WATER YEAR DATA SUMMARY

1997 and 1998

October 1, 1996 - September 30, 1998

by the DNR Waters Staff

St. Paul, MN

December 1999

Minnesota
Department of Natural Resources
Waters

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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 is 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 is vital to understanding complex hydrologic relationships. With expanding technologies, there is a greater need for even more data of higher quality.

This report is a continuation of Water Year reports published by DNR Waters in 1979, 1980, 1991, 1993, 1995 and 1997. This edition will also be available on our web site at www.dnr.state.mn.us/waters.

Water Year

The climatology, surface water and ground water data presented are for Water Years 1997 and 1998.

WY 1997: October 1, 1996 - September 30, 1997
WY 1998: October 1, 1997 - September 30, 1998

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 Jim Zicopula for graphic design.

COVER PHOTOGRAPH:
April 24, 1997 - looking westerly at Oslo, Minnesota.

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

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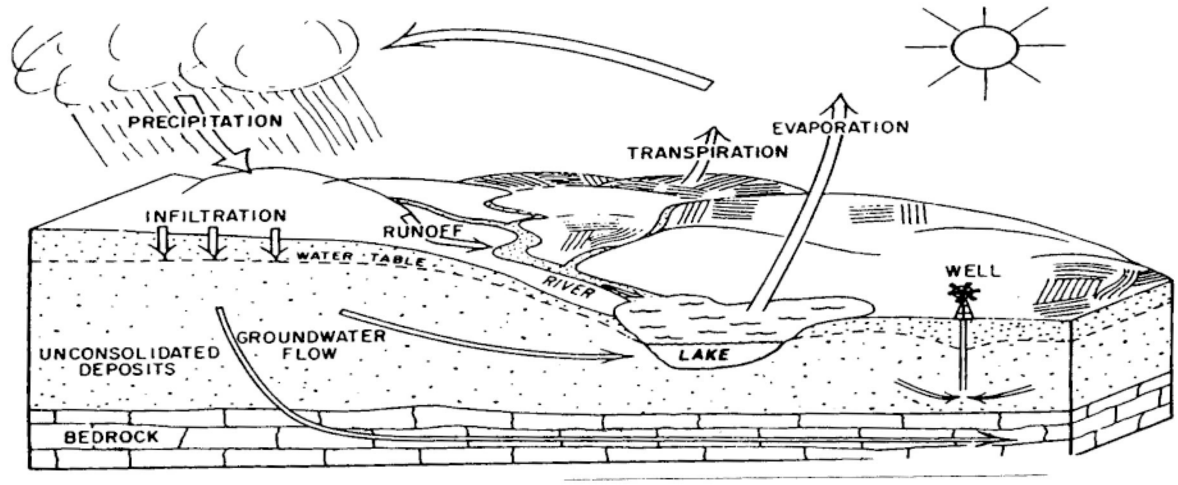
Hydrologic Cycle

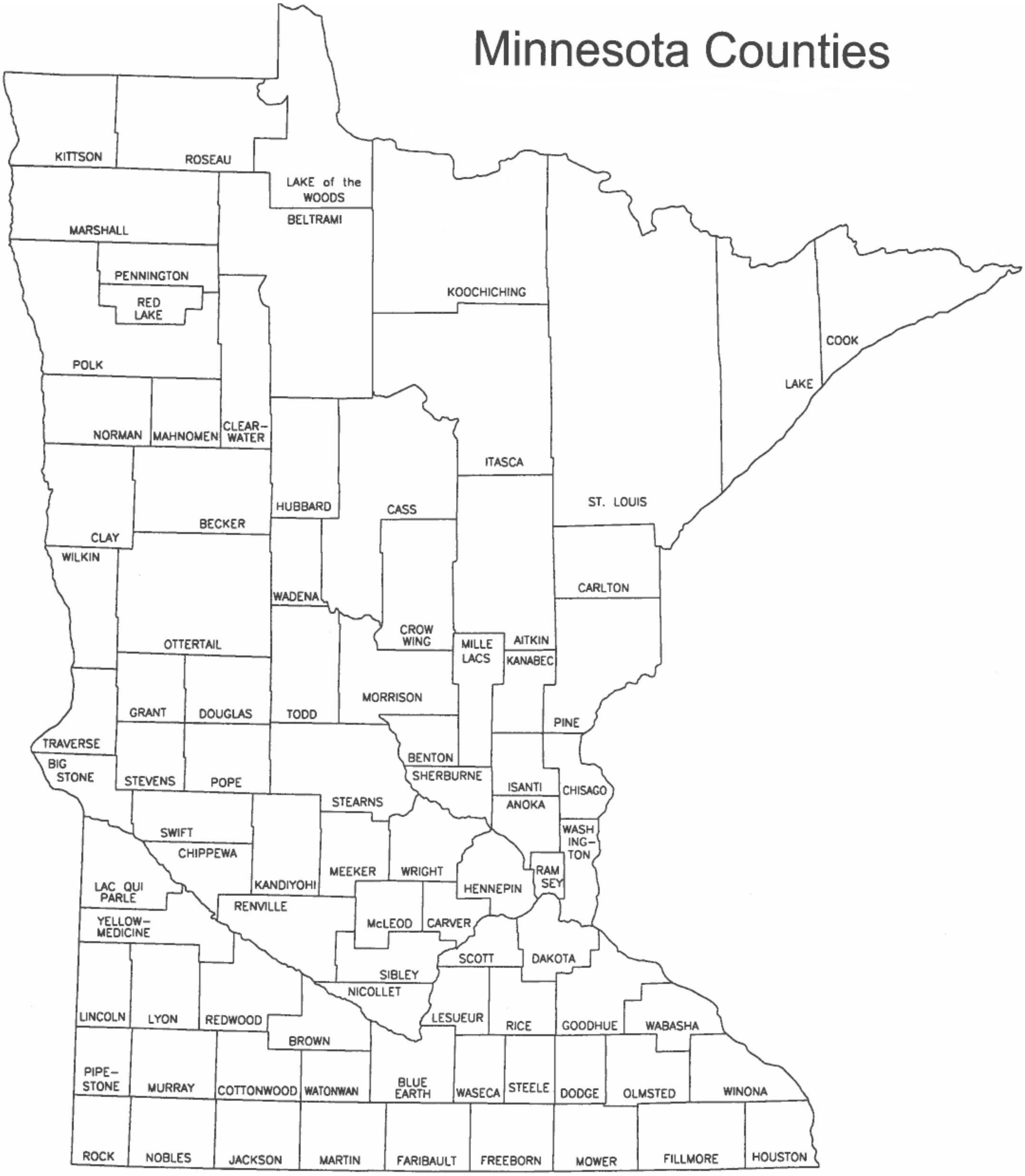


The hydrologic cycle is a concept used to explain the movement of water around the earth. This movement is continuous and has no beginning or end. Change at any point in the cycle will be reflected later in the cycle.

Surface water, which 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.

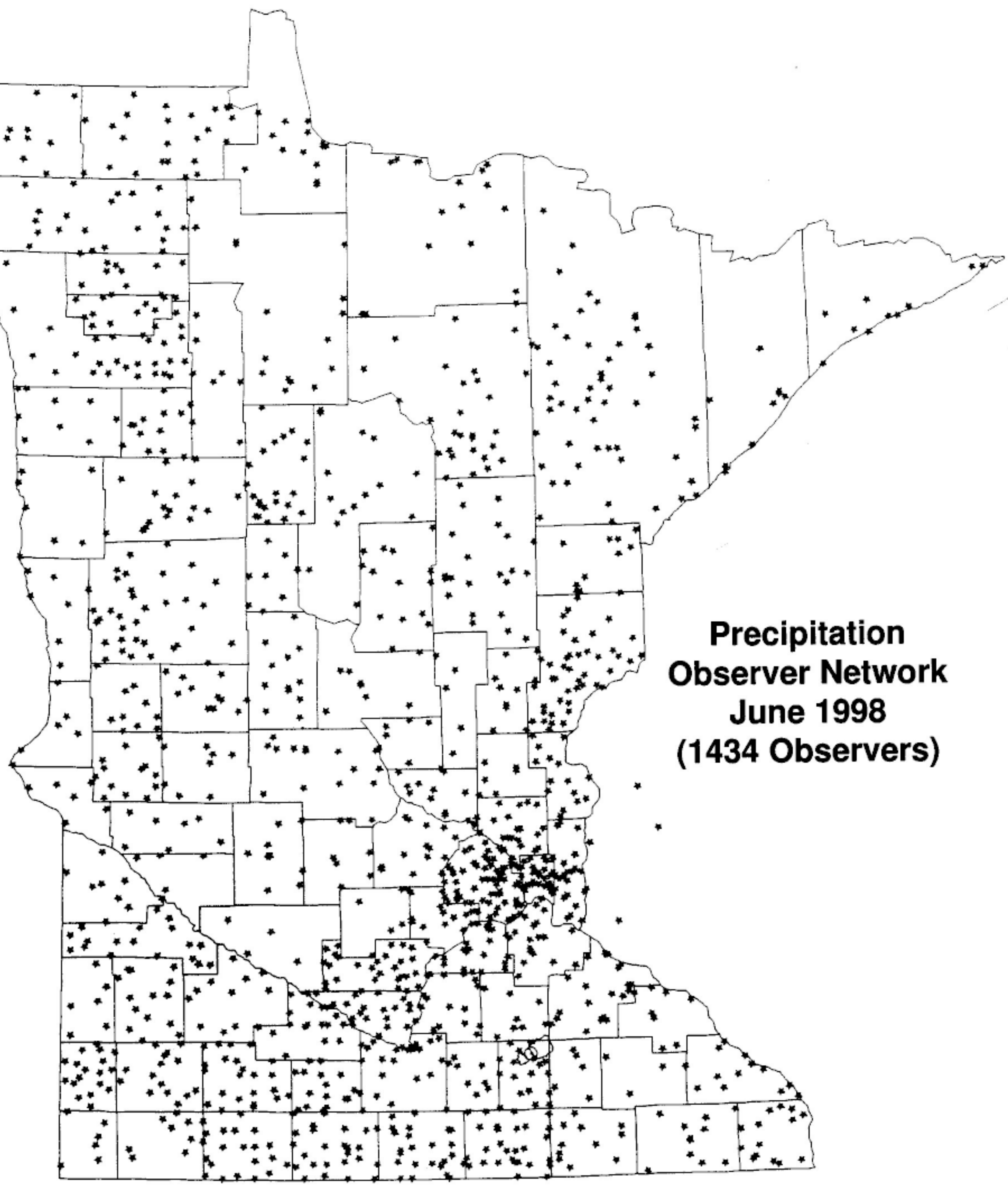
At any point where water is on the ground surface, it is subject to evaporation into the atmosphere or infiltration into the soil.

Minnesota Counties



Chapter 1

CLIMATOLOGY



Introduction

The 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 data base 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 identify emergency feeding needs for deer. Agricultural specialists use temperature and precipitation data to determine the types of crops that will grow in Minnesota. Other disciplines relying upon 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
(Forestry, Parks, Trails & Waterways)
State Climatology Office Back Yard Network
Metropolitan Mosquito Control District
Minnesota Association of Watershed Districts
Metropolitan Waste Control Commission
Deep Portage Conservation Reserve
Minnesota Power and Light Company
Emergency Management

The word 'normal' in this chapter refers to a 30-year mathematical average of measurements made over the period 1961-1990. Thirty-year averages are used as a compromise between shorter sampling periods that may not capture climatic variation, and longer sampling periods that may incorrectly filter out long-term climate change.

Water Year 1997

October 1, 1996 - September 30, 1997

Highlights

- Extremely Wet Fall, 1996
- Extraordinary Winter Snowfall, 1996-1997
- Cataclysmic Red River and Minnesota River Flooding, April 1997
- Very Dry Spring and early Summer,1997
- Very Wet mid-Summer, 1997

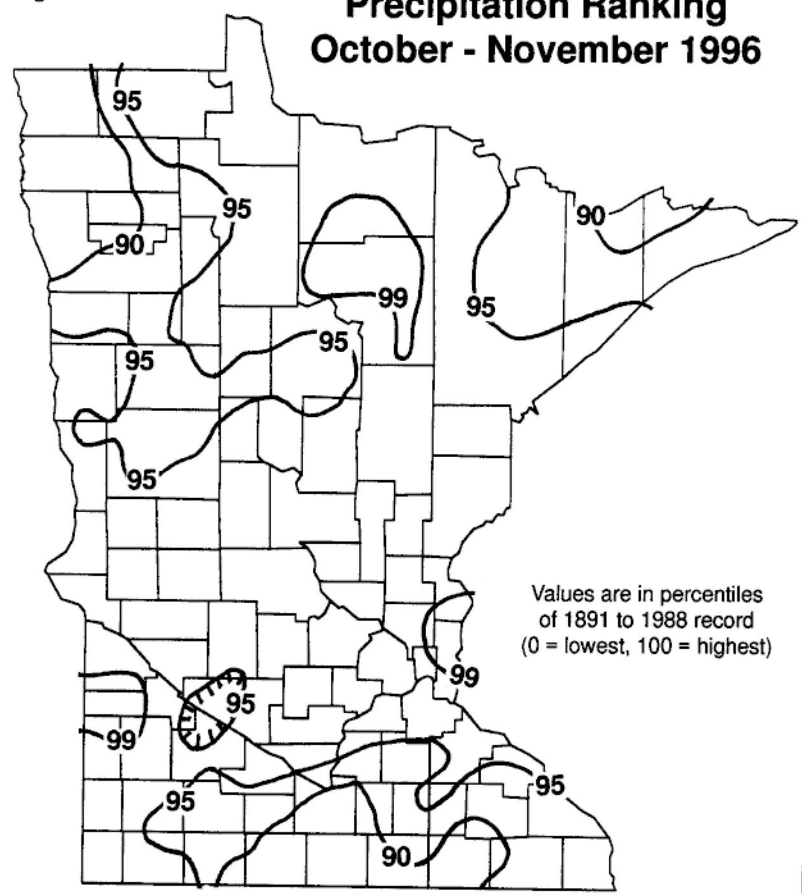
Fall 1996

After a dry growing season, much of Minnesota experienced an extremely wet fall. For considerable areas of the state, precipitation totals for October and November ranged from 4 to 8 inches. The October plus November precipitation totals ranked above the 95th percentile across large sections of the state (Figure 1). Much of this precipitation fell before the soil froze and helped to replenish diminishing soil moisture reserves.

A major wintry storm system passed through the central states including Minnesota in mid-November. Precipitation types included snow, rain, sleet and freezing rain. Some northwestern areas received over a foot of snow, making travel difficult. Portions of eastern Minnesota reported nearly four inches of rain, dampening basements and causing minor urban flooding. Freezing rain in the southwest brought down power lines, cutting electrical service to many. The southwest experienced yet another freezing rain event the following week, hindering recovery from the first ice storm.

Mean November temperatures were considerably colder than normal and, for many communities, it was one of the coldest of the century. November was also one of the wettest this century with significant freezing rain and snowfall.

Figure 1



Winter 1996-1997

December, 1996 featured freezing rain events, snow storms and blizzards throughout the month. Hardest hit was the western third of Minnesota, where the prairie landscape did little to slow the arctic winds. Schools and offices closed in mid-December, foreshadowing additional closures in January. Christmas Day was the coldest and most snow-covered on record for many communities.

Another major storm began to influence Minnesota late in the afternoon of January 3, with freezing rain in western sections of the state. The precipitation continued as a mix of rain, freezing rain, ice pellets and snow in the south and east on January 4, but changed over to all snow across western, central and northern Minnesota. Some west central and central areas received over two feet of snow, making this one of the larger snowfalls on record. The precipitation ended early January 5, but high winds throughout the day caused extensive blowing and drifting, which hampered travel.

Frequent occurrences of snow and blowing snow continued throughout the state during January. While none of the storms matched the snowfall totals recorded during the early-January event, moderate snowfall and high winds redistributed the snow pack. In the prairie terrain of southern, western, and northwestern Minnesota, the frequent blizzard or near-blizzard conditions closed roads, schools, government offices and businesses.

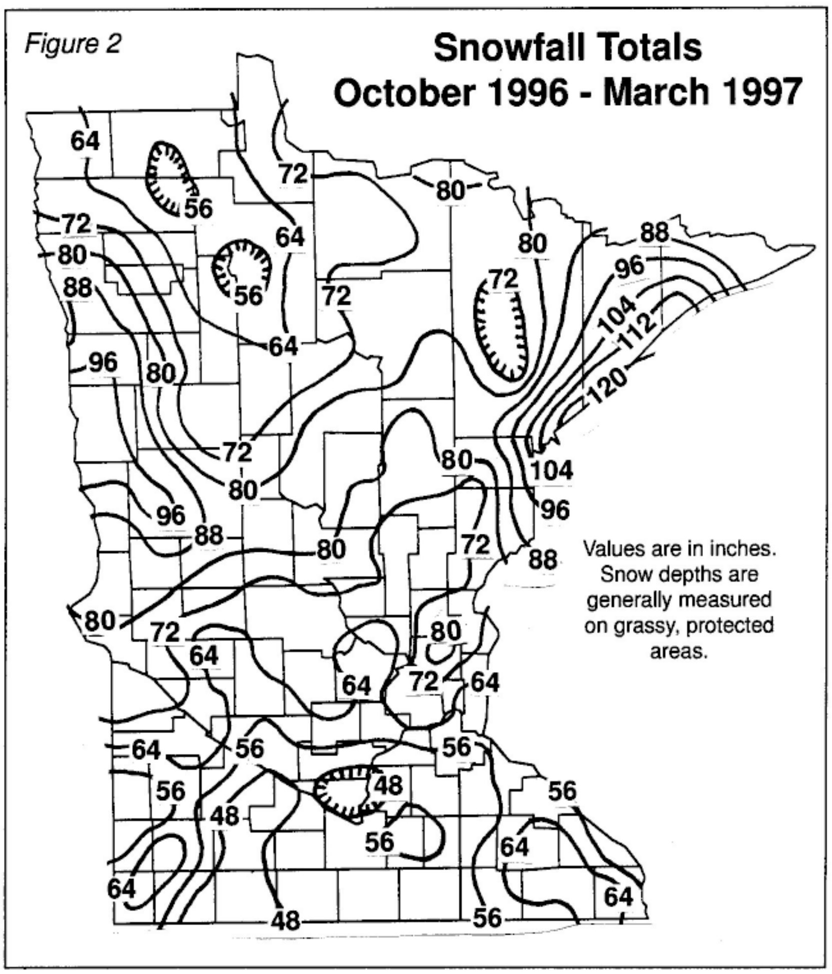


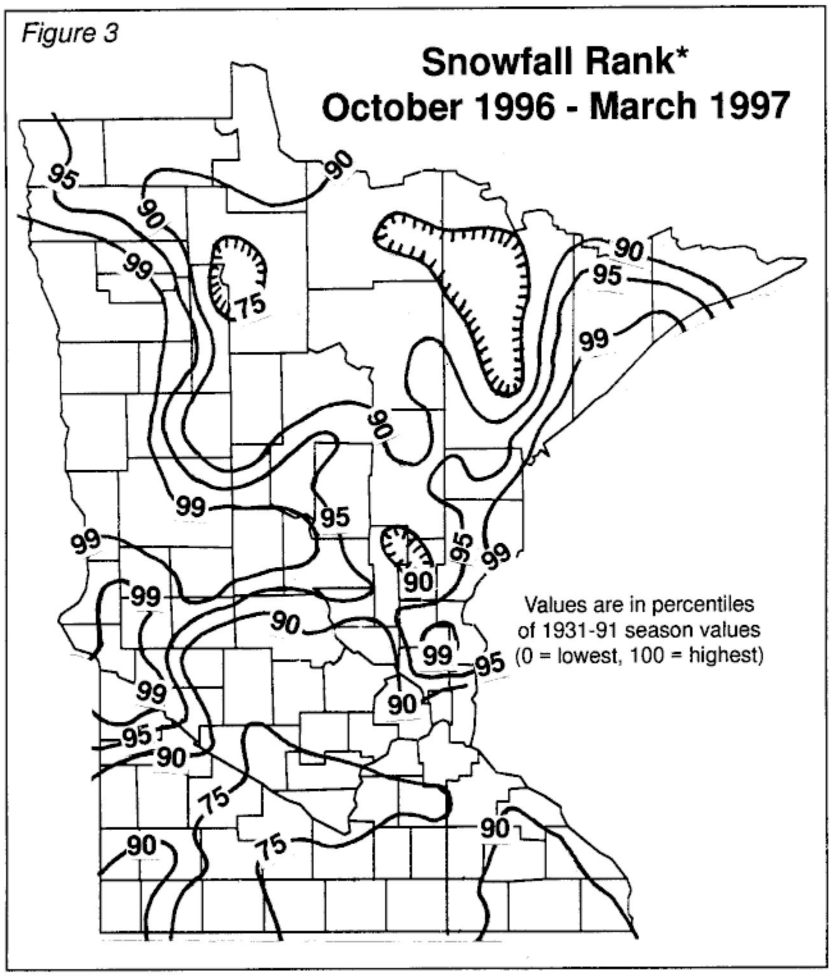
Figure 2 **Snowfall Totals October 1996 - March 1997**

Due to overburdened snow removal budgets, western Minnesota counties requested, and received, federal disaster assistance. Many outbuildings throughout western and central Minnesota collapsed under a heavy snow load, while leaks from snow-laden roofs led to home damage across much of the state. In addition to economic and social hardships, the harsh weather led to concern for the well-being of wildlife.

By the end of January, most communities had already received 100 to 200 percent of their total **seasonal** snowfall averages. February,1997 brought a welcome change to Minnesota with average temperatures more than two degrees above normal and monthly snowfall totals well below average. March, a typically snowy month, was cool and near average snowfall added to an already substantial snow cover (Figures 2 and 3).

Spring 1997

Cataclysmic April flooding along the Red River of the North and the upper reaches of the Minnesota River forced thousands from their homes and caused hundreds of millions of dollars in damage. In dollar value, the flooding was one of the worst natural disasters in midwestern history. DNR Waters Director, Kent Lokkesmoe, offered the following: “In the historical record, we have not seen a comparable sequence of such extreme precipitation events which have affected so much of the Red River basin in a single over-winter season." *See the sidebar on pages 5-6 for further discussion of this historic event.*



* Ranking maps are presented as percentiles, depicting the relative rarity of a climate scenario. The values shown on the map represent the number of years out of 100 exceeded by the existing condition. For example: a snowfall ranking of 95 means that the snowfall total surpassed the historical snowfalls (for the same season) in 95 out of 100 years.

Climatic factors contributing to the April, 1997 flooding in the Red River of the North and Upper Minnesota River basins

In the post-settlement era, no sequence of extreme precipitation events has impacted as much of the Red River and Upper Minnesota River basins as those experienced during the autumn of 1996 through the spring of 1997. The following events occurred:

- a very wet, late autumn
- record-breaking winter snowfall on an unprecedented geographic scale
- a less than ideal snowmelt scenario
- an intense early spring precipitation event

1) Heavy Autumn Precipitation

After a relatively dry growing season and early autumn, much of Minnesota received six or more inches of precipitation in late October and November of 1996. In many areas of the state, precipitation exceeded historical averages by four or more inches. October-November combined precipitation totals ranked in the 95th percentile over much of Minnesota (Figure 1). Precipitation at the 95th percentile means that the observed total was exceeded only five times in the previous one hundred years during the late autumn. Much of the precipitation fell before the winter freeze-up, filling the upper portions of the soil profile, which created a relatively impervious surface when the snowmelt runoff season commenced the following spring.

2) Extraordinary Winter Snowfall

The winter of 1996-1997 snowfall totals were the highest ever recorded over large areas of the Red River and Upper Minnesota River basins. Not only was the snowfall noteworthy in its intensity, but also in its geographical extent. Six to eight blizzards, and numerous smaller snow storms, dropped over six feet of snow on northwestern and west central Minnesota. (Figure 2). Some areas received an improbable (for the region) eight feet of snowfall, which is two to three times greater than long-term averages. Over 40 percent of the Red River basin (Minnesota portion), and the uppermost reaches of the Minnesota River basin, were near or exceeded seasonal snowfall records (as indicated by the 99th percentile lines in Figure 3). Historically, no greater area of the Red River basin has ever been in the record snowfall category. In comparison with another catastrophic Red River spring flood, the 1996-97 snowfall exceeded the 1896-97 snowfall by 25 to 50 percent.

As the spring snowmelt season approached, thigh-deep snow and towering drifts filled the landscapes of the eastern Dakotas and western Minnesota. Point measurements and remote sensing observations showed the water equivalent of the snow pack to exceed six inches over large areas. For a few locations, snow water equivalent approached an incredible nine inches.

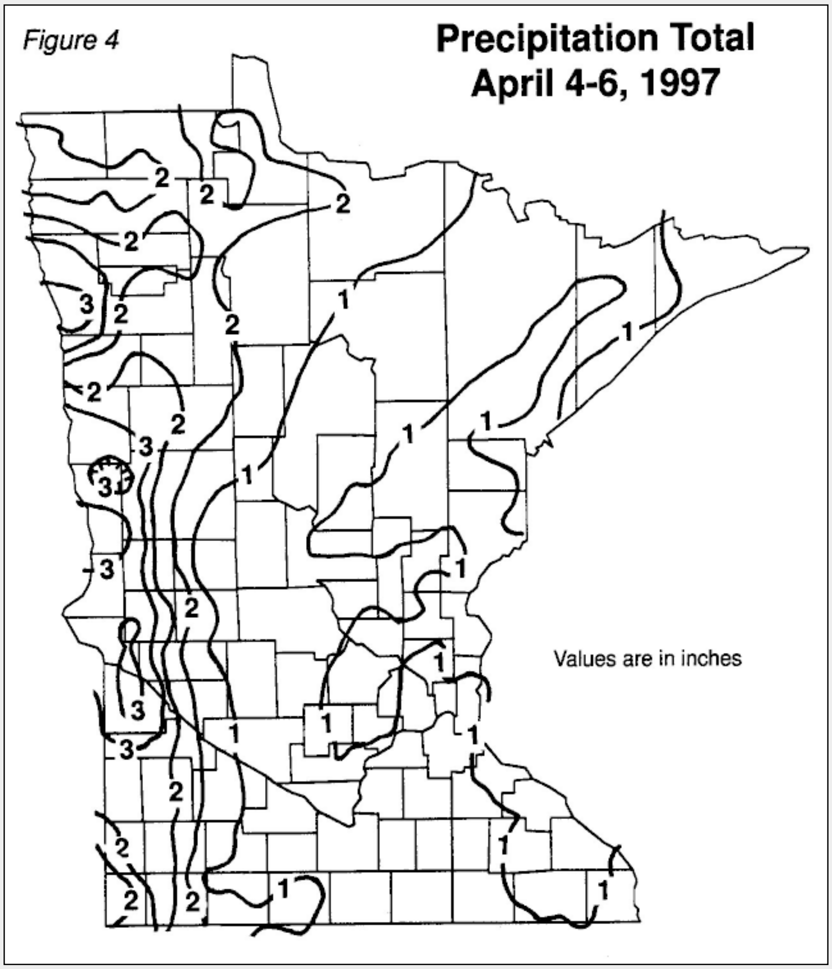


Figure 4 **Precipitation Total April 4-6, 1997**

3) Less Than Ideal Snowmelt Scenario

Few days during mid to late winter were warm enough to melt the snow pack and gradually release its water. Those few days that did top freezing settled the snow, but it retained its water content. Nearly the entire water equivalent of the over-winter precipitation was available for runoff when the snowmelt began in the spring of 1997.

In the Red River basin, April temperatures magnified the situation. The first week of the month was quite warm, triggering snowmelt runoff in the upper reaches of the basin. Temperatures turned bitterly cold during the second week, temporarily reducing flows in the Red and its tributaries farther downstream. When temperatures returned to normal in mid-April, runoff in the downstream tributaries synchronized with the flood crest released earlier in the month at the headwaters region.

4) Heavy Early Spring Precipitation

The conditions described above were enough to generate overwhelming flooding. However, a major winter storm blanketed the region from April 4 to April 6 and further aggravated an already dire situation. The storm began late on the 4th as rain and freezing rain. The wintry mix continued through the 5th, coating surfaces with ice, knocking out power and adding unneeded water to the already swollen streams and rivers. By the 6th, the precipitation turned entirely to snow which, in combination with high winds, led to blizzard conditions. Water totals for the storm exceeded two inches over most of western Minnesota and much of the eastern Dakotas (Figure 4). Some sections of northwestern Minnesota topped three inches - a record single storm total for the month of April. The normal **monthly** April precipitation total for the region is approximately two inches.

Conclusion

The extraordinary flooding of the Upper Minnesota River and the Red River of North was largely the result of an array of climate anomalies. It is not possible to place a quantitative estimate on the improbability of this series of climatic events. However, such a sequence of unlikely events was never before observed in the post-settlement period.

Summer 1997

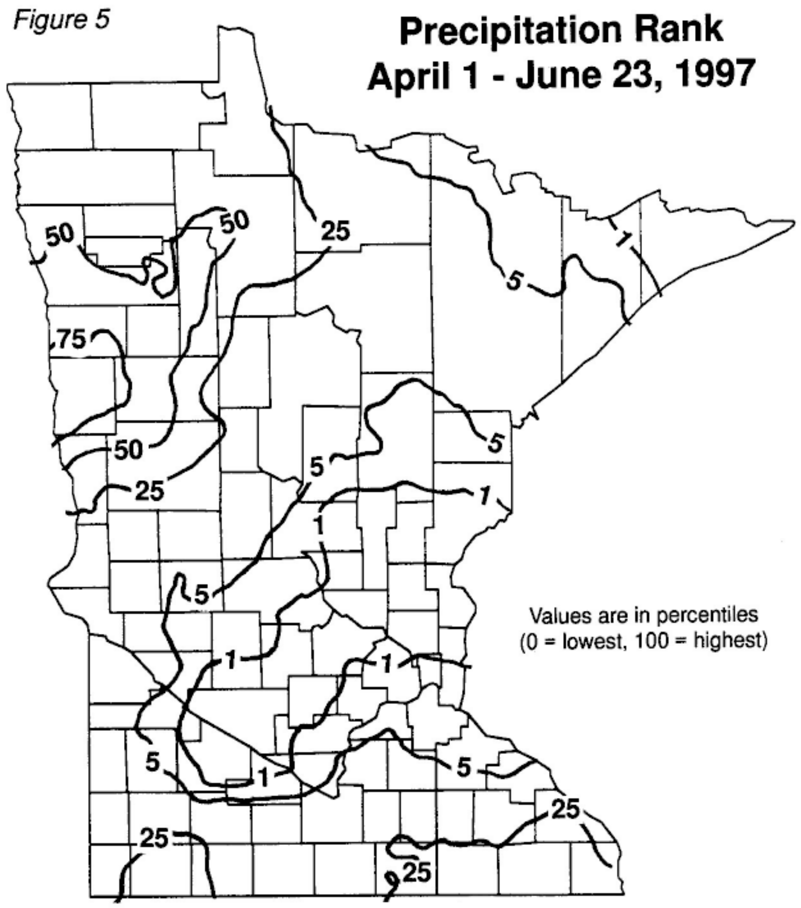
After the early rain and blizzard of April 5 and 6, the weather turned cold and dry for the remainder of the spring season. From early-April to late-June, much of Minnesota experienced below normal precipitation, with the driest areas being east central and central. Precipitation totals were less than four inches in many counties for the period which is less than 50 percent of their normal 10 inches. In some Minnesota communities, April 1 - June 23 precipitation totals were near or below all-time low precipitation records. A precipitation ranking map (Figure 5) shows that roughly one quarter of the state was at or below the 5th percentile (precipitation totals for the period were lower in only 5 of the last one hundred years). Cool weather mitigated the extreme dryness somewhat by reducing evaporation demand. Another alleviating factor was the wet autumn of 1996, especially in those eastern sections of the state where the spring dryness was most intense.

The dry spell ended abruptly in the northwest on June 22-24. A slow moving system brought two to three inches of rain to portions of Clay and Becker Counties during the first wave of storms. The rains resumed hours later, dousing portions of Norman, Polk, Red Lake, Clearwater and Beltrami Counties with three to six additional inches, resulting in flooded basements and closed roads.

Heavy rains returned on June 28-29 when a complex of thunderstorms brought downpours to portions of northwestern, central and southwestern Minnesota. A band of five inches or more fell over Kandiyohi, Meeker and McLeod Counties from this system.

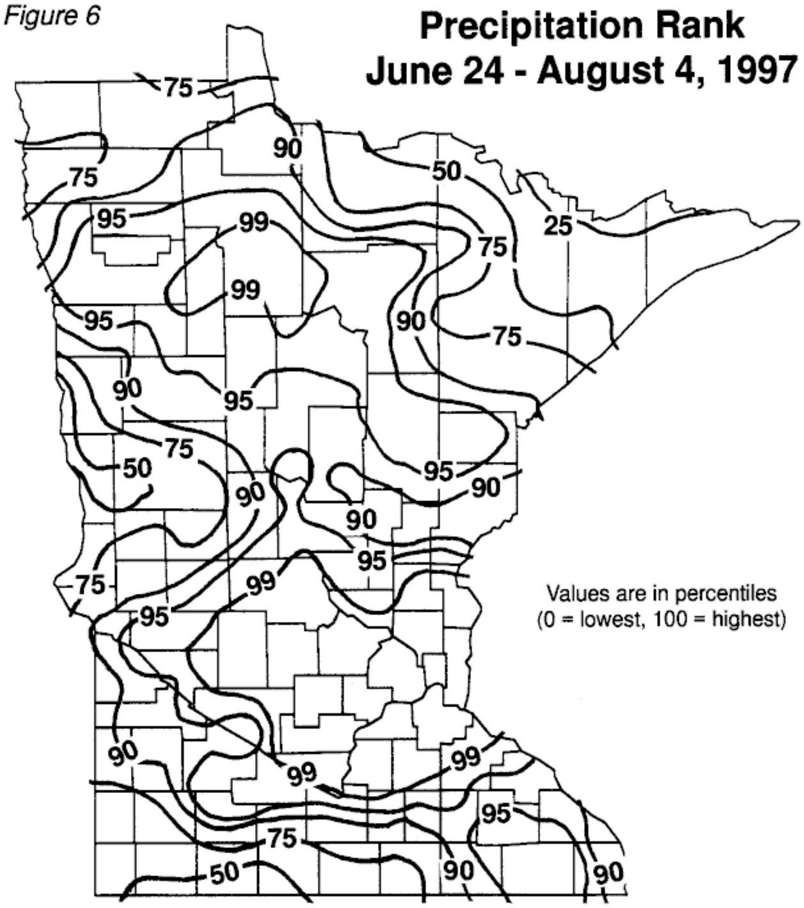
On July 1, for the third time in roughly a week, heavy rains fell across portions of northwestern and central Minnesota. Red Lake, Pennington, Marshall and Kittson Counties reported rainfall amounts of one to four inches, as did central Minnesota, from Lac Qui Parle and Yellow Medicine Counties through the Twin Cities Metropolitan Area. These rains fell on the drenched soils of portions of Kandiyohi, McLeod and Meeker Counties, which recorded weekly totals of over eight inches.

Figure 5



The July 1 event was notable not only for its volume, but also its intensity. The St. Paul campus of the University of Minnesota received three inches of rain in less than one hour. That intense rainfall rate exceeded the "100-year storm" total for the area (see side bar) and led to numerous occurrences of urban and small stream flooding as well as countless wet basements. The same system also caused extensive wind damage throughout central and east central Minnesota where high winds downed many trees and damaged numerous buildings. Hail-damaged fields, particularly in western Minnesota, became an increasingly common sight throughout late June and into July.

Figure 6

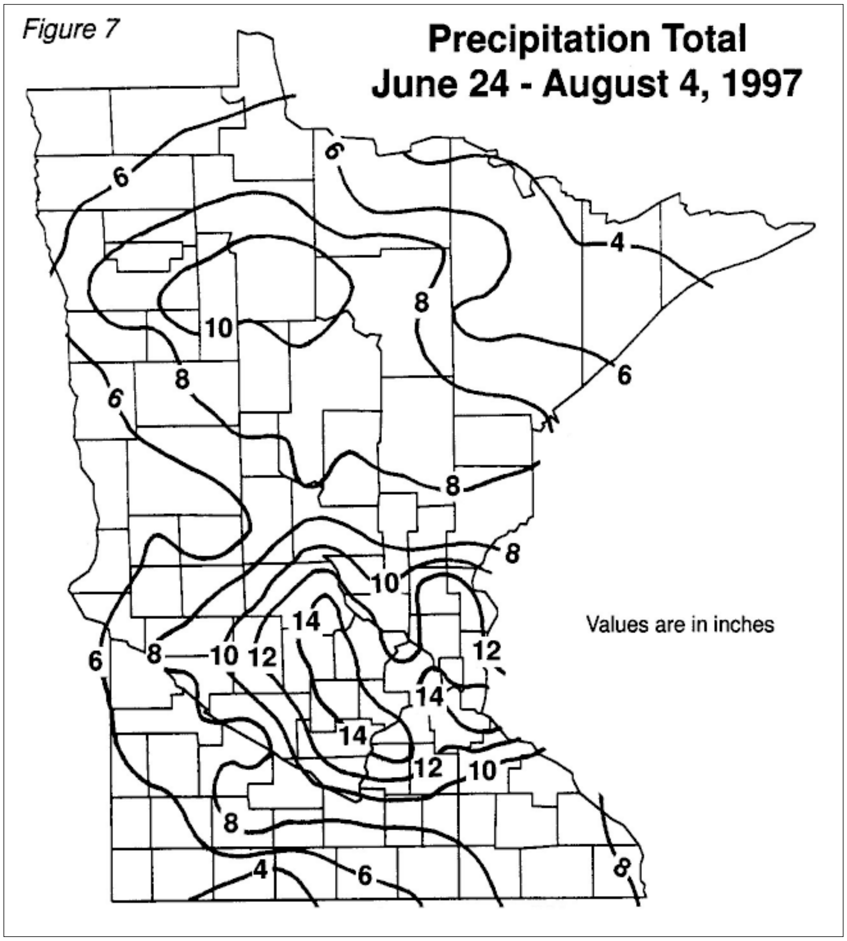


100-YEAR STORMS

One of the more confusing phrases used in meteorology and hydrology is “100-year storm”. The phrase implies that an intense rainstorm, dubbed as an “100-year” event brings rainfall totals heretofore unseen for 100 years, and not to be experienced again for another century. This is an incorrect conclusion to draw from the phrase. A “100-year storm” describes rainfall totals having a one percent probability of occurring **at that location** during that year. Encountering a “100-year storm” on one day does nothing to change your chances of seeing the same amount of precipitation the very next day.

Typically, intense rainfalls are geographically isolated. Therefore, increased population density and improved precipitation monitoring networks have improved the likelihood of more accurately measuring heavy rainfall events. Also, improved communication has allowed faster and more complete transfer of weather information, such as a “100-year storm” in a neighboring county. Invariably, we will vicariously “experience” that event and wonder why “100-year storms” seem to be occurring every other week!

The calculation of rainfall frequency statistics is relatively straightforward. The highest single-day precipitation total for each year in communities with extended climate records, are determined and then sorted. If a community has 100 years of climate data, the value at the top of this 100 year list is the “100-year, 24-hour storm event”. If a community has less than 100 years of data, statistical methods are used to extrapolate a 100-year record. A 24-hour “100-year storm” for most Minnesota communities is roughly six inches of rainfall.



The first week of July was one of the coldest July weeks in state history with temperatures averaging 10 degrees below normal. International Falls recorded a low of 34 degrees F on July 7, the coldest July temperature in their history. On the same morning, the observer three miles south of Tower recorded a low of 24 degrees F, tying the state record for the lowest July temperature. In contrast, the second half of the month was warm and very humid. Numerous communities around the state observed record dew point temperatures in the high 70s, and even 80 degrees F.

On July 22, heavy rains doused the Twin Cities for the third time that month. Rainfall amounts ranging from one to five inches fell on saturated ground, again leading to numerous reports of urban and small stream flooding and wet basements.

Extremely heavy rains began in the evening hours of July 24 in southwestern Minnesota and continued into the morning hours of July 25 in eastern counties. Some of the rain fell in relatively dry areas, however, much of the rain in central and southeastern counties fell on moist ground, leading to flooded roadways and other difficulties. The heaviest reported rainfall totals were four to five inches in northern Lincoln and Lyon Counties, portions of Sibley and Mcleod Counties and a portion of Goodhue County.

Yet another intense event drenched the St. Cloud area on August 2, dropping over three inches of rain in just a few hours. On August 14 and 15, a small area of Rice and Steele Counties received over six inches of rain while the Medford area of Steele County received a whopping 8.2 inches within a 24-hour period.

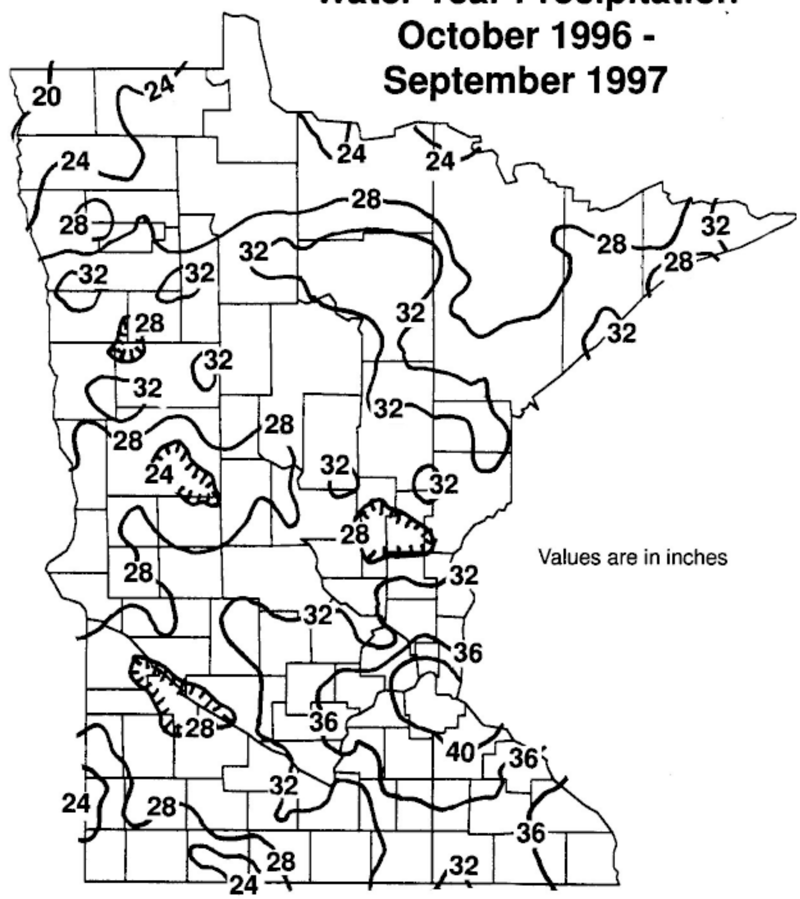
How wet was the summer of 1997? For the period June 24 to August 4, large areas of northwest, north central, central, and east central Minnesota were at the 99th percentile for precipitation (Figure 6). The 99th percentile indicates that these locations were near or above all-time precipitation records. Numerous communities recorded over a foot of rain in this six week period (Figure 7), which is two to three times the historical average. For many areas, the mid-summer of 1997 will be remembered as one of the wettest periods ever and also for its temperature quirks. The first week of July was one of the coldest July weeks in history, while numerous communities observed record high dew points during the second half of the month.

Water Year 1997

Figure 8 shows that 1997 Water Year (October, 1996 – September 1997) precipitation ranged from less than 22 inches in the northwest to over 40 inches in portions of the southeast. Historical averages were exceeded in some northwestern and southeastern counties by more than eight inches, while precipitation totals were at or below normal in the far northeast and in some areas of southwestern and west-central Minnesota.

Figure 8

Water Year Precipitation October 1996 - September 1997



Water Year 1998

October 1, 1997 - September 30, 1998

Highlights

- Extremely Mild Winter, 1997-1998
- Devastating Tornadoes, March 1998
- Severe Thunderstorms, May 1998
- Continuation of Above Normal Precipitation in the Northwest and Southeast

Fall 1997

Early to mid-fall of 1997 was a mix of dry and warm weather, leading to excellent harvesting conditions. For many locations, the first frost of the fall did not arrive until mid-October. After a wet week in mid-October, the weather once again turned dry, but temperatures plummeted and remained below normal throughout the end of November. The weather changed sharply in December, with seasonally warm temperatures, beginning one of the warmest winters in recorded history.

Winter 1997-1998

Meteorological winter is defined by climatologists as the months of December, January and February, and Minnesota experienced unusually mild temperatures in each of these months during the winter of 1997-1998. The statewide average temperature for December, 1997 was near 24 degrees F., which is 11 degrees above normal. The January, 1998 average was 14 degrees or 7 above the norm while February, 1998 was extremely warm, averaging 28 degrees or 15 above normal. The average temperature for the 1997-1998 meteorological winter was 22.6 statewide, second only to the winter of 1877-1878 (Figure 9).

Due to seasonally warm temperatures and light snowfall, many areas of Minnesota reported little or no snow cover by late February (Figure 10). Many areas were below the 10th percentile for snow depth at the point of the winter season when the maximum snow depth is typically reached.

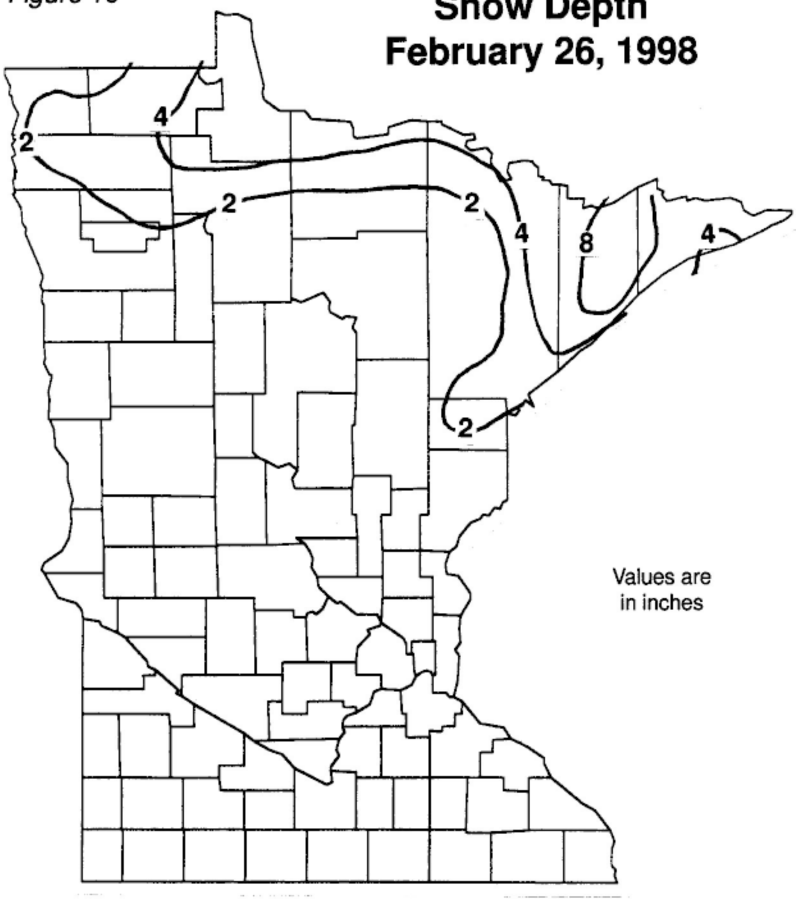
Figure 9

Warmest December - February Temperatures

Rank	Average Temperature	Winter
1	26.0 (est)	1877-1878
2	**22.6**	**1997-1998**
3	21.7	1986-1987
4	21.2	1930-1931
5	19.8 (est)	1881-1882
6	19.6	1991-1992
7	19.2	1982-1983

Figure 10

Snow Depth February 26, 1998



Spring 1998

The spring of 1998 was an active season for severe weather in most of the southern third of the state. On March 29th, a series of strong tornadoes carved a destructive path through several communities, notably including St. Peter, Comfrey, Hanska, and Le Center. Two lives were lost in these storms and total damage was in the hundreds of millions of dollars.

Severe weather in the forms of straight-line winds, tornadoes and hail pounded southern and central Minnesota on May 15. One life was lost in Stearns County, while hail and wind damage in the Twin Cities Metropolitan Area totaled hundreds of millions of dollars. On May 30th, a violent wind-storm and hail struck the Twin Cities, again leading to extensive damage.

These conditions led to lake ice-out dates approximately two weeks earlier than historical averages (Figure 11). Some lakes approached all-time records for earliest ice-free conditions. Only two years earlier, in 1996, lake ice-out dates were approximately two weeks later than average with some lakes in the northeast still ice-covered at the fishing opener.

Coincident with the stormy weather were unusually warm air and dew point temperatures, setting records in several communities. On May 18th, the thermometer reached 100 degrees in Redwood Falls, a rare occurance in Minnesota during the month of May.

Figure 11

Spring Ice-Out Dates

Lake/ County	1998 Ice-Out	Average Ice-Out	1996 Ice-Out
Minnetonka/ Hennepin	April 3	April 15	April 24
Gull/Cass	April 7	April 23	May 4
Detroit/Becker	April 10	April 24	May 5
Leech/Cass	April 13	April 29	May 10
Vermilion/ St. Louis	April 13	May 2	May 16

In spite of the stormy spring weather in many areas, dry growing season conditions were a concern in the southwest and the northeast. By late April, many wildfires were reported in northern Minnesota and burning restrictions were in place.

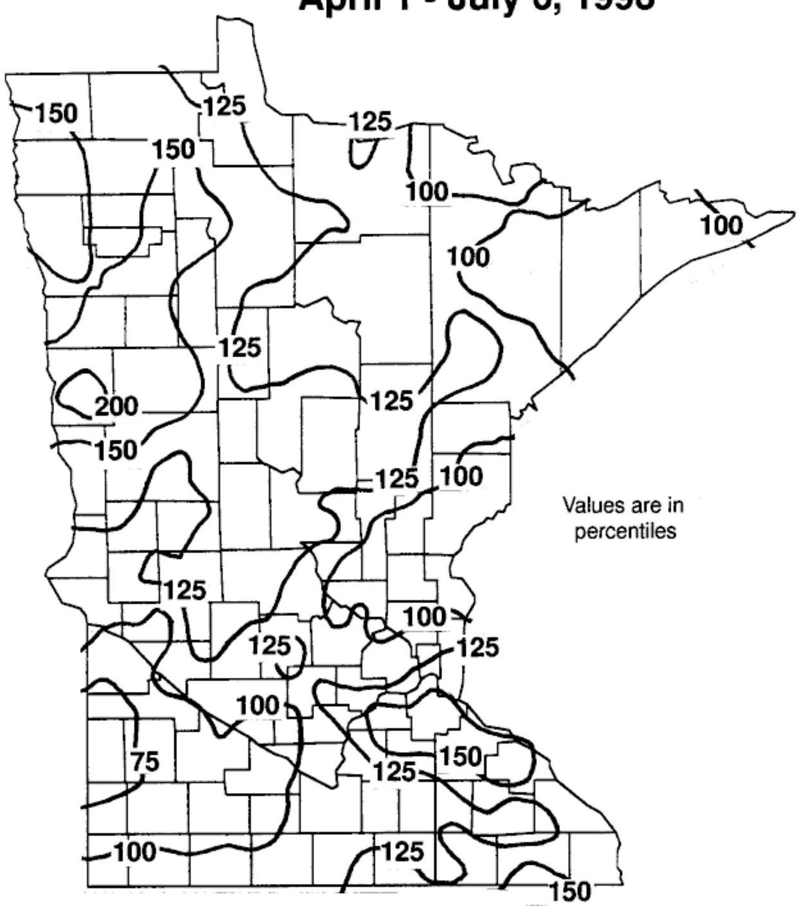
Summer 1998

While dry conditions persisted in northeastern Minnesota in June, fears of drought tapered off in the southern and north central regions after a series of rainstorms moved through much of the state. For the week ending June 28, multi-day precipitation totals exceeding eight inches were reported in several communities. One location near Zumbrota in Goodhue County reported 10.03 inches of precipitation over the period. The heaviest rains fell during the late afternoon and evening of June 26th, totaling three to six inches across Scott, Rice and Goodhue Counties in approximately six hours. The deluge created flash flooding which led to two deaths, serious soil erosion and significant property damage. By early July, some sections of southeastern and northwestern Minnesota had received more than 150 percent of normal precipitation for April 1 – July 6 (Figure 12).

Very heavy rains fell across much of Minnesota during the afternoon and evening of July 14. The heaviest rains fell in Otter Tail and Cass Counties where more than five inches were reported in portions of these counties. For many locations throughout the state, rainfall rates were roughly two inches per hour, leading to urban and small stream flooding. Damaging hail was also reported in many areas.

Figure 12

Percent of Normal Precipitation April 1 - July 6, 1998



Summer temperatures were near seasonal averages with one dramatic exception. The first half of June was one of the coldest on record with temperatures dropping 7 to 10 degrees below normal for the period. Temperatures moderated somewhat in the second half of the month, but the monthly average finished below normal. July temperatures were near average, and most of Minnesota avoided a heat spell. August temperatures were somewhat above average, but once again, Minnesota avoided extremely hot weather.

Mild temperatures persisted into September, which was the 4th warmest since 1895, when taken as an aggregate average from all reporting locations in Minnesota. Some communities observed their warmest September on record and, statewide, the 1998 calendar year was the 3rd warmest since 1891.

Water Year 1998

Much like the 1997 Water Year, the 1998 Water Year (October, 1997 – September, 1998) was quite wet in northwestern and southeastern Minnesota. In some areas of the southeast, more than 40 inches of precipitation were recorded during the Water Year (Figure 13). Parts of southeastern and northwestern Minnesota exceeded the annual normal by more than 10 inches (Figure 14). Consecutive years of unusually high precipitation totals in the northwest exaggerated already wet conditions, leading to unusually high lake levels and continued hardships in the agricultural community. While the northeast and southwest were very dry during the growing season, early autumn rains made up for much of the deficiency.

Figure 13 **Water Year Precipitation October 1997 - September 1998**

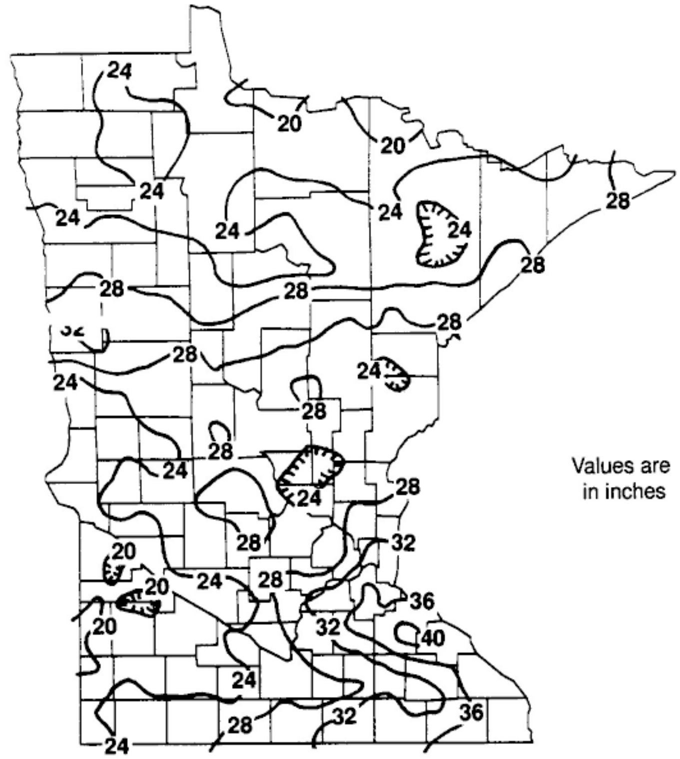
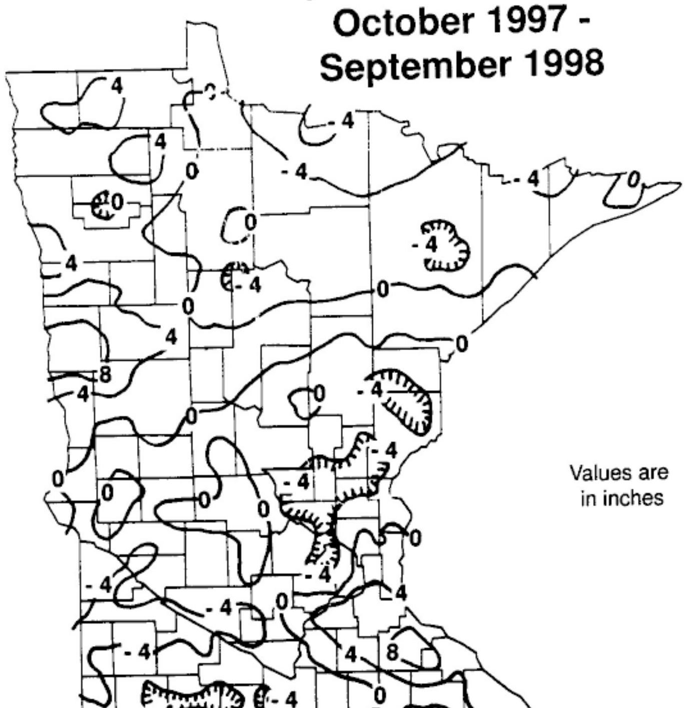
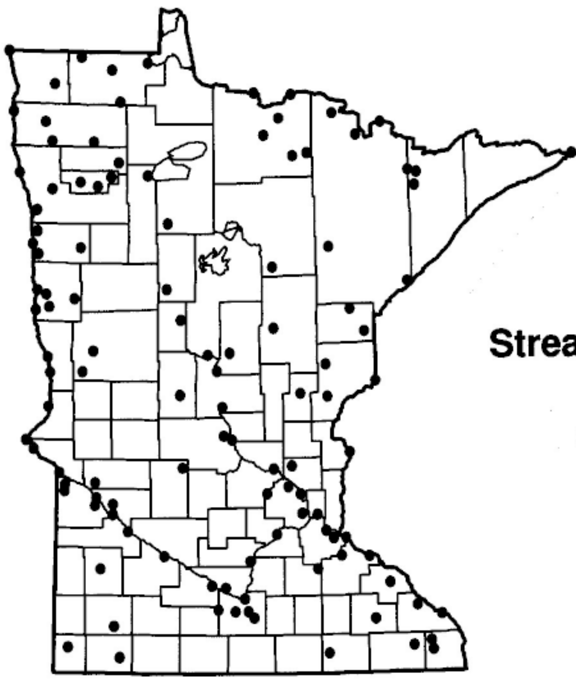


Figure 14 **Water Year Precipitation Departure from Normal October 1997 - September 1998**

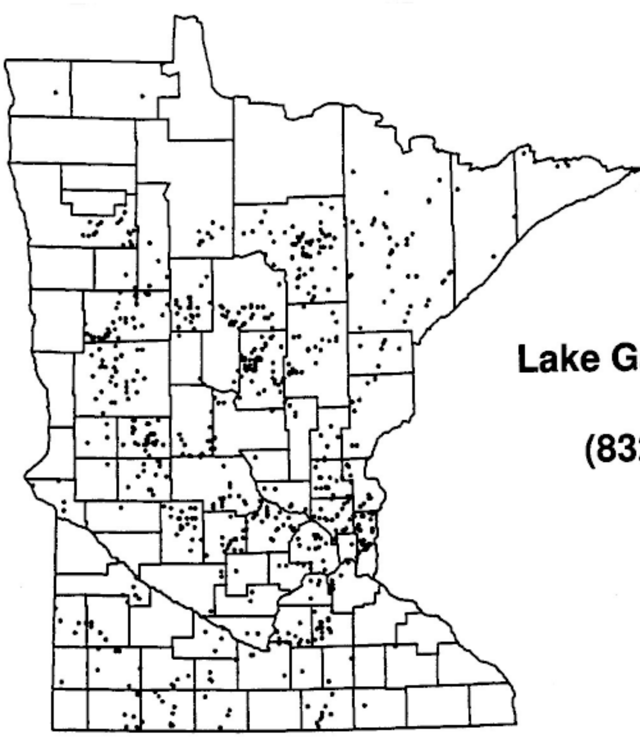


Chapter 2

SURFACE WATER



Stream Gage Network
1998
(102 Gages)



Lake Gage Network
1998
(832 Gages)

Stream Flow

Introduction

The Stream Hydrology Unit is responsible for collecting, distributing and analyzing 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 box below).

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.

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.

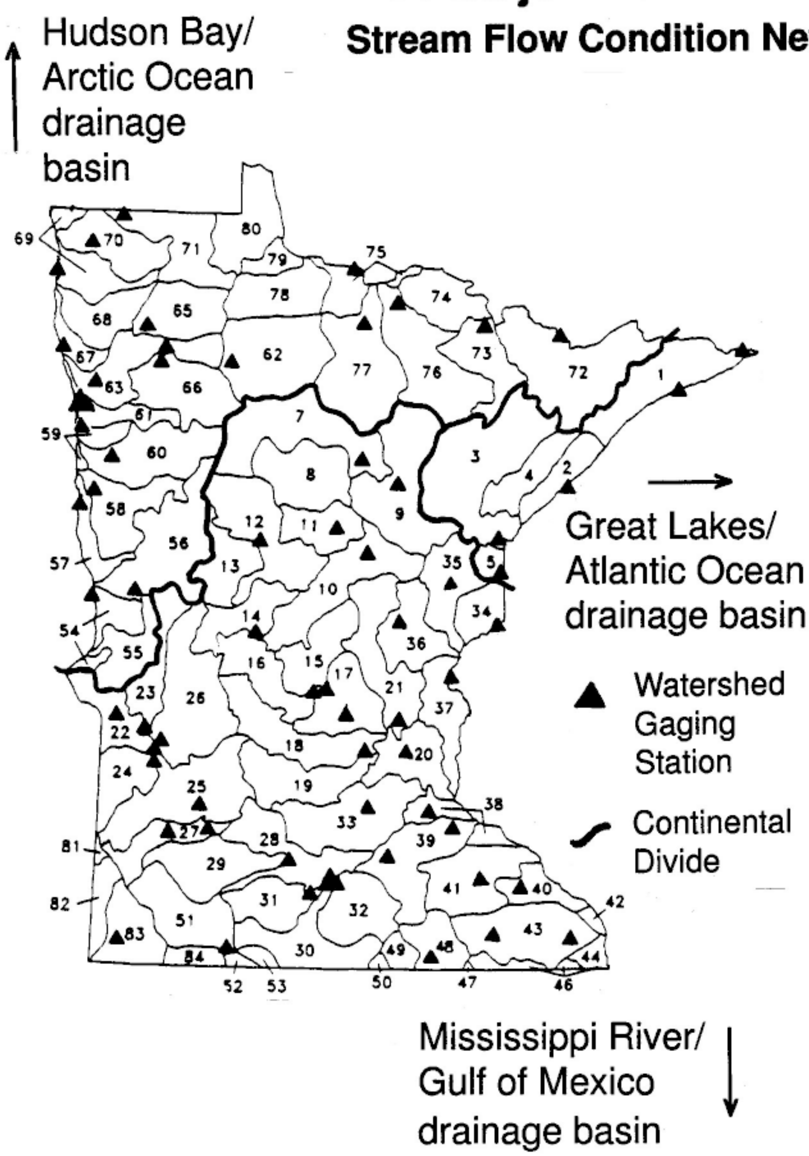
Critical Flow = < annual Q90
Low Flow = < monthly Q75
Normal Flow = monthly Q75 to Q25
High Flow = > monthly Q25
Flood Flow = > NWS* flood stage
(or highest monthly Q10)

*** National Weather Service**

Figure 1

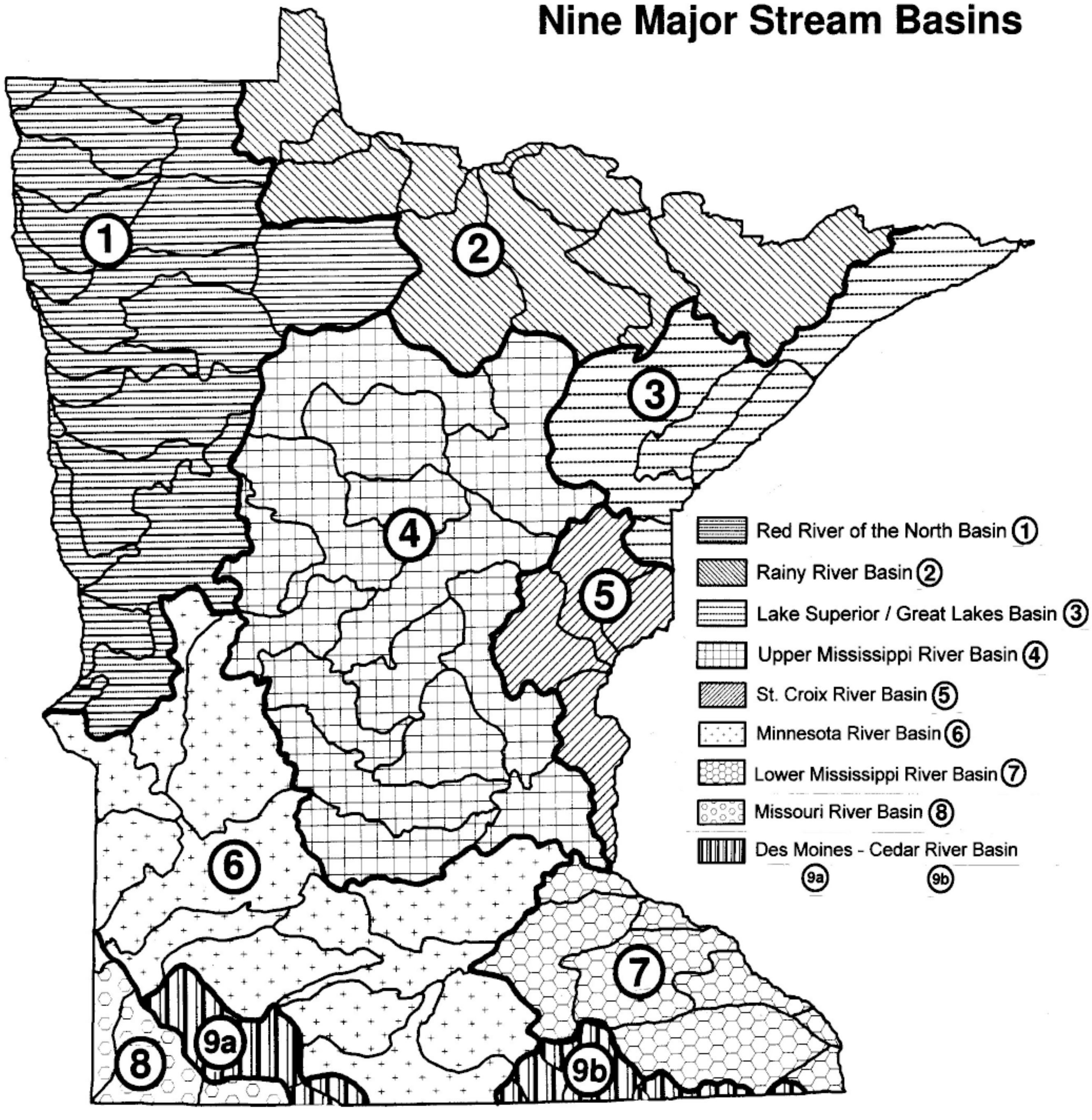
81 Major Watersheds

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



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 parts of the Blue Earth River from Iowa. Minnesota exports large volumes of water via the Red, Rainy, Mississippi, Minnesota and St. Croix Rivers, and through numerous smaller rivers.

Stream Gaging in Minnesota

Stream gaging is an essential tool in analyzing the flow characteristics of streams and rivers. A stream gage records the elevation of a stream at a specific point. State of the art stream gages record elevations continuously and transmit the elevation data to a central location for conversion to discharge in cubic feet per second (cfs) and for further analysis. Special equipment is used to measure water velocity and depths at the gaging location and multiple measurements are combined to develop an accurate relationship between discharge and elevation. Recorded stream elevations are converted to stream discharge using this relationship.

Most continuous recording stream gages in Minnesota are operated by the USGS with funding and assistance from the U.S. Army Corps of Engineers. DNR Waters supports about 1/3 of these network gages through the USGS's Cooperative Water Resource Data program. The USGS and the U.S. Army Corps of Engineers have been gaging Minnesota streams for over 100 years.

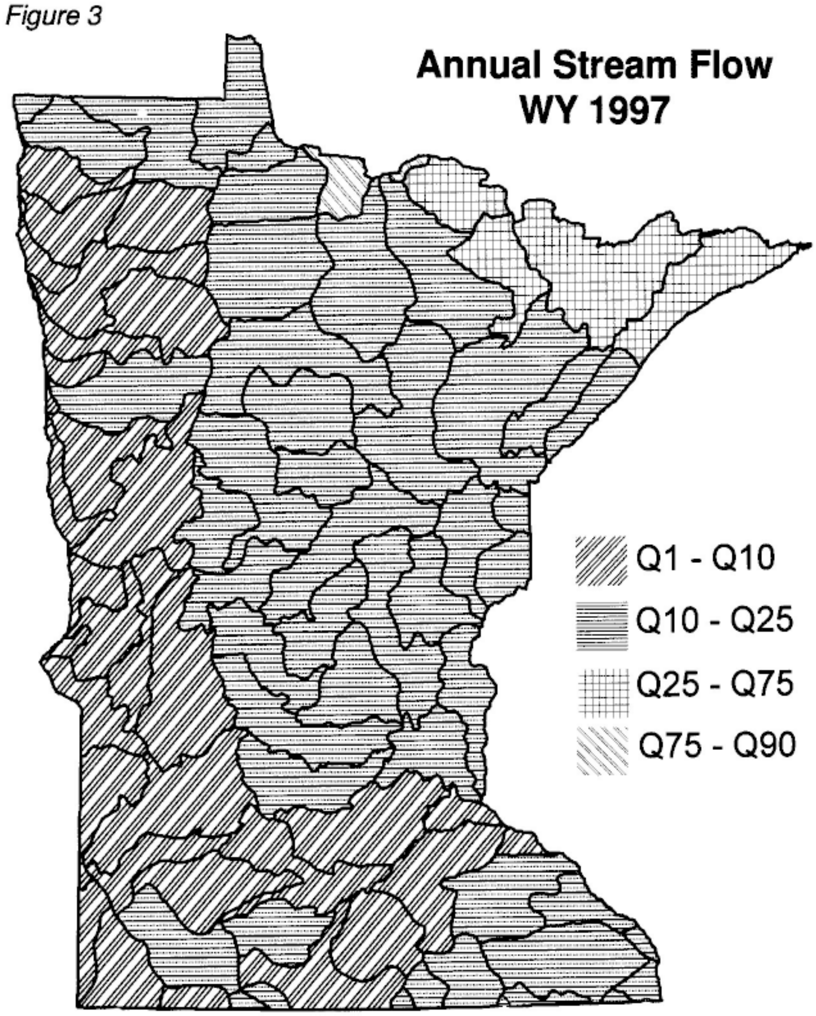
Currently, there are nearly 100 continuous recording stream gages maintained by the USGS. The U.S. Army Corps of Engineers, the Minnesota Department of Natural Resources, the Minnesota Department of Transportation, the Pollution Control Agency, and the Metropolitan Council and other state and local agencies, including watershed districts and lake associations, maintain and operate additional stream gages.

1997 Water Year

As the 1996 water year ended, stream flow conditions in most of Minnesota were in the normal range, with a few high flows scattered throughout the state. During the winter of 1997, snow fell in large amounts, with record amounts in the western portion of the state. Major to severe flooding was predicted by the National Weather Service as early as January, 1997.

The spring snow melt, which started in late March in southwestern Minnesota and early April in the Red River Valley, was less than ideal (see Climatology, Page 6). In addition to the large snow pack, significant precipitation fell during the melt to cause record flooding in the Red and upper Minnesota watersheds (see sidebar on pages 20-21). In the lower Minnesota watershed, the tributaries south of the Minnesota River experienced an early and gentle snow melt. This greatly reduced the severity of flooding on the lower Minnesota and lower Mississippi Rivers.

Figure 3



By late May, only the Red River and portions of the upper Minnesota River still had flows in the high range. Flows in the Roseau, Upper Mississippi and the lower Minnesota Rivers had fallen into the normal flow range, while flows in the St. Croix River fell below normal. Flows remained high for much of the Red River and upper Minnesota River well into June, but flows throughout the Roseau, Upper Mississippi, Great Lakes and St. Croix basins fell into the low range. By mid-June, low flows were occurring in the St. Croix, St. Louis and several Rainy River watersheds.

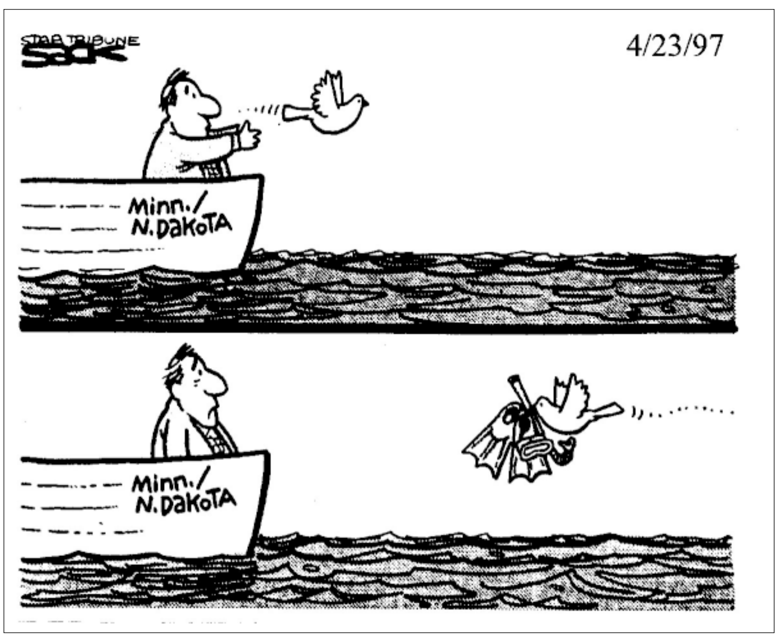
In July, stream flows increased significantly in much of the state. July rains increased flows for most of the state into the high range, and flood flows returned to the upper Mississippi River, Red Lake, Clearwater and Thief River watersheds.

With the exception of the Arrowhead Region and the St. Croix River basin, most of the state experienced flows greater than the Q25 in August and many parts of the state experienced flows greater than the Q10. The upper St. Croix River watershed increased to the normal range, while flows in the Arrowhead dropped well into the low range.

Flows decreased in September, with normal flows expanding from the St. Croix basin into the central part of the state to include parts of the upper Mississippi River Basin. Many areas that had been above the Q10 in August fell into the Q10 to Q25 range for September. Flows above the Q25 would continue throughout September for much of the Minnesota, Red and western watersheds of the upper Mississippi. The Arrowhead, which had flows below the Q75 in August, had all watersheds reporting flows below the Q90 in September.

Figure 3 is the annual stream flow map for 1997. It shows that the volume of water discharged in 1997 was greater than the annual Q25 for the state and greater than the Q10 for much of the Red River and Minnesota River systems.

The annual map makes it appear that 1997 was a very wet year. While 1997 was the flood of record for much of the western half of the state, much of the year was near normal in terms of discharge. The magnitude of the spring floods biases the annual map, making it appear that the entire year was very wet.



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April, 1997 Flooding in the Red River of the North and Upper Minnesota River basins

The Climatology section of this publication (pages 5-6) contains a description of factors contributing to the record flooding in April, 1997. The actual impacts, in terms of measured stream flow, are quantified in the mean daily stage graph below and instantaneous discharge graph on page 21. The flooding on the Minnesota River above New Ulm and on the entire Red River established many new records. Those records are shown in the table at the right.

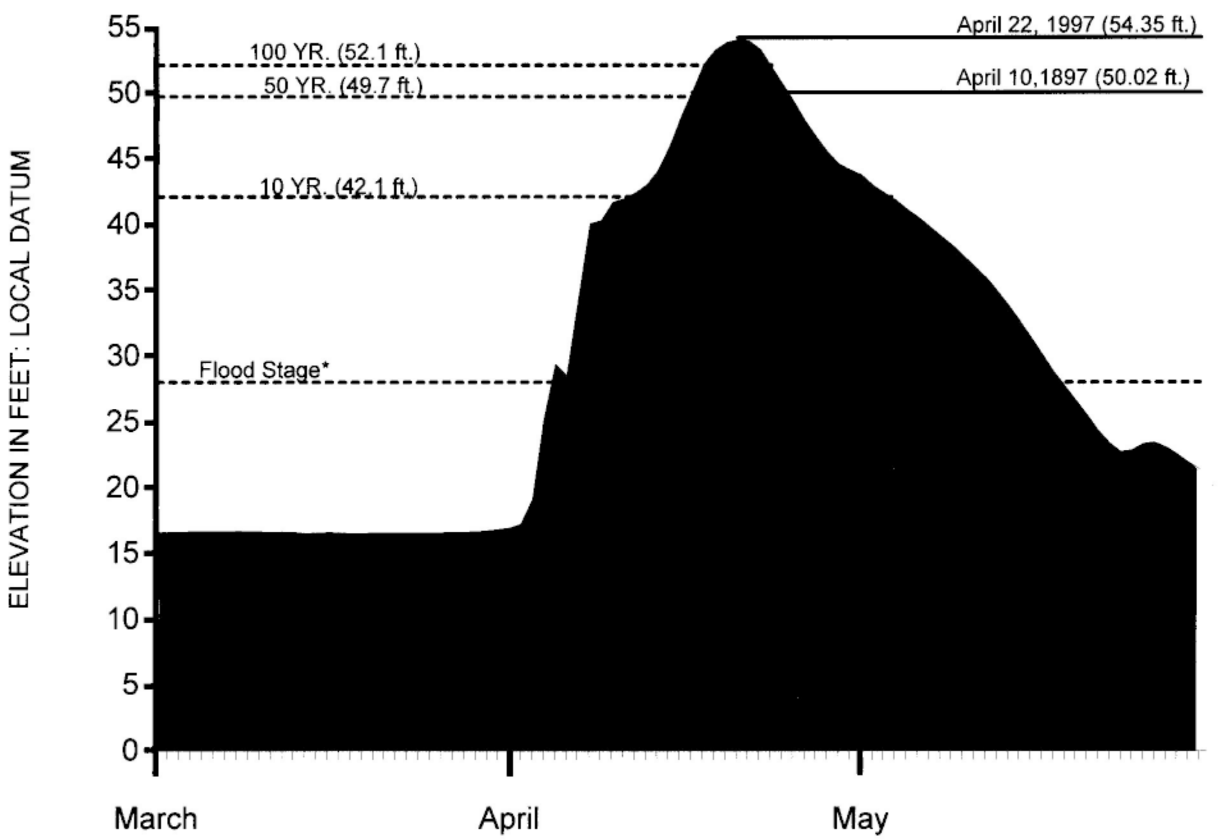
Minnesota River

Community	Previous Record (Year)	New Record - 1997
Montevideo	21.68 (1969)	23.90
Granite Falls	12.60 (1969)	15.40
New Ulm	30.50 (1969)	32.23

Red River of the North

Community	Previous Record (Year)	New Record - 1997
Breckenridge	17.95 (1989)	19.42
Moorhead	37.34 (1969)	39.72
Halstad	39.00 (1979)	40.74
East Grand Forks	50.02 (1897)	54.35
Drayton, N.D.	43.66 (1979)	45.55

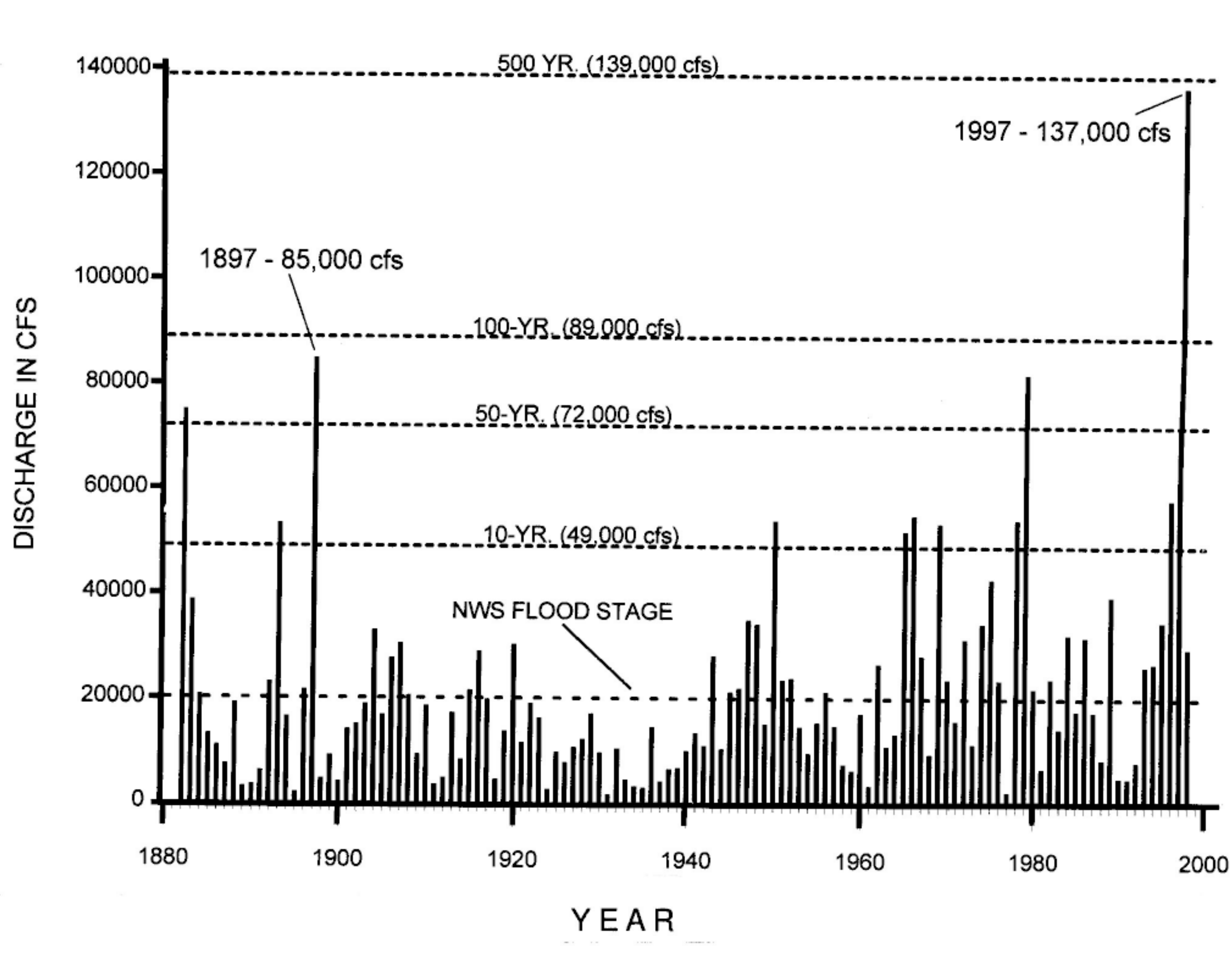
Red River at East Grand Forks
Mean Daily Stage



* From National Weather Service

MARCH 1 TO MAY 31, 1997

Red River of the North at Grand Forks, ND
Highest Annual Instantaneous Discharge



The stage hydrograph at the bottom of page 20 shows that flood waters reached an elevation of 54.35' (local datum) at Grand Forks, far exceeding the previous record of 50.02' set in 1897, 100 years earlier. The graph above compares the highest annual instantaneous discharge at Grand Forks for the period 1882 through 1998. The 1997 event reached a peak of 137,000 cfs, far greater than the previous record of 85,000 cfs, also set in 1897.

Some have identified the drainage of wetlands and agricultural and urban uses of land as factors causing the floods of 1997 to reach record proportions. Wetlands and land use can have significant effects on how much and how soon water runs off into streams and rivers, particularly when climatic conditions are near average or "normal". However, after receiving record or near-record amounts of precipitation over thousands of square miles of land in the river basin, the resulting runoff volume simply overwhelmed the hydrologic system and made wetland drainage and land use practices relatively insignificant when describing causes of the resulting record flooding.

1998 Water Year

As a result of the flooding in 1997, surface water levels throughout the Red River Valley and western Minnesota remained in the high range well into 1998. Stream flow conditions for much of April were near normal for the remainder of the state. By May, low flow conditions developed in parts of the St. Croix, the upper Mississippi and in the Arrowhead Region. High flows continued in parts of the Red River Valley. Low flow conditions expanded to the upper St. Croix River and the upper Minnesota River watersheds throughout much of May. The remainder of the state had near normal flows.

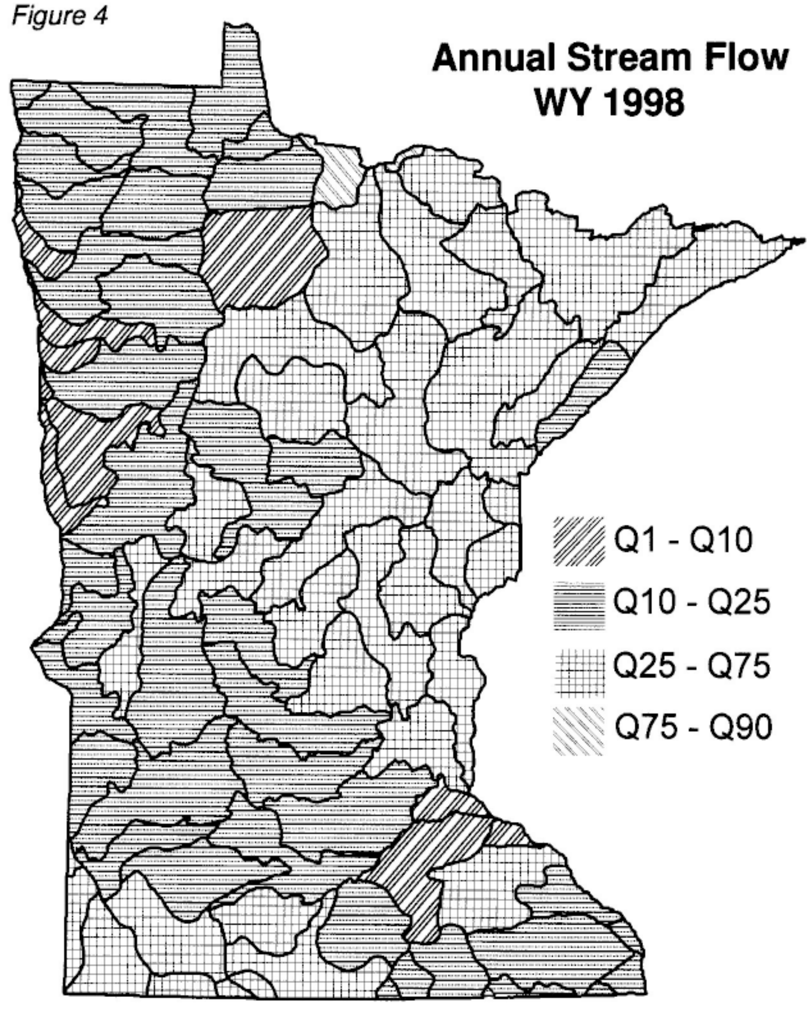
June flows in the Red River basin continued in the high range, while storms brought the lower Mississippi River into the high range. Low flow conditions continued to develop in the Arrowhead Region and in the St. Croix and the Missouri River watersheds.

During July, a series of strong storms produced significant precipitation trending from the northwest corner of the state to the southeast corner. Abnormally high flows for the month of July could be found along this line, including the Red River, the lower Mississippi River and the lower Minnesota River. Also in the high range were the southern-most watersheds of the upper Mississippi River. Normal conditions could be found in the upper Minnesota River basin and the northern third of the upper Mississippi River basin. Low flow conditions continued in the Missouri, St. Croix, the Arrowhead Region and portions of the Rainy River basin.

By August, rains increased flows in the Missouri River watersheds into the normal range. However, conditions in the Arrowhead worsened, with stream flows falling to near-record lows. Low flow conditions expanded in the Rainy River watersheds and into the upper Mississippi River watersheds. High flows continued in the Red River and lower Mississippi River watersheds.

In September, low and very low flows expanded to include all of the Rainy River, the upper Mississippi River, Lake Superior and the St. Croix basins. Stream flows in the Red River basin continued in the high range, though several watersheds fell into the normal range, as were flows in the Minnesota River watersheds. Flows in about half of the lower Mississippi River watersheds also fell to the normal range. Figure 4 is the annual stream flow map for Water Year 1998.

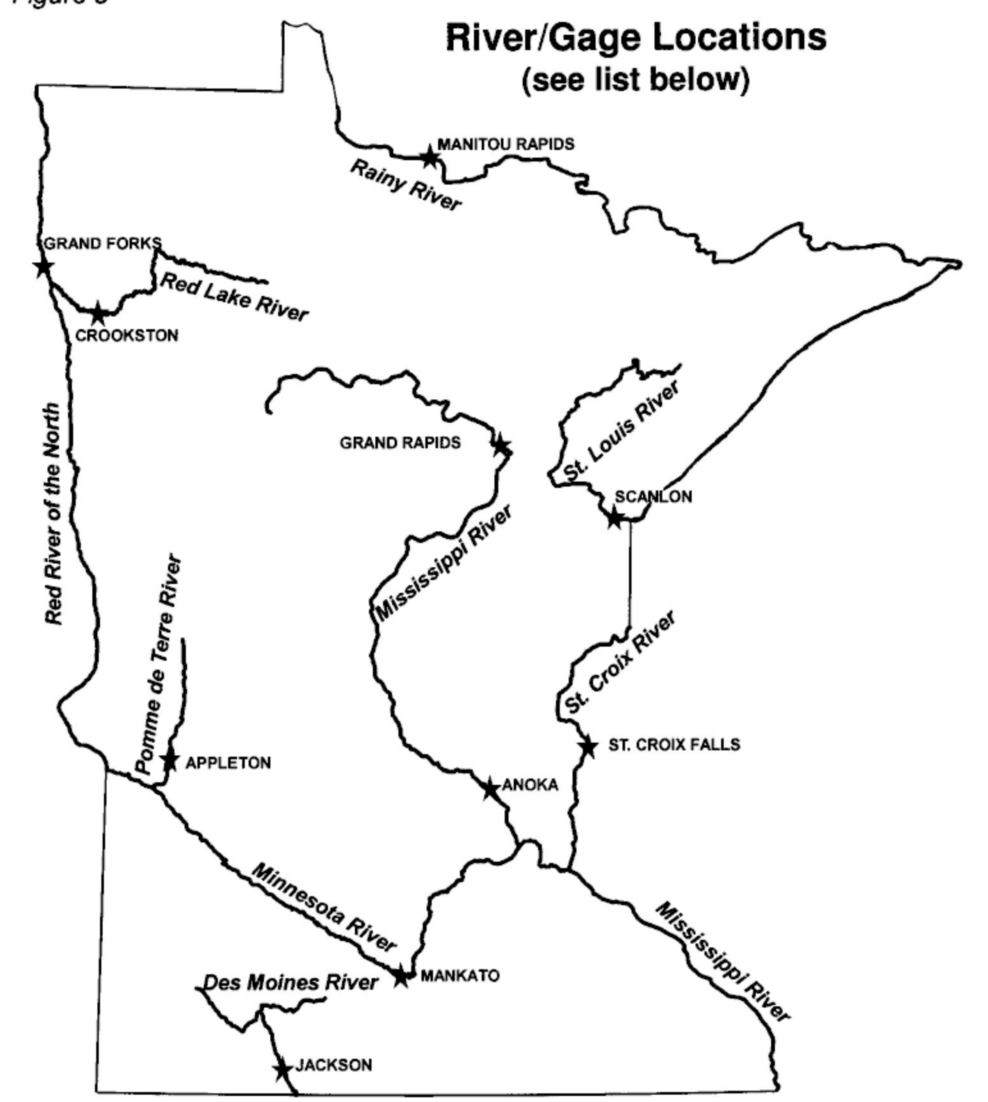
Figure 4



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.

Figure 5

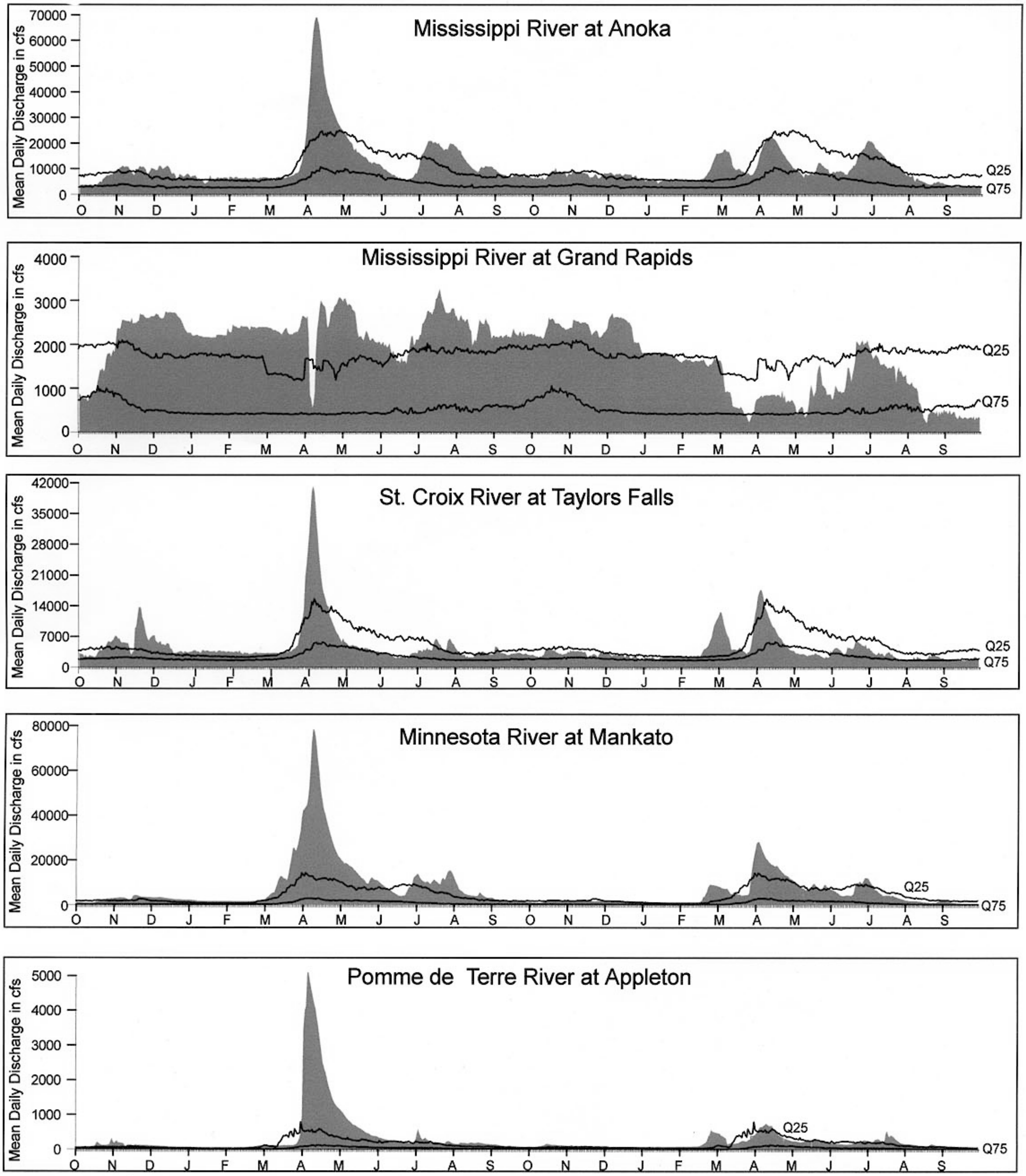


Figures 6 and 8 show two-year hydrographs for the ten selected sites. In addition to the mean daily discharge, the Q25 and Q75 exceedence levels are shown. The Q25 and Q75 are statistical parameters where the Q25 is the value a stream will exceed 25 percent of the time, and the Q75 is the value a stream will exceed 75% of the time. The range between Q25 and Q75, is called the interquartile range. Flows in the interquartile range are considered normal while flows exceeding the Q25 are considered high and flows below Q75 are considered low.

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.

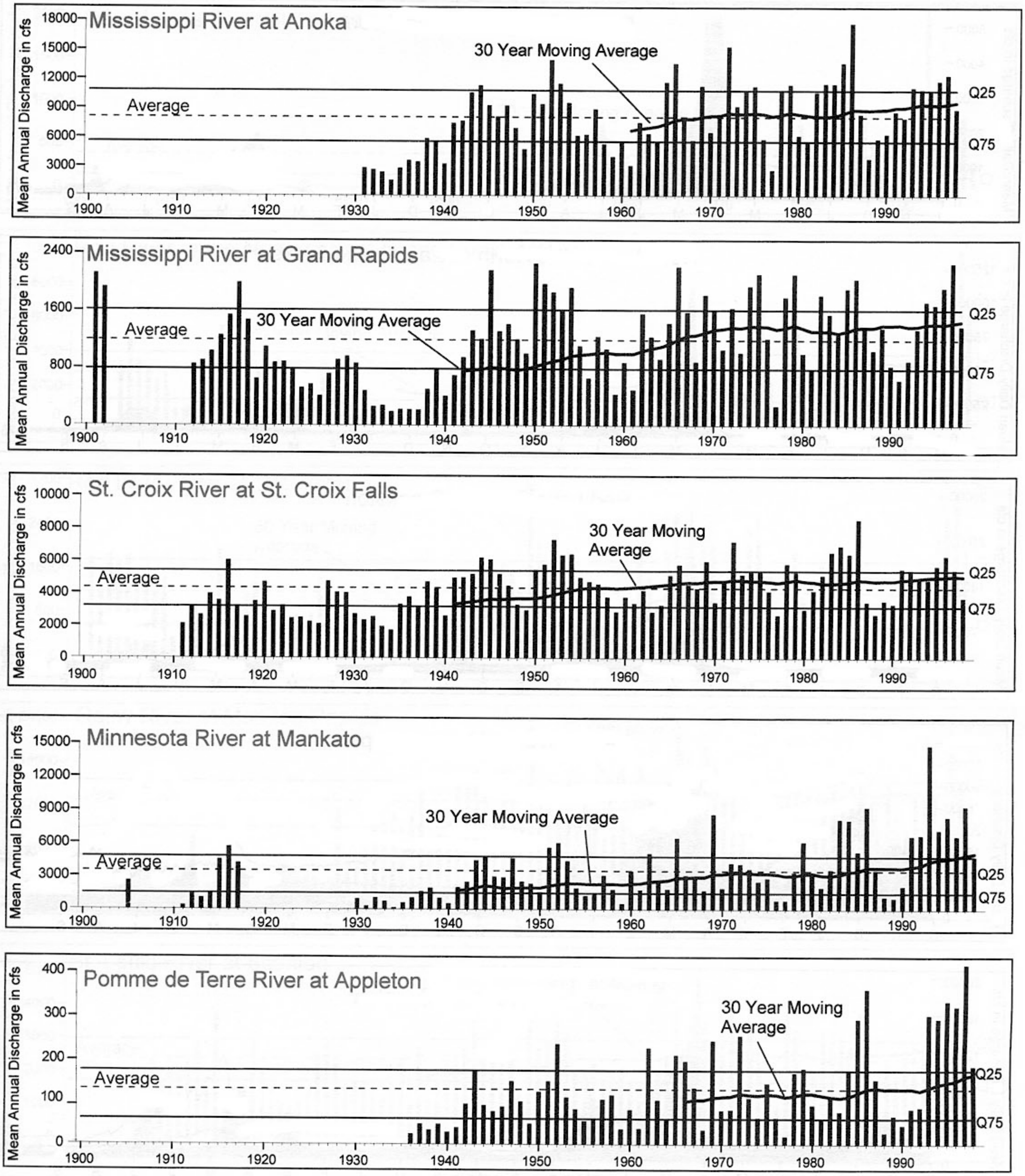
1) Mississippi River at Anoka
2) Mississippi River at Grand Rapids
3) St. Croix River at Taylors Falls
4) Minnesota River at Mankato
5) Pomme de Terre River at Appleton
6) Des Moines River at Jackson
7) Red River of the North at East Grand Forks
8) Red Lake River at Crookston
9) Rainy River at Manitou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

Figure 6



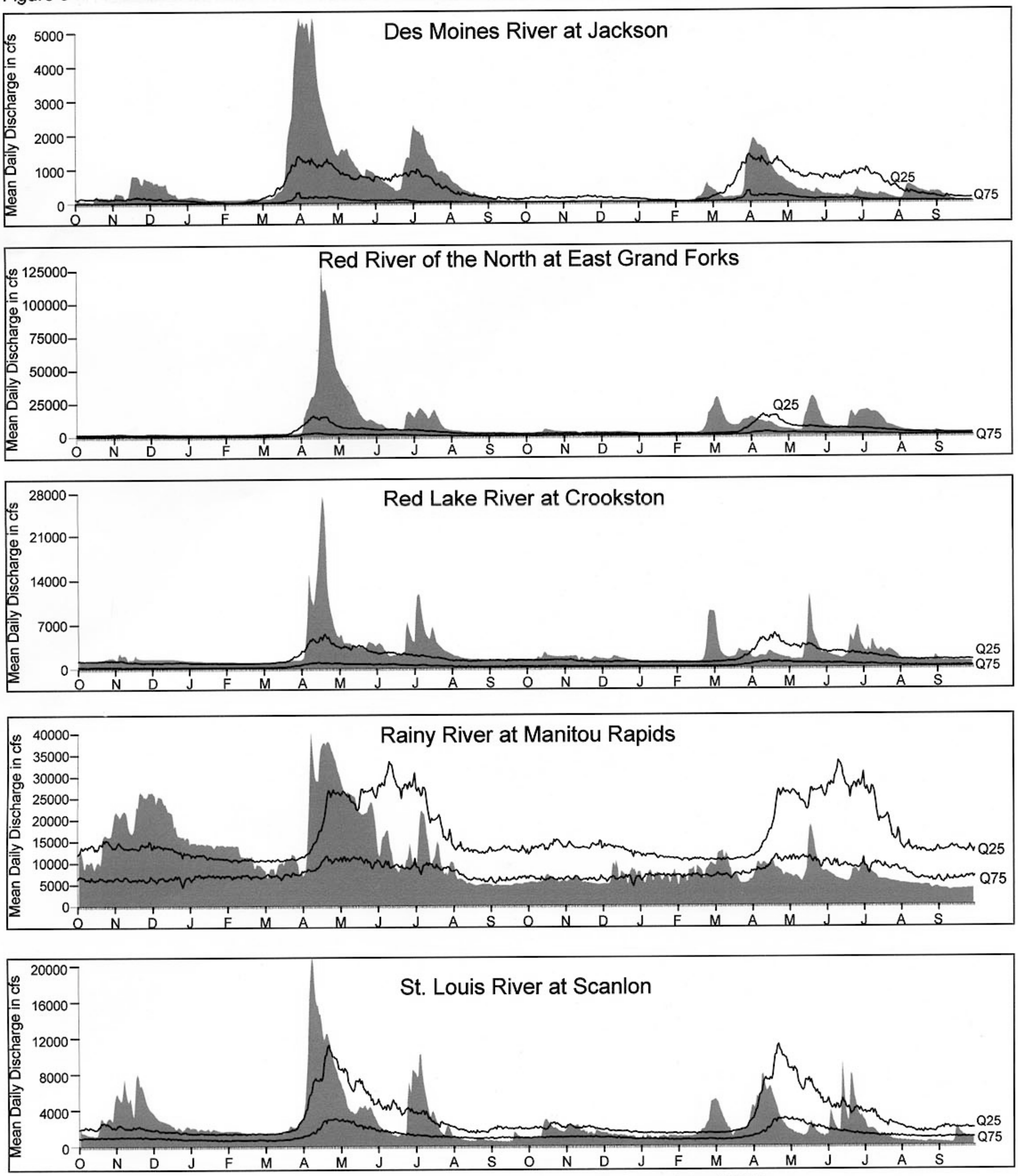
October 1, 1996, to September 30, 1998

Figure 7



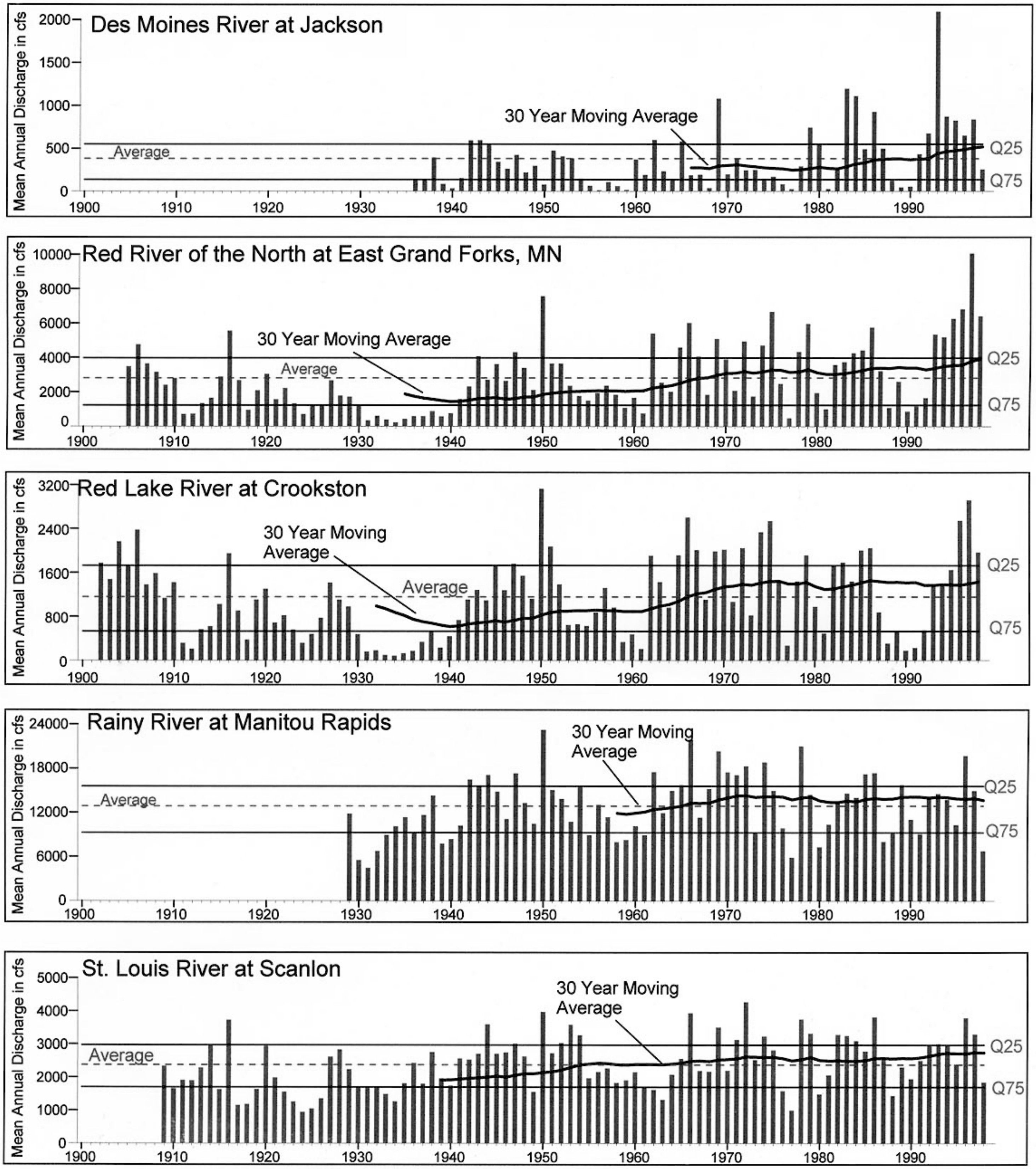
1900 to 1998

Figure 8



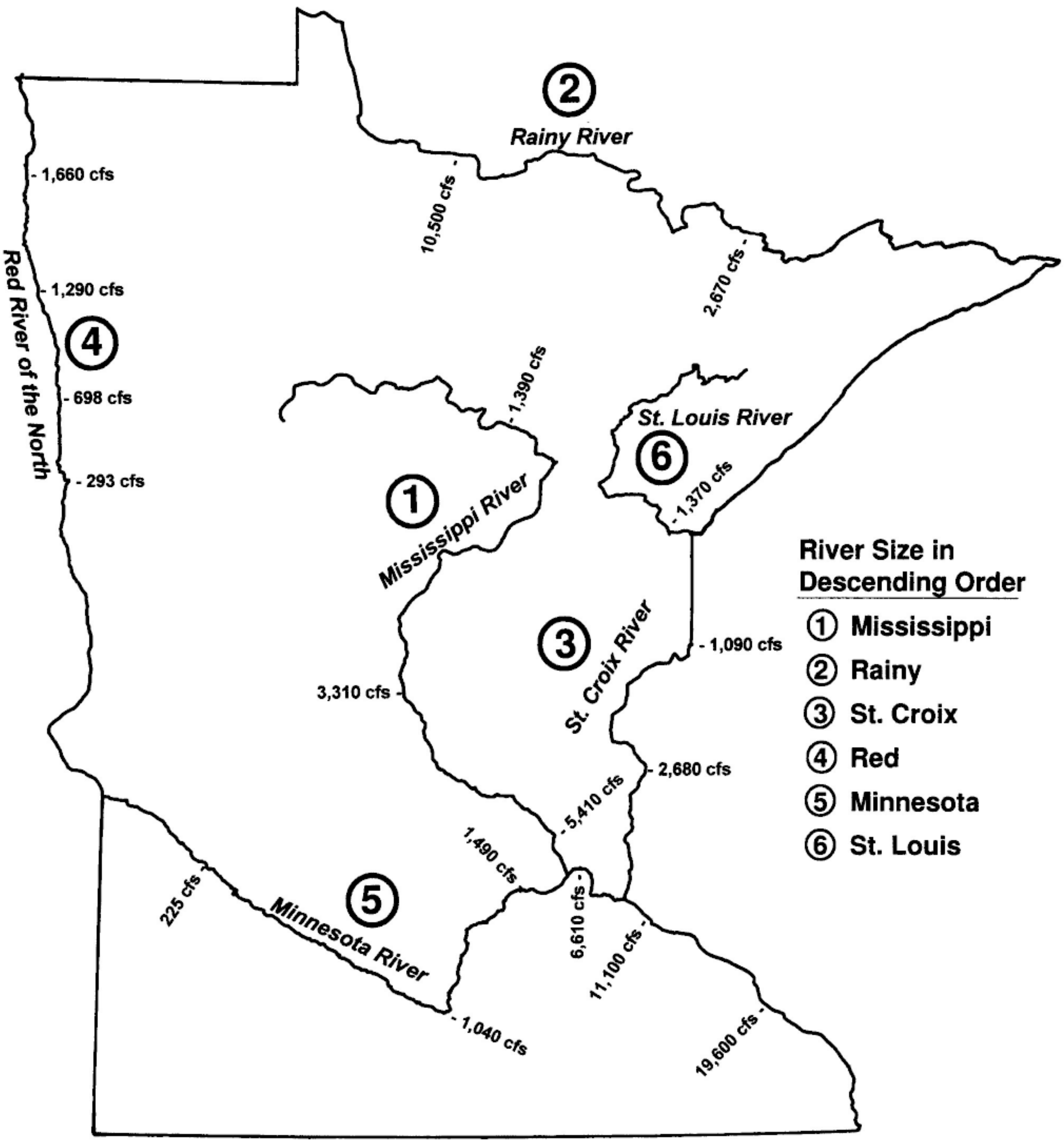
October 1, 1996, to September 30, 1998

Figure 9



1900 to 1998

Mean Annual Discharge of Selected Rivers



The relative size of the largest rivers in Minnesota is frequently the subject of discussion and debate. The map above shows the approximate size of the six largest rivers in terms of the mean annual discharge at specific gage locations.

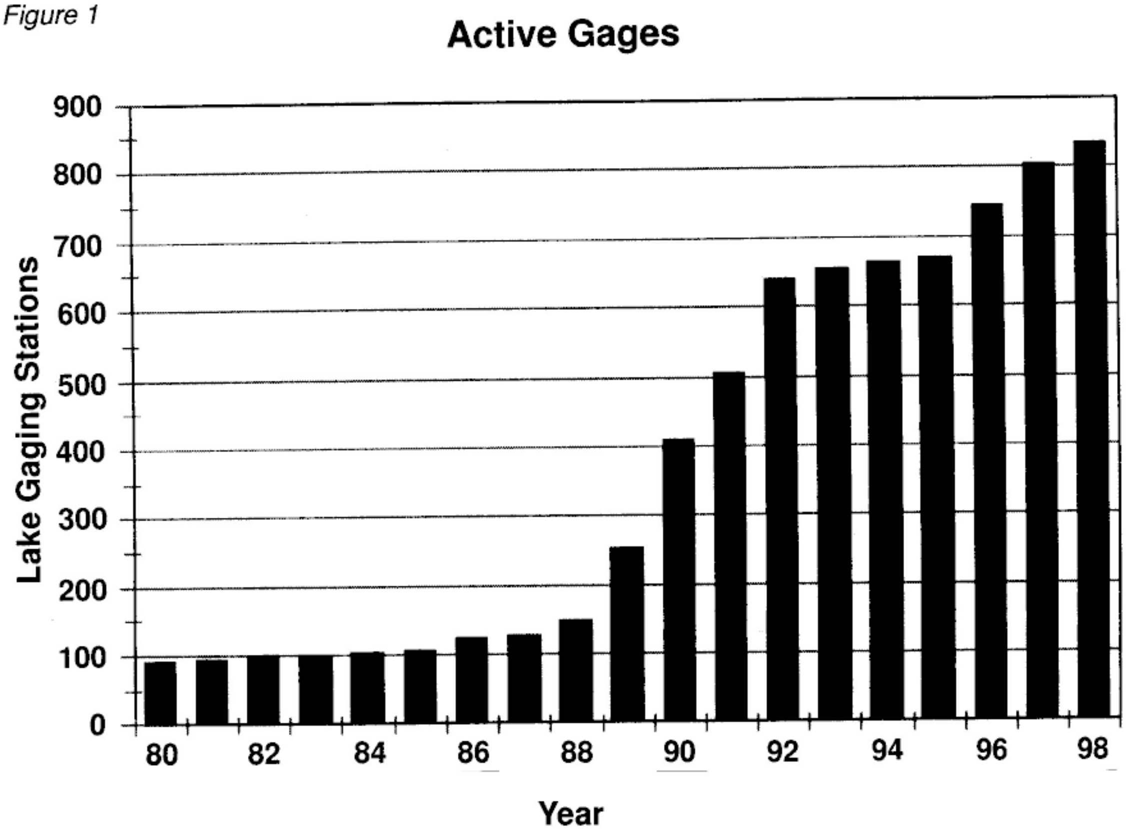
Lake Levels

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. Lake levels were actively monitored at 832 sites in 1998 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



Organizations are another key to the success of this program. These organizations include:

- Anoka County SWCD
- Thirty Lakes WD
- Cass County SWCD
- Ramsey-Washington Metro WD
- Douglas County SWCD
- Valley Branch WD
- Nobles County SWCD
- City of Big Lake
- Polk County SWCD
- City Chisholm
- Sherburne County SWCD
- City of Columbia Heights
- Washington County SWCD
- City of Fairmont
- Carver County
- City of Hendricks
- Douglas County
- City of Lakeville
- Nobles County
- City of Maple Grove
- Ramsey County
- City of Maple Plain
- Swift County
- City of St. James
- Jackson County
- City of Willmar
- Minnehaha Creek WD
- City of Worthington
- North Fork Crow River WD
- Otter Tail Power Company
- Minnesota Zoo

Lake gage readings received from volunteers and organizations are entered in Lakes db©, a database program for easy management and access of recorded lake levels and other useful information.

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. Water Year 1997 saw a statewide average fluctuation of 1.55 feet, which corresponds to the above-normal precipitation received during the year. Water Year 1998 had an average fluctuation of 1.04 feet (averages for six water years are shown in Figure 2). The tables on pages 36 to 43 display fluctuations for Water Year 1997, Water Year 1998 and an average fluctuation for the indicated period of record.

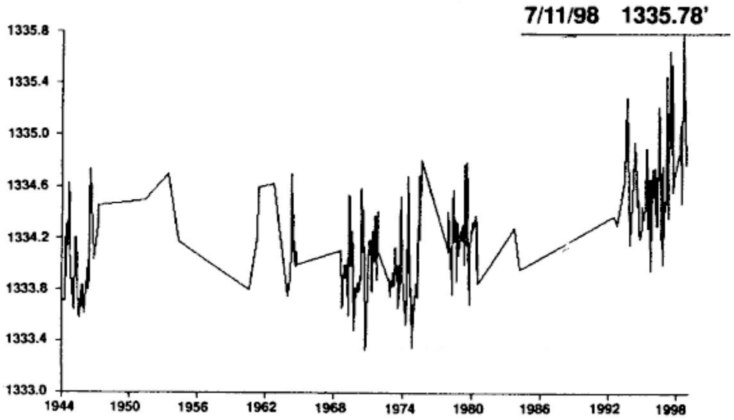
Figure 2

Water Year	Average Fluctuation Statewide (ft)
1993	1.61
1994	1.22
1995	1.03
1996	1.24
1997	1.55
1998	1.04

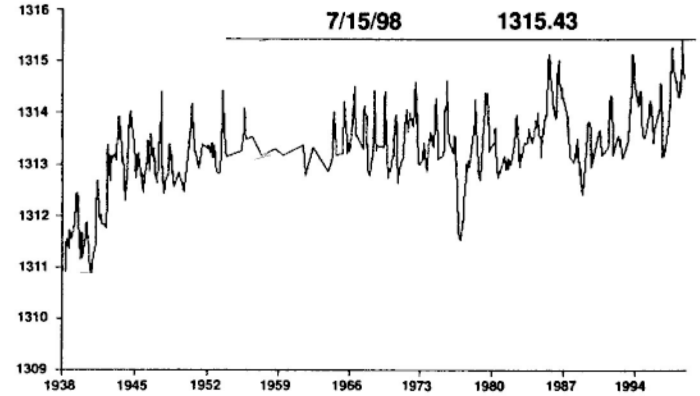
Lake Level Trends

Many lakes, primarily located in the central third of the state, experienced their highest recorded levels during 1997 or 1998. Lake level hydrographs for five representative lakes are shown on page 31, with their peak levels and corresponding dates highlighted.

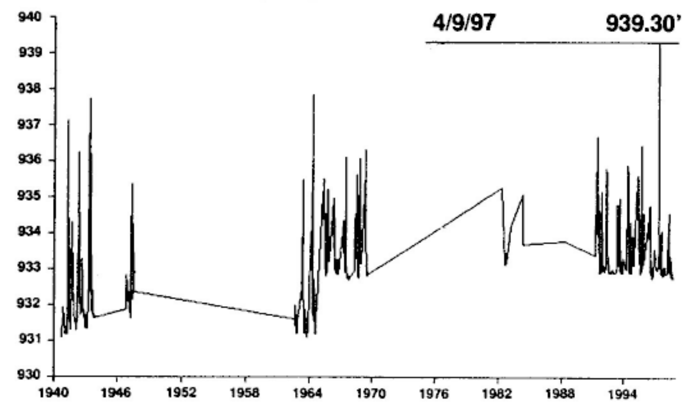
Detroit Lake (3-381) Becker County
Water Levels



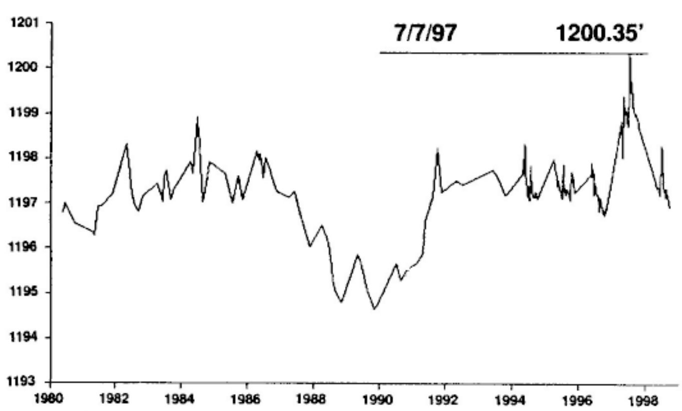
Lizzie Lake (56-760) Otter Tail County
Water Levels



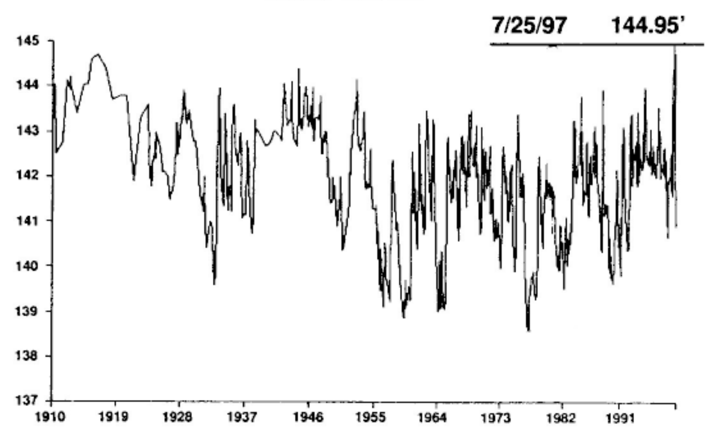
Pokegama Lake (58-142) Pine County
Water Levels



Norway Lake (34-251) Kandiyohi County
Water Levels



Lake Calhoun (27-31) Hennepin County
Water Levels



Landlocked Basins

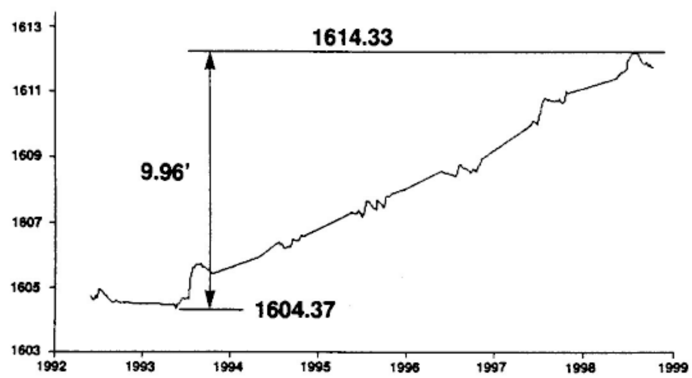
A landlocked lake has no functioning surface outlet channel, a small watershed, and typically experiences large, long-term water level fluctuations. The importance of ground water contributions to landlocked lakes can make them a good indicator of local ground water levels and movement.

The graphs on page 33 represent water levels for several landlocked basins that experienced their highest levels during 1997 or 1998. The graphs also display, numerically, the difference (in feet) between the highest and lowest observed water levels for the indicated period of record.

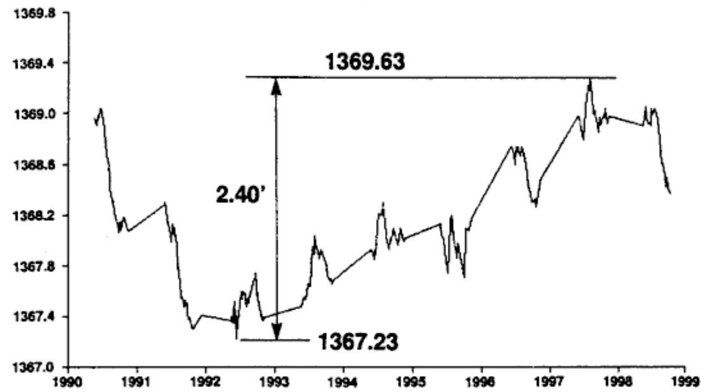
Ten-Year Trends

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. Many of the lakes graphed on pages 34 and 35 are above their ten-year average, generally in response to above-normal precipitation in recent years.

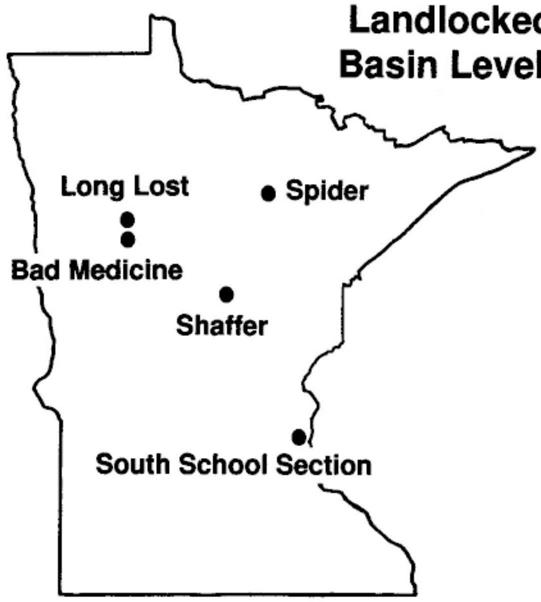
Long Lost Lake (15-68) Clearwater County
Water Levels



Spider Lake (31-538) Itasca County
Water Levels



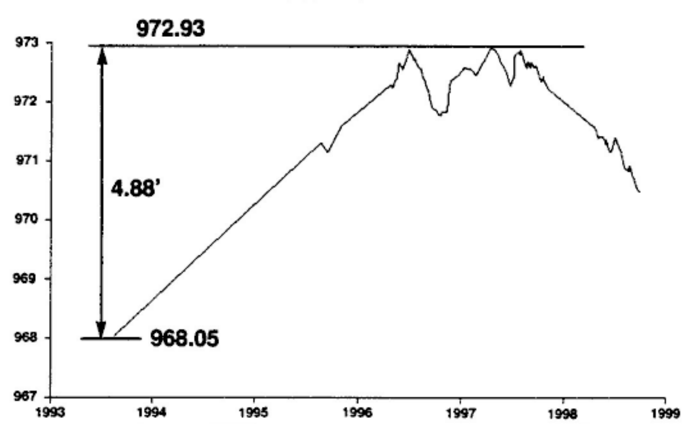
Landlocked Basin Levels



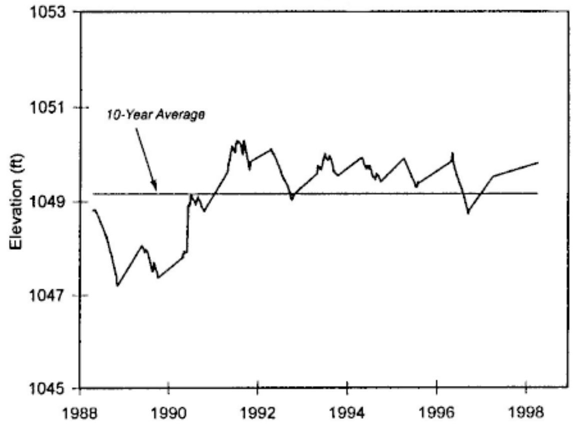
Bad Medicine Lake (3-85) Becker County
Water Levels

Shaffer Lake (18-348) Crow Wing County
Water Levels

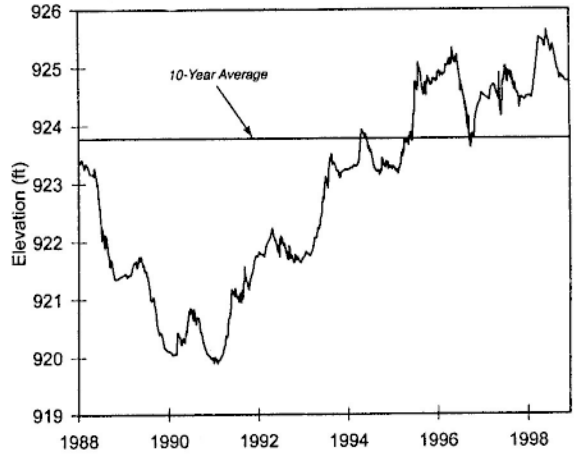
South School Section Lake (82-151) Washington County
Water Levels



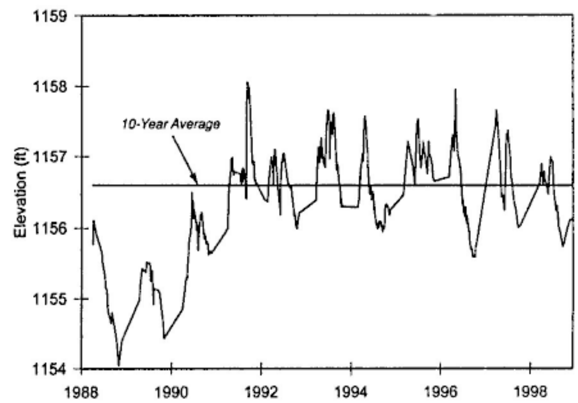
**Sylvia Lake (86-289) Wright County
Water Levels, 1988-1998**



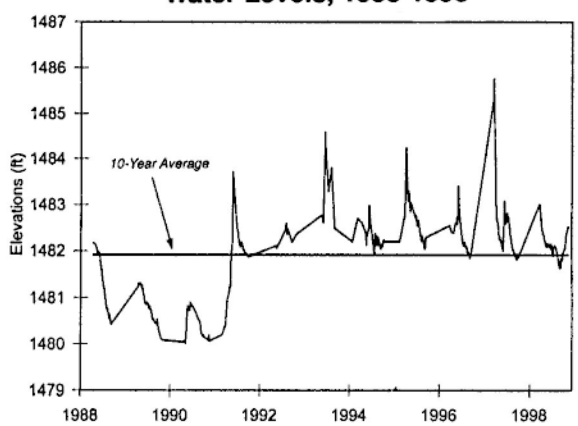
**White Bear Lake (82-167) Washington County
Water Levels, 1988-1998**



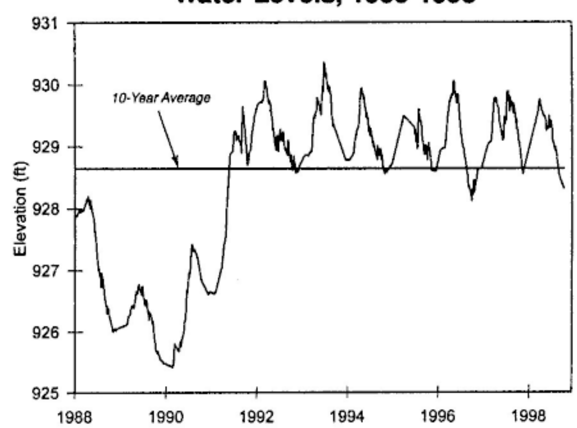
**Green Lake (34-79) Kandiyohi County
Water Levels, 1988-1998**



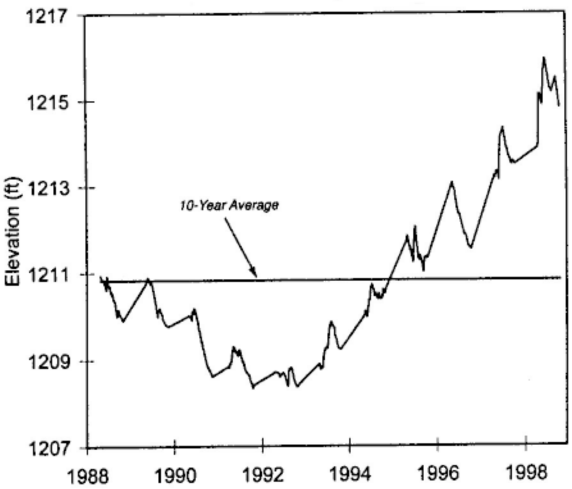
**Lake Shetek (51-46) Murray County
Water Levels, 1988-1998**



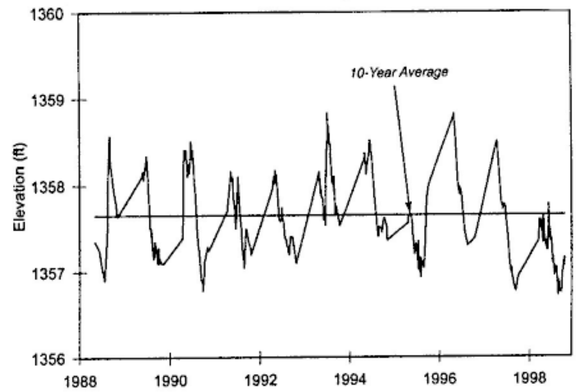
**Lake Minnetonka (27-133) Hennepin County
Water Levels, 1988-1998**



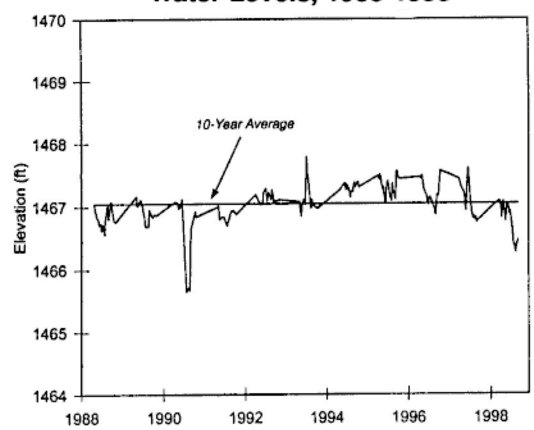
Union Lake (60-217) Polk County Water Levels, 1988-1998



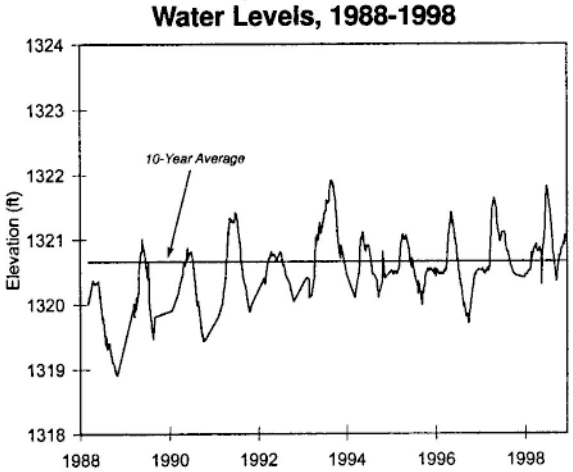
Lake Vermilion (69-378) St. Louis County Water Levels, 1988-1998



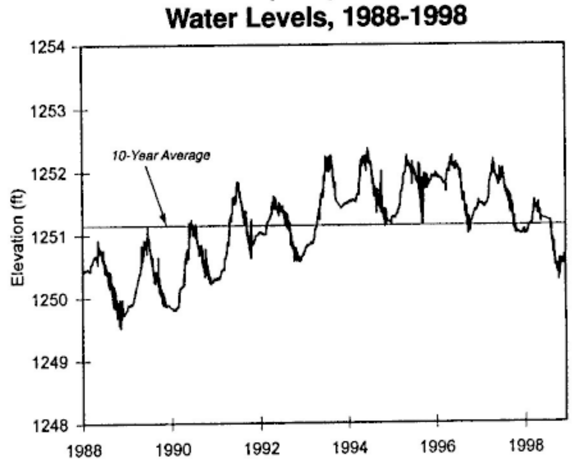
Lake Itasca (15-16) Clearwater County Water Levels, 1988-1998



Otter Tail Lake (56-242) Otter Tail County Water Levels, 1988-1998



Lake Mille Lacs (48-2) Mille Lacs County Water Levels, 1988-1998



Annual Lake Level Fluctuation (feet)

Lake Name	WY97	WY98	WY Ave.
AITKIN COUNTY			
Big Sandy (01-0062 00)	5.81	2.36	5.36 (100 yrs.)
Blackface (01-0045 00)	0.73	0.66	0.73 (7 yrs.)
Cedar (01-0209 00)	0.88	1.18	1.62 (48 yrs.)
Clear (01-0093 00)	0.49	0.71	0.86 (28 yrs.)
Dam (01-0096 00)	0.92	0.78	1.24 (15 yrs.)
Davis (01-0071 00)	3.77	2.87	3.32 (2 yrs.)
Elm Island (01-0123 00)	1.04	1.86	1.34 (5 yrs.)
Farm Island (01-0159 00)	1.12	0.90	0.99 (21 yrs.)
Gun (01-0099 00)	0.86	0.67	0.67 (9 yrs.)
Lone (01-0125 00)	0.72	0.72	0.68 (8 yrs.)
Long (01-0101 00)	0.58	0.70	0.55 (6 yrs.)
Minnewawa (01-0033 00)	0.80	0.80	0.80 (16 yrs.)
Rat (01-0077 00)	0.56	0.81	1.17 (6 yrs.)
Rock (01-0072 00)	0.76	0.54	0.74 (5 yrs.)
Round (01-0023 00)	0.50	0.69	0.66 (6 yrs.)
Round (01-0204 00)	0.49	0.97	0.91 (8 yrs.)
Spirit (01-0178 00)	1.16	0.24	0.55 (18 yrs.)
Sugar (01-0087 00)	0.34	0.64	0.74 (28 yrs.)
Waukenabo (01-0136 00)	2.02	1.16	1.35 (17 yrs.)
Wilkins (01-0102 00)	0.66	0.79	0.73 (2 yrs.)
ANOKA COUNTY			
Baldwin (02-0013 00)	2.84	3.92	3.03 (24 yrs.)
Bunker (02-0090 00)	0.82	1.46	1.62 (13 yrs.)
Coon (02-0042 00)	0.62	0.83	1.08 (30 yrs.)
Crooked (02-0084 00)	0.73	0.60	0.87 (14 yrs.)
Fawn (02-0035 00)	0.50	0.81	1.03 (10 yrs.)
George (02-0091 00)	1.11	1.39	1.26 (14 yrs.)
Golden (02-0045 00)	1.16	0.75	0.84 (10 yrs.)
Ham (02-0053 00)	0.59	0.73	1.03 (14 yrs.)
Howard (02-0016 00)	1.02	0.98	1.00 (9 yrs.)
Itasca (02-0110 00)	1.37	1.42	1.45 (9 yrs.)
Laddie (02-0072 00)	1.12	1.00	0.89 (7 yrs.)
Linwood (02-0026 00)	0.60	0.61	0.74 (23 yrs.)
Marshan (02-0007 00)	2.64	7.49	5.07 (2 yrs.)
Martin (02-0034 00)	1.66	1.34	1.18 (20 yrs.)
Moore (02-0075 00)	1.48	0.83	0.97 (10 yrs.)
Netta (02-0052 00)	0.88	0.98	1.09 (15 yrs.)
Otter (02-0003 00)	1.35	1.09	1.64 (76 yrs.)
Peltier (02-0004 00)	2.53	4.31	2.83 (48 yrs.)
Pet (02-0036 00)	0.66	1.13	1.00 (3 yrs.)
Reshanau (02-0009 00)	2.37	1.75	1.94 (9 yrs.)
Rice (02-0008 00)	2.85	3.92	3.25 (10 yrs.)
Rogers (02-0104 00)	1.14	1.53	1.34 (10 yrs.)
Rondeau (02-0015 00)	0.92	0.77	0.92 (7 yrs.)
Round (02-0089 00)	0.79	1.10	1.15 (14 yrs.)
Sand Shore (02-0102 00)	1.14	1.22	0.87 (7 yrs.)
Sandy (02-0080 00)	2.30	0.80	1.50 (7 yrs.)
Spring (02-0071 00)	1.71	1.14	1.61 (44 yrs.)
Unnamed (Highland) (02-0079 00)	0.58	0.13	0.46 (3 yrs.)
BECKER COUNTY			
Bad Medicine (03-0085 00)	1.40	1.32	0.88 (12 yrs.)
Big Cormorant (03-0576 00)	2.15	1.42	1.11 (33 yrs.)
Big Sugar Bush (03-0304 00)	1.09	1.45	1.00 (5 yrs.)
Buffalo (03-0350 00)	0.91	0.84	1.18 (18 yrs.)
BECKER COUNTY (cont):			
Detroit (03-0381 00)	1.50	1.30	0.96 (21 yrs.)
Elbow (03-0159 00)	1.33	1.48	1.33 (7 yrs.)
Eunice (03-0503 00)	0.84	0.88	0.65 (8 yrs.)
Fox (03-0358 00)	0.22	0.46	0.25 (6 yrs.)
Height of Land (03-0195 00)	1.36	1.60	1.54 (41 yrs.)
Ida (03-0582 00)	0.54	0.96	0.99 (11 yrs.)
Juggler (03-0136 00)	0.77	1.25	0.86 (6 yrs.)
Little Floyd (03-0386 00)	1.43	1.30	1.06 (16 yrs.)
Little Toad (03-0189 00)	0.48	0.99	0.65 (5 yrs.)
Long (03-0383 00)	0.49	0.60	0.55 (12 yrs.)
Maud (03-0500 00)	0.75	0.66	0.81 (7 yrs.)
Melissa (03-0475 00)	1.36	1.57	1.07 (23 yrs.)
Muskrat (03-0360 00)	1.20	1.02	0.90 (26 yrs.)
Pickerel (03-0287 00)	1.61	1.20	0.98 (7 yrs.)
Rock (03-0293 00)	1.60	1.50	1.18 (4 yrs.)
Round (03-0155 00)	1.00	1.40	1.12 (16 yrs.)
Sallie (03-0359 00)	2.10	1.50	1.26 (31 yrs.)
Straight (03-0010 00)	0.80	0.30	0.54 (13 yrs.)
Talac (03-0619 00)	2.04	3.50	1.46 (6 yrs.)
Toad (03-0107 00)	1.12	1.62	1.23 (18 yrs.)
Turtle (03-0657 00)	0.93	1.08	1.01 (2 yrs.)
Two Inlets (03-0017 00)	1.80	1.18	1.26 (17 yrs.)
Upper Cormorant (03-588 00)	2.22	1.69	1.09 (23 yrs.)
White Earth (03-0328 00)	0.76	1.62	0.98 (18 yrs.)
BELTRAMI COUNTY			
Bemidji (04-0130 00)	1.98	1.78	1.78 (15 yrs.)
Cass (04-0030 00)	2.15	1.45	1.90 (52 yrs.)
Gallagher (Rhoda) (04-92 00)	0.74	0.77	0.77 (26 yrs.)
Long (04-0076 00)	0.53	0.72	0.76 (12 yrs.)
Manomin (04-0286 00)	2.28	1.63	1.95 (2 yrs.)
Manomin (TW) (04-0286 TW)	2.47	1.31	1.89 (2 yrs.)
Pimushe (04-0032 00)	2.30	2.14	2.22 (2 yrs.)
Red (04-0035 00)	1.94	2.10	1.60 (53 yrs.)
Stump (04-0130 01)	2.66	1.94	2.32 (15 yrs.)
Turtle (04-0159 00)	0.83	0.94	0.89 (2 yrs.)
Turtle River (04-0111 00)	3.46	1.82	1.74 (26 yrs.)
BIG STONE COUNTY			
Big Stone (06-0152 00)	8.40	1.42	2.45 (29 yrs.)
East Toqua (06-0138 00)	2.02	1.24	1.72 (8 yrs.)
BLUE EARTH COUNTY			
Crystal (07-0098 00)	1.00	0.35	0.85 (28 yrs.)
Duck (07-0053 00)	1.08	1.04	1.09 (8 yrs.)
BROWN COUNTY			
Sleepy Eye (08-0045 00)	1.73	0.82	1.62 (11 yrs.)
Somsen (08-0018 00)	4.32	2.51	3.51 (8 yrs.)
CARLTON COUNTY			
Bear (09-0034 00)	0.78	1.76	1.27 (2 yrs.)
Big (09-0032 00)	0.38	0.74	0.56 (6 yrs.)
Chub (09-0008 00)	0.94	1.54	0.97 (12 yrs.)
Eagle (09-0057 00)	0.32	0.82	0.67 (6 yrs.)
Eddy (09-0039 00)	1.89	2.34	2.75 (5 yrs.)
Hanging Horn (09-0038 00)	1.70	0.46	1.98 (8 yrs.)

Annual Lake Level Fluctuation (feet)

Lake Name	WY97	WY98	WY Ave.
CARLTON COUNTY (cont):			
Little Hanging Horn (09-35 00)	1.70	2.02	2.17 (8 yrs.)
Park (09-0029 00)	0.44	0.88	0.66 (8 yrs.)
Torch Light (09-0025 00)	0.58	1.20	0.87 (6 yrs.)
CARVER COUNTY			
Ann (10-0012 00)	1.30	2.63	1.28 (28 yrs.)
Berliner (10-0103 00)	2.08	1.38	1.16 (8 yrs.)
Lotus (10-0006 00)	1.97	1.03	1.42 (28 yrs.)
Lucy (10-0007 00)	1.63	0.83	1.30 (28 yrs.)
Lundsten (10-0043 00)	1.09	0.12	1.17 (10 yrs.)
Minnewashta (10-0009 00)	1.80	0.97	1.33 (13 yrs.)
Oak (10-0093 00)	1.21	1.08	1.08 (4 yrs.)
Rice Marsh (10-0001 00)	1.25	1.11	1.42 (19 yrs.)
Riley (10-0002 00)	2.29	1.02	1.44 (28 yrs.)
Susan (10-0013 00)	1.14	0.73	1.35 (28 yrs.)
Swede (10-0095 00)	0.83	0.95	1.24 (3 yrs.)
Waconia (10-0059 00)	0.80	1.46	1.13 (30 yrs.)
CASS COUNTY			
Ada (11-0250 00)	0.58	0.76	0.80 (9 yrs.)
Agate (11-0216 00)	0.65	0.65	0.67 (8 yrs.)
Barnum (11-0281 00)	0.80	0.64	0.62 (5 yrs.)
Bass (11-0069 00)	0.67	0.60	0.66 (3 yrs.)
Big Rice (11-0073 00)	3.70	2.90	3.32 (3 yrs.)
Birch (11-0412 00)	1.48	0.70	1.00 (8 yrs.)
Blackwater (11-0274 00)	0.27	0.32	0.44 (4 yrs.)
Child (11-0263 00)	0.96	1.20	0.90 (9 yrs.)
Girl (11-0174 00)	0.86	0.92	0.80 (13 yrs.)
Gull (11-0305 00)	1.62	1.01	1.09 (17 yrs.)
Hay (11-0199 00)	0.70	0.75	0.91 (8 yrs.)
Inguadona (11-0120 00)	1.14	2.07	1.35 (7 yrs.)
Laura (11-0104 00)	0.90	1.10	0.78 (4 yrs.)
Leech (11-0203 00)	1.35	1.33	1.37 (34 yrs.)
Little Boy (11-0167 00)	2.20	1.59	1.18 (6 yrs.)
Long (11-0142)	0.52	0.85	0.93 (8 yrs.)
Lower Trelipe (11-0129 00)	0.48	0.96	1.09 (19 yrs.)
Mud (11-0100 00)	3.10	2.55	2.84 (7 yrs.)
Norway (11-0307 00)	0.41	0.36	0.39 (2 yrs.)
Paquet (11-0381 00)	1.37	1.08	1.18 (6 yrs.)
Pleasant (11-0383 00)	0.82	0.99	0.91 (2 yrs.)
Portage (11-0476 00)	1.40	0.90	0.85 (8 yrs.)
Stony (11-0371 00)	0.59	0.64	0.55 (7 yrs.)
Sylvan (11-0304 00)	0.86	0.96	0.86 (17 yrs.)
Ten Mile (11-0413 00)	0.84	0.67	0.79 (24 yrs.)
Vermillion (11-0029 00)	2.43	1.78	2.05 (5 yrs.)
Washburn (11-0059 00)	0.82	0.90	1.12 (20 yrs.)
Winnibigoshish (11-0147 00)	1.77	1.98	1.99 (39 yrs.)
Woman (11-0201 00)	0.86	0.98	0.82 (9 yrs.)
CHISAGO COUNTY			
Chisago(HW at outlet)(13-12 HW)	1.27	0.76	1.02 (2 yrs.)
Comfort (13-0053 00)	1.72	1.20	1.14 (26 yrs.)
Goose (13-0083 00)	2.09	1.35	1.63 (11 yrs.)
Green (13-0041 00)	0.87	0.68	1.08 (21 yrs.)
Kroon (13-0013 00)	1.55	1.37	1.26 (3 yrs.)
North Center (13-0032 00)	1.90	0.90	1.64 (26 yrs.)
North Lindstrom (13-0035 00)	1.57	0.77	1.72 (23 yrs.)

Lake Name	WY97	WY98	WY Ave.
CHISAGO COUNTY (cont):			
Sunrise (13-0031 00)	0.71	0.75	1.01 (11 yrs.)
Wallmark (13-0029 00)	1.05	0.59	0.86 (3 yrs.)
CLEARWATER COUNTY			
Itasca (15-0016 00)	0.86	0.82	0.73 (31 yrs.)
Lomond (15-0081 00)	0.55	0.64	0.61 (4 yrs.)
Long Lost (15-0068 00)	2.25	1.57	1.29 (7 yrs.)
Minerva (15-0079 00)	1.00	0.70	0.97 (3 yrs.)
Upper Rice (15-0059 00)	1.28	1.29	1.24 (5 yrs.)
COOK COUNTY			
Clearwater (16-0139 00)	1.23	0.70	1.04 (4 yrs.)
Flour (16-0147 00)	0.92	0.60	0.64 (9 yrs.)
Gunflint (16-0356 00)	1.71	1.58	1.77 (8 yrs.)
Hungry Jack (16-0227 00)	1.13	0.65	0.69 (8 yrs.)
Poplar (16-0239 00)	1.33	2.64	1.19 (10 yrs.)
Saganaga (16-0633 00)	2.78	1.44	1.96 (8 yrs.)
Sea Gull (16-0629 00)	2.28	0.99	1.90 (7 yrs.)
COTTONWOOD COUNTY			
Cottonwood (17-0022 00)	1.70	1.72	1.93 (11 yrs.)
CROW WING COUNTY			
Bass (18-0256 00)	1.11	0.72	0.68 (10 yrs.)
Bonnie (18-0259 00)	1.29	0.72	0.64 (9 yrs.)
Clark (18-0374 00)	0.78	0.67	0.86 (10 yrs.)
Crooked (18-0041 00)	0.30	0.58	0.70 (9 yrs.)
Crow Wing (18-0155 00)	0.77	0.95	1.46 (7 yrs.)
East Fox (18-0298 00)	0.47	1.31	0.64 (19 yrs.)
East Twin (18-0407 00)	0.52	0.78	0.62 (8 yrs.)
Edward (18-0305 00)	1.13	0.84	0.89 (31 yrs.)
Garden (18-0329 00)	0.90	0.57	0.47 (10 yrs.)
Gilbert (18-320)	1.18	2.02	1.08 (9 yrs.)
Gladstone (18-0338 00)	0.77	0.68	0.65 (10 yrs.)
Goodrich (18-0226 00)	0.69	0.54	0.52 (6 yrs.)
Hamlet (18-0070 00)	1.36	1.51	1.01 (35 yrs.)
Hartley (18-0392 00)	0.58	0.66	0.70 (10 yrs.)
Horseshoe (18-0251 00)	1.14	0.74	0.66 (10 yrs.)
Hubert (18-0375 00)	1.31	0.72	0.98 (18 yrs.)
Little Hubert (18-0340 00)	0.69	0.95	0.87 (10 yrs.)
Little Pelican (18-0351 00)	0.54	0.80	0.64 (10 yrs.)
Lougee (18-0342 00)	1.13	0.82	0.69 (10 yrs.)
Lower Mission (18-0243 00)	0.85	0.78	0.68 (22 yrs.)
Markee (18-0343 00)	1.04	0.88	0.90 (3 yrs.)
Mollie (18-0335 00)	0.92	0.74	0.71 (10 yrs.)
North Long (18-0372 00)	0.76	0.80	0.89 (28 yrs.)
O'Brien (18-0227 00)	0.58	0.52	0.61 (7 yrs.)
Ossawinnamakee (18-352 00)	0.75	0.80	0.81 (15 yrs.)
Pelican (18-0308 00)	0.64	0.86	0.87 (42 yrs.)
Perch (18-0304 00)	1.24	0.82	0.75 (10 yrs.)
Portage (18-0050 00)	0.78	0.88	0.83 (8 yrs.)
Rabbit (18-0093 00)	0.97	0.10	0.98 (41 yrs.)
Roger (18-0184 00)	0.38	0.78	0.78 (11 yrs.)
Ross (18-0165 00)	1.34	1.66	1.41 (15 yrs.)
Ruth (18-0212 00)	0.62	0.70	0.88 (32 yrs.)
Shaffer (18-0348 00)	0.97	1.13	0.68 (11 yrs.)
Sorenson (18-0323 00)	1.66	0.88	0.95 (10 yrs.)

Annual Lake Level Fluctuation (feet)

Lake Name	WY97	WY98	WY Ave.
CROW WING COUNTY (cont):			
South Long (18-0136 00)	1.05	1.25	1.10 (33 yrs.)
Stevens (18-0325 00)	0.66	0.88	0.77 (2 yrs.)
Upper South Long (18-0096 00)	0.99	1.16	1.11 (29 yrs.)
West Twin (18-0409 00)	0.84	0.70	0.57 (8 yrs.)
Whitefish (18-0001 00)	0.67	0.85	1.19 (7 yrs.)
Young (18-0252 00)	1.30	0.91	0.72 (10 yrs.)
DAKOTA COUNTY			
Kegan (19-0011 00)	1.85	1.20	1.52 (2 yrs.)
Marion (19-0026 00)	2.44	1.26	2.11 (40 yrs.)
Orchard (19-0031 00)	1.25	0.92	0.79 (7 yrs.)
Sunfish (19-0050 00)	1.14	0.71	1.05 (8 yrs.)
Unnamed (19-0294 00)	2.24	1.48	1.86 (2 yrs.)
Unnamed (Birger Pond)(19-0224 00)	3.30	0.50	1.78 (5 yrs.)
Unnamed (Building A Lake)(19-0190 00)	1.84	1.43	1.29 (8 yrs.)
Unnamed (Horse/Camel)(19-0205 00)	2.89	1.00	1.34 (7 yrs.)
Unnamed (Main Lake) (19-0203 00)	2.95	1.58	2.03 (7 yrs.)
Unnamed (Musk Ox Lake)(19-0204)	1.46	1.24	0.95 (7 yrs.)
Unnamed (Musk Ox Marsh) (19-0207)	1.36	1.08	1.20 (7 yrs.)
Unnamed (Reflection Pond)19-0199)	1.12	1.48	0.90 (8 yrs.)
Unnamed (Schwartz Pond) (19-0344)	1.50	0.50	1.00 (2 yrs.)
Unnamed (WaterTreatment)(19-0206)	1.73	1.30	1.24 (7 yrs.)
Unnamed (White Lake)(19-0008 00)	2.30	0.65	1.47 (2 yrs.)
Unnamed (Young Lake)(19-0203 01)	3.48	1.34	2.44 (7 yrs.)
Wood Park (19-0024 00)	1.19	0.93	1.06 (2 yrs.)
DOUGLAS COUNTY			
Aaron (21-0242 00)	0.90	1.04	0.87 (5 yrs.)
Andrew (21-0085 00)	1.20	0.76	1.01 (7 yrs.)
Burgen (21-0049 00)	0.42	0.74	0.81 (7 yrs.)
Chippewa (21-0145 00)	2.08	0.70	1.17 (15 yrs.)
Christina (21-0375 00)	0.98	0.57	0.95 (26 yrs.)
Devils (21-0213 00)	1.65	0.64	1.07 (3 yrs.)
Geneva (21-0052 00)	1.25	0.75	1.00 (5 yrs.)
Ida (21-0123 00)	1.20	0.88	1.14 (16 yrs.)
Irene (21-0076 00)	0.69	0.88	0.70 (9 yrs.)
Latoka (21-0106 00)	0.30	0.50	0.60 (6 yrs.)
Le Homme Dieu (21-0056 00)	1.25	0.80	1.02 (8 yrs.)
Lobster (21-0144 00)	1.73	0.75	1.19 (26 yrs.)
Louise (21-0094 00)	1.74	1.60	1.40 (12 yrs.)
Maple (21-0079 00)	0.64	0.80	0.83 (5 yrs.)
Mary (21-0092 00)	1.22	1.02	1.52 (8 yrs.)
Mill (21-0180 00)	1.96	0.90	1.27 (6 yrs.)
Miltona (21-0083 00)	1.30	0.78	1.09 (23 yrs.)
Moon (21-0226 00)	1.30	0.78	1.31 (14 yrs.)
Moses (21-0245 00)	1.55	0.72	1.65 (14 yrs.)

Lake Name	WY97	WY98	WY Ave.
DOUGLAS COUNTY (cont):			
Pocket (21-0140 00)	0.80	0.44	0.50 (3 yrs.)
Red Rock (21-0291 00)	2.17	1.07	1.41 (8 yrs.)
Smith (21-0016 00)	0.30	0.95	1.37 (10 yrs.)
Vermont (21-0073 00)	0.40	1.00	0.70 (2 yrs.)
Victoria (21-0054 00)	1.03	0.92	1.18 (17 yrs.)
Winona (21-0081 00)	0.72	0.67	0.74 (5 yrs.)
FREEBORN COUNTY			
Lower Twin (24-0027 00)	0.66	1.14	1.14 (6 yrs.)
Upper Twin (24-0031 00)	1.50	1.74	1.43 (6 yrs.)
GRANT COUNTY			
Elk (26-0040 00)	0.75	0.96	0.77 (4 yrs.)
HENNEPIN COUNTY			
Arrowhead (27-0045 00)	2.93	2.16	2.05 (35 yrs.)
Birch Island (27-0081 00)	1.81	0.84	1.93 (34 yrs.)
Bryant (27-0067 00)	1.29	0.46	1.14 (35 yrs.)
Bush (27-0047 00)	2.00	0.99	1.29 (36 yrs.)
Calhoun (27-0031 00)	4.27	3.28	1.87 (71 yrs.)
Cedar Island (27-0119 00)	1.52	0.72	1.17 (12 yrs.)
Cornelia (27-0028 00)	0.41	0.17	0.68 (34 yrs.)
Duck (27-0069 00)	1.39	0.61	1.60 (28 yrs.)
Eagle/Pike (27-0111 00)	1.58	0.45	1.08 (12 yrs.)
Edina (27-0029 00)	1.03	0.60	1.72 (34 yrs.)
Edward (27-0121 00)	0.87	0.48	1.06 (11 yrs.)
Fish (27-0118 00)	1.64	1.28	1.40 (11 yrs.)
Glen (27-0093 00)	4.31	1.04	1.47 (34 yrs.)
Harriet (27-0016 00)	2.36	0.93	1.22 (68 yrs.)
Haughey (27-0187 00)	1.01	0.86	0.94 (2 yrs.)
Hawkes (27-0056 00)	2.51	2.01	2.48 (35 yrs.)
Hyland (27-0048 00)	2.80	1.03	1.67 (27 yrs.)
Idlewild (27-0074 00)	0.33	0.26	1.20 (27 yrs.)
Independence (27-0176 00)	1.98	1.52	1.67 (18 yrs.)
Indianhead (27-0044 00)	2.48	0.61	1.26 (6 yrs.)
Lone (27-0094 00)	1.10	0.83	1.30 (34 yrs.)
Long (27-0160 00)	1.77	0.65	1.35 (13 yrs.)
Medicine (27-0104 00)	2.62	0.81	1.57 (26 yrs.)
Minnetoga (27-0088 00)	1.35	0.71	1.02 (25 yrs.)
Minnetonka (27-0133 00)	1.76	1.28	1.40 (93 yrs.)
Mirror (27-0055 00)	0.88	0.93	1.55 (35 yrs.)
Mitchell (27-0070 00)	2.85	1.16	1.87 (28 yrs.)
North Anderson (27-0062 01)	1.69	1.11	1.36 (36 yrs.)
Northwood (27-0627 00)	2.65	0.57	1.82 (6 yrs.)
Ox Yoke (27-0178 00)	4.68	6.76	4.63 (3 yrs.)
Oxboro (27-0011 00)	1.15	1.40	2.37 (34 yrs.)
Parkers (27-0107 00)	3.00	1.46	2.58 (26 yrs.)
Pauly's Pond (27-0008 00)	2.02	2.00	1.91 (34 yrs.)
Penn (27-0004 00)	1.18	0.86	2.29 (34 yrs.)
Red Rock (27-0076 00)	1.07	0.37	1.45 (28 yrs.)
Rice (27-0116 00)	5.24	5.49	2.00 (11 yrs.)
Rose (27-0092 00)	2.76	1.23	2.13 (32 yrs.)
Round (27-0071 00)	3.30	1.53	1.18 (28 yrs.)
Sarah (27-0191 00)	2.07	2.32	1.77 (5 yrs.)
Shady Oak (27-0089 00)	1.73	0.76	1.35 (35 yrs.)
Silver (27-0136 00)	1.67	1.43	1.23 (11 yrs.)

Annual Lake Level Fluctuation (feet)

Lake Name	WY97	WY98	WY Ave.
HENNEPIN COUNTY (cont):			
Skriebakken Pond (27-1049 00)	1.88	0.81	1.49 (34 yrs.)
Smetana (27-0073 00)	1.33	0.85	1.59 (25 yrs.)
Southeast Anderson (27-62 02)	2.00	1.00	1.55 (36 yrs.)
Southwest Anderson (27-62 03)	2.00	1.00	1.27 (36 yrs.)
Spurzem (27-0149 00)	1.87	0.88	1.40 (3 yrs.)
Staring (27-0078 00)	2.01	3.49	1.87 (28 yrs.)
Sweeney-Twin (27-0035 00)	1.12	0.24	0.49 (26 yrs.)
Twin (27-0042 00)	2.11	0.94	1.29 (8 yrs.)
Unnamed (Crane) (27-0734 00)	1.97	1.13	1.33 (24 yrs.)
Wanda Miller (27-0007 00)	2.36	1.90	2.33 (34 yrs.)
Weaver (27-0117 00)	0.98	0.56	1.01 (11 yrs.)
Westwood (27-0711 00)	1.67	0.56	1.30 (24 yrs.)
Wing (27-0091 00)	1.92	1.22	1.67 (33 yrs.)
Wirth (27-0037 00)	1.15	0.08	1.60 (44 yrs.)
HUBBARD COUNTY			
Belle Taine (29-0146 00)	1.87	0.87	1.37 (45 yrs.)
Big Sand (29-0185 00)	1.35	0.76	0.92 (8 yrs.)
Big Stony (29-0143 00)	0.76	0.60	0.62 (5 yrs.)
Blue (29-0184 00)	0.62	0.54	0.47 (4 yrs.)
Eagle (29-0256 00)	1.85	1.34	1.46 (8 yrs.)
East Crooked (29-0101 01)	1.58	0.81	0.91 (5 yrs.)
Eighth Crow Wing (29-72 00)	0.60	0.61	0.50 (3 yrs.)
Fifth Crow Wing (29-0092 00)	1.08	0.59	0.77 (5 yrs.)
Fish Hook (29-0242 00)	1.29	0.81	0.96 (8 yrs.)
Gilmore (29-0188 00)	0.58	0.42	0.53 (5 yrs.)
Grace (29-0071 00)	1.03	1.20	0.76 (8 yrs.)
Hinds (29-0249 00)	1.00	0.87	0.61 (5 yrs.)
Island (29-0254 00)	2.68	2.15	2.18 (8 yrs.)
Little Mantrap (29-0313 00)	0.71	1.15	0.93 (2 yrs.)
Long (29-0161 00)	0.52	0.40	0.49 (12 yrs.)
Middle Crooked (29-0101 02)	1.23	0.59	0.71 (4 yrs.)
Palmer (29-0087 00)	1.16	0.78	0.79 (8 yrs.)
Plantagenet (29-0156 00)	2.11	1.44	1.36 (17 yrs.)
Portage (29-0250 00)	0.30	0.78	0.54 (2 yrs.)
Potato (29-0243 00)	0.98	0.85	0.76 (8 yrs.)
Potato (HW)(29-0243 HW)	0.70	0.62	0.64 (19 yrs.)
Spider (29-0117 00)	0.82	1.37	0.71 (8 yrs.)
Stocking (29-0172 00)	0.82	0.51	0.51 (4 yrs.)
Third Crow Wing (29-0077 00)	1.36	0.86	1.11 (2 yrs.)
Upper Bottle (29-0148 00)	0.77	0.32	0.56 (7 yrs.)
West Crooked (29-0101 03)	0.58	0.58	0.53 (5 yrs.)
ISANTI COUNTY			
Spectacle (30-0135 00)	0.59	0.82	0.62 (6 yrs.)
Typo (30-0009 00)	1.32	1.32	1.72 (10 yrs.)
ITASCA COUNTY			
Ball Club (31-0812 00)	1.67	3.47	2.89 (8 yrs.)
Balsam (31-0259 00)	1.24	0.78	1.09 (16 yrs.)
Bass (31-0576 00)	0.66	0.70	0.81 (19 yrs.)
Beatrice (31-0058 00)	0.68	0.61	0.75 (7 yrs.)
Bello (31-0726 00)	0.66	0.56	0.66 (4 yrs.)
Bowstring (31-0813 00)	1.93	1.54	1.46 (20 yrs.)
Buck (31-0069 00)	0.46	0.62	0.49 (14 yrs.)
Burnt Shanty (31-0424 00)	0.83	0.81	0.64 (9 yrs.)
Burrows (31-0413 00)	0.83	0.71	0.65 (9 yrs.)

Lake Name	WY97	WY98	WY Ave.
ITASCA COUNTY (cont):			
Caribou (31-0620 00)	0.66	0.25	0.61 (10 yrs.)
Carlson (31-0366 00)	0.65	0.64	0.61 (4 yrs.)
Clearwater (31-0214 00)	0.96	0.96	0.82 (3 yrs.)
Crooked (31-0193 00)	6.00	4.78	5.74 (6 yrs.)
Deer (31-0719 00)	0.63	0.60	0.53 (5 yrs.)
Dixon (31-0921 00)	3.27	2.72	2.72 (5 yrs.)
Dora (31-0882 00)	2.40	2.60	1.83 (18 yrs.)
Grave (31-0624 00)	0.68	0.55	0.54 (6 yrs.)
Gunn (31-0480 00)	0.80	1.13	0.96 (2 yrs.)
Hale (31-0361 00)	1.30	1.08	1.12 (6 yrs.)
Hale (31-0373 00)	1.17	0.65	0.83 (40 yrs.)
Island (31-0913 00)	0.73	0.88	0.72 (3 yrs.)
Jessie (31-0786 00)	1.14	0.89	0.98 (9 yrs.)
Johnson (31-0586 00)	1.07	0.70	0.85 (9 yrs.)
Kelly (31-0299 00)	0.85	1.00	0.76 (3 yrs.)
Lawrence (31-0231 00)	4.00	3.42	3.71 (4 yrs.)
Link (31-0304 00)	0.27	0.60	0.42 (4 yrs.)
Little Bowstring (31-0758 00)	1.27	1.34	1.12 (5 yrs.)
Little Long (31-0266 02)	1.99	0.82	1.00 (7 yrs.)
Little Long (31-0613 00)	1.10	0.66	0.64 (8 yrs.)
Little Split Hand (31-0341 00)	2.20	0.31	1.72 (11 yrs.)
Little Winnibigoshish(31-0850 00)	5.07	5.62	5.44 (10 yrs.)
Long (31-0570 00)	1.55	0.66	0.92 (33 yrs.)
Loon (31-0571 00)	0.74	0.78	1.04 (34 yrs.)
McGuire (31-0078 00)	3.72	2.67	2.69 (7 yrs.)
Moose (31-0722 00)	1.08	1.32	0.70 (10 yrs.)
North Star (31-0653 00)	0.56	0.66	0.59 (10 yrs.)
Owen (31-0292 00)	1.25	1.17	0.70 (9 yrs.)
Pigeon Dam (31-0894 00)	0.70	1.60	0.97 (3 yrs.)
Pokegama (31-0532 00)	5.32	3.28	3.02 (45 yrs.)
Pughole (31-0602 00)	1.60	0.90	0.97 (9 yrs.)
Ruby (31-0422 00)	0.93	0.62	0.55 (9 yrs.)
Sand (31-0438 00)	1.30	0.76	0.79 (7 yrs.)
Sand (31-0826 00)	1.63	1.00	1.41 (16 yrs.)
Shallow (31-0084 00)	0.63	0.72	0.65 (7 yrs.)
Shoal (31-0141 00)	0.91	0.90	1.05 (5 yrs.)
Siseebakwet (31-0554 00)	0.54	0.58	0.75 (50 yrs.)
Smith (31-0650 00)	1.06	0.68	0.67 (9 yrs.)
Snaptail (31-0255 00)	1.02	0.78	0.96 (7 yrs.)
South Sturgeon (31-0003 00)	1.35	0.75	1.13 (5 yrs.)
Spider (31-0538 00)	1.01	0.69	0.73 (9 yrs.)
Split Hand (31-0353 00)	1.80	1.50	1.49 (17 yrs.)
Swan (31-0067 00)	1.70	1.04	1.54 (50 yrs.)
Trout (31-0216 00)	0.66	0.79	1.15 (38 yrs.)
White Swan (31-0260 00)	0.94	0.57	0.57 (9 yrs.)
JACKSON COUNTY			
Heron (South Heron) (32-0057 07)	4.76	3.64	3.65 (29 yrs.)
KANABEC COUNTY			
Fish (33-0036 00)	0.28	0.32	1.82 (7 yrs.)
KANDIYOHI COUNTY			
Andrew (34-0206 00)	1.58	1.16	1.52 (31 yrs.)
Big Kandiyohi (34-0086 00)	2.02	0.60	1.32 (34 yrs.)

Annual Lake Level Fluctuation (feet)

Lake Name	WY97	WY98	WY Ave.
KANDIYOHI COUNTY (cont):			
Calhoun (34-0062 00)	1.69	1.81	1.37 (27 yrs.)
Eagle (34-0171 00)	0.96	0.64	1.19 (29 yrs.)
Elizabeth (34-0022 00)	1.53	1.00	1.15 (18 yrs.)
Elkhorn (34-0119 00)	0.97	0.54	0.93 (17 yrs.)
Florida (34-0217 00)	1.11	0.85	1.43 (18 yrs.)
Foot (34-0181 00)	1.28	0.70	1.23 (16 yrs.)
Games (34-0224 00)	1.73	0.94	1.04 (20 yrs.)
Green (34-0079 00)	2.07	1.05	1.55 (43 yrs.)
Long (34-0066 00)	0.90	0.30	0.49 (16 yrs.)
Mud (34-0158 00)	1.13	0.60	1.34 (31 yrs.)
Nest (34-0154 00)	1.45	0.62	1.31 (30 yrs.)
Norway (34-0251 00)	3.61	1.89	1.41 (16 yrs.)
Skataas (34-0196 00)	0.72	1.06	1.25 (11 yrs.)
Sunburg (34-0359 00)	2.04	2.30	1.46 (4 yrs.)
Swenson (34-0321 00)	2.00	1.19	1.20 (11 yrs.)
Unnamed (Golden Pond)(34-0355 00)	1.19	0.88	0.84 (4 yrs.)
Wagonga (34-0169 00)	2.18	0.90	1.60 (14 yrs.)
LAKE COUNTY			
Farm (38-0779 00)	0.56	0.25	0.46 (6 yrs.)
Garden (38-0782 00)	0.98	0.64	1.53 (7 yrs.)
LE SUEUR COUNTY			
Emily (40-0124 00)	0.76	0.92	1.37 (21 yrs.)
Emily (40-0124 TW)	1.19	0.98	1.09 (2 yrs.)
Frances (40-0057 00)	0.84	1.04	0.83 (7 yrs.)
German (40-0063 00)	1.06	1.22	1.26 (24 yrs.)
Volney (40-0033 00)	1.52	1.78	1.32 (8 yrs.)
Washington (40-0117 00)	0.88	1.39	1.47 (20 yrs.)
West Jefferson (40-0092 02)	1.01	1.36	1.39 (24 yrs.)
LYON COUNTY			
Cottonwood (42-0014 00)	2.50	1.70	1.53 (8 yrs.)
MCLEOD COUNTY			
Winsted (43-0012 00)	3.31	1.44	1.67 (8 yrs.)
MAHNOMEN COUNTY			
Tulaby (44-0003 00)	1.05	1.70	1.22 (6 yrs.)
MARTIN COUNTY			
Amber (46-0034 00)	1.20	0.74	1.27 (6 yrs.)
Budd (46-0030 00)	1.00	1.02	1.13 (5 yrs.)
George (46-0024 00)	0.84	0.88	1.22 (6 yrs.)
MEEKER COUNTY			
Belle (47-0049 00)	1.71	0.90	1.24 (7 yrs.)
Big Swan (47-0038 00)	7.00	4.36	4.71 (5 yrs.)
Clear (47-0095 00)	1.10	1.47	1.37 (9 yrs.)
Dunns (47-0082 00)	2.28	1.39	1.70 (3 yrs.)
Francis (47-0002 00)	0.94	1.44	0.87 (16 yrs.)
Jennie (47-0015 00)	1.32	0.80	0.94 (7 yrs.)
Long (47-0026 00)	0.60	0.20	0.45 (4 yrs.)
Long (47-0177 00)	2.07	1.58	1.83 (2 yrs.)
Manuella (47-0050 00)	1.20	1.55	1.53 (10 yrs.)

Lake Name	WY97	WY98	WY Ave.
MEEKER COUNTY (cont):			
Minnie-Belle (47-0119 00)	1.94	1.18	1.39 (10 yrs.)
Richardson (47-0088 00)	1.86	1.26	1.24 (3 yrs.)
Ripley (47-0134 00)	1.60	0.90	0.93 (6 yrs.)
Spring (47-0032 00)	1.18	1.06	0.95 (7 yrs.)
Star (47-0129 00)	1.30	0.80	1.13 (3 yrs.)
Stella (47-0068 00)	1.60	1.16	1.03 (10 yrs.)
Thompson (47-0159 00)	2.04	0.90	1.45 (9 yrs.)
Washington (47-0046 00)	0.64	0.62	0.66 (10 yrs.)
MILLE LACS COUNTY			
Mille Lacs (48-0002 00)	1.18	0.85	1.33 (68 yrs.)
MORRISON COUNTY			
Fish Trap (49-0137 00)	0.53	0.26	0.99 (16 yrs.)
Green Prairie Fish (49-0035 00)	0.91	0.94	0.85 (3 yrs.)
Pierz (49-0024 00)	0.22	0.16	0.19 (2 yrs.)
Round (49-0056 00)	0.67	0.70	0.75 (4 yrs.)
Shamineau (49-0127 00)	0.96	1.06	0.84 (5 yrs.)
Sullivan (49-0016 00)	0.99	0.86	1.34 (20 yrs.)
MURRAY COUNTY			
Shetek (51-0046 00)	3.90	1.39	2.03 (49 yrs.)
NOBLES COUNTY			
Bella (53-0045 00)	2.75	2.16	2.22 (11 yrs.)
Indian (53-0007 00)	1.14	0.62	1.74 (11 yrs.)
Ocheda (53-0024 00)	0.61	0.52	1.37 (31 yrs.)
OTTER TAIL COUNTY			
Bass (56-0722 00)	0.61	1.18	0.82 (3 yrs.)
Beers (56-0724 00)	1.49	1.86	1.07 (5 yrs.)
Big McDonald (56-0386 01)	1.24	0.93	0.93 (4 yrs.)
Big McDonald (56-0386 00)	1.31	1.06	0.93 (5 yrs.)
Big Pine (56-0130 00)	1.72	0.92	1.54 (49 yrs.)
Blanche (56-0240 00)	0.30	0.71	0.57 (6 yrs.)
Clitherall (56-0238 00)	0.95	1.06	0.78 (6 yrs.)
Dead (56-0383 00)	0.93	0.75	0.83 (6 yrs.)
Eagle (56-0253 00)	0.99	1.03	0.81 (3 yrs.)
East Leaf (56-0116 00)	2.10	3.22	2.15 (4 yrs.)
East Lost (56-0378 00)	2.88	2.30	2.11 (6 yrs.)
Fladmark (56-0727 00)	3.49	1.29	1.55 (5 yrs.)
Grass (56-0723 00)	1.13	1.65	1.23 (3 yrs.)
Jewett (56-0877 00)	0.39	0.68	0.62 (4 yrs.)
Lida (56-0747 00)	1.78	1.45	1.06 (5 yrs.)
Little McDonald (56-0328 00)	1.43	1.14	1.05 (7 yrs.)
Little Pine (56-0142 00)	1.72	1.07	1.08 (34 yrs.)
Lizzie (56-0760 00)	2.10	1.12	1.20 (51 yrs.)
Long (56-0784 00)	2.06	1.18	1.22 (8 yrs.)
Middle Leaf (56-0116 01)	1.56	2.96	1.97 (4 yrs.)
Orwell (56-0945 00)	22.26	16.32	15.42 (29 yrs.)
Otter Tail (56-0242 00)	1.92	1.50	1.43 (69 yrs.)
Pelican (56-0786 00)	2.18	1.78	1.34 (25 yrs.)
Pickerel (56-0204 00)	1.15	1.04	1.10 (5 yrs.)
Pickerel (56-0475 00)	0.57	0.79	0.71 (20 yrs.)
Round (56-0297 00)	0.90	1.22	0.93 (3 yrs.)
Rush (56-0141 00)	2.00	1.70	1.56 (59 yrs.)

Annual Lake Level Fluctuation (feet)

Lake Name	WY97	WY98	WY Ave.
OTTER TAIL COUNTY (cont):			
Six (56-0369 00)	0.48	0.62	0.55 (2 yrs.)
South Turtle (56-0377 00)	0.97	1.01	0.99 (2 yrs.)
Star (56-0385 00)	1.44	1.22	1.06 (22 yrs.)
Stuart (56-0191 00)	1.30	1.52	1.35 (3 yrs.)
Swan (56-0781 00)	1.40	1.10	1.07 (7 yrs.)
Sybil (56-0387 00)	0.89	0.85	0.82 (3 yrs.)
Ten Mile (56-0613 00)	1.71	1.20	1.28 (9 yrs.)
Twenty-one (56-0728 00)	1.12	1.44	1.00 (4 yrs.)
Wall (56-0658 00)	0.34	0.60	0.38 (7 yrs.)
West Battle (56-0239 00)	1.38	1.15	1.12 (26 yrs.)
West Lost (56-0481 00)	1.44	2.49	1.99 (4 yrs.)
West McDonald (56-0386 02)	0.88	0.96	0.85 (5 yrs.)
PINE COUNTY			
Grindstone (58-0123 00)	0.60	0.60	1.09 (22 yrs.)
Pokegama (58-0142 00)	6.48	1.84	3.82 (19 yrs.)
Sand (58-0081 00)	1.00	1.30	1.40 (24 yrs.)
Upper Pine (58-0130 00)	0.58	0.83	0.66 (6 yrs.)
POLK COUNTY			
Badger (60-0214 00)	1.53	1.64	1.39 (12 yrs.)
Breeze (60-0144 00)	0.78	1.50	0.90 (6 yrs.)
Cable (60-0301 00)	1.43	0.87	0.93 (7 yrs.)
Cameron (60-0189 00)	0.89	0.98	0.78 (6 yrs.)
Cross (60-0027 00)	1.96	0.99	1.49 (10 yrs.)
Hill River (60-0142 00)	1.31	1.17	1.06 (7 yrs.)
Maple (60-0305 00)	1.11	1.06	1.17 (22 yrs.)
Poplar (60-0006 00)	0.73	1.98	1.72 (7 yrs.)
Sand Hill (60-0069 00)	1.49	1.22	0.99 (12 yrs.)
Sarah (60-0202 00)	3.65	2.85	2.81 (10 yrs.)
Spring (60-0012 00)	0.20	1.92	0.89 (7 yrs.)
Store (60-0130 00)	1.06	0.80	1.04 (8 yrs.)
Turtle (60-0032 00)	2.47	1.05	1.31 (11 yrs.)
Union (60-0217 00)	2.80	2.44	1.37 (13 yrs.)
POPE COUNTY			
Amelia (61-0064 00)	3.14	0.93	1.53 (13 yrs.)
Gilchrist (61-0072 00)	2.93	1.52	2.22 (8 yrs.)
Kettle (61-0544 00)	1.24	0.64	0.94 (2 yrs.)
Leven (61-0066 00)	1.18	1.59	1.60 (5 yrs.)
Linka (61-0037 00)	1.60	0.71	0.93 (5 yrs.)
Marlu (61-0060 00)	1.20	1.30	1.02 (5 yrs.)
Minnewaska (61-0130 00)	1.10	0.56	1.17 (54 yrs.)
Pelican (61-0111 00)	0.94	0.99	0.94 (6 yrs.)
Scandinavian (61-0041 00)	1.98	1.51	1.19 (6 yrs.)
Signalness (61-0149 00)	0.82	0.80	0.81 (2 yrs.)
Unnamed (Baby) (61-0245 00)	0.70	0.42	0.56 (2 yrs.)
Unnamed(Terrace Mill Pnd)(61-0055 00)	2.00	2.02	1.69 (5 yrs.)
Villard (61-0067 00)	3.14	0.87	1.70 (5 yrs.)
RAMSEY COUNTY			
Bald Eagle (62-0002 00)	1.25	0.94	1.29 (76 yrs.)
Beaver (62-0016 00)	2.79	1.46	1.99 (44 yrs.)
Bennett (62-0048 00)	4.78	1.39	2.91 (12 yrs.)
Birch (62-0024 00)	1.81	0.72	1.33 (69 yrs.)
Como (62-0055 00)	2.69	1.18	1.66 (21 yrs.)

Lake Name	WY97	WY98	WY Ave.
RAMSEY COUNTY (cont):			
Gervais (62-0007 00)	2.83	1.02	2.17 (75 yrs.)
Grass (62-0074 00)	5.66	1.97	3.25 (17 yrs.)
Island (62-0075 00)	1.84	1.01	1.42 (53 yrs.)
Johanna (62-0078 00)	2.37	0.84	1.99 (76 yrs.)
Josephine (62-0057 00)	1.72	0.88	1.18 (75 yrs.)
Long (62-0067 00)	2.75	1.57	1.72 (75 yrs.)
McCarron (62-0054 00)	1.91	0.46	1.16 (75 yrs.)
Owasso (62-0056 00)	1.96	0.81	1.16 (75 yrs.)
Phalen (62-0013 00)	4.61	1.65	3.51 (75 yrs.)
Pike (62-0069 00)	2.75	0.99	1.38 (30 yrs.)
Round (62-0009 00)	3.99	1.25	2.00 (65 yrs.)
Silver (East) (62-0001 00)	1.92	0.93	1.73 (74 yrs.)
Silver (West) (62-0083 00)	2.42	0.57	1.73 (65 yrs.)
Snail (62-0073 00)	1.96	1.10	1.61 (75 yrs.)
Teal Pond (North) (62-0026 01)	1.41	1.35	1.71 (6 yrs.)
Turtle (62-0061 00)	1.35	0.92	0.98 (76 yrs.)
Valentine (62-0071 00)	3.32	1.45	1.83 (74 yrs.)
Wabasso (62-0082 00)	1.88	1.00	1.41 (61 yrs.)
Wakefield (62-0011 00)	2.97	1.48	2.33 (46 yrs.)
Willow (62-0040 00)	1.79	0.47	1.04 (12 yrs.)
RENVILLE COUNTY			
Allie (65-0006 00)	1.84	1.50	1.30 (9 yrs.)
Preston (65-0002 00)	1.73	1.64	1.44 (6 yrs.)
RICE COUNTY			
Fox (66-0029 00)	0.89	2.37	1.48 (17 yrs.)
French (66-0038 00)	0.60	1.10	1.03 (8 yrs.)
ROSEAU COUNTY			
Hayes (68-0004 00)	2.63	2.97	2.54 (3 yrs.)
ST. LOUIS COUNTY			
Beaver (69-0501 00)	0.86	0.97	0.84 (10 yrs.)
Big Rice (69-0669 00)	1.21	1.27	1.03 (9 yrs.)
Boulder (69-0373 00)	5.03	1.96	3.50 (2 yrs.)
Burntside (69-0118 00)	1.50	1.14	1.00 (8 yrs.)
Cameron (69-0545 00)	0.78	0.92	0.71 (3 yrs.)
Crooked (69-0703 00)	0.51	0.98	0.75 (2 yrs.)
Eagles Nest (69-0285 00)	0.89	0.37	0.55 (6 yrs.)
Eagles Nest 3 (69-0285 03)	0.84	0.55	0.76 (7 yrs.)
Ely (69-0660 00)	0.57	0.45	0.83 (45 yrs.)
Embarrass (69-0496 00)	1.27	1.23	2.30 (40 yrs.)
Esquagama (69-0565 00)	1.40	0.40	2.45 (25 yrs.)
Fish Lake Flowage (69-0491 00)	1.95	1.52	1.73 (2 yrs.)
Fourteen (69-0793 00)	0.24	0.44	0.49 (8 yrs.)
Jacobs (69-0231 00)	0.26	0.97	0.62 (8 yrs.)
Janette (69-0887 00)	0.66	0.94	0.69 (6 yrs.)
Lieung (69-0123 00)	0.95	0.65	0.83 (3 yrs.)
Long (69-0509 00)	0.51	1.32	0.95 (9 yrs.)
Long (69-0653 00)	0.70	0.70	0.77 (7 yrs.)
Maple Leaf (69-0700 00)	0.52	1.30	0.86 (8 yrs.)
Nichols (69-0627 00)	0.84	0.57	0.67 (10 yrs.)
Pelican (69-0841 00)	0.83	0.53	1.21 (17 yrs.)
Pequaywan (69-0011 00)	0.45	0.54	0.74 (15 yrs.)
Perch (69-0932 00)	0.60	0.79	0.52 (8 yrs.)
Prairie (69-0848 00)	1.16	1.30	1.24 (15 yrs.)

Annual Lake Level Fluctuation (feet)

Lake Name	WY97	WY98	WY Ave.
ST. LOUIS COUNTY (cont):			
Sabin (69-0434 01)	1.92	1.17	2.03 (3 yrs.)
St. Mary's (69-0651 00)	1.26	0.44	1.20 (41 yrs.)
Stone (69-0027 00)	0.75	0.79	0.82 (9 yrs.)
Stone (69-0686 00)	0.71	0.72	0.95 (6 yrs.)
Sturgeon (69-0939 00)	2.24	0.83	1.45 (15 yrs.)
Thirteen (69-0794 00)	0.61	0.54	0.57 (2 yrs.)
Vermilion (69-0378 00)	1.72	1.06	1.63 (48 yrs.)
White Iron (69-0004 00)	1.29	0.46	1.32 (3 yrs.)
Whiteface Reservoir (69-0375 00)	3.46	1.63	2.54 (2 yrs.)
Wild Rice (69-0371 00)	1.39	1.27	1.78 (4 yrs.)
SCOTT COUNTY			
Cedar (70-0091 00)	1.15	1.12	0.97 (5 yrs.)
Spring (70-0054 00)	1.42	2.42	1.53 (8 yrs.)
Upper Prior (70-0072 00)	2.80	2.35	2.33 (27 yrs.)
SHERBURNE COUNTY			
Beaudry (71-0062 00)	0.82	1.58	1.28 (12 yrs.)
Forest Pond (71-0369 00)	2.53	0.95	2.29 (12 yrs.)
Keller (71-0083 00)	1.51	1.98	1.63 (7 yrs.)
Long (71-0159 00)	1.20	1.11	1.12 (7 yrs.)
Mitchell (71-0081 00)	0.85	3.24	1.52 (14 yrs.)
Rush (71-0147 00)	5.27	1.15	1.66 (9 yrs.)
STEARNS COUNTY			
Big (73-0159 00)	0.96	0.90	1.36 (9 yrs.)
Big Fish (73-0106 00)	1.02	0.84	0.97 (22 yrs.)
Big Watab (73-0102 00)	0.66	0.52	0.73 (14 yrs.)
Eden (73-0150 00)	1.06	1.48	2.53 (11 yrs.)
Grand (73-0055 00)	0.46	0.62	1.09 (18 yrs.)
Horseshoe (73-0157 00)	4.12	1.73	1.75 (13 yrs.)
Koronis (73-0200 00)	4.50	1.20	2.14 (18 yrs.)
Kraemer (73-0064 00)	1.46	0.46	1.03 (3 yrs.)
Long (73-0004 00)	1.69	0.74	1.19 (6 yrs.)
Lower Spunk (73-0123 00)	1.61	1.80	1.71 (2 yrs.)
Pearl (73-0037 00)	0.48	0.14	0.73 (13 yrs.)
Rice (73-0196 00)	3.59	2.17	3.18 (13 yrs.)
Two Rivers (73-0138 00)	5.94	3.75	3.39 (15 yrs.)
Willow (73-0034 00)	1.63	1.04	1.34 (2 yrs.)
STEVENS COUNTY			
Long (75-0024 00)	1.42	1.20	1.41 (19 yrs.)
Page (75-0019 00)	1.96	1.02	1.48 (19 yrs.)
SWIFT COUNTY			
Camp (76-0072 00)	1.94	1.68	1.73 (4 yrs.)
Oliver (76-0146 00)	0.52	0.44	0.61 (4 yrs.)
TODD COUNTY			
Beauty (77-0035 00)	0.56	0.83	0.73 (5 yrs.)
Big (77-0063 00)	1.04	0.86	0.87 (6 yrs.)
Big Birch (77-0084 00)	0.76	1.20	1.02 (22 yrs.)
Big Birch (HW) (77-0084 HW)	1.16	0.62	0.66 (8 yrs.)
Fairy (77-0154 00)	1.02	1.39	1.22 (10 yrs.)
Long (77-0027 00)	0.44	0.72	0.79 (6 yrs.)
Long (77-0149 00)	1.09	0.73	0.91 (2 yrs.)

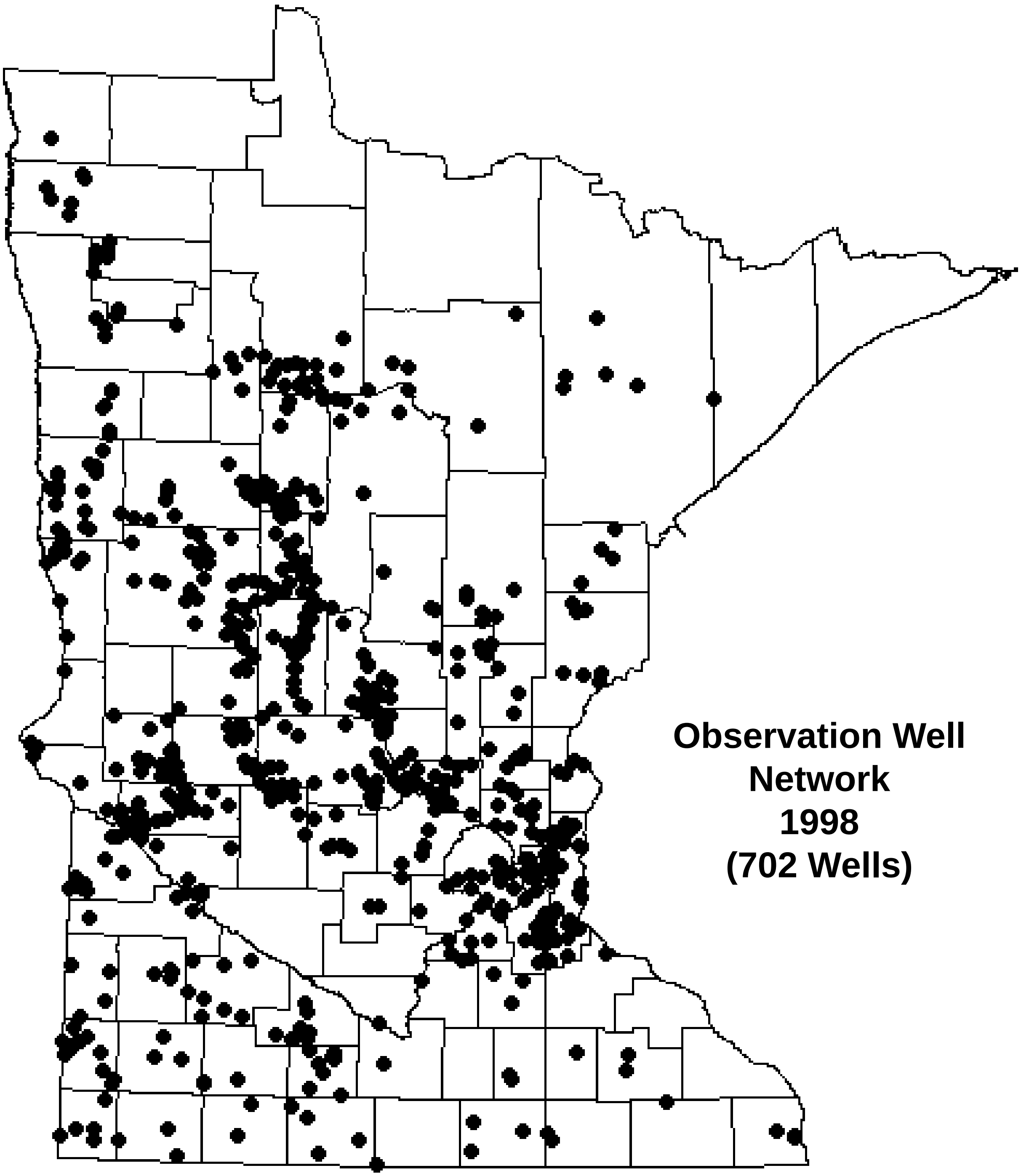
Lake Name	WY97	WY98	WY Ave.
TODD COUNTY (cont):			
Maple (77-0181 00)	1.15	1.02	1.34 (10 yrs.)
Moose (77-0026 00)	0.23	0.40	0.54 (4 yrs.)
Mound (77-0007 00)	0.32	0.87	0.62 (6 yrs.)
Osakis (77-0215 00)	4.12	0.40	1.56 (38 yrs.)
Sauk (77-0150 00)	3.28	2.08	1.79 (16 yrs.)
TRAVERSE COUNTY			
Traverse (78-0025 00)	7.71	1.28	2.82 (56 yrs.)
WADENA COUNTY			
Lower Twin (80-0030 00)	2.75	2.12	1.94 (4 yrs.)
Vogels (Hazel) (80-0005 00)	0.83	0.89	0.92 (19 yrs.)
WASHINGTON COUNTY			
Barker (82-0076 00)	1.20	1.60	1.40 (2 yrs.)
Bass (82-0035 00)	0.76	2.20	1.21 (4 yrs.)
Bass (82-0123 00)	0.62	1.13	0.88 (2 yrs.)
Battle Creek (82-0091 00)	0.44	1.62	1.40 (9 yrs.)
Big Marine (82-0052 00)	0.87	0.80	1.01 (25 yrs.)
Big Marine (Jellums) (82-0052 02)	1.04	1.02	1.03 (2 yrs.)
Bone (82-0054 00)	0.80	1.04	1.27 (18 yrs.)
Carol (82-0017 00)	1.33	1.58	1.40 (3 yrs.)
Carver (82-0166 00)	0.99	2.18	1.51 (8 yrs.)
Clear (82-0163 00)	0.84	1.05	1.16 (25 yrs.)
Cloverdale (82-0009 00)	1.91	1.54	2.50 (5 yrs.)
DeMontreville (82-0101 00)	1.54	0.62	1.51 (31 yrs.)
Downs (82-0110 00)	1.98	0.94	2.64 (17 yrs.)
Eagle Point (82-0109 00)	2.55	1.71	2.25 (24 yrs.)
Elmo (82-0106 00)	1.09	0.48	1.29 (24 yrs.)
Forest (82-0159 00)	0.71	0.64	0.76 (24 yrs.)
Goose (82-0059 00)	1.36	1.48	1.39 (5 yrs.)
Halfbreed (82-0080 00)	1.58	1.02	0.98 (9 yrs.)
Horseshoe (82-0074 00)	2.55	0.36	1.84 (21 yrs.)
Jane (82-0104 00)	0.89	0.52	1.71 (31 yrs.)
Lily (82-0023 00)	2.12	0.56	1.24 (4 yrs.)
Little Carnelian (82-0014 00)	1.69	1.42	4.37 (7 yrs.)
Long (82-0021 00)	2.05	1.44	1.63 (3 yrs.)
Long (82-0030 00)	0.46	1.50	0.79 (3 yrs.)
Long (82-0118 00)	3.64	1.30	3.29 (25 yrs.)
Loon (82-0015 00)	1.10	0.75	0.95 (3 yrs.)
Louise (82-0025 00)	1.06	1.03	1.01 (3 yrs.)
Masterman (82-0126 00)	0.58	0.96	0.77 (2 yrs.)
McDonald (82-0010 00)	1.52	0.61	1.13 (5 yrs.)
McKusick (82-0020 00)	1.22	0.74	0.99 (3 yrs.)
Mud (82-0026 00)	0.66	0.36	0.79 (4 yrs.)
Mud (82-0168 00)	0.56	1.29	0.93 (2 yrs.)
Mud-wetland (82-0026 01)	0.91	0.86	0.91 (4 yrs.)
North Twin (82-0018 00)	0.82	0.88	0.81 (3 yrs.)
Oneka (82-0140 00)	0.80	0.89	0.97 (20 yrs.)
Pat (82-0125 00)	0.68	1.35	1.02 (2 yrs.)
Sand (82-0067 00)	2.07	1.44	1.82 (3 yrs.)
Shields (82-0162 00)	1.15	1.05	1.12 (3 yrs.)
Silver (82-0016 00)	1.70	2.36	1.75 (3 yrs.)
South School Section (82-0151 00)	1.15	1.94	1.46 (3 yrs.)
South Twin (82-0019 00)	2.55	2.21	1.89 (3 yrs.)

Annual Lake Level Fluctuation (feet)

Lake Name	WY97	WY98	WY Ave.
WASHINGTON COUNTY (cont):			
Square (82-0046 00)	0.45	0.38	0.74 (22 yrs.)
St. Croix (82-0001 00)	15.61	5.23	10.61 (3 yrs.)
Staples (82-0028 00)	0.61	1.02	0.81 (2 yrs.)
Sunfish (82-0107 00)	0.83	0.46	1.64 (24 yrs.)
Sunnybrook (82-0133 00)	2.34	1.76	2.06 (6 yrs.)
Sunset (82-0153 00)	0.85	1.20	1.10 (5 yrs.)
Tanners (82-0115 00)	0.57	2.80	1.35 (8 yrs.)
Turtle (82-0036 00)	1.47	0.75	1.18 (5 yrs.)
Twin (82-0048 00)	1.60	2.62	2.11 (2 yrs.)
Unnamed (82-0334 00)	0.99	1.22	1.05 (3 yrs.)
Unnamed (Jackson WMA)(82-0305 00)	2.00	1.40	1.70 (2 yrs.)
Unnamed (July Ave) (82-0318 00)	1.46	2.13	1.79 (2 yrs.)
Unnamed (Maple Marsh)(82-0038 00)	0.86	1.14	1.00 (2 yrs.)
Unnamed (May Ave.Wetland) (82-0296 00)	0.60	1.02	0.84 (4 yrs.)
Unnamed -Kismet Basin(82-0333 00)	0.99	1.22	1.04 (3 yrs.)
West Boot (82-0044 00)	0.73	1.02	0.82 (4 yrs.)
White Bear (82-0167 00)	1.41	1.32	1.18 (82 yrs.)
Wood Pile (82-0132 00)	0.84	1.28	1.06 (2 yrs.)
WATONWAN COUNTY			
Fedji (83-0021 00)	0.73	0.90	0.95 (8 yrs.)
WRIGHT COUNTY			
Ann (86-0190 00)	6.79	2.80	4.03 (3 yrs.)
Augusta (86-0284 00)	0.80	1.75	1.06 (5 yrs.)
Beebe (86-0023 00)	0.59	0.27	0.97 (9 yrs.)
Birch (86-0066 00)	1.55	0.86	1.14 (6 yrs.)
Buffalo (86-0090 00)	7.15	4.53	3.38 (13 yrs.)
Charlotte (86-0011 00)	0.72	1.23	1.45 (14 yrs.)
Collinwood (86-0293 00)	1.05	0.99	0.94 (4 yrs.)
Deer (86-0107 00)	6.12	3.28	2.98 (23 yrs.)
Ida (86-0146 00)	0.50	0.57	0.42 (3 yrs.)
Indian (86-0223 00)	1.31	1.12	1.59 (13 yrs.)
Maple (86-0134 00)	0.65	0.83	1.17 (13 yrs.)
Mary (86-0193 00)	0.48	1.22	0.85 (2 yrs.)
Moose (86-0271 00)	0.82	0.56	0.69 (2 yrs.)
Mud (86-0021 00)	0.27	0.16	0.22 (2 yrs.)
Pelican (86-0031 00)	0.38	1.00	0.57 (4 yrs.)
Pulaski (86-0053 00)	1.09	1.14	1.42 (23 yrs.)

Chapter 3

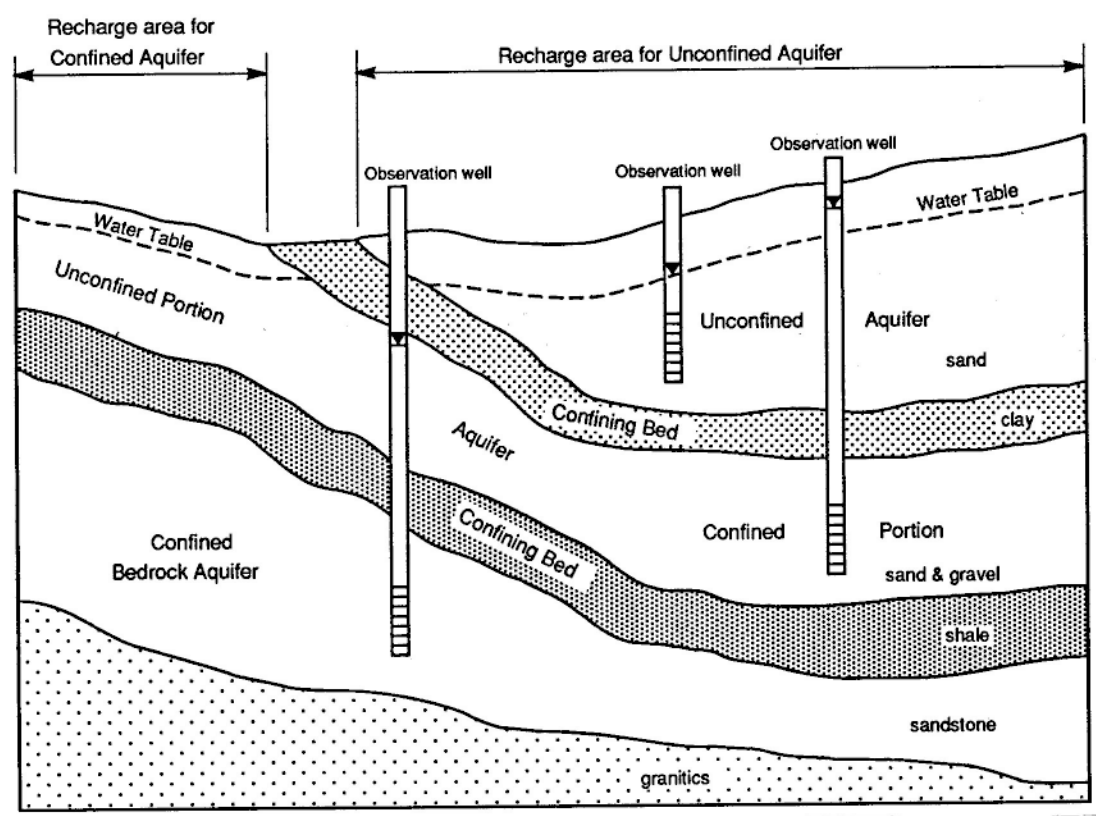
GROUND WATER



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). By the end of Water Year 1998 approximately 702 water level observation wells (obwells) had been established statewide. 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) under contract with DNR Waters measure the wells monthly and report the readings to DNR Waters. The United States Geological Survey also monitors some wells using continuous recorders. Readings are also obtained from volunteers at other locations.

Figure 1 **Hypothetical Unconfined and Confined Aquifer Systems**



Aquifers

An aquifer is any water-bearing bed or stratum of earth or rock capable of yielding groundwater in sufficient quantities that can be extracted (MR 6115.0630, Subp.2). 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. 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 artesian aquifers and bedrock aquifers.

Buried artesian 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 artesian aquifers require considerable effort to evaluate the local interconnection between these aquifers 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 artesian 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 1997 (WY97) and 1998 (WY98). This discussion focuses on a comparison of water levels in WY97 and WY98 at two times during the year – winter and late-summer. The water levels are presented in the context of their average as well as historical high and low values. To achieve meaningful comparisons, representative obwells were chosen from the network based on their length of record and their geographical location.

During these water years, the DNR monitored water levels in approximately 700 wells throughout the state. Figures 2, 3 and 4 show the locations of these wells, identifying those that were placed in unconfined aquifers, in buried artesian aquifers and in bedrock aquifers.

Figure 2 **Water Table Observation Wells**

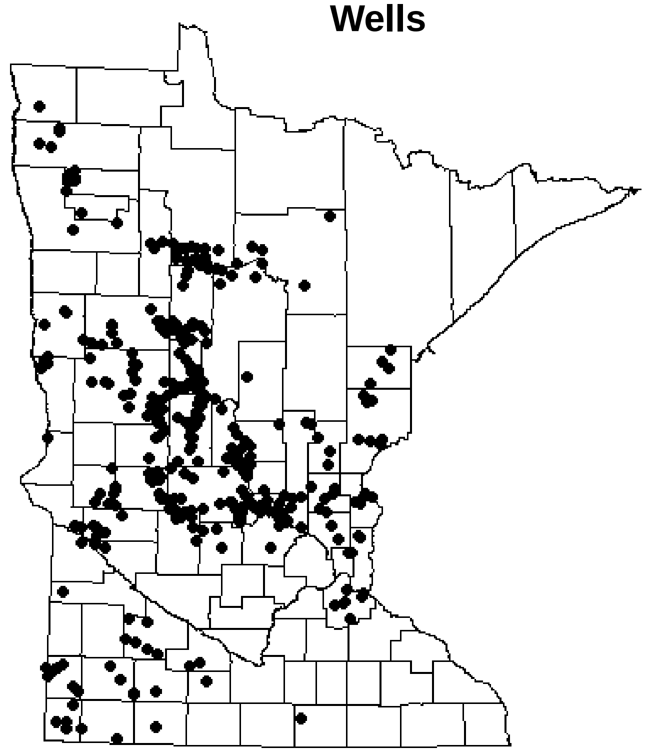


Figure 3 **Buried Artesian Observation Wells**

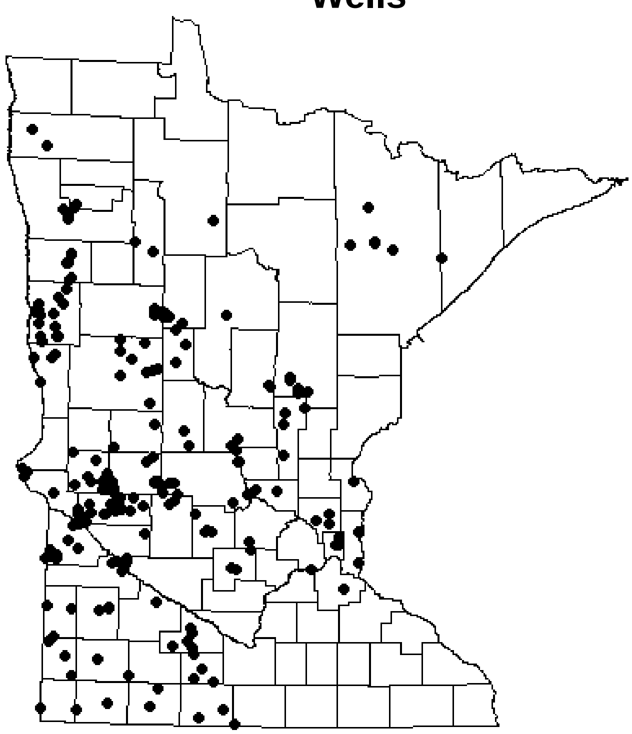
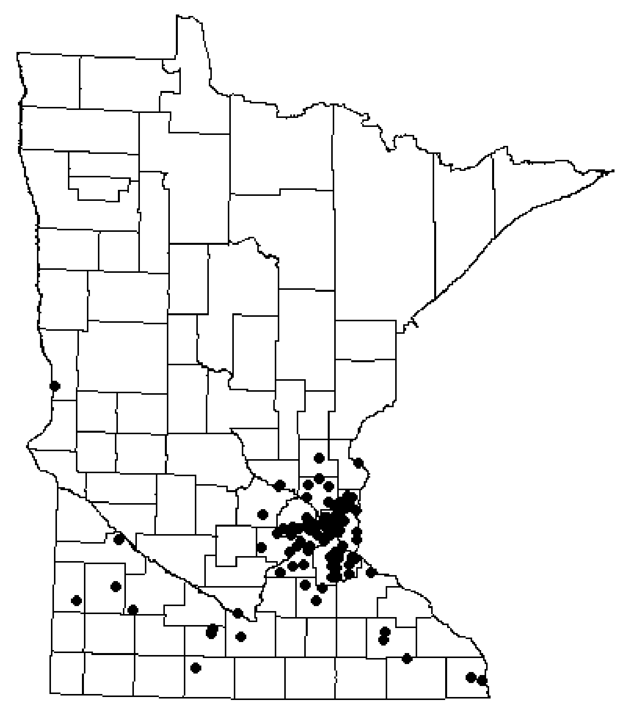


Figure 4 **Bedrock Observation Wells**



WY97 and WY98 Comparisons

For the selected representative obwells, water levels within each water year are compared. These levels are also compared to the historical average. Where data was available, water levels were analyzed twice per water year, usually in March and August. These months were chosen because they most likely show the aquifer's condition at the end of winter before snow melt and spring rains and again late in the summer season before the onset of fall rains. Where data was not available for one or both of these months, comparisons for other months were made. These exceptions are shown in the listing of actual measured water levels referenced later.

Historical averages used in these comparisons are computed for the appropriate month using data over the period of record for each well. Such periods are generally from 11 to 40 years, with one being 5 years and a couple being more than 40 years. The period of record for each well is indicated in the tables showing measured water levels.

The representative water table and buried artesian wells are identified with rough geographic areas representing western, southwest, central, north central or northeast, east central and Twin Cities Metro regions of Minnesota. These regional groupings are identified on the graphs.

One series of graphs labeled "Water Level Comparisons" (Figures 5, 9, 13, and 16) are intended to standardize all the data and present it relative to individual well averages. For each well, the average water level was computed for each of the two seasonal periods. The highest and lowest water levels during the period of record were also noted for each season. In the graphs, the highs and lows, as well as the measured WY97 and WY98 water levels, are presented as deviations from the computed average which is represented as the "0" baseline value on the Y-axis. In all cases, the record high water level is represented by the solid bar above the baseline, the record low water level is represented by the dashed bar below the baseline, and the WY97 and WY98 water levels are indicated by a triangle and diamond respectively.

Unconfined Aquifers

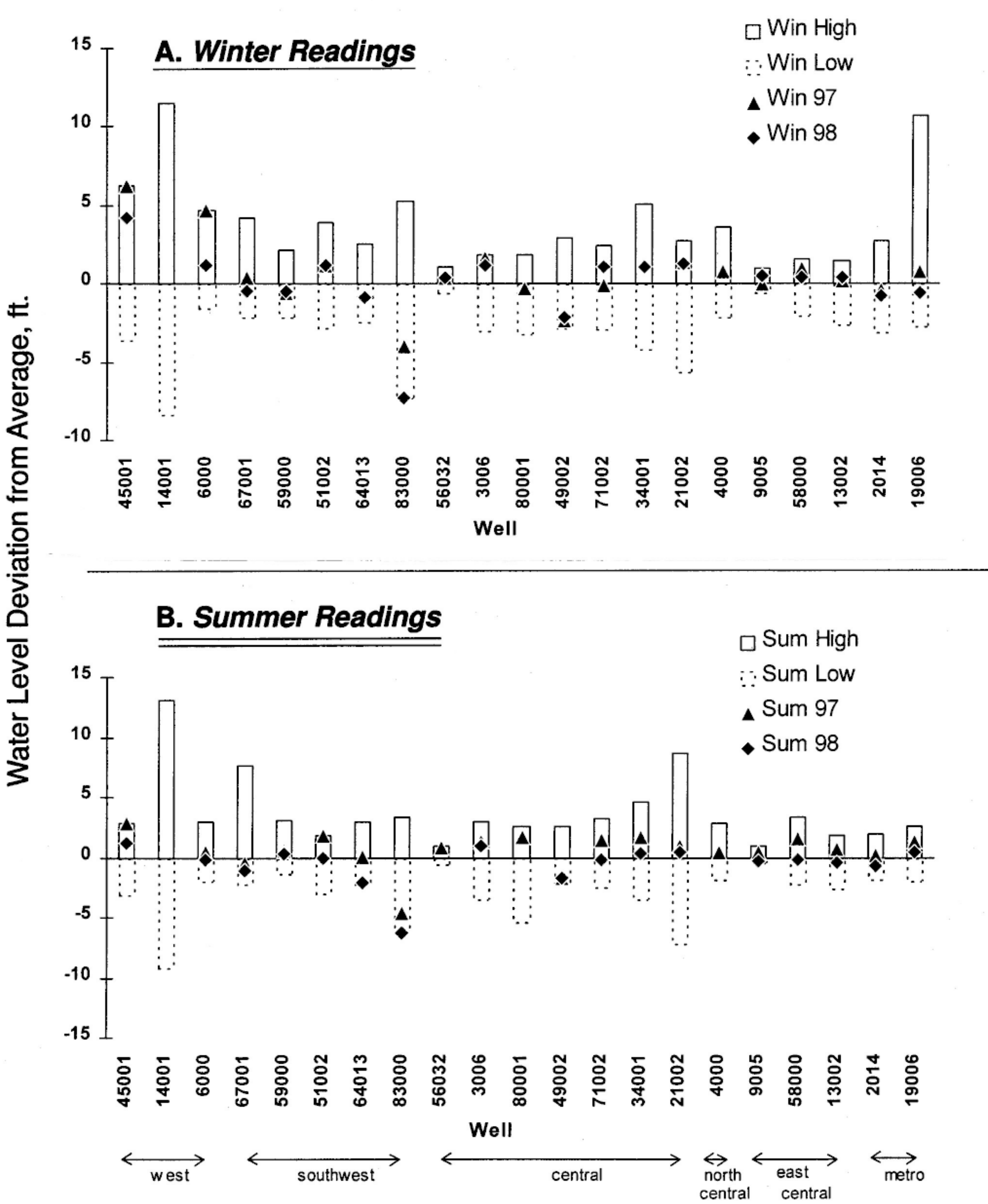
Figure 5a compares water levels during the winter months of WY97 and WY98 for selected water table wells throughout Minnesota; Figure 5b does the same for the late-summer months.

Winter water table levels in both WY97 and WY98 tended generally to be higher than average (Figure 5a). There were exceptions, however, they were not associated with any particular geographic region. This variation most likely results from the individual characteristics of isolated unconfined aquifers. Comparing water years, winter water tables were not consistently higher in either WY.

Summer water table levels in WY97 (Figure 5b) generally were average or higher with a few exceptions. Well number 83000 was also below average in winter readings, showing a wide range for readings as illustrated by the bars on the graphs. At one time in its history, well 83000 had a quite high water table and also registered a large deviation below the average. In fact, its water level is well below average and WY98 was the lowest reading obtained for this well. The other water table wells in the state are generally at or above average, therefore, the declining water level in well 83000 seems to represent a local condition. In WY98 the summer water table readings were average or below. Summer water levels in WY97 were higher than those in WY98 (Figure 5b).

Figure 5

Water Level Comparisons, Water Table Wells: A. *Winter*, B. *Summer*



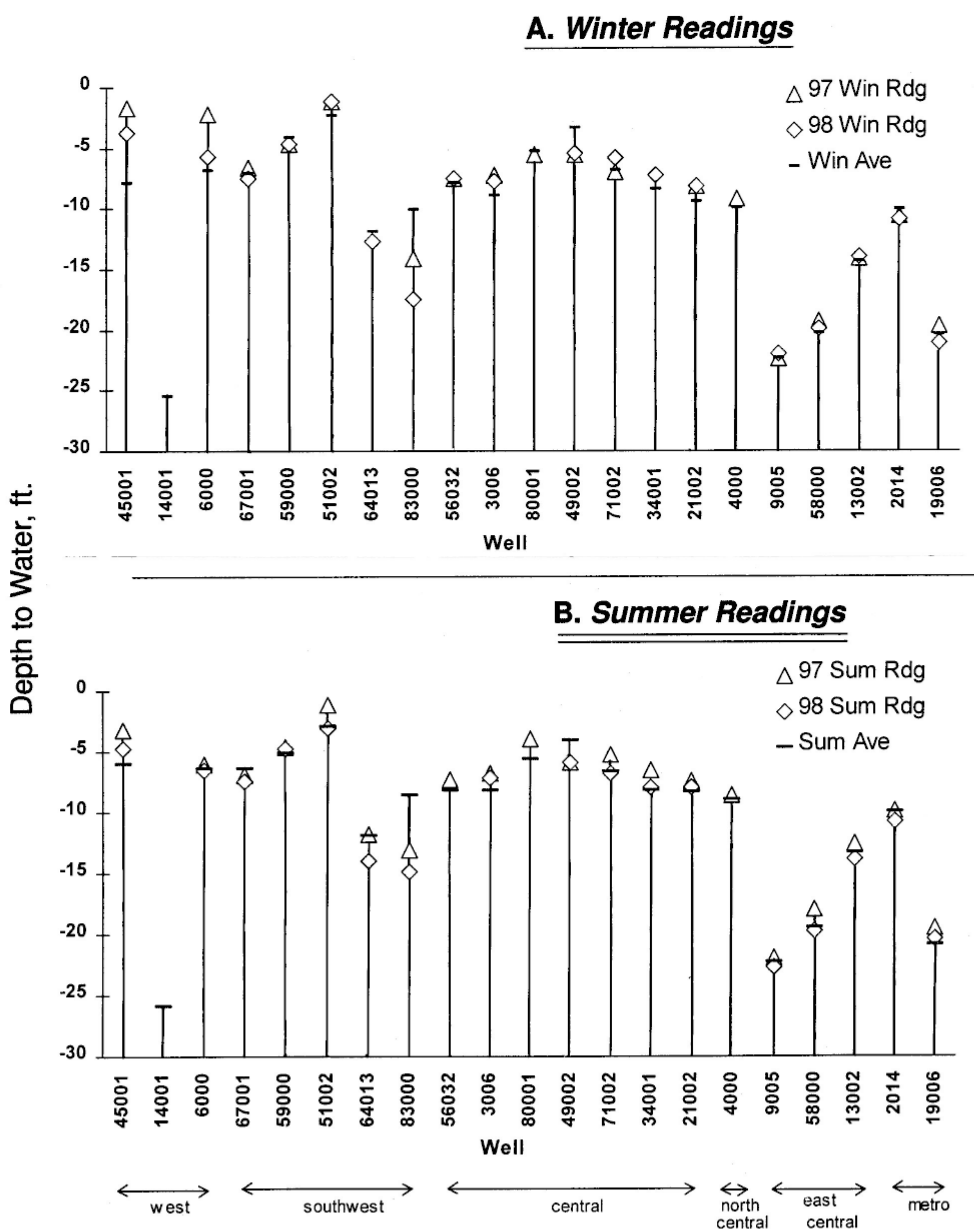
Figures 6a and 6b show the measured depth to water for the water table wells included here. While the water year relationships shown are the same as in Figures 5a and 5b, these graphs are provided for the benefit of those interested in the actual water table depths. Due to the individual characteristics of isolated unconfined aquifers, regional patterns are not evident. Measured depths included in this summary are presented in Table 1.

Table 1

Measured Depths to Water (ft) in Selected Water Table Observation Wells

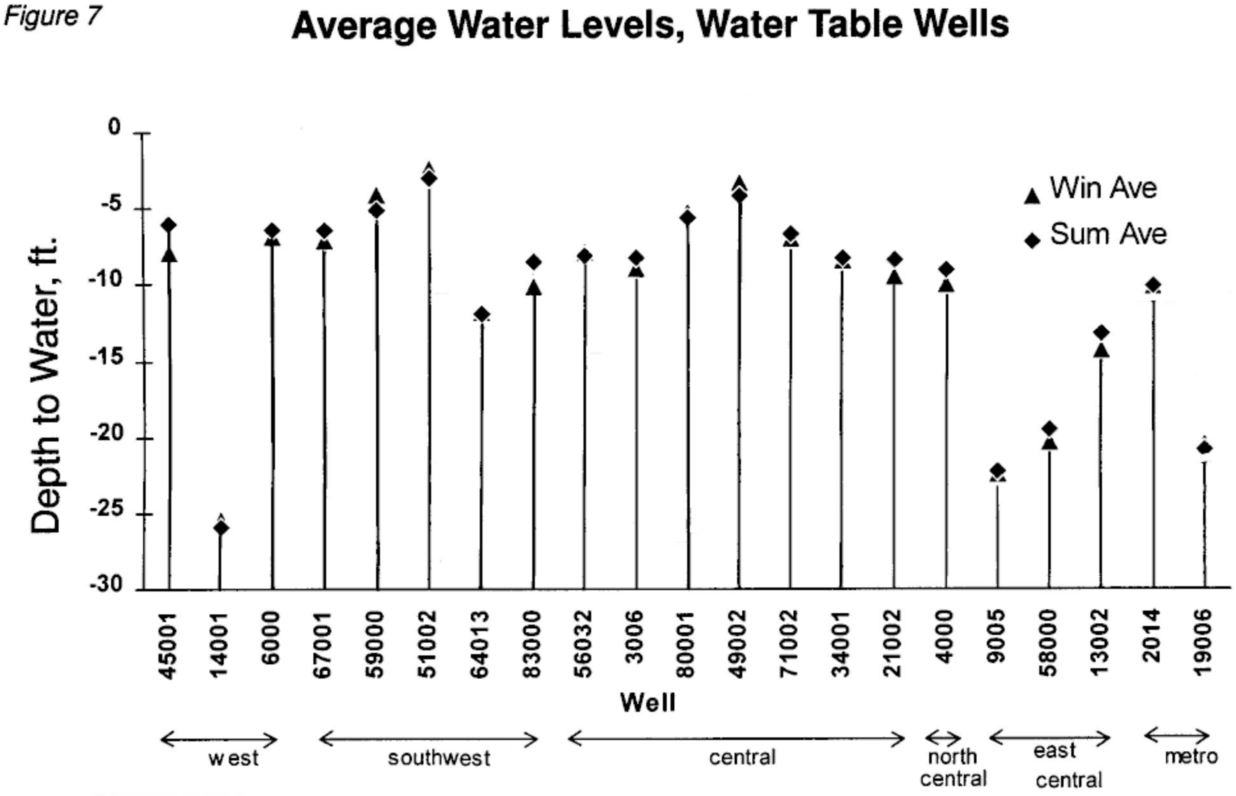
	WY97				WY98				
Well	Month	Depth	Month	Depth	Month	Depth	Month	Depth	Period of Record (yrs)
2014	3	11.29	8	9.98	3	10.52	8	9.93	29
3006	3	7.00	8	7.71	3	7.65	8	7.72	24
4000	3	9.29	8	8.75	3	9.21	8	8.86	27
6000	3	6.85	8	3.44	3	5.41	8	5.18	26
9005	3	21.45	8	22.35	3	22.54	8	21.87	31
13002	3	13.99	8	11.81	3	13.36	8	12.09	30
14001	4	33.63	8	34.79	3	28.91	8	30.37	49
19006	4	21.45	8	20.82	3	21.28	8	20.76	21
21002	3	7.96	8	7.35	3	7.42	8	8.23	26
34001	3	7.20	8	5.70	3	5.50	8	7.10	32
45001	3	4.75	8	5.47	3	6.13	8	5.82	35
49002	3	3.47	8	5.44	3	3.99	8	6.30	30
51002	3	1.73	8	1.19	3	1.15	8	1.15	21
56032	3	8.24	8	8.20	3	7.76	8	8.22	20
58000	3	20.28	8	19.49	3	19.52	8	18.12	30
59000	3	4.90	8	4.50	3	4.50	8	4.60	20
64013	3	11.80	8	9.38	3	11.16	8	11.80	21
67001	3	6.72	8	5.78	3	6.61	8	6.56	20
71002	3	7.17	8	6.19	3	6.97	8	6.46	29
80001	4	3.29	10/'97	3.14	4	2.13	10/'98	5.11	31
83000	3	14.46	9	13.88	3	14.45	8	13.69	33

Figure 6 **Water Levels, Water Table Wells: A. *Winter*, B. *Summer***



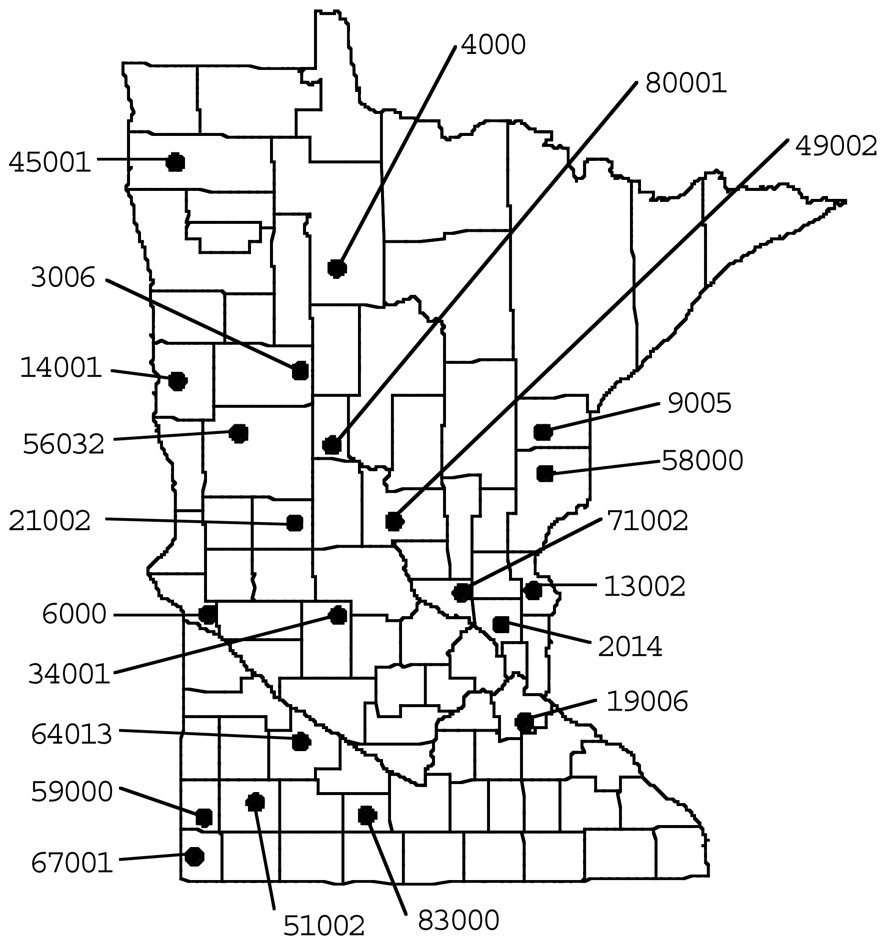
While drainage from an aquifer continues throughout the winter, recharge is restricted. In general, winter precipitation is stored as snowpack and frozen soil prevents or slows the infiltration and percolation of spring snow melt. By the end of winter, water table levels would be expected to be at a low point. As the soil thaws and spring rains occur, the aquifers are recharged resulting in the higher water levels. A comparison of March and August average water levels (Figure 7) tends to corroborate this theory. Thirteen of the twenty-one representative water table wells have higher average water levels in summer than in the winter.

Figure 7



The approximate locations of the water table wells used in this report are shown in Figure 8.

Figure 8 **Locations of Selected Water Table Wells**



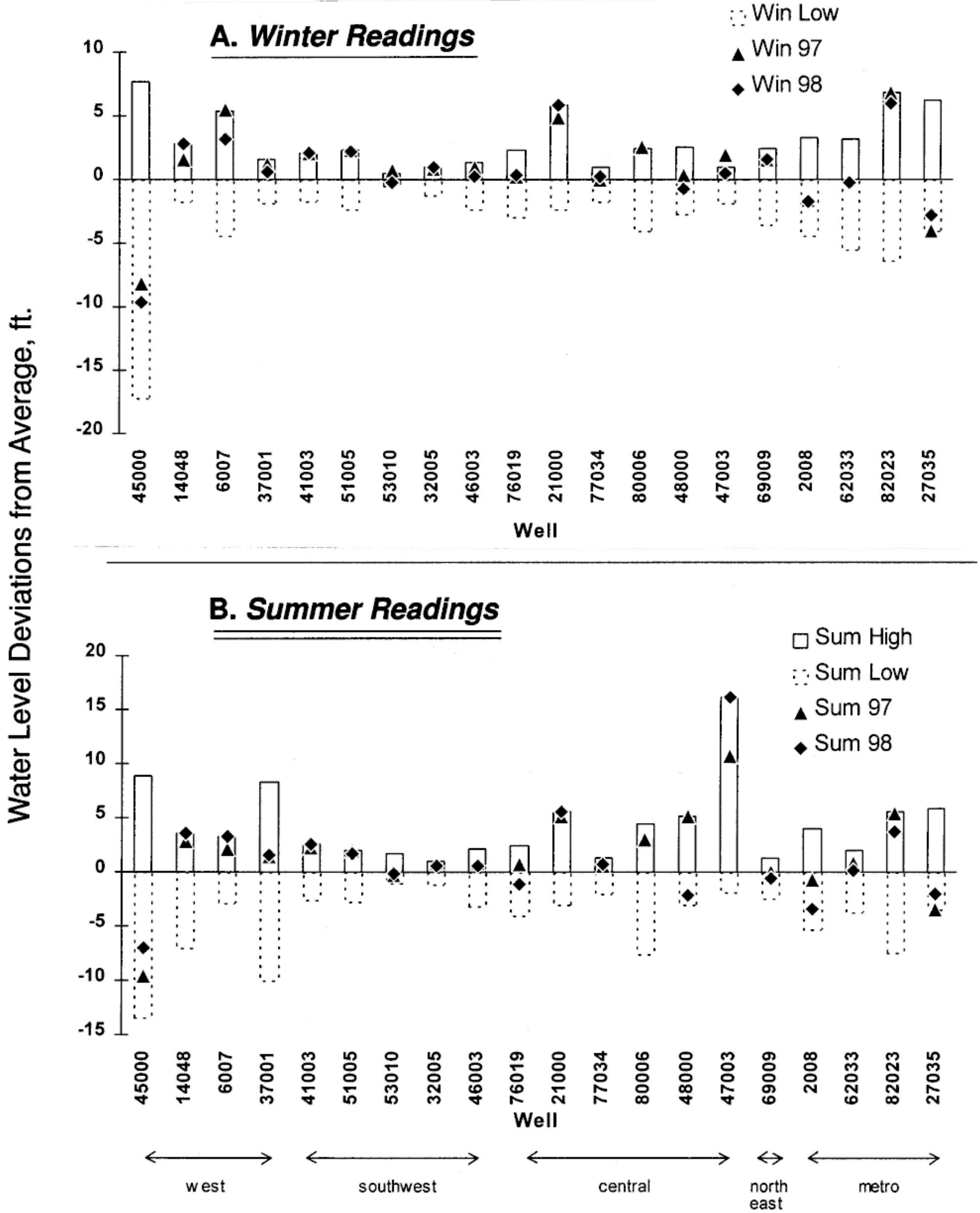
Confined Aquifers - Buried Artesian

Seasonal water levels in buried artesian aquifers are compared to historic averages in Figures 9a and 9b. Winter water levels tended to be higher than average during both WY97 and WY98. The exceptions were wells broadly classed as Twin Cities Metropolitan Minnesota. Two of the four metro wells were below average in winter and summer during both water years. Another of the metro wells was near or below average in WY98. The large amount of water use in the metro area, generally from bedrock aquifers, may be impacting these buried artesian wells.

Winter water levels for WY 97 and WY98 (Figure 9a) were not higher in one year than the other. However, WY97 summer water levels tended to be higher in metro wells (Figure 9b) while WY98 levels were higher in western wells.

Figure 9

Water Level Comparisons, Buried Artesian Wells: A. *Winter*, B. *Summer*



As with the water table wells, the actual measured depths to water are shown in Figures 10a and 10b. Table 2 lists the measured depths included in this summary.

Table 2

Measured Depths to Water (ft) in Selected Buried Artesian Observation Wells

	WY97				WY98				
Well	Month	Depth	Month	Depth	Month	Depth	Month	Depth	Period of Record (yrs)
2008	3	12.73	8	14.37	3	12.58	8	15.67	27
6007	3	4.17	8	4.39	3	4.11	8	6.15	21
14048	3	31.40	8	33.30	3	33.00	8	33.00	5
21000	3	76.72	8	76.11	3	75.70	8	75.79	34
27035	3	71.65	8	72.16	3	72.44	8	73.54	18
32005	3	85.72	8	85.59	3	85.43	8	85.76	10
37001	3	21.11	8	25.62	3	19.85	8	33.80	18
41003	3	104.50	8	103.80	3	103.50	8	103.90	12
45000	3	20.45	8	22.22	3	22.23	8	23.56	42
46003	4	23.40	8	23.88	3	23.98	8	24.66	10
47003	4	25.03	10/'97	25.12	4	25.17	10/'98	30.45	15
48000	3	38.86	8	38.88	3	39.23	8	39.29	31
51005	3	77.95	8	78.67	3	77.77	8	78.82	14
53010	3	26.47	8	25.77	3	26.43	8	26.30	10
62033	3	23.11	8	23.13	3	21.74	8	23.51	18
69009	3	18.51	8	13.15	4	11.41	8	12.03	44
76019	3	9.58	8	7.29	3	8.47	8	8.10	19
77034	3	20.01	8	19.55	3	19.70	8	19.75	13
80006	4	1.79	10/'97	2.51	4	2.22	10/'98	4.71	31
82023	3	125.84	7	125.28	3	124.73	8	123.45	18

Figure 10 **Water Levels, Buried Artesian Wells: A. *Winter,* B. *Summer***

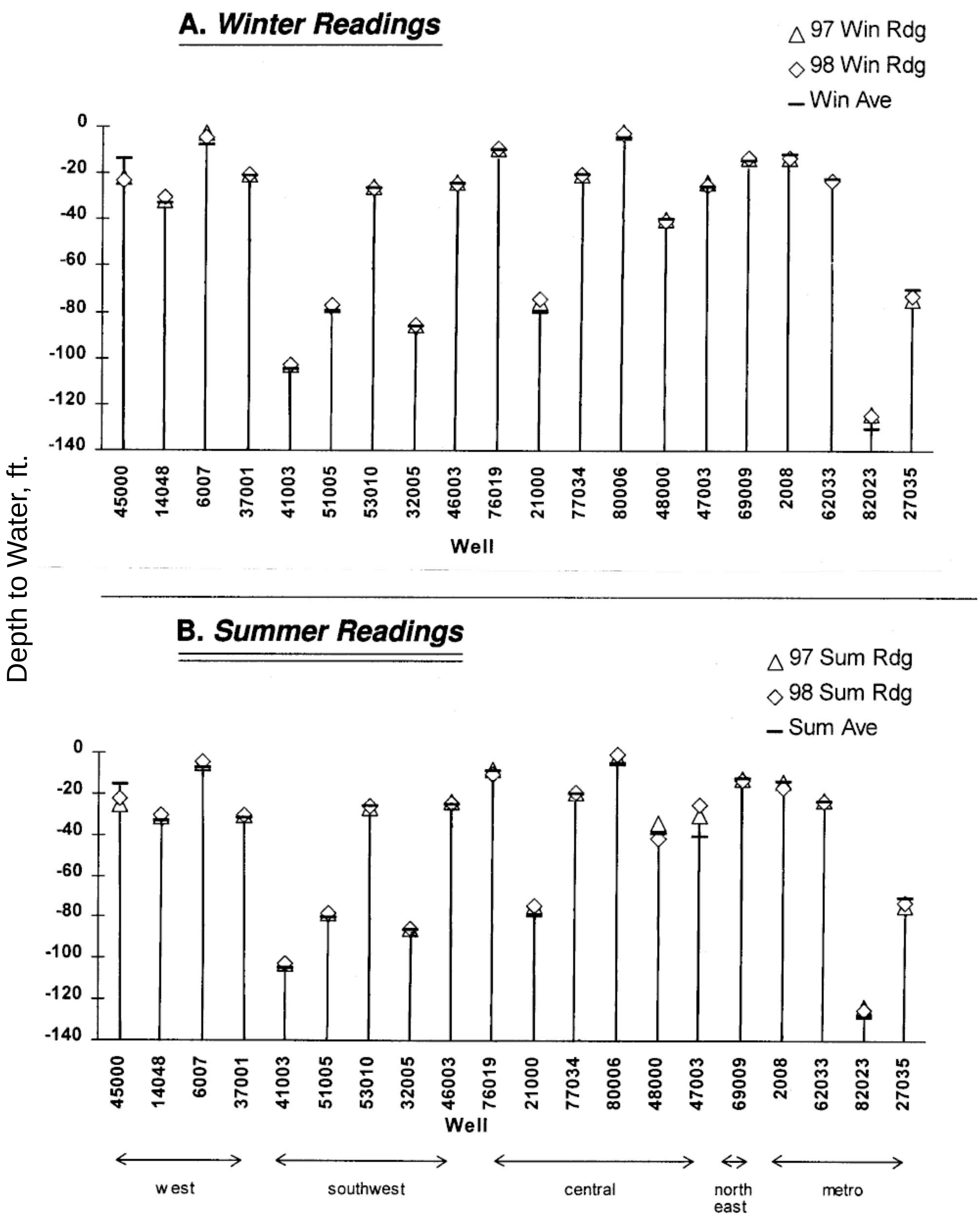
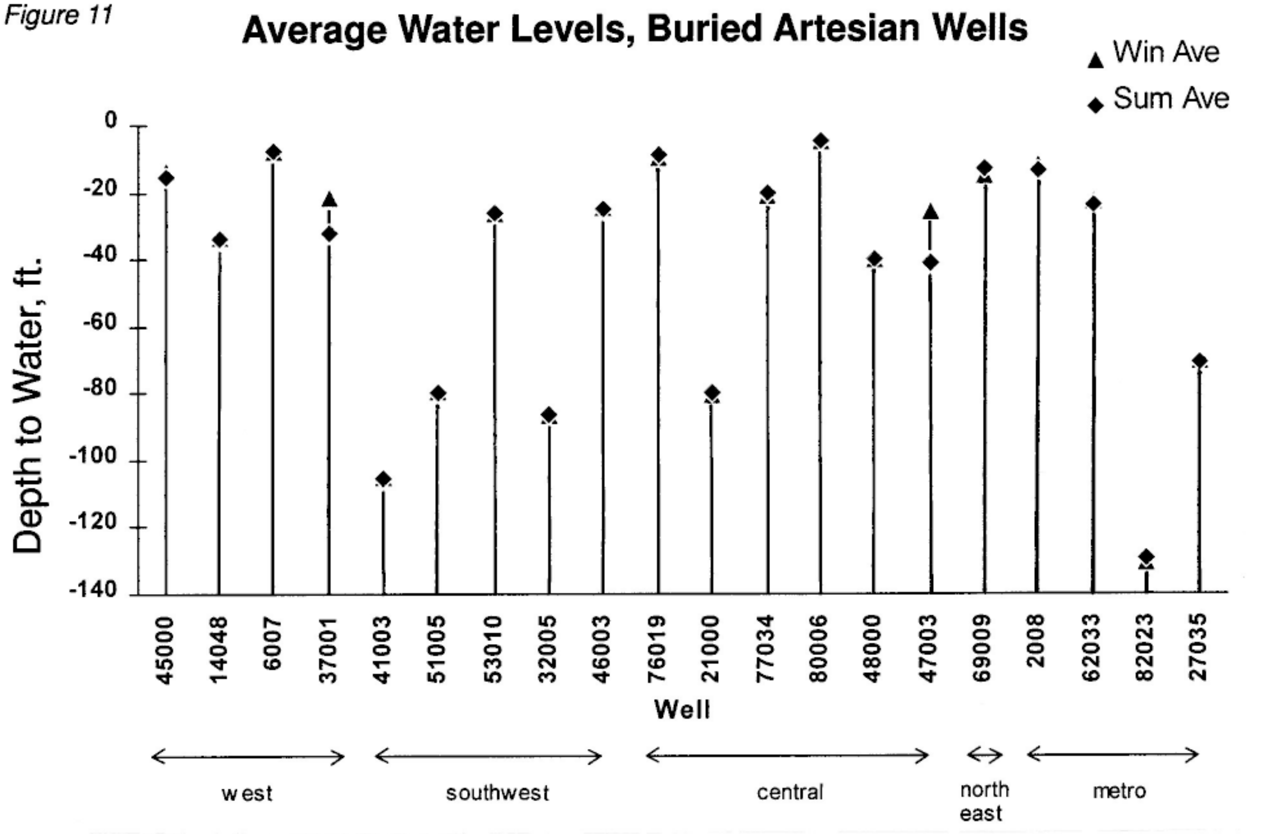


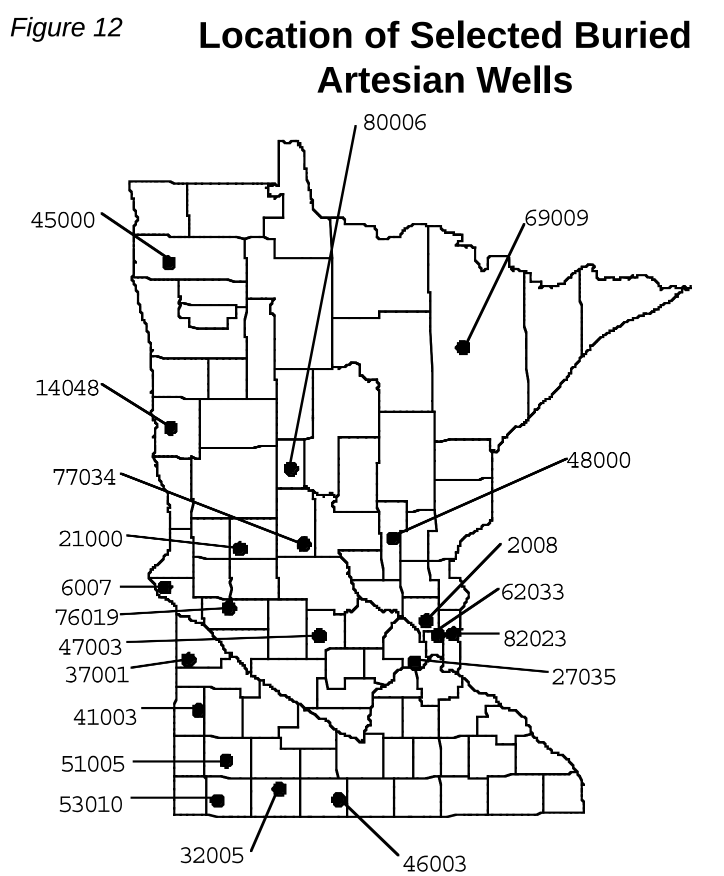
Figure 11



A comparison of historical winter and summer average water levels for buried artesian wells is presented in Figure 11. The small scale of the Y-axis may tend to mask some differences, but generally the two seasonal averages are similar. Under confined conditions, these aquifers generally respond more slowly to seasonal inputs from snow melt and precipitation than water table aquifers. However, buried artesian aquifers can be near the surface with their extent poorly defined and with some connection to adjacent unconfined aquifers. As a result, individual response of buried artesian aquifers to recharge is difficult to predict.

The approximate location of the buried artesian wells used in this summary are shown in Figure 12.

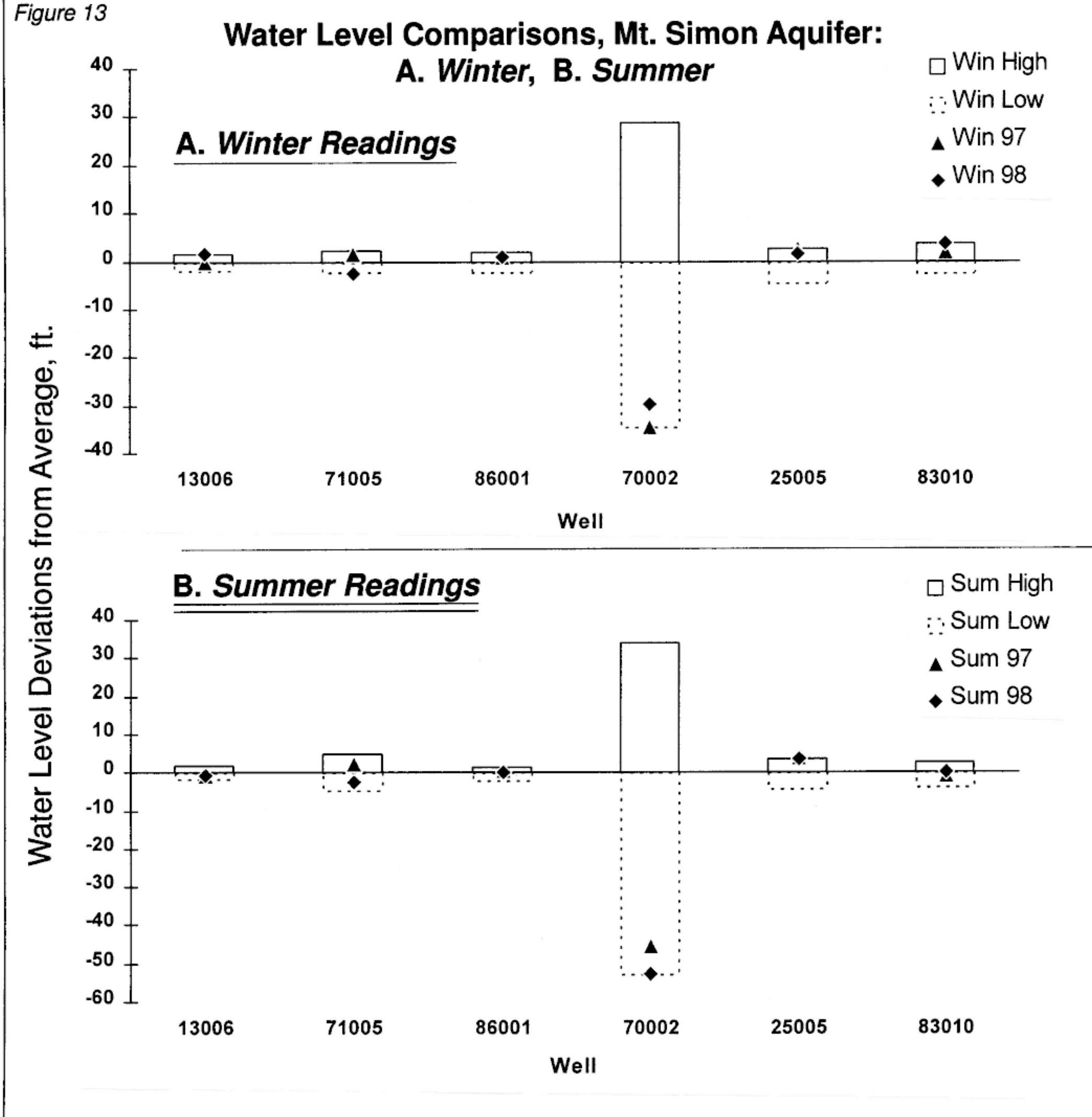
Figure 12



Confined Bedrock - Mt. Simon Aquifer

Figures 13a and 13b present a comparison of winter and summer water levels with seasonal averages for the Mt. Simon aquifer wells in this report. Water levels were, for the most part, above average in these wells. Two exceptions are worth noting. Well 83010, used for irrigation in Watonwan County, showed average or below summer water levels during both water years, indicating heavy irrigation use. Well 70002, located near Savage, MN, has been experiencing a decline in water levels since 1980. Evidence of this is shown in the range between the historical high and low levels indicated by the bars on the graph. Also, readings for WY97 and WY98 established new record low levels, indicating continuation of the declining levels. Differences between water years for either season were not evident (Figure 13a and 13b).

Figure 13



Seasonal average water levels (Figure 14a) indicate that water levels in the Mt. Simon aquifer tend to be slightly lower in summer. This was the case in WY97 and WY98 where summer water levels were lower (Figure 14b). Water levels measured during the WY97 - WY98 period are presented in Table 3. Locations of the Mt. Simon wells used for this summary are shown in Figure 15.

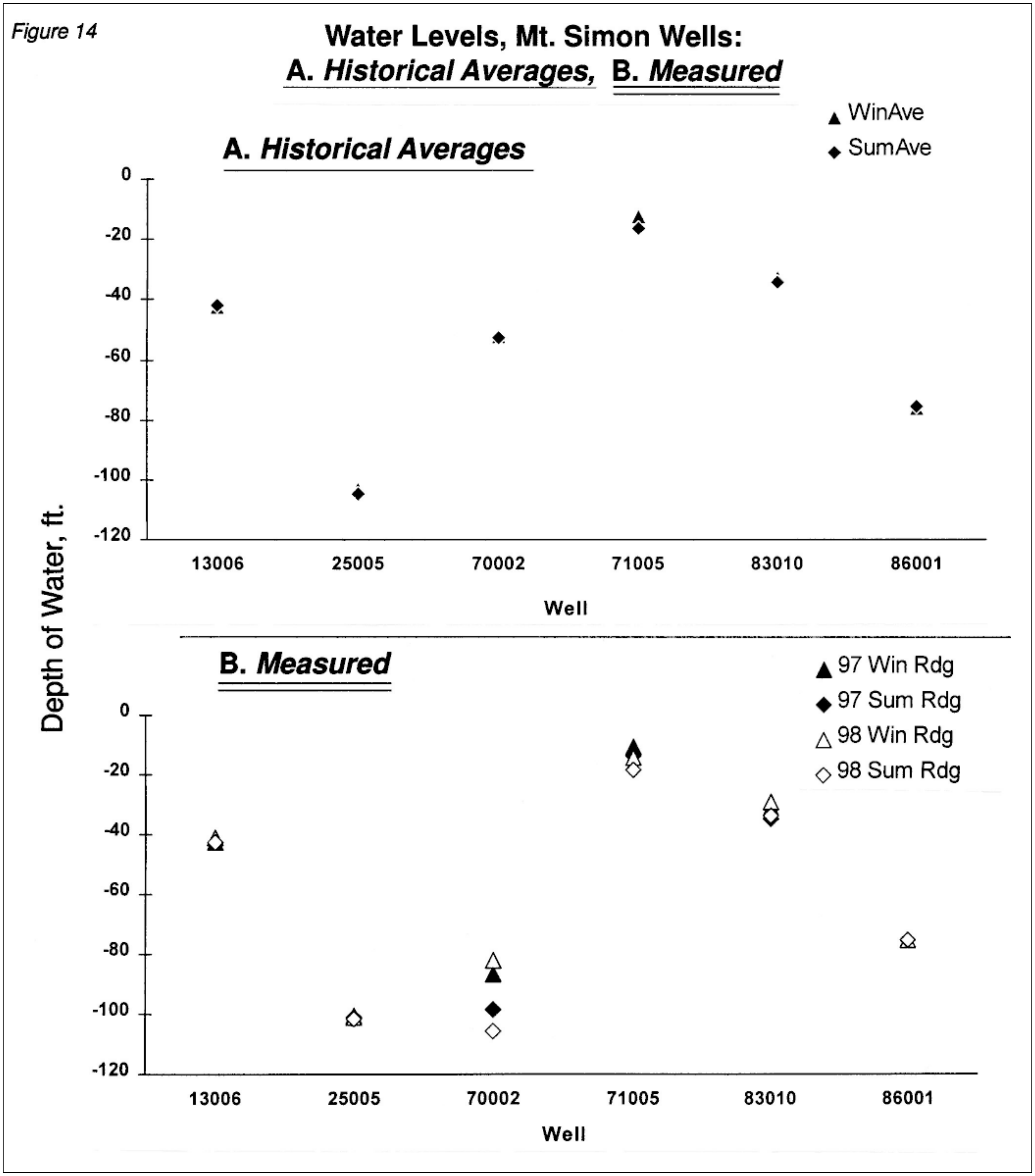


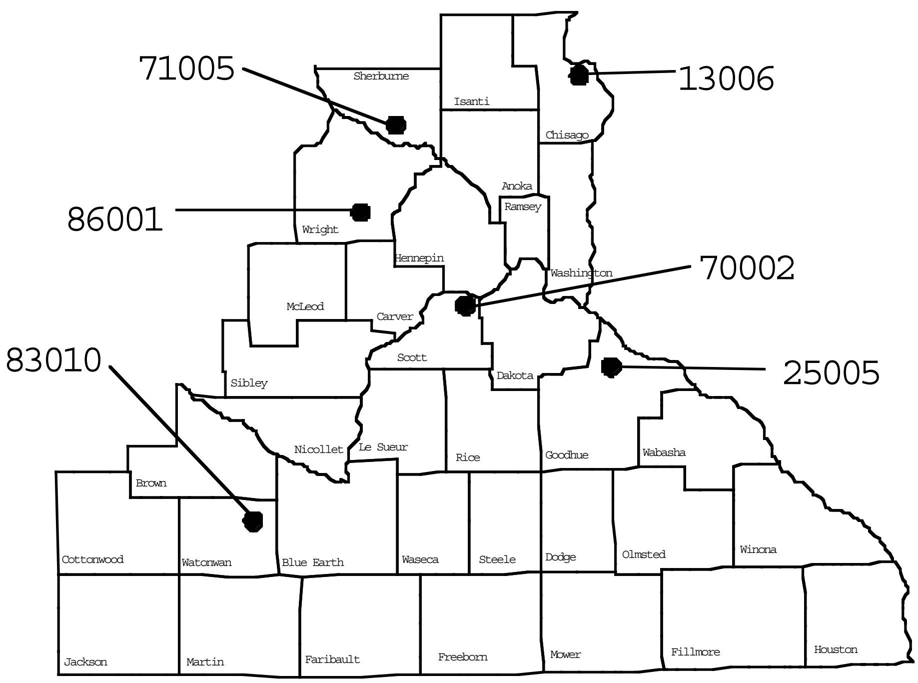
Table 3

Measured Depths to Water (ft) in Selected Mt. Simon Observation Wells

	WY97				WY98				Period of
Well	Month	Depth	Month	Depth	Month	Depth	Month	Depth	Record (yrs)
13006	3	42.41	8	42.69	3	40.83	8	42.55	21
25005	3	100.48	9	101.11	3	101.26	8	101.29	22
70002	3	86.73	8	98.31	3	82.15	8	105.67	27
71005	4	10.70	10/'97	14.10	4	14.58	10/'98	18.62	25
83010	4	31.09	10/'97	34.68	4	29.40	10/'98	33.80	18
86001	3	75.47	9	75.18	3	75.19	8	75.50	28

Figure 15

Location of Selected Mt. Simon Aquifer Wells



Confined Bedrock - Prairie du Chien - Jordan Aquifer

Seasonal water levels in the Prairie du Chien-Jordan Aquifer (PduC/J) are compared to historical averages in Figures 16a and 16b. There is no discernable pattern in the WY97 and WY98 PduC/J winter or summer water levels.

Table 4 **Measured Depths to Water (ft) in Selected Jordan Observation Wells**

	WY97				WY98				Period of Record (yrs)
Well	Month	Depth	Month	Depth	Month	Depth	Month	Depth	
2012	3	9.44	8	10.27					25
19007	3	15.79	8	14.32	3	12.73	8	12.26	25
27001	3	78.14	8	79.41					31
55000	3	66.00	8	69.82	3	65.29	8	70.13	24
62001			9	138.80	3	143.27	8	150.55	28
66015	3	8.22	8	12.10	3	8.01	8	12.94	18
70008	3	83.20	8	82.57	3	81.59	8	80.37	19
82016	3	65.39	9	56.75	3	62.10	9	58.94	19

Figure 16 **Water Level Comparisons, Jordan Aquifer: A. *Winter*, B. *Summer***

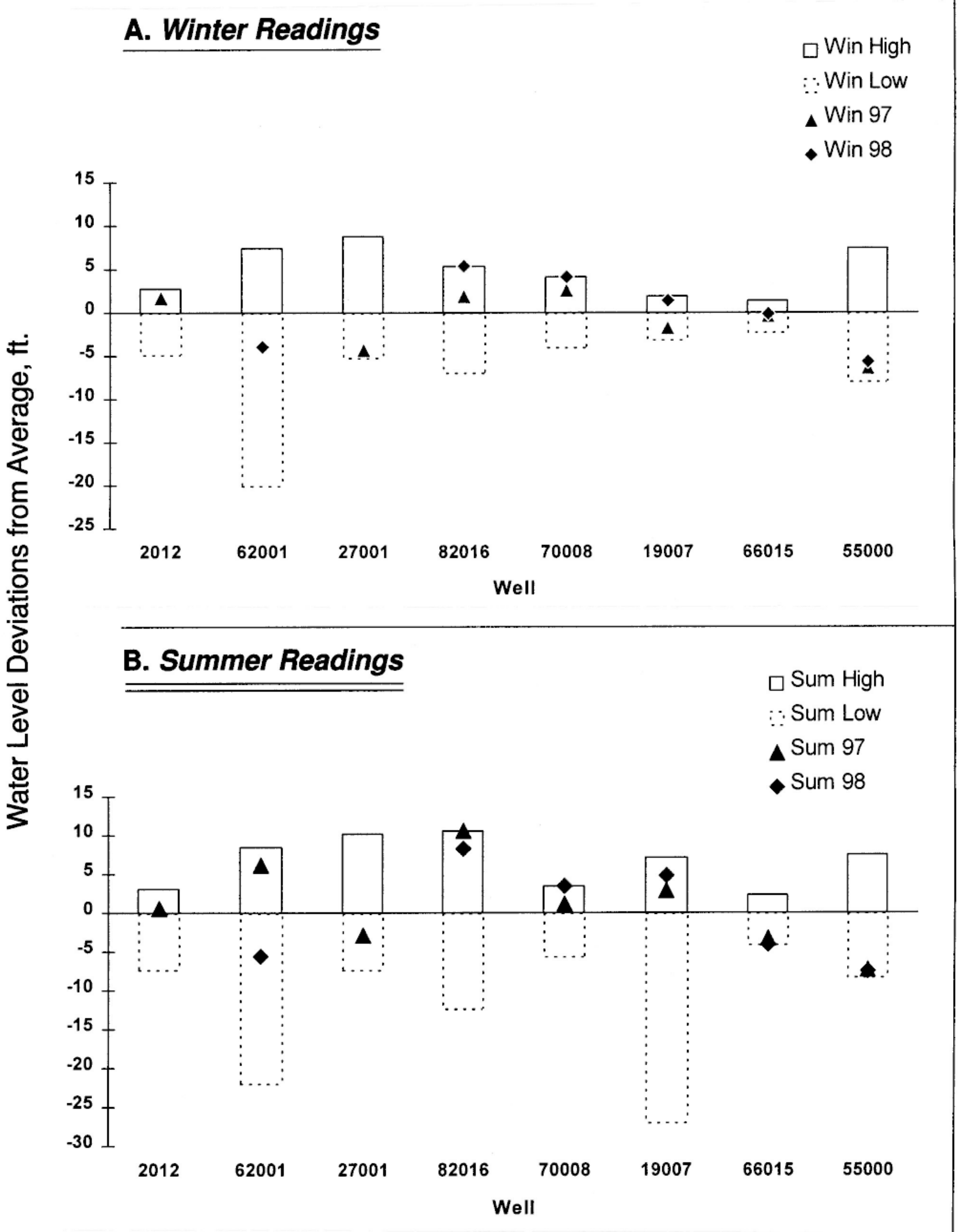
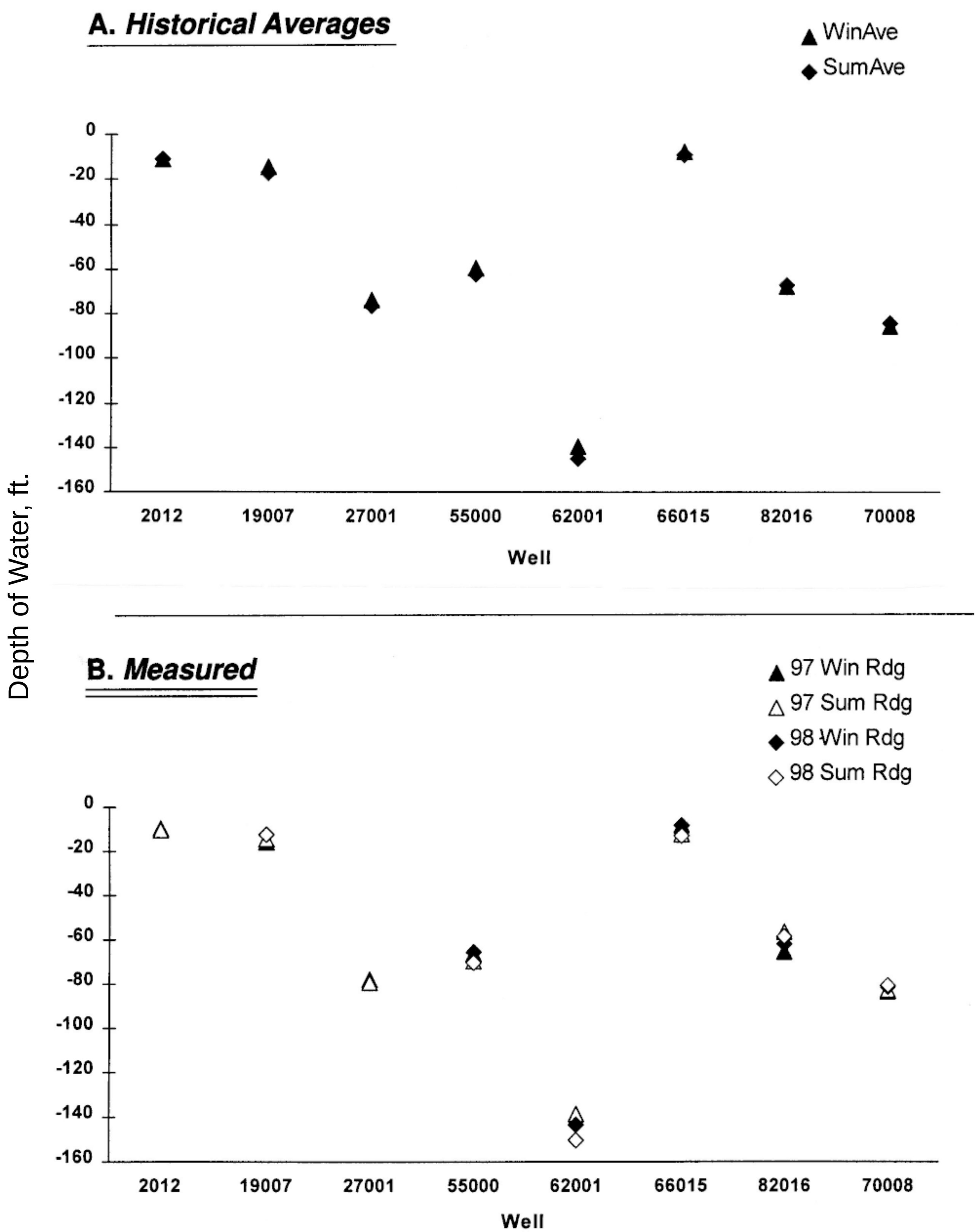


Figure 17 **Water Levels, Jordan Wells: A. *Historical Averages,* B. *Measured***

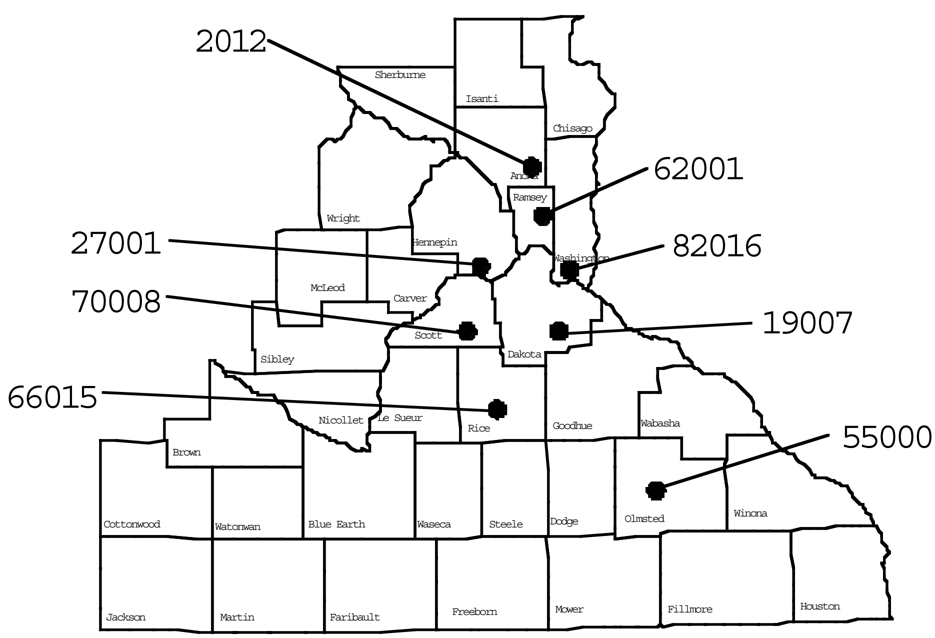


Average PduC/J water levels tend to be higher in winter than in summer (Figures 17a and 17b). Locations of the PduC/Jordan wells used in this report are shown in Figure 18.

Obwell Network Improvement

The obwell network was expanded by the addition of two Prairie du Chien/Jordan well nests in Scott County. Several new wells were installed in the mining districts of northeastern Minnesota, and also near Duluth. In addition, a few existing wells were reconstructed with completion in the Mt. Simon aquifer. Waters' program of exploratory drilling and observation well installation continued in southwest and west central regions with several new wells being installed in buried artesian aquifers. Some wells, which were lost during previous years due to a variety of circumstances such as inadvertent sealing, road construction, and well owners' decisions to eliminate the wells from their property, were replaced in cooperation with the Minnesota Pollution Control Agency using their drilling equipment.

Figure 18 **Location of Selected Jordan Aquifer Wells**

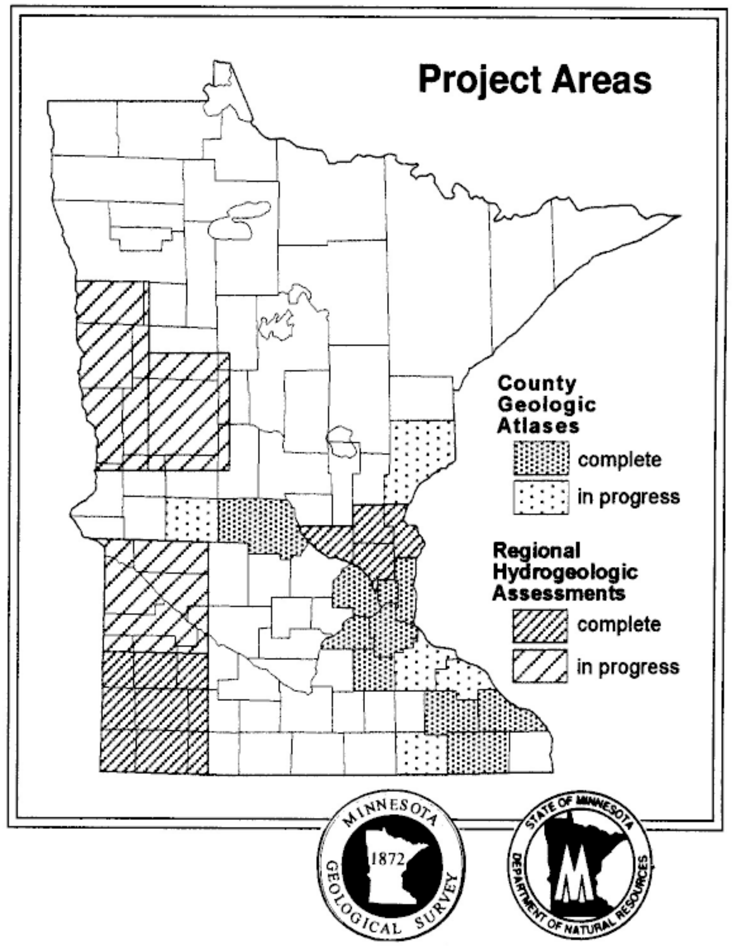


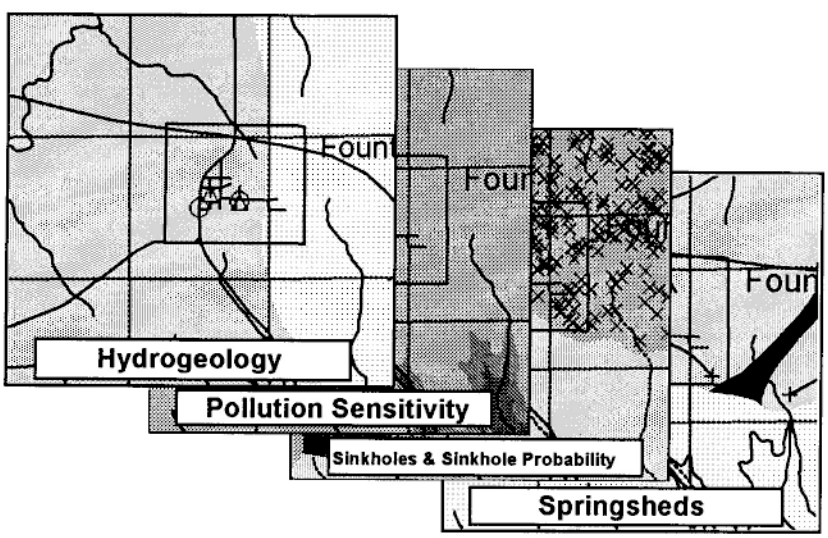
County Geologic Atlas and Regional Hydrogeologic Assessment Program

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 Observation Well 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.





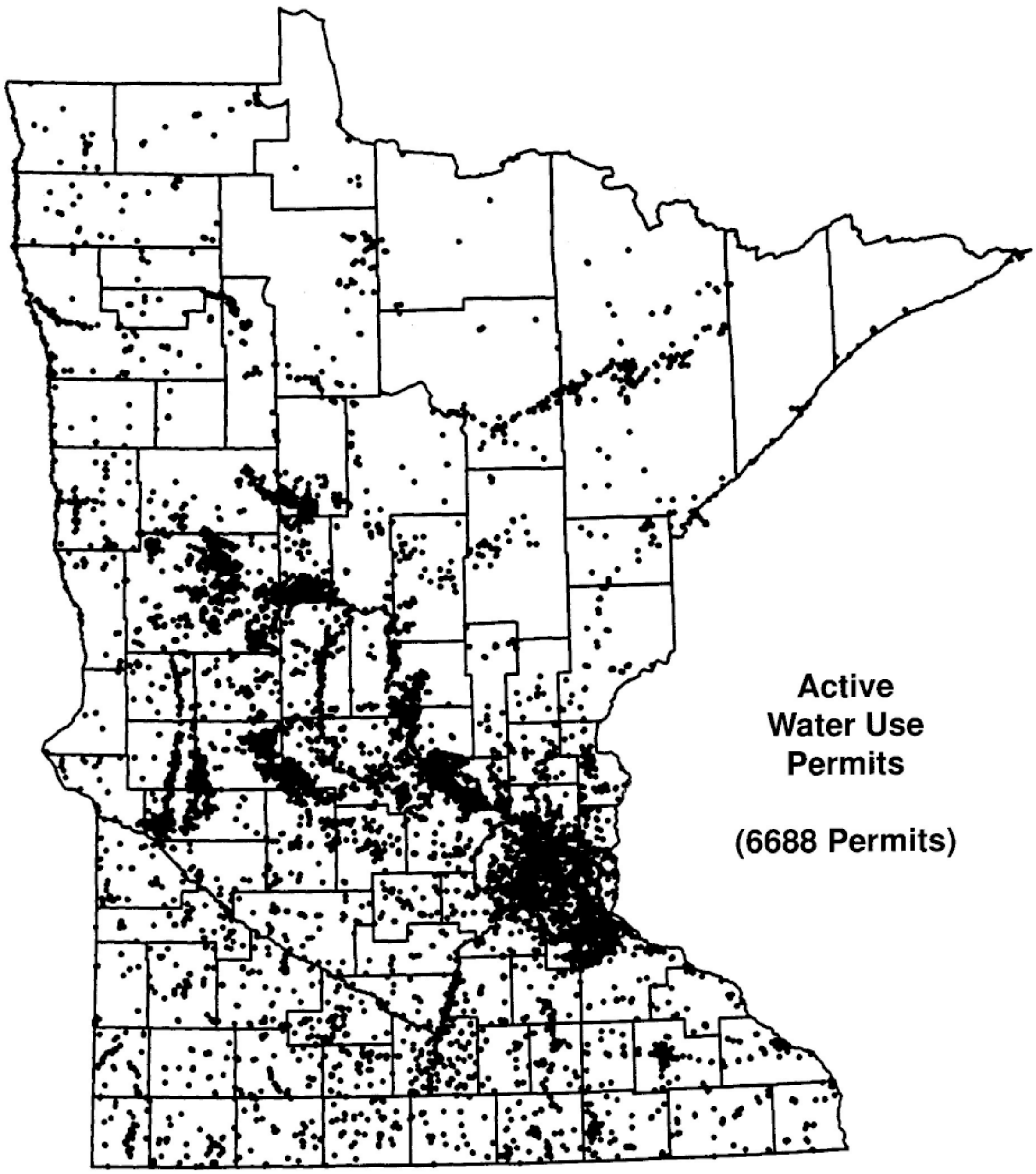
Layers show the area around the town of Fountain, Fillmore County; from Fillmore County Geologic Atlas, Part B, 1996

GIS-Based Mapping

The information collected is organized, displayed and analysed using Geographic Information System (GIS) technology, a computer-based tool for manipulating spatial information. Since 1993, all atlas and regional assessment reports have been developed using GIS technology and project data are filed for distribution at the Land Management Information Center, Department of Administration.

Chapter 4

WATER USE



Introduction

DNR water appropriations permits are required for all users withdrawing more than ten thousand gallons of water 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.

As a condition of each permit, the holder must report the volume withdrawn for the previous year within an accuracy of 10%. The data collected is 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) 1996 and 1997.

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 1996 and 1997

Total water use for calendar years 1996 and 1997 remained relatively stable. The totals for these two years average about 1% lower than the previous two-year average. The reported water use in 1997 was 1163 billion gallons (BG), down from 1182 BG in 1996. Figure 1 is a comparison of the two years by major category, volume and percent change between the years. The largest increase in use was for industrial processing, increasing by 12 BG or 8%. The largest decrease in use was for irrigation, decreasing by 22 BG or 27%.

Figure 2 graphically shows the changes in use patterns for 4 main use categories (excluding power generation) from 1986 to 1997. Noticeable is low irrigation use in 1986 and 1993, the peak of irrigation in 1988 and the overall increase in industrial processing use since 1986. The pattern in irrigation reflects low use in times of high precipitation and large use in times of drought. The changes in industrial processing appear to be due to local economic factors.

Figure 1

Water Use Comparison by Major Use Category: 1996 & 1997
(Billions of Gallons)

	1996		1997			
Use Category	**BG**	**% of Total**	**BG**	**% of Total**	**BG Change**	**% Change**
Power Generation	710	60%	701	60%	-9	-1%
Public Supply	188	16%	182	16%	-6	-3%
Industrial Processing	147	12%	159	14%	12	8%
Irrigation	80	7%	58	5%	-22	-27%
Other	57	5%	63	5%	6	9%
Totals	**1,182**	**100%**	**1,163**	**100%**	**-19 ***	**-2% ***

* change in totals from 1996 to 1997

A comparison of surface water versus ground water use for 1997 (Figure 3) shows that the majority of appropriations are from surface water sources. In 1997, 82% of withdrawals in Minnesota were from surface water sources, which compares closely with the national average of 80% (USGS data). However, if the non-consumptive use for most power generation is removed, use of ground water and surface water are more even (non-consumptive use means water that is immediately returned to its source after use). 60 to 65% of the water use in Minnesota is used for power plant cooling, a relatively non-consumptive use.

Surface water use increased slightly from 1996 to 1997, primarily due to increased appropriation for industrial processing and uses described in "other uses". Surface water withdrawals for power generation decreased, offsetting the industrial processing and "other uses" increases. Ground water use decreased slightly from 1996 to 1997 primarily due to decreased demand for irrigation water. However, ground water use for the 1996 and 1997 was slightly higher than for the previous two-year period.

Figure 2

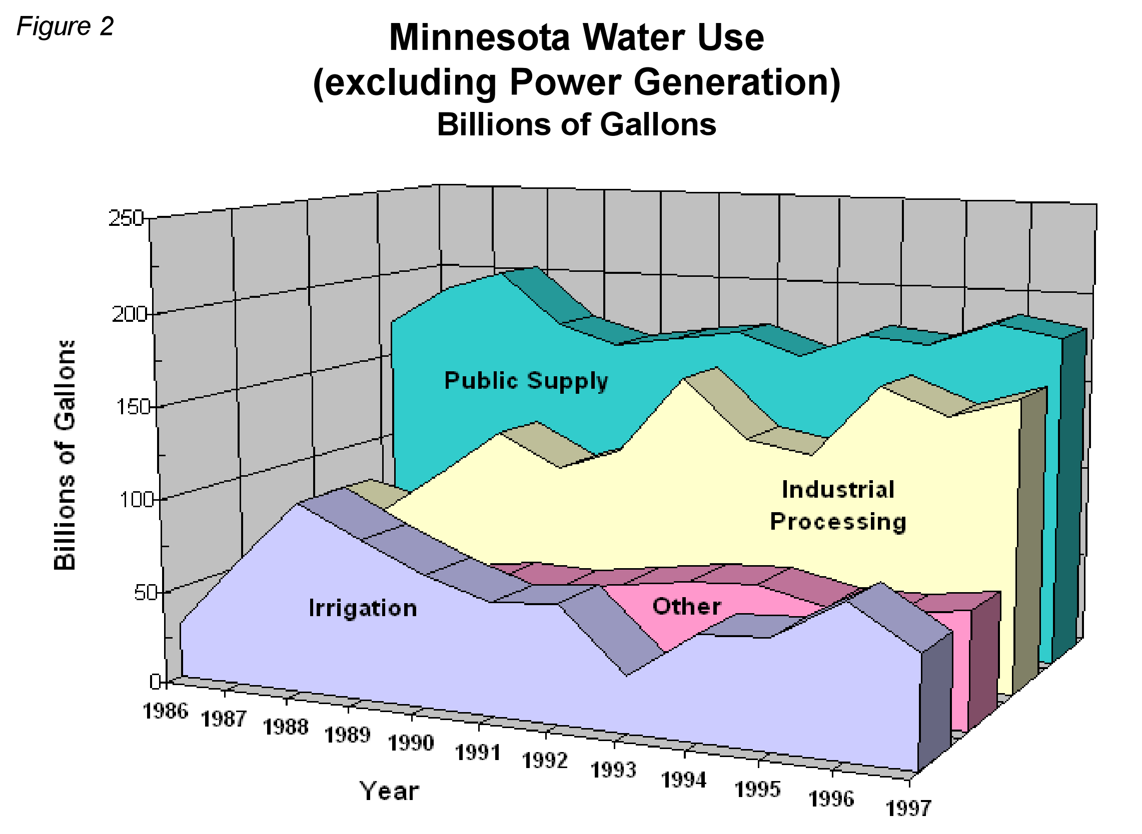
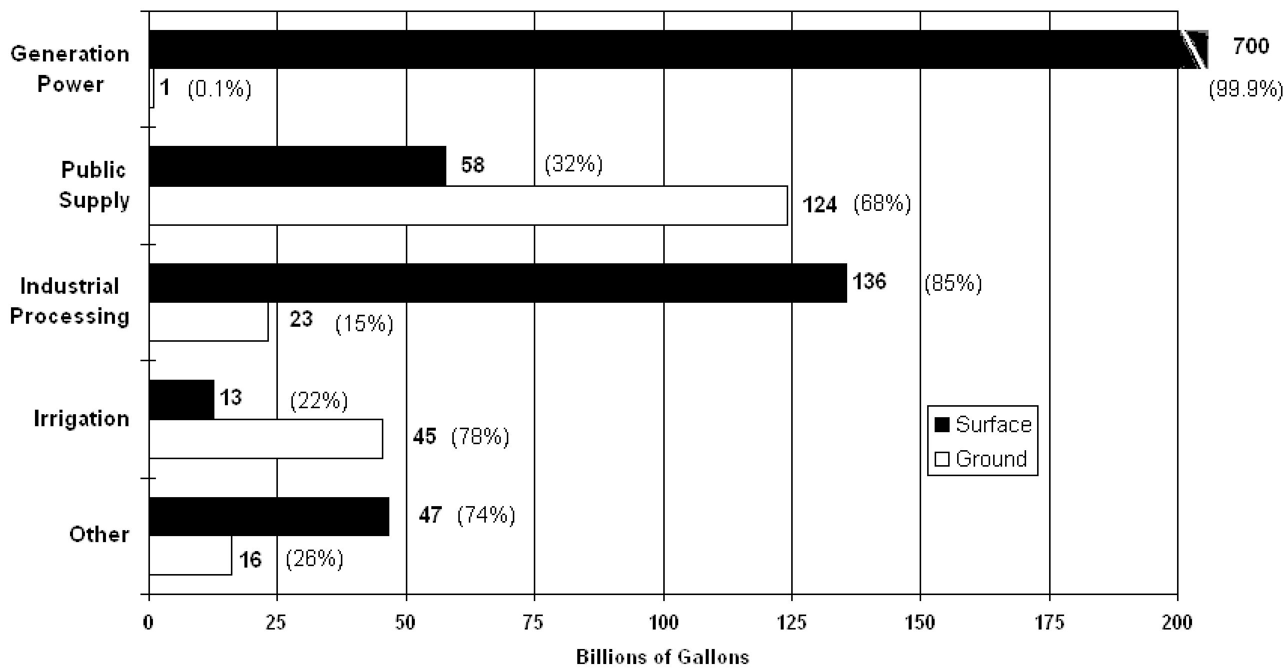


Figure 3

Comparison of Surface and Ground Water Use by Category - 1997
Billions of Gallons (% of category)



Surface Water Total: 953 BG
82% of 1997 Use

Ground Water Total: 210 BG
18% of 1997 Use

Power Generation

Power generation (nuclear power cooling and steam power cooling) was the primary use in 8 of the 11 counties with the highest total use in 1997 (Figure 4). Power generation accounted for 62% of all use reported in Minnesota for the year. Power generation in Goodhue and Wright Counties alone accounted for 24% of all reported use in 1997, 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 used for cooling purposes and is returned to the surface water source after use.

Public Water Supply

Water use for public water supplies remained fairly constant from 1989 to 1997 (Figure 2), dipping slightly in 1990 and 1993. Reported water use for 1996 and 1997 was 188 BG and 182 BG respectively. 68% of public water supply use comes from ground water, compared to 39% nationally (USGS data, 1986-1990).

In the Twin Cities Metropolitan Area, the majority of public water supply pumping locations are in the suburbs and form a ring around the central cities (Figure 5). Most of the locations are wells that pump from productive bedrock aquifers.

Minneapolis receives water from the Mississippi River in Fridley (Anoka County) north of the city. St. Paul has its major water intake also along the Mississippi River a few miles north of the Minneapolis intake. This is primarily why Anoka County is on the list of counties with greatest water use (Figure 4).

Local water conservation programs, that implement measures to improve efficiencies and promote wise use, 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

Appropriations by the Counties with the Greatest Use in CY 1997

	County	Surface Water	Ground Water	Total	Primary Use
1)	Goodhue	172	2	174	Nuclear Power Cooling
2)	Washington	104	11	115	Steam Power Cooling
3)	Wright	104	2	106	Nuclear Power Cooling
4)	St. Louis	99	1	100	Steam Power Cooling
5)	Hennepin	65	36	101	Steam Power Cooling
6)	Itasca	70	1	71	Steam Power Cooling
7)	Dakota	50	19	69	Steam Power Cooling
8)	Ramsey	42	17	59	Steam Power Cooling
9)	Lake	50	< 1	50	Mine Processing
10)	Anoka	37	10	47	Municipal Waterworks
11)	Cook	42	< 1	42	Mine Processing
	Total	**835**	**99**	**934**	
		88% of SW Use	*47% of* GW Use	*80% of* Total Use	

Irrigation

Yearly variation in the amount and distribution of rainfall greatly affects the demand for irrigation water. 1996 had a 40% increase in irrigation water use to 80 BG from the previous two-year average of 57 BG. 1997 irrigation use dropped down to a more average value of 58 BG. However, water use for irrigation has dropped considerably since the peak usage of 103 BG in 1988.

Irrigation accounts for only a small percentage of the total water use in Minnesota (5%). However, this use is significant because it is almost entirely consumptive and the majority is from groundwater sources (78%).

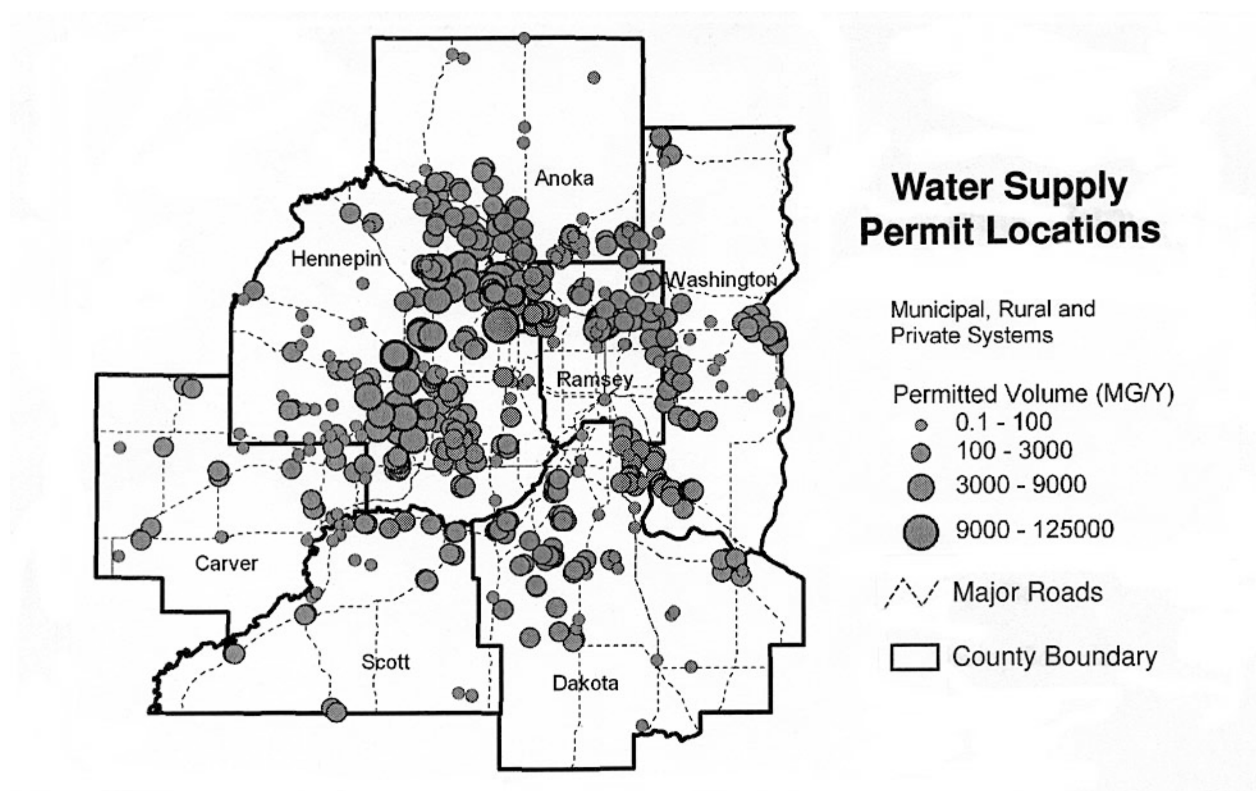
Otter Tail and Sherburne Counties reported the most water use for irrigation in 1997, using 8.1 BG and 6.6 BG respectfully. Roseau County was the only county that reported no water use for irrigation in 1997. Mahnomen, Traverse, Lake and Faribault Counties reported less than a half million gallons each for irrigation in 1997.

Industrial Processing

Industrial processing use increased 8% from 1996 to 1997, primarily due to increased use for mine processing in Cook and Lake Counties. Mine processing accounted for 65% of the reported total, while pulp and paper processing and agricultural processing accounted for 16% and 7% of the total, respectively (Figure 6).

Figure 5

Twin Cities Seven-County Metropolitan Area



Other Uses

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

General Permit

In 1997, the legislature passed a bill allowing the Department to issue a general permit for temporary appropriations such as construction dewatering, dust control, landscaping or hydrostatic testing of pipelines, tanks and wastewater ponds. The general permit significantly reduces the time to obtain permits for temporary projects that have minimal potential to cause adverse environmental impacts. The time between a contract award and the start of the project is often less than the 30-day legal requirement for local units of government to review a permit application and submit comments.

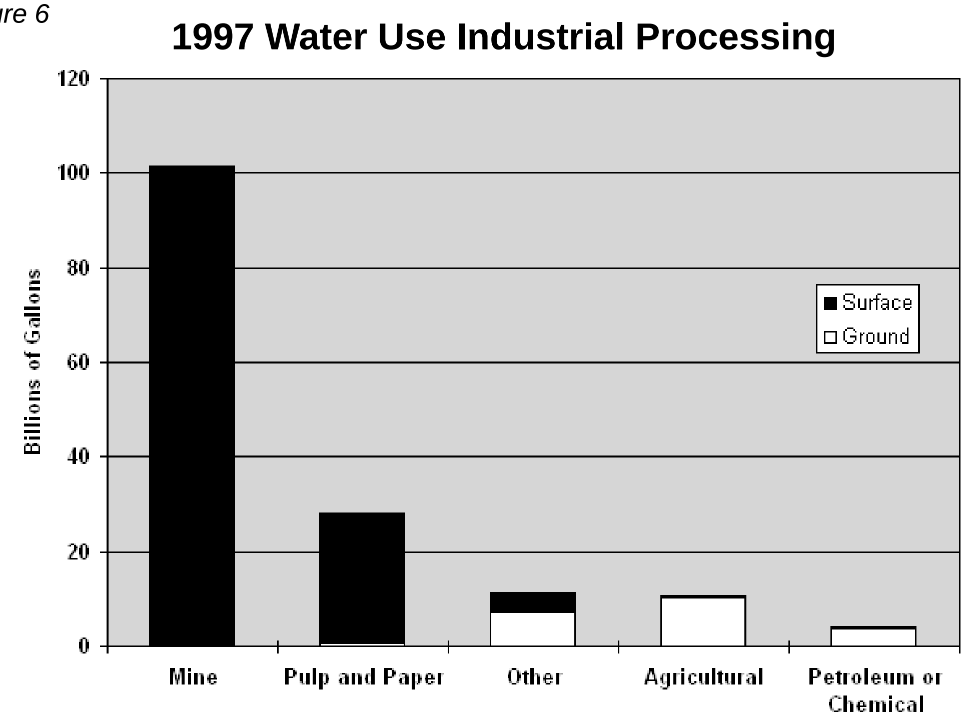
The advantage of the general permit is that it only requires an applicant to submit a notice describing the project five days prior to the start of pumping, so that an Area Hydrologist can determine if the project is eligible for a general permit. The general permit makes it easier for water appropriators to comply with the law and allows the Department to focus on other priorities by reducing the amount of time spent on projects with minimal impacts.

In 1997, 31 projects employed general permits for temporary dewatering, using a total of 141.4 million gallons. The majority of these projects involved construction dewatering.

Summary

Total water use from 1996 to 1997 remained relatively constant, decreasing by about 1% overall. Power generation continues to account for the majority of use totaling 701 BG of the 1163 BG reported for 1997 (60%). Surface water accounts for 82% of all appropriations.

Figure 6



Reported Water Use by County
1996 - 1997 (Millions of Gallons)

Reported Pumpage

	County	1996 Surface	1996 Ground	1996 Total	1997 Surface	1997 Ground	1997 Total	Primary Use	Percent of 1997 Total
1	Aitkin	1,634.9	108.9	1,743.8	1,844.3	95.1	1,939.4	Wild Rice Irrigation	89
2	Anoka	40,410.0	11,098.9	51,508.9	36,529.9	10,198.9	46,728.8	Municipal Waterworks	96
3	Becker	10.3	2,159.9	2,170.2	11.4	1,966.9	1,978.3	Major Crop Irrigation	54
4	Beltrami	1,484.2	844.9	2,329.1	1,399.4	678.1	2,077.5	Wild Rice Irrigation	65
5	Benton	3,592.2	3,218.7	6,810.9	3,441.6	2,526.1	5,967.7	Industrial Processing	57
6	Big Stone	64.2	361.8	426.0	87.6	436.8	524.4	Major Crop Irrigation	47
7	Blue Earth	6,328.0	3,847.3	10,175.3	7,722.8	3,706.3	11,429.1	Steam Power Cooling	67
8	Brown	136.9	691.7	828.6	113.5	653.7	767.2	Major Crop Irrigation	42
9	Carlton	3,601.6	690.6	4,292.2	1,281.7	672.4	1,954.1	Pulp/Paper Processing	62
10	Carver	15.8	2,653.6	2,669.4	8.8	2,504.9	2,513.7	Municipal Waterworks	86
11	Cass	55.2	1,028.8	1,084.0	28.3	892.3	920.6	Major Crop Irrigation	26
12	Chippewa	555.0	483.6	1,038.6	88.0	551.3	639.3	Municipal Waterworks	78
13	Chisago	214.2	913.4	1,127.6	193.1	865.3	1,058.4	Municipal Waterworks	57
14	Clay	1,492.2	1,232.6	2,724.8	1,426.9	1,055.1	2,482.0	Municipal Waterworks	76
15	Clearwater	2,513.3	124.7	2,638.0	3,799.4	129.3	3,928.7	Wild Rice Irrigation	96
16	Cook	31,140.5	7.8	31,148.3	41,593.4	11.5	41,604.9	Mine Processing	99.7
17	Cottonwood	100.1	783.4	883.5	156.0	854.5	1,010.5	Municipal Waterworks	40
18	Crow Wing	1,319.9	1,535.4	2,855.3	1,385.6	1,477.0	2,862.6	Pulp/Paper Processing	44
19	Dakota	55,826.0	23,111.4	78,937.4	49,826.2	19,168.8	68,995.0	Steam Power Cooling	66
20	Dodge	100.2	397.5	497.7	56.6	415.5	472.1	Municipal Waterworks	71
21	Douglas	162.8	1,079.5	1,242.3	148.8	1,086.8	1,235.6	Municipal Waterworks	50
22	Faribault	0.0	802.8	802.8	0.0	754.6	754.6	Municipal Waterworks	70
23	Fillmore	3,459.0	690.9	4,149.9	3,558.8	468.0	4,026.8	Hatcheries & Fisheries	88
24	Freeborn	25.3	2,003.7	2,029.0	7.4	1,769.2	1,776.6	Municipal Waterworks	81
25	Goodhue	184,221.3	2,799.5	187,020.8	172,272.5	2,100.8	174,373.3	Nuclear Power Cooling	90
26	Grant	0.0	787.9	787.9	0.0	544.0	544.0	Major Crop Irrigation	61
27	Hennepin	63,244.9	37,406.3	100,651.2	64,711.2	35,654.7	100,365.9	Steam Power Cooling	63
28	Houston	3.9	534.1	538.0	4.4	515.6	520.0	Municipal Waterworks	75
29	Hubbard	13.3	3,870.1	3,883.4	13.6	3,480.1	3,493.7	Major Crop Irrigation	74
30	Isanti	0.0	646.3	646.3	87.0	867.6	954.6	Municipal Waterworks	57
31	Itasca	70,809.3	936.1	71,745.4	69,955.9	1,062.8	71,018.7	Steam Power Cooling	81
32	Jackson	87.0	274.8	361.8	115.2	281.2	396.4	Municipal Waterworks	64
33	Kanabec	10.0	201.4	211.4	10.6	201.7	212.3	Municipal Waterworks	73
34	Kandiyohi	602.9	2,659.1	3,262.0	560.8	2,277.9	2,838.7	Municipal Waterworks	56
35	Kittson	93.4	330.0	423.4	161.0	317.4	478.4	Rural Waterworks	37
36	Koochiching	16,703.4	40.9	16,744.3	17,480.6	43.3	17,523.9	Pulp/Paper Processing	98
37	Lac Qui Parle	32.6	1,331.0	1,363.6	23.6	1,224.0	1,247.6	Agricultural Processing	52
38	Lake	46,438.6	0.2	46,438.8	49,597.8	0.1	49,597.9	Mine Processing	99
39	Lake of the Woods	271.2	81.9	353.1	293.4	74.7	368.1	Wild Rice Irrigation	77
40	Le Sueur	2,868.2	996.8	3,865.0	2,948.6	992.7	3,941.3	Quarry Dewatering	50
41	Lincoln	5.3	484.8	490.1	11.4	499.8	511.2	Rural Waterworks	75
42	Lyon	94.1	1,517.8	1,611.9	166.9	1,652.1	1,819.0	Municipal Waterworks	79
43	McLeod	167.8	2,143.1	2,310.9	234.5	2,138.1	2,372.6	Municipal Waterworks	53
44	Mahnomen	0.0	86.5	86.5	0.0	84.9	84.9	Municipal Waterworks	100

Reported Water Use by County
1996 - 1997 (Millions of Gallons)

Reported Pumpage

County		1996 Surface	1996 Ground	1996 Total	1997 Surface	1997 Ground	1997 Total	Primary Use	Percent of 1997 Total
45	Marshall	42.4	263.0	305.4	102.3	243.3	345.6	Municipal Waterworks	39
46	Martin	12,296.3	212.6	12,508.9	10,317.7	296.8	10,614.5	Steam Power Cooling	93
47	Meeker	44.2	1,490.7	1,534.9	36.0	1,033.8	1,069.8	Municipal Waterworks	51
48	Mille Lacs	81.7	552.2	633.9	71.7	520.2	591.9	Municipal Waterworks	61
49	Morrison	117.9	3,870.3	3,988.2	95.5	3,569.6	3,665.1	Major Crop Irrigation	78
50	Mower	67.4	2,281.2	2,348.6	47.0	2,091.2	2,138.2	Municipal Waterworks	56
51	Murray	41.0	230.3	271.3	45.8	223.2	269.0	Municipal Waterworks	81
52	Nicollet	10.6	1,957.1	1,967.7	13.6	2,026.7	2,040.3	Municipal Waterworks	85
53	Nobles	58.4	1,281.3	1,339.7	46.8	1,193.9	1,240.7	Municipal Waterworks	96
54	Norman	9.2	178.1	187.3	0.0	152.5	152.5	Municipal Waterworks	92
55	Olmsted	6,734.7	5,607.5	12,342.2	5,362.3	5,629.8	10,992.1	Steam Power Cooling	46
56	Ottertail	14,888.4	12,287.2	27,175.6	19,303.5	9,350.2	28,653.7	Steam Power Cooling	64
57	Pennington	782.2	24.2	806.4	892.3	23.7	916.0	Wild Rice Irrigation	52
58	Pine	3.7	516.2	519.9	6.3	485.3	491.6	Municipal Waterworks	59
59	Pipestone	39.6	746.4	786.0	33.3	833.9	867.2	Rural Waterworks	41
60	Polk	3,705.2	546.9	4,252.1	3,284.2	559.8	3,844.0	Municipal Waterworks	47
61	Pope	93.2	5,721.1	5,814.3	50.4	3,161.7	3,212.1	Major Crop Irrigation	89
62	Ramsey	35,486.0	17,311.4	52,797.4	42,391.3	16,684.0	59,075.3	Steam Power Cooling	70
63	Red Lake	105.7	221.8	327.5	93.1	210.6	303.7	Municipal Waterworks	68
64	Redwood	29.1	540.9	570.0	73.7	449.1	522.8	Municipal Waterworks	80
65	Renville	119.8	671.0	790.8	27.6	854.8	882.4	Municipal Waterworks	54
66	Rice	60.9	2,335.3	2,396.2	82.8	2,491.2	2,574.0	Municipal Waterworks	82
67	Rock	45.5	761.9	807.4	44.7	765.6	810.3	Municipal Waterworks	66
68	Roseau	0.0	418.3	418.3	0.0	369.4	369.4	Municipal Waterworks	92
69	St. Louis	96,083.6	1,570.5	97,654.1	99,119.7	1,479.3	100,599.0	Steam Power Cooling	52
70	Scott	2,421.7	3,496.7	5,918.4	1,934.6	3,735.8	5,670.4	Municipal Waterworks	43
71	Sherburne	21,252.5	9,300.5	30,553.0	21,683.2	7,698.8	29,382.0	Steam Power Cooling	44
72	Sibley	25.5	624.1	649.6	32.4	651.1	683.5	Municipal Waterworks	89
73	Stearns	3,067.4	9,113.1	12,180.5	3,119.6	6,285.0	9,404.6	Municipal Waterworks	50
74	Steele	416.2	1,801.4	2,217.6	499.5	1,636.2	2,135.7	Municipal Waterworks	74
75	Stevens	80.6	1,751.1	1,831.7	84.0	1,213.0	1,297.0	Major Crop Irrigation	60
76	Swift	11.2	3,160.9	3,172.1	23.5	2,177.5	2,201.0	Major Crop Irrigation	83
77	Todd	273.2	2,457.6	2,730.8	82.2	1,881.9	1,964.1	Major Crop Irrigation	67
78	Traverse	1.8	134.1	135.9	2.3	129.1	131.4	Municipal Waterworks	98
79	Wabasha	112.5	1,003.5	1,116.0	9.6	1,045.1	1,054.7	Municipal Waterworks	76
80	Wadena	568.1	2,923.0	3,491.1	376.5	2,028.6	2,405.1	Major Crop Irrigation	81
81	Waseca	27.2	695.5	722.7	29.3	831.1	860.4	Municipal Waterworks	94
82	Washington	96,750.1	11,306.8	108,056.9	104,459.7	10,886.0	115,345.7	Steam Power Cooling	88
83	Watonwan	21.0	954.5	975.5	9.0	912.7	921.7	Municipal Waterworks	82
84	Wilkin	114.6	348.1	462.7	113.8	239.6	353.4	Major Crop Irrigation	53
85	Winona	1,001.9	2,662.7	3,664.6	1,001.5	3,943.0	4,944.5	Municipal Waterworks	34
86	Wright	111,967.2	2,104.2	114,071.4	104,433.1	2,182.3	106,615.4	Nuclear Power Cooling	98
87	Yellow Medicine	60.6	458.6	519.2	63.8	580.0	643.8	Rural Waterworks	51
	Total			**1,181,923**			**1,162,566**		

Minnesota Reported Water Use

Category	1996	1997
Power Generation	(Millions of Gallons)	
Nuclear Power		
surface	279,044.2	261,168.3
ground	0.0	0.0
Steam Power Cooling		
surface	335,034.9	337,259.7
ground	263.0	245.8
Other Power		
surface	95,123.6	101,917.5
ground	778.8	741.5
Subtotal	**710,244.5**	**701,332.8**
Percent of Total	**60%**	**60%**
surface	709,202.7	700,345.5
ground	1,041.8	987.3
Public Supply		
Municipal Water Works		
surface	61,656.0	57,757.6
ground	121,895.4	120,067.1
Private Water Works		
surface	8.8	7.7
ground	816.1	721.1
Comercial & Institutional		
surface	0.0	0.0
ground	1,672.5	1,584.5
Cooperative Water Works		
surface	0.0	0.0
ground	1.8	1.8
Fire Protection		
surface	0.0	0.0
ground	30.1	28.3
State Parks, Waysides, Rest Areas		
surface	0.0	0.0
ground	29.0	29.3
Rural Water Districts		
surface	0.0	0.0
ground	1,583.4	1,677.4
Subtotal	**187,693.1**	**181,874.8**
Percent of Total	**16%**	**16%**
surface	61,664.8	57,765.3
ground	126,028.3	124,109.5

Irrigation		
Golf Course		
surface	1,037.5	905.3
ground	4,393.7	3,910.3
Cemetary		
surface	0.0	0.0
ground	38.9	41.6
Landscaping		
surface	62.7	48.5
ground	417.0	390.3
Sod		
surface	82.5	128.1
ground	159.3	218.3
Nursery		
surface	16.3	61.2
ground	390.4	347.3
Orchard		
surface	0.0	0.0
ground	8.6	4.9
Non Crop		
surface	22.7	22.8
ground	50.1	29.9
Major Crop		
surface	2,779.2	1,609.6
ground	62,261.6	40,447.6
Wild Rice		
surface	8,032.2	9,730.8
ground	0.1	0.1
Subtotal	**79,752.8**	**57,896.6**
Percent of Total	**7%**	**5%**
surface	12,033.1	12,506.3
ground	67,719.7	45,390.3

Industrial Processing		
Agricultural		
surface	478.6	532.2
ground	10,635.4	10,244.2
Pulp and Paper		
surface	27,868.9	27,370.5
ground	592.1	671.1

Mine		
surface	89,227.0	101,490.4
ground	32.6	29.9
Sand and Gravel Washing		
surface	1,805.1	1,810.1
ground	1,309.2	1,058.0
Sewage Treatment		
surface	0.8	0.8
ground	790.0	1,053.6
Petroleum or Chemical		
surface	315.0	261.3
ground	3,778.0	3,922.2
Metal		
surface	0.0	0.0
ground	958.7	991.4
Non-Metal		
surface	21.5	1.2
ground	780.7	1,445.2
Other		
surface	4,260.2	4,197.2
ground	4,077.6	3,756.3
Subtotal	**146,931.4**	**158,835.6**
Percent of Total	**12%**	**14%**
surface	123,977.1	135,663.7
ground	22,954.3	23,171.9
Other		
Air Conditioning		
Commercial & Institutional Building AC		
surface	0.0	7.8
ground	140.8	162.5
Heat Pumps & Coolant Pumps		
surface	421.1	635.1
ground	165.7	179.0
District Heating		
surface	0.0	0.0
ground	14.7	0.0
Once Through Heating or AC		
surface	0.0	0.0
ground	5,323.5	5,025.6
Other AC		
surface	68.8	77.6
ground	0.0	0.0

Temporary		
Temporary Construction Non-Dewatering		
surface	14.7	6.2
ground	0.0	0.0
Temporary Construction Dewatering		
surface	134.4	0.5
ground	1,388.2	3,101.1
Temporary Pipeline and Tank Testing		
surface	16.2	91.1
ground	0.0	0.0
Other Temporary		
surface	121.4	667.2
ground	117.3	0.0
Water Level Maintenance		
Basin (Lake) Level Maintenance		
surface	702.7	1,062.2
ground	184.3	170.5
Mine Dewatering		
surface	23,140.4	25,380.7
ground	0.0	0.0
Quarry Dewatering		
surface	11,081.2	11,299.9
ground	0.0	0.0
Sand/Gravel Pit Dewatering		
surface	754.1	577.9
ground	0.0	0.0
Tile Drainage & Pumped Sumps		
surface	21.7	31.8
ground	38.6	9.3
Other Water Level Maintenance		
surface	138.2	1,101.7
ground	455.1	572.9
Special Categories		
Pollution Confinement		
surface	0.0	0.0
ground	5,833.5	5,292.5
Hatcheries & Fisheries		
surface	5,439.9	5,543.8
ground	798.2	809.4

Snow Making		
surface	92.4	92.1
ground	317.3	289.8
Peat Fire Control		
surface	0.0	0.0
ground	0.0	2.3
Livestock Watering		
surface	0.0	0.0
ground	309.4	392.0
Other Special Categories		
surface	4.2	1.2
ground	63.8	42.5
Subtotal	**57,301.8**	**62,626.2**
Percent of Total	**5%**	**5%**
surface	42,151.4	46,576.8
ground	15,150.4	16,049.4
Grand Total (Millions of Gallons)	**1,181,923.6**	**1,162,566.0**
surface	**949,029**	**952,858**
ground	**232,895**	**209,708**

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