ALTERNATIVE SOURCES OF WATER FOR THE TWIN CITIES METROPOLITAN AREA

Working Paper No. 1 for the Long-Term Water Supply Plan

May 1991

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METROPOLITAN COUNCIL
Mears Park Centre, 230 East Fifth Street, St. Paul, Minnesota 55101
Publication No. 590-91-011

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ABOUT THIS REPORT

This report is Working Paper No. 1 in a series of eight. The reports are being prepared as background technical studies for the preparation of a long-term water supply plan for the Metropolitan Area. The long-term plan preparation was required by the 1989 legislature and must be presented to the legislature on February 1, 1992.

The other technical reports in the series are:

No. 2. Water Demand in the Twin Cities Metropolitan Area. Metropolitan Council Report No. 590-91-009.
No. 3. Water Availability in the Twin Cities Metropolitan Area: The Water Balance. Council Report No. 590-91-008.
No. 4. The Public Water Supply System: Inventory and the Possibility of Subregional Interconnection. Council Report No. 590-91-010.
No. 5. Water Conservation in the Twin Cities Metropolitan Area. Council Report No. 590-91-020.
No. 6. The Effects of Low Flow on Water Quality in the Metropolitan Area. Council Report No. 590-91-054.
No. 7. The Economic Value of Water. Council Report No. 590-91-065.
No. 8. The Institutional Framework for Water Supply Management. Council Report No. 590-91-064.

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INTRODUCTION

The material contained in this report addresses one component of the long-term plan. This report examines alternative sources of water that might be available to the Metropolitan Area during a water shortage caused by drought or by contamination of a currently used source. The report in large part is a re-examination of alternatives that have been explored previously; very few "new" alternatives have been identified. Previously identified alternatives will, however, be examined in light of today's environmental, social, economic and political values. Every attempt is made to identify alternative sources, no matter how limited their use might be, in order to expose them to some degree of discussion.

Many of the recommendations from previous studies have been implemented. Examples include the 1990 mandate by the legislature to phase-out all once-through air-conditioning systems by the year 2010; the adoption of a multi-agency emergency response matrix tied into specific Mississippi River flows; revisions by the Corps of Engineers to the Headwaters Reservoir system low flow operations plan; a revised Minnesota Department of Natural Resources (DNR) water appropriation system; the development of a Twin Cities ground water model by the U.S. Geological Survey (USGS); and the procurement of a supplemental supply system by the St. Paul Water Utility. There are also elements of previous studies that have not been implemented, such as development of upland/upstream reservoirs; institution of a regional water supply authority and regional water supply planning; large-scale water diversions; major industrial/commercial water recycling; procurement of a Minneapolis Water Works supplemental supply system; and large-scale artificial/enhanced recharge.

DISCUSSION OF NEED

There are two compelling reasons to plan for alternative sources of water supply. The first is a drought or water shortage problem caused by an inadequate volume, or rate of flow. The second, and at times more vexing problem, is one associated with a contamination event that would necessitate immediate closure of an intake. Each of these potential problems affects a large group of water users, with some users affected by both situations.

Volume Shortage

The drought that caused substantial problems in the summer of 1988 (Metropolitan Council, 1990) pointed to the type of problem that occurs when water does not flow at a rate sufficient to meet the demands of all users. Supply problems during this period resulted from shortages of both surface and ground water. The events of 1988 lead to such things as derating of Northern States Power (NSP) power-generating facilities, artificial aeration of Metro Plant wastewater effluent by the Metropolitan Waste Control Commission (MWCC), Department of Natural Resources (DNR) permit suspensions that included 143 irrigation permits on six tributaries to the Mississippi River, reevaluation of the dependability of many high capacity municipal wells, and mandatory conservation by many municipal water suppliers, including the Minneapolis Water Works and the St. Paul Water Utility. Water managers, public agencies, the Minnesota legislature and the public became aware that planning for water shortages in our "water rich" state was inadequate, even though a serious drought had occurred as recently as 1976. The locations of the major surface water users in the region and the NSP Monticello and Sherco power plants upstream of the Metropolitan Area are indicated for reference in Figure 1.

The solution to the volume supply problem requires long-term planning to assure an adequate and dependable source(s) of water to meet demand. A review of surface water supply and demand data show that most uses of surface water in the Metropolitan Area are from the three major rivers--- the Mississippi, Minnesota and St. Croix. When power plant cooling requirements are removed, the only river with much demand for its water is the Mississippi. Specifics on the use of water in the region are reported in another working paper (No.2), but are summarized in Table 1.

Table 2 shows the approximate amount of water that has been historically withdrawn in the Metropolitan Area. The data are approximate because reporting was less than inclusive until recently, when the DNR devoted a large effort to get all users under a permit and reporting program. Of particular note in Tables 1 and 2 is the nearly identical overall use from 1980 to the present.

An additional demand not noted in Table 1, but of substantial importance to the well-being of the region, is the volume of water required to cool the NSP power plants at Monticello and Sherco. As described in the short-term plan (Metropolitan Council, 1990), Monticello withdraws 645 cubic feet per second (cfs) at full power, while Sherco withdraws 67 cfs into its recirculating system. Monticello consumes a maximum of only 10 cfs because of its flow-through nature, while Sherco consumes up to 47 cfs due to evaporative losses in its recirculating system. A minimum flow of 250 cfs is required at these two plants in order to keep the intakes submerged. Substantial

Figure 1
SURFACE WATER USERS IN THE TWIN CITIES METROPOLITAN AREA

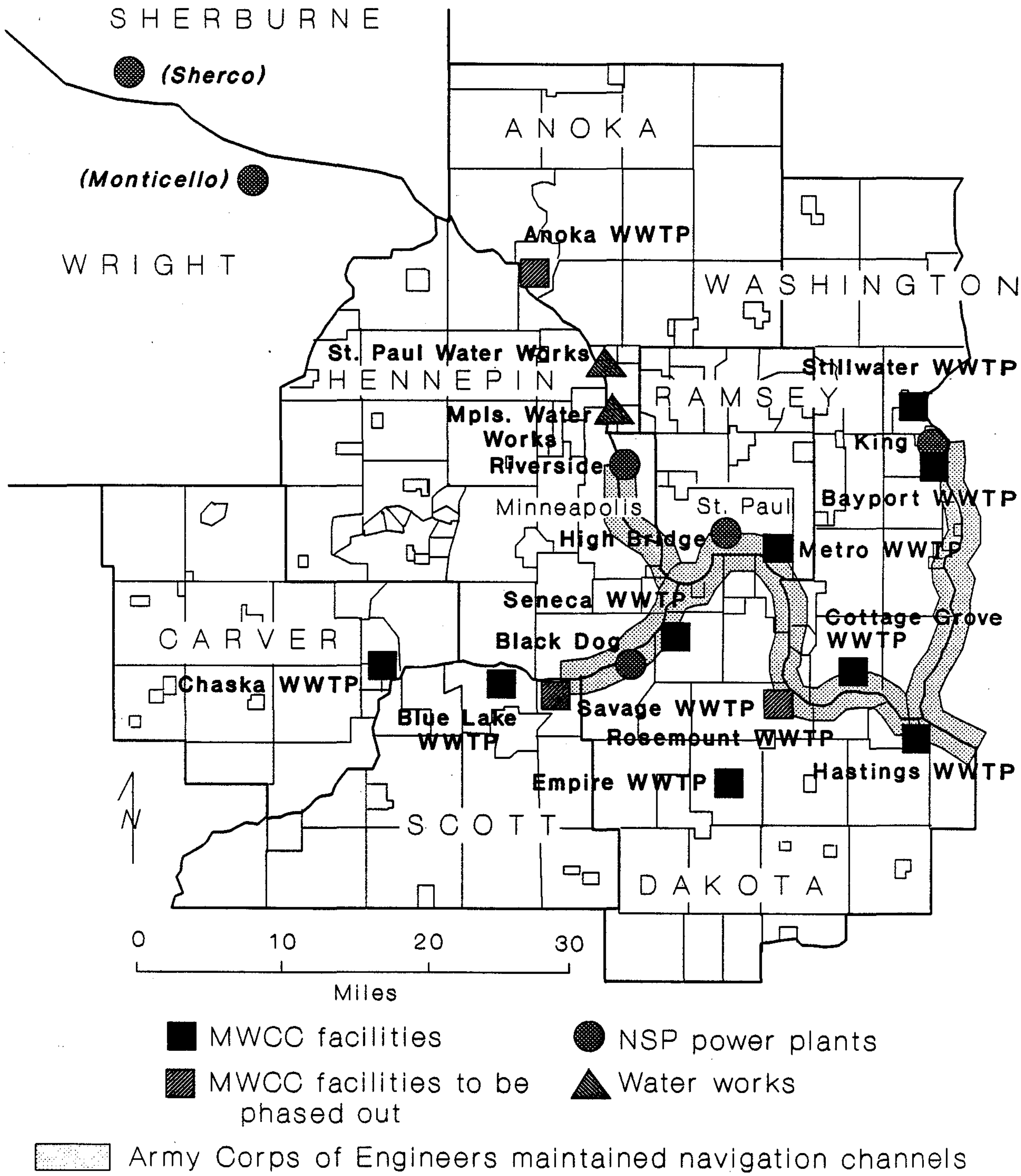


Table 1

SIX-YEAR AVERAGE REPORTED WATER USE FOR THE METROPOLITAN AREA*.

WATER USE (current DNR permitted volume,mgd)	AVERAGE 1984-1989 DNR-PERMITTED WATER USE IN MILLION GALLONS PER DAY (MGD)		
	Surface Water	Ground Water	Total
Municipal Waterworks (671)	132.4	144.8	277.2
Power Plant Cooling (1396) -Metro Area Only-	574.2	0.4	574.6
Air Cooling/Heating (32.4)	0	27.3	27.3
Industrial (97.2)	0.6	39.2	39.8
Water Level Maintenance (64.4)	25.5	2.4	27.9
Irrigation (52.1)	0.7	19.5	20.2
Miscellaneous (22.6)	0	9.3	9.3
Private Waterworks & Domestic Wells (**2.5)	--	***22.9	22.9
Total (2337.6)	733.4	265.8	999.2

* Does not include small industrial/commercial, agricultural and miscellaneous uses

** Permitted private waterworks only; no DNR permit required for uses less than 10,000 gallons per day or one million gallons per year

*** Assures per capita use of 102 gallons for population of 200,000

Table 2
APPROXIMATE HISTORIC WATER USE IN THE METROPOLITAN AREA

Year	Surface Water Use in MGD (Use without power generation)*	Ground Water Use In MGD	Total Use In MGD (Use Without Power Generation)*
1900	(36)	6	(42)
1920	(58)	24	(82)
1940	(70)	72	(142)
1960	(98)	142	(240)
1980	749 (98)	245	994 (343)

* Complete data on amount of water used for power plant cooling not available prior to 1970.
Source: UMRBC, 1976; HORN, 1983

reductions in power output would occur, however, before this critical flow is reached.

Discussions later in this report revolve around a need to meet an "emergency" demand of 250 cfs or 162 million gallons per day (MGD) in the Mississippi River from Monticello/Sherco through the Metropolitan Area. This value approximates the absolute minimum demand of 75 MGD for the Minneapolis Water Works; 45 MGD for the St. Paul Water Utility; 14 MGD for the city of St. Cloud water supply system; and, because such low flows would necessitate derating of the Monticello and Sherco plants, one-half of the 38 MGD (19 MGD) consumptive use required for these two plants, plus High Bridge and Riverside. This flow, incidentally, would also provide the minimum required to keep the NSP intakes at Monticello and Sherco submerged.

Efforts to relieve an emergency situation would of course start well before a flow of 250 cfs is reached. The Metropolitan Council's short-term plan emergency drought response matrix, which was adapted from a DNR-developed emergency response plan, and a similar matrix contained in the U.S. Army Corps of Engineers' report on its low flow plan for the Headwaters Reservoirs (U.S. Army Corps of Engineers, 1990) both contain a set of actions that would begin when flows in the river at Anoka fall below 2000 cfs. The Council obtained the verbal commitment of all parties to the short-term plan matrix that they would abide by the actions contained therein. The 1990 legislature also required the DNR to consider this matrix in its efforts to put together a statewide drought response plan.

Discussion so far has focused on the response to low volume problems on the river system. Serious problems can also occur with the available quantity of water in the ground water system, albeit much slower in most cases. Alternatives in this report will attempt to address not only the demand that is seen in Table 1 for about 260 MGD, but also the large increase in future ground water demand that is expected to result from growth in the suburban part of the region that relies solely on ground water for its supply. Concern must be raised over the fact that much of the anticipated growth in the Metropolitan Area will occur at the outer extremities, and beyond the lateral extent, of the Prairie du Chien-Jordan Aquifer. Some water level problems were seen in 1988 when levels in some communities dropped below the pump intakes. Additional problems were encountered by some rapidly growing communities that could not store enough water to meet peak demand. These shortages are symptoms of the ground water system's inability to keep up with a rapidly expanding demand. These difficulties are discussed further in Working Paper No. 4 on the public water supply system.

Contamination Shortage

Perhaps a more fearful event to many water suppliers is the accidental contamination of their principal water source. This can occur for both surface water and ground water systems. The "worst case" scenario for a single source supplier, like the Minneapolis Water Works for surface water, and most municipalities for ground water, is a slow moving, highly contaminated plume of water. Most ground water suppliers are at least partially protected by the mere distance of their intakes from a probable source of contamination and the presence of low permeability confining units between the land surface and the aquifer from which they extract water. Exceptions to this are suppliers that rely on the surficial drift, which is in direct contact with the surface of the land.

More serious repercussions would likely be seen for surface water suppliers in the event of a source contamination. A preliminary inventory of Mississippi River crossings (Appendix A) shows that 35 highways, eight railroads and one oil pipeline (Minnesota Pipeline Co.) cross the river from the outlet of Lake Winnibigoshish to the Minneapolis Water Works intake at Fridley. Another oil pipeline (Lakehead Pipeline Co.) crosses the Prairie River at Grand Rapids about 1.5 miles upstream of its confluence with the Mississippi River. There is also an eight-inch MWCC sanitary forcemain crossing from Champlin to Anoka and two 42-inch forcemains crossing from Brooklyn Park to Fridley. One of the highway crossings (I-494) and the Brooklyn Park-to-Fridley pipes cross downstream of the St. Paul Water Utility intake. In addition to the rail crossings, there are nine locations along the river where rail lines run within one-quarter of a mile for distances exceeding 10 miles. There is also NSP's nuclear power plant at Monticello, and numerous chemical and oil storage facilities that pose potential threats if leakage were to occur.

For the St. Paul Water Utility, immediate movement away from use of the Mississippi River as a primary source can occur because of its back-up lake and ground water supply. This, however, does mean that the Utility must be aware of the possibility of contamination at several locations other than the river. In fact, a spill into one of the Utility's reservoirs would present serious problems since flushing the system would be very difficult.

The Minneapolis Water Works, which relies entirely on the Mississippi River for its water supply, has expressed more of a concern (verbal communication, June 1990) over the possibility of a contamination event than a drought. Closing their Mississippi River intakes for longer than a 24-hour period (during low demand---less time during peak demand periods) would result in an inability to meet demand within the city of Minneapolis and the suburbs that it supplies (Crystal, Golden Valley, New Hope, Columbia Heights, Hilltop, and a portion of Bloomington and Edina). For this reason, efforts to obtain alternative supplies for Minneapolis must focus on the immediate, short-term, as well as on the longer-term, drought situation. The Minneapolis Water

Works has undertaken its own studies of alternative supplies, as referenced throughout this report.

Action has begun to at least develop a plan for protection of the Mississippi River from accidental spills and to respond to emergencies that might occur. The U.S. Army Corps of Engineers (USCE) annually makes funds available to each state on a cost-share basis to undertake some aspect of water planning. These funds are authorized under Section 22 of the Water Resources Development Act of 1974 (PL 93-251) and are made available to a coordinative state agency. This agency in Minnesota is the Environmental Quality Board (EQB), which this year decided that the program should address protection of the upper portion of the Mississippi River, above the Minneapolis and St. Paul water intakes. The EQB asked the Metropolitan Council to manage the study on its behalf and the Minneapolis Office of Emergency Preparedness was able to obtain the 10% match that the USCE requires for the program. The program, scheduled to begin approximately May 1, 1991, will inventory potential spill sources, hydraulically and chemically route spilled material down the river, and assess the need for emergency response programs to prevent the intake of contamination by downstream water users. The program is a two-year effort, although part of the first year's work and the entire second year of the effort remain unfunded at this point.

Wastewater Assimilation Shortage

A final note before proceeding to an examination of alternatives pertains to requirements for wastewater assimilation. State and federal law requires the design of wastewater treatment facilities in order to assure the attainment of water quality standards at a 7-day low flow with a frequency of occurrence of once in 10 years; this flow is called the "7Q10", currently established at St. Paul at a flow of 1419 for the annual time series, or 1830 cfs when only summer conditions are considered. In the summer of 1988, the Mississippi River flows dropped substantially below the 7Q10, thus relieving the MWCC from its responsibility to assure the attainment of standards. In spite of this, the MWCC was able to actually increase the levels of dissolved oxygen in the river as it passed the Metro Plant at Pig's Eye through artificial aeration. Even though the law does not require extremely advanced levels of wastewater treatment during flows less than the 7Q10, wastewater assimilation for maintenance of water quality objectives is a consideration that must be kept in mind, and if we are able to improve the quality of our receiving waters during these periods, we should certainly strive to do so.

In-depth discussion of water quality issues occurs in Working Paper No. 6 of this technical studies series.

CONSIDERATION OF ALTERNATIVES

This section of the report explores each of the extensive list of alternatives. The alternatives are not discussed in a priority manner or by their likelihood for success. Alternatives instead are presented in a categorical manner, with all alternatives identified in order to "air the facts" about each. All costs presented are approximate costs in June 1990 dollars. Alternative source considerations that must be kept in mind include temporal and volumetric reliability, response time to fully-operational status, costs, quality of available water, technical feasibility and competing uses. These aspects of each alternative will be addressed as the alternatives are presented.

A discussion of alternatives is necessitated because a "no action" alternative means that we will continue to react after the fact to future shortages. Unfortunately, the common tendency has been to forget about planning for shortages a brief time after a drought ends. The 1989 legislature, however, decided that a plan must be prepared so that the Metropolitan Area can adopt a proactive position as we become aware of an impending drought or a contamination event. The following discussion introduces options for action and the benefits/detriments of each.

Wise Use/Conservation

Without a doubt, the most effective and immediate thing to do to avoid supply problems is to institute a program that stresses the wise use of water. Before any other sources of water are examined for the region or for any locale, efficient use of available water should occur. Perhaps the most effective argument against releasing any water from the Headwaters Reservoirs in 1988 was the fact that the cities of Minneapolis and St. Paul did not have such a program in place. It is certainly true that pressure on the cities was misplaced, but the fact remains that there was a perception that excess water was being needlessly consumed by the cities. The short-term water plan presented to the legislature in February 1990 outlined an agreement by all large surface water users in the region to institute water use reductions as flow in the river lowers.

A recommendation was made in the short-term plan that all large volume users of water should be required under Chapter 103G (recodified from Ch. 105) to prepare contingency plans outlining measures they would take when they encounter a water shortage. Surface water users are now required to do this, but ground water users are exempt. Surface water users can also "opt-out" of their responsibility by signing a waiver accepting the consequences of a water shortage. This does not promote the wise use and forward thinking philosophies that are needed to aggressively address water problems. We again recommend that Chapter 103G.285 subd. 6 (recodified from Ch. 105.417) be amended to cover all major users and that the DNR prepare rules and regulations for these plans, and that signing a waiver to avoid contingency plan preparation no longer be allowed. We anticipate that agricultural users would be exempt from this requirement because of their limited use of water.

Municipal water supply conservation plans are best handled on a system-specific basis rather than regionally because of such variables as source of water, extent of existing efforts such as metering and sprinkling limitations, and demand conditions. For example, a rapidly growing community has a requirement for water to keep new landscaping alive in a drought, whereas an older city with a large amount of industry has a fairly uniform, yet high demand for water all year. Each city might at some time come under some regional mandate to conserve, but the methods it decides to pursue in order to achieve that goal might be entirely different.

A separate technical study is being done by the Metropolitan Council on effective conservation measures and the water savings that are likely to result from them (Working Paper No.5). The following discussion primarily addresses the concepts of wise use/conservation and will leave many of the specifics to be addressed in more detail in the other report.

In a presentation to the 1988 University of Minnesota conference on the drought (UMWRRC, 1989), a DNR spokesperson suggested that a Minnesota initiative for wise use/conservation should do three things:

- Use the present delivery system more efficiently by doing things like repairing leaks and reducing peak use;
- Reduce overall per capita (per product) demand; and
- Mandate more efficient installations, through such measures as elimination of once-through air-conditioning, revised plumbing codes and industrial reuse/recycling.

Implementation of this approach through a statewide or regional mandate is something the legislature should consider. Other available techniques to achieve the above include mandatory household and commercial water-saving plumbing/appliances; irrigation/sprinkling restrictions; increasing block pricing and water use metering; low water use landscaping; education; distribution leak detection and repair; and pressure reduction.

Previous assumptions on the institution of conservation predicted that about 10% could be saved by municipal suppliers through commonly used techniques, up to 40% in commercial establishments through similar efforts, and up to 60% in industrial and air-conditioning situations where water can be recycled (Metropolitan Council, 1983 and 1984; Minnesota Water Planning Board, 1979; Upper Mississippi River Basin Comprehensive study--UMRBC--1977).

Some examples of the type of savings that are possible can be seen within the Metropolitan Area. Minneapolis was able to realize a 44.5% demand reduction in the summer of 1988 by instituting a public education program and banning outside uses of water. During this same period and with the same type of efforts, the St. Paul Water Utility saw a 29% reduction in its demand, while Bloomington reduced its demand almost in half. The 1990 legislature decided that once-through use of water for air-conditioning is not an effective use of ground water resources and so they ordered the phase-out of all of these systems by the year 2010. This removes 100% of a use of water that has long been targeted in wise use scenarios.

Emergency measures undertaken in California have resulted in permanent reductions in water use of 20-50% (UMWRRC, 1989). The MWCC indicates that substantial reductions in industrial water use occurred when it instituted an industrial strength charge system for discharge of wastewater into its system. This has been beneficial to MWCC since the overall hydraulic load to its treatment plants has decreased.

Reuse of industrial cooling or non-contact process water should be explored to a greater extent than currently occurs. The latest DNR appropriation numbers indicate that approximately 40 million gallons is used by permitted self-supplied industry in their daily operations (Table 1).

Although some of this water is reused/recycled by some of the industries, overall the once-used water is "disposed" of in some fashion. The legislature should consider requiring at least an evaluation of the likelihood of reuse/recycling as part of the permit issuance procedure. Such an amendment would add another section to the permit form that would ask what considerations the permittee made as an alternative to immediate disposal of process or cooling water. Perhaps some tax incentives can be granted to those industries that make the extra effort to waste less water.

Another reuse option is one that was mentioned in the short-term plan, but not pursued at that time by the legislature, namely, reuse of treated pump-out water from contamination sites. A great example of this potential is unfolding as several possible users have expressed their desire to use discharge water from the Twin Cities Army Ammunition Plant (TCAAP) in New Brighton. Most of the water discharged from these treatment systems is at, or close to, drinking water standards and could be put to some sort of use rather than being discharged to a water body. We again urge the legislature to have the Minnesota Department of Health (MDH) and the Minnesota Pollution Control Agency (MPCA) look also at the feasibility of using treated water for ground water injection.

Conservation plans for all water users should include both short- and long-term components. The short-term component should focus on emergency conditions. Such a plan would identify uses and prioritize how they could be reduced if the need arises. For a municipality, this might include restrictions on outside uses and identification of commercial and industrial users that would have to shut down. For industry, it would likely involve a procedure for phasing down water-using processes until water again becomes available.

The long-term plan would look further in time and attempt to define a program for assuring the availability of water in the future. Components of this plan for both municipal and industrial/commercial users would include refining the short-term plan under non-emergency conditions; projection of water needs; examination of methods to reduce water consumption; and assessment of alternative or supplemental supplies of water. Preparation of this plan would yield long-term benefits such as deferred investments in water supply and treatment facilities, decreased energy costs, reduced potential for water use interference, improved coordination during an emergency and more equitable distribution of water among users (Metropolitan Council, 1983). In short, a community or a private enterprise will be much better prepared to deal with shortages or interruptions should either occur. Simple foresight could mean the difference between adequate volumes of water available during an emergency and major socio-economic upheaval.

As previously indicated, the use of water for once-through air-conditioning will gradually decline until the year 2010 when it becomes illegal. Before all systems move in that direction, the cities should consider centralized cooling systems that use water in a recycling mode with one central cooling facility. The Minneapolis Energy Center is one such approach, using about 277 million gallons of water in 1987 and 1988. This center provides cooled water to about 15 buildings in Minneapolis. Expansion of this facility to buildings being forced to restructure their cooling system and construction of a similar system, perhaps in conjunction with the District Heating system in St. Paul might be an efficient way to cool buildings without the high electrical energy consumption that might otherwise be required. Costs of building and operating these expanded centers could be recovered from user fees.

Reservoirs

One theme of a 1988 University of Minnesota conference (UMWRRC, 1989) was that conservation/wise use is indeed needed, but it cannot solve all of the complex supply problems that face the state. There must be consideration of alternative sources of water if we ever hope to be truly prepared for a water shortage. Perhaps the most studied alternatives in the past have been reservoirs that include enough storage to supplement flows in the Mississippi River during flow shortages. Historically, reservoirs have been relatively easy to design and build. They also can be engineered to fulfill certain flow requirements--an important factor when their primary function will be flow augmentation. It does appear, however, that the era of large-scale reservoir building has passed, as evidenced by the fact that none of the often-referenced recommendations for additional reservoir capacity made by the Upper Mississippi Comprehensive River Basin Study (1970) or by any subsequent studies have been built or even seriously considered. It will become evident in this section that economic, environmental, social and political factors all argue against new large reservoir construction. The facts, however, must be examined so that decision-makers have a basis upon which to act. It should be noted here that none of the reservoir proposals to be discussed involve an interbasin transfer of water into or out of the upper Mississippi River Basin.

The primary goal in the construction or enlargement of any reservoir is to assure proper flow in the Mississippi River past the Minneapolis and St. Paul water intakes, and through the reaches where wastewater assimilation occurs (refer to Figure 1). Historic low flows on the Mississippi River at Anoka include a flow of 602 cubic feet per second (cfs) on Sept. 10, 1934 and an instantaneous flow of 529 cfs on Aug. 29, 1976 that resulted from faulty automatic gate operation at the Coon Rapids dam. A flow of 632 cfs occurred at St. Paul on August 26, 1934. The lowest daily minimum flow in 1988 at Anoka was 842 cfs on July 30th, while the lowest instantaneous flow of 828 cfs occurred on July 31st. Flow reached a minimum daily flow of 752 cfs at St. Paul on July 8, 1988.

The Council's short-term water supply plan showed that a "critical" flow of 554 cfs at Anoka would meet the needs of Minneapolis and St. Paul at reduced demands of 85 MGD and 45 MGD, respectively, for a total of 130 MGD (202 cfs); a consumptive use of 2 cfs for the NSP plants at High Bridge and Riverside; and 350 cfs for navigation to continue through the St. Anthony Falls lock and provide for maintenance of pools from which the power plants pull water. The 554 cfs required under this scenario is less than the lowest unaltered flow recorded at Anoka (602 cfs), but it is above the instantaneous flow of 529 cfs that occurred in 1976 from faulty gate operation. The U.S. Geological Survey has determined that a flow of 554 cfs has a seven-day annual return frequency of about once every 100-years (7Q100). Table 3 summarizes the low flow frequency data for the USGS stations at Anoka and St. Paul.

The data in Table 3 are from both an annual and a summer time series. MWCC designs for low flow based on a summer time series. The net effect of this is a "low flow design" at St. Paul of 1830 cfs at the present time (May 1991).

Table 3

MISSISSIPPI RIVER SEVEN-DAY LOW FLOW FREQUENCY DATA FOR ANOKA AND ST. PAUL

	FLOW IN CUBIC FEET PER SECOND (cfs)			
Recurrence Interval (years)	Anoka (1933-90)		St. Paul (1895-1990)*	
	Annual	Summer**	Annual	Summer**
100	555	557	767	770
50	684	696	904	977
20	921	962	1151	1373
10	1182	1270	1419	1830
5	1571	1756	1818	2543
2	2565	3134	2868	4510

* Except 1896, 1898, 1899, 1900, 1906
** Period from May 1 - Sept. 30

At an inflow of 554 cfs and a removal of 202 cfs by Minneapolis and St. Paul, a flow passing Minneapolis would be as low as 350 cfs. At the confluence with the Minnesota River, an additional small volume of water would be added. However, even the total flows of the Mississippi and Minnesota Rivers would be substantially less than the summer 7Q10 flow of approximately 1830 cfs required at the MWCC Metro Plant. If power, navigation and further downstream requirements were ignored, the Minneapolis and St. Paul requirement for 202 cfs could easily be met even at the lowest historic river flow.

Extended periods of low flow would further exacerbate the problem. Flow records from the 1930s show that flows less than 1000 cfs occurred at Anoka for 68 days in 1934 and that flow dropped below 1500 cfs for over four months. During extended flows this low, the minimum needs of water users would likely be met, but water quality on the river would likely suffer. Table 3 indicates that the 7Q100 drops to 767 cfs, just slightly above the July 8, 1988 flow of 752 cfs recorded at St. Paul.

A reservoir system located somewhere in the upper Mississippi River Basin could address some of the problems that accompany extended low flow, and for that reason, options for site development are discussed in the following sections.

Headwaters Reservoirs

An extensive amount of analysis has occurred over the years on the use of the Mississippi River Headwaters Reservoir system for supplementing flow in the river. The most recent analysis of this system was done by the U.S. Army Corps of Engineers (1990) following the 1988 drought. Their analysis concluded that "...the routine low flow discharge rates for each project lake are adequate for present needs". The Corps arrived at this conclusion after reviewing their federally-mandated priorities and the role that the reservoir system could play in alleviating low water problems in the Metropolitan Area. The Corps did acknowledge that there definitely could be extreme emergencies under which additional releases could occur, but only after efforts are underway to reduce demand in the Metropolitan Area. A summary of the events leading up to, and immediately following, the governor's request of the Corps' District Engineer to release additional Headwaters Reservoir water in the summer of 1988 occurs in the 1990 Corps' document and in the Council's 1990 short-term plan.

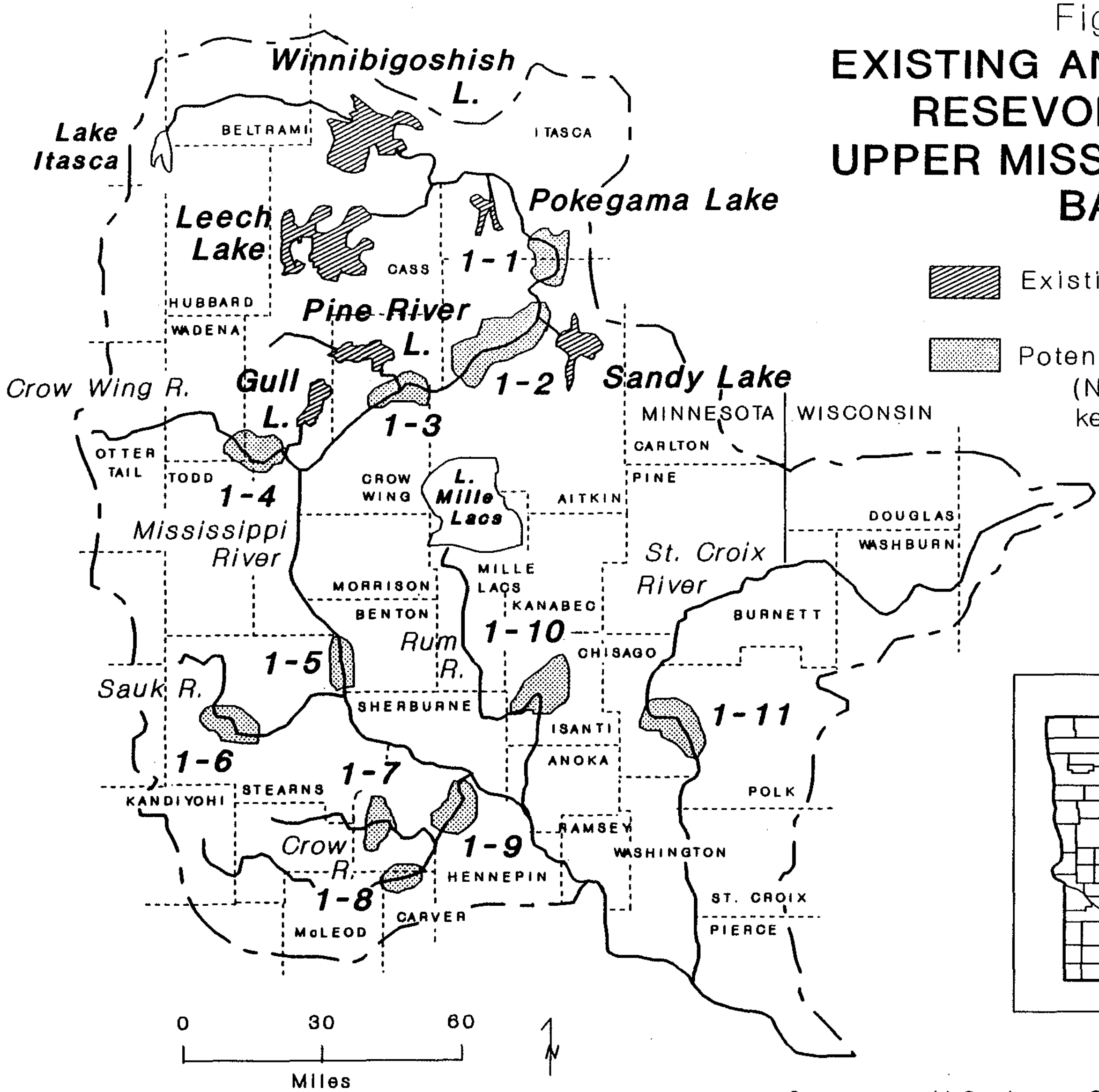
The six reservoir Headwaters system (Figure 2) consists of the following artificially enlarged lakes: Lake Winnibigoshish in Itasca and Cass Counties; Leech Lake in Cass County; Pokegama Lake in Itasca County; Big Sandy Lake in Aitkin County; Pine River Lake in Crow Wing County; and Gull Lake in Cass and Crow Wing Counties. These reservoirs have a combined surface area of over 370 square miles and a combined storage volume of approximately 1.6 million acre-feet (521 billion gallons) (U.S. Army Corps of Engineers, 1990). The routine low flow releases from this system total 270 cfs according to the following reservoir contributions:

- Winnibigoshish - 100 cfs
- Leech - 100 cfs
- Pokegama - sum of Winnibigoshish and Leech
- Sandy - 20 cfs
- Pine - 30 cfs
- Gull - 20 cfs

A major difficulty with relying upon additional releases from the Headwaters system is the travel time of 20-24 days required for released water to flow the approximate 400 miles to reach the Metropolitan Area. This fact means that even emergency releases cannot be relied upon to solve immediate needs that might arise from contamination events. Indirectly however, perhaps some releases could be made to fill downstream reservoirs that meet an emergency need (discussed later). These releases could be during periods when the reservoirs are low, but in all likelihood would occur as part of the drawdown of these facilities in anticipation of spring flood flows; that is, releases from storage in the fall and into the winter could be used to fill reservoirs that might be depleted during the summer.

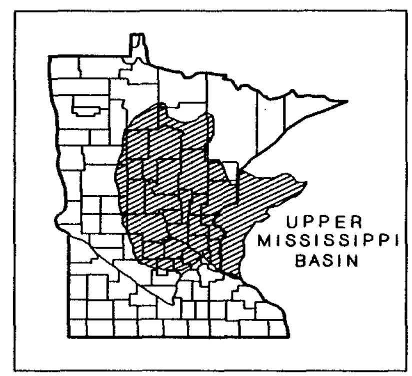
The Level B water supply planning effort of the late 1970s examined a potential increase in Headwater Reservoir releases to 1000 cfs. The final recommendation from the Level B study team (UMRBC, 1977) was not to increase releases before the impact of such a release on the "donor" was evaluated. This is in essence what the Corps did in its 1990 review of the low flow release scheme. The Corps' conclusion, as quoted previously, was that the donor region was entitled under federal law to have priority use of most water in the reservoir system in all but extreme circumstances. Downstream interests receive the routine release of 270 cfs, which has never been reduced even though the operating scheme allows for reductions as reservoir inflow falls.

Figure 2
EXISTING AND PROPOSED RESEVOIRS IN THE UPPER MISSISSIPPI RIVER BASIN



Existing resevoirs

Potential resevoir sites (Numbers refer to key in Table 3)



Sources: U.S. Army Corps of Engineers, 1990; UMRCBS, 1970.

In spite of the tremendous volume of water stored in the six reservoirs, increases in the routine volume of water released will likely not occur. The Metropolitan Region will have to accept the routine release of 270 cfs and the reassurance that the Corps would consider, but not automatically begin, emergency releases when flows at Anoka show a potential of dropping below the critical flow of 554 cfs. The socio-political conditions surrounding release of Headwaters system water and the federal mandates that regulate its priorities assure the status quo for the foreseeable future. The Metropolitan Area must proceed with alternate sources of supplemental supply and not rest comfortably thinking that Headwaters releases are our ultimate fall-back. If and when storage areas are available in the region and are in need of water to fill them, discussions should begin with the Corps and upstream interests to design a "release and fill" scheme that coincides with Headwater Reservoir lowering.

One final note on this alternative concerns the need to assure that the routine releases move effectively to the Metropolitan Area once they leave the reservoir. The Corps (1990) noted in 1988 that severe fluctuations in flow occurred at several locations along the Mississippi River. They attributed these fluctuations to small, low-head dams that pond water for short times in order to meet an immediate need. The Mississippi Headwaters Board has recognized the need to coordinate dam operation on the river and has begun discussions with most of the dam operators to achieve this. Continued efforts to coordinate operations should focus on the need to maintain the passage of water so that other downstream users do not experience unreliable plug flows.

Upper Mississippi River Basin Reservoirs

In addition to the Headwaters Reservoirs, there are several other locations where impoundment of water could perhaps supplement demand during periods of shortage. The most exhaustive study of these possible sites was prepared for the Upper Mississippi River Comprehensive Basin Study (UMRCBS) Coordinating Committee by the Corps of Engineers in 1970. Among many other things, this study identifies 11 potential multi-purpose reservoir sites with a maximum potential storage of over 6.3 million acre-feet (>2 trillion gallons). Development of these sites in the spring of 1990 would cost close to $1 billion. The potential sites are also shown in Figure 2 and listed in Table 3.

Although these 11 sites were proposed in 1970, no action has ever been taken on them. This fact, without considering their combined cost, portrays the fate of new reservoirs in today's society. Simply stated, the likelihood of constructing new reservoirs, with all of the environmental, social, political and economic implications of doing so, is minimal. As testimony to this, the Corps of Engineers points to the partially complete LaFarge Dam in Wisconsin, which was begun in the late 1960s and never completed because of environmental concerns.

The cost of many of the reservoirs in Table 4 would probably prevent construction even if major environmental and social concerns could be overcome. The Corps reported in 1988 (UMWRRC, 1989) that costs for developing storage range from $300-800 per acre-foot of storage. The unit costs in Table 4 fall low in this range, but they do not include all of the costs for evaluation required by today's environmental and social standards.

Other sites mentioned, but never developed for reservoir storage or supplemental supply, include Mille Lacs Lake (insufficient water), and 14 reservoir sites in the Minnesota River Basin (poor water quality, unreliable base volume, and inflow to the region downstream of water supply intakes). Proposals for the Rice Creek chain of lakes and for some Hennepin County lakes will be addressed later.

New large-scale reservoir sites should not be considered at this time as a serious possibility for supplementing water supply. The environmental, social and political constraints seem to rule-out any possibility for development at the scale that would be needed, even if the unit costs appeal when compared to other alternatives.

TABLE 4
POTENTIAL UPPER MISSISSIPPI RIVER BASIN RESERVOIR SITES

Reservoir Number	Name of Stream	Location	Storage Max. (acre-foot)	Estim. Cost* ($/acre-foot)
1-1	Mississippi R.	RM 1120	150,000	$ 48,180,000 ($321)
1-2	Mississippi R.	RM 1055	600,000	97,240,000 ($162)
1-3	Mississippi R.	RM 1015	374,000	57,380,000 ($153)
1-4	Crow Wing R.	Near Pillager	328,000	64,390,000 ($196)
1-5	Mississippi R.	RM 935	380,000	70,080,000 ($184)
1-6	Sauk R.	At Richmond	100,000	42,490,000 ($425)
1-7	North Fork Crow R.	Near Albright	60,000	26,280,000 ($438)
1-8	South Fork Crow R.	Near Watertown	92,000	38,980,000 ($424)
1-9	Crow R.	Near Dayton	99,000	40,300,000 ($407)
1-10	Rum R.	Near Isanti	190,000	52,560,000 ($277)
1-11	St. Croix R.	Near St. Croix Falls, WI	4,000,000	350,400,000 ($88)
TOTAL			6,373,000	$888,280,000 (avg. $139)

Source: UMRCBS, 1970.

* All costs adjusted to 1990 figures with ENR Construction Cost Index = 437.82

Rice Creek Chain of Lakes

Another often considered source of water primarily for the Minneapolis and St. Paul water systems is the series of lakes that occur on Rice Creek in Washington and Anoka Counties. Figure 3 shows the location of the 13 lake chain and Table 5 lists the lakes by DNR designation and size (USGS, 1976).

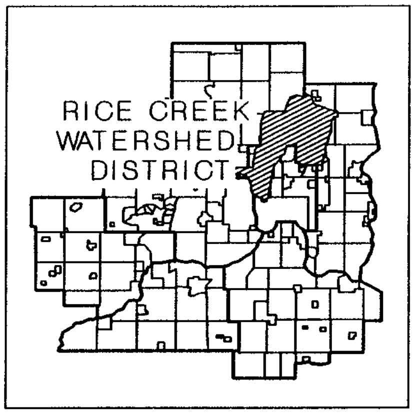
Table 5
LAKES IN THE UPPER RICE CREEK CHAIN.

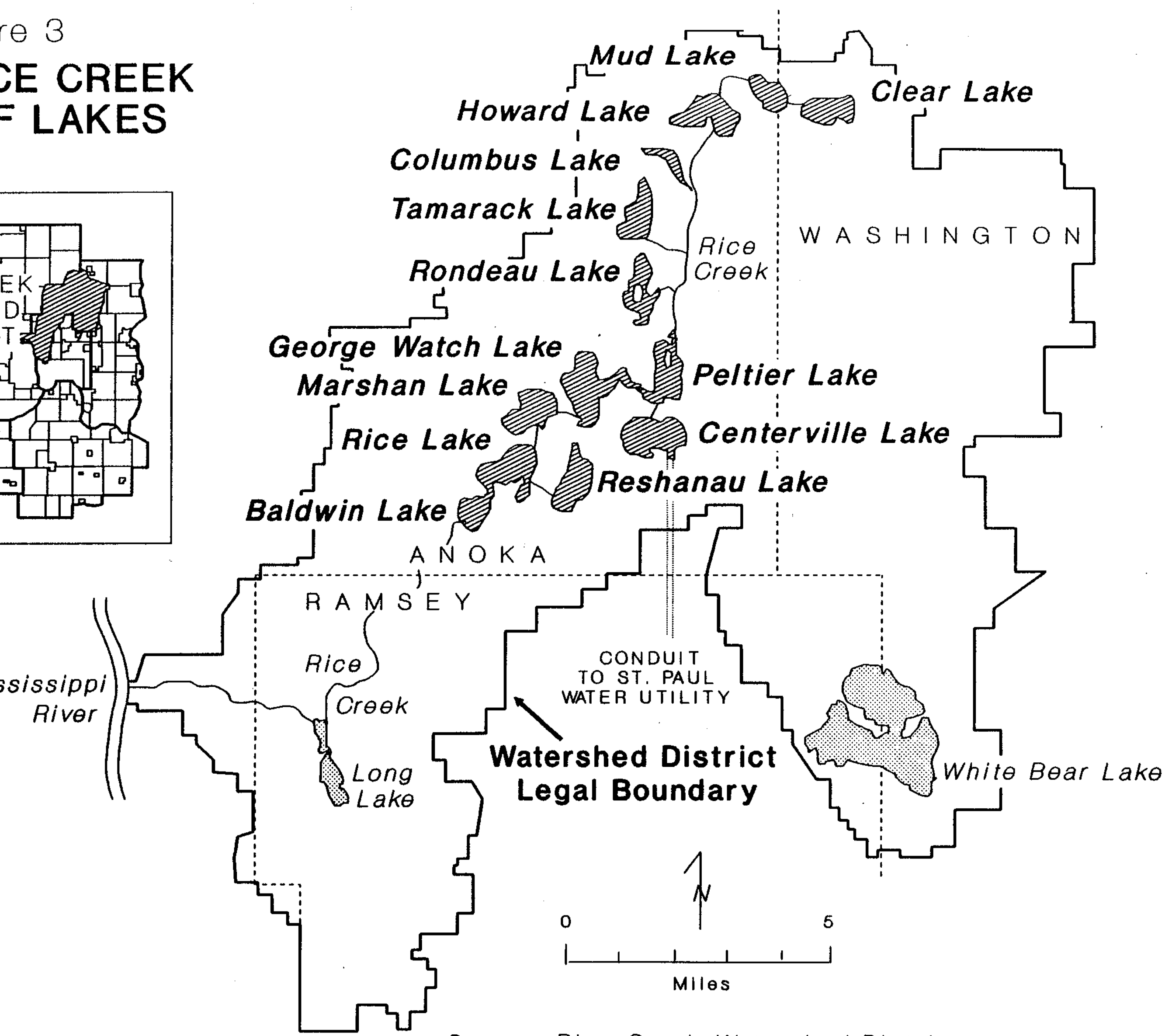
Name	DNR Designation (County)	Size in Acres
Clear	82-163 (Washington)	400
Mud	82-167 (Anoka and Washington)	290
Howard	2-16 (Anoka)	436
Columbus	2-18 (Anoka)	37
Tamarack (Crossways)	2-19 (Anoka)	355
Randeau	2-15 (Anoka)	594
Peltier	2-4 (Anoka)	483
Centerville	2-6 (Anoka)	464
George Watch	2-5 (Anoka)	528
Marshan	2-7 (Anoka)	230
Reshanau	2-9 (Anoka)	304
Rice	2-8 (Anoka)	433
Baldwin	2-13 (Anoka)	220
TOTAL		4774

The St. Paul Water Utility currently pumps water from Centerville Lake as needed into Vadnais Lake via an aqueduct. The Utility owns the lakeshore of both Centerville and Peltier Lakes, and controls the water levels of the lakes at the Peltier dam. The Utility put these lakes into use in 1904, at which time they purchased the shorelines and dredged the lakes to create additional storage for use in their water supply system. The Utility has indicated their willingness to assist Minneapolis in an absolute emergency by releasing stored water from these two lakes. However, it seems more prudent for Minneapolis to further develop storage in other lakes in the chain if it views the Rice Creek chain as a possible source of water.

Figure 3

UPPER RICE CREEK CHAIN OF LAKES





Source: Rice Creek Watershed District

The surface area of the Rice Creek chain totals 3,827 acres, without the inclusion of Peltier and Centerville Lakes, assuming their volume of water is reserved for St. Paul. Storage of only one foot of water as an emergency supply could provide close to 1.3 billion gallons of water, or enough to allow the Minneapolis Water Works to meet a demand of 100 mgd for 13 days. Realistically, the volume available would be reduced because of transmission losses, so 10 days of relief is probably more feasible. The benefit of using Rice Creek lake water is that it is a true backup in the event of Mississippi River contamination, provided the water can be intercepted prior to reaching the Mississippi River. It is less reliable for dry weather flow augmentation because the likelihood of the chain lakes being short of water at the same time is quite high.

To obtain the use of the 11 lake Rice Creek chain, the Minneapolis Water Works would have to overcome several obstacles. First, it would have to obtain the rights to stored water within the lake system. Much of the land surrounding Peltier Lake to Rice Lake is part of the Rice Creek Chain of Lakes Park Reserve---a part of the regional park system. After rights are obtained, it would need to build low-head control structures at each lake outlet or group of lakes if one outlet controls more than one lake level. Then the utility would need to negotiate "rights of flowage" so that other Rice Creek water users, such as St. Paul, would allow water to pass once it has been released from the chain. Part of this effort would need to evaluate the capability of the Rice Creek channel to transmit the volume of water needed. It is quite possible that there are some constraints on the channel that would not allow the passage of the desired volume (at about 150 cfs) of water without major flooding problems. Finally, in order to by-pass the Mississippi River, Minneapolis would have to consider the construction of an aqueduct to get Rice Creek water from the creek's channel to its Fridley treatment plant. None of these tasks would be easy to accomplish, but the alternative is available for Minneapolis to consider and the St. Paul Water Utility has expressed its intent to cooperate if Minneapolis pursues this option.

The detailed cost of pursuing this option is beyond the scope of this study, but some gross figures will help put it perspective with other options. In 1976, a Rice Creek Watershed District manager (Terry Skelton) testified at a Level B hearing (April 7, 1976) that the district had studied holding water in at least some of the Rice Creek chain. Manager Skelton testified that this alternative could supply Minneapolis (or St. Paul) with 100 MGD for 30 days, with releases as high as 150 cfs. The construction of some control structures was part of the proposal that was developed with the help of E.A. Hickok and Associates (now James M. Montgomery Engineers). The final cost in 1976 was approximately $1 million, which in 1990 dollars would have approximately doubled (ENR Water and Power Construction Cost Index; unit cost = $522 per acre-foot). In order to use the chain for emergency back-up during a contamination event, a pipeline from the creek to the Fridley facility would be required. This is a straight-line distance of approximately 3.5 miles. At a gross estimate of $1 million per mile for pipeline and pump costs, this would add another $3.5 million, for a total very gross estimate of $5.5 million ($1,437 per acre-foot). Montgomery Engineers has maintained the original engineering data and could make it available if any party is interested in pursuing this alternative.

The major impact of this alternative would be on the water levels of the chain lakes. However, the maintenance of an "emergency storage volume" in the lakes could also serve to stabilize lake levels during water shortage periods, when the lakes are of little value to the Minneapolis Water Works. This alternative deserves further study because of its promise for emergency storage and short-term delivery of water to Minneapolis in the event of a contamination event on the

Mississippi River. The implementation of this alternative would be difficult, given the cost and rights that have to be obtained, but its possibility as a dependable back-up cannot be overlooked.

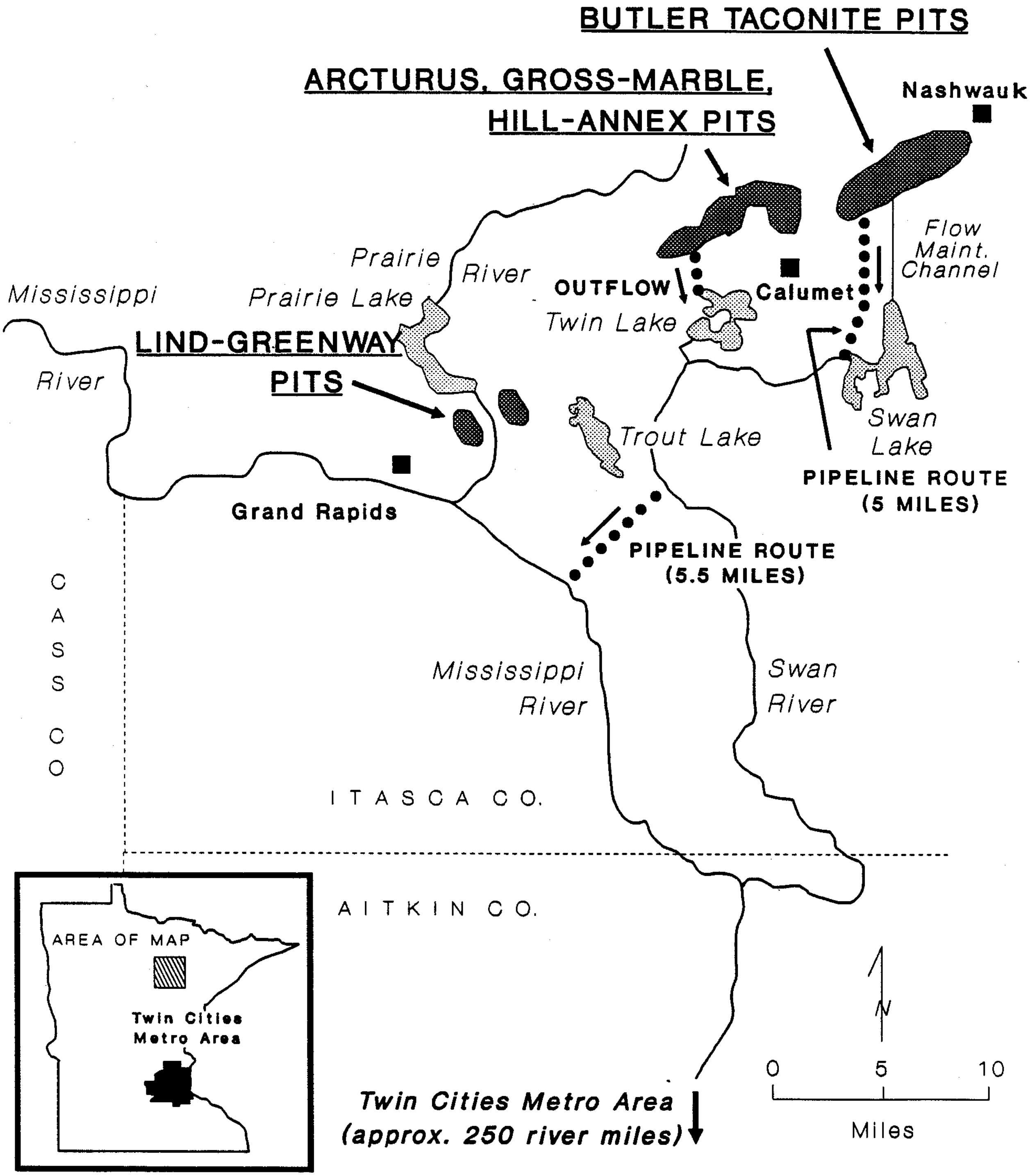
Abandoned Mesabi Iron Range Pits

At the suggestion of the authors of the legislation requiring the Metropolitan Council to prepare a water supply plan, we have looked into the possibility of using abandoned Mesabi Iron Range mining pits as a supplemental source of water supply for Mississippi River users, thus easing some of the pressure to use the Headwaters Reservoirs. The attraction of the pits is their large size, tremendous depth, and the fact that they are filled with good quality water. Although some of the abandoned pits are used for recreational activities, the ones under consideration are not used for other than small-scale recreation because the side slopes are too steep to provide for safe access. Incidentally, pits in the Cuyuna Iron Range are not being considered because of the amount of recreational use made of these abandoned pits. The distance of the Mesabi pits from the Metropolitan Area means that the pits can be used only for supplementing dry weather flows in the river or for filling emergency reservoirs closer to the region. The pits could not accommodate the needs of the downstream user who might need to respond to an immediate contamination event.

Three sets of abandoned pits were evaluated to see if they could supply an adequate volume of supplemental water without causing environmental or social problems. Two of the Itasca County pits were considered based on the suggestions of a number of parties approached with the idea; these are the Lind-Greenway pits in Arbo Township near Grand Rapids and the Butler Taconite pits in Greenway Township near Nashwauk (Figure 4). The Lind-Greenway site is owned by the township, whereas the Butler site is still in private ownership by the Hanna Mining Company. The Lind-Greenway pits lay on either side of the Prairie River approximately 5.5 miles above its confluence with the Mississippi River near La Prairie. The Butler Taconite pits do not currently overflow. However, the owners provide a 3000 gallon per minute (6.7 cfs) outflow to maintain flow in Oxhide Creek near Pengilly, which then flows into Swan Lake and the Swan River before reaching the Mississippi River via a circuitous channel of about 50 miles.

The DNR suggested that a third set of pits be evaluated because of a case of too much water being present. The DNR operates a state park at the site of the old Hill Annex mine at Calumet, which ceased mining operations in 1981. In order for the DNR to conduct tours in the pit and show details of how the pit operations used to function, a low water level is needed. Unfortunately, the Hill Annex pit is downstream from two adjacent abandoned pits, one of which (Gross-Marble, including the Hill Trumble mine) is currently overflowing, with the second (Arcturus) currently seeping ground water and threatening to join in the surface overflow within a matter of years. The DNR is spending over $100,000 annually to pump water out of the Hill Annex mine to maintain water levels low enough to accommodate tours of the operations facilities located low in the mine. The interest of the DNR, therefore, is to couple the need for supplemental water in the Metropolitan Area with their need to pump water from the Hill Annex mine.

Figure 4
LOCATIONS OF ABANDONED MINING PITS FOR SUPPLEMENTAL WATER STORAGE



In order to garner as many facts as possible about the feasibility of using these abandoned mine sites, a number of local sources of information were contacted. These sources included the regional DNR office at Grand Rapids and the office at the Hill Annex park, the Iron Range Resources and Rehabilitation Board (IRRRB), the Mississippi Headwaters Board, the MPCA and the Minnesota Geological Survey (MGS). Contacts with these sources allowed us to pull together some facts and make some estimates of what it would take to develop these pits as an alternate supply of supplemental water. It is, however, important to note that all of the information is very preliminary in nature and needs to be explored in much more detail to verify possible costs of, and constraints to, development. The purpose of this exercise is to determine feasibility, not to suggest that all details of engineering and operation are known. Extensive study would have to be done on such aspects as rate of mine refilling by water, environmental impact of various pipeline routes, social and economic impact on the local communities, and legal requirements associated with transfer of water at this magnitude.

The Lind-Greenway site consists of two pits located on either side of the Prairie River. The two pits are approximately 82 acres and 72 acres in size. The pits were actively mined by the Jones and Laughlin Steel Corporation until 1976, after which time the township acquired the pits and surrounding land. The pits were dewatered during operation, but have since filled with water. Maps of the pits show an average depth of the east and west pits at 104 and 116 feet, respectively. When combined with the areas, this yields a total volume of 16,863 acre-feet or close to 5.5 billion gallons. Outflow of a desired volume from the pits to the Mississippi River would be via a pump over a 10 foot high piece of land between each of the pits and the Prairie River. Discharge would occur directly into the Prairie River for its approximate 5.5 mile run to the Mississippi River. Extreme caution must be exercised for all releases to the Prairie River, since the Lakehead Pipeline Co. oil pipeline crosses the river three miles downstream of the Lind-Greenway pits.

The Butler Taconite site consists of a series of pits in a complex approximately four miles long by one-half mile wide. The pits were actively mined by Inland Steel Mining Company and the Itasca Pellet Company until 1985. These pits were also dewatered during operation at a rate of approximately 3000 gallons per minute (gpm), but not enough water has flowed back into the pits to refill them since dewatering stopped. Rather, the pits on the upper end of the complex have fully filled, and trickled water to the lower pits, which are slowly filling from this inflow plus ground water seepage. The lower pits still need 20-30 feet of water to be considered "full". Hanna Mining indicates that when the lower pits are filled within the next five years, depths within the pits in the complex will reach up to 205 feet. The combined volume of the Butler pits is 49,324 acre-feet or 16.1 billion gallons.

Outflow from the pit complex would be via a five mile pipeline southward around Oxhide Lake and southwestward to the Snowball Creek valley, with eventual discharge to Swan River downstream of the Swan Lake dam. This route avoids impacts to both Oxhide and Swan Lakes. The 3000 gpm flow to Oxhide Creek now provided by the mining company would continue during periods when the complex does not discharge naturally. Downstream of Swan Lake, the Swan River can carry up to 200 cfs before flooding becomes a problem. The long 50 mile route to the Mississippi River could be avoided by intercepting flow about 21.5 miles downstream at County Road 434 and diverting the allocated volume via a 5.5 mile pipeline to the Mississippi River. This pipeline route follows an electrical transmission line until it veers west to reach the Mississippi River near Blackberry at Mississippi Lake.

The three pits associated with the Hill Annex complex cover approximately 390 acres. The three pits are separated from one another by rock ledges, such that each mine has its own "pool" of water. Since 1986, the Gross-Marble mine has filled sufficiently to overflow into the Hill Annex mine. The Arcturus mine seeps ground water into Gross-Marble and is filling at such a rate as to pose overflow problems in the near future. If nature were allowed to take its course and fill all three mines, water would begin to overflow to the west and through Big Diamond Lake.

In 1987, a hydrologic study was done for the IRRRB in which proposed some options for routing water away from the lowermost Hill Annex pit were proposed. Option B in that study proposed a dike of approximately 50 feet in height between Gross-Marble and Hill Annex. This would result in a single continuous pool of water filling the two upstream pits at elevation 1267' MSL (mean sea level), as well as a minimum pool in the Hill Annex mine at elevation 1150' MSL. The combined volume of water at these elevations is approximately 29,450 acre-feet or 10.4 billion gallons (8555 acre-feet at Hill Annex; 15,910 acre-feet at Gross-Marble; and 4985 acre-feet at Arcturus). Under this scenario, water could be pumped into the Gross-Marble/Arcturus pool from the downstream Hill Annex pool at a lower cost than currently, with excess water then pumped over the 100 foot ledge on the south side of Arcturus and into a 0.8 mile pipeline draining to northern Twin Lake, and then via a short channel link to the Swan River. The connection via the 5.5 mile pipeline from the Swan River to the Mississippi River downstream of Trout Lake would still be needed. Natural drainage from the ledge at Arcturus could proceed westward to Big Diamond Lake, flowing eventually to Little Diamond and Holman Lakes, and the Swan River. However, the channel connecting the various lakes to the Swan River could not hold 200 cfs without flooding.

An alternate route to the east has been suggested by a citizen who lives on Swan Lake and would like to divert water through the lake to dilute the lake's high nutrient concentration. These options will be explored later in this section.

To put the economic feasibility of using the Mesabi pits in perspective, the Corps of Engineers suggested that the U.S. Bureau of Reclamation (BuRec) be contacted because of their expertise in constructing public works projects similar to the type that would be required to tap the pits. The BuRec office in Bismarck, North Dakota was contacted and agreed to estimate in general terms the cost of constructing the system that would be required to tap both of the pit sites.

Some assumptions had to be made in order for the BuRec to estimate costs. It was assumed that a flow of approximately 250 cfs has to reach to the NSP power plants at Sherco and Monticello to keep their intakes submerged and meet half (29 cfs) of their consumption needs of 57 cfs (assuming that NSP could not generate at full power during extremely low flows), then proceed to meet the demands of the St. Cloud water utility at 14 MGD (22 cfs), Minneapolis at a reduced demand of 75 MGD (116 cfs) and St. Paul at a similarly reduced demand of 45 MGD (70 cfs). Navigation interests and the MWCC would also benefit from these releases because of the increased flow in the river.

In order to get 250 cfs to the Metropolitan Area under worst case, which the Corps estimates to be a 40% loss, a release of 400 cfs would be needed from the Mesabi Range. Because of flow constraints in the Swan River, a flow of 200 cfs is the most that could be placed in the river without downstream flooding. This fact limits inputs to some mix of eastern pit options, or more reasonably, to one of the two sites actually being developed for use. Further volumes could be obtained, but only with additional expensive pipelines, as discussed later.

A flow of 400 cfs could be accomplished in several different ways. Under a scenario that pumps 200 cfs from Lind-Greenway and pipes 200 cfs from the eastern pits, flow could be maintained for approximately 42.5 days, after which time the Lind-Greenway pit would be dry, leaving only the eastern discharge. The Butler site could continue to discharge at 200 cfs for another 82 days before it would be dry, while the Hill Annex system could go for approximately 38 more days. This scenario obviously does not optimize the ability of the three sites to meet demand; however, for estimating costs, a two-200 cfs discharge system from the three sites is proposed. At 250 cfs, an upstream release would increase a critical flow (554 cfs) in the Metropolitan Area by almost 50%.

The BuRec emphasizes that their estimates are likely within 20%, based on similar projects they have built in the northern Midwest. The 200 cfs pump, housing, controls and various appurtenances for each pumping plant at 2200HP and 1640KW would be $1.7 million. The Lind-Greenway site would likely not require as strong a pump as the Butler site, but BuRec thought they were close enough to be conservative, so they priced them at the same size. A dynamic head of 95 feet was assumed for Butler to account for transmission losses due to friction in the pipes; this will be well beyond the needs to overcome friction at the Lind-Greenway site. This also approximates the 100' head difference to pump from Arcturus over the ledge and southward to northern Twin Lake.

Pipelines were priced at $1.75 million per mile of length for a 72 inch pipe with a terminal capacity of 200 cfs. The Lind-Greenway site does not require a pipeline since it would discharge directly into the Prairie River. The Butler route would cost approximately $20 million for a total of 10.5 miles of pipeline and a pump. Total cost to remove water from the Lind-Greenway/Butler sites for the two-200 cfs configuration would be about $21.7 million, plus or minus about $4 million. The Arcturus route would cost approximately $11 million for the pump and 6.3 miles of pipeline to connect the pit with the Swan river, and then the Swan River to the Mississippi River. The total cost for the Lind-Greenway/Arcturus combination would be about $12.7 million, plus or minus about $2.5 million.

Relying on a single source for all 400 cfs is another option that could be used. Total withdrawal from the Lind-Greenway pits would cost $3.4 million, assuming two-200 cfs pumps. This option could supply full demand, however, for only about 21 days. Total withdrawal from the Butler pits would require two pumps and two-200 cfs pipelines at a total cost of $3.4 million for the pumping plants and $36.75 million for the pipelines, <u>plus</u> an additional $17.5 million for the 10 miles of pipeline needed to transfer the 200 cfs that the Swan River could not handle between Swan Lake and the diversion to the Mississippi River. The second configuration would then total $57.65 million, a substantial increase, but one that could stretch the 400 cfs discharge to 62 days--about 1.5 times the length of time that a two-site system could provide.

In between the two previous options is full reliance on the Hill Annex system, which would cost $3.4 million for the two-200 cfs pumps, plus $2.8 million for the pipelines from the pit to northern Twin Lake, plus $19.25 for two pipelines to connect the Swan River to the Mississippi River, plus $14.9 million for the 8.5 miles of pipeline to carry the water that the Swan River could not handle without flooding. This totals about $40.4 million for a single system that could supply 400 cfs for about 40 days. The unit costs of the various alternatives range from $202-1169 per acre-foot, depending upon how much water is desired and which configuration is chosen.

Annual operating costs were determined by BuRec and the Minnesota Power Company of Duluth. The BuRec estimates that annual upkeep on pipelines is approximately 0.5% of original capital costs, which for Lind-Greenway, Hill Annex and Butler would be $8,500, $55,000 and $100,000, respectively, if two of the sites were used for 200 cfs each. They also recommend a full-time employee to maintain the system at an annual rate of $40,000. Minnesota Power was contacted to determine the annual electrical rate to operate the pumps. Choosing the more favorable of two use-charge rate structures yielded an annual cost of $350,000 to run two pumps continuously for a total of three months each; that is, for the equivalent of a summer. Total annual operating costs then for a scenario wherein the two pumps were pumped continuously for three months each, with an operator on-site, would range from a low of $453,500 for a Lind-Greenway/Hill Annex combination to a high of $498,500 for a Lind-Greenway/Butler combination. Use of a single source for all 400 cfs yields annual O&M costs of $407,000 for Lind-Greenway, $592,000 for Hill Annex, and $678,250 for Butler.

Table 6 summarizes the options for obtaining water from Mesabi abandoned pits. The costs of the abandoned pit system could obviously vary considerably depending upon system configuration, annual operating procedure and details of construction. The cost also <u>does not</u> include anything for acquisition of the abandoned pits, which has not been pursued given the preliminary nature of this evaluation, or for difficulties encountered in pipeline routing or engineering and site development. Assumedly, any user(s) would want title to the pits so that they would be assured of use in perpetuity. It appears then that a user or group of users could obtain a reasonably reliable water supply source(s) with large volumes of water for as low as $3.4 million plus site acquisition and operating costs---substantially less than the several hundred million dollars that reservoirs would require if constructed to achieve the same result and substantially less than the $75-110 million it would cost Minneapolis and St. Paul to acquire a similar volume from wells.

There are several other unknowns in addition to the cost of acquiring the pits. The reaction of the communities located near the pits is not known. The IRRRB indicated that the pits are currently abandoned and are thus a resource in wait of a use. They also indicated that the construction sounded feasible, although certainly the details are far from complete. We are also unsure of the ability of the ground water in the area to support continued pumping of the pits and are not sure of the impact or potential well interference that could result. The abandoned pits were, however, pumped while in operation, and to the knowledge of both DNR and MGS, there were no problems with interference. The refilling rate of the pits after a period of pumping is not known and should be determined as part of the technical feasibility studies that would certainly be required. If ground water does not refill the pits fast enough to allow for use in two successive years, a pumping system could also be installed at the downstream end of the pipelines to allow for refilling the pits with excess river water during periods of higher flow. This would entail an additional cost, but it would ensure that the pits would be full if supplemental water was needed. Coordination with DNR would be essential during the design of this flow reversal system.

The final unknowns are the institutional make-up of users interested in participating in the use of pits for supplemental water and the legal factors involved in such a consortium appropriating

Table 6
EVALUATION OF ABANDONED MESABI IRON RANGE PITS FOR WATER SUPPLY

	PIT EVALUATED Lind-Greenway	Butler	Hill Annex
Location	Near Grand Rapids	Near Nashwauk	Near Calumet
Volume of water	~5.5 bill.gall.	~16.1 bill.gall.	~10.4 bill.gall.
Pipeline needed*	None	10.5 miles	6.3 miles
Scenario #1 depletion - Volume	42.5 days	124.5 days	80.5 days
- Cost**	$1.7 million	$20 million	$11 million
O&M - Annual	$0.5 million (max.)		
Scenario #2 depletion - Volume	Not used	62 days	Not used
- Cost**	---	$57.7 million	---
O&M - Annual	0.7 million (max.)		
Scenario #3 depletion - Volume	21 days	Not used	Not used
- Cost**	$3.4 million	---	---
O&M - Annual	$0.4 million (max.)		
Scenario #4 depletion - Volume	Not used	Not used	40 days
- Cost**	---	---	$40.4 million
O&M - Annual	$0.6 million (max.)		

SCENARIO #1 - Pump pit at 200 cfs
SCENARIO #2 - Pump Butler only at 400 cfs (requires two sets of pipelines for 10.5 miles plus additional 10 miles of pipeline for excess flow that Swan River cannot handle)
SCENARIO #3 - Pump Lind-Greenway pits only at 400 cfs
SCENARIO #4 - Pump Hill Annex system pits at 400 cfs (requires two sets of pipelines for 6.3 miles plus additional 8.5 miles of pipeline for excess flow that Swan River cannot handle)

* Assuming a 200 cfs configuration
** None of the costs include acquisition of pits or engineering and site development costs

water from the Iron Range. Varying levels of interest in participation have been indicated by St. Paul, Minneapolis, and MWCC. NSP indicated a general level of interest, but feels that in spite of the difficulties seen in 1988, its annual fee for operation of the Headwaters Reservoirs should pay for any additional releases, should they be needed.

There are other interests that would benefit from supplemental releases from abandoned pits. The aquatic system of the river and associated wildlife would certainly benefit from increased flows during drought periods. In 1988, the aquatic system was stressed by the lack of flow in the river (Corps of Engineers, 1990), although major fish kills were avoided. Other benefiting parties that should in some way be tied institutionally to any consortium effort to obtain water from the pits include all of the small dam operators on the river, and those who rely on the river for water supply and wastewater assimilation. Small hydropower operators, the city of St. Cloud water utility, several paper mills and the wastewater treatment plants at Grand Rapids, Aitkin, Brainerd, Little Falls, Elk River and Anoka (MWCC) would all be beneficiaries of increased Mississippi River flows. Navigation interests would also benefit from increased flows through the region.

This alternative holds a great deal of promise and should be explored in greater detail with interested parties. The benefits include putting an unused resource to work, thus easing pressure for additional discharges from the Headwaters Reservoir system; obtaining a substantial, reliable source of good quality water (per MPCA, DNR and IRRRB) under the control of the participating interests, within DNR permit constraints; and contributing secondary benefits to the ecology of the river system and other, less direct users. Detriments of the proposal include its initial cost, the uncertainty of its local acceptance, the environmental impact of routing pipelines and increased surface flows, and the travel time to get to the Metropolitan Area from the Mesabi Range.

Off-Line Storage for Minneapolis

Much of the previous discussion addressed the need to get surface water to the Twin Cities during a period of drought. Of more immediate need for the Minneapolis Water Works, however, is the need to have a back-up in the event of a contamination event, since there would only be sufficient supply available in the system to meet demand for a maximum of one day. The St. Paul Water Utility will not be discussed here because of its system of back-up reservoirs and wells that could supply over one month of demand.

Minneapolis has studied options for ground water use in the past under different scenarios, but has not been successful in finding a source for the 50 MGD supply that it would like to have. This goal, incidentally, is far short of the minimum 75 MGD that the city believes it needs to meet minimum summer demand. Recent studies by the USGS indicate that pumping at the rate needed along the Mississippi River from the Fridley to the I-694 bridge would cause extensive drawdown in a far-reaching cone and that the contamination plumes from the FMC and NIROP sites would likely be captured (verbal communication, USGS). The contamination problem could be treated at some unknown expense, but the extensive drawdowns would cause considerable problems among neighboring wells.

Unless the Water Works changes its ground water development scenario in some fashion, it appears as though ground water will not be sufficient to meet demands for either short-term emergency needs or long-term system needs. Options for a different scenario could include development of wells along the "supply loop" that encircles Minneapolis and feeds the suburbs that Minneapolis supplies, as well as collection and treatment of discharged once-through air-conditioning water. The first option would require numerous expensive high capacity wells, treatment at the pump site and mixing of surface water with ground water, but the option is technically feasible. Since the pumps would have to routinely run to keep operable, excess water that would not be immediately needed could be used for such uses as watering parks. The second option becomes less feasible in light of the 1990 legislation mandating the elimination of all once-through systems. Unless the city could act quickly to design a collection system, the source of this water will gradually diminish. Difficulties in immediately implementing a plan to capture air-conditioning water include lack of control by the city over well operation; scattered well location and discharge points; lack of water quality control; and reliability of continued flow. Both of these options would be quite costly (one high capacity well alone could cost as much as $1.5 million), but the need for a back-up might skew costs in favor of one of these approaches.

In order to continue its search for supplemental supplies, the Minneapolis Water Works is conducting a study of alternative water supplies (Barr Engineering Co., 1990), similar in many ways to this Metropolitan Council study, only limited in scope to just Minneapolis. The Minneapolis study has searched the local literature and conducted interviews to obtain ideas for alternative sources. They will continue to refine the alternatives, ultimately coming up with some recommendations.

The city is also conducting an evaluation of what could happen during a cut-off of water. The city's Office of Emergency Preparedness is looking at a situation wherein contaminated water in the distribution system is used for non-potable purposes, as well as a situation where water intakes are totally closed. The economic and social impacts of these two scenarios have not been fully documented, but one need only think of the total closure of commercial/industrial activity and the termination of all residential supplies to gain an appreciation for the potential impact of a water cut-off for the city.

There are some alternatives that could be considered for the city. All of the alternatives discussed in this section focus on the need for the city to obtain an immediate source of water in the event of a spill on the river. One option--the Rice Creek chain of lakes--has been previously discussed and will not be repeated. The assumptions on demand herein are that Minneapolis would institute an emergency conservation program that would cut demand to 75 MGD and that the city would need a three-day supply to "wait-out" a passing spill. Given the fact that approximately 75 million gallons exist in storage currently within the Minneapolis system, a two-day supply of 150 million gallons would be required. The three-day scenario is rather arbitrary and should be adjusted to provide for more days if needed.

The most direct method for Minneapolis to obtain emergency supplies under its own control is to build the storage into its supply system. Surface concrete storage costs are approximately $0.50 per gallon, plus land acquisition and engineering costs. The cost for 150 million gallons would then be $75 million. Locating the storage on city property and using city staff for engineering would limit costs, but the expenditure is still substantial. The benefit, however, would be an immediately available source of water that could allow the city to withstand Mississippi River intake closure for three days. This approach is a commonly used method in Europe where water utilities frequently have to close intakes to let contamination plumes pass. The required additional volume equals approximately 460 acre-feet, a figure that will help readers appreciate the size of the required storage area. For example, at 20 feet deep, 23 acres of surface area would be needed just to store the water, with extra volume needed for the retaining structure; at 30 feet, 15.5 acres would be needed. Economies of scale are realized by storing more water at any one location, but there certainly would be no limit to options the city could consider in placing the storage within the treatment and distribution system. Another problem with fixed storage of this type is that solids tend to settle in them, eventually reducing the reliable storage volume available, resulting in either high maintenance costs or acceptance of reduced storage.

The most obvious source of surface water totally within the borders of Minneapolis is the chain of lakes from Brownie to Harriet. A system is currently in place and frequently used to supplement water levels in this system with Mississippi River water. It is technically feasible to keep the lakes in the chain "topped" with water from the river so that in an emergency this stored excess could somehow be used by the city. The five lakes in the chain (Brownie, Cedar, Isles, Calhoun and Harriet) have a combined surface area of 1098 acres. One foot of storage from the top of these filled water bodies could yield close to five days of supply at 75 MGD.

The most apparent difficulty with this option is the need to route water back from the lakes to the treatment facility at Fridley. The augmentation line from the Mississippi River begins at 28th Ave. North at the river. A 30 inch diameter pipe with a total capacity of 12,000 gallons per minute (17.28 MGD) runs to a storm sewer tributary to Bassett Creek near Plymouth Ave. The discharged water then flows in Bassett Creek to an intake station on the downstream side of Hwy. 55, which then pumps the water into Brownie Lake.

The limited capacity of this line, the flow through a storm sewer and open channel, and the distance of the line from Fridley render it useless for return flow; therefore, a new high capacity pipeline would have to be built to transfer water back to Fridley. The city has estimated that a 40 inch pipeline would be needed for approximately 5-7 miles, depending upon where in the lake chain the return pump(s) would be located. Costs for building this return line could easily reach $20 million, but, again, the control of the source would be entirely within the boundaries of the city and an immediate supply of emergency water would be available.

Another major water body that should be evaluated is Lake Minnetonka, simply because it is a 14,310 acre lake located "upstream" of Minneapolis. At this size, one foot of water from the top of the lake would yield 14,310 acre-feet or over 4.6 billion gallons of water. This could supply Minneapolis at 75 MGD for about two months. As good as this potential sounds, there are several difficulties with the use of Lake Minnetonka for supplemental water. First of all, Minneapolis has no water use rights or control over the lake level and would, therefore, have to rely on other governmental units to provide the city with this source of water. Secondly, the lake is located at its closest point 12 straight-line miles from the Fridley plant. This distance could be reduced to about nine miles by routing water down Minnehaha Creek, but a $20 million pipeline and pumping system would still be needed to get the water to Fridley. Finally, as we saw in the recent drought, Lake Minnetonka is fairly responsive to dry weather and its likelihood of being filled at a time when Minneapolis would need water is questionable. Filling the lake to assure water is available for an emergency condition would also be difficult because of the inability to pump enough ground water into it (even if this were allowed by DNR) or because of its distance from the Mississippi River, which could be used to fill the lake. Other sources of pump-in water, such as the Crow River, are equally undependable. Pursuing use of Lake Minnetonka for supplemental water for the Minneapolis Water Works does not appear to be feasible.

The final option for water storage for the city would be the construction of a large earthen reservoir for storage of raw water. This option is similar to the enclosed storage option addressed previously. The major problems with this type of storage reservoir are that the land would have to be taken out of use for any other type of activity and the area would have to be secured from the possibility of any contamination threat. The positive side of this option is that the city would be in full control of the water source, assuring that it keeps "topped" by tying it into the Mississippi River intake. The city should examine its land holdings near the intake and towards its treatment plants to see if any potential sites exist for a surface storage reservoir.

Interconnection with the St. Paul Water Utility is another commonly suggested option for Minneapolis. The Water Works explains that difficulties with this option exist because of the different approaches to distributing water between the two utilities. Minneapolis uses a "looped" system wherein a high pressure distribution loop is maintained around the entire city. Suburbs that are supplied by Minneapolis draw from the loop as it passes their city. St. Paul, on the other hand, uses a "tree" system wherein water is distributed outward from a central feeder line by decreasingly smaller distribution lines. St. Paul sends water to users in direct lines rather than having them draw from a high pressure line that passes them. Minneapolis must maintain a pressure of 80 psi in its system, whereas St. Paul can get by with 40 psi at any point where Minneapolis could interconnect. To overcome this pressure differential, a pump would be needed to equalize pressure.

The cost of building this equalization system and getting the volume of water that would be needed for Minneapolis to the feeder point has prevented the two cities from pursuing this option beyond the study stage. At best, the interconnection option between the two cities could be for short-term sharing. The St. Paul Water Utility would certainly share water for a short period of time, but their responsibility is to their customers, so releasing water from their system would not be in their best long-term interests. This option appears to have very little likelihood of succeeding, since neither city has expressed interest in pursuing such a system. Similar limitations are seen for interconnecting with other adjacent users, although future considerations could begin to move in that direction. Such a system of regional interconnections will be addressed later in this study.

As previously stated, Minneapolis has been looking into supply options more for short-term events than for long-term ones, and is obtaining some help from the Corps of Engineers through the Section 22 local planning assistance program to evaluate potential sources of contamination upstream of their intakes. The city is also interested in modeling likely scenarios for contamination and travel time to their intakes from the event location. This approach will not immediately eliminate the threat of a contamination event, but it will allow the city to prepare itself for such an event and to identify likely sources so that regulatory actions can focus on the potential for drinking water contamination. Minneapolis has also stated that they favor a watershed approach similar to the Metropolitan Surface Water Management Act to plan for watershed activities upstream of their intakes.

Presently, Minneapolis has noted that it has no single agency with which to deal in the event of a contamination event on the river, or even to discuss potential contamination problems it has identified. A watershed planning effort by a single responsible agency could institute a planning program for water quality so that spills and known sources of pollution can be identified and addressed, and a sampling program in the river (perhaps with St. Paul) begun to assure some lead time in the event a previously undetected contamination plume moves down the river.

Minneapolis pointed out a very good design idea that has recently been instituted by the Minnesota Department of Transportation (MnDOT). Minneapolis is most concerned with contamination of the river upstream of their intake. One possible source of this would be an accidental spill on a bridge surface. The new bridge that was built over the Mississippi River for T.H. 610 had built into it a runoff collection system that collects all of the runoff from the bridge deck and routes it to holding ponds via a system of collection pipes. We recommend that MnDOT incorporate this design into all new and rebuilt bridges in Minnesota, and even consider retrofitting existing bridges, so that all bridge deck runoff can be treated to some degree in the event of a spill. This system could also be used simply to treat the storm and melt runoff that occurs from these surfaces, thereby generating a secondary benefit to water quality.

The recommended course of action for Minneapolis is to continue its efforts to find alternative sources of water and to develop a protection scheme for the Mississippi River above its intake. The most promising alternatives for the city appear to be some type of off-line storage for a three-day emergency, ground water wells somewhere in their distribution system, and cooperating with St. Paul on Rice Creek chain of lakes releases. Longer term potential exists for participation in a Mesabi Iron Range consortium and in a regional distribution/interconnection system.

Improved Wastewater Treatment During Low-Flow

The first party in the Metropolitan Area to be impacted as flow drops to low levels on the Mississippi River is the MWCC (Metropolitan Council, 1990). The MWCC operates the Metro wastewater treatment facility at Pig's Eye (Figure 1) and must perform at a certain permitted level at defined low flows. A new permit has been negotiated (July 1990) for the Metro plant, laying forth very stringent treatment requirements. Unfortunately, in periods of extremely low flows, degradation of surface water is expected to occur since adequate volumes of water are usually not available to assimilate all of the pollutants entering the river from the plant.

Although not strictly a source of supplemental water, improved wastewater treatment during low flow means that more water can be withdrawn from the surface water system without seeing a negative water quality impact in the river. The Clean Water Act requires that effluent be treated to maintain water quality standards at a defined low flow. The low flow in question is the lowest seven-day flow with a recurrence interval of once every ten years. The abbreviation for this flow is "7Q10" and for an annual time series equals approximately 1180 cfs at Anoka and 1420 cfs at St. Paul (see Table 3). For a seasonal summer time series, the numbers increase to 1270 cfs at Anoka and 1830 cfs at St. Paul. Recall that the lowest recorded flows on the Mississippi River have reached a statistical flow equivalent to the 100-year, 7-day low flow (7Q100). The most direct method of achieving improved treatment is by increasing the level of treatment at the Metro plant. The plant, however, is currently treating at the advanced secondary level and cannot perform much better without very expensive additions.

In the summer of 1988, the MWCC was able to avoid water quality problems in the river by artificially aerating the wastewater effluent by cascading it over a 40 foot high floodwall. The cascading effluent picks-up enough oxygen to negate any deficits in the river, and in fact, oxygen levels in the river increased as the river passed the plant. Aeration cost the MWCC about $1300 per day for a period of four months. This is quite a bargain when compared with the millions of dollars that plant upgrades would cost. The MWCC has kept aeration as part of its low flow procedures for plant operation, thus assuring that an effort will be made to maintain good quality in the river no matter how low the flow becomes.

An alternative that was raised in a past DNR study of supply alternatives (Barr Engineering Co., 1973) is the pump-back of river water from downstream of the Metro plant to upstream of the plant. This does not tap a "new" source of supplemental water, but merely recirculates some water for use again in wastewater assimilation, thus lessening the impact caused by upstream withdrawals from the river. This approach would take advantage of the St. Croix River inflow by locating the pump-back intake at Point Douglas. A pipeline was then proposed from Point Douglas upstream by one of several routes to a discharge point about one mile upstream of the Metro plant. Variations on this theme include intakes at Lock and Dam #1 in Hastings or Grey Cloud Island and discharge as far upstream as St. Anthony Falls in order to maintain a pool deep enough for Minneapolis to withdraw water.

Pipeline length for the various pump-back configurations can reach from 20-40 miles upstream from intake. The annual cost of providing pump-back at the time of proposal (1973) varied from $450,000 to $4 million. Today, initial capital costs could exceed $50 million even for the short pipeline at relatively little capacity.

The excessive cost of this option is likely reason enough to rule it out as a feasible alternative, but other factors also contribute to its low priority. The environmental impact of routing a 20-40 mile pipeline along or above the Mississippi River corridor could be quite destructive in a populated area. Also, it is not conceptually wise in an age of environmental awareness and responsibility to propose "super-saturating" a reach of river with wastewater effluent, even if the ends are justifiable. This is particularly true since the MWCC seems capable of sustaining good river quality with its aeration scheme.

In short, we should continue with the programmed upgrade of the Metro plant and any supplemental aeration that might be needed to improve the quality of the river as it assimilates effluent. Pump-back of river water to gain additional assimilative capacity does not make good economic or environmental sense at this point.

Improved Ground Water Withdrawal

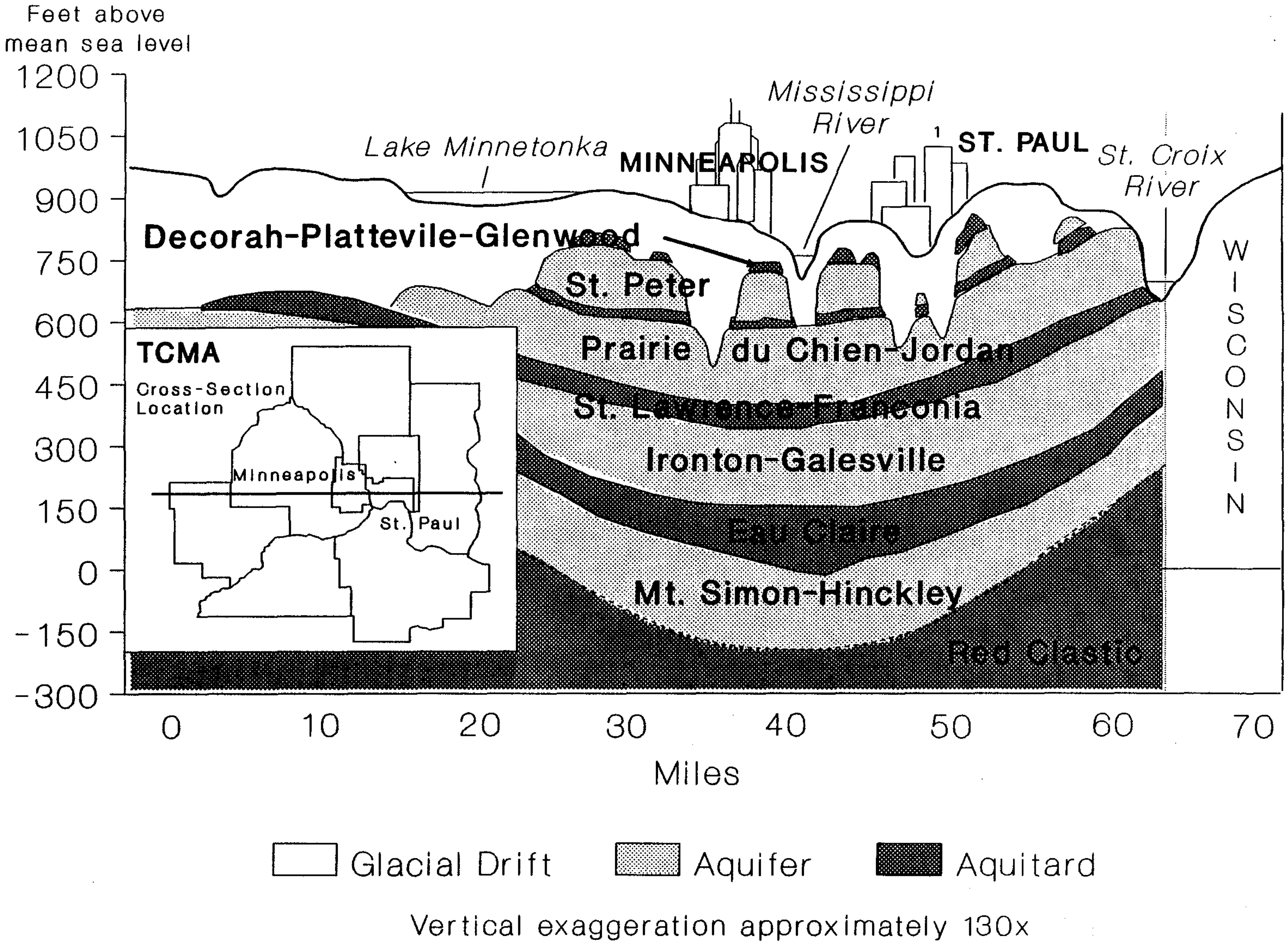
Perhaps the single biggest lesson to be learned from the drought of 1987-1989 is that water is a finite resource that might not always be available whenever and wherever we would like it. This point is particularly evident when we examine the occurrence and use of ground water in the region. We used to think that we could put a well down anywhere in the Metropolitan Area and be assured of an unlimited supply of good quality ground water. We now known that localized shortages and severe contamination can be just as likely.

Exploring an improved method of withdrawing from our regional ground water system has taken on new importance recently with the release of a joint USGS/Council/DNR computer model of the system (Schoenberg, 1990). As a result of this effort, USGS believes that our current approach to withdrawing water will yield only 500-800 MGD rather than the 1.1 BGD (billion gallons per day) we smugly thought we could pull from the system. This should not have come as a shock because the 1973 "Water Resources Outlook" prepared also by USGS said essentially the same thing. A discussion of the implications of this reduced capacity expectation will lead to some suggestions for improved management and use of the ground water system.

A geologic cross-section of the Twin Cities Basin is shown in Figure 5. Details of this system are fully explained in other technical publications (USGS, 1973; Schoenberg, 1990) and in a companion to this study that determines a water balance for the Metropolitan Area (Working Paper No. 3). Briefly, the ground water system comprising the Twin Cities Basin consists of alternating layers of sedimentary rock that transmit water to varying degrees. Those that transmit large volumes of water are called

Figure 5

GENERALIZED TCMA GEOLOGIC CROSS-SECTION



"aquifers", while those that do not are called "confining units" or "aquitards". Reference to Figure 5 indicates that there are five aquifer units in the system; from the surface downward, they are the surficial drift, the St. Peter Sandstone, the Prairie du Chien Dolomite-Jordan Sandstone, the Franconia-Ironton-Galesville Sandstones, and the Mt. Simon-Hinckley Sandstones. The intervening confining units are the Decorah Shale-Platteville Limestone-Glenwood Shale, the Lower St. Peter Sandstone, the St. Lawrence Sandstone, and the Eau Claire Sandstone. The confining sandstones might be locally acceptable for small volume supplies, but their overall ability to transmit water is limited.

Figure 6 is a plan view of the first bedrock unit encountered below the surface. The cross-section line portrayed in Figure 5 is noted. Of import in this figure is the lateral extent of the aquifer units, particularly the Prairie du Chien-Jordan; note that it does not underlay the entire region. The implication of this will be dealt with later in this section.

Schoenberg (1989) discusses some of his USGS model findings on factors affecting withdrawal from the ground water system in a Minnesota Academy of Sciences paper. The water balance findings of the Council agree with those presented by Schoenberg. Basically, 3-5 inches of the nearly 30 inches of rainfall we have yearly infiltrates far enough downward to be considered "recharge". This recharging water eventually reaches one of the aquifer units, where it is stored until it flows out either by pumping or by natural discharge to a water body. Recharge can be surprisingly fast when it occurs in remnant bedrock valleys that glacial streams left in aquifers, since vertical hydraulic conductivities of the drift can be 10-100 times that of the scoured bedrock (Schoenberg, 1989). Buried valleys are particularly effective recharge zones for the Prairie du Chien-Jordan. The movement of surficial water into the ground water system sustains the storage volume that is subsequently available for withdrawal.

Historic use of ground water in the region has reduced the pressure gradients (water levels) of the bedrock units. The surficial drift aquifer is a free-standing water table unit, separated from the surface of the ground by sporadically occurring clay and tills of less permeability. Schoenberg (1989) documents water level (potentiometric surface) drops of up to 90 feet and 240 feet, respectively, in the Prairie du Chien-Jordan and Mt. Simon-Hinckley Aquifers in the one-hundred year period from 1880 to 1980. He points out that increased withdrawals such as this tend to increase deeper recharge, thus decreasing shallow seepage to surface waters. Locally and seasonally, cones of depression around major pumping centers, like the downtown areas of Minneapolis and St. Paul, might experience significantly larger drops in water levels. The Mt. Simon-Hinckley Aquifer is far less capable of transmitting as large a volume of water as the Prairie du Chien-Jordan, and is far less responsive to recharge--a critical factor that will be addressed later.

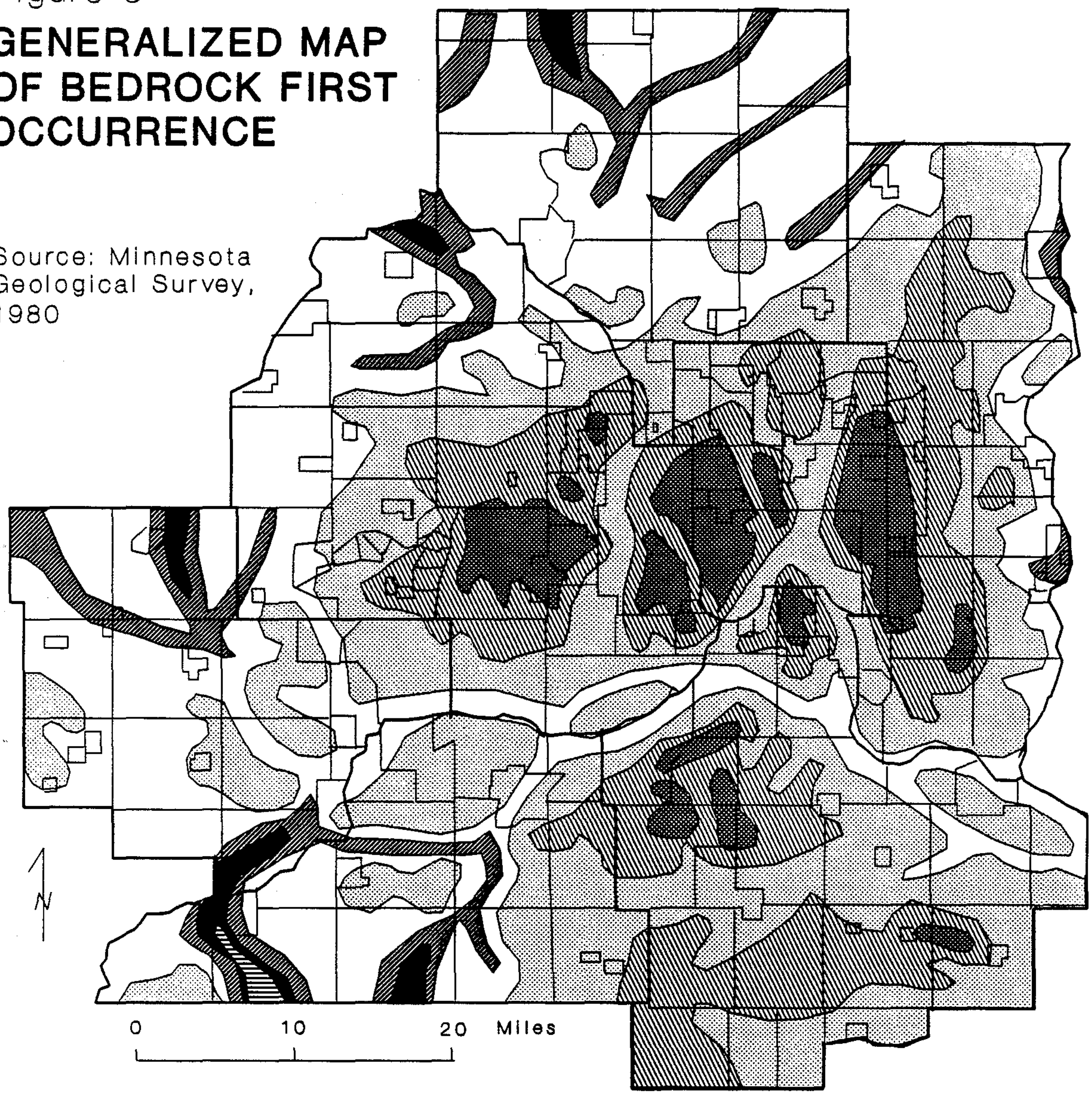
Schoenberg (1989) identifies three essential factors affecting the supply potential of the ground water system:

- the distance to, and character of, recharge;
- the distance to a natural point of discharge; and
- the character of the cone(s) of depression in the aquifer, which depends upon the hydraulic properties of the aquifer.

Figure 6

GENERALIZED MAP OF BEDROCK FIRST OCCURRENCE

Source: Minnesota Geological Survey, 1980



Bedrock Unit of First Occurrence

- Decorah-Platteville
- St. Peter
- Prairie du Chien-Jordan
- St. Lawrence-Franconia
- Ironton-Galesville
- Eau Claire
- Mt. Simon-Hinckley

Optimizing withdrawals from the ground water system requires knowledge of all of these factors and use of the system based upon them. This does not currently occur in the Metropolitan Area; rather, we have a system in place wherein ground water users can essentially drill a well at any location where special restrictions do not occur and where the well will not interfere with another. Appropriation of this ground water is permitted by DNR under Minnesota Statutes, Ch.103G.271 (recodified from Ch. 105.41). Coordination of well placement, however, is not planned, other than by individual users who do so based on service desires rather than on ground water system efficiency. It is for this reason that USGS believes that the "realistic" capacity of the Twin Cities Basin is closer to 650 MGD than the theoretically available 1.1 BGD.

The USGS projection of realistic capacity does not include any reductions for loss due to contamination. In other words, the 650 MGD assumes that all water brought to the surface will be useable. A Council evaluation of "impacted" ground water shows that up to 62 MGD of ground water is contaminated based on a 10-year withdrawal of the total impacted volume (Working Report No. 3), and is not useable without some form of treatment. Thus, the capacity of 650 MGD does not reflect the true cost of obtaining ground water, only its availability.

USGS also reports that use of the ground water system at its capacity will reduce surface water flow in the Mississippi River by 225 cfs, or about 25% of the long-term median annual instantaneous discharge to the river. This reduction in river flow is the result of lowering of water levels in the bedrock aquifers, which in turn increases deeper recharge of shallow water that would otherwise seep immediately into surface water. Shallow ground water is essentially "sucked" downward due to the increasing hydraulic gradient in that direction, as schematically portrayed in Figure 7.

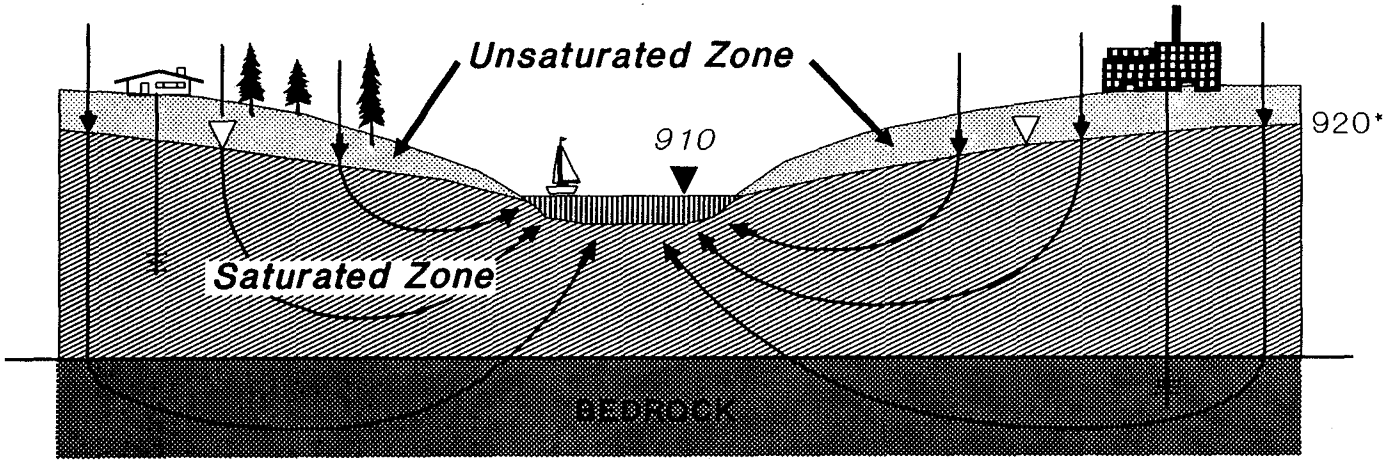
The detrimental results of using the ground water system at its maximum capacity include increased pumping costs to bring the water up from deeper levels; reduced ground water quality where increased inflow from lower quality surface water occurs; and potential conflict among ground water users (Schoenberg, 1989). Using the maximum amount of available ground water also eliminates its use for emergencies if surface water sources become contaminated or over-used.

It is imperative then that we not use the ground water system to the point where we imperil it and render it useless as a long-term supply of water. This is particularly important for the Mt. Simon-Hinckley Aquifer, which is far less able to replenish itself. Table 7 illustrates the differences between the Prairie du Chien and Mt. Simon-Hinckley Aquifers. Of particular note in this table is the enhanced ability of the Prairie du Chien-Jordan to provide water relative to the Mt. Simon-Hinckley, as measured by their relative transmissivities. USGS (1973) states that long-term declines in the water levels of the aquifer continue at a rate of 7-10 feet per year. This slow responsiveness, coupled with the fact that the Mt. Simon-Hinckley is truly our ultimate "reserve" ground water, caused the DNR commissioner in 1989 to adopt a policy position to "...protect the Mt. Simon-Hinckley Aquifer for future use and, where feasible alternatives are available, not to authorize appropriations from the Mt. Simon-Hinckley" (Policy Position from Joseph Alexander, Commissioner of DNR, January 11, 1989).

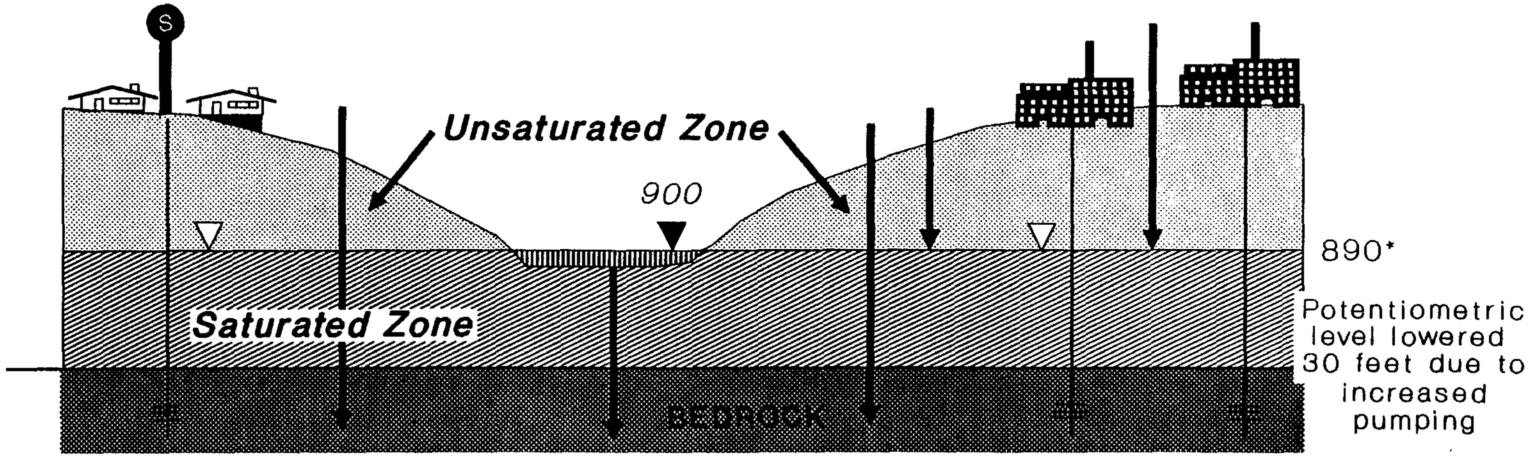
Figure 7

EFFECT OF INCREASED PUMPING ON SURFACE WATER AND GROUND WATER RECHARGE

a) Current Conditions



b) Increased Pumping from Bedrock Aquifers



* Elevations are potentiometric (pressure) levels.

Table 7
HYDROGEOLOGIC CHARACTERISTICS OF THE PRAIRIE DU CHIEN AND MT. SIMON-HINCKLEY AQUIFERS

Characteristic	Prairie Du Chien-Jordan	Mt. Simon-Hinckley
Thickness Range (avg.)	0-350' (200')	0-280' (200')
Horizontal Hydraulic Conductivity	25-50 feet/day	15 feet/day
Transmissivity Range (avg.)	37,200-198,000 gall./day/ft. (82,700 gpd/ft; n=11)	11,700-23,200 gall./day/ft. (19,300 gpd/ft; n=4)

Source: Schoenberg, 1989 AND USGS, 1973

Concerns about the ability of the Twin Cities Basin to continue meeting all of the demands placed upon it began to arise as early as 1961, when DNR's predecessor, the Department of Conservation, stated that the available ground water supply in the region was not adequate to meet all of its needs as it grew (Minnesota Department of Conservation, 1961). A similar conclusion occurred in the 1973 "Outlook" report, where the USGS suggested that a change must occur in our use and management of the system if we ever hoped to tap its full potential. Since that time, however, placement of wells has proceeded according to the same practices. Today, Metropolitan Area use of ground water occurs at about 260 MGD (Table 1). Ground water use reported in the 1973 report was about 180 MGD. Projections done in another Metropolitan Council report on water use (Working Paper No.2) indicate that ground water use by the year 2010 will be approximately 350 MGD, or well over one-half of the capacity of the system. The 1961 and 1973 reports each suggest the need for a central authority to plan for the withdrawal of ground water in an effective manner. Such an authority could optimize surface and ground water use to meet all demands.

The increased demand for ground water will occur because of the growth trends in the region. Figure 8 shows the projected areas of growth in the region for the next 20 years. Note that all of the anticipated, and currently served, growth centers ("Developing Ring") are supplied by ground water. Figure 9 is an overlay of Figures 6 and 8 showing that much of the anticipated growth in the next 20 years will occur at, or slightly beyond, the lateral extent of the Prairie du Chien-Jordan Aquifer; that is, much of the area experiencing the largest demand for new water supplies will be beyond the supply limits of our largest ground water supply source. In all likelihood, these areas will be supplied by the surficial drift and the Mt. Simon-Hinckley Aquifer. The surficial drift has been a reliable source of supply for many communities, but its capacity is limited and it is relatively

Figure 8
DEVELOPMENT RINGS IN THE TWIN CITIES METROPOLITAN AREA

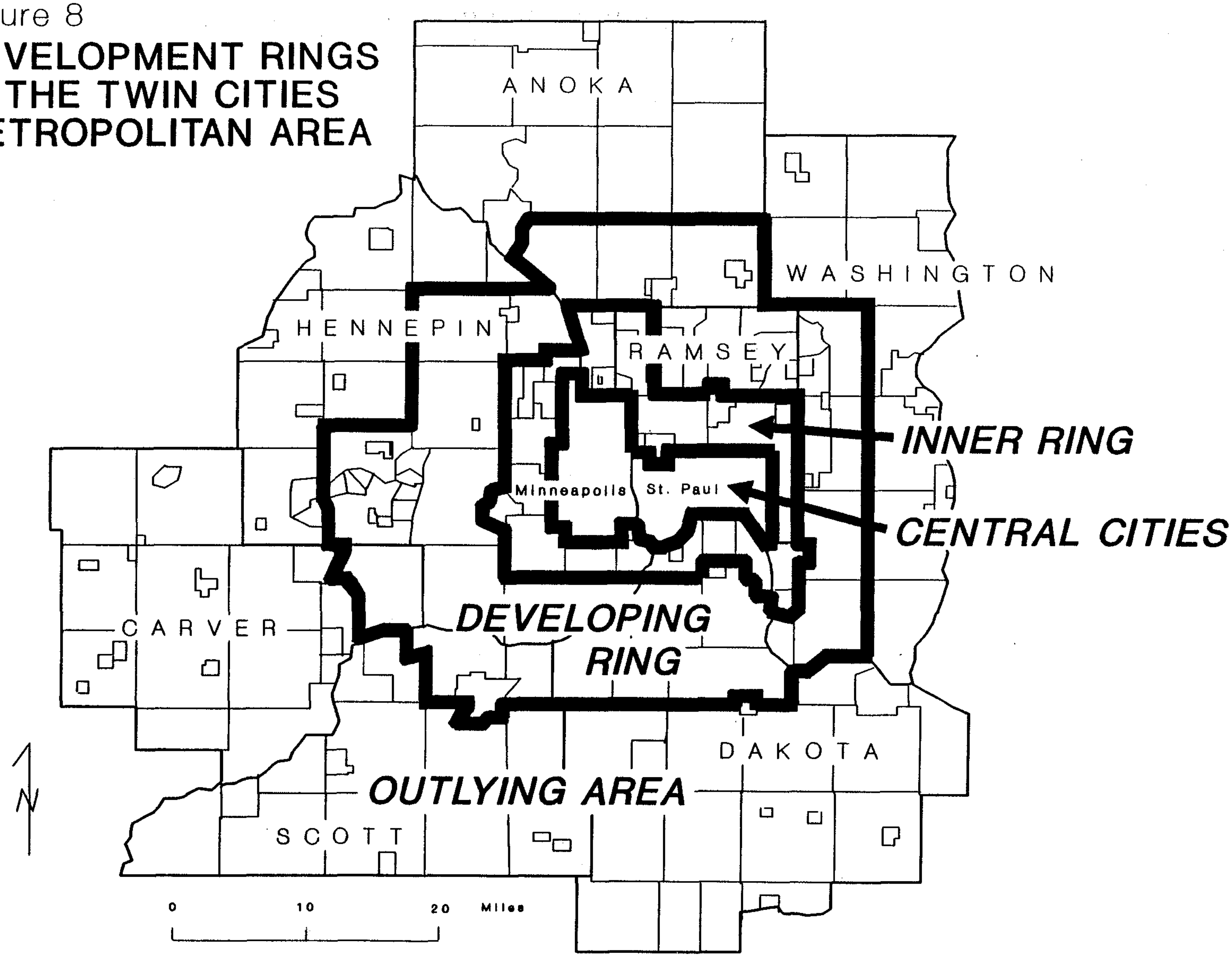
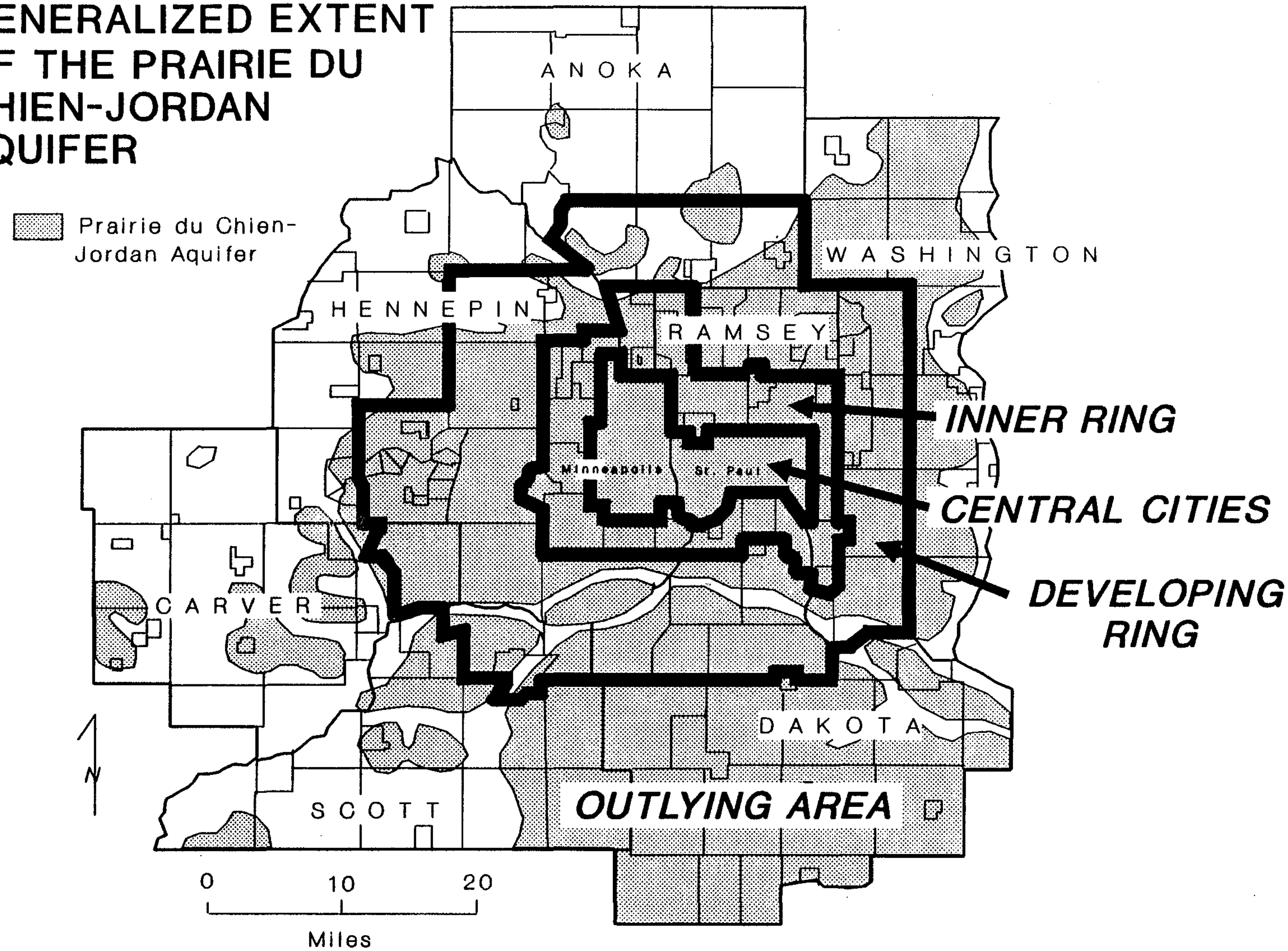


Figure 9

GENERALIZED EXTENT OF THE PRAIRIE DU CHIEN-JORDAN AQUIFER



unprotected from contamination that moves down from the surface. Horizontal hydraulic conductivity of drift can be as high as 650 feet per day (Schoenberg, 1989). Municipal wells tapping the drift (Figure 10a) currently have a pumping capacity of about 59 MGD, with about 5 MGD more being developed. The Mt. Simon-Hinckley, as pointed out previously, is limited in its ability to recharge and transmit water, and must be considered as a limited source of supply for the long-term. Figure 10b shows the existing municipal Mt. Simon-Hinckley wells with a capacity of about 130 MGD. The location of the wells in Figures 10a and 10b indicate the regional pattern that is likely to develop as we continue to grow outward away from the Prairie du Chien-Jordan Aquifer.

The Metropolitan Council attempted to document the difficulties that arose in 1988 because of localized shortages of ground water. A survey was sent out to municipal water suppliers in early 1990 asking the suppliers if they encountered any supply problems with their wells in 1988. This question was asked because of statements from DNR and MDH staff that they had heard of such problems, but lacked data to document them. Of the 100 respondents, eight noted problems quite severe in nature, while an additional eight noted minor problems mostly related to meeting a growing demand (Figure 11). Drawing conclusions on ground water system reliability is not possible from Figure 11, but it is clear that many of the acknowledged problems in the 1988 drought occurred in communities served by the surficial drift or by the Mt. Simon-Hinckley Aquifer (see also Figures 10a and 10b). Additional demand for water from these two units will only increase the occurrence of supply related problems.

USGS modeled the response of the ground water system for a number of future use scenarios. Two of the scenarios explored the response to a total ground water use of 370 MGD, with the increase in demand coming from a mix of the surficial drift, Prairie du Chien and Mt. Simon-Hinckley Aquifers. Model results showed a shift in major cones of depression outward from their current locations near the urban centers and first-ring suburbs to new pumping centers in northern Hennepin, northwest Ramsey and southern Anoka Counties. Continued pressure for ground water to supply growth in these areas could result in "ground water mining".

There has been much discussion of possible ways to enhance the capacity of the ground water system through induced recharge. Such elaborate schemes would typically involve major recharge centers where surface water would be routed and encouraged to infiltrate into highly permeable recharge basins. Problems with such a system abound from both a technical and an economic point of view. Routing water to recharge facilities assumes that we have institutional and hydraulic mechanisms in place to capture and move extremely large volumes of water that is of good quality at times when it is moving at peak flows. It also requires substantial recharge potential, a condition that does not exist at the points where water can be most easily collected (floodplains, wetlands), and maintenance of adequate infiltration capacity through the sediment interface with the water.

It is far more reasonable to approach recharge by protecting the infiltration properties of upland areas, as well as the natural drainage system, which allows interaction between surface and ground waters. This approach will preserve the natural recharge system as it has functioned for geologic eons. Regulation of activities such that infiltration capacity remains intact is a function that has an institutional framework currently in place through DNR, the Corps of Engineers and numerous local units of government and watershed management organizations. We need only

Figure 10a
EXISTING AND PLANNED MUNICIPAL WELLS IN SURFICIAL DRIFT, 1990

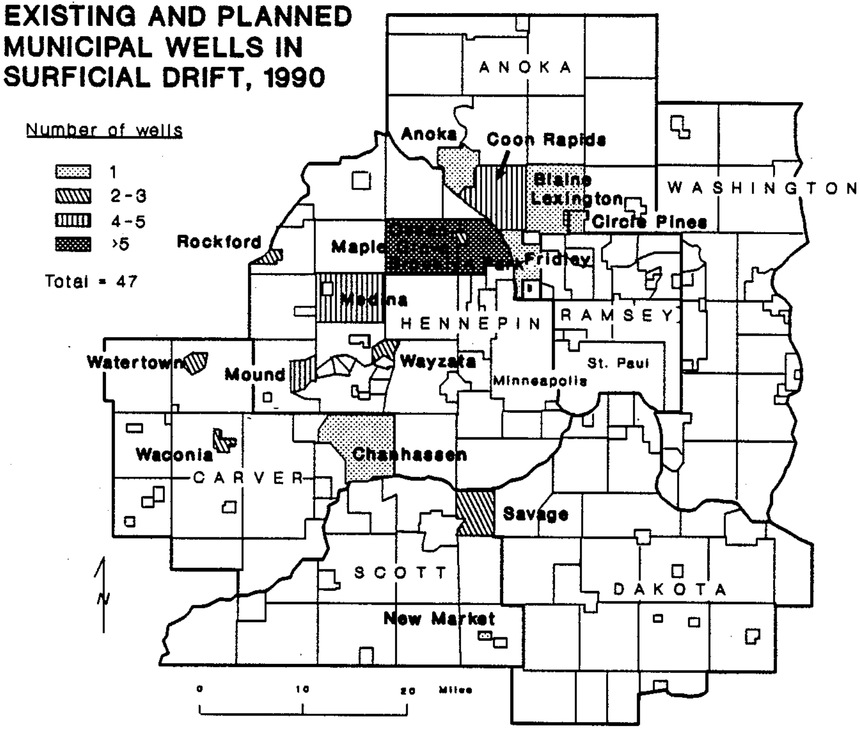


Figure 10b
EXISTING AND PLANNED MUNICIPAL WELLS IN THE MT. SIMON-HINCKLEY AQUIFER, 1990

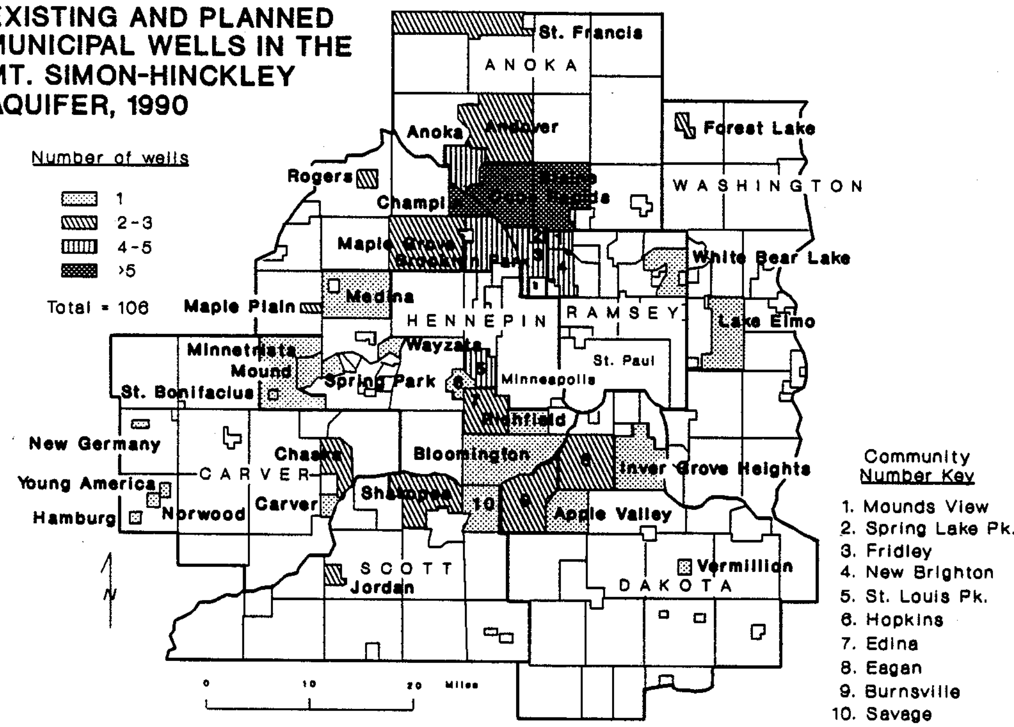
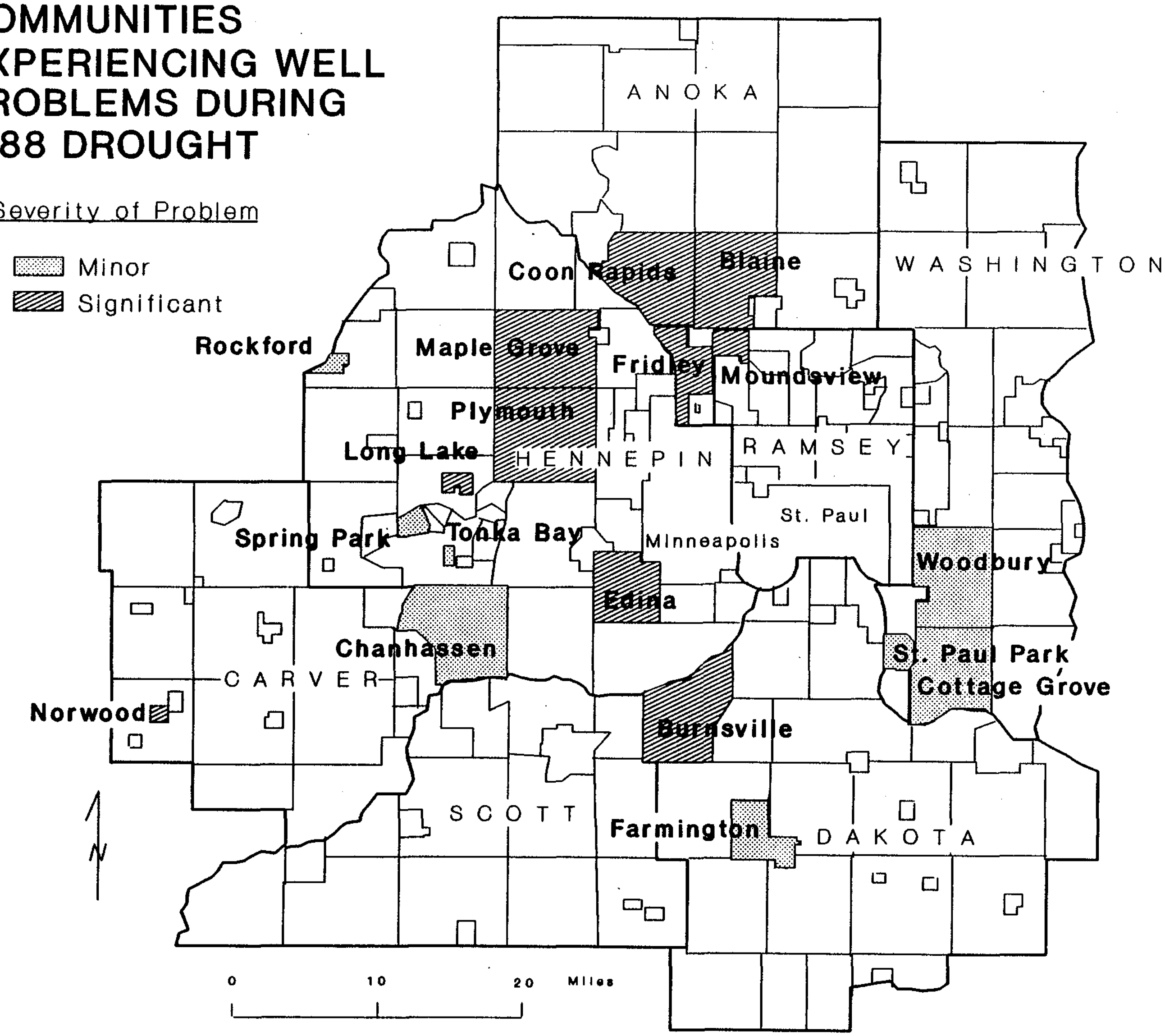


Figure 11
COMMUNITIES EXPERIENCING WELL PROBLEMS DURING 1988 DROUGHT



apply the available regulations in a more stringent manner to achieve and maintain the enhanced recharge that supports our increased withdrawals.

Enhanced maintenance and preservation of recharge functions is a goal that should guide water resource activities in the region. We must dedicate ourselves to this endeavor and strive to eliminate all activities that reduce the overall ability of the ground water system to replenish itself.

One area that should be explored to evaluate its potential for putting water in the ground is reinjection of treated wastewater and cooling water. The short-term plan (Metropolitan Council, 1990) urged the MDH, MPCA and DNR to evaluate their policies and the feasibility of using so-called "wastewater" for reuse and injection. Since then, the DNR has adopted language in its rules promoting the reuse concept. The tremendous level of interest for use of Twin Cities Army Ammunition Plants's treated water points to the value that wastewater can have once it is treated.

The MWCC and MPCA, as well as the Metropolitan Council, through its overall planning role, should explore beneficial use of MWCC wastewater treatment plant effluent. In a realistic sense, this reuse might be very difficult to achieve. All of the treatment plants are by necessity located adjacent to a waterway at a low elevation. Recirculating treated effluent up-gradient to a potential user would likely reduce overall resource savings because of the energy requirements. However, there could be local uses of the effluent for such things as park and grounds landscaping, water level maintenance, ground water injection and agricultural irrigation. A mandate to explore alternative uses for treated effluent could be part of the next Council wastewater treatment system plan. Any attempt to use reclaimed wastewater must be carefully monitored, with provisions made for rapid shut-off of flow if contamination is detected.

One of the largest, yet least understood threats to our regional ground water is abandoned wells. Wells that have not been properly abandoned can serve as a direct conduit for contaminating materials to one or more of the aquifers upon which we rely. The MDH (verbal communication, 1991) estimates that there are approximately 260,000 abandoned wells in the seven metropolitan counties. Continued efforts to locate and properly seal these wells must occur if we ever hope to secure our ground water from contamination and make optimum use of the water we have available to us.

It is very clear in looking at the potential demand for ground water and the problems currently encountered that a much better plan for future withdrawals is needed, or growth in the Metropolitan Area could be limited by water availability. Sustained growth in parts of the region supplied by the surficial drift and the Mt. Simon-Hinckley Aquifer cannot occur as in the past, when every supplier located their wells according to convenience and proximity to demand centers. Growing areas must begin to plan for ground water withdrawals in conjunction with neighboring communities so that available supplies are stretched as far as possible. Regional planning of the water supply system, as proposed in the next section, would be a major step toward achieving the goal of optimum ground water withdrawal with minimal developmental impact. Until such a planning mechanism is in place, decisions on well placement and ground water withdrawal will be piecemeal and isolated, two conditions that prevent us from reaching the full potential of our ground water supply.

As suggested in the Level B report (UMRBC, 1977), good ground water planning includes proper well spacing; better quantification of supply and demand, as well as a better monitoring network to record the response of ground water to certain stresses; limits on withdrawals in restricted problem areas; and movement towards optimizing surface and ground water withdrawals to meet demand. To protect the quality of ground water, the Level B report suggested sealing abandoned wells; closer monitoring of ground water quality to detect contamination; prohibiting the introduction of further contaminants into ground water; and, delineating major recharge areas so non-compatible land uses can be prohibited therein (that is, wellhead protection).

The Metropolitan Council must begin to factor the availability of water into the decision-making process it uses to guide regional development. If indeed water becomes a factor limiting growth in the region, the Council must begin to identify this phenomenon and attempt to orient its recommendations for growth potential away from water-limited areas. This will be a new concept for the Council, arguing even more for a regional planning approach for water supply.

Optimization of Surface and Ground Water Use Through Regional Management

One of the most evident conclusions that one draws when studying the Metropolitan Area water supply situation is that there really is no one planning how the system is used, both now and for the future. An overriding theme of a Council-sponsored December 1, 1989 meeting on water supply issues in the region was that there needed to be a regional oversight authority in water to coordinate the way in which water is withdrawn and used. The need is for a planning approach to the water system separate and distinct from the regulatory framework. Clearly, there is not a need to operate the system because operations are generally not a problem. There is, however, a need to coordinate among the 100-plus municipal water suppliers, the high-capacity ground water users, the regulating agencies, the small-scale users and the water researchers in order to assure knowledge of the system and adequate distribution of water to all users. As noted previously, the threat exists that water could become a limiting factor in the orderly and economic development of the region.

Most past studies of the water supply system, from the Department of Conservation's 1961 Bulletin No. 11, to the Council/USGS 1973 Water Resources Outlook, and the 1977 Level B Report, recommend the institution of a regional water planning authority. To be effective, such an authority would need power to plan for the system, as well as the ability to implement its plans through the operations of water suppliers and users. It also would need the technical expertise to understand the entire water system and be able to construct models, and possibly to collect data to evaluate alternative operation scenarios. Development trends indicate that much of the future growth of the Metropolitan Area will occur in areas fully dependent on ground water as a supply source, yet we have no method in place to assure that there will be enough water to sustain this growth and keep current users supplied as well.

Many of the recommended actions in the preceding text and in the other technical reports need to be implemented by someone other than a single water supplier. Recommendations on better ground water management, up-to-date modeling of the water system, interconnection of suppliers, regional conservation measures and pursuit of alternative water sources need to be pursued by an entity with an overall charge to provide for the good of the Metropolitan Area water supply. An organized effort is needed to do such things as examine in detail a regional distribution

Decreased Water Quality Standards for the Mississippi River

Lowering water quality standards in the Mississippi River so that low flows would not lead to water quality violations was not considered as an alternative to "free up" river water. This approach is contrary to federal, state and Metropolitan Council policy and is not in the spirit of environmental protection that should be fostered for the river.

Realistically, some detrimental impact will occur on the river during extended dry periods, since MWCC is not required to maintain standards during flows less than the 7Q10. However, a previous recommendation for continued upgrading and artificial aeration during these events is intended to minimize any adverse impacts of wastewater effluent discharge.

Minnesota River Reservoirs

The Upper Mississippi River Comprehensive Basin Study (1970) recommended 14 potential multi-use reservoir sites in the Minnesota River Basin, plus additional storage on some existing reservoirs in the basin. These sites were not pursued because of the poor quality of the river as it enters the region and because of the river's confluence with the Mississippi River at a point downstream from the Minneapolis and St. Paul intakes.

CONCLUSIONS

Several conclusions can be drawn from a current review of alternative sources of water for the Metropolitan Area. Foremost in any plan to supplement existing supplies is wise use or conservation of the resource. We absolutely cannot look elsewhere for water before eliminating all of the waste from our own water use practices. Extension of conservation planning requirements through Minnesota Statutes, Ch. 103G.285 subd. 6 to all municipal and large commercial/industrial users is essential if we ever hope to be fully prepared for water shortages. It is also apparent that new, large-scale reservoirs are not feasible for environmental, economic, social and political reasons. Viable options do exist, however, for better management, wiser use, and use of stored water from existing or enhanced bodies of water. Because limited options exist for supplementing available supplies, current sources have to be protected from contamination and overuse, and properly managed to assure equitable distribution in the event of a crisis. At the present time, there is not an institutional mechanism in place to plan for the provision of water, or for the coordination of water users within the Metropolitan Area.

Two situations lead to the need for supplemental water supplies for the Metropolitan Area. First is an extended drought lowering Mississippi River flows and leading to increased ground water withdrawals. Since droughts occur gradually, solutions can be implemented that require some amount of time, such as accelerated conservation, release of water from the upper part of the watershed or gradual limits on allowed withdrawal of ground water. The second situation is a contamination event of either a surface or ground water source. This problem requires an immediate response, such as obtaining water from existing storage, mandatory water use cut-backs or shared water through an interconnection.

A look at the growth that will occur in the region in the next 20 years shows that many of the rapidly-developing suburbs in the western half of the Metropolitan Area will be relying upon a ground water system that is at, or beyond, the lateral extent of the Prairie du Chien-Jordan Aquifer. The inability of these communities and their self-supplied commerce and industry to tap the Prairie du Chien-Jordan means that other aquifers with far less potential to meet demand will be called upon. The Mt. Simon-Hinckley Aquifer cannot yield the volumes of water that will likely be needed and the surficial drift is similarly limited and affords little protection from any contamination that might occur on the ground surface. It appears, then, that we must consider the fact that the lack of water could be a controlling factor in future growth of the region. Perhaps the availability of an adequate long-term water supply should be a controlling factor in future growth considerations.

A mix of other alternatives are available for meeting both the short- and long-term problems that could lead to serious water shortages. Table 8 summarizes the alternatives that were evaluated to meet these needs. The best promise appears to be from the use of existing storage or enhancement of existing water bodies. Under extreme emergencies, supplemental releases from the Mississippi River Headwater Reservoir system could occur, according to the latest operating plan from the Corps of Engineers. Releases beyond those now occurring, however, cannot be expected during routine low flows. The Rice Creek chain of lakes, if expanded one foot vertically, could provide over one billion gallons of storage, or enough to meet the short-term emergency needs of Minneapolis for over ten days. Large abandoned iron mining pits on the Mesabi Iron Range could supply large volumes of water if sources close to the Mississippi River or its tributaries can be found, or if a system of pipelines could be built to transfer the water

TABLE 8

SUMMARY OF ALTERNATIVES EVALUATED IN THIS REPORT

Alternative	Advantages	Disadvantages	Cost (in 1990 $)
Conservation/"wise use"/reuse	No need to find alternative supplies of water; resource-conscious; immediate results	Depends on cooperation and education of users and suppliers	Some revenue might be lost by suppliers unless they restructure their rates
Additional Mississippi River Headwaters Reservoir releases	Directly tributary to Mississippi River; large volume usually in storage	Use conflicts and priorities; travel time; susceptibility to drought	No additional direct costs but some impact costs to regional interests in Headwaters area
11 multi-purpose reservoirs in the Mississippi River Basin	Design storage volume of 6,373,000 acre-feet; directly tributary to Miss. River	Economic, environmental, social, political difficulties w/reservoirs	$888,280,000 for 11 reservoirs
Rice Creek Chain-of-Lakes (13)	Tributary stream to Mississippi River; could supply both St. and Minneapolis systems if Miss. R. contaminated	Limited volume; environmental and social impact; competing uses (recreation); aqueduct needed at mouth of stream	$5,500,000 estimate with pipeline from mouth to plant in Fridley
Abandoned mining pits (3) on Mesabi Range	Combined available volume over 95,000 acre-feet; use of existing supply	Rights to water; travel time; cost of installation and transport, annual O&M	Range of costs from $3.4 million to $58 million depending on volume needed and source(s) chosen

Alternative	Advantages	Disadvantages	Cost (in 1990 $)
3 day off-line storage for Minneapolis Water Works a) structure	Improves upon current 24-hour emergency storage; immediately available; under city's control	Economic impact	$75 mill. plus land acquisition (if needed)
b) existing water bodies (Mpls. chain and Lake Minnetonka)	New facility not needed; same as above except control less for Lake Minnetonka	Economic and social impact	$20 mill. per option
Interconnect Minneapolis and St. Paul systems	Shared water during an emergency; use existing systems	Incompatible systems; no interest by cities	Unknown; would include major hydraulic adaptations
Improved ground water withdrawals	Use existing system more efficiently	History of unilateral decision-making; all factors of system not known	Unknown; mostly involve creation of institutional solution
Optimization of surface and ground water use through regional planning	Regional self-reliance; optimization of available resource; least economic and environmental costs	Creation of new institutional structure	Unknown; detailed studies of management and design of system needed before cost can be determined
Aeration of wastewater effluent (Metro plant)	Maintain water quality in Miss. R. beyond 7Q10	Uncertain future with change in treatment requirements	Approx. $1500/day in 1988
Pump-back of Miss. R. to point above Metro plant or Fridley	Reuse of river for flow "augmentation"	Impact on river of repeated effluent input; disturbance of pipeline in river corridor	Minimum of $50 mill.

to the river. This source, however, could not supply water during a short-term emergency because of the travel time required to reach the Metropolitan Area.

The city of Minneapolis could obtain an immediate three day supply of water by expanding its existing storage system with 150 million gallons in artificial storage. Use of ground water appears to be limited and existing water bodies in the city would present serious control difficulties in other than an extreme emergency. Non- or less-structural options for the city to protect its current supply source include watershed planning to minimize the threat of contamination and retro-fitting of protective catchments on all river crossings. Interconnection with the city of St. Paul does not appear to hold much promise because of the difficulties in moving the large volume of water needed. However, release of Rice Creek water from the Centerville reservoir by St. Paul could offer some short-term benefits, provided the Mississippi River could be by-passed at the mouth of Rice Creek.

Aeration of wastewater effluent at the Metro plant by the MWCC provides a supply of oxygen to the river so that water quality standards can be maintained during very low flows. This is not an alternative supply of water, but it does help to alleviate problems that might arise during times when other alternatives are being sought.

Improved management of the existing supply system could help the Metropolitan Area achieve self-sufficiency. Current use of the ground water system, for example, will likely lead to shortages as the region expands outward into areas where the Prairie du Chien-Jordan Aquifer is thin or non-existent. Inefficient withdrawal practices have lead the USGS to estimate that our realistic ground water capacity is only two-thirds of what could be withdrawn under ideal circumstances. Clearly, careful planning will need to exist for the next 20 years of development so that water does not become a limiting factor to our growth. An analysis of surface and ground water availability indicates that preferential distribution of surface water during times when it is in excess, and use of ground water for peaking and back-up would be the best use of the water system to meet the demand of a growing region. Such a distribution system could be developed over the next 20 years before any serious shortages occur.

In order to implement the recommendations for action contained in this plan, an institutional mechanism will have to be put in place where none exist today. There is no single party planning for the efficient use of water in the Metropolitan Area. An agency that could plan for water use in the region and implement through the existing operational framework would be a long-term asset in developing a strategy for efficient water use. A very small surcharge on water withdrawals could provide the funding for such an agency.

Other alternatives that were evaluated (Table 8) but found not to be feasible at this time include large-scale reservoirs in the upper Mississippi River Basin, increased routine releases from the Headwaters Reservoirs, and pump-back of Mississippi River water from below wastewater effluent discharges to above them. Alternatives not even considered because of obvious infeasibility include use of Lake Superior and the St. Croix River, decreasing water quality standards and large-scale reservoirs in the Minnesota River Basin (Table 9).

Table 9

SUMMARY OF ALTERNATIVES NOT GIVEN SERIOUS CONSIDERATION

ALTERNATIVES ELIMINATED FROM FURTHER CONSIDERATION	
Alternative	**Reason for Elimination from Consideration**
Diversion of water from Lake Superior or St. Croix River	Environmental, social, political and economic (>$150M) costs of diverting international and/or interstate "Wild and Scenic" waters
Reduce water quality standards during drought	"Anti-backsliding" policy of EPA forbids reduction in water quality standards in this manner; negative policy implications for water quality improvement program
Potential multi-purpose storage reservoirs in the Minnesota River basin	Poor water quality and lack of usefulness for Minneapolis and St. Paul municipal systems; costs exceed $500 mill. for 13 reservoirs

RECOMMENDATIONS

1. The creation of a regional water management program, including a regional planning scheme for water supply, should be pursued. The Metropolitan Council should conduct this evaluation as part of the development of its long-term water supply plan, looking at possible institutional structures, responsibilities and funding. Consideration of "environmentally sustainable development" of land and water resources should enter into future Metropolitan Council deliberations of regional growth issues.

2. The legislature should amend Minnesota Statutes, Chapter 103G.285 subd. 6 (recodified 105.417) to include all major surface and ground water users and eliminate the waiver clause that allows a user to escape responsibility for contingency plan preparation. The DNR currently encourages conservation through its rules, but a specific requirement is needed from the legislature, along with a commitment of resources to accomplish the work. Also, the legislature should require commercial and industrial users to evaluate the likelihood of reuse/recycling prior to being issued a DNR water appropriation permit, and develop some incentives for those that proceed with such measures. A substantial water conservation effort can then be developed by a regional water planning agency, or similarly-charged body, in conjunction with state, federal and local agencies, and other water users.

3. The MDH and MPCA should examine the feasibility of using treated water for reinjection into the ground water system and for secondary uses, such as landscaping and water level maintenance. The Metropolitan Council, in its next revision to the wastewater policy plan, should examine the possibilities for reuse of treated effluent from MWCC facilities.

4. The Mississippi Headwaters Board and DNR should continue their efforts to coordinate operations of small dam operators on the Mississippi River, focusing on the need to eliminate incremental plug releases.

5. The Minneapolis Water Works, as part of its continuing effort to find an alternative source of water, should explore fixed storage, the upper Rice Creek chain of lakes, alternative locations for a system of ground water wells and localized treatment, and protection for the river upstream of the Fridley intake.

6. The use of abandoned Mesabi Iron Range pits for supplemental water supply should be pursued by interested parties, perhaps with the assistance of the Metropolitan Council, a new water planning agency, and/or a state agency.

7. The MWCC should continue to implement its use of artificial aeration during periods of low flow on the river, according to its "Trigger Conditions for Metro Effluent Aeration" plan.

8. Efforts should continue to define the capabilities and use of the Twin Cities Basin ground water system in order to optimize its withdrawals. This should be a high priority item because of the threat that exists from outward growth relying solely on units that are not likely to be capable of meeting this demand. Any new water planning agency should develop ground water modeling expertise so that it can evaluate various use trends as they occur.

9. Preservation of the natural recharge function is the key to effective replenishment of the region's ground water. Upland recharge areas and the natural drainage system should be protected and reclaimed if the possibility arises.

10. As part of the preparation of a long-term water supply plan, the Council should evaluate the practicability, necessity and feasibility of developing a regional water distribution system that uses surface water preferentially when it is in excess, and ground water to meet peaks and serve as backup. A new water planning agency could implement such a proposal over the long term.

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APPENDIX

INVENTORY OF MISSISSIPPI RIVER CROSSINGS

Bridge crossings- from USGS maps that might be old, 9/20/90
Start at Minneapolis intake at Fridley, ~RM 859 (SPWU ~RM 863)

- I-694 at Fridley
- State 610 at Coon Rapids
- US 169 at Anoka
- new State 101 at Elk River
- old State 101 at Elk River
- State 25 at Monticello
- State 24 at Clearwater
- US 52/State 23 at St. Cloud
- local (St. Germain St.) street at St. Cloud
- railroad crossing 1/8 mi. upstr. of St. Germain St. in St. Cloud
- State 152 at St. Cloud
- local road at Sartell
- local road nr. St. Stephens
- local road nr. Royalton
- railroad crossing 1/8 mi. downstr. of Blanchard Dam
- Minn. Pipeline Co. pipeline so. of Little Falls at Shays Island
- State 27 at Little Falls
- 2 railraod crossings at Little Falls
- US BYP 10 at Little Falls
- State 115 at Camp Ripley
- railroad crossing at State 115
- State 210/371 at Brainerd
- local street at Brainerd
- railroad crossing at Brainerd
- State 25 at Brainerd
- State 6 nr. Cuyuna
- 2 local road crossings on flood diversion channel around Aitkin
- local road at Aitkin
- US 169 no. of Aitkin
- State 232 at Palisade
- railroad crossing at Palisade
- State 200 at Jacobson
- local road nr. Blackberry
- Lakehead Pipeline Co. pipeline 1.5 mi. up Prairie R. at Gr. Rapids
- US 169 at Grand Rapids
- local road at Grand Rapids
- local road at Cohasset
- US 6 west of Cohasset
- local road nr. Little White Oak Lake
- local road nr. Ball Club Lake
- railroad crossing at US 2
- US 2 nr. Ball Club Lake
- local road at Winni. Dam

SUMMARY: 35 roads, 8 railroads, 2 pipelines

Railroad Lines Within 1/4 Mile of Mississippi River

- at Coon Rapids and Fridley
- at Elk River
- upstream and through Monticello
- at Clearwater
- near St. Augusta through St. Cloud and Sartell to near Little Rock Cr. at Watab
- through Little Falls
- at Camp Ripley
- at Fort Ripley (town)
- through Grand Rapids and Cohasset

MWCC Sanitary Sewer Pipe

- 2-CN-630 - 8" diameter forcemain at Anoka from Champlin
- MSB-69U1 - 2 forcemains at 42" each at Fridley from Brooklyn Park

NOTE: major 30-36" interceptor crossing scheduled to be built at Anoka in 1992 will replace 2-CN-630 and tie into CAB interceptor at Champlin, serving Anoka and Ramsey