1998 WATER AVAILABILITY ASSESSMENT REPORT

October 1998

Minnesota Department of Natural Resources

DNR Waters

Minn. Stat. 103A.43

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Minnesota Department of Natural Resources
St. Paul, MN

DNR Waters

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Executive Summary

DNR Waters is charged with gathering information about Minnesota water resources and regulating water withdrawals (appropriations) as well as changes to bodies of water. Data gathered by DNR Waters staff help to determine long-term trends in water availability and use. Staff in both the central office and the field help to resolve conflicts that may arise between water users. Staff are also actively involved in searching for new sources of water and safe-guarding both the quantity and quality of existing water sources. Through the County Geologic Atlas Program and other projects, water resource data are presented in ways that can be understood and put to use by local, state, and federal decision makers. This report presents some of the on-going work of DNR Waters to illustrate the water resources issues that are facing Minnesota today.

Water availability encompasses instream, inlake, and water surface uses as well as withdrawal uses. Minnesotans value lakes and rivers for recreational and aesthetic reasons as much as for the fish and wildlife habitat they provide. Because ground water and surface water are interconnected, as are water quality and water availability, understanding these connections is important to balancing both the withdrawal and inplace needs for water. Many state and local agencies have roles in the management of water and related land resources. This report notes areas of coordination and cooperation that are taking place among agencies to address common needs for safe and sustainable water resources.

A review of Minnesota's climatic record indicates that variations between drought and flood can occur at any time and any place. A broader view shows that Minnesota is midway between the more humid eastern states and the more arid west where evaporation exceeds precipitation. Because of Minnesota's position at the top of major watersheds, its renewable water supply is primarily derived from precipitation. The wide range of variation in the amount of precipitation requires planning to address these normal variations that affect the availability of water for all uses.

Water availability varies across the state, as do the demands imposed upon it. Problems of water quality and water availability both are common to southwestern Minnesota where agriculture and related industries are the major uses. Population growth in the Twin Cities Metropolitan area and the corridor from Rochester to St. Cloud are placing greater demands upon surface and ground water systems than in most other parts of the state. The karst topography of southeastern Minnesota poses other concerns for ground water sensitivity to surface water pollution. A sampling of the regional differences in water supply and demand is included in the report.

Safe and sustainable water resources depend upon local habits and decisions. DNR Waters will continue to gather information and present it in an understandable fashion so that it can effectively be put to use. We will work with local water planners, utilities, and the public at large to educate as well as address the issues of concern. Maintaining ample supplies of good quality water for use and for recreation by future generations will require participation by everyone.

1998 Water Availability Assessment Report

Introduction

This is the fourth biennial report for the Minnesota Environmental Quality Board (MEQB) on the assessment of Minnesota's water availability prepared to satisfy the requirements of Minnesota Statutes 103A.43(c).

Previous reports have looked at issues such as scarcity of water during times of drought and the various programs that have been established to help deal with them. This year, the report focuses on assessing the quantity of surface and ground water in Minnesota, its relationship to long-term physical processes, their variability, and the important interconnections among climatology, surface and ground water. Examples of various issues from across the state help show the great depth, complexity and variability that shape Minnesota's surface and ground water availability. The report ends with a look to the future in examining ways in which water availability may be conserved to meet both human and environmental needs.

Climate's Impact Upon Water Availability in Minnesota

Introduction

The impact of climate must be included in all evaluations of water availability in Minnesota. Human activity aside, surface and groundwater quantity are driven by the balance between atmospheric input from precipitation, and losses due to evapotranspiration. Very few of the watersheds in Minnesota extend beyond the borders of the State. Therefore, knowledge of Minnesota's climate patterns provides important insight into water availability issues.

Because it is located near the center of the North American continent, Minnesota is subject to a variety of air masses that make up its climate. Cold, dry continental polar air dominates the winter season, occasionally replaced by somewhat milder maritime polar air. During the summer, hot and dry continental air masses from the desert southwest share predominance with warm and moist maritime tropical air that originates over the Gulf of Mexico. The spring and fall seasons are transition periods composed of alternate intrusions of air from various sources. The diverse nature of the air masses impacting Minnesota's climate leads to a high degree of variability across space (*spatial variation*) and time (*temporal variation*).

Climate Variability over Space

The primary source of moisture for precipitation in Minnesota is the tropical maritime air that moves into the State from the south and southeast. The spatial variation of average (normal) annual precipitation across Minnesota is determined by proximity to these moist air masses coming northward out of the Gulf of Mexico. Therefore, southeastern Minnesota, averaging near 32 inches, receives more precipitation than northwestern Minnesota, less than 19 inches (see Figure 1). The normal annual precipitation for Minnesota (1961-1990) is 27.01 inches.

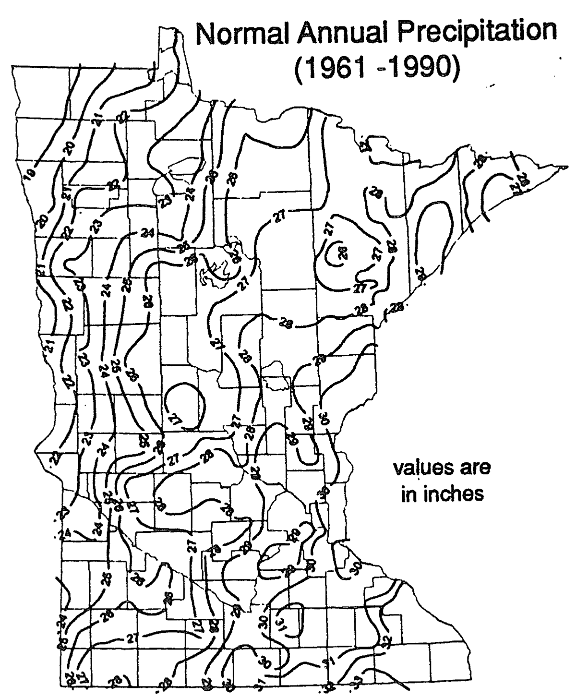


Figure 1

The presence of moist vs. dry air masses also helps to determine the atmosphere's ability to absorb water vapor evaporating from soil and open-water surfaces, or transpiring from leaf surfaces (evaporation plus transpiration is called "evapotranspiration"). Western Minnesota, more frequently under the influence of dry air masses, has higher evapotranspiration rates than the eastern half of the state. Temperature plays an important role in determining the amount of energy available for evapotranspiration. Because spatial temperature patterns are determined mainly by latitude, southern Minnesota experiences more evapotranspiration than in the north.

Due to its position on the continent, Minnesota is located on the boundary between the semi-humid climate regime of the eastern U.S., and the semi-arid regime of the west. Semi-humid climates are areas where average annual precipitation exceeds average annual evapotranspiration, leading to a net surplus of water. In semi-arid areas, evapotranspiration exceeds precipitation on average, creating a water deficit. In Minnesota, the boundary between the climate regimes cuts the State roughly into east-west halves (see Figure 2).

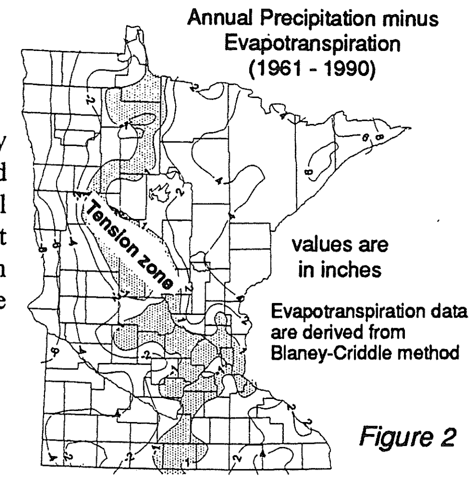


Figure 2

Climate Variability over Time

Seasonal variability occurs as different air masses are dominant. Nearly two thirds of Minnesota's annual precipitation falls during the growing season of May through September, a period during which Gulf of Mexico moisture is often available. Dry spells occur when this moisture source is obstructed or when atmospheric patterns divert storm systems around Minnesota. When hot, dry air prevails, increased evapotranspiration combines with deficient rainfall to create drought conditions. Drought can occur in all areas of Minnesota, however, it is more likely in western and northwestern areas more distant from Gulf of Mexico moisture. When Gulf moisture is abundant and numerous storms move through Minnesota, unusually heavy precipitation falls. Repeated rain events can overwhelm surface water systems, raising lake levels and forcing streams out of their banks. Singular, intense rain events can lead to flash floods anywhere in the State.

Only eight percent of average annual precipitation falls in the winter (December through February) when the dry polar air masses prevail. Yet, large scale spring flooding can occur as a result of a combination of a deep late winter snow pack, frozen soil which prohibits infiltration, rapid snow melt due to an intrusion of warm air, and heavy early spring precipitation.

East Central Minnesota Annual Precipitation

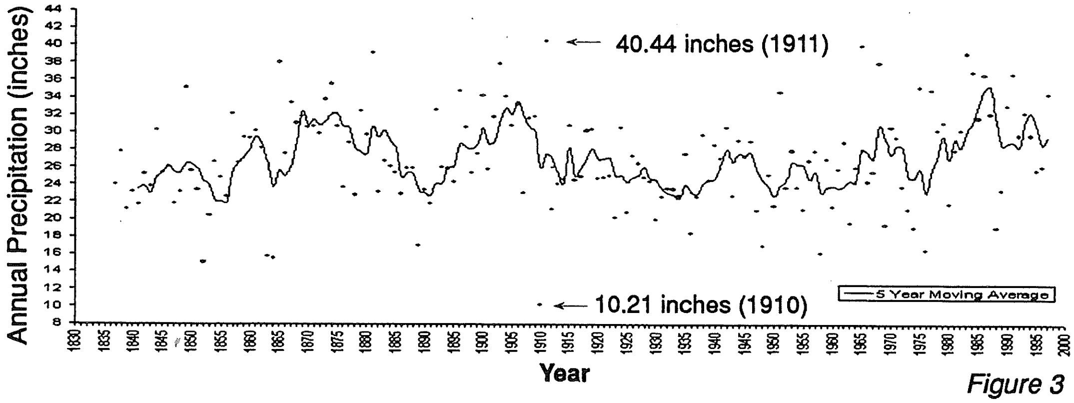


Figure 3

Given the multiple weather scenarios affecting Minnesota, wide ranges of climatic outcomes are the norm. "Normal" is merely a mid-point about which everything fluctuates. A look at one Minnesota region illustrates the point. Figure 3 depicts annual precipitation totals for east central Minnesota from pre-settlement times through the present. A striking feature of this time-series is the range of values. The lowest annual precipitation total recorded over the 161-year period was 10.21 inches in 1910. Only one year later, precipitation totaled 40.44 inches, the highest on record! Multi-year periods of similar weather also stand out in the climate record. For example, annual precipitation totals show a distinct drying pattern from the turn of the century though and including the "Dust Bowl" years of the 1930's. Note the relative lack of "wet" years over that period. Beginning in roughly 1940, the precipitation trend takes a ladder-step up to an era of tremendous variation including episodes such as the 1976 drought and the extraordinarily wet period in the mid-1980's. **It is important to note that climate extremes should not be considered as aberrations, but rather be treated as an inherent component of a continental climate**. The difficulty comes in learning to live within the extremes knowing that they are not only possible but likely to occur. Such knowledge does not prevent their occurrence, but does help to shape decisions and make plans that lessen the impact of the extremes upon human activity. When seen in this light, long-term efforts in areas such as water conservation, planning and flood damage reduction take on increased importance.

The Hydrologic Cycle in Minnesota

Water is constantly in motion on, over and underneath the earth in what is called the hydrologic cycle. Oceans cover 71% of the earth's surface and contain 97% of its water. Of the remainder, much occurs in polar and mountain ice. Only a very small amount (less than 0.6%) occurs as fresh water (atmospheric, surface and ground water). To understand water availability, one must study how water moves in response to changing conditions at both the large and small scales in time and space.

Over time, changes in land surfaces and climate have greatly affected the distribution of the earth's waters. Evidence of these changes can be seen in Minnesota's own landscape which was influenced by the great ice advances during Pleistocene times--the last, ending relatively recently--only 10,000 years ago. During the Pleistocene, there were four periods in which ice caps engulfed continents and grew to heights of over a mile. Water locked up in this ice caused the oceans to drop hundreds of feet, changing river gradients and coastlines. Then, as the ice began to melt back, great quantities of water were released to form ancient lakes and rivers. Signs of these ancient meltwaters may be seen in the lake and beach deposits of glacial Lake Agassiz and in the over-widened valley of the Minnesota River which once was its outlet. Old outwash plains, buried valley deposits and our many scattered lakes and wetlands all bear evidence to Minnesota's glacial history. By altering landscapes, reworking old material and depositing fresh, the effect of these glaciations on Minnesota's water resources--both surface and ground water--continue to this day. Much of Minnesota's surface water drainage was influenced by the work of the glaciers and their melt waters. Much of Minnesota's ground water resources occur in the surface materials that were deposited or reworked by glacial and post-glacial processes. Only the limestone karst topography of Southeastern Minnesota escaped the ravages of the ice. However, even there, the glacial meltwaters widened the Mississippi River Valley and left terraces formed of outwash material that now provide local sources for ground water.

Minnesota is the headwaters for three major watersheds. It is subdivided by the continental divide separating the Mississippi River drainage from drainage to the north and east. Water in the northwestern part of the state drains to the Red River and thence to Hudson's Bay. In the northeast, the drainage is through the Great Lakes to the St. Lawrence Seaway and the Atlantic Ocean. Much of the state drains via the Mississippi River to the Gulf of Mexico. The southwest corner drains to the Missouri River and, thence, the Mississippi. Ours is truly a Headwaters State. Essentially, what this means is that nearly all the water entering our state comes as precipitation where it either soaks into the ground to become ground water or runs off into surface lakes, rivers and wetlands. A good portion of the precipitation is stored in soil to be taken up by plants. Direct evaporation returns moisture to the atmosphere throughout the cycle.

The following figures show the 30 year average annual runoff (1961-1990). Reduction in runoff from east to west (Fig. 4) correlate with the increased evaporation and reduced precipitation shown by climatology. The high runoffs in the northeast are due to a combination of factors including climate, steep slopes and shallow soils. Figure Five distributes the average annual runoff among the three major drainage basins. If spread evenly across the state, the average annual runoff would cover the state with 5.89 inches of water.

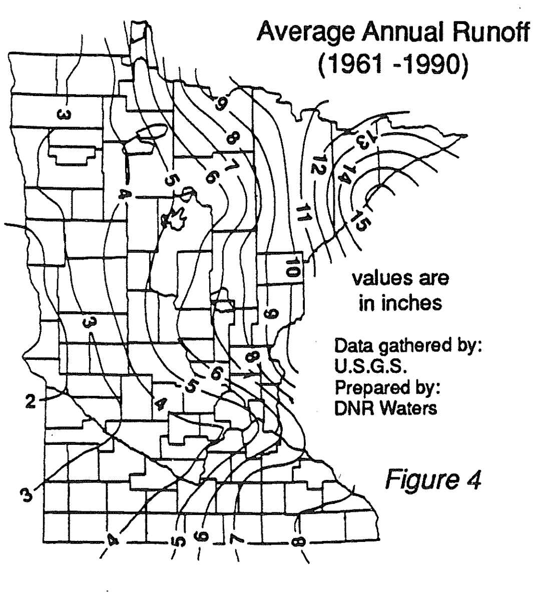


Figure 4

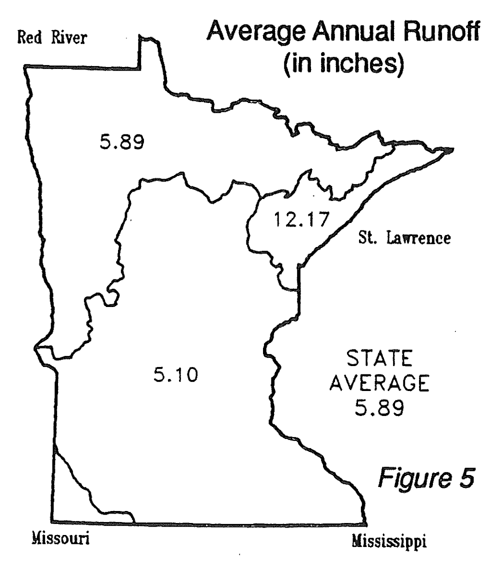


Figure 5

An estimate of ground water resources placed Minnesota's available water supply at 1.1 to 2 trillion gallons per year (Kanivetsky, 1979). If spread evenly across the state, this volume amounts to a depth of only 1.37 inches (roughly a fourth of the 5.89 inches of annual surface water runoff or 5% of the normal annual precipitation).

Surface/Ground Water Interactions

The following three examples show some of the interrelationships between surface and ground water and their connection to precipitation and climate changes.

White Bear Lake

In response to widespread concern over low water levels on White Bear Lake, the Legislative Commission on Minnesota Resources (LCMR) provided funding to DNR Waters to conduct a study of the problem and investigate the causes of these level fluctuations.

As part of the study, lake levels were compared with ground water levels in observation wells located north and south of White Bear Lake in different aquifers. The data extends from 1973 to 1997. As can be seen in Figure Six, fluctuations in all the observation wells correspond to the fluctuations of the lake. The timing of extreme highs and lows in all are essentially the same. Ground water levels are higher north of the lake and lower to its south. This indicates that the slope of the ground water table is to the south.

The close correspondence between surface and ground water fluctuations indicates that the lake is a window in the local ground water flow system and, over the long term, lake levels are dependent on ground water levels.

Short term variations in lake level, not seen in the ground water levels, are due to factors that directly impact the lake such as precipitation, runoff and evaporation. Vertical exaggeration in this and other graphs is used to help identify correlations.

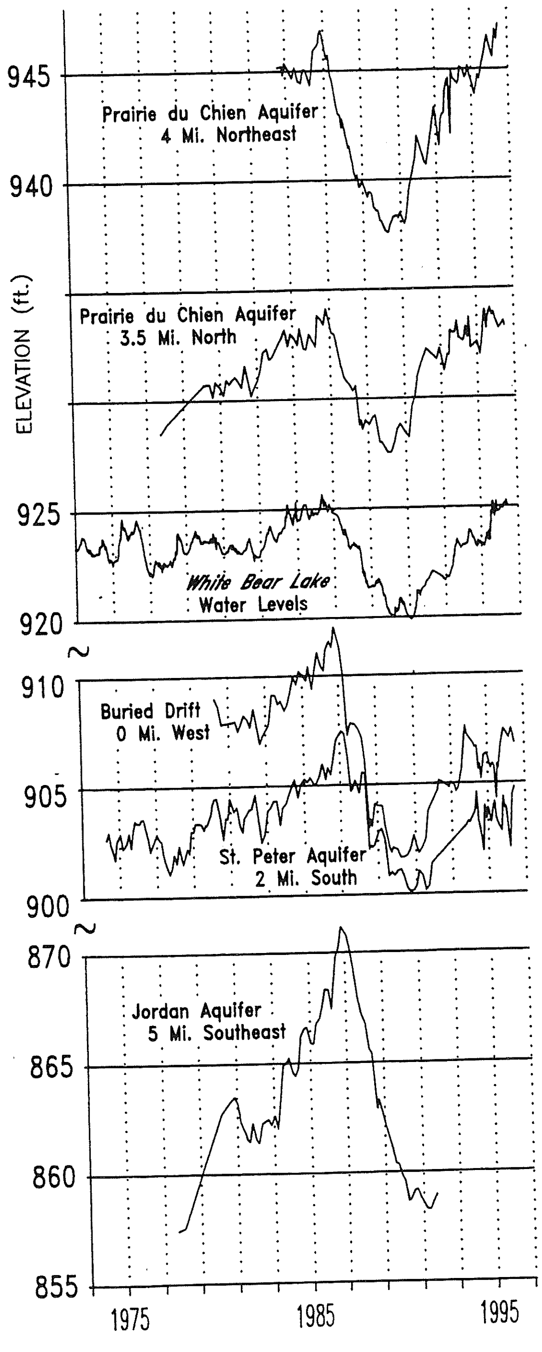


Figure 6

Dependence on ground water levels can be true of other surface water resources, most markedly, trout streams which maintain clear, cold stream flow thanks to the constancy of ground water outflow. DNR Waters is continuing to investigate impacts to ground water, surface water and the interrelationships between them.

Savage Fen, Scott County

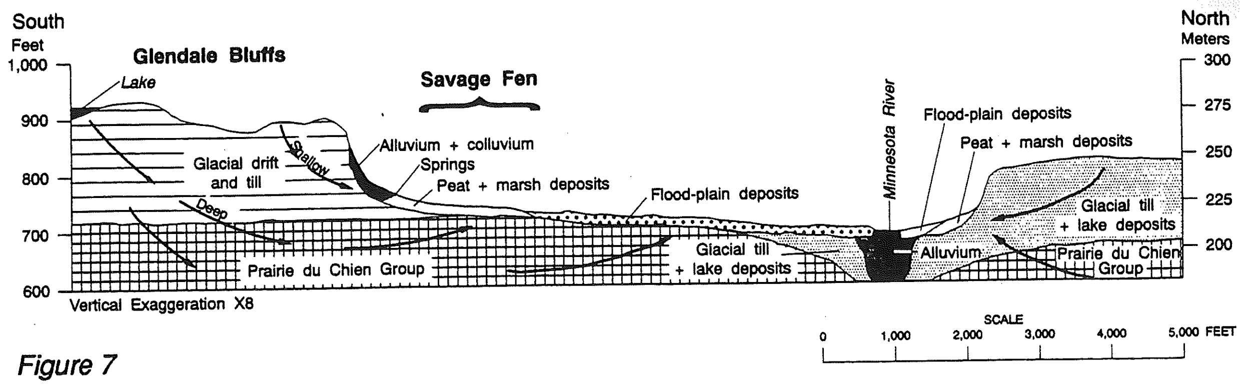


Figure 7

Extensive wetlands once blanketed the side slopes of the Minnesota River Valley. These wetland complexes were sustained by ground water seeping out of the valley sides. All of the near surface aquifers in the area are considered potential sources of water to these wetlands. Savage Fen (Fig. 7) is one of the largest remnants of that system. This calcareous fen is home to an unusual number of rare species of plants. Other ground water sustained features in the area include Eagle Creek, a designated trout stream. In recognition of the vulnerability of these ground water dependent features, the City of Savage conducted an alternative urban area wide review (AUAR) to guide its development. Regional planning for the Southwest Metro Area is now underway to guide the future development of water supply systems in the communities dependent upon the same ground water as the fen and trout stream. The situation is complicated by the fact that these communities are also experiencing increased growth which is placing greater demand upon the ground water supply system.

Pomme de Terre River, Swift County

The Pomme de Terre River was chosen because of its long period record of flow data coupled with adjacent precipitation and observation well data.

As shown in Figure 8, river flow (mean annual runoff) and ground water level both follow the same trend as precipitation. In addition, nearby Lake Oliver in northwestern Swift County has risen eight feet in the past four years. Lake Oliver is one of many landlocked lakes (lakes without an established outlet) in western Minnesota that have been on the rise since 1993. It is not graphed because of its relatively short period of record. As with many landlocked lakes, Lake Oliver appears to follow local ground water fluctuations.

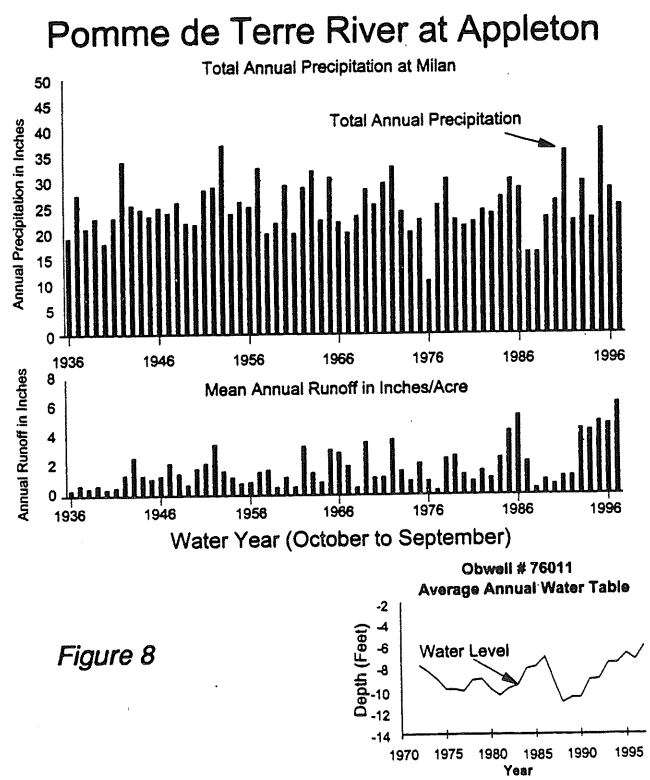


Figure 8

Notice that for the period of 1993-1997, the lake level, mean annual runoff (river flow) and the average annual ground water level (obwell measurements) have continued to rise while the total annual precipitation has fluctuated. This could be due to a number of factors such as timing and intensity of storm events, relationship to soil moisture, and lag between precipitation and ground water/base flow.

Representative Areas of Concern Across the State

Because of the overarching effect of weather variability upon all of Minnesota's water resources, it can safely be said that all the work that DNR Waters does--from water permits and land use decisions to technical analysis of surface and ground water concerns--is influenced by it. Differences in physical landforms and subsurface materials contribute variability in storage and runoff in addition to the variable nature and location of human enterprises. The following descriptions and examples provide a sampling of the broad issues DNR Waters is attempting to address.

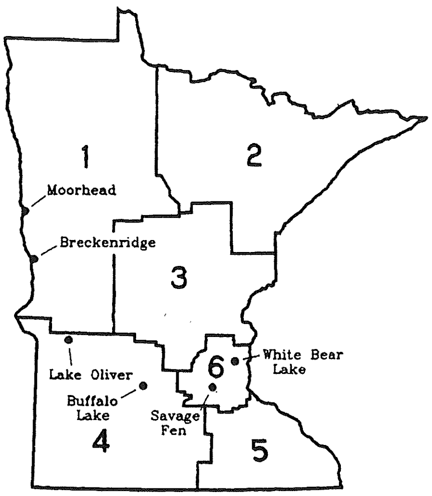


Figure 9

Region 1.
Northwestern Minnesota was once largely covered by glacial Lake Agassiz. The flat terrain and rich, poorly-drained soils have provided both incentives and problems for agriculture and other forms of economic development in this part of the state. Deep bedrock aquifers are generally not used because of poor water quality. The Red River Valley is still suffering from the after-effects of the 1997 flood. Shallow ground water levels and water levels in landlocked lakes are high. Increases in potato farming in sandy soils are being closely monitored for their effect on surface waters and shallow ground water resources--particularly, the possible introduction of nitrates. Collaborative groups involving agencies from both North Dakota, Minnesota, the Federal Government and Canada, local watershed districts and units of government and stakeholders are coming together to deal with the complicated issues involved.

Region 2.
Much of the northeast is covered by bedrock and/or a thin veneer of surficial materials reworked by the glaciers. Because of the relatively abundant surface water resources in the northeast, water availability has, to date, not been a major issue for the main economic activities of timber harvesting, wood/paper processing and the mining industry. Refinements to the protected flow program will provide limits to surface water appropriations during periods of low precipitation or drought. Low water levels in lakes and streams can impact not only natural systems, but people where they live, work and play. Fluctuations in water levels in lakes and rivers and the fire hazards in dry forests are a source of concern for tourism and recreation interests.

Region 3.
Central Minnesota is known for the large number of lakes which draw people in to both live and visit. It is a major recreation area for both residents and tourists. There is a growing belief that these lake resources will not maintain their resource quality with increased development and use. New ways to account for watershed-based impacts must be developed. The counties located immediately north of the Twin Cities are experiencing large blocks of urbanization as part of the population growth corridor that runs from Rochester through the Twin Cities to St. Cloud. Population growth in the St. Cloud area is putting new strains upon both the natural resources and human resources and infrastructure. Demand for ground water resources will generate conflict between agriculture and urban growth. This growth and the new expectations being brought by the people will continue to challenge traditional water management activities such as the management of the public ditch systems and wetland preservation. Rivers, for the most part, still remain an undiscovered water resource to those seeking to develop and urbanize. Careful attention needs to be given to the preservation of resource values within these systems.

Region 4.
Agriculture and related industries are the major economic resources for this important food producing area of the state. Rural water supply systems have been set up to help deal with the problems of limited water supplies and poor quality water. The limited supply of quality water is resulting in increased competition and conflicts as communities strive to find inexpensive sources that will allow them to support competitive economic growth in business and industry. However, the desire to provide a boost to the region by encouraging new industries and other economic incentives must be balanced with other users and uses for present and future generations. The search for reliable sources of quality water coupled with improved economical technology in water treatment will be necessary to ensure that long-term sustainability of the environment, economy and communities is realized. Like northwestern Minnesota, the southwest also suffers from the after-effects of recent severe flooding that affected

many communities and counties. Additionally, the relationship between drainage and agricultural flooding needs significant attention to help understand and preserve optimum agricultural productivity while minimizing impacts to natural and human systems. Current practices and lack of comprehensive oversight are causing an increasing economic burden to society and downstream landowners as well as impacting natural resources.

Region 5.
The primary water supply source for the region is ground water. Adequate supplies are generally available, although care has to be taken to avoid grouping high capacity withdrawals from the same aquifer. Use of the uppermost aquifer (referred to as the upper carbonate aquifer of the Paleozoic Era) will be limited because of the high risk of contamination due to poor land practices, spills and other contaminant releases. A common perception of this upper aquifer is that it is now polluted and not a reliable source of quality water, although it does provide quality water for some communities and individual residences. Most of the high capacity withdrawals, however, come from deeper, older formations which are less subject to contamination and provide a better quality of water.

The bedrock aquifers also provide base flow for the many high quality trout streams in southeastern Minnesota. However, the trout streams fed by the springs originating in the fractured limestone formations are also vulnerable to contamination. The character of the formations can allow any contaminants that are introduced by way of sinkholes or infiltration to travel rapidly and become part of the spring discharge to the stream.

The surface water resources of the region--from the Mississippi River in the east to the shallow lakes and wetlands in the west and the spring-fed trout streams within its many valleys--are appreciated for both their recreational and aesthetic value. However, the shallow lakes and wetlands are also subject to contamination and over-fertilization from adjacent land activities. To conclude, the amount of water available for use in southeastern Minnesota is just as dependent upon sustaining good water quality as it is upon sustaining water quantity.

Region 6.
The Metro Region continues to experience rapid growth in its expanding suburbs. Most of these areas rely solely upon ground water for their public water supply. This reliance on ground water is putting strain upon the remaining natural resources (trout streams, fens, etc.) that are also dependent upon ground water. If growth continues as predicted, it is possible that the sustainable yields from good quality Twin Cities aquifers may be exceeded. Adverse impacts would result on the natural resources of the area, and water production costs would greatly increase. On-going, concerted efforts in water conservation and education as well as better coordination and planning among local water suppliers are needed to prevent this potential negative outcome.

Southwestern Minnesota

Interagency Cooperation in Resolving Nitrate Problem in Southwestern Minnesota

The Lincoln Pipestone Rural Water Supply District (LPRW) serves 24 communities and 2830 farms in southwestern Minnesota. Three well fields have been developed. Two pump from shallow sand and gravel aquifers. Water tables often lie within ten feet of the ground surface. DNR Waters rated the geologic sensitivity of these aquifers to pollution as VERY HIGH which means that waterborne surface contaminants would reach the aquifers within hours to months. Deeper water supplies have not been used because the high sulfate content makes them costly to treat.

The Verdi Well Field was completed in 1979 and consists of five wells in a semi-confined aquifer within the Silver Creek Watershed. Its wells have always tested relatively high in nitrate-N, but below the national drinking water limit of 10 parts per million (ppm). Recently, nitrate levels have been observed to be approaching the 10 ppm limit.

The Holland Well Field also consists of five wells and was completed in 1989. It is located in unconfined sand and gravel deposits of an old glacial stream channel that was cut into the surrounding glacial clays. This field serves the southern third of the District. In July, 1997, the District sent warnings to approximately 1000 households that the national drinking water quality standard for nitrates had been exceeded (a measured value of 12 ppm nitrate). The Burr Well Field located west of Canby was completed in 1995 in the Prairie Coteau Aquifer. Its deeper wells are less sensitive to nitrates. Increased pumpage, however, could affect local lakes and wetlands that are sustained by the Prairie Coteau Aquifer.

The Minnesota Department of Health (MDH) convened an Interagency Technical Work Group in the summer of 1997 to deal with the growing problem of nitrates in the LPRW system. Agency representatives from MDH, DNR Waters, Minnesota Department of Agriculture (MDA), Pollution Control Agency (PCA), and the Board of Water and Soil Resources (BWSR) all participated in this work. The Technical Committee submitted a report on December 9, 1997. Efforts to characterize the hydrogeology and nitrate concentrations in the surface and ground water of both well fields are ongoing. Potential sources for nitrate pollution including abandoned feedlots, tile lines and agricultural practices are also being investigated. LPRW is determining the capture zones of the Holland and Verdi Well Fields. This information will be used for the wellhead protection plans for the two well fields that will be developed for MDH approval.

The PCA is developing feedlot management guidelines which will be especially useful for areas within wellhead protection. DNR Waters is prepared to limit pumping through its water appropriation permits if it is determined that drawdown is causing nitrates to be drawn into a public water supply from surface sources. MDA will work with the University of Minnesota to develop best management practices for shallow soils overlying shallow aquifers. These practices will involve better nutrient management. Through a concentrated, on-going effort by all parties including the agencies, the Water Supply District and the farm operators, it may be possible to safeguard the quality of this local water supply.

Ground Water Exploration Project

The 1995 Legislature funded this project from a proposal initiated by the Minnesota Water Well Contractors Association. Exploratory drilling was undertaken to characterize the geologic and hydrologic conditions in southwestern Minnesota where water supplies are difficult to locate. Five local major water appropriators participated with DNR Waters on a cost share basis. A total of 29 test holes with depths ranging from 120' to 979' were drilled, logged and then sealed. (Figure 10).

Results from this project will help local drilling efforts to find additional ground water resources in this part of the state. Funding received from the 1998 Legislature will allow DNR Waters to continue exploratory drilling and to install observation wells for water level measurement.

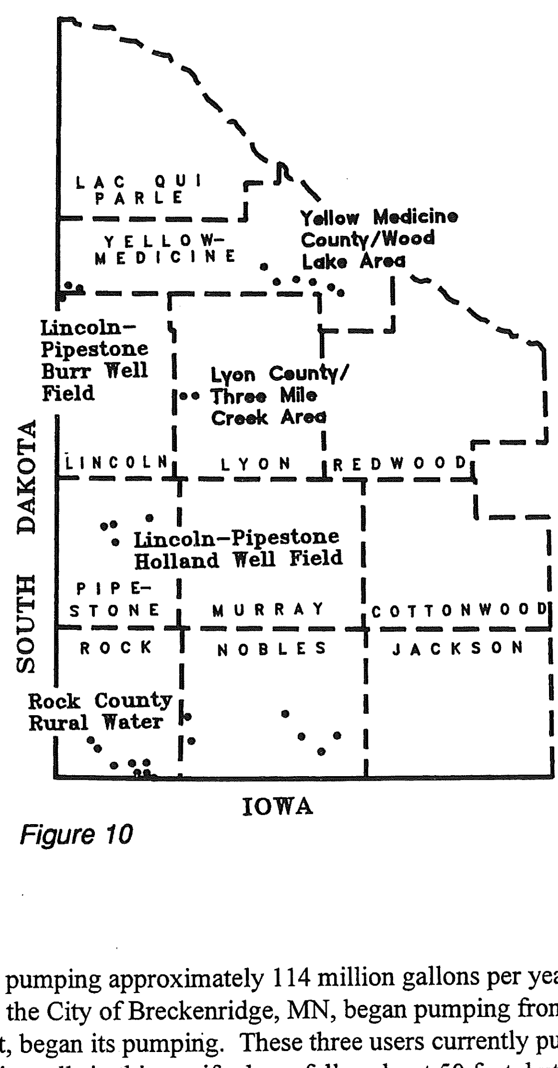


Figure 10

Northwestern Minnesota

Wahpeton Buried Valley Aquifer (Breckenridge)

In 1973, the City of Wahpeton, North Dakota, began pumping approximately 114 million gallons per year (mgy) from the Wahpeton Buried Valley Aquifer. In 1978, the City of Breckenridge, MN, began pumping from the same aquifer. In 1986, MN DAK, a sugar processing plant, began its pumping. These three users currently pump about 586 mgy from the aquifer. Since 1973, water levels in wells in this aquifer have fallen about 50 feet, but appear to have stabilized. In 1996, the North Dakota State Water Commission permitted Pro Gold, Inc. (Now Cargill, Inc.) to pump up to 977 mgy from the aquifer when the Red River is below 40 cubic feet per second (cfs) in winter or 80 cfs in summer.

In response to what could be a potential local water shortage, DNR Waters and the ND State Water Commission have begun a joint study of the aquifer. Twenty-two monitoring wells or test holes have been installed in Minnesota and eight in North Dakota to determine the size and location of the aquifer and its relationship to other aquifers in the area. An additional fifteen to twenty test holes are planned for installation in the fall of 1998. Data gathered from the test drilling and monitoring of water levels and water chemistry will be used to develop information on the aquifer's sustainability. A report containing the results of this work will be completed during the winter of 1998-'99. (Figure 11).

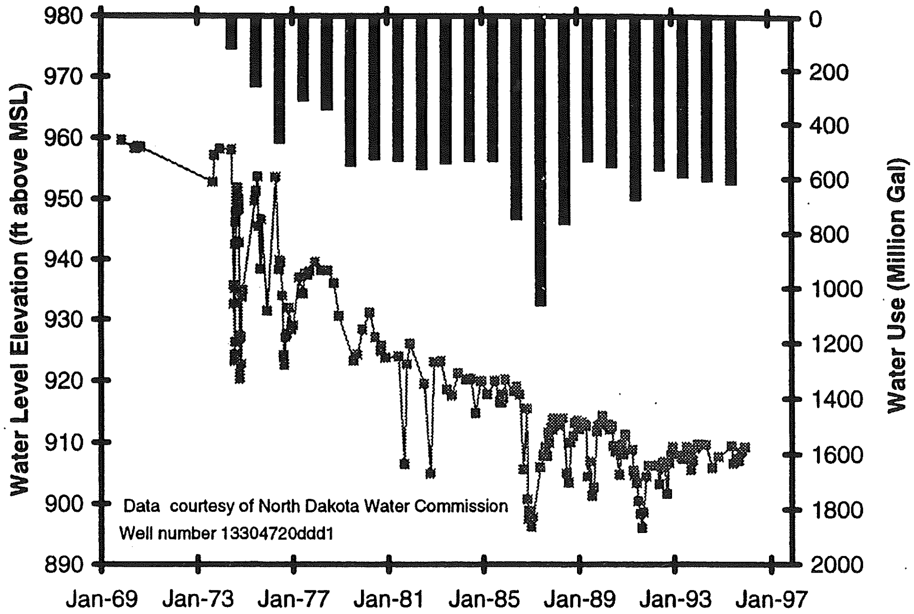


Figure11. Wahpeton Buried Valley Aquifer.

Conjunctive Use of Surface and Ground Water Sources (Moorhead)

The City of Moorhead is one of a few Minnesota cities that have chosen to use both ground and surface water in combination (conjunctive use) for its drinking water supply. Historically, 60 percent of all water appropriated by Moorhead came from the Red River of the North. This will increase to 80 percent when the new water treatment plant is completed. Ground water generally requires less water treatment for drinking water use than surface water, which is why it is preferred by most public water suppliers if given a choice between using surface or ground water supplies.

As Moorhead has grown, it has tried various sources of water to meet its needs. The Red River was the sole source of water until wells were installed in the West and East Moorhead aquifers. These wells were the sole source of water from 1918-1947 when the West Moorhead aquifer wells failed and the City was forced to ration its water.

Fortunately, the U.S. Geological Survey had begun an extensive test drilling program in the Buffalo Aquifer for Moorhead in 1946 in anticipation of the problem. Water from the Buffalo Aquifer was added to the City supply in 1948. Wells in the East Moorhead and Buffalo aquifers provided an adequate water supply until extensive water level declines in the Buffalo Aquifer (Figure 12) prompted the City to again use Red River water in the 1960's. In 1988, based partially upon seismic exploration work conducted by DNR Waters, the City drilled additional wells in the Buffalo Aquifer. Presently, Moorhead draws water from two well fields in the Buffalo Aquifer, one in the East Moorhead Aquifer, and from the Red River. Conjunctive water use has enabled the City of Moorehead to meet its water needs in an area of limited ground water resources and variable surface water supplies.

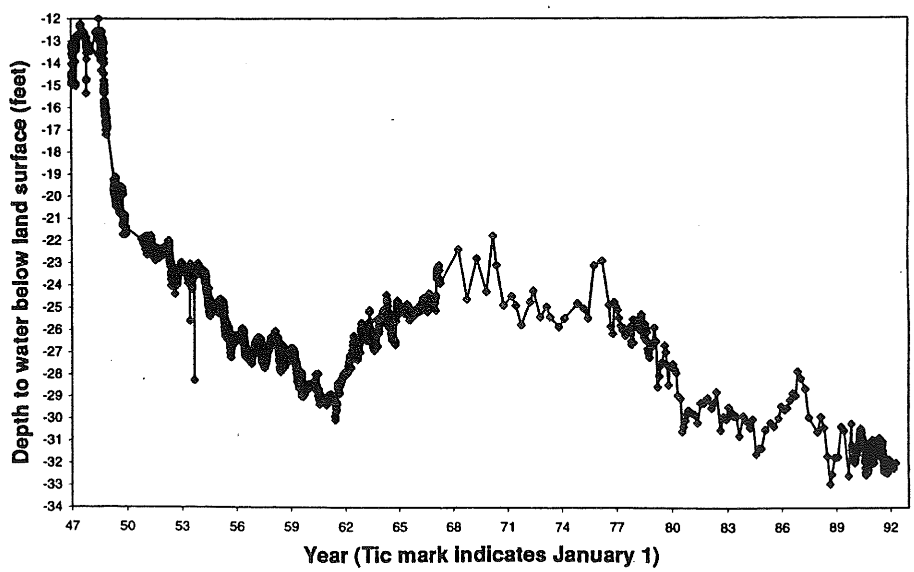


Figure 12. Decline of Buffalo Aquifer.

Northeastern Minnesota
Management of Minnesota's Newest Large Lakes and Their Watersheds

Natural ore and taconite mining on the Mesabi Iron Range has created numerous, large, open pits. Today, some of these pits exceed five miles in length and a mile in width. Future mining over the next several decades will create even larger pits, some perhaps exceeding 15 miles in length. Each pit collects large amounts of surface and ground water inflow.

After abandonment, water will evaporate from the water surface in the pit, and some will leave as ground water outflow when the water level rises into the glacial drift. These two losses, for most large pits, are not expected to balance inflows. The result is that the pit water level will rise to the lowest rim elevation and spill out as surface water outflow. Outflow locations need to be identified, and outflow characteristics quantified throughout the life of each mine so that proper planning can be conducted, including an evaluation of downstream impacts and mitigation of the expected new flows.

Formation of these large pit lakes creates an opportunity to provide thousands of acres of additional surface water for a variety of public uses. Potential biological productivity of future pit lakes could be enhanced through selective in-pit stockpiling during active mining to create a littoral zone. An understanding of the hydrology of each pit is necessary in order to predict future water levels for in-pit stockpile design, and in order to model potential outflow for outlet design and downstream impact evaluation. Funding has been requested to continue to study these resources and develop a plan for the future of these "new" bodies of water.

Southeastern (SE) Minnesota
County Geologic Atlas Program and Field Studies

The County Geologic Atlas program began about 1980 with Scott County. Since then, nine other atlases have been completed either in the Twin Cities metro area or to the southeast, in the area of the Paleozoic bedrock aquifers. Of the five additional atlases currently underway, three are in SE Minnesota. Although these atlases cover only 8.5 percent of Minnesota's area, they include over half (53.1 percent) of its population.

A County Geologic Atlas is a systematic study of geologic and ground water resources. Geologic studies of surficial deposits and bedrock define the framework within which ground water resources occur and, to a large extent, the water resource properties of the respective aquifers. The ground water studies describe flow systems, aquifer properties, water chemistry and age, and potential for contamination.

Atlases include maps, data, and text describing aquifers and water resources. Maps of aquifer potential yield are usually included in each atlas. Maps of saturated thickness were prepared for the Dakota and Rice County atlases. The Rice County atlas also included an interpretation of recharge conditions. Analysis of isotopes in ground water samples helps to provide insight into ground water recharge, flow systems, and surface /ground water interactions.

Atlas maps of hydrogeology and sensitivity help planners and managers better understand ground water resources so they may protect ground water resources for public needs. The maps help identify areas where there may be limited availability of ground water or potential for conflicting uses. Atlas studies and maps can also assist in the evaluation of the effect of ground water usage on surface water resources. Training workshops and field trips conducted by DNR Waters staff at the completion of each project help introduce users to the information in each report and provide staff-guided exercises based on real-world applications.
Generally, in SE Minnesota, an adequate water supply can be obtained from the Paleozoic bedrock aquifers that underlie the entire region. Yields range from 300 to 1000+ gallons per minute depending upon the formation and its characteristics. In a few areas, the Mississippi River terraces in the east and Wisconsan age glacial deposits in the west, water can also be obtained from sands and gravels for both domestic and high capacity wells.

Traditionally, SE Minnesota was considered to have four aquifers, the uppermost informally called the "Upper Carbonate." Regional DNR Waters, working with Minnesota Geological Survey and University of Minnesota Geology Department staff have found that this aquifer can be subdivided into as many as four distinct aquifers.

The limestone karst topography of SE Minnesota is the source for unique problems of ground water quality and flow. Regional DNR Waters staff have done many ground water traces using fluorescent dyes to evaluate these problems. These traces have provided information on ground water flow direction, travel time, and hydrogeologic sensitivity. Dye tracing has also been used to evaluate the impacts of road construction and drainage work on caves and springs. Karst hydrology investigations using dye tracing continue in Fillmore County and Mower County in conjunction with the South Branch Root River Clean Water Partnership project and the Mower County Geologic Atlas program.

Figure 13 shows dye concentration versus time at the Lanesboro State Fish Hatchery. The hatchery had been plagued by poor water quality in its springs after runoff events. This trace demonstrated that runoff water was entering a sinkhole 2 1/3 miles away and traveling to the hatchery underground in approximately ten hours. This demonstrates how rapidly surface contamination can impact ground water resources in karsted terrain.

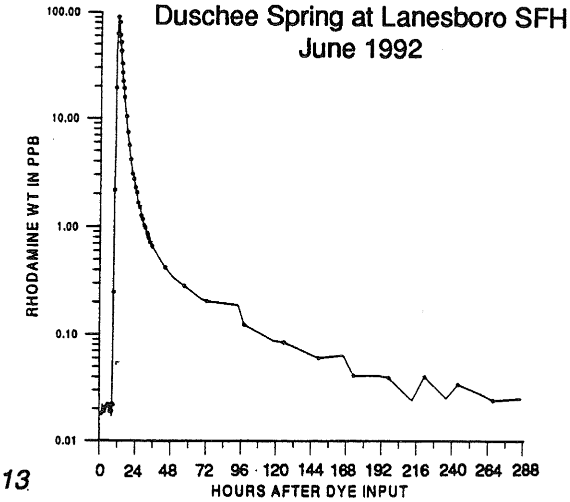


Figure 13

South Central Minnesota
Buffalo Lake

In 1997, an ethanol plant in Buffalo Lake, Renville County, drilled two wells into a thin, buried aquifer which is also the source of water for the City of Buffalo Lake and adjacent domestic and agricultural users. As shown in Figure 14, an average pumping rate of 600,000 gallons per day resulted in a drop of approximately 60 feet in the observation well in the aquifer. This, in turn, caused numerous cases of well interference with adjacent wells. Lower winter pumping rates and a switch to mechanical cooling allowed some recovery of the ground water level by the spring of 1998.

Both pumping rates and water levels will continue to be monitored to ensure the sustainability of this limited local resource of ground water.

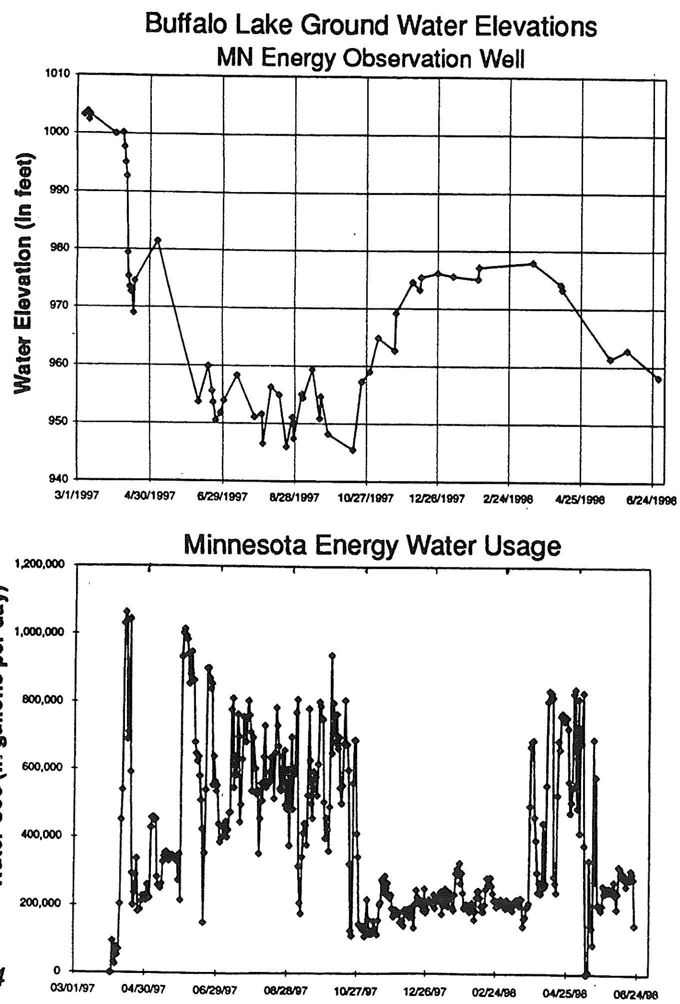


Figure 14

Twin Cities Metropolitan Area (Metro)
Water Availability Issues

Water availability is becoming a major issue in the Metro Region. At least five factors are involved:

1. Contamination of upper bedrock aquifers by surface pollutants limits their full availability;
2. Legal protection afforded to unique water resources, such as calcareous fens, trout streams and wetlands, requires the DNR to limit appropriations that adversely affect these resources;
3. Provisions of State law (M.S. 103G) limit use of the Mt. Simon/Hinckley (MTSH) aquifer;
4. Enforcement of EPA standards for radium will require additional treatment of some aquifer waters and may lead cities to seek alternative water sources;
5. Rapid growth in second and third tier suburbs is increasing demand in areas dependent upon ground water.

A number of major suburbs are currently looking for replacement sources of ground water due to contamination of the Prairie du Chien/Jordan Aquifer by various sources. While the water can be treated, as the U.S. Army is doing for the City of New Brighton, the treatment costs are high, and it is generally cheaper to drill new wells into the deeper Franconia Ironton Galesville (FIG) or MTSH formations to blend with or replace the contaminated wells. The FIG is an unknown source of water in many parts of the Metro due to variable yields. Thus, there is pressure on the state to ease the restrictions of M.S. 103G and allow use of the MTSH.

The high growth communities in the southwestern part of the Metro (Shakopee, Savage, Prior Lake and Burnsville) also face the contamination issue to some degree, but additionally have a number of calcareous fens and trout streams that are fed by the Prairie du Chien/Jordan Aquifer which is currently the main water source for these communities. These resources are protected by the Wetland Conservation Act and other laws which require the DNR to manage the effects of human activities in order to limit impacts upon them. Studies indicate that current uses are adversely affecting the fens. One alternative would be to draw more water from the MTSH, but this conflicts with the MTSH limitations. The Metropolitan Council is facilitating a team of City and Agency representatives to develop water management/supply options.

Some cities, such as Blaine, Forest Lake and Medina are more affected by the MTSH restriction than others. Traditionally, these communities have relied solely on the MTSH for water supply. Other supply options have not been fully examined. If the provisions of M.S. 103G were strictly interpreted, the state should be requiring these cities to limit MTSH use which might restrict growth, particularly, industrial and commercial. The state has instead chosen to develop a process that allows variances to these prohibitions, provided the cities make extra efforts to conserve water and look for alternative sources of water.

With 109 municipal water utilities supplying 122 communities in the Metro Region, the challenge has been to encourage community cooperation in resolving and safe-guarding water supplies for the entire area. Water is a resource and commodity that each community depends upon for both its development and revenue. Differences in pressure, pipe sizes and water quality make interconnections between communities or ground and surface waters difficult to achieve. While it may not be feasible to create a water supply system for the entire region, greater cooperation in forming subregional water supply systems is needed in order to safeguard future water availability.

On the positive side, these circumstances have encouraged many cities to improve their water conservation efforts. Through water conservation, cities, such as St. Louis Park and Edina have been able to keep their water appropriations from increasing. Other cities, through aggressive leak detection and other means, have been able to reduce their unaccounted-for water use by large percentages. Some cities have been able to eliminate the need for costly new wells by changing rate structures and billing procedures, and through public education about water conservation, all of which serve to reduce peak water usage. These efforts have just begun, but the benefits will continue to grow as agencies and municipalities increase their understanding of how best to ensure sustainable water for all users.

Water Use Trends

Water availability, in addition to climate is, in part, determined by water use. As with climate, water use varies both in space and time across the state. This report considers only the consumptive use of water--that is, water which is taken from its source and not returned directly to the source following its use.

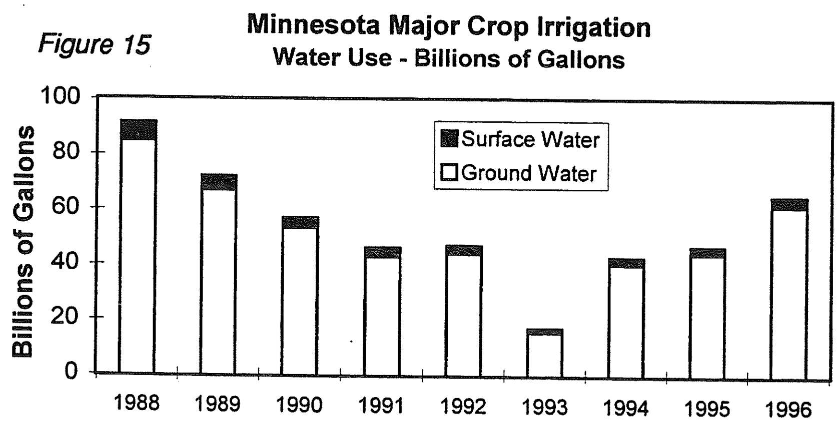
Water use trends analysis can help to identify possible future problem areas. For purposes of this report, only major water use trends are considered. Information is based upon data reported by water appropriation permit holders and from Jerry Wright, Minnesota Extension Service, Morris, on the number of irrigated acres of farmland in Minnesota. The change in the number of active permits in major water uses from 1994 - 1998 is shown in Table One. The slight reduction in the number of public water supply permits is due largely to systems consolidation (rural water supply systems, etc.).

Table 1. Change in the Number of Active Permits in Major Water Uses from 1994 to 1998.

	Number of Active Permits	
	1994	1998
Public Water Supply	970	944
Industrial Processing	407	438
Agricultural Irrigation	3807	4053
Once-through Cooling	105	60

Once-through Cooling. The downward trend in once-through cooling systems reflects the legislation passed in 1989 which requires this use to be phased out by the year 2010. Since 1989, once-through cooling has dropped from a total of 11 billion gallons per year (bgy) to 5.3 bgy in 1996. By reducing this wasteful and inefficient use of high quality ground water, more water is made available for higher priority uses--especially, in the Twin Cities Metropolitan Area.

Figure 15



Agricultural Irrigation. (Figure 15). Numbers of DNR permitted irrigated acres of farmland increased from 23,000 acres in 1965 to 470,000 acres in 1980. For the last ten years, the number has gradually increased to about 520,000 acres, suggesting a leveling off in the growth of irrigated farmland. Actual water use, however, depends upon seasonal variations in precipitation. Less water is used during wet years than dry.

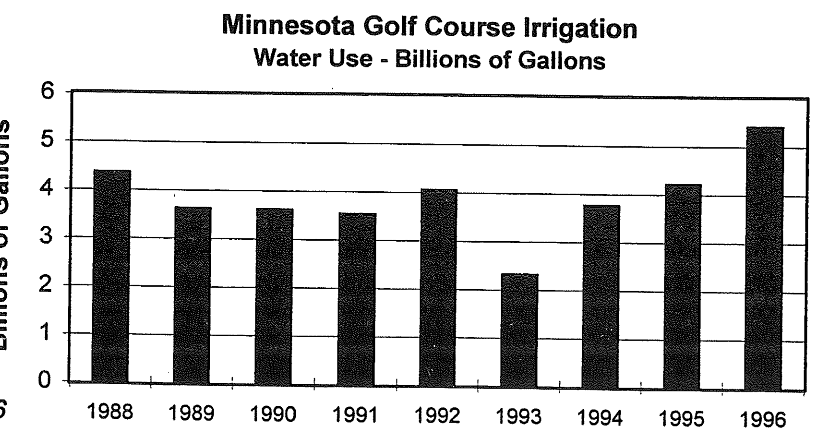


Figure 16

Golf Course Irrigation. (Figure 16). Although golf course water use is small in comparison to other seasonal uses of water (agriculture irrigation and lawn watering), the number of Minnesota's golf courses is rising and so is water use. Water conserving designs and proper turf management help, but expansion of irrigation to water roughs adjacent to greens does not.

Public Water Supply. (Figure 17).
Trends in public water supply usage follow similar patterns to agricultural irrigation and golf courses. Use varies both by season and by year. Water use peaks during the summer, primarily, due to lawn watering, considered a non-essential use. During dry years, more water is used. During the period of 1988-1996, the 1988-89 drought produced the most marked effect. In 1988, the statewide summer peak was two times the winter average use. In 1989, it was 1.8 times the winter average. In comparison, the summer peak in a wet year such as 1993 was only 1.3 times the winter average use for that year. These figures are more pronounced if just the Twin Cities Metropolitan Area is considered; the 1988 summer peak being 2.4 times the winter average (2.0 in 1989).

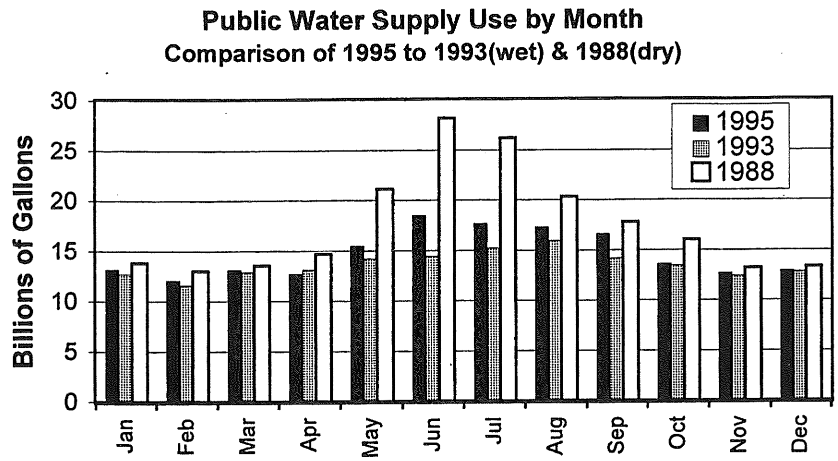


Figure 17

Lawn watering is seen as a major contributor to the summer peak usage. Much more work is required in both public education and demonstrations of sustainable landscaping before the public will begin to accept alternatives to the use of Kentucky bluegrass which is highly dependent upon both water and fertilizer to keep it green. Planting of native vegetation and smaller sized lawns would help to reduce the amount of water used.

Urban Growth. While pockets of residential growth exist across the state, they are most pronounced in the Twin Cities Metropolitan Area where much of Minnesota's population is located. Growth is outward into the suburbs which are almost totally dependent upon ground water for their public water supplies. The Metropolitan Council has predicted an additional 650,000 people by the year 2020. If this increase happens, it may generate a demand that causes significant declines in ground water levels, especially during peak summer usage. Working with the Metropolitan Council and the municipal public water suppliers, the MDNR is seeking solutions to the problems of maintaining sustainable water supplies that are sensitive to natural resources in an area undergoing rapid growth. Cities located on major rivers might consider conjunctive use of both surface and ground water to balance their growing water supply needs.

Industrial Processing. Although increasing, the use of water in industry and mine processing is largely driven by economic factors. Economics also play a role in water conservation. Rising treatment costs and water quality standards for waste water discharge encourage overall reduction in water use and more recycling of process water.

Safeguarding Future Water Supplies

Effective planning is an important element in safeguarding future water supplies. One way that DNR Waters assists in the planning effort of local units of governments and consultants is through field studies and the preparation of county geologic atlases. Education and conservation go hand-in-hand through the development of an informed, concerned public. Other programs such as the on-going Well Sealing Program and Protected Flow Program help to ensure long-term water quality and availability. A brief description of some of these efforts is included here.

Water Conservation, Education and Planning

As Minnesota's population continues to grow, the demand for safe and sustainable water supplies grows with it. This requires ongoing efforts to safeguard sources of water and determine their sustainability. Linkages between comprehensive planning and sustainable water supply are growing in importance in the decision making process. In 1993, the Legislature required all of the Twin Cities metropolitan communities to amend their local comprehensive plans to include a water supply element. Legislation also required all public water suppliers in Minnesota serving more than 1000 people to develop water conservation and emergency supply plans and to implement demand reduction measures on new wells or increased volumes. Because of the concentration of municipal water suppliers in the Twin Cities Metropolitan Area (metro), their story is highlighted in this report.

Currently, nearly all of the 109 metro municipal water suppliers have complied with the legislation. The results of this compliance are included in the Metropolitan Council Regional Report dated March, 1997. Follow-up calls to some of the leading municipal water suppliers in water conservation yielded the following information:

Many communities now have some form of sprinkling ordinance based upon certain conditions. Mandatory non-sprinkling between noon and 5 p.m. is now in its third year at Eden Prairie. This allows time to refill water supply reservoirs. The City also applies a summer surcharge when usage exceeds certain amounts. Apple Valley bans sprinkling from 3-10 p.m. when the system reaches 70% of its peak capacity. This coincides roughly to peak energy demands. Both St. Paul and Cottage Grove have had successful joint programs with Northern States Power in its showerhead replacement program. Public response in Cottage Grove was 76%; in St. Paul, about half of its 95,000 residential customers responded. Cottage Grove is also setting up a Water Conservation Board involving city staff, council members, a teacher and youth representative. Based on its successful program with Northern States Power, it is considering the possibility of joint energy/water audits. Many communities have upgraded their meters, providing water conservation materials with the upgrade. Many communities are also involved in aggressive, on-going leak detection programs. The City of Savage has begun a pilot project providing native seed mixtures free to residents in the Eagle Creek watershed in an effort to encourage use of native vegetation in yards and corporate open spaces. Eden Prairie is in the process of opening its education wing which is at the entrance to its new water plant. Attractive hands-on displays, lab space and outdoor examples of water-conserving landscaping will make this a landmark and teachable moment for all who enter the building and not just the schools which benefit directly from Eden Prairie's enlightened education/outreach program.

Conservation, education and planning are helping to reduce the demand for water in the Twin Cities Metropolitan Area--especially, during summer peaks. Such efforts take time to become established. What might work in one community may not be effective in another. In its 1997 report, the Metropolitan Council noted that the average water cost has increased from $1.16 to $1.63 per thousand gallons from 1991 to 1997 (a 40% increase). Many of the supply systems have also moved from decreasing block pricing to either uniform or increasing block rates. Much work, however, remains before water use is based more upon needs and not just increasing supplies. This will come with public realization and acceptance that water is not an unlimited resource.

Well Sealing Program

Minnesota state law requires that abandoned wells be sealed to prevent ground water contamination. The DNR is charged with identifying and sealing unused wells on state lands. To date, 465 wells have been sealed. Lands that were once in private ownership are being searched for old wells; 645 such locations have been searched to date. DNR is working with other agencies to address wells on lands managed by them.

This project involves locating and sealing both known "visible" wells and suspected buried wells. The "visible" wells are relatively easy to find and seal. Locating buried wells is more difficult. The investigation process to locate buried wells is as follows:

- Plat maps are reviewed for possible abandoned well sites (often old homesteads or pasture wells).

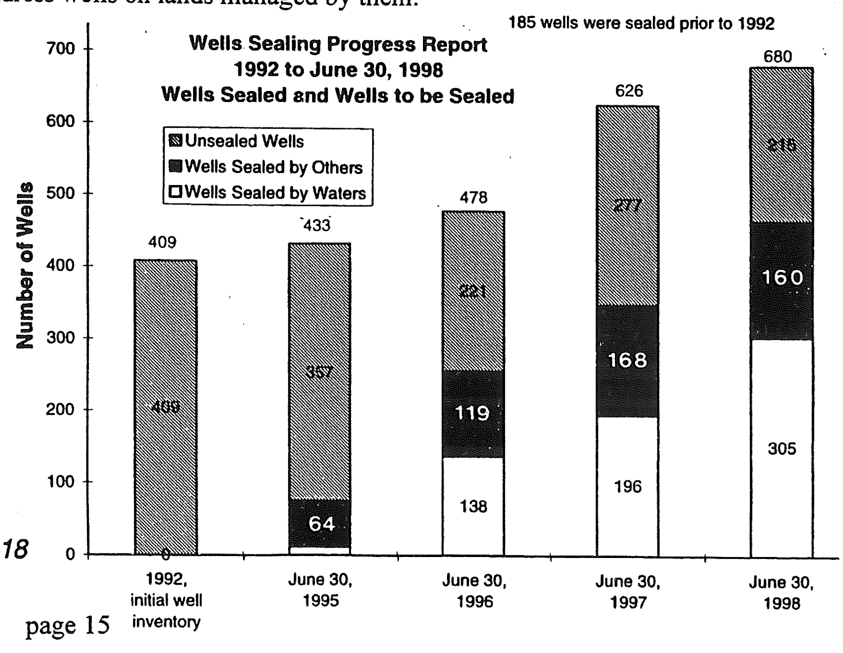


Figure 18

- Historical aerial photographs are used along with information from well drillers, local senior residents, current and former site managers to refine the search.
- Potential sites are systematically searched with a magnetometer. Localized anomalies in the magnetic field can suggest a buried well. If a well is found, a well driller is contracted to seal it.

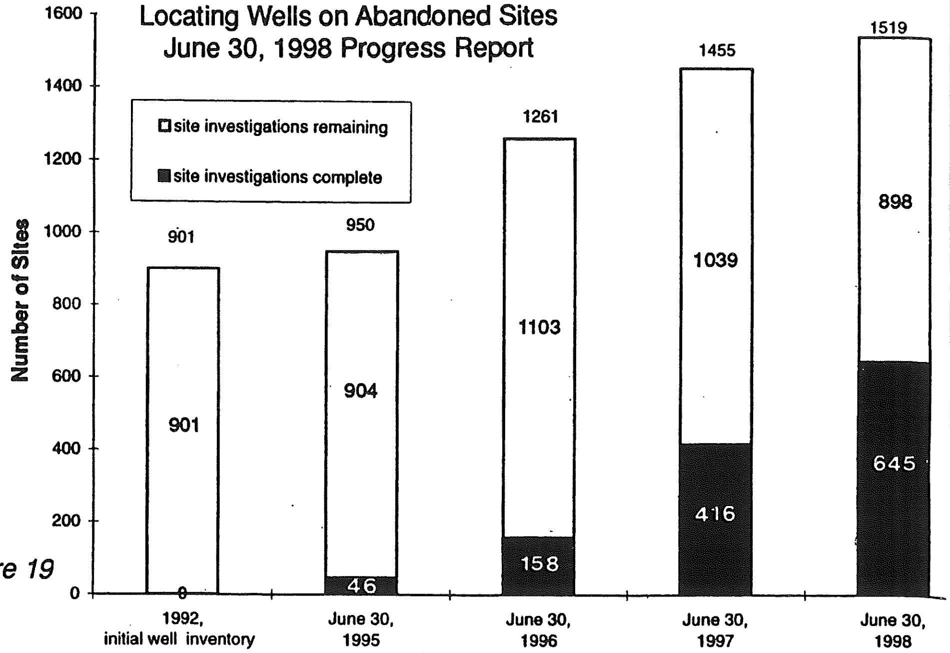


Figure 19

Protected Flow Program

By protecting low flows and volumes in rivers, lakes and streams, DNR Waters helps to ensure a sustainable water supply for all--from public water supplies to power generation, from recreational use to fish and wildlife needs. This protection is a result of the Instream Flow/Protected Flow Program which is being improved by DNR Waters and Fish & Wildlife for the protection of fish and wildlife, recreation, and other instream uses.

The instream flow program, through ongoing research and data collection, identifies and quantifies stream flow levels that are required for fish and wildlife, recreation and other instream uses. By monitoring stream flows and lake levels, conditions can be applied to DNR appropriations permits in order to maintain needed instream flows.

DNR Waters and Fish & Wildlife will be developing an educational program to inform and promote public awareness and involvement with instream flow. The result will be greater recognition of how water quantity and the demands we impose impact on natural resources we value for recreation.

Conclusions, New Initiatives

As shown by this report, water availability is dependent upon variables of both space and time. Looking back in time, we find scattered episodes of drought and flood. At any given period of time, there are also pockets within the state that may be experiencing localized dryness or wetness. Such is the current situation during the summer of 1998 when much of northeastern Minnesota's lakes and streams are low while lakes and streams in the western part of the state are at high levels. As noted in the section on climate, these extremes of water excess or deficit in either space or time are not aberrations, but, rather, represent our mid-continental location and the normal variations of a continental climate.

Various geological formations, soils and topography also affect water availability. In turn, water availability helps to determine the biological make-up of a given area, its plant and animal species. Mixed in with this is human activity which is also dependent upon water availability. Conflicting uses or increasing use of a given water supply raise questions about overall sustainability of water resources and the natural resource systems which depend upon them.

Through its permitting authority, DNR Waters is able to address and help resolve local problems of water availability. Staff trained in surface and ground water testing, monitoring and modeling are available to deal with localized problems as they arise. Larger problems such as the exploratory drilling project in southwestern Minnesota or the minepit lake study in the northeast require greater time and staff and normally require legislative funding in order to be accomplished.

Permits, however, do not take the place of good water planning and management at the local level. The county geologic atlas staff, obwell staff and DNR Water's field staff all help to provide some assistance to local decision makers and planners. DNR Waters provides the information that is needed for informed decisions.

Population growth places additional demands upon water supplies wherever it occurs. The Twin Cities Metropolitan Area is of particular concern because of its rapid growth into areas dependent upon ground water. Lowered ground water levels are affecting sensitive natural resources such as calcareous fens and trout streams, and could ultimately impact economic growth if not restrained. Conservation will require increased coordination among the municipalities, better education on water resources, and, possibly, the formation of subregional water supply systems where conflicting needs can be balanced.

Comprehensive planning, water conservation and education are sorely needed wherever rapid population growth occurs. Large lawns and thirsty bluegrass are indicators of the increasing demand they have upon summer water supplies. In order for change to take place, it will require an informed and supportive public and enlightened decision making at all levels (state and local government, planners, developers, consultants, home owners, educators).

Recognizing that ground water issues cross many diverse lines of authority, an interagency task force consisting of representatives of the Departments of Agriculture, Health, Natural Resources, Pollution Control Agency and Board of Water and Soil Resources met in August, 1998, and identified two basic areas of needs:

1. Enhanced ground water education to increase understanding of ground water occurrence and movement;
2. Field-based implementation of services to protect and manage ground water resources.

DNR Waters currently has one field-based ground water specialist stationed in southeastern Minnesota. His presence has demonstrated the effectiveness of having people in place within a given area to deal with local problems and assist with local planning and education. Depending upon funding, the goal is to establish similar specialists in the central and western parts of the state to assist with the solving of local water availability problems there.

The demand for water imposes an ongoing demand for water resources information which increases with development. The DNR also wishes to develop the capability to measure aquifer characteristics and report the results as part of its County Geologic Atlas series. To do so requires ability to pump selected wells and monitor water level changes in nearby wells over controlled periods of time. Because these tests are costly, additional staff and funding is being sought for this effort.

Ongoing support is also needed for the County Geologic Atlas Program, well sealing, expansion of observation well network, exploration drilling program and other initiatives that help to characterize and analyze the availability and sustainability of Minnesota's water resources. Most important, however, is the continued coordination and cooperation among agencies, local units of government, water suppliers and users in understanding the importance and dependence that all have upon a safe and sustainable water supply.

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