2001 Water Year Data Summary 2002

April 23, 2001
Mississippi River/St. Paul Airport
(Holman Field)

May 2003

Minnesota
Department of Natural Resources
Waters

WATER YEAR DATA SUMMARY 2001 and 2002

October 1, 2000 - September 30, 2002

by the DNR Waters Staff
St. Paul, MN

May 2003

Minnesota
Department of Natural Resources
Waters

"Helping people ensure the future of our water resources"

This information is available in an alternative format upon request

Equal opportunity to participate in and benefit from programs of the Minnesota Department of Natural Resources is available to all individuals regardless of race, color, national origin, sex, sexual orientation, marital status, status with regard to public assistance, age or disability. Discrimination inquiries should be sent to: MN/DNR, 500 Lafayette Road, St. Paul, MN 55155-4031; or the Equal Opportunity Office, Department of the Interior, Washington, D.C. 20240.

The DNR Information Center phone numbers:
Twin Cities: (651) 296-6157
MN Toll Free: 1-888-646-6367 (or 888-MINNDNR)
Telecommunication Device for the Deaf:
(651) 296-5484
MN Toll Free: 1-800-657-3929

World Wide Web Address:
http://www.dnr.state.mn.us/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 follow the hydrologic cycle (see diagram) and provide important facts 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 web site at **www.dnr.state.mn.us/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 and 2001. This edition is also available on our web site.

water year

The climatology, surface water and ground water data presented are for Water Years 2001 and 2002.

WY 2001: October 1, 2000 - September 30, 2001
WY 2002: October 1, 2001 - September 30, 2002

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 is reported and presented on a calendar year basis.

acknowledgements

We wish to express our gratitude to the listed authors and others who contributed to this publication. Special thanks to Doug Schaffer, and especially Jim Zicopula for assistance with layout and design.

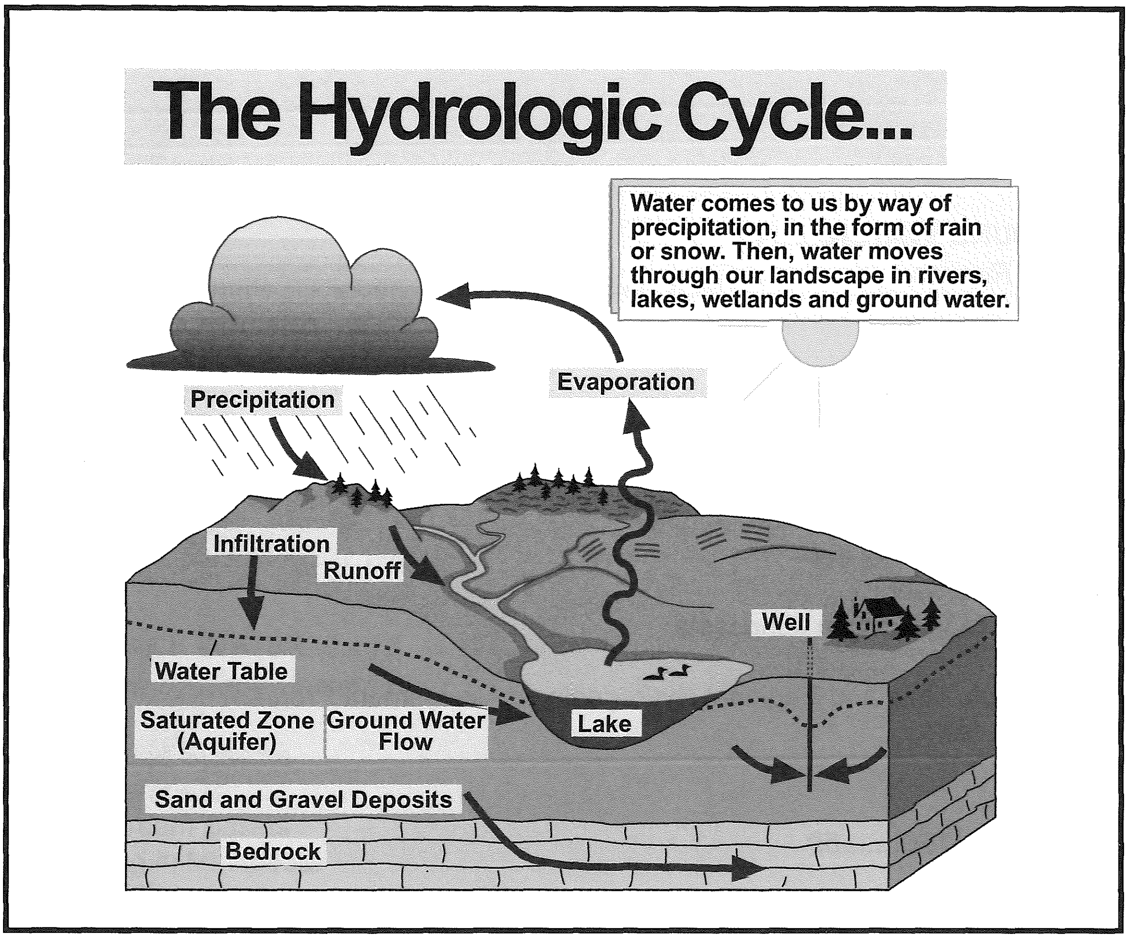
COVER PHOTOGRAPH:
Mississippi River/St. Paul Airport (Holman Field), April 23, 2001
Courtesy of the Office of Aeronautics, Minnesota Department of Transportation

Glen Yakel, *Editor* Kent Lokkesmoe, *Director*

table of contents

table of contents

hydrologic cycle

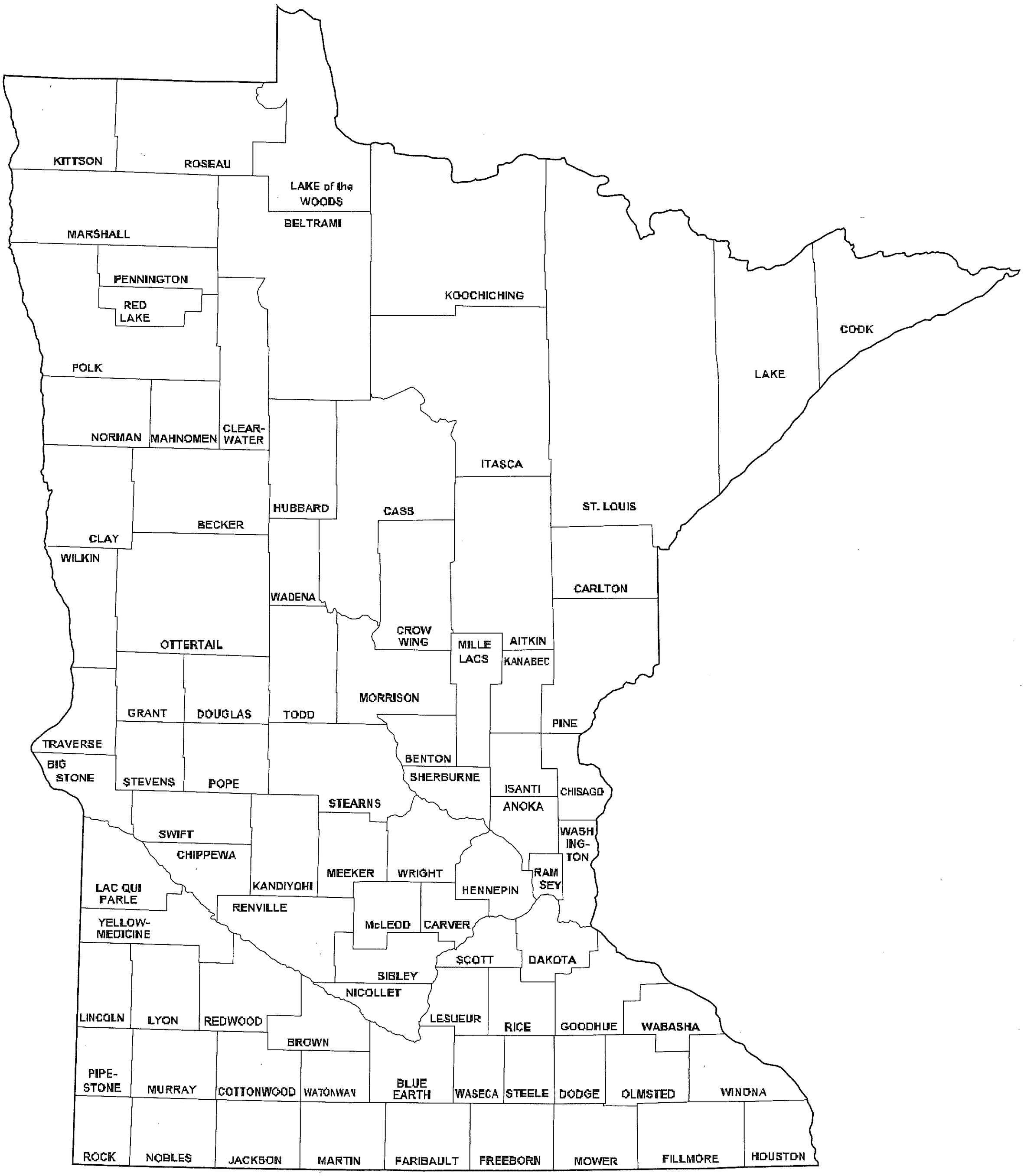


The hydrologic cycle is a concept used to explain the movement of water around the earth. This movement is continuous and has no beginning or end. Change at any point in the cycle will be reflected later in the cycle.

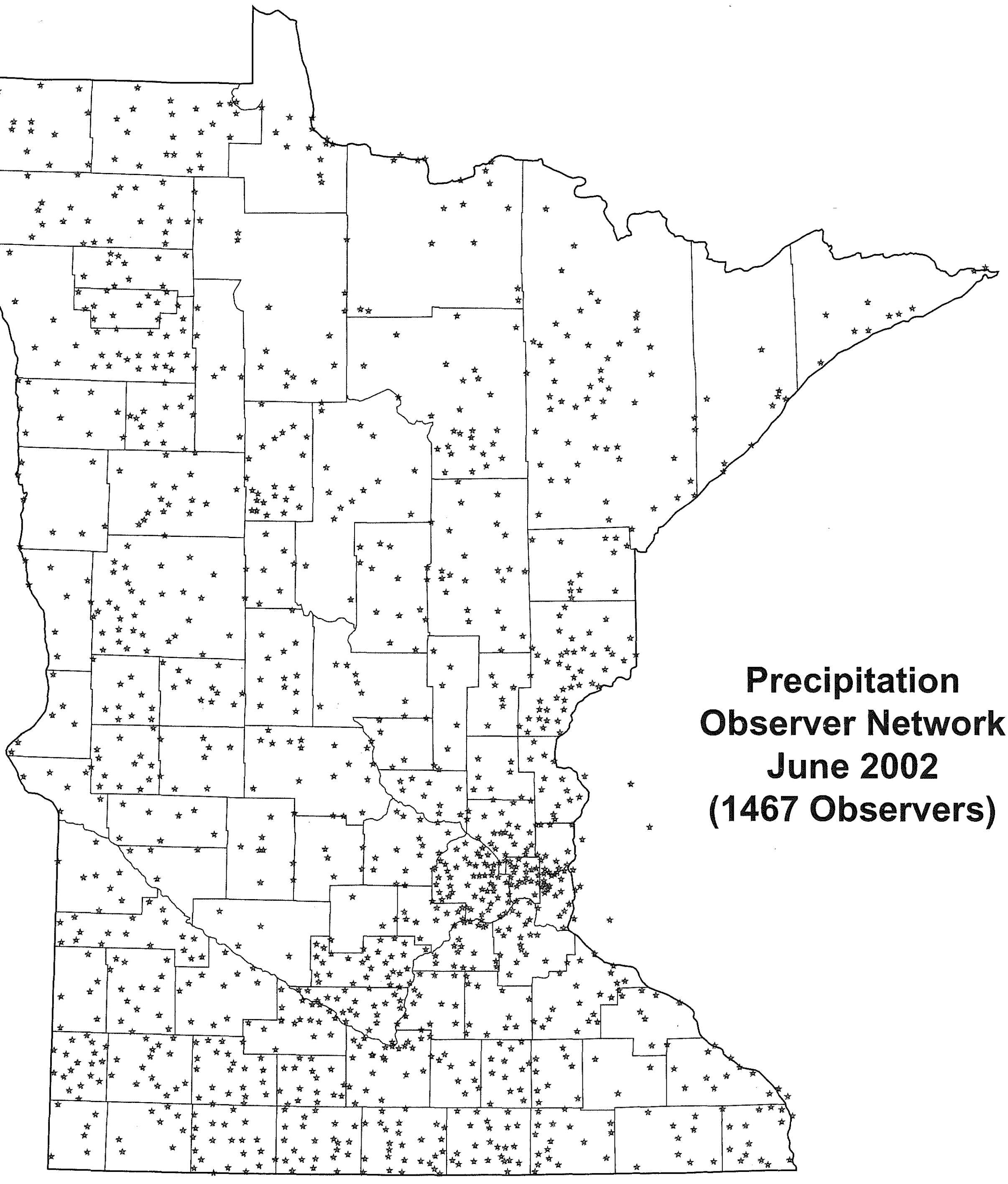
Surface water, which predominately exists in oceans, is evaporated into the atmosphere by the energy of the sun. It returns to the earth as precipitation (rain or snow). As precipitation falls, it may be intercepted by vegetation and evaporate or it may reach the ground surface. Water that reaches the surface may either soak into the soil 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



chapter one
climatology



Precipitation Observer Network June 2002 (1467 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
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
County Environmental Services

"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."

Water Year 2001

October 1, 2000 — September 30, 2001

Highlights
- Wet November 2000
- Cold December 2000
- Snowy Winter 2000-2001
- Near-record Mississippi River Flooding, April 2001
- Extraordinarily Wet Spring 2001
- Very Dry Mid- to Late-Summer 2001

Winter 2000-2001

Mid-November and late-November 2000 storms covered much of Minnesota with snow that lasted the entire winter. December accumulation in some southern counties was over two feet; two and even three times the historical average. By month's end, the entire state was covered by at least eight inches of snow. December temperatures were extremely cold, averaging 10 degrees below normal statewide. It was the coldest December since 1985 and one of the coldest Decembers ever. Minimum temperature records were set on the December 12, 22, 24 and 25.

Autumn 2000

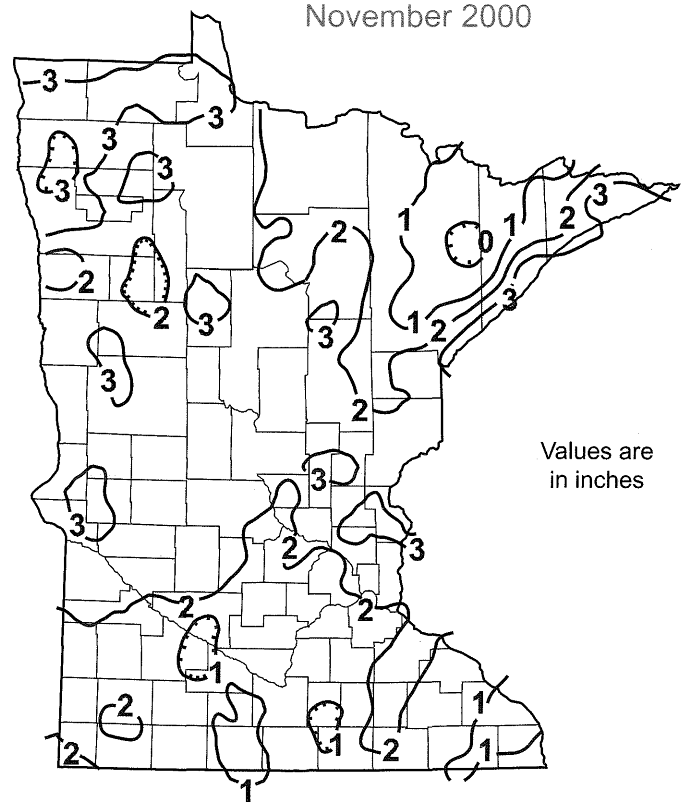
October 2000 precipitation was below normal with deficits of up to one inch in most communities. October temperatures were two to five degrees above normal. A cold snap on October 8-9 was counterbalanced by record high temperatures on October 19.

Above-normal November rainfalls (Figure 1) brought relief to much of the state that was affected by significant precipitation deficits of the previous 15 months. However, precipitation totals over southwestern, central, east central and northeastern Minnesota remained four to seven inches below normal for the calendar year. In contrast, the November rains also fell over northwestern Minnesota, a region already wet from late summer and autumn rains. In many northwestern counties, streams were at or above bank full and crop harvesting conditions were poor.

November temperatures ranged from one to five degrees below normal in the southern two-thirds of Minnesota and from one to three degrees above normal in the northern third of the state. For only the third time in recorded history, Minnesota experienced a November tornado. On November 1, a tornado damaged power lines and outbuildings in Kandiyohi County.

Figure 1

Departure from Normal Precipitation
November 2000



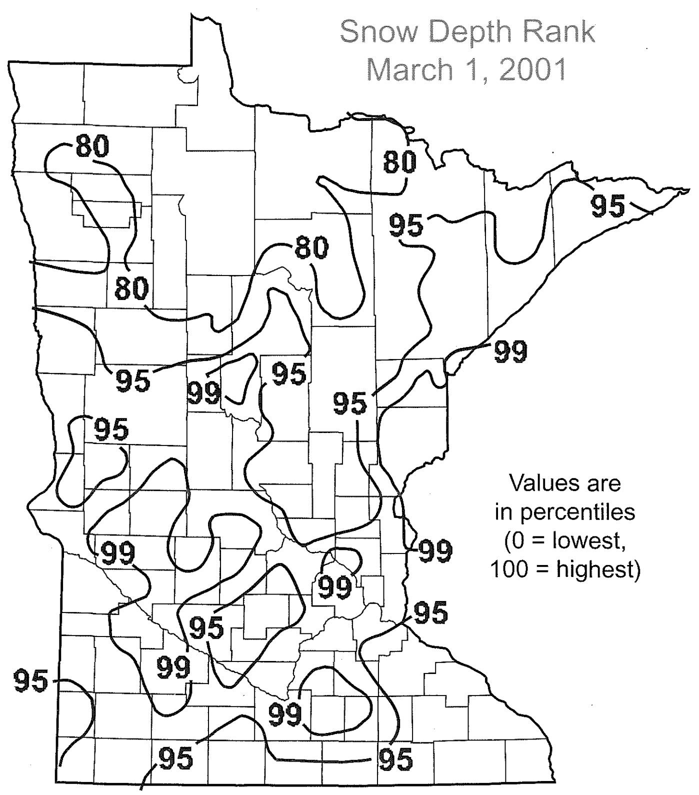
January 2001 precipitation was near to above normal across the southern two-thirds of Minnesota and below normal in the northern third of the state. January temperatures were mild and averaged six to 12 degrees above normal across Minnesota. However, temperatures remained cold enough to retain most of the snow cover accumulated during November and December. Snow depths exceeded 12 inches across large areas of Minnesota at the end of January.

February precipitation was two or three times the historical normal during this typically dry month. Much of the February precipitation fell during the weekend of February 23-25. Snowfall totals in excess of 12 inches were reported in west central and central Minnesota and approached 24 inches in portions of Minnesota s Arrowhead region. February temperatures were cold, at four to eight degrees below normal. It was the coldest February since 1994 and, for some communities, the coldest February since 1989.

March snow depths in the southern two-thirds of Minnesota ranked above the 95th percentile and were above the 60th percentile in the northern third of the state. In some areas of west-central and southwestern Minnesota, snow depths were at or near all-time record values for the date (Figure 2). Snow water equivalent data gathered by the National Weather Service and the Army Corps of Engineers revealed that the snow pack across the state generally contained three to six inches of water as of March 6. While March precipitation totals were about one inch below normal, much of the month's precipitation fell during a single storm of six to 10 inches of wet, heavy snow across southern, central and northeastern Minnesota. March temperatures were near normal in the northern third of Minnesota, but finished three to six degrees below normal elsewhere. Late winter snows and near-normal to below-normal temperatures caused snow cover to persist into early April in most areas.

The 2000-2001 winter season snowfall totals exceeded 60 inches throughout the west and south and were in excess of 72 inches in the northeast. Snowfall totals ranked above the 80th percentile across much of southern, western and northeastern Minnesota and, in some communities, exceeded the 95th percentile (Figure 3). In contrast, snowfall in areas of far north central Minnesota fell well below the median.

Figure 2



Spring 2001

April 2001 river levels approached floods of record in many locations as a result of four contributing climatic factors:

1. significant autumn precipitation (heavy early November rains before soil freeze-up);
2. heavy winter snowfall (18 to 24 inches above average in many southern Minnesota locations);
3. less than ideal snowmelt scenario (below-normal March temperatures);
4. record-breaking April precipitation.

April precipitation totals were extraordinarily high across most of the state. Parts of southwestern, central, east central and northeastern Minnesota received over six inches of precipitation from April 1 to April 23, surpassing normal by more than four inches in these areas (Figure 4). Three storm sequences (April 6-7, April 10-11 and April 21-23) accounted for most of the precipitation. During the later stages of the April 21-23 event, up to a foot of snow fell in a 100-mile wide band from Browns Valley into northeastern Minnesota.

April temperatures were near normal across much of the state, but finished nearly three degrees above normal in south central and southeastern locations. Lake ice-out in the southern three-fourths of Minnesota occurred one to two weeks later than historical averages, and close to historical averages in the far north. These conditions were notably in contrast to the early lake ice-out in the spring of 2000.

May precipitation totals were normal in some areas, while the remainder of the state was one to two inches above normal for the month. The precipitation was not only heavy in some areas, but also unusually persistent. A very slow-moving storm system brought daily rains to some locations for eight consecutive days (May 19-26). Compared with historical data, April-May precipitation totals ranked near all-time record high values for much of Minnesota (Figure 5). Field preparation, spring planting and early crop growth was far behind historical averages due to wet soil across the state. May temperatures were near to slightly above normal across most of Minnesota, but ranged from record highs at some locations on May 15 to record lows on May 22 and 23.

Figure 3

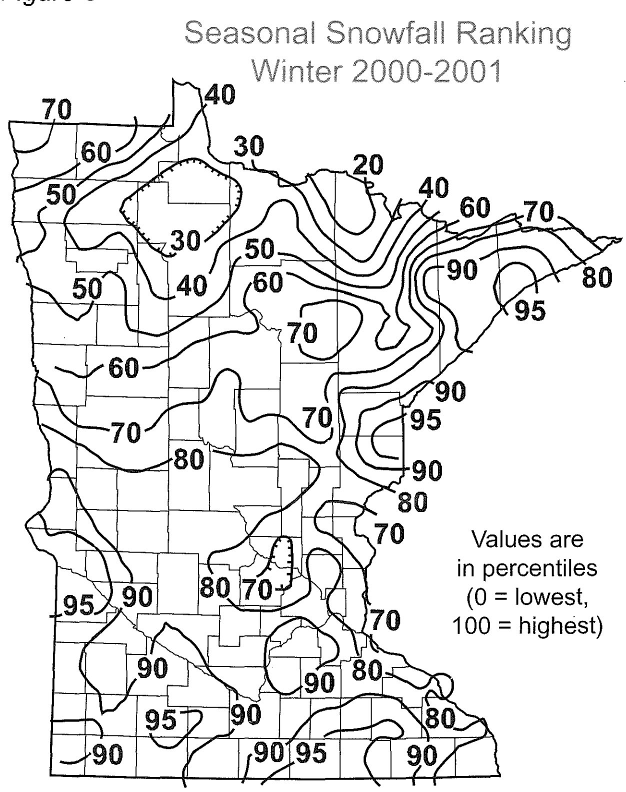
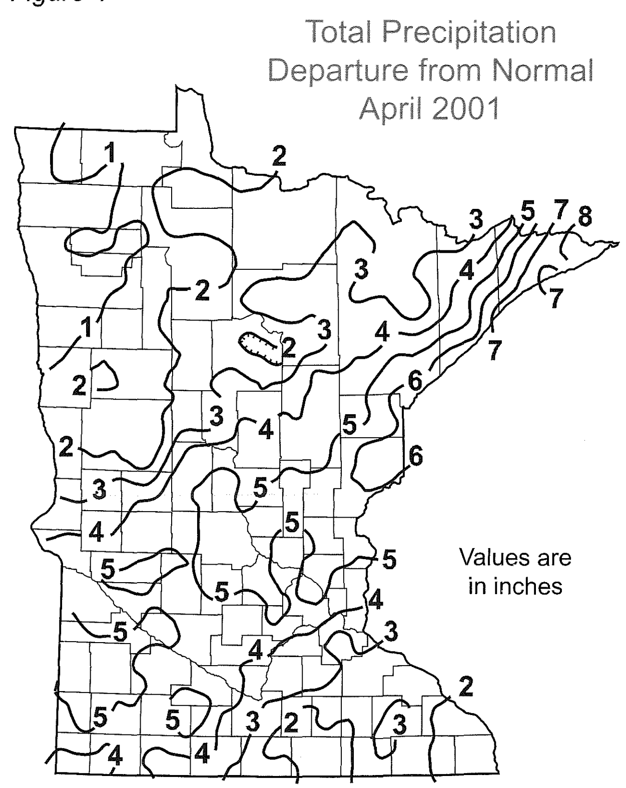


Figure 4

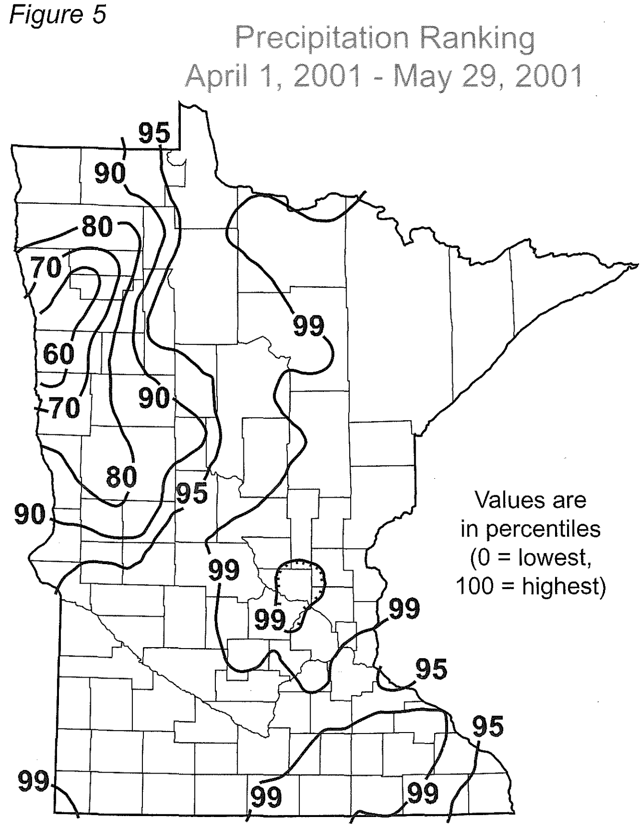


Summer 2001

June 2001 precipitation totals varied widely across Minnesota. Some areas reported above-normal amounts while the northern third of the state was as much as one inch below normal. Most measureable rainfall came from a sequence of storms that occurred on June 11-14, with cumulative totals of over four inches in many areas. Tornadoes, severe thunderstorm winds and hail accompanied the storms and caused significant damage. Precipitation totals were generally light for the final two weeks of the month. Overall, June temperatures finished very close to historical averages, but were the result of very warm, month-ending temperatures, which counterbalanced cool weather early in the month.

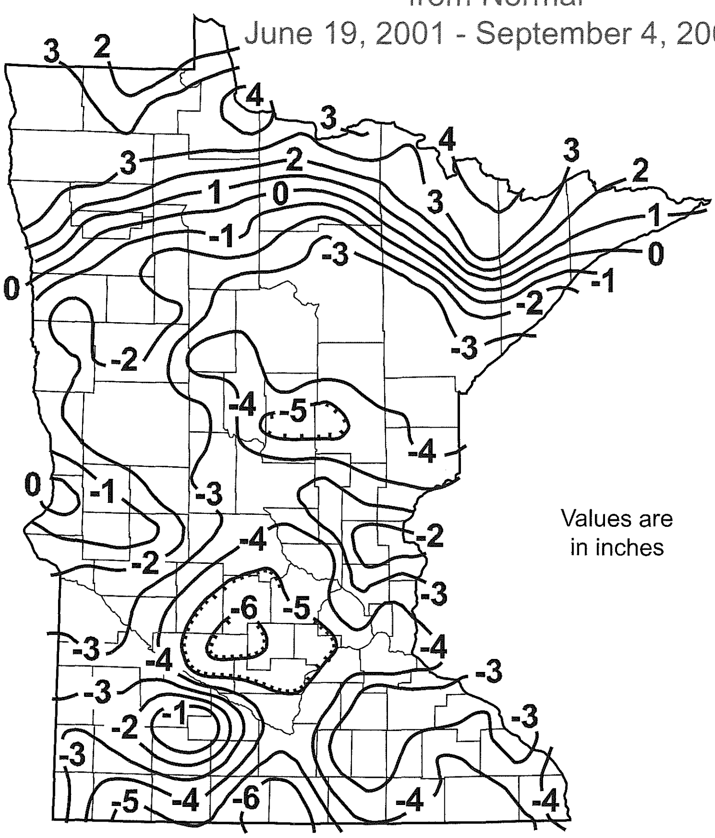
Continuing a dry spell that commenced during the second half of June, July precipitation totals were generally below average across most of Minnesota and fell short of historical averages by one to two inches. For the four-week period of June 19-July 16, precipitation totals were less than half of normal and shortfalls developed in areas of central and southeastern Minnesota. The exception to general July dryness was in far northern Minnesota, where thunderstorms occurred in mid-July and again on July 31. A band of two to six inches of rain was reported from Kittson County east to Cook County in late July. The heaviest amounts fell in portions of Lake of the Woods, Beltrami and Koochiching Counties, where five-inch totals were common. Precipitation totals were near or above all-time records for the April through early-August period in parts of north central and northeastern Minnesota. July average temperatures were slightly above historical normals, but were the result of very warm mid-month and late-month temperatures offsetting cool early-month weather. Most of Minnesota experienced significant episodes of extreme heat and humidity (July 17-18 and July 30-August 1), with temperatures in the 90s, dew points in the upper 70s and heat index values in excess of 100 degrees.

Figure 5



Similar to the second half of June and most of July, August precipitation totals across much of the southern two-thirds of Minnesota were generally short of historical norms by one to two inches. Scattered areas of the northwest and the southeast finished the month with above-normal precipitation, but August was generally dry from a statewide perspective. August average temperatures finished above historical norms by two to three degrees. Most of Minnesota experienced extreme heat and humidity on August 4-8, with temperatures in the 90s, dew points in the upper 70s and heat index values in excess of 100 degrees.

Figure 6 Total Precipitation Departure from Normal June 19, 2001 - September 4, 2001



Mid-summer and late-summer rainfall was below historical averages in all areas except far northern Minnesota. During the 11-week period from June 19 through September 4, rainfall deficits were two to four inches in many areas and four to six inches in others (Figure 6). The dryness was especially acute in areas of central and southwestern Minnesota, where precipitation totals ranked below the 5th percentile compared to historical records for the period. Mid-to late-summer precipitation across most of the northern tier of counties was adequate to abundant, in some cases ranking above the 90th percentile for the period.

September 2001 precipitation patterns were highly variable, ranging from above average in northwestern and west central Minnesota, to as much as two inches below normal in the south central and northeast areas. Elsewhere across the state, September precipitation was close to the long-term mean. September average temperatures finished near historical averages statewide. Record warm temperatures early in the month were counterbalanced by cool mid- and late-September weather.

Water Year 2001

The 2001 Water Year (October, 2000-September, 2001) precipitation totals were above normal across all of Minnesota and exceeded the norm by eight or more inches in some areas (Figure 7). Precipitation totals ranged from less than 24 inches in portions of the northwest to more than 40 inches in the far northeast (Figure 8).

Figure 7

Water Year Precipitation
Departure from Normal
October 2000 - September 2001

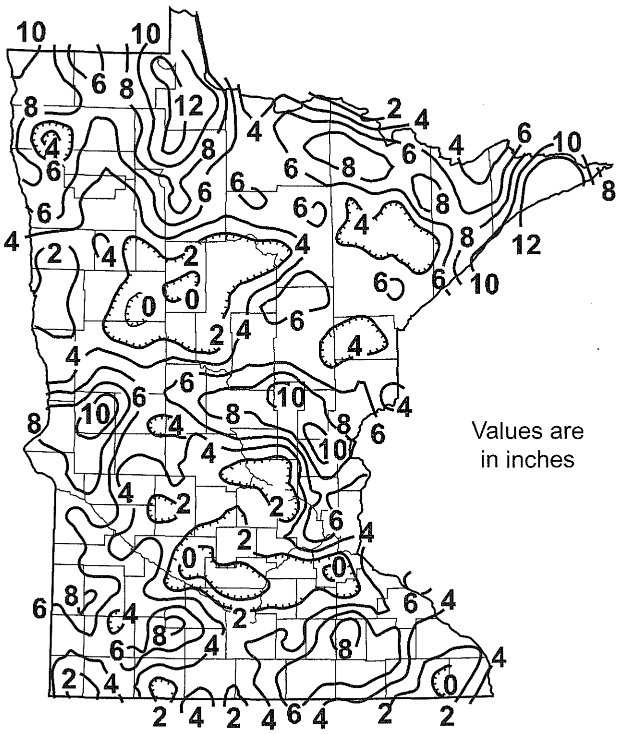
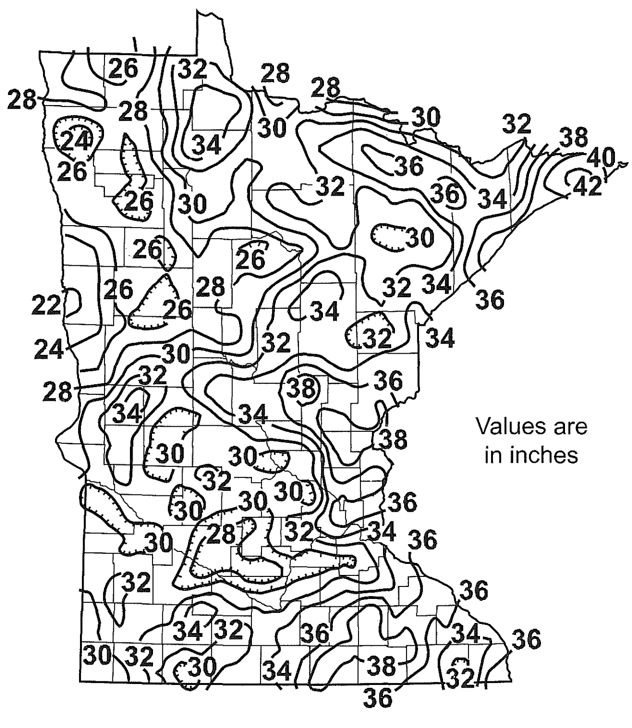


Figure 8

Water Year Precipitation
October 2000 - September 2001



Water Year 2002

October 1, 2001 — September 30, 2002

Highlights

- Heavy, Late November 2001 Precipitation
- Warm November 2001 through February 2002
- Snow-Scarce December 2001 through February 2002
- Cold and Snowy Late Winter 2002
- Record-Breaking Rainfall June 2002
- Extraordinarily Wet Summer 2002

Autumn 2001

October 2001 precipitation was highly variable across Minnesota. The northern third of the state was somewhat average, whereas the remainder of the state fell short of normal by about one inch. The first blizzard conditions and heavy snow of the season occurred on October 24-25, setting records in many northwestern locations. The City of Argyle in Marshall County received 14 inches, while four inches was common across the northern half of the state. October temperatures were close to the historical norms but featured wide fluctuations, with record or near-record highs early in the month, followed by very chilly weather.

Dry autumn weather led to an expanded area of moisture deficits in southwestern, central and east central Minnesota. Lake levels dropped significantly in many areas from record or near-record elevations reported earlier in 2001. Unusually warm early November temperatures, a lack of rainfall and strong winds led to significant wildfires in central Minnesota.

The growing season of 2001 was divided into two very distinctive precipitation regimes. The period from April 1 through the third week of June was extraordinarily wet, ranking among the wettest springs on record. During the third week of June, the jet stream abruptly pushed north. The shift in the storm track prevailed into autumn, causing many storm systems to miss the state or to brush only the northern tier of counties. Surface hydrology in central Minnesota, including soil profiles, were maintained during the growing season only by reserves built up during the wet spring.

November precipitation was scarce during the first three weeks of the month. Then, a slow-moving storm system passed through the midwest on November 23-24, dropping one to three inches of rain across a large area of Minnesota. Yet another major storm moved through the region two days later, leaving a blanket of wet, heavy snow. Snowfall totals topped 24 inches in Kandiyohi County and exceeded 12 inches in many southwestern and central Minnesota communities. Heavy late-November rainfall and snowfall brought relief to areas affected by precipitation deficits during the later part of the 2001 growing season. November temperatures averaged nine to 13 degrees above the historical mean across the state and it was Minnesota s warmest November on record. Nearly every community set a monthly temperature record.

Winter 2001-2002

December 2001 precipitation was below normal, although a rare (but not unprecedented) complex of thunderstorms dropped nearly one-half inch of rain on December 5 in southeastern Minnesota. A December 22 snow event deposited two to six inches of snow across much of the state, just in time for the holiday season. Like November, December temperatures were unusually warm, at eight to 11 degrees above normal. Many southern Minnesota communities experienced maximum temperature records on December 5. For the 57-day period, October 28 to December 23, the Twin Cities International Airport reported above-normal average temperatures each day.

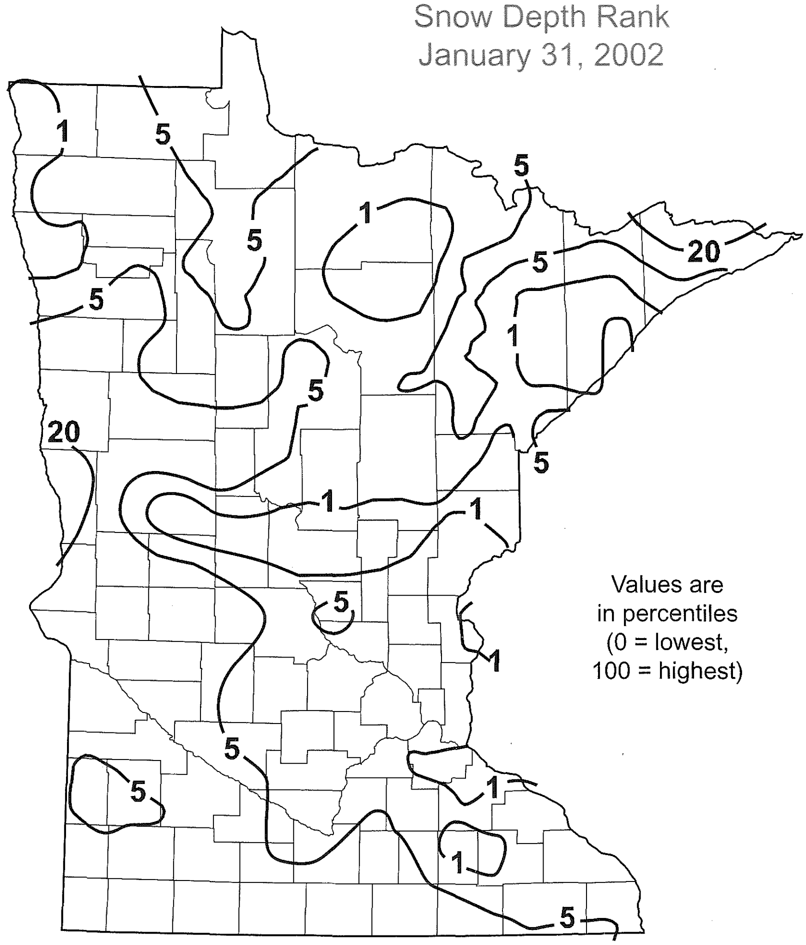
January 2002 precipitation was very light and by late January, snow depths were less than four inches in the southern two-thirds of the state and in the far northwest. The January 31 snow depth ranking map indicated that nearly all of Minnesota ranked below the 20th percentile for the date (Figure 9). Snow depths in many areas were below the 5th percentile and a significant number of locations were at the 1st percentile. January temperatures exceeded normal by nine to 14 degrees in many Minnesota communities, setting maximum temperature records on January 8, 9 and 25. The November 2001 through January 2002 period was the warmest such period for Minnesota by more than two degrees.

February precipitation was generally below normal, although moderate to heavy rains fell on some southeastern communities on February 18-19, with totals ranging from one to two inches. Late February snow depths were less than eight inches and large sections of northwestern and southern Minnesota reported less than two inches. Snow depths ranked below the 20th percentile for the date and, combined with warm temperatures, contributed to unusual February grassland and peat fires. February temperatures were eight to 13 degrees above normal, for Minnesota s fifth warmest February on record. Minnesota experienced the second warmest December through February ("meteorological winter") period in the modern record and some communities reported the warmest meteorological winter in history. For the third time in five years (1997—1998, 1999-2000, 2001-2002), winter temperatures ranked among the warmest on record.

March precipitation was generally normal across much of the state. During the three-day period, March 7-9, two major winter storms dropped heavy snow on central and northeastern Minnesota, and freezing rain fell in the southeast. A third storm, from March 13-15, dropped 15 inches of snow along a 70-mile wide band from Canby to Hinckley, while six or more inches of snow was reported over much of the remainder of the southern two-thirds of the state. In sharp contrast with a winter-long trend of unusually warm weather, March temperatures finished significantly below normal. Temperatures across the state were four to nine degrees below the historical average. The March mean temperature was colder than any of the preceding winter months in many communities.

Figure 9

Snow Depth Rank
January 31, 2002



Spring 2002

April 2002 precipitation varied widely, although total amounts were either slightly above or slightly below normal. Precipitation fell in many forms, including snowstorms on April 1, 21 and 27. Both St. Cloud and the Twin Cities area reported the second-snowiest April on record. Thunderstorms on April 16, 18 and 24 produced damaging wind, hail and heavy rain. April temperatures were near to somewhat below normal statewide, but were extraordinarily variable during the month. Early April temperatures were 10 to 15 degrees below normal, while mid-April temperatures were above historical averages by more than 20 degrees. Lake ice-out dates were quite close to historical averages, ranging from early April in southern Minnesota to early May along the Canadian border.

May precipitation totals were generally below normal by one-half to one and one-half inches. By late May, the potential for wildfires was rated "high to extreme" in many north central and northeastern areas. May temperatures were four to eight degrees cooler than normal, and continued a pattern that persisted throughout the spring. Without the brief warm spell in mid-April, the meteorological spring (March — May) would have ranked among the coldest on record.

Summer 2002

June 2002 was one of the wettest months in Minnesota s post-settlement history. Precipitation totals exceeded 10 inches in many areas, and surpassed 12 inches in many others (Figure 10). Precipitation departures from normal ranged from a **half foot** to nearly **one foot** (Figure 11). In some northwestern communities, rainfall on June 9-10 alone exceeded half the normal **annual** precipitation. The excessive rainfall led to devastating flooding in northwestern communities such as Roseau, Ada and Mahnomen.

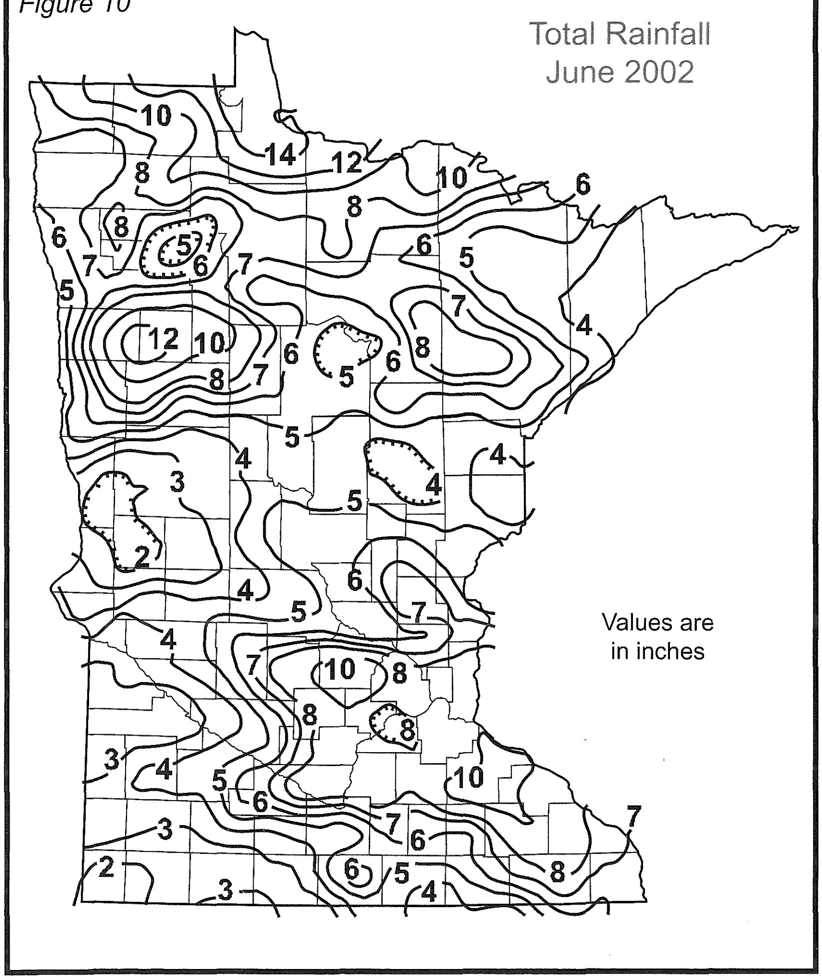


Figure 10

On June 9-10, portions of northwestern and north central Minnesota experienced one of the most significant precipitation events ever recorded (Figure 12). While not unprecedented, the event was extraordinarily rare in its intensity and geographical extent. Rainfall totals for the 48-hour period exceeded six inches over a multi-county area and topped eight inches in portions of Norman, Mahnomen, Marshall, Kittson, Roseau and Koochiching Counties. All of Lake of the Woods County fell within the eight inch contour and an incredible 12 inches of rain fell over portions of Roseau, Lake of the Woods and Koochiching Counties. The maximum rainfall reported was 14.55 inches near Lake of the Woods on the Roseau/Lake of the Woods County border, with anecdotal reports of 15 or more inches in other areas of Lake of the Woods County. Two weeks later, on June 22-23, a broad area of northern Minnesota received four inches to as much as eight inches of additional rainfall. Some of the communities that received six to eight inches of rain earlier in the month were again drenched by another six to eight inches.

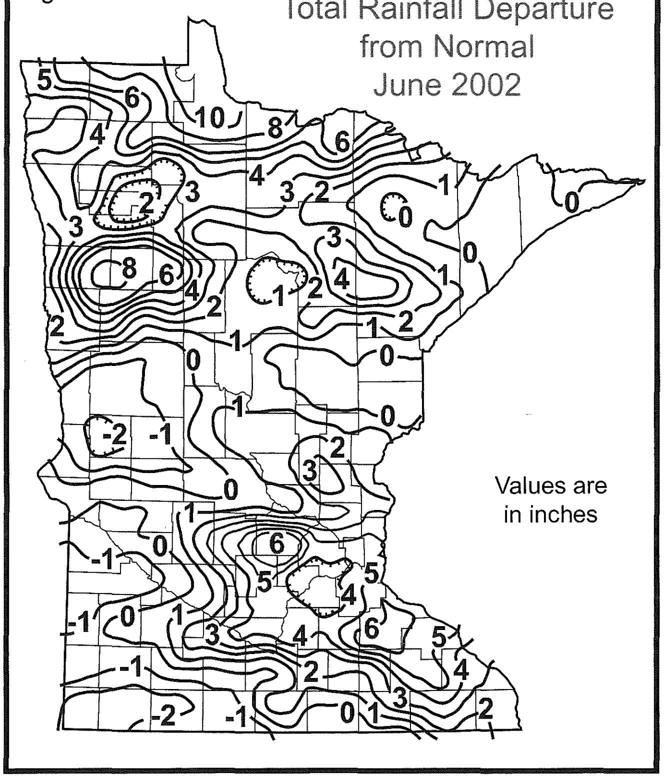


Figure 11

The final few days of June were sweltering with temperatures in the mid-90s, dew points above 70 degrees and heat index values exceeding 100 degrees.

With some exceptions, July was a wet month across much of the northern three-fourths of Minnesota. Rainfall totals exceeded normal by two inches, to as much as four inches, in parts of Minnesota as a result of two very intense rainfall events during the first half of July. The first event drifted across central Minnesota on July 6 and continued into the early morning hours of July 8. The highest multi-day totals were 10 inches in northern Kanabec County and more than nine inches in southwestern Aitkin County. The second event occurred on July 9-10, with rainfall totals exceeding four inches in some communities. The maximum rainfall total from this event was 8.33 inches in western Polk County. July temperatures were generally two to four degrees warmer than normal. Maximum temperatures topped 90 degrees numerous times during the month and minimum temperatures above 70 degrees were common. The summer heat reached its peak on July 20, when some locations in west central and southern Minnesota reported dew points in excess of 80 degrees. High dew points combined with air temperatures in the mid-90s to create heat index values topping 110 degrees.

Heavy June 2002 rains were not limited to northern counties. Four to six inches of rainfall was reported in Wright County and surrounding areas during a relatively short period on the evening of June 24. The rain fell on a landscape that was already saturated from a two to three inch event that occurred on June 21. Rainfall totals exceeding seven inches over the four-day period were reported in sections of Wright, McLeod, Meeker, Carver and Hennepin Counties. Flooding rains were also reported on June 18 in portions of Faribault County and on June 20-22 in parts of Rice and Goodhue Counties. June temperatures were generally two to three degrees warmer than normal.

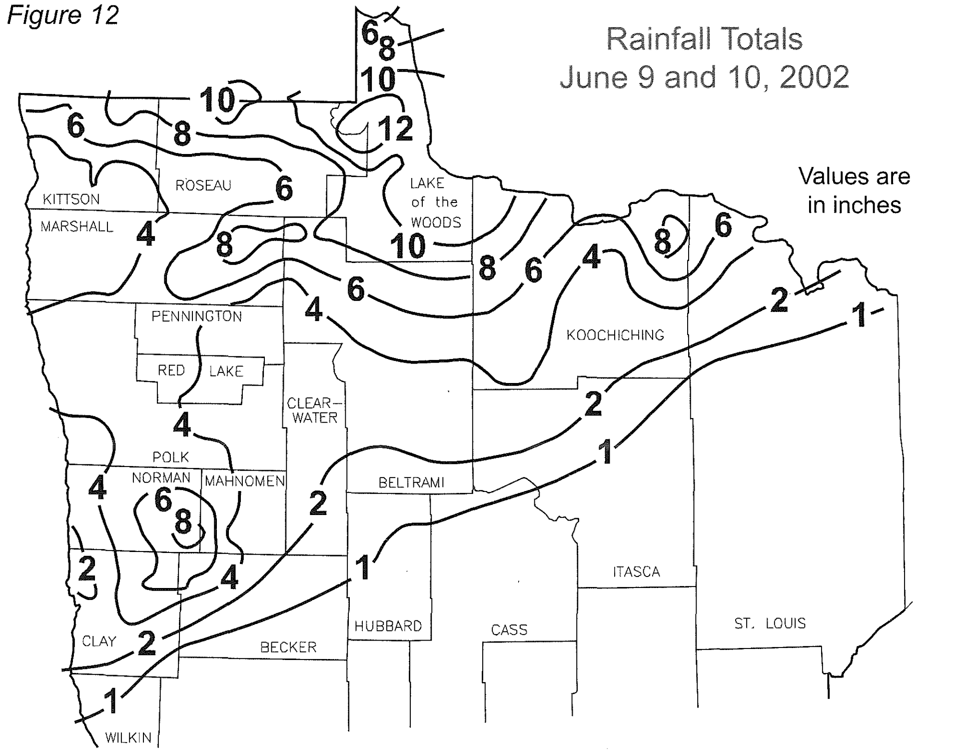
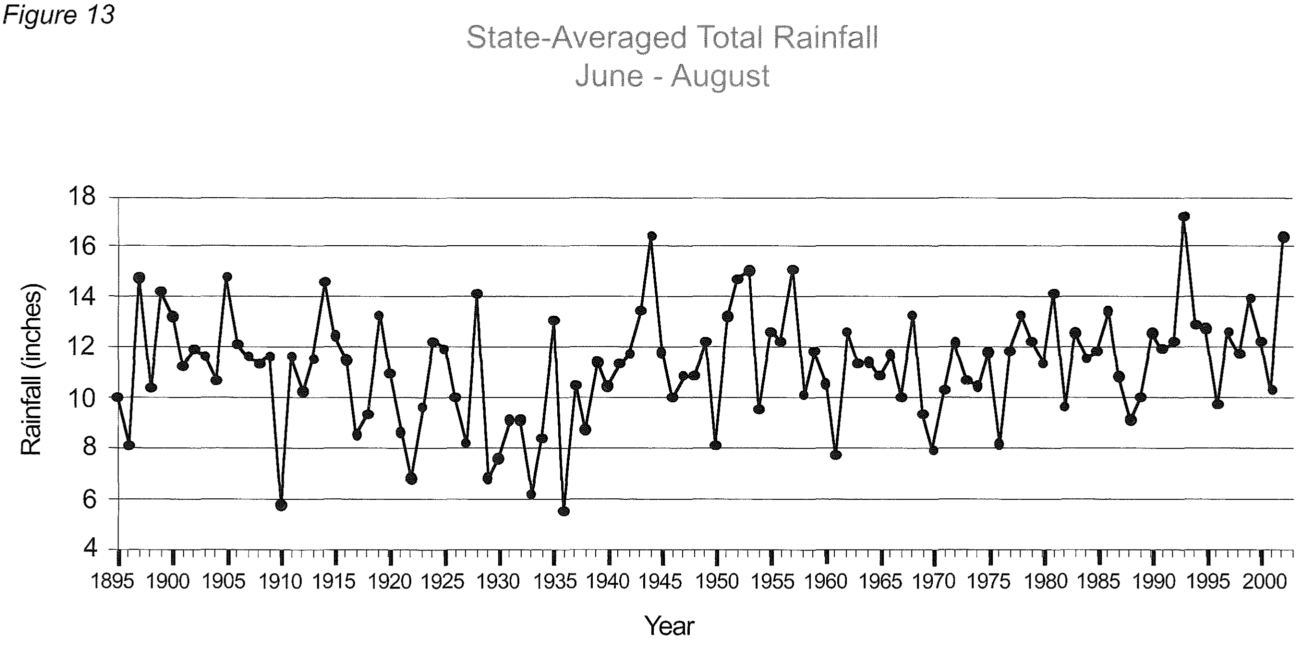


Figure 12

For the third consecutive month, August 2002 rainfall totals across much of Minnesota were well above historical norms. Rainfall totals of more than eight inches were reported at a number of locations around the state. Intense rainfall events occurred on numerous dates during August, however, in most cases the heaviest rain fell over geographically isolated areas. The most substantial rainfall event of the month occurred in central and southern Minnesota on August 20-21. A succession of slow-moving thunderstorms spanned the width of the state, and rainfall totals exceeded five inches in some locations. August temperatures were very close to historical averages. A chilly period during the middle of the month was counterbalanced by warm temperatures at the end of the month.

During the summer of 2002, Minnesota was an oasis of wetness, wedged between drought-ravaged states to the west and east. The June through August period was Minnesota's third wettest on record, with the state-averaged summer (June-August) rainfall total at 16.35 inches (Figure 13). Growing season precipitation totals through late summer were very high relative to historical values across large sections of Minnesota and exceeded averages by more than 50 percent (Figure 14). In contrast, some sections of northeastern Minnesota reported significant rainfall deficits for the season. In portions of Cook County, for example, growing season precipitation totals fell short of the historical average by 30 to 50 percent.

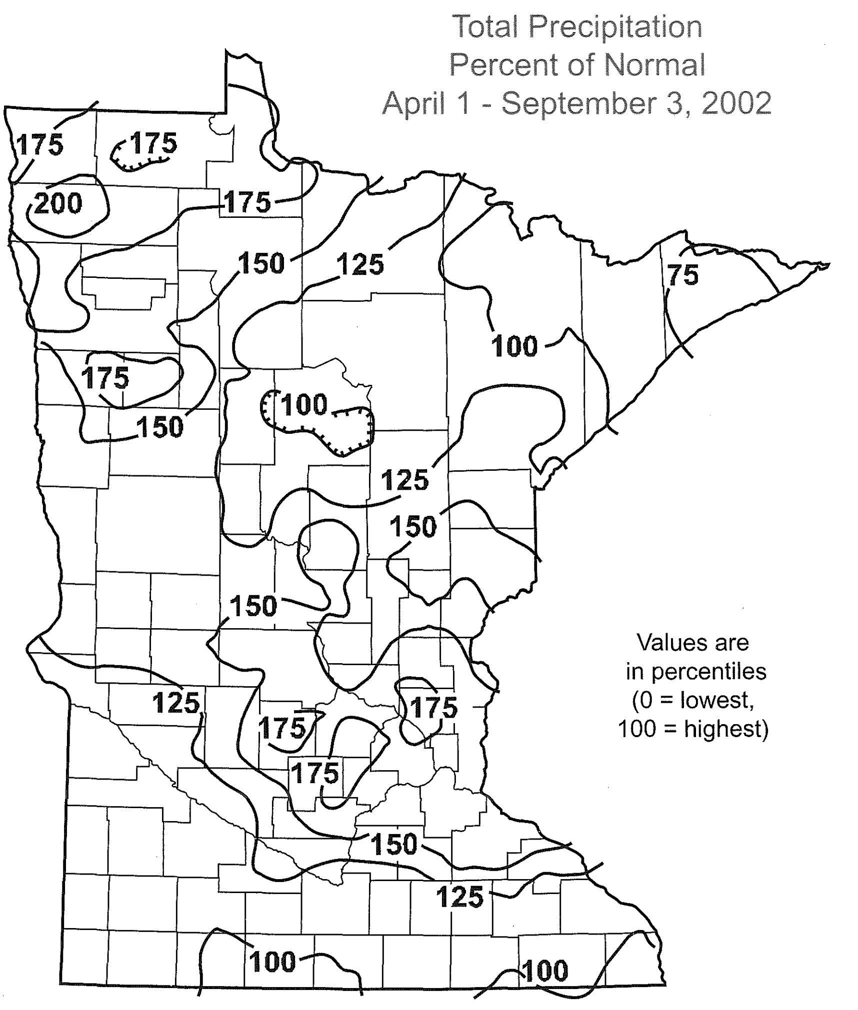
Figure 13



Early Autumn 2002

September 2002 rainfall totals were generally below normal, notably in the western and northern areas of the state, where monthly totals were below the historical average by more than one inch. Exceptions could be found in central and east central Minnesota, where some communities topped normal precipitation by more than two inches, much of it due to intense rainfall on September 5-6. During this event, two waves of thunderstorms dropped three to five inches of rain on portions of Benton, Stearns, Sherburne, Wright, Hennepin and Dakota Counties, causing urban flooding and road washouts. September temperatures were generally above normal for the first half of the month, then cooled to somewhat below normal readings. On average, September temperatures finished three to five degrees warmer than normal, although widespread frost occurred on the morning of September 24.

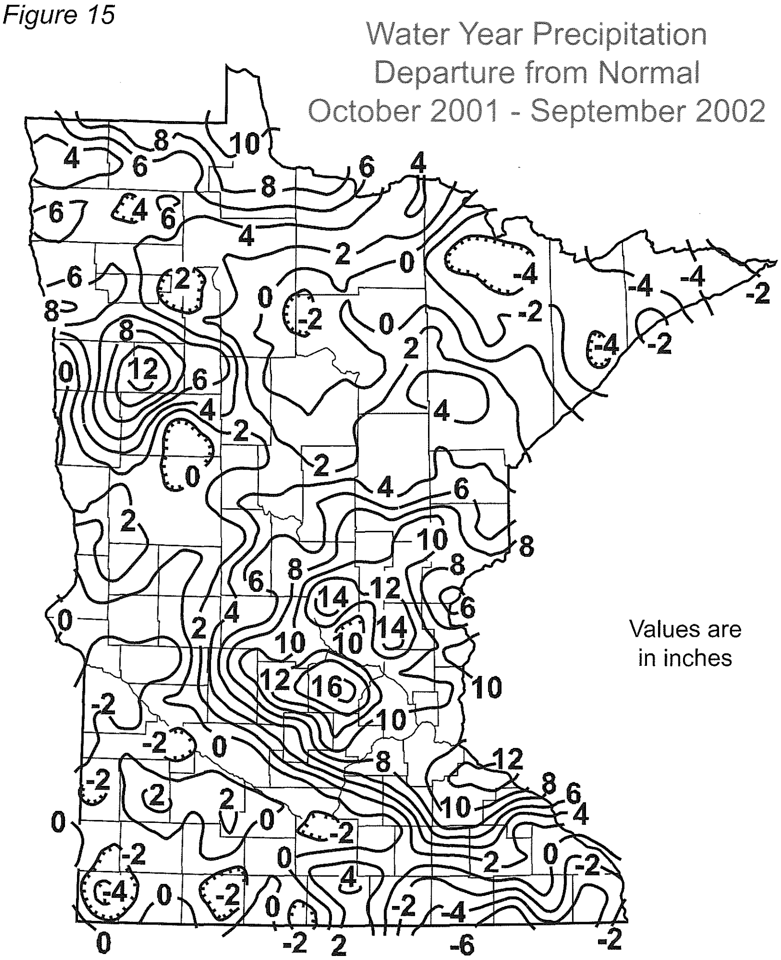
Figure 14



Water Year 2002

The 2002 Water Year (October, 2001-September, 2002) was highlighted by extraordinarily heavy precipitation totals that exceeded historical averages by more than eight inches across significant portions of Minnesota. In contrast, relatively small areas in the southwest and northeast fell short of normal (Figure 15). Precipitation totals ranged from less than 24 inches in far western counties to over 44 inches across much of Wright County (Figure 16).

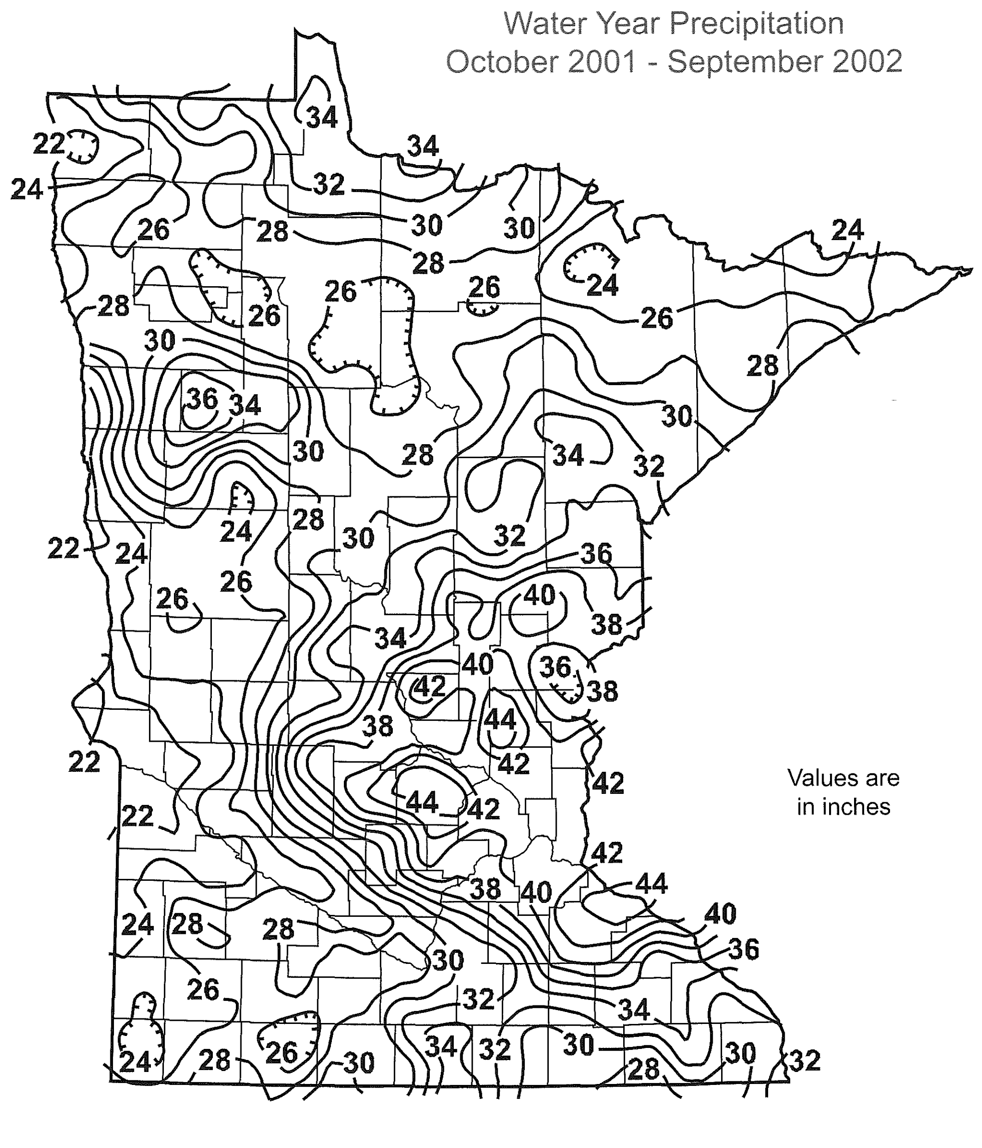
Figure 15



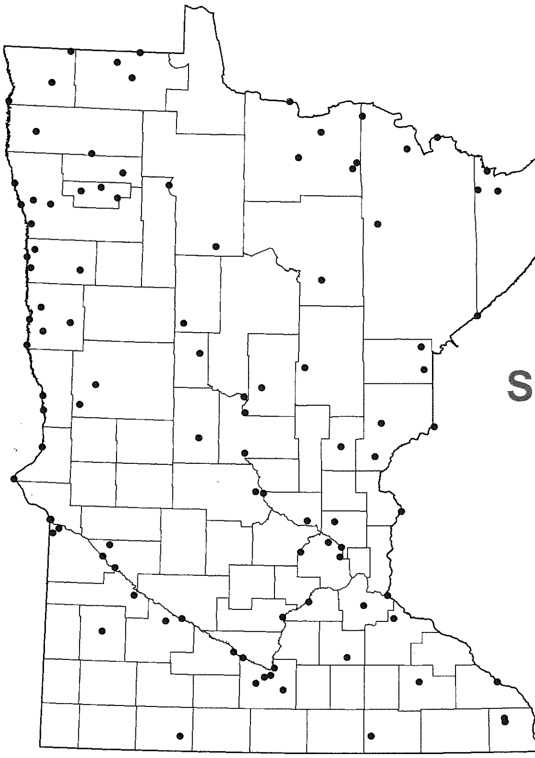
The State Climatology Office analyzes rainfall events that lead to significant damage or events where rainfall totals are near or above the threshold established as a 1 percent probability occurrence (often referred to as the "100-year storm"). For communities in Minnesota, a 1 percent probability occurrence is six or more inches of rain in a 24-hour period. The State Climatology Office evaluated 12 such rainfall events during the 2002 growing season (at right):

- June 9-10, Northwest and North Central Minnesota
- June 20-21, Southeast Minnesota
- June 21-24, Wright County and Vicinity
- June 22-23, Northern Minnesota
- July 6-8, Central Minnesota
- July 9-10, Northwest, Central and South Central Minnesota
- August 3-4, Central and Southern Minnesota
- August 6-7, North Central Minnesota
- August 20-21, Central and Southern Minnesota
- August 27-28, Marshall County
- August 28, Wilkin County
- September 5-6, Central Minnesota

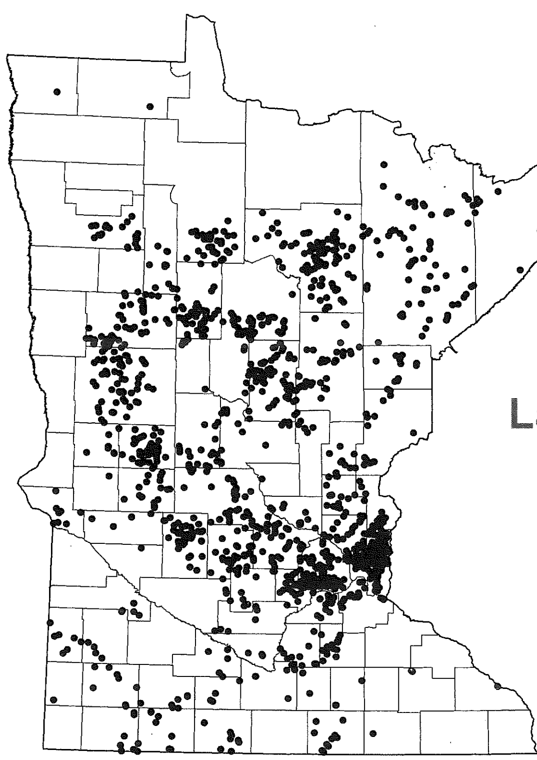
Figure 16


Water Year Precipitation
October 2001 - September 2002
Values are in inches

chapter two
surface water



Stream Gage Network
2002
(100 Gages)



Lake Gage Network
2002
(953 Gages)

Stream Flow

Introduction

The Stream Hydrology Unit is responsible for collecting, analyzing and distributing flow data for rivers and streams in Minnesota. Data for these activities comes from a network of stream gages located throughout Minnesota. Figure 1 shows the 81 major watersheds of the state and the location of the continuous recording gages that the DNR uses to monitor statewide watershed stream flow conditions. These gages are used to gather data including historic high and low flows, and information for computing statistics such as flood frequencies and exceedence values (see sidebar).

Engineers use stream flow data to design the hydraulic capacity of bridges, culverts and control structures. 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 works.

Stream Drainage Systems

There are many types of rivers and streams in Minnesota. Along the North Shore of Lake Superior, and along the Mississippi River blufflands in the southeast, are high gradient streams that have scoured channels into bedrock. In the northwest are highly meandered streams that are situated in an ancient lake bed and are prone to flooding. In the southern third of the state, streams are often entrenched with well developed channels and are largely 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 pass through it. These two continental divides separate river flows into three major drainage basins: the Hudson Bay/Arctic Ocean, the Great Lakes/Atlantic Ocean and the Mississippi River/Gulf of Mexico. Within these three basins are nine major river basins: the Red River of the North, Rainy River, Lake Superior, Upper and Lower Mississippi River, St. Croix River, Minnesota River, Missouri River and the Des Moines - Cedar River (Figure 2).

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.

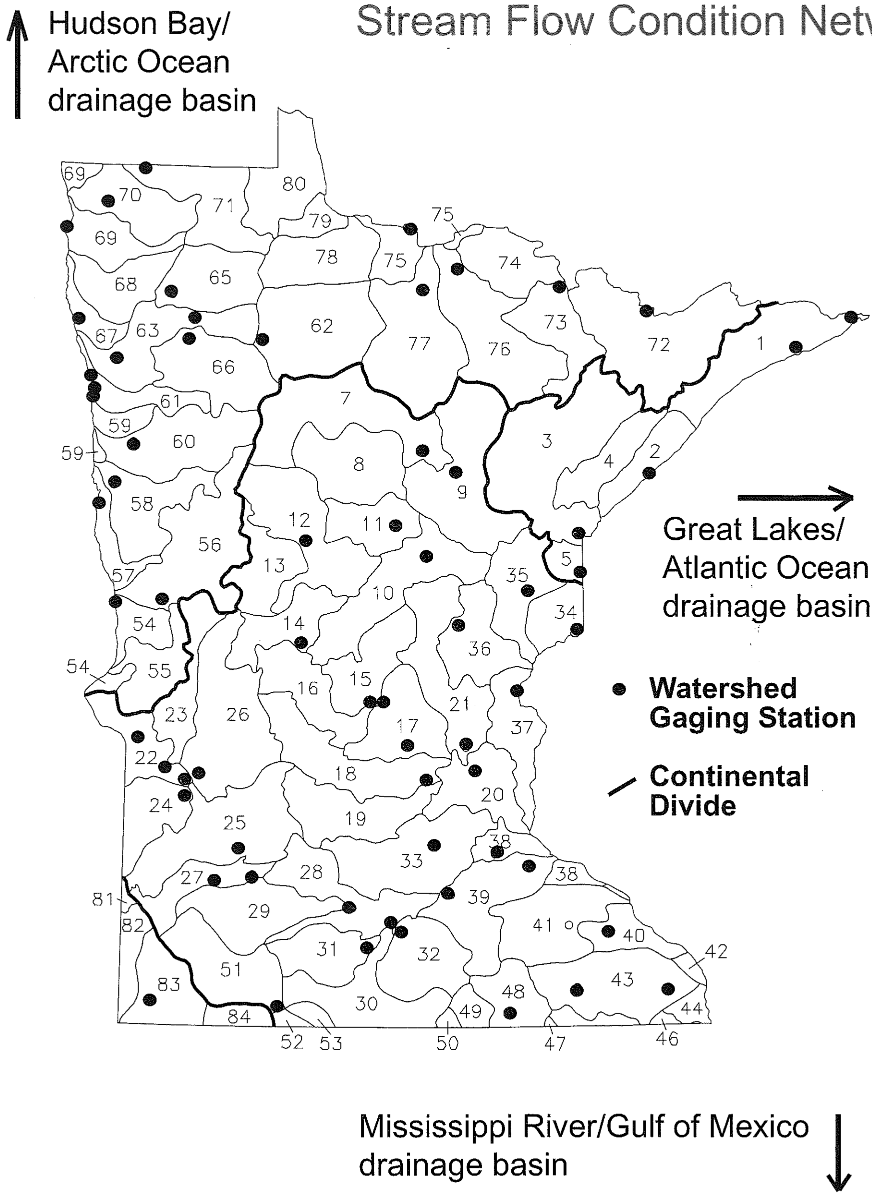
Stream flow reports are based upon the following exceedence values during the open water season.

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 1

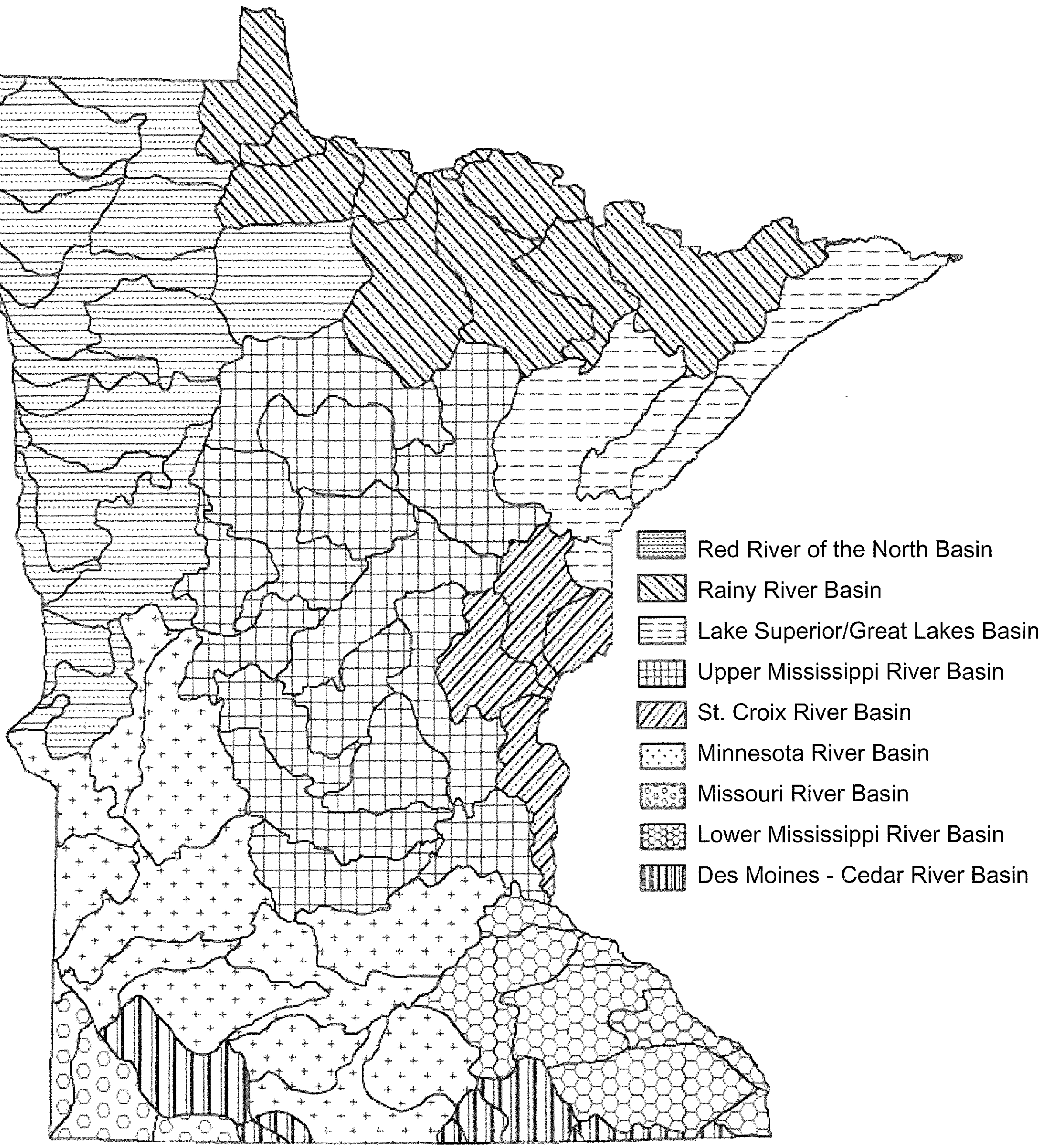
81 Major Watersheds
Stream Flow Condition Network



1 Lake Superior (north) ●
2 Lake Superior (south) ●
3 St. Louis River ●
4 Cloquet River
5 Nemadji River ●
*
7 Mississippi River (Headwaters, Lake Winnibigoshish) ●
8 Leech Lake River
9 Mississippi River (Grand Rapids)
10 Mississippi River (Brainerd) ●
11 Pine River ●
12 Crow Wing River ●
13 Redeye River (Leaf River)
14 Long Prairie River ●
15 Mississippi River (St. Cloud)
16 Sauk River ●
17 Elk River (Elk River) ●
18 North Fork Crow River ●
19 South Fork Crow River
20 Mississippi River (Metro) ●
21 Rum River ●
22 Minnesota River (Headwaters)
23 Pomme de Terre River ●
24 Lac qui Parle River ●
25 Minnesota River (Montevideo) ●
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 (St. Croix Falls) ●
38 Vermillion River (Empire) ●
39 Cannon River ●
40 Mississippi River (Winona) ●
41 Zumbro River ●
42 Mississippi River (La Crescent)
43 Root River ●
44 Mississippi River (Nevo)
*
46 Upper Iowa River
47 Wapsipinican River (Headwaters)
48 Cedar River ●
49 Shell Rock River
50 Winnebago River (Lime Creek)
51 West Fork Des Moines River (Headwaters) ●
52 West Fork Des Moines River (Lower)
53 East Fork Des Moines River
54 Bois de Sioux River ●
55 Mustinka River
56 Otter Tail River ●
57 Red River of the North (Headwaters) ●
58 Buffalo River ●
59 Marsh River ●
60 Wild Rice River ●
61 Sandhill River ●
62 Upper and Lower Red Lake ●
63 Red Lake River ●
*
65 Thief River ●
66 Clearwater River ●
67 Grand Marais Creek (Red River of the North) ●
68 Snake River
69 Tamarack River (Red River of the North) ●
70 Two River ●
71 Roseau River ●
72 Rainy River (Headwaters) ●
73 Vermillion 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 River (Medary Creek)
82 Big Sioux River (Pipestone)
83 Rock River
84 Little Sioux River

Figure 2

Nine Major Stream Basins



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 and streams in the southeast blufflands.

Stream Gaging in Minnesota

Gaging is an essential tool in analyzing stream flows in Minnesota. A stream gage is used to record the water 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 quantity of flow in the stream. If this relationship is developed, recorded stream elevations can be converted to discharge in cubic feet per second (cfs). State-of-the-art gages in Minnesota record stream elevations continuously and transmit the data to a central location for conversion to discharge and use in hydrologic analysis.

Most continuous recording stream gages in Minnesota are operated by the United States Geological Survey. DNR Waters supports about one third of these network gages through the USGS s Cooperative Water Resource Data program. In addition, the DNR maintains approximately forty flood warning gages. The USGS has been gaging Minnesota streams for over 100 years.

Currently, there are nearly 100 continuous recording stream gages maintained by the USGS. Additional stream gages are operated and maintained by the Corps of Engineers, the Department of Natural Resources, the Department of Transportation, the Pollution Control Agency, the Metropolitan Council and other state and local agencies, including watershed districts and lake associations.

Unfortunately, at least five stream gages were eliminated in 2000 due to budget constraints and another was destroyed by flooding. The loss of a stream gage can significantly impact flood prediction and low flow protection. The loss of a stream gage with a long-term record also can seriously degrade the historical record of the stream. It is this long-term record that is important in determining stream flow trends, drought and flood frequency calculations and other historical parameters.

Water Year 2001

Stream flow conditions at the end of Water Year 2000 consisted of high to very high flows for the Red River basin and in the southeast, with near normal flows for the remainder of the state. The following winter brought high to near-record snowfalls, creating an exceptional snow pack.

In April 2001, snow melt and heavy rains produced very high stream flow conditions throughout the state. On the Red River of the North, major flooding occurred from the headwaters well into Canada. Based on the Federal Emergency Management Agency s [FEMA] Flood Frequency Analysis, 50-year flood events were common through out the basin. In the Minnesota River basin, stages commonly exceeded the 100-year flood event at gages near the headwaters of the basin. However, by the time these events arrived at gages in the lower portion of the basin, the peak stages had attenuated to approximately a 50-year flood event. At St. Paul, the 50-year flood event from the Mississippi River combined with the 50-year flood event from the Minnesota River, resulting in a 100-year flood event. Downstream of St. Paul, a 100-year flood event on the St. Croix River merged into the Mississippi River and, with several tributary streams from Wisconsin, created a 100-year flood event past Winona.

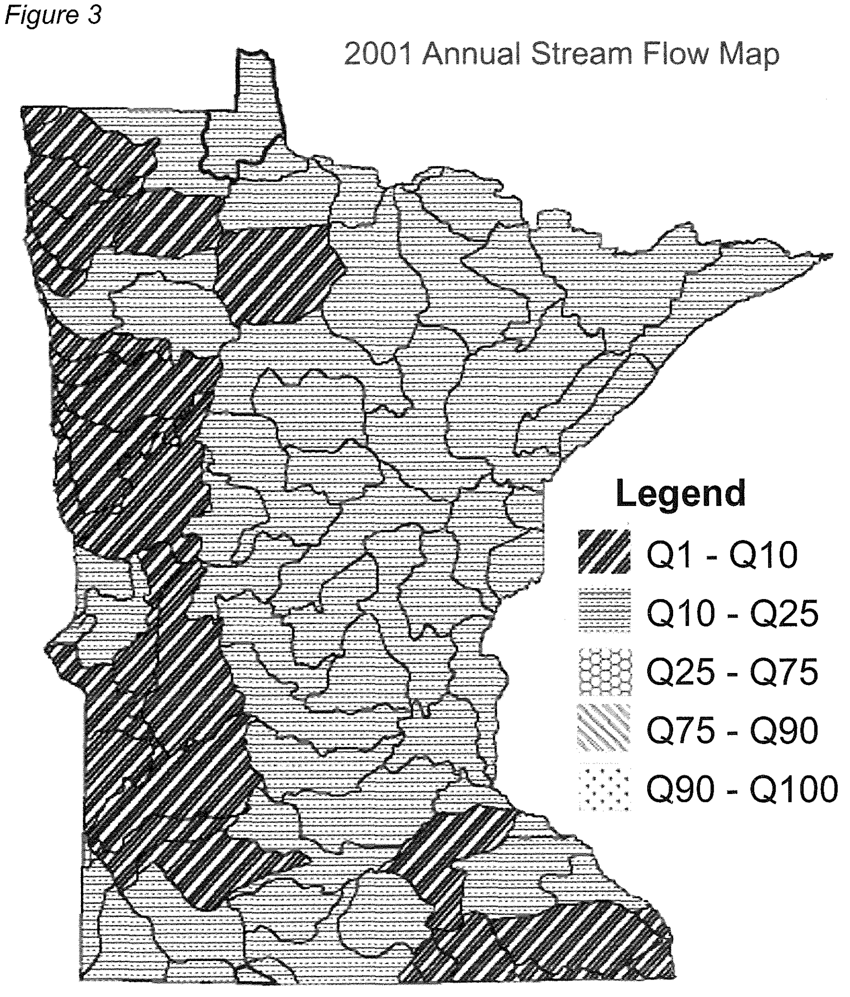
Flooding continued throughout May and June over much of Minnesota as a result of continued heavy spring rains falling on already saturated soils, swollen lakes and streams. However, most of the stages during the May and June flooding were significantly lower than the April flood events. Flooding caused by localized storms could be found well into August.

By July, most regional flooding had ended as precipitation amounts receded significantly from earlier months. Near normal stream flow conditions could be found in the Arrowhead region, in the south and in the west. By late July, flows in the Arrowhead fell into the low range, with normal flows common in the central part of the state. High flows remained only in the west in the Red River headwaters and Minnesota River headwaters.

Precipitation continued to be below normal in August and early September, causing stream flow levels to continue to fall, although flows remained above normal for much of northern Minnesota and the Red River basin. By late September, increasing precipitation and a slowing of evaporation and transpiration, resulted in a slight increase in stream flows.

Figure 3 is the annual stream flow map for Water Year 2001. The very wet conditions found in April, especially in the Red River basin and the Minnesota River basin, have significantly skewed the annual map. The average annual discharges for Water Year 2001 were in the top 15% of stream flow for much of the state and in the top 5% for the Red River and the Minnesota River basins.

Figure 3



Water Year 2002

Stream flow conditions during the spring of 2002 were very different than those of 2001. The winter snow pack was significantly less than the prior winter, April precipitation was also much less and, as a result, there was very little spring flooding in 2002.

In April, normal stream flow conditions could be found throughout most of the state. The St. Croix River basin experienced localized minor flooding due to heavy rain. High flows also existed in the eastern portion of the upper Mississippi River basin and the St. Louis River basin related to this same storm event. Localized low flows could be found around the state, especially in the Arrowhead region.

For the month of May, stream flow conditions were mostly normal throughout the state. Stream flows climbed into the high flow range in the St. Croix River basin and the upper Minnesota River basin in mid May, but quickly returned to normal. Low flows in the Arrowhead region persisted and expanded into parts of the Rainy River basin.

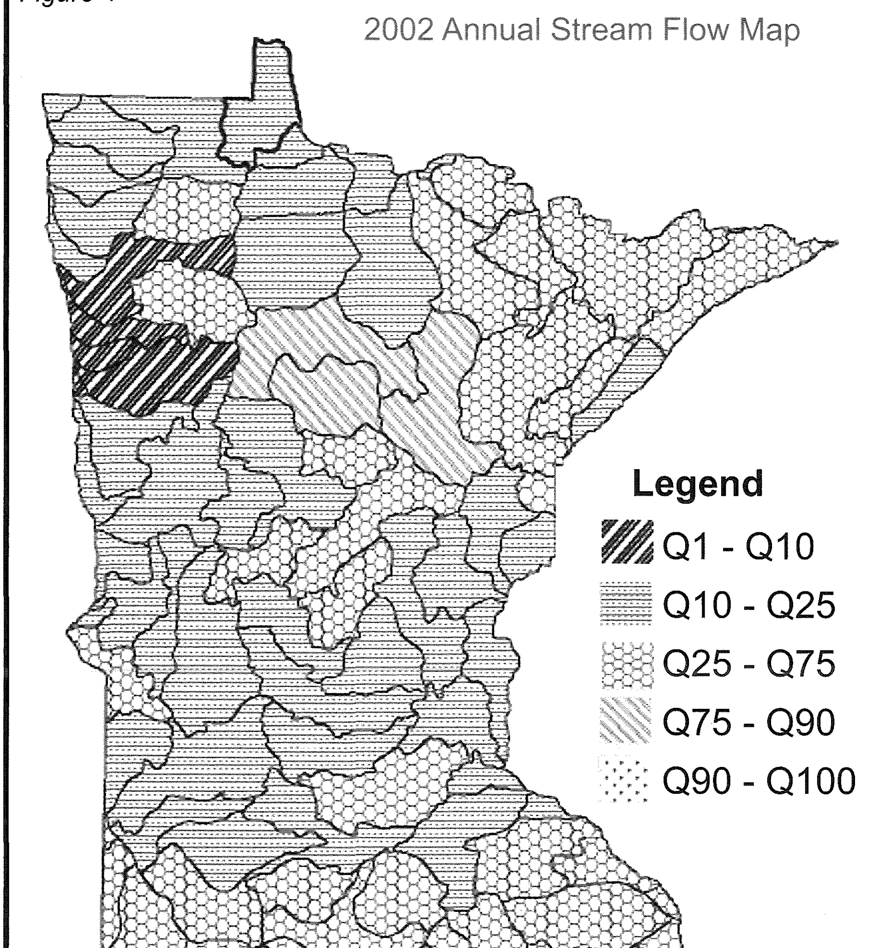
In early June, a series of large storms tracked across northwestern Minnesota and produced 100-year flood events on the Roseau and Wild Rice Rivers in the northern half of the Red River basin (see page 11). These 100-year flood events lead to significant property damage in the communities of Ada and Roseau, and caused the failure of a dam on the Wild Rice River. Concurrently, low flow conditions expanded from the Arrowhead region into the Upper Mississippi River basin, near normal conditions existed in the southwest and high flow conditions existed in the southeast.

July rains over much of the northern two-thirds of the state, pushed stream flows from the low range back to the high range. In the south, near normal conditions prevailed with low flows developing in the Missouri River basin and other watersheds adjacent to Iowa.

Throughout August and September, high flow conditions in the north gradually fell into the normal range, while flows in the south remained in the normal range. An occasional low flow could be found in the southern part of the state as low flow conditions developed in the Arrowhead region and extended into the Rainy River basin. By the end of September, critical flows could be found along much of the Canadian border.

Figure 4 is the annual stream flow map for Water Year 2002. The average annual discharges were in the top 15% of stream flow for much of the state and exceeded the top 5% for the Wild Rice and the Red Lake River watersheds. Flows in the Roseau River watershed fell to just below the 5% range. The upper Mississippi River ended in the lower 25% range, while flows in the Arrowhead barely managed to reach into the normal range.

Figure 4



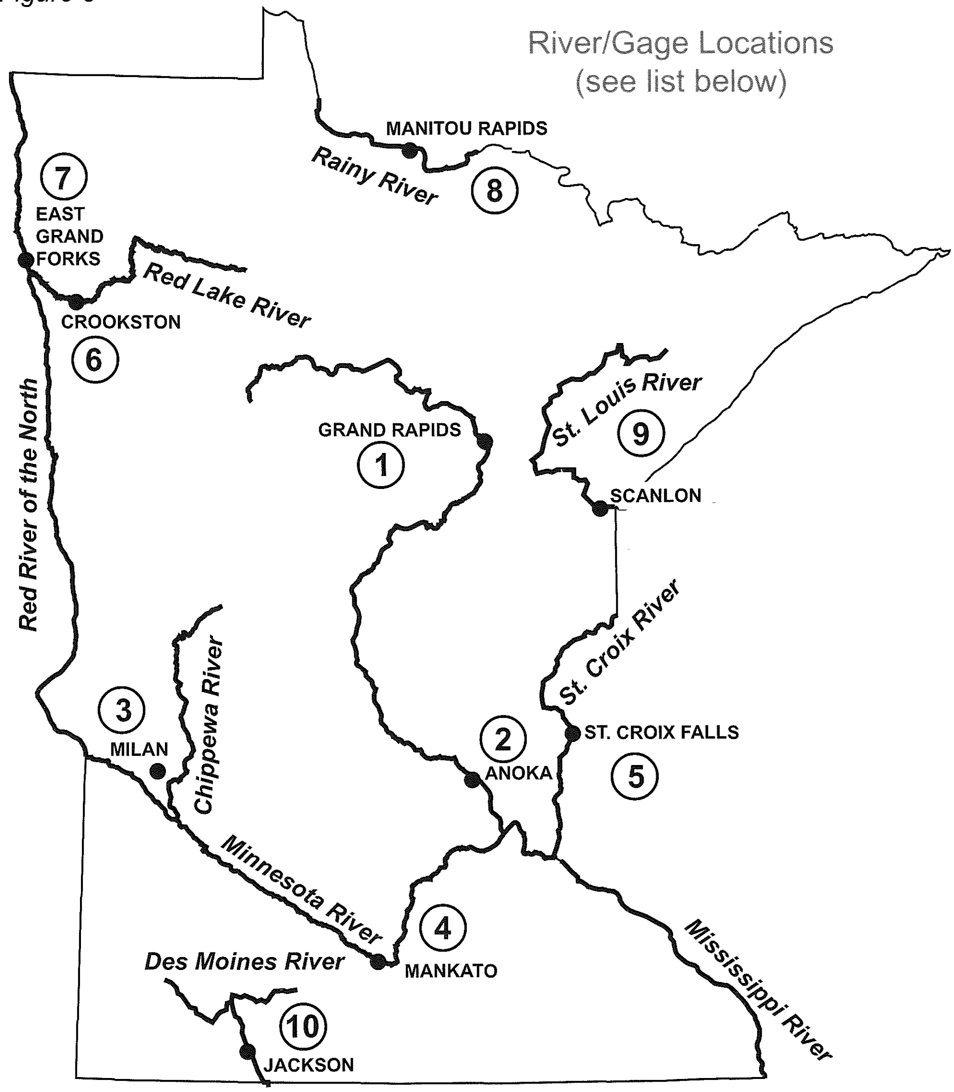
Hydrographs

Stream hydrographs show the volume of water discharged during a specific time period. Figure 5 shows the location of ten rivers and stream gaging stations where discharge hydrographs have been created.

Figures 6 and 8 show two-year hydrographs for the ten selected sites. In addition to the mean daily discharge, the daily Q25 and Q75 exceedence levels are shown.

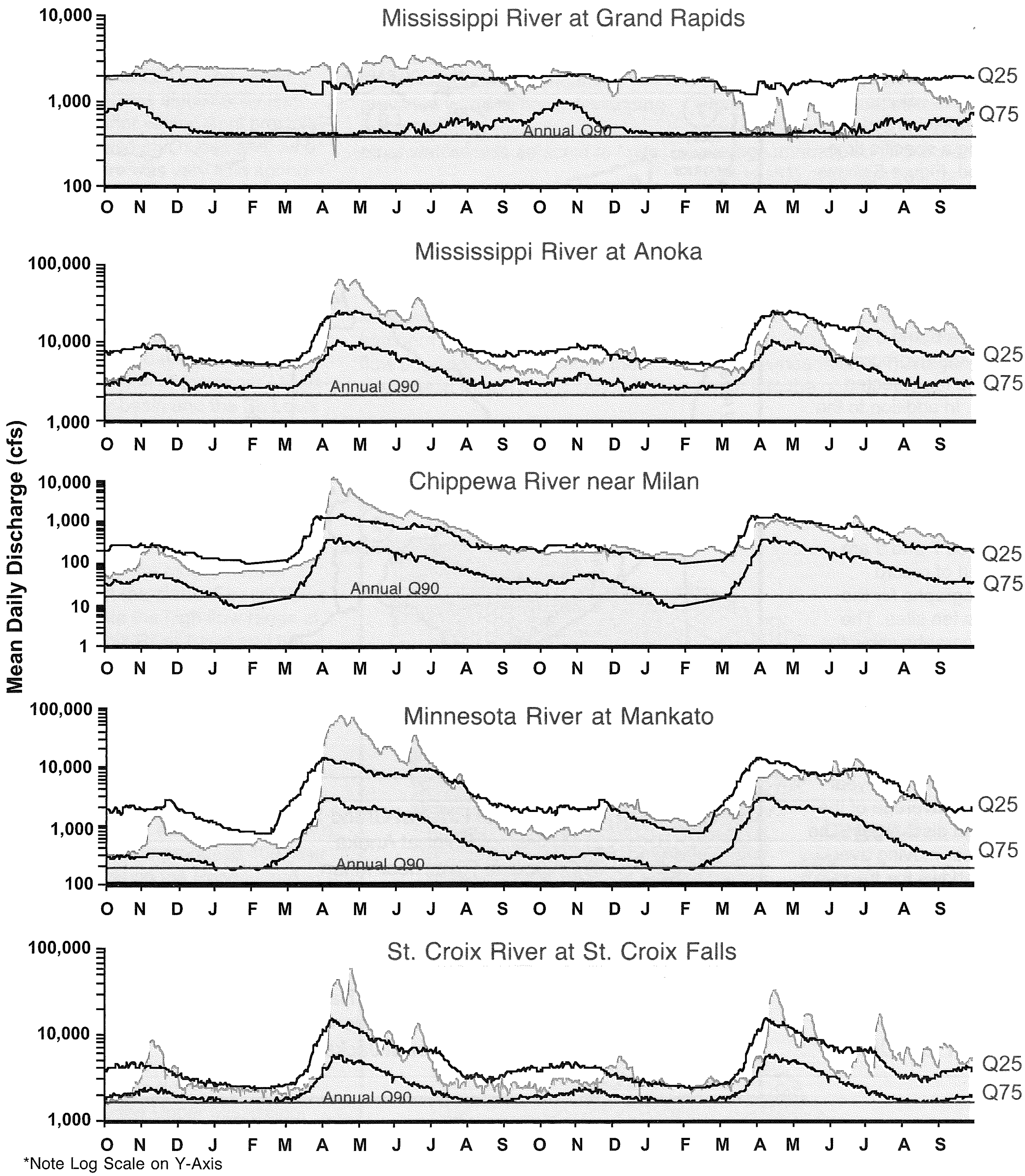
Figures 7 and 9 are period of record hydrographs for the same ten sites. The hydrographs show the average annual volume of water discharged during the water year, the annual Q25 and Q75 exceedence values and a 30-year moving average of the annual discharges. The 30-year moving average shows the trend in the volume of water flowing in a stream.

Figure 5



1) Mississippi River at Grand Rapids
2) Miisissippi 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

Figure 6



October 1, 2000 to September 30, 2002

Figure 7

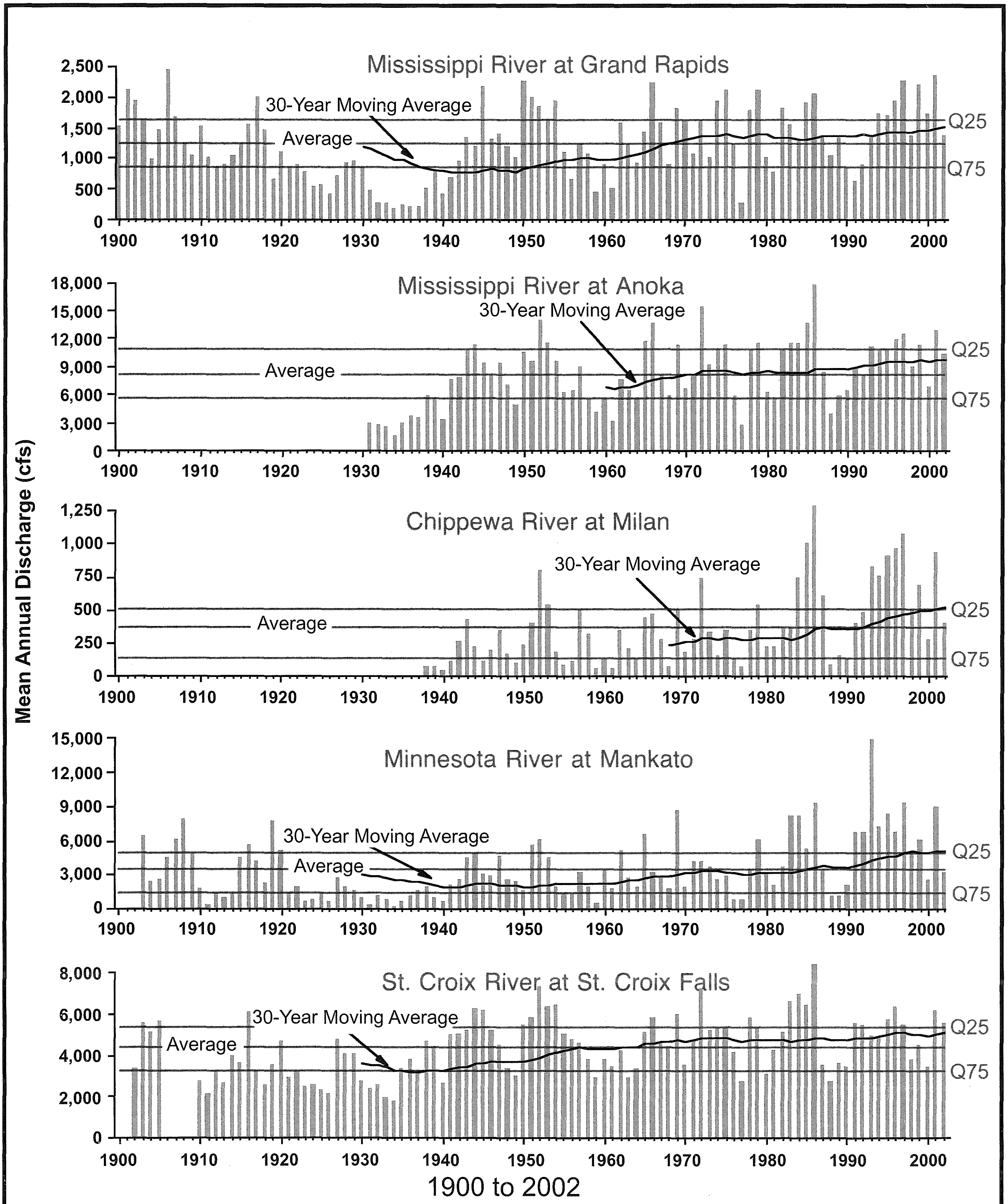
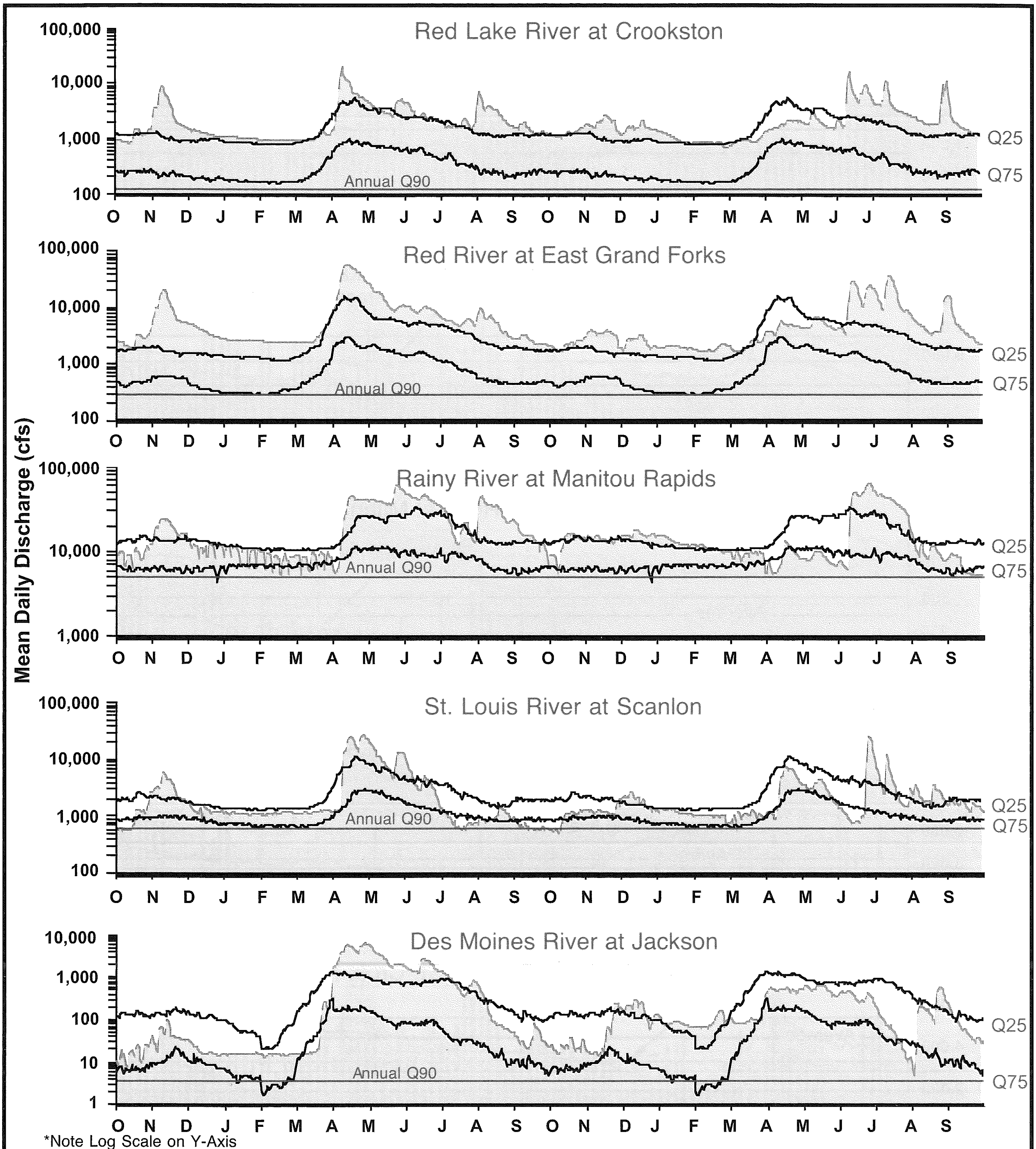
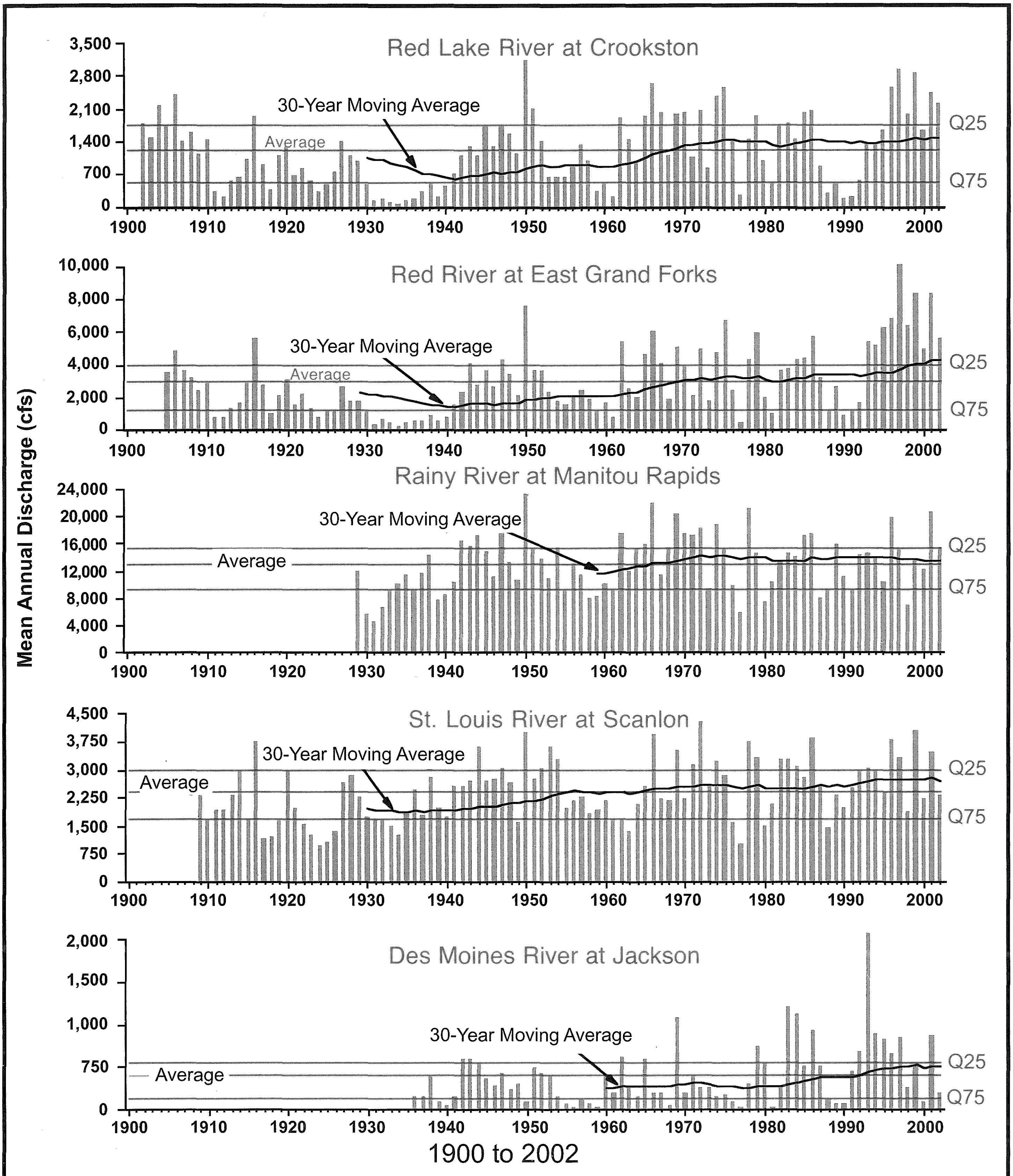

Mississippi River at Grand Rapids
30-Year Moving Average
Average
Q25
Q75
Mississippi River at Anoka
30-Year Moving Average
Average
Q25
Q75
Chippewa River at Milan
30-Year Moving Average
Average
Q25
Q75
Minnesota River at Mankato
30-Year Moving Average
Average
Q25
Q75
St. Croix River at St. Croix Falls
30-Year Moving Average
Average
Q25
Q75
Mean Annual Discharge (cfs)
1900 to 2002

Figure 8



October 1, 2000 to September 30, 2002

Figure 9


Mean Annual Discharge (cfs)
Red Lake River at Crookston
30-Year Moving Average
Average
Q25
Q75
Red River at East Grand Forks
30-Year Moving Average
Average
Q25
Q75
Rainy River at Manitou Rapids
30-Year Moving Average
Average
Q25
Q75
St. Louis River at Scanlon
30-Year Moving Average
Average
Q25
Q75
Des Moines River at Jackson
30-Year Moving Average
Average
Q25
Q75
1900 to 2002

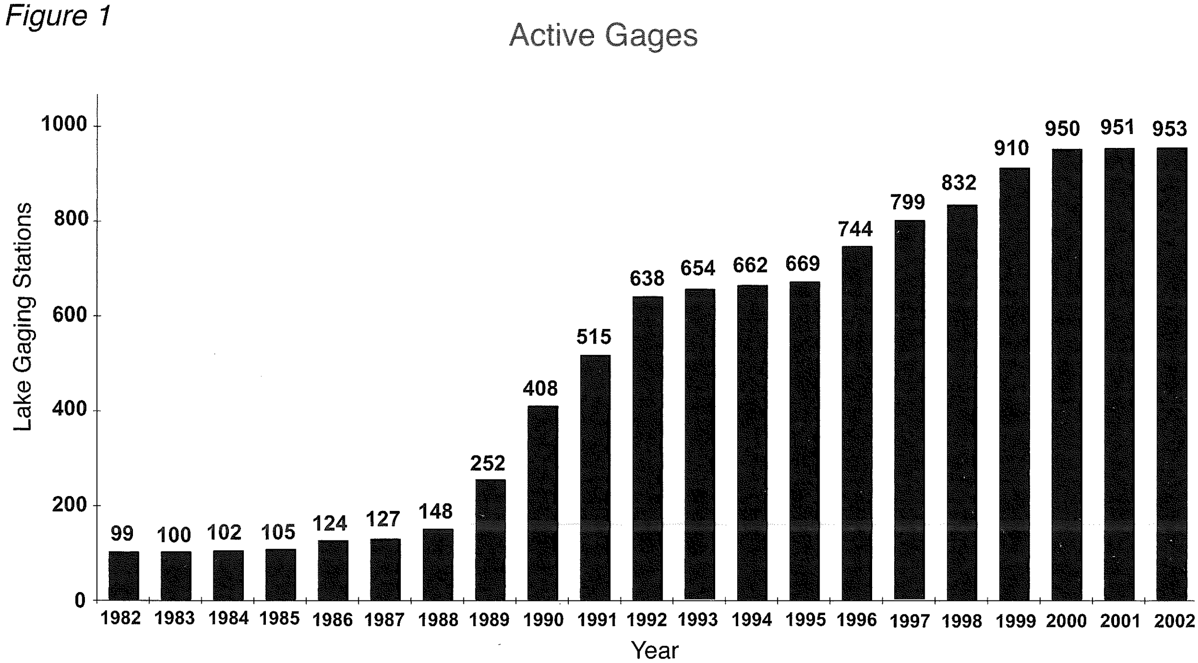
Lake Levels

The water levels of all lakes fluctuate, some more than others. The primary factor that affects water level changes is the quantity and distribution of precipitation (rain & snow). Other factors that contribute to water level changes are outlet conditions, beaver dams, ground water movement and watershed characteristics. Knowing and understanding the history of water level fluctuations can help lake users deal with problems associated with the changing levels.

Historical water level data are useful in calibrating hydrologic and hydraulic computer models. These data also benefit watershed management authorities and other governmental units in preparing local water management plans and to locate building and sewage treatment sites.

The success of monitoring water levels is greatly dependent on citizen volunteers and cooperating organizations who participate in the DNR Waters Lake Level Minnesota (LLM) program. Lake levels were actively monitored at nearly 1000 sites in 2002 by citizen volunteers and cooperative organizations (Figure 1). Volunteer observers usually live on or near a lake, which makes it convenient to obtain weekly or more frequent readings. There is no cost to the volunteers to be in this program as the gage and installation are provided by DNR Waters. Each year the volunteer receives an updated water level graph and summary sheet that contains the information they provided.

Figure 1



Lake level monitoring has also been accomplished in cooperation with various public and private organizations including:

- Federal (USGS, COE, NRCS)
- State (DNR)
- Counties
- Cities
- Soil & Water Conservation Districts
- Watershed Districts
- Consulting Land Surveyors and Engineers
- Power and Mining Companies

In order to improve geographic coverage, pull together all available data and eliminate possible duplication of efforts, DNR Waters has initiated cooperative programs with these organizations. This component of LLM accounts for approximately 300 lakes, up slightly from Water Year 2000.

All lake level readings received are entered into Lakes-DB©, a database program for easy management and access of recorded lake levels and other useful information. This information is now available on the internet (see "Lake Finder" sidebar on next page).

Lake Level Trends

In the fall of 2000, many lakes in the state were at moderately low water levels. Others were at their all-time recorded low water levels, including many in central Minnesota (see page 31).

However, spring 2001 precipitation events raised many lakes above their all-time recorded high levels. For example, Lake Belle Taine in Hubbard County attained its highest level in 67 years of lake level readings. But as quickly as lake levels recovered in spring, a very dry period, extending nearly statewide from summer through fall, caused many of these same lakes to recede to average or below average water levels at years end.

During the summer of 2002, many lakes again rose to near or above all-time recorded high water levels in response to several significant precipitation events. White Bear Lake and Mille Lacs Lake experienced very high water level conditions, with Lake Minnetonka registering its highest ever water level in 96 years of monitoring. The 2002 storm events were more isolated than during the spring of 2001, with the central and east central portion of Minnesota receiving the highest rainfall amounts. Concurrently, the northeast and southwest remained relatively dry and corresponding lake levels in those areas reflected the lack of precipitation.

Lake Level Data on the DNR Website

Storing and Retrieving Data

Lake level readings received from volunteers and organizations are entered into Lakes-DB©, a data base program for easy management and access of recorded lake levels and other useful information.

"Lake Finder" is a feature of both the DNR website (www.dnr.state.mn.us) and the DNR Waters website (www.dnr.state.mn.us/waters). Lake Finder provides access to DNR Fisheries lake surveys and lake maps, Pollution Control Agency water quality and clarity data and the Health Department fish consumption advisory.

In 2000, DNR Waters added a new option titled "lake water levels". A single click on the checkmark below "lake water levels" will display a concise summary of recorded lake levels for the indicated period of record, a lake level graph for the last ten years (if enough data points are available), the ordinary high water (OHW) elevation, datum adjustment and reference benchmark (see Figure 3).

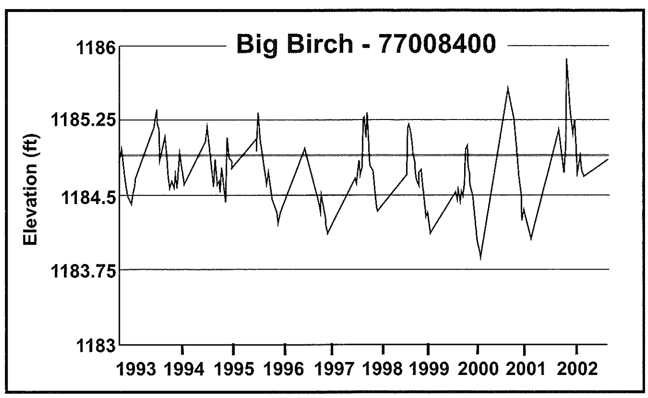
Most of the recorded water levels for each lake are collected by volunteers involved with the Lake Level Minnesota program. DNR Waters presently has water level information for approximately 3300 lakes.

Lake Name: Big Birch Lake

County: Todd/Stearns

Water Level Data

Period of record: 08/13/1937 to 11/04/2002
\# of readings: 1188
Highest recorded: 1185.87 ft (07/12/2002)
Highest known: 1185.87 ft (07/12/02)
Lowest recorded: 1182.64 ft (07/19/1988)
Recorded range: 3.23 ft
Average Water Level: 1184.64 ft
Last reading: 1184.69 ft (11/04/2002)
OHW elevation: 1184.9 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.)

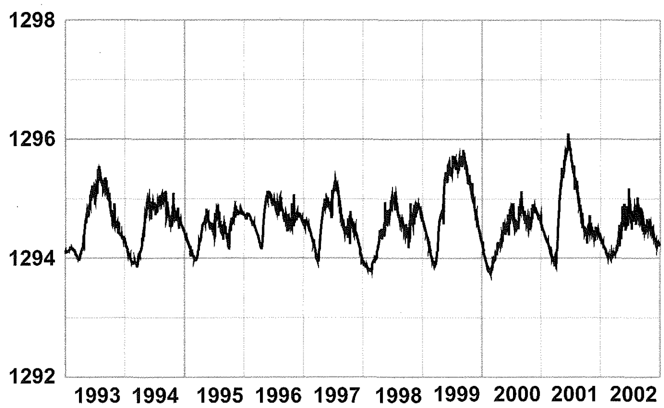
Benchmarks

Elevation: 1189.96 ft **Date Set:** 01/03/1990
Datum: 1929 ft

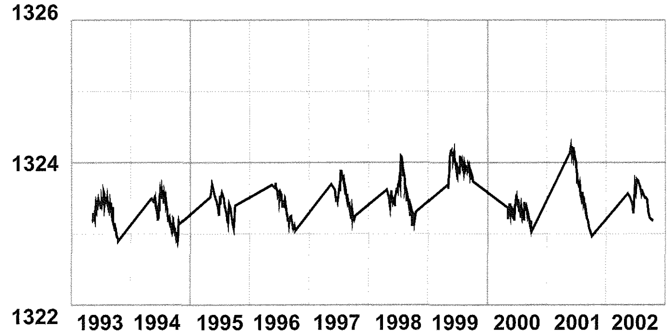
Benchmark Location
Township: 127 Range: 32 Section: 17

Description: A 3/8"x8" vert.spk. in the E-NE root of a 4.5' cottonwood, 87' west of an inlet culvert and 36' south of centerline of road at west fenceline.

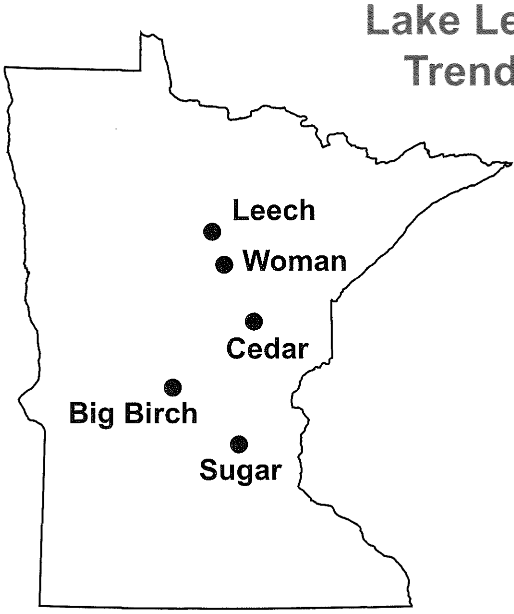
Leech Lake (11-203) Cass County



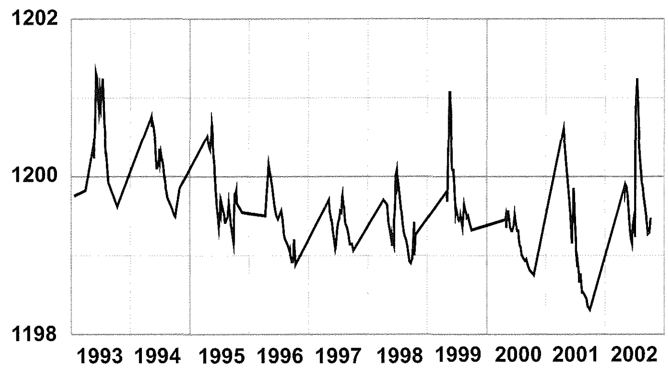
Woman Lake (11-201) Cass County



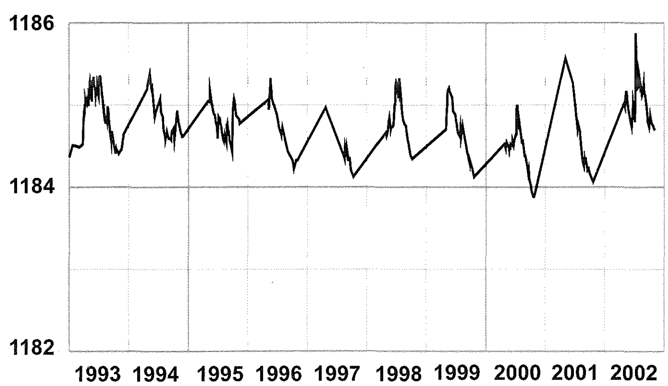
Lake Level Trends



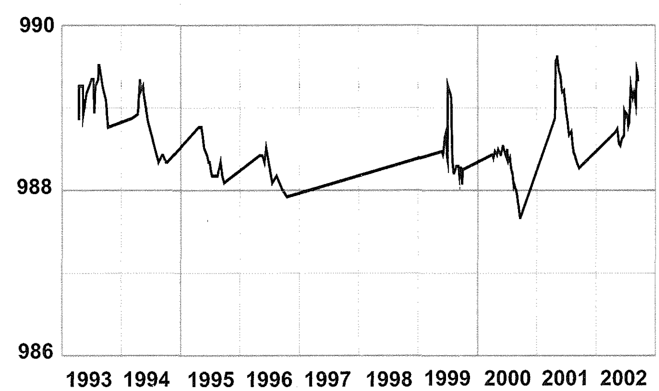
Cedar Lake (1-209) Aitkin County



Big Birch Lake (77-84) Todd County



Sugar Lake (86-233) Wright County



Landlocked Basins

A landlocked lake has no regularly-functioning surface outlet channel, a small watershed and typically experiences large, long-term water level fluctuations. The importance of ground water contributions to landlocked lakes can make them a good indicator of local ground water levels and movement.

The graphs on page 33 represent water levels for five landlocked basins that have experienced their highest levels in recent years.

Ten-Year Trends

For many lakes that are presently monitored, reliable information has been collected for more than ten years. A ten-year average is used as a reference mark when comparing water year data to a longer-term average, and is useful in locating trends in a particular basin. Lakes graphed on pages 34 and 35 show above average levels in Water Year 2001 in response to above average precipitation (see Figure 7 on page 7). With sharp geographical differences in precipitation in Water Year 2002 (see Figure 15 on page 14), lakes in the center of the state continued to be above their ten-year average while lakes in northeast and southwest Minnesota were below average.

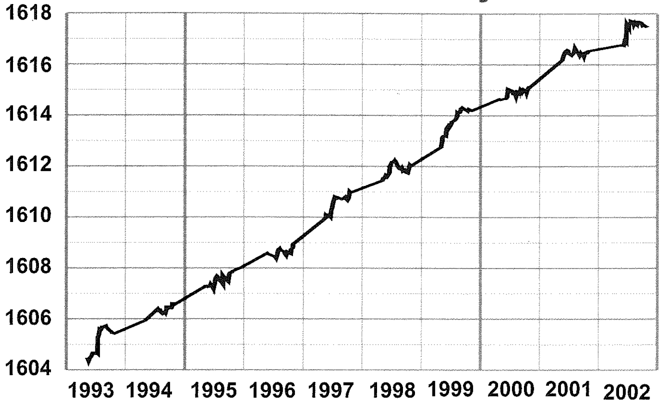
Annual Lake Level Fluctuation

Minnesota lakes typically fluctuate one to two vertical feet in a given year, but historical fluctuations have been recorded in excess of ten feet. Statewide average fluctuation for Water Year 2001 was 1.97 feet, which corresponds to the above-normal precipitation received during the year. Average fluctuation during Water Year 2002 was 1.33 feet (averages for the past eight years are shown in Figure 2). The tables on pages 36 to 42 display fluctuations for Water Year 2001, Water Year 2002, an average fluctuation for the indicated period of record and the range between the historical high and low.

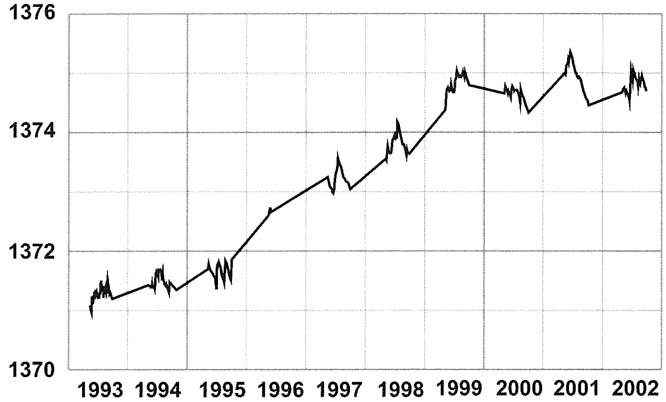
Figure 2

Water Year	Average Fluctuation Statewide (ft)
1995	1.03
1996	1.24
1997	1.55
1998	1.04
1999	1.24
2000	1.05
2001	1.97
2002	1.33

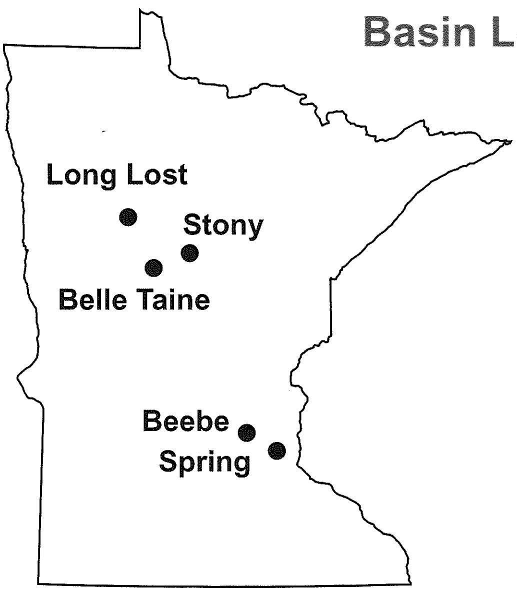
Long Lost Lake (15-68) Clearwater County



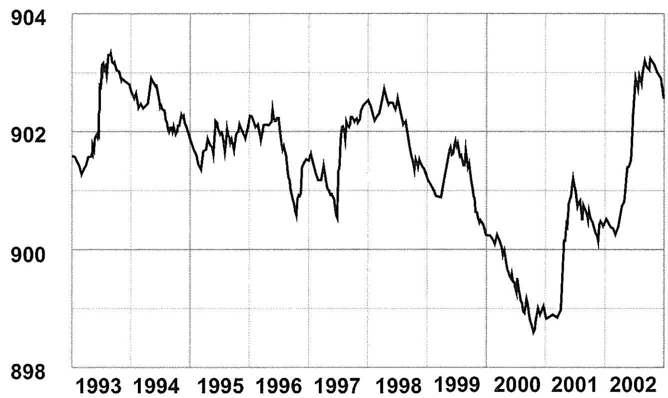
Stony Lake (11-371) Cass County



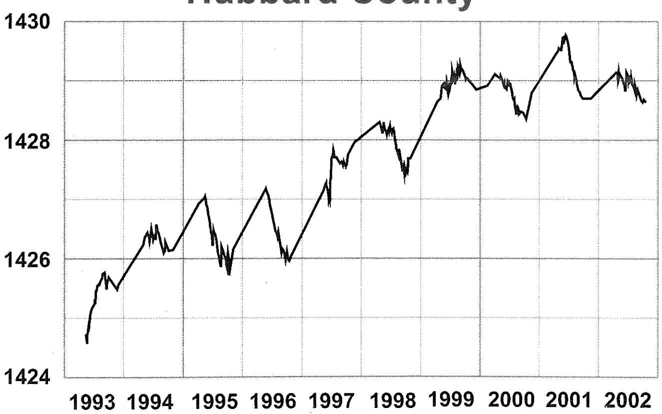
Landlocked Basin Levels



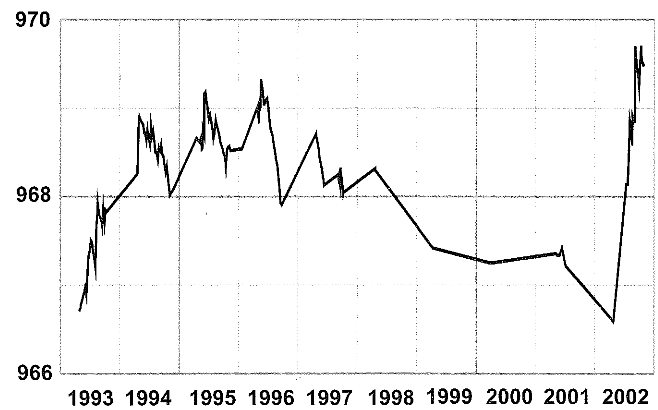
Spring Lake (2-71) Anoka County



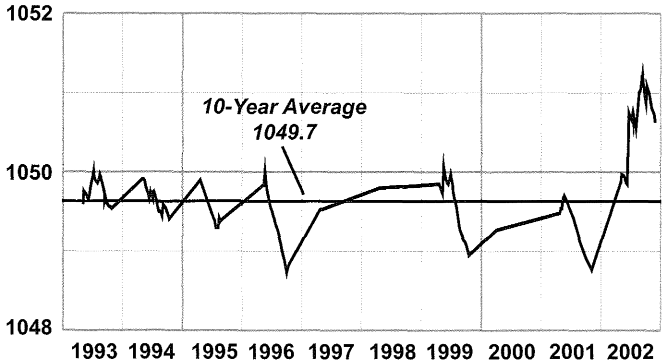
Belle Taine Lake (29-146) Hubbard County



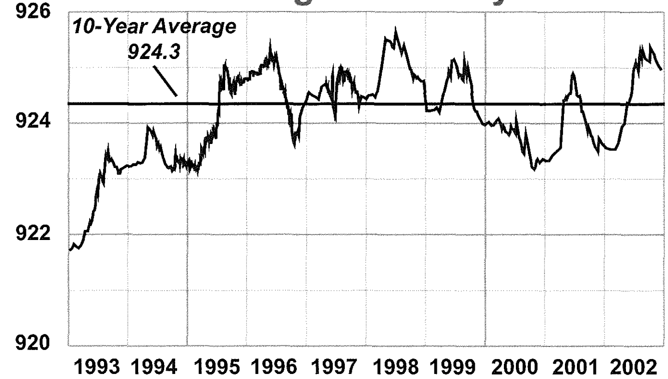
Beebe Lake (86-23) Wright County



Sylvia Lake (86-289) Wright County

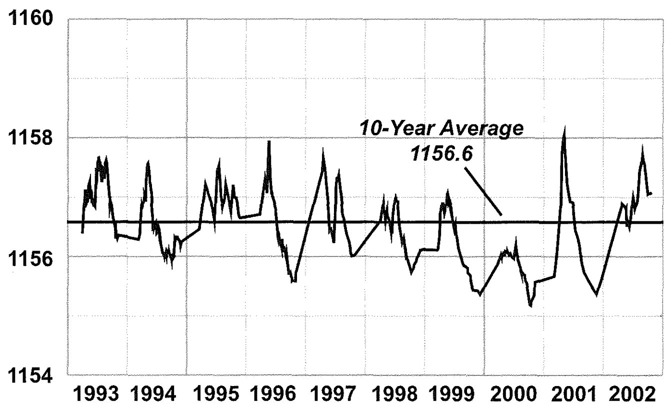


White Bear Lake (82-167) Washington County

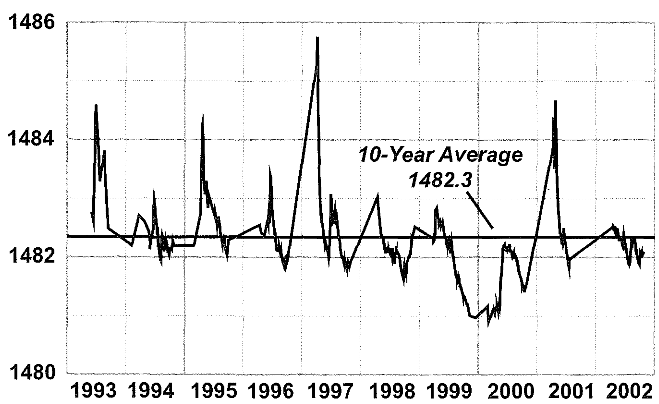


Ten-Year Trends

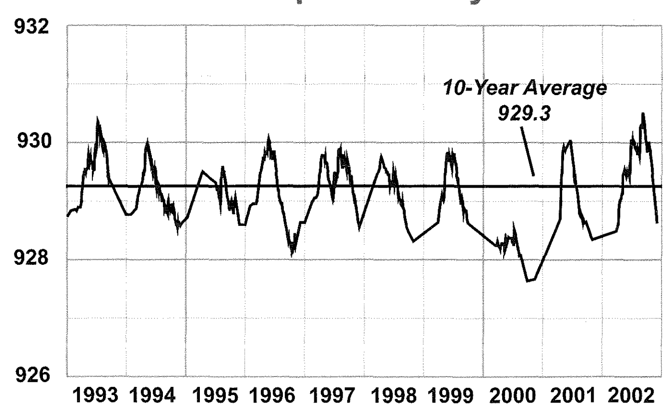
Green Lake (34-79) Kandiyohi County



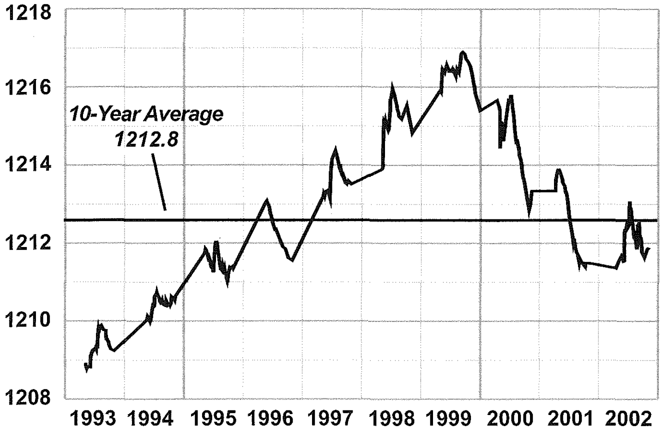
Shetek Lake (51-46) Murray County



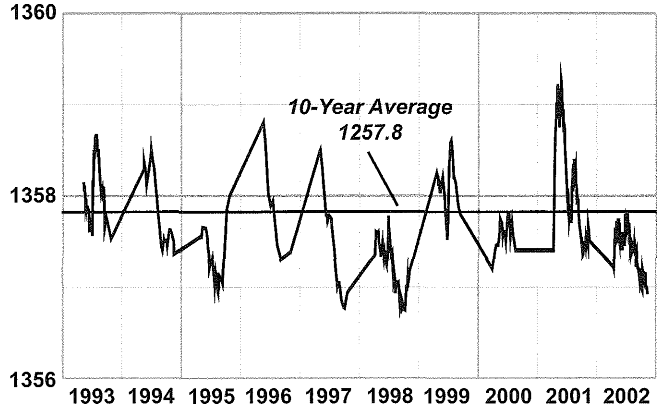
Lake Minnetonka (27-133) Hennepin County



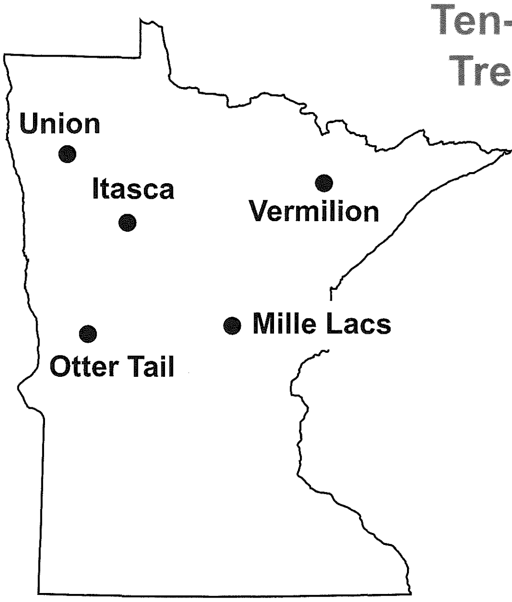
Union Lake (60-217) Polk County



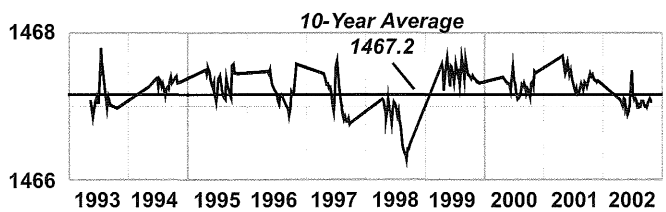
Vermilion Lake (69-378) St. Louis County



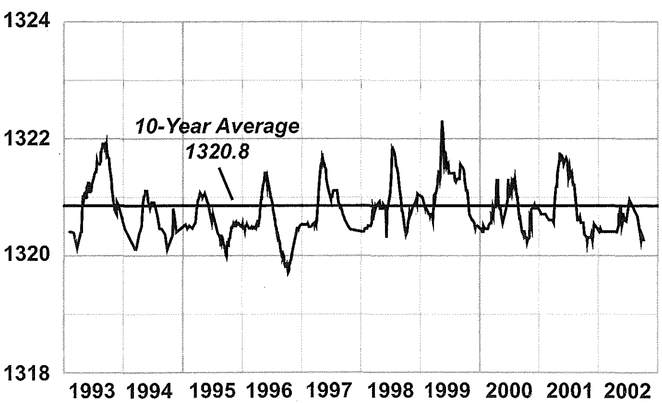
Ten-Year Trends



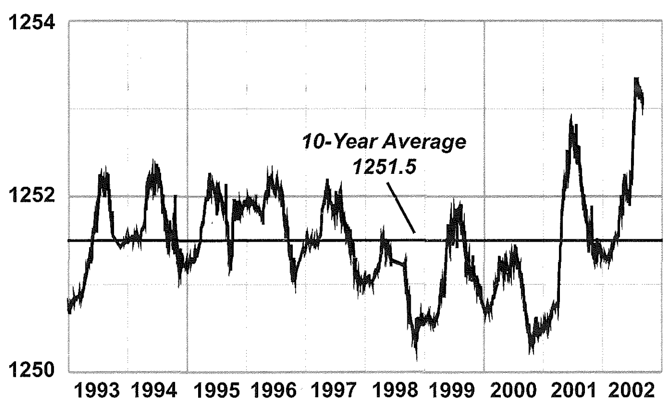
Lake Itasca (15-16) Clearwater County



Otter Tail Lake (56-242) Otter Tail County



Mille Lacs Lake (48-2) Mille Lacs County



Annual Lake Level Fluctuation (feet)

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
AITKIN COUNTY					
Big Sandy (1-62)	7.40	2.49	5.31	(104 yrs.)	16.83
Blackface (1-45)	0.99	0.53	0.75	(11 yrs.)	1.25
Cedar (1-209)	2.29	2.09	1.65	(51 yrs.)	4.02
Clear (1-93)	1.67	0.69	0.87	(32 yrs.)	4.39
Dam (1-96)	1.95	1.45	1.28	(19 yrs.)	2.66
Elm Island (1-123)	2.76	2.84	1.65	(9 yrs.)	3.57
Farm Island (1-159)	2.34	1.88	1.10	(25 yrs.)	3.64
Fleming (1-105)	1.66	0.94	0.84	(11 yrs.)	1.93
Gun (1-99)	1.53	0.55	0.74	(13 yrs.)	1.71
Hanging Kettle (1-170)	1.58	2.43	1.53	(17 yrs.)	3.75
Horseshoe (1-34)	1.48	0.84	0.82	(8 yrs.)	1.48
Little Pine (1-176)	0.88	1.13	0.95	(37 yrs.)	3.67
Lone (1-125)	1.64	0.75	0.73	(12 yrs.)	4.65
Long (1-101)	0.74	0.66	0.55	(10 yrs.)	1.40
Minnewawa (1-33)	1.35	0.75	0.85	(20 yrs.)	1.82
Rabbit (1-91)	1.40	0.99	0.95	(11 yrs.)	1.72
Rat (1-77)	0.75	1.36	1.08	(10 yrs.)	3.99
Rock (1-72)	1.44	0.68	0.83	(9 yrs.)	2.05
Round (1-23)	1.06	0.42	0.66	(10 yrs.)	1.43
Round (1-204)	1.04	1.04	0.96	(12 yrs.)	2.41
Spirit (1-178)	0.59	0.58	0.53	(22 yrs.)	3.03
Sugar (1-87)	0.99	0.42	0.73	(32 yrs.)	2.65
Waukenabo (1-136)	1.73	1.92	1.40	(21 yrs.)	4.34
Wilkins (1-102)	2.23	1.03	1.00	(6 yrs.)	2.51
ANOKA COUNTY					
Baldwin (2-13)	6.06	4.20	3.13	(28 yrs.)	6.86
Bunker (2-90)	4.01	2.64	1.88	(17 yrs.)	7.87
Coon (2-42)	2.33	1.28	1.12	(34 yrs.)	4.84
Crooked (2-84)	2.25	0.46	0.99	(18 yrs.)	3.40
Fawn (2-35)	1.24	1.66	1.06	(14 yrs.)	4.64
George (2-91)	1.02	0.98	1.23	(17 yrs.)	6.14
Golden (2-45)	1.06	0.93	0.88	(14 yrs.)	2.44
Ham (2-53)	3.75	1.69	1.26	(18 yrs.)	4.78
Howard (2-16)	1.64	1.30	1.03	(13 yrs.)	2.46
Itasca (2-110)	3.79	1.42	1.73	(13 yrs.)	8.25
Laddie (2-72)	2.84	0.91	1.18	(11 yrs.)	4.19
Linwood (2-26)	1.08	0.50	0.73	(26 yrs.)	2.29
Martin (2-34)	2.28	1.38	1.20	(24 yrs.)	4.08
Moore (2-75)	1.08	1.28	0.97	(14 yrs.)	1.98
Netta (2-52)	3.31	2.04	1.27	(19 yrs.)	5.56
Otter (2-3)	2.02	1.73	1.63	(80 yrs.)	6.72
Pet (2-36)	2.03	1.72	1.22	(7 yrs.)	3.41
Reshanau (2-9)	3.75	1.61	2.00	(13 yrs.)	4.54
Rice (2-8)	6.06	4.20	3.37	(14 yrs.)	6.64
Rogers (2-104)	3.62	1.71	1.61	(14 yrs.)	5.35
Rondeau (2-15)	1.86	1.34	1.00	(11 yrs.)	1.94
Round (2-89)	2.07	1.16	1.26	(18 yrs.)	5.93
Sand Shore (2-102)	2.03	1.21	1.04	(11 yrs.)	2.32
Sandy (2-80)	2.20	2.40	1.53	(11 yrs.)	2.98
Spring (2-71)	2.60	3.05	1.64	(48 yrs.)	6.60
BECKER COUNTY					
Bad Medicine (3-85)	1.06	0.77	0.90	(16 yrs.)	6.99
Big Cormorant (3-576)	1.02	0.64	1.08	(37 yrs.)	10.30
Big Sugar Bush (3-304)	0.70	0.70	1.02	(8 yrs.)	4.76
Buffalo (3-350)	0.54	0.26	1.09	(21 yrs.)	5.12
Cotton (3-286)	1.09	0.72	0.98	(36 yrs.)	5.15
Detroit (3-381)	0.90	0.60	0.94	(24 yrs.)	2.44
Elbow (3-159)	0.73	0.98	1.16	(11 yrs.)	3.42
Eunice (3-503)	0.54	0.64	0.58	(12 yrs.)	1.87
Floyd (3-387)	1.16	0.77	1.09	(11 yrs.)	2.89

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
(Becker County continued)					
Fox (3-358)	0.49	0.59	0.33	(9 yrs.)	0.79
Height of Land (3-195)	1.88	1.14	1.52	(45 yrs.)	4.45
Ice Cracking (3-156)	0.90	1.01	1.09	(13 yrs.)	4.64
Ida (3-582)	0.90	0.78	0.96	(15 yrs.)	4.50
Island (3-153)	0.75	0.44	0.58	(7 yrs.)	1.05
Juggler (3-136)	0.74	0.90	0.79	(10 yrs.)	5.62
Little Toad (3-189)	0.40	0.64	0.65	(9 yrs.)	1.81
Long (3-383)	0.24	0.30	0.50	(16 yrs.)	1.64
Maud (3-500)	0.90	0.96	0.77	(11 yrs.)	1.86
Melissa (3-475)	1.30	0.40	1.07	(27 yrs.)	6.30
Middle Cormorant (3-602)	1.04	0.90	0.74	(7 yrs.)	4.27
Pickerel (3-287)	0.84	0.91	0.98	(11 yrs.)	5.83
Rock (3-293)	1.40	0.66	1.21	(8 yrs.)	2.15
Round (3-155)	2.48	0.97	1.24	(20 yrs.)	2.97
Straight (3-10)	0.25	0.47	0.50	(17 yrs.)	6.16
Talac (3-619)	1.26	1.10	1.27	(10 yrs.)	9.72
Toad (3-107)	1.62	0.65	1.20	(22 yrs.)	5.20
Turtle (3-657)	1.70	0.70	1.37	(6 yrs.)	6.53
Two Inlets (3-17)	0.72	1.50	1.22	(21 yrs.)	3.91
Upper Cormorant (3-588)	1.01	0.89	1.05	(27 yrs.)	3.89
BELTRAMI COUNTY					
Bemidji (4-130)	2.54	2.58	1.86	(19 yrs.)	4.25
Cass (4-30)	2.85	1.70	1.93	(56 yrs.)	4.83
Long (4-76)	0.72	0.55	0.74	(16 yrs.)	2.85
Movil (4-152)	0.94	0.68	0.76	(18 yrs.)	1.91
Pimushe (4-32)	2.63	0.84	1.83	(6 yrs.)	3.22
Red (4-35)	2.21	0.85	1.62	(57 yrs.)	6.93
Stump (4-130)	3.03	1.84	2.26	(19 yrs.)	5.70
Turtle (4-159)	0.92	0.34	0.95	(6 yrs.)	1.90
Turtle River (4-111)	1.58	1.32	1.80	(30 yrs.)	6.15
BENTON COUNTY					
Little Rock (5-13)	3.73	1.88	1.12	(9 yrs.)	4.79
BIG STONE COUNTY					
Big Stone (6-152)	5.75	1.70	2.45	(33 yrs.)	10.83
East Toqua (6-138)	1.46	0.87	1.50	(12 yrs.)	4.90
BLUE EARTH COUNTY					
Duck (7-53)	1.86	1.52	1.18	(12 yrs.)	3.21
Madison (7-44)	2.30	1.46	1.68	(45 yrs.)	15.98
BROWN COUNTY					
Hanska (8-26)	4.74	2.14	2.10	(10 yrs.)	5.79
Sleepy Eye (8-45)	1.62	0.90	1.46	(15 yrs.)	5.54
Somsen (8-18)	6.96	2.72	3.38	(12 yrs.)	8.93
CARLTON COUNTY					
Big (9-32)	1.50	0.41	0.66	(10 yrs.)	1.99
Chub (9-8)	1.21	0.46	0.95	(16 yrs.)	3.47
Eagle (9-57)	0.66	0.54	0.75	(10 yrs.)	1.88
Eddy (9-39)	4.49	2.92	2.83	(9 yrs.)	4.55
Little Hanging Horn (9-35)	1.66	2.02	2.14	(12 yrs.)	3.53
Park (9-29)	1.02	1.03	0.75	(12 yrs.)	2.02
Torch Light (9-25)	1.43	0.52	0.94	(10 yrs.)	1.92
CARVER COUNTY					
Ann (10-12)	1.64	0.24	1.26	(32 yrs.)	5.13
Berliner (10-103)	1.75	2.79	1.37	(12 yrs.)	3.95
Hydes (10-88)	2.17	1.33	0.98	(9 yrs.)	4.31
Lotus (10-6)	2.10	1.59	1.36	(32 yrs.)	3.90

Annual Lake Level Fluctuation (feet)

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
(Carver County continued)					
Lucy (10-7)	2.24	0.45	1.28	(32 yrs.)	4.00
Minnewashta (10-9)	2.14	1.06	1.34	(17 yrs.)	3.46
Oak (10-93)	2.09	2.66	1.41	(8 yrs.)	3.85
Parley (10-42)	1.62	2.25	1.55	(19 yrs.)	4.87
Patterson (10-86)	2.20	1.75	1.34	(13 yrs.)	3.40
Rice Marsh (10-1)	2.27	0.99	1.46	(23 yrs.)	4.81
Riley (10-2)	1.91	1.50	1.45	(32 yrs.)	4.74
Susan (10-13)	2.49	0.95	1.35	(32 yrs.)	3.76
Swede (10-95)	1.74	1.42	1.20	(7 yrs.)	6.06
Waconia (10-59)	2.50	1.94	1.19	(34 yrs.)	5.90
Zumbra-Sunny (10-41)	1.60	1.84	1.98	(18 yrs.)	7.28
CASS COUNTY					
Ada (11-250)	1.22	1.04	0.83	(13 yrs.)	2.36
Agate (11-216)	1.41	1.04	0.77	(12 yrs.)	3.62
Barnum (11-281)	0.84	0.44	0.68	(9 yrs.)	2.12
Bass (11-69)	0.60	0.36	0.70	(7 yrs.)	1.82
Big Rice (11-73)	4.33	1.80	2.22	(35 yrs.)	5.00
Birch (11-412)	1.46	0.72	0.94	(12 yrs.)	2.18
Blackwater (11-274)	0.36	0.37	0.52	(8 yrs.)	3.93
Child (11-263)	1.37	1.03	0.96	(13 yrs.)	1.98
Five Point (11-351)	0.18	0.28	0.34	(9 yrs.)	1.09
Gull (11-305)	1.42	1.27	1.10	(21 yrs.)	1.99
Hand (11-242)	1.90	0.60	0.85	(19 yrs.)	4.90
Hay (11-199)	0.91	0.60	0.86	(12 yrs.)	3.32
Horseshoe (11-358)	0.60	0.42	0.53	(12 yrs.)	3.09
Laura (11-104)	1.00	0.70	0.74	(17 yrs.)	1.85
Leech (11-203)	2.21	1.18	1.41	(38 yrs.)	3.40
Little Boy (11-167)	1.54	0.92	1.12	(10 yrs.)	2.50
Long (11-142)	1.30	0.32	0.94	(12 yrs.)	5.16
Lower Trelipe (11-129)	0.96	0.63	1.08	(23 yrs.)	4.63
Mud (11-100)	3.80	2.60	2.65	(28 yrs.)	6.70
Norway (11-307)	0.76	0.38	0.50	(6 yrs.)	0.94
Paquet (11-381)	0.95	0.80	1.04	(10 yrs.)	2.32
Pleasant (11-383)	0.95	0.49	0.74	(6 yrs.)	2.65
Portage (11-476)	1.36	0.40	0.95	(12 yrs.)	4.62
Stony (11-371)	0.82	0.60	0.58	(11 yrs.)	4.43
Sylvan (11-304)	1.28	0.81	0.86	(21 yrs.)	3.21
Ten Mile (11-413)	1.01	0.59	0.78	(28 yrs.)	2.74
Vermillion (11-29)	1.63	2.06	1.95	(9 yrs.)	5.25
Winnibigoshish (11-147)	3.20	1.74	2.02	(43 yrs.)	3.90
Woman (11-201)	1.20	0.80	0.86	(13 yrs.)	1.77
CHISAGO COUNTY					
Comfort (13-53)	1.94	1.49	1.18	(29 yrs.)	3.52
Ellen (13-47)	1.34	1.44	0.89	(6 yrs.)	2.02
Goose (13-83)	3.00	2.35	1.70	(15 yrs.)	3.47
Green (13-41)	0.92	1.61	1.07	(25 yrs.)	9.10
Kroon (13-13)	1.80	1.08	1.08	(7 yrs.)	2.63
North Center (13-32)	3.30	2.10	1.66	(30 yrs.)	7.26
North Lindstrom (13-35)	3.44	1.93	1.77	(26 yrs.)	11.42
Rush (13-69)	2.52	1.23	1.42	(36 yrs.)	3.28
South Lindstrom (13-28)	3.73	1.96	1.64	(21 yrs.)	14.13
Sunrise (13-31)	1.87	0.90	1.02	(15 yrs.)	4.00
Wallmark (13-29)	1.56	1.29	0.89	(7 yrs.)	2.12
CLEARWATER COUNTY					
Itasca (15-16)	0.55	0.60	0.70	(35 yrs.)	2.21
Long Lost (15-68)	1.73	1.39	1.42	(11 yrs.)	13.37
Minerva (15-79)	1.47	1.50	1.00	(7 yrs.)	2.41

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
COOK COUNTY					
Clearwater (16-139)	1.31	0.70	1.08	(8 yrs.)	1.57
Flour (16-147)	0.86	0.47	0.64	(13 yrs.)	1.88
Saganaga (16-633)	3.21	1.19	1.86	(12 yrs.)	5.26
Sea Gull (16-629)	3.98	1.70	1.92	(11 yrs.)	4.92
COTTONWOOD COUNTY					
Cottonwood (17-22)	6.65	1.06	2.20	(15 yrs.)	9.90
Mountain (17-3)	1.18	0.46	1.53	(19 yrs.)	5.00
CROW WING COUNTY					
Bass (18-256)	0.87	0.42	0.67	(14 yrs.)	3.21
Bonnie (18-259)	0.90	0.36	0.65	(13 yrs.)	3.10
Clark (18-374)	0.92	0.53	0.81	(14 yrs.)	1.73
Crooked (18-41)	1.68	0.98	0.86	(13 yrs.)	2.39
Crow Wing (18-155)	2.04	0.70	1.42	(11 yrs.)	3.85
East Fox (18-298)	0.53	0.55	0.58	(22 yrs.)	2.32
East Twin (18-407)	0.99	1.20	0.70	(12 yrs.)	2.57
Edward (18-305)	1.29	0.40	0.89	(35 yrs.)	7.18
Garden (18-329)	0.76	0.50	0.50	(14 yrs.)	1.29
Gilbert (18-320)	1.74	1.20	1.18	(13 yrs.)	4.71
Gladstone (18-338)	0.63	0.54	0.64	(14 yrs.)	1.21
Goodrich (18-226)	0.75	0.47	0.54	(10 yrs.)	1.30
Hamlet (18-70)	1.59	1.25	1.05	(39 yrs.)	6.70
Hartley (18-392)	0.97	0.80	0.71	(14 yrs.)	3.28
Horseshoe (18-251)	0.89	0.52	0.70	(14 yrs.)	2.49
Hubert (18-375)	1.61	0.64	0.98	(22 yrs.)	3.56
Island (18-183)	1.74	2.04	1.52	(14 yrs.)	2.98
Little Hubert (18-340)	0.94	0.81	0.95	(14 yrs.)	3.29
Little Pelican (18-351)	1.08	0.40	0.69	(14 yrs.)	**.**
Lougee (18-342)	1.27	0.36	0.74	(14 yrs.)	2.40
Portage (18-50)	1.37	1.34	0.97	(12 yrs.)	3.11
Rabbit (18-93)	1.00	0.65	0.95	(45 yrs.)	3.24
Rogers (18-184)	1.25	0.68	0.83	(15 yrs.)	2.30
Ross (18-165)	1.60	1.32	1.42	(19 yrs.)	3.05
Ruth (18-212)	0.95	0.60	0.85	(36 yrs.)	6.31
Shaffer (18-348)	1.17	0.40	0.74	(15 yrs.)	2.84
Sorenson (18-323)	1.11	0.94	0.96	(14 yrs.)	3.17
South Long (18-136)	2.61	1.75	1.18	(37 yrs.)	3.24
Stevens (18-325)	1.30	0.46	0.86	(6 yrs.)	1.32
Upper South Long (18-96)	3.31	1.86	1.20	(33 yrs.)	4.13
West Twin (18-409)	1.06	0.46	0.64	(12 yrs.)	2.28
Whitefish (18-1)	2.31	1.56	1.30	(11 yrs.)	3.75
Young (18-252)	1.45	0.42	0.80	(14 yrs.)	2.48
DAKOTA COUNTY					
Marion (19-26)	2.70	2.22	2.11	(44 yrs.)	13.22
Orchard (19-31)	1.02	0.94	0.81	(11 yrs.)	1.51
Sunfish (19-50)	1.27	1.23	1.04	(12 yrs.)	3.42
Unnamed (Building A Lake) (19-190)	2.52	0.80	1.32	(12 yrs.)	3.62
Unnamed (Horse/Camel) (19-205)	3.77	2.62	1.79	(11 yrs.)	5.60
Unnamed (Main Lake) (19-203)	2.56	2.36	2.21	(11 yrs.)	3.70
Unnamed (Musk Ox Lake) (19-204)	2.87	1.00	1.13	(11 yrs.)	4.79
Unnamed (Musk Ox Marsh) (19-207)	2.00	1.38	1.30	(11 yrs.)	3.89
Unnamed (Reflection Pond) (19-199)	0.98	0.73	0.84	(12 yrs.)	2.88
Young (19-203)	1.48	0.92	2.06	(11 yrs.)	6.38

Annual Lake Level Fluctuation (feet)

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
DOUGLAS COUNTY					
Andrew (21-85)	1.88	0.40	0.98	(11 yrs.)	3.87
Burgen (21-49)	1.30	0.80	0.83	(10 yrs.)	3.23
Carlos (21-57)	1.18	0.54	0.98	(22 yrs.)	5.83
Chippewa (21-145)	2.08	0.92	1.23	(19 yrs.)	3.81
Devils (21-213)	1.80	0.70	1.02	(7 yrs.)	2.77
Geneva (21-52)	2.06	0.65	1.03	(9 yrs.)	2.39
Ida (21-123)	1.20	0.80	1.07	(20 yrs.)	7.94
Irene (21-76)	1.16	0.74	0.73	(13 yrs.)	1.54
Latoka (21-106)	1.10	0.48	0.60	(10 yrs.)	5.98
Le Homme Dieu (21-56)	1.99	0.58	1.02	(12 yrs.)	2.16
Little Chippewa (21-212)	1.92	0.63	1.44	(17 yrs.)	9.09
Lobster (21-144)	2.46	0.85	1.21	(30 yrs.)	11.20
Louise (21-94)	3.21	1.24	1.58	(16 yrs.)	5.94
Maple (21-79)	0.99	0.55	0.76	(9 yrs.)	2.93
Mary (21-92)	2.32	1.68	1.44	(12 yrs.)	5.31
Miltona (21-83)	1.68	0.84	1.09	(27 yrs.)	4.77
Moon (21-226)	1.80	0.92	1.27	(18 yrs.)	10.59
Pocket (21-140)	2.07	1.46	0.91	(6 yrs.)	2.33
Red Rock (21-291)	2.30	0.52	1.45	(12 yrs.)	4.21
Unnamed (21-467)	1.48	0.32	0.96	(6 yrs.)	2.57
Vermont (21-73)	1.63	1.26	1.11	(6 yrs.)	2.98
Victoria (21-54)	1.91	0.88	1.18	(21 yrs.)	3.48
Winona (21-81)	0.90	0.93	0.74	(9 yrs.)	1.66
FREEBORN COUNTY					
Bear (24-28)	2.60	0.50	1.22	(19 yrs.)	5.58
GRANT COUNTY					
Elk (26-40)	2.26	0.58	0.92	(8 yrs.)	3.85
Pomme de Terre (26-97)	1.30	0.56	1.09	(14 yrs.)	3.20
HENNEPIN COUNTY					
Arrowhead (27-45)	2.92	1.05	2.04	(39 yrs.)	7.23
Birch Island (27-81)	2.77	0.44	1.89	(38 yrs.)	13.37
Bryant (27-67)	1.45	0.56	1.10	(39 yrs.)	5.50
Bush (27-47)	1.78	0.15	1.32	(40 yrs.)	10.90
Cedar Island (27-119)	2.15	0.86	1.18	(16 yrs.)	6.50
Cornelia (27-28)	2.35	0.15	0.70	(38 yrs.)	6.00
Duck (27-69)	2.99	0.50	1.55	(32 yrs.)	4.64
Eagle/Pike (27-111)	1.66	1.10	1.06	(16 yrs.)	3.27
Edina (27-29)	0.90	0.62	1.66	(38 yrs.)	7.58
Edward (27-121)	1.04	1.36	1.02	(15 yrs.)	3.75
Fish (27-118)	2.18	1.63	1.53	(15 yrs.)	2.87
Gleason (27-95)	1.72	3.68	1.73	(14 yrs.)	5.14
Glen (27-93)	1.88	0.29	1.43	(38 yrs.)	6.57
Hawkes (27-56)	2.80	0.79	2.37	(39 yrs.)	11.31
Hyland (27-48)	2.62	0.36	1.63	(31 yrs.)	7.02
Idlewild (27-74)	1.24	0.15	1.14	(31 yrs.)	7.68
Independence (27-176)	2.26	1.43	1.66	(22 yrs.)	7.88
Indianhead (27-44)	1.95	1.69	1.36	(10 yrs.)	3.19
Langdon (27-182)	1.99	0.60	1.30	(11 yrs.)	3.54
Lone (27-94)	1.82	0.16	1.26	(38 yrs.)	5.70
Long (27-160)	1.71	1.40	1.38	(17 yrs.)	3.35
Medicine (27-104)	1.50	1.57	1.56	(30 yrs.)	5.08
Minnetoga (27-88)	1.82	0.86	1.01	(29 yrs.)	3.00
Minnetonka (27-133)	2.38	2.17	1.45	(97 yrs.)	8.74
Mirror (27-55)	3.10	0.32	1.53	(39 yrs.)	7.47
Mitchell (27-70)	2.42	0.21	1.91	(32 yrs.)	8.13
Nancy (27-677)	0.46	0.14	0.43	(34 yrs.)	2.27
North Anderson (27-62)	1.30	0.21	1.30	(40 yrs.)	5.37
Ox Yoke (27-178)	5.47	1.59	3.50	(7 yrs.)	6.99
Oxboro (27-11)	5.63	0.99	2.39	(38 yrs.)	12.70
Parkers (27-107)	1.98	2.12	2.55	(30 yrs.)	11.65
(Hennepin County continued)					
Pauly s Pond (27-8)	3.39	0.56	1.92	(38 yrs.)	9.36
Penn (27-4)	2.72	0.87	2.18	(38 yrs.)	8.85
Red Rock (27-76)	1.45	0.23	1.35	(32 yrs.)	6.91
Rice (27-116)	1.74	1.30	1.80	(15 yrs.)	10.94
Rose (27-92)	3.49	0.45	2.10	(36 yrs.)	8.80
Round (27-71)	3.78	0.93	2.17	(32 yrs.)	8.97
Sarah (27-191)	3.25	3.27	1.93	(11 yrs.)	4.60
Shady Oak (27-89)	1.75	0.16	1.33	(39 yrs.)	6.65
Silver (27-136)	2.08	0.20	1.29	(15 yrs.)	5.50
Skriebakken Pond (27-1049)	1.57	0.31	1.58	(38 yrs.)	9.93
Smetana (27-73)	0.20	0.05	1.49	(29 yrs.)	10.40
Southeast Anderson (27-62)	1.29	0.16	1.47	(40 yrs.)	7.27
Southwest Anderson (27-62)	1.29	0.16	1.21	(40 yrs.)	5.60
Staring (27-78)	1.80	0.57	1.80	(32 yrs.)	7.16
Twin (27-42)	1.40	1.04	1.27	(12 yrs.)	3.56
Wanda Miller (27-7)	2.13	1.01	2.27	(38 yrs.)	9.32
Weaver (27-117)	0.97	1.12	0.95	(15 yrs.)	3.19
Wing (27-91)	2.21	0.43	1.63	(37 yrs.)	8.02
HUBBARD COUNTY					
Bad Axe (29-208)	0.47	0.40	0.51	(7 yrs.)	2.42
Belle Taine (29-146)	1.41	0.50	1.34	(49 yrs.)	14.36
Big Sand (29-185)	1.29	0.58	0.85	(12 yrs.)	2.91
Big Stony (29-143)	1.62	0.48	0.77	(9 yrs.)	2.31
Blue (29-184)	0.56	0.78	0.60	(8 yrs.)	1.07
Eagle (29-256)	1.71	2.34	1.63	(12 yrs.)	2.78
East Crooked (29-101)	0.77	0.63	0.81	(9 yrs.)	3.54
Eighth Crow Wing (29-72)	0.45	0.42	0.44	(7 yrs.)	0.70
Eleventh Crow Wing (29-36)	0.36	0.21	0.28	(6 yrs.)	0.56
Fifth Crow Wing (29-92)	0.62	0.74	0.72	(9 yrs.)	1.26
Fish Hook (29-242)	0.34	0.64	1.01	(12 yrs.)	2.12
Gilmore (29-188)	1.03	0.55	0.56	(9 yrs.)	1.41
Grace (29-71)	1.10	0.76	0.74	(12 yrs.)	2.75
Island (29-254)	2.06	1.82	2.11	(12 yrs.)	3.92
Little Mantrap (29-313)	0.94	1.17	0.94	(6 yrs.)	2.47
Little Sand (29-150)	1.01	0.55	0.71	(29 yrs.)	3.48
Long (29-161)	0.44	0.48	0.50	(16 yrs.)	1.18
Palmer (29-87)	1.12	0.60	0.84	(12 yrs.)	2.91
Plantagenet (29-156)	1.73	2.22	1.45	(21 yrs.)	3.47
Potato (29-243)	0.88	1.38	0.79	(11 yrs.)	1.71
Potato (HW at outlet dam) (29-243)	1.20	1.35	0.71	(23 yrs.)	1.72
Potato (TW at outlet dam) (29-243)	1.74	0.56	1.26	(12 yrs.)	2.78
Spider (29-117)	0.90	0.54	0.74	(12 yrs.)	2.61
Third Crow Wing (29-77)	0.65	1.60	1.01	(6 yrs.)	2.13
West Crooked (29-101)	0.88	0.60	0.70	(9 yrs.)	2.02
ISANTI COUNTY					
Green (30-136)	3.43	2.44	1.58	(20 yrs.)	4.93
Long (30-72)	0.28	0.82	0.53	(9 yrs.)	1.94
Skogman (30-22)	2.97	1.26	1.29	(24 yrs.)	4.29
Spectacle (30-135)	0.34	0.72	0.63	(10 yrs.)	2.80
ITASCA COUNTY					
Balsam (31-259)	1.71	1.64	1.18	(20 yrs.)	3.26
Bass (31-576)	0.54	0.97	0.81	(23 yrs.)	3.68
Beatrice (31-58)	1.41	0.58	0.88	(11 yrs.)	2.03
Bello (31-726)	0.78	0.80	0.77	(8 yrs.)	1.87
Bowstring (31-813)	2.64	2.32	1.69	(24 yrs.)	4.40
Buck (31-69)	0.78	1.32	0.58	(18 yrs.)	1.38
Burnt Shanty (31-424)	0.68	0.55	**.**	(13 yrs.)	**.**

Annual Lake Level Fluctuation (feet)

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
(Itasca County continued)					
Burrows (31-413)	0.94	0.63	0.72	(13 yrs.)	2.18
Clearwater (31-214)	1.26	1.43	1.01	(7 yrs.)	1.51
Crooked (31-193)	8.14	8.68	6.49	(10 yrs.)	9.53
Deer (31-719)	0.88	0.79	0.59	(9 yrs.)	1.28
Dixon (31-921)	3.65	2.70	2.86	(9 yrs.)	4.43
Dora (31-882)	2.82	2.43	2.03	(22 yrs.)	4.35
Grave (31-624)	0.91	1.58	0.71	(10 yrs.)	1.62
Gunn (31-480)	1.39	0.84	1.11	(6 yrs.)	2.86
Hale (31-361)	1.66	1.20	1.11	(10 yrs.)	2.46
Hale (31-373)	1.03	0.61	0.83	(44 yrs.)	3.16
Island (31-913)	1.30	1.00	0.79	(7 yrs.)	1.82
Jessie (31-786)	1.58	2.55	1.30	(13 yrs.)	4.66
Johnson (31-586)	1.38	0.78	0.94	(13 yrs.)	3.01
Kelly (31-299)	1.36	0.52	0.93	(7 yrs.)	1.97
Lawrence (31-231)	7.87	8.28	5.57	(8 yrs.)	10.98
Link (31-304)	1.06	0.13	0.60	(7 yrs.)	1.90
Little Bowstring (31-758)	0.56	2.56	1.25	(9 yrs.)	2.56
Little Long (31-613)	1.19	0.80	0.80	(12 yrs.)	5.68
Long (31-570)	0.88	0.44	0.91	(37 yrs.)	3.39
Loon (31-571)	1.04	0.57	1.03	(38 yrs.)	3.62
McGuire (31-78)	3.27	4.78	2.89	(11 yrs.)	4.99
Moose (31-722)	0.78	0.72	0.76	(14 yrs.)	1.77
Owen (31-292)	1.31	0.68	0.77	(13 yrs.)	2.28
Pigeon Dam (31-894)	1.80	1.56	1.30	(15 yrs.)	3.30
Pokegama (31-532)	5.94	3.70	3.13	(49 yrs.)	8.89
Pughole (31-602)	1.14	0.73	0.93	(12 yrs.)	3.32
Ruby (31-422)	0.56	0.72	0.59	(13 yrs.)	2.21
Sand (31-438)	0.89	0.74	0.82	(11 yrs.)	3.14
Sand (31-826)	2.67	2.35	1.74	(20 yrs.)	4.40
Shallow (31-84)	0.70	0.65	0.62	(11 yrs.)	1.12
Shoal (31-141)	1.04	1.73	1.09	(9 yrs.)	1.92
Siseebakwet (31-554)	0.82	0.73	0.74	(54 yrs.)	2.19
Smith (31-650)	1.25	0.66	0.83	(13 yrs.)	3.17
Snaptail (31-255)	1.55	3.00	1.24	(11 yrs.)	3.08
Snowball (31-108)	0.64	2.07	1.00	(37 yrs.)	4.28
South Sturgeon (31-3)	1.96	1.75	1.47	(9 yrs.)	3.40
Spider (31-538)	0.98	0.74	0.80	(13 yrs.)	2.40
Split Hand (31-353)	1.50	1.10	1.53	(21 yrs.)	3.65
Swan (31-67)	2.03	2.30	1.54	(54 yrs.)	4.65
Trout (31-216)	1.39	0.85	1.10	(42 yrs.)	6.09
Turtle (31-725)	0.97	0.80	0.66	(11 yrs.)	2.07
White Swan (31-260)	1.39	0.63	0.65	(13 yrs.)	**.**
JACKSON COUNTY					
Heron (Duck) (32-57)	4.27	0.84	1.68	(12 yrs.)	7.00
Heron (North Marsh) (32-57)	7.94	3.20	4.31	(26 yrs.)	10.33
Heron (South Heron) (32-57)	7.81	2.00	3.62	(33 yrs.)	8.94
Heron (Tailwaters) (32-57)	9.84	2.42	4.58	(12 yrs.)	9.90
Loon (32-20)	1.97	0.81	1.43	(17 yrs.)	4.58
Pearl (32-33)	1.97	1.16	1.69	(12 yrs.)	4.21
KANABEC COUNTY					
Fish (33-36)	8.13	7.50	2.91	(11 yrs.)	8.26
Knife (33-28)	1.70	1.68	2.10	(35 yrs.)	11.99
KANDIYOHI COUNTY					
Andrew (34-206)	2.66	1.38	1.49	(36 yrs.)	13.60
Big Kandiyohi (34-86)	3.23	1.58	1.37	(38 yrs.)	5.81
Calhoun (34-62)	2.48	1.13	1.38	(31 yrs.)	3.85
Diamond (34-44)	1.76	1.56	1.06	(21 yrs.)	3.95
Eagle (34-171)	2.21	1.12	1.12	(33 yrs.)	5.22
East Solomon (34-246)	1.71	1.79	1.27	(14 yrs.)	4.50

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
(Kandiyohi County continued)					
Elizabeth (34-22)	2.43	1.89	1.20	(23 yrs.)	3.12
Elkhorn (34-119)	2.07	1.21	0.85	(21 yrs.)	3.34
Florida (34-217)	2.65	1.90	1.54	(22 yrs.)	5.22
Foot (34-181)	1.86	1.47	0.99	(19 yrs.)	3.41
Games (34-224)	1.76	1.20	1.03	(25 yrs.)	4.09
George (34-142)	1.59	1.39	1.07	(27 yrs.)	3.88
Green (34-79)	2.87	2.34	1.58	(47 yrs.)	4.91
Henderson (34-116)	1.86	1.26	1.10	(20 yrs.)	5.57
Lillian (34-72)	2.25	1.15	1.23	(14 yrs.)	5.23
Little Kandiyohi (34-96)	2.27	1.44	1.45	(31 yrs.)	5.08
Long (34-66)	0.92	0.76	0.50	(20 yrs.)	1.59
Long (34-192)	1.84	1.07	1.13	(22 yrs.)	12.31
Mud (34-158)	1.82	1.31	1.34	(35 yrs.)	3.64
Nest (34-154)	2.44	2.30	1.26	(34 yrs.)	3.96
Norway (34-251)	2.22	1.25	1.30	(20 yrs.)	4.29
Point (34-193)	1.75	1.43	1.06	(15 yrs.)	11.23
Ringo (34-172)	1.81	1.18	1.16	(18 yrs.)	7.64
Saint Johns (34-283)	1.24	0.75	1.13	(13 yrs.)	3.31
Skataas (34-196)	1.30	1.27	1.20	(15 yrs.)	4.81
Swenson (34-321)	1.75	0.76	1.15	(15 yrs.)	5.63
Unnamed (Golden Pond) (34-355)	0.54	0.39	0.85	(8 yrs.)	2.54
Wagonga (34-169)	3.41	2.26	1.72	(18 yrs.)	4.92
LAKE COUNTY					
Farm (38-779)	0.57	0.31	0.44	(10 yrs.)	0.96
Garden (38-782)	1.11	0.85	1.25	(11 yrs.)	3.67
LE SUEUR COUNTY					
Frances (40-57)	1.87	0.76	0.96	(11 yrs.)	13.14
German (40-63)	1.80	1.05	1.28	(27 yrs.)	6.20
Tetonka (40-31)	0.31	1.16	1.79	(38 yrs.)	5.50
Volney (40-33)	1.96	1.47	1.35	(12 yrs.)	3.60
Washington (40-117)	1.88	1.24	1.49	(24 yrs.)	5.35
West Jefferson (40-92)	1.92	1.03	1.40	(28 yrs.)	6.92
LINCOLN COUNTY					
Benton (41-43)	2.10	1.74	1.55	(28 yrs.)	5.98
Shaokotan (41-89)	1.52	0.92	1.42	(10 yrs.)	4.27
MCLEOD COUNTY					
Marion (43-84)	2.29	0.84	1.11	(13 yrs.)	3.05
Winsted (43-12)	1.75	2.51	1.67	(12 yrs.)	3.54
MAHNOMEN COUNTY					
Tulaby (44-3)	0.75	1.40	1.09	(10 yrs.)	2.44
MARTIN COUNTY					
Amber (46-34)	2.45	0.94	1.46	(10 yrs.)	3.89
Budd (46-30)	2.60	1.42	1.60	(9 yrs.)	5.32
George (46-24)	2.08	1.40	1.40	(10 yrs.)	8.84
MEEKER COUNTY					
Belle (47-49)	2.27	2.43	1.40	(11 yrs.)	11.84
Big Swan (47-38)	8.21	8.01	5.48	(8 yrs.)	9.86
Clear (47-95)	2.50	1.12	1.36	(13 yrs.)	4.21
Dunns (47-82)	1.42	2.94	1.60	(7 yrs.)	2.94
Francis (47-2)	0.93	1.58	0.91	(20 yrs.)	4.95
Jennie (47-15)	1.63	1.60	1.04	(11 yrs.)	9.04
Long (47-177)	4.05	1.90	1.96	(6 yrs.)	4.05
Minnie-Belle (47-119)	1.36	1.84	1.35	(14 yrs.)	5.92

Annual Lake Level Fluctuation (feet)

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
(Meeker County continued)					
Richardson (47-88)	1.62	1.70	1.24	(7 yrs.)	2.59
Ripley (47-134)	2.46	0.75	1.05	(10 yrs.)	9.61
Stella (47-68)	1.97	1.78	1.12	(14 yrs.)	2.55
Washington (47-46)	1.34	1.30	0.75	(14 yrs.)	2.23
MILLE LACS COUNTY					
Mille Lacs (48-2)	2.58	2.12	1.36	(72 yrs.)	7.69
Onamia (48-9)	3.14	1.92	1.62	(37 yrs.)	6.12
Onamia (TW) (48-9)	3.64	2.50	2.00	(18 yrs.)	5.77
MORRISON COUNTY					
Fish Trap (49-137)	2.93	0.50	1.07	(20 yrs.)	4.36
Green Prairie Fish (49-35)	1.72	1.30	1.21	(7 yrs.)	2.09
Long (49-15)	0.62	0.66	0.67	(6 yrs.)	1.72
Round (49-56)	1.75	0.70	0.89	(8 yrs.)	1.75
Shamineau (49-127)	1.83	0.75	0.93	(9 yrs.)	5.11
Sullivan (49-16)	2.33	1.78	1.41	(24 yrs.)	3.79
MURRAY COUNTY					
Currant (51-82)	2.02	1.06	1.36	(10 yrs.)	4.56
Sarah (51-63)	2.43	1.16	1.30	(8 yrs.)	4.41
Shetek (51-46)	3.24	0.68	2.00	(53 yrs.)	7.67
NOBLES COUNTY					
Bella (53-45)	3.70	2.36	2.34	(13 yrs.)	9.68
East Graham (53-20)	3.33	0.28	1.45	(7 yrs.)	5.15
Indian (53-7)	1.73	1.56	1.71	(15 yrs.)	4.48
Ocheda (53-24)	2.48	1.34	1.41	(35 yrs.)	5.42
West Graham (53-21)	1.90	0.14	1.22	(6 yrs.)	5.12
OTTER TAIL COUNTY					
Big McDonald (56-386)	0.82	0.61	0.87	(8 yrs.)	1.60
Big McDonald(West McDonal (56-386)	0.88	0.62	0.85	(9 yrs.)	7.70
Big Pine (56-130)	1.15	0.85	1.51	(53 yrs.)	4.73
Blanche (56-240)	1.46	0.50	0.64	(10 yrs.)	1.77
Clitherall (56-238)	0.81	0.33	0.73	(9 yrs.)	2.11
Deer (56-298)	2.21	2.14	1.66	(6 yrs.)	3.07
Eagle (56-253)	1.72	0.60	0.88	(7 yrs.)	9.43
East Battle (56-138)	1.50	1.04	1.12	(16 yrs.)	4.21
East Leaf (56-116)	1.81	1.56	1.99	(8 yrs.)	3.22
East Lost (56-378)	2.47	1.58	2.02	(10 yrs.)	3.38
Jewett (56-877)	1.47	0.09	0.68	(8 yrs.)	3.80
Little McDonald (56-328)	1.41	0.78	1.06	(11 yrs.)	4.55
Little Pine (56-142)	1.34	0.58	1.06	(38 yrs.)	3.30
Lizzie (56-760)	1.18	0.42	1.17	(55 yrs.)	4.56
Long (56-388)	1.26	1.00	0.79	(19 yrs.)	5.78
Long (56-784)	1.58	0.82	1.19	(11 yrs.)	2.08
Middle Leaf (56-116)	1.94	1.64	1.82	(8 yrs.)	3.61
Orwell (56-945)	23.26	3.68	15.18	(33 yrs.)	25.79
Otter Tail (56-242)	1.53	0.72	1.42	(73 yrs.)	4.63
Otter Tail (TW) (56-242)	1.70	1.00	1.74	(13 yrs.)	3.78
Pelican (56-786)	1.34	0.94	1.28	(29 yrs.)	4.94
Pickerel (56-204)	1.58	0.70	1.15	(9 yrs.)	3.16
Pickerel (56-475)	0.78	0.46	0.69	(24 yrs.)	3.03
Prairie (56-915)	1.08	0.43	0.80	(22 yrs.)	4.70
Rush (56-141)	2.08	1.20	1.56	(63 yrs.)	3.87
Rush (TW) (56-141)	2.44	1.10	1.82	(18 yrs.)	5.08
Silver (56-302)	1.43	0.46	0.98	(6 yrs.)	3.10
Six (56-369)	0.51	0.38	0.46	(6 yrs.)	1.53
Star (56-385)	0.89	0.49	1.02	(26 yrs.)	3.79
Stuart (56-191)	2.29	0.62	1.28	(7 yrs.)	6.26
Otter Tail County continued)					
Swan (56-781)	1.00	0.48	0.97	(11 yrs.)	3.63
Sybil (56-387)	0.92	0.61	0.73	(7 yrs.)	3.04
Ten Mile (56-613)	1.19	0.59	1.21	(11 yrs.)	2.69
Wall (56-658)	0.32	0.22	0.37	(11 yrs.)	0.75
West Battle (56-239)	2.59	0.77	1.11	(30 yrs.)	8.42
West Lost (56-481)	2.62	1.11	1.78	(8 yrs.)	**.**
West McDonald (56-386)	0.84	0.61	0.87	(9 yrs.)	2.00
PINE COUNTY					
Grindstone (58-123)	3.73	1.84	1.19	(26 yrs.)	3.73
Pokegama (58-142)	3.11	4.79	3.73	(23 yrs.)	8.20
Sand (58-81)	2.38	2.37	1.48	(28 yrs.)	5.99
Upper Pine (58-130)	1.84	0.74	0.76	(10 yrs.)	2.04
POLK COUNTY					
Badger (60-214)	0.68	1.85	1.44	(15 yrs.)	2.95
Breeze (60-144)	1.90	0.13	0.96	(10 yrs.)	3.65
Cable (60-293)	1.02	1.13	0.92	(11 yrs.)	7.90
Cameron (60-189)	0.68	1.39	0.79	(10 yrs.)	3.08
Cross (60-27)	1.10	1.92	1.46	(14 yrs.)	3.46
Hill River (60-142)	0.68	1.16	0.98	(11 yrs.)	1.94
Maple (60-305)	0.95	0.93	1.14	(26 yrs.)	11.22
Poplar (60-6)	0.50	0.34	1.43	(11 yrs.)	3.55
Sarah (60-202)	2.77	2.89	2.91	(14 yrs.)	14.89
Spring (60-12)	0.60	0.96	0.84	(11 yrs.)	2.35
Turtle (60-32)	1.06	1.49	1.31	(15 yrs.)	4.18
Union (60-217)	2.40	1.72	1.59	(17 yrs.)	8.55
Whitefish (60-15)	0.75	1.10	0.98	(6 yrs.)	3.25
POPE COUNTY					
Gilchrist (61-72)	4.82	3.00	2.44	(12 yrs.)	5.50
Leven (61-66)	3.38	1.16	1.73	(9 yrs.)	3.38
Linka (61-37)	1.46	0.90	0.93	(9 yrs.)	2.07
Marlu (61-60)	2.70	1.04	1.15	(9 yrs.)	2.70
Minnewaska (61-130)	1.86	0.70	1.18	(58 yrs.)	10.01
Pelican (61-111)	4.34	1.62	1.40	(10 yrs.)	6.83
Signalness (61-149)	1.12	0.76	0.82	(6 yrs.)	1.68
Villard (61-67)	5.95	2.53	2.17	(9 yrs.)	6.03
RAMSEY COUNTY					
Bald Eagle (62-2)	1.30	1.25	1.25	(80 yrs.)	6.69
Beaver (62-16)	1.75	1.65	1.94	(48 yrs.)	7.10
Bennett (62-48)	2.53	2.23	2.79	(16 yrs.)	6.60
Birch (62-24)	1.73	1.44	1.33	(73 yrs.)	7.13
Como (62-55)	2.45	1.60	1.70	(25 yrs.)	4.19
Gervais (62-7)	2.23	1.34	2.14	(79 yrs.)	7.20
Grass (62-74)	7.46	5.52	3.57	(21 yrs.)	9.65
Island (62-75)	1.81	1.57	1.41	(57 yrs.)	9.32
Johanna (62-78)	1.07	1.25	1.98	(79 yrs.)	10.92
Josephine (62-57)	1.28	1.00	1.17	(79 yrs.)	4.20
Long (62-67)	2.85	2.15	1.74	(79 yrs.)	5.20
McCarron (62-54)	1.17	0.72	1.14	(79 yrs.)	4.45
Owasso (62-56)	1.83	1.63	1.17	(79 yrs.)	5.79
Phalen (62-13)	2.77	1.82	3.46	(79 yrs.)	12.32
Pike (62-69)	1.25	0.80	1.36	(34 yrs.)	4.57
Round (62-9)	2.93	2.16	2.02	(69 yrs.)	11.67
Silver (East) (62-1)	1.70	1.66	1.68	(78 yrs.)	10.05
Silver (West) (62-83)	1.17	0.90	1.70	(69 yrs.)	13.25
Snail (62-73)	1.97	2.13	1.61	(79 yrs.)	7.15
Turtle (62-61)	1.55	1.93	1.00	(80 yrs.)	4.40
Valentine (62-71)	2.47	1.39	1.82	(78 yrs.)	6.95
Wabasso (62-82)	2.99	3.02	1.45	(65 yrs.)	5.53
Wakefield (62-11)	2.01	1.34	2.27	(50 yrs.)	10.53
Willow (62-40)	0.97	1.12	1.01	(16 yrs.)	2.01

Annual Lake Level Fluctuation (feet)

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
RENVILLE COUNTY					
Allie (65-6)	2.28	2.26	1.40	(13 yrs.)	8.56
Preston (65-2)	2.64	1.56	1.45	(10 yrs.)	3.74
RICE COUNTY					
Cedar (66-52)	1.53	1.09	1.11	(16 yrs.)	3.22
Roberds (66-18)	0.97	0.98	1.25	(18 yrs.)	2.42
ST. LOUIS COUNTY					
Aerie (69-701)	1.80	0.50	0.73	(6 yrs.)	1.80
Beaver (69-501)	2.15	0.89	0.93	(14 yrs.)	3.38
Big Rice (69-669)	1.30	1.30	1.14	(13 yrs.)	2.43
Boulder (69-373)	6.66	6.57	4.66	(6 yrs.)	6.69
Burntside (69-118)	1.33	0.71	0.99	(12 yrs.)	4.76
Cameron (69-545)	0.67	1.15	0.88	(7 yrs.)	1.87
Colby (69-249)	3.74	2.29	2.56	(37 yrs.)	7.02
Comstock (69-412)	1.03	2.32	1.59	(9 yrs.)	2.64
Crooked (69-703)	1.29	0.81	0.89	(6 yrs.)	1.37
Eagles Nest #1 (69-285)	0.72	0.36	0.76	(10 yrs.)	3.10
Eagles Nest #3 (69-285)	1.60	1.20	0.93	(11 yrs.)	1.61
Eagles Nest No. Four (69-218)	0.38	0.33	0.41	(10 yrs.)	0.97
Ely (69-660)	0.65	0.54	0.81	(49 yrs.)	2.80
Embarrass (69-496)	3.04	2.02	2.33	(44 yrs.)	6.29
Esquagama (69-565)	2.70	1.40	2.39	(28 yrs.)	8.10
Fish Lake Flowage (69-491)	3.24	2.37	2.28	(6 yrs.)	3.34
Fourteen (69-793)	1.01	0.56	0.56	(11 yrs.)	1.34
Horseshoe (69-232)	0.97	0.60	0.78	(6 yrs.)	3.42
Island Lake Reservoir (69-372)	11.84	10.62	18.30	(27 yrs.)	32.25
Jacobs (69-231)	1.46	0.64	0.82	(12 yrs.)	2.31
Janette (69-887)	0.72	1.78	0.78	(10 yrs.)	2.37
Leora (69-521)	1.48	1.03	0.86	(6 yrs.)	1.56
Lieung (69-123)	1.70	1.38	1.04	(7 yrs.)	2.53
Little Stone (69-28)	1.66	0.84	0.98	(11 yrs.)	2.99
Long (69-509)	0.14	0.65	0.89	(13 yrs.)	2.24
Long (69-653)	0.73	1.02	0.79	(11 yrs.)	1.47
Maple Leaf (69-700)	1.44	1.33	0.90	(12 yrs.)	1.78
Merrill (69-891)	0.86	1.47	0.77	(10 yrs.)	1.55
Nichols (69-627)	1.18	1.00	0.72	(14 yrs.)	1.71
Perch (69-932)	0.36	0.40	0.52	(12 yrs.)	2.35
Prairie (69-848)	1.54	1.20	1.24	(19 yrs.)	3.34
Sabin (69-434)	5.21	1.07	2.92	(7 yrs.)	5.71
Sand (69-736)	0.79	0.29	0.64	(11 yrs.)	2.13
Schubert (69-546)	1.80	1.80	1.20	(8 yrs.)	2.27
Shagawa (69-69)	1.74	0.90	1.58	(14 yrs.)	3.31
Stone (69-27)	1.51	0.52	0.83	(13 yrs.)	1.76
Stone (69-686)	1.04	0.76	1.12	(10 yrs.)	3.01
Sturgeon (69-939)	2.05	1.76	1.56	(19 yrs.)	3.00
Thirteen (69-794)	0.64	0.50	0.54	(6 yrs.)	1.25
Vermilion (69-378)	1.86	0.83	1.60	(52 yrs.)	3.19
White Iron (69-4)	2.20	1.36	1.58	(7 yrs.)	2.58
Whiteface Reservoir (69-375)	5.15	4.17	3.55	(6 yrs.)	5.44
Wild Rice (69-371)	3.15	1.55	1.82	(8 yrs.)	4.23
SCOTT COUNTY					
Cedar (70-91)	0.87	0.74	0.89	(9 yrs.)	2.42
Lower Prior (70-26)	3.08	1.59	2.36	(30 yrs.)	10.22
Markley (70-21)	3.16	2.91	3.13	(6 yrs.)	6.20
O Dowd (70-95)	2.53	1.01	1.25	(10 yrs.)	5.08
Spring (70-54)	1.85	2.25	1.61	(13 yrs.)	2.98
Thole/Schneider (70-120)	2.68	1.06	1.69	(6 yrs.)	5.45
Upper Prior (70-72)	3.08	1.59	2.32	(31 yrs.)	12.20

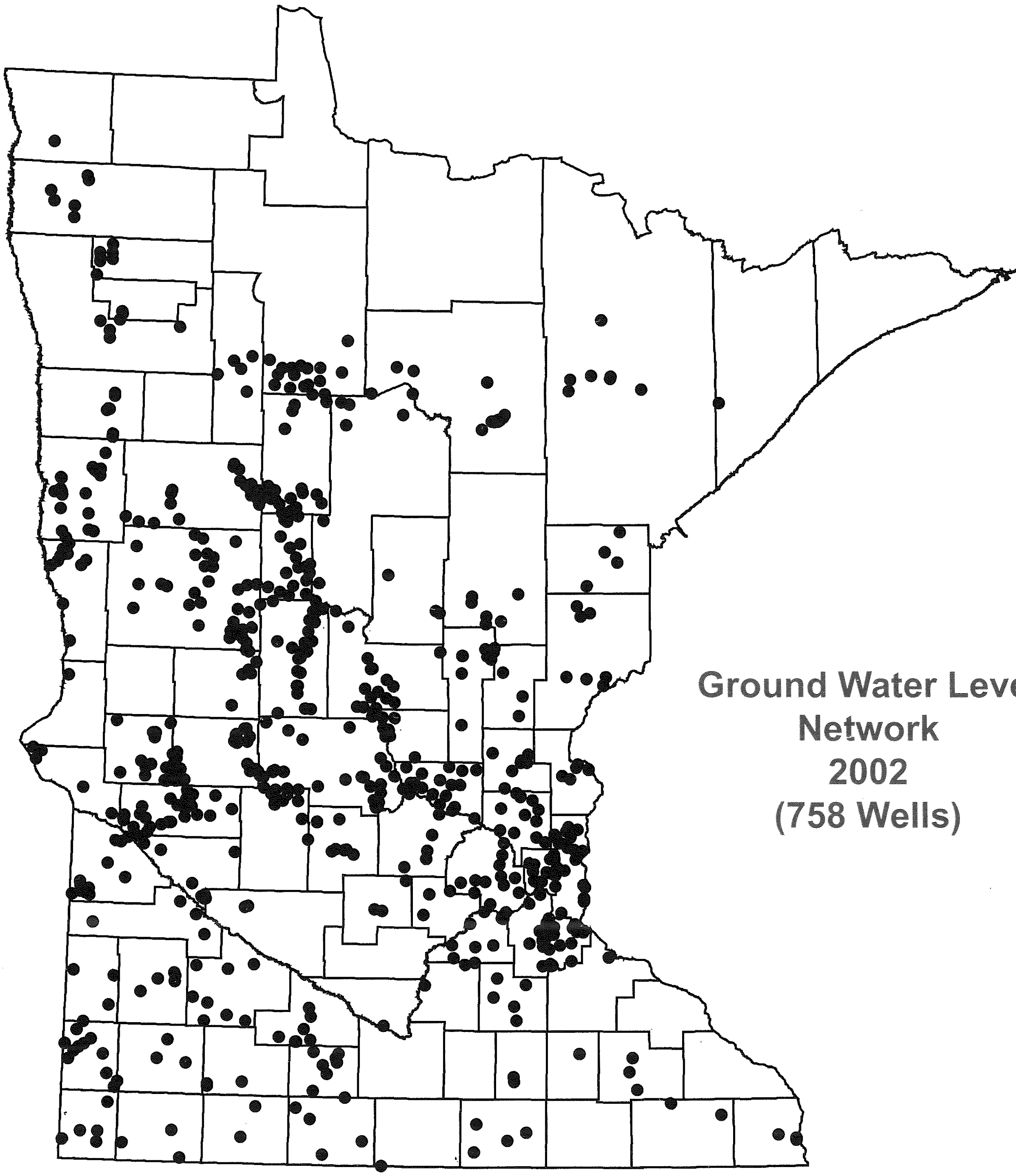
Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
SHERBURNE COUNTY					
Elk (71-141)	2.16	2.90	1.81	(8 yrs.)	4.87
Long (71-159)	2.37	1.92	1.33	(11 yrs.)	9.04
Mitchell (71-81)	1.32	1.93	1.53	(17 yrs.)	8.28
Rush (71-147)	5.72	4.42	2.08	(13 yrs.)	5.72
STEARNS COUNTY					
Big (73-159)	3.06	1.70	1.45	(13 yrs.)	5.20
Big Fish (73-106)	1.84	1.41	1.03	(26 yrs.)	4.06
Big Watab (73-102)	1.00	0.52	0.73	(18 yrs.)	1.90
Carnelian (73-38)	1.98	0.84	1.51	(11 yrs.)	10.56
Eden (73-150)	4.83	3.40	2.64	(15 yrs.)	10.38
Grand (73-55)	0.98	0.84	1.05	(22 yrs.)	3.21
Horseshoe (73-157)	4.92	2.80	1.96	(17 yrs.)	5.42
Knaus (73-86)	3.34	3.03	1.44	(8 yrs.)	4.66
Koronis (73-200)	3.68	0.76	2.06	(22 yrs.)	6.00
Kraemer (73-64)	1.90	2.00	1.29	(7 yrs.)	3.65
Long (73-4)	2.27	1.98	1.42	(10 yrs.)	3.38
Lower Spunk (73-123)	2.26	2.50	1.78	(6 yrs.)	2.51
North Brown s (73-147)	4.31	2.91	2.19	(11 yrs.)	4.93
Rice (73-196)	5.06	2.35	3.11	(17 yrs.)	6.94
School Section (73-35)	0.80	2.21	1.58	(6 yrs.)	9.28
Two Rivers (73-138)	5.94	3.48	3.34	(19 yrs.)	7.51
Willow (73-34)	2.26	0.84	1.24	(6 yrs.)	2.65
STEVENS COUNTY					
Page (75-19)	2.89	2.49	1.54	(23 yrs.)	8.08
Perkins (75-75)	1.42	0.56	1.24	(20 yrs.)	4.86
SWIFT COUNTY					
Camp (76-72)	2.63	0.81	1.76	(8 yrs.)	4.42
Oliver (east portion) (76-146)	3.35	0.71	1.77	(8 yrs.)	18.91
TODD COUNTY					
Beauty (77-35)	1.38	0.44	0.78	(9 yrs.)	2.55
Big (77-63)	1.92	0.77	0.98	(10 yrs.)	1.92
Big Birch (77-84)	1.68	1.81	1.07	(26 yrs.)	3.23
Big Birch (HW at outlet) (77-84)	1.38	0.90	0.76	(12 yrs.)	1.48
Fairy (77-154)	3.33	1.20	1.37	(14 yrs.)	9.91
Little Birch (77-89)	1.22	2.04	1.07	(23 yrs.)	3.42
Long (77-27)	1.70	0.86	0.84	(10 yrs.)	2.09
Long (77-149)	1.97	1.37	1.15	(6 yrs.)	6.44
Maple (77-181)	1.60	1.97	1.36	(14 yrs.)	3.02
Mound (77-7)	1.30	0.60	0.65	(10 yrs.)	1.30
Osakis (77-215)	3.90	2.17	1.60	(42 yrs.)	7.93
Sauk (77-150)	3.22	3.24	1.89	(20 yrs.)	5.47
TRAVERSE COUNTY					
Traverse (78-25)	7.04	1.25	2.83	(60 yrs.)	9.06
WADENA COUNTY					
Hazel (80-5)	1.34	0.68	0.93	(23 yrs.)	3.33
Stocking (80-37)	0.64	0.76	0.57	(15 yrs.)	1.58
WASHINGTON COUNTY					
Barker (82-76)	2.91	1.75	1.56	(6 yrs.)	3.96
Bass (82-35)	1.40	0.80	1.38	(8 yrs.)	3.75
Bass (82-123)	1.00	1.85	1.21	(6 yrs.)	8.50
Big Carnelian (82-49)	1.20	0.87	1.26	(26 yrs.)	14.26
Big Marine (82-52)	1.33	1.35	1.04	(29 yrs.)	7.10
Big Marine (Jellums) (82-52)	2.38	1.03	1.19	(6 yrs.)	2.38

Annual Lake Level Fluctuation (feet)

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
(Washington County continued)					
Carol (82-17)	1.22	0.68	1.17	(7 yrs.)	1.63
Clear (82-45)	3.86	2.25	2.53	(6 yrs.)	28.25
Cloverdale (82-9)	2.15	2.49	2.23	(9 yrs.)	9.21
DeMontreville (82-101)	1.32	1.30	1.46	(35 yrs.)	6.40
Downs (82-110)	4.09	2.62	2.60	(21 yrs.)	7.73
Eagle Point (82-109)	3.33	3.11	2.23	(28 yrs.)	7.40
Egg (82-147)	0.64	0.84	0.78	(13 yrs.)	3.41
Elmo (82-106)	1.12	0.50	1.22	(28 yrs.)	9.58
Forest (82-159)	1.00	0.55	0.75	(28 yrs.)	2.78
Goose (82-59)	5.41	1.92	1.89	(9 yrs.)	6.00
Halfbreed (82-80)	1.55	0.72	0.94	(13 yrs.)	3.05
Horseshoe (82-74)	0.82	1.10	1.66	(25 yrs.)	15.74
Jane (82-104)	1.23	1.04	1.53	(35 yrs.)	8.99
Lily (82-23)	2.70	2.30	1.70	(8 yrs.)	11.98
Little Carnelian (82-14)	4.20	1.59	3.60	(11 yrs.)	35.67
Long (82-21)	2.52	2.59	1.99	(7 yrs.)	2.88
Long (82-30)	1.40	1.55	0.90	(7 yrs.)	5.25
Long (82-118)	5.01	4.35	3.35	(29 yrs.)	10.34
Long (82-130)	2.55	2.39	1.71	(6 yrs.)	2.90
Loon (82-15)	2.30	2.22	1.34	(7 yrs.)	4.20
Louise (82-25)	1.76	1.78	1.23	(7 yrs.)	3.64
Masterman (82-126)	1.95	0.99	1.03	(6 yrs.)	1.95
McDonald (82-10)	1.13	1.28	1.07	(9 yrs.)	3.92
McKusick (82-20)	0.91	1.88	1.12	(7 yrs.)	5.13
Mud (82-26)	0.64	0.65	0.46	(8 yrs.)	0.87
Mud-wetland so of Co.4 (82-26)	0.96	0.89	0.92	(9 yrs.)	1.68
North Twin (82-18)	1.96	0.75	0.91	(7 yrs.)	2.18
Oneka (82-140)	1.40	1.30	0.98	(24 yrs.)	4.13
Pat (82-125)	1.60	1.94	1.31	(6 yrs.)	4.28
Sand (82-67)	3.93	3.05	2.31	(7 yrs.)	4.61
Shields (82-162)	1.81	2.05	1.25	(7 yrs.)	2.39
Silver (82-16)	2.25	1.48	1.57	(7 yrs.)	3.12
South School Section (82-151)	1.03	1.51	1.53	(7 yrs.)	4.91
South Twin (82-19)	2.55	1.12	1.64	(7 yrs.)	4.71
Square (82-46)	0.35	0.43	0.69	(26 yrs.)	5.34
Staples (82-28)	1.73	1.43	1.08	(6 yrs.)	3.33

Lake Name	WY01	WY02	WYAv.	#Yrs.	Range
(Washington County continued)					
Sunfish (82-107)	0.55	0.82	1.53	(28 yrs.)	18.15
Sunnybrook (82-133)	2.90	2.81	2.09	(10 yrs.)	3.40
Sunset (82-153)	1.10	1.79	1.20	(9 yrs.)	2.72
Turtle (82-36)	0.92	1.40	1.02	(9 yrs.)	3.52
Twin (82-48)	2.44	2.70	2.35	(6 yrs.)	3.26
Unnamed (82-334)	2.30	2.23	1.37	(7 yrs.)	4.82
Unnamed (Jackson WMA) (82-305)	2.76	2.69	2.10	(6 yrs.)	3.17
Unnamed (July Ave) (82-318)	5.31	3.94	3.41	(6 yrs.)	6.63
Unnamed (Maple Marsh) (82-38)	2.48	1.31	1.38	(6 yrs.)	2.61
Unnamed (May Ave.Wetland) (82-296)	1.62	0.86	0.93	(9 yrs.)	2.18
West Boot (82-44)	1.16	0.71	0.78	(8 yrs.)	2.13
White Bear (82-167)	1.72	1.82	1.21	(79 yrs.)	6.81
White Rock (82-72)	1.49	1.69	1.28	(6 yrs.)	3.50
Wood Pile (82-132)	1.75	2.39	1.36	(6 yrs.)	4.18
WATONWAN COUNTY					
Long (83-40)	0.88	1.49	1.48	(18 yrs.)	10.65
WRIGHT COUNTY					
Ann (86-190)	3.45	6.62	3.76	(7 yrs.)	7.33
Augusta (86-284)	0.91	2.38	1.13	(9 yrs.)	2.97
Beebe (86-23)	0.20	3.11	1.10	(11 yrs.)	7.20
Birch (86-66)	1.96	1.65	1.28	(10 yrs.)	6.19
Charlotte (86-11)	1.68	3.32	1.52	(18 yrs.)	8.68
Collinwood (86-293)	1.97	1.91	1.17	(8 yrs.)	3.88
Ida (86-146)	1.13	0.24	0.60	(7 yrs.)	3.59
Indian (86-223)	1.16	2.38	1.51	(17 yrs.)	9.76
Little Waverly (86-106)	1.43	2.04	1.39	(13 yrs.)	6.82
Maple (86-134)	1.40	2.39	1.28	(17 yrs.)	5.34
Mary (86-193)	1.91	1.87	1.21	(6 yrs.)	2.85
Pulaski (86-53)	1.65	4.03	1.54	(27 yrs.)	17.69
Sugar (86-233)	1.36	0.92	0.80	(26 yrs.)	4.43
Sylvia (86-289)	0.58	2.46	0.92	(24 yrs.)	4.03

chapter three
ground water



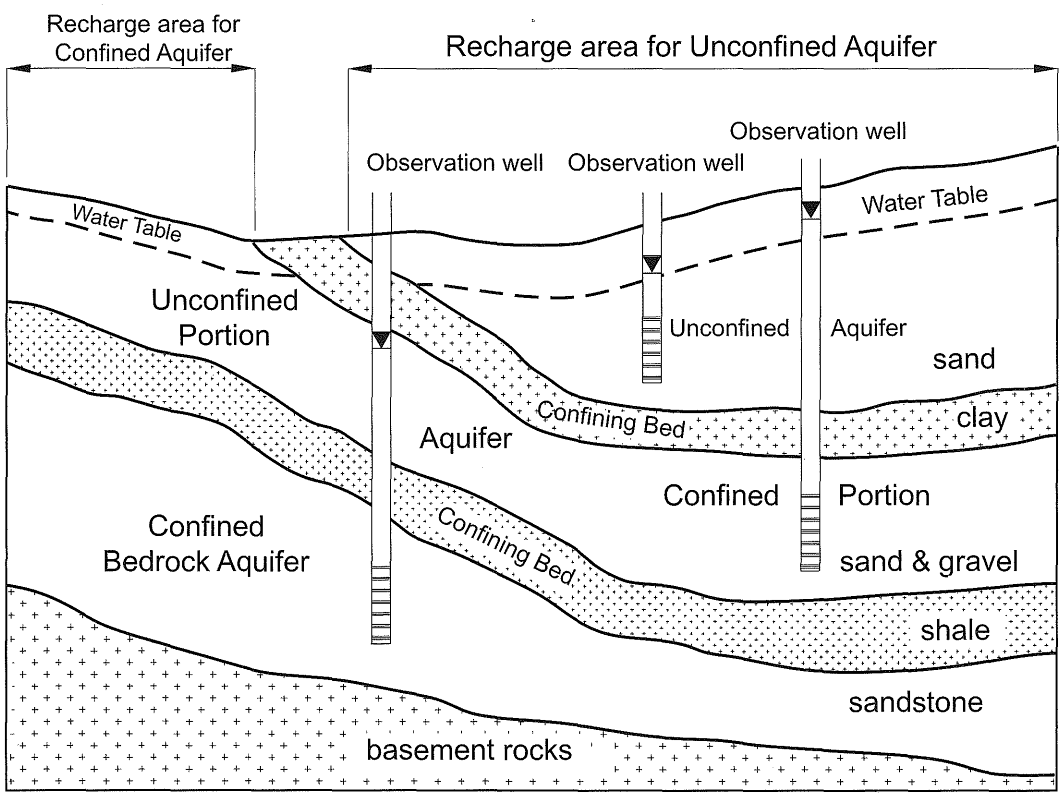
Ground Water Level
Network
2002
(758 Wells)

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 700-750 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 agreements with DNR Waters, measure the wells monthly and report the readings to DNR Waters as part of the Ground Water Level Program. Readings are also obtained from volunteers and electronically 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 are composed 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 obwell 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, and/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

The remainder of this chapter discusses the ground water levels in unconfined and confined aquifers during Water Years 2001 (WY01) and 2002 (WY02). This discussion focuses on a comparison of water levels in WY01 and WY02 to the water levels over the period of record for the observation wells analyzed in this report. Hydrographs of representative obwells illustrate the analysis. To achieve meaningful comparisons, representative obwells were chosen from the network based on their length of record and their geographical location. Such periods of record are generally from 10 to 40 years.

During these water years, the DNR monitored water levels in approximately 750 wells throughout the state. Water levels are usually recorded monthly except for January and February. Figures 2, 3 and 4 show the locations of these wells, identifying those that were placed in unconfined (water table) aquifers, in buried drift aquifers and in bedrock aquifers.

Figure 2

Unconfined Observation Wells

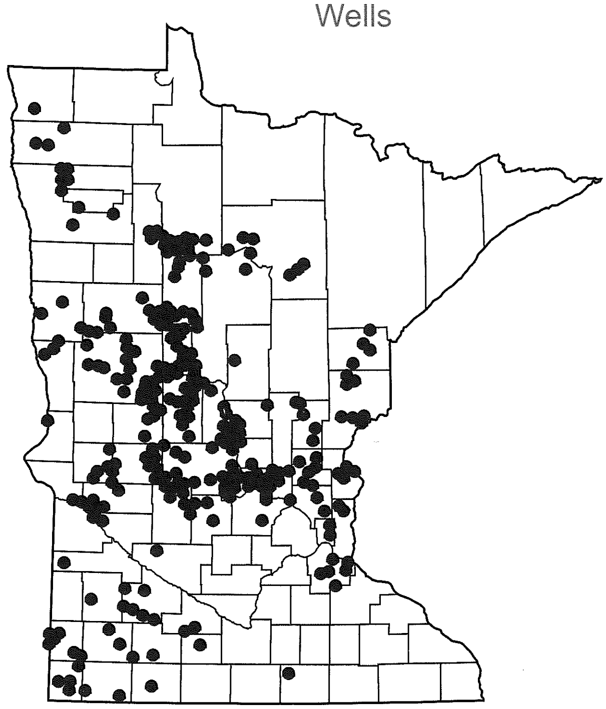


Figure 3

Buried Drift Observation Wells

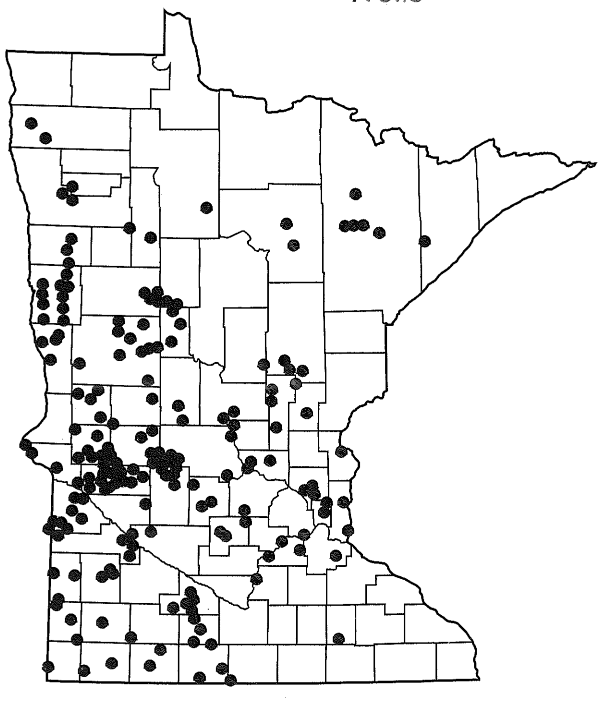
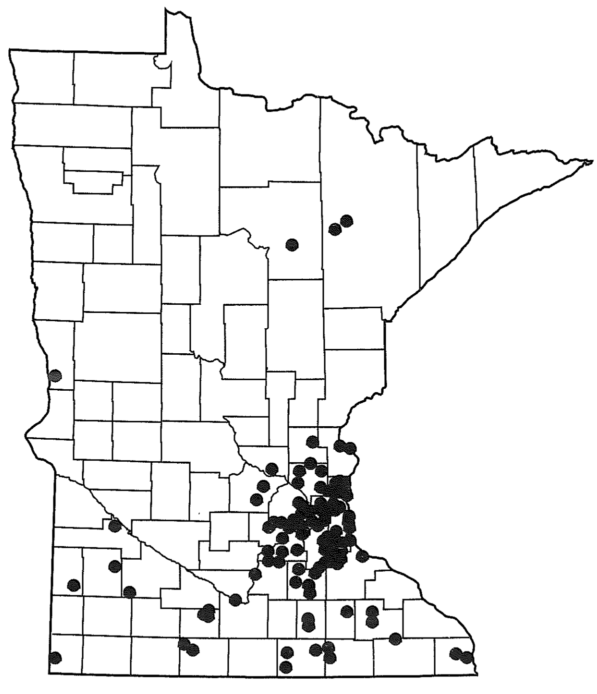


Figure 4

Bedrock Observation Wells



Unconfined Aquifers (Water Table)

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 snow melt. 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 5. The wells identified by number are also the subject wells in Figure 6. Figure 6A shows the standard hydrographs for these wells over the entire period of record. Figure 6B shows hydrographs for the two-year period under discussion. Also shown on Figure 6B is the monthly precipitation recorded at a station near each well.

The representative unconfined obwells reflect the precipitation patterns throughout the state overlaid on the normal seasonal fluctuations. In WY02, high precipitation in late summer produced unusually high late summer unconfined aquifer water levels.

Figure 5 Location of Representative Unconfined Wells

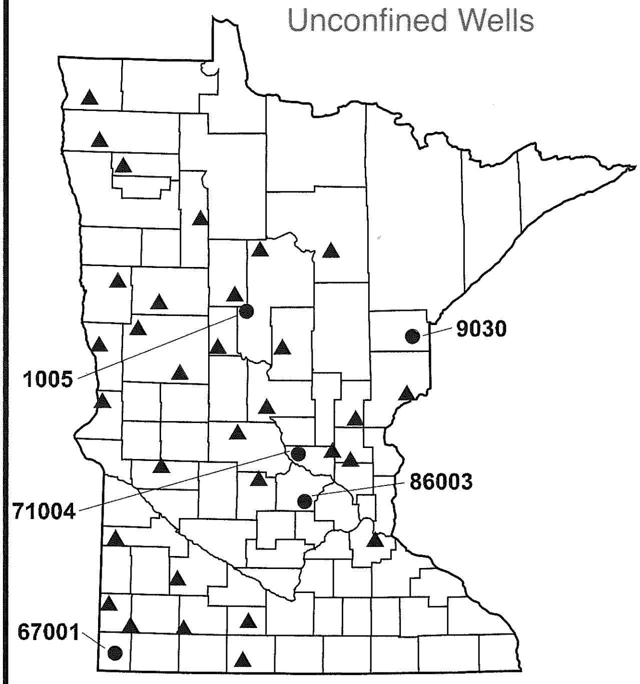


Figure 6A.

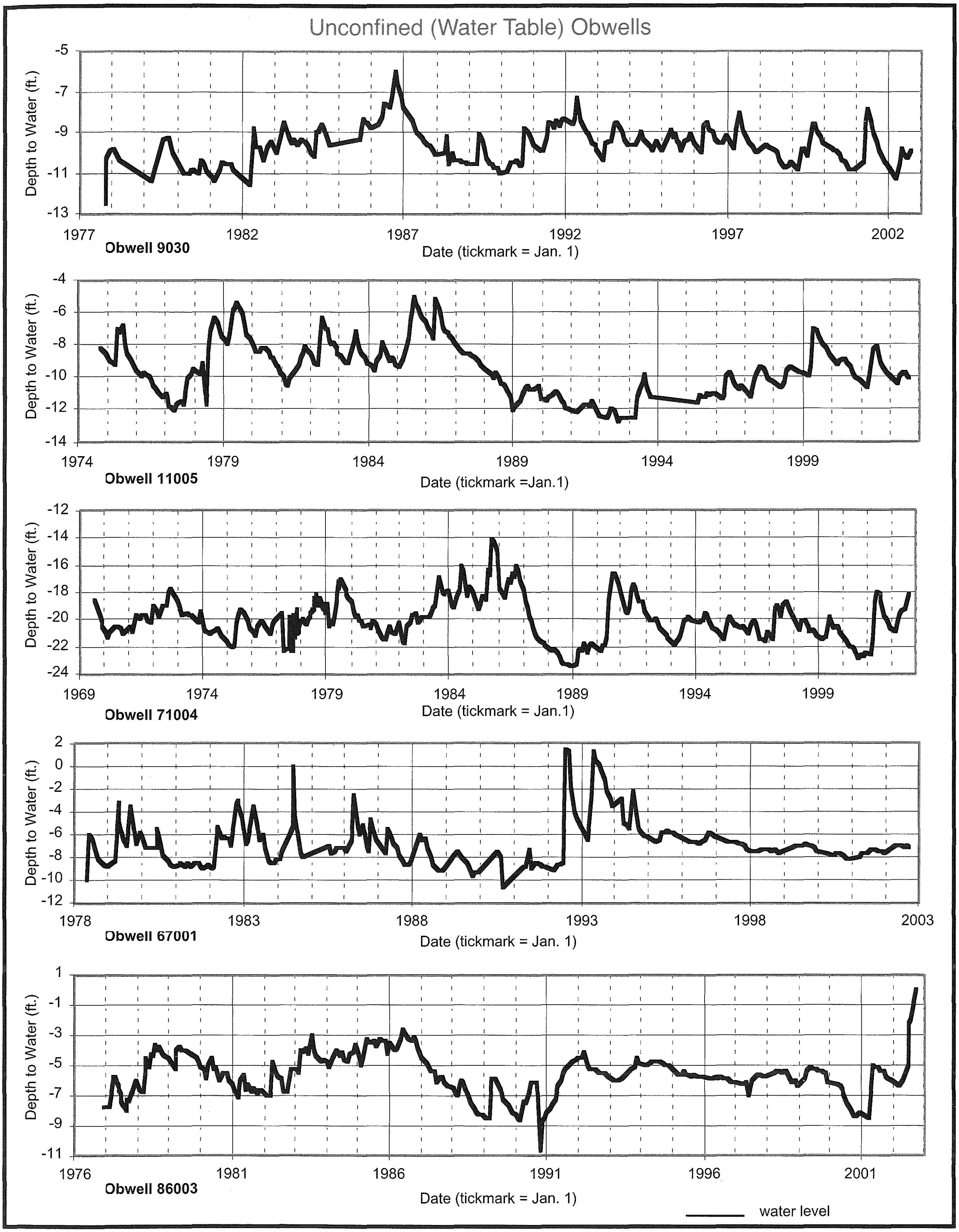
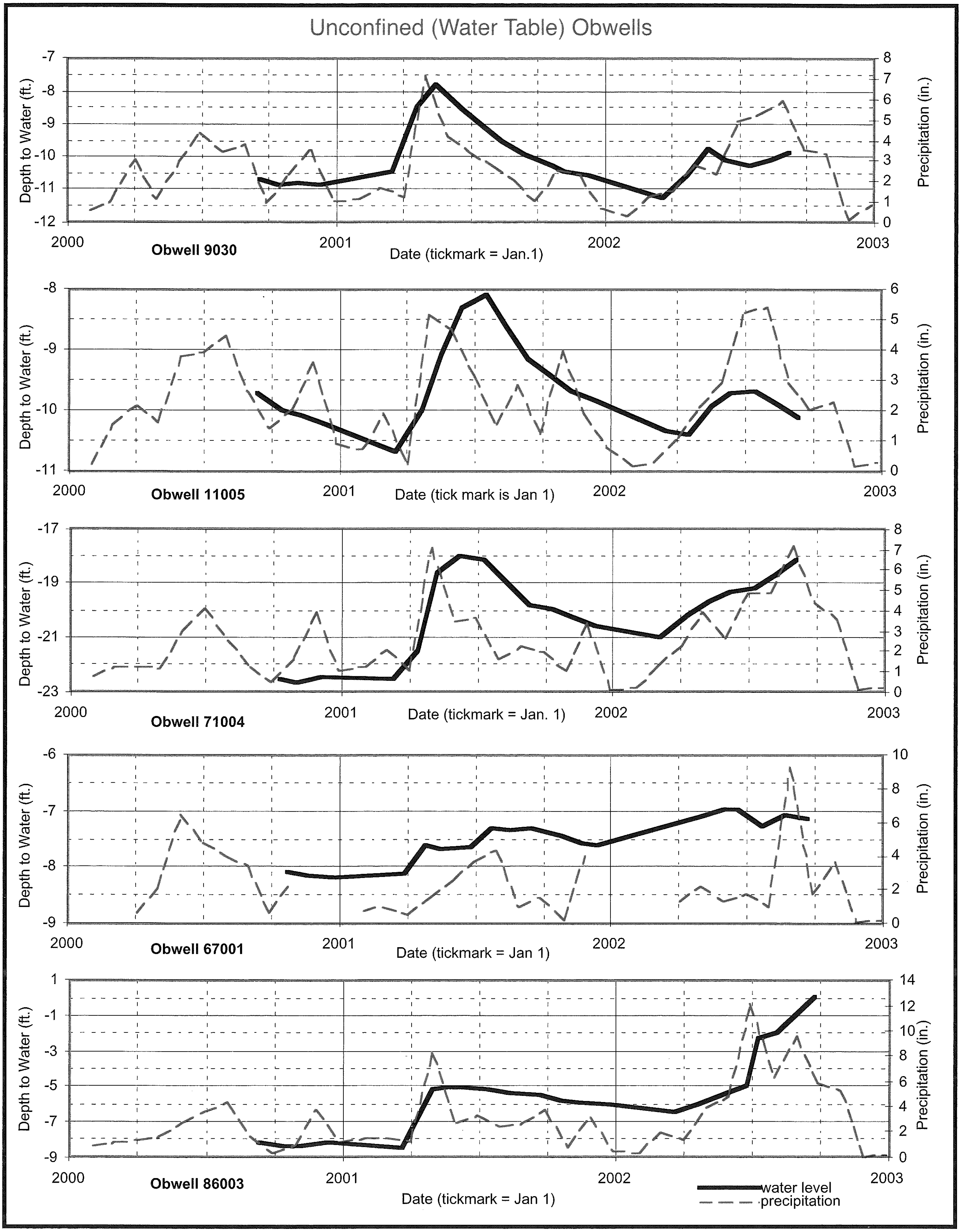

Unconfined (Water Table) Obwells
Depth to Water (ft.)
Obwell 9030
Date (tickmark = Jan. 1)
Obwell 11005
Date (tickmark =Jan.1)
Obwell 71004
Date (tickmark = Jan.1)
Obwell 67001
Date (tickmark = Jan. 1)
Obwell 86003
Date (tickmark = Jan. 1)
water level

Figure 6B


Unconfined (Water Table) Obwells
Depth to Water (ft.)
Precipitation (in.)
Obwell 9030
Date (tickmark = Jan.1)
Obwell 11005
Date (tick mark is Jan 1)
Obwell 71004
Date (tickmark = Jan. 1)
Obwell 67001
Date (tickmark = Jan 1)
Obwell 86003
Date (tickmark = Jan 1)
2000
2001
2002
2003
water level
precipitation

Confined Aquifers

Changes in precipitation patterns are usually not reflected in confined aquifers until after the extreme (dry or wet) precipitation pattern has been in existence for an extended period or has ended. This is due primarily to the presence of an overlying confining bed, which inhibits a direct response to the precipitation pattern. Observation wells in confined aquifers reflect that general rule.

Buried Drift Aquifers

Under confined conditions, these aquifers generally respond more slowly to seasonal inputs from snow melt and precipitation than water table aquifers. 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.

The approximate locations of the buried drift wells used in this summary are shown in Figure 7. The wells identified by number are also the subject wells in Figure 8. This illustrates the standard hydrographs of these wells over the entire period of record.

In the northern portion of the state, buried drift water levels continue the downward trend established in recent water years. In central Minnesota, the downward trend is also evident and is emphasized by irrigation use. In the southern portion of the state, no trend is discernable, but fewer extremes, high or low, are evident.

Buried drift levels in the Twin Cities Metro are muddled by induced recharge to the bedrock system. That is, most public supply is pumped from the underlying bedrock aquifers, which causes a downward draw on buried drift water levels and an enhanced leakage to the bedrock.

Bedrock - Prairie du Chien - Jordan Aquifer

The Prairie du Chien/Jordan aquifer is usually considered to be in a confined condition. However, locally, it may respond as an unconfined aquifer in situations where the aquifer is adjacent to unconfined materials. Examples might include areas where buried glacial valleys intersect the aquifer or where the aquifer is the first bedrock under surficial, unconfined sands.

Locations of the Prairie du Chien/Jordan wells used in this report are shown in Figure 9. Wells identified by number are those wells for which hydrographs are shown in the figures that follow. Prairie du Chien/ Jordan water levels reflect the intensity of human use for water supply. Annual pumping cycles are clearly visible in these hydrographs. Figure 10 shows the hydrograph for the period of record of these wells.

Figure 7 Location of Representative Buried Drift Wells

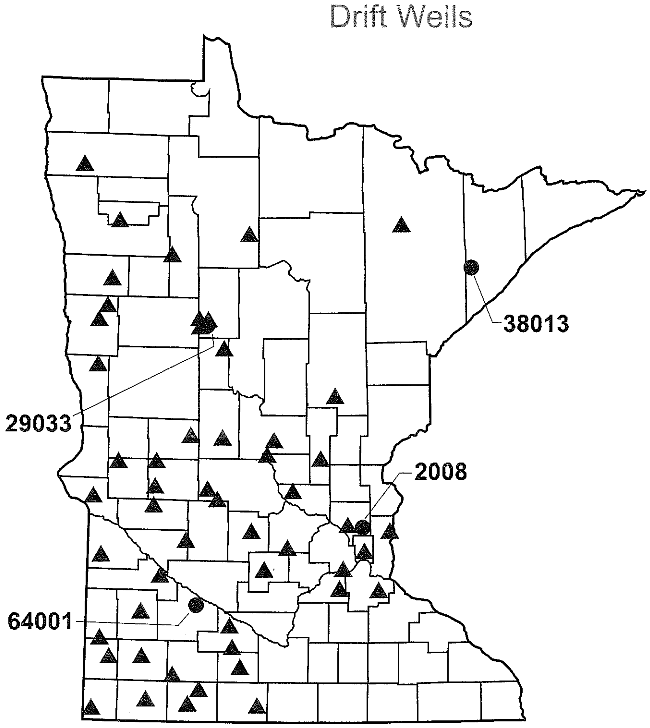
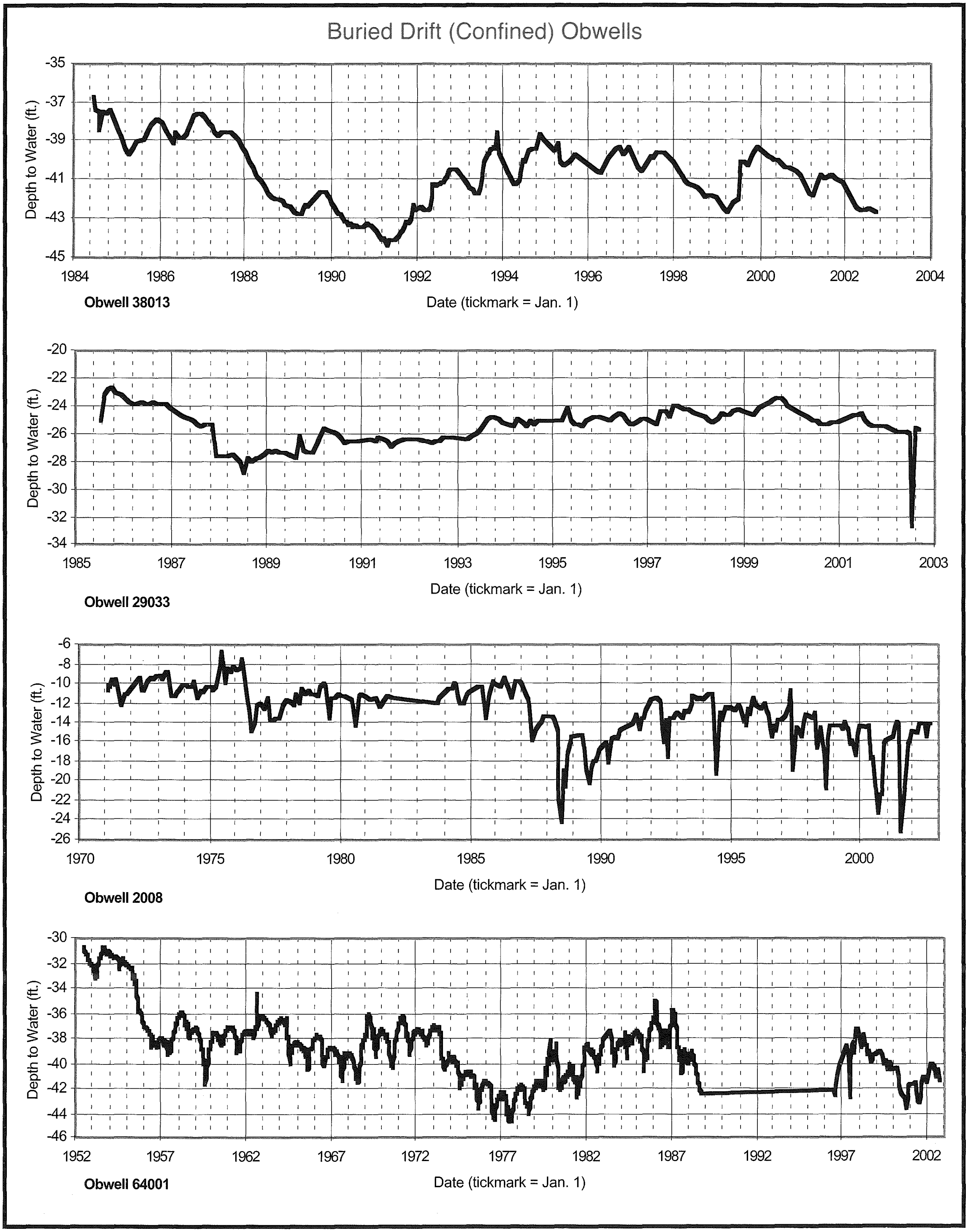


Figure 8


Buried Drift (Confined) Obwells
Depth to Water (ft.)
-35
-37
-39
-41
-43
-45
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
Obwell 38013
Date (tickmark = Jan. 1)
Depth to Water (ft.)
-20
-22
-24
-26
-28
-30
-32
-34
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
Date (tickmark = Jan. 1)
Obwell 29033
Depth to Water (ft.)
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
1970
1975
1980
1985
1990
1995
2000
Date (tickmark = Jan. 1)
Obwell 2008
Depth to Water (ft.)
-30
-32
-34
-36
-38
-40
-42
-44
-46
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
Obwell 64001
Date (tickmark = Jan. 1)

Bedrock - Mt. Simon Aquifer

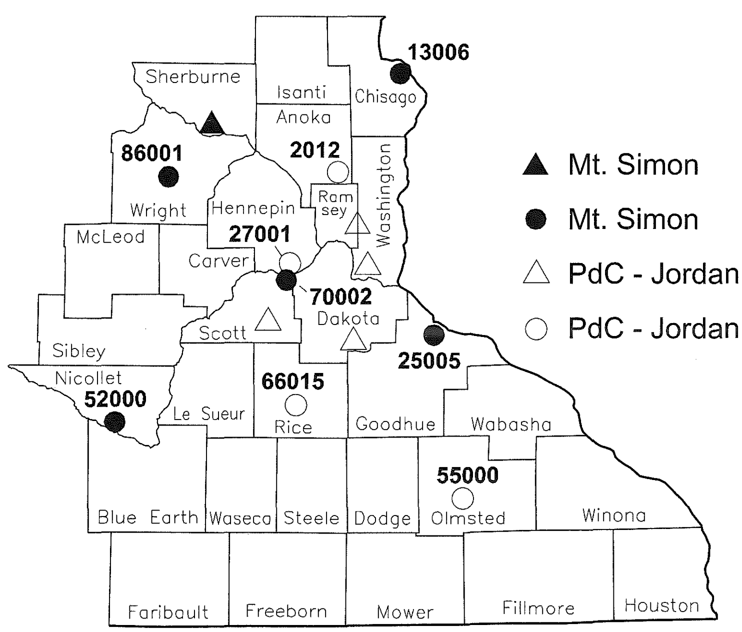
With some exceptions, the Mt. Simon aquifer is everywhere confined. It may respond as an unconfined aquifer in the atypical instances where the aquifer is adjacent to unconfined materials, such as along deeply incised buried glacial valleys.

Locations of the Mt. Simon wells used for this summary are shown in Figure 9. The wells identified by number are also the subject wells in the hydrographs that follow. Figure 10 shows the standard hydrographs for these selected wells over their entire period of record plotted against elevation.

The trace of Obwell 70002 shows the impacts of human use on this aquifer. The overall impact of the entire basin has been to reduce heads approximately 40' since predevelopment. This does not imply that the Mt. Simon aquifer is being depleted, but rather it illustrates that this aquifer is vulnerable to overuse.

Figure 9

Location of Representative Prairie du Chien-Jordan and Mt. Simon Wells



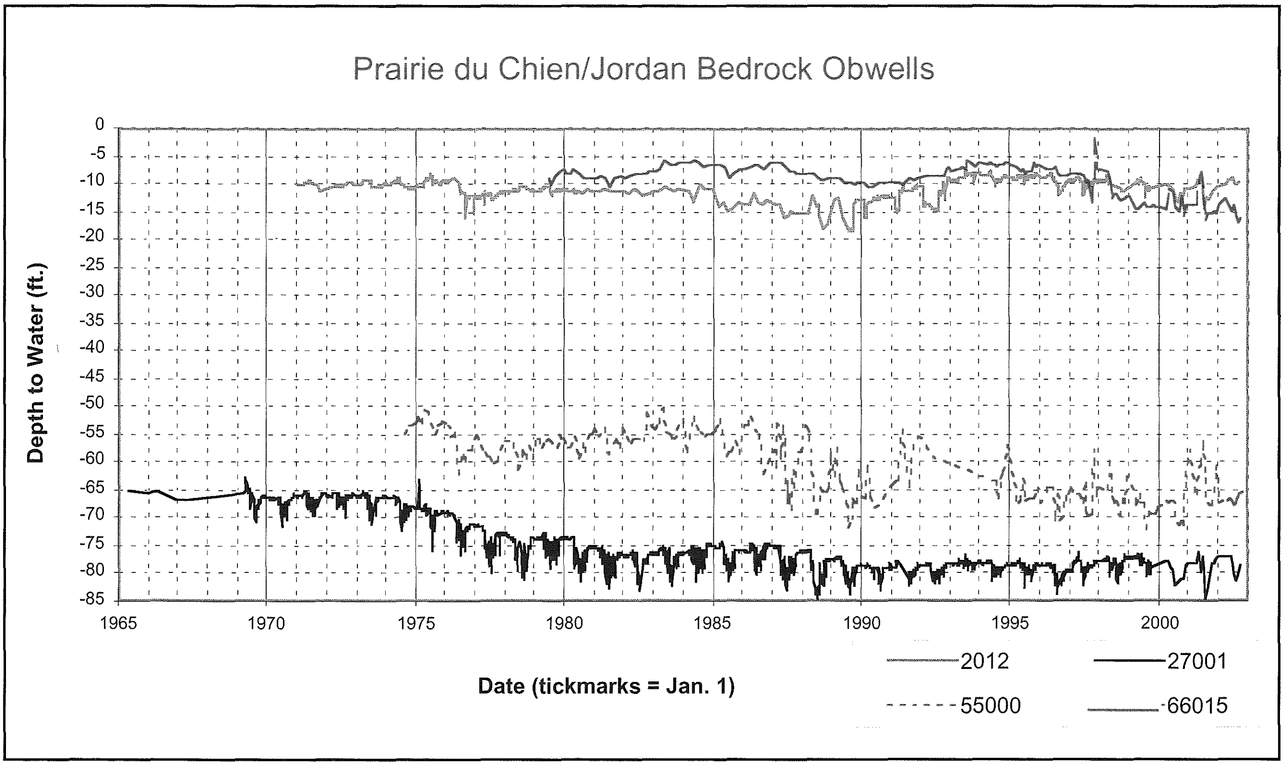
Network Improvement

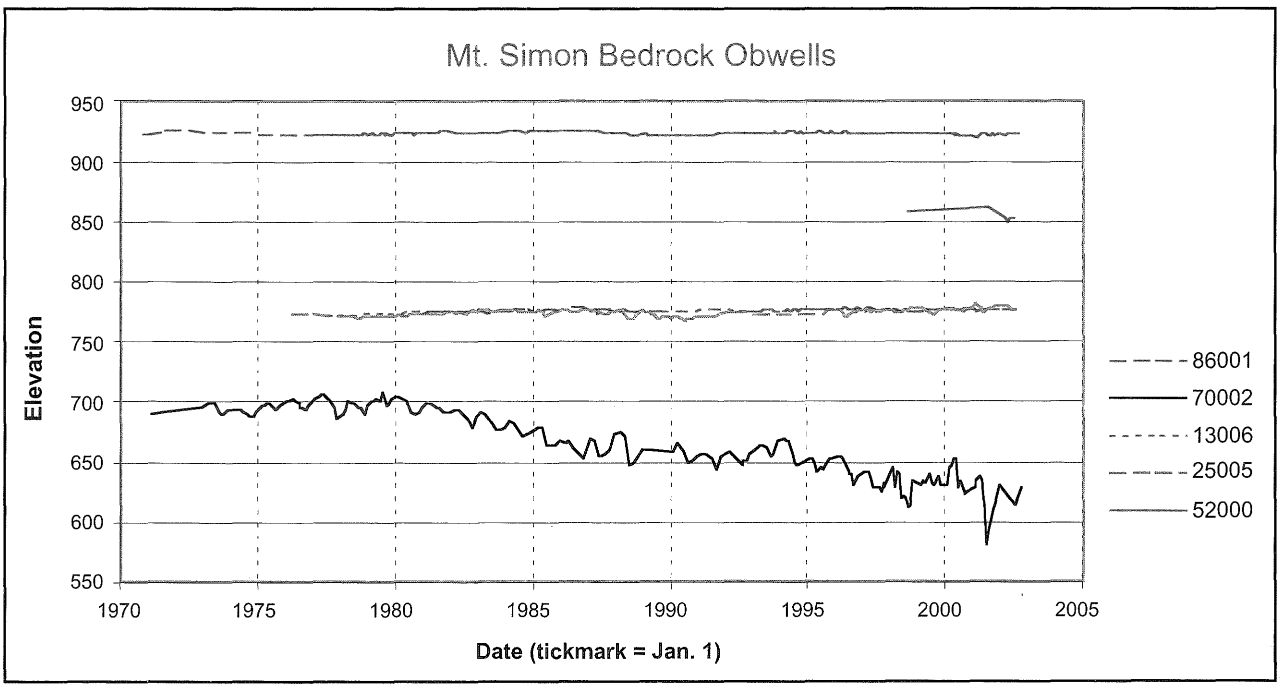
A systematic review of each obwell continues. During this review, each obwell will be visited by DNR hydrogeologists. When feasible, physical tests, such as slug tests and gamma logging, will be performed on obwells in order to confirm their quality and usefulness within the network. In addition, an elevation for each obwell will be obtained using global positioning system (GPS) equipment. Although around 750 obwells are actively monitored, the database contains some information for nearly twice that many obwells. The fate of the inactive obwells will be determined so that appropriate management actions can occur. The review of each aquifer will include an analysis of the coverage and water levels, which could result in a change of monitoring frequency or obwell distribution. This review will take several years to complete.

DNR Waters' program of exploratory drilling and observation well installation continued on a more limited basis. Several shallow obwells that were no longer functioning properly or that were lost due to a variety of circumstances such as inadvertent sealing, road construction, and land-owners' decisions to eliminate the wells from their property, were replaced.

The vibrating wire piezometer, a technology used in civil engineering, has been adapted to monitor ground water levels. The piezometer is placed at the desired depth in a borehole or well and is sealed in place. Measurements are taken at the ground surface using a computer and a data logger. This technique was first used by DNR Waters in WY99 to continue the record of a Mt. Simon aquifer obwell, which was sealed due to development. The technique has now been used for many wells throughout the state. In addition, drilling for a multi-point piezometer in southern Dakota County is proceeding. Several vibe wires have already been installed at this location. When complete, piezometers will be inplace in each aquifer and confining layer from the Shakopee Formation down into the Mt. Simon aquifer. These data points are expected to contribute valuable data for understanding the interaction and replenishment of our water supply aquifers.

Figure 10


Prairie du Chien/Jordan Bedrock Obwells
Depth to Water (ft.)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
1965
1970
1975
1980
1985
1990
1995
2000
Date (tickmarks = Jan. 1)
2012
27001
55000
66015


Mt. Simon Bedrock Obwells
Elevation
950
900
850
800
750
700
650
600
550
1970
1975
1980
1985
1990
1995
2000
2005
Date (tickmark = Jan. 1)
86001
70002
13006
25005
52000

all ground water monitoring is not the same...

What is a ground water level observation well?

Ground water levels may be obtained from wells that are drilled for the exclusive purpose of measuring ground water levels. They are just as likely though to be obtained from other types of wells or piezometers, which are or were used for some other purpose. For instance, some ground water level observation wells (obwells) are large diameter municipal water supply or irrigation supply wells. Others are or were smaller diameter domestic supply wells. And yet other wells were installed as part of an aquifer study or a ground water quality study of an area of specific interest. Instead of drilling new wells, existing wells are incorporated into the ground water level network whenever possible if the existing well meets the specifications for well construction and if the existing well is in a location where ground water levels are needed.

Minnesota Statutes and Rules contain the well code that the Minnesota Department of Health uses to determine the type of well construction needed for a particular well use. For at least the last eleven years, wells for the ground water level network were installed by DNR Waters to higher construction standards than the well code requires so that these wells may also be used by other agencies for water quality monitoring (water withdrawn).

Why isn't all ground water monitoring for both water quality and water levels completed at the same well at the same time?

Many differences in the location, construction, measurement technique and purpose exist between ground water quality monitoring wells and ground water level observation wells. A water level taken at a water quality monitoring well may not be useful for the study of ground water levels and the requirements for obtaining useable water quality samples are often not compatible with the needs for ground water level data. Why? There are several reasons...

• Location - Obwells are usually located away from points of pumping influence in order to monitor the general water level of the aquifers although obwells may also be placed near points of appropriation for compliance monitoring. Much water quality monitoring is done in relation to a point of contamination or at a statistically based location for background water quality monitoring (that is wells to be sampled are selected on a location grid regardless of the aquifer). If an obwell happens to match the statistical location, that obwell may be used for water quality sampling. Most often though, the location where ground water level data is needed is seldom where water quality data is wanted. DNR Waters avoids using contaminated wells for ground water level measurement in order to avoid health risks.

• Quality control -Although DNR Waters assembles ground water level data collected by many sources, obwell data collected by the SWCDs is separated from water level data collected by others because we cannot be certain of the measurement method used by others. Water quality sampling is even more exacting. Persons taking water quality samples must be trained in the quality control methods that are applicable and must be trained about the health risks associated with contaminated water.

• Well construction -

Materials: Water quality is affected by well construction. PVC, which is used for most new obwells, can't be monitored for some chemicals because of interference from the PVC or the glue used. On the other hand, steel may be inappropriate for other water quality parameters.

Diameter: Many shallower obwells are 2" or less in diameter. It can be difficult to obtain water quality samples from many such small diameter wells. The deeper obwells that DNR Waters drills are usually constructed of 4" steel. Because DNR Waters' ground water level wells are constructed to a higher standard than is required, other agencies may use these wells for water quality monitoring; however, those wells may not be at a location where water quality monitoring is needed.

Screen: The screen of ground water level wells is usually placed as deep into an aquifer as feasible in order to always have a water level if the ground water level of the aquifer drops. However, for some water quality monitoring, such as for nitrates, the screen is set right at the existing water level in order to detect the substance of interest as it reaches the water table.

• Frequency and trip saving- Water level readings are generally taken once per month and sometimes more frequently. Water quality samples are collected much less frequently, perhaps once or twice per year. Fifteen to twenty or more water levels can be taken in one day depending on distance between the wells, but the number of wells from which water quality samples can be taken in a day is considerably less so several days would be needed instead of one in order to visit each well for both reasons.

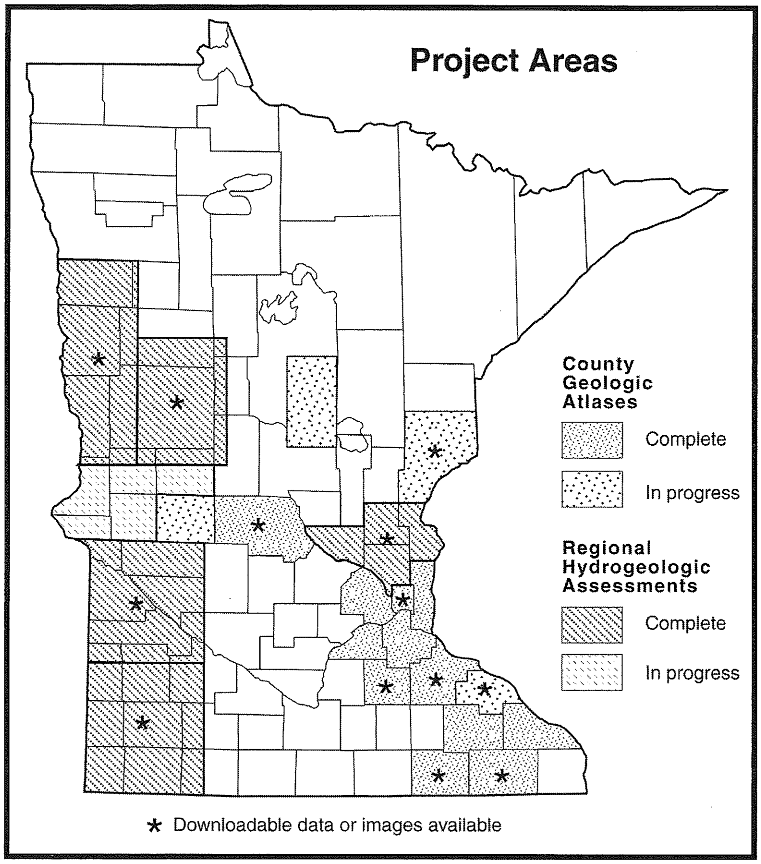
Local, state and federal water management agencies are aware of and have access to the location of the obwells. The Minnesota Pollution Control Agency is reviewing obwell locations for their newest monitoring program. The Minnesota Department of Agriculture and the Minnesota Department of Health have used obwells for other monitoring studies and the Minnesota Geological Survey has recently been using obwells for their Prairie du Chien fracture flow study. Ground water level wells are also used for water quality sampling by DNR Waters' hydrogeologists to determine the geochemical properties of the ground water for use in mapping aquifers and ground water flow patterns.

County Geologic Atlas and Regional Hydrogeologic Assessment Program

Ground Water Data Use

For nearly twenty years the Minnesota Geological Survey (MGS) has been conducting county and regional-scale basic geologic and hydrogeologic data gathering and interpretation. About ten years ago, DNR Waters joined the MGS in this effort, concentrating on the hydrogeology of the study areas. The results of this work are the County Geologic Atlases and Regional Hydrogeologic Assessments.

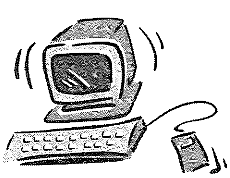
In addition to the well and geologic data collected by the MGS, project staff utilize DNR Waters databases, particularly data available from the Ground Water Level Program. Other DNR Waters data sources are also used, including climatology, water use permits, and geophysical study reports. Project staff also measure water levels in wells and collect water samples for chemical and isotopic analysis.



Data Available Online

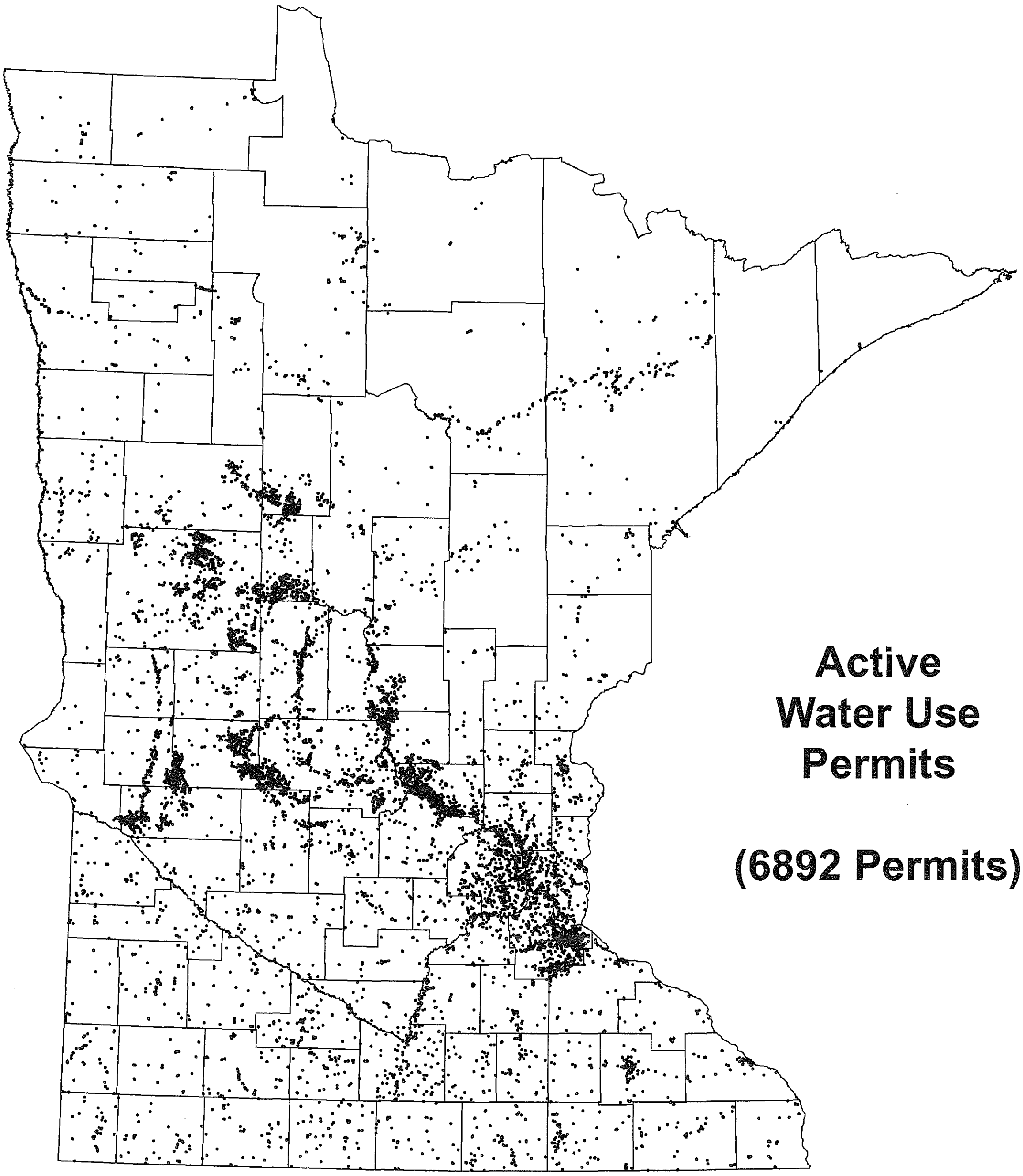
Digital data for many Atlas and Assessment projects, including geographical information systems (GIS) and related resource data can be downloaded over the internet. Some map plate images and documents are also available as portable document format (PDF) files. Many GIS files have detailed data descriptions (metadata) available.

Digital data for many projects can be downloaded for use in GIS programs such as ArcView and EPPL7. Map viewers (at no or low cost) such as ArcExplorer can also be used to visualize the downloaded data. Some project digital data is not downloadable but is available on request.



Project data can be found on the DNR Waters web site at
http://www.dnr.state.mn.us/waters/
Links to MGS project data on their ftp site are also on the DNR Waters web site.
For more information on MGS project data see the MGS web site at
http://www.geo.umn.edu/mgs/.

chapter four
water use



Active Water Use Permits

(6892 Permits)

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 (CY) 2000 and 2001.

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 in mining activities, paper mill operations, food processing, etc. Three-fourths or more of withdrawals are from surface water sources. Consumptive use varies depending on 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.

Statewide Water Use Comparison for 2000 and 2001

Water use in 2000 was 1340.5 billion gallons (BG) and was the highest use ever reported. 2001 reported use represents a 5% decrease from the 2000 total and is closer to the values reported in 1998 and 1999. 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 use was for public supply, increasing by 14 BG or 7%. The largest decrease in use was for industrial processing, decreasing by 63 BG or 37%.

Figure 2 graphically shows the changes in use patterns for 4 main use categories (excluding power generation) from 1985 to 2001. Water use in 2001 for irrigation and public supply was the highest since the drought year 1988. The pattern seen in irrigation reflects low use in times of high precipitation and large use in times of drought. Industrial processing use is influenced by economic vitality. In 2001, water use for industrial processing decreased from past years mainly due to a decline in mine pit dewatering for hard rock mining.

Figure 1

Water Use Comparison by Major Category: 2000 & 2001
(Billions of Gallons)

	Water Use				Change from 2000 to 2001	
	2000		2001			
Use Category	**BG**	**% of Total**	**BG**	**% of Total**	**BG**	**%**
Power Generation	829.3	62%	798.5	63%	-31	-4%
Public Supply	196.5	15%	210.6	16%	14	7%
Industrial Processing	173.0	13%	109.8	8%	-63	-37%
Irrigation	83.0	6%	96.2	8%	13	16%
Other	58.7	4%	58.2	5%	-1	-1%
Totals	**1,340.5**	**100%**	**1,273.3**	**100%**	**-68**	**-5.0%**

A comparison of surface water versus ground water use for 2001 (Figure 3) shows that the majority of appropriations are from surface water sources. However, if the non-consumptive water use for power generation is removed, uses of ground water and surface water are more even (non-consumptive use means water that is immediately returned to its source after use). Figure 4 shows the long-term trend of ground water versus surface water use. Ground water is the primary source for irrigation and public supply, categories that increase in dry years due to demands for crop irrigation and for lawn watering. In 2001, 80% of withdrawals in Minnesota were from surface water sources with 63% of the total use for power plant cooling, a relatively non-consumptive use.

Surface water use decreased from 2000 to 2001 due to decreased appropriation for power generation and industrial processing. Ground water use increased from 2000 to 2001 due to greater demand for irrigation.

Figure 2

Minnesota Water Use - 1985 to 2001
(Billions of Gallons)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Power Generation	508	539	637	663	664	698	694	679	722	765	748	710	701	785	812	829	798
Public Supply	171	170	192	203	174	164	170	175	164	178	180	189	185	192	184	197	211
Industrial Processing	109	76	69	94	120	102	115	158	127	120	160	147	159	169	166	173	110
Irrigation	49	30	67	103	86	71	60	63	30	56	62	80	58	77	72	83	96
Other	49	42	38	42	48	53	52	58	63	64	60	57	63	58	65	59	58
	886	**857**	**1003**	**1105**	**1092**	**1088**	**1091**	**1133**	**1106**	**1183**	**1210**	**1183**	**1166**	**1281**	**1299**	**1341**	**1273**

column totals may not sum due to independent rounding

Minnesota Water Use
(excluding Power Generation)
in Billions of Gallons

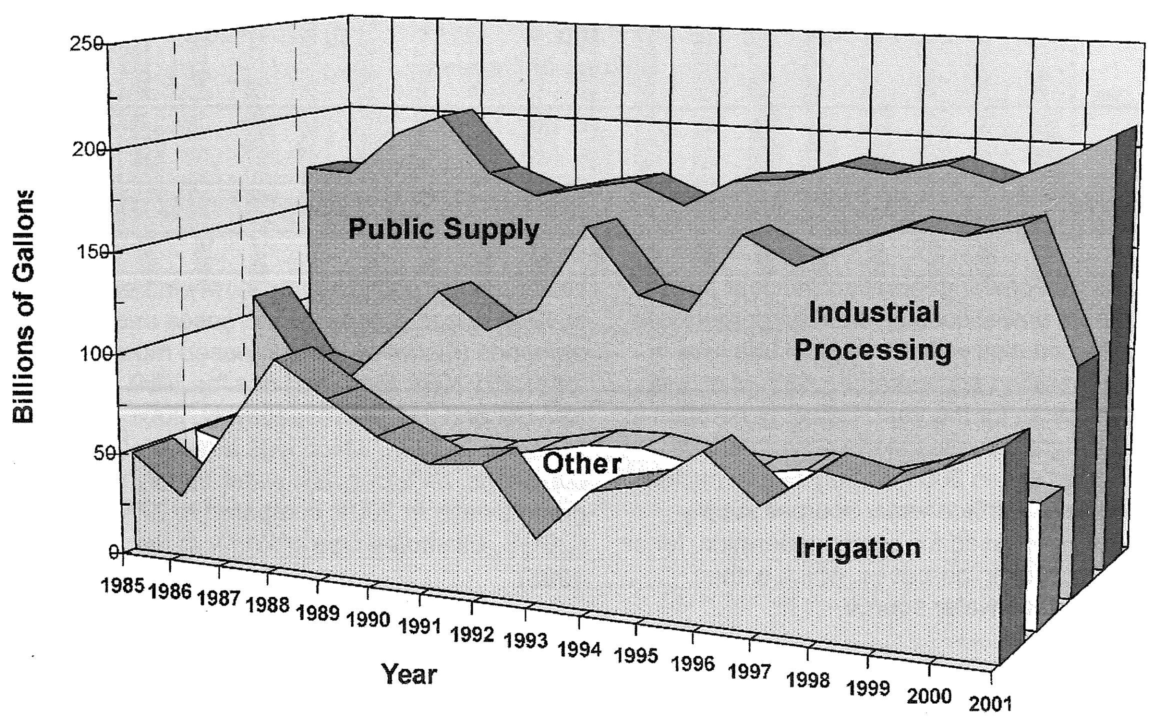
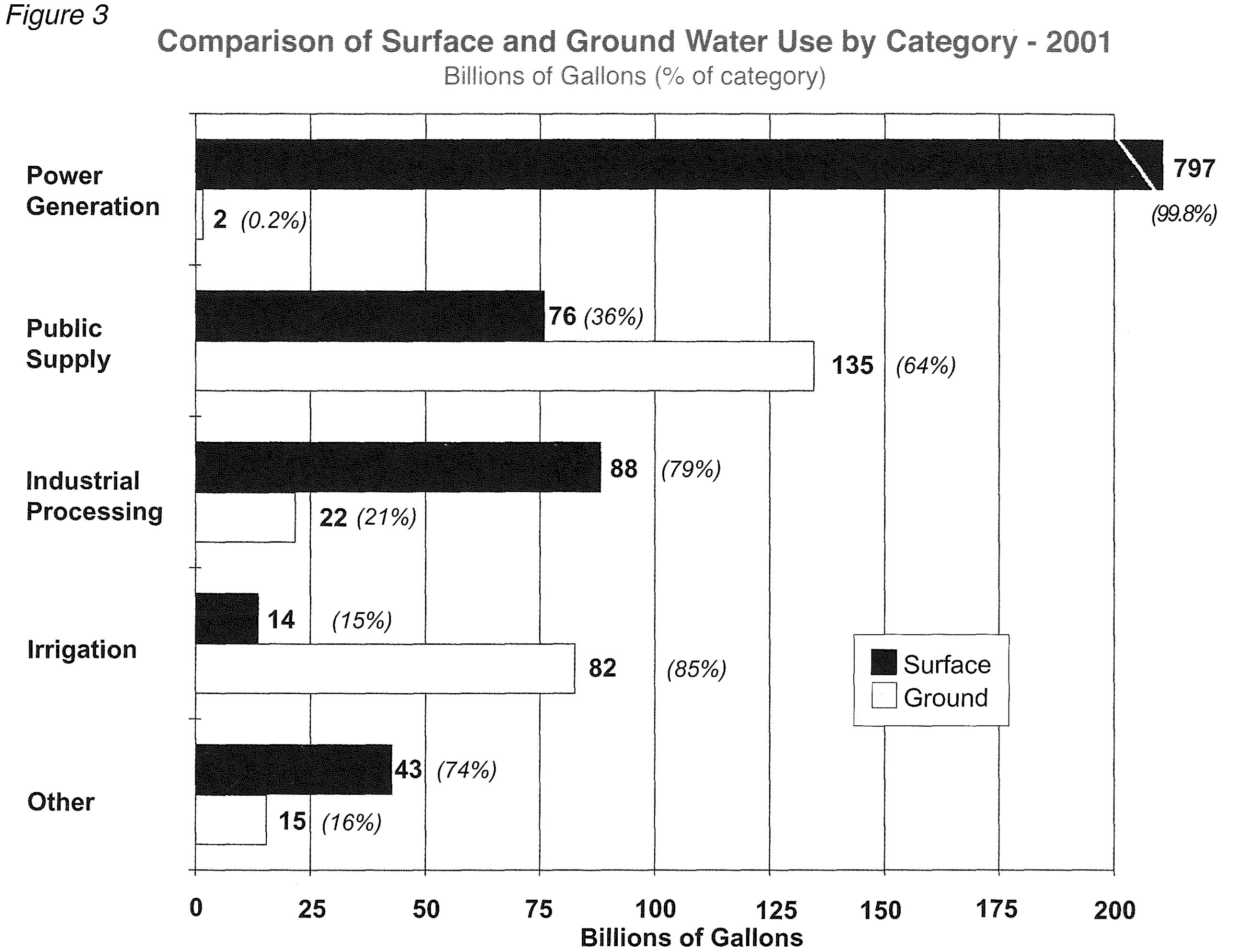


Figure 3



Power Generation

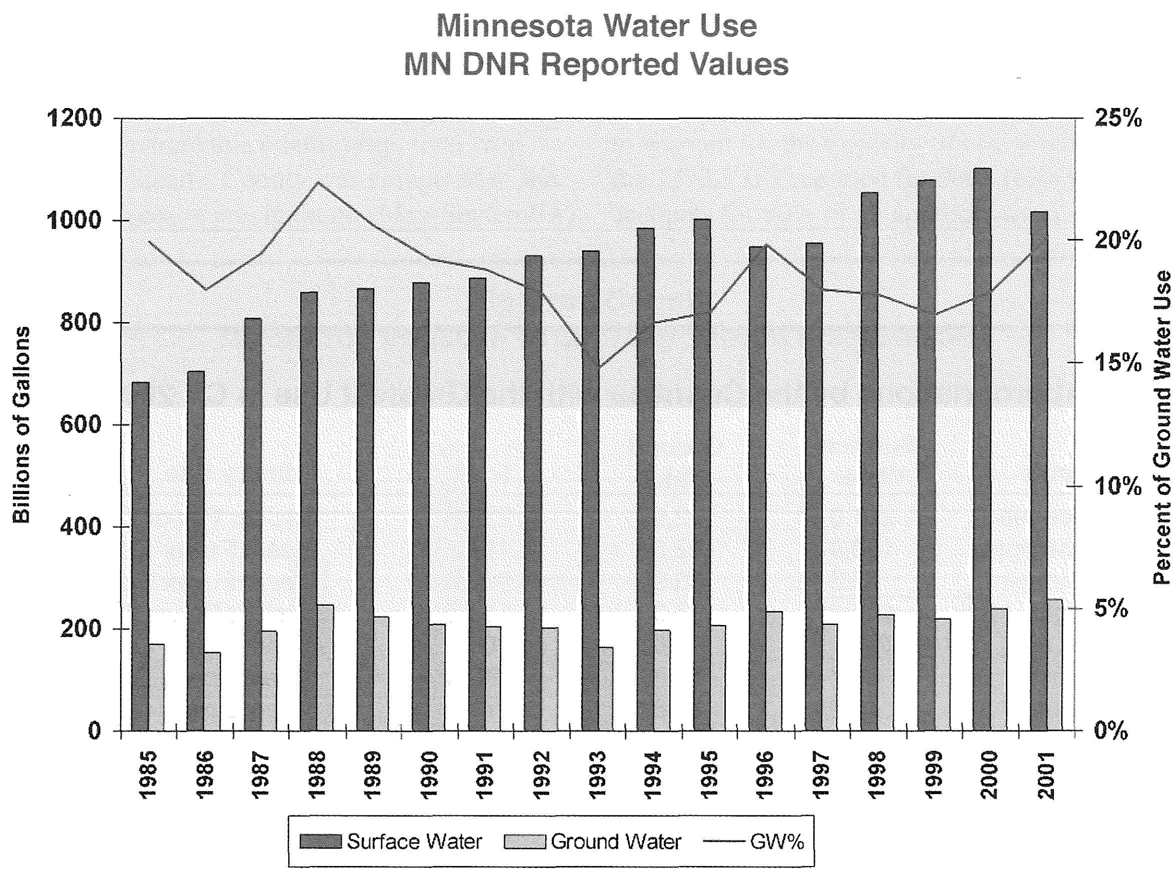
Figure 5 shows that power generation (nuclear power cooling and steam power cooling) was the primary use in nine of the 10 counties with the highest total use in 2001. Power generation accounted for 63% of all use reported in Minnesota for the year. Power generation in Goodhue and Wright Counties alone accounted for 26% of all reported use in 2001, largely due to nuclear power plant cooling. Surface water sources supply almost all of the water used for power generation. Most of the water is for cooling purposes, which is then returned to the surface water source.

Public Water Supply

Water use for public supply slowly increased from 1990 to 1999 due to population increases and industrial demands (Figure 2), but increased more dramatically in 2000 and 2001. Reported use for 2000 and 2001 was 197 BG and 211 BG respectively. 2001 use surpassed the spike in 1988, which was a result of drought conditions. 64% of public water supply use came from ground water in 2001, compared to 37% nationally (USGS, *Estimated Use of Water in the United States in 1995*).

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 municipal 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.

Figure 4



Irrigation

Annual variations in the amount and distribution of rainfall greatly affect the demand for irrigation water. Combined irrigation use for calendar years 2000-2001 was 20% higher compared to the previous two-year period.

Irrigation accounts for only a small amount (8%) of total use in Minnesota. However, this use is significant because it is almost entirely consumptive and the majority is from ground water sources (86%). The timing of irrigation use can be significant when evaluating regional water supplies and the potential for well interferences. Almost all irrigation use is compacted into the five-month period from May to September of each year.

Otter Tail and Sherburne Counties reported the highest water use for irrigation in 2001, using 20.7 BG and 17.7 BG respectively. Roseau County was the only county that reported no use for irrigation in 2001, while Lake and Traverse Counties each reported less than 10 million gallons for the year.

Industrial Processing

Industrial processing use decreased 36% from 2000 to 2001, a very large drop. Mining use decreased by 50%, accounting for most of the decline. Pulp and paper processing and agricultural processing accounted for 23% and 9%, respectively, of the total volume reported in this category.

Figure 5

Appropriations by the Counties with the Greatest Use in CY 2001

	County	Surface Water	Ground Water	Total	Primary Use
1)	Goodhue	221.0	2.6	223.6	Nuclear Power Cooling
2)	Washington	100.9	12.3	113.2	Steam Power Cooling
3)	Hennepin	75.3	36.9	112.2	Steam Power Cooling
4)	Wright	107.6	3.2	110.7	Nuclear Power Cooling
5)	St. Louis	107.1	2.0	109.1	Steam Power Cooling
6)	Ramsey	64.7	13.7	78.4	Steam Power Cooling
7)	Dakota	48.6	26.8	75.4	Steam Power Cooling
8)	Itasca	70.4	1.3	71.7	Steam Power Cooling
9)	Anoka	38.2	12.0	50.1	Municipal Waterworks
10)	Lake	47.6	0.0	47.6	Steam Power Cooling
	Total	**881.4**	**110.8**	**992.0**	
	millions of gallons	*87% of* SW Use	*43% of* GW Use	*78% of* Total Use	

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 4% of Minnesota's total water use.

Irrigation-Precipitation Connection

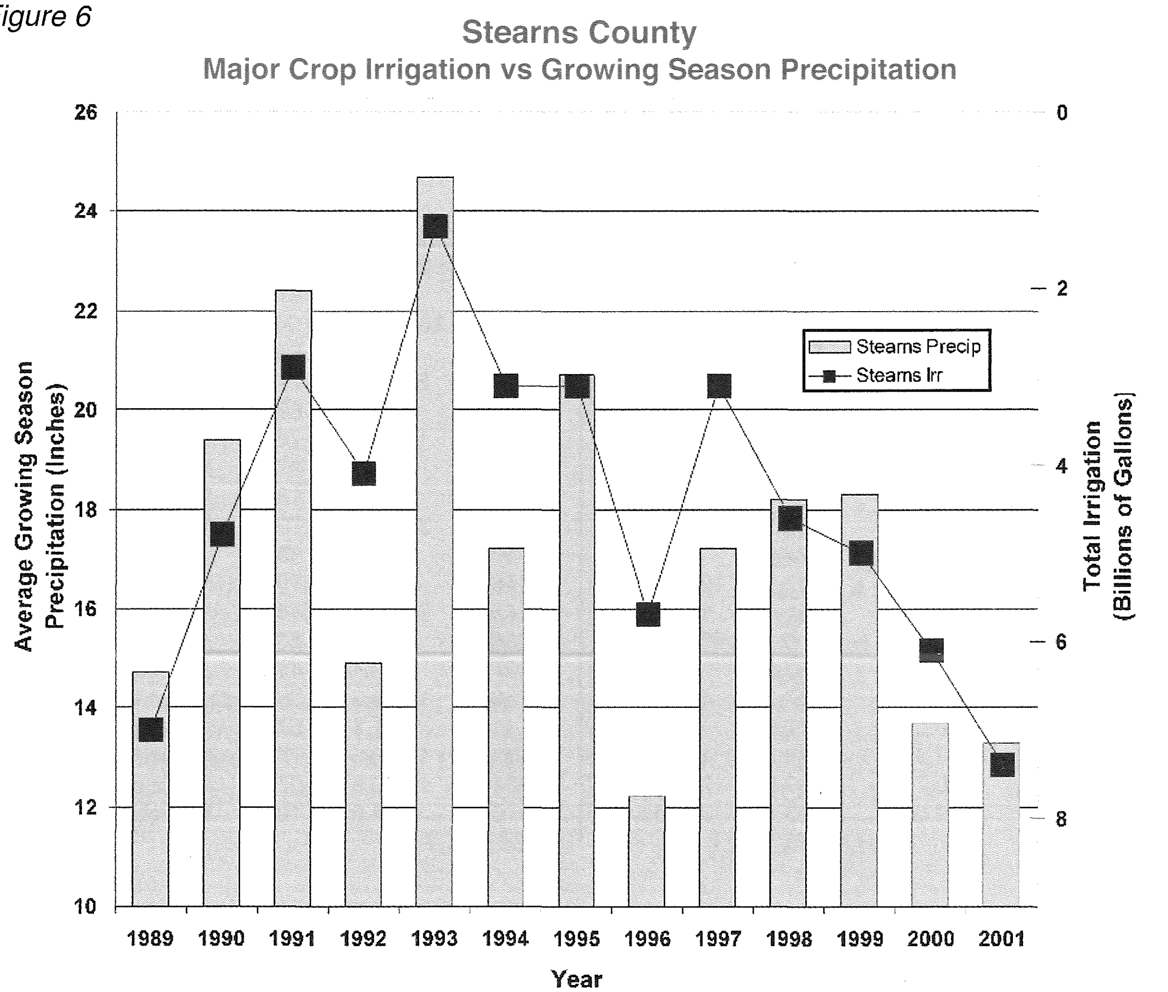
A strong correlation exists between precipitation and irrigation water demand for a given area: the higher the amount of precipitation received, the lower the need to add moisture to the soil to ensure vigorous plant growth. To demonstrate this relationship, total crop irrigation use for Stearns County was compared to the average growing season precipitation (May-September) recorded for the county (Figure 6). Note that the data axis for irrigation (on the right side of the graph) is reversed to visually show a positive correlation.

In addition to amounts and distribution of precipitation, irrigation demand is also influenced by the soil moisture conditions that exist before the growing season starts, temperatures during the growing season and the water demands of the various crops grown.

Summary

Total water use in 2001 decreased from the record water use reported in 2000. Power generation continues to account for the majority of use, totaling 798.5 BG of the 1273.3 BG reported for 2001 (63%). Surface water accounts for 80% of all appropriations.

Figure 6



Reported Water Use by County 2000 - 2001 (Millions of Gallons)

Reported Water Use

County	2000 Surface	2000 Ground	2000 Total	2001 Surface	2001 Ground	2001 Total	Primary Use	% of 2001 Total
1 Aitkin	1,255.8	89.1	1,344.9	971.7	93.2	1,064.9	Wild Rice Irrigation	86
2 Anoka	38,801.0	12,181.4	50,982.4	38,152.0	11,961.7	50,113.7	Municipal Waterworks	95
3 Becker	23.2	2,749.1	2,772.3	34.1	3,150.6	3,184.7	Major Crop Irrigation	68
4 Beltrami	1,131.3	690.2	1,821.5	1,465.9	762.0	2,227.9	Wild Rice Irrigation	63
5 Benton	3,572.6	3,752.8	7,325.4	3,635.0	4,485.9	8,120.9	Industrial Processing	43
6 Big Stone	16.2	373.0	389.2	11.6	488.8	500.4	Major Crop Irrigation	55
7 Blue Earth	7,686.2	3,731.2	11,417.4	8,765.0	3,768.9	12,533.9	Steam Power Cooling	69
8 Brown	113.8	1,009.1	1,122.9	107.5	999.6	1,107.1	Major Crop Irrigation	44
9 Carlton	2,961.9	657.3	3,619.2	2,915.2	744.5	3,659.7	Pulp/Paper Processing	74
10 Carver	48.1	3,161.8	3,209.9	27.4	3,171.7	3,199.1	Municipal Waterworks	83
11 Cass	23.8	1,026.0	1,049.8	38.4	1,198.0	1,236.4	Major Crop Irrigation	35
12 Chippewa	131.6	570.9	702.5	56.1	584.1	640.2	Municipal Waterworks	75
13 Chisago	270.7	1,187.1	1,457.8	128.6	1,096.4	1,225.0	Municipal Waterworks	58
14 Clay	1,589.1	901.5	2,490.6	1,717.0	1,047.1	2,764.1	Municipal Waterworks	69
15 Clearwater	3,980.4	117.7	4,098.1	3,537.3	118.3	3,655.6	Wild Rice Irrigation	96
16 Cook	54,084.5	10.9	54,095.4	3,892.0	8.8	3,900.8	Mine Processing	96
17 Cottonwood	186.9	997.4	1,184.3	270.9	1,101.1	1,372.0	Municipal Waterworks	38
18 Crow Wing	1,359.9	2,012.1	3,372.0	1,303.6	2,036.9	3,340.5	Municipal Waterworks	36
19 Dakota	66,259.3	23,827.4	90,086.7	48,564.0	26,827.8	75,391.8	Steam Power Cooling	58
20 Dodge	64.5	434.7	499.2	14.0	459.4	473.4	Municipal Waterworks	75
21 Douglas	123.2	1,489.2	1,612.4	140.7	1,700.3	1,841.0	Municipal Waterworks	36
22 Faribault	0.0	743.3	743.3	0.0	702.5	702.5	Municipal Waterworks	72
23 Fillmore	3,883.2	671.8	4,555.0	3,836.5	632.6	4,469.1	Hatcheries & Fisheries	85
24 Freeborn	23.0	1,847.1	1,870.1	25.9	1,858.1	1,884.0	Municipal Waterworks	82
25 Goodhue	227,210.4	2,329.3	229,539.7	221,022.6	2,610.9	223,633.5	Nuclear Power Cooling	92
26 Grant	0.0	660.1	660.1	0.0	815.5	815.5	Major Crop Irrigation	78
27 Hennepin	74,100.8	36,976.6	111,077.4	75,346.2	36,898.0	112,244.2	Steam Power Cooling	67
28 Houston	79.8	524.8	604.6	26.4	543.2	569.6	Municipal Waterworks	74
29 Hubbard	28.3	4,536.7	4,565.0	61.7	5,711.0	5,772.7	Major Crop Irrigation	81
30 Isanti	4.4	736.3	740.7	3.2	691.3	694.5	Municipal Waterworks	51
31 Itasca	71,446.0	1,397.5	72,843.5	70,406.8	1,336.9	71,743.7	Steam Power Cooling	87
32 Jackson	17.4	283.6	301.0	78.1	293.9	372.0	Municipal Waterworks	64
33 Kanabec	13.2	193.7	206.9	40.3	147.7	188.0	Municipal Waterworks	76
34 Kandiyohi	663.3	3,209.7	3,873.0	650.9	3,139.7	3,790.6	Municipal Waterworks	44
35 Kittson	101.2	424.0	525.2	20.3	312.7	333.0	Rural Waterworks	50
36 Koochiching	19,262.3	32.1	19,294.4	16,748.5	43.9	16,792.4	Pulp/Paper Processing	97
37 Lac Qui Parle	44.2	1,331.4	1,375.6	46.2	1,403.6	1,449.8	Agricultural Processing	44
38 Lake	49,415.2	0.1	49,415.3	47,556.8	1.2	47,558.0	Mine Processing	99
39 Lake of the Woods	333.2	63.2	396.4	337.1	73.4	410.5	Wild Rice Irrigation	80
40 Le Sueur	3,469.2	1,087.3	4,556.5	5,750.2	1,319.3	7,069.5	Quarry/Mine Dewatering	65
41 Lincoln	10.0	517.6	527.6	11.4	561.1	572.5	Rural Waterworks	74
42 Lyon	132.4	1,639.3	1,771.7	133.9	1,638.5	1,772.4	Municipal Waterworks	66
43 McLeod	120.7	2,039.9	2,160.6	207.9	1,867.8	2,075.7	Municipal Waterworks	56
44 Mahnomen	2.0	93.1	95.1	0.0	104.9	104.9	Municipal Waterworks	89

Reported Water Use by County 2000 - 2001 (Millions of Gallons)

Reported Water Use

County	2000 Surface	2000 Ground	2000 Total	2001 Surface	2001 Ground	2001 Total	Primary Use	% of 2001 Total
45 Marshall	124.3	219.2	343.5	150.7	236.5	387.2	Municipal Waterworks	28
46 Martin	6,545.3	316.7	6,862.0	6,232.7	314.6	6,547.3	Steam Power Cooling	87
47 Meeker	14.4	1,677.2	1,691.6	13.9	1,827.2	1,841.1	Major Crop Irrigation	62
48 Mille Lacs	34.0	614.1	648.1	76.2	565.1	641.3	Municipal Waterworks	59
49 Morrison	57.3	4,124.9	4,182.2	72.5	4,230.4	4,302.9	Major Crop Irrigation	80
50 Mower	173.2	2,630.0	2,803.2	144.1	2,756.4	2,900.5	Municipal Waterworks	44
51 Murray	36.9	228.7	265.6	77.1	232.8	309.9	Municipal Waterworks	73
52 Nicollet	56.6	1,781.7	1,838.3	49.8	1,985.0	2,034.8	Municipal Waterworks	85
53 Nobles	47.8	1,094.3	1,142.1	53.5	1,143.1	1,196.6	Municipal Waterworks	94
54 Norman	5.0	146.4	151.4	0.0	144.2	144.2	Municipal Waterworks	90
55 Olmsted	8,010.1	6,599.9	14,610.0	9,314.8	6,542.8	15,857.6	Steam Power Cooling	58
56 Ottertail	26,856.9	10,361.5	37,218.4	27,392.2	12,441.0	39,833.2	Steam Power Cooling	66
57 Pennington	728.1	28.1	756.2	827.0	32.0	859.0	Municipal Waterworks	50
58 Pine	20.2	496.2	516.4	20.9	475.7	496.6	Municipal Waterworks	64
59 Pipestone	55.9	981.3	1,037.2	26.8	938.0	964.8	Rural Waterworks	46
60 Polk	4,674.5	1,113.7	5,788.2	4,159.4	1,055.2	5,214.6	Municipal Waterworks	66
61 Pope	108.0	6,199.0	6,307.0	124.9	7,490.0	7,614.9	Major Crop Irrigation	95
62 Ramsey	50,946.9	14,409.3	65,356.2	64,720.8	13,654.0	78,374.8	Steam Power Cooling	61
63 Red Lake	843.2	381.1	1,224.3	603.8	388.5	992.3	Wild Rice Irrigation	59
64 Redwood	72.1	521.1	593.2	161.6	485.3	646.9	Municipal Waterworks	64
65 Renville	111.7	950.7	1,062.4	55.9	908.4	964.3	Municipal Waterworks	47
66 Rice	289.3	2,432.8	2,722.1	95.5	2,654.2	2,749.7	Municipal Waterworks	78
67 Rock	53.3	611.3	664.6	41.1	630.1	671.2	Municipal Waterworks	53
68 Roseau	0.0	330.8	330.8	0.0	330.5	330.5	Municipal Waterworks	92
69 St. Louis	106,905.3	3,001.6	109,906.9	105,940.0	3,208.9	109,148.9	Steam Power Cooling	63
70 Scott	323.8	4,479.8	4,803.6	164.1	5,488.7	5,652.8	Municipal Waterworks	64
71 Sherburne	25,186.5	10,193.9	35,380.4	21,050.9	10,938.3	31,989.2	Steam Power Cooling	40
72 Sibley	0.4	701.5	701.9	6.8	689.0	695.8	Municipal Waterworks	80
73 Stearns	3,027.0	9,231.9	12,258.9	3,291.3	10,556.0	13,847.3	Major Crop Irrigation	54
74 Steele	1,069.5	1,790.7	2,860.2	1,642.2	1,884.7	3,526.9	Municipal Waterworks	50
75 Stevens	80.6	1,724.0	1,804.6	71.6	2,296.6	2,368.2	Major Crop Irrigation	76
76 Swift	45.9	3,528.4	3,574.3	37.0	4,733.6	4,770.6	Major Crop Irrigation	89
77 Todd	200.1	2,715.5	2,915.6	228.6	2,994.5	3,223.1	Major Crop Irrigation	73
78 Traverse	6.0	120.1	126.1	3.1	105.2	108.3	Municipal Waterworks	97
79 Wabasha	2.7	1,097.4	1,100.1	0.9	1,004.2	1,005.1	Municipal Waterworks	85
80 Wadena	618.4	3,155.5	3,773.9	670.3	3,553.7	4,224.0	Major Crop Irrigation	91
81 Waseca	29.4	801.2	830.7	30.4	759.7	790.1	Municipal Waterworks	88
82 Washington	108,022.1	11,911.6	119,933.7	100,897.7	12,277.5	113,175.2	Steam Power Cooling	87
83 Watonwan	109.5	1,062.4	1,171.9	17.3	1,106.5	1,123.8	Municipal Waterworks	61
84 Wilkin	38.5	155.6	194.1	89.8	161.8	251.6	Municipal Waterworks	50
85 Winona	1,070.5	2,119.7	3,190.2	1,085.0	2,231.4	3,316.4	Municipal Waterworks	38
86 Wright	117,864.5	2,944.1	120,808.6	107,557.5	3,169.4	110,726.9	Nuclear Power Cooling	97
87 Yellow Medicine	67.5	658.5	726.0	72.0	813.1	885.1	Rural Waterworks	48
Total			**1,340,530**		**1,273,277**			

Minnesota Reported Water Use

Category	2000	2001
Power Generation	(Millions of Gallons)	
Nuclear Power		
surface	328,887.5	313,032.8
ground	0.0	0.0
Steam Power Cooling		
surface	392,919.1	382,537.0
ground	988.3	756.0
Other Power		
surface	105,610.3	101,289.0
ground	855.7	867.9
Subtotal	**829,260.9**	**798,482.7**
Percent of Total	**62%**	**63%**
surface	827,416.9	796,858.8
ground	1,844.0	1,623.9
Public Supply		
Municipal Water Works		
surface	63,107.2	75,857.0
ground	129,163.7	130,572.1
Private Water Works		
surface	9.3	11.5
ground	820.2	800.4
Comercial & Institutional		
surface	0.0	0.0
ground	1,493.1	1,446.2
Cooperative Water Works		
surface	0.0	0.0
ground	1.6	1.5
Fire Protection		
surface	0.0	0.0
ground	20.3	15.5
State Parks, Waysides, Rest Areas		
surface	0.0	0.0
ground	24.2	25.6
Rural Water Districts		
surface	0.0	0.0
ground	1,908.2	1,912.6
Subtotal	**196,547.8**	**210,642.4**
Percent of Total	**15%**	**17%**
surface	63,116.5	75,868.5
ground	133,431.3	134,773.9

Minnesota Reported Water Use

Category	2000	2001
Irrigation		
Golf Course		
surface	1,441.5	1,503.0
ground	5,591.3	5,531.8
Cemetary		
surface	0.0	0.0
ground	55.0	53.2
Landscaping		
surface	54.4	65.5
ground	584.2	747.2
Sod		
surface	146.3	99.1
ground	265.5	270.6
Nursery		
surface	24.1	152.9
ground	447.4	427.1
Orchard		
surface	1.7	1.2
ground	3.7	7.9
Non Crop		
surface	10.8	9.4
ground	50.9	47.4
Temporary		
surface	0.0	0.0
ground	0.0	38.7
Major Crop		
surface	2,426.1	2,848.0
ground	61,900.9	75,342.5
Wild Rice		
surface	9,920.9	9,014.3
ground	49.7	0.3
Subtotal	**82,974.4**	**96,160.1**
Percent of Total	**6%**	**8%**
surface	14,025.8	13,693.4
ground	68,948.6	82,466.7

Minnesota Reported Water Use

Category	2000	2001
Industrial Processing		
Agricultural		
surface	287.7	272.7
ground	9,981.6	10,365.5
Pulp and Paper		
surface	34,954.7	28,327.1
ground	845.5	888.2
Mine		
surface	112,731.5	56,649.5
ground	28.9	24.7
Sand and Gravel Washing		
surface	2,631.6	2,406.8
ground	1,403.3	1,440.6
Industrial Process Cooling Once-through		
surface	235.0	197.1
ground	1,730.4	1,774.7
Petroleum or Chemical		
surface	203.4	221.4
ground	3,845.0	3,900.0
Metal		
surface	0.0	0.0
ground	1,323.0	1,458.5
Non-Metal		
surface	0.8	0.6
ground	1,680.0	1,557.8
Other		
surface	0.0	0.0
ground	1,137.8	343.5
Subtotal	**173,020.2**	**109,828.7**
Percent of Total	**13%**	**9%**
surface	151,044.7	88,075.2
ground	21,975.5	21,753.5

Category	2000	2001
Other		
Air Conditioning		
Commercial & Institutional Building AC		
surface	79.7	199.3
ground	119.3	181.2

Minnesota Reported Water Use

Category	2000	2001
Heat Pumps & Coolant Pumps		
surface	74.2	96.8
ground	0.0	0.0
District Heating		
surface	0.0	0.0
ground	0.0	1.6
Once Through Heating or AC		
surface	0.0	0.0
ground	2,912.5	2,806.3
Other AC		
surface	67.2	67.6
ground	0.0	0.0
Temporary		
Temporary Construction Non-Dewatering		
surface	13.9	24.1
ground	9.1	0.3
Temporary Construction Dewatering		
surface	22.2	352.5
ground	1,965.3	2,786.7
Temporary Pipeline and Tank Testing		
surface	27.3	10.6
ground	2.8	14.5
Other Temporary		
surface	212.2	18.0
ground	0.0	0.0
Water Level Maintenance		
Basin (Lake) Level Maintenance		
surface	3,384.3	1,099.3
ground	216.9	311.5
Mine Dewatering		
surface	24,445.6	21,582.5
ground	13.0	51.3
Quarry Dewatering		
surface	9,702.1	12,588.1
ground	0.0	0.0
Sand/Gravel Pit Dewatering		
surface	566.4	420.3
ground	0.0	0.0

Minnesota Reported Water Use

Category	2000	2001
Tile Drainage & Pumped Sumps		
surface	17.8	29.7
ground	175.4	183.7
Other Water Level Maintenance		
surface	6.4	63.1
ground	1,160.9	1,128.6
Special Categories		
Pollution Confinement		
surface	2.1	4.7
ground	4,763.1	4,571.6
Hatcheries & Fisheries		
surface	6,028.1	5,929.9
ground	675.1	643.7
Snow Making		
surface	127.6	178.1
ground	315.7	267.4
Peat Fire Control		
surface	0.0	0.0
ground	0.3	0.1
Livestock Watering		
surface	0.0	0.0
ground	786.6	947.8
Other Special Categories		
surface	7.9	3.3
ground	825.8	1,599.2
Subtotal	**58,726.8**	**58,163.4**
Percent of Total	**4%**	**5%**
surface	44,785.0	42,667.9
ground	13,941.8	15,495.5
Grand Total (Millions of Gallons)	1,340,530	1,273,277
surface	**1,100,389**	**1,017,164**
ground	**240,141**	**256,113**

This document is also available on our web site at www.dnr.state.mn.us/waters