WATER YEAR DATA SUMMARY 2005-2006

2007

Minnesota

Department of Natural Resources

Waters

Introduction

This publication provides a review and summary of basic hydrologic data gathered through DNR Waters programs. There are four major areas of data collection, including climatology, surface water, ground water and water use. These areas are arranged in order of the hydrologic cycle (see diagram on page iv), and important facts are provided concerning the distribution and availability of Minnesota's water resources.

Basic hydrologic data are essential to a variety of water resource programs and related efforts. The extent of our knowledge depends on the quality and quantity of hydrologic data. Analysis and use of data are vital to understanding complex hydrologic relationships. With expanding technologies, there is a greater need for even more data of higher quality.

The DNR Waters website at **mndnr.gov/waters** provides a wealth of information on Minnesota's lakes, rivers and streams, wetlands, ground water and climate - much more than can be included in this summary report. Maps, publications, forms, educational resources and answers to common water resources questions can be found on the site. Visitors will find access to lake level data, stream flow information and ground water level data. The site, which is updated regularly, is intended to help the citizens of Minnesota become better stewards of the state's water resources by providing comprehensive information about those resources.

This report is a continuation of Water Year reports published by DNR Waters in 1979, 1980, 1991, 1993, 1995, 1997, 1999, 2001, 2003 and 2005. This edition is also available on our website.

Water Year

The climatology, surface water and ground water data presented are for Water Years 2005 and 2006.

WY 2005: October 1, 2004 - September 30, 2005
WY 2006: October 1, 2005 - September 30, 2006

Use of water year as a standard follows the national water supply data publishing system that was started in 1913. This convention was adopted because responses of hydrologic systems after October 1 are practically all a reflection of precipitation (snow and rain) occurring within that water year.

Water use data are reported and presented on a calendar year basis.

Acknowledgements

My first year of editing the Water Year Data Summary Report has been an eye-opener. I have increased respect for the work that has been completed in the past by recently-retired Glen Yakel and the writers/producers of previous reports. In addition, a lot of time and effort goes into the data gathering, data compilation and summary reports. As mentioned in virtually every chapter here, the usefulness of the data for interpretation of water-related issues is invaluable. Many thanks to all who make it happen.

Because of the increasing sophistication of data users, we thought that we would try a new way of providing the report. Desiring the flexibility of color and size, and the ability to link to websites of interest, we have opted to distribute the report in full color via the DNR Waters website. There will be an option of downloading separate chapters of the report. If you would like a printed version or compact disk (CD) of any portion of the report, please let us know and we will accommodate you.

Photographs have been added this year, most of which were taken by DNR staff, particularly from the Division of Waters. Although we weren't able to use all photos submitted, we thank all those people who took the time to respond to our request.

We wish to express our gratitude to the listed authors and others who contributed to this publication. Thank you to Nick Kroska for his proof-reading skills in refining this report. Special thanks to Jim Zicopula for assistance with layout and design.

Judy Boudreau, Editor

Kent Lokkesmoe, Director

Cover photo by Michele Hanson

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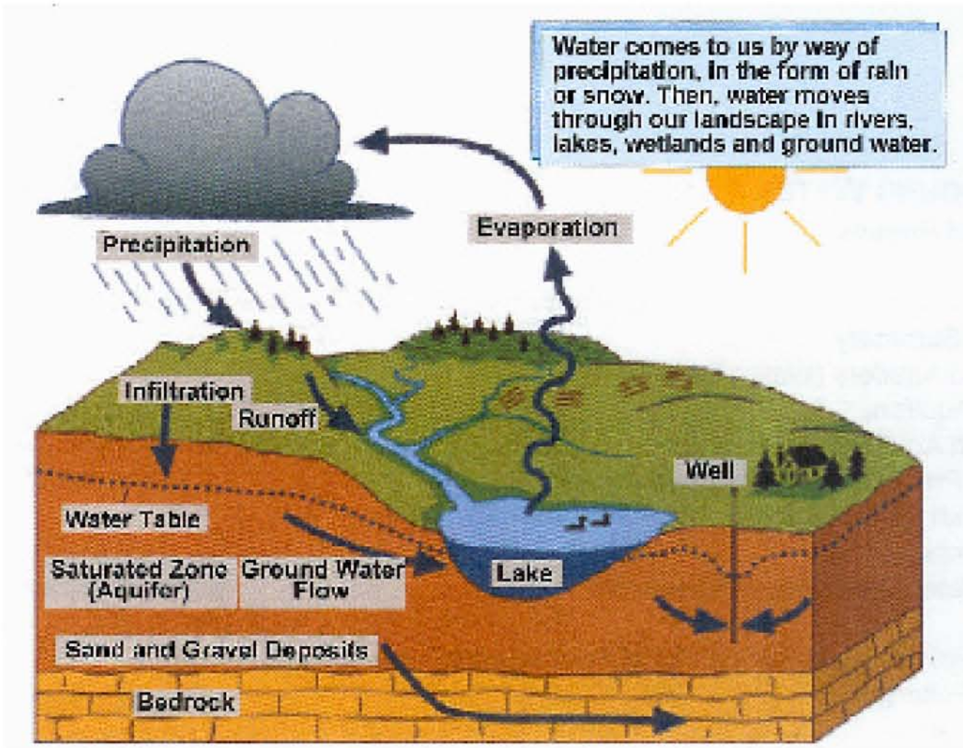
Hydrologic Cycle

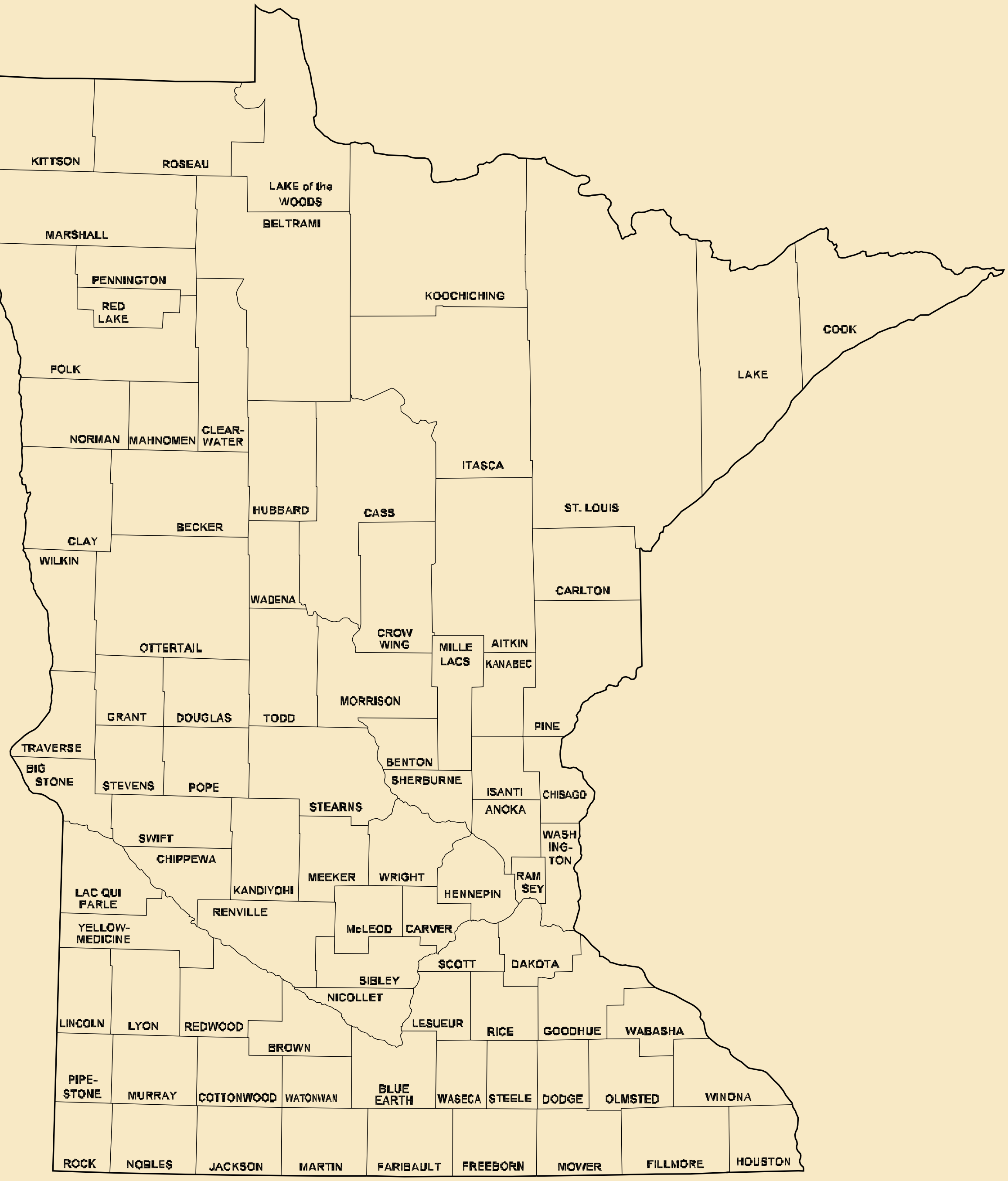


The hydrologic cycle is a concept used to explain the movement of water around the earth. This movement is continuous and has no beginning or end. Change at any point in the cycle will be reflected later in the cycle.

Surface water, which predominantly exists in oceans, is evaporated into the atmosphere by the energy of the sun. It returns to the earth as precipitation (rain or snow). As precipitation falls, it may be intercepted by vegetation and evaporate or it may reach the ground surface. Water that reaches the surface may either soak into the ground or move downslope. As it soaks into the soil (infiltration), it may be held in the soil or continue to move downward and become ground water. Ground water may be stored in the ground, returned to the surface as a spring, flow into a concentrated body such as a stream or lake, or be returned to the atmosphere by plant transpiration. Water that does not infiltrate the soil moves downslope, until concentrated areas form a stream. Streams lead to lakes and into other streams, which ultimately return the water to the oceans.

At any point where water is on the ground surface, it is subject to evaporation into the atmosphere or infiltration into the soil.

Minnesota Counties



Climatology

Chapter 1

Precipitation
Observer Network
June 2006
(1480 Observers)

**Precipitation
Observer Network
June 2006
(1480 Observers)**

Introduction

The DNR Waters State Climatology Office exists to gather and analyze climate data for the benefit of the State of Minnesota and its citizens. A variety of organizations provide climate data. These organizations rely primarily on the efforts of volunteer observers. The data are consolidated into a unified database and climate information is distributed to many users.

A review of climate information can assist in explaining a prior event or condition. Climate information aids long-range planning efforts by characterizing what is typical or extreme, likely or unlikely. Users of climate information include government agencies (local, state, federal), academic institutions, media, private sector professionals and the general public. Specifically, engineers use temperature and precipitation data to design roads and storm sewers. Wildlife managers use temperature and snow depth information to research animal health and mortality. Agricultural specialists use temperature and precipitation data to determine the types of crops that will grow in Minnesota. Others who rely on climate information include hydrologists, foresters, meteorologists, attorneys, insurance adjusters, journalists and recreation managers.

Climate Data Sources:

Soil and Water Conservation Districts
National Weather Service
University of Minnesota
Department of Natural Resources
- ***Division of Forestry***
- ***Division of Parks***
- ***Division of Trails and Waterways***
- ***Division of Waters***

State Climatology Office Back Yard Network
Metropolitan Mosquito Control District
Minnesota Association of Watershed Districts
Metropolitan Waste Control Commission
Minnesota Power and Light Company
Emergency Management Offices

Lorraine Hammerstrom

photo by Deb Rose

"Normal"

The word "normal" in this chapter refers to a 30-year mathematical average of measurements made over the period 1971-2000. Many individuals tend to (erroneously) perceive "normal" weather as what they should expect. Dr. Helmut E. Landsberg, former Director of Climatology for the U.S. Weather Bureau, summarized this misconception as follows: "The layman is often misled by the word. In his every-day language, the word 'normal' means something ordinary or frequent...When (the meteorologist) talks about 'normal,' it has nothing to do with a common event. For the meteorologist, the 'normal' is simply a point of departure or index which is convenient for keeping track of weather statistics."

The 2005 Water Year

October 2004-September 2005

Highlights

- Wet October and very dry November
- Snowy winter northeast, meager snow south
- Damp and cool spring
- Warm and wet June
- Dry and warm late summer
- Wet autumn 2005 south, continued dryness north

Autumn 2004

October

October 2004 was wetter than normal everywhere in the state except portions of the south. One of the main rainmakers was an event that stretched from Montevideo to Pine City on October 28, dumping a narrow streak of 5 or more inches of rain in southwestern Chippewa and southwestern Kandyohi counties. Considering the average monthly precipitation for October is just over 2 inches, this was a significant rainfall. Heavy Rains Fall on Central Minnesota October 28, 2004

The month started out more or less seasonably but there was a burst of summery weather with warm temperatures at the end of the month. Some record late-October dew point temperatures were recorded. Record Late-October Dew Point Temperatures in Southern Minnesota October 29, 2004

November

There was a significant lack of rain or snow across the state in November 2004, with the driest areas in the north. November was among the driest on modern record for a few communities with a scant 0.05 inch of melted precipitation recorded at Moorhead. But a swath of snow fell over the western and northern counties late in the month that brought some needed moisture.

November continued the mild fall that began in September. November wasn't record breaking but it was mild enough to contribute to the sixth warmest autumn (September to November) in the Twin Cities. The warm weather for both October and November was especially noted for mild overnight lows. As a result, lake ice freeze-up was delayed. Mild Autumn in the Twin Cities

Winter 2004-2005

December

December 2004 was another warm and dry month statewide. A taste of winter appeared with a strong Alberta Clipper on December 12. This clipper brought snow to the northeast and some very gusty winds statewide including a peak gust of 71 miles per hour (mph) at Welch in northern Goodhue County. Otherwise, snow was meager for the month and concerns about not having a white Christmas were widespread. Although just

An *Alberta Clipper*, also known as a Canadian Clipper, is a fast-moving, low-pressure area that generally affects the central provinces of Canada, as well as parts of the Upper Midwest and Great Lakes regions of the United States. Most clippers occur in winter but can occur outside of the season; generally, off-season clippers would occur in November.

enough snow fell to put those fears to rest, the month stayed dry overall.

December's monthly mean temperatures exceeded historical averages by 3 to 6 degrees in most locations. The warm temperatures on December 30 broke records in some communities, making the weather ideal for removing outdoor holiday decorations. Lamberton had a record high of 59 degrees on December 30. Balmy December 30th in southern Minnesota

January

Monthly mean temperatures in January 2005 were slightly below average in the northern one-third of Minnesota and somewhat above average in the southern two-thirds of the state. A bitterly cold period during the middle of the month was offset by above average temperatures later in January. Cold Mid-January

January precipitation finished from nearly normal to above normal statewide. The Arrowhead had especially high precipitation for the month. Many northeastern locales recorded 40 inches or more snow for the month. Duluth experienced its second snowiest January on record with 45.7 inches.

Numerous significant weather events occurred during January. A wintry mix of weather on January 1 brought heavy snows to northern Minnesota and a sheet of freezing rain and sleet to southeastern counties New Year's Day Winter Storm January 1-2, 2005. It was like shoveling shaved ice in the Twin Cities. On January 12, a narrow swath of 3 to 8 inches of snow fell across western and central Minnesota. Lake effect snow blanketed North Shore communities with a foot or more of snow on January 20, 21, and 22 Deep Snow in Northeast Minnesota. On January 21, a strong storm system dropped into Minnesota from the Canadian prairie, leaving behind 6 to 9 inches of snow across west-central, central, and southeastern Minnesota. Snowstorm and Blizzard: January 21-22, 2005 For many east-central Minnesota communities, this was the first substantial snow of the season.

February

In February 2005, northern Minnesota missed some of the winter storms and finished nearly average or somewhat below average for monthly totals of precipitation. The southern one-third of the state reported above normal precipitation. A mid-month storm hit the south, with some southern communities reporting around three-quarters of an inch of liquid from this event, which set new daily precipitation records for February 13.

Warm temperatures eroded the snow pack until no snow lay on the landscape southwest of the Twin Cities by early February. The monthly mean temperatures were quite warm and finished 3 to 7 degrees above the historical average. For the meteorological winter 2004-2005 (December to February) it was the eighth time in 9 years that the average winter temperature finished above normal. Record Warmth: February 3-4, 2005

Spring 2005

March

A "tournament snowstorm" punctuated March precipitation Boy's Basketball Tournament Snowstorm: March 17-18, 2005. Heavy snows fell on March 17-18 from northern Iowa to the Twin Cities. The greatest snowfall was 21 inches at Kiester in Faribault County. This storm, and an area of heavy rain and thunderstorms later in the month, helped the south have monthly precipitation totals close to normal. The northern and central parts of the state finished with somewhat below normal precipitation.

March 2005 monthly mean temperatures were near the historical average across Minnesota. Warmer than average temperatures at the end of March were offset by cooler than average temperatures early in the month.

April

April 2005 monthly precipitation totals varied widely across Minnesota. Monthly precipitation totals across much of the northern one-third of the state were well below average, whereas portions of the central and south received above average precipitation. Many areas in the northwest and northeast reported less than a half inch of precipitation for April. By contrast, places like Mankato received more than 4 inches of rain for the month.

April arrived with temperatures more like May. The first 17 days of the month were 10 degrees above average statewide. Even the Arrowhead, which still retained a snow pack at the beginning of the month, was 7 degrees above average. The balmy conditions accelerated ice-out across the state. In general, lakes were ice-free from 3 days to a week ahead of average in central parts of the state and 7 to 10 days ahead of average in the north. A cold spell in the final days of the month came after virtually all the lakes in the state were ice-free. Minnesota's Lake Ice-Out Status as of April 25, 2005

May

Soggy tomato plants and scarce sunshine dominated the first 3 weeks in May. May 1-18 was the least sunny start of May since solar records began at the St. Paul Campus Climate Observatory in 1963. Gloomy May 1-18 in the Twin Cities Many locations reported rainfall on more than half the days in May. Monthly rainfall totals topped 7 inches in some southwestern and south-central counties. Precipitation totals exceeded normal by more than 2 inches across much of the southwestern, south-central and north-central parts of the state.

Stream discharge values for two-thirds of Minnesota's rivers and streams ranked above the 75th percentile by the end of May. In a few areas, streamflows exceed the 90th percentile when compared to historical data for this date. Some minor flooding occurred in the Red River basin.

May was cool with a statewide average temperature of 3 degrees below normal. The first 3 days of the month averaged 14 to 16 degrees below normal. Record low maximum temperature records were set in some locations on May 1, 2, and 12.

Summer 2005

June

Rainfall was frequent and abundant in June 2005. June rainfalls exceeding 6 inches were common across the state. There were a few heavy rain events of note during the month. The first one affected southeastern counties on June 7 and 8. Multiple waves of thunderstorms led to flooding in Wabasha, Goodhue, Rice, and Le Sueur counties. The flooding was responsible for one fatality in Goodhue County. Heavy Rains and Severe Weather Over Southeast Minnesota June 7-8, 2005

On June 20, a powerful line of thunderstorms rolled across Minnesota, creating extensive wind damage in west-central Minnesota and urban flooding in communities such as Worthington, St. Cloud, and the Twin Cities. Heavy Rains and Severe Weather Over Minnesota June 20, 2005

June 2005 was the start of a warm summer with warmer than normal temperatures statewide. Monthly mean temperatures were 1 degree or 2 degrees above normal in the north and 3 to 5 degrees above normal in the south. In some southern communities, June mean monthly temperatures ranked among the 10 warmest on record. The mean monthly temperatures were elevated largely because of a preponderance of very warm nighttime conditions.

July

Precipitation totals fell short of historical averages across much of the state in July 2005. Totals were less than 3 inches across much of Minnesota and less than 2 inches across significant portions of central and northern counties. Monthly rainfall deviated below historical averages by 2 or more inches in many areas. Rainfall deficits exceeded 3 inches in portions of east-central and northeastern Minnesota. When compared to other July rainfall totals in the historical database, July 2005 rainfall totals rank among the lowest on record for some central and northern locales. Combined with high evaporation rates due to warm July temperatures, the precipitation shortfall led to low streamflows and increased wildfire danger in many communities. Dry July 2005 - maps

Despite the dryness, there were two significant precipitation events. The heaviest rainstorm came on July 2. Because of very strong thunderstorms skirting the Canadian border, a small area of north-central Kittson County received more than 5 inches of rain in a relatively short time. Falling on already saturated ground, the deluge led to significant overland flooding. Heavy Rains and Severe Weather Over Kittson County July 2-3, 2005 Some beneficial rains came with thunderstorms on July 25 that soaked a substantial portion of the state's corn and soybean growing areas. From 1 inch to 3 inches of rain fell over many south-central and southeastern counties.

July 2005 monthly mean temperatures were 1 degree to 3 degrees above normal in most areas. As happened in June, temperatures in July were consistently warm. Roughly two-thirds of all July days were at or above average. Relatively few cool spells broke up July's typically warm weather. Mark Seeley's July 29, 2005 Minnesota WeatherTalk for MPR's Morning Edition

August

The dry spell that began in July continued into August. Dry July and August 2005 Some heavy rain events brought relief to some areas, but most places remained dry. The Arrowhead was extremely dry, with precipitation totals falling short of historical averages by 2 or more inches. August rainfall totals in sections of Carlton, St. Louis, and Lake counties were among the lowest on record. July plus August 2005 rainfall totals ranked among the lowest on record in some locales. By contrast, northwestern, west-central, south-central, and southeastern parts of the state reported very heavy August rainfall. The above normal precipitation in these areas was the result of a few, very intense rainfall events.

On August 17 and 18, intense thunderstorms dropped more than 5 inches of rain on portions of Cottonwood, Jackson, Watonwan, Martin, and Blue Earth counties. Nearly 8 inches of rain fell in a small portion of south-central Watonwan County. Heavy Rains Drench South Central Minnesota August 17-18, 2005

On August 25 and 26, severe thunderstorms produced hail, high winds, and torrential rain over a multicounty area of west-central Minnesota. Rainfall totals topping 5 inches were reported in sections of Douglas, Pope, Stearns, Swift, Kandiyohi, and Chippewa counties. More than 8 inches of rain was recorded in northwestern Kandiyohi County during this event. Torrential Rains Fall Upon West Central Minnesota August 25-26, 2005

August 2005 monthly mean temperatures were near average in most areas. The very warm temperatures of June and July persisted into the first week of August. Temperatures then moderated for the remainder of August, leading to a rather remarkable stretch of pleasant weather.

Autumn 2005

September

September 2005 was more of an extension of summer than the beginning of autumn. For the southern half of Minnesota, the 2005 growing season ended on a very wet note. For many locations in the central and southern Minnesota, September 2005 precipitation totals exceeded 7 inches. Precipitation totals for some locations in east-central counties topped 10 inches for the month. Rainfall totals across large sections of southern Minnesota were 4 or more inches above normal for September. Precipitation departures were 6 inches above normal in some areas. Wet September 2005 - Southern Minnesota

In contrast, rainfall totals were well below historical averages across much of northeastern and north-central Minnesota in late summer and early autumn 2005. Dry July and August conditions experienced throughout Minnesota persisted into September in these areas. Dry July through September 2005 in Northeastern Minnesota

Monthly mean temperatures for September 2005 were much above normal across the state. September mean temperatures topped the historical average by 4 or more degrees in most locales. In the Twin Cities, the mean daily temperature was above average for 25 of 30 September days.

Water Year 2005 Summary

For the 2005 Water Year, precipitation totals were above normal for the most of the southern tier counties and the western counties as well. Some of the wettest spots were Martin County; the northern part of the county was 10 inches above normal. Wilkin County in west-central Minnesota was about 8 eight inches above normal. Another region with above normal precipitation was just southwest of International Falls, which was 8 inches above normal. Some drier than normal areas were found in a few pockets scattered around the state, most notably in the northeast with parts of southern St. Louis County 4 inches below average.

Figure 2

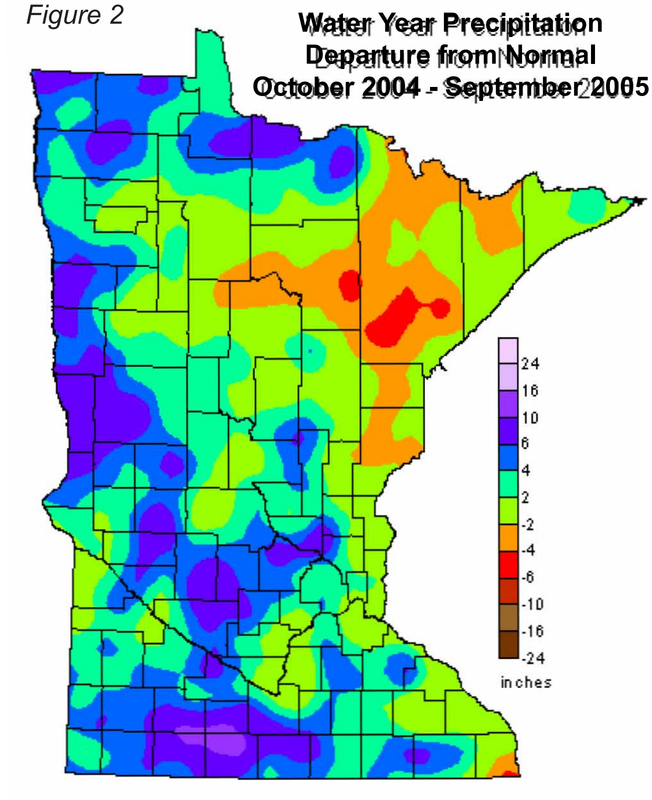


Figure 1

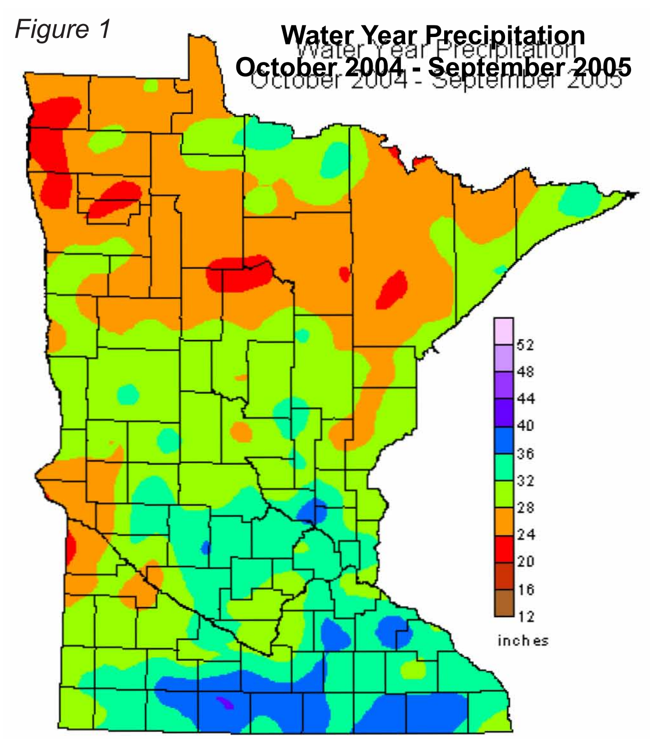
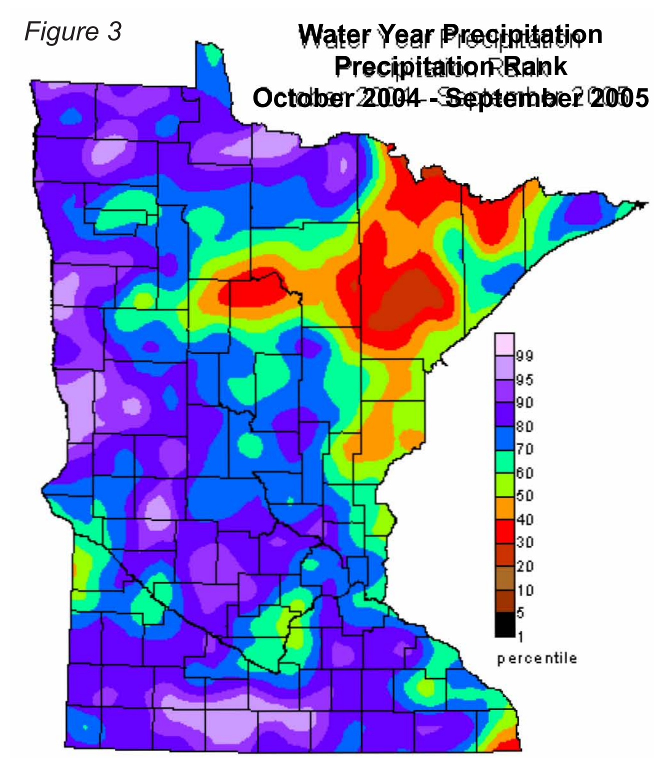


Figure 3



The 2006 Water Year

October 2005-September 2006

Highlights

- Very warm and wet autumn
- Record warm January
- Wet spring
- Worst drought since 1988 from late spring to autumn

Autumn 2005 cont'd...

October

October began with a rare deluge for this time of year. A large portion of central and southern Minnesota received more than 2 inches of rain. Central and east-central counties received the most rain, recording up to 6 inches. A 6-inch daily rainfall total in October is nearly without precedent, occurring only one other time in the historical record. The 6.61-inch rainfall report from Wild River State Park (Chisago County) is now the largest single-day October value reported by a National Weather Service Cooperative Observer. Needless to say, the monthly totals for east-central counties exceeded average due to this one event. The parched northeastern part of the state received some beneficial rains. The southeast was largely missed in October 2005 and fell about an inch below average for the month.

photo by Z

October was warm statewide. During the first few days, warm and muggy air fueled the intense rainfall and set the stage for above normal temperatures for several days during the month. The average statewide temperature for October finished nearly 3 degrees above normal.

November

The wet autumn continued into November. A powerful storm moved through on November 28th and 29th. Redwood Falls and Willmar both saw more than an inch of precipitation. Duluth had just under an inch. The normal precipitation for the month of November is around 2 inches in eastern Minnesota, and about 1 inch to 1.5 inches over western Minnesota. At the same time, cold air prevailed over western and northern Minnesota and the rain that fell there became glaze ice. The ice coated branches and power lines especially throughout western Minnesota. The strong winds associated with the storm caused frozen power lines and poles to snap in places in southwest and west-central Minnesota, bringing back memories of the spring blizzard of 1997. Most places in the state wound up with above normal precipitation for the month. From September to November, St. Cloud had the wettest fall in 113 years of record-keeping.

November was another mild month. The average statewide temperature was 4.5 degrees above normal, which left few excuses for not completing that fall yard clean up. In fact, September through November 2005 was tied for the sixth warmest autumn in the Twin Cities. Until the storm of November 28-29, there was little snow of any consequence in the state. Top Ten Warm Autumns in the Twin Cities 1891-2005

Winter 2006

December

The first three weeks of December were reminiscent of the winters of yore with temperatures like January and a decent snowstorm as well. This and a second winter storm late in the month were enough to boost the monthly precipitation into the above normal category for the state. The first storm was a double-barreled system that brought a significant blanket of snow across much of the eastern half of Minnesota beginning in the evening hours of December 13. Winter Storm: December 13-14, 2005 Another winter storm swept through the state on December 29 and 30, dropping a swath of snow across much of the state. The highest snow total for this event was 11 inches in Madison of Lac Qui Parle County. Precipitation and Temperature Summary for December 2005

Colder than normal Decembers have been unusual in recent years and December 2005 was no exception. Despite the first three weeks of the month being cooler than normal, warm and cloudy conditions pushed the statewide average to 2.4 degrees above normal. A gloom settled over the region for the last week of December and persisted into the start of the New Year. The Twin Cities had its third gloomiest 12-day stretch in 42 years. Gloomy Conditions in Minnesota: December 24, 2005 - January 4, 2006

January

January 2006 was warm and dry, thanks mainly to a west to east wind pattern that persisted for much of the month. January snowfall was light; only areas along the Canadian border were blessed with any appreciable snow. The statewide average precipitation was about a third of an inch below normal.

The pinnacle of the nearly nonwinter of 2005-2006 was the warmest January in the modern record for the state. The persistent clouds and fog during the first week in January elevated overnight low temperatures. This was a major contributor to the record-breaking January. The average statewide temperature was an incredible 17 degrees above normal. Minnesota's Warmest January on Record: 2006

Winter 2006 cont'd...

February

February 2006 had some semblance to a "normal" winter. Colder weather returned along with some snow, at least for parts of the state. A classic Colorado winter storm moved from Iowa to Chicago during the day on February 16, bringing just flurries to the Twin Cities but a sizable blanket of snow to the southeast. Measurable snow fell roughly south and east of a line from Jackson to Farmington. Another storm dropped some heavy snow from Fargo to Duluth on February 24-27. Precipitation totals statewide were somewhat below historical averages, except for an 80-mile wide swath in the north that was the recipient of the heavy snows late in the month. Snowstorm Clips Southeast Minnesota: February 15-16, 2006

February 2006 monthly mean temperatures were near average in the southern half of Minnesota. In the northern half of the state, February temperatures were 2 to 5 degrees cooler than average. A warm start to the month was counterbalanced by a midmonth cold snap. The arctic outbreak on February 17 and 18 led to dangerous wind chill temperatures in many areas. Despite the somewhat cooler February, the meteorological winter of 2005-2006 finished well above normal. It was the ninth warmest winter on record for the Twin Cities. Yet Another Balmy Winter: 2005-2006

Spring 2006

March

Precipitation totals for March 2006 were above average in the northern and southern thirds of Minnesota. Precipitation topped historical averages by 0.5 inch to 1.5 inches in these areas. In the central one-third of the state, precipitation generally fell short of average by 0.5 inch to 1 inch.

Two of the larger snow producers of March occurred during the third week of the month. On March 12 and 13, 6 to 12 inches of moisture-laden snow fell on southern and east-central Minnesota. Heavy Snow over Southern and Central Minnesota: March 12-13, 2006 A location near Hastings reported 19 inches of snow during this event. Just two days later (March 15-16), another winter storm dropped 4 to 8 inches of snow over many of these same areas. More Snow over Southern and Central Minnesota: March 15-16, 2006

Moderate to heavy rain fell on March 30 and 31 across much of the state. Rainfall totals were generally from 0.5 inch to 1 inch. Daily rainfall records were set in some communities on the March 31. This rain exacerbated the flooding situation already in place for the Red River of the North.

Mean temperatures for March were above average in the northern third of the state and somewhat near average in the south. The middle of the month featured a cold wave that lasted about a week and delayed the snowmelt. The rapid transition to warmer temperatures in the month caused the snow pack to collapse in a few days to heighten the flood risk.

April

The wet weather that started at the end of March continued into April. Far southern Minnesota had one of the wettest Aprils on record. Along the southern tier of counties, monthly rainfall totals topped 6 to 8 inches.

The heaviest rainfall events of April occurred during the first and last weeks of the month. Rainfall totals topped 3 inches during the first week of April along the southern tier of Minnesota counties. An April 6-7 event broke daily rainfall records for Fairmont, Albert Lea, Rochester, and elsewhere. On April 6, 2.58 inches of rain fell at the Twin Cities International Airport, the wettest April day of the modern record. Heavy Springtime Rains over Southern Minnesota: April 6-7, 2006 The month of April ended on a wet note as well. A remarkably persistent rain event dropped 1 inch to 3 inches of rain over a large portion of Minnesota during the final three days of the month. A Wet Finish to April: April 28-May 1, 2006; Precipitation Map for April 25 - May 1, 2006

Moderate to major flooding was in progress for the Red River of the North during the first week of April. Thanks to past flood mitigation efforts, damage was not as severe as in the floods of past years. The Red River of the North remained near or above flood stage for the rest of April.

April 2006 mean temperatures exceeded the historical average by 4 to 8 degrees in the state. Daily mean temperatures during a 9-day period in mid-April were consistently 10 to 20 degrees above normal. Many new records were broken in southern Minnesota on April 13 when maximum temperatures reached well into the 80s. These warm April temperatures hastened ice out progress on lakes in the state.

Ice out began more or less near average over the far southern lakes at the beginning of the April, then accelerated though the month to be 2 weeks early along the Canadian border. By the third week in April, virtually all the lakes in the state were ice-free.

May

May 2006 will be remembered as the month when the drought began. It was referred to as a "flash drought" due to its sudden onset. May precipitation totals in many communities fell short of the historical average by an inch or more. Combined with the extreme heat of late May, this precipitation shortage led to a rapid drying of the landscape. The only significant exceptions to the overall dryness were portions of St. Louis and Lake counties and small sections of west-central Minnesota where May precipitation exceeded the historical average by 2 or more inches.

One of the more notable rain events of May was produced by a sequence of thunderstorms that passed over Big Stone, Traverse, and Stevens counties on May 23. Nearly 3 inches of rain fell over a 3-hour period leading to small stream flooding and a road washout in Stevens County.

May 2006 monthly mean temperatures were slightly above average for most locations. Chilly temperatures encountered over the Mother's Day weekend were offset by very hot weather during the Memorial Day weekend. Except for North Shore areas, most communities reported temperatures in the 90s at least once over the holiday weekend. Many high temperature and high minimum temperature records were set on May 24, 27, and 28. High Heat Over Memorial Weekend: May 27-May 29, 2006

Summer 2006

June

June 2006 was the second consecutive month of below normal rainfall in Minnesota. June precipitation totals in many areas fell short of the historical average by 1 inch to 3 inches. For most communities, it was the second consecutive month of below average rainfall. The only significant exceptions to the overall dryness were isolated areas of southern Minnesota bolstered by a single, intense rainfall event. During the overnight hours of June 9-10, a storm dropped 2 to 4 inches of rain along a very narrow band that extended from Redwood County in the west to Winona County in the east. The heavy rain led to a mudslide in Mankato and urban flooding in Owatonna. Heavy Rains Over Southern Minnesota: June 9, 2006.

June was not excessively hot, with a few days reaching the low 90s. The month finished near to somewhat above average. The statewide average was 1.3 degrees above normal, with the warmest averages in the northwest.

July

The drought intensified in July. For most communities it was the third month in a row of below average rainfall. Rainfall deficits ranged from 1 inch to 3 inches. Some welcome rains that fell on July 19, 2006, focused primarily on south-central and southeastern Minnesota. Martin and Faribault counties were among the drier places in the southern half of the state. The 2- to 4-inch rains in these counties were beneficial to agricultural interests. Another streak of heavier rain, roughly from Mankato to Rochester, fell on an area that was somewhat better off than the rest of southern Minnesota. No significant widespread rain fell north of a line from Ortonville to Forest Lake. Rain Brings Some Relief to Southern Minnesota: July 19, 2006

The heat really set July apart. Monthly mean temperatures were 3 to 5 degrees above the historical average. For many Minnesota communities, July 2006 was among the five hottest months on record. The temperature climbed above 90 degrees on numerous occasions and many Minnesota communities reported at least one occurrence of 100 degrees. The hottest temperature reported was 107 degrees on July 30 at Browns Valley in Traverse County. Hot July 2006 This heat elevated evaporation levels not seen since the 1988 drought. Pan Evaporation at the St. Paul Campus Climate Observatory for July was 9.15 inches.

August

August 2006 precipitation totals varied widely across the state. For the fourth consecutive month, rainfall was below average for much of the northern half of Minnesota. Monthly rainfall totals fell short of average by 1 inch to 3 inches in many northern counties. Conversely, August was a very wet month in portions of east-central and southeastern Minnesota. Rainfall in these areas topped the historical average by 2 or more inches. Unfortunately, the heaviest of the August rains did not fall on those areas suffering the greatest from this season's drought.

Three extremely heavy rainfall events occurred during August. Very heavy rain fell on south-central Minnesota on August 1 and 2. Heavy Rains Fall on South Central Minnesota August 1-2, 2006

Portions of Martin and Faribault counties received more than 5 inches of rain in a 30-hour period. During the late evening of August 16 and early morning of August 17, nearly 6 inches of rain fell along a very narrow corridor in central Marshall County. On August 24, intense thunderstorms dropped more than 5 inches of rain on portions of Dodge and Olmsted counties. Heavy Rains Over Southern and Central Minnesota: August 24, 2006

After the rash of 100-degree temperatures on the last day of July, the heat wave broke and temperatures were more moderate in August. Minnesota's average temperatures finished near to slightly above normal when compared to historical averages.

Autumn 2006

September

September 2006 precipitation totals were nearly average to above average across much of the state. In some west-central and central counties, September rainfall topped average by 2 or more inches. The heavier rain brought welcome relief to central Minnesota communities that had experienced precipitation shortfalls earlier in the season. Unfortunately, many of the drought-stricken areas of north-central and northeastern Minnesota received below average rainfall for the month. In these northern locales, the dry September marked the fifth consecutive month of precipitation deficits.

Monthly mean temperatures for September 2006 were generally cooler than normal in most areas of the state, except in northern counties. The average temperature for the month ranged from 1 degree to 3 degrees cooler than normal in the southern two-thirds of the state, but near to slightly above normal in the far north. There were multiple frosts in the north and single frosts in some central and southern counties during the month.

The Drought of May 16 - September 30, 2006

The second half of the 2005-2006 water year featured an intensifying drought entrenched across northern and central Minnesota. The timing of the dry weather was most unfortunate. The period from mid-May through early September is historically the wettest time of the year in Minnesota. Long-term average rainfall rates during this time interval are around 1 inch per week. Very dry weather, occurring during a time of year when ample rain is typical, rapidly intensified the drought. The lack of precipitation, along with one of the hottest Julys on record, produced deteriorating crop conditions, low stream flows and lake levels, and increased the danger of wildfire.

Twenty-week rainfall totals from mid-May to the end of September were below historical averages by more than 4 inches across most of the northern half of Minnesota. Rainfall deficits exceeded 6 inches in many northern and central Minnesota communities. When compared with other rainfall totals for mid-May to the end of September in the historical database, the totals for the period rank below the fifth percentile (1 year in 20) in many northern and central Minnesota counties. For isolated areas of northern Minnesota, rainfall totals are among the lowest on record for the 20-week period. As the state settled into autumn, concerns about the drought for the next water year persisted.

Water Year 2006 Summary

Figure 4 shows the water year precipitation and departure from normal from October 2005 to September 2006. The effects of the drought of 2006 reflect in the map with the driest spots in north central and northeast. Some areas in St. Louis County saw departures up to six inches below normal. A good part of central and southern Minnesota saw enough precipitation to finish near normal for the water year. There were few places in the state significantly wetter than normal for the water year. One exception was Traverse County, where an area near the South Dakota border was six inches above normal. For many areas of the central and south, a wet September 2006 helped to ease the effects of the drought. However, the replenishing rains of autumn did not fall over the north where the drought continued into the 2007 water year.

Figure 3

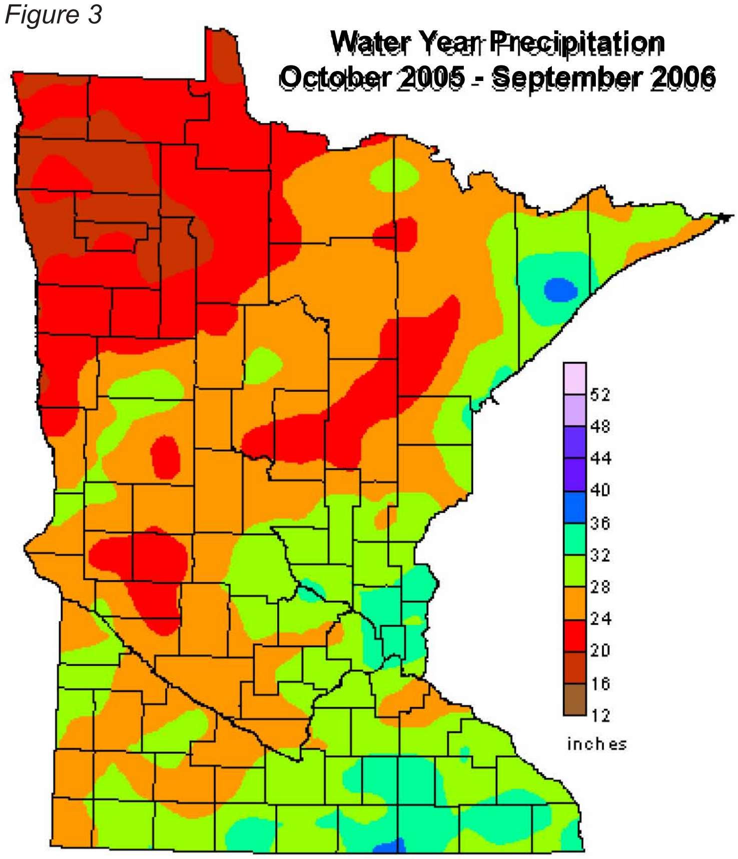
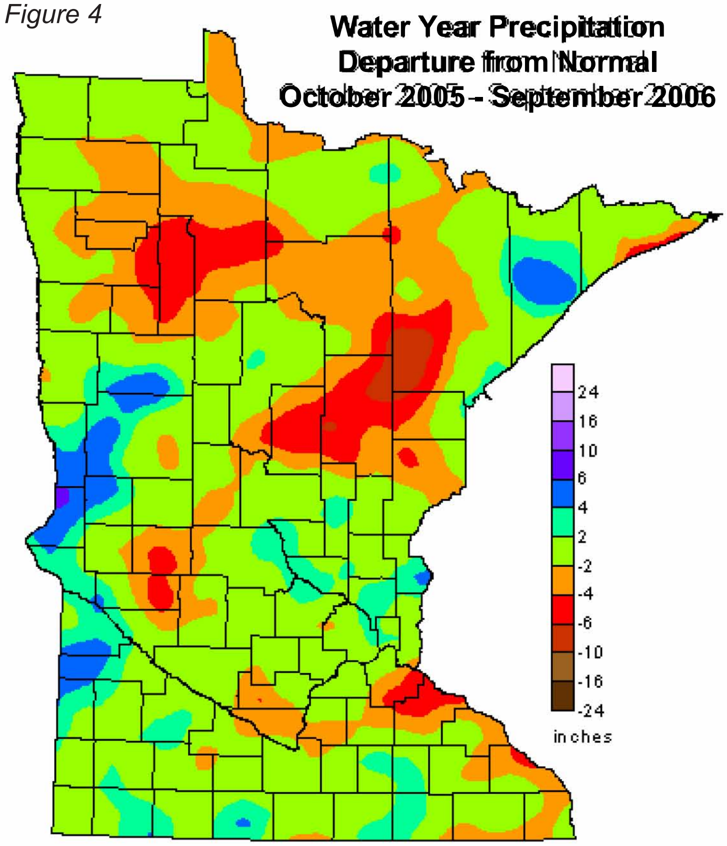


Figure 4



Surface Water

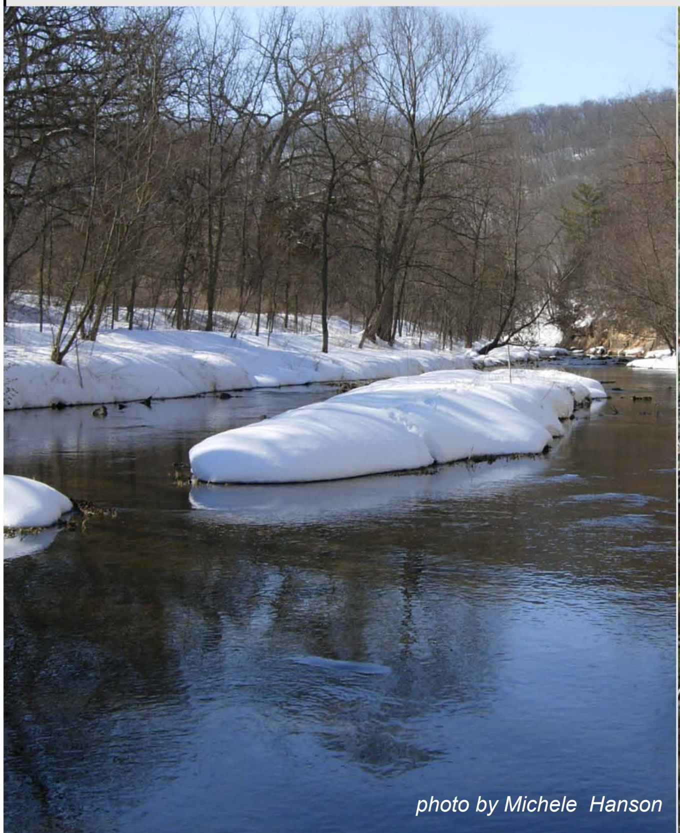


photo by Michele Hanson

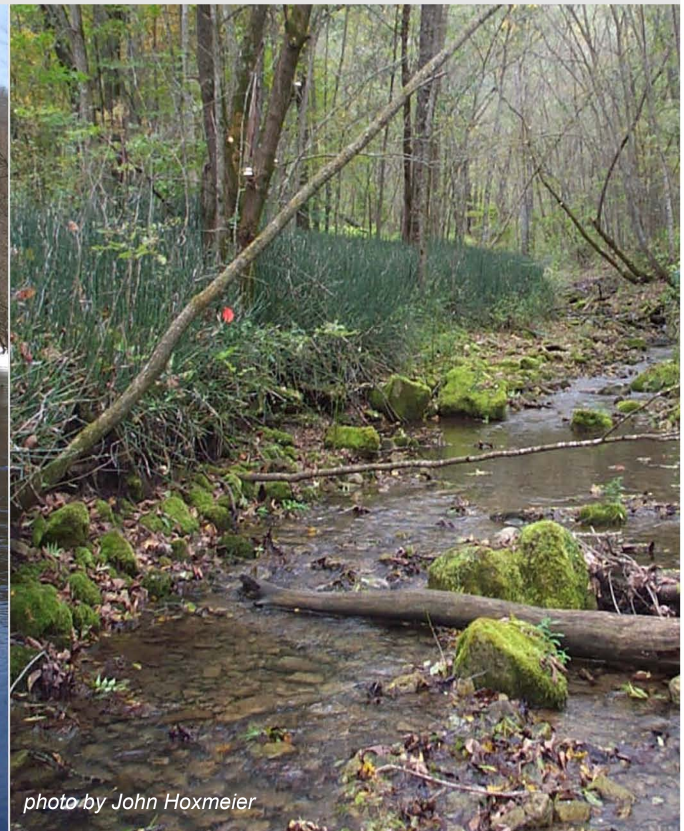


photo by John Hoxmeier

photo by Michele Hanson

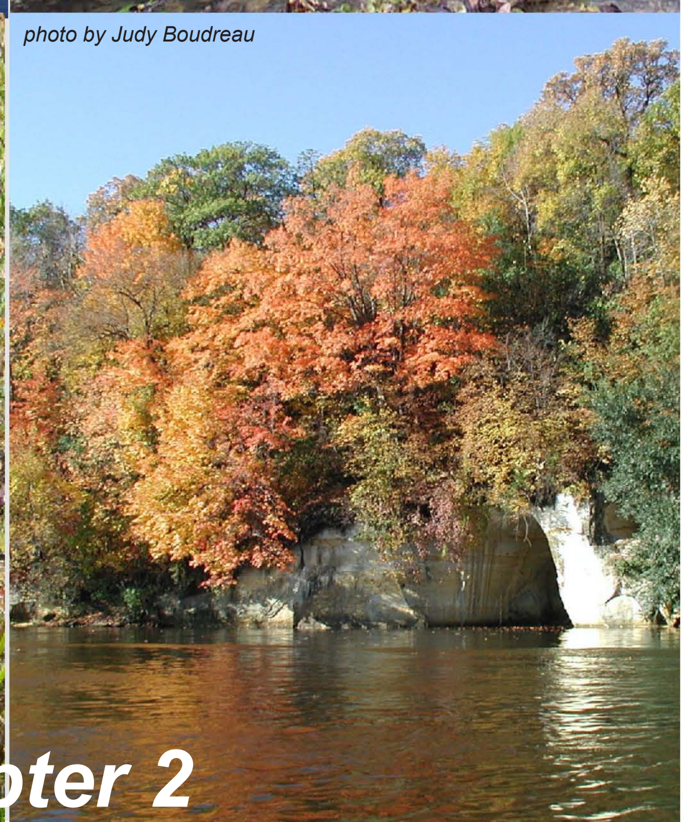


photo by Judy Boudreau

Chapter 2

Stream Flow

Introduction


submitted by Michele Hanson


photo by Michele Hanson

There are many types of rivers and streams in Minnesota. Along the north shore of Lake Superior and the Mississippi River bluff lands in southeast Minnesota, fast flowing streams have scoured channels in bedrock. In the northwest, slow-moving, highly-meandered streams flow through the soft soils of an ancient lake bed and, due to their low gradient, are prone to flooding. In the southern third of the state, streams are often entrenched with well-defined channels, and are highly impacted by agricultural practices. North-central streams can be impacted by both agricultural and forest land uses.

Minnesota is unique in that two of the three Continental Divides in North America cross through it, meeting at a point near Hibbing. These Continental Divides separate surface water runoff into three drainage basins (and their major river basins): the Hudson Bay/Arctic Ocean (Red River of the North, Rainy River), the Great Lakes/Atlantic Ocean (Lake Superior) and the Mississippi River/Gulf of Mexico (Upper and Lower Mississippi River, St. Croix River, Minnesota River, Missouri River and the Des Moines – Cedar River). (See Figure 1)

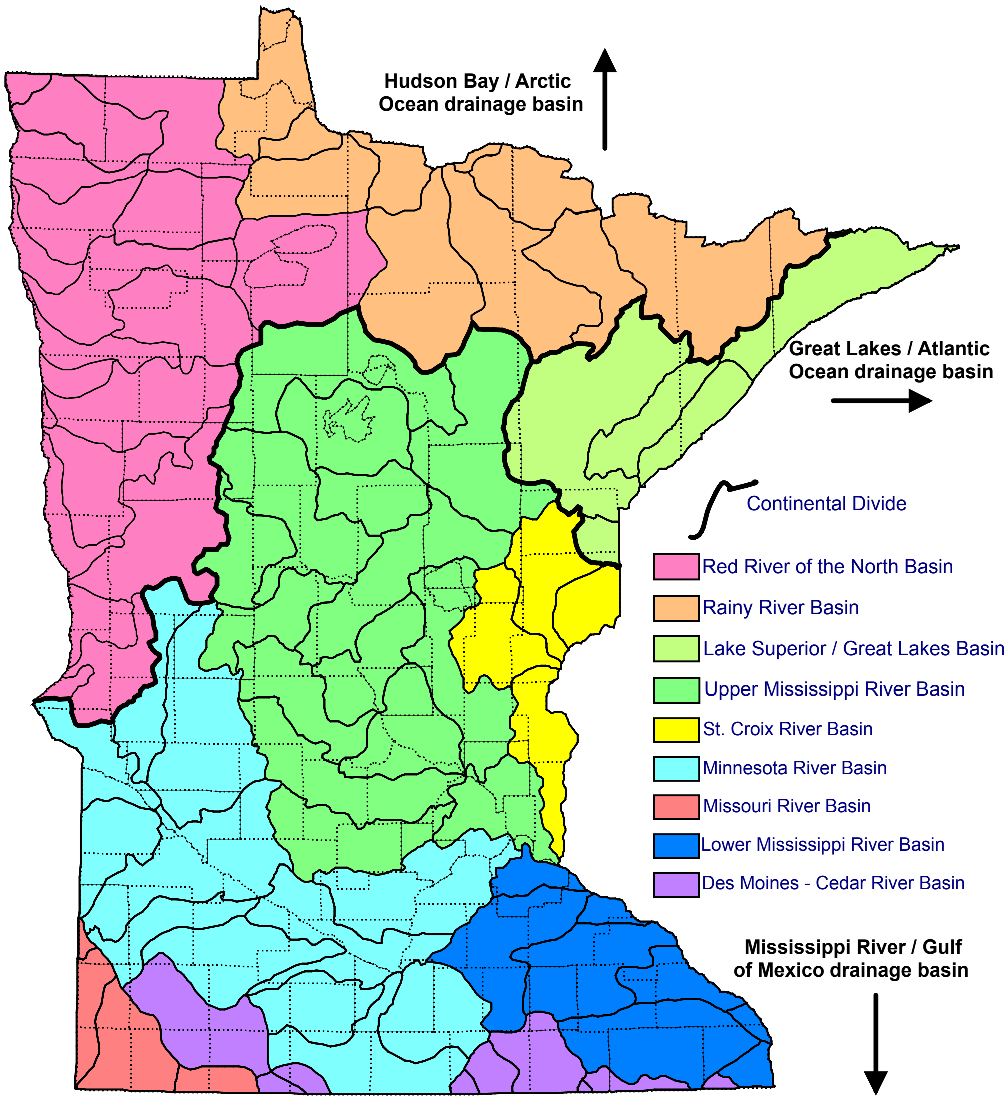
Minnesota is further unique in that very little water flows into the state. Only two rivers receive out-of-state water: the headwaters of the Minnesota River from South Dakota, and the Blue Earth River from Iowa. Minnesota exports large volumes of water via the Red, Rainy, Mississippi (including the Minnesota and St. Croix Rivers), and through the numerous North Shore streams.

A standardized set of watersheds was developed by the DNR in 1979. This Watershed Mapping Project delineated 81 Major Watersheds covering the state and approximately 5600 Minor Watersheds that make up these Major Watersheds (Figure 2).

Even earlier in the 1970's, the United States Geological Survey (USGS) and the Natural Resources Conservation Service (NRCS) developed the Hydrologic Unit system (HU for short) to divide and subdivide the U.S. into successively smaller watersheds. This system has been recently expanded and now adopted by the DNR with some modifications for its Lake Watershed Delineation Project (see website for more detail).

Figure 1

Nine Major Stream Basins



Stream Gaging in Minnesota

The United States Geological Survey (USGS) is the primary agency doing nationwide stream gaging. At the present time, the USGS maintains a network of approximately 125 continuously recording stream gages and approximately 400 high-flow and miscellaneous flow gages in Minnesota. However, as needs for additional stream information become necessary, additional agencies and organizations are gaging as well.

Other federal agencies doing stream gaging in Minnesota include the United States Army Corps of Engineers, with approximately 40 gages, and the National Weather Service.

The Minnesota Department of Natural Resources (DNR Waters Stream Hydrology Unit) is the primary state agency doing stream gaging, with a total of approximately 40 continuously recording gages and 60 seasonal gages. Other agencies having or supporting stream gaging in Minnesota include the Minnesota Department of Transportation and the Minnesota Pollution Control Agency. The Metropolitan Council also has several stream gages to monitor flows for public water supply and the discharge of treated waste waters. In addition, several watershed districts and lake associations operate gages.

Gaging is an essential tool in analyzing stream flows. A stream gage is used to record the water surface elevation of a stream at a specific location. Measurements of stream discharge must be made periodically at the gage location to develop the relationship between stream elevation and the volume of flow at that location. Once this relationship is developed, recorded stream elevations can be converted to discharge in cubic feet per second (cfs). Telemetered gages record stream elevations continuously and transmit the data to a central location for conversion to discharge and for use in hydrologic analysis.

There are many uses of information obtained from stream gages. Water surface elevation, the most basic information, assists in the determination of flood elevations, flood plains, and sizing of bridges and is useful for municipal zoning and planning. Planners use stream flow data for land use development and to determine water availability for industrial, domestic and agricultural consumption. Biologists use stream flow data to assist in evaluating aquatic habitat potential in streams. Knowing how much water is flowing or available in a stream is very important for flood and drought planning, as well as for the development of municipal and industrial water supplies.

Figure 2 shows the 81 major watersheds of the state and the location of the continuous recording gages that the DNR uses to monitor statewide stream flow conditions. These gages are used to gather data, including historic high and low flow and information for computing statistics such as flood frequencies and exceedence values (below).

A recent trend in stream gages is to include a chemical sampling unit at the gage. The sampler will then measure a chemical in the water, and with the discharge data, calculate how many pounds of that chemical have flowed past that gage. (See discussion on page 21)

If stream gages are lost due to budget constraints, flood prediction and low flow protection can be significantly compromised. The loss of a stream gage with a long-term record can seriously degrade ability to determine stream flow trends, drought and flood frequency calculations and other historical parameters. The long-term goal for DNR Waters is to establish and maintain at least one automated stream gaging station in each of Minnesota's 81 major watersheds to provide water quantity information needed to quantify pollutant loadings and develop Total Maximum Daily Loads (TMDLs).

The USGS has a water science website which includes a section on "How streamflow is measured". Click here for a primer geared toward high school students.


Photo by Lisa Pearson

EXCEEDENCE VALUE

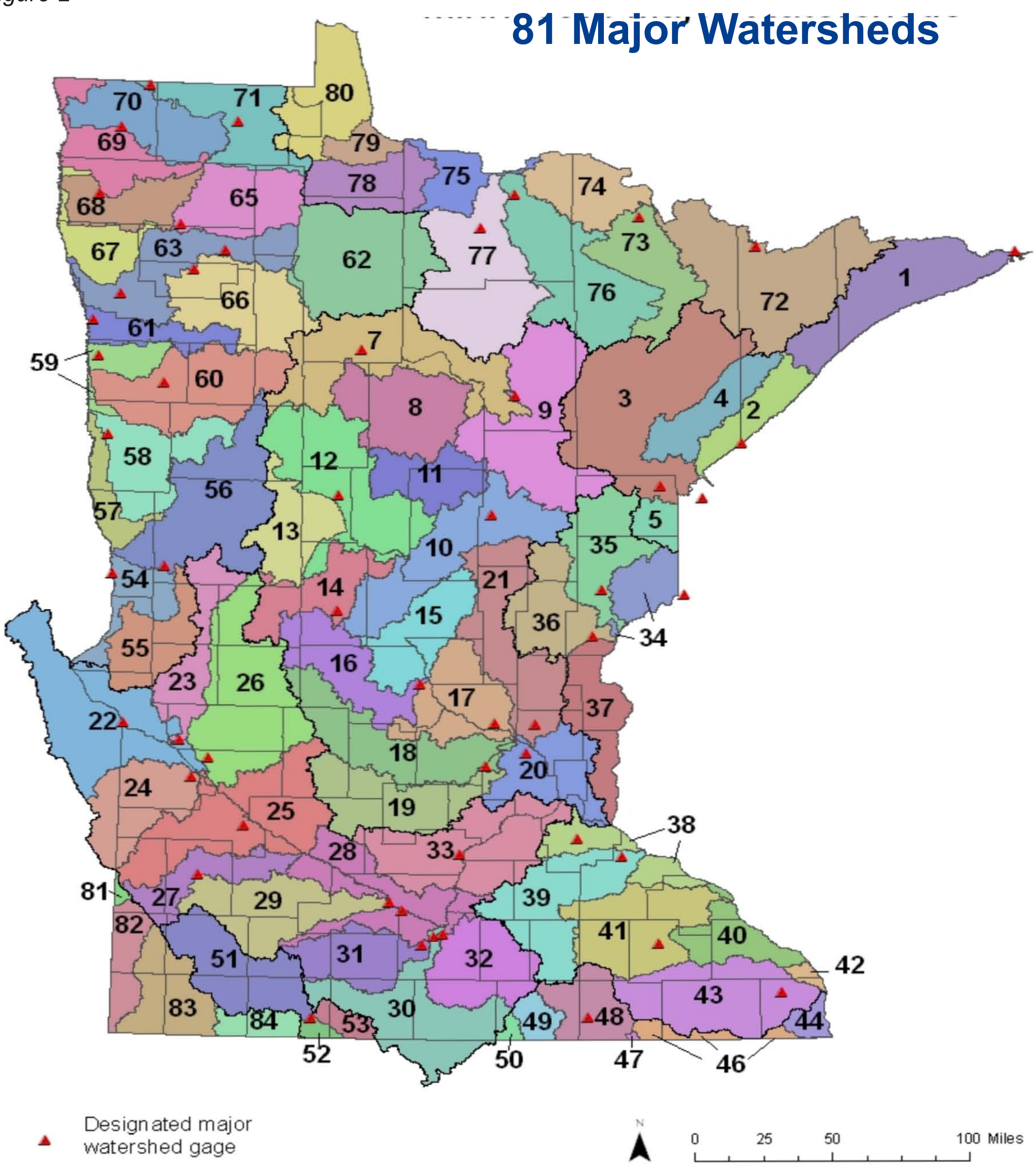
An exceedence value is a statistical parameter, based upon historical discharge records, and is the probability of stream flow exceeding a certain value. A 50% exceedence value (Q50) indicates that the discharge at that reporting station has been equalled or exceeded 50% of the time during a specific period. Exceedence values can be calculated on a daily, monthly or annual basis.

Stream flow reports are based upon the following exceedence values during the open water season.

Critical Flow = < annual Q90
Low Flow = < monthly Q75
Normal Flow = monthly Q75 to Q25
High Flow = > monthly Q25
Flood Flow = > NWS* flood stage
(or highest monthly Q10)

* National Weather Service

Figure 2



1. Lake Superior – North
2. Lake Superior – South
3. St. Louis River
4. Cloquet River
5. Nemadji River
6. (none)
7. Mississippi River – Headwaters
8. Leech Lake River
9. Mississippi River - Grand Rapids
10. Mississippi River – Brainerd
11. Pine River
12. Crow Wing River
13. Redeye River
14. Long Prairie River
15. Mississippi River – Sartell
16. Sauk River
17. Mississippi River - St. Cloud
18. North Fork Crow River
19. South Fork Crow River
20. Mississippi River
21. Rum River
22. Minnesota River – Headwaters
23. Pomme de Terre River
24. Lac Qui Parle River
25. Minnesota River - Granite Falls
26. Chippewa River
27. Redwood River
28. Minnesota River – Mankato
29. Cottonwood River
30. Blue Earth River
31. Watonwan River
32. Le Sueur River
33. Minnesota River – Shakopee
34. St. Croix River – Upper
35. Kettle River
36. Snake River
37. St. Croix River – Stillwater
38. Mississippi River & Lake Pepin
39. Cannon River
40. Mississippi River – Winona
41. Zumbro River
42. Mississippi River - La Crescent
43. Root River
44. Mississippi River – Reno
45. (none)
46. Upper Iowa River
47. Wapsipinican River
48. Cedar River
49. Shell Rock River
50. Winnebago River
51. West Fork Des Moines – Head
52. West Fork Des Moines – Lower
53. East Fork Des Moines
54. Bois de Sioux River
55. Mustinka River
56. Otter Tail River
57. Red River of the North
58. Buffalo River
59. Marsh River
60. Wild Rice River
61. Sandhill River
62. Upper/Lower Red Lake
63. Red Lake River
64. (none)
65. Thief River
66. Clearwater River
67. Grand Marais Creek
68. Snake River
69. Tamarac / Joe Rivers
70. Two River
71. Roseau River
72. Rainy River – Headwaters
73. Vermilion River
74. Rainy River - Rainy Lake
75. Rainy River – Manitou
76. Little Fork River
77. Big Fork River
78. Rapid River
79. Rainy River – Baudette
80. Lake of the Woods
81. Big Sioux - Medary Creek
82. Big Sioux – Pipestone
83. Rock River
84. Little Sioux River

MDNR/PCA Cooperative Stream Gaging Website

The Cooperative Stream Gaging Website is the final product resulting from over two years of hard work from several individuals within the Department of Natural Resources (DNR), the Pollution Control Agency (PCA) and the National Weather Service (NWS), along with the cooperation of the United States Geological Survey (USGS).

The website features data from over 200 stream gaging locations with near real-time capabilities as well as several hundred gaging stations with historic data operated by the USGS, DNR and PCA.

This website will continue to change over the next year as additional gages and features come on line to support the Clean Water Legacy and as historic data is added to the website.

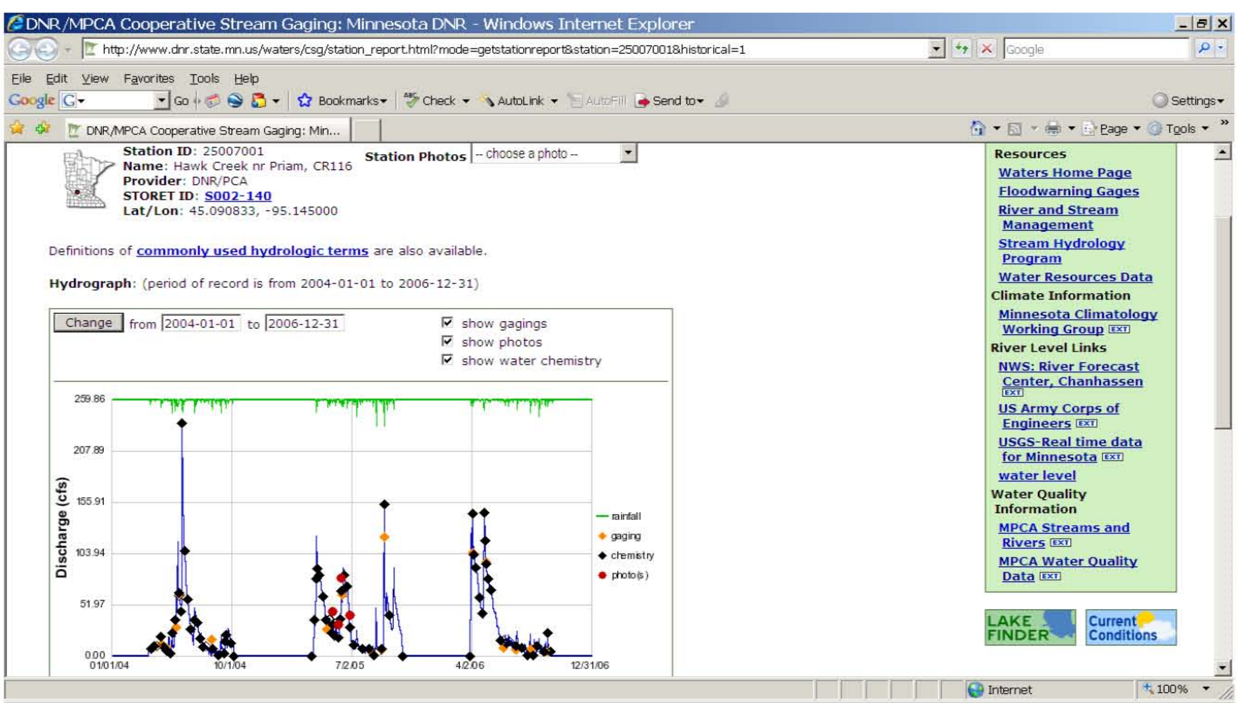
An example of chemical sampling of data can be found at the Hawk Creek (near Priam @ CR 116) website. Check the "show water chemistry" box above the graph and click on "Change" and you will be taken to a new graph which shows water chemistry data when hovering over the black diamonds (see example below).

The Minnesota Stream Flow Report

During the open water season, April 1 to September 30, a weekly Minnesota Stream Flow Report is produced on Mondays. The Stream Flow Report consists of a map showing current stream flow conditions by watershed (Flooding, High, Normal, Low, or Protected) as well as tabular data showing the prior week's stage and discharge, current stage and discharge, Flood Stage, the protected flow and the Q25 and Q75 exceedence discharges. Once the Stream Flow Report has been generated, it is forwarded to interested users and posted on the Internet for public viewing.

Recipients of the Stream Flow Report use it to monitor current water issues such as flooding, drought, and water availability. The Stream Flow Report also gives a good representation of soil moisture and agricultural conditions throughout the state.

The DNR Division of Waters may use the Stream Flow Report to encourage conservation and a reduction of water use during periods of Low Flow. When the Stream Flow Report identifies a river as having fallen to the Critical Flow Level, DNR Waters may suspend water appropriations in order to maintain some water in the river for downstream public water supplies, power generation and other higher priority uses. This minimal protected flow also provides water to help protected fish and wildlife dependant on the river.



Water Year – 2005

In the fall of 2004 (the 2005 Water Year began October 1, 2004), statewide stream flow conditions were around the Q25. Flows continued around the Q25 through the fall and winter, and into the spring of 2005. For most reporting stations, spring runoff remained near the Q25 exceedence value. However, in the southern half of the state, cold weather persisted and the spring snowmelt occurred as much as 2 weeks later than normal. In the northern half of the state, spring snow melt occurred at the normal time. Spring snowmelt flooding was not widespread, occurring mostly in the northern half of Red River of the North watersheds.

By early May, with the snowmelt passed, the volume of water in many streams dropped to near the Q75 Low Flow level. However, heavy rains in late May and June restored flows throughout the state. In many cases, the May and June storms produced a greater volume of water than the spring snowmelt event. Flows in the mainstem and many tributaries of the Red River of the North exceeded flood stage. These May-June storms provided sufficient water to maintain stream flows in the normal range through the remainder of the water year for much of the state. However, these storms provided less water to the eastern portion of the state, including the Arrowhead region and the St. Croix River watersheds. By early August, Low Flow and Critical Flow conditions could be seen in these two areas.

The 2005 Water Year ended with the southern half of the state in the High Flow range, flows in the northwestern quarter in the normal flow range and flows in the northeastern quarter in the Low or Critical Flow range.

Figure 3 shows the 2005 Average Annual Stream Flow Map. Statewide, all watersheds had an annual average flow greater than the historic average or normal flow.

photo by Judy Boudreau

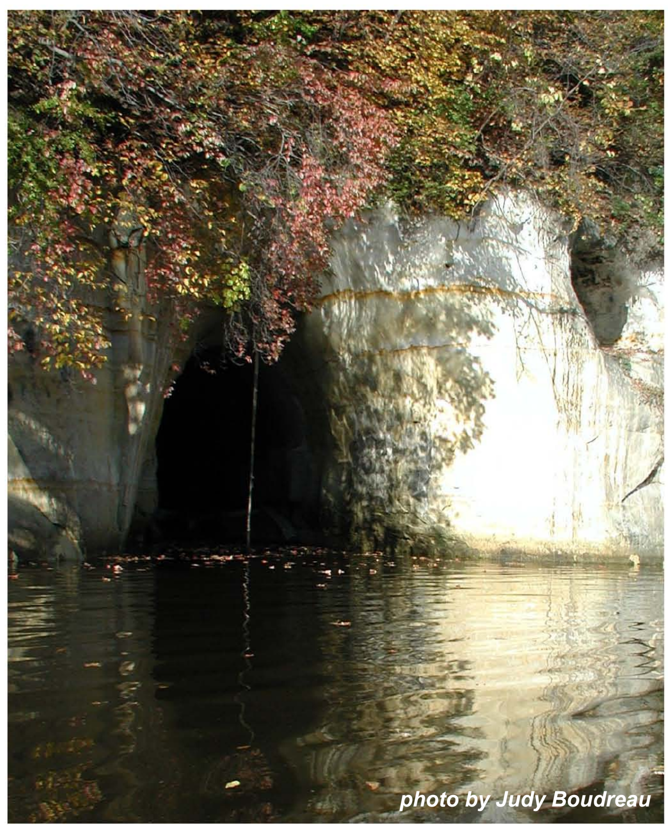
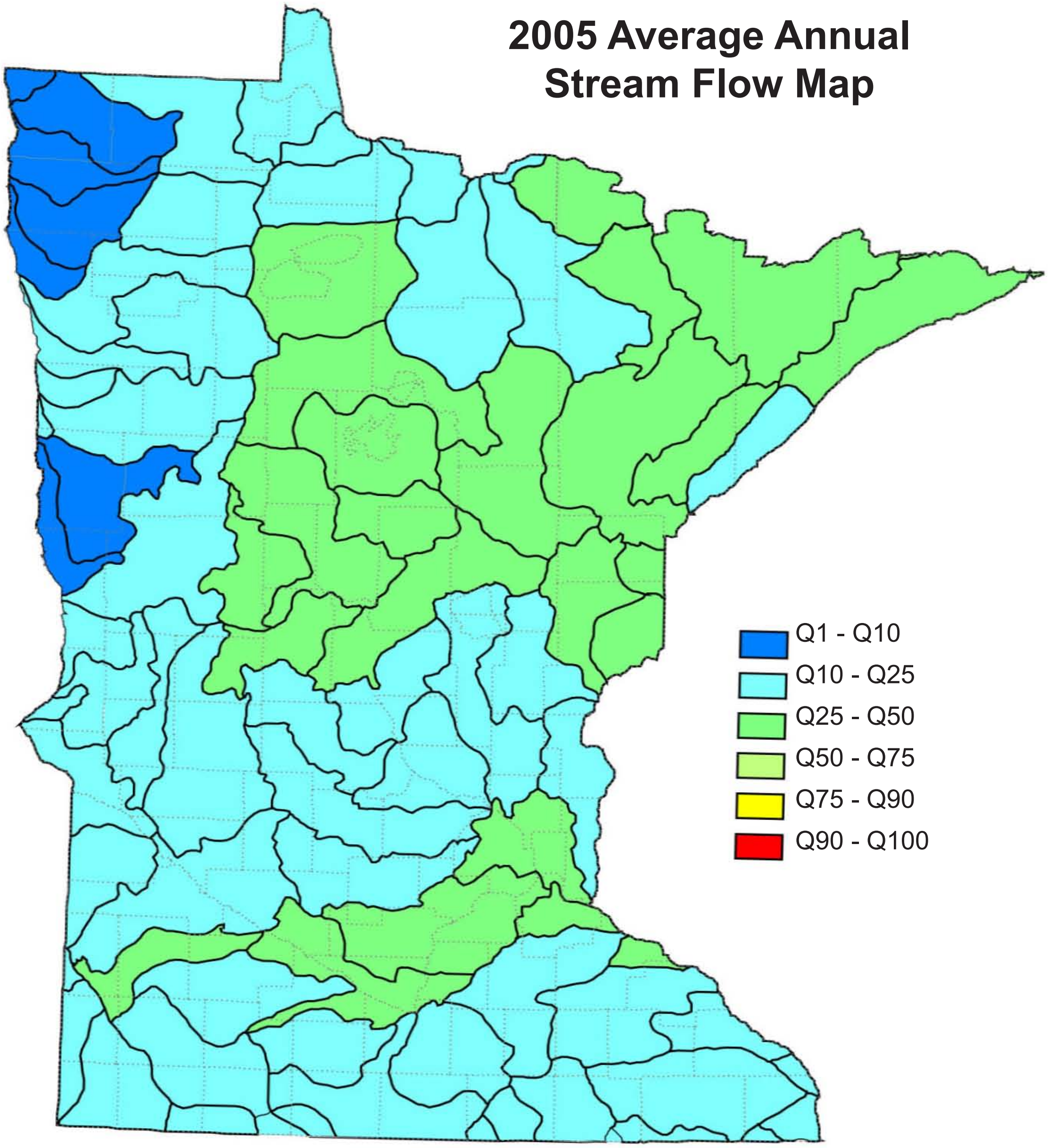


photo by Judy Boudreau

Figure 3


2005 Average Annual
Stream Flow Map
Q1 - Q10
Q10 - Q25
Q25 - Q50
Q50 - Q75
Q75 - Q90
Q90 - Q100

Water Year - 2006

Figure 4 shows the 2006 Average Annual Stream Flow map. The 2006 map is very similar to the 2005 map. For the 2006 water year, only one watershed gage, the Mississippi River at Aitken, had average flows below the statistical average or normal value.

The 2006 water year started off with a very large precipitation event covering the southern half of the state. As flows in the southern half of the state were already in the High Flow range at the end of the 2005 water year, this large event provided sufficient water to maintain flows in the High Flow range through the fall of 2005 and winter of 2006. The St. Croix River watersheds also received excessive precipitation from this event and were lifted from the Low/Protected Flow range into the High Flow range through the winter of 2006.

In the southern half of the state and the Red River watersheds, the snowmelt runoff during the spring of 2006 produced a significantly larger runoff event than observed in 2005. Both the peak stage and total volume exceeded that of 2005 and what would be considered normal stage and volumes. Spring flooding was again observed in most of the Red River watersheds as well as in scattered locations in the southern half of the state.

photo by Michele Hanson

In the northeastern quarter of the state, the spring runoff was near normal. Unlike 2005, the timing of the 2006 spring runoff event matched historic normals.

In 2006, little precipitation occurred during the months of May through September. In the southern half of the state and Red River watersheds, wet antecedent conditions and high ground water levels maintained the flows in the normal range well into summer. However, by mid-June, Low Flows were common throughout much of northeastern Minnesota.

By early July, Low Flows encroached into the central portion of the state, with Protected Flows occurring in the St. Croix Valley.

Dry conditions persisted trough the remainder of the summer and water year with Protected Flows occurring predominantly in the Arrowhead, northern Minnesota, the Mississippi River headwaters and the St. Croix Valley.

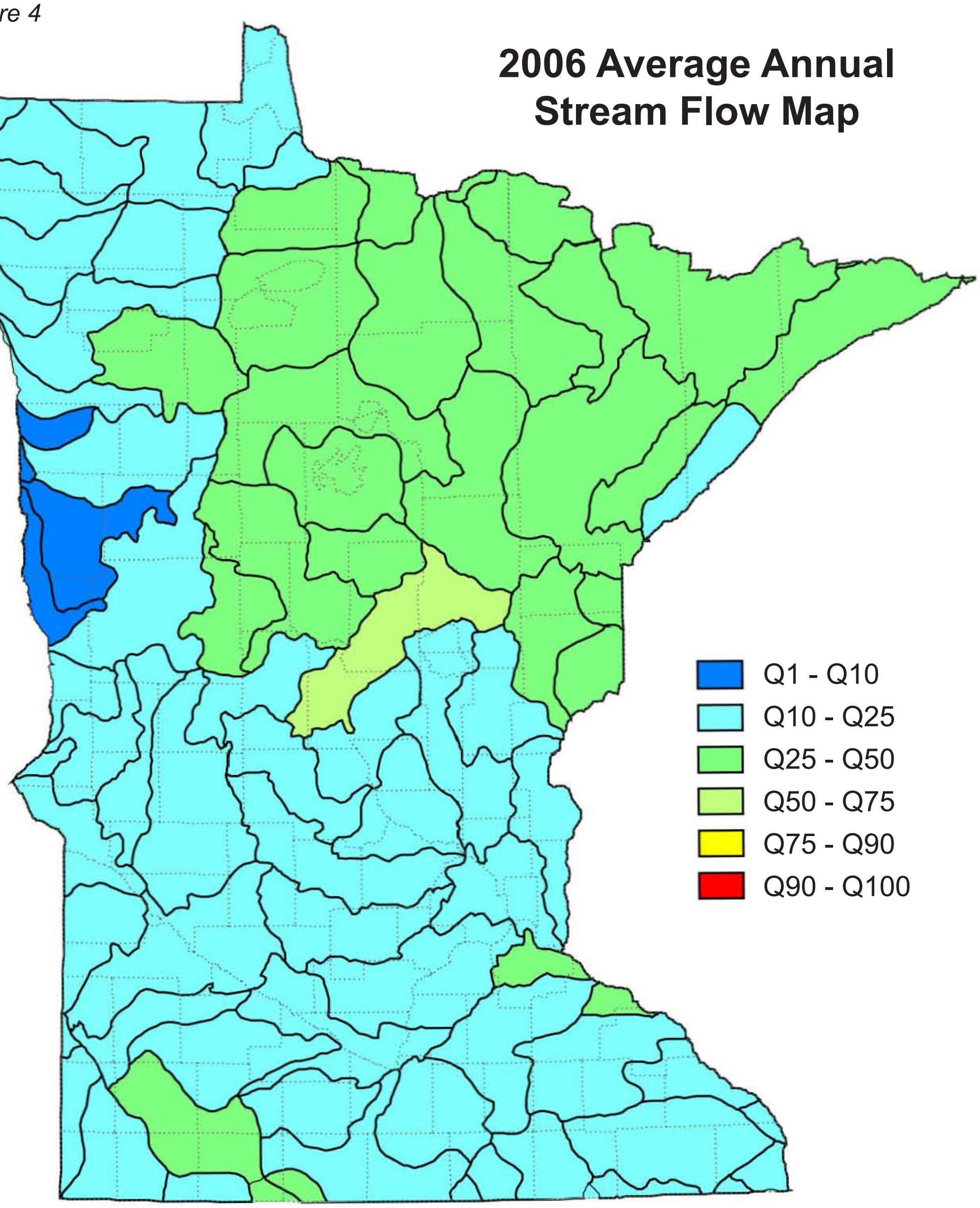
"Who shut the faucet off?"

A phrase often heard during the drought of 1987 and 1988 was "Who shut the faucet off?" or some variant. The question was pointed at the sudden cessation of precipitation.

In June 2006, the faucet was again shut off. While Figures 3 and 4 show that water levels were greater-than to much-greater-than normal for the 2005 and 2006 water years, Figure 4 does not show the sudden drop in water levels and flows that occurred in the last four months of the 2006 water year.

This sudden drop can be observed in the hydrographs in Figures 7 and 9. Note the drop in water levels to near the Q90 Protected Flow for the months of July, August and September, 2006. (Flows remained at this level for the first four months of the 2007 water year.)

Figure 4


2006 Average Annual
Stream Flow Map
Q1 - Q10
Q10 - Q25
Q25 - Q50
Q50 - Q75
Q75 - Q90
Q90 - Q100

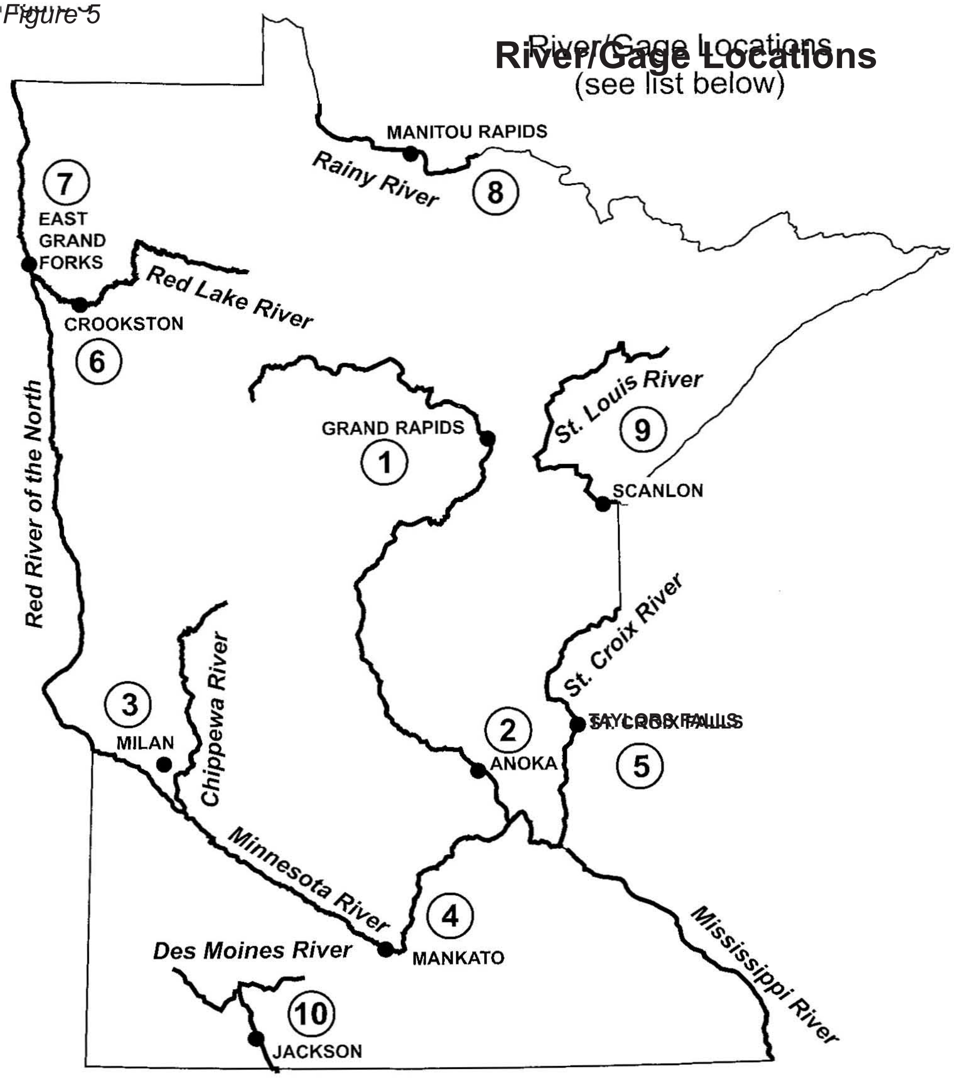
Hydrographs

To give a general summary of flow conditions around the state for the 2005 and 2006 Water Years, discharge hydrographs were created for 10 selected streams. These streams and their locations are shown in Figure 5.

For these 10 selected streams, mean daily discharges are shown in Figures 7 and 9 (pages 28 and 30). Included on those figures are the daily Q25 and Q75 exceedence numbers and the Q90 Protected Flow.

Figures 8 and 10 (pages 29 and 31) show the mean annual discharge for each of the 10 selected sites. In these figures, the graphs, by water year, extend from 1900 to 2010. As with the other figures, the Q25 and Q75 exceedence values are included. Note, however, that these exceedence values are based on annual flows and are different than the Q25 and Q75 values calculated from daily flows. Also included on the graphs is the 30-Year Moving Average, showing the general flow trend.

Figure 5



1) Mississippi River at Grand Rapids
2) Mississippi River at Anoka
3) Chippewa River near Milan
4) Minnesota River at Mankato
5) St. Croix River at Taylors Falls
6) Red Lake River at Crookston
7) Red River of the North at East Grand Forks
8) Rainy River at Manitou Rapids
9) St. Louis River at Scanlon
10) Des Moines River at Jackson

Mean Monthly Discharge

Mean Monthly Discharge was calculated for the 2005 and 2006 Water Years for each of the 10 selected streams shown in Figure 5. These monthly values were then divided by the historic monthly mean. The resultant value is a monthly mean value as a percentage of normal. For example, the January 2005 monthly flow for the Mississippi River at Anoka was 4775 cfs, and the historic average January flow is 4350 cfs. As a percentage, the January 2005 flow is 4775/4350 = 109.8%. For a completely "normal" year, each monthly value would be 100%. The advantage of this technique is that it normalizes the data and allows for the comparison of flows on different streams on the same scale.

Figure 6 is a step graph showing the maximum, minimum, and average monthly value for the 10 selected streams as a group. (The individual streams are not included in this graph as the numerous lines make it difficult to read.)

For the period from October 2004 to June 2006, the average of the monthly flows was above the 100% value. The maximum values for this period were significantly above the 100% level. The monthly minimum values were often below the 100% level, especially during the summer of 2005. However, these minimum values were usually due to one or two streams that had lower flow levels during the water years.

In July 2006, the dramatic fall in flows in these rivers can be observed in Figure 6. For the remainder of the 2006 Water Year (and into the 2007 Water Year), the average flow of the 10 selected streams was 50% of normal, with the maximum at approximately 75% and the minimum at approximately 25%. As the 10 selected streams are scattered throughout the state, the narrow range between minimum and maximum indicates that the Low Flow conditions after July 2006 were statewide.

Figure 6

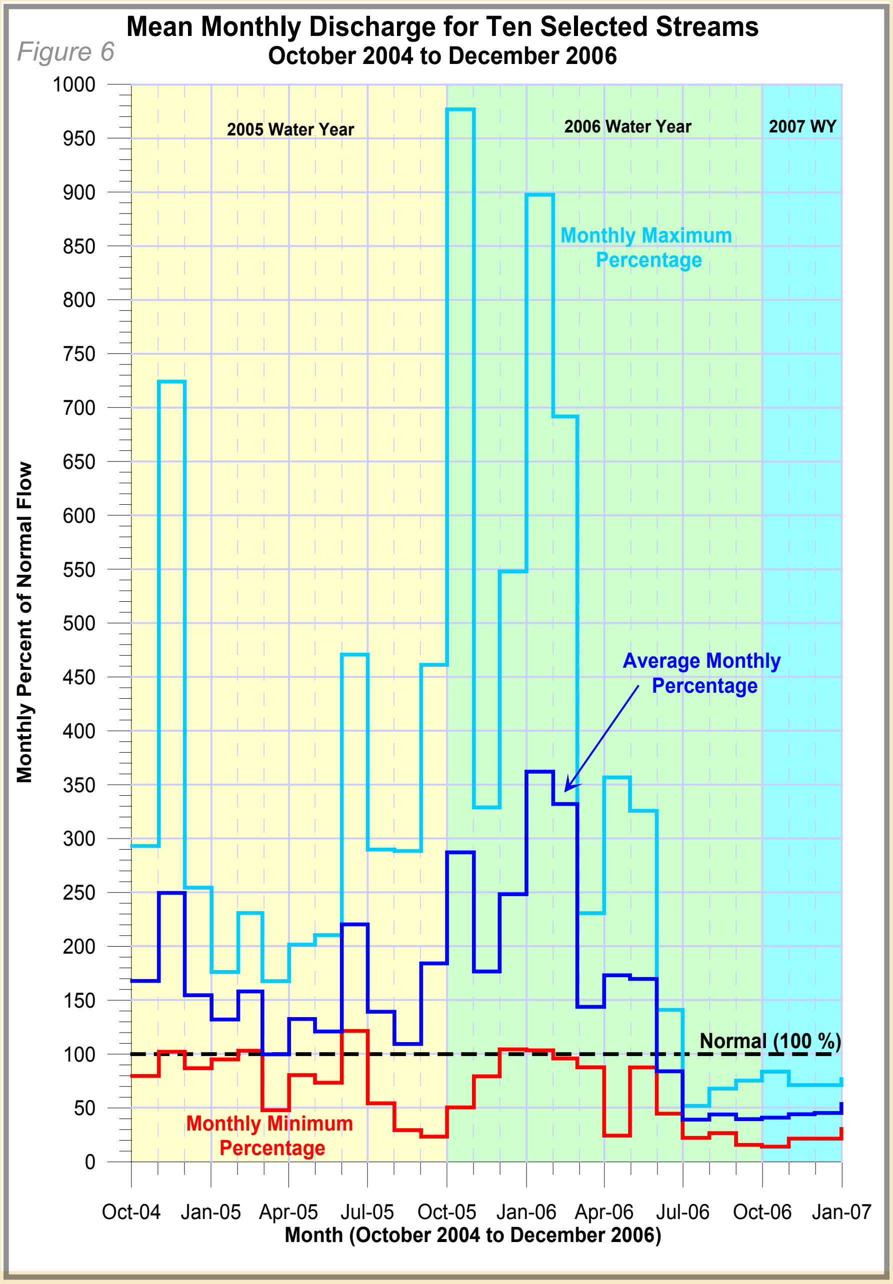


Figure 7

Mean Daily Discharge

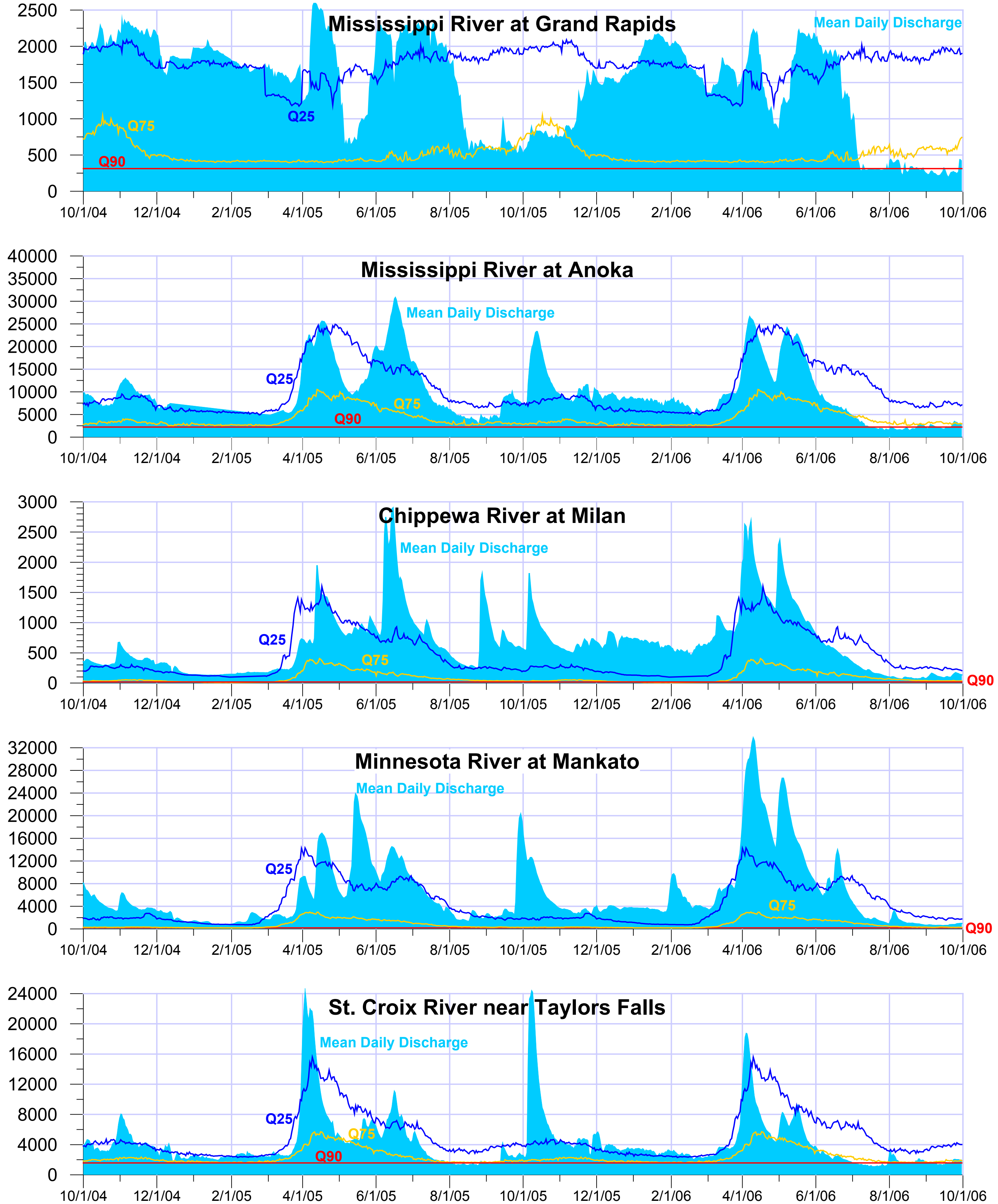


Figure 8

Mean Annual Discharge

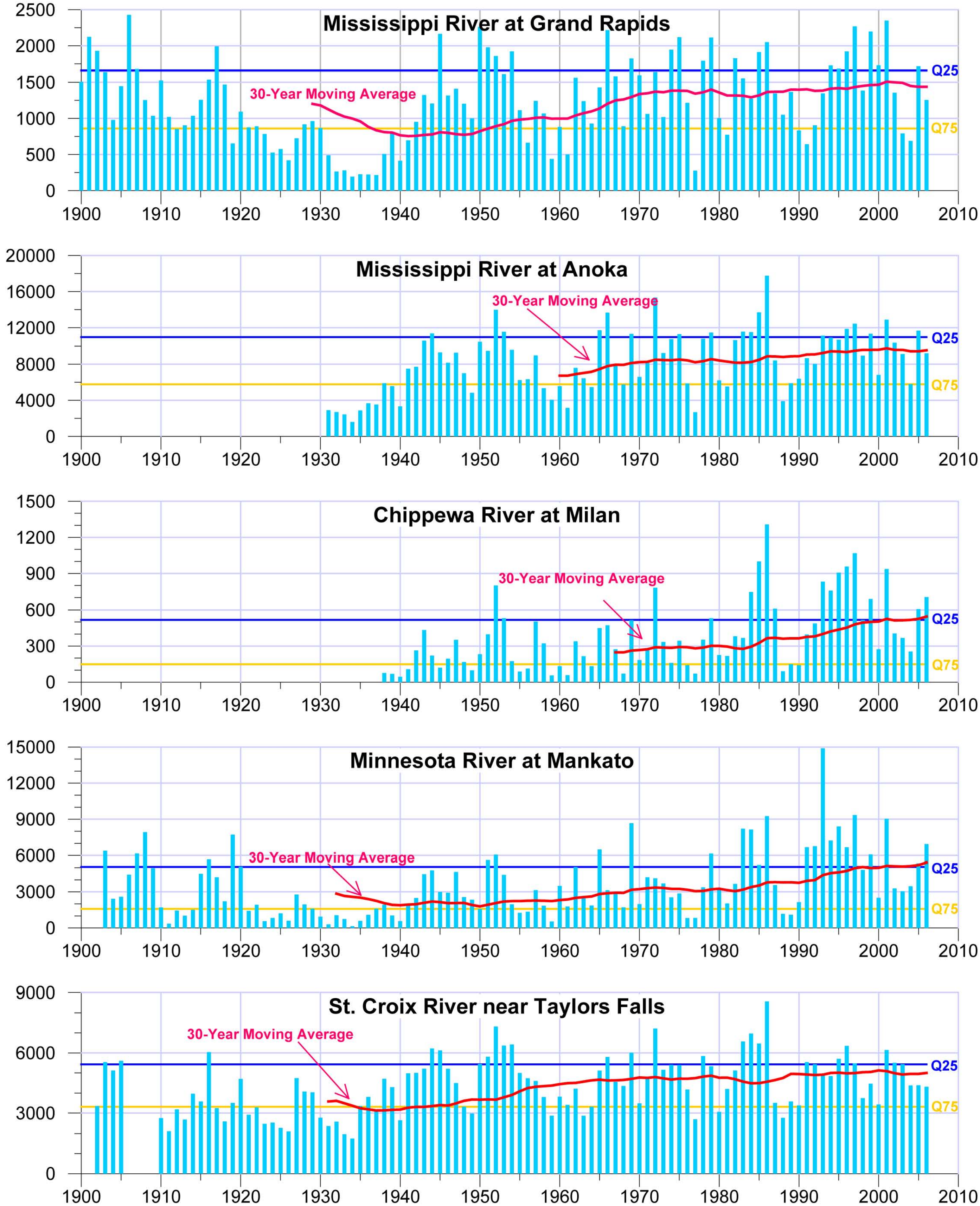


Figure 9

Mean Daily Discharge

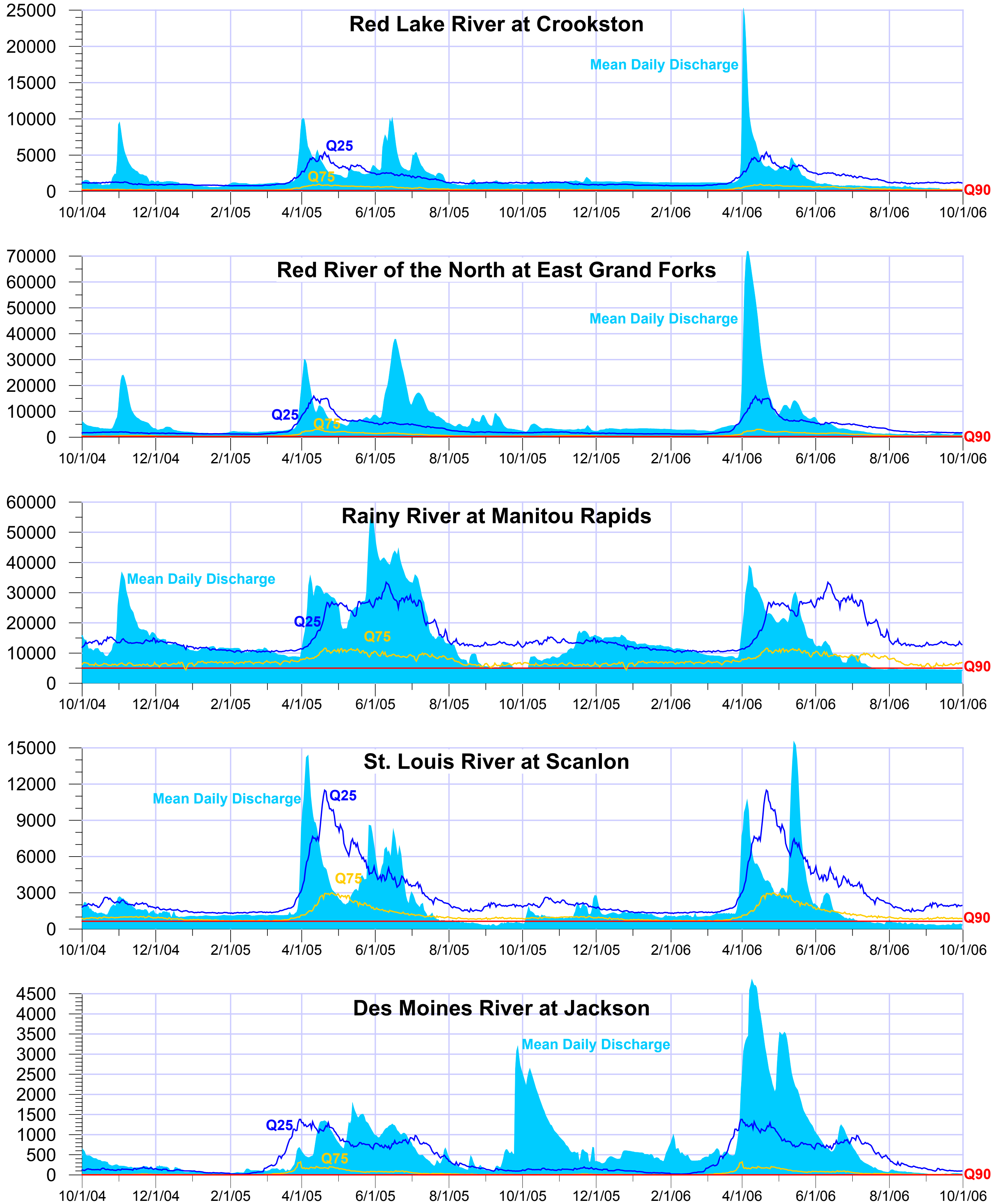
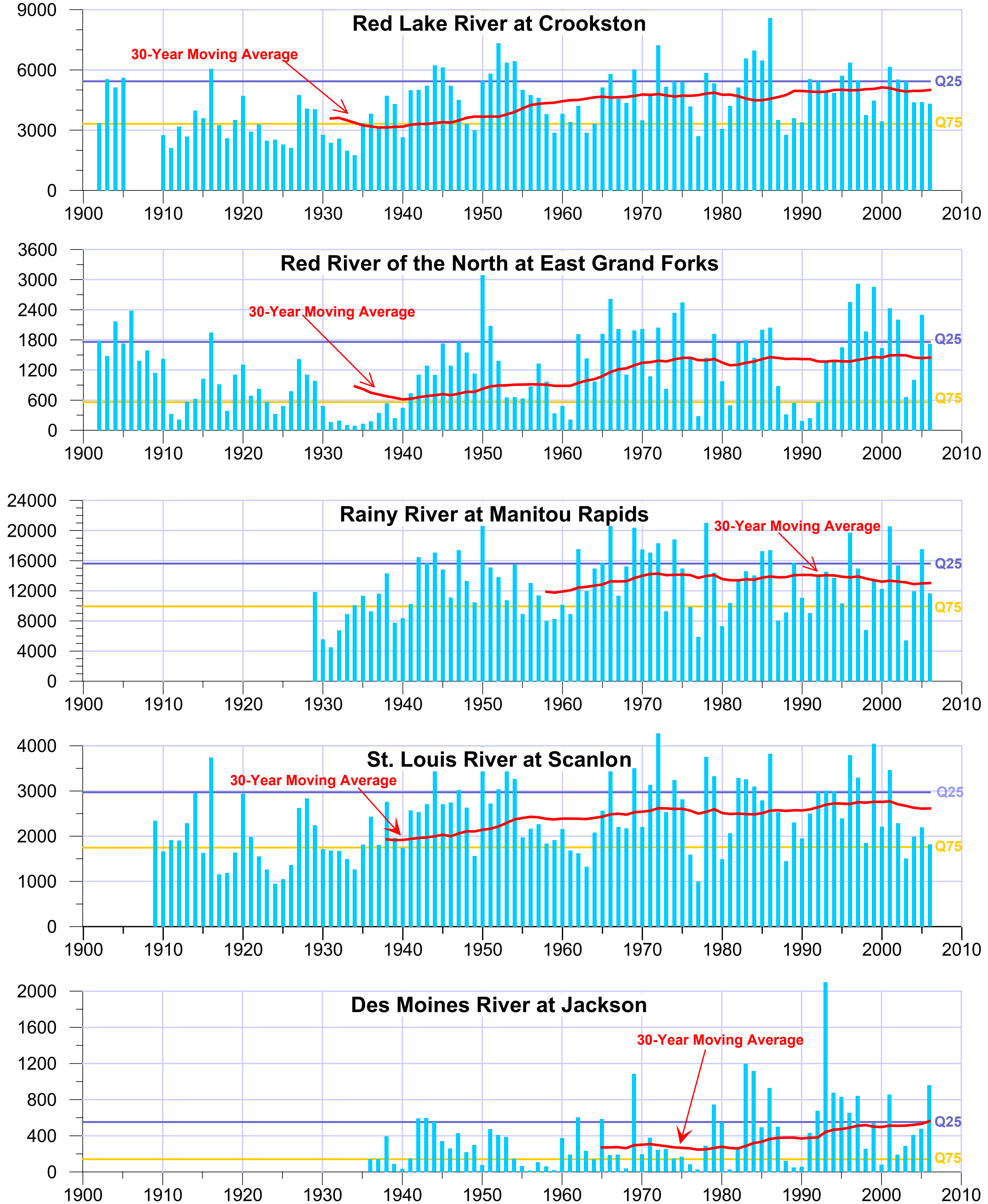


Figure 10

Mean Annual Discharge



Lake Levels

Introduction

The Lake Hydrology Program exists to support the DNR Waters director and staff by collecting and providing data on lake levels and other lake characteristics that are needed to effectively carry out DNR Waters' statutory responsibilities and management programs.

A key component of the Lake Hydrology Program is the development and maintenance of the Lake Level Minnesota Monitoring Program (LLMP). The LLMP primarily uses both temporary (movable) and permanent lake gages as indicators for measuring and determining the water surface level of certain lakes. DNR Waters currently oversees a network of over 1000 lake gages. The program relies on over 700 citizen volunteers and local government partners who record lake levels on a regular basis and submit the data to DNR Waters. Approximately 25% of the monitoring sites are managed currently under oral cooperative agreements with governmental units. In addition, DNR Waters purchased three continuous water level gaging systems in 2005 – 2006 for installation on high-profile lakes.

Data Uses

Water level data are used by DNR field staff as rationale for decision making in the public waters permit program and appropriations permit program. The records are used as supporting data for establishing ordinary high water levels and historical high water elevations, which are also the foundation for setbacks within the land use management programs.

photo by Sandy Fecht

The data are used by local zoning officials for platting, locating structure sites, and for establishing low floor elevations for new construction. Watershed managers and planners use historical lake level data while preparing local water management plans and modeling lake water quality characteristics. Fisheries staff use data as one variable in studying impacts on habitat. Other researchers use the data for climate change studies. Water level data are used for decisions by lakeshore owners on dock location/timing, vegetative shoreline protection, and understanding the natural fluctuations of a lake.

Lake level data support many DNR Waters hydrologic and hydraulic analyses. A consistent record of lake levels provides a long-term indication and understanding of the hydrology of the lake, watershed, and the relation between surface water and ground water. Long-term records show normal fluctuations, as well as the extreme highs and lows. Data are used to calibrate hydrologic models, especially applications for flood levels and lake outlets. The information is crucial to surface water and ground water interaction studies for appropriations decisions.

Lake Level Minnesota Gage Locations

photo by Skip Wright

Information Management

All lake level readings received are entered into Lakes-DB©, a database program for storing and retrieving a variety of information on Minnesota's lake basins.

The Lake Finder web site is the best means for the public to access available data on more than 4,500 Minnesota lakes and rivers relating to lake water levels, fisheries information, lake area and maximum depth, depth maps, water quality and clarity, air photos, and topographic maps. After searching by county, lake name, or identification number for a particular lake, a click on the word "*go*" below *"lake water/levels ruler"* displays the Lake Water Level Report page. This report contains information, including:

- reported historical and current lake levels
- period of record and number of readings
- highest recorded lake level
- highest known lake level
- lowest recorded lake level
- recorded range
- average water level of reported readings
- ordinary high water level [also shown as the red line on the 10-year graph]
- datum
- benchmarks
- most recent 10-year graph [X-axis Year tick mark references mid-year]

About 1,300 of the lakes have a historical record of more than 100 water level readings. In addition to the summary information, a Lake Finder user can retrieve and view all the reported lake elevations for a specific lake via the download of lake level data as dBase or ASCII from the center of the Lake Water Level report page.

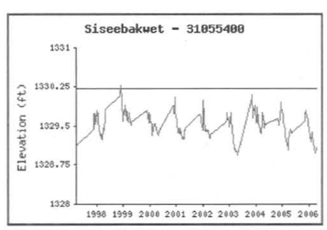
Clicking on ASCII is the most common method used to view the water surface elevations and the date of the readings. The chronological water surface elevation data can then be viewed, saved, or highlighted and copied into a computer software spreadsheet for sorting and graphing. The levels of a chosen lake can be compared by the user to other historical drought or wet years or other lakes.

Lake water level report

Lake name: Siseebakwet **County: Itasca**

Water Level Data

Period of record: 08/31/1937 to 09/25/2006
# of readings: 2175
Highest recorded: 1330.59 ft (05/21/1943)
Lowest recorded: 1328.4 ft (10/23/1978)
Recorded range: 2.19 ft
Average water level: 1329.54 ft
Last reading: 1329.07 ft (09/25/2006)
OHW elevation: 1330.2 ft
Datum: 1929 (ft)



Last 10 years of data, click to enlarge.

Download lake level data as: [dBase] [ASCII]
(If you have trouble try right clicking on the appropriate link and choosing the "Save ... As" option.)

Benchmarks

Elevation: 1333.39 ft
Datum: 1929 (ft)
Date Set: 09/01/1998

Benchmark Location
Township: 54 Range: 26 Section: 21

Description: At gage site on east side of lake - a 60d spike in the lakeside of a 1.1' spruce about 50' from water's edge and 20' right of dock.

Lake Levels

The primary factor that affects water level changes is the quantity and distribution of precipitation. Other factors that contribute to water level changes are soil moisture conditions, runoff, evapotranspiration, outlet conditions, beaver dams, human-made dams, ground water movement, and watershed characteristics and size.

The water levels of all lakes fluctuate depending on their unique water budget — some more than others. A water budget is the sum of “incoming” resources minus “outgoing” resources. It is an estimation of the water resources available to “spend” or “save” and must take into account all available ground and surface water. Water enters the lake as precipitation, surface-water inflow, and ground-water inflow. Water leaves the lake as evaporation, surface-water outflow, and ground-water outflow.

In a prolonged dry cycle, runoff and rain may be absorbed first by the soil and not contribute to lake levels. Knowing, understanding, and accepting the history of water level fluctuations can help lake users deal with expectations and problems associated with the changing levels.

Drought

Our volunteer readers’ remarks definitely told the story of the dry spell and drought of 2005 – 2006 (Figure 1 hydrographs).

“I have been on the lake for 40 years, and lived in the area for 56 years, and the months of September-November are the lowest I have ever seen the lake.”

“Most of this summer I’ve had about 8-10 feet of beach that I never had before in 20 years.”

“I have never seen our lake as low as this in 30 years.”

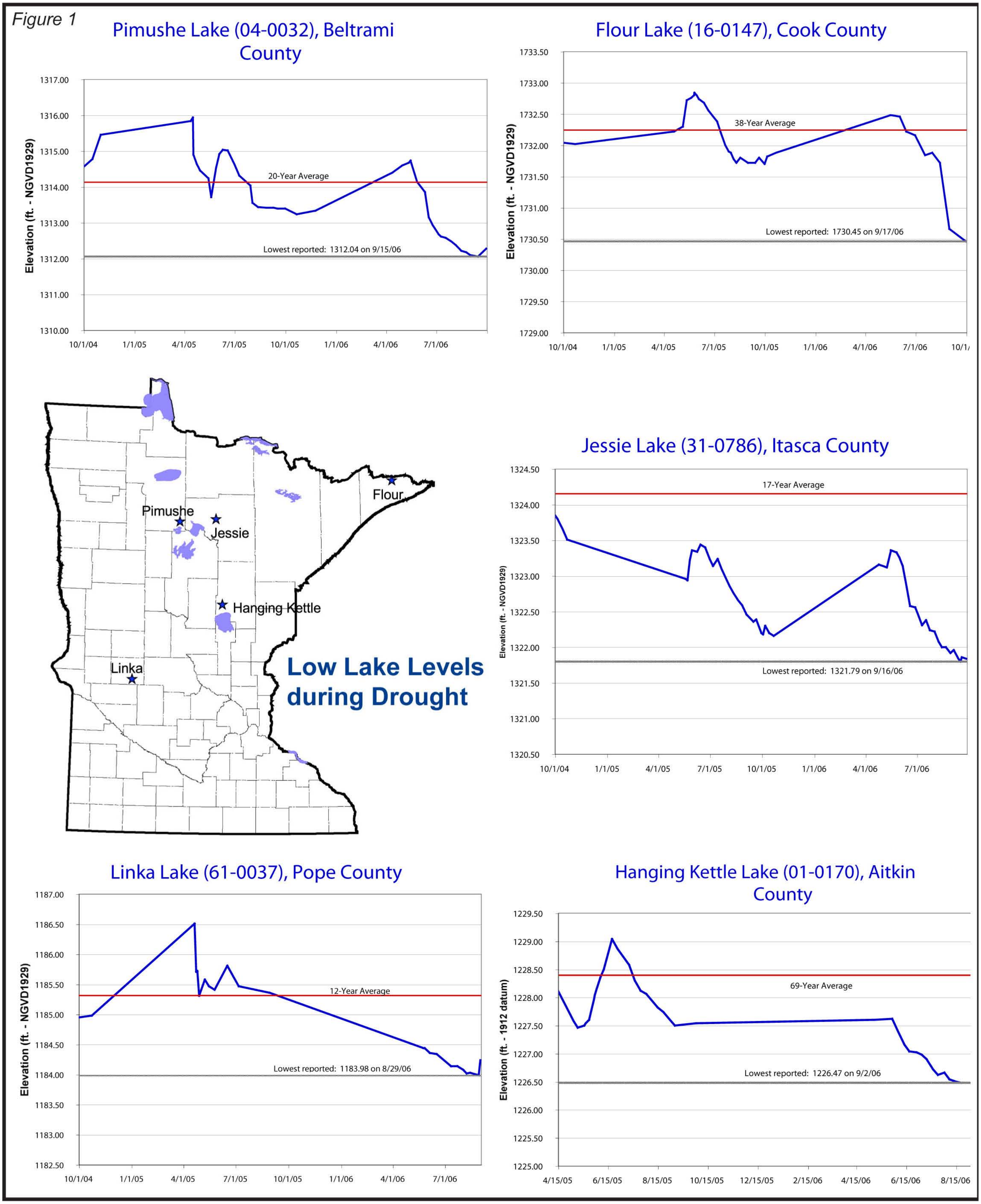
“The lowest anyone has ever seen it!”

“Lowest level in 13-14 years.”

“SEND RAIN NOW!!!!!”

July 2005 rainfall totals ranked among the lowest on record for some central and northern locales. The Arrowhead region remained extremely dry in August 2005, and the dry conditions persisted into September 2005 in northeastern and north-central Minnesota. In response to the lack of precipitation, many lakes receded to low water levels. A large number of lakes in Itasca County were at their all-time recorded low water levels.

Figure 1


Pimushe Lake (04-0032), Beltrami County
Elevation (ft. - NGVD1929)
20-Year Average
Lowest reported: 1312.04 on 9/15/06
1317.00
1316.00
1315.00
1314.00
1313.00
1312.00
1311.00
1310.00
10/1/04
1/1/05
4/1/05
7/1/05
10/1/05
1/1/06
4/1/06
7/1/06
Flour Lake (16-0147), Cook County
Elevation (ft. - NGVD1929)
38-Year Average
Lowest reported: 1730.45 on 9/17/06
1733.50
1733.00
1732.50
1732.00
1731.50
1731.00
1730.50
1730.00
1729.50
1729.00
Flour
Pimushe
Jessie
Hanging Kettle
Linka
Low Lake Levels during Drought
Jessie Lake (31-0786), Itasca County
Elevation (ft. - NGVD1929)
17-Year Average
Lowest reported: 1321.79 on 9/16/06
1324.50
1324.00
1323.50
1323.00
1322.50
1322.00
1321.50
1321.00
1320.50
Linka Lake (61-0037), Pope County
Elevation (ft. - NGVD1929)
12-Year Average
Lowest reported: 1183.98 on 8/29/06
1187.00
1186.50
1186.00
1185.50
1185.00
1184.50
1184.00
1183.50
1183.00
1182.50
Hanging Kettle Lake (01-0170), Aitkin County
Elevation (ft. - 1912 datum)
69-Year Average
Lowest reported: 1226.47 on 9/2/06
1229.50
1229.00
1228.50
1228.00
1227.50
1227.00
1226.50
1226.00
1225.50
1225.00
4/15/05
6/15/05
8/15/05
10/15/05
12/15/05
2/15/06
4/15/06
6/15/06
8/15/06

Although most lake levels in these dry areas recovered somewhat by spring 2006, the relief of landowners was short-lived. Very dry and hot weather from mid-May to September intensified conditions into a drought that was entrenched across northern and central Minnesota. Lake levels continued to drop steadily and significantly over the summer. Over 100 gaged lakes in our network experienced their lowest reported water levels in summer 2006, including a long list from Beltrami, Itasca, St. Louis, Aitkin, Todd, Stearns, and Pope counties. A number of gages had to be reset one to three times over the summer in deeper locations in order to capture any water level readings.


photo by Sandy Fecht

Lake Level Responses

In contrast to the drought, other areas' significant rainfalls were reflected in lake level increases during the 2005-2006 Water Year (Figure 2 hydrographs). Frequent and abundant rainfalls across the state in spring 2005 were exemplified by the fact that many lakes in Otter Tail County reported their highest water levels. Severe thunderstorms and large amounts of rainfall in late August 2005 raised water levels and kept them high throughout late summer in Kandiyohi County. A large portion of east-central counties received up to seven inches of rain in one day in October 2005. This rare occasion overtopped lake gages and spiked lake levels to a number of highest reported levels in the metropolitan area, as well as Chisago, Stearns and Sherburne counties.

Wet weather in spring 2006 caused over a dozen Otter Tail County lakes to rise and experience their highest reported water levels. After May, only a few lakes reached their highest lake level as the drought intensified. August 2006 rainfall events resulted in lake level responses in spots; unfortunately, the rains did not fall on those areas in the midst of the drought.

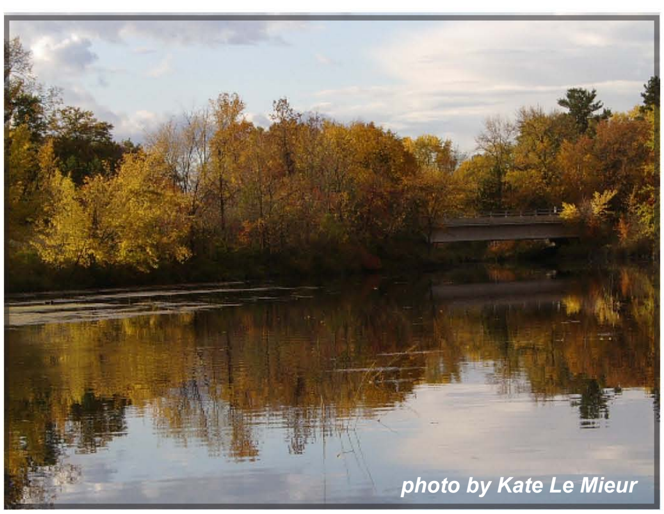


photo by Kate Le Mieur

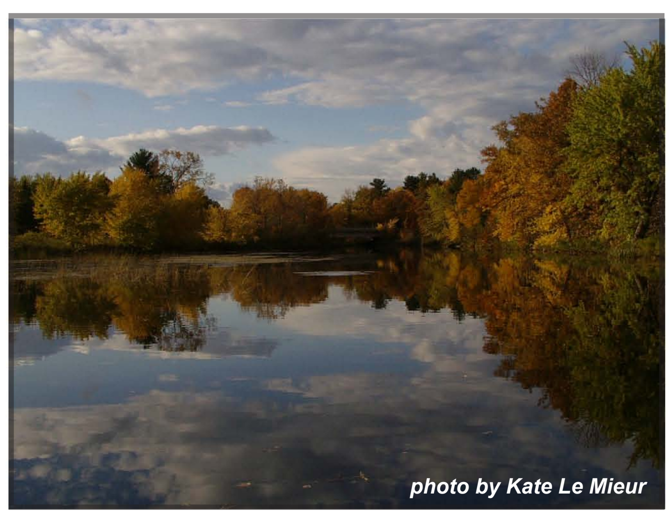
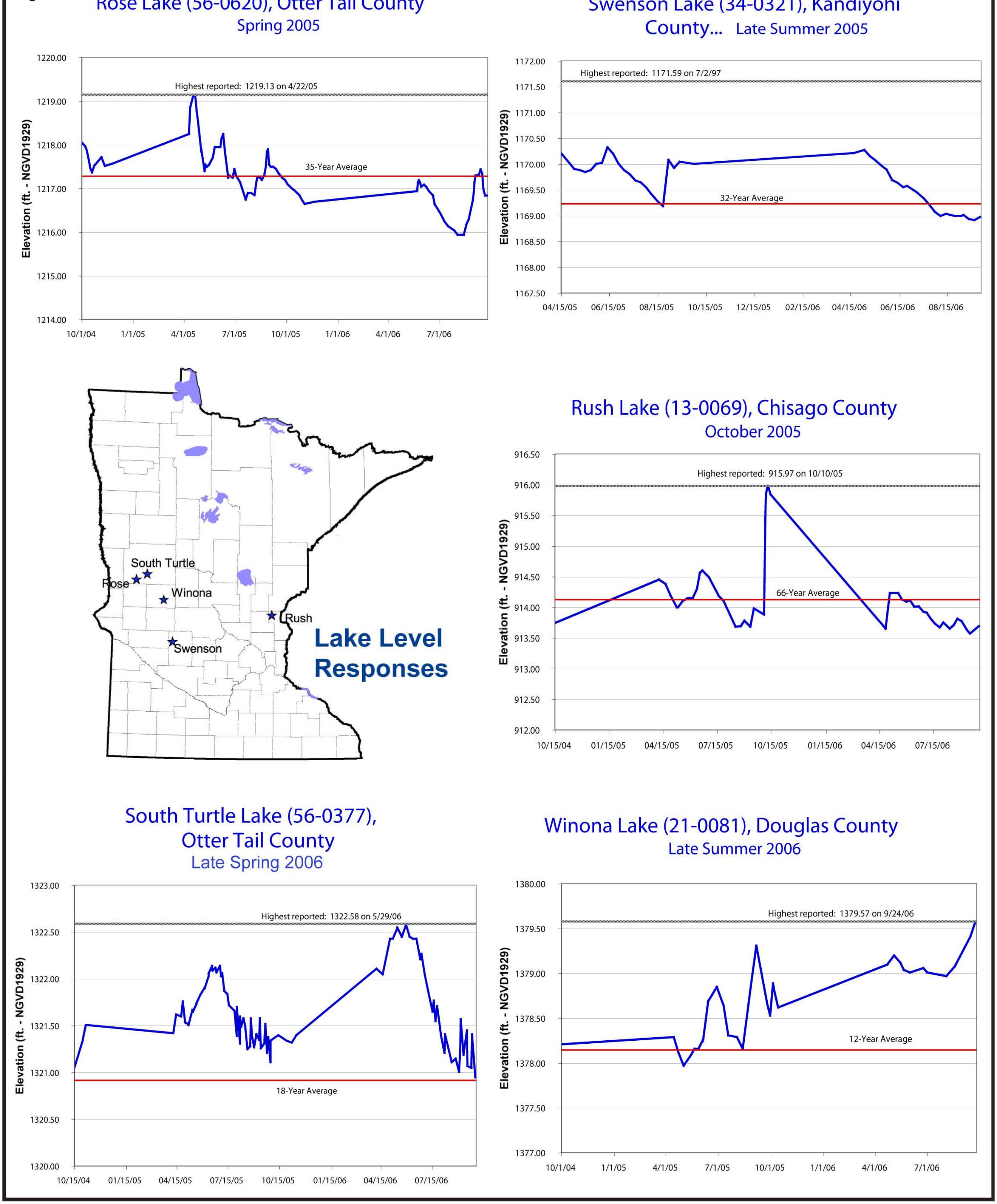


photo by Kate Le Mieur

Figure 2


Rose Lake (56-0620), Otter Tail County
Spring 2005
Elevation (ft. - NGVD1929)
Highest reported: 1219.13 on 4/22/05
35-Year Average
Swenson Lake (34-0321), Kandiyohi County... Late Summer 2005
Elevation (ft. - NGVD1929)
Highest reported: 1171.59 on 7/2/97
32-Year Average
Rush Lake (13-0069), Chisago County
October 2005
Elevation (ft. - NGVD1929)
Highest reported: 915.97 on 10/10/05
66-Year Average
South Turtle
Rose
Winona
Rush
Swenson
Lake Level Responses
South Turtle Lake (56-0377), Otter Tail County
Late Spring 2006
Elevation (ft. - NGVD1929)
Highest reported: 1322.58 on 5/29/06
18-Year Average
Winona Lake (21-0081), Douglas County
Late Summer 2006
Elevation (ft. - NGVD1929)
Highest reported: 1379.57 on 9/24/06
12-Year Average

Ten-Year Trends

Information has been collected and reported over a period of more than 10 years for many of the lakes that are currently monitored. A 10-year average may be used as a point of reference when comparing water year data to a shorter or longer time period, or a 10-year climate cycle. It may be useful in discerning trends for an individual basin.

A selection of lakes is shown in Figures 3 and 4. Nine out of 10 of these lakes indicated responses to the dry climate. Any lake level recoveries during the spring were not retained, as the lakes from the northern half and many of the lakes in the central part ended Water Year 2006 below average. Three of the five northern lakes reported their lowest levels of the last 10 years, as well as White Bear Lake from the metro area.

Landlocked Basins

A landlocked lake has no regularly-functioning surface outlet channel, and usually a small watershed. These types of lakes typically experience large, long-term water level fluctuations. The importance of ground water contributions to a landlocked lake can make the lake a good indicator of local ground water levels and movement. Examples of landlocked basins are shown in Figure 5. These lakes also reflect responses to the dry conditions of 2005 and 2006.

Annual Lake Level Fluctuation

Minnesota lakes typically fluctuate one to two vertical feet in a given year, but historical fluctuations have been recorded in excess of 10 feet. Assessing the annual fluctuation can be done by looking at the changes from one Water Year to the next. Another primary evaluation tool is the "starting point," (i.e., the elevation of the lake in spring), and how that compares to the end of the open water season and how that year compares to the "starting point," "end point," and pattern of other years. The lake levels and their patterns can then be evaluated in the context of historical climate data.

The statewide average fluctuation for Water Year 2005 was 1.07 feet, but increased to 1.29 feet for the statewide average during Water Year 2006. Average fluctuations for the past 10 Water Years are shown in the figure below. Link here to tables which display fluctuations, spring and fall elevations, ranges, reported highest and lowest lake levels and their dates, and averages for selected lakes grouped by county.

Additional summary information, 10-year trend graphs, and a comprehensive list of all reported lake levels for an individual lake may be found on the DNR Lake Finder web site.

Water Year	Average Fluctuation Statewide (ft.)
1997	1.55
1998	1.04
1999	1.24
2000	1.05
2001	1.97
2002	1.33
2003	1.42
2004	1.24
2005	1.07
2006	1.29

Figure 3

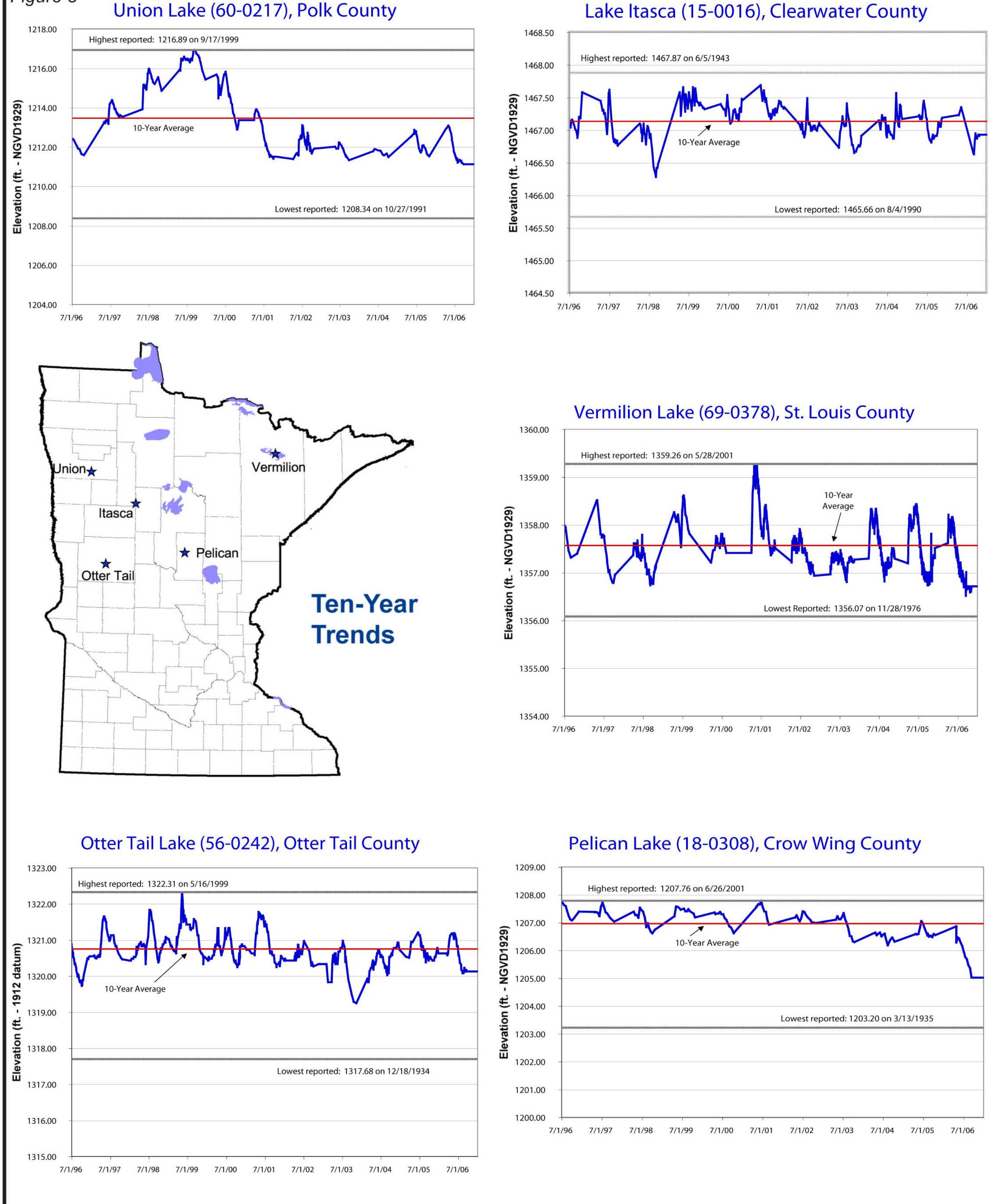

Union Lake (60-0217), Polk County
Highest reported: 1216.89 on 9/17/1999
10-Year Average
Lowest reported: 1208.34 on 10/27/1991
Elevation (ft. - NGVD1929)
Lake Itasca (15-0016), Clearwater County
Highest reported: 1467.87 on 6/5/1943
10-Year Average
Lowest reported: 1465.66 on 8/4/1990
Elevation (ft. - NGVD1929)
Union
Itasca
Vermilion
Pelican
Otter Tail
Ten-Year Trends
Vermilion Lake (69-0378), St. Louis County
Highest reported: 1359.26 on 5/28/2001
10-Year Average
Lowest Reported: 1356.07 on 11/28/1976
Elevation (ft. - NGVD1929)
Otter Tail Lake (56-0242), Otter Tail County
Highest reported: 1322.31 on 5/16/1999
10-Year Average
Lowest reported: 1317.68 on 12/18/1934
Elevation (ft. - 1912 datum)
Pelican Lake (18-0308), Crow Wing County
Highest reported: 1207.76 on 6/26/2001
10-Year Average
Lowest reported: 1203.20 on 3/13/1935
Elevation (ft. - NGVD1929)
7/1/96
7/1/97
7/1/98
7/1/99
7/1/00
7/1/01
7/1/02
7/1/03
7/1/04
7/1/05
7/1/06

Figure 4

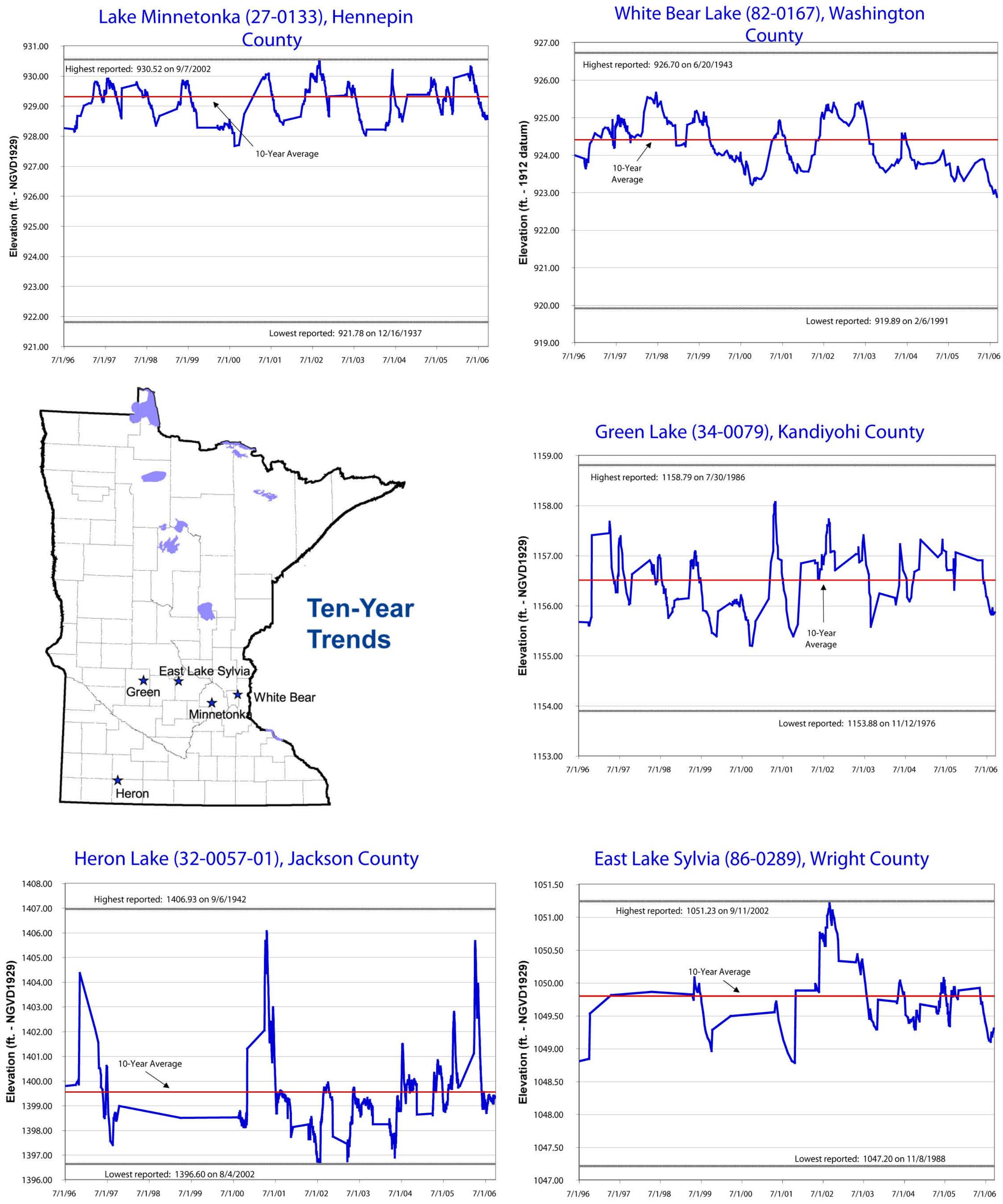
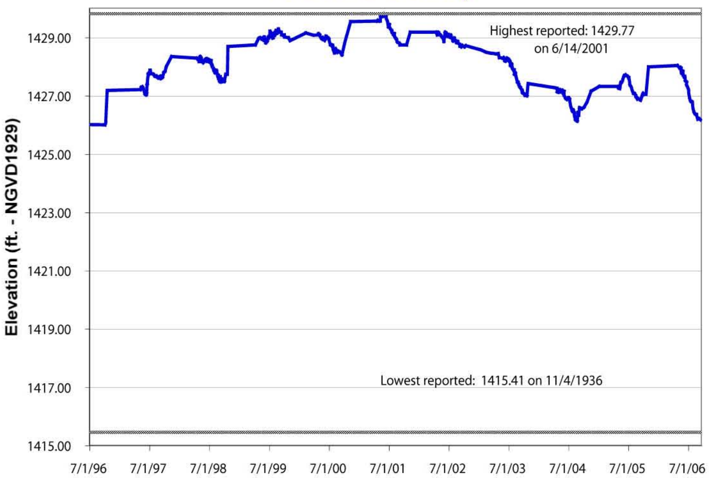
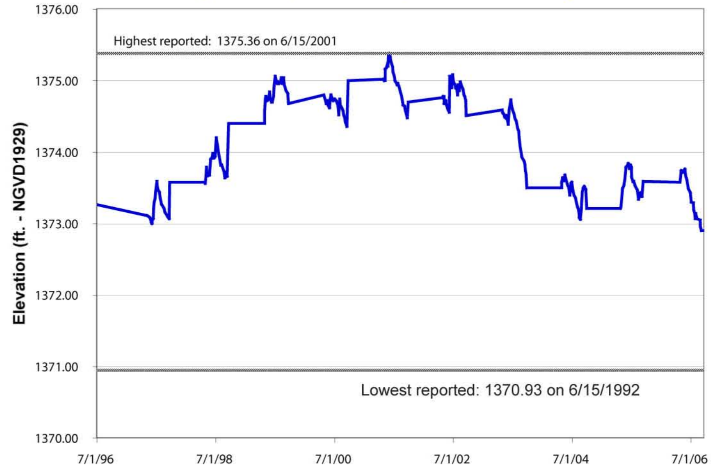

Lake Minnetonka (27-0133), Hennepin County
Highest reported: 930.52 on 9/7/2002
10-Year Average
Lowest reported: 921.78 on 12/16/1937
Elevation (ft. - NGVD1929)
White Bear Lake (82-0167), Washington County
Highest reported: 926.70 on 6/20/1943
10-Year Average
Lowest reported: 919.89 on 2/6/1991
Elevation (ft. - 1912 datum)
Ten-Year Trends
East Lake Sylvia
Green
White Bear
Minnetonka
Heron
Green Lake (34-0079), Kandiyohi County
Highest reported: 1158.79 on 7/30/1986
10-Year Average
Lowest reported: 1153.88 on 11/12/1976
Elevation (ft. - NGVD1929)
Heron Lake (32-0057-01), Jackson County
Highest reported: 1406.93 on 9/6/1942
10-Year Average
Lowest reported: 1396.60 on 8/4/2002
Elevation (ft. - NGVD1929)
East Lake Sylvia (86-0289), Wright County
Highest reported: 1051.23 on 9/11/2002
10-Year Average
Lowest reported: 1047.20 on 11/8/1988
Elevation (ft. - NGVD1929)
7/1/96
7/1/97
7/1/98
7/1/99
7/1/00
7/1/01
7/1/02
7/1/03
7/1/04
7/1/05
7/1/06

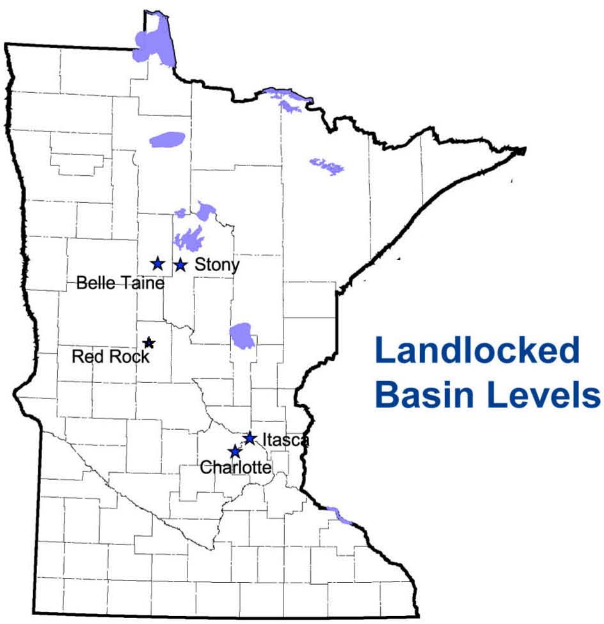
Figure 5

Belle Taine Lake (29-0146), Hubbard County

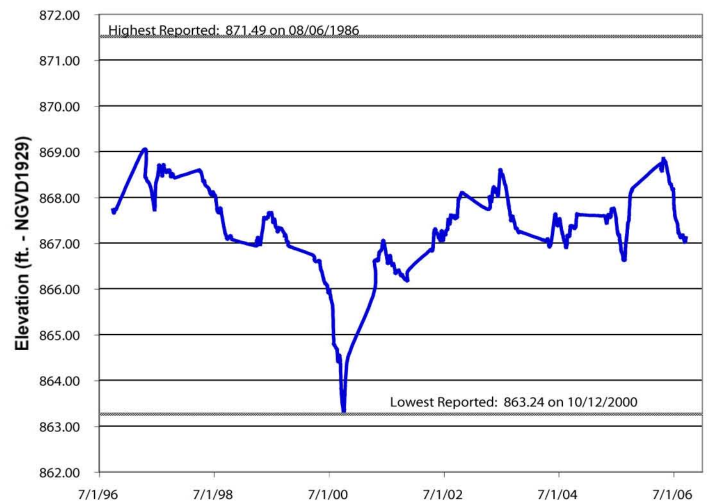


Stony Lake (11-0371), Cass County

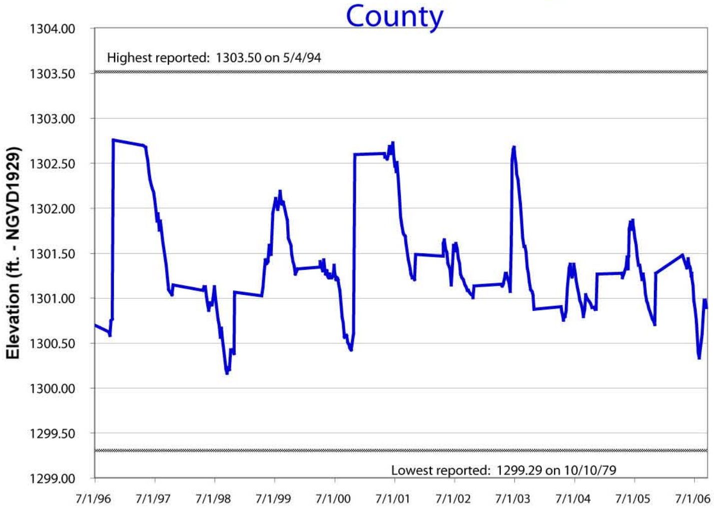




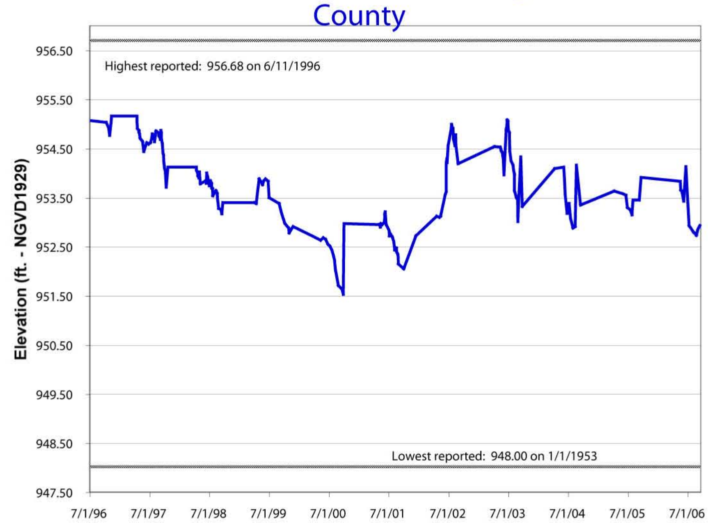
Itasca Lake (02-0110), Anoka County



Red Rock Lake (21-0291), Douglas County



Charlotte Lake (86-0011), Wright County



Ground Water

Chapter 3

photo by Jeff Green

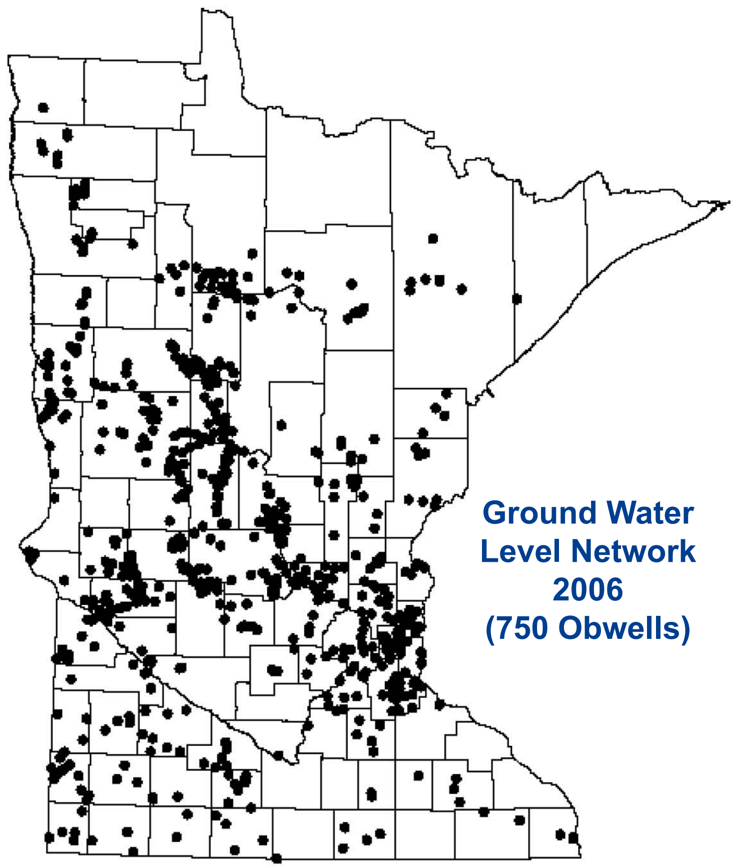

Ground Water
Level Network
2006
(750 Obwells)

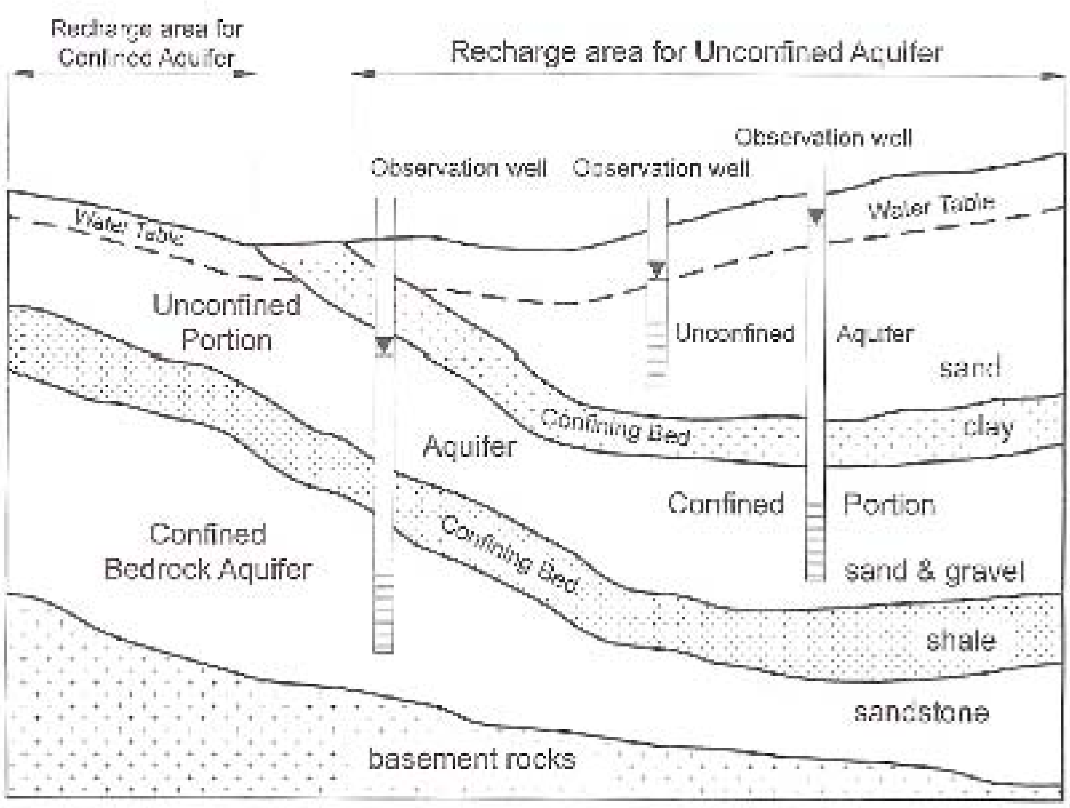

photo by Laurel Reeves

Introduction

Monitoring of ground water levels in Minnesota began in 1942 and, starting in 1947, was expanded by a cooperative program between the DNR and the United States Geological Survey (USGS). The number of observation wells (obwells) has remained constant at about 750 obwells over the last few water years. Data from these wells are used to assess ground water resources, determine long term trends, interpret impacts of pumping and climate, plan for water conservation, evaluate water conflicts, and otherwise manage the water resource. Soil and Water Conservation Districts (SWCD) and other cooperators under agreement with DNR Waters measure the wells monthly and report the readings to DNR Waters as part of the Ground Water Level Monitoring Program. Readings are also obtained from volunteers and electronic sources at other locations.

Figure 1

Hypothetical Unconfined and Confined Aquifer Systems



Aquifers

An aquifer is a water-saturated geologic formation which is sufficiently permeable to transmit economic quantities of water to wells and springs. Aquifers may exist under unconfined or confined conditions (Figure 1).

UNCONFINED AQUIFERS - In an unconfined aquifer, the ground water surface that separates the unsaturated and saturated zones is called the water table. The water table is exposed to the atmosphere through openings in the overlying unsaturated geologic materials. The water level inside the casing of a well placed in an unconfined aquifer will be at the same level as the water table. Unconfined aquifers may also be called water table or surficial aquifers.

For most of Minnesota, these aquifers are composed of glacial sand and gravel. Their areal extent is not always well defined nor is their hydraulic connection documented. They are often locally isolated pockets of glacial outwash deposited over an area of acres to square miles. Recharge to these units may be limited to rainfall over the area of the aquifer or augmented by ground water inflow. Consequently, care must be taken in extrapolating water table conditions based upon the measurements of a single water table well.

CONFINED AQUIFERS - When an aquifer is separated from the ground surface and atmosphere by a material of low permeability, the aquifer is confined. The water in a confined aquifer is under pressure, and therefore, when a well is installed in a confined aquifer, the water level in the well casing rises above the top of the aquifer. This aquifer type includes buried drift aquifers and most bedrock aquifers.

Buried drift aquifers consist of glacially deposited sands and gravels, over which a confining layer of clay or clay till was deposited. Their areal extent and hydraulic connections beneath the ground surface are often unknown; therefore, an obwell placed in one of these units may be representing an isolated system. Ground water investigations involving buried drift aquifers require considerable effort to evaluate the local interconnection between these aquifer units.

Bedrock aquifers are, as the name implies, geologic bedrock units which have porosity and permeability such that they meet the definition of an aquifer. Water in these units is either located in the spaces between the rock grains (such as sand grains) or in fractures within the more solid rock. While these aquifers can be unconfined, the ones measured in the ground water level monitoring network are generally bounded above and below by low-permeability confining units. Unlike buried drift aquifers, bedrock aquifers are fairly well defined in terms of their areal extent and the units are considered to be connected hydrologically throughout their occurrence.

Seasonal climatic changes affect the water levels in aquifer systems. Recharge, which is characterized by rising water levels, results as snow melt and precipitation infiltrate the soil and percolate to the saturated zone. Drawdown, characterized by the lowering of water levels, results as plants transpire soil water; ground water discharges into lakes, springs, and streams; or well pumping withdraws water from the aquifer. An unconfined aquifer generally responds more quickly to these changes than a confined aquifer since the water table is in more direct contact with the surface. However, the magnitude of change in water levels will usually be more pronounced in a confined aquifer.

Statewide Summary

For many years, the DNR has maintained a network of observation wells throughout the state for the purpose of monitoring aquifer water levels. During the last few years, the DNR monitored water levels in approximately 750 wells. Water levels are usually recorded monthly from March through November. Figures 2, 3, 4 and 5 show the locations of these wells, identifying those that were placed in unconfined (water table) aquifers, in buried drift aquifers and in bedrock aquifers.

As reflected in observed ground water levels, several parts of the state experienced fairly dry conditions at times during Water Years 2003, 2004 and 2005. And then Water Year 2006 saw a rapid decline statewide into drought conditions. The impacts of this drought serve as the focus for this report on ground water levels. To this end, water levels were investigated over a timeframe from 1989 (the last major drought in Minnesota) to the present.

The remainder of this chapter discusses the ground water levels in unconfined and confined aquifers during Water Years 2005 (WY05) and 2006 (WY06). This discussion focuses on a comparison of obwell water levels in WY05 and WY06 to water levels over the timeframe noted above. Obwells were chosen to represent regions of the state that seemed to experience varying degrees of the 2006 drought. Hydrographs of these representative obwells illustrate the analysis (pages 52-68).

photo by Jeff Green

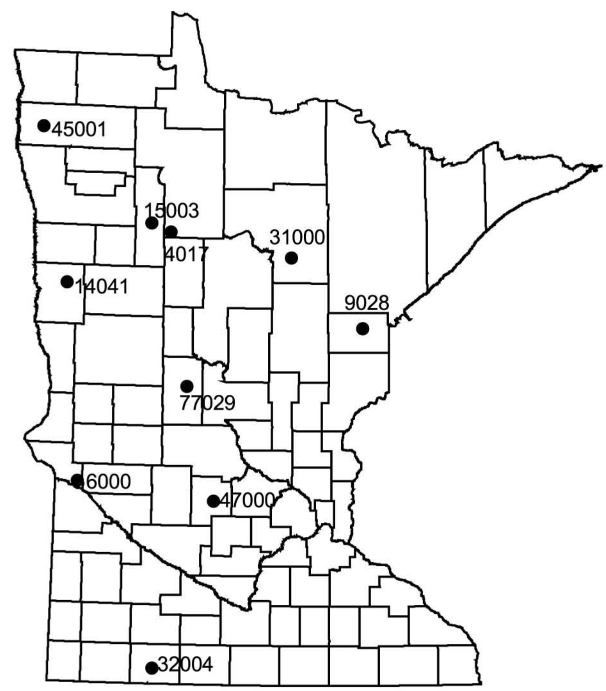
Unconfined (Water Table) Aquifers

While drainage from an unconfined aquifer continues throughout the winter, recharge is restricted. In general, winter precipitation is stored as snowpack, and frozen soil prevents or slows the infiltration and percolation of spring snowmelt. By the end of winter, water tables would be expected to be at a low point. As the soil thaws and spring rains occur, the water table aquifers are recharged resulting in the higher water tables.

The approximate locations of the water table wells used in this report are shown in Figure 2. Hydrographs for these wells, over the period from 1989 to present, are shown in Figures 6A-6J. In this figure, the portion of the hydrograph representing WY05 and WY06 is shown in bold red and can easily be compared to previous water levels.

Figure 2

Water Table Obwells



The hydrographs show that throughout the state, spring recharge in both WY05 and WY06 raised the water table to levels either equivalent to, or more generally, higher than in the immediately preceding few years. As summers progressed, water levels declined. As the drought presented itself in WY06 these summer declines

Measuring water levels

lowered the water table to levels lower than those of WY05. An exception was in the west-central part of the state (represented by the Clay County obwell) where the drought was not as severe.

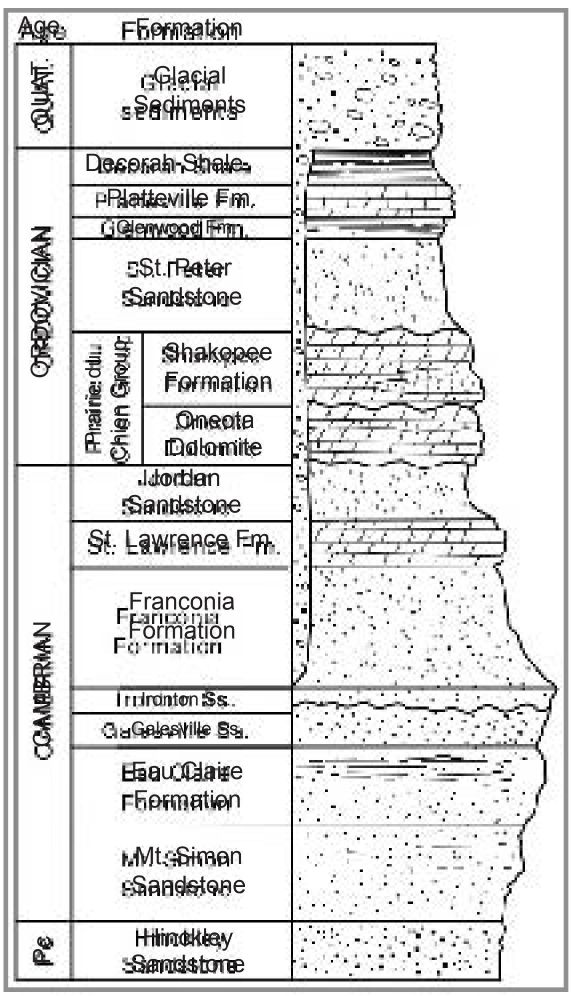
Even though the drought was severe in WY06, in general, the water table did not drop to levels to warrant major concern. There were, however, a few areas that showed some impact from the drought. In northwest Minnesota, as represented by the Clearwater County obwell, both WY05 and WY06 water table lows were slightly below those of 1989, but in the range of readings for the previous recent years. Also, the Todd County obwell, situated in an area where the drought was severe, registered a slightly low water level in WY06, but was still well above the levels of the 1989 drought. The Itasca County obwell indicated water table levels in WY06 that were lower than those of 1989. However, these levels were higher than the water table in 2003 and 2004 which was the low-point for a 4-year water level decline.

On site obwell drilling

Confined Aquifers

Water levels in confined aquifers may respond to changes in precipitation patterns differently than they would in water table aquifers – the presence of an overlying confining bed inhibits the movement of rain or snowmelt downward into the confined aquifer thereby delaying the recharge of the aquifer. During dry periods, the demand for increased water use from a confined aquifer will be reflected in declining water levels. As the dry period ends and precipitation returns to normal, recovery of water levels will be delayed due to the slow movement of water into the confined aquifer. Recovery may take two, three, or more years.

Wetter than normal periods may not cause rising water levels in confined aquifers for a few years because, again, of the slow water movement through the confining layers.



Example of a generalized geologic column for the 7-county metropolitan area.

Buried Drift Aquifers

Under confined conditions, buried drift aquifers generally respond more slowly to seasonal inputs from snowmelt and precipitation than water table aquifers do. However, buried drift aquifers can be near the surface with their extent poorly defined and with some connection to adjacent unconfined aquifers. As a result, response of buried drift aquifers to recharge is determined by individual characteristics. The response is therefore difficult to predict.

Figure 3

Buried Drift Obwells

The approximate locations of the buried drift wells used in this report are shown in Figure 3. Hydrographs for these wells, over the period from 1989 to present, are shown in Figure 7. In this figure, the portion of the hydrograph representing WY05 and WY06 is shown in bold red and can easily be compared to previous water levels.

As in the case with water table wells, the buried drift hydrographs show that throughout the state, spring recharge in both WY05 and WY06 raised the water levels to equivalent, or more generally, higher levels than in the immediately preceding few years. As summers progressed, water levels declined. It is interesting to note that this summer decline was generally as great in WY05 as in WY06. Two exceptions were in the southwest (represented by Big Stone and Jackson County obwells) and in the north-central part of the state (Wadena and Hubbard Counties) where WY05 levels were in the normal range.

As summers progressed, water levels declined. As the drought developed in WY06 these summer declines lowered the water levels to lower levels than those of WY05. An exception was in the west-central part of the state (represented by the Clay County obwell) where the drought was not as severe.

The most dramatic mid-summer 2006 water level declines occurred in the central and north-central parts of the state. This is shown in the Meeker, Wadena, Hubbard and Aitkin Counties' hydrographs.

Nearly all of the buried drift aquifer hydrographs show the beginnings of, or nearly complete, return to water levels similar to those before the onset of the drought. In a couple of cases where the last available reading in WY06 did not show recovery, subsequent readings in WY07 confirm the recovery.

Bedrock - Prairie du Chien and Jordan Aquifers

In past years, the Prairie du Chien and Jordan aquifers have been considered hydrologically linked and generally considered as one hydrologic unit. Conditions in the "Prairie du Chien/Jordan Aquifer" were considered to be to be represented by water level monitoring wells completed in the Prairie du Chien, the Jordan or in both the Prairie du Chien and Jordan formations.

Studies in recent years, especially those of the Minnesota Geological Survey (MGS), have begun to question the lumping of the two formations into one hydrologic unit. The information presented here relative to water levels in WY05 and WY06 is not meant to offer support for either the "lumping" or the "splitting" of these two geologic units; however, it appears in some cases that the two units are responding to the drought of '06 in differing ways, and this will be discussed.

Locations of the Prairie du Chien (PDC) and Jordan (JDN) wells used in this report are shown in Figure 4. Wells identified by number are those wells for which hydrographs are shown in Figures 8A-9K which follow.

photo by DNR Waters

For this report there were adequate numbers of wells distributed around the metro area to allow the JDN and PDC aquifer levels to be looked at separately. One exception was in Dakota County where totally JDN wells were not available. Looking at many of the wells completed in both the PDC and JDN in Dakota County, it appeared as if they were responding to climatic events in a manner similar to JDN wells. Consequently, in examining the Jordan aquifer levels in the metro area, one PDC/JDN well in southern Dakota County was included.

Jordan Aquifer

Water levels in the Jordan aquifer system throughout the metro area generally showed summertime declines below recent levels in both WY05 and WY06. However, there were some exceptions in WY05. Hennepin County's City of Bloomington and City of New Hope obwells and the St. Lawrence Creamery well in Rice County all showed minimal, or no summer declines during WY05.

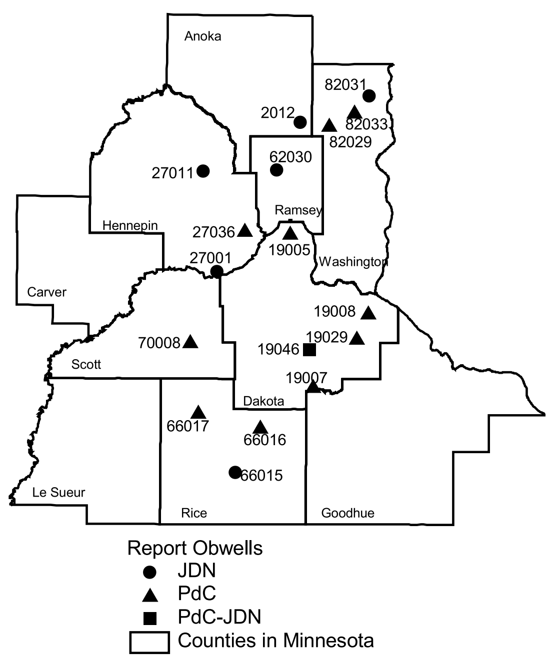
The drought of 2006 manifested in extremely low water levels for parts of the metro Jordan aquifer system; this was represented by Hennepin County's obwells at the City of Bloomington and City of New Hope, Rice County's St. Lawrence Creamery, and the obwell in the Prairie du Chien/Jordan aquifer in southern Dakota County. However, all of these extreme declines ceased and water levels recovered as the wetter fall of WY07 began.

Prairie du Chien

Water levels in the Prairie du Chien aquifer showed variable response to the conditions of WY05 and WY06. In Hennepin, Scott and Rice counties, water levels fluctuated in a manner similar to recent preceding years, with no appreciable declines in either water year. Dakota County PDC obwells showed a lot of variation: obwell 19005 in the north looked like a continuation of recently increasing water level trends. Obwells 19008 and 19029 exhibited severe water level declines; obwell 19007 showed a large decline in water level for summertime WY06, but this was in keeping with patterns of recent years. And, in northern Washington County, water levels showed a decline similar to those in Dakota County. It is interesting to note that the hydrograph for PDC well 82033 and JDN well 82031 are very similar. These two wells are located in close proximity and one would probably conclude that the two formations are functioning as one, interconnected aquifer.

Figure 4

Prairie du Chien & Jordan Obwells



Bedrock - Mt. Simon Aquifer

Figure 5

Mt. Simon Obwells

With some exceptions, the Mt. Simon aquifer is everywhere confined. It may respond as an unconfined aquifer in the atypical instances where the aquifer is adjacent to unconfined materials, such as along deeply incised buried glacial valleys.

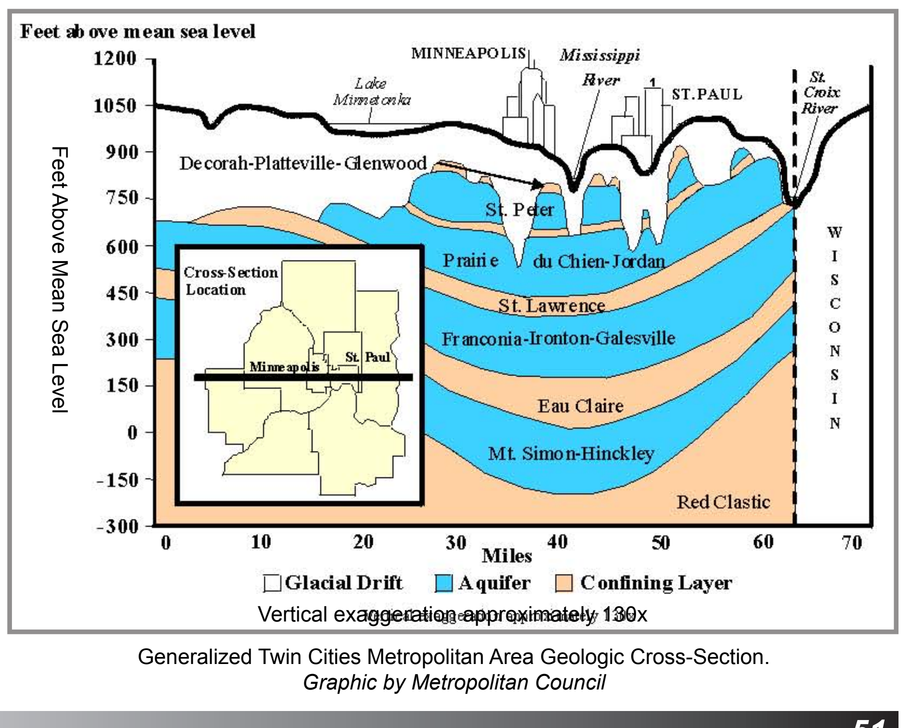
Locations of the Mt. Simon wells used for this summary are shown in Figure 5. Hydrographs depicting representative water levels across the metro area are shown in Figures 10A-i.

Many of the Mt. Simon obwells have a fairly short period of record. Consequently it is difficult to place the WY05 and WY06 readings in a long-term perspective. However, the data that are available provide a look at how the aquifer is responding to recent climate.

Generally the WY05 and WY06 Mt. Simon water levels fluctuated within the bounds of recent previous years, and springtime high water levels were similar to preceding recent spring times.

A couple of exceptions did occur, however. In the northern reaches of the aquifer, shown as the Isanti obwell, WY05 showed drawdowns far exceeding the previous years. There was no spring recovery and WY06 saw the water levels decline even more. In Washington County, WY06 water levels were drawn down to a point lower than any time in the preceding short history of that well. And finally, in the south metro, the Scott County obwell showed a situation where the springtime high levels in WY05 and WY06 did not show recovery to preceding levels and where WY06 water level declined to a new low.

One can also note on this Scott County hydrograph that the Mt. Simon aquifer water levels in the Savage area are continuing their long-term decline. While some of this is climatically induced, part of the decline must be attributed to pressures exerted on this aquifer by increasing development in the area.



Generalized Twin Cities Metropolitan Area Geologic Cross-Section.
Graphic by Metropolitan Council

Figure 6A

Beltrami County - Water Table #4017

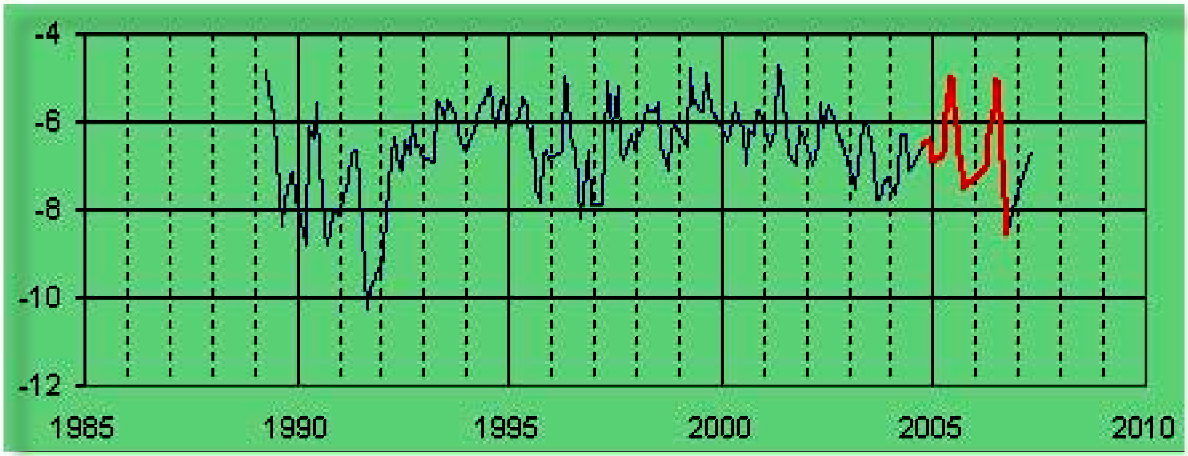
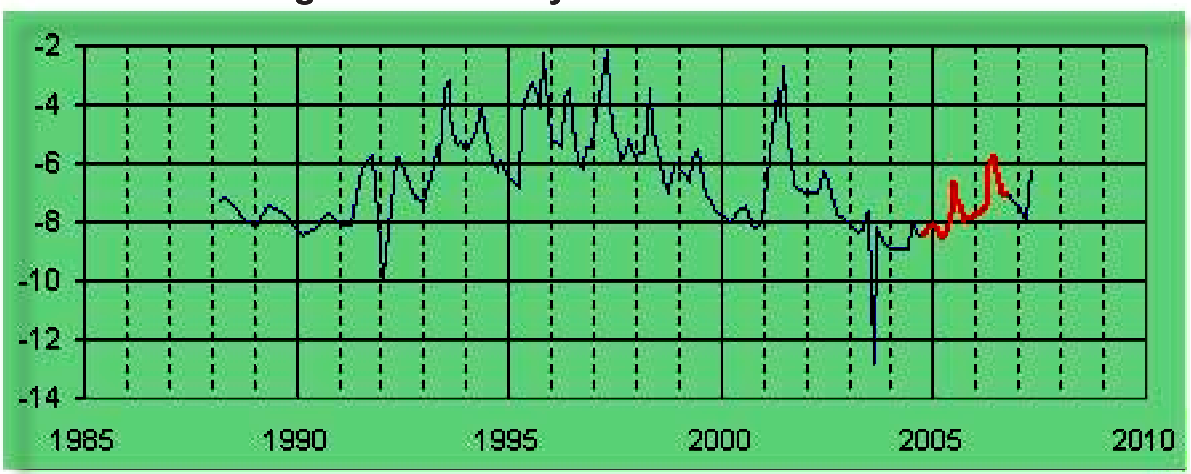


Figure 6B

Big Stone County - Water Table #6000



Depth to Water, ft.

Figure 6C

Carlton County - Water Table #9028

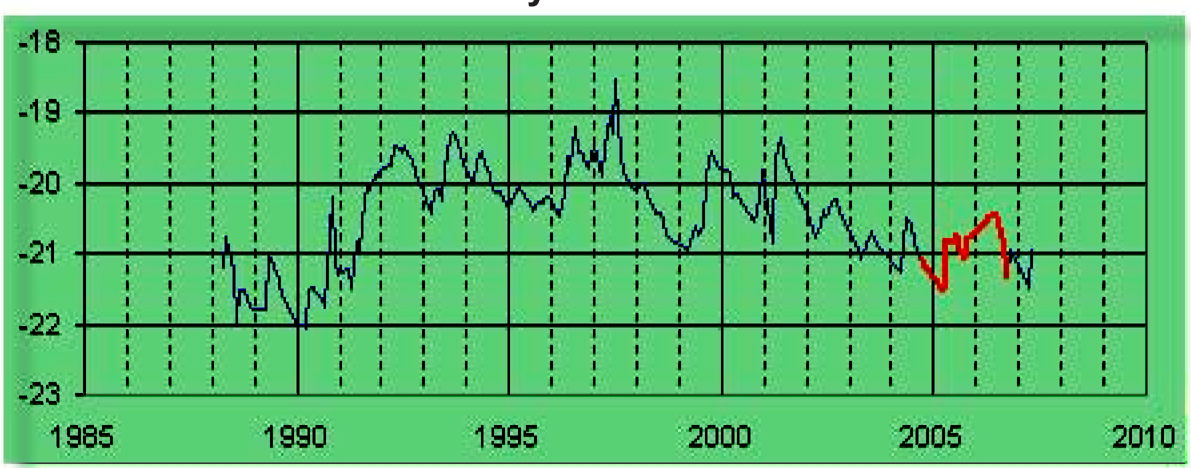


Figure 6D

Clay County - Water Table #14041

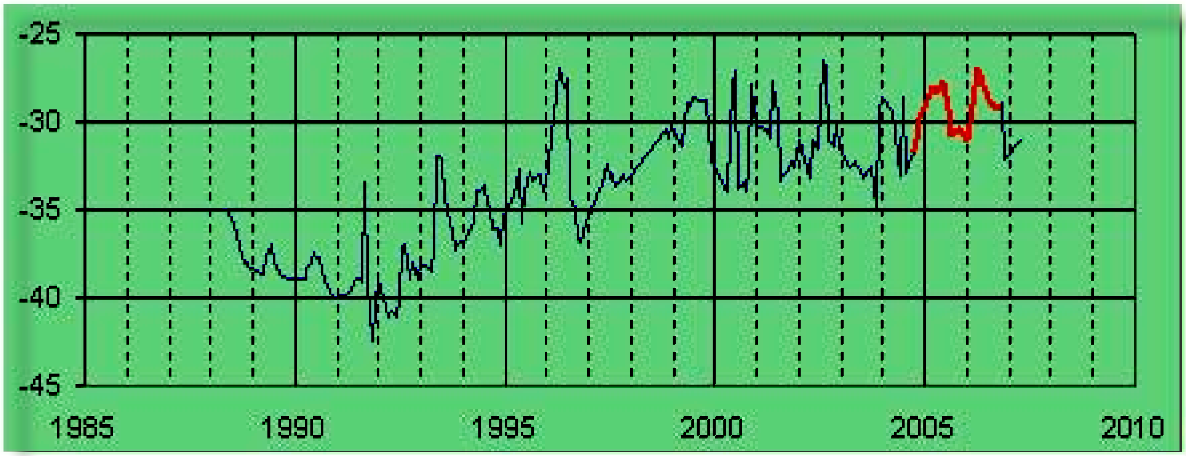


Figure 6E

Clearwater County - Water Table #15003

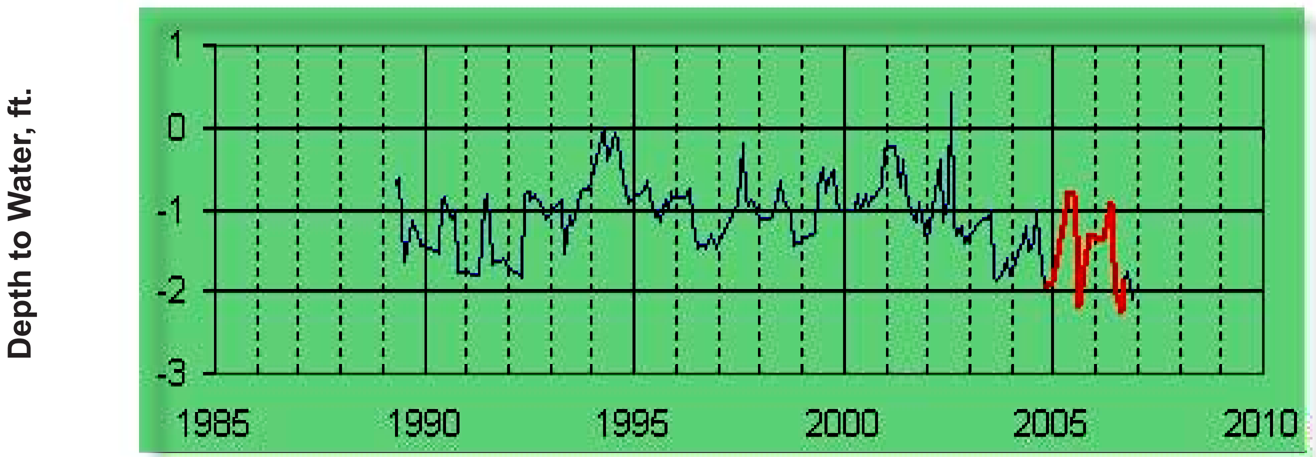


Figure 6F

Itasca County - Water Table #31000

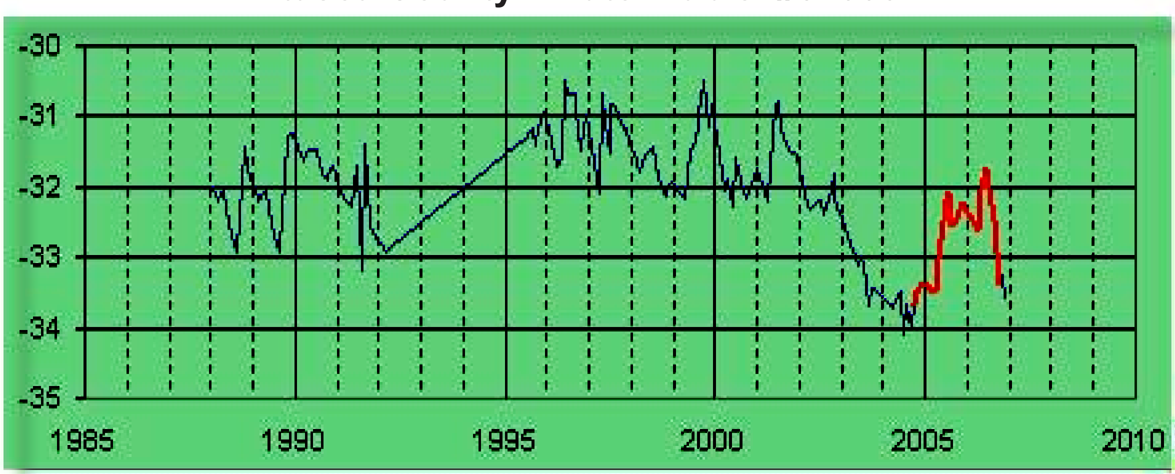


Figure 6G

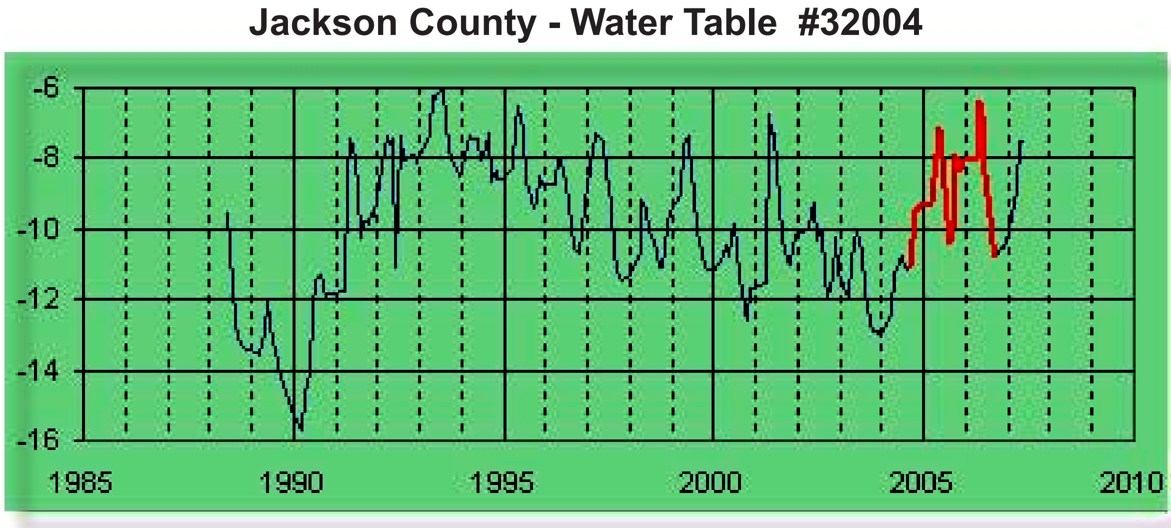


Figure 6H

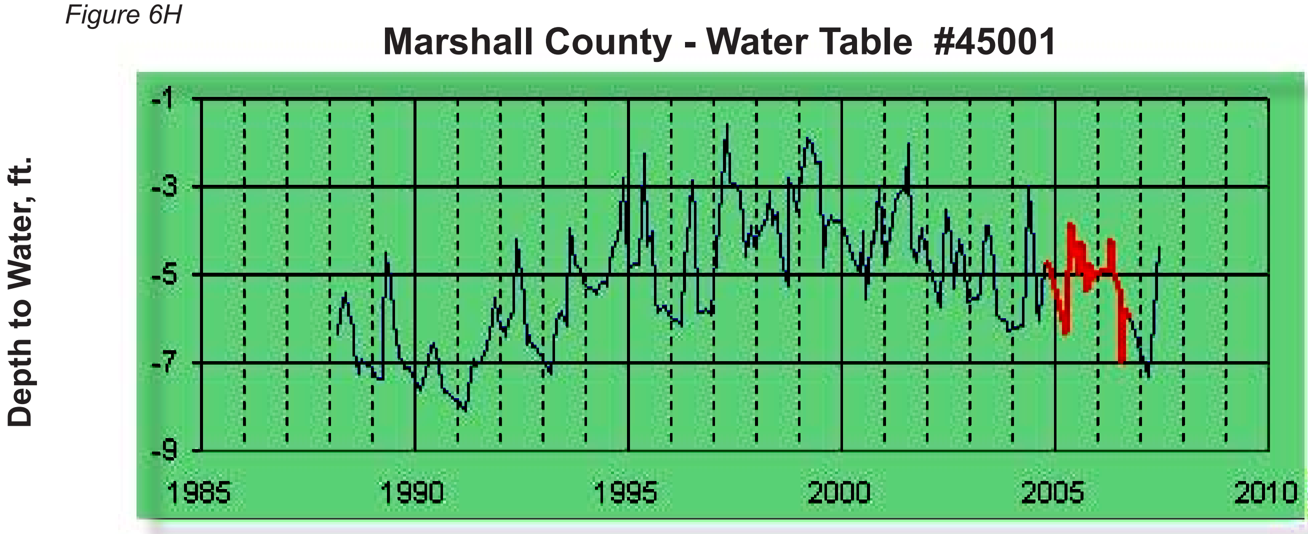


Figure 6i

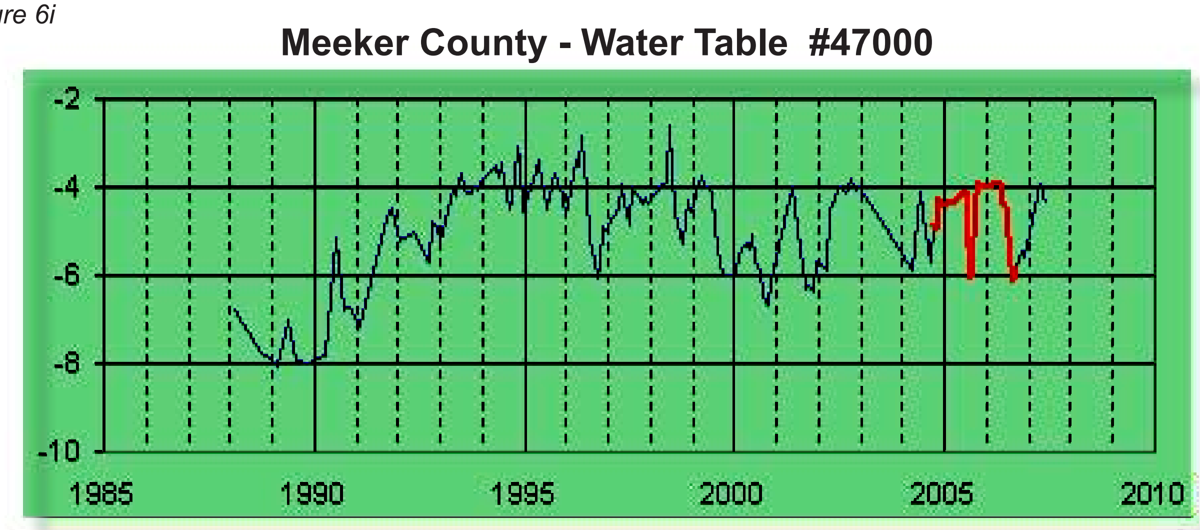


Figure 6J

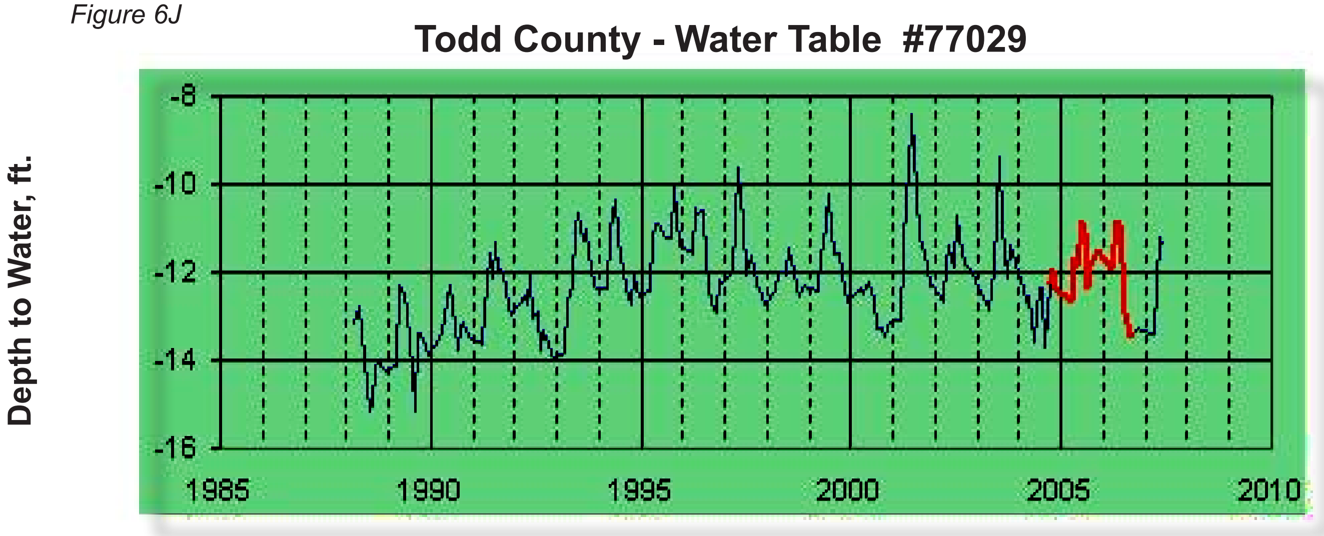

Todd County - Water Table #77029
Depth to Water, ft.
-8
-10
-12
-14
-16
1985
1990
1995
2000
2005
2010

Figure 7A

Aitkin County - Buried Drift #1007

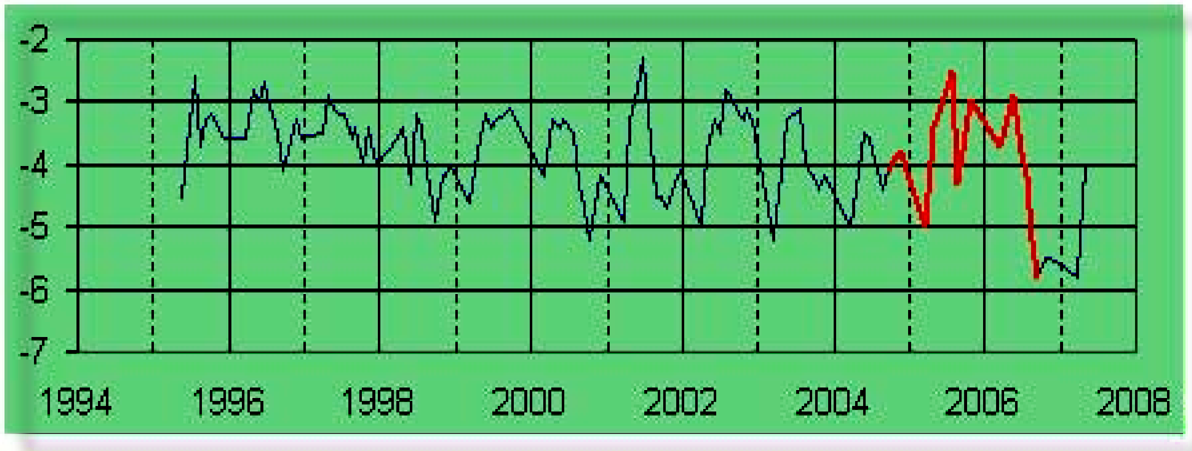
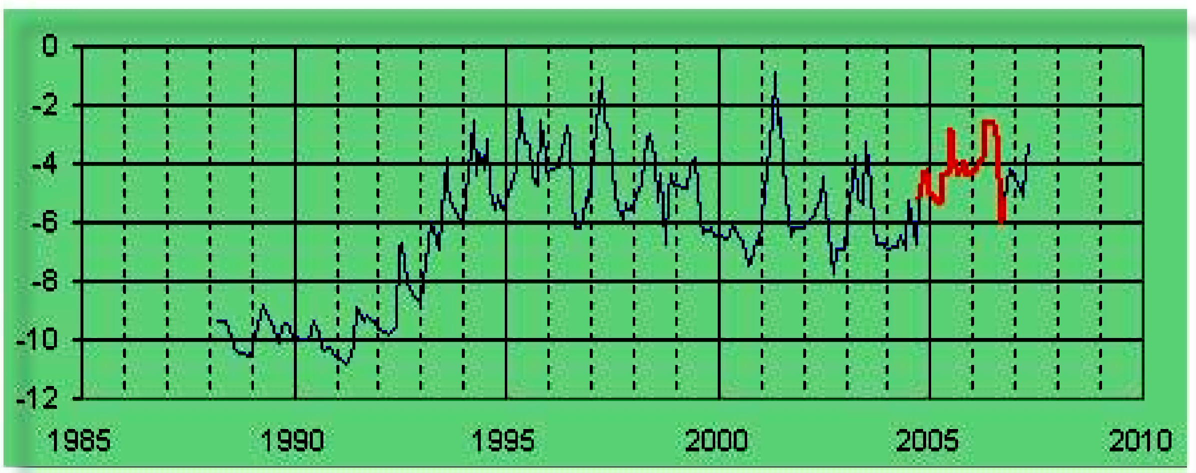


Figure 7B

Big Stone County - Buried Drift #6007



Depth to Water, ft.

Figure 7C

Clay County - Buried Drift #14038

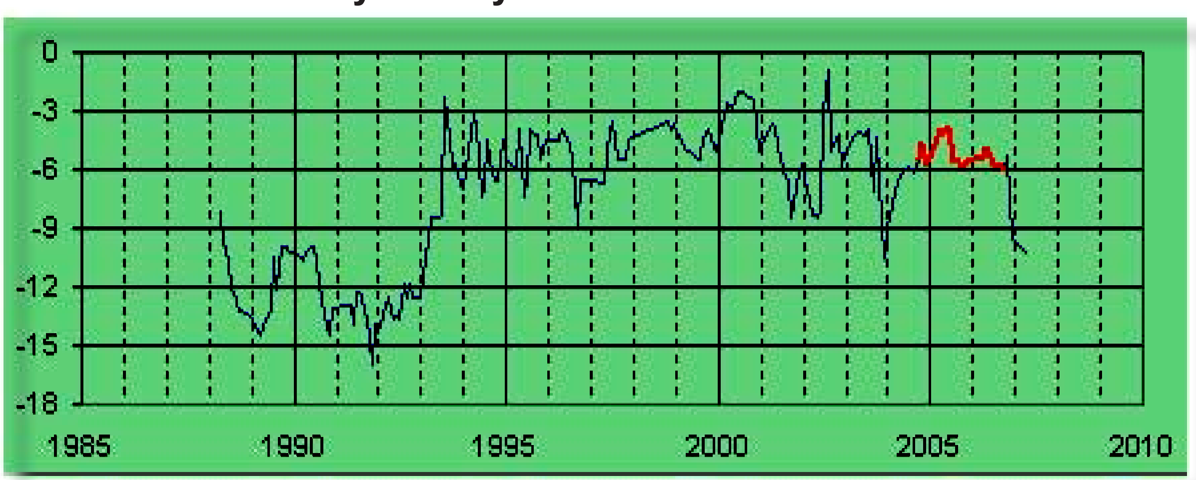


Figure 7D

Clearwater County - Buried Drift #15002

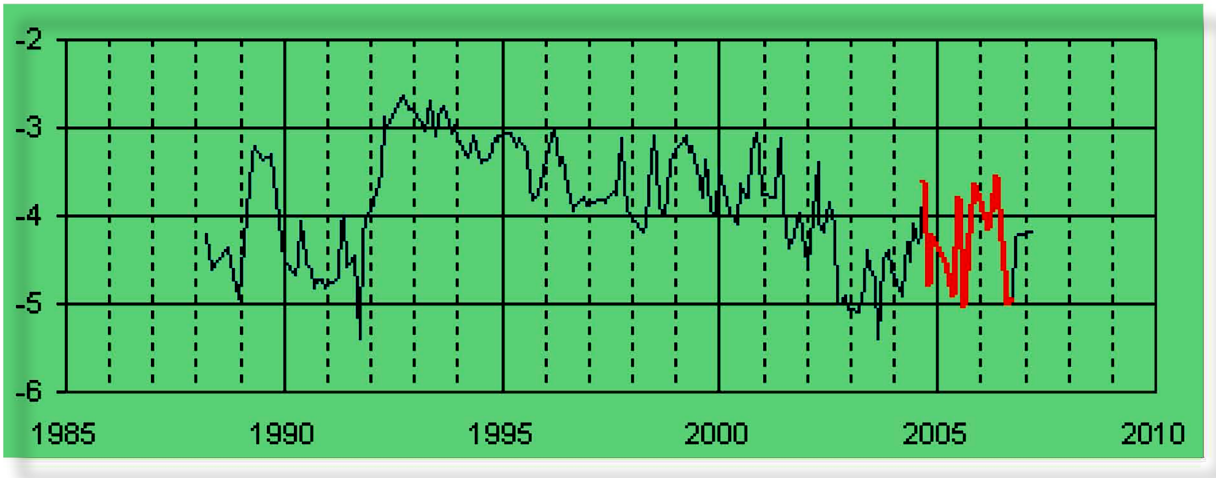


Figure 7E

Hubbard County - Buried Drift #29032

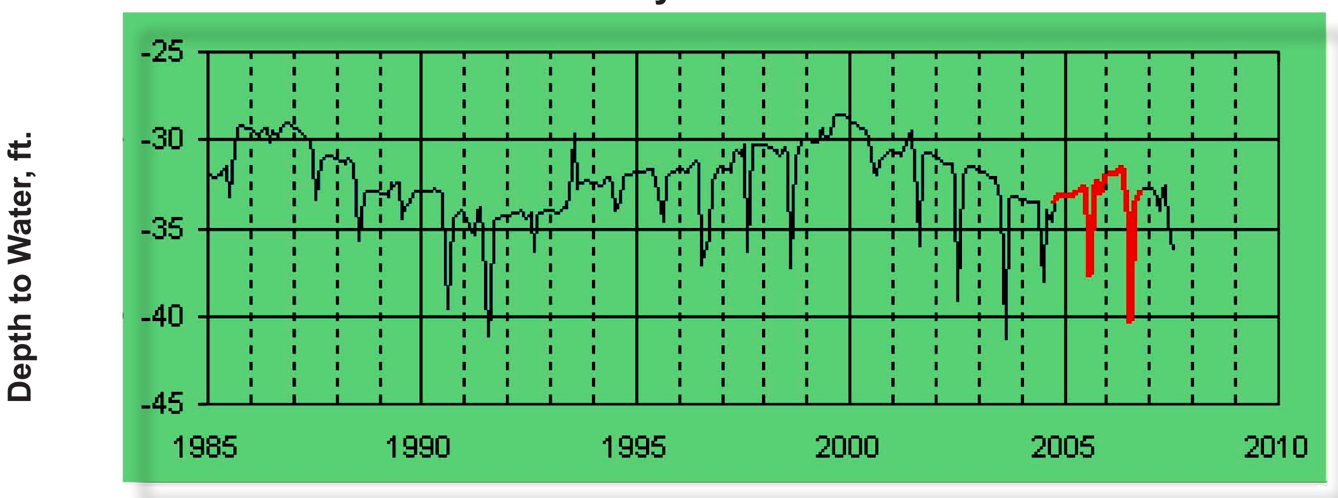


Figure 7F

Jackson County - Buried Drift #32003

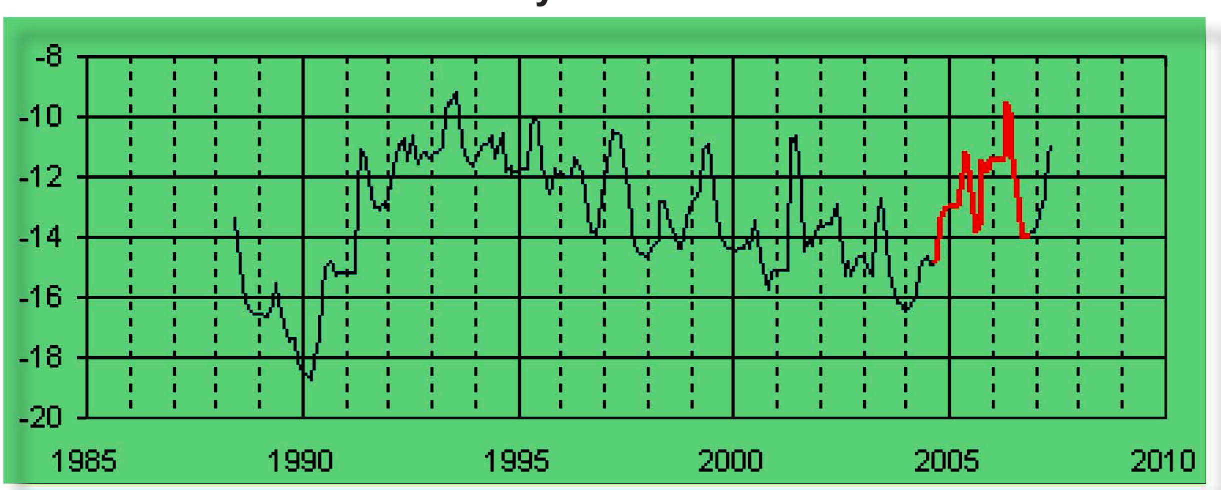


Figure 7G

Marshall County - Buried Drift #45000

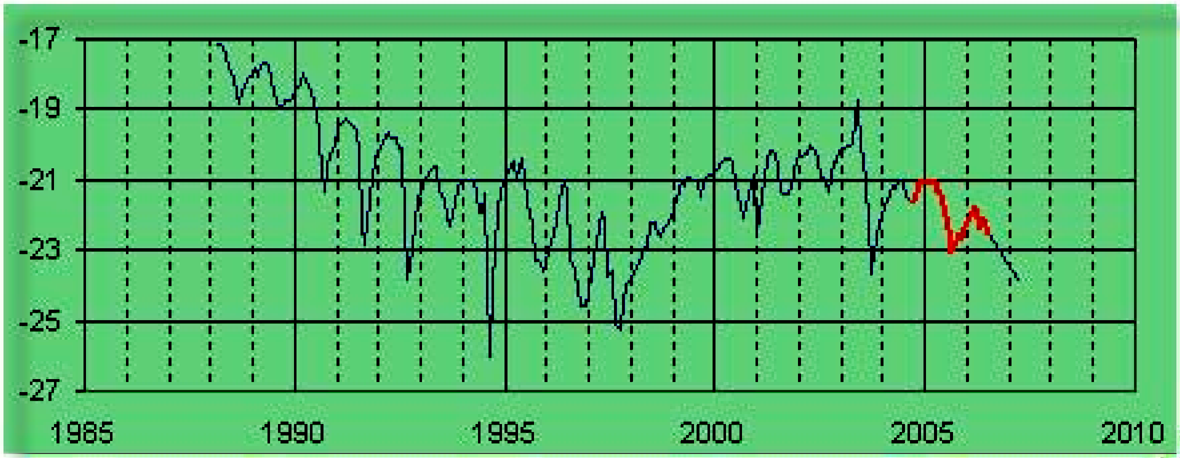


Figure 7H

Meeker County - Buried Drift #47007

Depth to Water, ft.

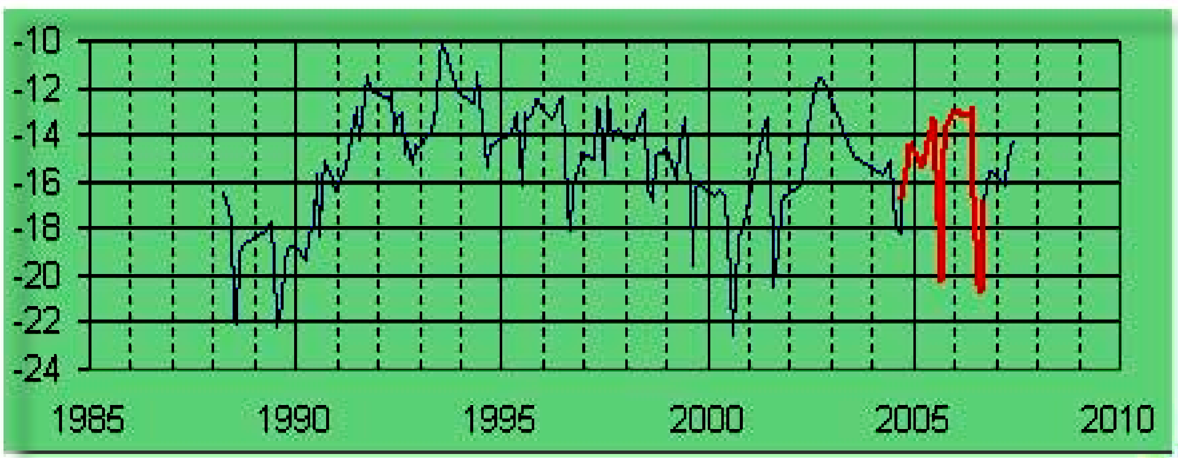


Figure 7i

North St. Louis County - Buried Drift #69050

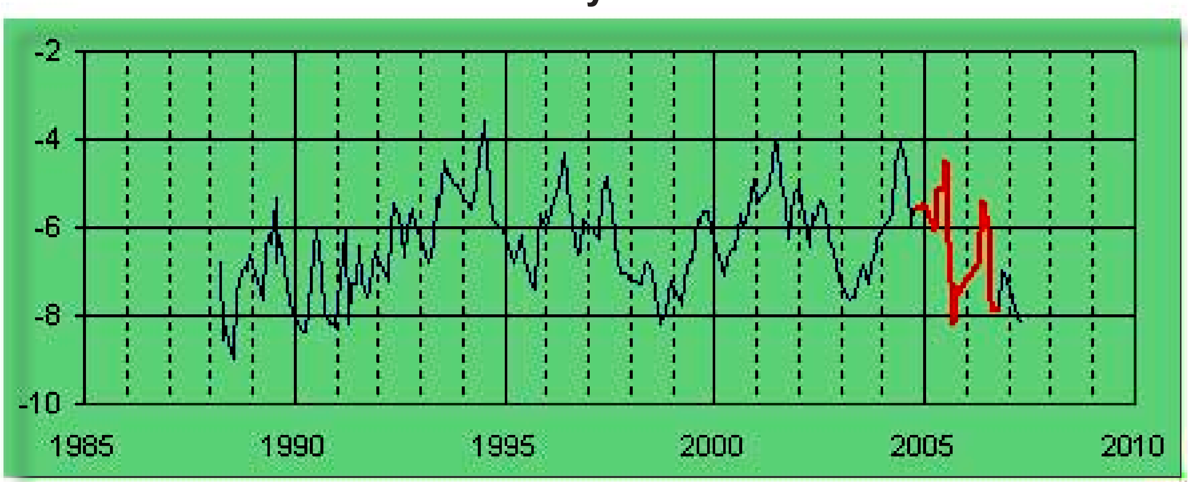


Figure 7J

Rice County - Buried Drift #66015

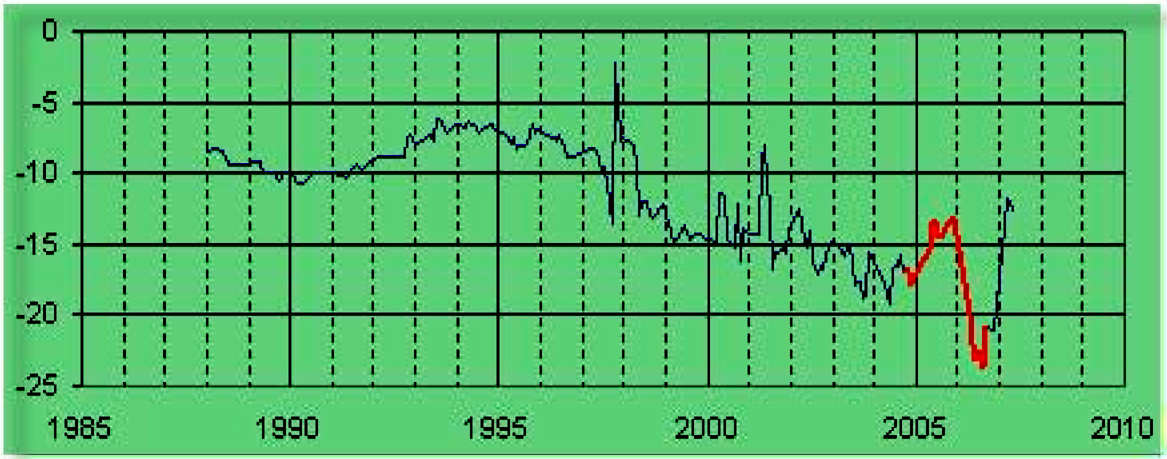


Figure 7K

Todd County - Buried Drift #77034

Depth to Water, ft.

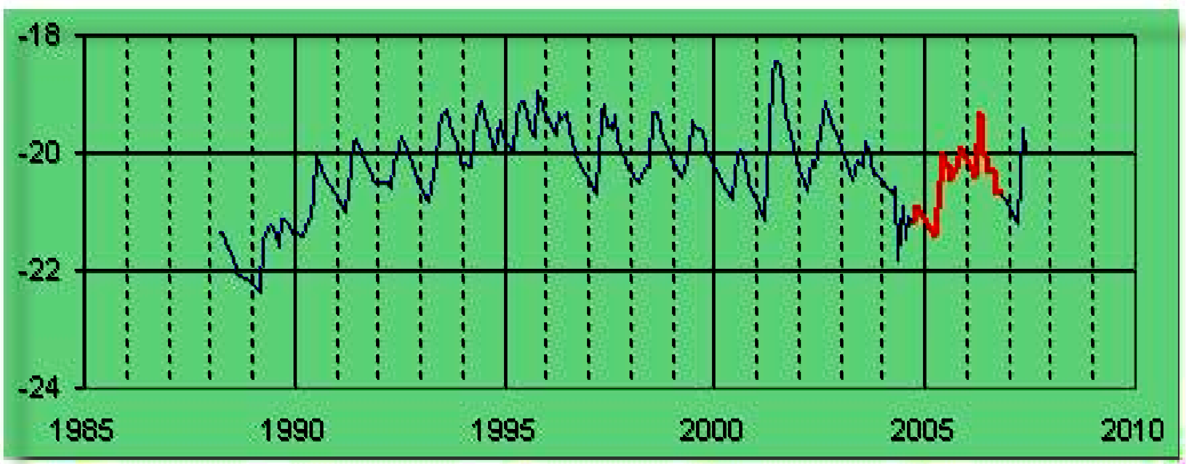


Figure 7L

Wadena County - Buried Drift #80029

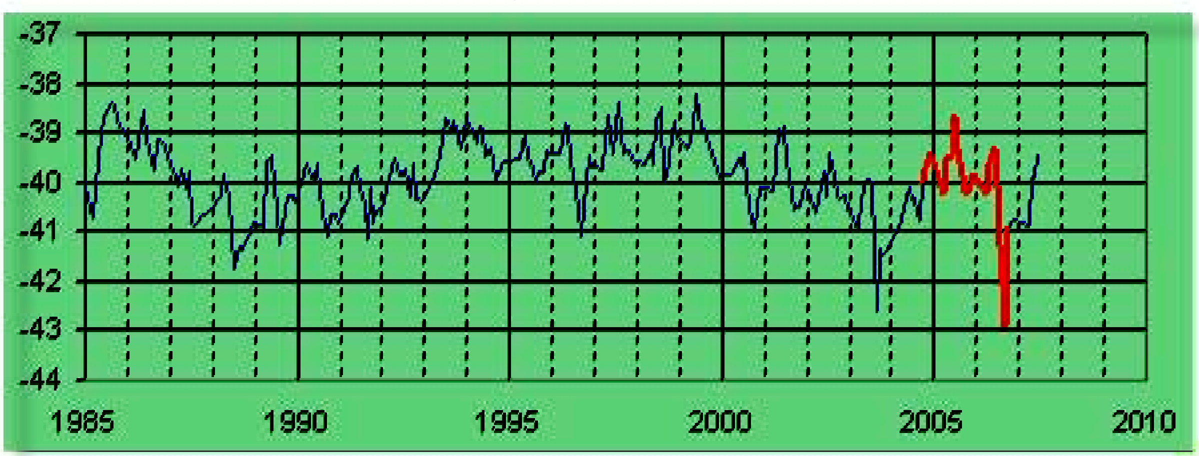


Figure 8A

Anoka County - Jordan #2012

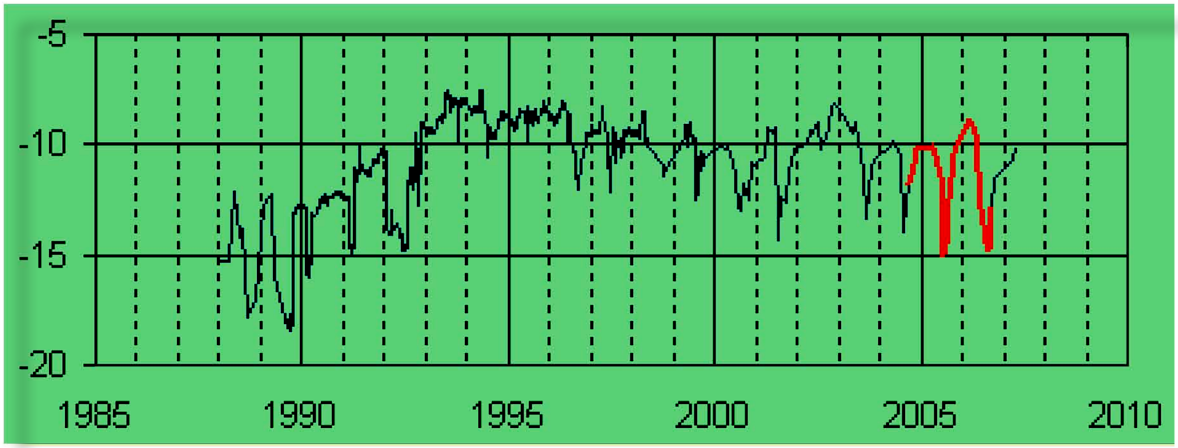


Figure 8B

Hennepin County - Jordan #27001

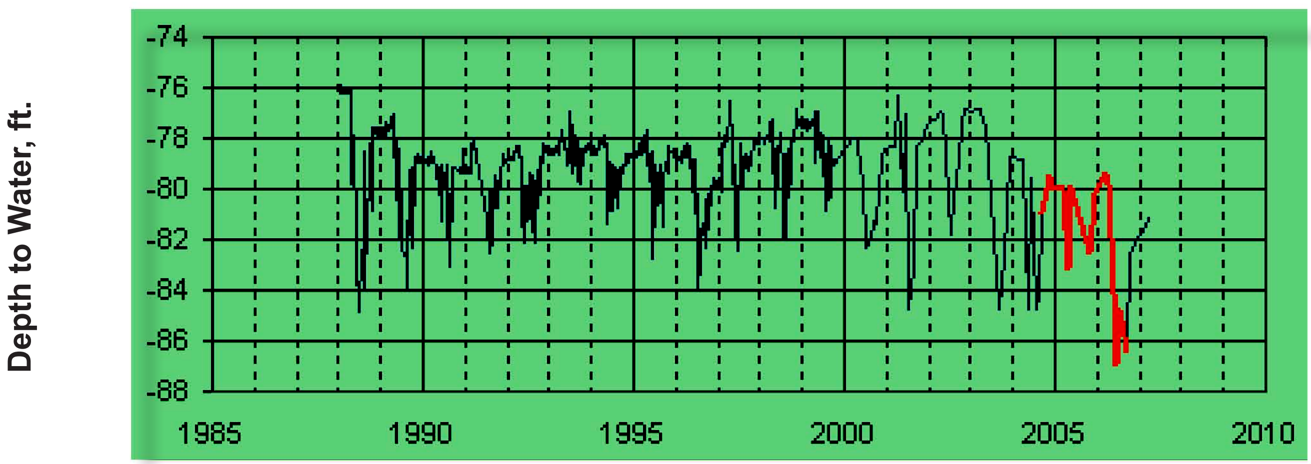


Figure 8C

Hennepin County - Jordan #27011

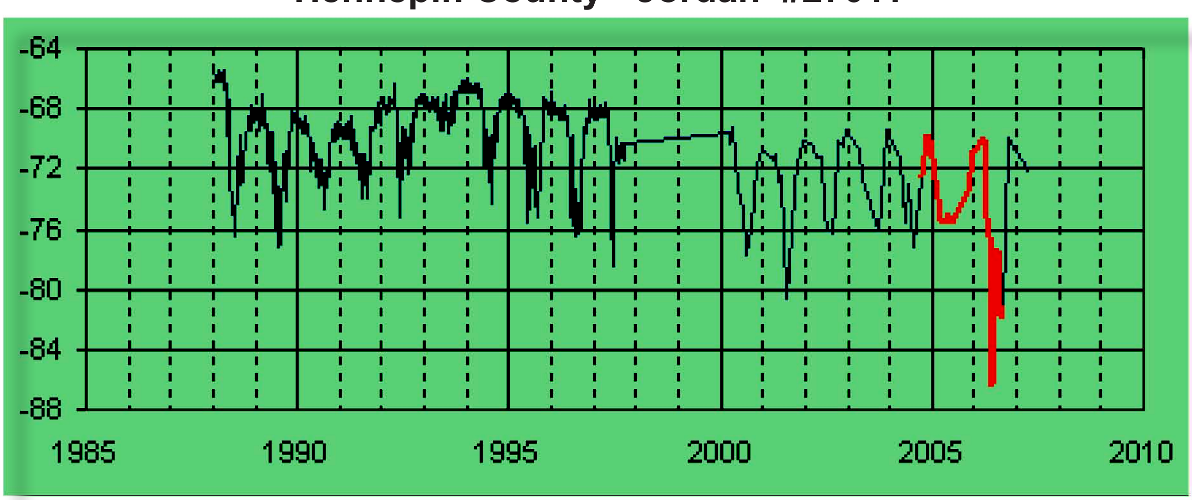


Figure 8D

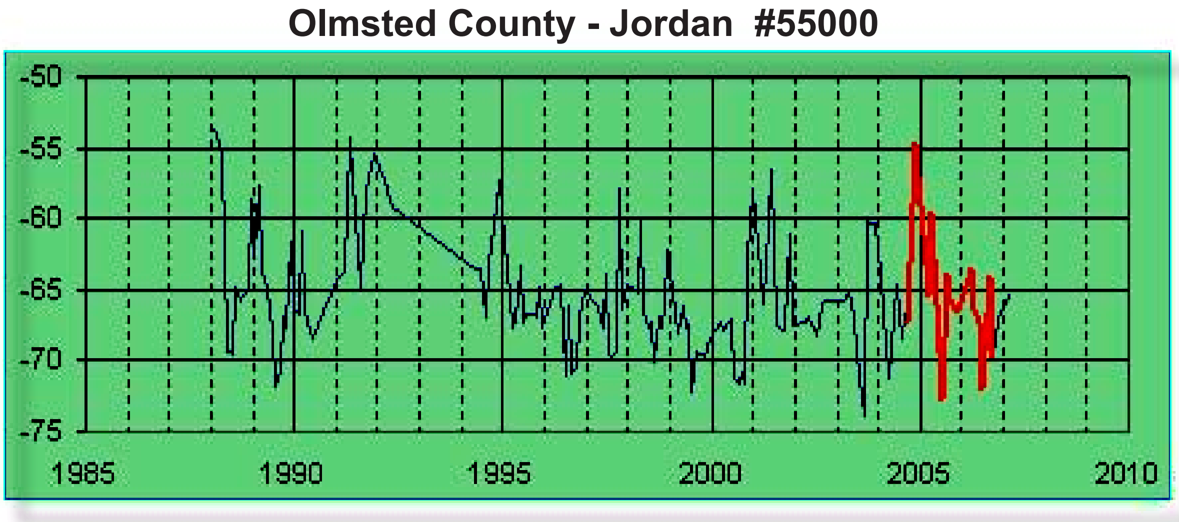


Figure 8E

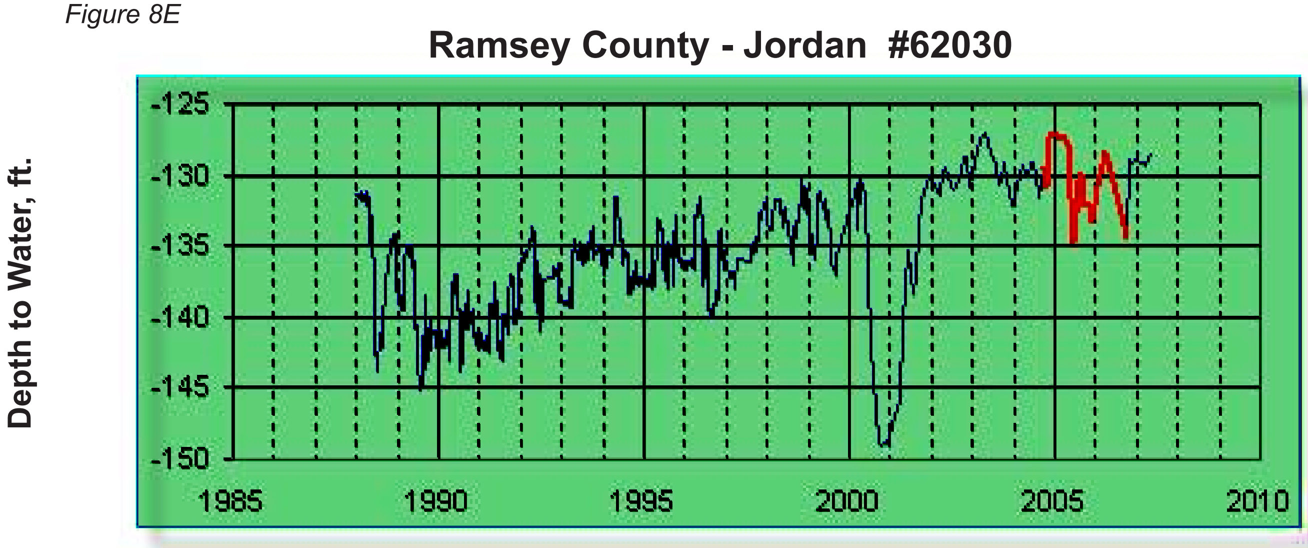


Figure 8F

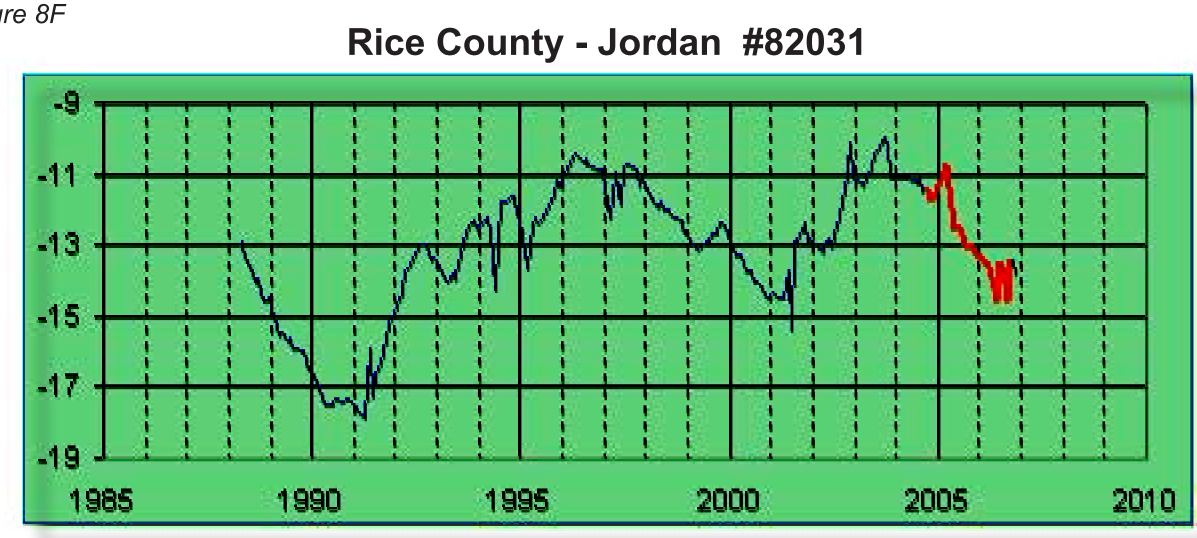


Figure 9A

Dakota County - Prairie du Chien #19005

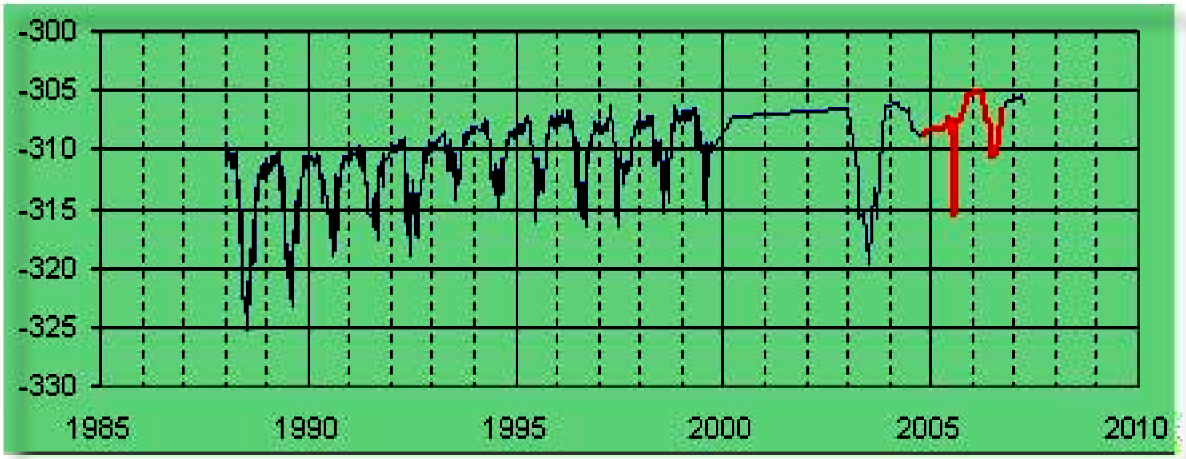


Figure 9B

Dakota County - Prairie du Chien #19007

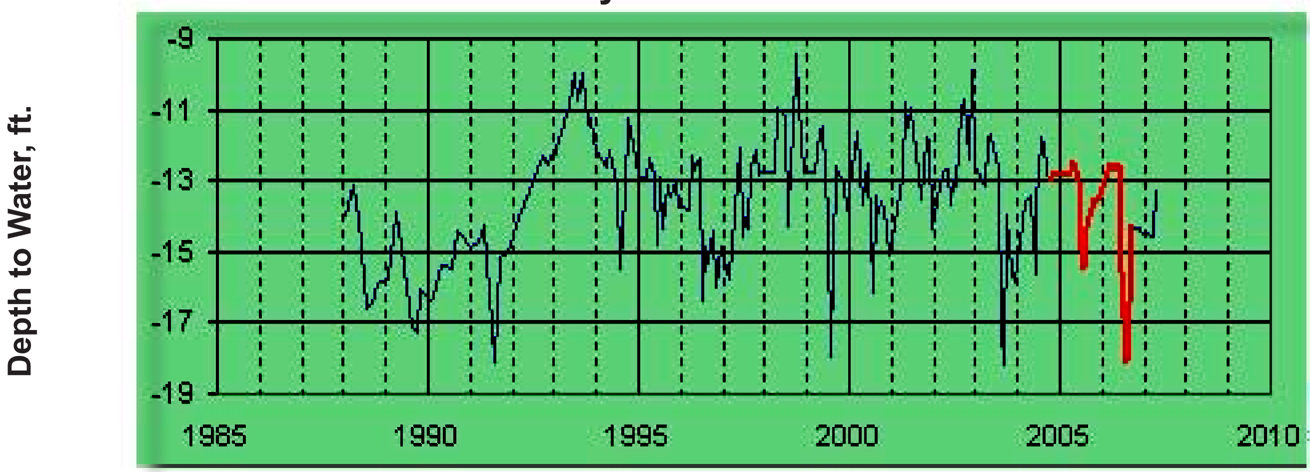


Figure 9C

Dakota County - Prairie du Chien #19008

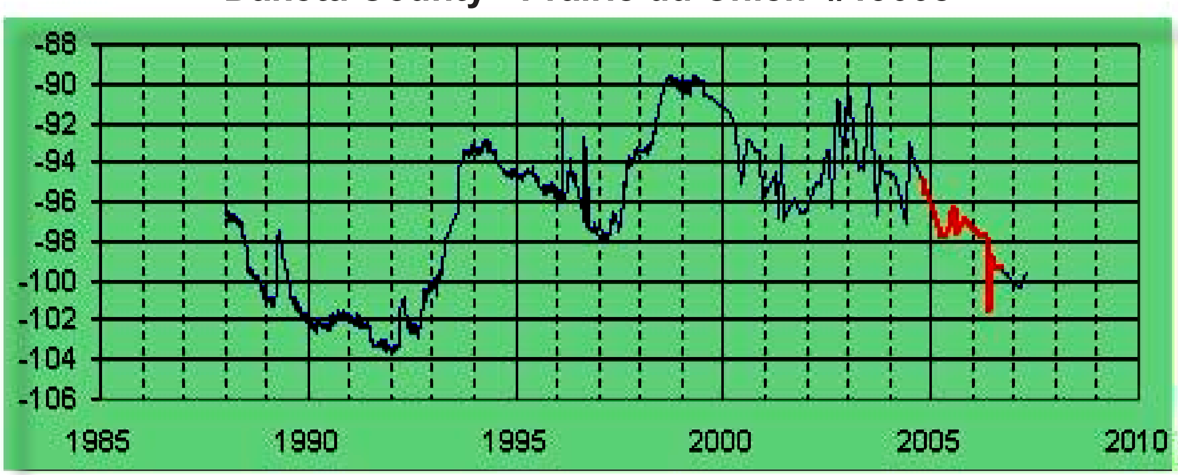


Figure 9D

Dakota County - Prairie du Chien #19029

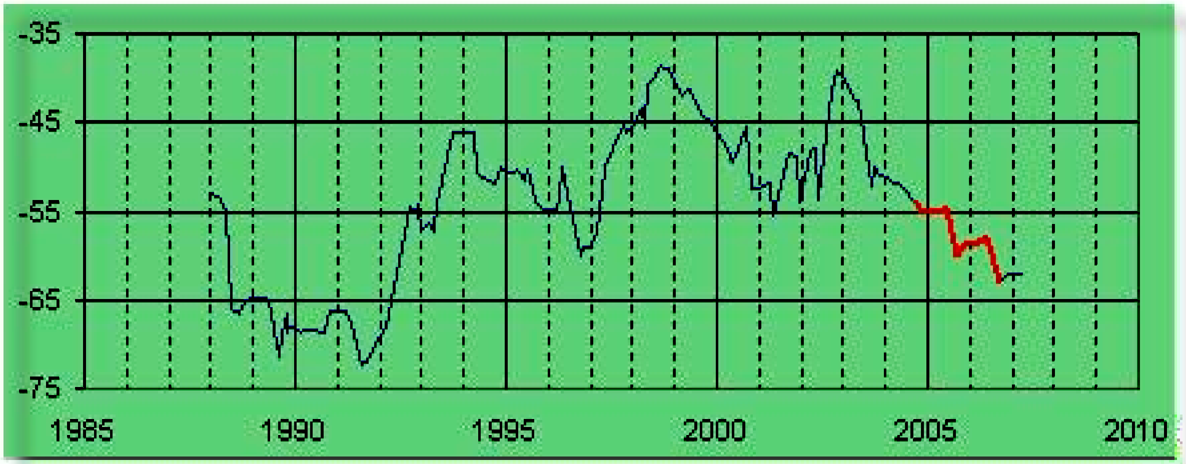
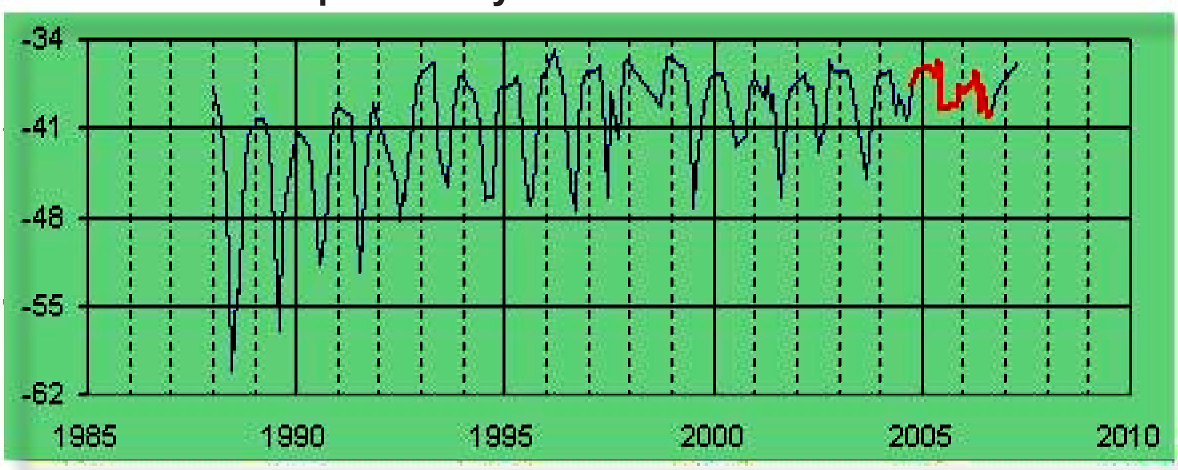


Figure 9E

Hennepin County - Prairie du Chien #27036



Depth to Water, ft.

Figure 9F

Rice County - Prairie du Chien #66016

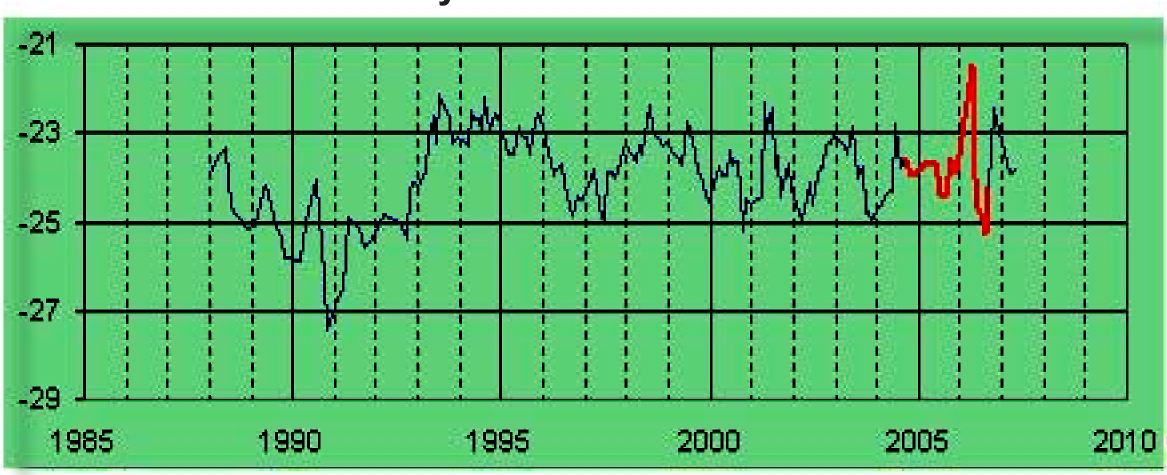


Figure 9G

Rice County - Prairie du Chien #66017

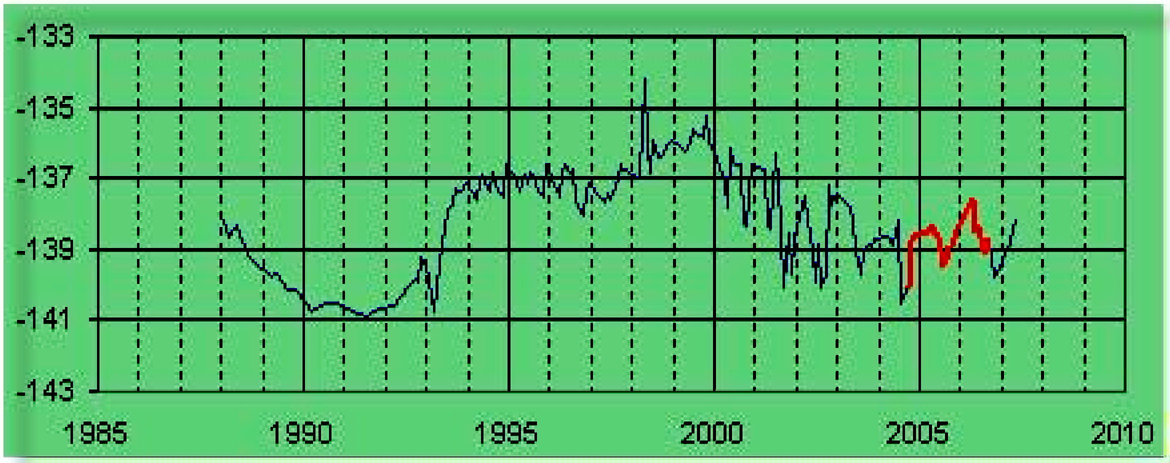


Figure 9H

Scott County - Prairie du Chien #70008

Depth to Water, ft.

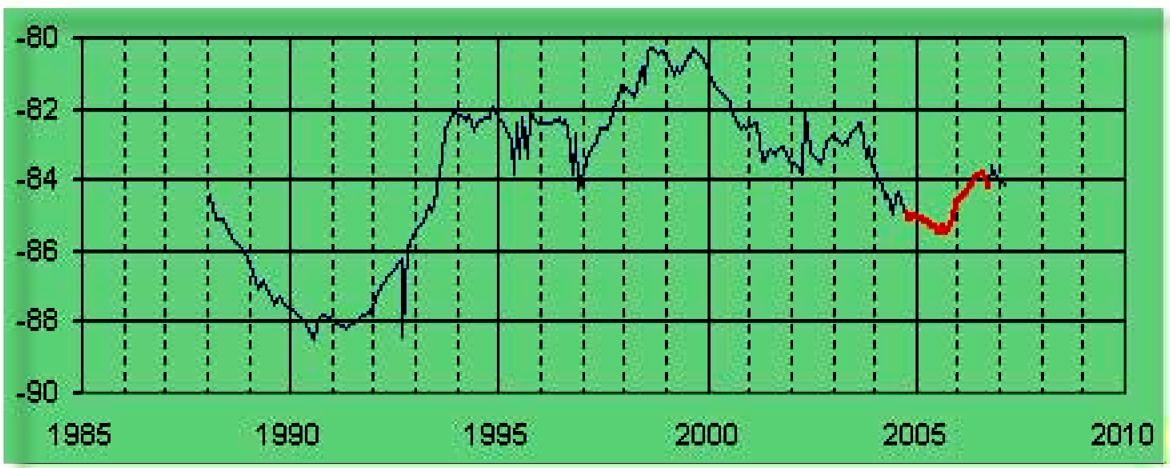


Figure 9i

Washington County - Prairie du Chien #82029

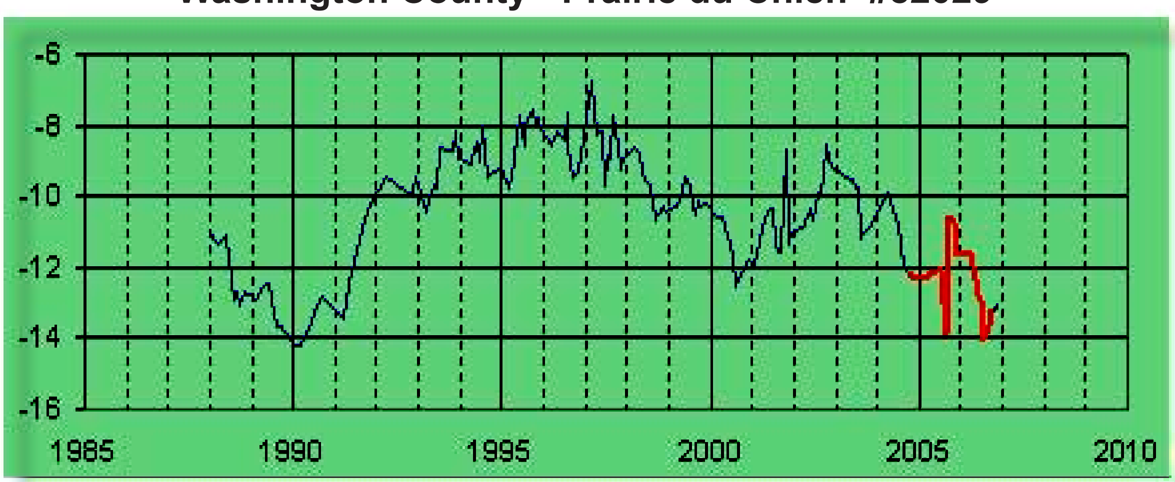


Figure 9J

Washington County - Prairie du Chien #82033

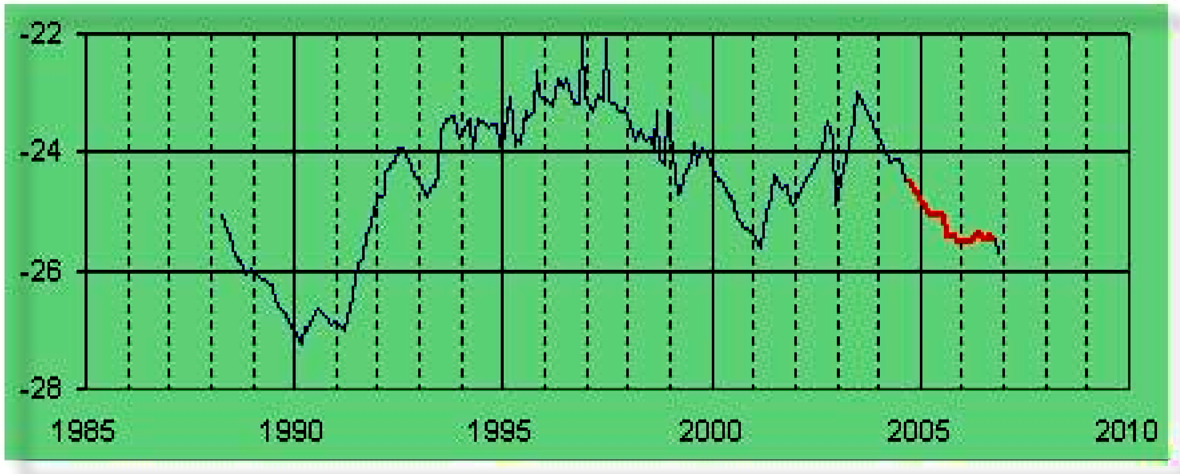


Figure 9K

Dakota County - Prairie du Chien/Jordan #19046

Depth to Water, ft.

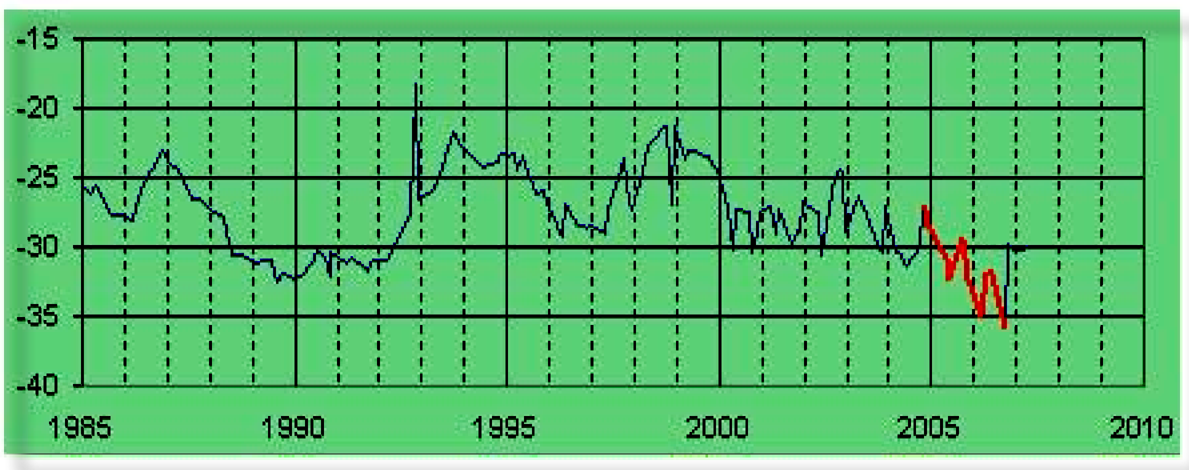


Figure 10A

Anoka County - Mt. Simon #2028

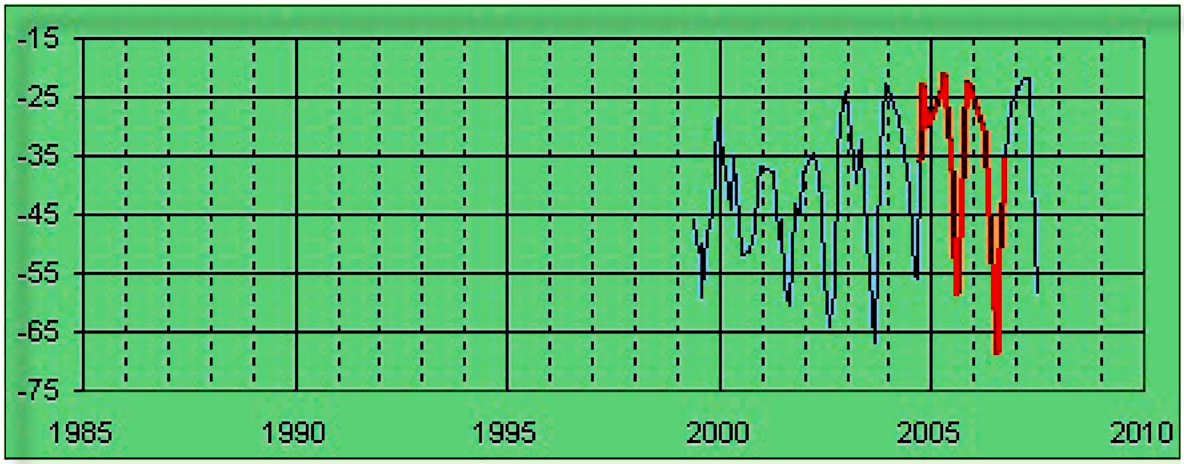
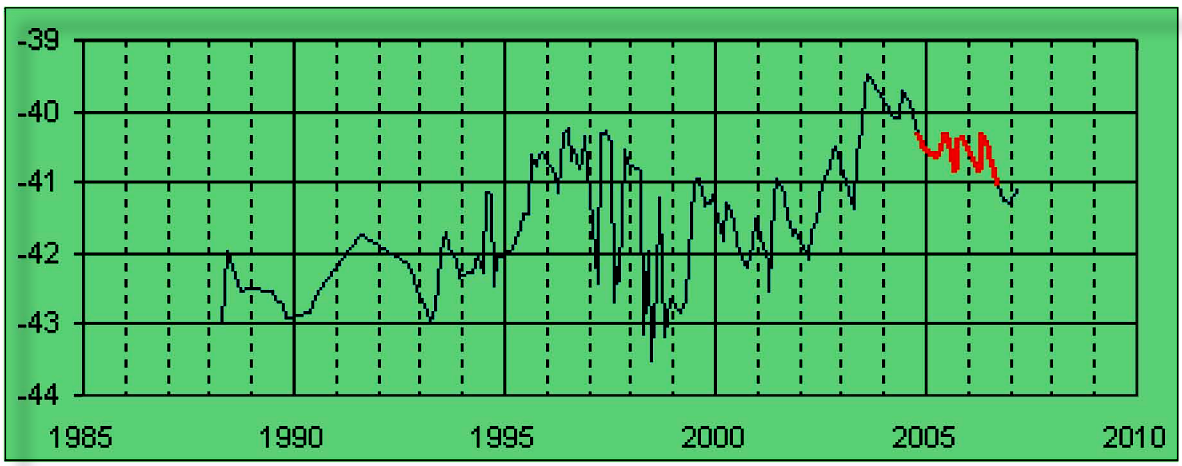


Figure 10B

Chisago County - Mt. Simon #13006



Depth to Water, ft.

Figure 10C

Hennepin County - Mt. Simon #27004

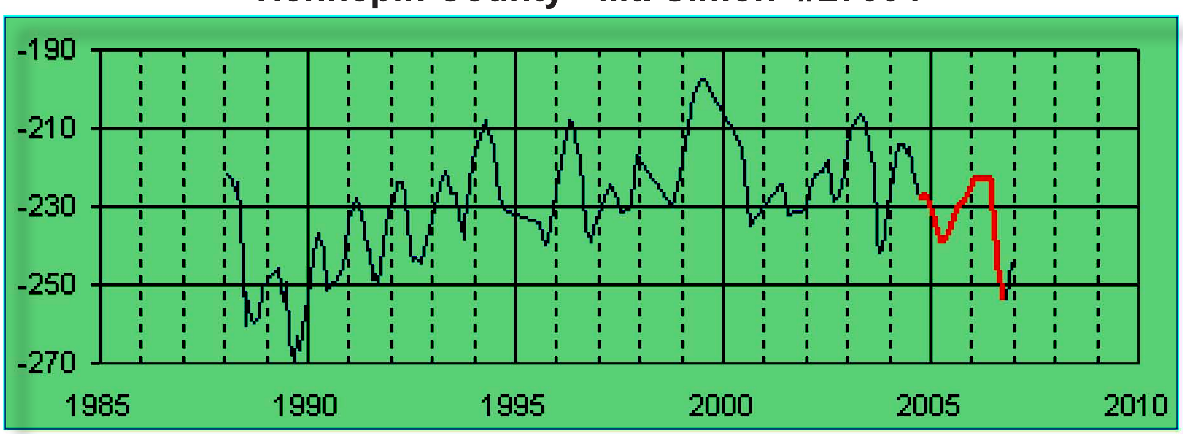


Figure 10D

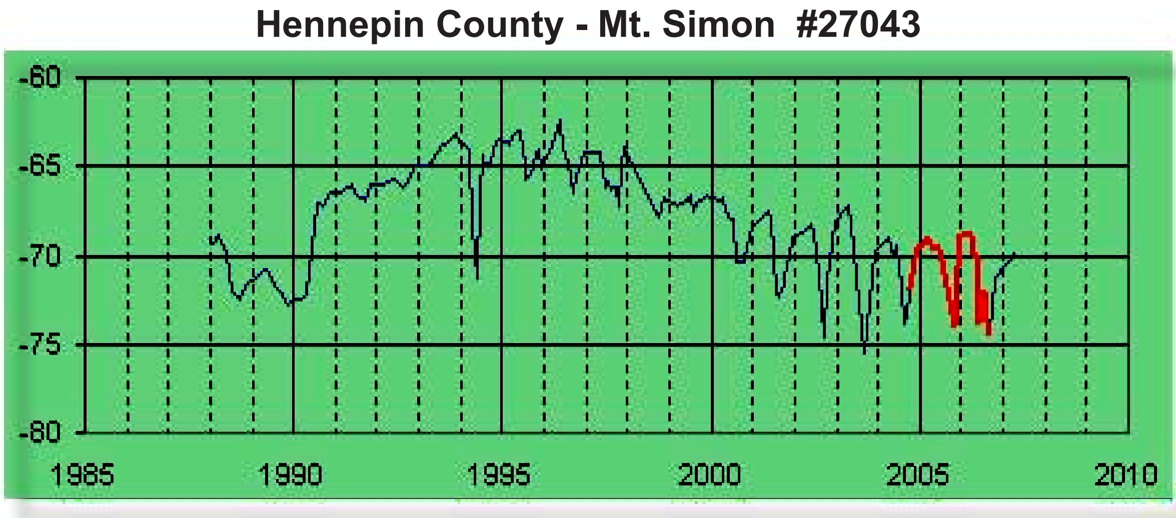


Figure 10E

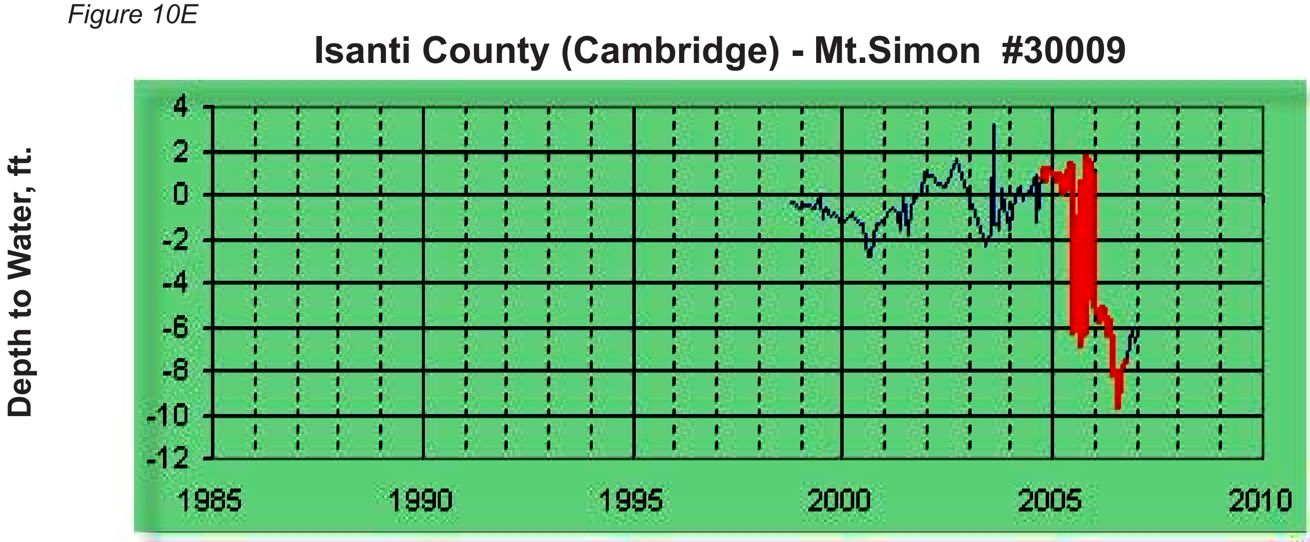


Figure 10F

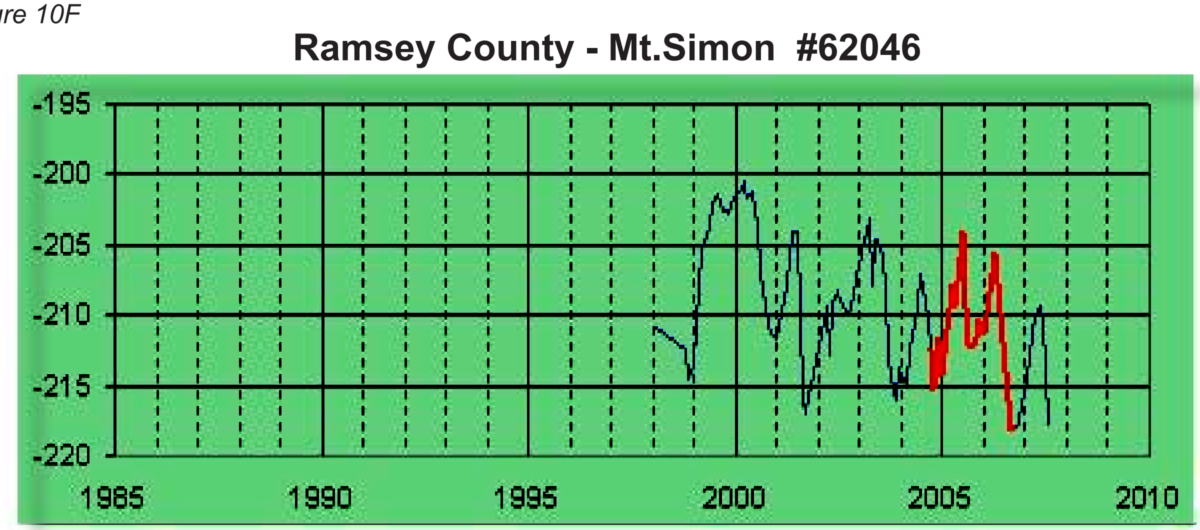


Figure 10G

Scott County (Savage) - Mt.Simon #70002/70030

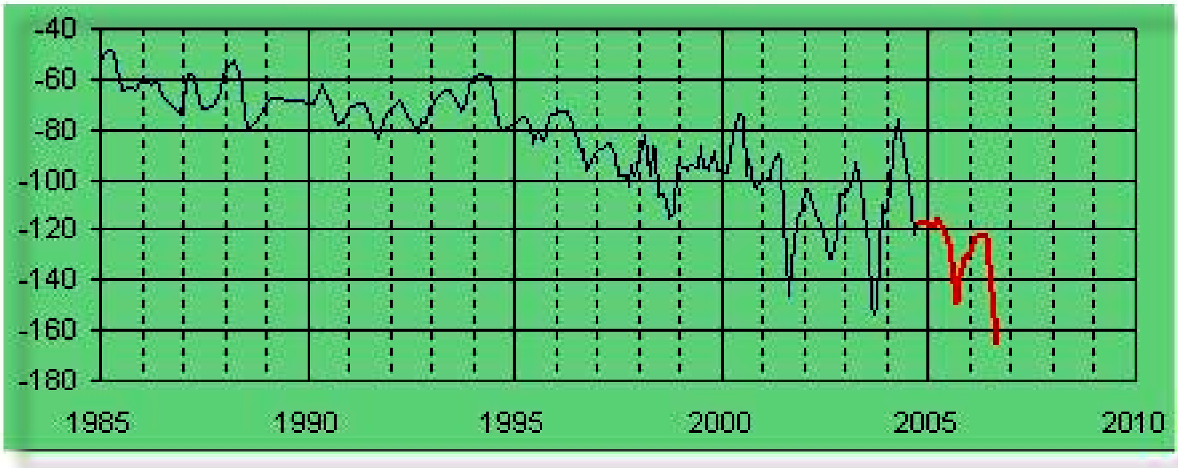


Figure 10H

Washington County - Mt.Simon #82046

Depth to Water, ft.

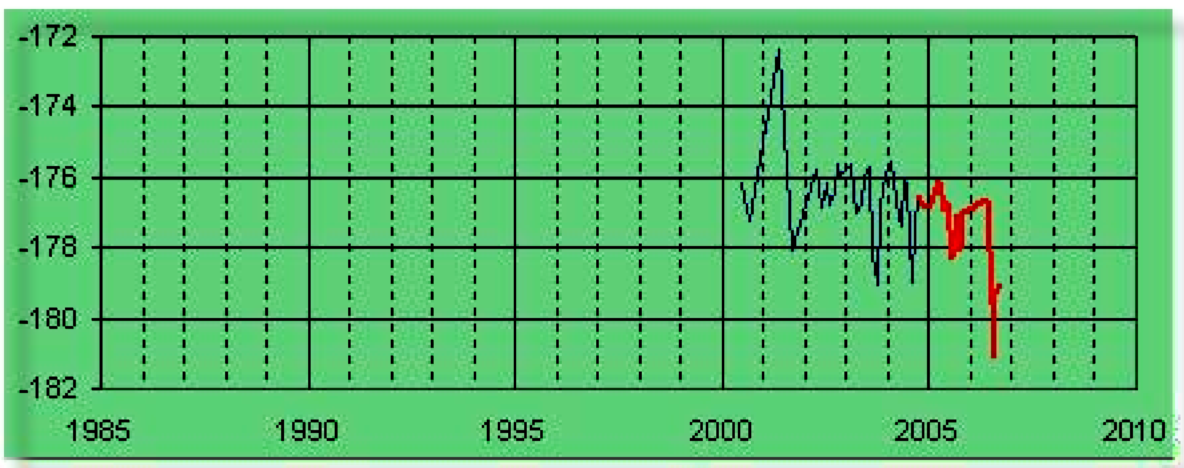
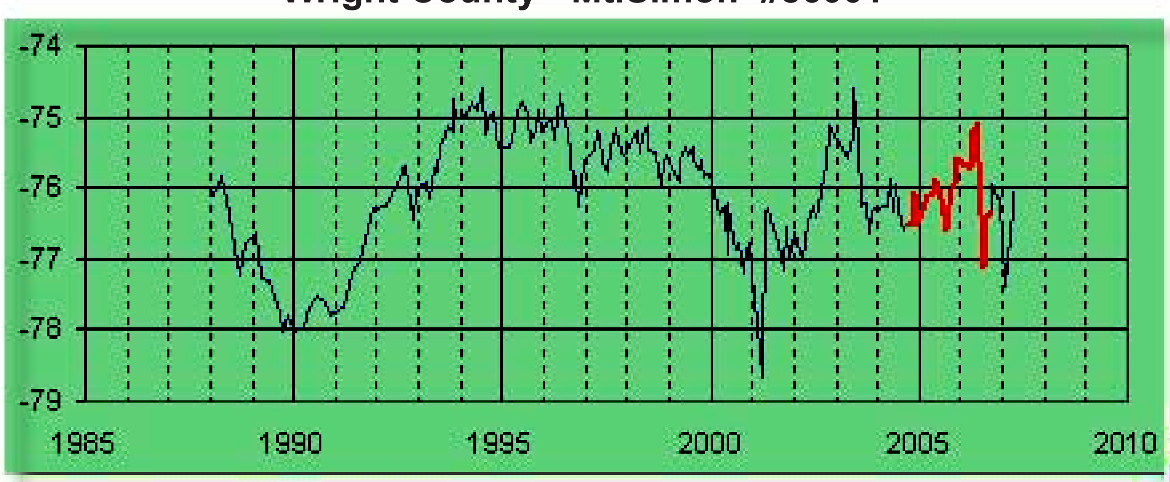


Figure 10i

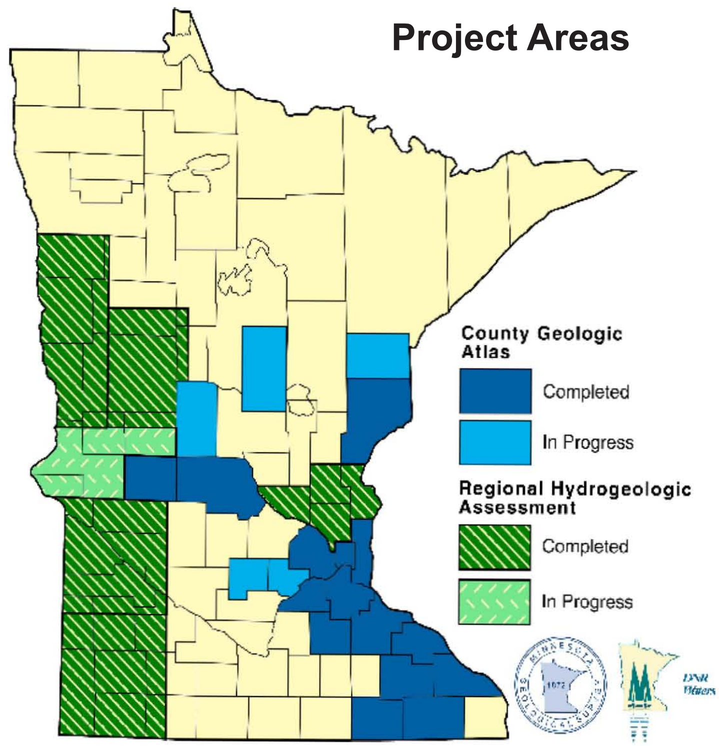
Wright County - Mt.Simon #86001



County Geologic Atlas and Regional Hydrogeologic Assessment Program

Ground Water Data

DNR Waters and the Minnesota Geological Survey (MGS) collaborate preparing the maps and reports of the County Geologic Atlases and Regional Hydrogeologic Assessments. The geologic data collection, mapping, and interpretation of the rock and sediment beneath the earth's surface by the MGS provide the framework for ground water studies by DNR Waters of how water moves through those materials and interacts with water at the land's surface. DNR Waters staff measure water levels in wells and collect water samples for chemical and isotopic analysis. They also use ground water level monitoring data, climatology records, water use permits, and geophysical study reports. Atlases and assessments are used in planning, environmental protection, and education. A better understanding of the physical environment and ground water systems enables better environmental decision-making.



Data Available Online

Digital data for many Atlases and Assessments, including geographical information systems (GIS) and related resource data, can be downloaded over the internet. Some map images and documents are also available as portable document format (PDF) files. Digital data for many reports can be downloaded for use in GIS programs such as ArcView, ArcGIS, and EPPL7. Map viewers (at no or low cost) such as ArcExplorer can also be used to visualize the downloaded data. Some report digital data is not downloadable but is available on request.

An introduction to the recently completed county geologic atlas for Pope County (that part of the project published by DNR Waters) can be found in the September 2006 issue of the Minnesota Ground Water Association (pages 6 through 12).

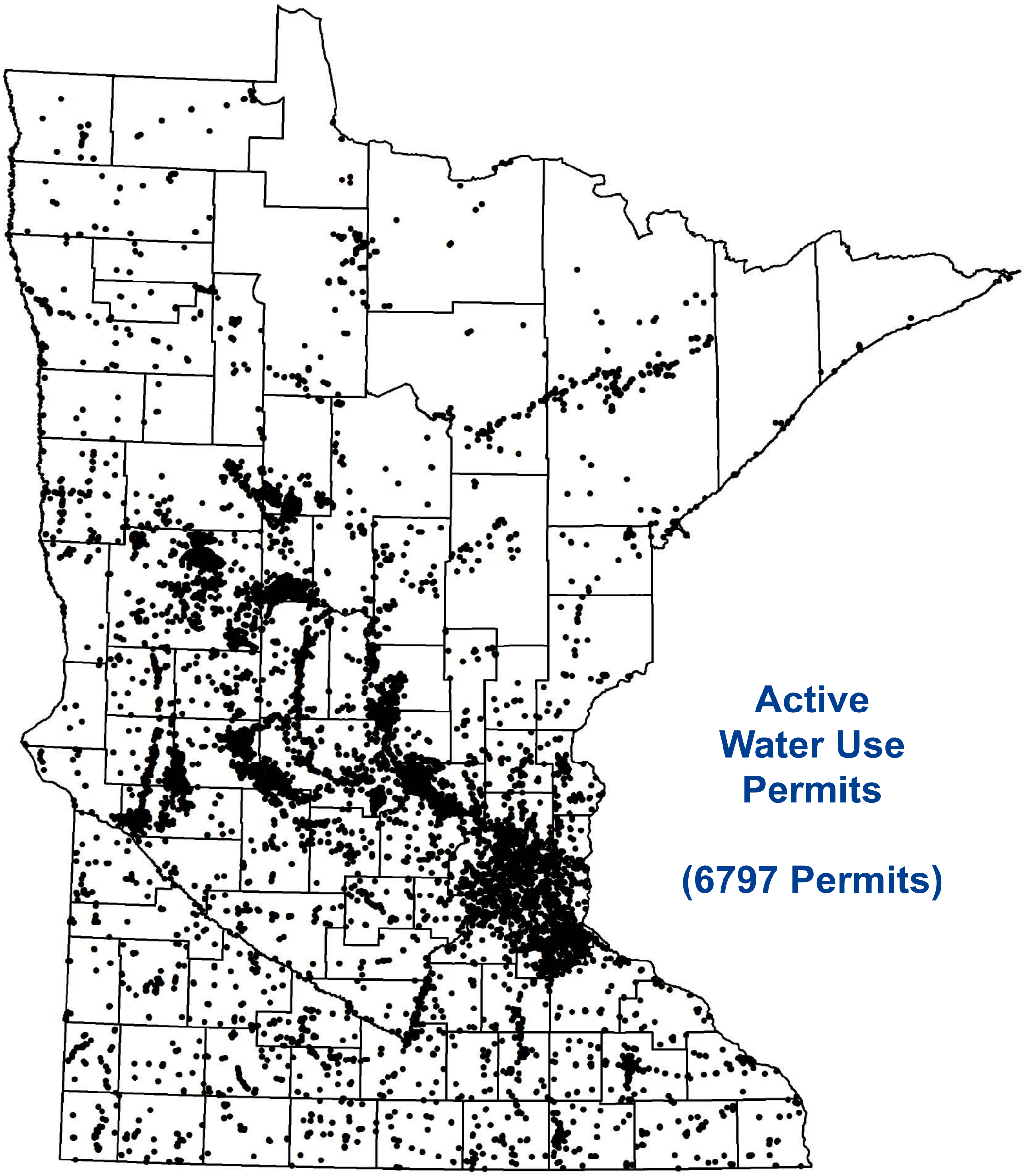
The full atlas report is published in two parts, Part A (Geology) and Part B (Ground Water and Pollution Sensitivity). The web page for the Pope County Geologic Atlas project lists the contents and provides links to the data.

Other county atlas and assessment report data, including MGS report data, can be accessed on the DNR Waters website here.

For more information on MGS atlas and assessment report data see the list of current publications on the MGS website.

Water Use

Chapter 4




Car Wash *photo by James Japs*


Public Fountain *photo by James Japs*

Introduction

DNR water appropriations permits are required for all users withdrawing surface or ground water in excess of ten thousand gallons per day or one million gallons per year. Uses less than this, such as rural domestic use, do not require a permit from the DNR and therefore are not included in this chapter.

All permittees must use a flow meter or other approved method of measurement to determine the volume of water withdrawn and must submit an annual report of water use. Reported water use data are used for many purposes, such as documenting water conflicts, understanding the hydrology of aquifers from which water is withdrawn, and evaluating existing water supplies by monitoring use and the impact of that use. The data are reported on a calendar year basis. This chapter summarizes the reported water use data for calendar years 2004 and 2005.

photo by DNR Waters

MAJOR WATER USE CATEGORIES

THERMOELECTRIC POWER GENERATION - water used to cool power generating plants. This is historically the largest volume use and relies almost entirely on surface water sources. Thermoelectric power generation is primarily a nonconsumptive* use in that most of the water withdrawn is returned to its source.

PUBLIC WATER SUPPLY - water distributed by community suppliers for domestic, commercial, industrial and public users. This category relies on both surface water and ground water sources.

INDUSTRIAL PROCESSING - water used especially in mining activities, paper mill operations, and food processing, etc. Three-fourths or more of withdrawals are from surface water sources. Consumptive use varies, depending upon the type of industrial process.

IRRIGATION - water withdrawn from both surface water and ground water sources for major crop and noncrop uses. Nearly all irrigation is considered to be consumptive use.

OTHER - large volumes of water withdrawn for activities including air conditioning, construction dewatering, water level maintenance and pollution confinement.

*Consumptive use is defined as water that is withdrawn from its source and is not directly returned to the source (M.S. 103G.005, Subd. 8). Under this definition, all ground water withdrawals are consumptive unless the water is returned to the same aquifer. Surface water withdrawals are considered consumptive if the water is not directly returned to the source so that it is available for immediate further use.

Comparison of 2004 and 2005 Statewide Water Use

Water use in calendar year 2005 was 1431.2 billion gallons (BG) and was the highest yearly recorded use since the advent of reporting. Reported use in 2004 was 4% less than the 2005 total and is nearly the same as the value reported in 2003. Figure 1 is a comparison of the two years showing use by major category and the volume and percent change between the years. The largest increase in the two-year period was for power generation, increasing by 19 BG or 3%. The smallest increase in use was for the category public water supply, increasing by 1 BG or 0.5%. No category showed a decrease in use.

Figure 2 graphically shows the changes in use patterns for four main use categories (excluding power generation) from 1985 to 2005. Water use in 2005 for irrigation and public supply remained relatively high, matching closely the amount used in 2001, a high-use year. The pattern seen in irrigation reflects low use in times of high precipitation and large use in times of lower precipitation. Industrial processing water use is generally influenced by overall economic vitality and can be heavily influenced by fluctuations in large mine processing and mine pit dewatering operations on the Minnesota Iron Range.

A comparison of surface water versus ground water use for 2005 (Figure 3) shows that the majority of appropriations are from surface water sources. However, if the nonconsumptive water use for power generation is removed, uses of ground water and surface water are more even (nonconsumptive use means water that is immediately returned to its source after use). Eighty-two percent of total 2005 use was from surface water sources. Sixty-three percent of total 2005 use was for power plant cooling, a relatively nonconsumptive use.

Surface water use increased from 2003 to 2005, due to increased demand for power generation (nuclear power cooling and steam power cooling). Ground water use decreased due to less demand for irrigation and public water supply.

Figure 1

Water Use Comparison by Major Use Category: 2004 & 2005

(Billions of Gallons)

	2004		2005		Change From 2004 to 2005	
Use Category	**BG**	**% of Total**	**BG**	**% of Total**	**BG Change**	**% Change**
Power Generation	872.5	63%	901.6	63%	29.1	3%
Public Supply	207.8	15%	208.8	15%	1.0	0.5%
Industrial Processing	159.2	12%	163.6	11%	4.4	3%
Irrigation	83.6	6%	88.9	6%	5.3	6%
Other	54.8	4%	68.3	5%	13.5	25%
Totals	**1,377.9**	**100%**	**1,431.2**	**100%**	**+53.3**	**+3.9%**

column totals may not sum due to independent rounding

Figure 2

Minnesota Water Use - 1985 to 2005

(Billions of Gallons)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Power Generation	508	539	637	663	664	698	694	679	722	765	748	710	701	785	812	829	798	814	825	873	902
Public Supply	171	170	192	203	174	164	170	175	164	178	180	189	185	192	184	197	211	199	222	208	209
Industrial Processing	109	76	69	94	120	102	115	158	127	120	160	147	159	169	166	173	110	162	169	159	164
Irrigation	49	30	67	103	86	71	60	63	30	56	62	80	58	77	72	83	96	70	105	84	89
Other	49	42	38	42	48	53	52	58	63	64	60	57	63	58	65	59	58	53	54	55	68
Total	**886**	**857**	**1003**	**1105**	**1092**	**1088**	**1091**	**1133**	**1106**	**1183**	**1209**	**1184**	**1167**	**1281**	**1300**	**1341**	**1273**	**1299**	**1374**	**1378**	**1431**

column totals may not sum due to independent rounding

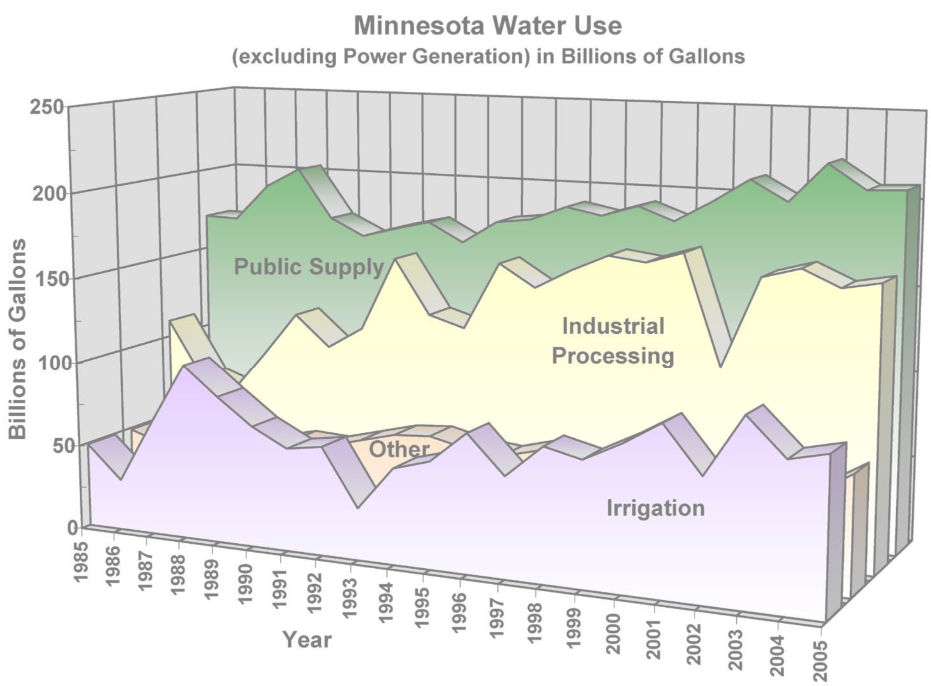
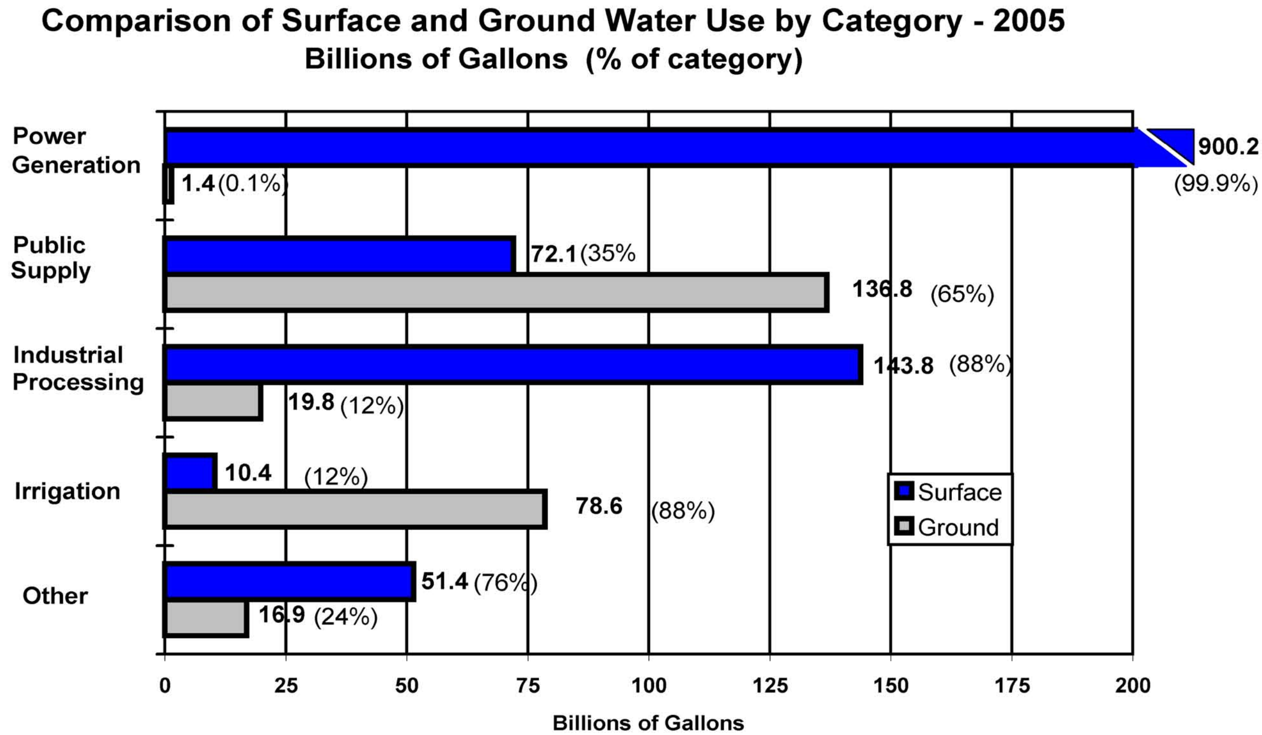


photo by Molly Shodeen

photo by Molly Shodeen

Figure 3



Power Generation

Figure 4 shows that power generation was the primary use in 8 of the 11 counties with the highest total use in 2005. Power generation accounted for 63% of all use reported in Minnesota for the year. Power generation in Dakota and Wright counties alone accounted for 26% of all reported use in 2005, largely due to power plant cooling. Surface water sources supply almost all of the water used for power generation. Most of the water is used for cooling purposes and is returned to the surface water source.


photo by Julie Ekman

Public Water Supply

Public supply water use gradually increased from 1990 to 1999 due to population increases, higher demand for outdoor uses such as lawn watering and demands by industrial customers. After some fluctuations from 2001 to 2004, use in this category has leveled off for the past two years at about 2001 levels. Sixty-five percent of public water supply use came from ground water in 2005, compared to 37% nationally (USGS, *Estimated Use of Water in the United States in 2000*).

Local water conservation programs that implement measures to improve water use efficiencies and promote the wise use of water can help communities reduce the need for expensive new municipal wells and water/wastewater treatment plants. Public water suppliers that serve more than 1,000 people are required to develop water emergency and conservation plans and also implement demand management measures before requesting approvals for new supply wells. These efforts can help water customers and communities save money while helping to protect Minnesota's valuable water resources for future domestic and economic uses.

Irrigation

Annual variations in the amount and distribution of rainfall greatly affect the demand for irrigation water. Combined irrigation water use for calendar years 2004-05 was relatively stable increasing only slightly.

Irrigation accounts for only a small amount (6%) of total water use in Minnesota. However, this use is significant because it is almost entirely consumptive and the majority is from ground water sources (88% in 2005). The timing of irrigation water use can be significant when evaluating regional water supplies and the potential for well interferences. Almost all irrigation water use is compacted into the five-month period from May to September of each year.

Industrial Processing

Industrial processing use maintained at a fairly stable level from 2002 to 2005 averaging 164 BG over the 4 year period. Mine processing and pulp and paper processing accounted for the majority of water use reported for industrial processing.

Other Uses

Other uses include air conditioning, water level maintenance, fisheries, temporary construction dewatering, pollution confinement, snow making and other specialty uses that represent about 5% of Minnesota's total water use.

Summary

Total water use in 2005 increased to a new high of 1431 billion gallons. Power generation continues to account for the majority of use totaling 901.6 BG (or 63%) in 2005. Surface water accounts for 82% of all appropriations.

Figure 4

Appropriations by the Counties with the Greatest Use in CY 2005
Billions of Gallons

	County	Surface Water	Ground Water	Total	Primary Use
1)	Goodhue	223.2	2.0	225.2	Nuclear Power Cooling
2)	Dakota	113.6	30.7	144.3	Steam Power Cooling
3)	Washington	120.4	12.1	132.5	Steam Power Cooling
4)	Wright	116.4	4.0	120.4	Nuclear Power Cooling
5)	Hennepin	81.3	36.1	117.4	Steam Power Cooling
6)	St. Louis	107.5	1.9	109.4	Steam Power Cooling
7)	Ramsey	63.5	12.3	75.8	Steam Power Cooling
8)	Itasca	69.7	1.0	70.7	Steam Power Cooling
9)	Cook	62.4	0.0	62.4	Mine Processing
10)	Lake	47.7	0.0	47.7	Mine Processing
11)	Anoka	34.2	12.0	46.2	Municipal Waterworks
	Billions of gallons	*88% of all* surface water use	*40% of all* ground water use	*80% of* total use	

Reported Water Use by County
2004 - 2005 (Millions of Gallons)

Reported Water Use

		2004			2005				% of 2005
	County	Surface	Ground	Total	Surface	Ground	Total	Primary Use	Total
1	Aitkin	1,063.1	112.0	1,175.1	1,026.5	118.8	1,145.3	Wild Rice Irrigation	86
2	Anoka	34,949.6	11,998.4	46,948.0	34,188.5	11,950.9	46,139.4	Municipal Waterworks	95
3	Becker	9.4	2,969.5	2,978.9	51.2	3,256.4	3,307.6	Major Crop Irrigation	66
4	Beltrami	1,141.6	685.0	1,826.6	1,088.6	712.1	1,800.7	Wild Rice Irrigation	60
5	Benton	3,663.6	3,806.5	7,470.1	3,722.0	4,347.7	8,069.7	Pulp/Paper Processing	45
6	Big Stone	12.4	443.5	455.9	119.4	501.1	620.5	Major Crop Irrigation	44
7	Blue Earth	8,032.0	3,589.1	11,621.1	7,118.0	3,864.1	10,982.1	Steam Power Cooling	64
8	Brown	127.2	876.1	1,003.3	99.8	962.2	1,062.0	Municipal Waterworks	47
9	Carlton	2,144.1	751.4	2,895.5	2,373.3	696.7	3,070.0	Pulp/Paper Processing	69
10	Carver	42.3	3,237.2	3,279.5	37.1	3,364.3	3,401.4	Municipal Waterworks	84
11	Cass	19.9	1,059.3	1,079.2	48.0	1,131.8	1,179.8	Major Crop Irrigation	37
12	Chippewa	13.9	555.6	569.5	44.6	569.3	613.9	Municipal Waterworks	77
13	Chisago	144.6	1,151.9	1,296.5	210.2	1,249.7	1,459.9	Municipal Waterworks	55
14	Clay	1,615.4	865.9	2,481.3	1,641.5	786.8	2,428.3	Municipal Waterworks	79
15	Clearwater	3,511.8	125.9	3,637.7	1,694.0	113.4	1,807.4	Wild Rice Irrigation	92
16	Cook	57,684.1	8.5	57,692.6	62,445.8	8.8	62,454.6	Mine Processing	99.7
17	Cottonwood	132.9	1,103.3	1,236.2	176.0	1,135.5	1,311.5	Municipal Waterworks	42
18	Crow Wing	209.8	2,012.0	2,221.8	939.0	2,144.4	3,083.4	Municipal Waterworks	42
19	Dakota	112,113.5	29,083.5	141,197.0	113,580.8	30,693.3	144,274.1	Steam Power Cooling	76
20	Dodge	39.9	552.1	592.0	16.1	571.6	587.7	Municipal Waterworks	62
21	Douglas	119.4	1,635.1	1,754.5	89.4	1,714.8	1,804.2	Major Crop Irrigation	42
22	Faribault	0.0	658.8	658.8	0.0	703.1	703.1	Municipal Waterworks	58
23	Fillmore	3,315.9	625.6	3,941.5	3,822.0	640.8	4,462.8	Hatcheries & Fisheries	85
24	Freeborn	20.2	1,418.1	1,438.3	6.6	1,437.4	1,444.0	Municipal Waterworks	77
25	Goodhue	201,239.9	2,068.2	203,308.1	223,243.3	1,992.3	225,235.6	Nuclear Power Cooling	92
26	Grant	0.0	592.2	592.2	0.0	504.7	504.7	Major Crop Irrigation	71
27	Hennepin	77,193.5	35,672.5	112,866.0	81,348.8	36,123.4	117,472.2	Steam Power Cooling	69
28	Houston	9.0	516.9	525.9	17.1	545.2	562.3	Municipal Waterworks	76
29	Hubbard	51.6	4,613.5	4,665.1	72.6	4,523.8	4,596.4	Major Crop Irrigation	75
30	Isanti	2.6	760.6	763.2	5.6	945.2	950.8	Municipal Waterworks	54
31	Itasca	70,834.0	959.7	71,793.7	69,735.6	980.6	70,716.2	Steam Power Cooling	85
32	Jackson	71.7	332.2	403.9	28.0	348.2	376.2	Municipal Waterworks	63
33	Kanabec	9.4	186.6	196.0	9.5	198.5	208.0	Municipal Waterworks	68
34	Kandiyohi	460.0	2,724.3	3,184.3	513.8	3,329.3	3,843.1	Municipal Waterworks	46
35	Kittson	74.5	362.7	437.2	116.5	283.1	399.6	Rural Waterworks	40
36	Koochiching	17,572.6	42.2	17,614.8	17,146.6	40.2	17,186.8	Pulp/Paper Processing	97
37	Lac Qui Parle	40.8	1,293.7	1,334.5	43.8	1,306.0	1,349.8	Major Crop Irrigation	41
38	Lake	48,762.5	0.4	48,762.9	47,691.0	0.4	47,691.4	Mine Processing	99
39	Lake of the Woods	292.4	65.2	357.6	313.9	65.5	379.4	Wild Rice Irrigation	81
40	Le Sueur	5,264.0	1,280.9	6,544.9	5,375.3	1,382.6	6,757.9	Quarry/Mine Dewatering	79
41	Lincoln	15.2	452.9	468.1	12.2	415.2	427.4	Rural Waterworks	77
42	Lyon	96.7	1,507.9	1,604.6	148.5	1,631.9	1,780.4	Municipal Waterworks	70
43	McLeod	153.8	1,905.7	2,059.5	283.3	1,953.8	2,237.1	Municipal Waterworks	52
44	Mahnomen	10.5	79.9	90.4	0.0	83.8	83.8	Municipal Waterworks	95

Reported Water Use by County
2004 - 2005 (Millions of Gallons)

Reported Water Use

	County	2004 Surface	2004 Ground	2004 Total	2005 Surface	2005 Ground	2005 Total	Primary Use	% of 2005 Total
45	Marshall	116.7	204.3	321.0	100.9	192.2	293.1	Municipal Waterworks	34
46	Martin	3,842.5	295.1	4,137.6	5,380.6	291.9	5,672.5	Steam Power Cooling	85
47	Meeker	13.4	1,343.4	1,356.8	33.6	1,604.1	1,637.7	Major Crop Irrigation	58
48	Mille Lacs	19.2	499.7	518.9	27.6	587.2	614.8	Municipal Waterworks	64
49	Morrison	113.6	4,318.1	4,431.7	205.1	4,829.6	5,034.7	Major Crop Irrigation	78
50	Mower	60.5	2,388.4	2,448.9	69.6	2,686.2	2,755.8	Municipal Waterworks	47
51	Murray	81.7	229.4	311.1	83.3	201.7	285.0	Municipal Waterworks	68
52	Nicollet	116.4	1,900.1	2,016.5	119.4	1,847.5	1,966.9	Municipal Waterworks	83
53	Nobles	62.5	1,104.8	1,167.3	59.7	1,121.2	1,180.9	Municipal Waterworks	94
54	Norman	9.8	145.1	154.9	0.0	144.9	144.9	Municipal Waterworks	89
55	Olmsted	9,879.9	6,124.4	16,004.3	10,862.5	6,079.6	16,942.1	Steam Power Cooling	61
56	Ottertail	20,670.7	12,064.1	32,734.8	30,179.5	12,273.0	42,452.5	Steam Power Cooling	69
57	Pennington	801.3	24.8	826.1	760.6	44.6	805.2	Municipal Waterworks	58
58	Pine	29.0	511.5	540.5	28.7	521.1	549.8	Municipal Waterworks	58
59	Pipestone	56.8	833.1	889.9	44.9	885.5	930.4	Rural Waterworks	57
60	Polk	4,526.4	644.1	5,170.5	4,608.4	477.3	5,085.7	Municipal Waterworks	61
61	Pope	35.4	6,226.9	6,262.3	28.7	7,434.5	7,463.2	Major Crop Irrigation	95
62	Ramsey	66,080.3	11,267.7	77,348.0	63,472.3	12,253.4	75,725.7	Steam Power Cooling	61
63	Red Lake	376.2	357.5	733.7	202.3	296.4	498.7	Municipal Waterworks	59
64	Redwood	60.1	433.6	493.7	133.1	423.5	556.6	Municipal Waterworks	68
65	Renville	43.2	840.1	883.3	61.6	833.0	894.6	Municipal Waterworks	50
66	Rice	144.5	2,617.6	2,762.1	375.6	2,681.2	3,056.8	Municipal Waterworks	73
67	Rock	50.6	561.2	611.8	27.6	575.6	603.2	Municipal Waterworks	51
68	Roseau	6.3	313.7	320.0	7.4	283.2	290.6	Municipal Waterworks	88
69	St. Louis	102,479.7	1,901.7	104,381.4	107,485.8	1,876.5	109,362.3	Steam Power Cooling	63
70	Scott	181.6	5,523.2	5,704.8	177.5	5,446.8	5,624.3	Municipal Waterworks	71
71	Sherburne	19,805.3	9,685.5	29,490.8	30,150.7	10,565.3	40,716.0	Steam Power Cooling	35
72	Sibley	11.3	693.1	704.4	23.0	693.2	716.2	Municipal Waterworks	75
73	Stearns	3,263.1	8,588.1	11,851.2	3,277.3	10,428.1	13,705.4	Major Crop Irrigation	49
74	Steele	1,170.0	1,700.0	2,870.0	374.3	1,881.0	2,255.3	Municipal Waterworks	79
75	Stevens	69.1	1,912.2	1,981.3	72.3	2,032.4	2,104.7	Major Crop Irrigation	71
76	Swift	22.8	4,144.3	4,167.1	24.7	4,254.9	4,279.6	Major Crop Irrigation	87
77	Todd	127.0	2,774.5	2,901.5	189.7	2,973.0	3,162.7	Major Crop Irrigation	73
78	Traverse	2.7	88.6	91.3	1.6	81.2	82.8	Municipal Waterworks	98
79	Wabasha	72.7	1,022.9	1,095.6	21.4	1,130.9	1,152.3	Municipal Waterworks	80
80	Wadena	487.3	3,099.9	3,587.2	542.2	3,073.0	3,615.2	Major Crop Irrigation	89
81	Waseca	33.3	661.2	694.5	29.3	689.8	719.1	Municipal Waterworks	91
82	Washington	121,236.6	12,124.5	133,361.1	120,358.6	12,078.8	132,437.4	Steam Power Cooling	89
83	Watonwan	0.7	1,126.2	1,126.9	9.8	1,048.6	1,058.4	Municipal Waterworks	69
84	Wilkin	80.6	146.3	226.9	41.0	156.8	197.8	Municipal Waterworks	68
85	Winona	1,004.3	2,356.2	3,360.5	996.7	2,445.9	3,442.6	Municipal Waterworks	42
86	Wright	126,608.2	3,666.9	130,275.1	116,409.1	4,025.6	120,434.7	Nuclear Power Cooling	97
87	Yellow Medicine	64.1	742.7	806.8	83.8	765.3	849.1	Rural Waterworks	54
	Total			1,378,148			1,431,330		

Minnesota Reported Water Use

Category	2004	2005
Power Generation	(Millions of Gallons)	
Nuclear Power		
surface	311,140.1	323,949.6
ground	54.4	66.2
Steam Power Cooling		
surface	437,025.2	454,380.3
ground	659.1	554.5
Other Power		
surface	122,869.4	121,843.7
ground	831.0	821.2
Subtotal	**872,579.2**	**901,615.5**
Percent of Total	**63%**	**63%**
surface	871,034.7	900,173.6
ground	1,544.5	1,441.9
Public Supply		
Municipal Water Works		
surface	73,454.1	72,053.4
ground	130,527.1	132,815.9
Private Water Works		
surface	10.4	9.6
ground	719.6	768.0
Comercial & Institutional		
surface	0.0	0.0
ground	1,136.5	1,155.9
Cooperative Water Works		
surface	0.0	0.0
ground	1.7	2.2
Fire Protection		
surface	0.0	0.0
ground	18.5	17.4
State Parks, Waysides, Rest Areas		
surface	0.0	0.0
ground	37.4	47.3
Rural Water Districts		
surface	0.0	0.0
ground	1,907.9	1,977.5
Subtotal	**207,813.2**	**208,847.2**
Percent of Total	**15%**	**15%**
surface	73,464.5	72,063.0
ground	134,348.7	136,784.2

Minnesota Reported Water Use

Category	2004	2005
Irrigation	(Millions of Gallons)	
Golf Course		
surface	1,602.2	1,587.7
ground	5,950.2	5,657.9
Cemetary		
surface	3.2	3.7
ground	56.3	57.1
Landscaping		
surface	60.9	59.9
ground	690.6	699.6
Sod		
surface	26.1	20.7
ground	136.8	205.2
Nursery		
surface	188.8	161.4
ground	526.7	565.4
Orchard		
surface	6.9	10.6
ground	6.9	7.0
Non Crop		
surface	3.1	0.0
ground	22.4	5.7
Temporary		
surface	0.6	0.0
ground	13.6	33.2
Major Crop		
surface	1,727.5	2,042.4
ground	64,018.5	71,343.7
Wild Rice		
surface	8,410.6	6,480.9
ground	215.2	3.0
Subtotal	**83,667.1**	**88,945.1**
Percent of Total	**6%**	**6%**
surface	12,029.9	10,367.3
ground	71,637.2	78,577.8

Minnesota Reported Water Use

Category	2004	2005
Industrial Processing	(Millions of Gallons)	
Agricultural		
surface	33.2	46.5
ground	9,127.8	8,790.4
Pulp and Paper		
surface	25,232.1	25,864.9
ground	835.5	838.0
Mine		
surface	110,308.0	114,951.7
ground	163.9	118.9
Sand and Gravel Washing		
surface	2,726.8	2,583.9
ground	1,434.9	1,275.2
Industrial Process Cooling Once-through		
surface	189.2	191.6
ground	2,091.6	1,964.8
Petroleum or Chemical		
surface	156.7	126.4
ground	4,038.8	4,128.5
Metal		
surface	0.0	0.0
ground	1,407.9	1,281.7
Non-Metal		
surface	0.4	0.1
ground	1,089.9	1,078.5
Other		
surface	0.0	0.0
ground	383.0	367.7
Subtotal	**159,219.7**	**163,608.8**
Percent of Total	**12%**	**11%**
surface	138,646.4	143,765.1
ground	20,573.3	19,843.7
Other		
Air Conditioning		
Commercial & Institutional Building AC		
surface	248.8	244.7
ground	59.8	68.3

Minnesota Reported Water Use

Category	2004	2005
	(Millions of Gallons)	
Heat Pumps & Coolant Pumps		
surface	54.6	90.9
ground	0.0	0.0
District Heating		
surface	0.0	0.0
ground	87.7	116.6
Once Through Heating or AC		
surface	0.0	0.0
ground	1,768.3	1,863.3
Other AC		
surface	0.0	0.0
ground	0.0	0.0
Temporary		
Temporary Construction Non-Dewatering		
surface	14.9	28.5
ground	1.9	15.3
Temporary Construction Dewatering		
surface	183.2	350.5
ground	2,946.6	5,447.4
Temporary Pipeline and Tank Testing		
surface	0.0	1.6
ground	1.9	0.0
Other Temporary		
surface	156.6	55.9
ground	13.5	9.0
Water Level Maintenance		
Basin (Lake) Level Maintenance		
surface	358.3	9,221.9
ground	209.8	236.3
Mine Dewatering		
surface	21,963.9	21,664.7
ground	7.0	7.2
Quarry Dewatering		
surface	11,791.2	12,259.2
ground	0.0	0.0
Sand/Gravel Pit Dewatering		
surface	636.3	972.9
ground	74.5	42.4

Minnesota Reported Water Use

Category	2004	2005
	(Millions of Gallons)	
Tile Drainage & Pumped Sumps		
surface	35.5	41.2
ground	134.3	32.1
Other Water Level Maintenance		
surface	37.4	55.9
ground	1,551.9	1,555.4
Special Categories		
Pollution Confinement		
surface	0.0	0.0
ground	4,646.0	4,687.9
Hatcheries & Fisheries		
surface	5,109.5	5,650.6
ground	475.0	577.9
Snow Making		
surface	203.9	200.2
ground	258.0	232.5
Peat Fire Control		
surface	0.0	0.0
ground	0.0	0.0
Livestock Watering		
surface	0.0	0.0
ground	779.1	821.3
Other Special Categories		
surface	228.8	578.1
ground	830.7	1,183.9
Subtotal	**54,868.9**	**68,313.6**
Percent of Total	**4%**	**5%**
surface	41,022.9	51,416.8
ground	13,846.0	16,896.8
Grand Total (Millions of Gallons)	**1,378,148**	**1,431,330**
surface	1,136,198	1,177,786
ground	241,950	253,544

DNR Information Center

Twin Cities: (651) 296-6157
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