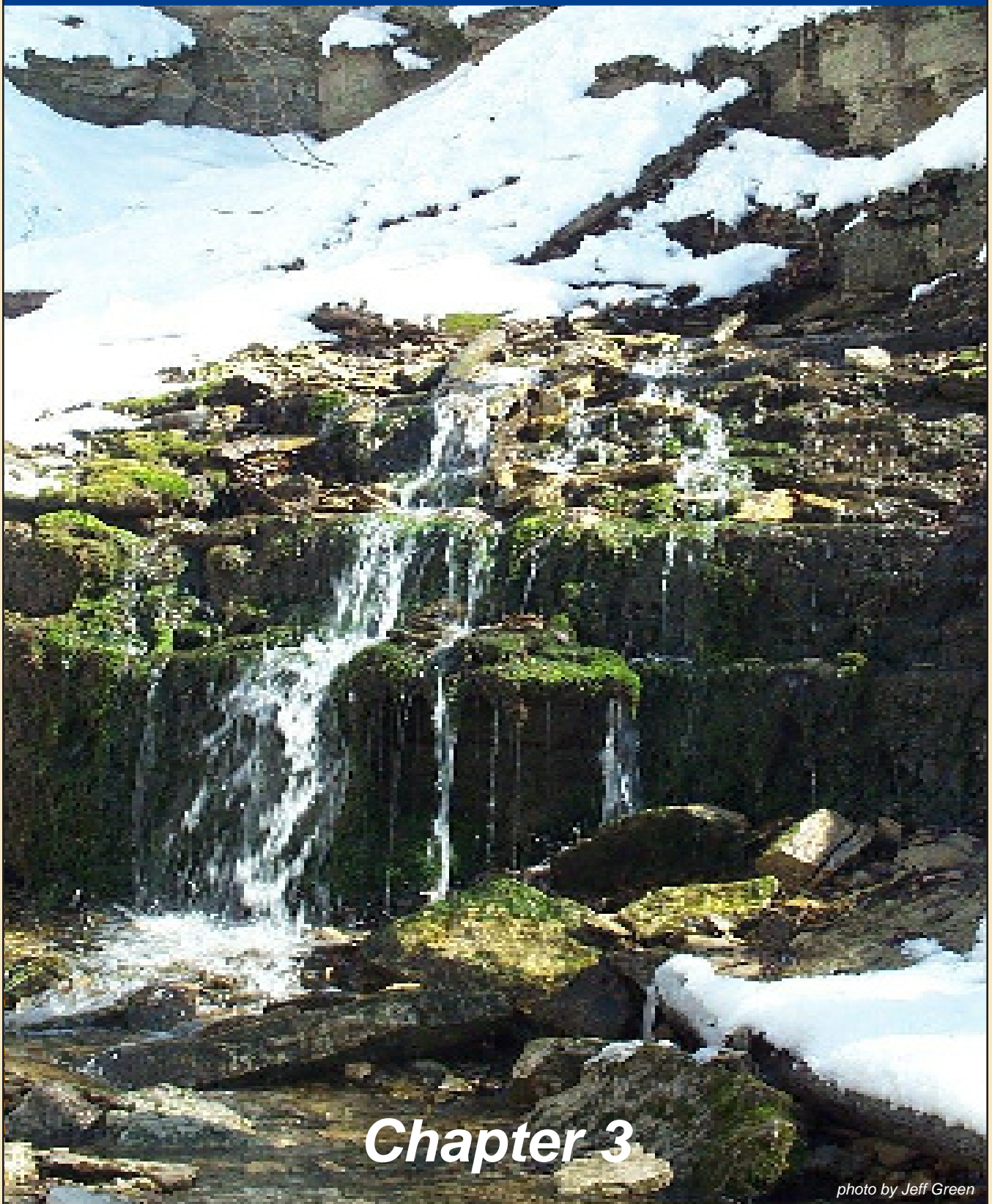
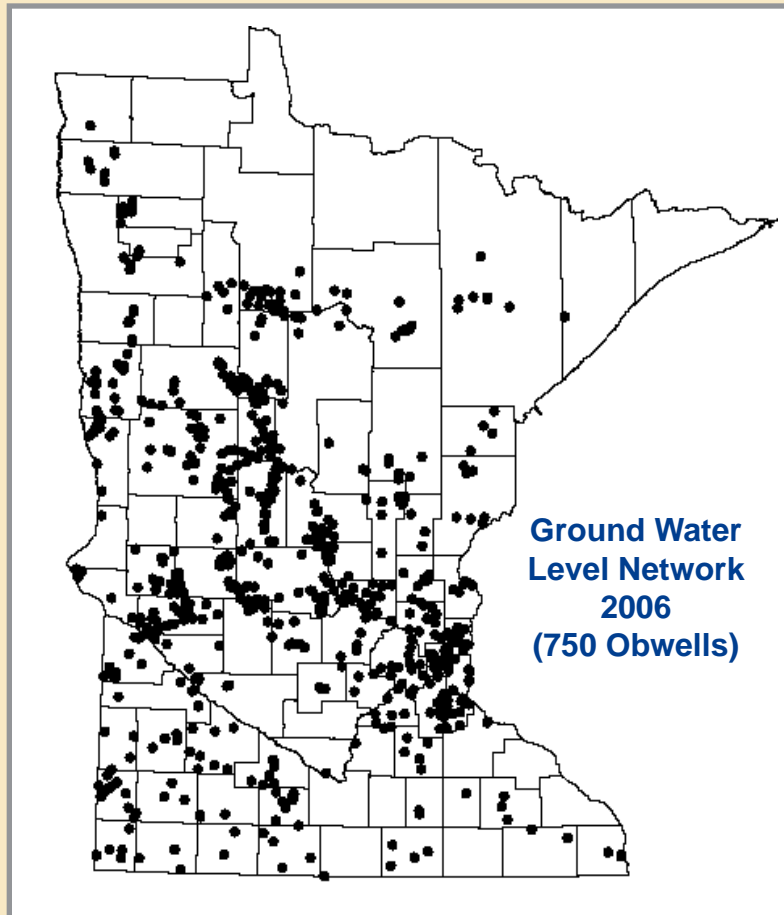


Ground Water



Chapter 3

photo by Jeff Green



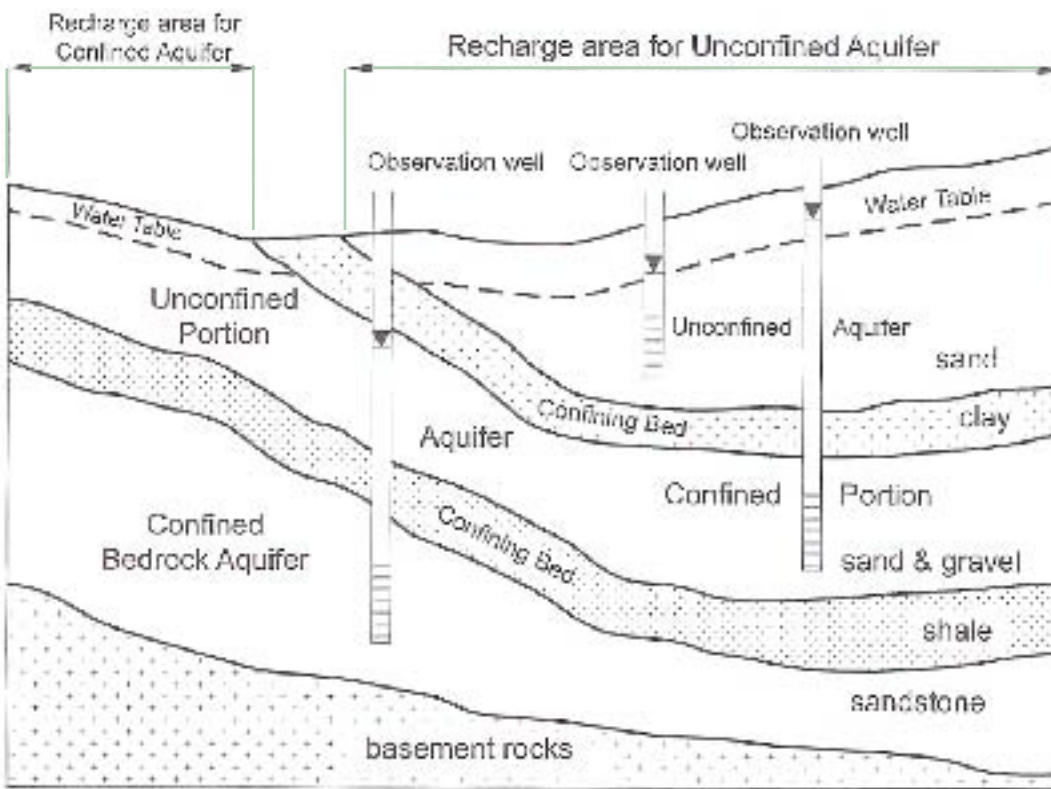
Introduction

Monitoring of ground water levels in Minnesota began in 1942 and, starting in 1947, was expanded by a cooperative program between the DNR and the United States Geological Survey (USGS). The number of observation wells (obwells) has remained constant at about 750 obwells over the last few water years. Data from these wells are used to assess ground water resources, determine long term trends, interpret impacts of pumping and climate, plan

for water conservation, evaluate water conflicts, and otherwise manage the water resource. Soil and Water Conservation Districts (SWCD) and other cooperators under agreement with DNR Waters measure the wells monthly and report the readings to DNR Waters as part of the Ground Water Level Monitoring Program. Readings are also obtained from volunteers and electronic sources at other locations.

Figure 1

Hypothetical Unconfined and Confined Aquifer Systems



Aquifers

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

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

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

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

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

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

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

Statewide Summary

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

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

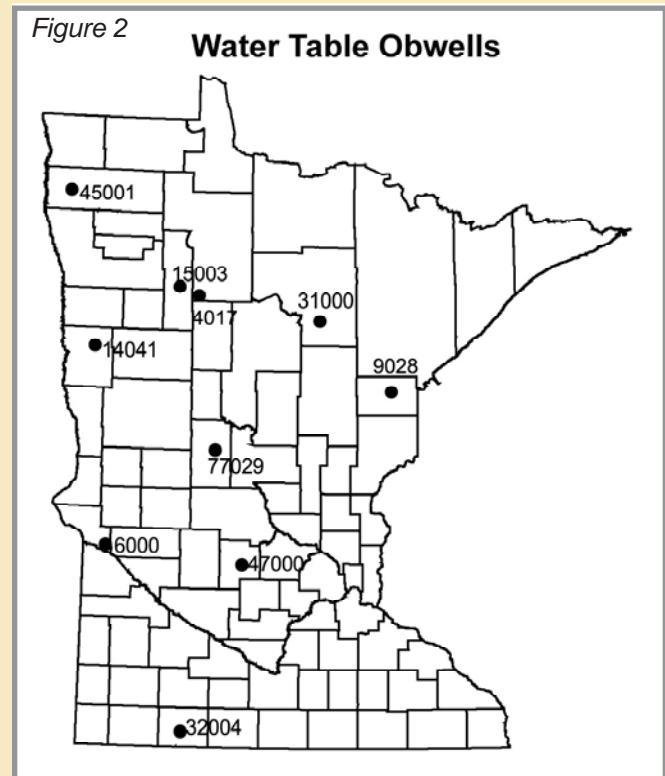
The remainder of this chapter discusses the ground water levels in unconfined and confined aquifers during Water Years 2005 (WY05) and 2006 (WY06). This discussion focuses on a comparison of obwell water levels in WY05 and WY06 to water levels over the timeframe noted above. Obwells were chosen to represent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



Unconfined (Water Table) Aquifers

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

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



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



Measuring water levels

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

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

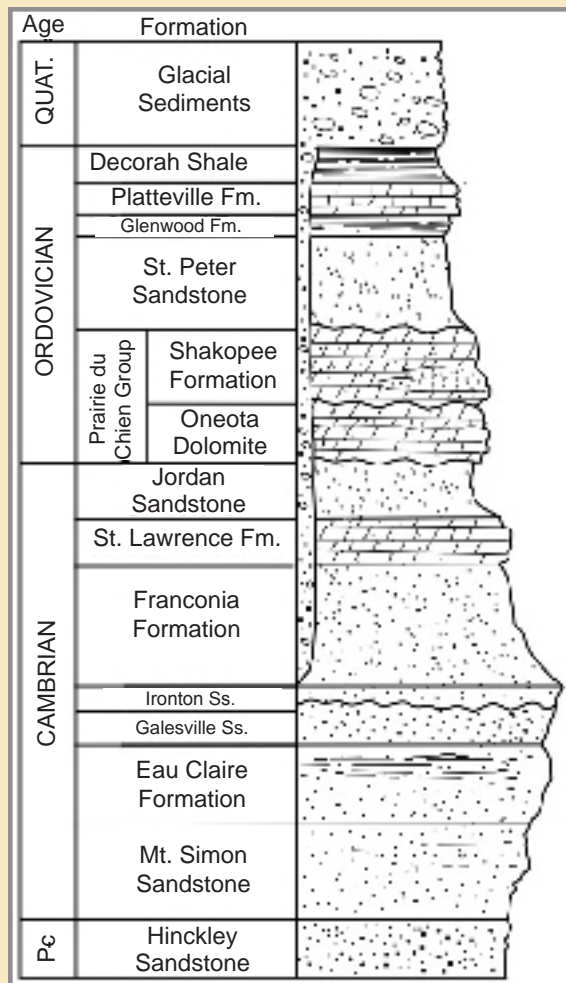


On site obwell drilling

Confined Aquifers

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

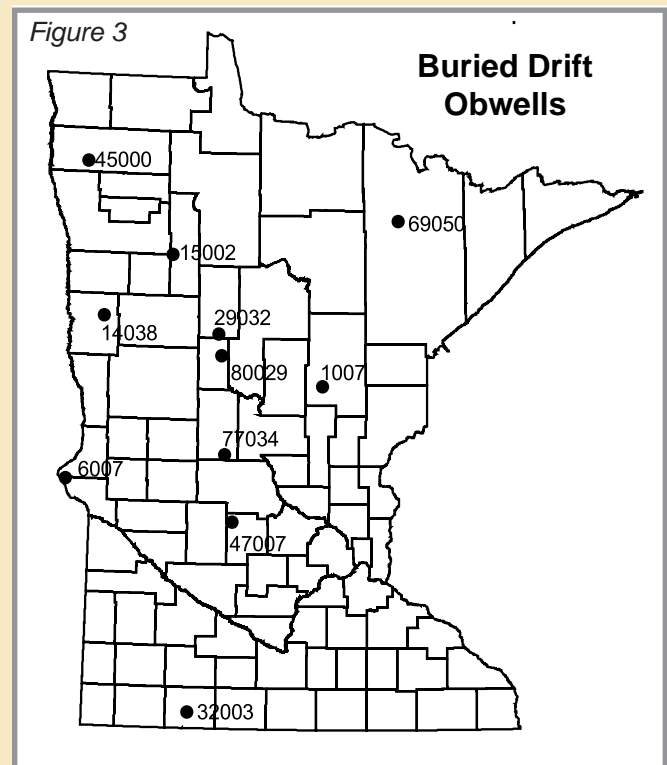
Wetter than normal periods may not cause rising water levels in confined aquifers for a few years because, again, of the slow water movement through the confining layers.



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

Buried Drift Aquifers

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



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

Bedrock - Prairie du Chien and Jordan Aquifers

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

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

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

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

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

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

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



photo by DNR Waters

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

Jordan Aquifer

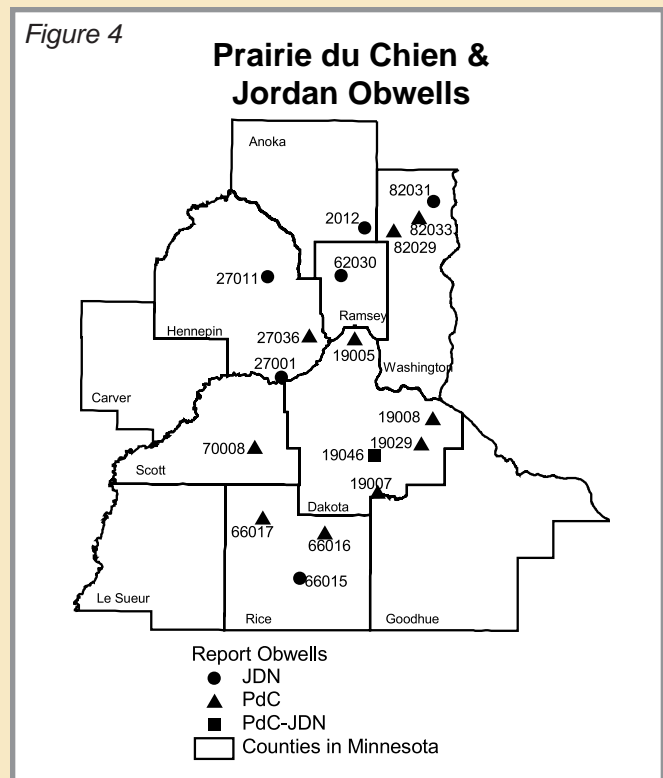
Water levels in the Jordan aquifer system throughout the metro area generally showed summertime declines below recent levels in both WY05 and WY06. However, there were some exceptions in WY05. Hennepin County's **City of Bloomington and City of New Hope obwells** and the **St. Lawrence Creamery well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

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

Prairie du Chien

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

Figure 4



Bedrock - Mt. Simon Aquifer

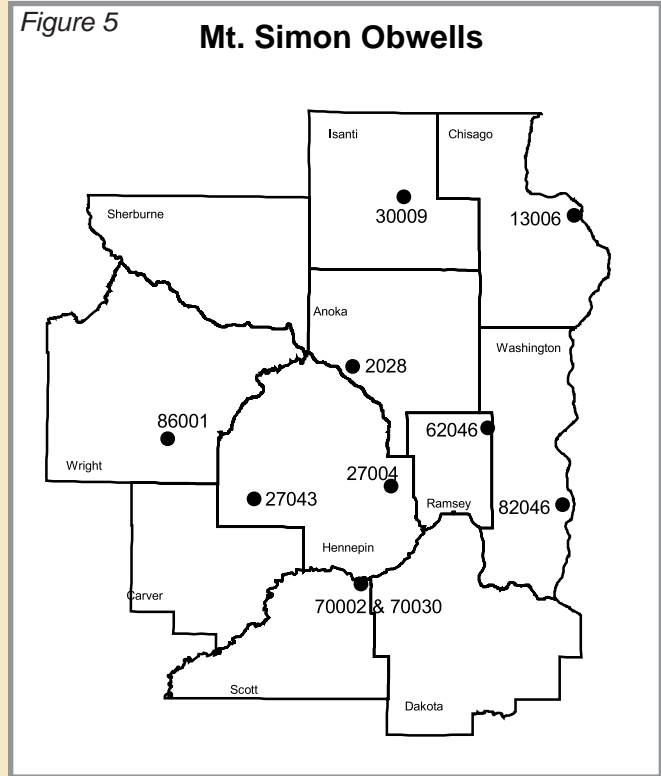
With some exceptions, the Mt. Simon aquifer is everywhere confined. It may respond as an unconfined aquifer in the atypical instances where the aquifer is adjacent to unconfined materials, such as along deeply incised buried glacial valleys.

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

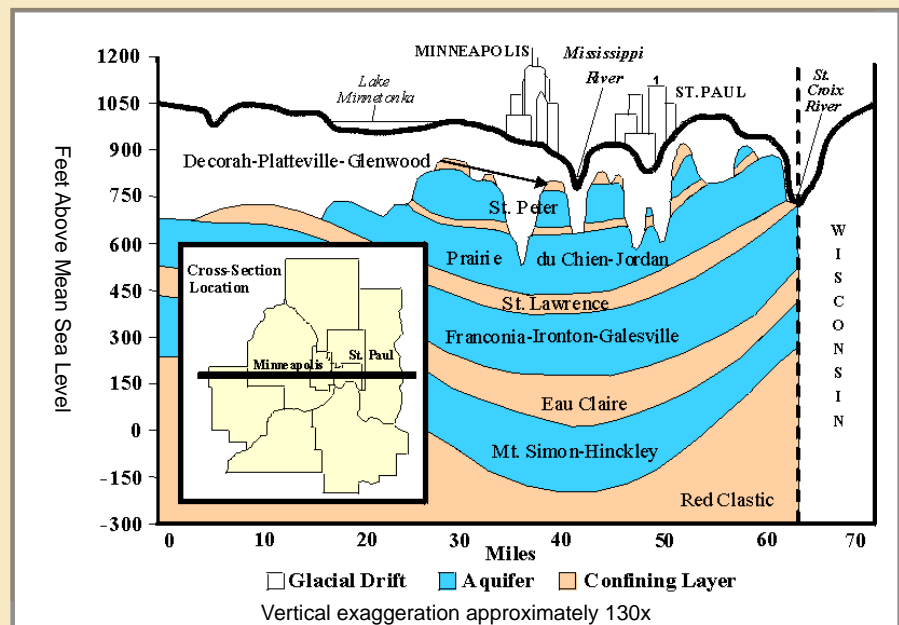
Many of the Mt. Simon obwells have a fairly short period of record. Consequently it is difficult to place the WY05 and WY06 readings in a long-term perspective. However, the data that are available provide a look at how the aquifer is responding to recent climate.

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

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



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



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

Figure 6A

Beltrami County - Water Table #4017

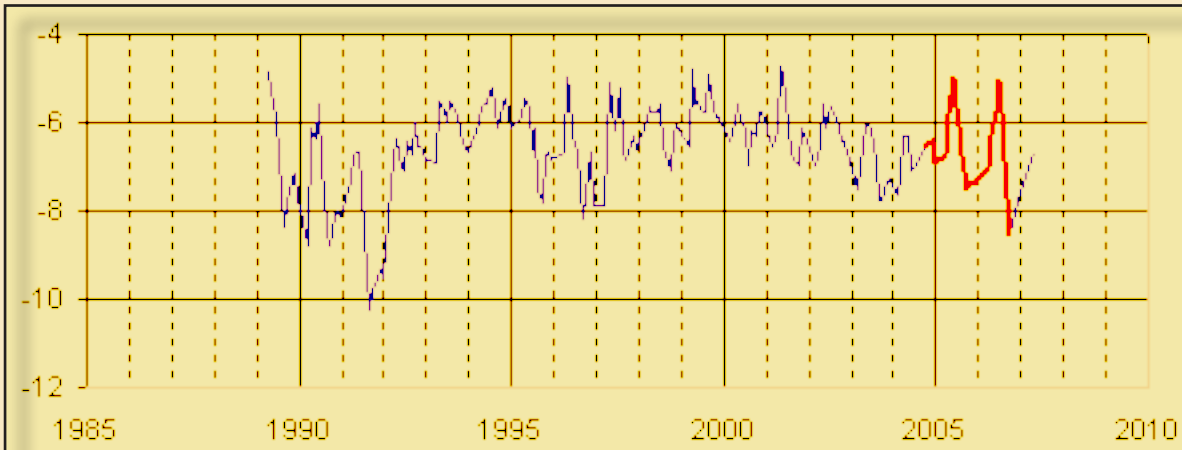


Figure 6B

Big Stone County - Water Table #6000

Depth to Water, ft.

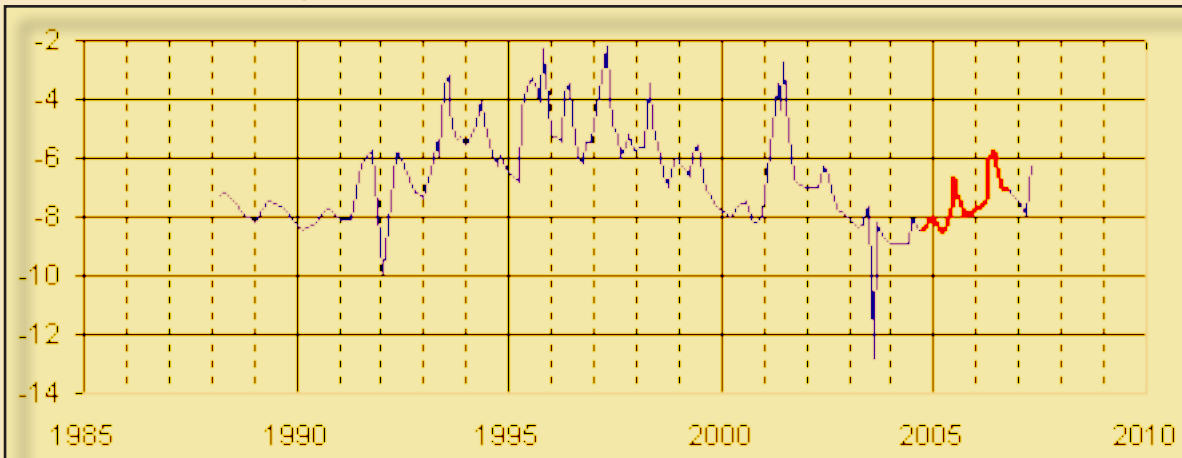


Figure 6C

Carlton County - Water Table #9028

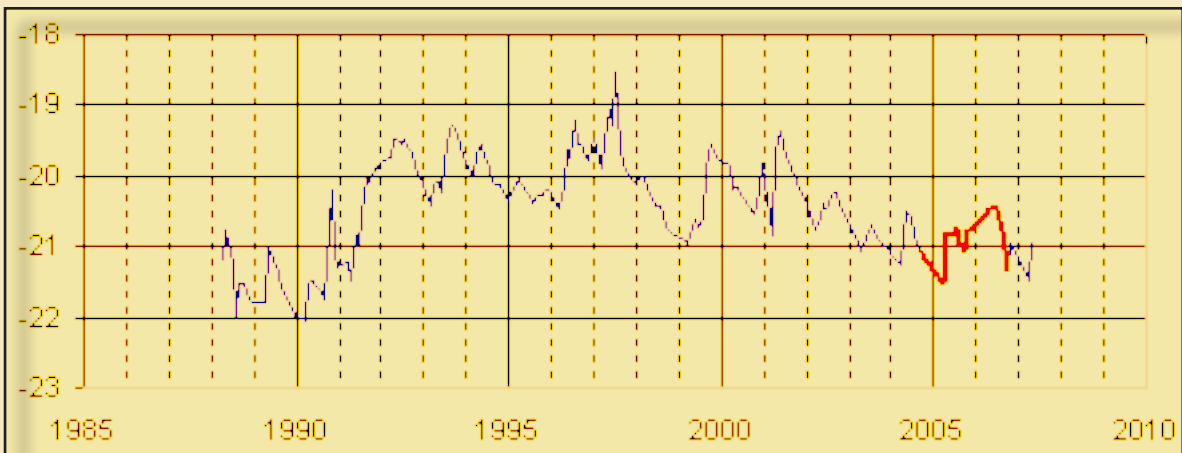


Figure 6D

Clay County - Water Table #14041

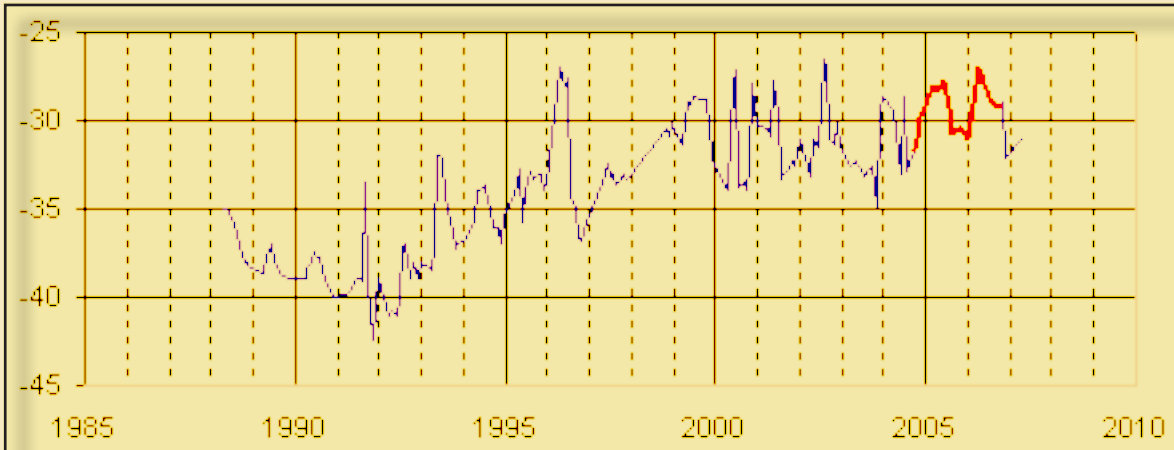


Figure 6E

Clearwater County - Water Table #15003

Depth to Water, ft.

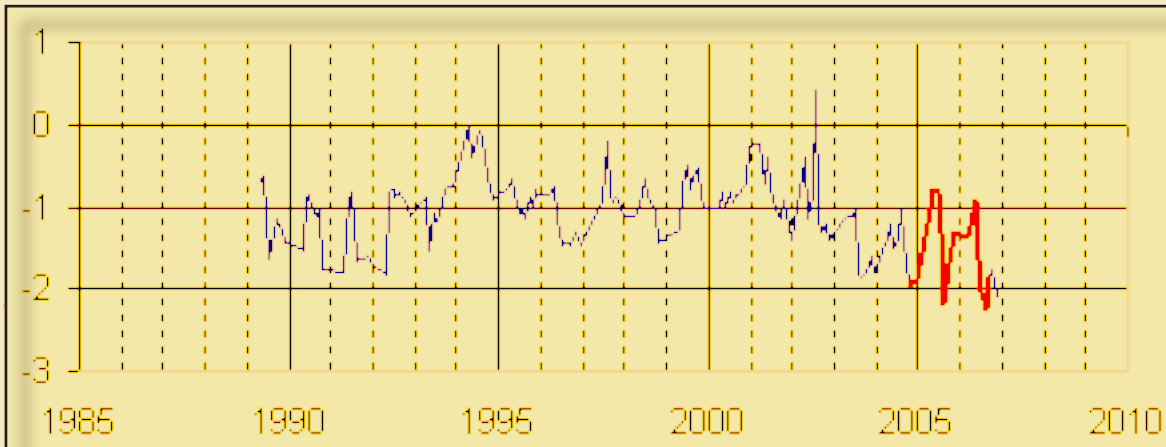


Figure 6F

Itasca County - Water Table #31000

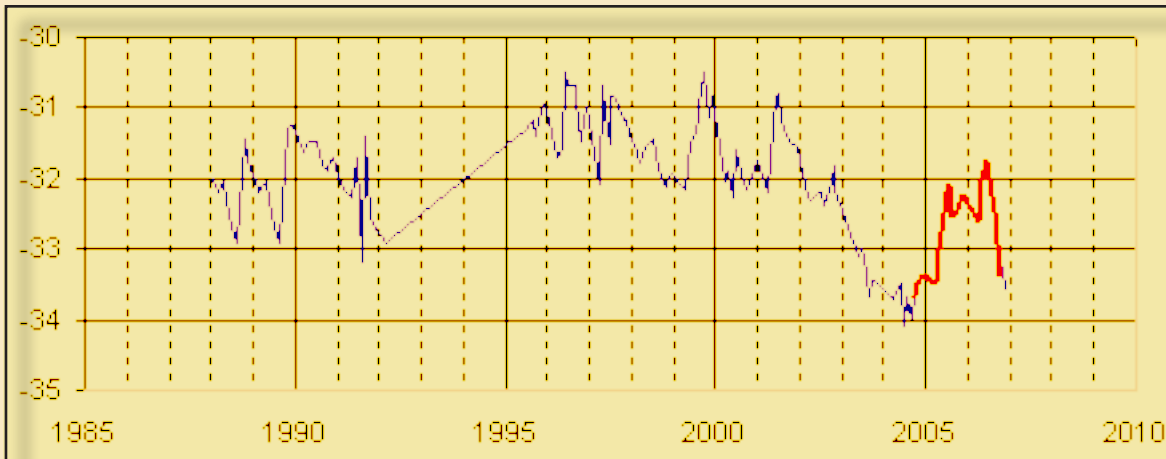


Figure 6G

Jackson County - Water Table #32004

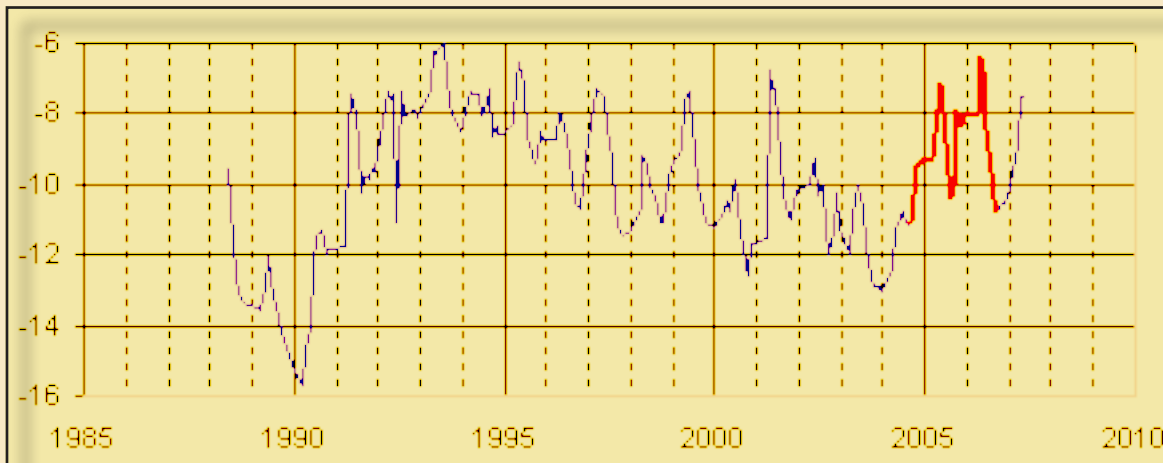


Figure 6H

Marshall County - Water Table #45001

Depth to Water, ft.

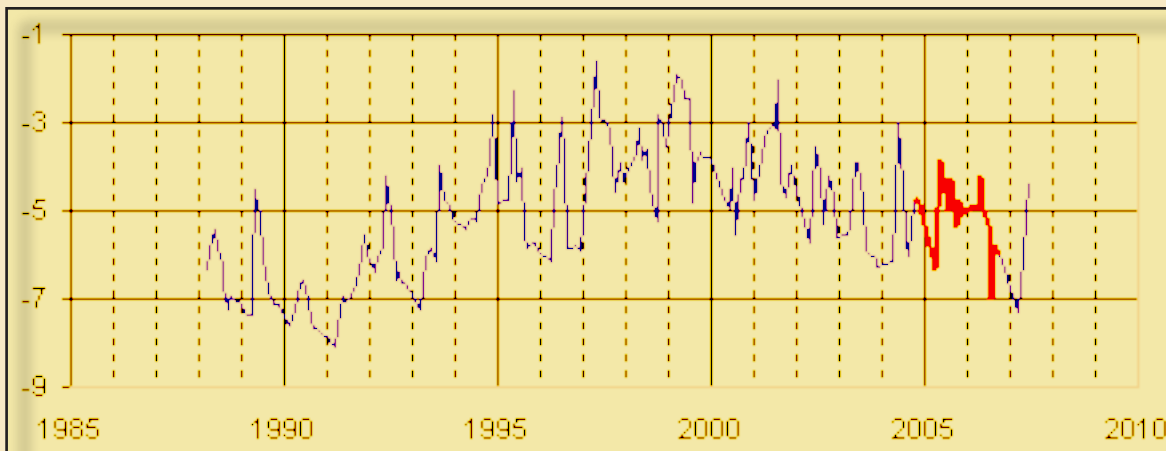


Figure 6i

Meeker County - Water Table #47000

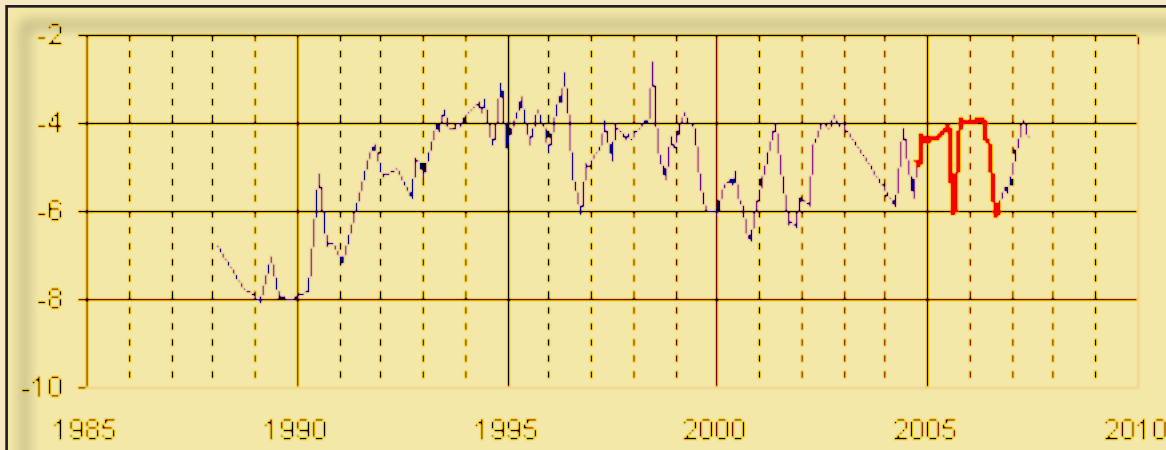


Figure 6J

Todd County - Water Table #77029

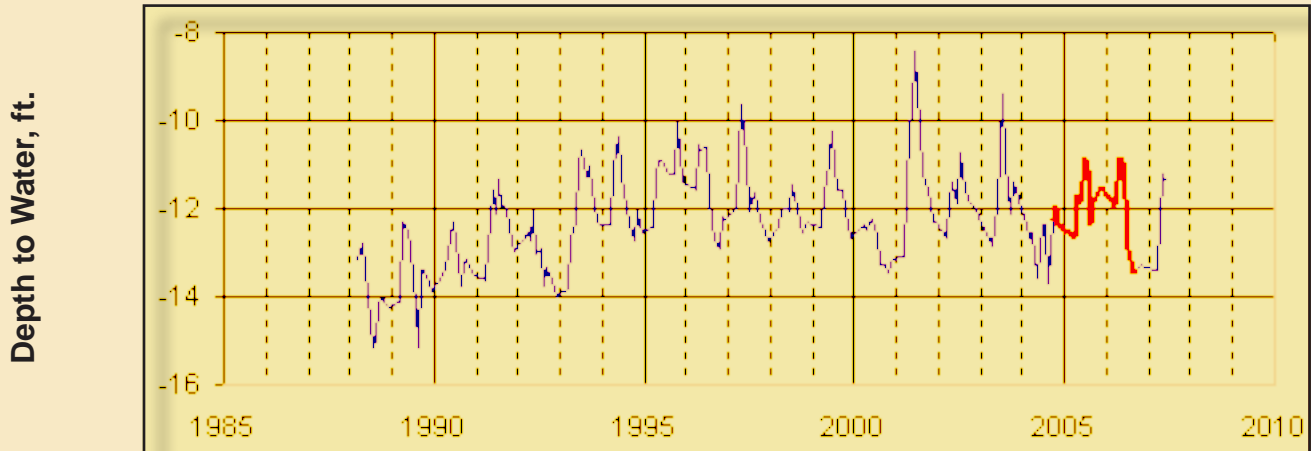


Figure 7A

Aitkin County - Buried Drift #1007

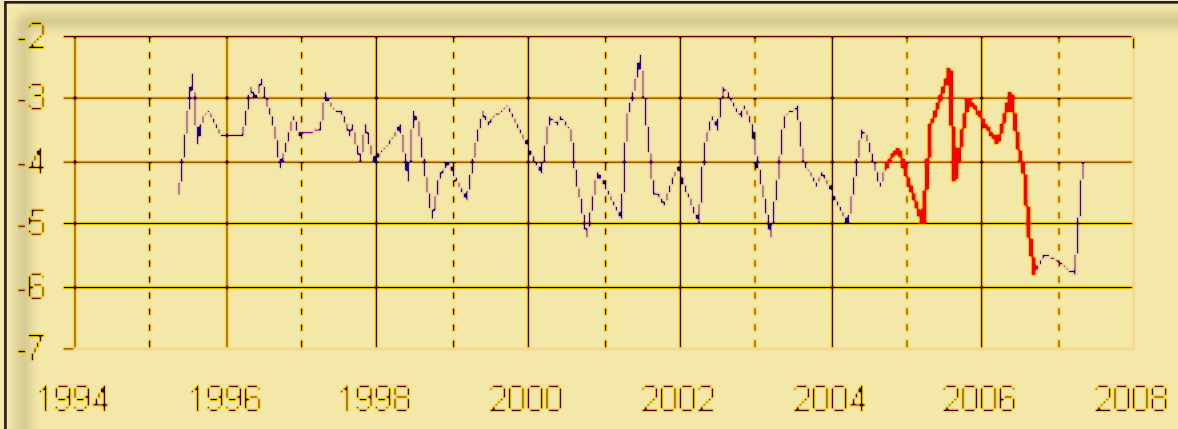


Figure 7B

Big Stone County - Buried Drift #6007

Depth to Water, ft.

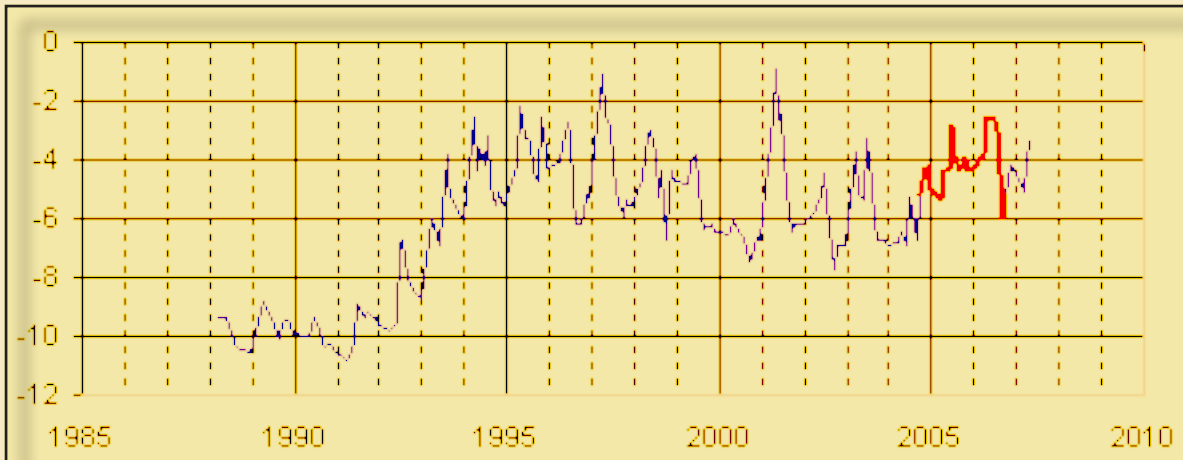


Figure 7C

Clay County - Buried Drift #14038

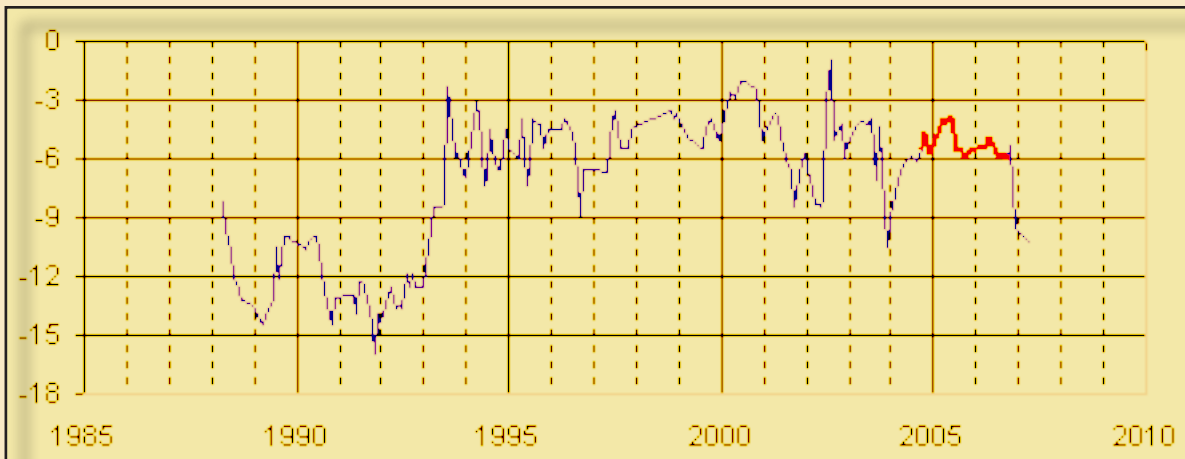


Figure 7D

Clearwater County - Buried Drift #15002

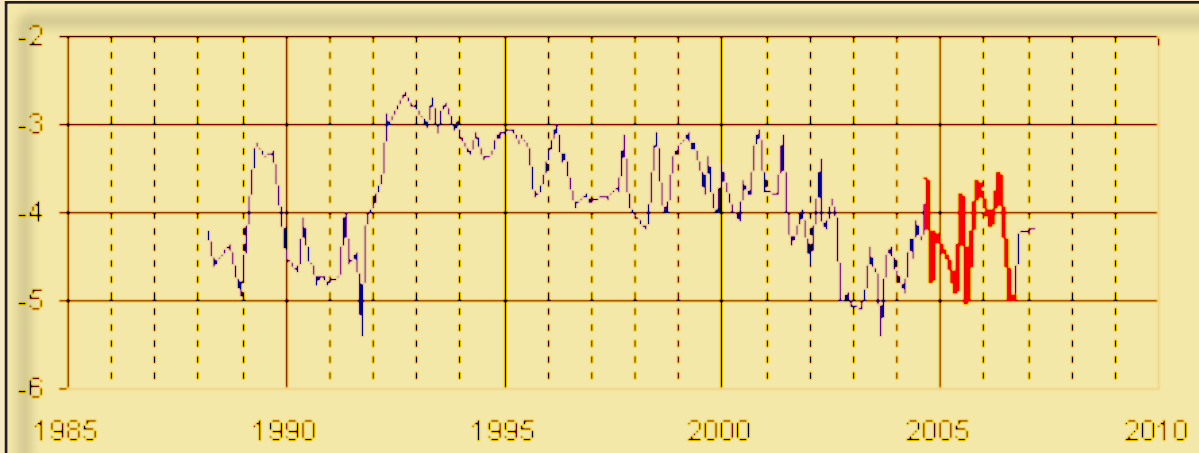


Figure 7E

Hubbard County - Buried Drift #29032

Depth to Water, ft.

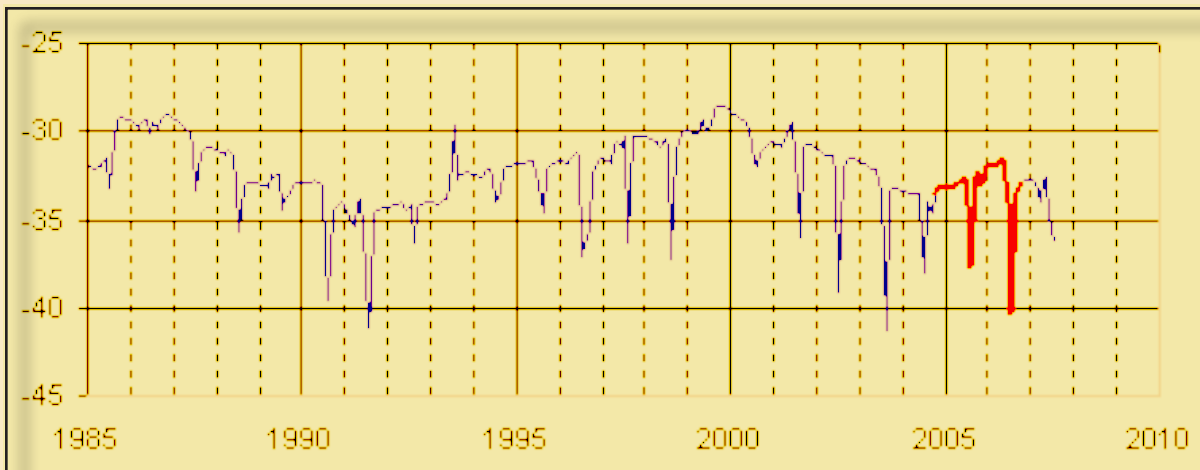


Figure 7F

Jackson County - Buried Drift #32003

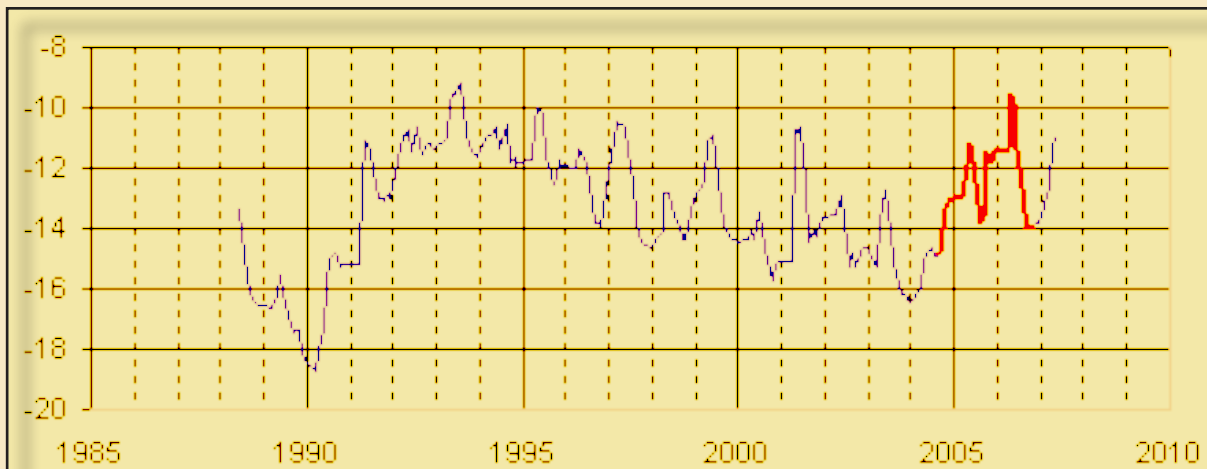


Figure 7G

Marshall County - Buried Drift #45000

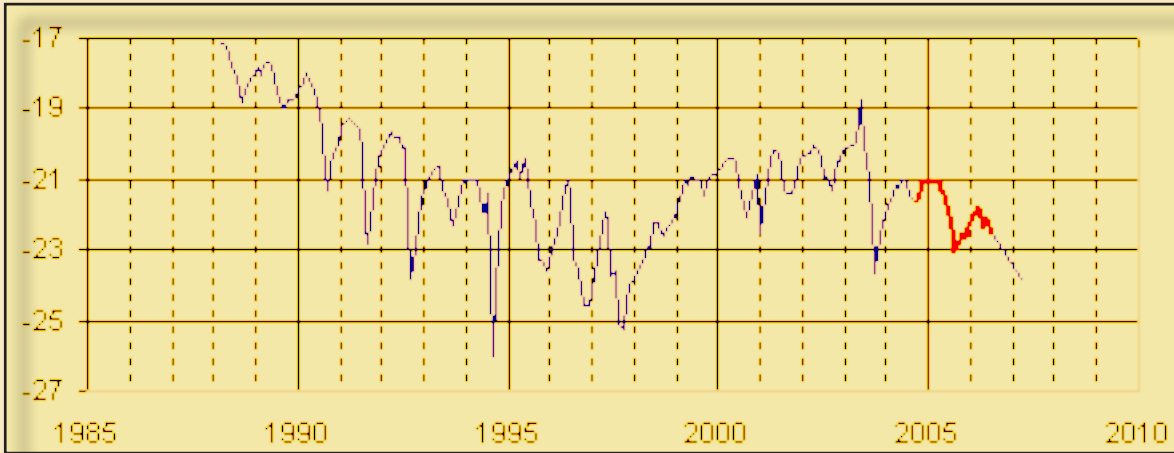


Figure 7H

Meeker County - Buried Drift #47007

Depth to Water, ft.

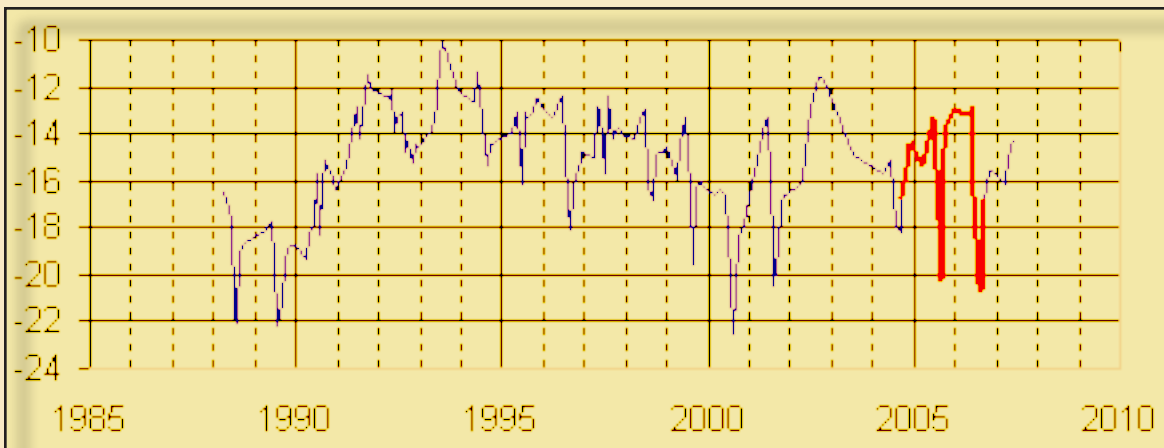


Figure 7i

North St. Louis County - Buried Drift #69050

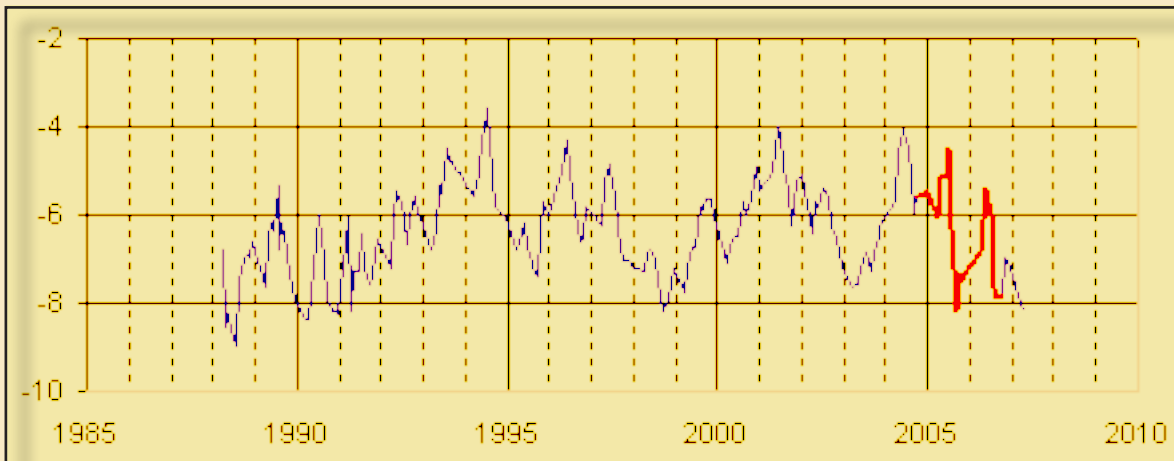


Figure 7J

Rice County - Buried Drift #66015

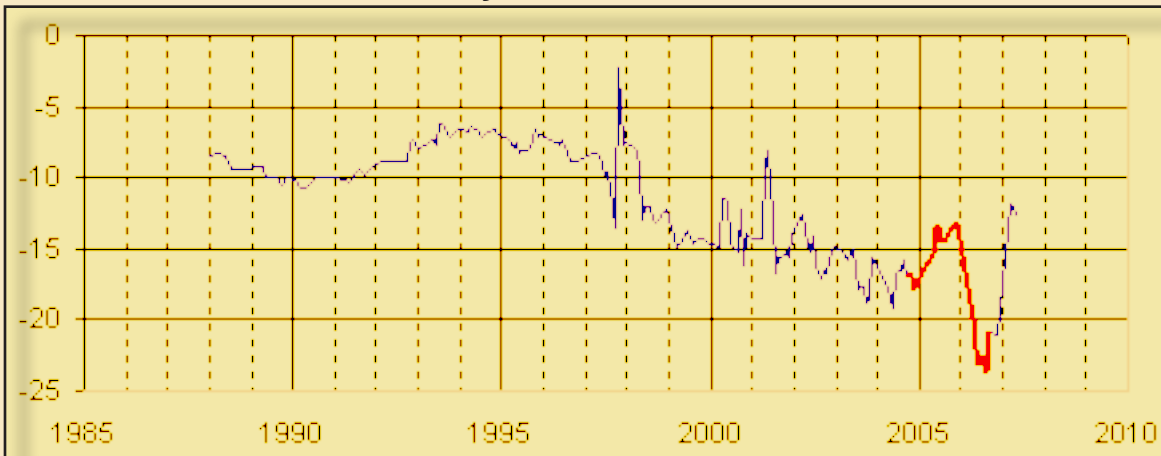


Figure 7K

Todd County - Buried Drift #77034

Depth to Water, ft.

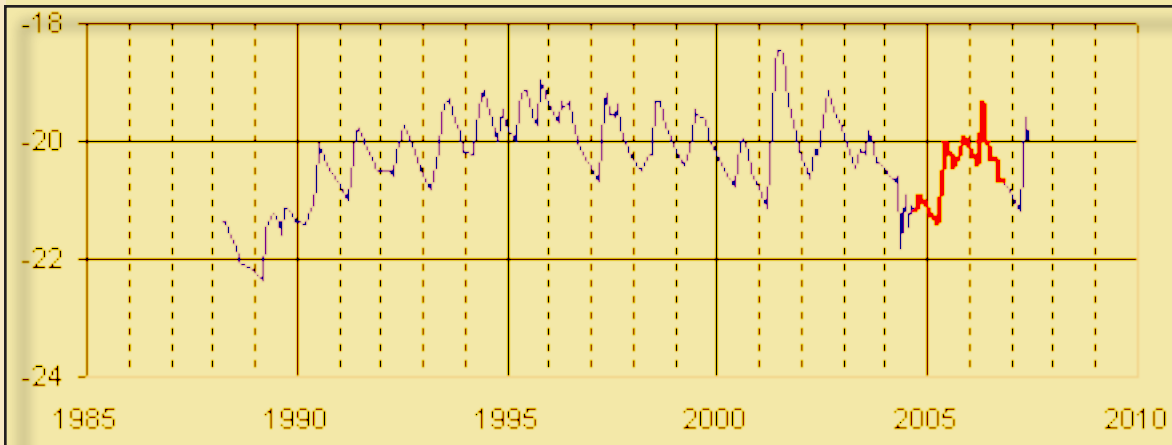


Figure 7L

Wadena County - Buried Drift #80029

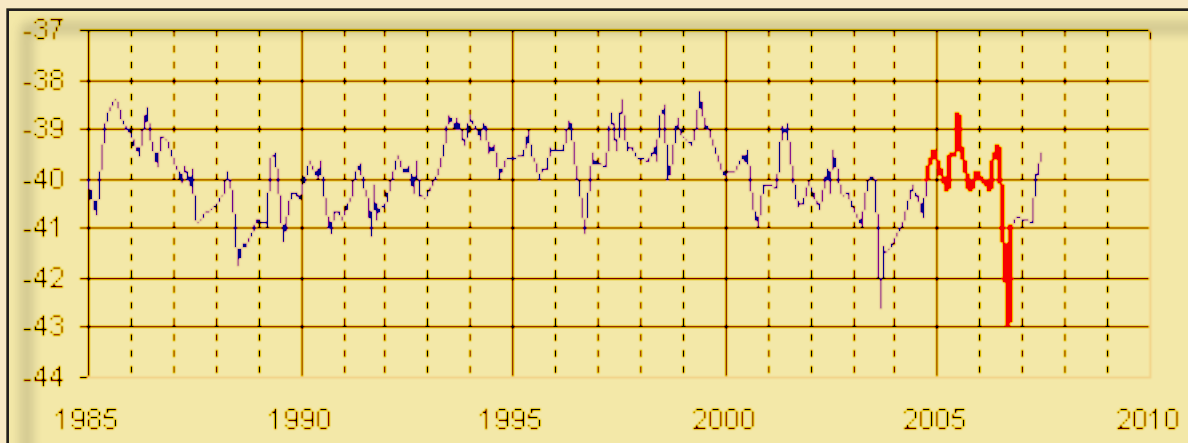


Figure 8A

Anoka County - Jordan #2012

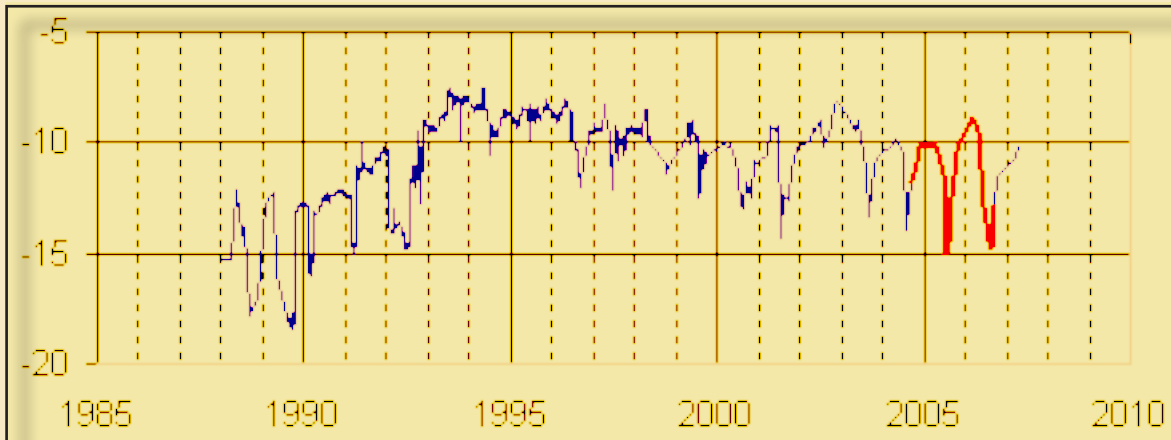


Figure 8B

Hennepin County - Jordan #27001

Depth to Water, ft.

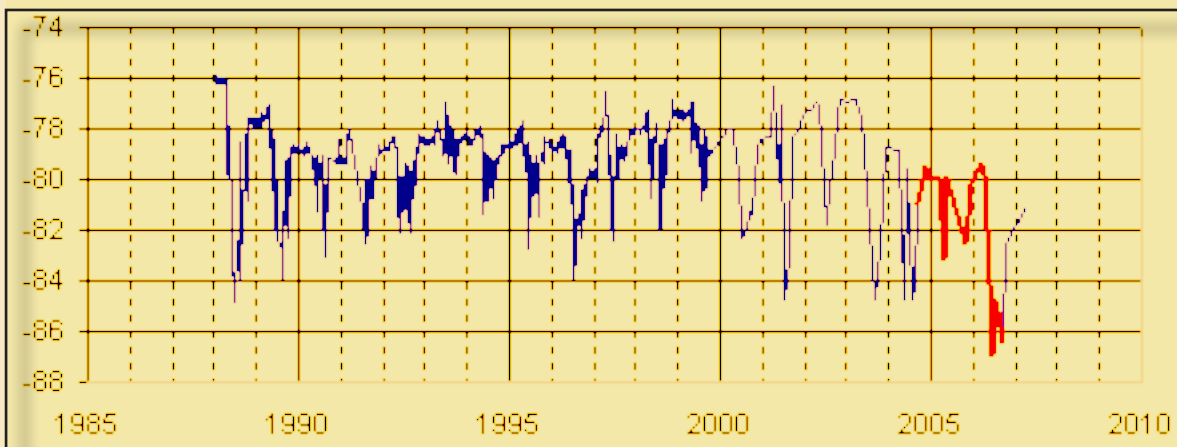


Figure 8C

Hennepin County - Jordan #27011

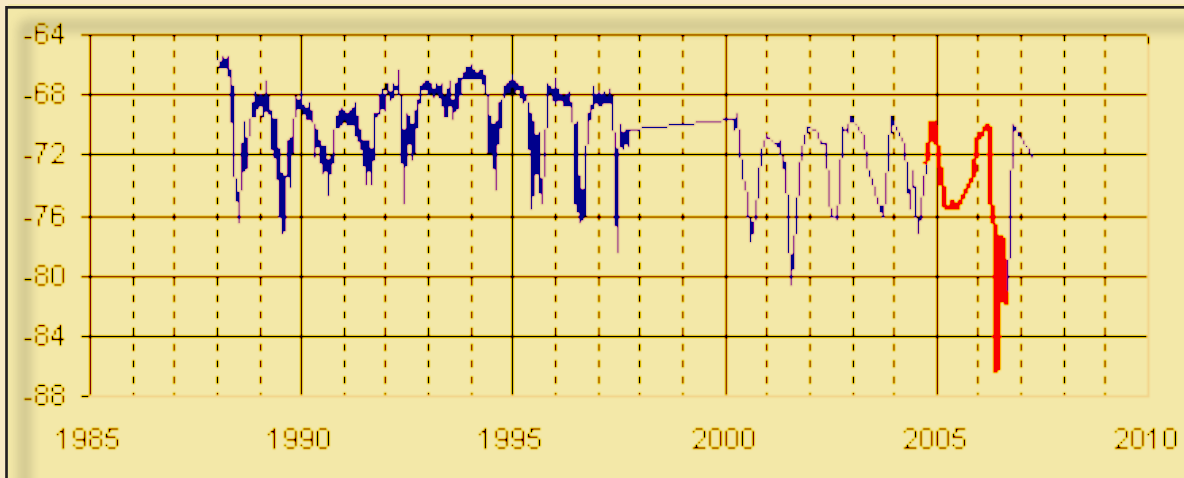


Figure 8D

Olmsted County - Jordan #55000

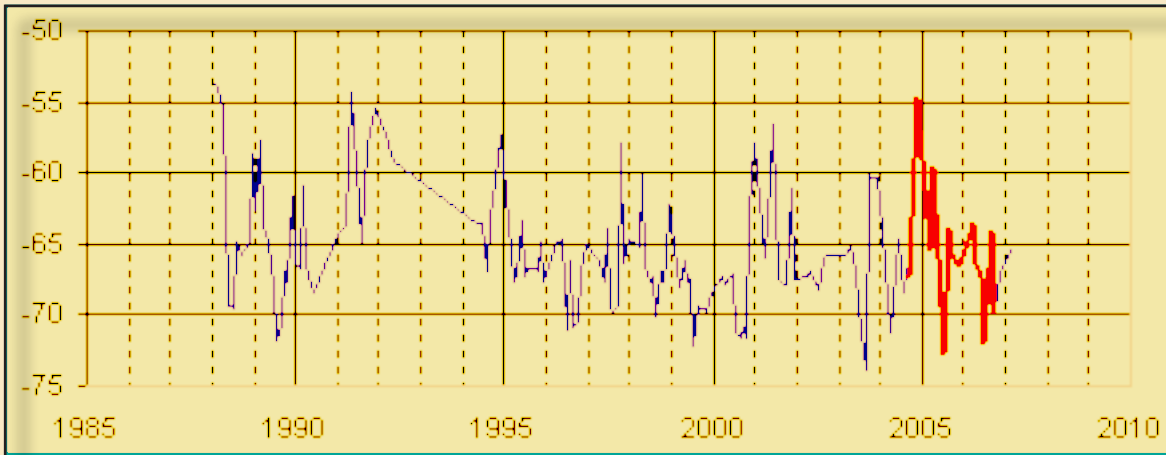


Figure 8E

Ramsey County - Jordan #62030

Depth to Water, ft.

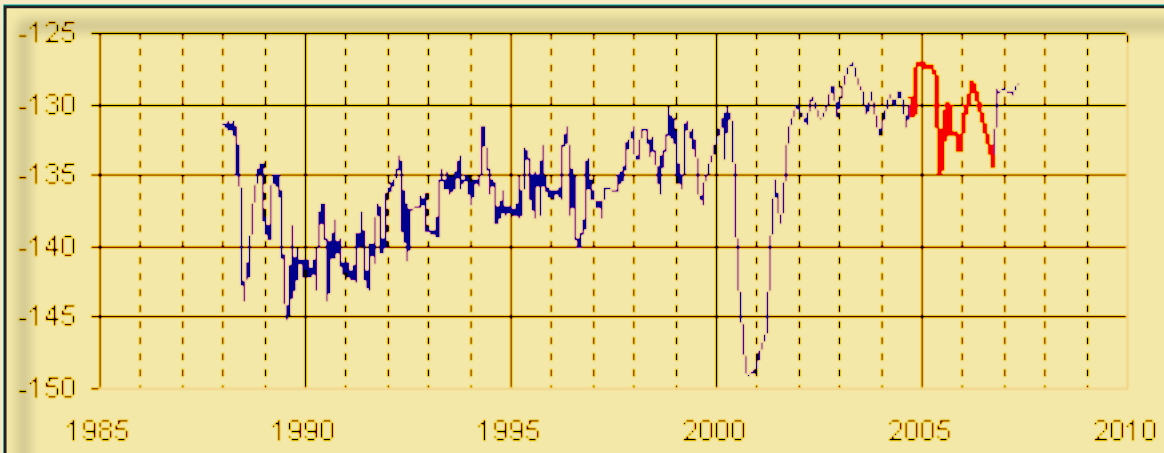


Figure 8F

Rice County - Jordan #82031

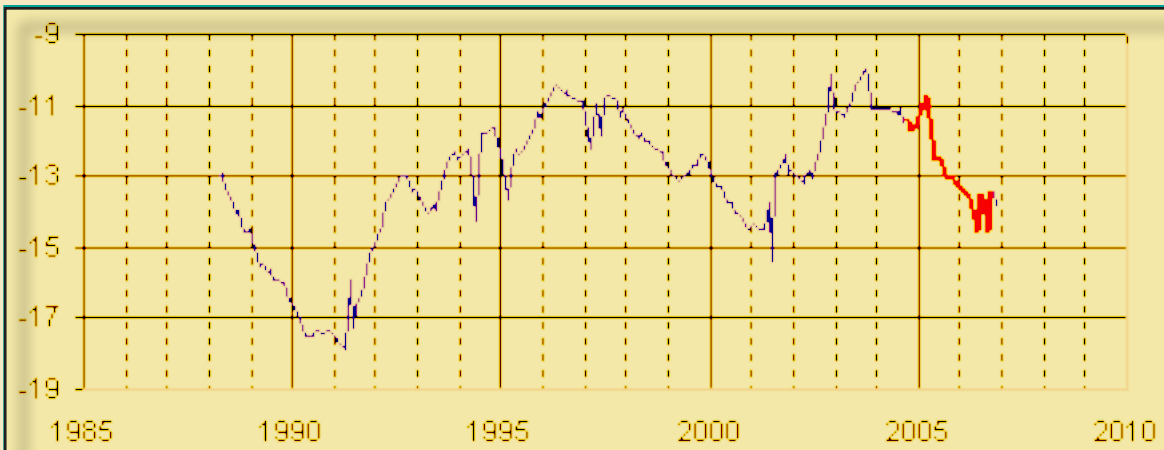


Figure 9A

Dakota County - Prairie du Chien #19005

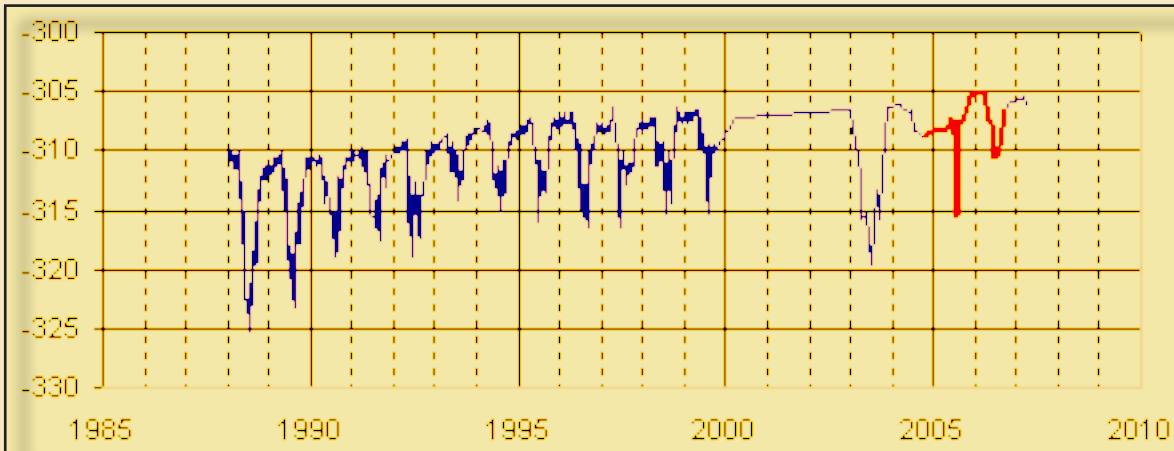


Figure 9B

Dakota County - Prairie du Chien #19007

Depth to Water, ft.

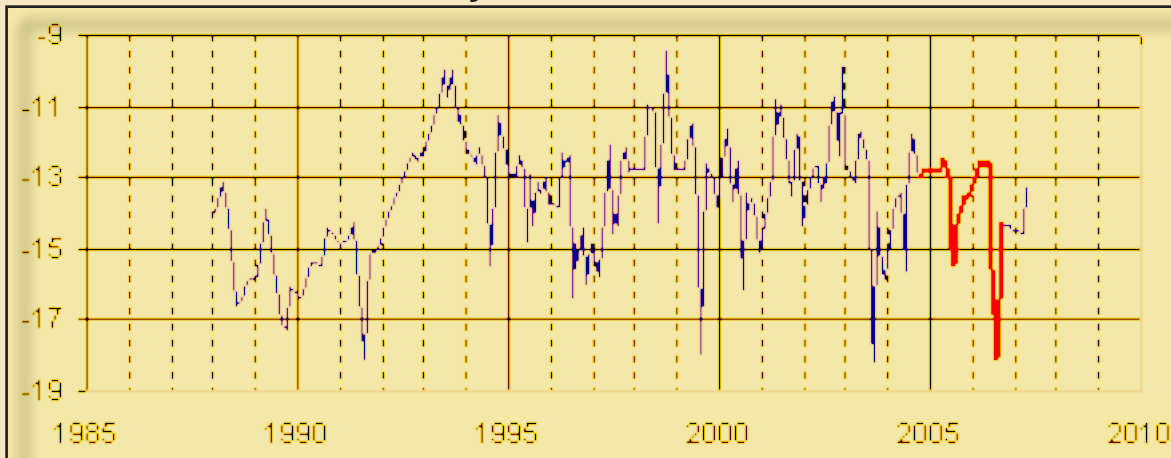


Figure 9C

Dakota County - Prairie du Chien #19008

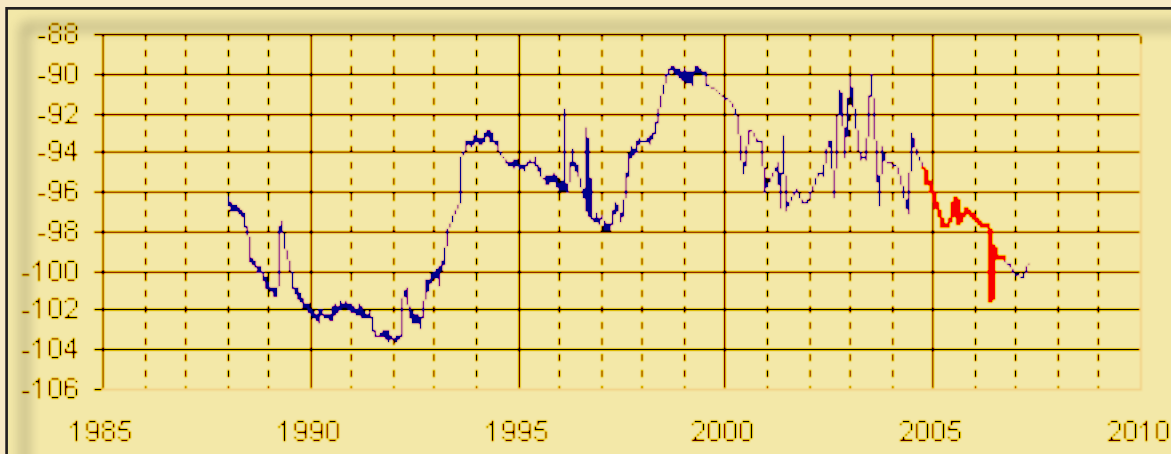


Figure 9D

Dakota County - Prairie du Chien #19029

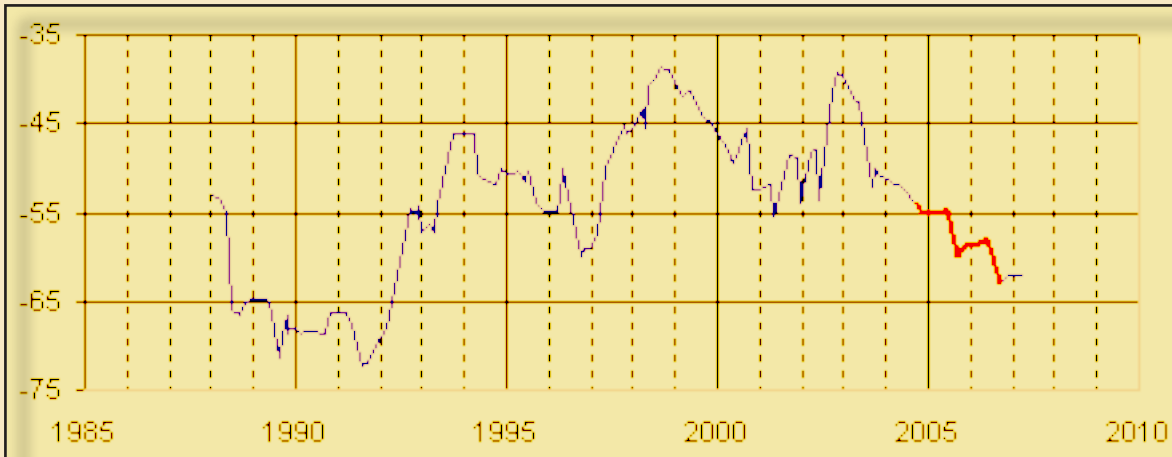


Figure 9E

Hennepin County - Prairie du Chien #27036

Depth to Water, ft.

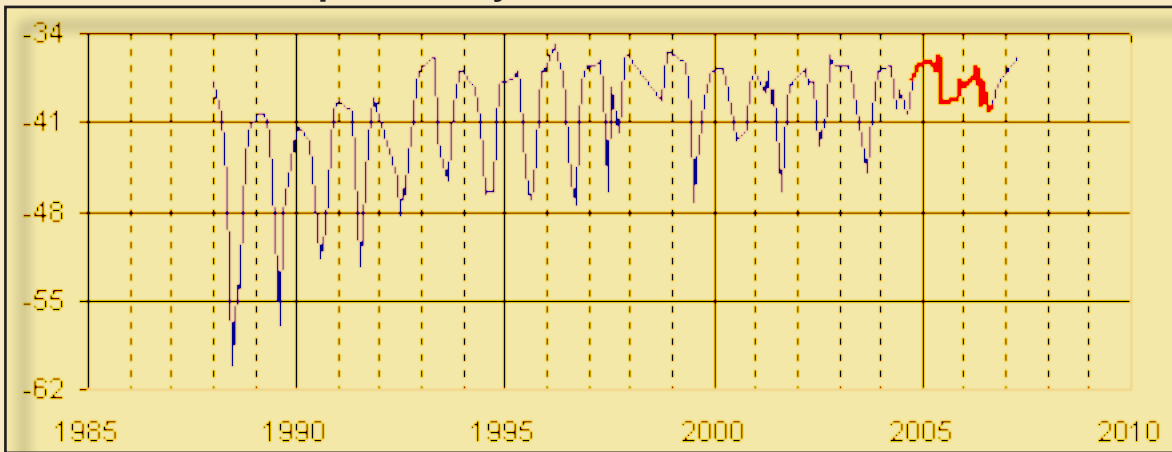


Figure 9F

Rice County - Prairie du Chien #66016

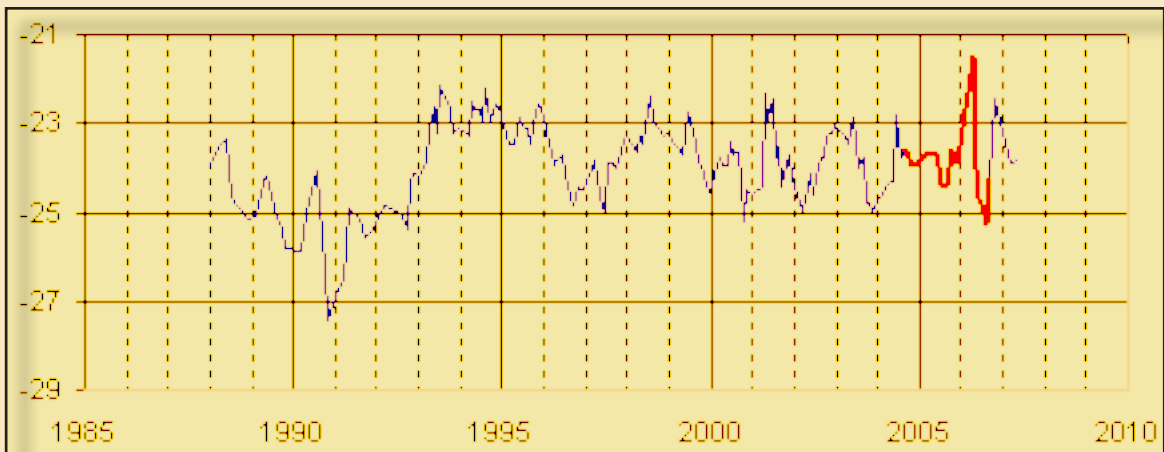


Figure 9G

Rice County - Prairie du Chien #66017

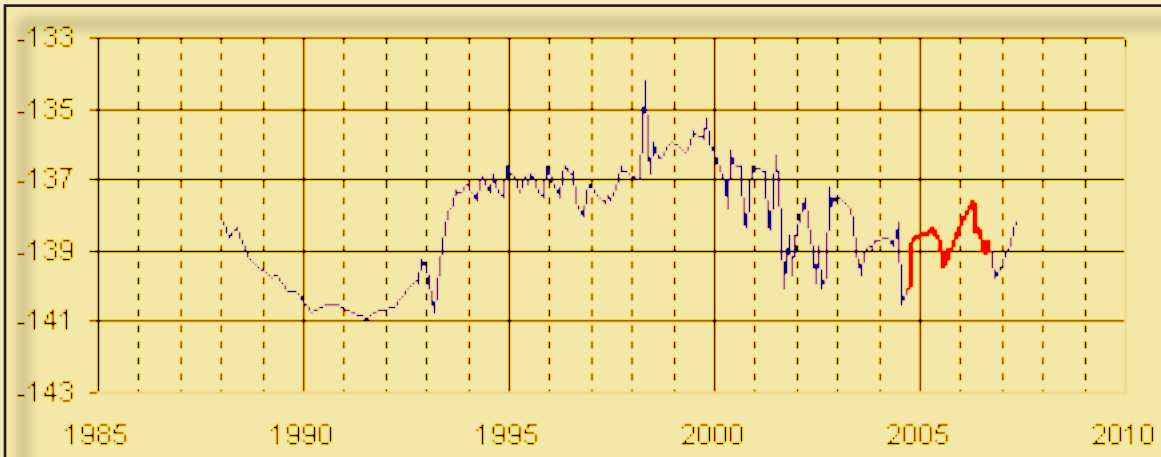


Figure 9H

Scott County - Prairie du Chien #70008

Depth to Water, ft.

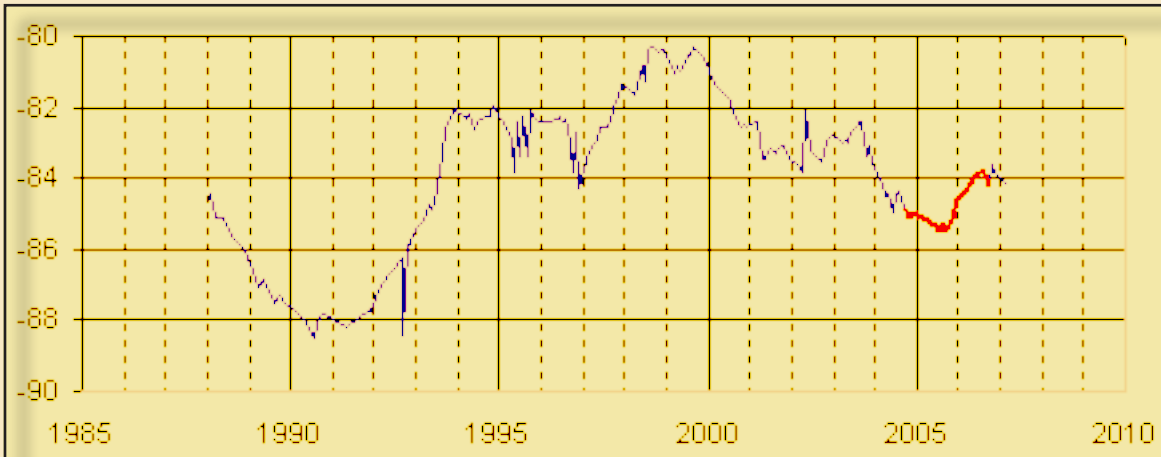


Figure 9i

Washington County - Prairie du Chien #82029

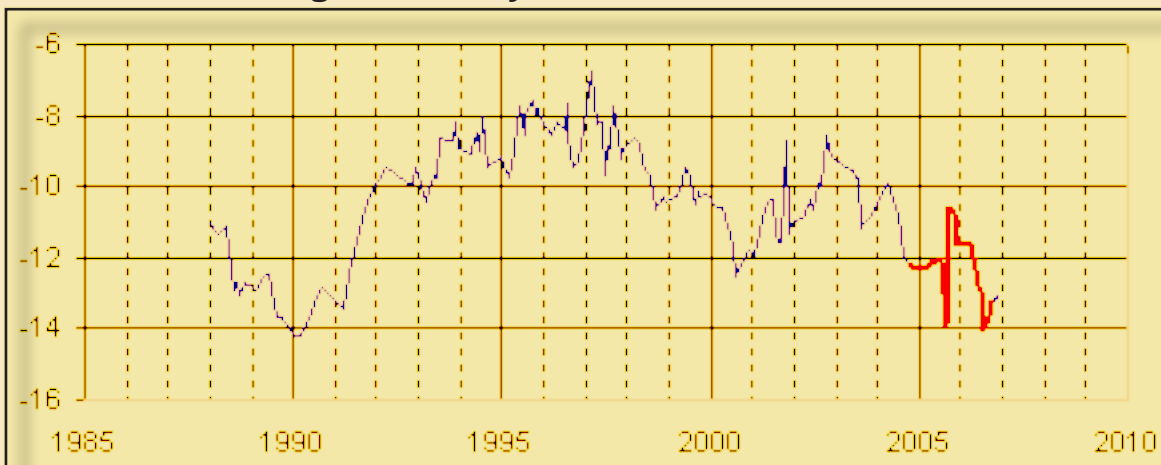


Figure 9J

Washington County - Prairie du Chien #82033

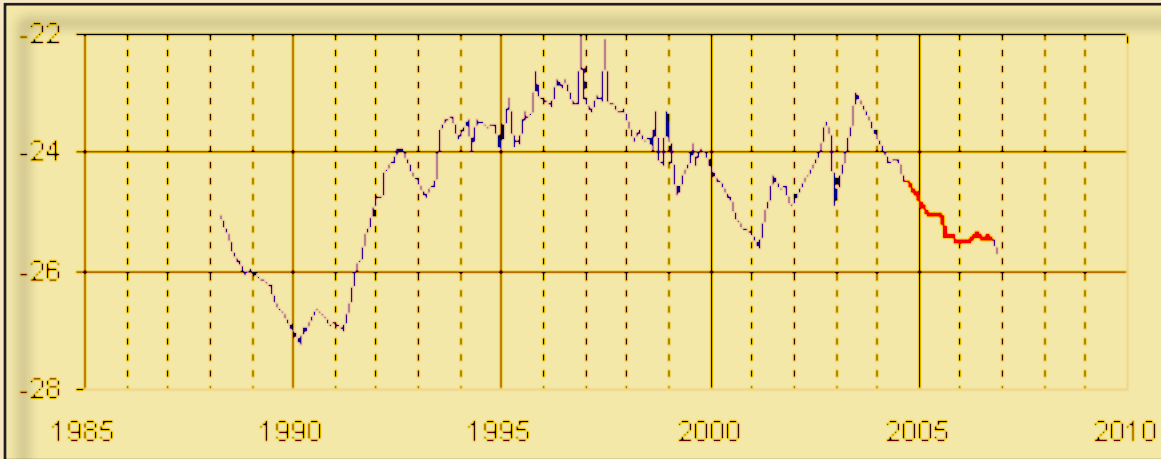


Figure 9K

Dakota County - Prairie du Chien/Jordan #19046

Depth to Water, ft.

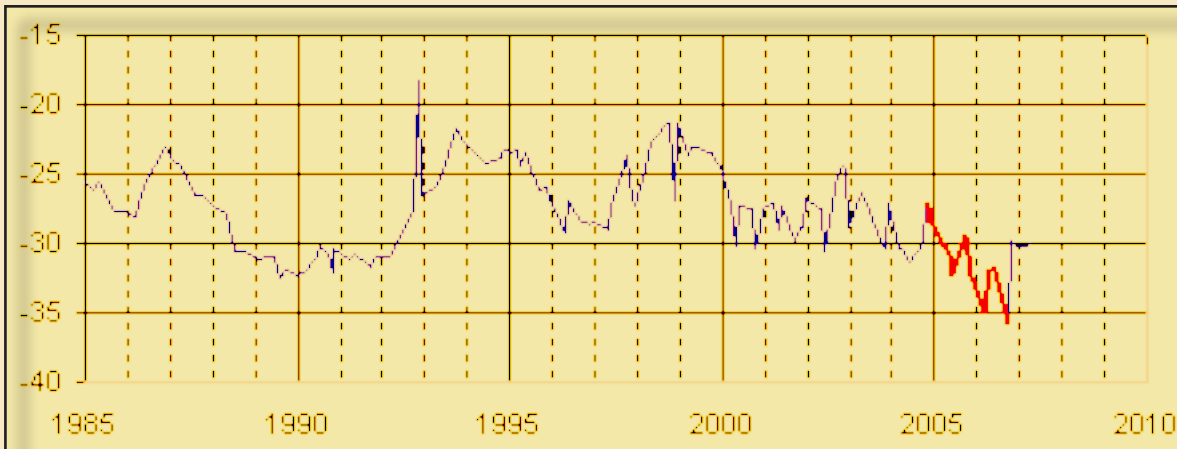


Figure 10A

Anoka County - Mt. Simon #2028

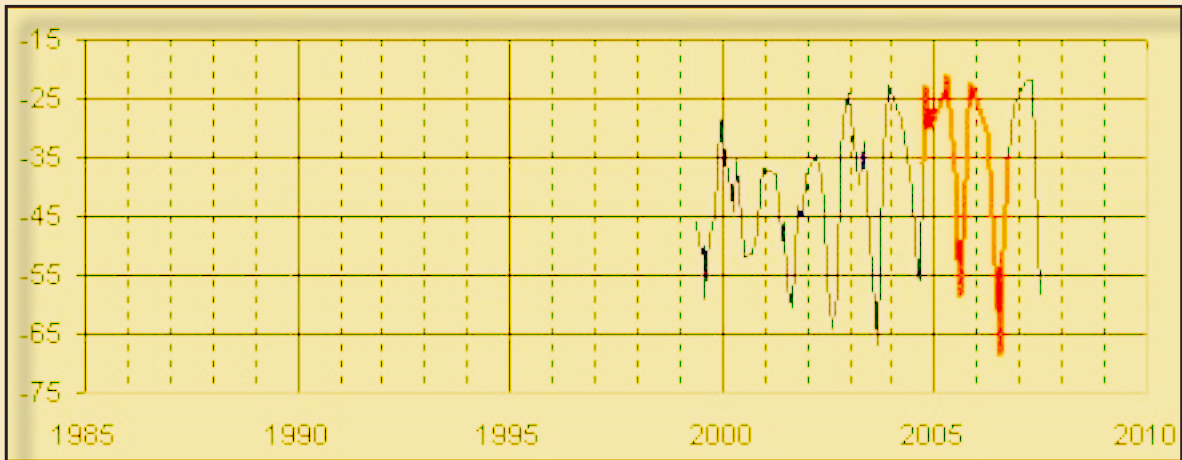


Figure 10B

Chisago County - Mt. Simon #13006

Depth to Water, ft.

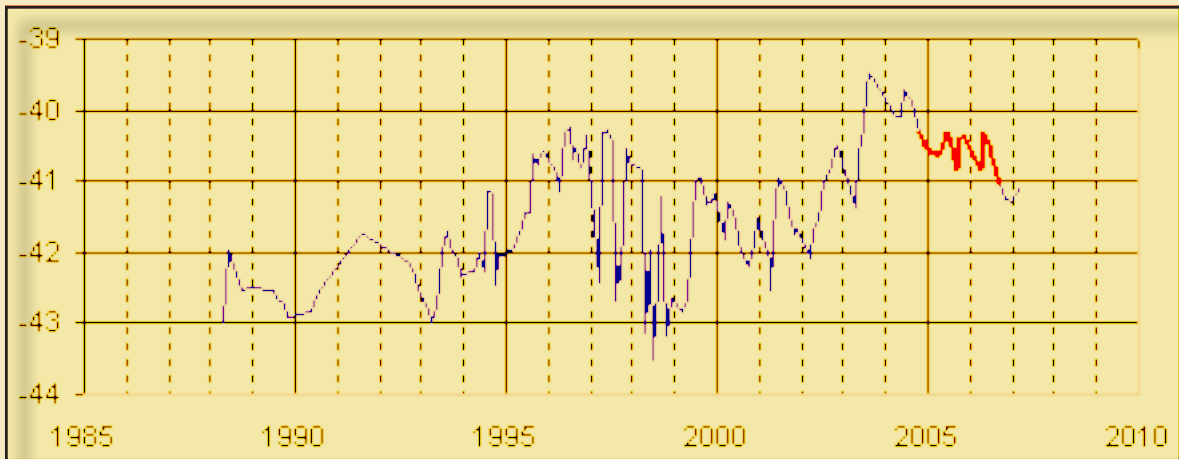


Figure 10C

Hennepin County - Mt. Simon #27004

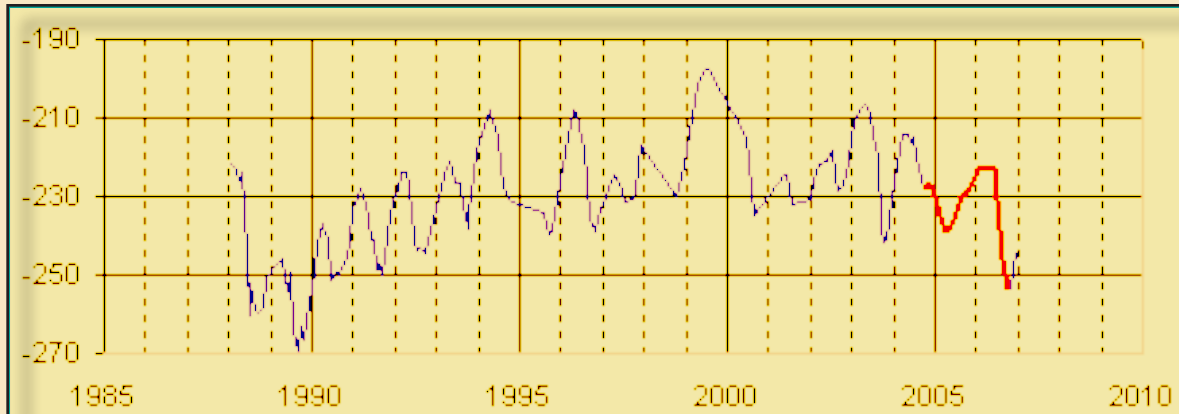


Figure 10D

Hennepin County - Mt. Simon #27043

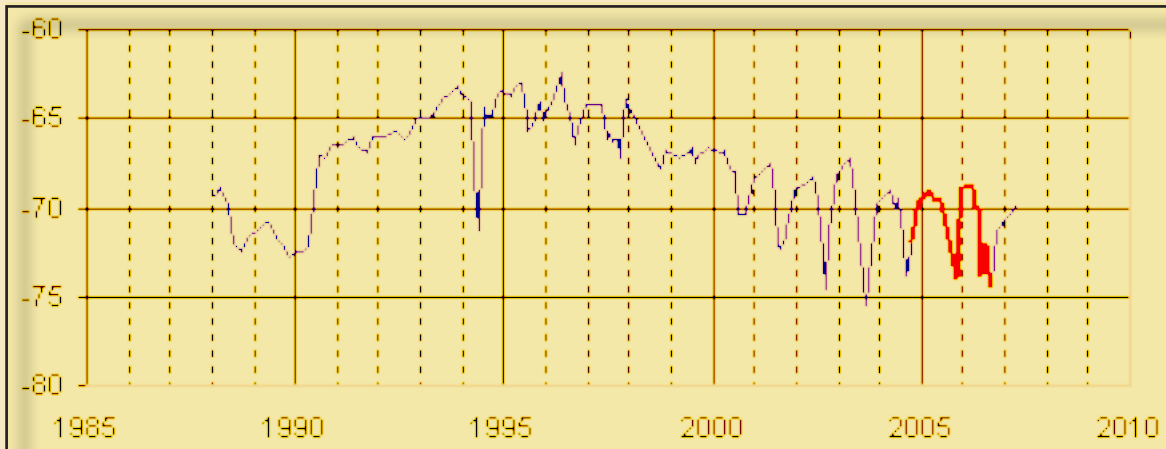


Figure 10E

Isanti County (Cambridge) - Mt.Simon #30009

Depth to Water, ft.

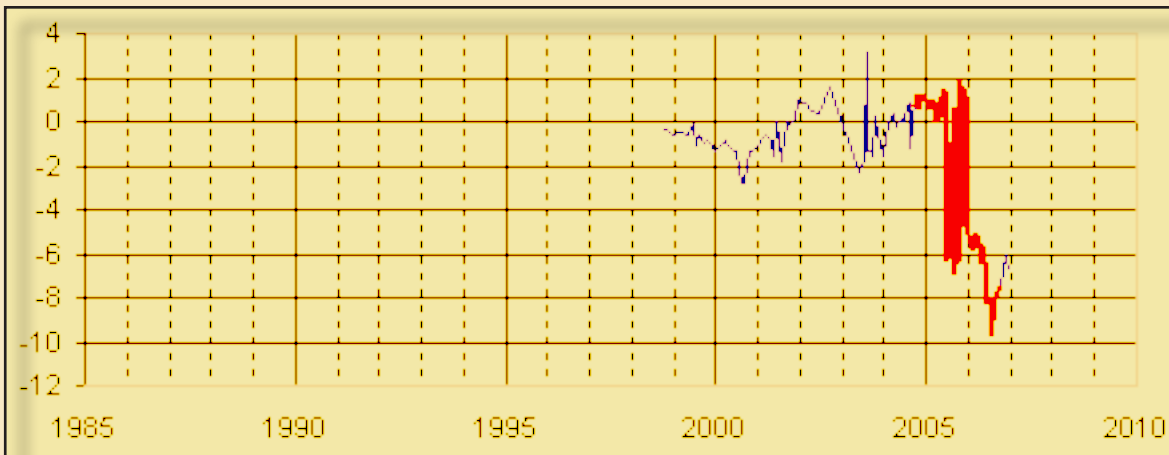


Figure 10F

Ramsey County - Mt.Simon #62046

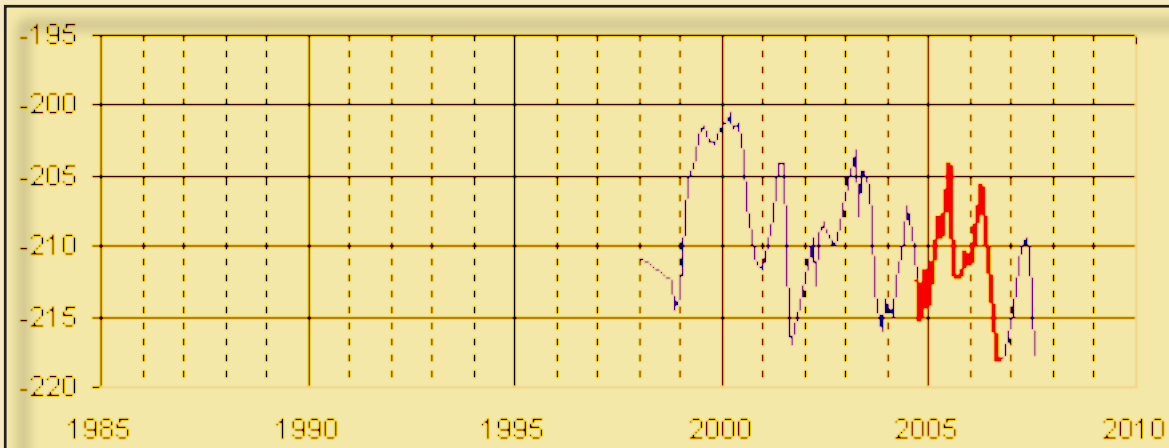


Figure 10G

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

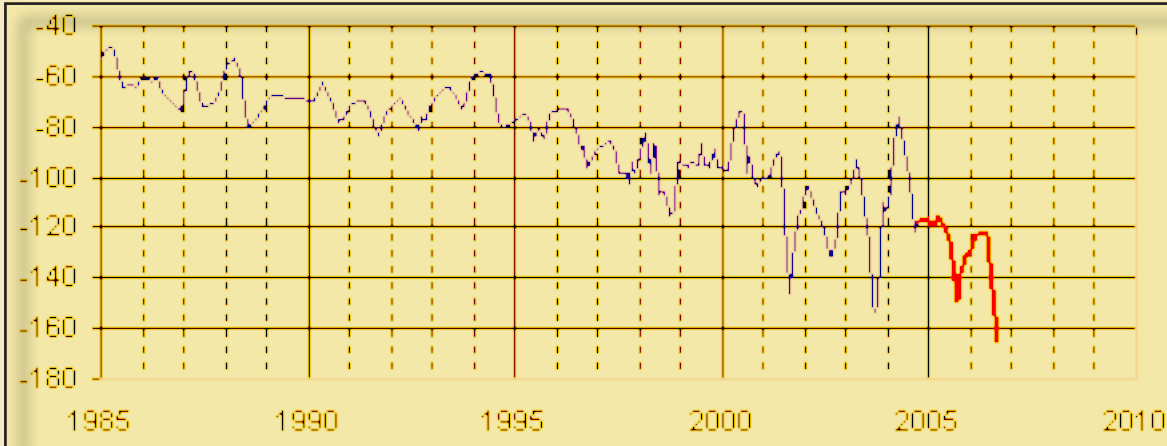


Figure 10H

Washington County - Mt.Simon #82046

Depth to Water, ft.

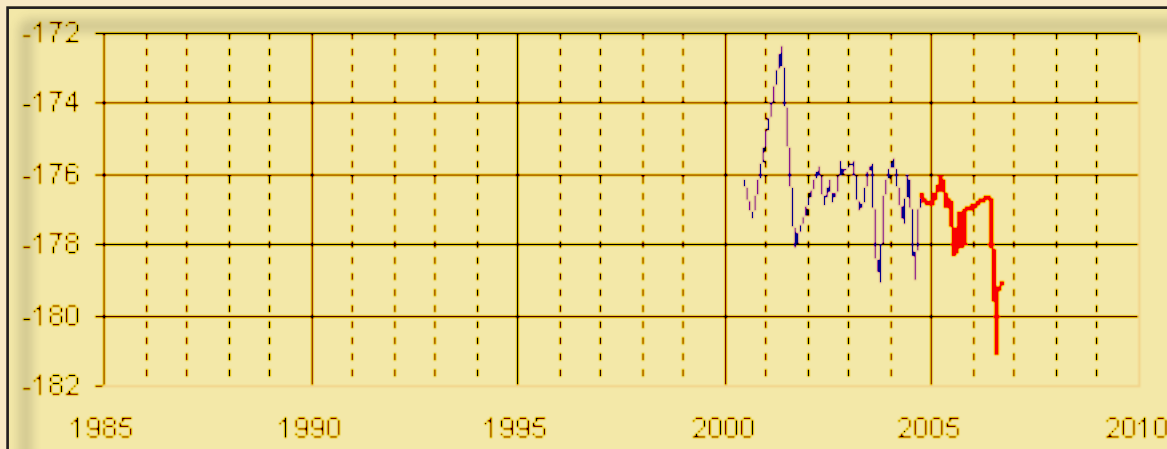
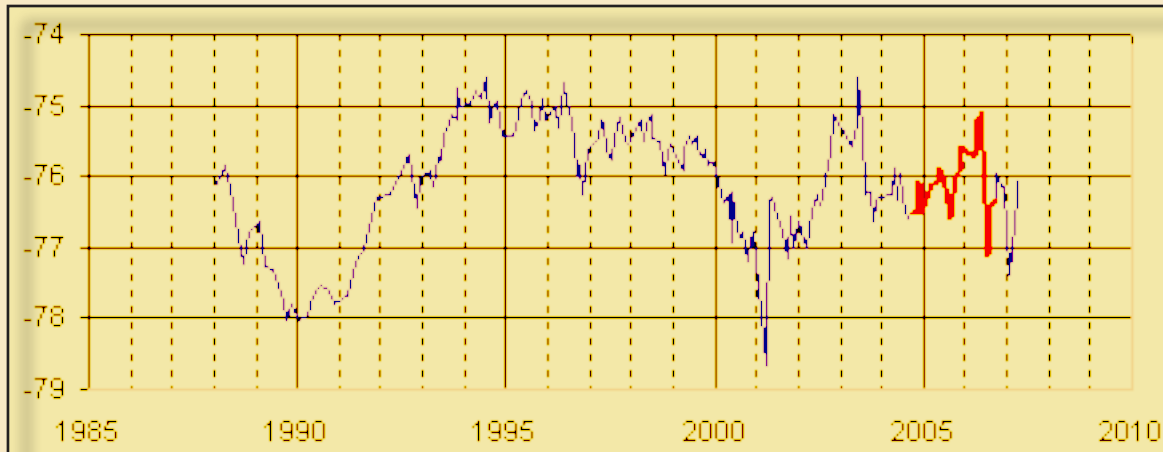


Figure 10i

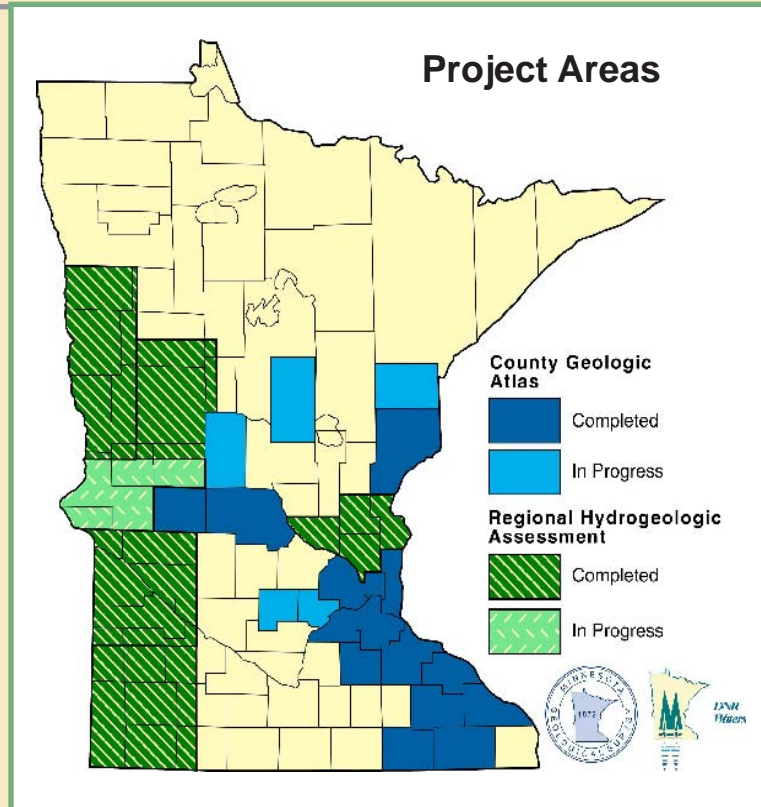
Wright County - Mt.Simon #86001



County Geologic Atlas and Regional Hydrogeologic Assessment Program

Ground Water Data

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



Data Available Online

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

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

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

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

For more information on MGS atlas and assessment report data see the list of current publications on the [MGS website](#).

