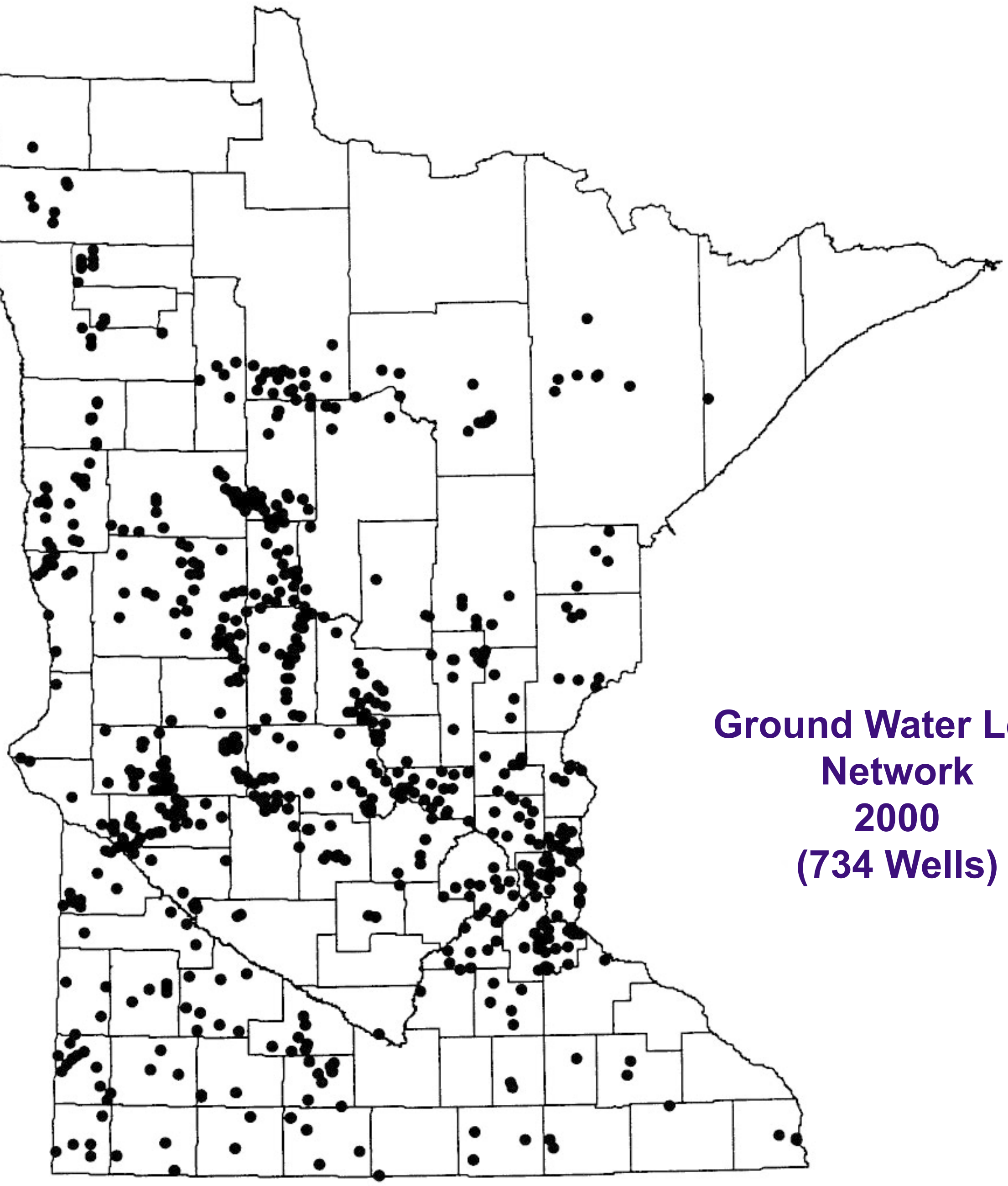
Chapter Three GROUND WATER



Ground Water Level
Network
2000
(734 Wells)

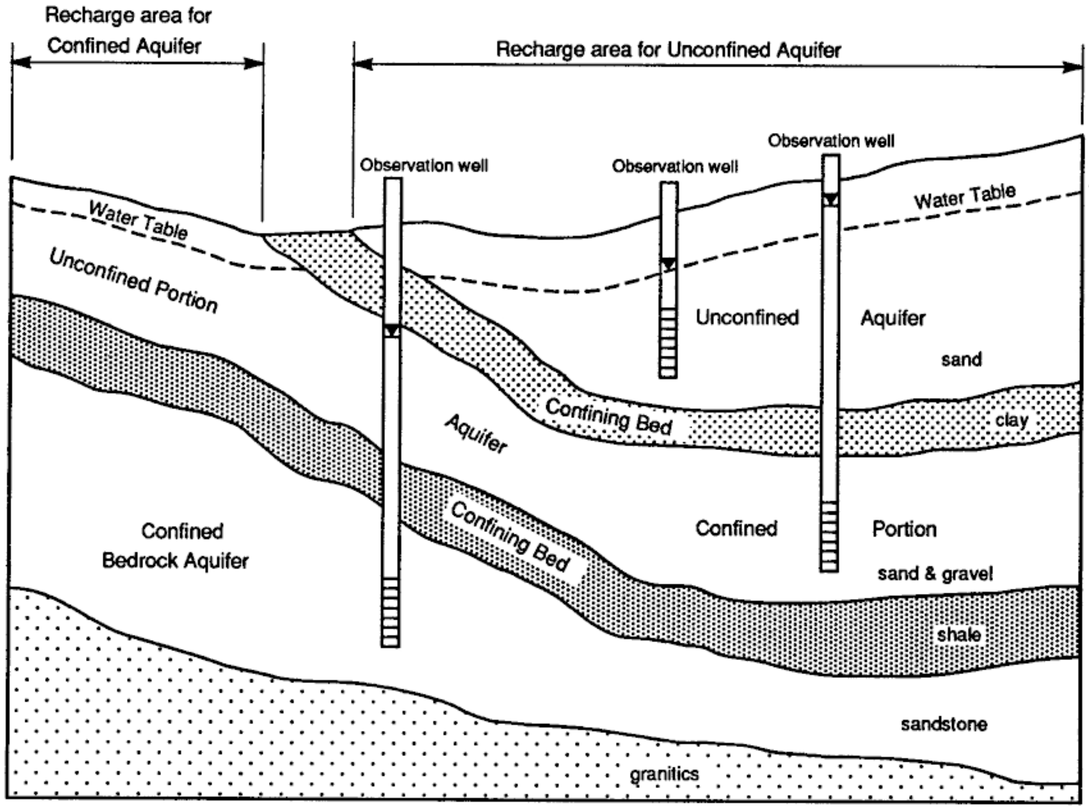
Introduction

Monitoring of ground water levels in Minnesota began in 1942 and, starting in 1947, was expanded by a cooperative program between the DNR and the United States Geological Survey (USGS). In Water Year 1999, the participation of the USGS ended.

The number of observation wells (obwells) has remained constant at about 700 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) under contract with DNR Waters measure the wells monthly and report the readings to DNR Waters. Readings are also obtained from volunteers at other locations.

Figure 1

Hypothetical Unconfined and Confined Aquifer Systems



Aquifers

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

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

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

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

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

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

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

Statewide Summary

The remainder of this chapter discusses the ground water levels in unconfined and confined aquifers during Water Years 1999 (WY99) and 2000 (WY00). This discussion focuses on a comparison of water levels in WY99 and WY00 to the water levels over the period of record for the observation wells analyzed in this report. The water levels for these two water years are presented for each month in the context of the median reading, highest and lowest reading and quartiles of all previous readings in each month. (See sidebar on page 44 for expanded explanation.) To achieve meaningful comparisons, representative obwells were chosen from the network based on their length of record and their geographical location. Such periods of record are generally from 15 to 30 years, with the shortest being 10 years and a few as long as 38 years.

During WY99 and WY00, the DNR monitored water levels in approximately 700 wells throughout the state. Water levels are usually recorded monthly except for January and February. Figures 2, 3 and 4 show the locations of these wells, identifying those that were placed in unconfined (water table) aquifers, in buried drift aquifers and in bedrock aquifers.

Figure 2 Water Table Observation Wells

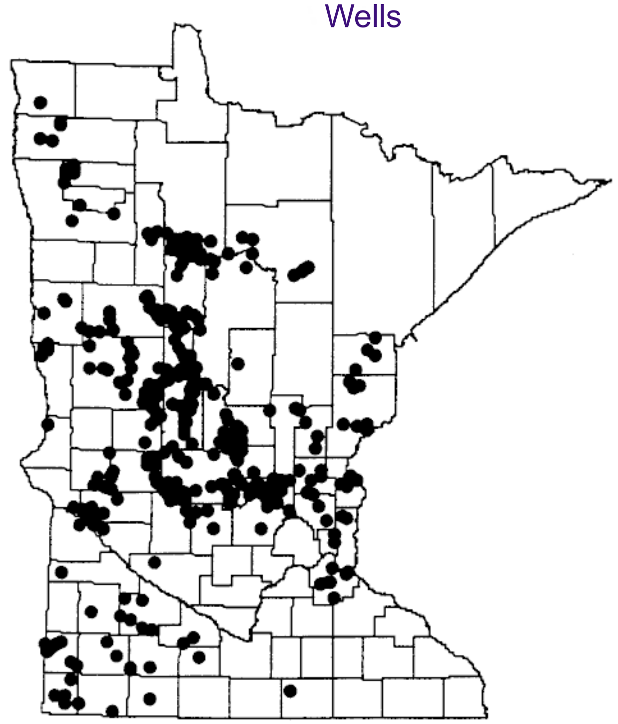


Figure 3 Buried Drift Observation Wells

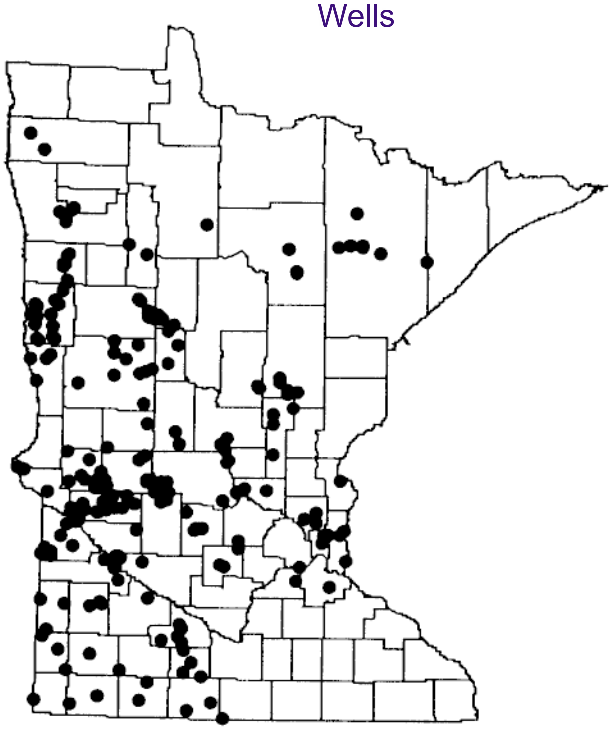
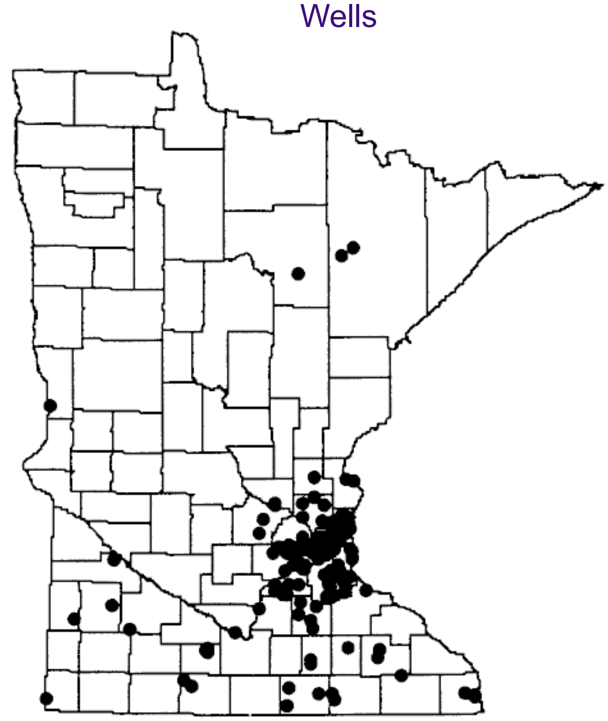


Figure 4 Bedrock Observation Wells

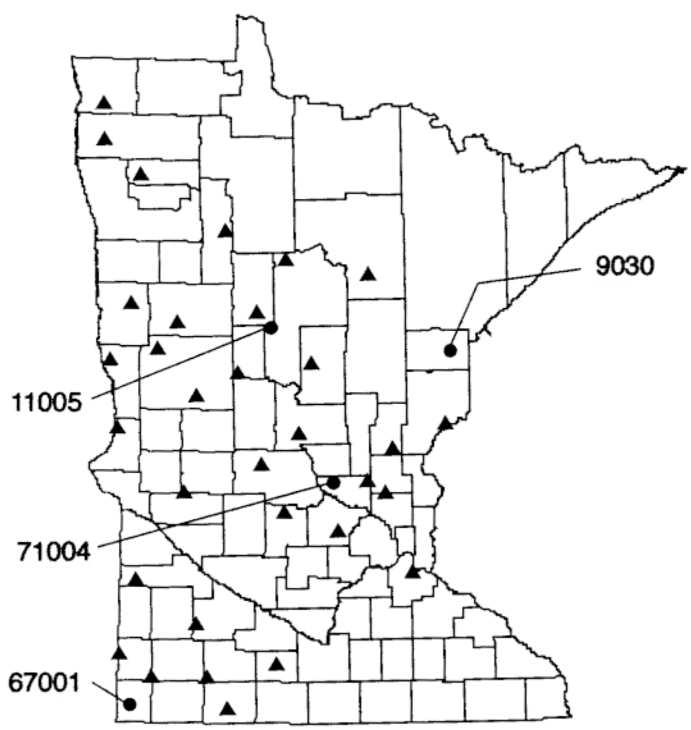


Statistical Analyses

Water levels are presented, for selected observation wells, as hydrographs superimposed over a set of descriptive statistics. Statistics used in these comparisons are computed for the appropriate month using data over the period of record preceding WY99. For each well, all existing data prior to this summary's period were statistically processed to provide, for each month, the median water level value, the 25th and 75th percentile water level, and the maximum and minimum recorded water level. The spread of values between the 25th and 75th percentile represent the range of water levels in which 50% of the previously measured water levels would be found. Median water levels were used instead of mean (average) water levels, because, for these data, the median provides a better estimate of the central tendency of the data.

The accompanying hydrographs indicate the measured and statistical depth to water from the ground surface. When plotted as they are with negative values, these depths reflect water levels and behave accordingly. As water levels rise in a well, points on the graph also rise toward the surface datum. On the statistical hydrographs, quartiles are plotted and identified as Q1 and Q3. In a statistical interpretation relative to water levels, Q1 represents the 75th percentile water level (a high level) and Q3, the 25th percentile water level (a low level). One fourth of all measured water levels were below Q3 and one-fourth were above Q1.

Figure 5 Location of Representative Unconfined Wells



Unconfined Aquifers (Water Table)

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

The approximate location of the water table wells used in this report are shown in Figure 5. The wells identified by number are also the subject wells in Figures 6A and 6B. Figure 6A on page 46 illustrates hydrographs for several obwells showing water levels in WY99 and WY00 compared to analyses of data over the preceding period of record. Figure 6B on page 47 shows the standard hydrographs for the same wells over the entire period of record.

The representative unconfined obwells are roughly grouped according to precipitation patterns observed during WY99 and WY00. These precipitation patterns are shown in Figures 5 and 14 (pages 5 and 12) of the Climatology Chapter. The “wet” area stretched from the northwest corner of the state south to Lac Qui Parle County. Portions of those western counties from Clay and Becker to Lac Qui Parle were very wet. In WY99 there was also a “wet” area from the central and southern Twin Cities metro area into northern Rice and Goodhue Counties, which became dryer in WY00. “Dry” encompasses much of the state from the middle of Itasca and St. Louis Counties extending southwest in a wide band to the southwestern corner of the state.

“Wet” area – Unconfined water table wells in this area reflect the precipitation excess throughout this period, especially in WY99. In some instances water levels were the highest on record, although normal seasonal fluctuations were observed. Water levels remained high in WY00, but showed some decline toward the end of the year.

Comparison of the WY99 water levels to the analyzed historical record shows that water levels in the west and northwest were above the median and often in the upper quartile. In the center of the state, there was no discernable trend except that water levels declined from above the median in mid-WY99 to below median at the end of WY00.

“Dry” area – Unconfined water table wells in this area reflect the precipitation deficit throughout this period. Water levels in the “dry” area were generally elevated during the winter of WY00, but dropped during the following summer. Water levels in the center of the dry area were similar to those of the very dry period from WY89 to WY91.

When compared with analyzed water levels for the period of record preceding WY99, water levels in the summer of WY00 often fall below the 25th percentile and, in some instances, near the lowest levels recorded. During the earlier portions of this period, water levels were generally within the 25% to 75% range, but most often below the median.

Figure 6A. Unconfined (Water Table) Obwells: Historical monthly statistics compared to WY 1999 and WY 2000 readings.

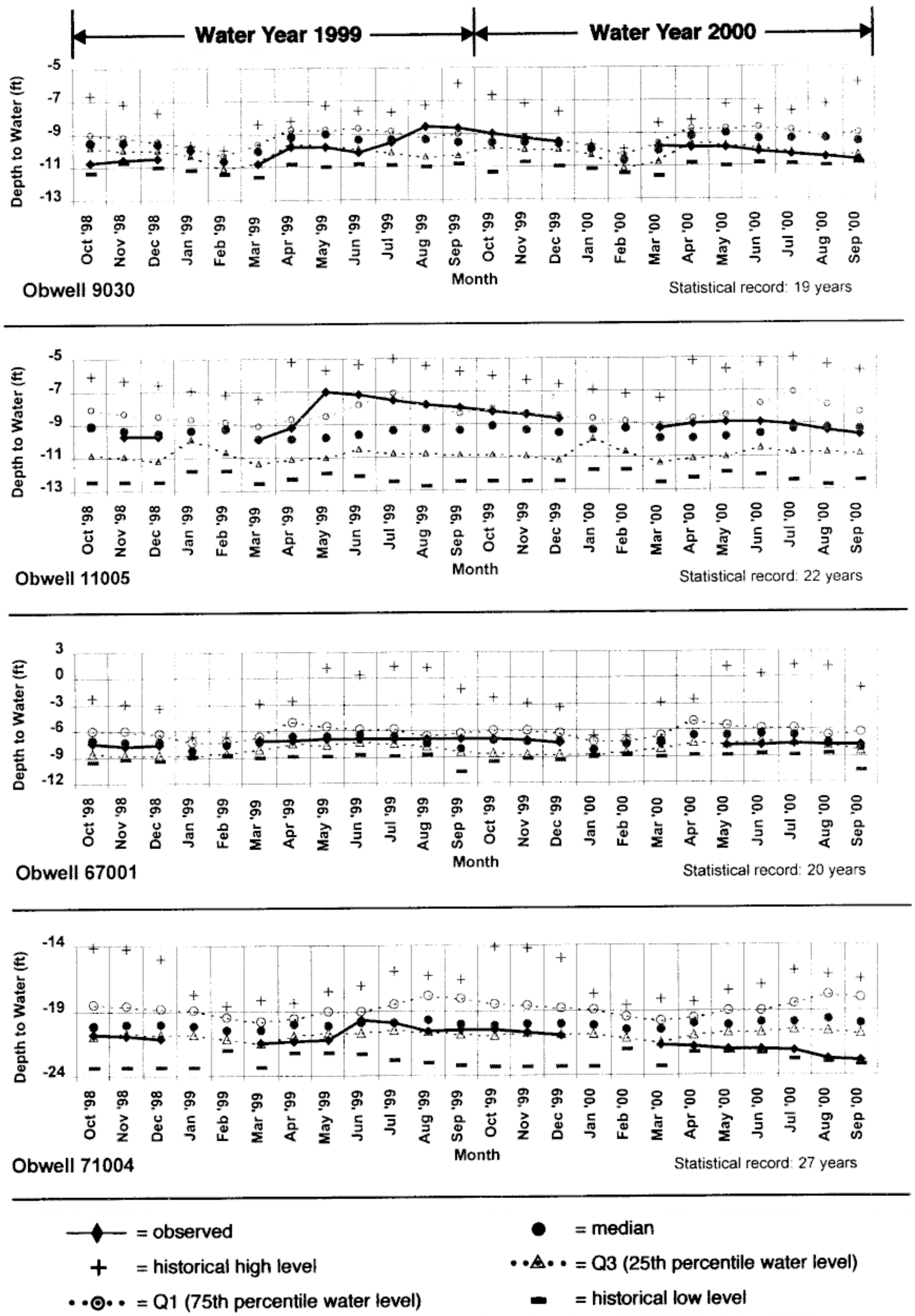
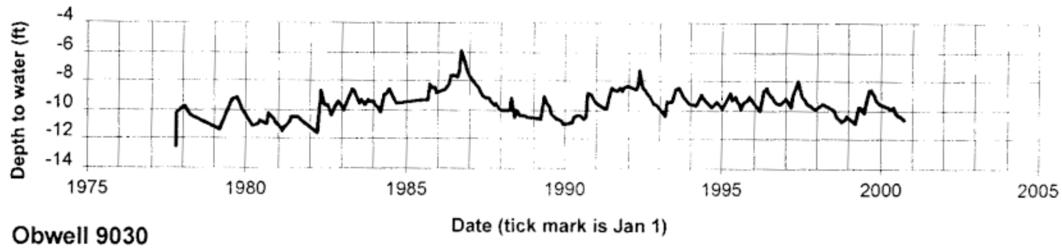
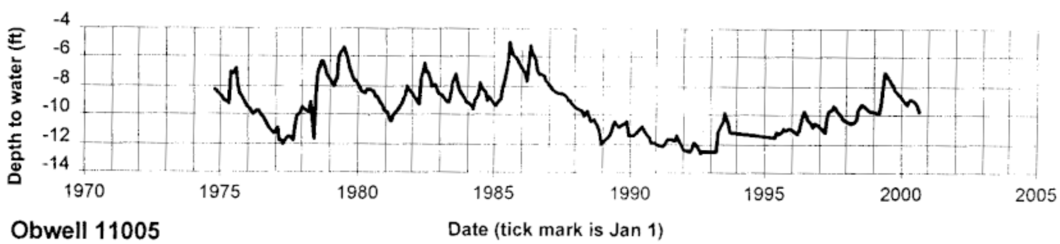


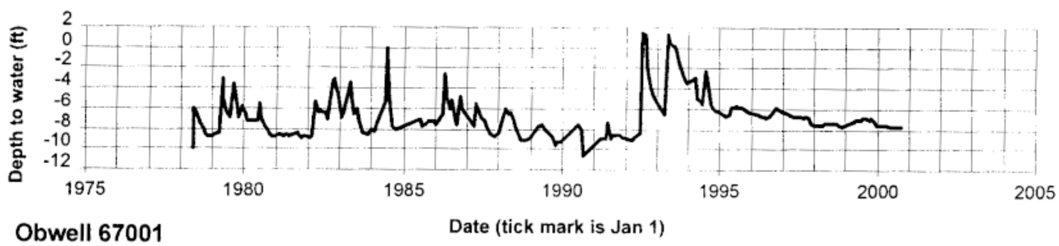
Figure 6B. Unconfined (Water Table) Obwells: Water levels for the entire period of record.



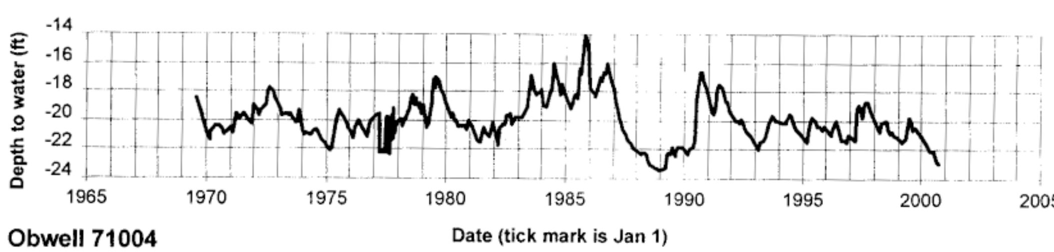
Obwell 9030



Obwell 11005



Obwell 67001



Obwell 71004

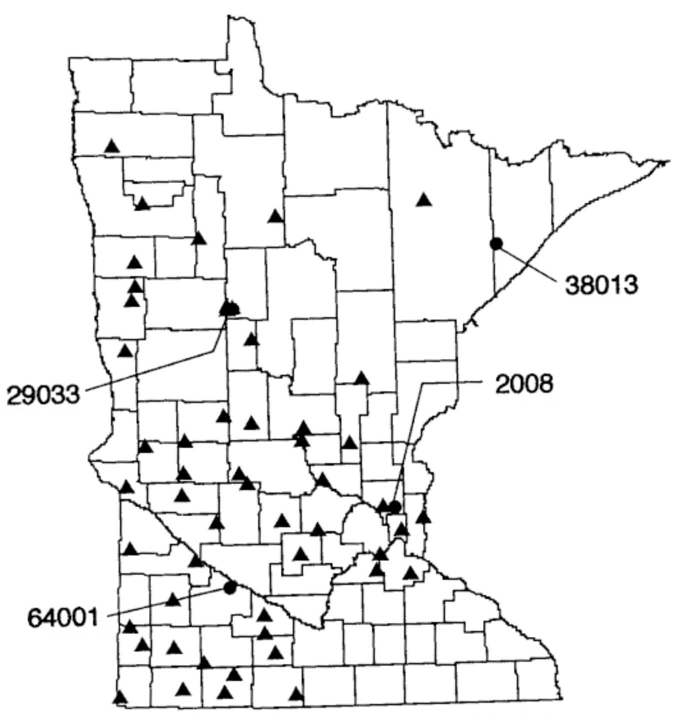
Confined Aquifers

Confined buried drift and bedrock aquifers are not separated according to precipitation patterns in this summary. Usually, changes in precipitation patterns are not reflected in confined aquifers until after the extreme (dry or wet) precipitation pattern has been in existence for an extended period or has ended. This is due primarily to the presence of an overlying confining bed which inhibits a direct response to the precipitation pattern.

Buried Drift Aquifers

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

Figure 7 Location of Representative Buried Drift Wells



The approximate location of the buried drift wells used in this summary are shown in Figure 7. The wells identified by number are also the subject wells in Figures 9A and 9B. Figure 9A on page 50 illustrates hydrographs for several obwells showing water levels in WY99 and WY00 compared to analyses of data over the preceding period of record. Figure 9B on page 51 shows the standard hydrographs of these same wells over the entire period of record.

For the state as a whole, a downward trend in buried drift water levels is evident toward the end of WY00.

In the northeast, buried drift aquifer water levels were higher in WY00 than WY99. In WY99, these levels were below the 25th percentile but rose to near the median between the 25th and 75th percentile by WY00.

Buried drift levels in the Twin Cities Metro area responded similarly to those of the water table aquifers in the same area. In the southeast, Dakota County buried drift levels in WY 99 were well above the median and, in a few instances, were the highest recorded in a particular month. These levels show a downward trend in WY00. In Anoka County on the northern edge of this area, buried drift water levels were well below the median, dropping into the first quartile. These water levels dropped throughout both water years and ended near the lowest levels on record.

In northwestern Minnesota, buried drift water levels were generally above the median and occasionally above the 75th percentile. In areas which experienced very wet conditions, buried drift water levels were near or above the highest recorded level. Even at these high levels, a slight downward trend is discernable from WY99 to WY00.

From central Minnesota to the southwestern corner of the state, buried drift water levels generally were below the median. Toward the end of WY00 these levels had an apparent downward trend and had dropped into the lowest percentile.

Bedrock - Prairie du Chien-Jordan Aquifer

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

Locations of the Prairie du Chien-Jordan wells used in this report are shown in Figure 8. Wells identified by number are those wells for which hydrographs are shown in the figures that follow. Prairie du Chien-Jordan water levels tended to decline slightly through WY99 and WY00. However, no aquifer-wide trend can be discerned when the WY99 and WY00 water levels are compared to the analyzed historical records, except that levels in these years seem to be at the extremes, either below the 25th or above the 75th percentiles. Figure 10A on page 52 includes a comparison of the analyzed historical records with the actual readings for WY99 and WY00 for selected wells. Figure 10B on page 53 shows hydrographs over the period of record for selected wells.

Bedrock - Mt. Simon Aquifer

With some exceptions, the Mt. Simon is a confined aquifer. 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 8. The wells identified by number are also the subject wells in the hydrographs that follow. Figure 11A on page 54 presents a comparison of WY99 and WY00 readings with the analyzed historical record for several Mt. Simon aquifer wells in this report. Figure 11B on page 55 shows the standard hydrographs for these selected wells over their entire period of record. Water levels in the west and southwest were below the median for these wells; in the southeast were above the median and, in several months, were the highest on record; and in the north, water levels were above the median in some months. Obwell 70002, located near Savage, MN has been experiencing a decline in water levels since 1980. Several readings in Obwell 70002 for WY99 and WY00 established new record low levels and most were below the 25th percentile, however, these readings appear to have a very slight upward trend over the two water years.

Figure 8

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

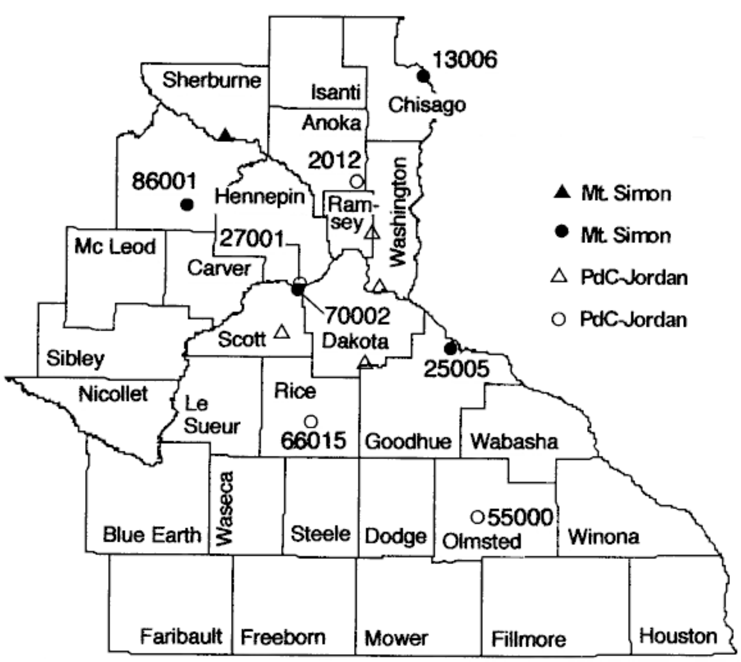


Figure 9A. Buried Drift Obwells: Historical monthly statistics compared to WY 1999 and WY 2000 readings.

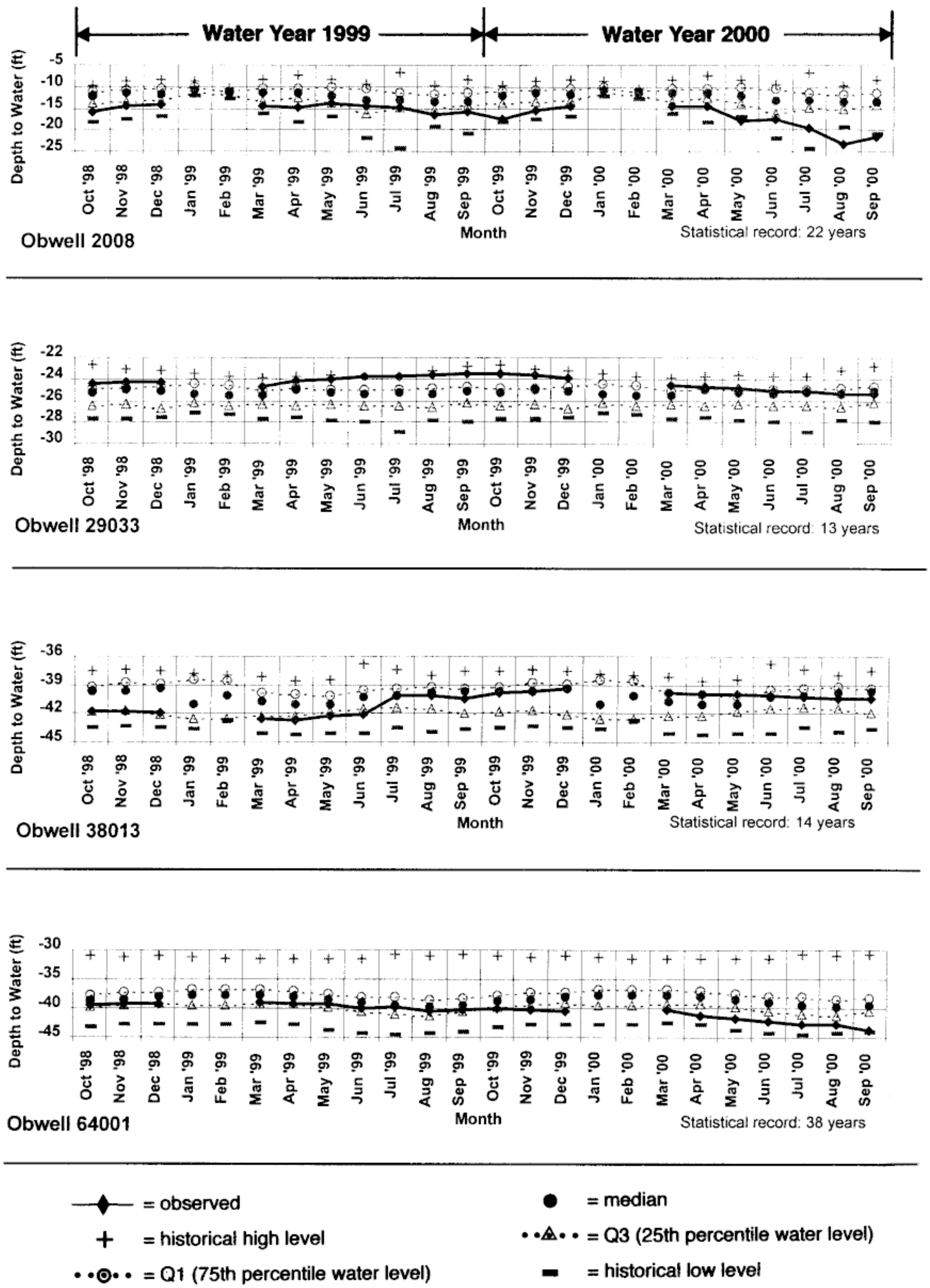
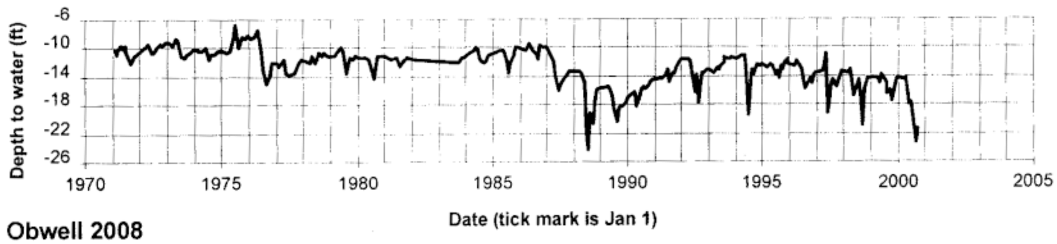
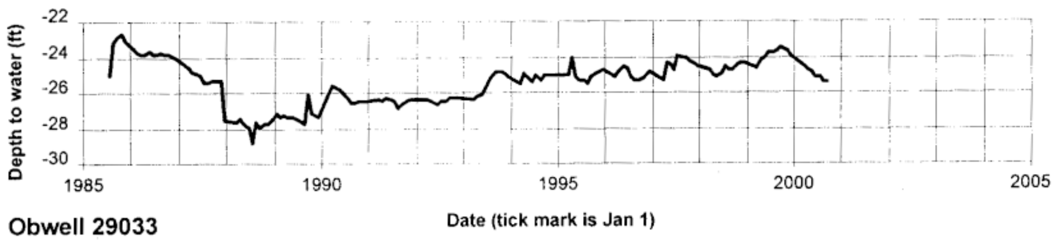


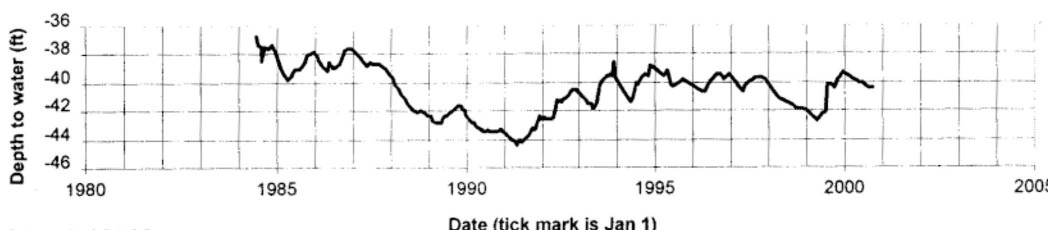
Figure 9B. Buried Drift Obwells: Water levels for the entire period of record.



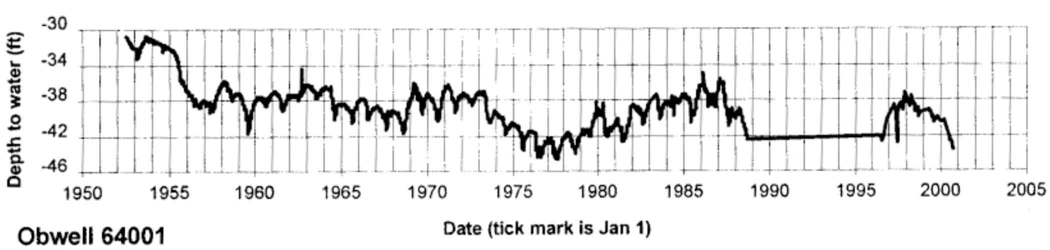
Obwell 2008



Obwell 29033



Obwell 38013



Obwell 64001

Figure 10A. Prairie du Chien- Jordan Bedrock Obwells: Historical monthly statistics compared to WY 1999 and WY 2000 readings.

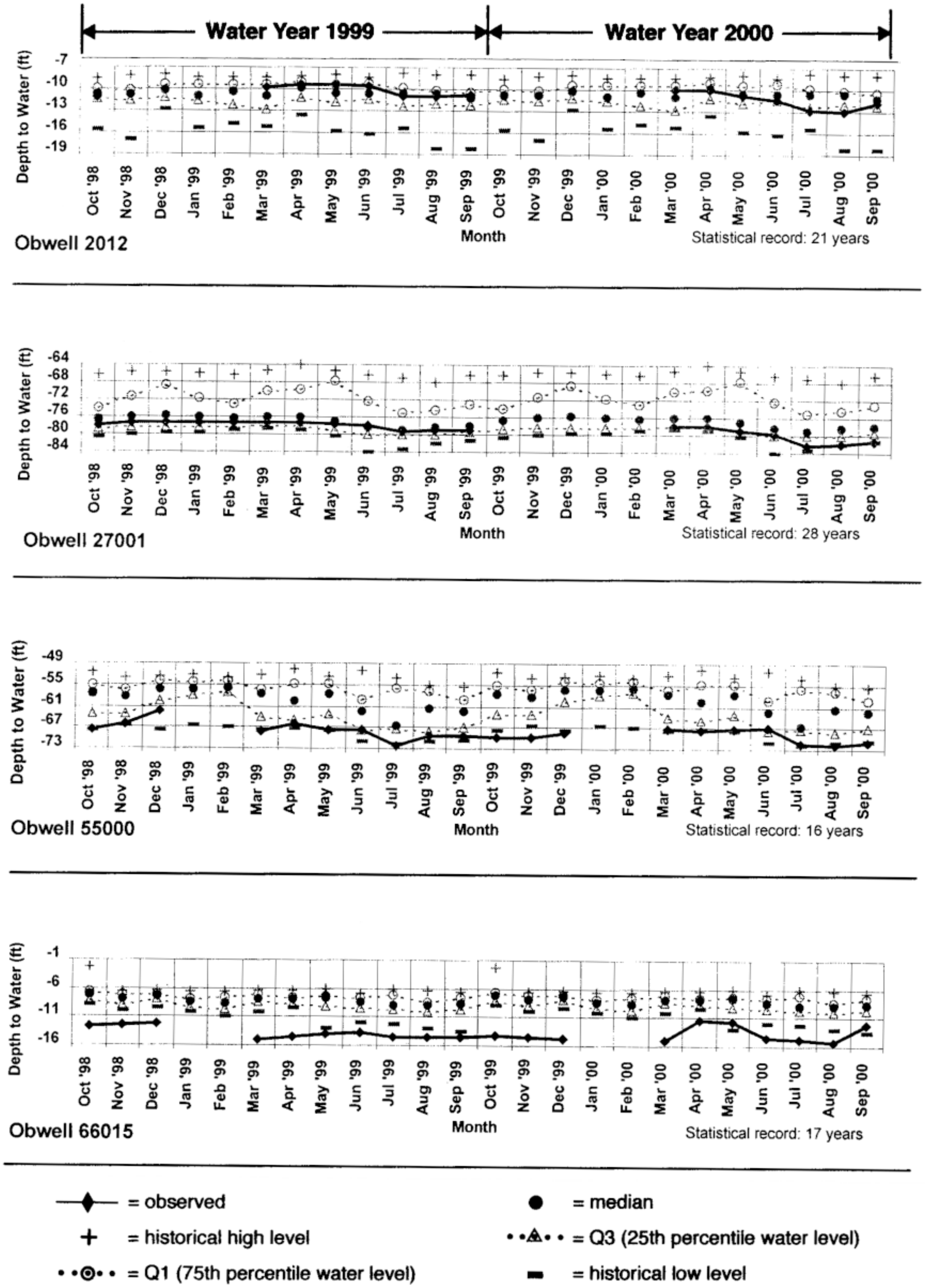
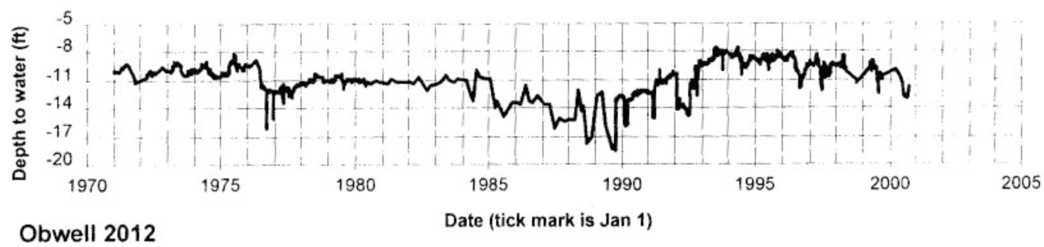
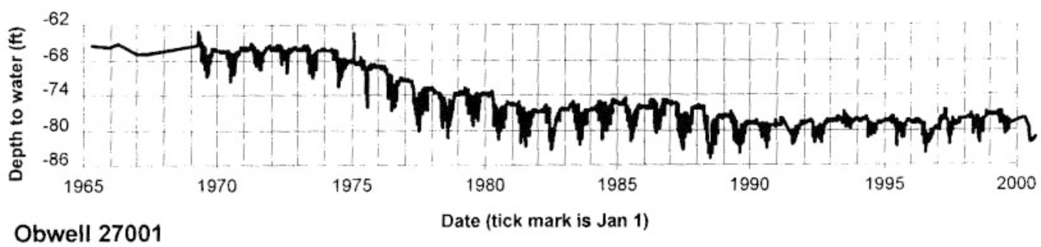


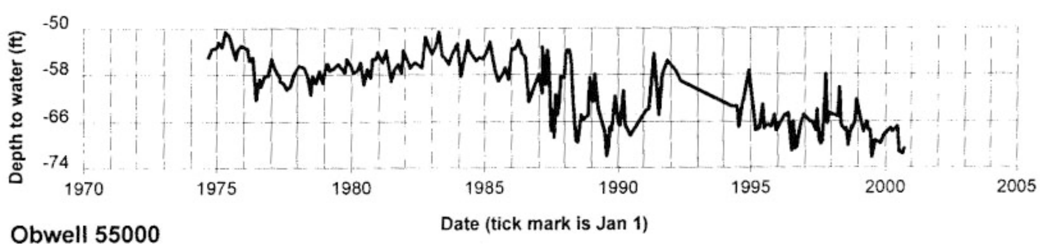
Figure 10B. Prairie du Chien- Jordan Bedrock Obwells: Water levels for the entire period of record.



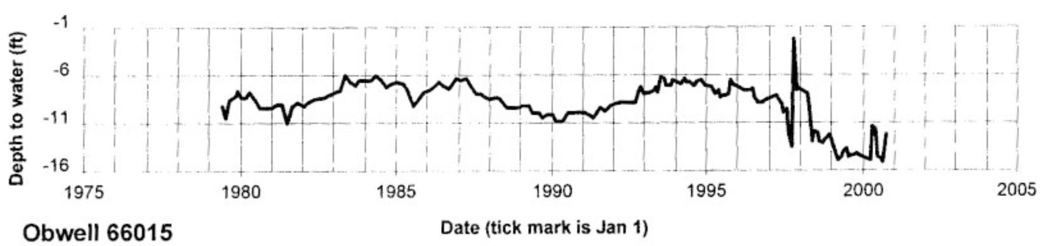
Obwell 2012



Obwell 27001



Obwell 55000



Obwell 66015

Figure 11A. Mt. Simon Bedrock Obwells: Historical monthly statistics compared to WY 1999 and WY 2000 readings.

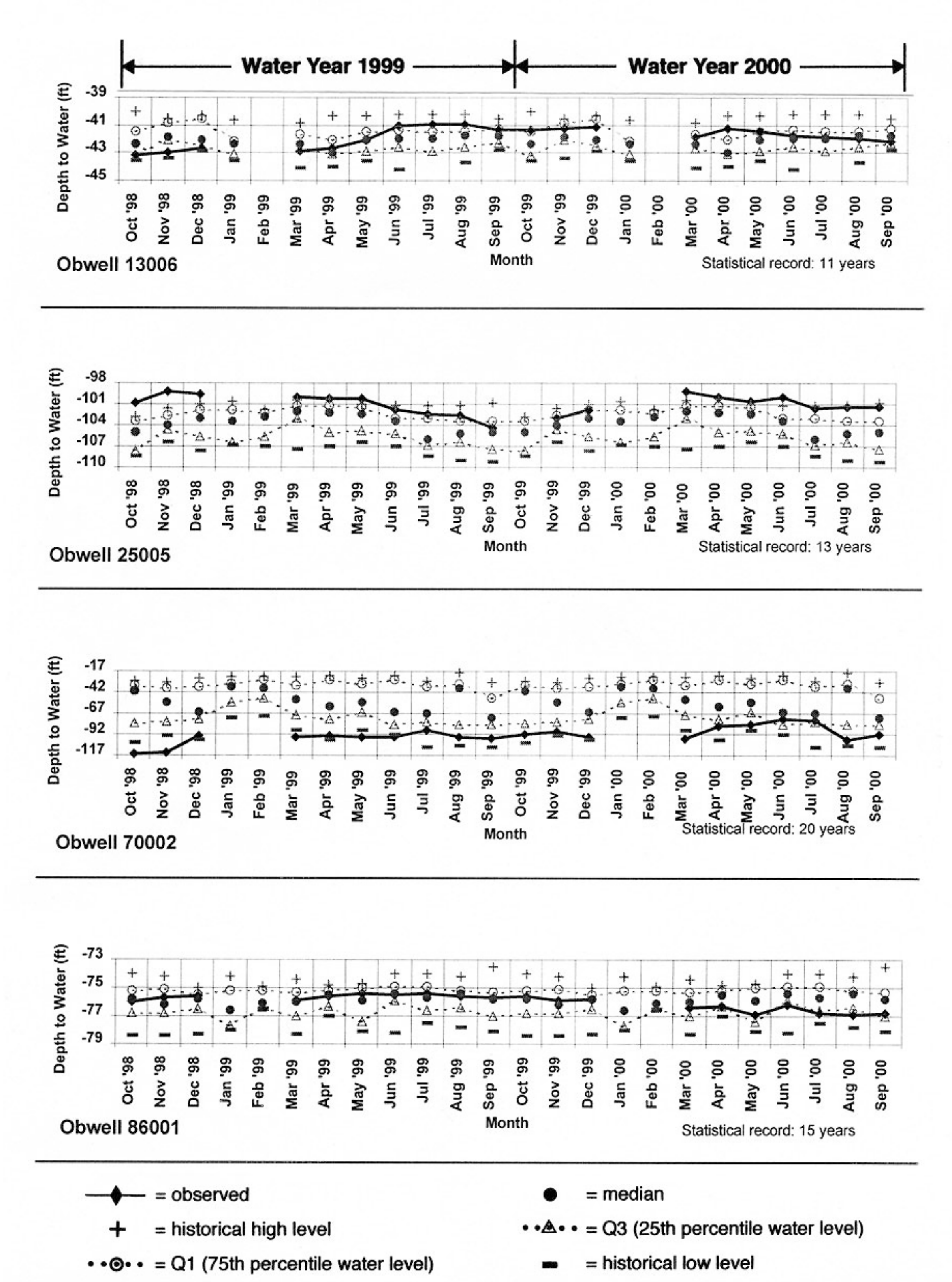
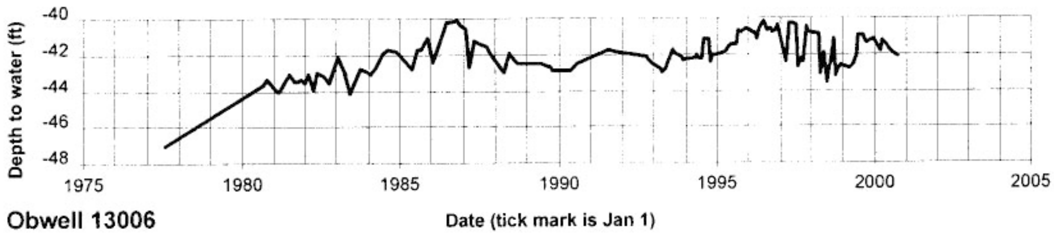
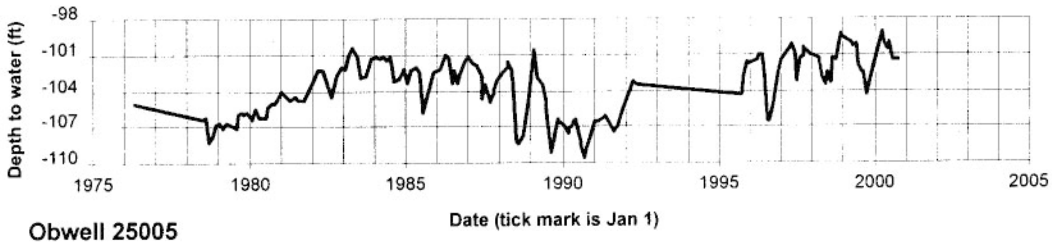


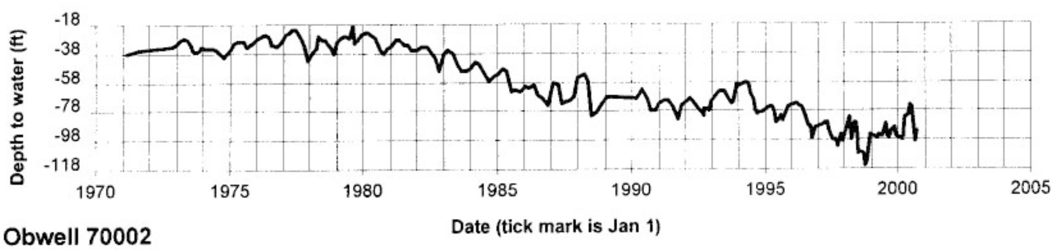
Figure 11B. Mt. Simon Bedrock Obwells: Water levels for the entire period of record.



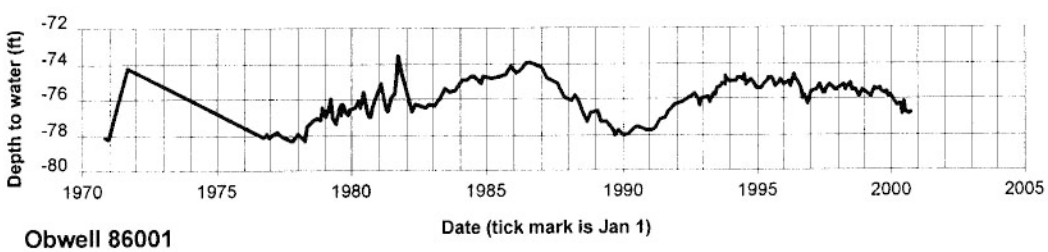
Obwell 13006



Obwell 25005



Obwell 70002



Obwell 86001

Ground Water Level Network Improvement

A systematic review of each obwell has been implemented and will involve a visit to each site by DNR hydrogeologists. When feasible, physical tests such as slug tests and gamma logging will be performed in order to confirm the quality and usefulness of the obwell within the network. Although around 700 obwells are actively monitored, the database contains some information for nearly twice that many sites. The fate of inactive obwells will be determined so that appropriate management actions can occur. The review of each county or aquifer will include an analysis of the coverage and water levels, which could result in a change of monitoring frequency or obwell distribution. This review will take several years to complete.

The DNR Waters program of exploratory drilling and observation well installation continued in the southwest and west central regions, with several test holes and a few obwells being installed. In anticipation of continued industrial growth, two obwells were installed near the City of Renville in Renville County. Test holes were drilled in Yellow Medicine and Chippewa Counties, while two obwells were added in Washington County to monitor the effect of development on ground water levels around the City of Stillwater. DNR Waters, in cooperation with the Minnesota Pollution Control Agency, replaced a number of shallow (less than 50’ deep) wells which were lost due to a variety of circumstances such as inadvertent sealing, road construction and land owner decisions to eliminate wells from their property.

The vibrating wire piezometer, a technology used in civil engineering, has been adapted to monitor ground water levels. Basically, a transducer is placed at the desired depth in a borehole or well and is sealed in place. Measurements are then taken at the ground surface using a computer and a data logger. This technique was first used by DNR Waters in WY99 to continue the record of a Mt. Simon aquifer obwell which was sealed due to development. This technique has also been used for a Franconia/Ironton/Galesville well, sealed by the property owner, so that a new monitoring point has been added to the network. The technology holds great promise for enhancement of ground water level monitoring.

all ground water monitoring is not the same...

What is a ground water level observation well?

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

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

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

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

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

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

• Well constuction -
- materials: Water quality is affected by well construction. PVC, which is used for most new obwells, can't be monitored for some chemicals because of interference from the PVC or the glue used. On the other hand, steel may be inappropriate for other water quality parameters.
- diameter: Many shallower obwells are 2" or less in diameter. It can be difficult to obtain water quality samples from many such small diameter wells. The deeper obwells that DNR Waters drills are usually constructed of 4" steel. Because DNR Waters' ground water level wells are constructed to a higher standard than is required, other agencies may use these wells for water quality monitoring; however, those wells may not be at a location where water quality monitoring is needed.
- screen: The screen of ground water level wells is usually placed as deep into an aquifer as feasible in order to always have a water level if the ground water level of the aquifer drops. However, for some water quality monitoring, such as for nitrates, the screen is set right at the existing water level in order to detect the substance of interest as it reaches the water table.

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

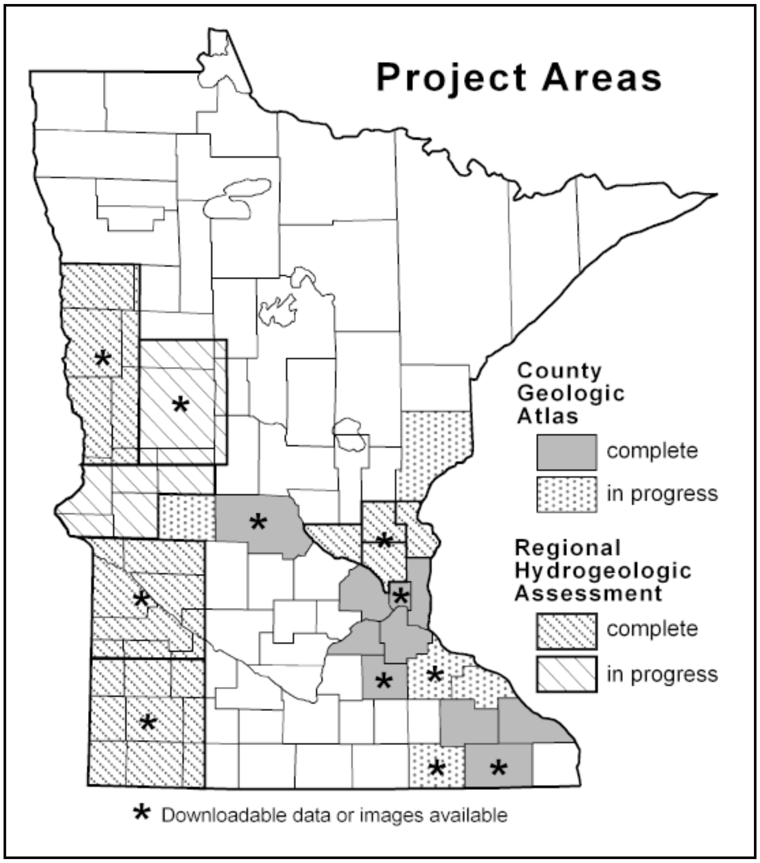
Local, state and federal water management agencies are aware of and have access to the location of the obwells. The Minnesota Pollution Control Agency is reviewing obwell locations for their newest monitoring program. The Minnesota Department of Agriculture and the Minnesota Department of Health have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

County Geologic Atlas and Regional Hydrogeologic Assessment Program

Ground Water Data Use

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

In addition to the well and geologic data collected by the MGS, project staff utilize DNR Waters databases, particularly data available from the 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.



Data Available Online

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

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

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