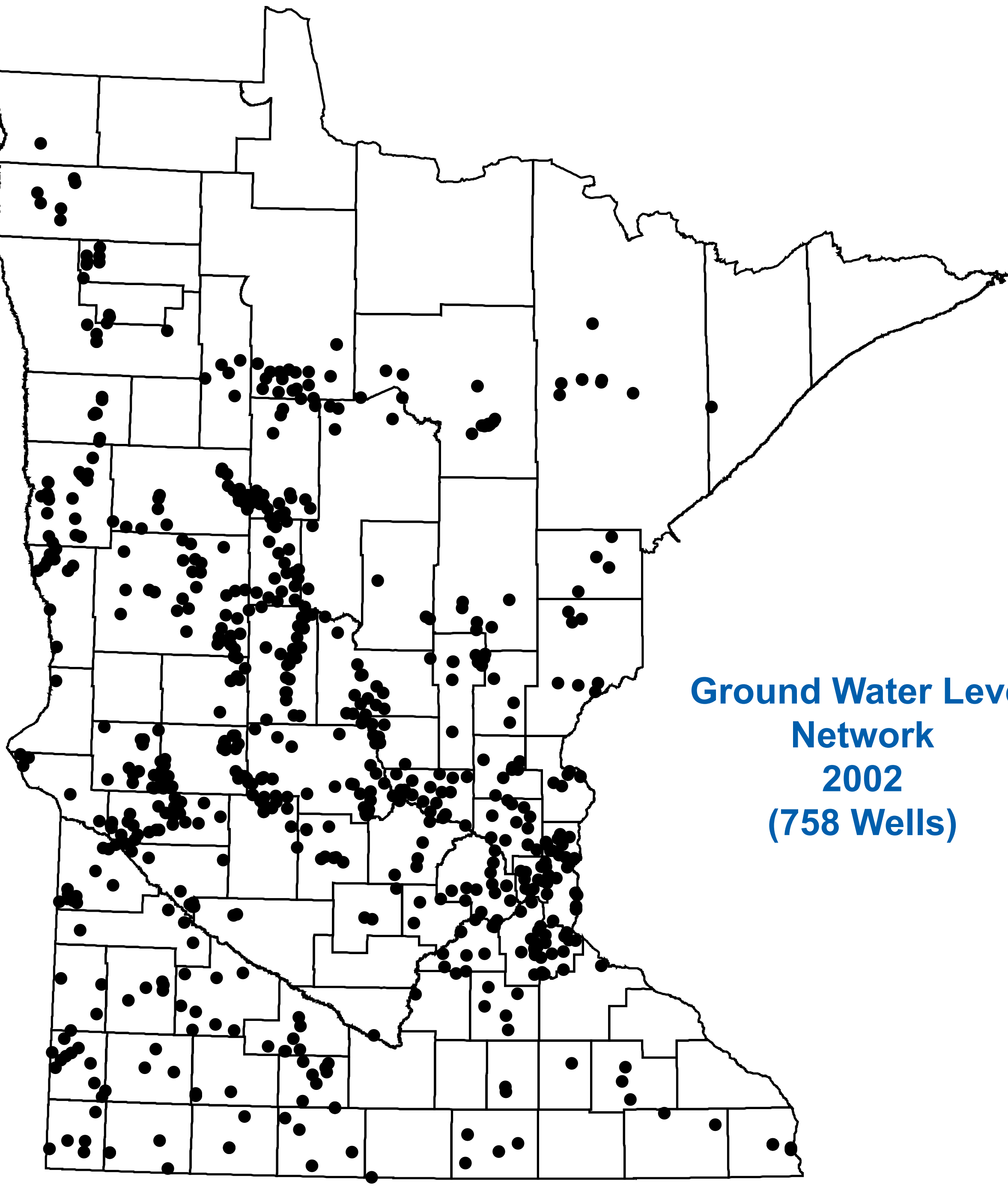
chapter three
ground water

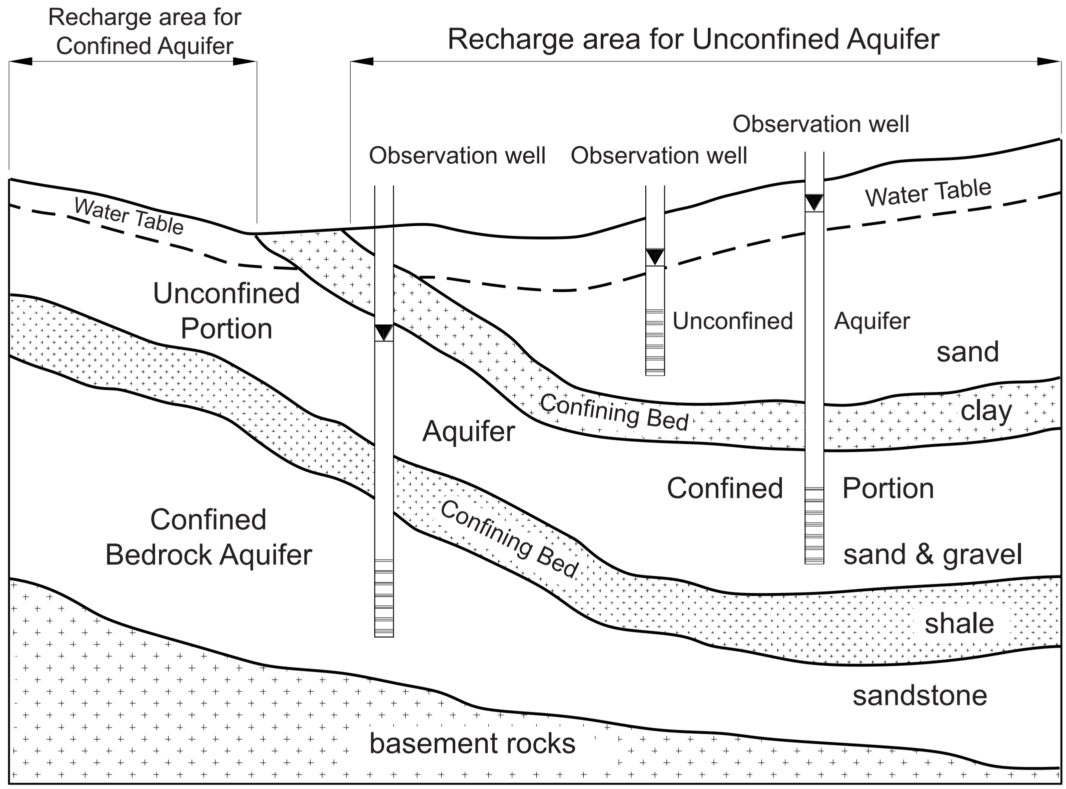


Introduction

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). The number of observation wells (obwells) has remained constant at about 700-750 obwells over the last few water years. Data from these wells are used to assess ground water resources, determine long term trends, interpret impacts of pumping and climate, plan for water conservation, evaluate water conflicts and otherwise manage the water resource. Soil and Water Conservation Districts (SWCD) and other cooperators, under agreements with DNR Waters, measure the wells monthly and report the readings to DNR Waters as part of the Ground Water Level Program. Readings are also obtained from volunteers and electronically at other locations.

Figure 1

Hypothetical Unconfined and Confined Aquifer Systems



Aquifers

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

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

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

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

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

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

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

Statewide Summary

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

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

Figure 2

Unconfined Observation Wells

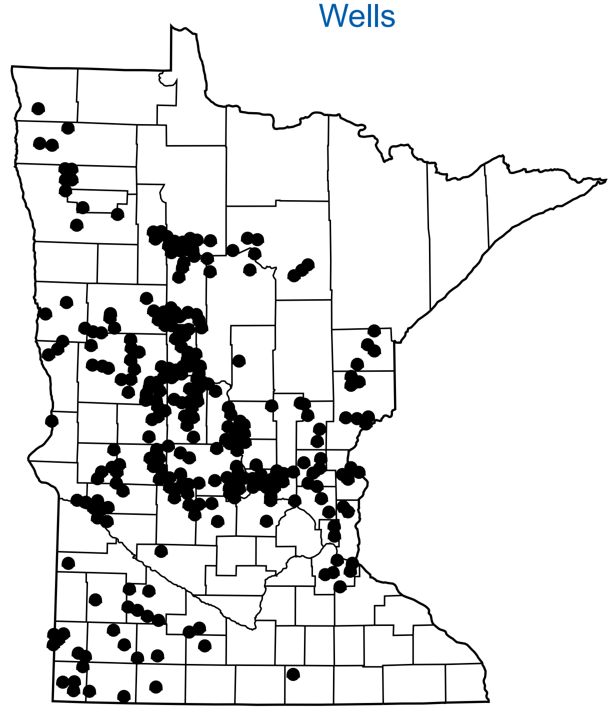


Figure 3

Buried Drift Observation Wells

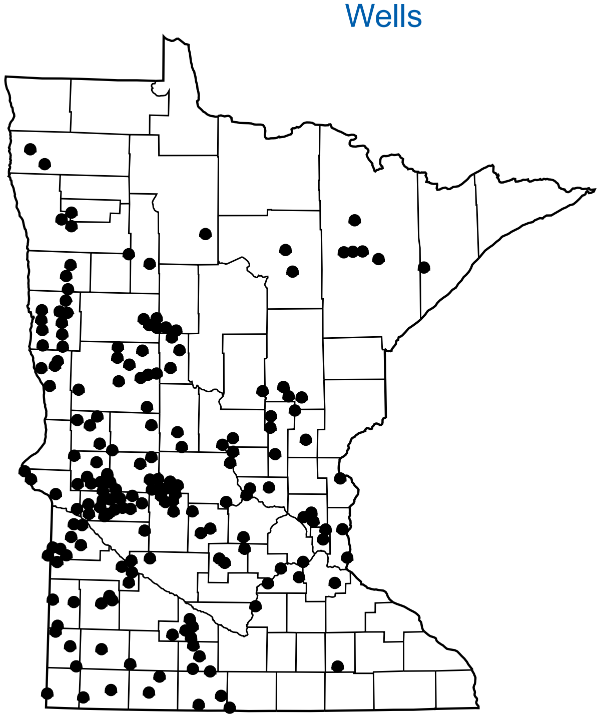
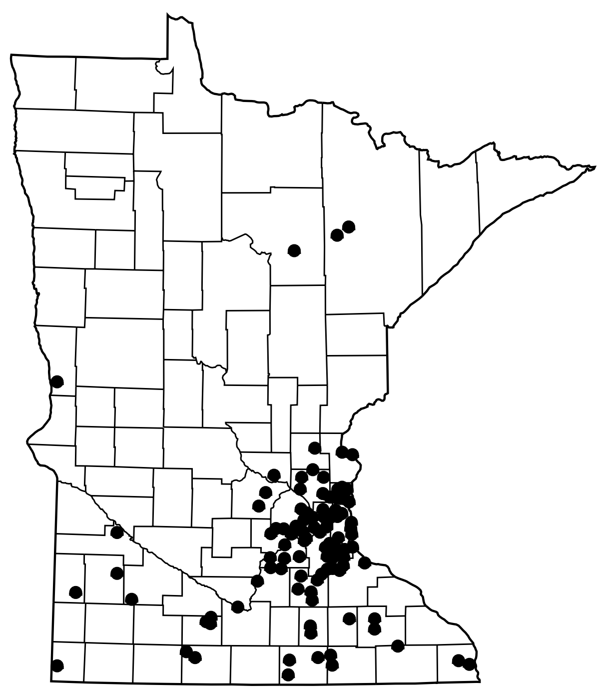


Figure 4

Bedrock Observation Wells



Unconfined Aquifers (Water Table)

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

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

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

Figure 5 Location of Representative Unconfined Wells

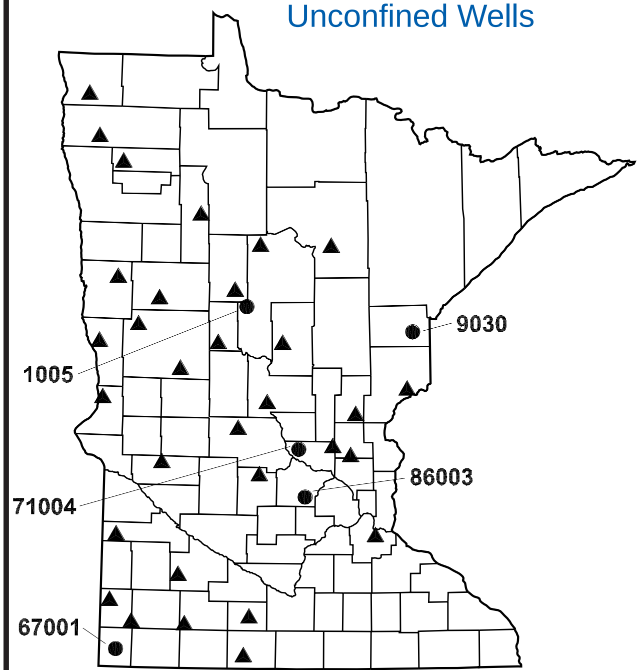


Figure 6A.

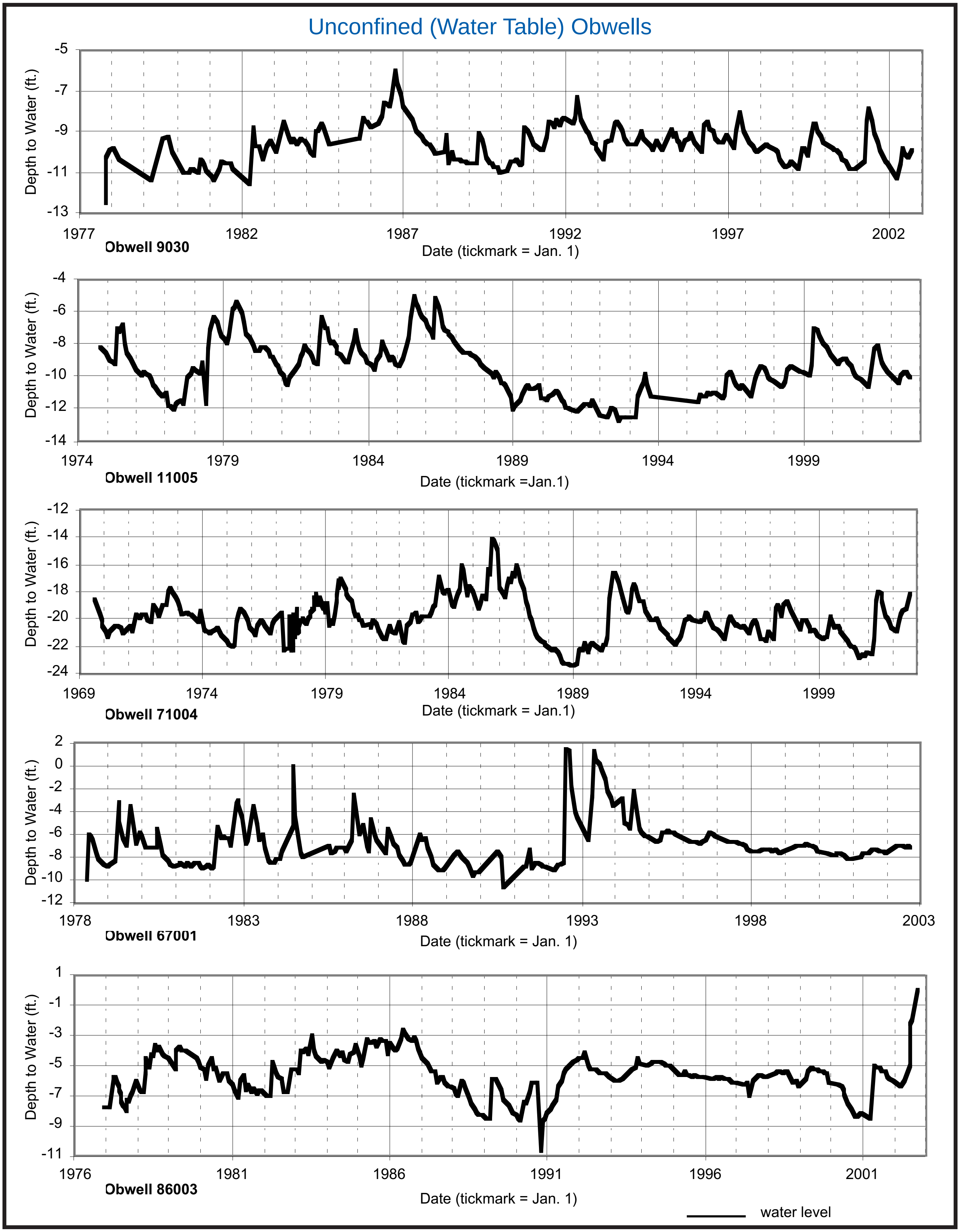
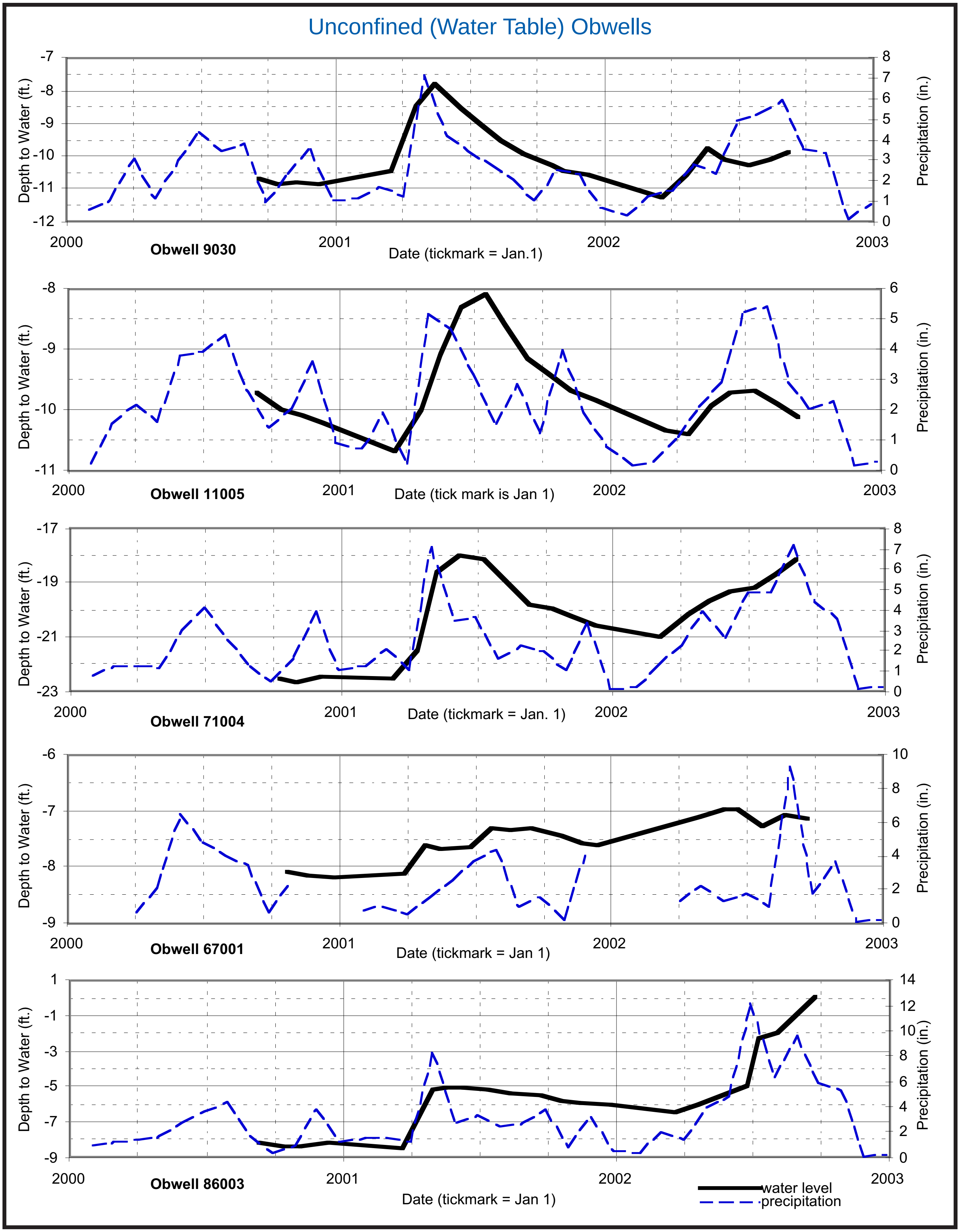

Unconfined (Water Table) Obwells
Depth to Water (ft.)
Obwell 9030
Date (tickmark = Jan. 1)
Obwell 11005
Date (tickmark =Jan.1)
Obwell 71004
Date (tickmark = Jan.1)
Obwell 67001
Date (tickmark = Jan. 1)
Obwell 86003
Date (tickmark = Jan. 1)
water level

Figure 6B


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

Confined Aquifers

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

Buried Drift Aquifers

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

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

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

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

Bedrock - Prairie du Chien - Jordan Aquifer

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

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

Figure 7 Location of Representative Buried Drift Wells

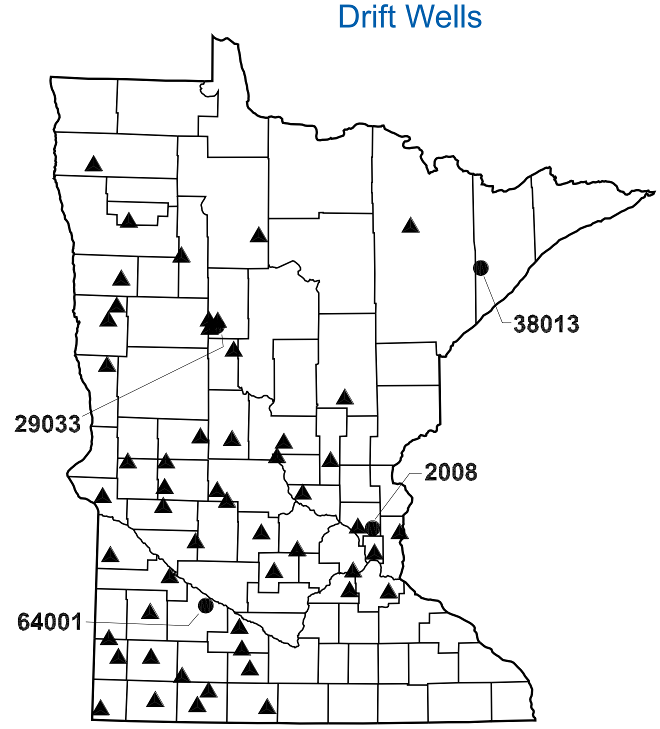
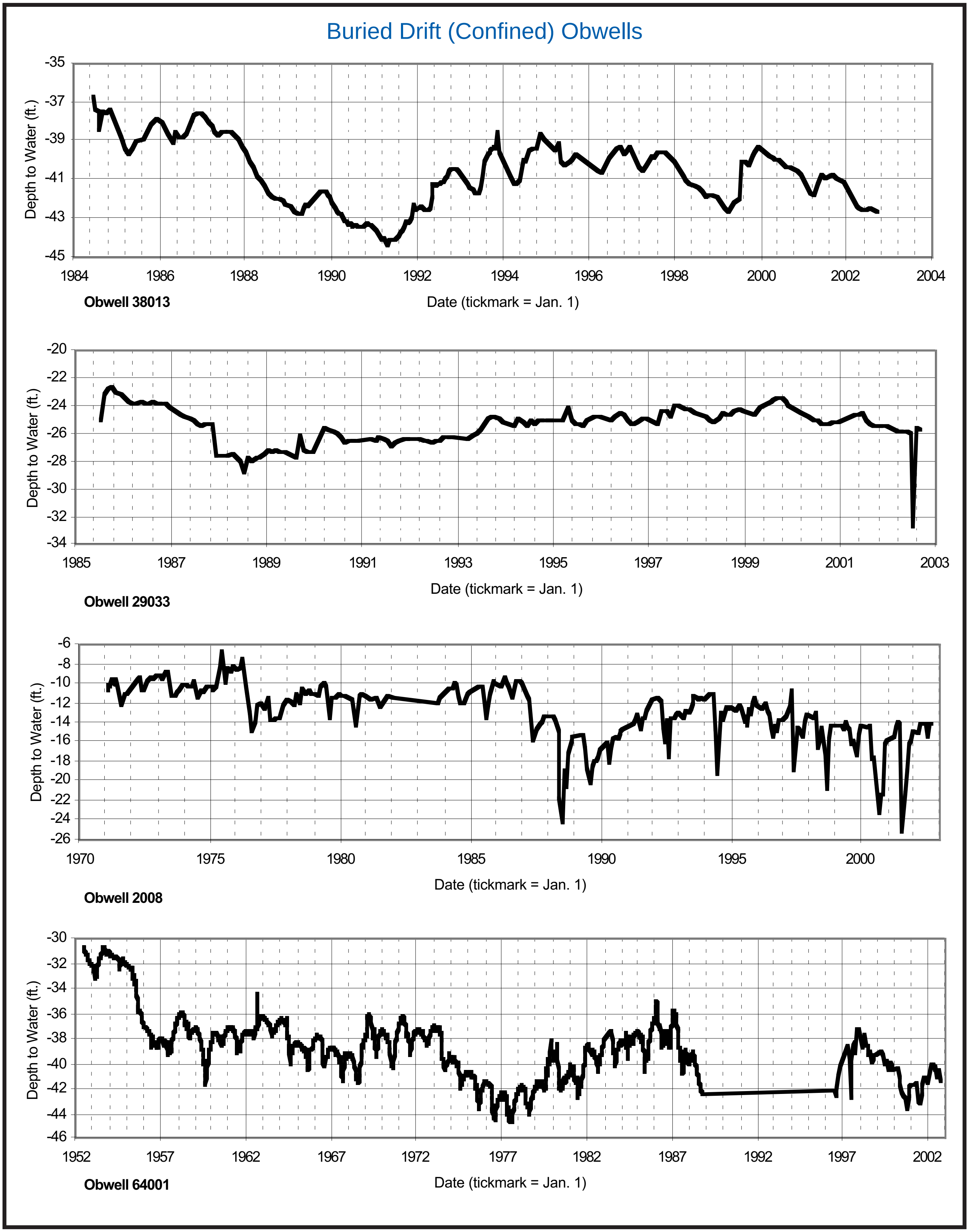


Figure 8


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

Bedrock - Mt. Simon Aquifer

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

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

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

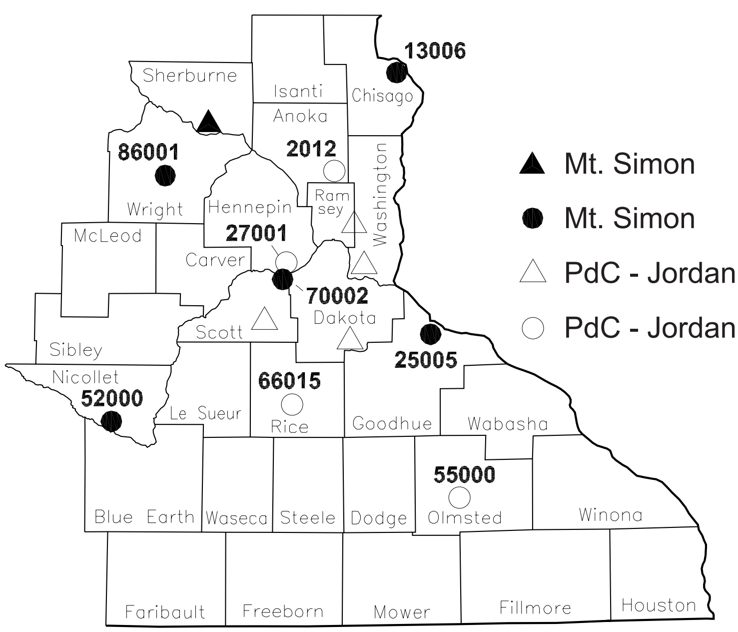
Network Improvement

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

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

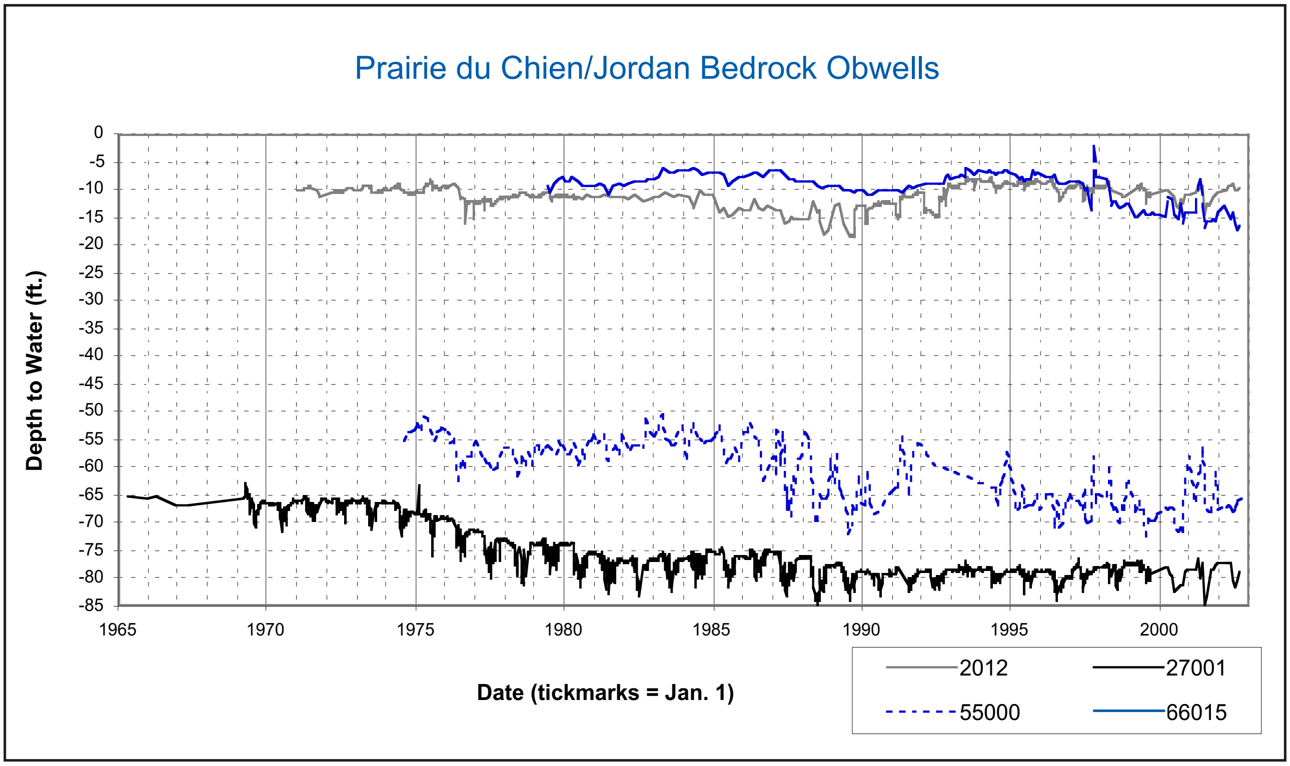
Figure 9

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

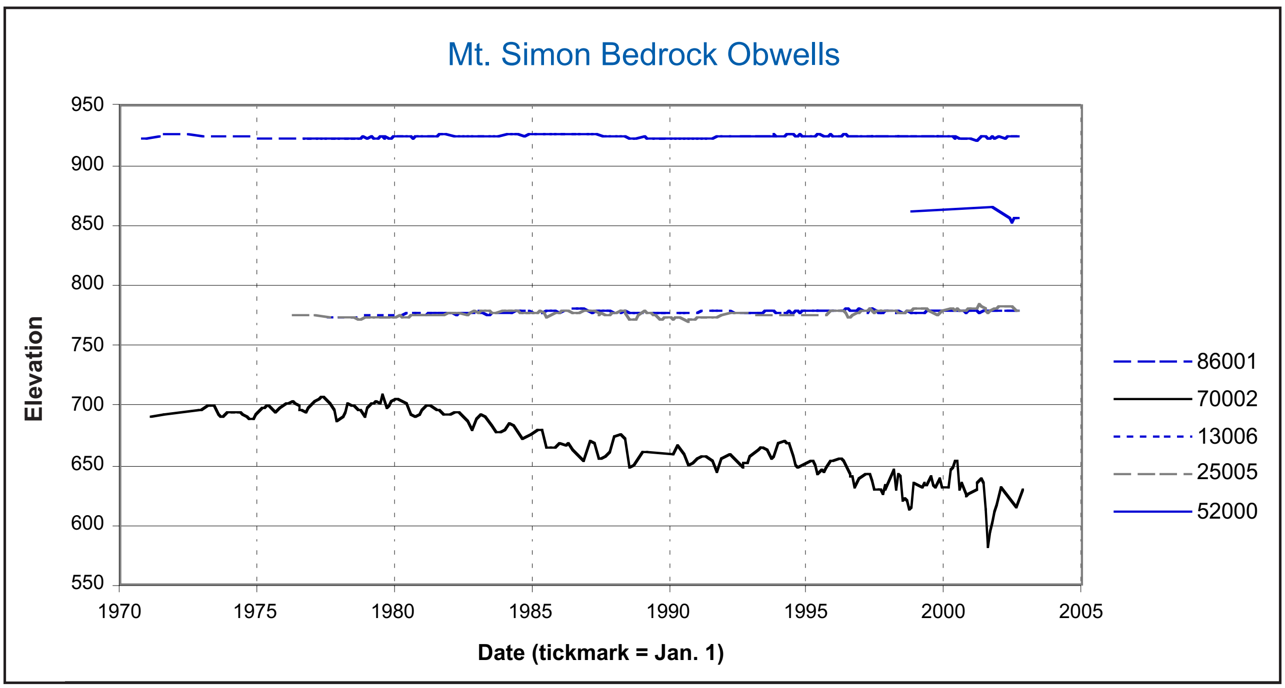


The vibrating wire piezometer, a technology used in civil engineering, has been adapted to monitor ground water levels. The piezometer is placed at the desired depth in a borehole or well and is sealed in place. Measurements are taken at the ground surface using a computer and a data logger. This technique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

Figure 10



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



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

all ground water monitoring is not the same...

What is a ground water level observation well?

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

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

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

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

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

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

• Well 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.

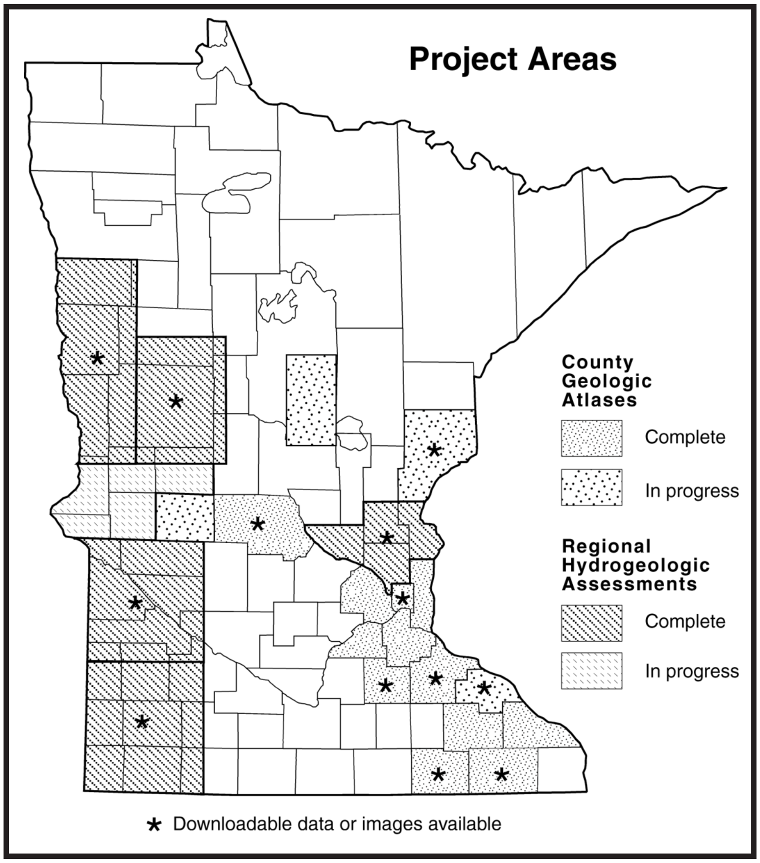
Local, state and federal water management agencies are aware of and have access to the location of the obwells. The Minnesota Pollution Control Agency is reviewing obwell locations for their newest monitoring program. The Minnesota Department of Agriculture and the Minnesota Department of Health have 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 Ground Water Level Program. Other DNR Waters data sources are also used, including climatology, water use permits, and geophysical study reports. Project staff also measure water levels in wells and collect water samples for chemical and isotopic analysis.



Data Available Online

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

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

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