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STATE OF MINNESOTA

CONSUMPTIVE WATER USE STUDY

(Pursuant to Laws of Minnesota, Chapter 326, Article 4, Section 8)

Minnesota Department of Natural Resources
Division of Waters

February 15, 1990

LEGISLATIVE REFERENCE
Saint Paul, Minnesota

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Pursuant to 1989 Laws, chap 326
Article 4, Section 8

CONSUMPTIVE WATER USE STUDY

By

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REPORT TO THE LEGISLATIVE WATER COMMISSION

St. Paul, Minnesota
February 15, 1990

Minnesota Department of Natural Resources
Division of Waters
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PREFACE

This report includes the conclusions and recommendations from the Consumptive Water Use Study mandated Laws of Minnesota 1989, Chapter 326, Article 4, Section 8. The study conclusions and recommendations will be stated in the beginning of this report after a brief introduction section. Following the report recommendations are more detailed sections on Minnesota water use, the use and disposal of once-through heating and cooling water and Minnesota ground water resources. A separate document completed by Orr Schelen Mayeron and Associates, Inc., evaluates the mechanical aspects of heating and cooling systems.

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

We would like to thank the members of the Advisory Committee and others who attended meetings and provided comments during the preparation of this report.

The cooperation of General Mills, Methodist Hospital, Gaviidae Commons, and Honeywell, Inc., is greatly appreciated for volunteering their facilities to be used in this study. The staff and information provided by these companies helped to complete this study in the limited time available.

Contributions to this report were provided by the following DNR staff:

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TABLE OF CONTENTS

INTRODUCTION

Legislative Background

The Comprehensive Ground Water Act of 1989 was passed and signed into law. The legislation became Chapter 326 of the Laws of Minnesota 1989. Article 4 contains three sections pertaining to once-through cooling systems:

> The Department may no longer issue any new appropriation permits for ground water sources used in once-through cooling systems appropriating in excess of five million gallons annually.
>
> The Department must prescribe a water use processing fee of five cents per thousand gallons until December 31, 1991; ten cents per thousand gallons from January 1, 1992 through December 31, 1996; and fifteen cents per thousand gallons after January 1, 1997. During the first year this would provide approximately $535,000 in revenue.
>
> The Department must conduct a study of consumptive water use and its impact on the existing aquifers. This report must be provided by the Commissioner to the Legislative Water Commission by February 15, 1990.

MINNESOTA'S WATER APPROPRIATION PROGRAM

Minnesota's water appropriation law was first enacted in 1937 (Re: Minnesota Statutes Chapter 105) as a result of the drought of the 1930's. The Legislature sought, by the original act, to establish a water policy for the state and a permit system to regulate water users.

The most important changes to the original law include requirements for submitting annual water use reports, the repeal of the exemption for so called "grandfather appropriators", the establishment of a priority system for water use, and the requirement to establish rules governing the allocation of waters which were adopted in August of 1980.

Minnesota Rules Part 6115.0620 requires that a permit be obtained for appropriation of water in excess of 10,000 gallons per day or one million gallons per year. Applications to appropriate water are evaluated to determine the effects of the proposal on the environment and other high priority water users.

In 1973, the Legislature established five priority classes of water use. After the 1988 drought the original priorities were modified by the 1989 Legislature to include certain power production requirements under first priority water uses. This change is intended to provide essential power requirements during a widespread drought when other power suppliers within a grid may be having difficulty meeting demand. The current water use priorities as amended in 1989 are:

> First Priority. Domestic water supply, excluding industrial and commercial uses of municipal water supply, and use for power production that meets contingency planning requirements.
>
> Second Priority. A use of water that involves consumption of less than 10,000 gallons per day.
>
> Third Priority. Agricultural irrigation and processing of agricultural products.
>
> Fourth Priority. Power production in excess of the use provided for in the contingency plan requirements.
>
> Fifth Priority. All other uses, involving consumption in excess of 10,000 gallons per day, including non-essential uses of public water supplies.

These priorities of water use become important during periods of limited water supplies and competing demands. While environmental protection is not given in the priority system it is provided for in Minnesota Statutes and Rules by the establishement of resource limitations below which no appropriation can occur. The conservation and allocation of Minnesota's water resources will be discussed further in this report.

Report Methodology

From the beginning of this study, the Division of Waters recognized that a lack of expertise in the area of mechanical cooling and heating systems existed within the Division. An advisory committee was formed of building owners, industry and trade representatives, power producers, consulting engineers, and environmental interests in order to assit in the development of this report. The primary purpose of this committee was to provide additional expertise, due to their experience with the installation and operation of air conditioning and heating equipment. This support was important in the development of various components of this study and report.

The services of a consulting engineer were requested through a State Request for Proposal. The services of Orr-Schelen-Mayeron and Associates (OSM) were contracted, in order to do an engineering analysis of the mechanical systems currently used. Their report provides descriptions of common systems that exist throughout the state and operating and conversion costs.

The Division compiled a list of permits, within the State, that were issued, utilizing groundwater sources for air conditioning and heating. The State Water Use Data system was used to identify potential once-through permits. This list identified 131 permits throughout the state that were potentially operating once-through types of systems.

In order to acquire the necessary information about these systems, a survey was developed and sent to all the permittees on the list. This survey was reviewed and approved by the committee. Each permittee was asked to respond to questions regarding their water source, mechanical system, water usage, water disposal, and any conservation methods used. The information was used by the Division and OSM for the analysis in this report. The survey allowed us to identify and categorize the systems. The surveys were then used to identify candidates in each category for further study. This allowed for general evaluation within the categories, since time was a limiting factor for any in depth study.

Staff within the Ground Water and Permits Units of the Division, contributed on the analysis of water use, water disposal methods, and aquifer impacts. Annual Water Use Reports were used in compiling the water use statistics. The survey was combined with existing permit information to better identify the aquifers involved in air conditioning. The state observation well network was also used in evaluating aquifer trends.

CONSUMPTIVE WATER USE STUDY
CONCLUSIONS AND RECOMMENDATIONS

Laws of 1989, Chapter 326, Article 4, Section 8, required the Department of Natural Resources to study and evaluate:

1) Consumptive water use and its impact on existing aquifers.

2) Methods of reducing consumptive water use, including the conversion of once-through systems to alternative systems.

The Department is also required to provide recommendations to the Legislative Water Commission on the following items:

1) The use of deep aquifers for once-through heating and cooling.

2) The advisability of systems that recharge aquifers.

3) Alternatives to once-through systems, including the environmental and economic impacts of the alternatives.

4) Alternative technologies available to accomplish the conversion of existing once-through systems.

5) Recommendations on authorizing systems of better efficiency.

6) Options for converting once-through systems and a time schedule for phasing out existing systems.

7) A fee structure that will make once-through systems and conventional systems equal in operating costs.

This report will start with a summary of the conclusions from the Consumptive Water Use Study followed by specific recommendations in the order outlined above. The remainder of this report is divided into more detailed sections related to water use, once-through heating and cooling systems, and ground water. A separate document completed by Orr Schelen Mayeron and Associates, will evaluate the mechanical aspects of heating and cooling systems.

IMPACTS OF CONSUMPTIVE WATER USE ON GROUND WATER RESOURCES

Minnesota Rules 6115.0630, Subpart 7, defines "consumptive use" as water withdrawn and not directly returned to the same waters as the source for immediate further use in the area. Therefore, all ground water withdrawals are considered consumptive, because the water is not returned to the source. Cases where water is used and then reinjected into the same aquifer would not be considered consumptive.

Historic water level data from observation wells used in conjunction with water use data provide an indication of the impacts from consumptive use. The ground water section of this report discusses water level data in detail and also provides good background information on ground water resources. This section will briefly discuss some of the general findings from the ground water section and the implications of resource impacts.

It is necessary to focus on a specific area when evaluating the impacts of consumptive water use on ground water resources. Hennepin and Ramsey Counties were selected for analysis of consumptive water use impacts because of the concentration of large ground water withdrawals. These two counties also account for 106 of the 124 permits in Minnesota authorizing ground water for heating and cooling systems.

Observation well data indicate long term declining water levels in areas of Hennepin and Ramsey Counties where water use has increased. The movement of industries and population concentrations from downtown areas to suburban areas within the last 30 years is reflected in the water level data. While observation well data is site specific for each aquifer it can be said that most wells show seasonal declines in water levels during summer months when water use is highest. Water level changes are expected to continue a downward trend due to increased summer pumpage to offset effects from the on going drought. Without increased monitoring and more data it is not possible to quantify specific long term ground water impacts. Later in this report recommendations are given regarding the need for more monitoring and protection of ground water resources.

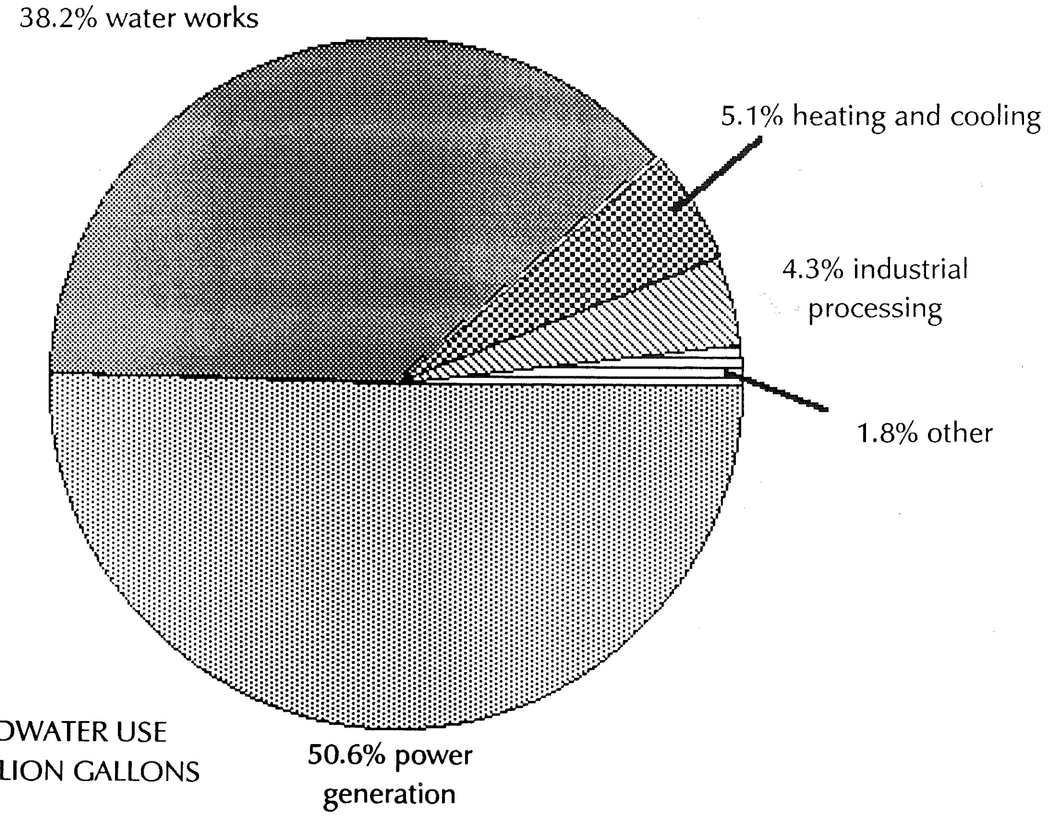
What the impacts of consumptive use on ground water resources are and whether or not a problem exists can be debated. However, it is not sound management to treat ground water as an unlimited resource until a problem develops. The efficient and wise use of Minnesota's ground water resources should be done before there is a problem that can be quantified. The protection and conservation of ground water now is important to future economic development and the quality of life in Minnesota.

METHODS TO REDUCE CONSUMPTIVE WATER USE

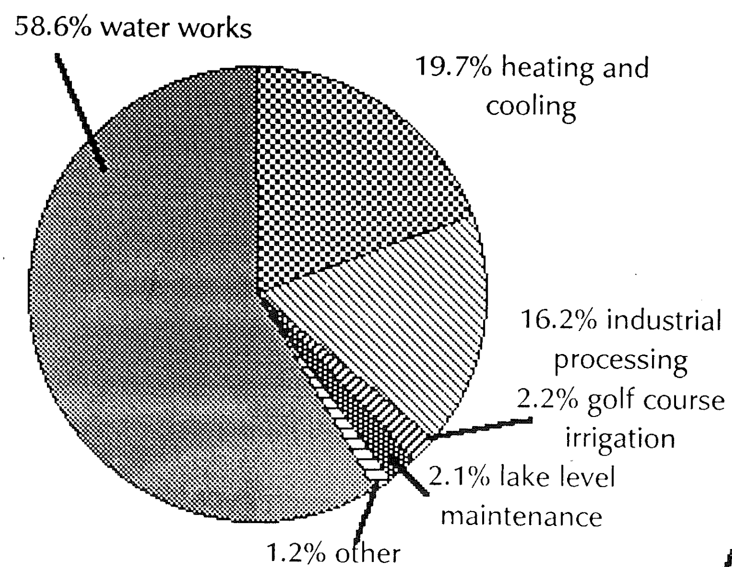
The Department is required to review methods of reducing consumptive water use, including the conversion of once-through systems to alternative systems. In order to evaluate methods to reduce consumptive water use it is necessary to look at the general categories of water users. Figure 1 on page 6 shows 1988 total water use data for surface and ground water sources in Hennepin and Ramsey Counties. Statewide data are given in Figure 2 on page 7 for comparison purposes. Of the total 55.6 billion gallons of reported ground water use in Hennepin and Ramsey Counties 58.6% was withdrawn by municipalities, 19.71% for heating and cooling, 16.2% by

1988 REPORTED WATER USE
RAMSEY AND HENNEPIN COUNTIES

TOTAL WATER USE
212,968 MILLION GALLONS



GROUNDWATER USE
55,636 MILLION GALLONS



SURFACE WATER USE
157,332 MILLION GALLONS

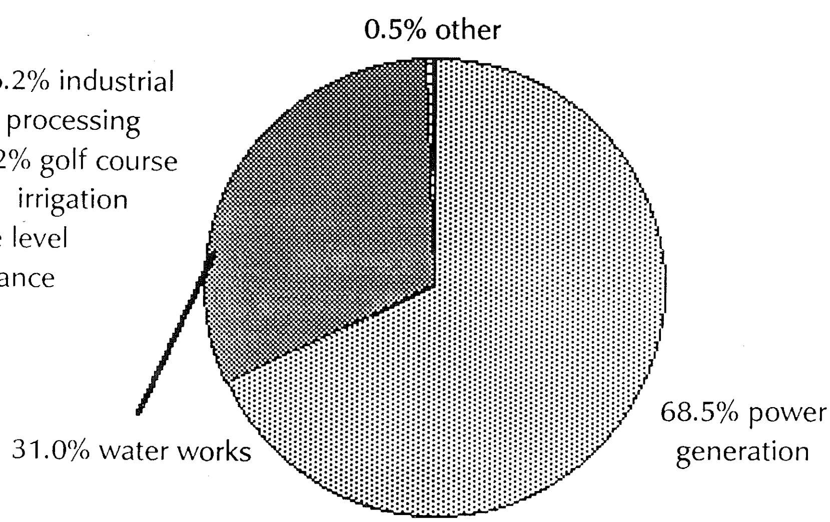
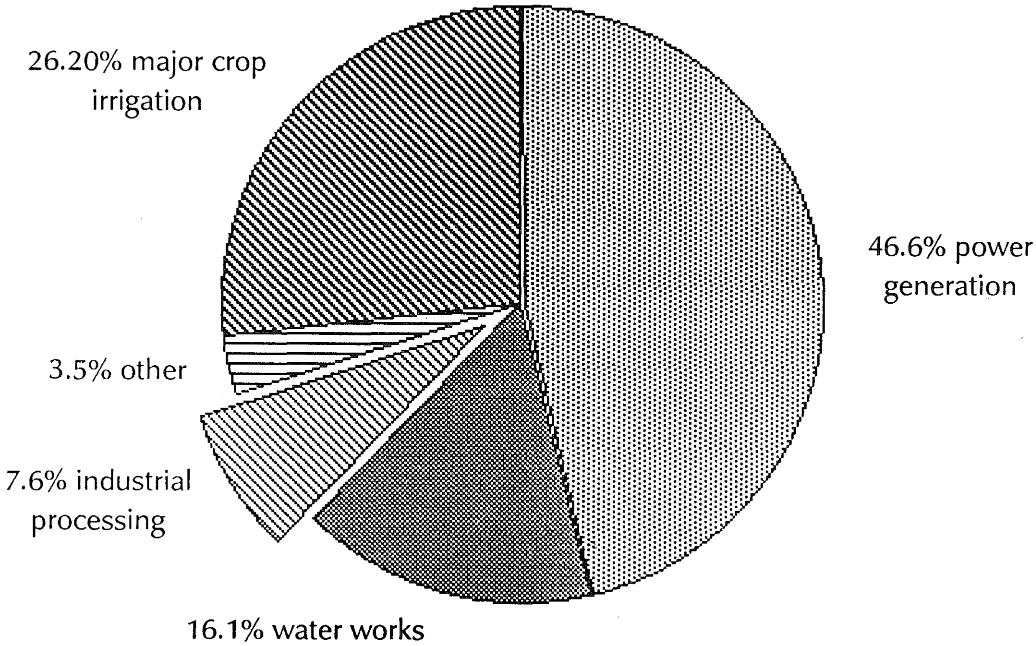


FIGURE 1

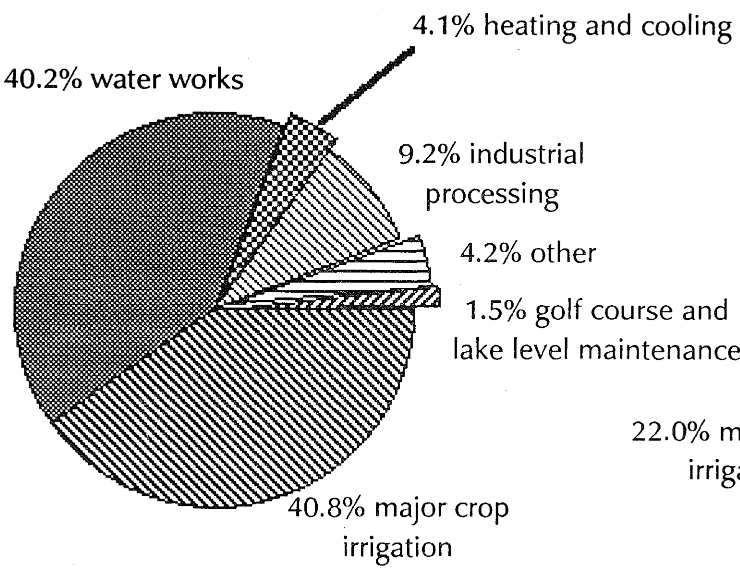
1988 REPORTED WATER USE
STATE OF MINNESOTA

TOTAL WATER USE
1,210 BILLION GALLONS

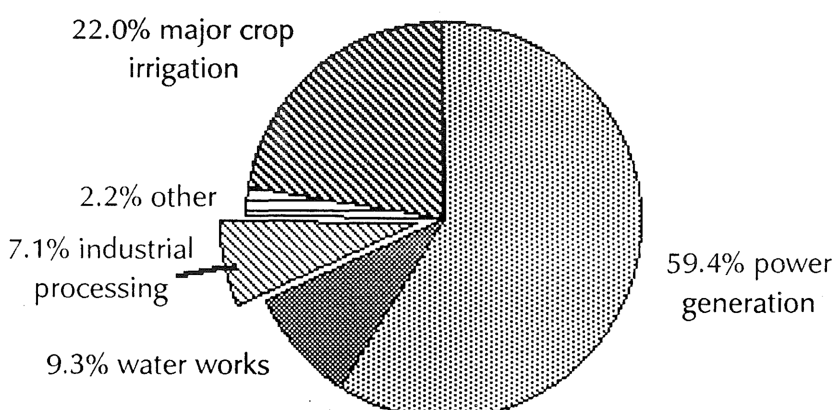


GROUND WATER USE
267.6 BILLION GALLONS

FIGURE 2



SURFACE WATER USE
942.9 BILLION GALLONS



2.2% for golf course irrigation, 1.2% to augment lake or pond levels and 1.2% for other various uses.

This section discusses methods to reduce water use within the major categories of users. Water use data will concentrate on ground water rather than surface water with the exception of power production and municipal water use categories.

POWER PRODUCTION

Water withdrawals for power production is the largest water user in Minnesota. However, power production uses surface water for cooling purposes and returns much of the water back to the source.

Reducing electrical demand is the primary method of reducing water use for power production. While the supply and demand of electricity are outside the scope of this study the issue is also related to the conversion of once-through systems to conventional systems that use more electricity. The publication Energy: Minnesota's Options for the 1990's by the Minnesota Department of Public Service is a good reference on this issue. This report identifies a potential for reducing overall electrical demand by 52% with existing energy efficient technology. Commercial lighting accounts for one fifth of the total potential energy savings.

MUNICIPAL WATER USE

In 1988, municipalities withdrew 32.6 billion gallons of ground water accounting for 58.6% of the total reported ground water use in Hennepin and Ramsey Counties. Surface water use by Minneapolis and St. Paul withdrew an additional 48.8 billion gallons or 31% of the total surface water use in Hennepin and Ramsey Counties. Municipal summer water use increases by at least three to four times over winter water use. The increase in summer water use is related mostly to demand for lawn irrigation, golf course irrigation, car washing, and other non-essential uses of water. Municipalities also supply some buildings with make-up water for air conditioning systems that use cooling towers.

Similar to power production, efforts to reduce municipal water consumption must emphasize reduction in demand to conserve supplies rather than development of additional supplies to satisfy increased demands. Despite all the information and technology available on reducing demands, public water suppliers are reluctant to promote conservation because water is a source of revenue. Municipalities often equate water conservation with decreased revenues, when in fact conservation rate structures can reduce water use and increase revenues. Higher water fees can cause economic hardship on low income households. However, some of the increased revenues from conservation rate structures could be used to provide credit for low income households instead of funding expensive projects to augment existing supplies.

Reducing water demand is considered only when there is a water supply problem. Typically new wells are constructed to meet demand rather than implementing conservation measures. In addition to the high economic costs of constructing new well fields there can be substantial environmental costs. Long term declining water levels in the Mt. Simon-Hinckley aquifer have been cited to support protection of this aquifer for essential domestic water needs. However, a problem is developing because many new municipal wells are being constructed in the Mt. Simon-Hinckley aquifer only to meet peak demands for non-essential water uses in the summer.

Protecting this aquifer as a potable water supply for high priority domestic requirements when in fact the water is being used for lawn sprinkling, car washing and other non-essential uses is not good resource management. To address this problem approval of construction plans for new wells by the Department of Health should be contingent on development and implementation of water conservation programs.

Municipalities are responsible for supplying water for many high priority domestic requirements. Minnesota Statutes 105.41 specifically defines all commercial, industrial, and non-essential water uses supplied by municipalities as a fifth priority water use. Public water suppliers may be required to restrict or suspend low priority water uses to protect essential domestic water requirements. In the case of contamination or other water supply problems, municipalities would be required to allocate available water based on the water use priorities established by the legislature. Therefore, allocation/conservation plans should be developed by municipalities, which require disclosure of specific water use information from each municipal water user. These plans should address the issue of restricting non-essential water uses before limiting efficient commercial and industrial water users. Plans should also require implementation of demand reduction techniques that include rationing, pricing, leak detection, and retrofitting. Local building codes should also be evaluated with respect to water conservation considerations.

Another option that should be required when feasible, is the reuse of treated water from pump-outs for the containment and removal of contamination. Contrary to public perceptions most pump-out water can be treated to drinking water standards. The Cities of St. Louis Park and New Brighton currently use treated pump-out water for part of their municipal water supplies.

The Twin Cities Army Ammunition Plant will be discharging up to six million gallons of water per day for up to 20 years. After treatment this water could be used for municipal purposes rather than discharging the water to the Mississippi River. The Pollution Control Agency, which approves discharge permits, should require the investigation of options for reuse of treated pump-out water in remedial action plans.

BUILDING HEATING AND COOLING

In 1988, space heating and cooling of buildings withdrew almost 11 billion gallons or 19.71% of the total reported ground water use in Hennepin and Ramsey Counties. Almost all of this water is used in once-through heating and cooling systems. There are indications that once-through systems are used elsewhere in the United States, but to what degree is unknown. It is apparent that once-through systems in other parts of the United States are not used to the extent they are in Minnesota and that reinjection of water may be involved.

The use of cooling towers to recycle water back through the heating or cooling systems or a closed loop district heating and cooling systems can reduce water use by up to 95%. Other alternatives and recommendations to once-through water use are discussed in more detail later in this report.

INDUSTRIAL WATER USE

In 1988, industries reported appropriating just over 9 billion gallons or 16.2% of all ground water withdrawn in Hennepin and Ramsey Counties. Industrial uses include chemical, metal and non-metal processing, which may involve cooling of machinery and even computers. Once-through systems are used for some industrial applications to provide space cooling for computer rooms, processing paper, manufacturing computer chips, producing paper and other uses. Once-through applications required for industrial space cooling are being cited as a loophole to the human comfort provision in the legislative definition. While these systems also provide space cooling for employees, permittees are stating the primary use is for industrial cooling, not human comfort, and therefore the once-through fee schedule and prohibition should not apply. This is a space heating and cooling application that is no different than other once-through systems and should be subject to the same prohibition and fee schedule.

Individual analysis of each industrial water use is needed to provide specific recommendations on reducing consumptive water use. Industries are large water users and should be required to use water as efficiently as possible.

GOLF COURSE IRRIGATION

In 1988, golf courses withdrew 1.2 billion gallons or 2.2% of the total reported ground water use in Hennepin and Ramsey Counties. Additional water for golf course irrigation is supplied by municipal water systems. Golf courses require an inch or more of water per acre per week. A 26 week golfing season from May to September could use over two feet of water per acre which is twice the average use for upland agricultural crops.

Methods to minimize consumptive water use for golf course irrigation include: the use of drought tolerant grasses suitable for fairways and roughs; maintaining a proper fertilizer balance; the use of soil moisture meters to determine water needs; irrigating from dusk to dawn to minimize evaporation; and setting up watering systems to avoid overlaps in water coverage.

LAKE LEVEL MAINTENANCE

In 1988, water withdrawn for the purpose of maintaining lake levels amounted to 1.16 billion gallons or 2.1% of the total reported ground water appropriation in Hennepin and Ramsey Counties. In the Twin Cities Metropolitan Area there is an average of 5.5 inches of evaporation in July. Therefore, lake levels are impacted by water losses from evaporation and also seepage into the ground.

Pumping ground water for purposes of maintenance/augmentation of water levels for lakes, ponds or other impoundments is not the best or most efficient use of a high quality ground water resource. A recent proposal to raise the water level of Lake Minnetonka would require 4.5 billion gallons to raise the lake one foot, however, this does not even take into account evaporation and seepage losses. This is more water than the Cities of Minnetonka, Wayzata and Mound use in a year.

To reduce consumptive water use there should be a prohibition on issuance of new permits for water level maintenance and existing permits should be terminated.

GROUND WATER RECOMMENDATIONS

Recommendations on the use of deep aquifers for once-through heating and cooling:

1) Protection of the Mt. Simon-Hinckley Aquifer in the Twin Cities Area

To create a "bank" of high quality drinking water for the future, the Mt. Simon-Hinckley aquifer should be eliminated for any new non-essential water supply, unless approved conservation plans are in effect and there are not any practical alternatives. Education regarding conservation of this aquifer is needed because of declining ground water levels and the lack of sufficient recharge.

2) Expanded Monitoring Program

Without increased monitoring and more data it is not possible to quantify specific long term ground water impacts from consumptive water withdrawals. To better understand aquifer characteristics and water level trends including seasonal pumping impacts, river interaction, and local aquifer variability, it is recommended that the following actions be taken:

a) Construct 14 new Prairie du Chien-Jordan observation wells and eight Mt. Simon-Hinckley observation wells in the seven county metropolitan area. Several of these wells are needed in downtown areas to monitor effects of seasonal pumping and impacts on the base flow of the Mississippi River. Water quality monitoring of the downtown wells is also needed to determine if there is reverse flow into aquifers from the river.

b) Installation of continuous recorders on observation wells in areas with concentrations of large ground water withdrawals.

c) Conduct yearly mass water level measurements on ground water levels in the Twin Cities Area. Currently the U.S. Geological Survey conducts mass water level measurements in the Twin Cities Area on a five year basis.

d) Municipalities are the largest ground water users and have the most potential to impact ground water levels. In 1988, municipalities accounted for 40% of total ground water withdrawals in Minnesota and 58.6% of the withdrawals in Hennepin and Ramsey Counties. Municipalities should install observation wells and monitor water levels in all production and standby wells on a monthly basis. This data along with pumping records will provide useful information on impacts from large ground water withdrawals. Other large water users should also be required to install observation wells and monitor water levels.

3) Mandatory Flow Metering

It is recommended that all permittees be required to install flow meters capable of measuring the volume of water appropriated within a ten percent (10%) accuracy. This degree of accuracy is required on each permit and in Minnesota Rules, but it is difficult to obtain without a flow meter due to varying pumping rates and pressures in the water supply systems. Meters could increase the accuracy of water use reporting and provide better data for analysis of ground water trends.

4) Require Alternative Use Considerations

Reuse of water should be considered when designing facilities and as part of regulatory processes. Currently Department of Health regulations and policies prohibit reuse of untreated water from once-through systems for potable supplies because of contamination concerns. However, non-potable uses of the water are not prohibited and should be considered for industrial processing, irrigation or other applications.

Obtaining the maximum use of ground water through reuse is a valid goal. Reuse of water will reduce ground water demands. When feasible, municipalities and other water users should consider using treated water from once-through heating and cooling systems, pump-outs to contain or remove contamination, and other sources.

Recommendations on the advisability of systems that recharge aquifers.

The reinjection of ground water is regulated by the Pollution Control Agency and the Department of Health, which have legitimate concerns about possible contamination of the ground water. Supporting this concern are survey results that indicate 58% of once-through waters are treated with additives to control fouling of the heating and cooling equipment. There are also technological restraints, including insufficient space to separate reinjection wells in downtown areas of St. Paul and Minneapolis.

It is recommended that existing reinjection systems be maintained and that the Pollution Control Agency and Department of Health procedure for approving new reinjection systems continue.

RECOMMENDATIONS ON ALTERNATIVES TO ONCE-THROUGH SYSTEMS

Laws of Minnesota 1989, Chapter 326, Article 4, Section 4, Subdivision 1c, Item b defines "once-through":

> "A once-through cooling system means a cooling or heating system for human comfort that draws a continuous stream of water from a groundwater source to remove or add heat for cooling, heating, or refrigeration."

A problem is created by this definition because it is based on the purpose for the water use rather than the actual type of system. Space cooling required for maintaining temperatures for manufacturing paper products, cooling computers and other industrial processes do not fit this definition because the primary cooling need is not for human comfort. Another problem relates to the requirement for a continuous stream of water. Continuous pumpage is not always required because of changing building loads and the use of holding tanks.

The definition of once-through should be based on the type of system regardless of the purpose for which the water is used. All once-through heating and cooling applications are in the same water use priority and should be subject to the same restrictions and fees. Therefore, it is recommended that the definition of "once-through" under Section 4, Subdivision 1c, Item b, should be changed to:

> A once-through system is any heating, ventilating or air conditioning (HVAC) system used for any type of temperature or humidity control application, utilizing ground water, which circulates through the system and is then discharged without recirculating the majority of the water, in the system components.

Alternatives to once-through systems, including the environmental and economic implications of the alternatives.

The economic impacts of alternative systems are very site specific and will have a wide variation between system designs. The range of total statewide conversion costs were estimated in two separate studies. A study commissioned by a group of building owners and managers (BOMA) estimated total statewide conversion costs to be $42.4 million. The Department's consultant (OSM) estimated total statewide conversion costs to be $71 million. The increase in costs associated with operating a conventional cooling tower system as opposed to the four once-through systems studied by OSM, was an average of $.0041/TON-HR. This included a decrease in operating costs for one of those systems. **These should not be considered the average increase for any system. Each system will have unique operating costs.**

It is also important to note that, these are the suggested alternatives but may not be practical as system conversions. These systems can reduce direct water requirements for the heating and cooling system by 95 to 100%.

1) <u>Conventional Open Cooling Towers</u>

   These systems utilize open cooling towers to reject building heat to the atmosphere. A closed chilled water loop or refrigerant direct expansion, delivers the cooling effect to the building.

2) Split Systems, Air Cooled Remote Condenser Units

These systems circulate freon refrigerant through a fan cooled condenser which is similar to a car radiator. These systems are typically smaller size and would require multiple units on a facility.

3) Vertical and Horizontal Closed Loop Ground Source Heat Pump Systems

These systems use water in a buried pipe network that would use the earth as a "source" or "sink" of heat. The constraints on the use of this technology are systems size (tonage) and space requirements.

4) Packaged, Air Cooled, Direct Expansion Systems

These systems are usually roof-mounted or slab-mounted units incorporating air-cooled condenser coils for heat rejection. Two examples of these systems include:

-air-cooled reciprocating water chillers
-packaged rooftop units

5) District Heating and Cooling

Purchase of steam and/or chilled water from a central source. St. Paul District Energy Inc. converted to a closed loop system several years ago and now uses municipal water for minimal make-up water requirements. The Minneapolis Energy Center has two plants in Minneapolis. The larger downtown plant uses cooling towers, however, the smaller Riverside Plant is a once-through system which is used only as needed.

6) Packaged Terminal Air Conditioners

These units are similar to a window air conditioner but "through the wall".

7) Industrial Heat Pump

These systems utilize a reciprocating or centrifugal compressor to amplify waste heat from water or solar energy to a useable temperature. These systems produce chilled water as a byproduct.

8) Absorption Chillers with Cooling Tower

These systems use steam or hot water, as the main energy input, to provide chilled water for cooling purposes. These are typically used in conjunction with a cooling tower on the condenser.

Alternative Design Approaches

The following are design concepts which can utilize a number of the options listed above.

9) Off Peak Systems

These systems utilize cooling or heating storage facilities to produce a reservoir (typically ice) over the night (off-peak) hours which is then tapped during the peak hours of operation. Cooling can be provided by a number of the systems listed above, to produce the ice. This allows a rate break (reduction in demand charge) and also would shift the extra power generation to the time of day in which the power companies can best handle the increased load.

10) Heat Recovery Designs and Energy Efficient Building Design

Energy efficient approaches may be employed in building designs to reduce electrical energy consumption, solar load, and heat loss. Heat recovery designs may be employed to recover waste heat. Current State Building Codes address this issue.

The environmental concerns have been focused in three areas:

1) The added electrical demand and associated pollution:

Once-through systems are used because of the cost savings realized by the reduced energy requirements of the chiller. Any changes to existing systems will be at the expense of increased electric demand in these systems. However, the report Energy: Minnesota's Options for the 1990's, by the Department of Public Service, identifies a potential for a 52% reduction in total electric power consumption through conservation measures.

2) The additional use of chloroflourocarbons (CFC):

CFC's have been determined to contribute to the depletion of the ozone layer in the upper atmosphere. CFC's are used in many of the compressorized air conditioners as refrigerant. Federal as well as State and local governments are moving towards very strict regulation on CFC use and replacement of the ozone depleting CFC's with replacement compounds that do not damage ozone.

3) The addition of cooling tower vapor plumes and noise:

The MPCA has standards for noise output. Vapor plumes from cooling towers are more of an aesthetic issue and the current technology available, has greatly reduced the plumes produced by cooling towers.

Alternative technologies available to accomplish conversion.

This is a list of conversion alternatives. Each system would need to be evaluated individually to determine the appropriate technology for conversion, allowing building managers to account for system component ages and possible future expansion of facilities.

1) Cooling towers for condenser cooling. In most cases this common technology will be feasible and cost effective. This is a reliable and proven technology that has been greatly improved on over the years.

2) Purchase of steam and/or chilled water from a central source. Steam and chilled water are available for downtown Minneapolis, and steam is available in St. Paul. It should be noted that St. Paul District Energy is considering a chilled water system. Also, Minneapolis Energy Center's small Riverside Plant utilizes a once-through system to supply part of their chilled water requirements.

3) Closed chilled water loop. On systems which utilize well water in once-through air handler coils, this may require that larger coils be installed and/or flow rates increased and/or additional chillers installed.

4) Use of off-peak technology (e.g. cold storage). This will reduce demand charges for the operator and also shift the added electric load to the off-peak period creating less impact on power production.

5) The use of closed-loop ground source heat pump technology. These types of systems use water in a closed loop piping network and the ground as the source and sink of heat.

6) The use of traditional air cooled systems.

7) The use of absorption chillers utilizing an existing ability to produce steam or hot water and a cooling tower.

8) New technology that would be even more efficient in water and power, as introduced.

Recommendations on authorizing systems of better efficiency.

1) Laws of Minnesota 1989, Chapter 326, Article 4, Section 4, Subdivision 1c, Item a, prohibits the Department from issuing permits to appropriate ground water for once-through cooling systems using in excess of five (5) million gallons annually. Issuance of amended permits to authorized higher volumes of water for existing systems would also be prohibited by this legislation.

   There has been little or no objection to continuing the prohibition on new once-through systems, in part because planning and designing of new facilities can incorporate the use of alternative systems. However, there is concern that existing systems be allowed to continue to operate because the systems were built in compliance with the regulations in effect during planning, design and construction of the facility. The World Trade Center, Gaviidae Commons, and the Ordway Theater are just a couple of the buildings constructed recently that have made considerable investments based on previous regulations. Several permit applications are also pending for newly constructed or expanded systems that applied after the prohibition went into effect.

Water use reports for 1988 indicate that 30 once-through heating and cooling permittees exceeded their authorized volume of water. Amending these permits to authorize historic water use levels would generate approximately $75,000 based on the new fee schedule for once-through permittees.

It is recommended that the prohibition on issuance of permits for once-through systems continue. It is also recommended that new and amended permits for once-through systems constructed before 1990 be allowed. This exemption from the prohibition should be allowed so that existing systems can amend permits to reflect actual water use and also allow new permits for systems in construction prior to the prohibition. This will permit facilities to recover some of their investment by amortization of new systems over a time period to be specified for conversion.

2) This study attempted to define a measure of water use efficiency for once-through systems. Various measures were proposed by the advisory committee, Orr Schelen Mayeron and Associates and the Division of Waters. Typically proposed measures of efficiency tried to balance water and electricity use. It is clear that much more analysis is needed to derive an acceptable efficiency standard. This analysis is not warranted considering the recommendation to continue the prohibition on new once-through systems.

3) Require Energy Management and Water Conservation

In order to decrease the load on heating and air conditioning systems and the subsequent water demand, devices such as, more efficient lighting, better building insulation, and energy management systems can be used. These devices also can be cost effective over the long term life of a building. Water demand can also be reduced, by the use of conservation practices on all water supply systems.

It is recommended that the State, through the State and Local Building and Mechanical Codes, encourage greater energy efficiency in buildings. In addition, water conservation standards should be broadened to include all potable and non-potable water supplies. The current Codes include requirements on insulation, energy efficiency of HVAC equipment, and potable water used in lavatories, toilets, and showers.

Options for converting once-through systems and a time schedule for phasing out existing systems.

1) If once-through water were reused for other industrial purposes or by municipalities (after treatment) there would be less objection to the initial use of the water for heating and cooling. One option could allow ground water permits for systems that reuse all once-through waters to offset other water requirements, excluding non-essential uses. Once-through systems utilizing ground water from pump outs for containment or removal of contamination could also be allowed for the life span of the pump out.

2) Keep prohibition on new once-through systems and allow non-conforming existing systems to continue operating until specific impacts to the ground water resources are documented. This is the option preferred by many building owners and operators.

   Almost everyone agrees about the need to monitor ground water impacts. The difference of opinion is centered on whether to curtail water use now or wait until further monitoring and research provide documented impacts. Waiting until there is a problem before requiring the efficient use of Minnesota's ground water is not sound resource management. The old adage "an ounce of prevention is worth a pound of cure" may apply to this situation. The efficient use of water is the only option to reduce or prevent impacts from occurring.

3) The no action option is to leave the existing prohibition and fee structure in place, but not require mandatory conversion.

   Prohibiting new uses and allowing existing non-conforming uses to continue has been done in other circumstances. However, allowing the continuation of non-conforming uses is contrary to Minnesota's riparian water use doctrine. In Minnesota, if there is not enough water to supply all demands, each user is required to limit their water use to allow for new users. Allowing some non-conforming uses while prohibiting new users is more aligned with the appropriative rights doctrine or "first in time, first in right" which is common in the Western United States. This "water right" can increase the value of property.

4) The present escalating fee schedule or a greater fixed rate fee could be imposed, allowing market forces to dictate conversion time.

5) Conversion by the year 2010 to allow for a twenty year normal life cycle for new equipment.

6) Each system could be evaluated to determine the normal life cycle for the main components of existing equipment and required to convert by the unique time frame.

It is recommended that the time schedule for conversion be based on the life cycle of the equipment at each facility. This would allow recent capital investments into systems to be utilized without as great a loss. This also allows for conversion, to take advantage of advancements in new heating and cooling technology as it occurs.

It is also recommended that all conversions be completed by the year 2010. This will allow for the practical life-cycle of twenty years on equipment.

A fee structure that will make once-through systems and conventional systems equal in operating costs.

1) There is no single fee that will make all systems equal in operating cost. There is tremendous variability in operating costs between system designs. An estimated fee range by Orr Schelen Mayeron and Associates, for different system types, using the costs of operating a cooling tower system as a base for comparison. This resulted in a range of $.095 to $.275 per 1000 gallons.

It is recommended that the escalating fee structure established in 1989 remain unchanged. Should the legislature decide not to require conversion it is recommended that a fee structure be implemented that will make once-through systems and alternative conventional systems equal in operating cost. This would require individual analysis of each facility to be conducted by the building owner.

2) All ground water users contribute to impacts on the resource. Non-essential and inefficient water uses should all be charged on the same fee schedule. It is not equitable to charge once-through heating and cooling permittees a higher fee than water use for non-essential purposes. Some non-essential uses include but are not be limited to: lake level maintenance, golf course irrigation and lawn watering, including all non-essential uses supplied by municipal water systems. It is recommended that all non-essential water uses be required to pay the same fees as once-through heating and cooling permittees. Municipalities should also be required to pay the higher fee schedule for the increase in summer water use for non-essential purposes.

3) Permittees are required to pay water use fees based on the authorized volume of water. Appropriators must submit written requests to amend permits to reflect increased water use prior to exceeding authorized limits. Permittees that exceed the permitted volume should be required to pay the additional fees. Therefore, it is recommended that water use fees be based on the permitted volume of water or the actual volume of water appropriated whichever is greater.

Summary of Recommendations

Recommendations followed by one asterisk (*) are changes requiring legislation. Two asterisks (**) are changes that can be done by legislation or rulemaking.

1) Protection of the Mt. Simon-Hinckley Aquifer in the Twin Cities Area from non-essential uses.**

2) Expand Monitoring of Ground Water Resources.

   a) Construct fourteen new Prairie du Chien-Jordan observation wells and eight Mt. Simon-Hinckley observation wells.

   b) Add continuous water level recorders on observation wells in areas with concentrations of large ground water withdrawals.

   c) Conduct yearly mass water level measurements on ground water levels in the Twin Cities Area.

   d) Require municipalities to install observation wells and also monitor water levels in production and standby wells.

3) Mandatory flow meters for all permittees.**

4) Require reuse of water when practical and feasible.**

5) Change the once-through definition to describe the type of system rather than the purpose for which the water is used. The recommended definition is:

> A once-through system is any heating, ventilating or air conditioning (HVAC) system used for any type of temperature or humidity control application, utilizing ground water, which circulates through the system and is then discharged without recirculating the majority of the water, in the system components.*

6) Continue prohibition on once-through systems, but allow new and amended permits for existing systems constructed prior to 1990.*

7) Encourage energy management and water conservation aspects in building designs.

8) Require once-through systems to convert to water efficient alternatives within the life cycle of the heating and cooling equipment, but no later than the year 2010.*

9) Keep the present escalating fee schedule for once-through heating and cooling systems.. However, if conversion is not required the fee schedule should be modified to make once-through systems and conventional systems equal in operating costs.*

   Non-essential water uses such as lawn watering, lake level augmentation and car washing, including those supplied by municipal water systems should be subject to the once-through fee schedule.*

   Water use fees should be based on permitted volume of water or actual water use, whichever is greater.*

WATER USE SECTION

WATER USE IN MINNESOTA

Water Use Reporting Requirements

Minnesota Statutes 105.41, subdivision 5 requires all permittees who use state waters to record the total volume of water appropriated monthly. Permittees must submit a water use report on forms supplied by the commissioner no later than February 15 of the following year.

Minnesota Statutes 105.41, subdivision 5 also requires that permittees submit a processing fee with the water use report. These processing fees are established by the Minnesota Legislature. Failure to pay the fee is sufficient grounds for revocation of the permit. A copy of the fee structure is included in the appendix.

Accuracy of Water Use Reporting: Metering

Minnesota Rules 6115.0750, subpart 3, requires that each installation must be equipped with a means of measuring the quantity of water appropriated. Flow meters are required on installations where appropriations exceed 1500 gallons per minute. Permittees with pumping rates less than 1,500 gallons per minute, are required to report water use within 10% of actual withdrawal, but are not required to have flow meters.

Timing devices are also used to determine the total volume of water pumped. Permittees who use timing devices simply record the time the pump operates and multiply that value by the flow rate of the pump. Timing devices, however, do not take into account variable speed pumps and periods of reduced demand.

Heating and air conditioning permittees use a range of measurement devices. Results from the 92 Geothermal Surveys returned for Hennepin and Ramsey Counties indicated that 68 of these permittees used flow meters to determine the total volume pumped. Nineteen permittees estimated the total volume of water pumped, four permittees reported using timing devices and one permittee used the volume of water reported on a sewer statement. The most common method used to estimate water use was to take the maximum pumping rate and multiply by an estimated pumping time. One permittee reported throttling a 350 gallon/minute (GPM) pump back to "approximately 250 GPM" and multiplied this value by an estimated pumping time. This permittee reported water use of "approximately 25-30 million gallons annually."

Summary

While many municipalities and industries use flow meters, there are others that use timing devices or estimate water use. Mandatory flow metering for all permittees can improve the accuracy of water use data for use in evaluating impacts on surface and ground water resources.

WATER USE IN HENNEPIN AND RAMSEY

In 1988, approximately 213 billion gallons of water was consumed in Hennepin and Ramsey Counties as shown in Table 1. 56 billion gallons of this (26%), was drawn from ground water sources and 157 billion gallons (74%), was drawn from surface water sources.

TABLE 1
1988 TOTAL REPORTED WATER USE
Hennepin and Ramsey Counties

TYPE WATER USE	MILLION GALLONS	% OF TOTAL	% CHANGE FROM 1987
Hydroelectric/Steam Power Cooling	107,709.5	50.6%	8.0%
Waterworks (Municipal and Private)	81,395.4	38.2%	4.1%
Heating and Cooling	10,964.6	5.1%	11.3%
Industrial	9,134.7	4.3%	6.3%
Basin/Lake Level Maintenance	1,660.3	0.8%	-3.6%
Golf Course Irrigation	1,422.6	0.7%	39.2%
Other [1]	619.3	0.3%	-67.4%
TOTALS	212,906.4	100.0%	5.9%

[1] Includes construction dewatering, sod, landscaping, non-crop irrigation, pollution confinement, etc.

Total Surface and Groundwater Use in 1988

Table 1 shows the total reported water use for Hennepin and Ramsey Counties in 1988. At the time this information was compiled, approximately 95% of all permittees had completed and returned their 1988 water use reports. Therefore, the total reported water use is slightly less than actual use. Water use data for 1987 is included in the appendix and is approximately 98% complete. The few non-reporting permittees, like those in 1988, are mostly small volume users. Therefore, the numbers should give a fairly accurate representation of total water use and the change of water use between 1987 and 1988. The data for ground water and surface water use (Tables 2 and 3), in the following sections, have the same constraints.

The largest use of water in Hennepin and Ramsey Counties was for hydroelectric power generation and steam power cooling. These uses represented 108 billion gallons, or almost 51% of the total use. Municipal water suppliers were the second largest user, appropriating approximately 81 billion gallons, or 38% of the total water use.

The consumption of water for heating and cooling accounted for almost 11 billion gallons. This represents slightly over 5% of the total water use and almost 20% of groundwater use.

GROUND WATER USE

In 1988, the reported volume of ground water pumped in Hennepin and Ramsey Counties was 55.6 billion gallons as indicated in Table 2.

TABLE 2
1988 GROUNDWATER USE
Hennepin and Ramsey Counties

TYPE WATER USE		MILLION GALLONS	% OF TOTAL	% CHANGE FROM 1987
Waterworks (Municipal and Private)		32,600.2	58.60%	5.1%
Heating and Cooling		10,964.6	19.71%	11.3%
Industrial		9,038.1	16.25%	6.2%
Processing	2,092.2			
Food & Livestock	2,869.3			
Paper & Pulp	1,525.8			
Metal Processing	1,757.1			
Other	793.7			
Golf Course Irrigation		1,209.6	2.17%	32.3%
Basin/Lake Level Maintenance		1,156.5	2.08%	100.3%
Other [1]		667.0	1.20%	-63.3%
TOTALS		55,636.0	100.00%	5.6%

[1] Includes construction dewatering, sod, landscaping, non-crop irrigation, pollution confinement, etc.

The largest users of groundwater were the municipalities, which pumped approximately 33 billion gallons or almost 60 percent of the total ground water pumped. Municipal users of ground water tend to be in the suburban and outlying areas of Hennepin and Ramsey Counties. The cities of Minneapolis and St. Paul draw most of their water from surface water sources.

The second largest use of ground water was for heating and cooling. The 106 permits of ground water, for heating and cooling, reported pumping almost 11 billion gallons, or 20% of all the ground water pumped in Hennepin and Ramsey Counties. Some permittees reported using a portion of that groundwater for uses other than heating and cooling. These other primary and secondary uses include domestic supply, industrial processing and lawn irrigation which account for about 10% of the total water use for heating and cooling. Since few permittees meter the auxiliary systems, this volume is unknown and can only be estimated. Some of the permits do not indicate secondary uses and should be amended accordingly.

In Hennepin and Ramsey Counties, 106 permits were authorized for the pumping of ground water for heating and cooling. The total volume authorized by permit was 12,941 million gallons. Table 2 shows the total volume of water reported in 1988 was 10,965 million gallons. Of the 106 permits, 30 permittees exceeded the authorized volume. These 30 permittees were authorized 3,893.7 million gallons or 30% of all heating and cooling water. They pumped 5,801.0 million gallons, or, 53% of all heating and cooling water.

SURFACE WATER USE

Table 3 summarizes 1988 surface water use in Hennepin and Ramsey Counties.

TABLE 3
1988 SURFACE WATER USE
Hennepin and Ramsey Counties

TYPE OF WATER USE	MILLION GALLONS	% OF TOTAL	% CHANGE FROM 1987
Waterworks (Municipal and Private)	48,795.2	31.01%	3.4%
Hydroelectric/Steam Power Cooling	107,709.5	68.46%	8.0%
Industrial	96.6	0.06%	9.3%
Basin/Lake Level Maintenance	503.8	0.32%	-56.0%
Golf Course Irrigation	213.0	0.14%	97.2%
Other [1]	13.8	0.01%	-83.2%
TOTAL	157,331.9	100.00%	6.1%

[1] Includes construction dewatering, sod, landscaping, non-crop irrigation, pollution confinement, etc.

Electric power production is the largest user of surface water in Hennepin and Ramsey Counties. The utilities appropriated approximately 108 billion gallons, or more than two-thirds of all surface water use.

Municipalities were the second largest surface water user. Municipalities appropriated 49 billion gallons, or 31 percent of the total surface water used. The largest municipal user was the City of Minneapolis, drawing about 30 billion gallons of Mississippi River water. Even though the intake for Minneapolis water supply is actually located in Anoka County, essentially all of the water is used in Hennepin County. Therefore, it was included with the Hennepin and Ramsey County totals.

Summary of Ground and Surface Water Use

Between 1987 and 1988, the reported water use in Hennepin and Ramsey Counties increased by 6%. Municipal water usage increased by about 3%. Municipal water use would have increased by a larger percentage if conservation measures had not been employed during the 1988 drought. Water used for heating and cooling increased approximately 11% while golf course irrigation increased by 39%. Water use for hydroelectric power generation and steam power cooling increased by 8%.

The total volume of water used for basin and lake level maintenance decreased by 3%. Groundwater used for basin and lake level maintenance increased by 100% while surface water used for the same purpose decreased by 56%. The decrease in surface water use was caused by a mechanical problem at the water intake for the Minneapolis Chain of Lakes. Without this mechanical failure, the volume of water used from surface water would probably have increased greatly.

There was also a decrease in the "other" category of 67% between 1987 and 1988. The percentage change appears excessively large because the water volume is small. Most of this decline can be accounted for in three areas. There was a significant decline in construction dewatering and water used for hatcheries. There was also a decline in non-crop irrigation (cemetery, sod, landscaping) of approximately 153 million gallons. This may have been due to watering restrictions.

Water Use by Priority Class

The Minnesota Legislature established five water use priorities. These priorities are listed in the introduction of this report.

First priority includes domestic water use, excluding industrial and commercial uses of the municipal water supply. However, water use reporting by municipalities does not separate residential from industrial, commercial or other fifth priority water use. A large volume of municipal water is not used as first priority water. An example of this occurs in the City of Eden Prairie.

The City of Eden Prairie has 10 municipal wells, all of which draw water from the Prairie du Chien-Jordan aquifer.

TABLE 4
EDEN PRAIRIE WATER USE - 1988

Month	Million Gallons (MG)	Million Gallons/Day	Percent
January	101,224	3.27	4.47
February	94,017	3.24	4.15
March	101,769	3.28	4.49
April	128,864	4.30	5.69
May	267,531	8.63	11.51
Jun	419,530	13.98	18.52
July	352,437	11.37	15.56
August	245,283	7.91	10.83
September	188,166	6.27	8.31
October	140,617	4.53	6.21
November	105,868	3.52	4.67
December	119,797	3.86	5.29
TOTAL	2,265,103	6.21	100.0%

Table 4 shows that Eden Prairie pumped 2.265 billion gallons of groundwater. Of that 2.265 billion gallons, 1.285 billion gallons, or almost 57% of the water was pumped in the summer months of May, June, July and August. Water use in June was four times the amount supplied in January. The supervisor of the water plant indicated that most of the water pumped in the summer months was for lawn irrigation. Therefore, a significant volume of water pumped by Eden Prairie went for non-essential uses.

Differing Priorities within Fifth Priority Water Use

The fifth priority includes all water consumption greater than 10,000 gallons per day. Fifth priority water uses include some heating and cooling, industrial processing, mining and construction applications. Also, included in the fifth priority is water used for non-essential purposes. Non-essential water uses include basin and lake level maintenance, lawn sprinkling, car washing, and golf course and park irrigation.

During periods of critical water deficiency, the governor may restrict non-essential water use. These non-essential uses should be specified and placed in a lower priority class in order to protect other fifth priority users. It is not always easy to classify a specific type of water use as non-essential. For example, golf course irrigation for greens and tees, which are not drought tolerant and very expensive to replace could be considered a commercial use of water. Irrigation of roughs and fairways is similar to lawn sprinkling and is clearly a non-essential water use.

Summary

The Minnesota Legislature has defined five water use priorities. Fifth priority water use basically covers all uses not specifically identified in priorities one through four. In 1988, fifth priority water users withdrew approximately 20 billion gallons of ground water. A undetermined but large amount of municipal water is also supplied to fifth priority water users. Non-essential water uses are also included in the fifth priority but should be separated into a lower priority classification to protect other fifth priority uses.

ONCE-THROUGH HEATING AND COOLING SECTION

SOURCES OF WATER FOR HEATING AND COOLING

Ground water is the primary source of water for heating and cooling systems. Its high yields and temperature range of 45 to 50 degrees Fahrenheit are the main reasons for the use of ground water. Ground water quality can also reduce the costs of water treatment necessary to control scaling and corrosion in the heating and cooling system.

Surface water sources can be used for heating and cooling, but have less desirable temperature ranges and usually have higher water treatment costs. Surface water temperatures, compared to ground water, are warmer in the summer and colder in the winter. No existing permittees have been identified, which use surface water sources for heating and air conditioning.

Municipal water supplies are another source of water available to some buildings for heating and cooling. Municipalities charge for water based on volume and have little information on actual use of the water. Therefore, the amount of water supplied by municipalities for heating and cooling is unknown.

The Minneapolis public works department indicated, that buildings using municipal water for heating or cooling, have closed loop systems that require only make up water. Considering the cost of municipal water this is, probably, a valid assumption. Also, municipal water temperatures in the summer months range from 65 to 75 degrees Fahrenheit. The warmer water temperatures can reduce the cost effectiveness of once-through systems.

The state capital complex is a good example of a closed loop system supplied by a municipal water source. The capital complex has its own plant to meet cooling requirements and is serviced by District Energy St. Paul, Inc. for heating requirements. District Energy also supplies heating water to over 100 buildings in St. Paul. In 1984 District Energy withdrew 71 million gallons of ground water for district heating purposes. By 1986 District Energy virtually eliminated the use of ground water by converting to a closed loop system which uses municipal water for minimal make up water requirements.

DISPOSAL OF HEATING AND COOLING WATER

The primary method for disposing of heating and cooling water is discharge into the local storm or sanitary sewer system. The Geothermal Heating and Cooling Survey found that approximately 9.9 billion gallons, or 90% of the heating and cooling water pumped in 1988 for Hennepin and Ramsey counties was disposed of in this way. The remaining 10% was discharged directly into surface water bodies, lawn irrigation, evaporation from cooling towers, reinjection, or others.

On the survey, permittees were asked to identify their discharge method, percentage of water discharged, and the receiving point for the water. Combining the survey results with the 1988 Water Use Reports, allowed for comparison of the volumes discharged by the various methods and the volumes expected at the receiving waters.

Table 5 lists the receiving points for discharged heating and cooling water. The chart was compiled by taking the reported pumpage from 1988 Water Use Reports and the discharge method from the Geothermal Survey. Nine Hennepin and Ramsey County permittees are not included in the chart because they either did not pump any water in 1988, or they did not file a water use report. Another five permittees, who did not respond to the survey, were assumed to discharge used heating and cooling water into the local storm sewer system. Based on the location of these permittees, all heating and cooling water discharged into the sewers would enter the Mississippi River.

TABLE 5
RECEIVING POINTS FOR HEATING AND COOLING WATER
Hennepin and Ramsey Counties

Receiving Water	Number Permits	Million Gallons	Volume Percent
Mississippi River (via sewers)	67	7371.5	67.2
Minnehaha Creek	1	337.2	3.1
Bassett Creek	4	506.4	4.6
Lake Cornelia	3	378.5	3.5
Minnesota River Basin	4	581.8	5.3
Other surface waters [1]	17	1380.3	12.6
Landscape Irrigation	9	246.3	2.2
Cooling Tower Evaporation	4	115.5	1.1
Reinjection	1	47.1	0.4
TOTALS	110[2]	10,964.6	100.0

[1] Includes isolated lakes and ponds that did not receive heating and cooling water from more than two permittees.

[2] The total number of permits discharging to any specific receiving point is greater than the 97 Hennepin and Ramsey County permittees because several permittees reported multiple methods of discharge.

In Hennepin and Ramsey Counties, a potential of approximately 9,175.4 million gallons, or 83.7% of all heating and cooling water, discharged to the Mississippi River or its' tributaries via the storm and sanitary sewer systems. This assumes there is no water loss within sewer systems, lakes and watercourses. However, water discharged to metropolitan lakes that have connections to the Mississippi River, only outlet under high water level conditions. The Minneapolis Chain of Lakes, Lake Cornelia, and other lakes and ponds have surface connections to Mississippi River tributaries. When lake levels are high, this allows excess water to drain to the river.

Heating and cooling water is also discharged to a variety of unconnected lakes, ponds and wetlands. Nineteen permittees reported disposing of water in this way. In these lakes and ponds, the heating and cooling water helps to maintain water levels. There are, however, detrimental affects on lakes, ponds and wetlands associated with the discharge of heating and cooling water. Among these are increased algae growth due to the higher temperature of heating and cooling water.

Alternative Uses and Disposal

Minnesota Rules 6115.0600 require the Department of Natural Resources to conserve and utilize the water resources of the state in the public interest. These rules also require the analysis of the quantity, quality and timing of any waters returned after use and the impact on receiving waters. Minnesota Rules 6115.0670, subparagraph 2.A.(7), also requires the Department to consider "the efficiency of use and intended application of water conservation practices".

A. Reuse of Heating and Cooling Water

Minnesota Rules (4725.2300), administered by the Department of Health, state that "... water used for air conditioning, shall not be returned to any part of the potable system". The Rules do not specifically prohibit the reuse of heating and cooling water for processing applications, lawn and garden irrigation or other non-potable uses.

Without treatment, heating and cooling water is not acceptable for reuse in any part of the potable water supply because it may have come in contact with a contaminant while in the system. From the survey, approximately 6,399 million gallons, or 58% of the heating and cooling water used in Hennepin and Ramsey Counties has been treated with compounds to kill bacteria and prevent system corrosion. The expense and physical constraints related to conveyance of used water to a treatment facility are often cited as reasons for not reusing heating and cooling water for municipal water supplies.

Heating and cooling water is reusable in the non-potable water supply. Most users of heating and cooling water are located in the downtown areas of Minneapolis and St. Paul. At these locations, there are few non-potable options for reuse. Therefore, the cheapest option is to dispose of heating and cooling water in the sewer systems.

There are heating and cooling permittees that do reuse some of the water. Survey data indicates that nine permittees reported reusing 246.3 million gallons of heating and cooling water for lawn irrigation. This amount of water is adequate to irrigate 370 acres of lawn with one inch of water per week for 24 weeks. There are two other permittees that reuse water, by blending it with processing water to meet discharge temperature limitations.

B. Reinjection of Heating and Cooling Water

Reinjection is the process of returning water to an aquifer through one or more injection wells. Under Minnesota Rule 4725.2300, administered by the Department of Health, "A well shall not be used for disposal of surface water, near surface water, or groundwater or any other liquid, gas or chemical". Reinjection is also not allowed under Minnesota Rule 7060.0600, administered by the Pollution Control Agency, which states, "No sewage, industrial waste, or other waste shall be discharged directly into the zone of saturation by such means as injection wells ...".

The main concern related to reinjection is the possibility of pumping a contaminant directly into the aquifer. This could occur as a system breach, where a contaminant enters a heating or cooling system and is then pumped into the aquifer or by the accidental cross connection of pipes. Although the accidental cross connection of pipes may not sound likely, it is possible. There have been cases where sewer and industrial pipelines were connected to potable supplies. The breaching or cross connecting of any pipes on a reinjection system could contaminate an aquifer and jeopardize the use of that resource.

Reinjection is further complicated by the fact that heating and cooling water has experienced significant temperature changes during use. Heat is specifically listed as an "other waste" in Minnesota Statute 115.01, subdivision 4. Pumping heating and cooling water back into an aquifer may cause the aquifer stability to change. By injecting heated water back into the aquifer, the chemical composition of the minerals associated with the water may change. Certain minerals may be dissolved by the warmer water while other minerals, may precipitate out of solution. As the water chemistry changed, the treatment of the water for potable purposes would become more complicated and costly.

Finally, based on survey data, 6,399 million gallons, or 58% of the heating and cooling water has had chemical compounds added to it prevent fouling of equipment. This water could not be reinjected without being treated first.

In 1988, the University of Minnesota Aquifer Thermal Energy Storage Project reinjected approximately 47.1 million gallons of heating and cooling water. This is an experimental project that is providing valuable information on reinjection.

The Department of Health currently has reinjection permits for about 6 residential heat pump operations. These operations require less than 10,000 gallons per day and less than one million gallons per year and therefore do not require a DNR permit. The Department of Health reports that these types of systems have had numerous technical problems and are often abandoned after a few years.

The Pollution Control Agency, is currently reviewing their policy on reinjection.

C. Drainfields

Drainfields are another method that could be used to dispose of water for small systems in rural areas. A drainfield is a series of horizontal or near horizontal underground porous pipes or hoses that drain water directly into the ground. The water is then allowed to percolate through the soil into the near surface water supply. These systems do not necessarily return heating and cooling water to the same aquifer (from which the) water was withdrawn.

Currently, only one permittee, located in Crow Wing County, uses a drainfield. In the downtown areas of Minneapolis and St. Paul, drainfields are not feasible because of the large volume of water discharged and the lack of space needed for the size of drainfield that would be required to meet the volume.

D. Retention Basins and Ponds

Retention basins and ponds are small surface water bodies that store water in a specified surface area. Some of the water entering these basins or ponds will remain in the pond as surface storage while other water will leave the basin or pond by either evaporation into the atmosphere or percolation into the ground. These systems do not, however, recharge deep aquifers.

Summary

Currently, the use of the sewer systems is the most economical and feasible method of disposal available for large volume users. It is practically the only method of disposal within the downtown areas of Minneapolis and St. Paul. Retention basins or ponds, are often part of the storm water drainage system. Reuse and reinjection of water is restricted under Minnesota Department of Health and Minnesota Pollution Control Agency rules. Drainfields are not practical for large volume systems and in downtown areas, but can easily be applied to smaller facilities in outlying areas.

GROUND WATER SECTION

INTRODUCTION

The Minnesota State Legislature, under the Laws of Minnesota 1989, has mandated that the Commissioner of Natural Resources conduct a study of consumptive water use and the impact of consumptive use on existing aquifers. The Minnesota Department of Natural Resources, Division of Waters (DOW), was assigned the task of identifying the sources of heating and cooling waters and determining the impact of these withdrawals on the ground water and surface water resource of the Twin Cities Metropolitan Area.

Permitted heating and cooling ground water users were identified using the DOW's Statewide Water Use Data System (SWUDS). The SWUDS data base allows categorization of permittees by water use. Once users were identified, information about their wells was collected. The principal sources of well information were the Minnesota Geological Survey and permit files.

GROUND WATER DEFINED

The term ground water is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated. An aquifer is a geologic unit that can store and transmit water in sufficient quantities to supply wells. Ground water does not, as many believe, flow in great underground rivers and lakes. The closest thing to underground rivers are solution-enlarged fractures in carbonate bedrock (found in southeastern Minnesota).

Aquifers are assumed to have certain idealized characteristics and are assumed to be one of two distinct kinds, either confined (artesian) or unconfined (water table). A confined aquifer is an aquifer that is sandwiched between two aquitards. An aquitard is a layer of rock or unconsolidated material that limits the flow of water (for example clay or shale). An unconfined aquifer is bounded on the top by the water table. In a confined aquifer, the water level in a well rises above the top of the aquifer. Such wells are called artesian wells and the aquifer is said to exist under artesian conditions. The water level in a well screened in an unconfined aquifer rests at the water table (Figure GW-1).

When a well is pumped, a zone of influence, called a cone of depression, is formed near the well (Figure GW-2). The greatest impact or drawdown is at the well itself. When several closely spaced wells pump, the cones of depression caused by the pumping combine (Figure GW-3), forming a much larger cone of depression. This situation exists in the downtown Minneapolis and St. Paul area, and many municipal well fields.

Minnesota's 14 major aquifers (Adolphson, Ruhl, Wolf, 1981) can be classified by general rock type into crystalline (igneous and metamorphic) rocks, sedimentary rocks (sandstones and carbonates), and unconsolidated sands and gravel deposits (Figure GW-4).

Only five of the 14 aquifers under the Twin Cities area can provide good quality water in the volumes necessary for heating and cooling purposes. Glacial buried and surficial sand and gravel aquifers of Quaternary age overlie the bedrock aquifers throughout the Twin Cities. The first bedrock aquifer found in the Twin Cities is the St. Peter sandstone. The remaining aquifers in increasing geologic age and depth from the surface are the Prairie du Chien-

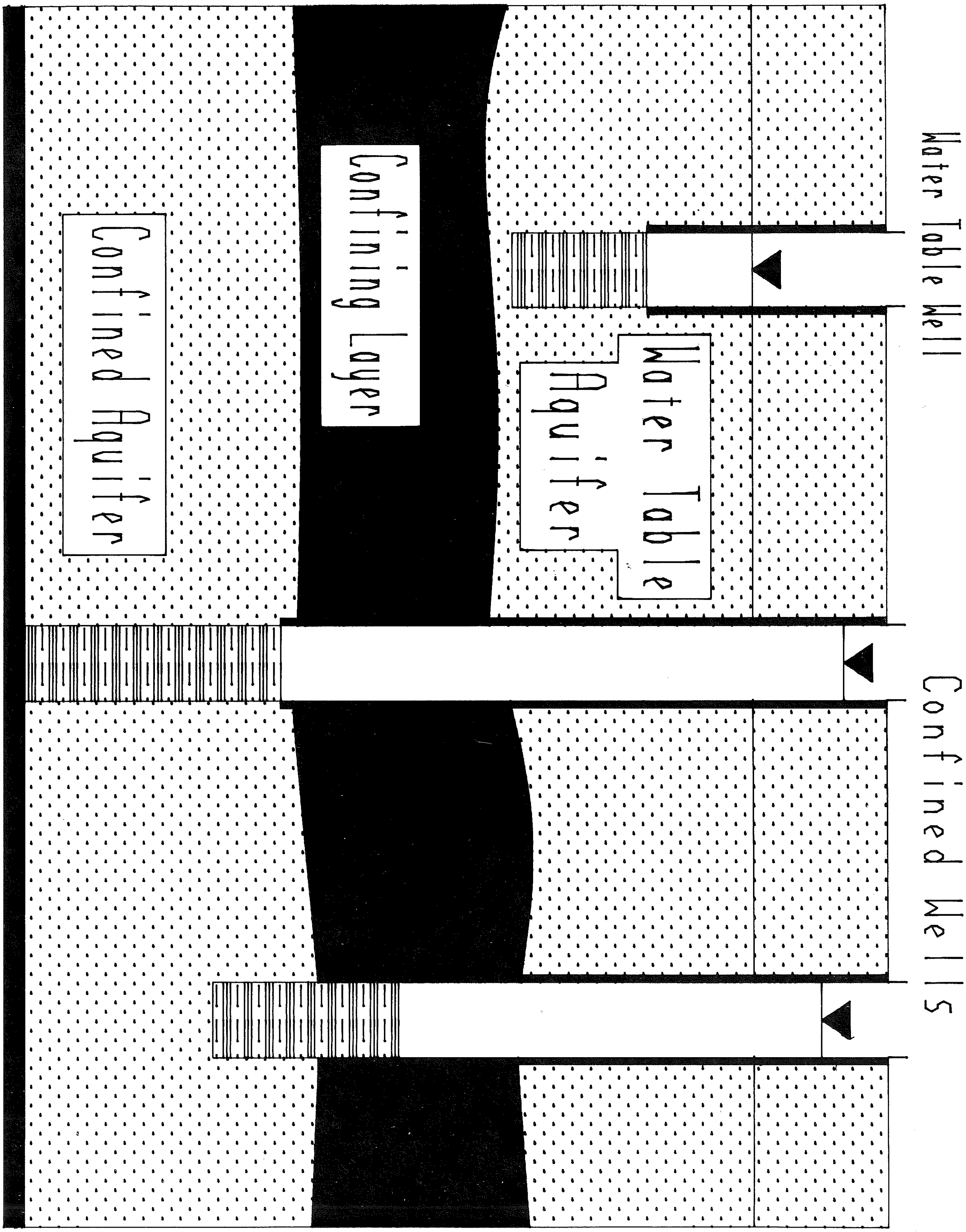


Figure GW-1: Confined (Artesian) vs. Unconfined (Water Table) Wells

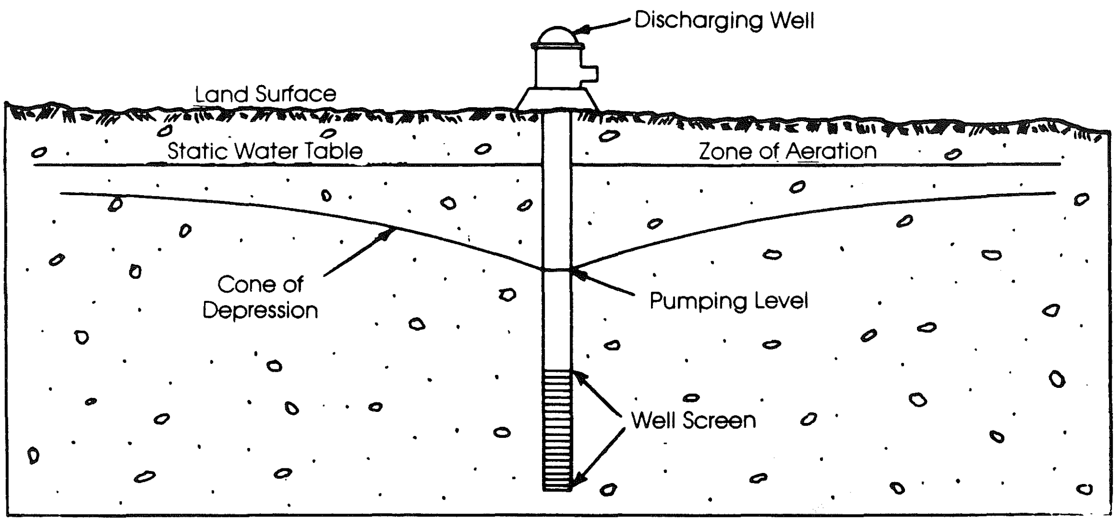


Figure GW-2: Example of the Cone of Depression formed by pumping one well.
U.S. Geological Survey

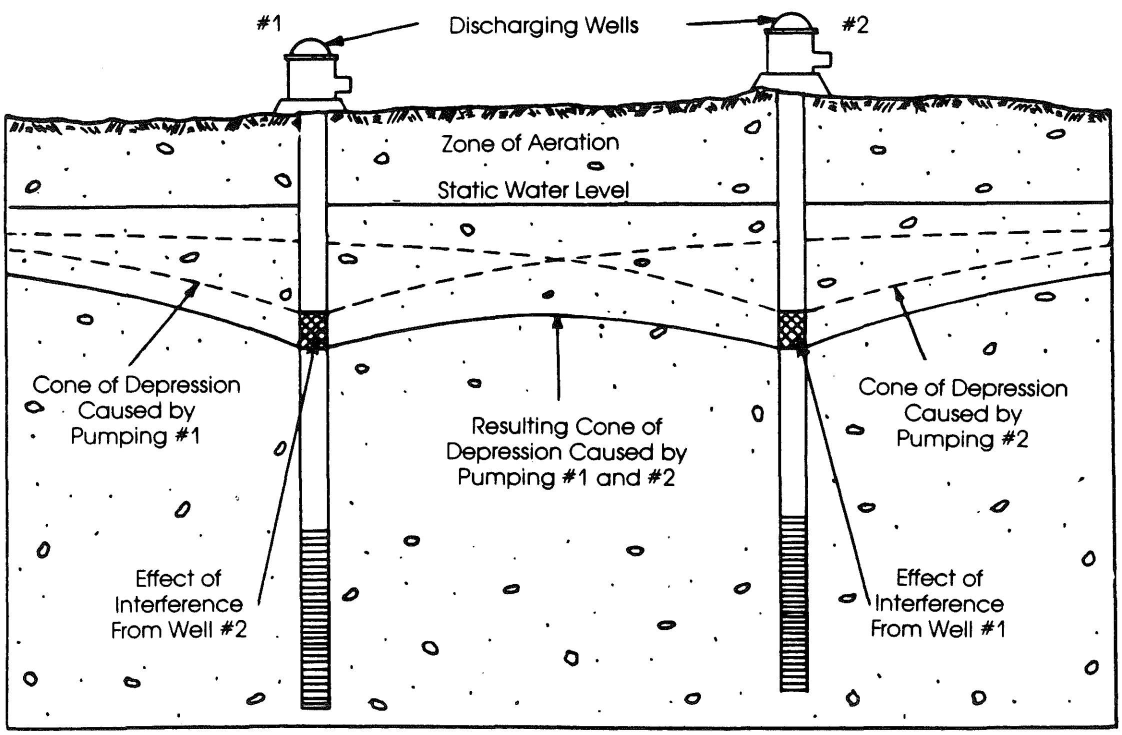


Figure GW-3: Example of the Mutual Cone of Depression formed by pumping multiple wells.
U.S. Geological Survey

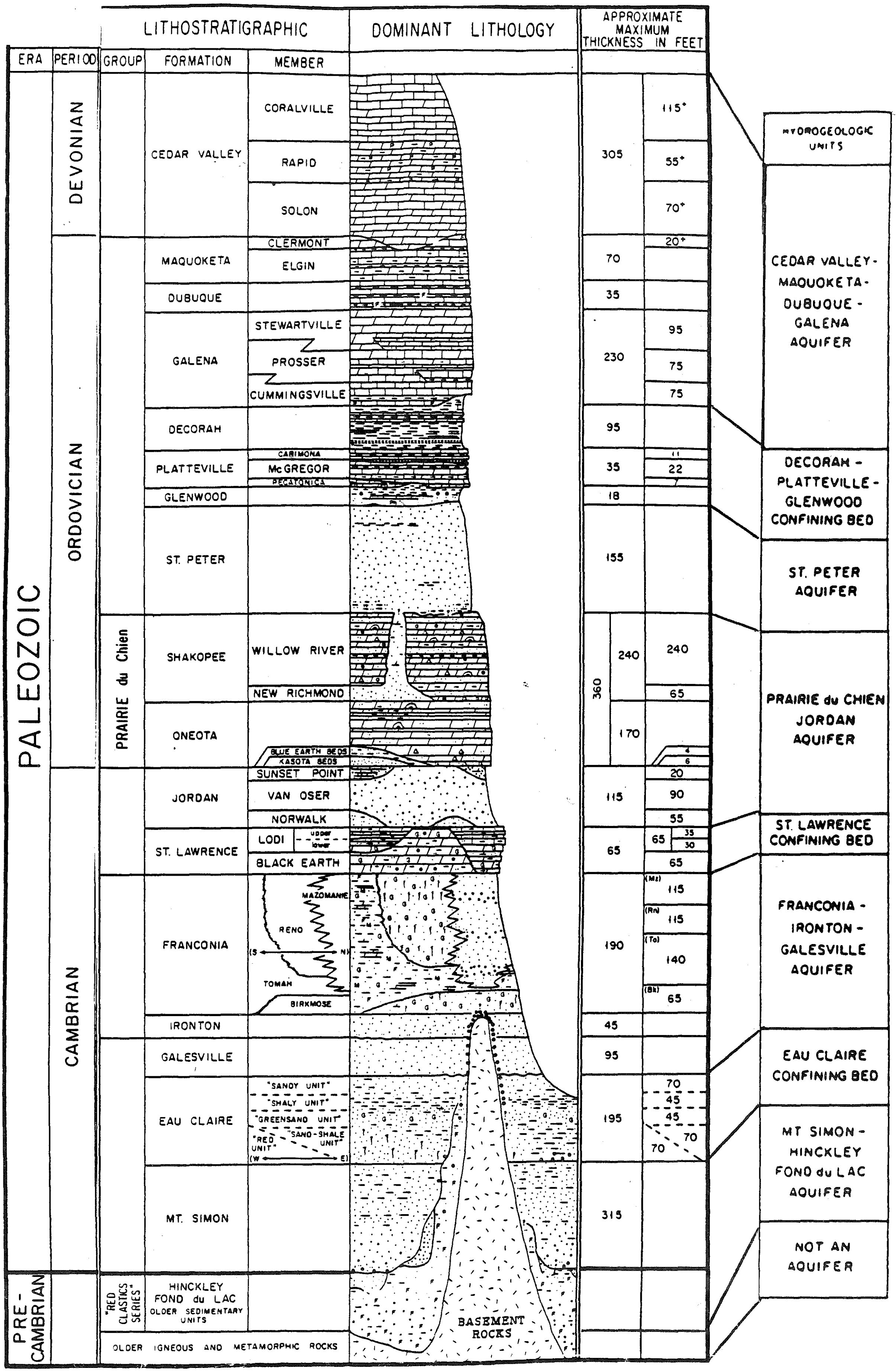


Figure GW-4: Minnesota Geologic Column.
After Woodward, 1986. U.S. Geological Survey.

Jordan, the Franconia-Ironton-Galesville, and the basal unit-the Mt. Simon-Hinckley-Fond du Lac (Figures GW-5 & GW-6).

The following aquifer descriptions are drawn from U. S. Geological Survey (Adolphson, Ruhl and Wolf, 1981) and Minnesota Geological Survey (Jirsa, Olsen, and Bloomgren, 1986) publications.

1. Buried and surficial gravel aquifers: These types of aquifers can be found in most parts of the State including most of the Twin Cities Area. These aquifers consist of fine to coarse-grained sands and gravels of varying thickness and well yields. These sands and gravels provide much of the drinking water in the northern suburbs where the bedrock aquifers are thin or non-existent.

2. St. Peter sandstone: The aquifer, a white, fine- to medium-grained sandstone, is the first bedrock aquifer in most of the Twin Cities. The aquifer is heavily incised by streams and is quite discontinuous. Ground water occurs under both confined and unconfined conditions. The St. Peter aquifer is usually not pumped for public supplies. Well yields generally range from 10 to 100 gallons per minute (gpm) but yields of up to 1000 gpm have been reported. The unit has a typical thickness of 155 feet.

3. Prairie du Chien-Jordan: The aquifer is composed of two distinctly different lithologic units. The Prairie du Chien overlies the Jordan and is predominantly a sandy dolomite with fractures and joints. These fractures and joints provide the flow pathways for water in this 280 foot thick unit. The Jordan is a uniform, highly permeable sandstone with an average thickness of 100 feet. The Prairie du Chien-Jordan is the most heavily used aquifer in the Twin Cities area. It provides 80 percent of the annual ground water supply (Horn, 1983). Wells completed in the Prairie du Chien-Jordan yield as much as 2,400 gpm from the Jordan sandstone and 1,800 gpm from the fractured Prairie du Chien. The Jordan is thin or absent along the north and northwestern edge of the metro area.

4. Franconia-Ironton-Galesville: This unit consists of fine to coarse sandstones interbedded with shales, dolomitic sandstone, and dolomitic siltstone. The Franconia-Ironton-Galesville is approximately 240 feet thick. It is not a regionally significant source of water in the Twin Cities. Yields range from 40 to 400 gpm.

5. Mount Simon-Hinkley-Fond du Lac aquifer: The aquifer is a 250 foot thick series of sandstone, siltstone, and shale found throughout the southeastern part of Minnesota. The aquifer provides 10 percent of the ground water used in the Twin Cities area (Horn, 1983). The aquifer is much shallower and more heavily used north of the Twin Cities. Yields are generally about 500 gpm but, locally, yields of 2,000 gpm are possible.

WATER USE TRENDS

Winchell (1905) reported that most early industrial and public supply wells were completed in the uppermost bedrock unit. Throughout most of Ramsey, eastern Hennepin, and western Washington counties this is the St. Peter sandstone. In Dakota, eastern Washington, and parts of Ramsey and Hennepin counties, the uppermost bedrock unit is the Prairie du Chien-

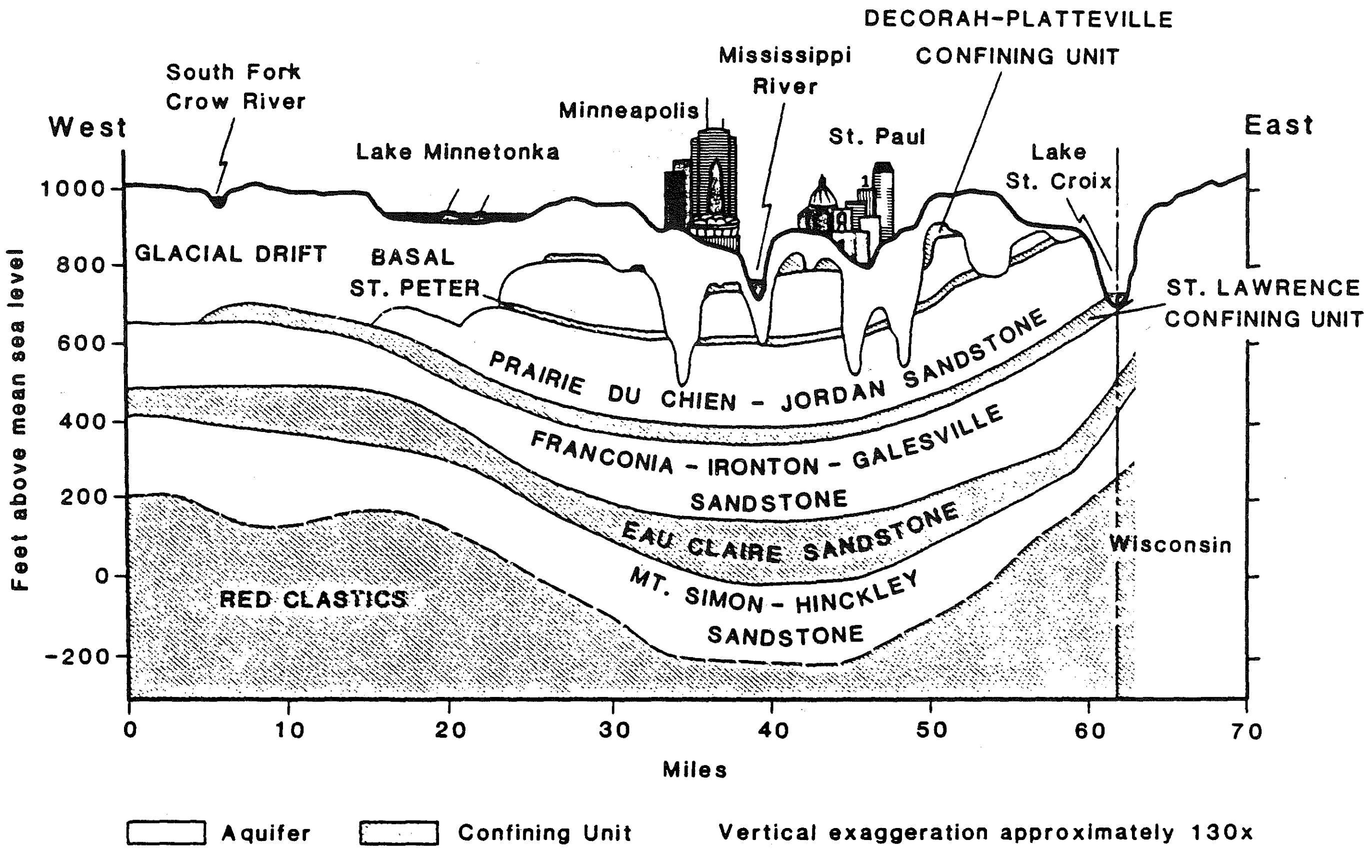


Figure GW-5: Aquifers of the Twin Cities Metropolitan Area.
Metropolitan Council, 1986.

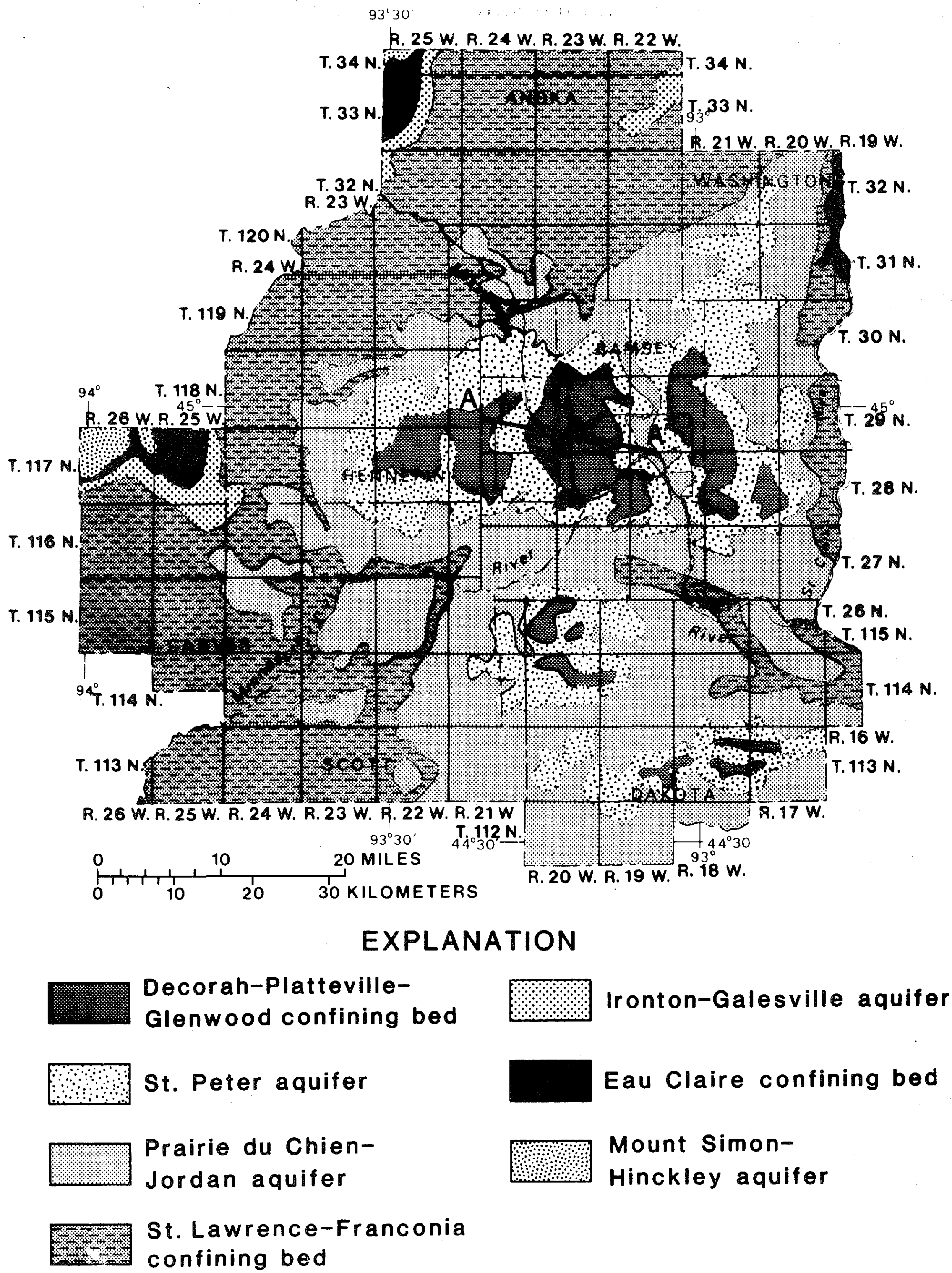


Figure GW-6: Bedrock hydrogeology in the Twin Cities area.
Horn, 1983. U.S. Geological Survey.

Jordan formation. In the northwest and western edge of the seven county metro area this unit is the Ironton-Galesville.

Horn (1983) reports that the Prairie du Chien-Jordan became the primary public source for ground water withdrawn in both Minneapolis and St. Paul after 1910 for several reasons: 1) higher available yields, 2) lower dissolved-solids concentrations, and 3) wells completed in the St. Peter frequently pumped fine sand particles. The first downtown Mt. Simon-Hinckley wells were drilled in 1922 (Minneapolis Water Supply Commission, 1932). The Mt. Simon-Hinckley yields water with very low dissolved-solid concentrations. This very soft water made this aquifer the source of choice for hospitals, laundries and breweries. Many railroad wells were cased to the Mt. Simon because soft water helped prevent scale buildup in the boilers of railroad steam engines.

Many older high-capacity wells are open to multiple aquifers. Although this practice usually results in higher yields, it also dramatically increases the possibility of contaminant movement between aquifers. The Minnesota Department of Health no longer allows the installation of multiple aquifer wells and those that still exist present a growing problem as they age.

Schoenberg (Draft, 1987) reports that predevelopment potentiometric heads in the Prairie du Chien-Jordan flowed from topographically controlled potentiometric highs in northern Washington and central Hennepin counties toward the major rivers-Mississippi, Minnesota, and St. Croix (Figure GW-7). The major rivers are important natural ground water boundaries (discharge points) for all the aquifers between the glacial drift and the Ironton-Galesville. No historical data exists for the southern counties. Schoenberg reports that water level measurements taken during the winter of 1980 indicated that current ground water flow directions were similar to pre-development ground water flows for Washington and Hennepin counties. This data suggests there is no *major* cone of depression in the winter in the Prairie du Chien-Jordan. Ground water in southern Dakota and southern Scott counties currently flows toward the major rivers (Figure GW-8).

Summer water level measurements indicate that the ground water flow in the Prairie du Chien-Jordan is diverted by major pumping centers. Schoenberg (1984) reports "locally...major pumping centers disrupt the natural flow pattern in the Prairie du Chien-Jordan aquifer by diverting ground water enroute to the major streams. In some areas, such as near the depression in the water-level surface in southwestern Ramsey County...pumping may have reversed the natural direction of flow and caused water from the Mississippi River to enter the aquifer." Pumping centers in downtown Minneapolis and the western suburbs also cause local water level depressions. Schoenberg (Draft, 1987) reports localized long-term declines of the potentiometric surface of about 90 feet.

The major metro rivers are the principal natural ground water sinks of the flow system where ground water is discharged from the aquifer to the rivers. Ground water movement from the rivers to the aquifer system may occur under two conditions: 1) When the river is at flood stage, it is possible that the elevation of the water surface could be above the water level in the aquifer along the river; thus water would be forced into the aquifer, and 2) During the summer months, seasonal pumping -(principally for cooling and municipal use)- may lower water levels in the aquifer below the level of the water in the river and induce flow from the river to the aquifer. Buried bedrock valleys also act as discharge/recharge points because vertical flow in gravel-filled buried channels can usually occur much faster than through the stack of geologic units which cover the aquifer in other areas.

Before pumping started in the metro area, ground water flow in the Mt. Simon-Hinckley aquifer was probably to the east toward the St. Croix and Mississippi Rivers from a potentiometric high in the northwestern seven county metro area (Figure GW-9).

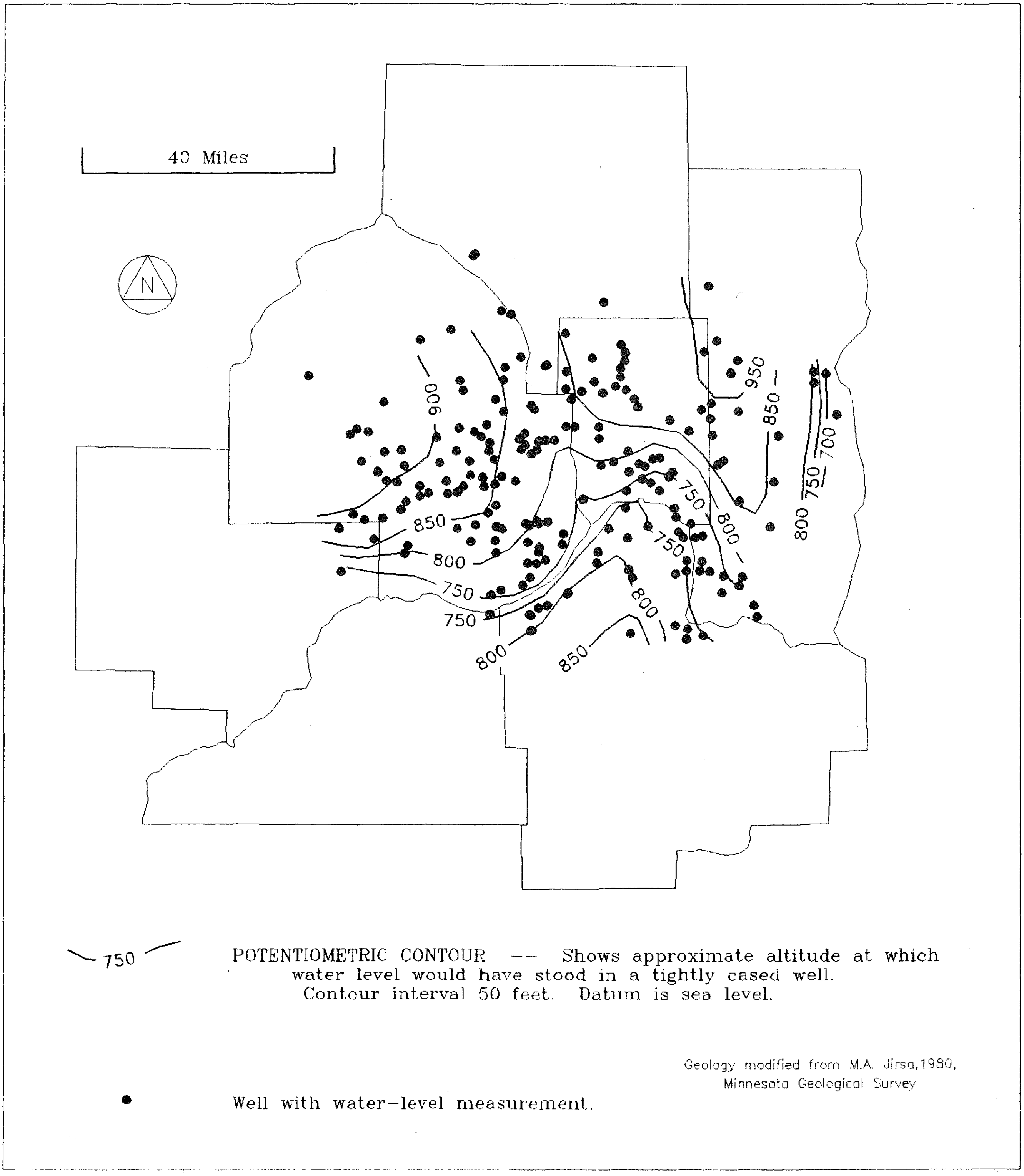


Figure GW-7: Predevelopment potentiometric surface, Prairie du Chien-Jordan aquifer.
Schoenberg, 1987. U.S. Geological Survey.

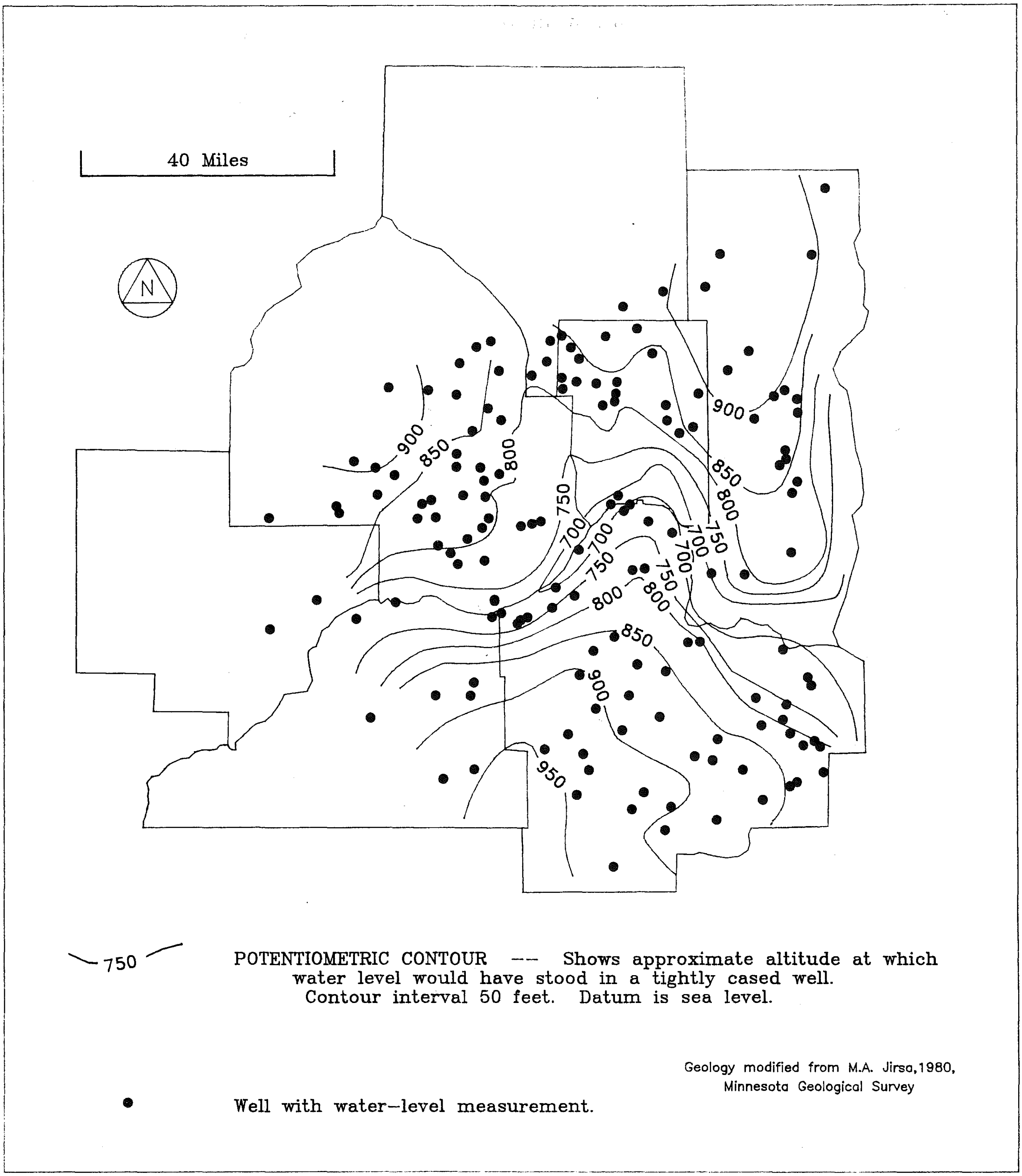


Figure GW-8: Potentiometric surface during winter 1980, Prairie du Chien-Jordan aquifer.
Schoenberg, 1987. U.S. Geological Survey.

Schoenberg (Draft, 1987) reports that water level measurements in winter 1980 revealed a change in flow direction. Ground water flow is now southeasterly from the same potentiometric high toward a large cone of depression near the Mississippi and Minnesota Rivers. Furthermore, ground water flow toward the cone of depression was induced from potentiometric highs south (Delin and Woodward, 1985) and west (Schoenberg, 1984) of the Metro area (Figure GW-10). The hydraulic connection to the rivers reduces the impact on the Prairie du Chien-Jordan aquifer resulting in a less pronounced cone of depression. The lack of connection between the Mt. Simon-Hinckley and the rivers results in a much more dramatic effect to pumping stress in that aquifer.

Water in all the aquifers between the glacial drift and the Ironton-Galesville is replenished in several ways: 1) downward infiltration of rain water through the soil to the water table, 2) induced infiltration of surface water through the sediments on the bottoms of lakes and rivers into the aquifers, 3) accelerated vertical ground water movement due to the high-permeability connection in buried bedrock valleys, and 4) lateral movement of water from the major aquifer recharge areas north and northwest of the Twin Cities. Recharge through the overlying units is not a major source of water for the Mt. Simon-Hinckley aquifer, therefore, the aquifer relies on lateral movement of water from recharge areas for replenishment.

WATER USE HISTORY

The U. S. Geological Survey (Horn, 1983) has analyzed and described ground water use trends in the Twin Cities from 1880-1980. The following is a review of that report.

Horn defined five major ground-water-use categories in the Twin Cities area. From greatest to least amount of use they are:

(1) municipal,

(2) self-supplied industrial (including air-conditioning),

(3) irrigation,

(4) dewatering,

and (5) lake-level maintenance.

Each category has its own characteristics and Horn discusses each separately - this report addresses the self-supplied industrial and municipal.

Self-supplied industrial ground water use was less than 1 million gallons per day (Mgal/d) until the period 1911-1920 when it increased to 8.8 Mgal/d. This initial increase in water use was in response to population increases and expansion of the industrial base of Minneapolis and St. Paul. From 1920 to 1940 ground water use continued to climb in response to the continued growth of agricultural processing (grain milling, breweries, stockyards, and creameries) and heavy industry within the Twin Cities.

From post-World War II to the early 1960's the self-supplied industrial ground water use increased by 70 percent from 57 to 97 Mgal/d. The largest single increase was in ground water used in commercial buildings (6.6 to 19.6 Mgal/d). The post-war construction boom of stores, office buildings and hotels relied on ground water as the source for water-cooled air

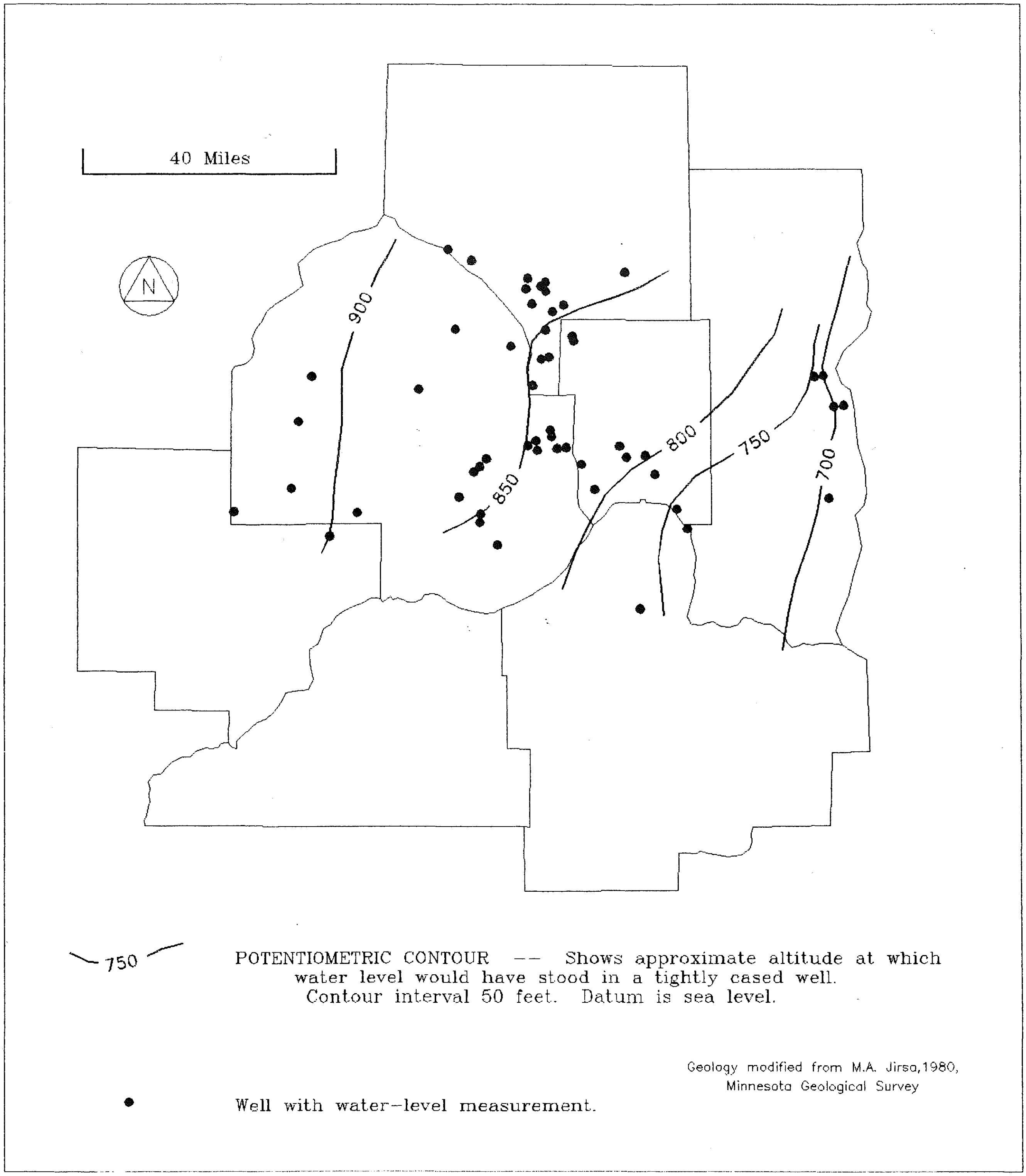


Figure GW-9: Predevelopment potentiometric surface, Mount Simon-Hinkley aquifer.
Schoenberg, 1987. U.S. Geological Survey.

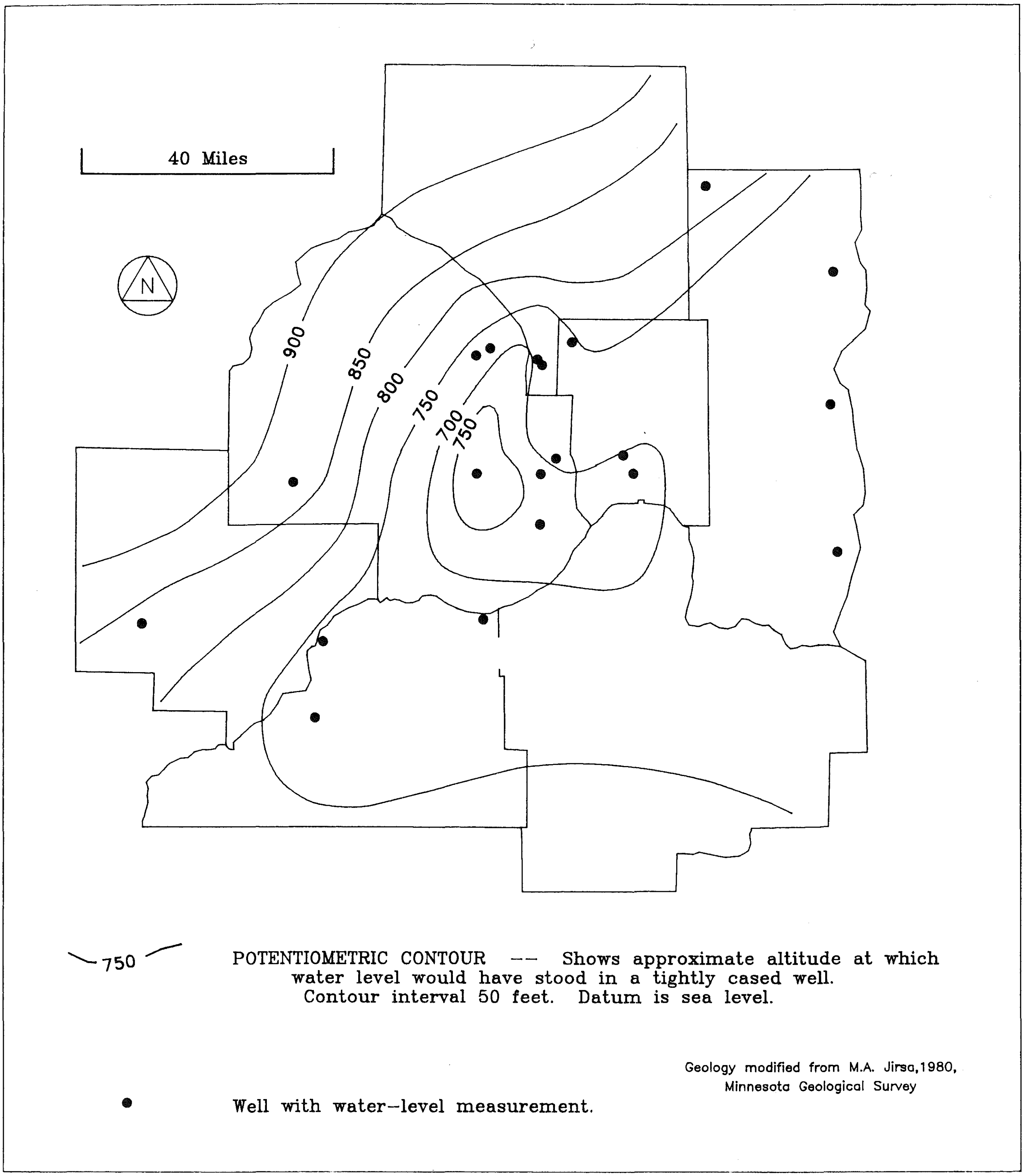


Figure GW-10: Potentiometric surface during winter 1980, Mount Simon-Hinkley aquifer.
Schoenberg, 1987. U.S. Geological Survey.

conditioning. This ground water was generally pumped through the cooling system once and then disposed of through the storm sewers. Because of air conditioning, commercial water use has become seasonal: much greater water demand occurs during the summer months.

Between the early 1960's and the late 1970's, self-supplied industrial ground water use declined 15 percent to 82.0 Mgal/d. The decline can be attributed to several factors: reduced activity at the stockyards, higher sewage disposal charges, and three major techniques used to conserve water used for cooling. The first technique, recirculation through cooling towers, allows reuse for cooling. The second technique, use of holding tanks, allows a constant water pressure to be maintained by replacing water as it is used rather than pumping continuously. The third technique, installation of variable speed pump drives, decreases the volume of water circulating through a system when demand is low (winter conditions).

During the 1960's the industrial, commercial and business base of the Twin Cities gravitated toward the suburbs. This shift of pumping centers out of the downtown area to the suburbs helped to distribute ground water pumping over a larger area and thus reduced the stress on the aquifers in the downtown area.

During the late 1970's, the use of ground water for many self-supplied uses declined. Some industries formerly located downtown had moved to the suburbs where new industries were also growing. This further dispersed the pumping centers. Industries began to supplement their self-supplied ground water sources with municipal water supplies thus further diminishing the stress on the aquifers beneath the downtown area.

During the mid to late 1980's, ground water withdrawals for self-supplied uses continued to decline in the downtown area. Ground water withdrawals for pollution confinement and expansion of the non-metallic product industries increased slightly. The continued movement to the suburbs, particularly the western suburbs, has shifted not removed much of the pumping stress on the aquifers.

Municipal ground water users include all domestic, commercial, industrial, and city (sanitation, fire) users supplied by municipal waterworks (Horn, 1983). Until the 1911-1920 decade, when it increased to a scant 1.7 Mgal/d, municipal systems supplied less than 1 Mgal/d of ground water. From the 1940's through the late 1970's, municipal ground water withdrawals increased from 8.9 Mgal/d to 87.6 Mgal/d. In 1987 and 1988 respectively, reported municipal ground water withdrawals averaged 155.0 Mgal/d and 156.4 Mgal/d.

WATER USE BY AQUIFER

The records of the Division of Waters currently contain a statewide total of 124 permits covering 188 wells for heating and cooling water withdrawals (Appendix I and Figures GW-11 & GW-12). The aquifers drawn from by these 188 wells range from surficial glacial outwash aquifers to the deep Mt. Simon-Hinckley bedrock aquifer (Figure GW-5). The total volume of permitted withdrawals is approximately 13.5 billion gallons per year.

Most of these permits, 106 covering 158 wells located in Ramsey and Hennepin Counties (Table I). For this reason, the scope of review for pumping impacts is limited to the metropolitan area. This is not meant to minimize the impact of ground water withdrawals on water levels in greater Minnesota. For example, the areas around Winona and Rochester have multiple pumping wells in bedrock units. The cone of depression generated by each high capacity pumping well will impact the resource to varying degrees.

Figure GW-11: Metropolitan Heating and Cooling Well Locations

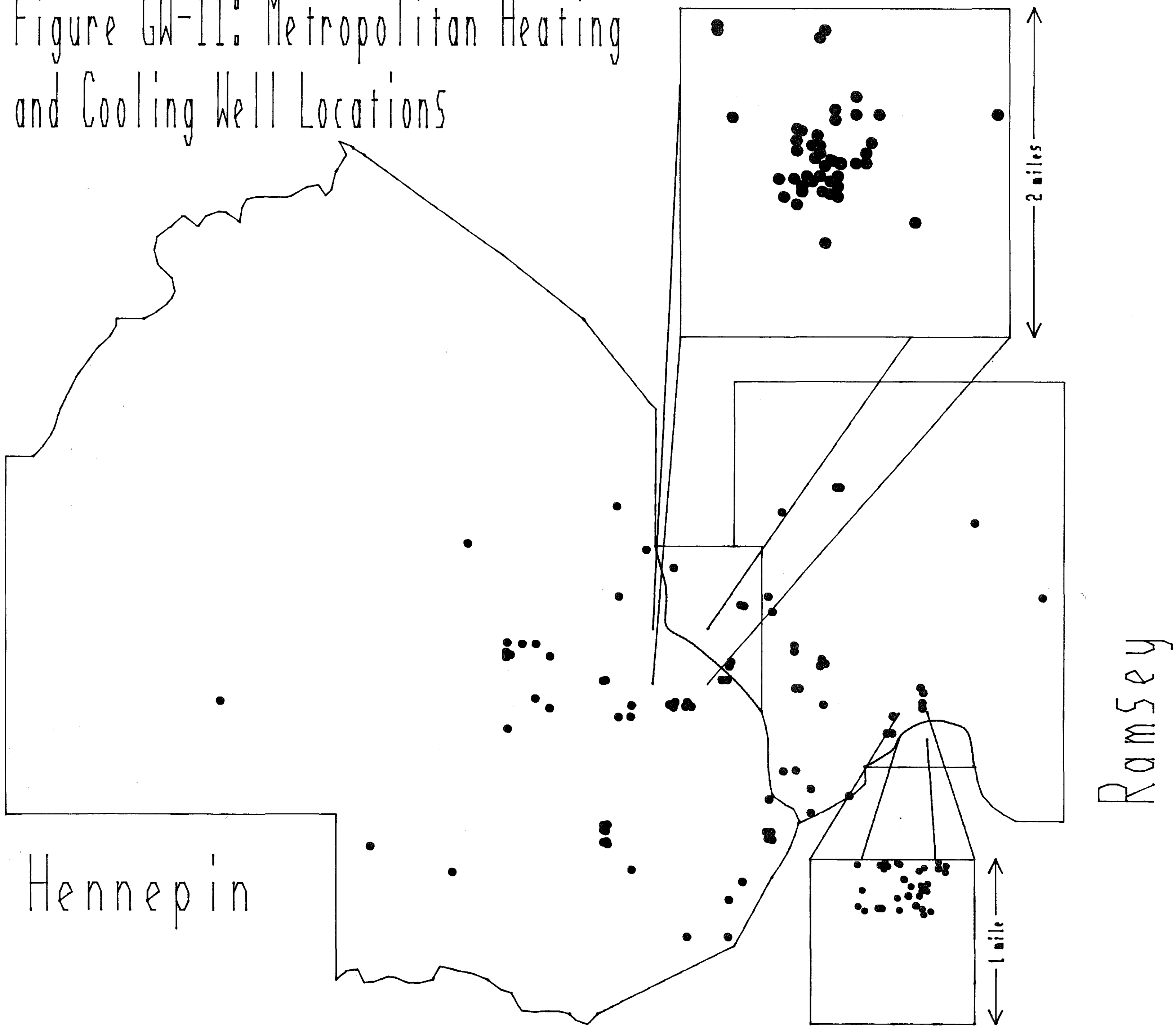


Figure GW-12: OutState Heating and Cooling Well Locations

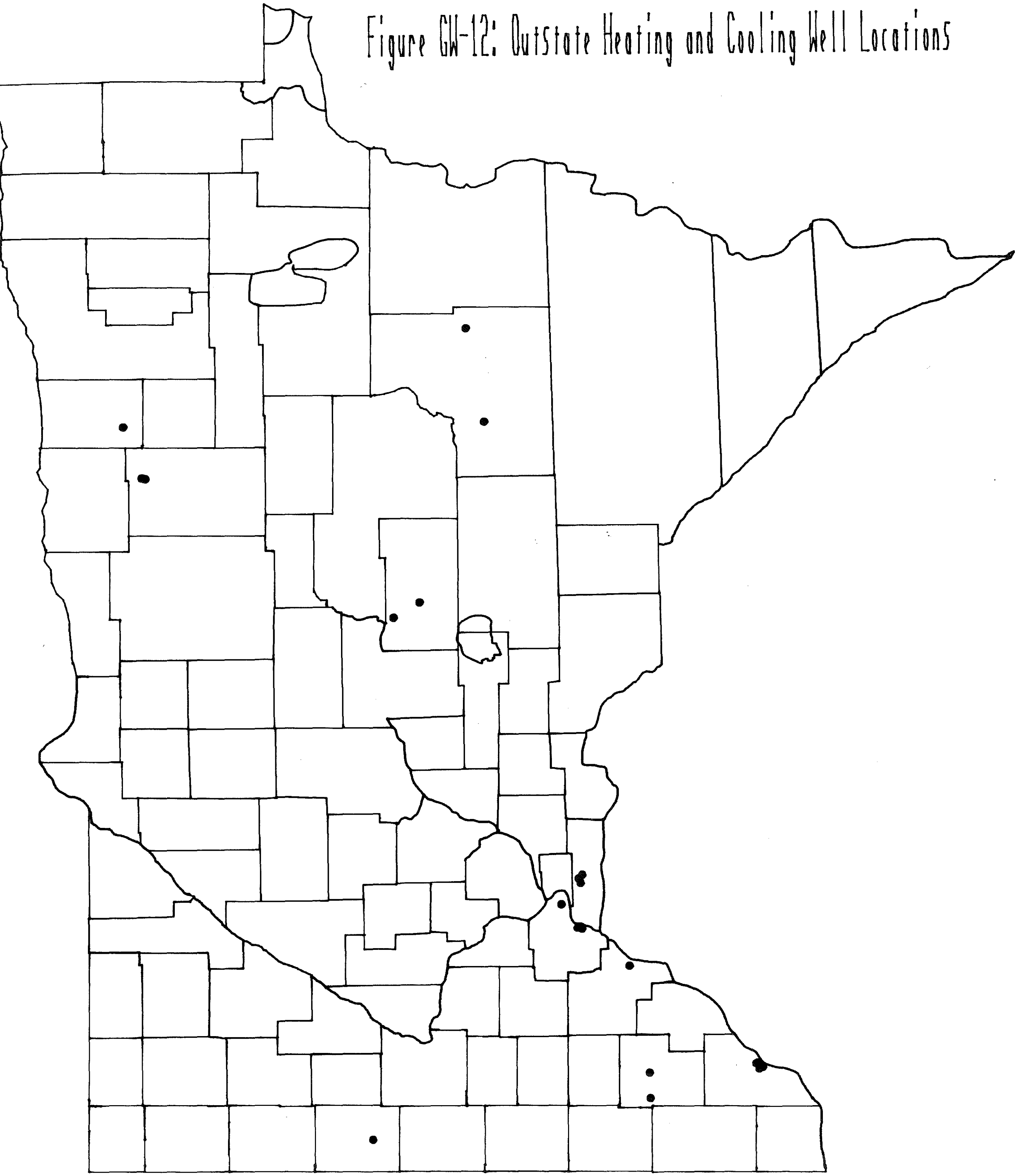


Table I: Statewide: Number of Permits, Permitted Volumes, and Reported Volumes by Aquifer

Hennepin County # of wells by aquifer		
Quaternary	1	
St. Peter	10	
OPDCCJDN	78	
FIG	3	
CMTS	0	
MULTIPLE	6	***2 MT SIMON, 4 FIG
UNKNOWN	2	

Hennepin County Permitted and Reported Volume Use by Aquifer

	PERMIT	1984	1985	1986	1987	1988
Quaternary	50.75	32.9	24.3	24.1	38.9	41.6
St. Peter	634.72	290.6	535.7	416.4	423.8	408.5
OPDCCJDN	6409.9	4443.2	4159.5	4176.6	4953.2	5442
FIG	435.05	331	296.5	331.4	394	20.3
CMTS	85.5		64.7	87.9	161.3	72
UNKNOWN	95					
TOTALS	7710.92	5097.7	5080.7	5036.4	5971.2	5984.4

Ramsey County # of wells by aquifer		
Quaternary	0	
St. Peter	1	
OPDCCJDN	53	
FIG	2	
CMTS	1	
MULTIPLE	1	***FIG
UNKNOWN		

Ramsey County Permitted and Reported Volume Use by Aquifer

	PERMIT	1984	1985	1986	1987	1988
Quaternary	0					
St. Peter	10		19.2	17.2	17.2	17.2
OPDCCJDN	4984.4	3501.3	3968	4068.6	4257.9	4913.4
FIG	110.5	0.9	0.5	1	0.5	47.2
CMTS	10	4.5	3.6	2.8	2.1	2.4
UNKNOWN						
TOTALS	5114.9	3506.7	3991.3	4089.6	4277.7	4980.2

Dakota County # of wells, permitted volume and reported use by aquifer

	# wells	Permit	1984	1985	1986	1987	1988
OPDCCJDN	2	52.9	11.9	13.4	10.7		57.6
CMTS	1	20					

Total Number of Permits by County

County	# Permits
Crow Wing	2
Dakota	2
Goodhue	1
Hennepin	64
Itasca	2
Martin	1
Norman	1
Olmstead	2
Otter Tail	2
Ramsey	42
Washington	1
Winona	3

Table I: Statewide: Number of Permits, Permitted Volumes, and Reported Volumes by Aquifer

Crow Wing County # of wells, permitted volume and reported use by aquifer							
	# wells	Permit	1984	1985	1986	1987	1988
QBAA	1	6	1.2	1.3	1.3	1.4	1.5
QWTA	1						
Goodue County # of wells, permitted volume and reported use by aquifer							
	# wells	Permit	1984	1985	1986	1987	1988
CFRNPMFL	1	9.2	6.5	5.4	6	9.6	9.8
Itasca County # of wells, permitted volume and reported use by aquifer							
	# wells	Permit	1984	1985	1986	1987	1988
QBAA	1	5			3	5.2	4.2
UNKNOWN	1	4.2				3.4	10.4
Martin County # of wells, permitted volume and reported use by aquifer							
	# wells	Permit	1984	1985	1986	1987	1988
UNKNOWN	1	3					
Norman County # of wells, permitted volume and reported use by aquifer							
	# wells	Permit	1984	1985	1986	1987	1988
UNKNOWN	1	4.2	9.1	9.1	9.1		
Olmstead County # of wells, permitted volume and reported use by aquifer							
	# wells	Permit	1984	1985	1986	1987	1988
OPDCCJDN	1	52	8	7.5	8.3	7.7	8.7
CJDNCIGL	1	60	28.7	17.3	26	34.2	45.6
Otter Tail County # of wells, permitted volume and reported use by aquifer							
	# wells	Permit	1984	1985	1986	1987	1988
QBAA	1	9			15.6	16.1	18.62
QWTA	1	6					
Washington County # of wells, permitted volume and reported use by aquifer							
	# wells	Permit	1984	1985	1986	1987	1988
OSTP	3	4.2	1.7	1.4		1.3	1.3
Winona County # of wells, permitted volume and reported use by aquifer							
	# wells	Permit	1984	1985	1986	1987	1988
QWTA	10	12	11.3	5.7	7.2	6.2	10.1
CMTS	2	278.7	60	70.8	86.05	64.2	79.4
CECRCMTS	1	18.8	11.5	5.1	4.7	6.1	8

131 of the 158 wells (82.9%) in Hennepin and Ramsey counties are completed in the Prairie du Chien-Jordan aquifer. During the 1988 pumping season, this aquifer provided 94.4% (10.4 billion gallons) of the ground water withdrawn for heating and cooling. Horn (1983) reported that in 1982 the Prairie du Chien-Jordan provided 80 percent of the ground water for all uses in the Twin Cities area.

The remaining 27 wells provided 842.4 million gallons (8%) of ground water during the 1988 pumping year. The St. Peter sandstone and upper Prairie du Chien dolomite provided approximately 1/2 of this volume. Only 3 wells are completed in the Mt. Simon-Hinckley aquifer, the reported total volume taken from this aquifer in 1988 was 74.4 million gallons-less than 1% of the total heating and cooling volume withdrawn in Hennepin and Ramsey counties.

The water pumped from multiple aquifer wells was categorized based upon specifications outlined by Horn (Table II).

Table II. -Estimated percentage of water contributed by each aquifer to multiaquifer wells-after Horn, 1983.

St. Peter	Prairie du Chien-Jordan	Ironton-Galesville	Mount Simon-Hinckley
35%	65%	-	-
30%	65%	5%	-
25%	60%	5%	10%
-	95%	5%	-
-	70%	5%	25%
-	-	15%	85%

OBSERVATION WELL DATA

The Division of Waters, in cooperation with the U.S. Geological Survey, maintains a network of 108 observation wells in the Twin Cities area (Figure GW-13). Water level measurements are taken in these wells on a regular basis throughout the year. Most wells in the network are open to the full thickness of the individual aquifer, and thus the recorded water level is a representation of average aquifer conditions.

Water level trends in the Prairie du Chien-Jordan aquifer are diverse and depend on the construction of the observation well, its proximity to natural recharge and discharge areas, and its proximity to pumping wells. A hydrograph is a plot of water level measurements over time. Figures GW-14, GW-15, GW-17, and GW-18 are hydrographs for observation wells completed in the Prairie du Chien-Jordan aquifer. Figure GW-14 is a hydrograph of observation well 27010 in west-central Hennepin county near Lake Minnetonka. The well is west of Minneapolis and shows the impacts of municipal growth and the subsequent increase in ground water withdrawals from this aquifer. The hydrograph shows a long-term downward trend, with sharp seasonal declines due to increased summer pumping.

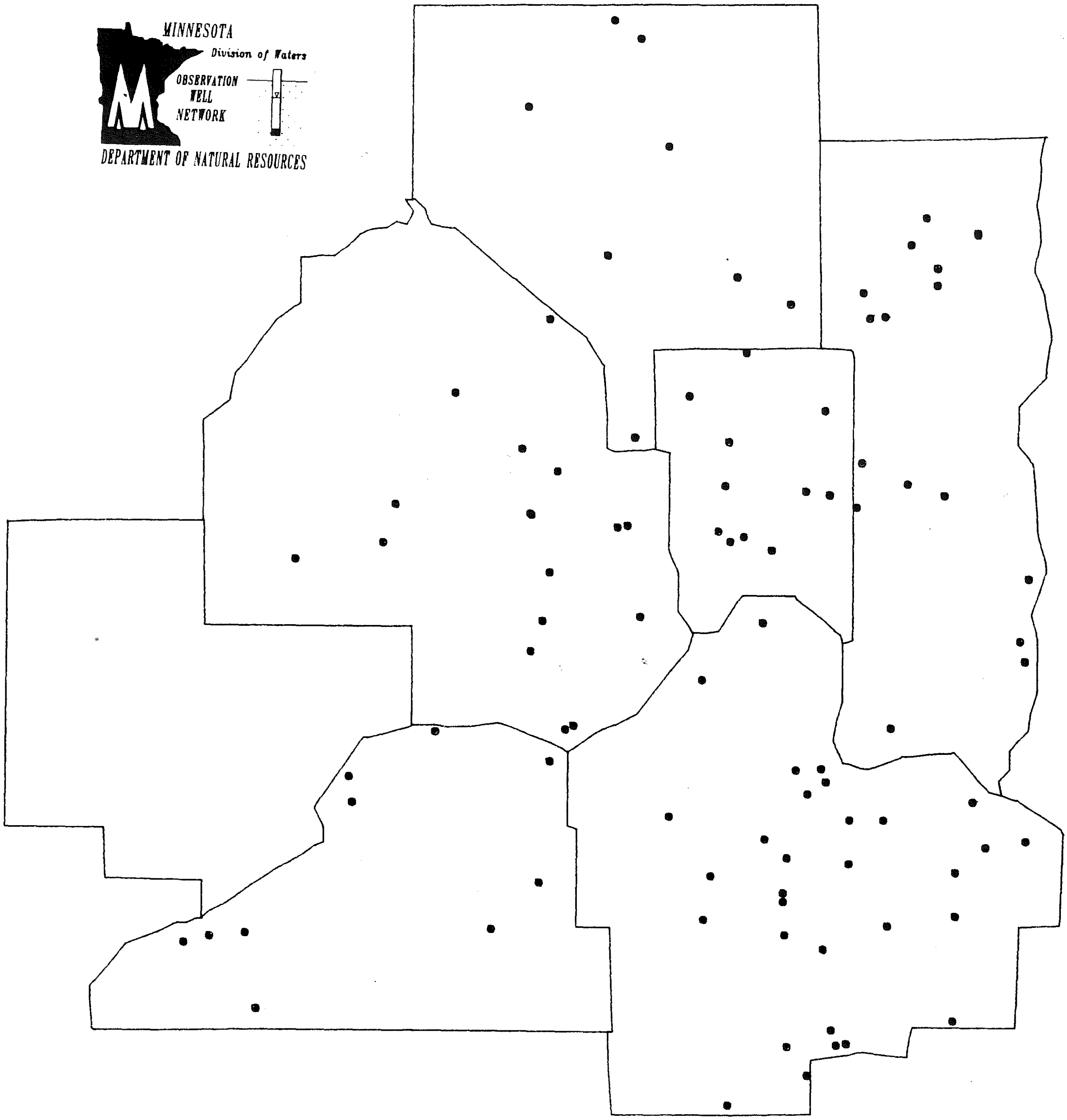


Figure GW-13: Metropolitan Observation Well Distribution.

Figure GW-14: Well 27010 Prairie du Chien-Jordan Aquifer
T117N R23W S11 BBD

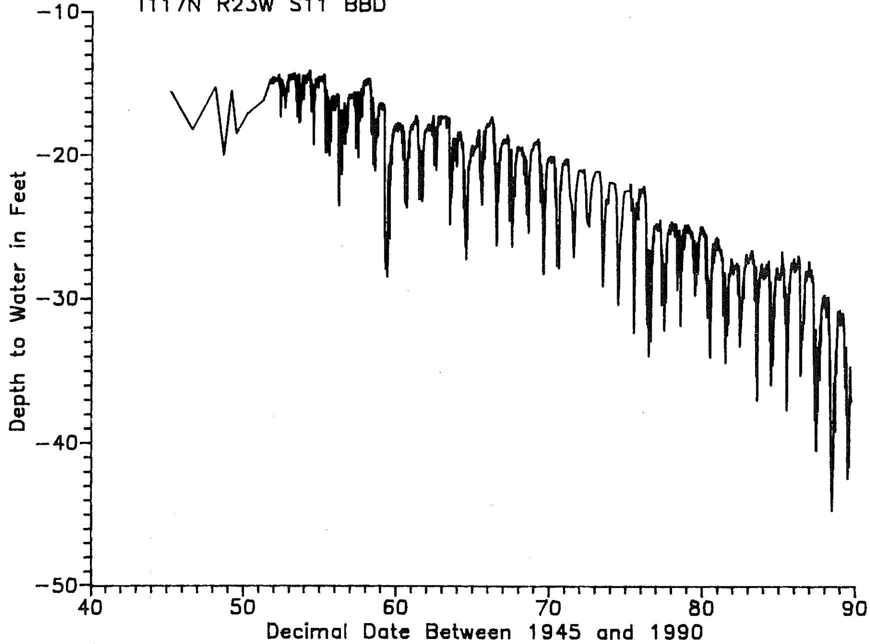


Figure GW-15: Well 27039 Prairie du Chien-Jordan Aquifer
T29N R24W S26 BAB

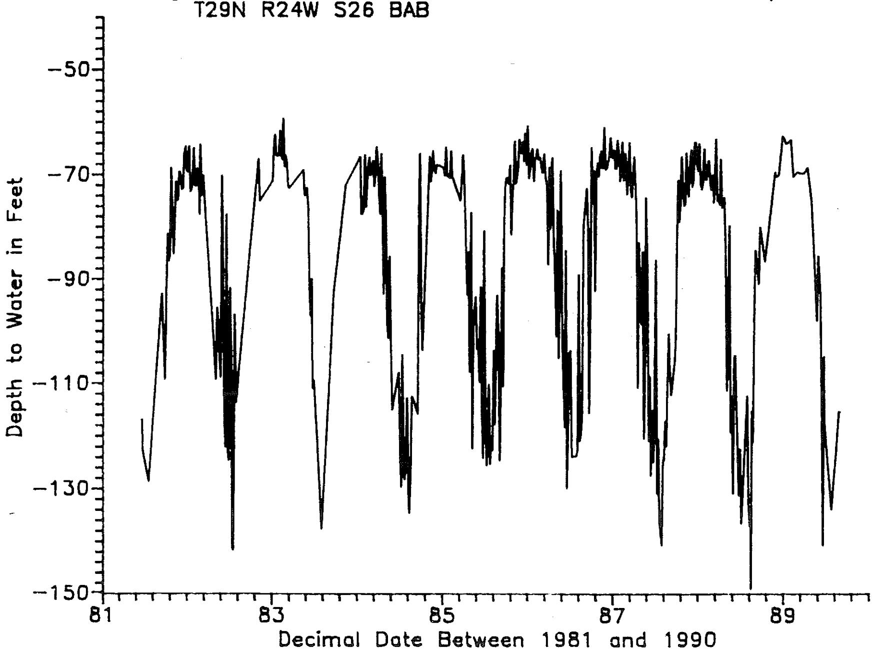


Figure GW-15 is the hydrograph for observation well 27039 in downtown Minneapolis. This figure graphically illustrates the response of the aquifer to the seasonal pumping demands of heating and cooling ground water withdrawals. The seasonal water level changes are excessive (up to 90 feet) because the amount of water pumped in summer is commonly more than 4 to 5 times greater the amount pumped during the winter months (Figure GW-16). The hydrograph shows that the average water level declined slightly during the period 1981 to 1989.

Jordan aquifer measurements in observation well 62001 (Figure GW-17) show an average water level rise from 1970 to 1986 in east central Ramsey county. This rise is most likely due to a decrease in pumpage near the observation well (Horn 1983). The seasonal pumping spike is much more subdued and is most likely due to nearby municipal and commercial pumping. Figure GW-18 shows water level trends in the Prairie du Chien-Jordan in northern Washington county from observation well 82030. The record shows a slight rise between 1980-87 and a drop in water levels since 1987. The water level decline is most likely due to climate.

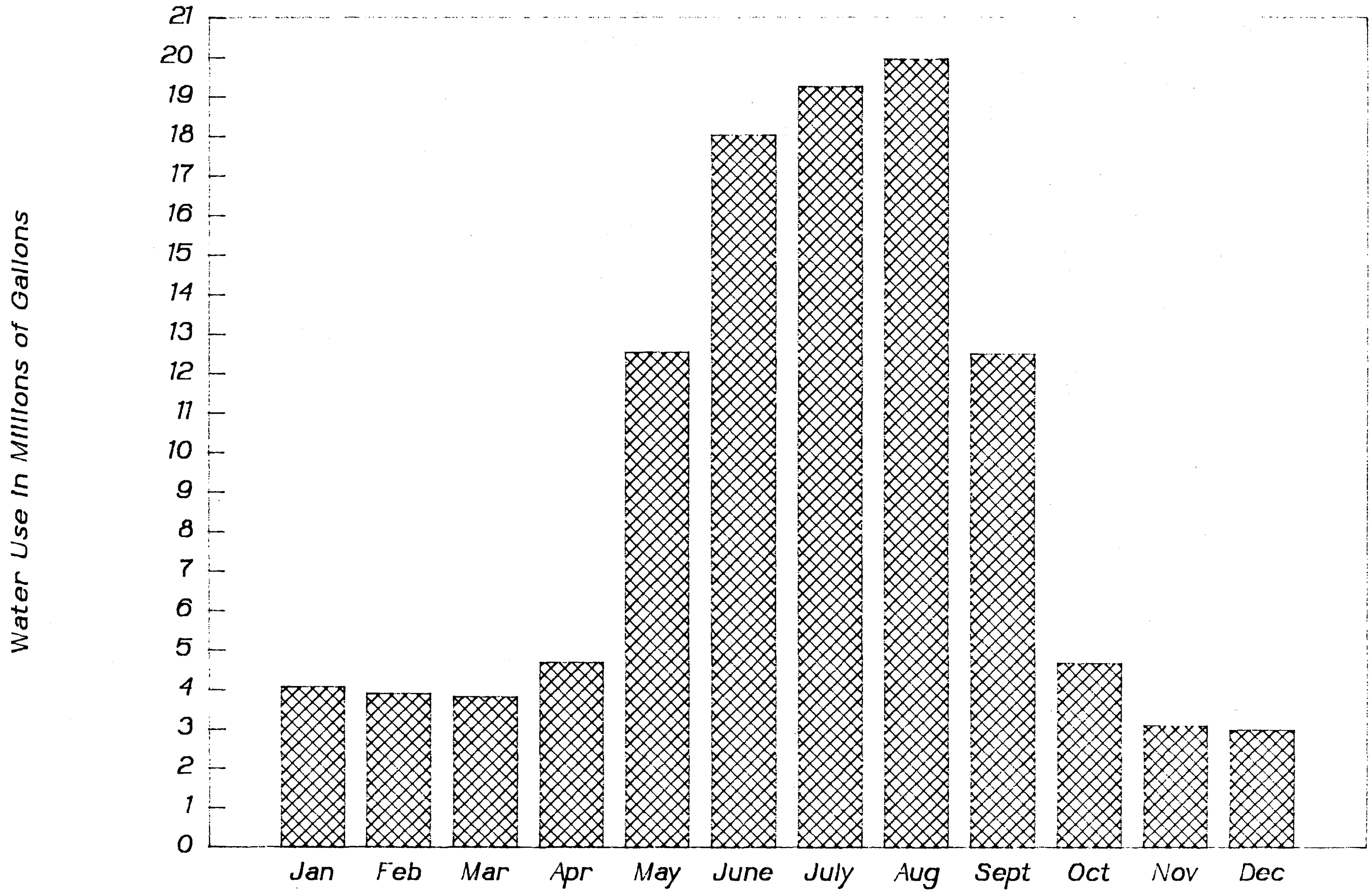
Water level declines in the Mt. Simon-Hinckley aquifer have been large despite the relatively low rate of ground water withdrawals from the aquifer. The lack of connection between the Mt. Simon-Hinckley and the rivers results in dramatic effects to the pumping stress in that aquifer. Static water levels have fallen drastically since the first wells were drilled into the aquifer. Figures GW-19 and GW-20 are for wells completed in the Mt. Simon-Hinckley aquifer. Figure GW-19 is a hydrograph for observation well 27015, located in southeast Hennepin County in Edina. This observation well is located near the center of a large cone of depression in the Mt. Simon-Hinckley aquifer. The cone of depression is centered on municipal well fields in Edina and St. Louis Park. The net change in the static water level since 1962 is a large decrease of nearly 110 feet.

Mt. Simon-Hinckley aquifer water level measurements recorded in observation well 62004 (Figure GW-20), located in St. Paul, reveal two important trends. First, the early rise in water levels between 1976-80 reflects the aquifer's response to decreased pumping by industrial users (Horn, 1983). Second, the general decrease in ground water levels and summer spikes are probably due to increased use of the aquifer by municipalities west and north of the observation well.

IMPACTS OF HEATING AND COOLING PUMPING

Ground water withdrawals for heating and cooling have the greatest impacts on the Prairie du Chien-Jordan aquifer. Geothermal ground water withdrawals comprise approximately 20% of the total ground water pumped in Hennepin and Ramsey counties. Although it is not possible to quantify specific long term impacts of heating and cooling pumping on the aquifer, it is fair to say these withdrawals contribute to the localized declines in southwestern Ramsey and downtown Minneapolis. It is difficult to quantify long-term heating and cooling pumping impacts because long-term trends are masked both by the seasonal pumping peaks and by the effect of wet and dry years. Seasonal effects due to this type of pumping are easily seen in observation well measurements. The dramatic fluctuations in the water levels near downtown Minneapolis and St. Paul are due almost entirely to heating and cooling pumpage. Water levels in active pumping wells can be drawn down as much as 150 feet during the summer months.

Figure GW-16: Seasonal Variation in Heating and Cooling Withdrawals



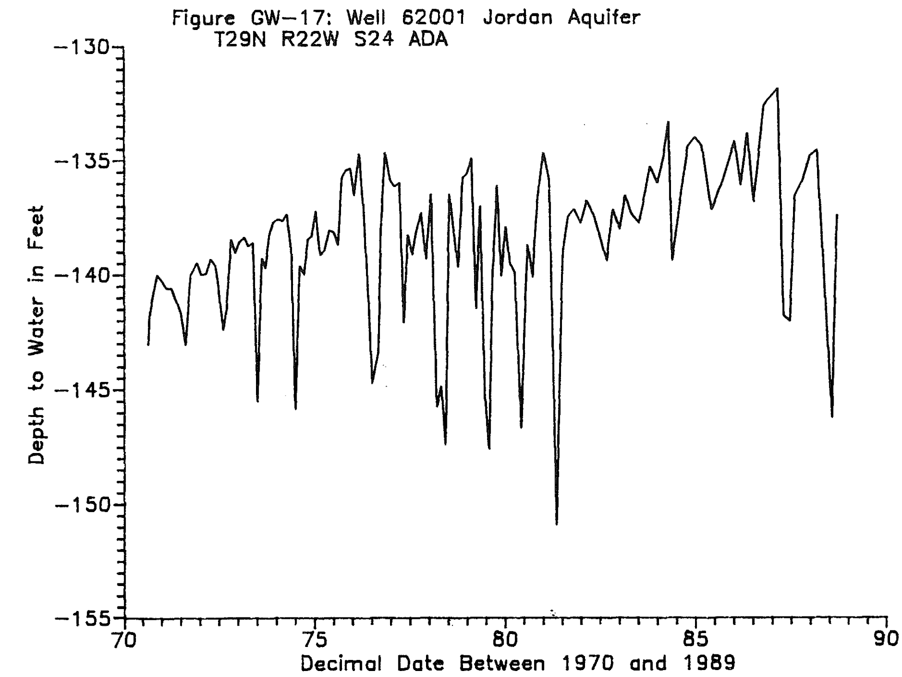


Figure GW-17: Well 62001 Jordan Aquifer
T29N R22W S24 ADA
Depth to Water in Feet
-130
-135
-140
-145
-150
-155
70
75
80
85
90
Decimal Date Between 1970 and 1989

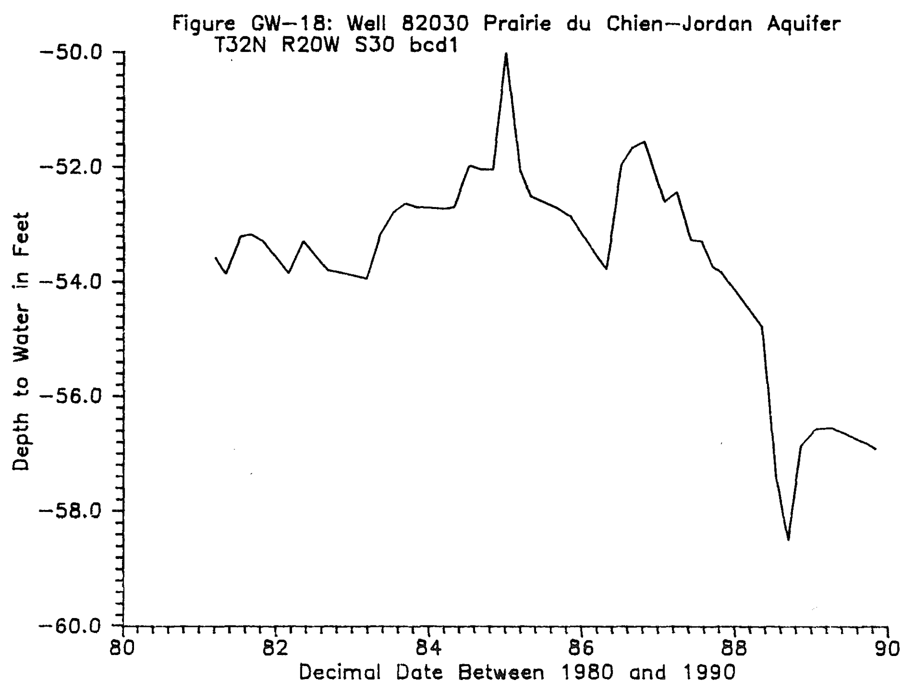


Figure GW-18: Well 82030 Prairie du Chien-Jordan Aquifer
T32N R20W S30 bcd1
Depth to Water in Feet
-50.0
-52.0
-54.0
-56.0
-58.0
-60.0
80
82
84
86
88
90
Decimal Date Between 1980 and 1990

Figure GW-19: Well 27015 Hinckley-Fond du Lac Aquifer
T117N R21W S32 DAD

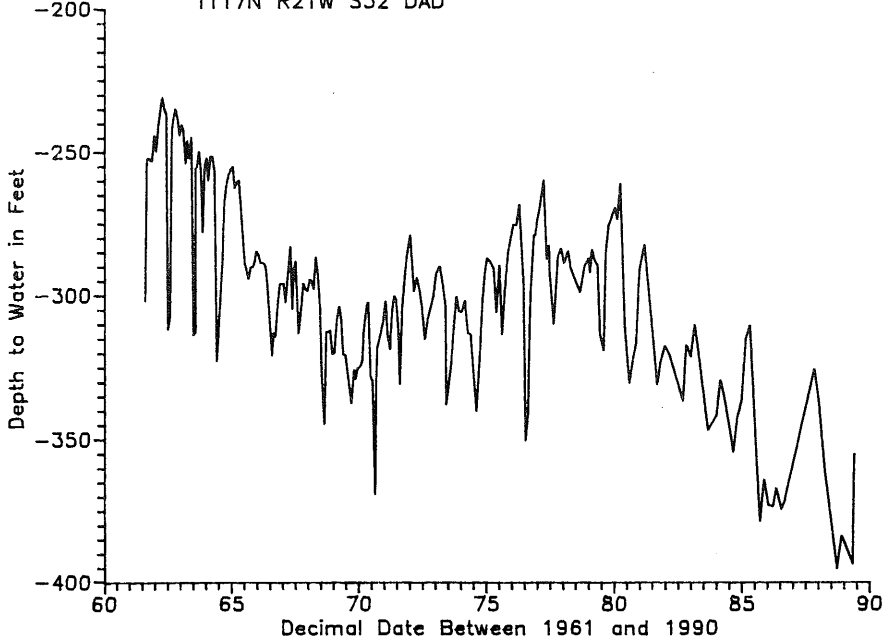
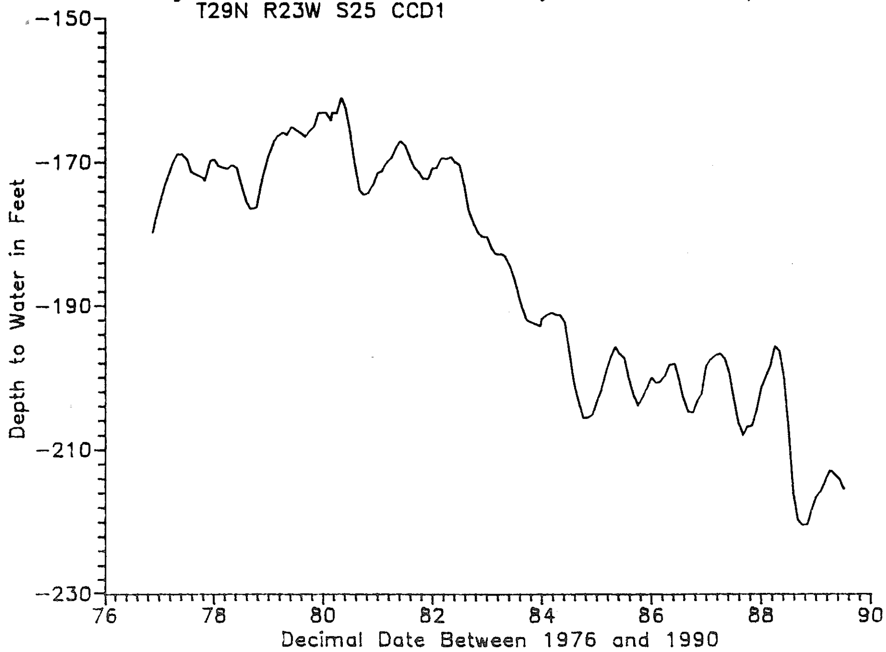


Figure GW-20: Well 62004 Hinckley-Fond du Lac Aquifer
T29N R23W S25 CCD1



The cone of depression caused by downtown pumping wells may impact the Mississippi River's base flow. Pumping near the Mississippi intercepts ground water that normally discharges into the river as base flow. At the peak of the drought in 1988, most of the flow in the Mississippi River was attributable to base flow. Ground water used by heating and cooling systems is typically discharged after use into storm sewers. The water ultimately reaches the river with some reduction in volume and increase in temperature. Given these facts, one might say that the heating and cooling systems are only "borrowing" the water for a short time.

Pumping centers near the rivers may in fact lower the head in the aquifer so much that the natural flow of water from the aquifer to the river is reversed, resulting in a migration of lower quality river water into the aquifer. Under these conditions, there is a risk that the water entering the aquifer would be contaminated. The ground water quality in the aquifer would potentially be degraded.

Where concentrations of heating and cooling wells exist away from the rivers, localized cones of depression are created in the Prairie du Chien-Jordan aquifer. These drawdowns combine with those of other ground water users and have an even greater impact upon the aquifer. Locally these drawdowns may approach the top of the aquifer - thus violating safe yield (Appendix II). In Minnesota, the safe yield of an artesian aquifer is defined as that volume of water which can be withdrawn without degrading the water quality or without changing the aquifer from an artesian to a water table condition. This condition is most likely to occur in the summer when municipalities are usually pumping stand-by wells to supply peak water demands. Most heating and cooling wells are not located near municipal well fields thus reducing the potential of well interference.

The impact on the Mt. Simon-Hinckley aquifer of withdrawals by heating and cooling systems is not as great as first suspected. This is due simply to the fact there are very few heating and cooling wells completed in this aquifer. Two of the three wells completed in the Mt. Simon-Hinckley are multi-aquifer wells which limits the impacts on the aquifer. The third well is to be taken out of service (replaced by city water) in the summer of 1990. The seasonal nature of pumping from these wells aggravates the large cone of depression caused by municipal pumping in the Mt. Simon aquifer. This cone of depression is greatest in the Edina - St. Louis Park area where ground water levels are down as much as 300 feet from the pre-development highs of the late 1800's.

SUMMARY

Permitted heating and cooling ground water users were identified using the DOW's Statewide Water Use Data System. The principal source of ground water for heating and cooling in the Twin Cities Metropolitan Area is the Prairie du Chien-Jordan aquifer.

The effect that the withdrawal of this water has on the aquifer is seasonal because more water is used for this purpose during the summer months. Geothermal ground water withdrawals comprise approximately 20% of the total ground water pumped in Hennepin and Ramsey counties, it is fair to say these withdrawals contribute to localized declines observed in both counties. It is not possible to quantify the specific long-term impacts of heating and cooling withdrawals on the Prairie du Chien-Jordan aquifer, in part because of uncertainties involving the relationship of the water levels in the aquifer and water levels in the rivers with which the aquifer is in hydrologic connection. One significant concern is that flow of river water, through the river's bottom sediments, into the aquifer, may be induced during summer

low flow. In addition, local drawdowns may be severe enough to violate the State's rule on safe yield (Appendix II).

There are currently only three wells in the Mt. Simon - Hinckley aquifer which are used for heating and/or cooling water. One of these is scheduled for abandonment, the other two are multiaquifer wells, drawing on the Franconia - Ironton - Galesville as well as the Mt. Simon - Hinckley. Even so, the impacts of these wells are added to the already severe impacts on this aquifer due to pumping for municipal water supplies. Water level declines in Mt. Simon - Hinckley wells are especially large near well fields in the western suburbs of the Twin Cities area. Municipal water utilities are supplying part of their pumped volume to heating and cooling users.

REFERENCES AND FURTHER SOURCES

Adolphson, D. G., Ruhl, J. F., and Wolf, R. J., 1981, Designation of principal water-supply aquifers in Minnesota: U.S. Geological Survey Water-Resources Investigations Report 81-51, 19 p.

Delin, G. N., and Woodward, D. G., 1985, Hydrogeologic setting and the potentiometric surfaces of the regional aquifers in the Hollandale embayment, southeastern Minnesota, 1980: U.S. Geological Survey Water-Supply Paper 2219

Freeze, R. A., and Cherry, J. A., 1979, Groundwater, New Jersey: Prentice-Hall, Inc., 604 p.

Frischman, J. R., and Leete, J. H., 1989, Ground Water Technical Guidelines, For Use in the Evaluation of Ground Water Appropriation Permit Applications, Minnesota: Minnesota Department of Natural Resources

Horn, M. A., 1983, Ground-water-use trends in the Twin Cities Metropolitan Area, Minnesota: U.S. Geological Survey Water-Resources Investigations Report 83-4033.

Jirsa, M. A., Olsen, B. M., and Bloomgren, B. A., 1986, Bedrock geologic and topographic maps of the seven-county Twin Cities Metropolitan Area, Minnesota: Minnesota Geological Map Series Map M-55.

Leete, J. H., 1985, Development of an Operational Ground Water Management Policy Based on Safe Yield, Minnesota: Minnesota Department of Natural Resources

Metropolitan Council of the Twin Cities Area, 1986, Part 3 Water Resources Management Development Guide/Policy Plan, Minnesota: 54 p.

Minneapolis Water Supply Commission, 1932, Report to the City Council of Minneapolis, Minnesota: 207 p.

Mossler, John H., 1987, Paleozoic Lithostratigraphic Nomenclature for Minnesota, Minnesota Geological Survey Report of Investigations 36, 36 p.

Schoenberg, M. E., 1984, Water levels and water-level changes in the Prairie du Chien-Jordan and Mount Simon-Hinckley Aquifers, Twin Cities Metropolitan Area, Minnesota, 1971-80, U.S. Geological Survey Water-Resources Investigations Report 83-4237.

Schoenberg, M. E., 1987 (Draft), Effects of present and future ground-water withdrawals on the Twin Cities aquifer system, Minnesota, U.S. Geological Survey Water-Supply Paper, (In press).

Winchell, N. H., 1905, Deep wells as a source of water supply for Minneapolis, in The question of pure water for Minneapolis: Minneapolis, Lumberman Publishing Co., 29 p.

Woodward, D. G., 1986, Hydrogeologic framework and properties of regional aquifers in the Hollandale embayment, southeastern Minnesota: U.S. Geological Survey Hydrologic Investigations Atlas HA-677.

APPENDICES

County	Name	Twp	Rng	Sec	QQQQ	Permit	Unique	Aquifer	Permitted Volume
Dakota	Brady High	28	22	17	DBD	631040	201161	CJDNCJDN	32.9
Dakota	Minnesota Veterans Home	115	17	34	ACC	856224	207642	OPDCCJDN	40
Dakota	Minnesota Veterans Home	115	17	34	ACB	856224	236104	CMTS?	
Hennepin	Normandale Properties	29	24	22	DDDB	590896	200366	OPDCCJDN	70
Hennepin	St. Mary's Hospital	29	24	25	DBCB	600010	200396	OPDCCJDN	10
Hennepin	St. Mary's Hospital	29	24	25	DBCB	600010	200397	OSTPCMTS	
Hennepin	Thorpe Bros. Inc.	29	24	22	DCAD	600061	200356	OPDCCJDN	100
Hennepin	Thorpe Bros. Inc.	29	24	22	DCAD	600061	Data for only 1 well.		
Hennepin	MAC #3	28	23	29	CBBB	600131	151585	OPDCCJDN	500
Hennepin	MAC #2	28	23	29	CBBB	600131	208321	OPDCCJDN	
Hennepin	MAC #1	28	23	29	CBBB	600131	208322	OPDCCJDN	
Hennepin	MAC #4	28	23	29	CBBB	600131	Well being installed.		
Hennepin	Heitman Minnesota Management#3	29	24	22	DDDD	600196	200369	OPDCCSTL	200
Hennepin	Heitman Minnesota Management#1	29	24	22	DDDD	600196	200371	OPDCCJDN	
Hennepin	Heitman Minnesota Management#2	29	24	27	AAAA	600196	200373	OPDCCJDN	
Hennepin	Lyndahl Motors Corp.	28	24	33	CCDD	600379	206222	OPDC	1
Hennepin	General Mills, Inc. #1	118	21	30	CDDA	600603	223780	OPDCCJDN	576
Hennepin	General Mills, Inc. #2	118	21	30	CDDD	600603	223880	OSTPCJDN	
Hennepin	General Mills, Inc. #3	118	21	30	CDAD	600603	223779	OPDCCJDN	
Hennepin	John Deere Company of Minneapolis	27	24	16	BBBA	610294	223053	CJDNCJDN	61.2
Hennepin	Marquette Bank Minneapolis	29	24	22	DDCD	610320	200625	OPDCCJDN	45
Hennepin	Product Design & Eng.	117	21	5	ADBD	610378	206425	OPVLOSTP	70
Hennepin	NWB of Minneapolis	29	24	23	CCCC	620138	200380	CJDN	74
Hennepin	NWB of Minneapolis	29	24	23	CCCC	620138		OPCJCFIG	
Hennepin	NWB of Minneapolis	29	24	23	CCCC	620138		OPCJCFIG	
Hennepin	Whittaker Corp.	29	24	3	DAB	620615	200208	OPDCCJDN	3
Hennepin	Abbott Northwestern Hospital #3	29	24	35	CABC	630066	112248	CJDNCJDN	175
Hennepin	Abbott Northwestern Hospital #1	29	24	35	CABC	630066	201082	CJDNCJDN	
Hennepin	Abbott Northwestern Hospital #2	29	24	35	CABC	630066	201083	CJDNCJDN	
Hennepin	Northwest National Life	29	24	23	CBCC	631113	200377	CJDN	35
Hennepin	Independent School District 271	27	24	15	AC	640014		CJDN	3.6
Hennepin	THS Northstar Association	29	24	27	AAAD	640643	201001	OPDCCJDN	350
Hennepin	THS Northstar Association #2	29	24	27	AAAD	640643	201002	OPDCCJDN	
Hennepin	THS Northstar Association	29	24	27	AAAD	640643		OSTPOPDC	
Hennepin	McCourtney Plastics	117	21	8	CADB	660906	206438	OSTPOPDC	290
Hennepin	Rosemount Engineering	116	22	14	BACD	690167	224097	OPDCOPDC	10
Hennepin	Federal Reserve Bank	29	24	22	DADD	690707	232318	CJDNCJDN	250
Hennepin	Federal Reserve Bank	29	24	23	DADD	690707	200623	OPDCCJDN	
Hennepin	Federal Reserve Bank	29	24	23	CBCC	690707	200651	OPDCCJDN	
Hennepin	Appletree Properties Inc.	27	23	6	BDBB	720569	242332	CJDN	101
Hennepin	Control Data Corp.	27	24	1	DABD	731413	205574	CJDNCJDN	30
Hennepin	General Mills #3	117	21	6	BBA	745231	226208	OPDCCSTL	650
Hennepin	General Mills #1	117	21	6	BBA	745231	224098	OPDCCSTL	
Hennepin	General Mills #2	117	21	6	BCB	745231	224099	OPDCCSTL	
Hennepin	General Mills #4	118	21	31	CCB	745231	161405	OPDCCSTL	
Hennepin	Richard Ellis, Inc.	28	24	5	ABAA	756161	223938	OPDCCJDN	65

County	Name	Twp	Rng	Sec	QQQQ	Permit	Unique	Aquifer	Permitted Volume
Hennepin	Red Owl Stores, Inc.	117	21	19	CBDD	756162	204575	OPDCCJDN	150
Hennepin	Medical Arts Building	29	24	27	AB	756188	231892	OPDCCJDN	71.18
Hennepin	Honeywell, Inc.	29	23	18	BBC	756231		CSFL	400
Hennepin	Honeywell, Inc.	29	23	18	BBC	756231		CSFL	
Hennepin	Equitable Life Assurance	118	21	2	CBBB	756259	203424	OSTPOPDC	3.8
Hennepin	United Properties	28	24	29	BCCD	756268	206374	OPDCCJDN	101.5
Hennepin	United Properties	28	24	29	BCC	756268	232321	QBAAQBAA	
Hennepin	Equitable Life Insurance #3	28	24	29	CBAD	756269	218109	OPDCCJDN	210
Hennepin	Equitable Life Insurance #5	28	24	29	CBA	756269	433288	OPDCCJDN	
Hennepin	Church of St. Anne	29	24	8	DDD	756282		CJDN	1.2
Hennepin	Hazelden Pioneer House	118	22	23	AAC	766231	112221	OPDCOPDC	20
Hennepin	Rosewood 5th & Marquette	29	24	22	DDDB	776345	200368	OSTPCGSL	28
Hennepin	Trach Properties, Inc.	118	21	31	D	786257		OSTPOPDC	5
Hennepin	Independent School District 272	116	22	8	BDBB	796148	165562	OPDCOPDC	12
Hennepin	Prudential	29	24	29	CBB	806275	201013	OPDCCJDN	60
Hennepin	Prudential	29	24	29	CBB	806275	201014	OPDCCJDN	
Hennepin	Metrobank Building	29	24	22	DDD	826127		OPDCCJDN	45
Hennepin	B.A.P.U.T. #2	29	24	27	AAB	846232	239452	OPDCCJDN	90
Hennepin	B.A.P.U.T. #3	29	24	27	AAB	846232			
Hennepin	Northwest Bank of Camden	29	24	4	ADA	846233		OSTPOSPC	3
Hennepin	Methodist Hospital	117	21	20	ADA	856010	216067	OPDCCSTL	300
Hennepin	Minneapolis Grain Exchange	29	24	23	CCB	856037	200627	CJDN	100
Hennepin	Lakewood Cemetary	28	24	4	BDB	856048	235856	OPDCCJDN	1
Hennepin	WCCO Building	29	24	27	AAA	856052		OPDCCJDN	20
Hennepin	Hillcrest Development	29	24	22	CAC	856055	200353	CSTL	50
Hennepin	Fairview Southdale Hospital	28	24	29	BCA	856073	206373	OPDCOPDC	90
Hennepin	Fairview Southdale Hospital	28	24	29	BCB	856073	233257	OPDCOPDC	
Hennepin	Bell Cold Storage-1	29	24	22	DBB	856079		CJDN	160
Hennepin	Bell Cold Storage-2	29	24	22	DBB	856079		CJDN	
Hennepin	Minneapolis Athletic Club #1	29	24	22	AAA	856081	200365	OPDCCSLF	60
Hennepin	Minneapolis Athletic Club #2	29	24	22	AAA	856081	235734	OPDCCJDN	
Hennepin	Minnegasco, Inc.	29	24	27	AAA	856083	201003	CJDN	70
Hennepin	614 Company	29	24	27	ABD	856090	201006	CJDN	20
Hennepin	Honeywell, Inc. #1	29	24	34	DAD	856129	235776	OPDCCJDN	380
Hennepin	Honeywell, Inc. #3	29	24	34	DAD	856129	235777	OPDCCJDN	
Hennepin	Honeywell, Inc. #2	29	24	34	DAD	856129	201076	OPDCCJDN	
Hennepin	Orpheum Theatre	29	24	27	ABB	856172		OPDC	10
Hennepin	Carson Pirie Scott	28	24	29	CAC	856202	206375	OPDCCJDN	30
Hennepin	Minneapolis Health Center	29	24	23	CCC	856226	200379	OPDCCJDN	30
Hennepin	Dayton's Minneapolis #2	29	24	27	ABA	856227	233215	OPDCCJDN	300
Hennepin	Dayton's Minneapolis #1	29	24	27	ABA	856227	236022	OPDCCECR	
Hennepin	Dayton's Minneapolis #3	29	24	27	ABA	856227	236023	CSTLCMTS	
Hennepin	Norwest Bank Building Co. #1	29	24	27	AAB	856267	201007	OPDCCJDN	250
Hennepin	Norwest Bank Building Co. #2	29	24	27	AAB	856267	231899	OPDCCJDN	
Hennepin	MCC Development C. Inc.	29	24	22	DDC	856295	235775	OPDCCJDN	250
Hennepin	MCC Development C. Inc.	29	24	22	DDC	856295	151586	OPDCCJDN	

County	Name	Twp	Rng	Sec	QQQQ	Permit	Unique	Aquifer	Permitted Volume
Hennepin	Lund's Inc.	29	24	33	CDD	856361	239685	OSTP	7
Hennepin	Minneapolis Public Library	29	24	22	DDB	866003	200360	OPDCCJDN	20
Hennepin	William Ulrich	117	23	8	DDD	866178	420486	CSTLCFRN	11
Hennepin	University of Minnesota #1	29	24	25	AAB	866315	412572	OSTPOSTP	120
Hennepin	University of Minnesota #2	29	24	25	AAB	866315	427501	OSTPOSTP	
Hennepin	Valley Plaza	118	21	32	CBC	876098	241384	OPSP	10
Hennepin	Minneapolis Energy Center	29	24	22	BBA	876193	151591	OPDCCJDN	73
Hennepin	Minneapolis Energy Center	29	24	22	BBA	876193	151600	OPDCCJDN	
Hennepin	Metro Medical Center	29	24	26	BDA	876288	233239	OPDCCJDN	195
Hennepin	Veterans Administration	28	23	20	BBC	886011	161497	OPDCCJDN	195
Hennepin	IDS Financial Services	29	24	27	ADD	896129	242317	OPDCOPDC	89
Ramsey	St. Paul Civic Center	28	22	6	BDBB	590420	200049	OPDCCJDN	60
Ramsey	St. Joseph Hospital	28	22	6	BABB	590736	200044	OPDCCJDN	69
Ramsey	Midland Hills Country Club	29	23	17	BDA	590760	200149	CJDNCJDN	20
Ramsey	Carson Pirie Scott	28	23	17	AADA	590771	200435	OPDCCJDN	30
Ramsey	Welsh Companies	28	22	6	ABA	600022	200515	OPDCCJDN	130
Ramsey	Degree of Honor Building	28	22	6	ABDC	600229	200035	OPDCCJDN	40
Ramsey	United Hospitals	28	23	1	DBB	600466	200402	OPDCCJDN	360
Ramsey	United Hospitals	28	23	1	DBB	600466		OPSTCJDN	
Ramsey	EcoLabs	28	23	23	ABAB	610538		CJDNCJDN	8.7
Ramsey	Diocess of St. Paul	28	23	1	AADC	620599	200401	OPDCOPDC	6
Ramsey	Dayton's St. Paul #1	28	22	6	ABB	620727	233089	OPDCCJDN	95.4
Ramsey	Dayton's St. Paul #2	28	22	6	ABB	620727	233090	OPDCCJDN	
Ramsey	St. Paul Ramsey Medical Center	29	22	31	ACCA	630519	200494	OPDCCJDN	385
Ramsey	St. Paul Ramsey Medical Center	29	22	31	ACCA	630519	200495	OPDCCJDN	
Ramsey	Control Data Corp. #2	30	23	22	DACD	630746	206770	CJDNCJDN	10
Ramsey	Control Data Corp. #1	30	23	22	DDA	630746	206771	CJDNCJDN	
Ramsey	Radison St.Paul Hotel	28	22	6	ACA	650519	233286	OPDCCSTL	160
Ramsey	Farm Credit Banks	28	22	6	AABB	651258	200012	OPDCOPDC	36
Ramsey	Maxwell Communications	28	23	15	DCD	651286	200434	OPDCCJDN	115
Ramsey	Economics Laboratories	28	22	6	ABCA	651327	200028	OPDCOPDC	102
Ramsey	Towle Real Estate	28	22	6	ABAC	661196	200022	OPDCCJDN	33
Ramsey	West Publishing Co. #1	28	22	6	ACAD	756172		OPDCCJDN	17
Ramsey	West Publishing Co. #2	28	22	6	ACAC	756172		OPDCCJDN	
Ramsey	Seventh Place Limited Partnership	28	22	6	BAA	756198		CJDN	40
Ramsey	University of Minnesota Office	29	23	33	BCB	756206	200186	OPDCCJDN	37.8
Ramsey	St. Paul YWCA	28	22	6	ABDD	756232	200036	OPDCCJDN	10
Ramsey	Vance Pioneer Associates	28	22	6	AAB	756252	200013	OPDCCJDN	14
Ramsey	Ramsey County Sheriff's Department	28	22	6	ACA	766201	233530	OPDCCJDN	30
Ramsey	District Heating & Development #2	28	22	6	BDDB	766346	225686	OPDCCJDN	120
Ramsey	District Heating & Development	28	22	6	BDDB	766346	234002	OPDCCJDN	
Ramsey	District Heating & Development	28	22	6	ABCD	766346	200030	OPDCCJDN	
Ramsey	BCED Devel&Properties #1	28	22	6	ABD	786254	226578	OPDCCJDN	325
Ramsey	BCED Devel&Properties #2	28	22	6	ABD	786254	226579	OPDCCJDN	
Ramsey	BCED Devel&Properties #3	28	22	6	ABD	786254	226580	OPDCCJDN	
Ramsey	BCED Devel&Properties #4	28	22	6	ABD	786254	127300	OPDCCJDN	

County	Name	Twp	Rng	Sec	QQQQ	Permit	Unique	Aquifer	Permitted Volume
Ramsey	University of Minnesota-ATES	29	23	21	CBAD	806201	135503	CFRNCIGL	110
Ramsey	University of Minnesota-ATES	29	23	21	CCAA	806201	135502	CFRNCIGL	
Ramsey	HB Fuller Company	30	22	33	ADB	806214	151562	OPDCCJDN	185
Ramsey	St. Paul Port Authority - Energy Park	29	23	27	BCCC	826002	161420	OPDCCJDN	1386
Ramsey	St. Paul Port Authority - Energy Park	29	23	27	BCDB	826002	161422	OPDCCJDN	
Ramsey	St. Paul Port Authority - Energy Park	29	23	27	BCBB	826002	122210	OPDCCSTL	
Ramsey	Northwest Publications	28	22	6	ABD	846069	200032	OPDCCJDN	65
Ramsey	St. Paul Hotel	28	22	6	BAD	856011		OPDCCJDN	70
Ramsey	St. Paul Burlington Ltd. Partner	28	22	6	AAB	856033		CJDN?	20
Ramsey	Ramsey County Courthouse	28	22	6	ACB	856051	200039	OPDCCFRN	10
Ramsey	Northwestern Bell	28	22	6	ACB	856061		OPDC	110
Ramsey	Highland Center, Inc.	28	23	16	BBB	856097		CJDN	30
Ramsey	Unisys Corporation	28	23	21	DBB	856115	200438	OPDCCJDN	110
Ramsey	Unisys Corporation	29	23	33	BAB	856116	233505	OPDCCJDN?	30
Ramsey	Metro Square Partnership	29	22	31	DCD	856128	200516	OPDCCJDN	60
Ramsey	Montgomery Ward	29	23	34	CAC	856130	200190	CMTSCMTS	10
Ramsey	HSF Properties	29	22	31	DCD	856140		CJDN	220
Ramsey	Specialty Manufacturing	30	23	29	DCC	856171	235778	OPDCOPDC	20
Ramsey	Berwald Investment	29	22	12	CDB	856210	208225	OSTPOPDC	10
Ramsey	Ordway Music Theatre	28	22	6	BDB	866129	236147	OPDCCJDN	110
Ramsey	BCED Minnesota INC.	28	22	6	BAA	876169	420951	OPDCCJDN	420
Ramsey	BCED Minnesota INC.	28	22	6	BAA	876169	420952	OPDCCJDN	
Ramsey	BCED Minnesota INC.	28	22	6	BAA	876169	420953	OPDCCJDN	
Washington	Jesuit Retreat House	29	21	4	CDAB	670032	208429	OSTPOPDC	4.3
Washington	Jesuit Retreat House	29	21	4	CDA	670032		OSTP	
Washington	Jesuit Retreat House	29	21	4	CDA	670032		OSTP	
									12941.38
Crow Wing	Widseth, Smith, Nolting & Assoc. Inc	133	28	5	CCD	813229	180690	QBAAQBAA	6
Crow Wing	Acrometal Companies, Inc.	45	30	19	C	903026	437425	QWTAQWTA	
Goodhue	Sargent Industries	113	15	29	AC	600929	218627	CFRNPMFL	9.2
Itasca	ABRA Corp.	55	25	28	BDC	862114	191485	QBAAQBAA	5
Itasca	Northern Itasca Hospital	61	26	27	ADC	872145	163185		4.2
Martin	Martin Luther H.S	103	30	9	ACD	864132	184622		3
Norman	Donald Eckhoff	144	46	9	CDC	761087			4.2
Olmsted	Rochester Airport	105	14	10	CAC	580243	219560	OPDCCJDN	52
Olmsted	IBM, Corp.	107	14	21	BDC	755133	220817	CJDNCFRN	60
Otter Tail	Pamida Inc. Store #008	133	43	35	CCC	861090	236517	QBAAQBAA	9
Otter Tail	David Lundeen	133	43	34	DDD	881123	431251	QWTAQWTA	6
Winona	Brom Machine & Foundary	107	7	20	B	650563		QWTA	12
Winona	Independent School 861	107	7	28	A	651349		CMTS?	260
Winona	Fiberite Corporation #1	107	7	22	DBBA	661194	219104	CECRCMTS	37.5
Winona	Fiberite Corporation #2	107	7	22	DBBA	661194	242818	CECR?	

Code	Old Code	Stratigraphic Unit or Aquifer	Age
BSMT		BASEMENT	
CAMB		CAMBRIAN, UNDIFFERENTIATED.	CAM
CDRE		DRESBACHIAN STAGE	CAM
CECR		EAU CLAIRE	CAM
CEMS		EAU CLAIRE-MT. SIMON	CAM
CFIG		FRANCONIA-IRONTON-GALESVILLE	CAM
CFRA		FRANCONIAN STAGE	CAM
CFRN		FRANCONIA	CAM
CGEC		GALESVILLE-EAU CLAIRE	CAM
CGSL		GALESVILLE	CAM
CIGE		IRONTON-GALESVILLE-EAU CLAIRE	CAM
CIGL		IRONTON-GALESVILLE	CAM
CIRN		IRONTON	CAM
CJDN		JORDAN	CAM
CJSL		JORDAN-ST.LAWRENCE	CAM
CMSH		MT. SIMON-HINCKLEY	C-P
CMTS		MT. SIMON	CAM
CSLF		ST. LAWRENCE-FRANCONIA	CAM
CSTL		ST. LAWRENCE	CAM
DCOG		CEDAR VALLEY-GALENA	D-O
DCOM		CEDAR VALLEY-MAQUOKETA	D-O
DCVA		CEDAR VALLEY	DEV
DEVO		DEVONIAN, UNDIFFERENTIATED	DEV
DSPL		SPILLVILLE FORMATION	DEV
DWAP		WAPSIPINICON FORMATION	DEV
JURA		JURASSIC-HALLOCK REDBEDS	JUR
KCLR		COLERAINE	CRE
KCRL		CARLISLE SHALE	CRE
KDKT		DAKOTA	CRE
KGRN		GREENHORN EQUIVALENT	CRE
KGRS		GRANEROS SHALE	CRE
KNBR		NIOBRARA EQUIVALENT	CRE
KPRR		PIERRE SHALE	CRE
KREG		CRETACEOUS REGOLITH	CRE
KRET		CRETACEOUS, UNDIFFERENTIATED	CRE
KWND		WINDROW	CRE
MTPL		MULTIPLE AQUIFER	
NRCD		NO RECORD	
ODCR		DECORAH	ORD
ODGL		DUBUQUE-GALENA	ORD
ODPL		DECORAH-PLATTEVILLE	ORD
ODUB		DUBUQUE	ORD

Code	Old Code	Stratigraphic Unit or Aquifer	Age
OGAL		GALENA	ORD
OGCM		CUMMINGSVILLE MBR(GALENA FM)	ORD
OGDC		GALENA-DECORAH	ORD
OGPR		PROSSER MBR(GALENA FM)	ORD
OGSP		GLENWOOD-ST. PETER	ORD
OGSV		STEWARTVILLE MBR(GALENA FM)	ORD
OGWD		GLENWOOD	ORD
OMAQ		MAQUOKETA	ORD
OMQG		MAQUOKETA-GALENA	ORD
OPCJ		PRAIRIE DU CHIEN-JORDAN	O-C
OPDC		PRAIRIE DU CHIEN GROUP	ORD
OPGW		PLATTEVILLE-GLENWOOD	ORD
OPNR		NEW RICHMOND MBR(SHAKOPEE FM)	ORD
OPOD		ONEOTA FM(PRAIRIE DU CHIEN)	ORD
OPSH		SHAKOPEE FM(PRAIRIE DU CHIEN)	ORD
OPSP		PLATTEVILLE-ST. PETER	ORD
OPVC		PLATTEVILLE/CARIMONA	ORD
OPVF		PLATTEVILLE/MIFFLIN	ORD
OPVH		PLATTEVILLE/HIDDEN FALLS	ORD
OPVL		PLATTEVILLE	ORD
OPVM		PLATTEVILLE/MAGNOLIA	ORD
OPVP		PLATTEVILLE/PECATONICA	ORD
OPWR		WILLOW RIVER MBR(SHAKOPEE FM)	ORD
ORDO		ORDOVICIAN, UNDIFFERENTIATED	ORD
ORRV		RED RIVER	ORD
ORWN		RED RIVER-WINNIPEG	ORD
OSPC		ST. PETER-PRAIRIE DU CHIEN	ORD
OSTM		STONY MOUNTAIN	ORD
OSTP		ST. PETER	ORD
OSTW		STONEWALL	ORD
OWIN		WINNIPEG	ORD
PAAR		ARGO GNEISS	PCA
PAAU	PWAU	ALGOMAN GRANITES, UNDIVIDED	PCA
PABL	PWBL	BELLINGHAM GRANITE	PCA
PABR	PWBR	BURNTSIDE GNEISS	PCA
PADL	PWDL	DEER LAKE COMPLEX	PCA
PAES	PWES	SOUDAN IRON FORMATION	PCA
PAEY	PWEY	ELY GREENSTONE	PCA
PAFR	PWFR	FORT RIDGLEY GRANITE	PCA
PAGF	PWGF	GRANITE FALLS GNEISS	PCA
PAGR	PWGR	GIANTS RANGE GRANITE	PCA
PAGU	PWGU	ARCHEAN GRANITIC PLUTONS	PCA

Stratigraphic (and Aquifer) Codes

Code	Old Code	Stratigraphic Unit or Aquifer	Age
PAKG	PWKG	KNIFE LAKE GROUP	PCA
PALG	PWLG	LAURENTIAN GRANITES	PCA
PALL	PWLL	LAC LA CROIX GRANITE	PCA
PALV	PWLV	LAKE VERMILION FORMATION	PCA
PAMC	PWMC	MCGRATH GNEISS	PCA
PAMR	PWMR	MORTON GNEISS	PCA
PAMV	PWMV	MONTEVIDEO GNEISS	PCA
PANL	PWNL	NEWTON LAKE	
PAOD	PWOD	ODESSA GRANITE	PCA
PAOR	PWOR	ORTONVILLE GRANITE	PCA
PARG	PWRG	RICHMOND GNEISS	PCA
PASF	PWSF	SEAFORTH GNEISS	PCA
PASG	PWSG	SAGANAGA TONALITE	PCA
PASH	PWSH	SACRED HEART GRANITE	PCA
PASR	PWSR	SAUK RAPIDS META. COMPLEX	PCA
PAST	PWST	SARTELL GNEISS	PCA
PASW	PWSW	ST. WENDEL METAGABBRO	PCA
PAUD	PWUD	ARCHEAN ROCKS UNDIVIDED	PCA
PAVC	PWVC	VERMILION GRANITIC COMPLEX	PCA
PAWT	PWWT	WATAB AMPHIBOLITE	PCA
PCCR		PRECAMBRIAN CRYSTALLINE ROCKS	PC
PCRG		PRE-CROIXAN REGOLITH	PRC
PCUU		PRECAMBRIAN, UNDIFFERENTIATED	PC
PEAG	PXAG	ANIMIKIE GROUP	PCE
PEAT		PEAT	
PEBC	PXBC	BRADBURY CREEK GRANODIORITE	PCE
PEBI	PXBI	BIWABIK IRON FORMATION	PCE
PECM	PXCM	CEDAR MOUNTAIN COMPLEX	PCE
PEDN	PXDN	DENHAM FORMATION	PCE
PEFH	PXFH	FREEDHEM GRANODIORITE	PCE
PEGI	PXGI	GUNFLINT IRON FORMATION	PCE
PEGT	PXGT	GLEN TOWNSHIP	PCE
PEGU	PXGU	E.PROTEROZOIC GRANITE PLUTON	PCE
PEHL	PXHL	HILLMAN MIGMATITE	PCE
PEIL	PXIL	ISLE GRANITE	PCE
PELF	PXFL	LITTLE FALLS FORMATION	PCE
PEML	PXML	MILLE LACS GROUP	PCE
PEMN	PXMN	MAHNOMEN FORMATION	PCE
PEPK	PXPK	POKEGAMA QUARTZITE	PCE
PEPZ	PXPZ	PIERZ GRANITE	PCE
PERB	PXRB	RABBIT LAKE FORMATION	PCE
PERD	PXRD	RANDALL FORMATION	PCE

Stratigraphic (and Aquifer) Codes

Code	Old Code	Stratigraphic Unit or Aquifer	Age
PERE	PXRE	RABBIT LAKE FORMATION	PCE
PERF	PXRF	REFORMATORY GRANITE	PCE
PERK	PXRK	ROCKVILLE GRANITE	PCE
PERL	PXRL	RABBIT LAKE LOWER MEMBER FM	PCE
PERU	PXRU	RABBIT LAKE UPPER MEMBER FM	PCE
PERV	PXRV	ROVE FORMATION	PCE
PESC	PXSC	ST. CLOUD GRANITE	PCE
PEST	PXST	STEARNS GRANITIC COMPLEX	PCE
PETL	PXTL	TROUT LAKE FORMATION	PCE
PETM	PXTM	THOMSON FORMATION	PCE
PETR	PXTR	TROMMALD FORMATION	PCE
PEUD	PXUD	EARLY PROTEROZOIC ROCKS UND.	PCE
PEVR	PXVR	VIRGINIA FORMATION	PCE
PEWR	PXWR	WARMAN GRANITE	PCE
PEYV	PXYV	PROTEROZOIC BASALT DIKES	PCP
PITT		PIT	
PMBB	PYBB	BEAVER BAY COMPLEX	PCM
PMCV	PYCV	CHENGWATANA VOLCANIC GROUP	PCM
PMDA	PYDA	ANORTHOSITIC SERIES-DULUTH CPLX	PCM
PMDC	PYDC	DULUTH COMPLEX	PCM
PMDF	PYDF	FELSIC SERIES-DULUTH COMPLEX	PCM
PMDT	PYDT	TROCTOLITIC SERIES-DULUTH CPLX	PCM
PMFL	PYFL	FOND DU LAC FORMATION	PCM
PMHF	PYHF	HINCKLEY-FOND DU LAC	PCM
PMHN	PYHN	HINCKLEY SANDSTONE	PCM
PMLG	PYLG	LOGAN INTRUSIONS	PCM
PMNP	PYNP	NOPEMING SANDSTONE	PCM
PMNS	PYNS	NORTH SHORE VOLCANIC	PCM
PMPK	PYPK	PUCKWUNGE FORMATION	PCM
PMPR	PYPR	PIGEON RIVER INTRUSIONS	PCM
PMRC		RED CLASTIC SERIES	PCM
PMSC	PYSC	SOLOR CHURCH FORMATION	PCM
PMSU	PYSU	MID PROTEROZOIC SEDIMENTARY	PCM
PMSX	PYSX	SIOUX QUARTZITE	PCM
PMUD	PYUD	MIDDLE PROTEROZOIC ROCKS UND.	PCM
PMVU	PYVU	KEWEENAWAN VOLCANICS, UND.	PCM
PUDF		PALEOZOIC, UNDIFF.	PZC
PVMT		PAVEMENT	
QBAA		QUATERNARY BURIED ARTESIAN	QUA
QTUU	TILL	TILL	QUA
QUAT		QUATERNARY	
QUUU	PLTS	PLEISTOCENE	QUA

QWTA	QUATERNARY WATER TABLE	QUA

Appendix II: Safe Yield Defined

In the 1985 *Development of an Operational Ground Water Management Policy Based on Safe Yield*, Leete discusses the legal framework under which appropriation permits are issued in reference to safe yield. Following are excerpts from that document.

"The approval of an appropriation permit is subject to limits set up to safeguard aquifers and protect surface water supplies. As stated in the Public Water Resources Rules for the Appropriation and Use of Water (Rules) 6115.0670:

"C (1). The amounts and timing of water appropriated shall be limited to the safe yield of the aquifer to the maximum extent feasible and practical."

"C (2). If the commissioner determines, based on substantial evident, that a direct relationship of ground and surface waters exists such that there would be adverse impact on the surface waters through reduction of flows or levels below protected flows or protection elevations the amount and timing of the proposed appropriation from ground water shall be limited."

"C (3). Appropriation of ground water shall not be approved or shall be issued on a conditional basis in those instances where sufficient hydrologic data are not available to allow the commissioner to adequately determine the effects of the proposed appropriation. If a conditional appropriation is allowed, the commissioner shall make further approval, modification, or denial when sufficient hydrologic data are available."

Definitions for safe yield are provided in the Rules (6115.0630):

"Subp. 15 Safe yield for water table condition means the amount of ground water that can be withdrawn from an aquifer system without degrading the quality of water in the aquifer and without allowing the long term average withdrawal to exceed the available long term average recharge to the aquifer system based on representative climatic conditions."

"Subp. 16 Safe yield for artesian condition means the amount of ground water that can be withdrawn from an aquifer system without degrading the quality of water in the aquifer and without the progressive decline in water pressures and levels to a degree which will result in a change from artesian condition to water table condition."

APPENDIX III

1987 REPORTED WATER USE FOR HENNEPIN AND RAMSEY COUNTIES, MN

Groundwater Use

Type		Volume (MGY)	Percent
Municipal		31,022.8	58.87
Heating and Cooling		9,851.9	18.70
Air Conditioning	6984.2		
Institutional AC	1436.5		
District Heat	1431.2		
Processing (Food, Sewage, Petro, Metal, Plastics, etc.)		8,508.8	16.15
Golf Course		914.2	1.73
Basin/Lake Level Maintenance		577.4	1.10
Other (Construction, Landscaping)		1,817.9	3.45
TOTAL		52,693.0	100.00

Surface Water Use

Type	Volume (MGY)	Percent
Municipal (including Anoka intake)	47,190.4	31.82
Power Generation	59,120.8	39.87
Steam Cooling	40,641.1	27.41
Processing	88.4	0.06
Basin/Lake Level Maintenance	1,144.3	0.77
Golf Course	108.0	0.07
Other (Construction, Landscaping)	82.0	0.06
TOTALS	148,293.0	100.06

Total Water Use

Type		Volume (MGY)	Percent
Municipal (including Anoka intake)		78,213.2	38.90
Hydroelectric\Steam Power Cooling		99,761.9	49.62
Heating and Cooling		9,851.9	4.90
Air Conditioning	6984.2		
Institutional AC	1436.5		
District Heating	1431.2		
Processing		8,597.2	4.28
Other (Construction, Landscaping)		1,899.9	0.94
Basin/Lake Level Maintenance		1,721.7	0.86
Golf Course		1,022.2	0.51
TOTALS		201,068.0	100.0

APPENDIX IV

1989 Water Use Fee Scheduled
Laws of 1989, Chapter 326, Article 4,
Section 5, Subdivision 5a

Subd. 5a. [WATER USE PROCESSING FEE.] (a) Except as provided in paragraph (b), a water use processing fee not to exceed $2,000 must be prescribed by the commissioner in accordance with the following schedule of fees for each water use permit in force at any time during the year;

(1) 0.05 cent per 1,000 gallons for the first 50 million gallons per year; and

(2) 0.1 cents per 1,000 gallons for the amounts greater than 50 million gallons per year.

(b) For once-through cooling systems as defined in subdivision 1c, a water use processing fee must be prescribed by the commissioner in accordance with the following schedule of fees for each water use permit in force at any time during the year:

(1) 5.0 cents per 1,000 gallons until December 31, 1991;

(2) 10.0 cents for 1,000 gallons from January 1, 1992, until December 31, 1996, and

(3) 15.0 cents per 1,000 gallons after January 1, 1997.

(c) The fee is payable based on the amount of water permitted during the year and in no case may the fee be less than $25.00.

(d) Failure to pay the fee is sufficient cause for revoking a permit.

APPENDIX V

Geothermal Heating and Cooling

Laws of Minnesota 1989

Chapter 326, Article 4

Section 4, Subdivision 1c.

Certain Cooling System Permits Prohibited

(a) The commissioner may not issue a water use permit from a groundwater source for a once-through cooling system using in excess of five million gallons annually.

(b) For purposes of this subdivision, a once-through cooling system means a cooling or heating system for human comfort that draws a continuous stream of water from a groundwater source to remove or add heat for cooling, heating, or refrigeration.

Section 5, Subdivision 5a, Item b

(b) For once-through cooling systems as defined in subdivision 1c, a water use processing fee must be prescribed by the commissioner in accordance with the following schedule of fees for each water use permit in force at any time during the year.

(1) 5.0 cents per 1,000 gallons until December 31, 1991;

(2) 10.0 cents for 1,000 gallons from January 1, 1992, until December 31, 1996; and

(3) 15.0 cents per 1,000 gallons after January 1, 1997.

(c) The fee is payable based on the amount of water permitted during the year and in no case may the fee be less than $25.

Section 8.

Consumptive Water Use Study

The commissioner of natural resources shall conduct a study of consumptive water use and its impact on existing aquifers. The commissioner shall review methods of reducing consumptive water use, including the conversion of once-through cooling systems to alternative systems. The commissioner shall report to the legislative water commission by February 15, 1990, the commissioner's recommendations for alternatives to the once-through cooling systems, including the environmental and economic implications of the alternatives. The recommendations must include: options for converting once-through cooling systems; a time schedule for phasing out existing systems; recommended technologies to be used to accomplish the conversion; recommendations for a fee structure that will make once-through cooling systems and conventional systems equal in operating costs; recommendations on the use of deep aquifers for once-through cooling; recommendations on authorizing systems of better efficiency; and advisability of systems that recharge aquifers.

STATE OF
MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

Celebrate MINNESOTA 1990

DNR INFORMATION
(612) 296-6157

500 LAFAYETTE ROAD • ST. PAUL, MINNESOTA • 55155-40

August 18, 1989

Dear Permittee:

GEOTHERMAL HEATING AND COOLING SYSTEMS

As you may be aware, the 1989 Legislature passed laws that will effect many geothermal heating and cooling operations. Enclosed, for your information is a summary of the 1989 laws pertaining to appropriation of ground water for once-through heating and cooling systems. Please read the new laws and be aware of the changes affecting your installation(s).

One important change in the law is that the Department is prohibited from issuing new or amending existing water appropriation permits for once-through systems using more than five million gallons per year. Existing requests for amendments will be held in a pending status until the prohibition is lifted. All appropriations are therefore bound to the conditions and limitations authorized by the present permit.

Another important change relates to the processing fee for the Annual Report for Water Use. A separate fee schedule exists for once-through heating and cooling permits that use ground water. Please note that there is no maximum fee limit for these permits. This may be a substantial fee increase for your permit. Systems that do not fit the definition of once-through heating and cooling will have a minimum fee of $25.00 for any amount of water authorized up to 50 million gallons. An additional one-tenth of one cent per 1,000 gallons authorized above 50 million gallons is added to the minimum fee up to a maximum of $2,000. These new fees are in effect for 1989 and will be required with the Annual Report of Water Use due on February 15, 1990.

In order to assess the correct processing fee the Department must update your permit file to reflect your specific type of system and water use. Your system has been identified as a possible once-through heating or cooling system as defined in the new legislation. Therefore, you are required to complete the enclosed GEOTHERMAL HEATING AND COOLING SURVEY and return the survey by September 15, 1989. If you system does not use ground water for heating or cooling (air conditioning), please provide a complete description of the use of water, the type of system, and submit the enclosed well information after verifying the well log data or completing the water well information form(s).

AN EQUAL OPPORTUNITY EMPLOYER

All geothermal heating and cooling water users are being required to complete the survey. Please take care in filling out the requested information. If there is not sufficient space on the survey form attach any additional sheets and/or information necessary.

In addition to updating your permit this information will be used in the study the Department is required to complete for the legislature by February 15, 1989. You may be contacted for additional information by the Department and/or the consultant associated with the study. An advisory committee comprised of persons representing various interests, including building owners and managers, will provide expertise and input during the preparation of the study report. We hope this process will provide a comprehensive study that will be helpful to the legislature in making future decisions regarding these systems.

The GEOTHERMAL HEATING AND COOLING SURVEY does not include any space for comments, however, please feel free to submit any specific comments that you have regarding this issue. Thank you for your cooperation. If you have any questions, please contact me at (612) 297-2835.

Sincerely,

DIVISION OF WATERS

James Japs
Water Appropriation Program Coordinator

JJ:tjb

Enclosures

APPENDIX VII

GEOTHERMAL HEATING AND COOLING SURVEY

PERMIT NUMBER ____________________

PERMITTEE ____

SYSTEM LOCATION ____

NAMES AND LOCATIONS OF FACILITIES:

____

____

____

TOTAL AREA SERVICED: ________Square feet

WATER SOURCE

Number of wells connected to the system ______

Enclosed is the well information we have on file regarding this installation. Please indicate if this data is accurate and/or submit any additional well data that is available. If no information is enclosed or available, please complete the enclosed Water Well Information form(s).

Are water level measurements taken on the production well(s) or observation well(s)? [ ] Yes [ ] No If yes, please submit a summary of the data.

SYSTEM INFORMATION

Number of years since original system was installed:_________

Date system was put on line: _________________

Is this a once through or closed loop system (describe and attach a simple schematic drawing) ?

____

____

____

____

____

____

____

Describe any major system modifications and give the completion date:

____

____

____

____

____

Average water temperature:

Heating ________ intake; ________ discharge
Cooling ________ intake: ________ discharge

System size rating:

Heating ________ (BTU/H) Cooling ________ (Tons/H)

Actual peak load:

Heating ________ (BTU) Cooling ________ (Tons)

Energy efficiency of systems:

Number of chillers/heat pumps in system ________
Coefficient of Performance (COP) for heat pump ________
Average Energy Efficiency Ratio (EER) for heat pump ________
If no heat pump, chiller efficiency rating ________
Number of chillers or heat pumps in system ________
Size rating of chillers/heat pumps ________

General Water Use Efficiency:

Average Efficiency of Water Use ________ (gal/ton) cooling
________ (gal/BTU) heating
How much water is recirculated? ________
How much water is lost in the system, where is it lost and how is the amount of water loss determined?

____

____

If cooling towers are part of the system, how many are there, how much evaporative loss occurs in this loop, and how is the amount of water loss determined?

____

____

What is the design capacity of the towers? ________________
If cooling towers are not present in the system please describe the feasibility of adding towers including any site and/or system limitations.

____

____

____

____

____

____

____

WATER USAGE

Indicate the percentage of all primary and secondary uses of the water:

_____ Heating _____ Air conditioning
_____ Processing _____ Other: ____________________

Average pumpage: ________gpm; _____hours/day; _____months/year

Are flow meters used to determine water usage? [ ]Yes [ ]No

If meters are not used, describe how the amount of water appropriated is determined.

____

____

____

WATER DISPOSAL

Indicate any water treatment that is done before or after the water goes through the system.

____

____

What percentage of the water is discharged and what is the water discharged to?

____

If water is discharged into a storm sewer indicate the receiving water for the sewer outlet, if known.

____

List any discharge authorizations required for the system.

____

____

Indicate any regulated discharge limitations relating to water temperature, quality or quantity.

____

____

____

WATER CONSERVATION

Does the system use variable speed pumps? [ ] Yes [ ] No
Are any load or system controls used to reduce water requirements by reducing the operating load conditions (i.e. load shedding, temperature set points)?

____

____

____

List any other measures utilized to reduce water use:

____

____

____

What changes can be done to the system to reduce water use?

____

____

What alternatives exist for reuse of the discharge water?

____

____

____

Indicate any anticipated future changes in water use and state reasons for projected increases or decreases.

____

____

____

Please provide us the following information about the person that completed the survey.

Name ____

Title ____

Telephone Number ____

Please give the name and phone number of someone that can provide additional information, if different than above.

Contact Person ____

Telephone Number ____

This survey is to be completed and mailed by <u>September 15, 1989</u> to:

Department of Natural Resources - Division of Waters
Attn: Jim Japs
Geothermal Heating and Cooling Survey
Box 32, 500 LaFayette Road
St. Paul, MN 55155-4032

APPENDIX VIII

CONSUMPTIVE WATER USE STUDY RELATING TO ONCE-THROUGH HEATING AND COOLING SYSTEMS

Department of Natural Resources, Division of Waters
500 Lafayette Road, St. Paul, MN 55155-4032
Principal Contact Person: James Japs 612/297-2835

ADVISORY COMMITTEE

MN Mechanical Contractors Association
Gary Thaden 612/646-2121
766 Transfer Road, St. Paul, MN 55114-2121

Owens Services Corporation
Floyd Thomas 612/854-3868
930 East 80th Street, Minneapolis, MN 55420

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Tony Rohr 612/647-9920 FAX/647-1566
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Glossary

Aquifer penetrations - The actual portion of the aquifer that is screened or open for use by the well.

Aquifer test - A controlled field experiment conducted to determine the hydraulic properties of an aquifer. the test involves pumping a well at a known discharge rate and measuring the drawdown and resulting recovery in the production well, one or more observation wells, and possibly one or more domestic wells.

Area of influence - The area influenced by the cone of depression.

Buried outwash aquifer - An aquifer usually consisting of glacially derived sands and gravels buried beneath a confining layer. This aquifer is a confined aquifer.

Cone of depression - A depression-shaped like an inverted cone - in the groundwater table or piezometric surface centered on and due to a pumping well. The cone edge defines the area of influence of the well.

Confined (artesian) aquifer - An aquifer that is completely saturated and whose uppe and lower boundaries are impervious layers. In this type of aquifer the water pressure is greater than the atmospheric pressure resulting in a hydraulic head high than the top of the aquifer.

Confining layers\beds - a unit - usually clay, silt, or shale - of "impermeable" material which overlies an aquifer resulting in hydraulic pressures greater than the ambient atmospheric pressure.

Drawdown - The difference between the original static water level and the depth to water at any given time during the pumping phase.

GPM. - Gallons per Minute

Grain size - The nomenclature assigned to describe the size of sands and gravels encountered during drilling.
Head, total - the sum of the elevation head, the pressure head, and the velocity head at a given point in an aquifer.

High-capacity well - a well capable of pumping large volumes of water - often for municipal, industrial, or agricultural purposes.

Infiltration - The movement of water downward from the land surface into and through the soil layer.

K (hydraulic conductivity) - The rate of flow of water in gallons per day through a cross section of one square foot under a unit hydraulic gradient, at the prevailing temperature (gpd/ft^2).
Lateral extent - The imaginary surficial traces of the boundaries of an aquifer.

Lithology - A term usually applied to sediments, referring to their general characteristics.

Pumping schedule - length of pumping specified on the permit application in days.

Partial penetration - When the screen or open hole of a well does not extend the full thickness of the aquifer.

Potentiometric surface - A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Priority of users - These priorities are derived from Minnesota Statutes Chapter 105.41, Subd. 1a.

First Priority: Domestic water supply, excluding industrial and commercial uses of municipal water supply.

Second Priority: Any use of water that involves consumption of less than 10,000 gallons of water per day. For purposes of this section "consumption" shall mean water withdrawn from a supply which is lost for immediate further use in the area.

Third Priority: Agricultural irrigation, involving consumption in excess of 10,000 gallons per day, and processing of agricultural products.

Fourth Priority: Power production, involving consumption in excess of 10,000 gallons per day.

Fifth Priority: Other uses, involving consumption in excess of 10,000 gallons per day.

Production test - A test usually conducted by the driller on a new well to determine the potential yield of a well. The test often includes measurement of depth to water within the production well for both the pumping and recovery periods.

Pumping water level (PWL) - The water level in a well that is being affected by ground water withdrawal. Also known as dynamic water level.

Residual Drawdown - The difference between the original static water level and the depth to water at a given instant during the recovery period.

Saturated aquifer thickness - That portion of the aquifer which is fully saturated. In confined aquifers this is the whole aquifer, for unconfined aquifers this is only that portion below the water table.

Specific Capacity - The rate of discharge of a well per unit of drawdown, this is most often expressed as gpm/ft.

Static water level (SWL) - The water level in a well that is not being affected by ground water withdrawal.

Storage coefficient (S) - The volume of water an aquifer release form or takes into storage per unit surface area of an aquifer per unit change in water level.

Surficial outwash aquifer - An aquifer usually consisting of glacial outwash materials under water table conditions.

Thickness - The thickness in feet of an aquifer or other stratigraphic unit.

Transmissivity (T) - The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. In short, it describes the rate at which an aquifer transmits water. Transmissivity values are often expressed in gallons per day per foot (gpd/ft) or feet square per day (ft^2/day).

Unconfined (water table) aquifer - An aquifer where ground water is exposed to the atmosphere. The water table elevation is thus under atmospheric pressure.

Well Yield - The volume of water per unit of time discharged form a well, either by pumping or by flow. It is commonly measured as the pumping rate in gallons per minute. Referred to as "Q."

Yield test - A test usually conducted on a production well at the time of drilling to determine the well's potential to yield water.