peak Streamflow 1881-2008



Source: USGS

Major Floods 1881-2009: Historical Crests at USGS Gaging Sites

	1881	1919	1951	1952	1965	1969	1986	1993	1997	1998	2001	2009
Savage			3	4	4	4	2	4	4		4	
Shakopee			3	3	4	3		3	3	2	3	
Jordan					4	3	2	3	3		3	
Henderson					4	3		4	3		3	
Mankato	3		2	2	3	3		4	3		3	
New Ulm						4			4	2	4	2
Granite Falls		3	2	3	2	4					3	
Montevideo		3	3	4	3	4	3	3			4	3

4=Major Flood Stage
3=Moderate Flood Stage
2=Flood Stage

Source: USGS

Rivers & Streams: Water Quality

Water Quality Monitoring

State and federal agencies have collected water quality data at various times in various locations throughout the Minnesota River Basin during the past thirty years. The most comprehensive study of water quality Minnesota River Basin, the Minnesota River Assessment Project, was conducted 1989-1994. The study concluded that the Minnesota River was impaired by excessive nutrient and sediment concentrations. Subsequent to those findings, considerable attention and support have been given to clean up efforts. Today, large portions of the Basin do not meet state water quality standards for bacteria, turbidity, dissolved oxygen, ammonia, and biota and are listed on Impaired Waters List (303(d) List). Learn more about Impaired waters on the MPCA website: http://www.pca.state.mn.us/water/tmdl/index.html).

– means decreasing trend/pollutant decreasing
+ means increasing trend/pollutant increasing
NT means no statistically significant trend
ID Insufficient data
mixed means trend tests vary

Pat Baskfield

Rapidan Dam on the Blue Earth River

Water Quality Trend Analysis

Since 2000, surface water quality data across the Basin has been collected and assembled in the State of the Minnesota River reports (produced every two years). These can be found on the Minnesota River Basin Data Center website: http://mrbdc.mnsu.edu. As the length of water quality records grew to a decade in many locations, there was sufficient data to run trend modeling programs to investigate if we can see any water quality trends in the Minnesota River mainstem, major tributary, and minor tributaries.

Minnesota State University, Mankato Water Resources Center recently completed a trend study headed by mathematics professor Deepak Sanjel and an interagency team. The study tested two trend models to examine water quality trends in the Minnesota River Basin: Seasonal Kendall trend model and the USGS Quality of Water trend program (QWTREND). Enough data was available to perform trend tests on 3 mainstem, 8 major tributary, and 4 minor tributary monitoring sites. Each monitoring site was analyzed for four primary water quality pollutants of concern: Total Suspended Sediment, Total Phosphorus, Nitrate-Nitrogen, and Orthophosphorus. A summary of results is presented in the table below. The study is available on the Minnesota River Basin Data Center website: http://mrbdc.mnsu.edu

	Total Suspended Solids	Total Phosphorus	OrthoPhosphorus	Nitrate-Nitrogen
Mainstem				
Judson	–	–	–	mixed
Mankato (SSC)	–	ID	ID	ID
St. Peter	–	mixed	–	NT
Major Tributaries				
Chippewa River	mixed	NT	–	NT
Hawk Creek	–	NT	NT	NT
Redwood River	–	NT	NT	mixed
Cottonwood River	–	NT	–	+
Watonwan River	–	–	–	–
Blue Earth	NT	–	–	–
Le Sueur	+	–	–	–
High Island	NT	NT	NT	NT

Rivers & Streams: Water Quality continued

Comparison of Trend Studies

Percent overall change over time period indicated (Seasonal Kendall Trend Test)

Total Suspended Solids	Fort Snelling 1976-2001	Jordan 1976-2001*	Blue Earth 1967-2001	St. Peter 1971-2006	Judson 1998-2008
MPCA (Christopherson)	-40%	-31%	-49%	n/a	n/a
University of Minnesota (Johnson)	-48%	-39%	-52%	n/a	n/a
MSU,M Water Resources Center (Sanjel)	n/a	n/a	No Trend	-30%	-28%

Nitrate-Nitrogen	Fort Snelling 1976-2001	Jordan 1976-2001	Blue Earth 1974-2001	St. Peter 1971-2006	Judson 1998-2008
MCPA	No Trend	No Trend	No Trend	n/a	n/a
University of Minnesota	No Trend	-39% (76-01) -29% (76-02)	No Trend	n/a	n/a
MSU,M Water Resources Center	n/a	n/a	No Trend	-14%	+37

Total Phosphorus	Fort Snelling 1976-2001	Jordan 1976-2001	Blue Earth 1967-2001	St. Peter 1971-2006	Judson 1998-2008
MCPA	-35%	No Trend	-47%	n/a	n/a
University of Minnesota	-37%	-24% (76-01) -22% (76-02)	-52%	n/a	n/a
MSU,M Water Resources Center	n/a	n/a	-45% (99-08)	-30% (98-08) -47% (71-06)	No trend

* For the Jordan Site, For TSS MPCA analyzed 1976-2001 and U of M analyzed 1976-2002. For Nitrate-N and TP: MCPA 1979-2001, U of M 1979-2002

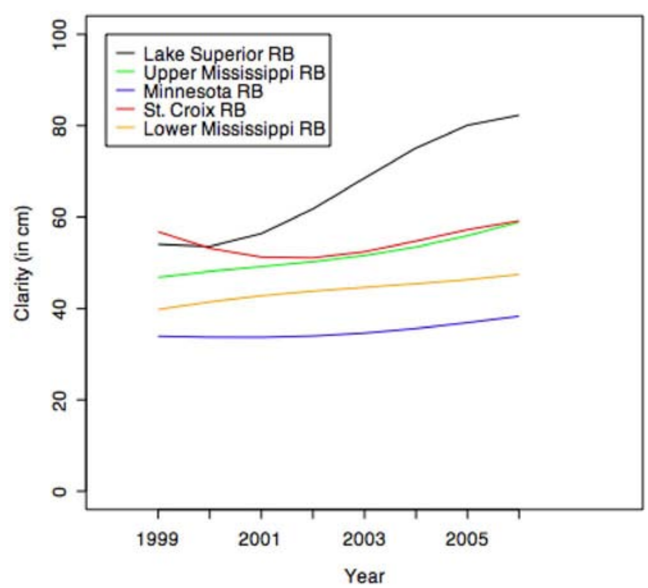
Pat Baskfield

Minnesota River Trend Studies have been performed by Minnesota Pollution Control Agency (Christopherson, 2002), University of Minnesota (Johnson, 2006), and Minnesota State University, Mankato Water Resources Center (Sanjel, 2009). The table at left illustrates that the trend studies all found reduction in TSS and TP in numerous mainstem sites during various time frames. For Nitrate-N, the studies indicated no trends or found mixed results. Taken together, these studies would suggest that at least some aspects of water quality in the mainstem of the Minnesota River have improved and continue to improve.

River Clarity Improving

Another statistical and graphical analysis was performed on data collected as part of Minnesota Pollution Control Agency's volunteer Citizen Stream Monitoring Program (CSMP). The study concluded that streams within the Minnesota River Basin (shown in blue below) had increasing water clarity over the study period 1999-2006 (Le, 2009).

Water Clarity Trends
Major River Basins of Minnesota



Minnesota River Basin Water Quality Links

State of the Minnesota River Reports
http://mrbdc.mnsu.edu/mnbasin/state/index.html

Environmental Data Access — Water Quality Data
http://www.pca.state.mn.us/data/eda/

DNR/MPCA Cooperative Stream Gaging
http://www.dnr.state.mn.us/waters/csg/index.html

MPCA Impaired Waters
http://www.pca.state.mn.us/water/tmdl/

Impaired Waters

More waters have been assessed and listed

What are Impaired Waters?

A water body is considered impaired if the water quality in the stream or lake does not allow it to meet its designated use (such as swimming, fishing or for maintaining a healthy population of fish and other aquatic life). Water quality standards are set on a wide range of pollutants, including bacteria, nutrients, turbidity and mercury. A water body is "impaired" if it fails to meet one or more of Minnesota's water quality standards. The waterbody is then placed on the "303(d)" list, commonly known as the "impaired waters list." It is named after the section of the Clean Water Act in which the impaired waters law is found. Lakes, rivers and streams on the list are known to exceed water quality standards. Every two years, the Minnesota Pollution Control Agency (MPCA) releases the 303(d) list of impaired waters in Minnesota.

Blue Earth River and transparency tube

TMDL Program

The process of dealing with "impaired waters" comes under the 303(d) Total Maximum Daily Load (TMDL) program. Each state is required to publish and update a list of "impaired waters" under Section 303(d) of the Clean Water Act. According to this act, a TMDL is a calculation of the maximum amount of pollutant from both point and non-point sources, that a waterbody can receive and still meet water quality standards. Once placed on the impaired waters list, the stream or lake needs a water quality improvement (TMDL) plan written.

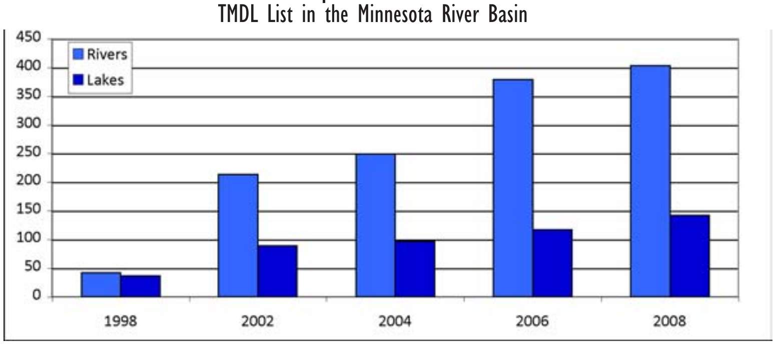
Minnesota's Impaired Waters

The most recent list of Minnesota's TMDLs came out in 2008 with a total of 1,475 impairments on 336 rivers and 510 lakes. A significant decrease occurred between this latest list and the 2006 TMDL list, which recorded 2,250 impairments on 284 rivers and 1,013 lakes. The major reason for the dramatic change was the approval of the statewide Mercury TMDL by the U.S. Environmental Protection Agency (mercury impairments made up two-thirds of the 2004 TMDL list). A second part of the 2008 TMDL List is an Inventory of all impaired waters that contains a total of 2,575 impairments including the approved Statewide Mercury TMDL and Southeast Regional Fecal Coliform TMDL. According to MPCA, "waters in the Inventory of impaired waters will remain there until they meet water quality standards."

The Minnesota River Basin has 336 impaired waters on the 2008 TMDL list and 546 on the Inventory of impaired waters. Pollutants or stressors for the basin include: fecal coliform bacteria, turbidity, chloride, mercury, fish bioassessments, dissolved oxygen, ammonia, PCB, Acetochlor and Nutrient/Eutrophication.

Impaired Waters

TMDL List in the Minnesota River Basin



The Impaired Waters graph (above) shows the number of impaired waters that have been placed on the Impaired Waters (303(d) List. The increase is largely a reflection of more waters being assessed.

Clean Water Act

Originally passed in 1972, the Federal Clean Water Act established the basic structure for regulating discharge of pollutants into the waters of the United States. It requires all states to adopt water standards that protect the nation's waters. One of its most important functions is to spell out requirements on setting water quality standards for all contaminants in surface waters. These standards define how much of a pollutant can be in a surface and/or ground water while still allowing it to meet its designed uses – drinking water, fishing, swimming, irrigation or industrial purposes.

The Clean Water Act requires each state to do the following:

- Assign designated uses to waters and develop standards to protect those uses,
- Monitor and assess their waters,
- List waters that do not meet standards,
- Identify pollutant sources and reductions needed to achieve standards,
- Develop a plan to implement restoration activities.

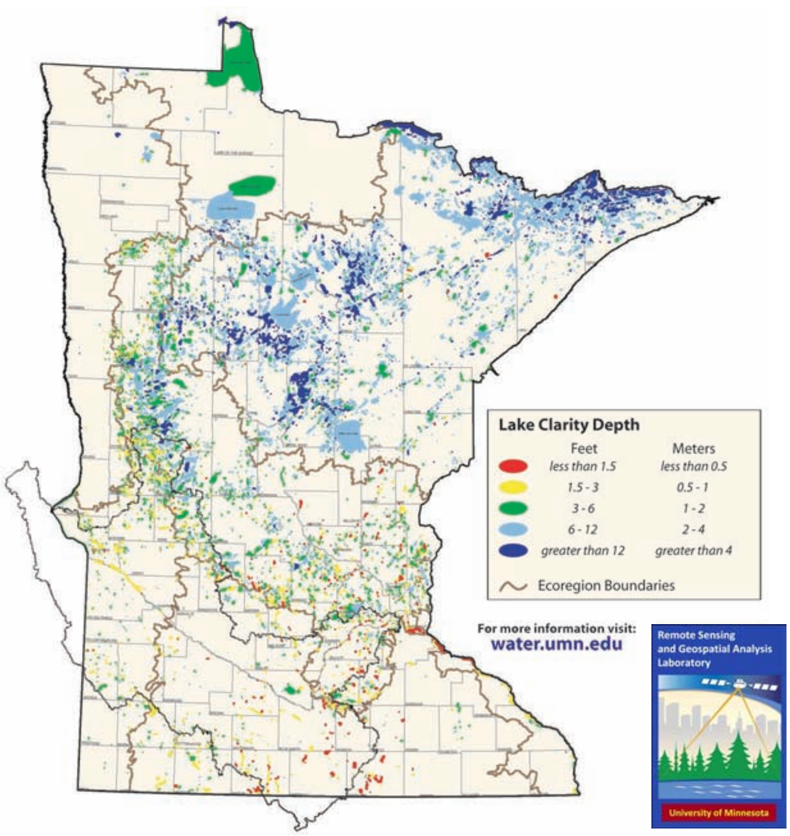
Lakes: Water Quality
Lakes studies show mixed trends

The Long View: Diatom Reconstruction of Lake Sediments

A study of fossilized single-celled organisms called diatoms was revealing about the history of Minnesota's lakes. MPCA and Science Museum of Minnesota scientists (Heiskary and Swain) collected sediment cores from 55 Minnesota lakes. They examined diatom communities and estimated the amount of phosphorus in each lake over time by identifying sediment layers from around 1750, 1800, 1970, and 1993. They discovered that most of the lakes they examined in Minnesota's cities and agricultural areas showed serious eutrophication (see box below) since European settlement. But they found no change in lakes studied in forested northern Minnesota.

Decreasing lake water clarity in southern Minnesota

A University of Minnesota study examined lake water clarity using satellite data from 1985-2005. Researchers found strong geographic patterns in Minnesota: lakes in the south and southwest have low clarity, and lakes in the north and northeast tend to have the highest clarity. Over the 20 year period, researchers found mean lake water clarity in central and northern Minnesota stable while decreasing water clarity trends were detected in southern Minnesota (Western Corn Belt Plains and Northern Glaciated Plains ecoregions) (Olmanson et al 2008).



Matt Niebuhr

Lake Minnewaska, Chippewa River Watershed

"From the time they were created at the end of the Ice Age 10,000 years ago, Minnesota's lakes have been aging—slowly filling with sediment and increasing in fertility, with more plants, more plankton, less clarity."
Paula West
Minnesota Lakes Association (DNR, 2003)

"People seem to realize the state of our lakes is changing," said Paula West, executive director of the Minnesota Lakes Association. "More weed growth, more boat traffic, and there's more development—their experience isn't what it used to be." Older residents "are concerned that their children and grandchildren won't be able to have the same experience that they did," West said.

"From the time they were created at the end of the Ice Age 10,000 years ago, Minnesota's lakes have been aging—slowly filling with sediment and increasing in fertility, with more plants, more plankton, less clarity. But human influence on land can kick this aging, or eutrophication, into high gear. Leaky septic systems, agricultural runoff, and storm-water runoff contribute nutrients to surface waters, fertilizing algae blooms and turning lakes green and cloudy. Phosphorus plays a particularly big role in fertilizing lakes" (DNR, 2003).

What is Eutrophic?

A eutrophic body of water, commonly a lake or pond, that has high primary productivity caused by excessive nutrients and is subject to algal blooms resulting in poor water quality. The bottom waters of such bodies are commonly deficient in dissolved oxygen which can be detrimental to aquatic organisms.

Statewide Lake Monitoring—Secchi Disk Readings Show No Overall Patterns

Lake monitoring records indicate not all lakes are deteriorating measurably. “There are no overall patterns,” said Steve Heiskary, Minnesota Pollution Control Agency lakes research scientist. Heiskary has compiled Secchi disk readings (a measure of clarity based on the visibility of a white disk submerged in the water) from the MPCA’s Citizen Lake Monitoring Program (CLMP) on more than 800 lakes in Minnesota. “If we look at a hundred lakes for these kinds of trends,” he said, “we’ll find perhaps 70 percent with no trends at all” (DNR 2003).

Statewide Comparison of Lake Water Quality

Parameter	Northern Lakes and Forests	North Central Hardwood Forests	Western Corn Belt Plains	Northern Glaciated Plains
Total Phosphorus (ug/l)	14 - 27	23 - 50	65 - 150	130 - 250
Chlorophyll mean (ug/l)	4 - 10	5 - 22	30 - 80	30 - 55
Chlorophyll max (ug/l)	< 15	7 - 37	60 - 140	40 - 90
Secchi Disk (feet) (meters)	8 - 15 (2.4 - 4.6)	4.9 - 10.5 (1.5 - 3.2)	1.6 - 3.3 (0.5 - 1.0)	1.0 - 3.3 (0.3 - 1.0)
Total Kjeldahl Nitrogen (mg/l)	0.4 – 0.75	< 0.60 - 1.2	1.3 - 2.7	1.8 - 2.3
Nitrite + Nitrate-N (mg/l)	<0.01	<0.01	0.01 - 0.02	0.01 - 0.1
Alkalinity (mg/l)	40 – 140	75 - 150	125 - 165	160 - 260
Color (Pt-Co Units)	10 – 35	10 - 20	15 - 25	20 - 30
pH (SU)	7.2 - 8.3	8.6 - 8.8	8.2 - 9.0	8.3 - 8.6
Chloride (mg/l)	0.6 – 1.2	4 - 10	13 - 22	11 - 18
Total Sus. Solids (mg/l)	< 1 – 2	2 - 6	7 - 18	10 - 30
Total Sus. Inorganic Solids (mg/l)	< 1 – 2	1 - 2	3 - 9	5 - 15
Turbidity (NTU)	< 2	1 - 2	3 - 8	6 - 17
Conductivity (umhos/cm)	50 – 250	300 - 400	300 - 650	640 - 900
TN:TP ratio	25:1 - 35:1	25:1 - 35:1	17:1 - 27:1	7:1 - 18:1

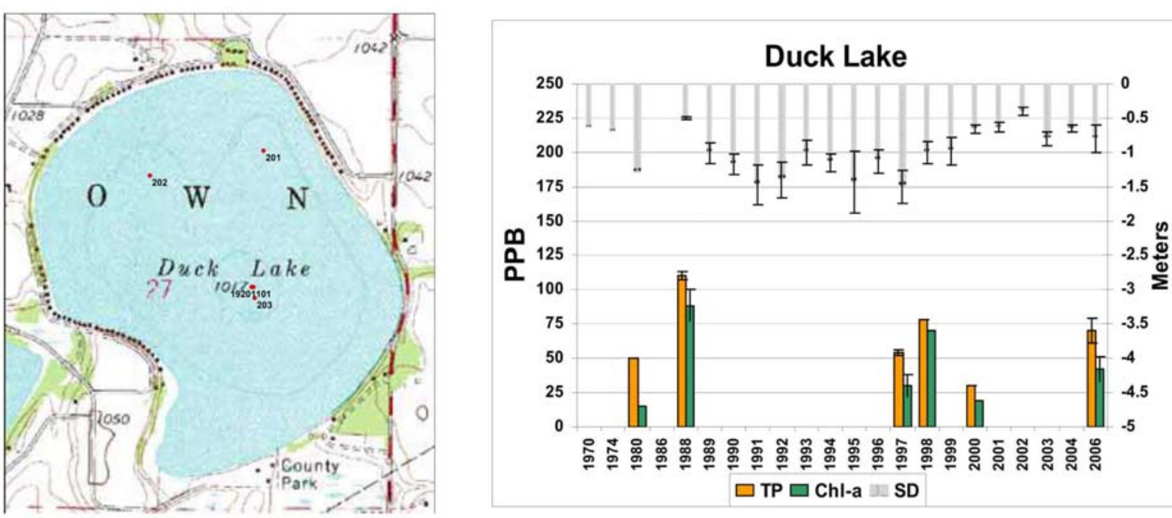
The Minnesota River Basin lies predominantly in the Western Corn Belt Plains (WCBP) and Northern Glaciated Plains (NGP) ecoregions. The chart above illustrates the different characteristics of this part of the state. Note the generally higher TP, chorophyll, Nitrates, TSS, and turbidity in these regions (MPCA, 2003).

Shallow Lakes—Nutrient Rich

A MPCA Study of Shallow Lakes of Southwestern Minnesota concluded: Most of the lakes are very nutrient rich. The high Total Phosphorus (TP) concentrations contribute to high chlorophyll-a, which is expressed as nuisance blooms of algae. Many of the lakes are dominated by blue-green algae that float near the surface and contribute to perceptions of “swimming impairment’ or “no swimming.” All lakes have highly agricultural watersheds, which is typical for lakes in these two regions. Agriculturally- dominated watersheds have higher P export values (expressed as stream TP) than watersheds characterized by forested and wetland land uses. Most of the lakes in this study did not have adequate data to assess trends. CLMP data, which is often a primary database for assessing trends in Minnesota lakes, are spotty or absent for most of the lakes. However, based on modern-day data (used in this report) and diatom-inferred data (Heiskary and Swain, 2002) no region-wide statements regarding trends can be made for the Western Corn Belt Plains (WCBP) and Northern Glaciated Plains (NGP) ecoregions.

Blue Earth County Lake Study—Mixed Trends

Figure 29. Duck Summer Mean Water Quality Trend and Sampling Locations



A MPCA study examined 6 lakes in Blue Earth County and found mixed trends. The example above shows Duck Lake, a small lake in Blue Earth County. It showed a significant decrease in transparency from 1997-2002. Total Phosphorus (TP) and chlorophyll-a are variable and show no consistent trends (MPCA, 2006).

Lakes: Water Quality continued

Toxic Blue Green Algae—When in Doubt, Stay Out

Toxic Blue Green Algal bloom
Crystal Lake, MN

Blue Green Algal bloom
Bass Lake, MN

Most algae are harmless but in high concentrations, a type of algae called "blue-green" (cyanobacteria) algae can be toxic. People or animals who contact toxic blue-green algae blooms can become sick. In recent years Minnesota has had increased reports and documentation of harmful algal blooms (HAB). People or animals may develop skin irritation or upper respiratory problems from exposure to HAB, and in extreme cases, dogs and other animals have even died after drinking lake water containing these toxins.

Blue green blooms typically occur on lakes with poor water quality (high in nutrients), and are often described to look like green paint, pea soup, or a thick green cake. A combination of factors will typically cause an algae bloom. Excessive nutrients, still waters, warm temperatures, and lots of sunlight all encourage the growth of blue-green algae. Recently Minnesota has done several studies and outreach efforts to better understand the risk of HAB and to improve public awareness. http://www.pca.state.mn.us/water/clmp-toxicalgae.html Unfortunately, there is no visual way to assess the toxicity of an algae bloom. Protect yourself and animals by staying away from dense algal blooms. When in doubt stay out!

Pesticides in Lakes

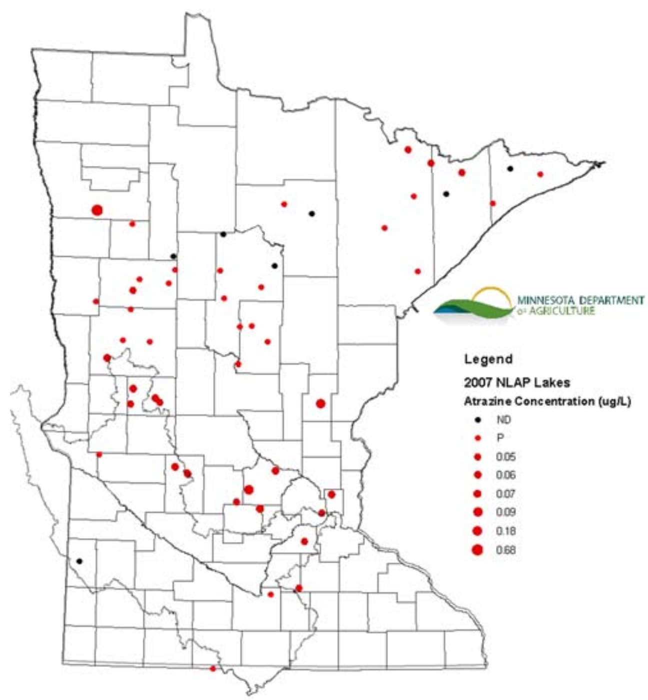
The Minnesota Department of Agriculture monitors for pesticides in lakes across the state. The MDA sampled 53 lakes for the 2007 Pesticides in Minnesota Lakes Study. Key findings include:

- **Pesticides Detected in Most Lakes:** A pesticide or a pesticide degradate was detected in 91 percent of the samples collected from Minnesota lakes. Concentrations of all detected pesticides were well below the Minnesota aquatic life standards and other reference values used by the Minnesota Department of Agriculture.

- **Atrazine** was detected in 87 percent of the 53 sampled lakes in Minnesota including lakes far from areas of assumed atrazine application. The concentration of atrazine was higher in samples collected from rivers then those measured in lakes located in the same Pesticide Monitoring Regions (PMR). Atmospheric deposition is suspected as the primary method of transport in lakes where pesticides, primarily atrazine, are detected far from areas of application. The degradate detected at the greatest frequency was deethyl atrazine a breakdown product of atrazine. Other pesticide degradates were found less frequently but at higher concentrations.

- **Agricultural Watersheds:** Lakes in lakesheds with row crop agriculture as a dominant land use had higher concentrations of total pesticides. This may be the result of direct runoff from adjacent lands or from greater atmospheric deposition due to closer proximity to areas of application. Lakes within lakesheds dominated by cultivated agriculture had substantially higher total pesticide concentrations than lakes within lakesheds dominated by urban and forest/water land use (MDA, 2008).

Pesticides Detected in Lakes: Atrazine in 2007



Fifty-five pesticide samples were collected from lakes throughout Minnesota in 2007. The map above shows Atrazine concentrations in lakes (MDA, 2008).

Ground Water: Quantity

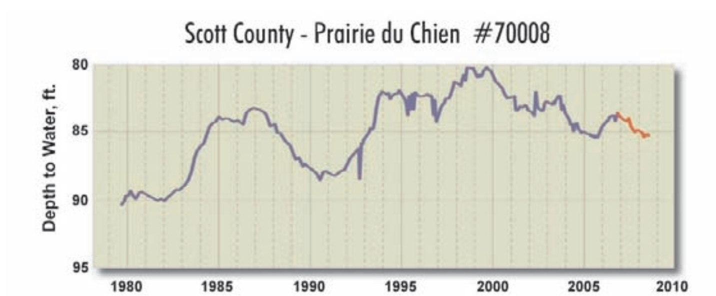
Moderate to limited availability

Researchers are still learning about the extent of ground water supplies in the state. The Minnesota Department of Natural Resources (MDNR) is the primary state agency responsible for managing the quantity of Minnesota's ground and surface waters. The MDNR maps aquifers and issues water-use permits to balance competing demands and to protect natural resources.

Ground Water Availability

MDNR's map of ground water availability shows that Minnesota's ground water resources are not evenly distributed. Ground water in the Minnesota River Basin is illustrated primarily within areas "5" and "2" on the map at right. Ground water of adequate quality for drinking and other desired uses has always been scarce in southwest (and northwest) Minnesota because of the natural geologic and hydrologic conditions in these areas. To overcome the problem of finding water of adequate quality and quantity for drinking and other needs, rural water systems have been constructed in some communities in the southwest. (MDNR, 2005 map, MPCA 2007).

The MDNR is the agency responsible for ground water level monitoring. The extent of ground water supply is not well understood and is currently being studied. Jim Sehl, MDNR's ground water specialist in southern Minnesota stated that "in many cases, there's considerable uncertainty about how much water is available underground." Ground water level monitoring began in 1942 and now consists of a network of 750 observation wells across the state. Data from these wells is used to determine many issues including the impact of pumping and climate and to assess long term trends. There is a diversity of results depending on the aquifer type (unconfined, confined) location, and use. A couple examples from observation wells within the Minnesota River Basin provide some insight into ground water trends.



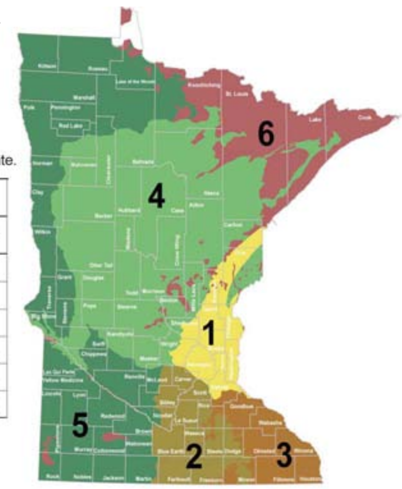
Jordan and Prairie du Chien Aquifers (confined bedrock)

The Jordan and Prairie du Chien aquifers are bedrock aquifers (see map next page). The observation well in Scott County Prairie du Chien aquifer (above) has varied water levels from 1980 to present. The water levels have decreased since the levels observed in 2006 but the same decrease is not observed for the same aquifer in neighboring Rice and Hennepin county observation wells,

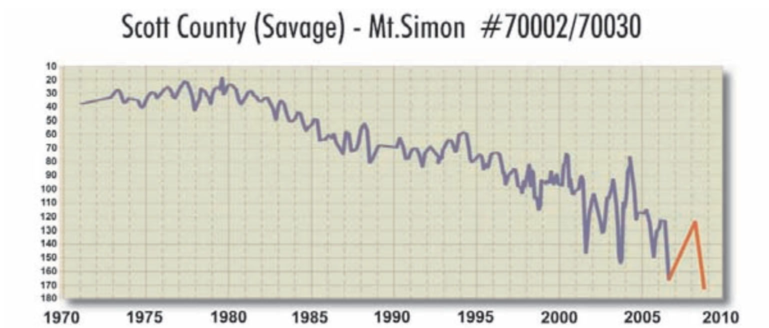
Minnesota's Ground Water Provinces

TABLE 1. Ground-water availability in the state.

Area	General Availability of Ground Water by Source		
	Surficial Sands	Buried Sands	Bedrock
1	Moderate	Moderate	Good
2	Limited	Moderate	Good
3	Limited	Limited	Good
4	Good	Moderate	Limited
5	Moderate	Limited	Limited
6	Limited	Limited	Limited



Source: MDNR 2005



Mt. Simon Aquifer (confined)

Results from the southern Metro observation well in Scott County near Savage showed water levels in 2008 the lowest ever measured and continues a downward trend in water levels that began in 1980. MDNR attributes this long term decline partly to climate and partly to pressures exerted on this aquifer from development in the area (MDNR, 2009).

What is an Aquifer?

An aquifer is a body of rock or sediment that stores and transmits large amounts of ground water. An aquifer typically consists of sands and gravels with interconnected pore spaces or rocks with numerous interconnected fractures or cavities. Aquifers may be unconfined or confined.

Confined Aquifer–These aquifers are separated from the ground surface by a material of low permeability. Confined aquifers include buried drift and bedrock aquifers.

Unconfined Aquifer–In Minnesota, unconfined aquifers are typically composed of glacial sand and gravel. These aquifers have the water table exposed to the atmosphere. They are also called water table or surficial aquifers.

Ground Water: Water Quality

Nitrates and Arsenic are pollutants of concern

Ground Water Timeline

1960s
In the early 1960s the Minnesota Geological Survey (MGS) began to investigate Minnesota's bedrock aquifers, beginning with aquifers in urban areas.

1972
The MGS published a comprehensive survey on the geology of Minnesota that noted "reliable data on the … aerial extent of bedrock aquifers are generally only available for the major urban centers. However, even in the urban areas, specific information on the physical and chemical environments of the geologic units generally is poorly known."

1978
MPCA and USGS develop a ground water monitoring plan

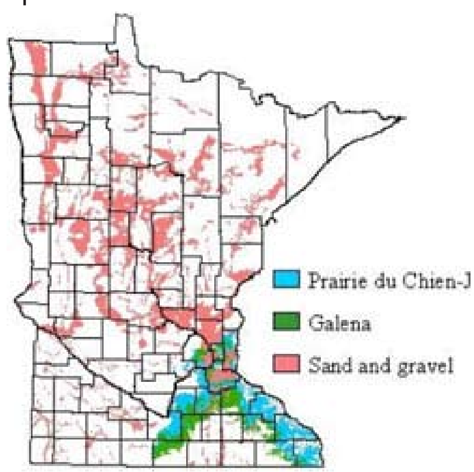
1989 Minnesota's Ground Water Protection Act
By the mid-1980s the presence of ground water contamination around the sate and its considerable impact on those affected was becoming well known. This protection act was triggered by severe drought in 1988.

1992-1996
MPCA collected ground water samples from domestic water supply wells from most Minnesota counties.

1998
Baseline Study published by MPCA provided information about ambient ground water quality in Minnesota's principal aquifers.

The Minnesota Pollution Control Agency (MPCA), Minnesota Department of Agriculture (MDA), and Minnesota Department of Health (MDH) each have important statutory responsibilities in protecting the quality of Minnesota's ground water, but only the MPCA and the MDA conduct statewide ambient ground water quality monitoring. The MDH conducts ground water monitoring in order to regulate public and private water supply wells and public water supplies, and evaluate the risk to human health from contaminants in ground water.

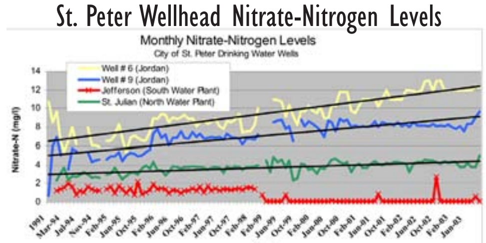
Aquifers Vulnerable to Pollution



Source: MPCA 2006

In Minnesota, geology largely dictates aquifers that are vulnerable to pollution. Aquifers that meet the designation of "vulnerable" include water table or unconfined aquifers, and the Prairie du Chien, Jordan and Galena bedrock aquifers at locations where there is no significant protective soil cover overlying the bedrock. The water table aquifers are typically composed of unconsolidated sand and gravel that was deposited by glacial activity in recent geologic time; these near surface aquifers occur throughout the state. The Prairie du Chien, Jordan, and Galena bedrock aquifers are considered vulnerable primarily in the Twin Cities and southeast Minnesota, where they outcrop at or near the ground surface.

St. Peter Wellhead Nitrate-Nitrogen Levels



Major Pollutants: Nitrates & Arsenic

Major ground water pollutants of concern in the basin include nitrates and arsenic. Nitrate is a common contaminant found in many wells throughout Minnesota. Wells most vulnerable to nitrate contamination include shallow wells, dug wells, and wells with damaged or leaking casings. Major sources of nitrate contamination can be from fertilizers, animal waste, and human sewage. Arsenic occurs naturally in some soil and rock and can leach into groundwater. Almost all arsenic in drinking water is from underground deposits of naturally occurring arsenic. Statewide arsenic sampling in Minnesota indicates that a significant area of the state has detectable concentrations of arsenic in ground water (MCPA, 1995), Approximately 14% of sampled wells exceeding the arsenic standard of 10 µg/l., Arsenic is particularly concentrated in western Minnesota where over 50% of the 900 sampled private drinking water wells had arsenic over 10 µg/l (MDA, 2001).

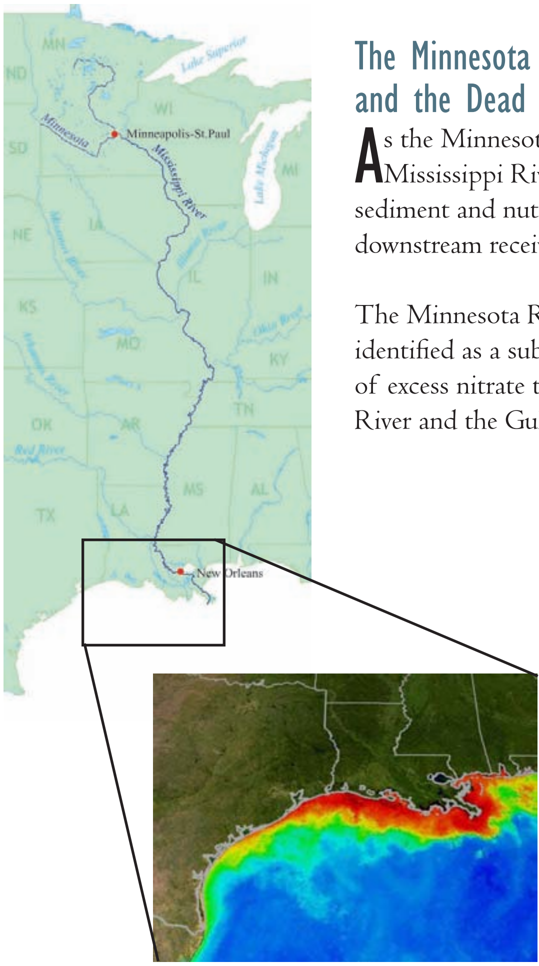
Municipal Systems - MDH

Municipal systems are monitored closely by MDH to meet health standards. Their source water protection program is designed to help prevent contaminants from entering public water sources. The program includes wellhead protection (capture zone for the well), source water assessments (description of water source), and where needed protection of surface water intakes.

St. Peter Wellhead Protection Program
States are required to have wellhead protection programs under the provisions of the 1986 amendments to the federal Safe Drinking Water Act. A case study example includes the St. Peter Wellhead Protection Program where nitrate is the primary contaminant of concern. The graph (at left) shows nitrate concentrations steadily increasing from 1991-2003. The city blends water from different wells to stay within public health guidelines (BNC, 2003).

Downstream Impacts: Nitrates & The Dead Zone

A substantial contributor of excess nitrate



NASA Visible Earth Program
Image from 2004

In 2008, the Dead Zone in the Gulf of Mexico stretched 7,988 square miles measuring second largest since measurements began in 1985. Source: NOAA, 2008

The Minnesota River and the Dead Zone

As the Minnesota River flows into the Mississippi River, it carries excess sediment and nutrients which impact downstream receiving waters.

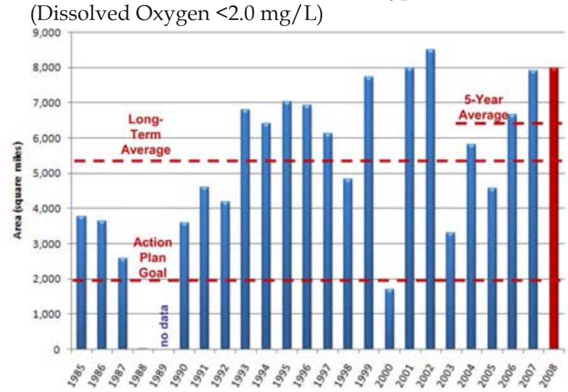
The Minnesota River has been identified as a substantial contributor of excess nitrate to the Mississippi River and the Gulf Region.

Science Museum of Minnesota

Gulf of Mexico algal blooms

Size of the Gulf of Mexico Dead Zone

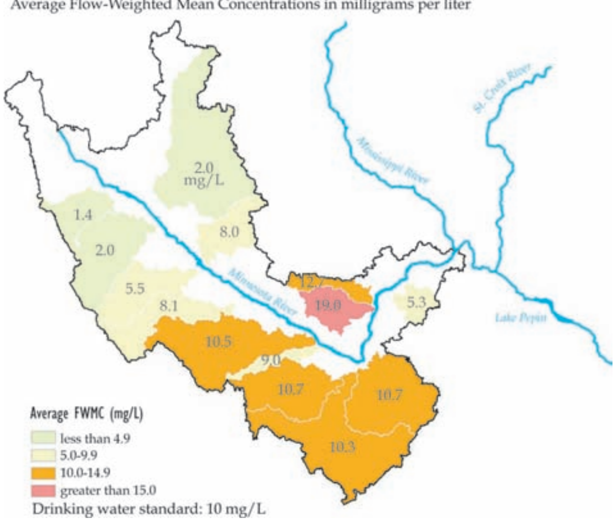
Area of Mid-Summer Bottom Water Hypoxia
(Dissolved Oxygen <2.0 mg/L)



The size of the Gulf of Mexico Dead Zone is increasing. The average size of the Dead Zone over the past 5 years has been 6,600 square miles. The long term average is 5,300 square miles (NOAA, 2008).

Total Nitrate-Nitrogen

Average Flow-Weighted Mean Concentrations in milligrams per liter



This map shows the average flow-weighted mean concentrations of Nitrate-Nitrogen across the Minnesota River Basin 2000-2005. Elevated Nitrate levels can stimulate excessive levels of algal growth in streams.

Met Council

Algal blooms and dead fish

What is the Dead Zone?

In recent years, this problem has been particularly severe in the Gulf of Mexico where development of a hypoxic zone (hypoxia means "low oxygen") has been linked to elevated nitrate levels carried to the Gulf by the Mississippi River. Reduced oxygen levels in the hypoxic zone, brought on by decomposition of algae, have damaged the shellfish industry and continue to threaten the aquatic ecosystem of the Gulf Region.

Downstream Impacts: Sediment, Phosphorus & Lake Pepin

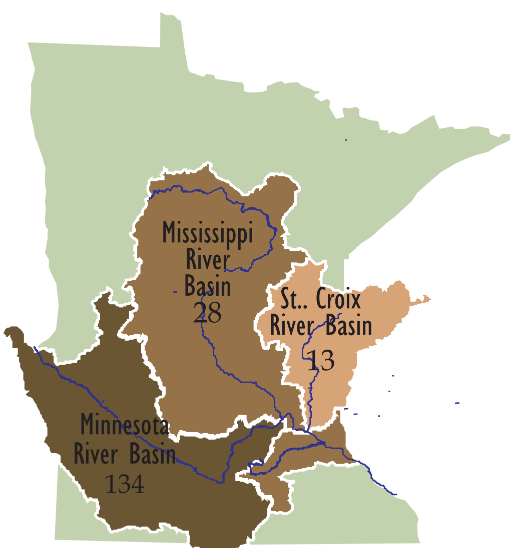
Lake Pepin is filling in with sediment at about 10 times its natural rate. At this rate, it will be completely filled with sediment within 340 years.

Lake Pepin lies downstream of the confluence of the Minnesota and Mississippi Rivers. It is a naturally occurring lake, and part of the Mississippi River on the border between Minnesota and Wisconsin.

Lake Pepin is filling in

As the Minnesota River flows into the Mississippi, it carries excess sediment and nutrients. Three rivers contribute sediment to Lake Pepin: The Minnesota, St. Croix, and Mississippi Rivers. Scientists have studied sources of sediment into the lake and determined that the Minnesota River contributes approximately 85 percent of the sediment load.

Total Suspended Sediment Yield
(Pounds per acre, per year)

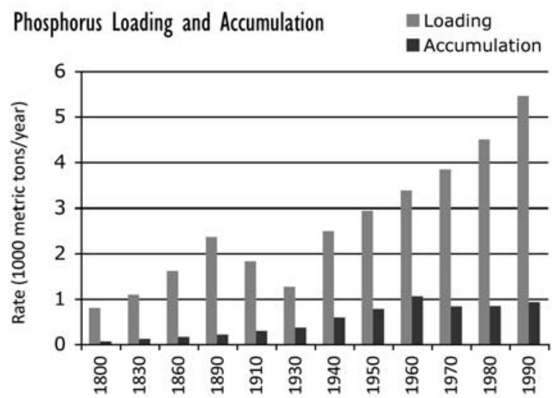


Sources: Engstrom and Almendinger, 2000
Nater and Kelley, 1998

Elevated Phosphorus Levels

Lake Pepin

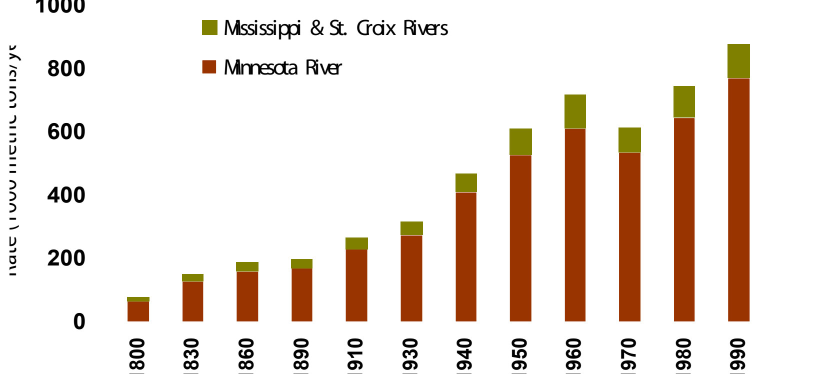
Phosphorus is accumulating in the sediment at 15 times the natural rate. Phosphorus loading to the lake appears to have increased by about seven times (or more) above natural rates. Lake water Total Phosphorus concentrations have increased from about 50 ppb (parts per billion) to 200 ppb, making Lake Pepin highly eutrophic. Eutrophic means waters rich in mineral and organic nutrients promote a proliferation of plant life, especially algae (see photo below), which reduces the dissolved oxygen content and can cause fish kills.



Total phosphorus loading and accumulation from 1800 to 1990.
Source: Engstrom and Almendinger, 2000

Excess phosphorus concentrations can lead to algal blooms in Lake Pepin.

Sediment Accumulation and Sources Lake Pepin, 1800s-1990s



Sources: Kent Johnson, Metropolitan Council, 2000 & Engstrom and Almendinger, 2000