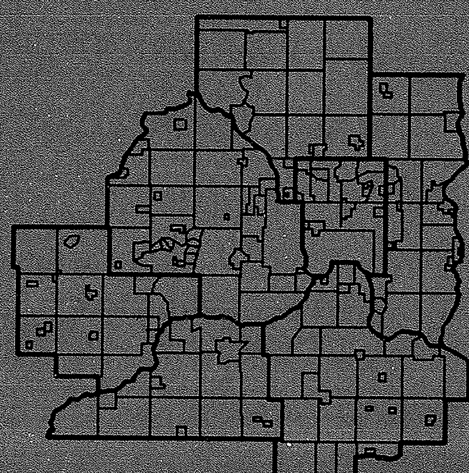
METROPOLITAN AREA SHORT-TERM WATER SUPPLY PLAN

Metropolitan Council Report To The Legislature

February 1, 1990



Metropolitan Council
Mears Park Centre
230 E. 5th Street
St. Paul, MN 55101

Publication No. 590-90-035

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METROPOLITAN COUNCIL

Steve Keefe, Chair

The Metropolitan Council coordinates the planning and development of the seven-county Metropolitan Area. The Council is authorized by state and federal laws to plan for highways and transit, sewers, parks and open space, airports, land use, air and water quality, health, housing, aging and arts.

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1. INTRODUCTION

"Responsive drought water management programs can protect our water and environmental systems and help avoid hardship, financial problems, economic setbacks and crisis or haphazard responses." (From Drought Water Management: Preparing and Responding to Drought; a report to the Natural and Man-Made Hazards Mitigation Program of the National Science Foundation, prepared by Colorado State University, June 1989)

HISTORY

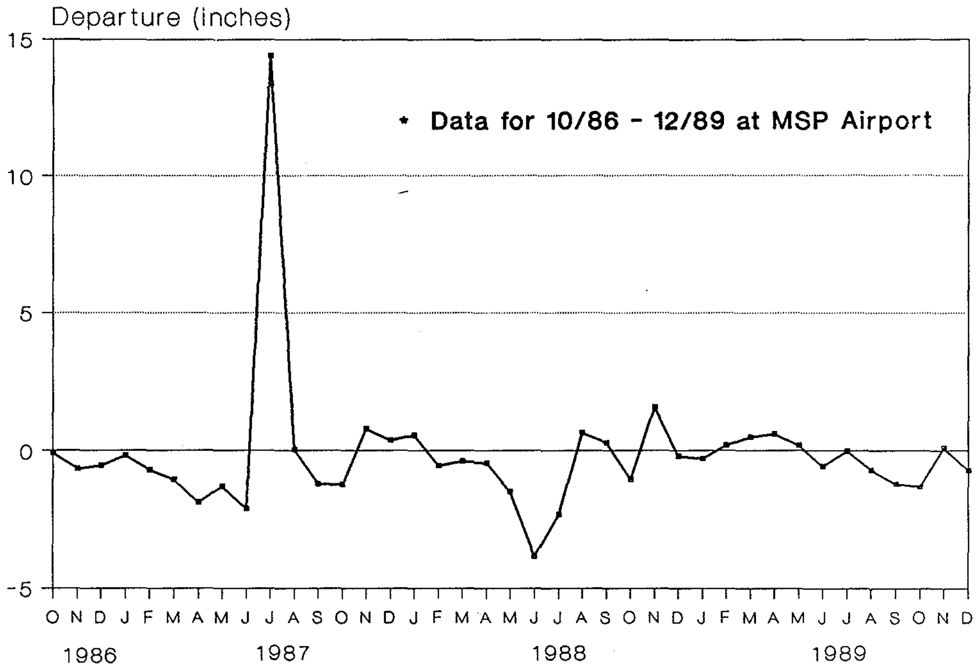
The summer of 1988 was a difficult time in the state of Minnesota. That year, a severe drought gripped the entire state. Different government agencies had differing accounts of the severity of the water shortage that hit the Metropolitan Area. While some said water was plentiful and conservation measures were not needed, others were convinced that water had to be conserved and sources outside of the region, specifically the Mississippi River Headwaters area, had to be tapped.

The confusion was further fueled by a seeming inability of public officials to identify the regulatory authority in charge of water flowing into and down the river. Thus, like 1976, we found ourselves reacting to the drought, unable to meet the situation in a well planned fashion. We had forgotten that droughts are cyclical natural events that can be anticipated and planned for. We did survive the summer of 1988 and learned several valuable lessons, most important of which is the need to have a plan at hand, ready to implement when the next drought takes place---perhaps this summer.

The 1980s have shown how rapidly a condition of excess moisture changes to one of severe water shortage. Experts believe that the current drought began in October 1986. At that time, Minnesota was at the end of an extremely wet period that lasted for almost 10 years (Department of Natural Resources [DNR], 1989). From 1982 to 1986 alone, portions of the Metropolitan Area received more than 40 inches of precipitation above normal. Flooding on landlocked lakes had become a chronic problem, both in this region and in Greater Minnesota. Groundwater levels were at record highs. In October 1986, however, the water situation began to change. By the spring of 1988 it was apparent that a serious drought was underway, and the driest June (0.22 inches) in recorded history was about to occur.

Figure 1 illustrates the departure from normal precipitation levels that occurred from October 1986 to December 1989, using U.S. Weather Bureau data for the Minneapolis-St. Paul International Airport (MSP). The total departure over the 40-month period is -5.8 inches. If the July 1987 "super storm" surplus monthly volume of 14.39 inches is not included, the departure from normal for the period would have been -20.19 inches. Of particular note in Figure 1 is the continued dryness underway until disrupted in July 1987; the lack of moisture in the summer of 1988; and the continued dry conditions through the end of 1989. The graph shows that drought conditions still exist in Minnesota, as evidenced by continued reports of low monthly precipitation, extremely dry soil conditions, and low surface and groundwater levels.

Figure 1. MSP *Precipitation Departure From Normal



Accounts of drought-related events during the summer of 1988 have been documented by various agencies (DNR, 1989; University of Minnesota, Water Resources Research Center, 1988; U.S. Army Corps of Engineers, 1989) and will not be repeated in detail here. Rather, analyses of the impacts of the 1988 drought will be recounted throughout this report. Among the major lessons from 1988 is that we must be prepared for water shortage with a well thought-out plan in advance of problems occurring rather than in the midst of an emotionally stressed situation. We learned in the past to be prepared for flooding problems; we must now apply that experience to respond to water shortage problems. We can no longer be complacent that we survived the severe drought of the early 1930s, when our Metropolitan Area population was only slightly over 900,000, nor that we survived 1976, when our population was around 1.9 million. With a current population of about 2.3 million and rising, and given the limited supply of our water resources, the necessity for drought-preparedness becomes all the more compelling.

THE WATER SUPPLY TASK FORCE AND LEGISLATIVE RESPONSE

Gov. Rudy Perpich formed a Twin Cities' Water Supply Task Force on Sept. 23, 1988 to recommend a course of action for meeting future water demands during the Mississippi River's low-flow periods. The task force met seven times and made a series of recommendations in January 1989. These included the following: (a) the DNR should prepare a drought contingency plan for the summer of 1989; (b) the Metropolitan Council should prepare a long-term water supply plan for the Metropolitan Area; (c) the U.S. Army Corps of Engineers should review the management plan for the operation of the Headwaters Reservoir system; (d) the Minnesota Pollution Control Agency (MPCA) should consider options for meeting Mississippi River water quality

standards during periods of low flow; and, (e) the Minnesota Legislature should consider changing the water appropriation priority system to better reflect uses and environmental protection.

In response to these recommendations, the DNR immediately convened a group of affected parties and prepared a drought contingency plan for 1989. This plan was agreed upon by all of the parties and was in effect by the summer of that year. The plan comprises the "heart" of the short-term water supply plan contained in the Institutional Aspects section of this report.

The Corps of Engineers, meanwhile, prepared a study of the Headwaters Reservoir system operation plan; the draft report is currently under internal Corps of Engineers review. The report found that "...the existing low-flow discharge figures for each project lake are adequate for present needs," but further concluded that institutional aspects related to drought response are inadequate. Further discussion of the Corps findings occurs throughout this report.

Also in reaction to the task force recommendations, the 1989 state legislature passed the "Big Water Bill" (Laws of Minnesota, Chapter 326) which contained a revised set of water appropriation priorities that have been incorporated into Minnesota Statutes, Chapter 105.41. The water-use priority system mandated under this law made domestic consumption and essential electrical power production (after conservation according to the power suppliers contingency plan) first priorities. This new system better reflects the realities of maintaining commerce and industry, and a minimum quality of life during a water shortage emergency. The legislature also took a stance against the use of large volumes of groundwater for once-through heating and cooling by prohibiting the DNR from issuing appropriation permits for once-through use in excess of five million gallons per year. The legislation also requires the DNR to study the impacts of existing once-through use on the aquifer system; it also institutes a new system that charges large volume once-through users a permit fee based on the volume of water used.

Another legislative action that occurred as a result of the task force recommendations was the passage of a bill requiring the Metropolitan Council to prepare both short-term and long-term water use and supply plans for the Metropolitan Area. This report to the legislature is in fulfillment of the short-term requirement. At a minimum, the plan aims to address the amount of water available and used in the region, alternative courses of action in a drought, and recommended approaches to solving water supply and use problems. This short-term plan will focus on getting a process in place for immediate response to drought-related problems until a long-term plan can be developed. The final section of this report outlines the course that will be pursued to prepare the long-term counterpart to this plan.

2. WATER SUPPLY AND USE

WATER USE IN THE REGION

Information on the authorized and actual use of water in the region comes predominantly from the DNR water appropriation permit program. The DNR issues these permits according to the process and priorities contained in Chapter 105, Minnesota Statutes, for all uses over 10,000 gallons per day or one million gallons per year. Details on the supply specifics of municipal and non-municipal public water suppliers comes from the Minnesota Department of Health (MDH).

Data were obtained from DNR records on the amount of water withdrawal currently authorized and the amount of use reported in 1984-88. The DNR currently (1989) authorizes the withdrawal of about 912 billion gallons per year (bgy) or 2498 million gallons per day (mgd). Actual reported use from 1984 through 1988 is summarized by use and source in Tables 1 and 2. Noteworthy in Table 1 is the large increase in water used from 1986 to 1987. This jump resulted from the onset of drought conditions early in 1987. Drought conditions remained all the way through 1988. A substantial part of the increase from 1986 to 1987 was from power plant cooling, where an increase of over 50 percent occurred. Power plant water withdrawals are from surface water sources and are returned in essentially the same amount as withdrawn. Within the Metropolitan Area, NSP operates two plants (Riverside and High Bridge) on the Mississippi River, one plant (Allen King) on the St. Croix River and one plant (Black Dog) on the Minnesota River. The Mississippi River and Minnesota River plants withdraw tremendous volumes of water, but consume at a maximum only one cubic foot of flow per second (cfs; 1 cfs = 0.65 mgd). The King plant on the St. Croix River uses a cooling tower to cool the discharged water from approximately Memorial Day through Labor Day, consuming a maximum summer day average of 14 cfs (about 9 mgd) of the 660 cfs permitted.

The large NSP facilities upstream of the Metropolitan Area on the Mississippi River similarly consume small volumes of water relative to their withdrawals. The Monticello nuclear power plant is permitted by the DNR to withdraw 645 cfs under normal operating conditions and river flow, and consumes a maximum of 10 cfs. The Sherco coal-fired plant at Becker is permitted to withdraw 67 cfs because of the internal recycling of cooling water through a cooling tower. The Sherco plant consumes about 47 cfs of the water it withdraws to make up for evaporative losses in the tower. Together, the two plants consume a maximum of 57 cfs. Three important points must be kept in mind when dealing with power plant use of water: (a) they are entirely dependent upon the flow of water passing the plants; (b) they must withdraw large volumes of water to condense steam in the generating process; and (c) they return essentially all the water they withdraw.

Further notes pertaining to Table 1 are that the air-conditioning entry includes heating make-up water from district heating systems; the water level maintenance category includes lake level maintenance, as well as sand and gravel quarry dewatering; and the miscellaneous category includes temporary construction, landscaping, hatcheries, snow-making and pollution confinement. Also, both air-conditioning and water level maintenance are seasonal uses that are

Table 1. Metropolitan Area Water Withdrawals*, 1984-88 (data from DNR, Division of Waters).

	Water Used in Million Gallons Per Day (mgd)				
Use Type (DNR permitted)	1984	1985	1986	1987	1988
Municipal (709.0 mgd)	274.0	285.2	284.4	337.2	345.1
Power Plant Cooling (1428.6 mgd)	463.0	400.4	486.5	739.9	456.8
Air-Conditioning (33.4 mgd)**	21.9	23.0	23.0	28.1	27.4
Industrial Processing (103.6 mgd)	47.9	51.0	47.2	36.5	47.6
Water Level Maintenance (64.9 mgd)**	30.4	25.1	29.7	23.7	28.2
Irrigation (48.7 mgd)	11.8	18.5	6.7	15.8	35.7
Private Domestic*** (no permit required)	15.4	15.4	15.4	15.4	15.4
Misc.-temporary, special (109.5 mgd)	5.0	6.1	6.7	4.1	7.5
TOTAL (2497.7 mgd)	869.4	824.7	899.7	1200.7	963.7
Percent of Permitted****	34.8	33.0	35.9	48.0	38.6

* Figures are for withdrawal only and do not reflect consumption
** Seasonal use
*** Estimated by Metropolitan Council
**** Comparison to DNR's 1989 permitted levels

much higher in the summer; the data in Table 1 reflect only the annual usage.

The large volume of surface water used in power plant cooling is reflected in Table 2. This water use accounts for approximately 80 percent of the river/stream use. When summed, surface water sources account for approximately 75 percent of water used in the region, leaving groundwater supplying the remaining 25 percent.

Table 2. Metropolitan Area Water Use 1984-88, by Source (data from DNR, Division of Waters)

	Water Used in Million Gallons Per Day (mgd)				
Source (DNR permitted)	1984	1985	1986	1987	1988
Groundwater (500.6 mgd)	229.8	241.1	227.8	257.4	295.2
Surface Water (1997.1 mgd)	639.6	583.6	671.9	942.3	668.5
TOTAL (2497.7 mgd)	869.4	824.7	899.7	1200.7	963.7

MDH data on public and non-public (mobile home parks, institutions, small housing developments) municipal supply systems is summarized in Tables 3a and 3b.

System design specifics and demand projections on the various systems are available from the Metropolitan Council in a separate data report. Some very general projections were made to determine the number of wells that will be required to meet the year 2010 populations. An assumption was made that one new well will be required for each population gain of 2000. This very simplistic approach indicates that approximately 196 new wells (beyond the current 471) will be needed to meet the municipal demand by the year 2010. In preparing the long-term plan, the Council and the Corps of Engineers will use the Corps' IWR-MAIN water use projection model for the Metropolitan Area. This model will project water demand for domestic, commercial and industrial uses.

Although the actual demand on the non-public systems is not available, it can be assumed that there are about 75 gallons per capita per day used in a supply system without industrial/commercial use. Therefore, the total non-public municipal demand is approximately 2.1 mgd. This demand should remain fairly constant because these systems supply institutions and small housing enclaves, such as mobile home parks. An additional 205,000 people use their own wells. Assuming an average use of 75 gallons per capita per day, these private wells provide about 15.4 mgd currently and, at a year 2010 estimate of 282,200 people served, a total of 21.2 mgd.

Table 3a. Public Municipal Water Supply System Summary (data from MDH).

Communities served - 111 supplied by 98 suppliers
Population served - 2,007,504 at 532,996 connections
Total design capacity - 875.6 million gallons per day (mgd)
Average daily demand - 264.1 mgd
Highest daily demand - 700.8 mgd
Average daily per capita use - 122 gallons
Highest daily per capita use - 338 gallons
Storage capacity - approx. 502 million gallons
Number of wells (1989) - 471 with 22 additional planned
Well capacity - 467,415 gallons per minute (676 mgd)
Projected population served by year 2010 - 2,303,860
Projected average demand by year 2010 - 311.2 mgd
Projected number of new municipal wells needed by year 2010 - 196

Table 3b. Non-Public Municipal Water Supply Systems (data from MDH).

Permitted systems - 65
Population served - 27,461 at 7,379 connections
Total design capacity - data not available
Storage capacity - 1.4 million gallons
Number of wells in use - 103 (Capacity not available)

SURFACE WATER AVAILABILITY AND USE

The Mississippi River flow followed quite closely the climatic pattern of spring and summer, 1988. A "trigger" level flow of 1,000 cfs for 72 hours at Anoka was determined by the DNR Drought Task Force to be the level when the Governor would request additional releases from the Headwaters Reservoirs; this additional release was beyond the 270 cfs that is released as part of normal operations. The 1,000 cfs flow was thought to be sufficient to allow for a volume of water to travel 20-30 days, and reach the Metropolitan Area when flow would be close to 800 cfs. Flow dropped all spring and summer toward 1,000 cfs and finally passed it for a 72 hour period on July 25-27, with the National Weather Service River Forecast Center predicting that flows could reach as low as 550 cfs by mid-August. On July 28, Gov. Perpich requested that the Corps of Engineers release an additional 300 cfs from the Headwaters. A minimum flow of 842 cfs occurred at Anoka shortly thereafter. This was the second lowest average daily flow ever recorded at Anoka, following only the 602 cfs level set on Sept. 10, 1934. An instantaneous flow of 529 cfs occurred on Aug. 29, 1976, but this was the result of automatic gate operation at the Coon Rapids dam (DNR, 1989). A minimum flow of 752 cfs at St. Paul was recorded for 1988 on July 8. Following is a synopsis of how each of the major water users and agencies dealt with the situation as it developed.

METROPOLITAN WASTE CONTROL COMMISSION (MWCC) AND RELATED WATER QUALITY

The first water user in the Metropolitan Area to feel the impact of low flows on the Mississippi River is the MWCC. In the summer of 1988 the flow at St. Paul at which the MWCC was required to meet water quality standards was 1703 cfs; this flow is the minimum seven-day low-flow value with a recurrence interval of once every ten years--the so-called 7Q10. This figure, incidentally, dropped to 1,250 cfs as a result of the low flows during the summer of 1988. The MWCC recognized early that a very low-flow was likely to occur on the Mississippi River, and undertook a low-flow survey to assess the response of the river under stressed conditions and to verify their water quality models (MWCC, 1989). The flow at St. Paul during the survey varied from 1,103 cfs to 2,246 cfs, averaging about 1,800 cfs.

The MWCC also recognized by early summer that dissolved oxygen (DO) levels in the river were quite low and that an opportunity existed to improve its wastewater effluent so that river conditions would not be worsened. From June 2 to October 7, the MWCC artificially aerated its effluent at the Metropolitan Wastewater Plant (Pig's Eye) by lifting the effluent via a pumping system and cascading it over a 40-foot floodwall. This raised the entrapped oxygen to such an extent that DO levels in the river actually increased as the river passed the plant and received the wastewater effluent. The decision to begin aeration is based on a pre-arranged set of flow and DO conditions in the river. This system is incorporated into the drought response matrix presented in the Institutional Aspects section of this report.

It is important to note that even though the MWCC was not required by state or federal law to meet water quality standards on the river at the extremely low 1988 flows, it was able to do so and at a minimal amount of only $1,300 per day in pumping costs. This effort was successful in holding oxygen levels above standards in the river for the entire length of the 1988 summer drought. Even at extreme low flows, when water quality conditions upstream of the plant were poor and the discharge from the Metro Plant constituted about one-quarter of the river flow below the plant, no bottom was seen in the ability to artificially raise oxygen levels. However, any operational or treatment changes in the future could impact MWCC's ability to use the aeration pumps as it did in 1988. The pumps were run for a period of 13 days in August, 1989 because of low DO downstream of the plant. Oxygen problems also did not occur at other MWCC-operated plants 1988 during the low flow. The MWCC is studying methods to keep oxygen levels high in the effluent from all of their plants, particularly those on the Minnesota River.

One additional aspect of the water quality situation was studied by the Corps of Engineers; the results were incorporated in its 1989 draft operations report. The Corps began to evaluate water quality in pool 2 to see if the requested additional 300 cfs from the Headwaters would increase oxygen levels in the pool. The Corps concluded that a critical flow of 3000 cfs into the lower pool would be required to make a difference in its oxygen behavior and, therefore, a release of only 300 cfs several hundred miles upstream is inconsequential to water quality in the pool.

The Corps also said in its 1989 draft report that there were no significant fish kills on the mainstem Mississippi River above the Metropolitan Area as a result of low flows in 1988. It did report minor local aquatic life impacts resulting from low volumes, increased pollutant concentrations, increased temperatures, overcrowding, predation/angling pressures, and reduced food availability. The Corps speculated, however, that increased releases from the Headwaters Reservoir system would have made a difference in aquatic life impact only for the first 50 to 100 miles below the system. The Corps may study this impact with the DNR and explore further in-stream needs immediately below the reservoirs.

NORTHERN STATES POWER COMPANY (NSP) AND POWER PLANT COOLING

NSP is another major river user that had to cope with low Mississippi River flows. Of primary concern to NSP were the two plants located upstream of the Metropolitan Area at Monticello and Becker (Sherco plant); these plants account for roughly one-half of NSP's base-load generating system. The operation of these two upstream plants will be discussed because the 1989 legislation requires evaluation of all conditions, upstream and within the region.

The operation of NSP's Monticello and Sherco plants relies heavily on the volume of available cooling water in the Mississippi River. It is important to note here that the reaches of river that flow by the two upstream plants are not pooled-- that is, water available is only that volume flowing by at any particular time. The Monticello nuclear power plant has a generating capacity of 545 megawatts (MW). It uses the river in a "helper" cycle, wherein cooling towers cool the water prior to discharge and have the capability to recycle a portion of the discharge when flow and river temperature conditions dictate. This portion of the plant's operation is regulated through an MPCA discharge permit, as well as through operational procedures regulated by the Nuclear Regulatory Commission. The Monticello plant is allowed by a DNR permit to withdraw up to 645 cfs, but it cannot withdraw more than 75 percent of the river flow. Therefore, when river flow falls below 860 cfs (the flow at which 645 cfs equals 75 percent), the plant may have to begin to recirculate a portion of the cooling tower discharge if it is at full load. As a result of complicating factors brought about by low flows on the Mississippi River in the summer of 1988, the Monticello plant intermittently lost generation capability up to 160 MW, or 30 percent of its capacity. This derated output from Monticello, combined with other plant derates and load requirements from the NSP system, led to the purchase of about 25 percent of NSP's peak demand, which cost the average residential customer an additional $0.07-0.09 per month.

NSP's Sherco plant is a coal-fired plant rated at 2,300 MW. Sherco uses a closed (recirculating) system that withdraws a maximum of 67 cfs from the river, and consumes a maximum of 47 cfs through evaporative losses that must be made up from the river. In July 1988, the Sherco plant withdrew an average of 55 cfs, with average consumption at 38 cfs.

NSP said that flow past the Monticello and Sherco plants in the summer of 1988 bottomed-out at 640 cfs, although a much lower flow of 353 cfs was released from the St. Cloud dam (Corps of Engineers, 1989). The "critical" flow rate required in the unpooled reaches of the river at the two plants is 250 cfs. Levels of flow below 250 cfs do not yield enough flow to keep the cooling water intakes fully submerged, resulting in federal regulatory problems and likely plant shutdowns and resultant power shortages. While the loss of power generation capacity at these two plants can be made up to a certain extent with purchases from the Mid-Continent Area Power Pool (MAPP), loss to the state's economy, potential damage to power-generating equipment and customer equipment/appliances, and the general disruption in lifestyle are compelling reasons why planners should attempt to assure that adequate volumes of water are available for this reach of the river. The existing release of 270 cfs (minus losses during travel) from the Headwaters Reservoir system assures that a portion of the required river flow will be provided except in extremely dry years.

The two plants located upstream of the Metro Area consume a maximum of 57 cfs. Even though this amount of consumption is very low compared to the volume of water withdrawn, it could be a noticeable percentage of flow under very low-flow conditions. At a flow of 860 cfs, when NSP must begin to limit its intake of river water, 57 cfs represents close to 7 percent of the flow in the river. NSP's cooling water withdrawals and consumption would decrease as flows drop below the 860 cfs level.

Other NSP facilities located in the Metropolitan Area are aided to some degree by pooling the major river on which they operate. The Riverside plant in Minneapolis and the High Bridge plant in St. Paul withdraw water from the Mississippi River at maximum rates of 543 and 490 cfs, respectively; each consumes approximately 1 cfs of the amount withdrawn. The Black Dog plant on the lower Minnesota River at Burnsville withdraws a maximum of 633 cfs, while consuming only 1 cfs. The Allen King plant on the St. Croix River at Oak Park Heights operates a cooling tower during the summer months and withdraws a maximum of 660 cfs, while consuming 14 cfs. The Black Dog plant experienced some capacity derating in 1988, as it does in most years because of the high ambient water temperature of the Minnesota River. Again, it is necessary to emphasize that most of the water withdrawn by NSP-- both inside the region and upstream-- is not consumed. The water is returned shortly downstream of withdrawal, but at a higher temperature. The impact of this use on Metro Area water consumption is variable depending upon the volume of flow and the demand conditions. It should also be noted that NSP files a forecast report each year with the Minnesota Public Utilities Commission (PUC) stating how it will supply its customer needs. NSP must also keep on file with the Federal Energy Regulatory Commission (FERC) an Emergency Procedure, which forms the basis for NSP's drought contingency plan. NSP has filed this drought contingency plan with the DNR.

MINNEAPOLIS WATER WORKS

Perhaps the largest perception problem of 1988 was the use of the Mississippi River for municipal supply by both Minneapolis and St. Paul. The Minneapolis Water Works withdraws water from the Mississippi River at Fridley to supply a total population of close to 500,000 in Minneapolis, Columbia Heights, Hilltop, Golden Valley, Crystal, New Hope, and portions of Bloomington and Edina. The average daily demand on the system in February 1989 was 72.25 mgd, with a total withdrawal capacity of about 200 mgd. Another 80 mgd could be obtained from an emergency station at the Camden Bridge; however, to reach these peak levels of pumping, some by-pass of treatment would be required because the treatment plant at Columbia Heights can only process 120-170 mgd, depending on conditions.

The pool from which the Minneapolis Water Works obtains its water is controlled by the dam at St. Anthony Falls (SAF). According to the Water Works, the elevation of the Minneapolis intake at Fridley is 795.8 feet, while the crest of the SAF dam at Minneapolis is between 796.5 and 796.8 feet. At flows less than 1,000 cfs at Fridley, there is no difference in water surface elevation on the river between the Minneapolis intake location and the SAF dam. Therefore, as long as water flows into the SAF pool, Minneapolis will have water available. Raising the flashboards at the SAF dam could raise the level to 799.2 feet, providing some excess storage in the event of an emergency. This action, however, would have serious water quality implications downstream, as river flow would be markedly decreased.

Since Minneapolis has only one source of water, any severe water quality problems with the river water or the pool, such as chemical or nuclear spills, means that the intake system must shut down and rely on the amount of water in storage at that time. Since Minneapolis has approximately 128 million gallons in storage, and uses about this much on an average summer day without a stringent conservation plan, Minneapolis would have about a one-day water supply if forced to close its intakes. Dramatic conservation could probably extend this supply to two days. It is primarily for this reason that Minneapolis joined with the U.S. Geological Survey to evaluate the feasibility of obtaining a 50 mgd groundwater back-up to its river source. The preliminary study results show that a groundwater withdrawal of this magnitude will be virtually impossible to obtain within the constraints placed on the study.

Minneapolis' demand for water in the spring of 1988 was very high because of the extremely dry conditions. By the end of May, the demand was approximately 122 mgd. By June 6, demand had skyrocketed to 176 mgd, which was 25 percent higher than the previous year's and 59 percent higher than 1986, a relatively normal year. It became obvious to the utility that continued demand at this very high rate would stress the treatment system, which was at capacity. On June 29, the city imposed an odd-even sprinkling ban in Minneapolis and all cities supplied by them. At the same time, the Water Works asked all users to conserve because of the high demand anticipated. A Water Works spokesman believes that the request for conservation-- rather than the sprinkling ban (which usually spreads out use and does not reduce demand)-- was responsible for a reduction to an average June 29 to July 26 demand of about 117 mgd. This was a reduction over the previous one-month period of over 21 percent.

On July 27 the city agreed with the DNR to a total ban on all outside uses. From the imposition of this ban to the time it was lifted on Aug. 16, the average use was cut to about 83 mgd-- or by another 29.5 percent-- for a total reduction of 44.5 percent from the time the first conservation effort began. Given a late July flow above 850 cfs (550 mgd, the lowest daily average flow recorded at Anoka) into the SAF pool, the voluntary reduction in withdrawal by the St. Paul Water Utility to about 70 cfs (45 mgd), and pumping levels by the Water Works of less than 100 mgd, Minneapolis was never short of water. The final demand figure of just over 80 mgd is close to the average yearly use of 72.25 mgd, but short of the summer average use of approximately 100 mgd. The Minneapolis Water Works estimates that extreme conservation, including mandatory shut-downs of non-priority uses, could cut demand to about 50 mgd--hence, the suggested groundwater back-up rate. The Water Works also notes, however, that the likelihood of keeping demand reduced to this level decreases with each passing day, especially since many people lost lawns believing the advice of "experts" that grass would go dormant.

ST. PAUL WATER UTILITY

Just upstream of the Minneapolis Water Works intakes at Fridley is the St. Paul Water Utility intake structure. In a typical year, the Utility relies on the river to meet about 70 percent of its total water demand, which averaged 50.6 mgd in January 1989. Ten percent of its demand is met through the use of the Centerville-Rice Creek chain of lakes and 20 percent from groundwater wells located near the Vadnais Lake pumping station.

The St. Paul Water Utility is operated by an independent board and is not a unit of the city of St. Paul. The Utility supplies St. Paul, Lauderdale, Falcon Heights, Roseville, Arden Hills, Little Canada, West St. Paul, Maplewood, Mendota Heights, and a portion of St. Anthony. The total population served in these 10 cities is about 385,000.

Although the Utility usually gets about 70 percent of its water from the Mississippi River, it can easily turn its river intakes off and rely on its supplemental lake and groundwater sources to meet all of its needs. With this supplemental system and the amount of storage in its distribution system, the Utility could go off-line for over one month before water in its reservoir system would reach unacceptable levels. During the driest portion of 1988, the Utility held its river intake at first at 53 mgd, then lowered it to 45 mgd at a time when average monthly demand was 80-95 mgd and peak demand was 115 mgd (peak use in 1976 was 125 mgd). Average summer usage in St. Paul is approximately 70 mgd. As with Minneapolis, the imposition of sprinkling restrictions and a request for conservation yielded immediate results, with demand dropping by about 15 percent. The Utility did not impose a ban on all outside uses as Minneapolis did.

The St. Paul Water Utility also could have, and perhaps should have, withdrawn all of the water it needed in 1988 from the Mississippi River. Another 50-75 mgd withdrawal from the river, as indicated in the Minneapolis discussion, would have been quite possible, even at the lowest 1988 flows. Perhaps a better resource approach for St. Paul would have been to use the river to the maximum extent, while holding the reservoirs and the chain of lakes system as reserve. This would have maximized surplus river flow while it was available. In fact, in anticipation of a serious low-flow problem, the Utility could have pumped surplus river flow, while it lasted, into its reservoir system for later use. Such an effort, however, requires close scrutiny because of the potential water quality impacts of decreasing flows upstream from major poor quality tributary inflows (Minnesota River) and wastewater treatment plants.

MISSISSIPPI RIVER NAVIGATION

Another non-consumptive use of the Mississippi River is navigation. The required flow rate for a minimum of one lockage per hour at the SAF lock is 350 cfs or 225 mgd (Corps of Engineers, 1989). This is considered "unrestricted" navigation by the Corps. Reductions in the number of lockages, and hence the volume of water passed through the lock, could be undertaken upon order of the District Engineer as a conservation measure. Total closure of the locks, along with alteration of the SAF pool depth, could be undertaken as an emergency measure to assure that the Minneapolis Water Works intakes remain submerged.

Related to the operation of the navigation system was the release of water from the lock and dam structures. The Corps of Engineers supplemented the naturally occurring aeration through the turbulent release of water through small openings in the dam gates and stop-logs. These releases were considered by the Corps and the MPCA to have helped locally with oxygen levels in the river. Releases were made through dams at SAF and at pools 1 to 3.

HEADWATERS LOW-FLOW OPERATION

The Headwaters resort community, the Leech Lake and Mille Lacs Bands of Chippewa Indians, and a large numbers of Headwaters' area residents and business organizations have a strong interest in the management of the Headwaters Reservoir system. Because of the reliance of the Headwaters community on the reservoirs, opposition to any additional release of water was heavy. The reservoirs are operated according to a low-flow plan, prepared by the Corps of Engineers, in consultation with Headwaters interests and the DNR. In reviewing the operation plan in response to the 1988 drought, the Corps concluded that "...the existing low- flow discharge figures for each project lake are adequate for present needs" (Corps of Engineers, 1989). The Corps did conclude, however, that some institutional aspects of the low-flow plan are inadequate. It proposed instituting an interagency coordination process with specific triggers for stepped responses, a St. Paul District Corps of Engineers drought management team and a public information plan.

Federal mandates imposed upon the Corps' decision-making process state that the Corps must consider several priorities in its operation of the Headwaters reservoirs. First priority in this process is navigation. This aspect of the flow system has decreased in importance dramatically since construction in the 1930s of the nine-foot navigation channel and the lock and dam system. As mentioned previously, a flow of 350 cfs (225 mgd) is required to allow one lockage per hour at the SAF lock.

Second priority in the Corps process is recognition of the Native American Treaty Trust. This Trust requires the Corps to protect the Indian reservation resources located on three of the reservoirs (Winnibigoshish, Leech and Sandy). This priority has essentially become the first consideration since navigation in the nine-foot channel is rarely a problem. To fulfill its obligation to protect the Trust, the Corps strives to maintain stable operating levels on the Headwaters lakes and to keep levels above minimum elevations. The tribal interests that the Corps strives to protect include wild rice crops, Headwaters area fish and wildlife resources, and cultural sites impacted by erosion. The current low-flow releases were arrived at in consultation with the affected parties and the DNR. However, the DNR does not necessarily agree with the Corps on all of the Indian rights issues and will be trying to resolve its differences with the Corps in future discussions. Table 4 shows the total releases by lake, as well as the "half-releases" that take over when lake levels drop to specific elevations.

The third priority that the Corps considers is the "general public good." It is within this priority that the Corps would consider the welfare of the resort community, as well as the downstream interests affected by any release. The Corps considers human health and safety issues in its deliberations on downstream public good.

Table 4. Headwaters Lakes Low-Flow Releases (from Corps of Engineers, 1989).

Reservoir	Minimum Daily Release (cfs)	Minimum Daily Release Trigger Elevation*	Half Minimum Daily Release (cfs)	Half Minimum Daily Release Elevation**
Winnibigoshish	100	1297.94	50	1294.94
Leech	100	1294.50	50	1292.70
Pokegama	***	1273.17	***	1270.42
Sandy	20	1216.06	10	1214.31
Pine	30	1229.07	15	1225.32
Gull	20	1193.75	10	1192.75
TOTAL	270		135	

* Bottom of desirable summer range
** Bottom of extreme regulation limit
*** Pokegama releases limited to sum of discharges from Winni. and Leech Lakes

OTHER UPSTREAM INTERESTS

Other major uses of Mississippi River upstream of the Metropolitan Area include hydropower structures located at St. Cloud, Royalton (Blanchard Dam), Sartell, Little Falls and Grand Rapids; the St. Cloud municipal water system; and agricultural irrigation, primarily in tributaries to the river. The hydropower facilities are "run-of-the-river" structures that basically use water as it flows by, with a limited amount of pooling. The Corps' 1989 report shows, however, that this use of water can lead to surges of water during release for power generation, followed by periods of decreased flow when water is pooled for later release. Corps' graphics (1989) show that a 600 cfs fluctuation in flow occurred from July 28 to Aug. 1, 1988, as the result of Mississippi River pooling in the vicinity of St. Cloud.

Such fluctuation has implications for large downstream users, such as NSP, that rely on continuous flow. The Corps has proposed that coordination begin among the hydropower users to smooth out releases in order to avoid major bounces in river water levels.

The city of St. Cloud relies mostly upon the Mississippi River for its municipal water supply. A back-up groundwater system of about 1.5 mgd exists, but the city gets up to 14 mgd from the river. Plans are being prepared to increase the municipal supply.

The use of surface water for such purposes as agricultural irrigation in the upper Mississippi River basin was scrutinized carefully by the DNR as the summer of 1988 progressed. As a result of dropping water levels in 13 tributary streams that had

DNR-adopted "protected flows", water appropriation permits were suspended. Table 5 lists information on the six watersheds in the upper Mississippi River basin in which surface water use was suspended. These suspensions accounted for 143 of the 195 permits suspended in the summer of 1988. In 1989, because of continued dry weather, these 13 watersheds, plus two additional basins, were again suspended by the DNR. The suspension of surface water appropriation is not something that the DNR is anxious to do because of the tremendous economic implication that suspension has on individual users. Suspension of irrigation water might mean total loss of crops to a farmer. It was often perceived upstream in 1988 that surface water use was suspended in these watersheds in order to save the water for less important purposes in the Metropolitan Area. In fact, the primary reason for establishing protected flows is to minimize ecological harm to the stream in question. The small amount of flow involved would not be enough to have a substantial impact on the flows through the Metropolitan Area.

Habitat protection on the mainstem is, however, influenced to a limited degree by water releases from the Headwaters reservoirs. The Corps suspects that the aquatic system for the first 50 to 100 miles below the reservoirs is directly supported in times of low-flow by the release of waters from the Headwaters dams. It is unclear, however, how far the impact reaches and to what extent aquatic life is actually affected by the flows. Although no significant fish kills were reported on the river in 1988, overcrowding, increased predation, increased temperatures, decreased food and suitable habitat, and exposure of floodplain soil and vegetation are all adverse ecological impacts associated with decreased flows. The Corps of Engineers proposes in its 1989 report that it conduct a joint project with the DNR to study the habitat needs of the river during periods of low-flow. The MPCA and the MWCC should also participate in this study to evaluate the impact of low flows on the assimilative capacity of the river.

Table 5. Upper Mississippi Basin DNR Surface Water Suspensions, 1988.

Watershed	Number of Permits Suspended	Date of Suspension
Elk River	31	June 22
Rum River and Tribs.	13	June 29
Sauk River and Tribs.	18	July 8
Long Prairie River and Tribs.	30	July 12
Crow Wing River and Tribs.	33	July 22
Crow River and Tribs.	18	Aug. 1
TOTAL	143	

GROUNDWATER AVAILABILITY AND USE

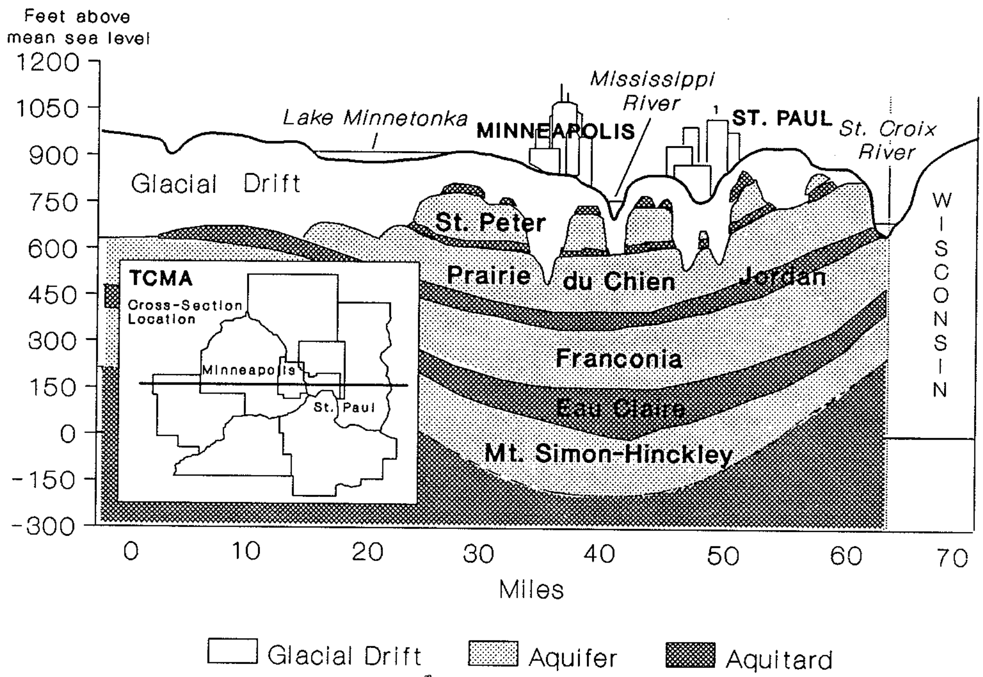
Groundwater use in the region is substantial (Table 2). In the past, we usually thought that our supply of groundwater available from a series of sedimentary rock strata (Figure 2) was almost unlimited. The U.S. Geological Survey (USGS) estimated in 1973 (USGS, 1973) that there was a supply capacity of one billion gallons per day from the Prairie du Chien-Jordan and Mt. Simon-Hinckley Aquifers alone, with more volume available from the remaining components of the regional groundwater system. Recent groundwater modeling efforts by the USGS indicate that with the current, concentrated placement of wells in the Metropolitan Area, the capacity is closer to 500 to 800 mgd, or an average of about 650 mgd (University of Minnesota, 1988; Schoenberg, 1990). A more evenly distributed withdrawal system throughout the region could mean that more volume would be available. The current method of groundwater extraction is that every user drills the desired number of wells generally in clustered well fields. The USGS estimate does not remove from available capacity those portions of the system that have been contaminated by such sources as landfills and industrial spills. Assuming that grossly contaminated groundwater will not be available for use, the estimate of available capacity will be further reduced by some yet undetermined amount. A study of this is proposed for the long-term water plan.

Concerns on the local availability of groundwater have risen lately because of the continued dry situation. Extremely low soil moisture and continued lack of precipitation during critical recharge periods mean that reduced volumes of water are percolating down to deeper groundwater storage areas. The reduction in groundwater levels has been noted by both DNR and USGS, and has resulted in some occasions of dry municipal wells. The number and location of dry municipal wells has not yet been documented, but will be a part of a municipal water supply survey in the long-term plan. The DNR (1989) received over 300 complaints of well interference statewide in the summer of 1988; approximately 20 of these turned out to be actual interferences. It also states that the confined aquifer units in the Metropolitan Area were strongly influenced by the drought conditions in 1988, with the Prairie du Chien-Jordan reaching record lows in June and July 1988. The Prairie du Chien-Jordan seemed to recover quickly after the cessation of irrigation and air-conditioning pumping in 1988, but the Mt. Simon-Hinckley aquifer, a much-deeper unit, was still 35 feet below normal levels well after the summer of 1988 and did not appear to show signs of recovery even as recent as late 1989.

Substantial increases in the use of groundwater are expected as the Metropolitan Area expands outward to areas served only by groundwater sources. Very preliminary estimates of groundwater demand in the year 2010 show that close to 200 new large-capacity wells will be needed to supply the rapidly-growing area shown in Figure 3. A total demand on the groundwater system at that time will be close to 325 mgd, or one-half of the estimated capacity, not including an as-yet-undetermined future demand by privately supplied commerce and industry. This demand estimate also does not include any increases in the demand for groundwater by the cities of Minneapolis and St. Paul, both of which have a desire to use groundwater as a supplemental supply---Minneapolis perhaps as much as 50 mgd and St. Paul adding to its current 20 mgd groundwater capacity.

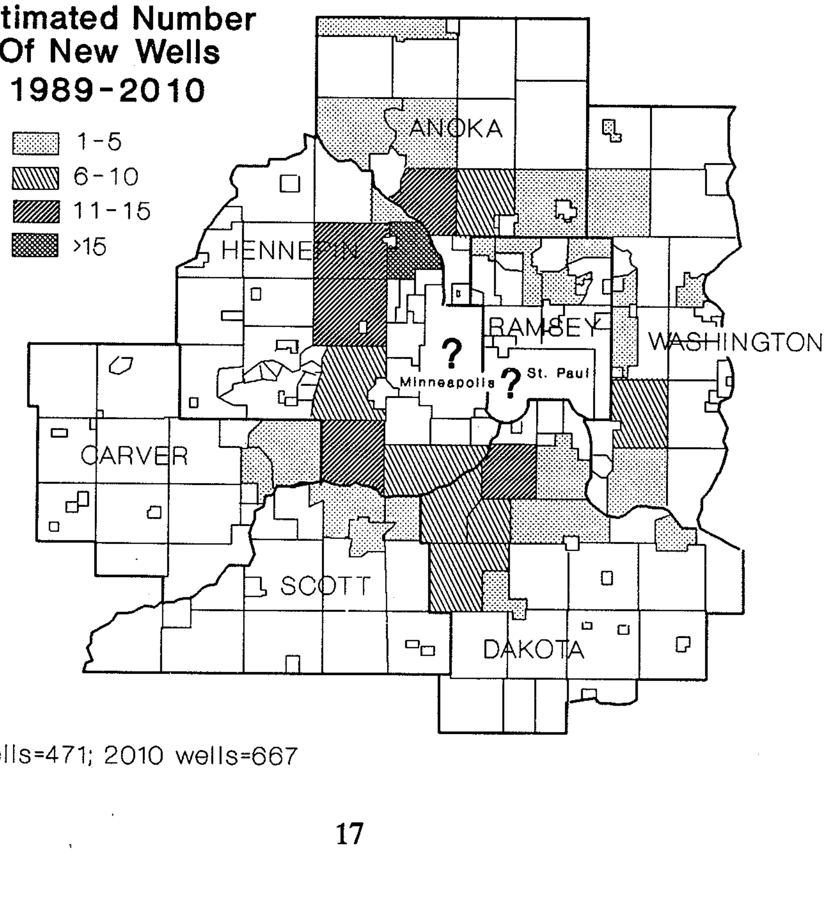
An increase in groundwater use will also have an impact on surface water flow

Figure 2. Generalized TCMA Geologic Cross-Section



Vertical exaggeration approximately 130x

Figure 3. Estimated Number Of New Wells 1989-2010



1989 wells=471; 2010 wells=667

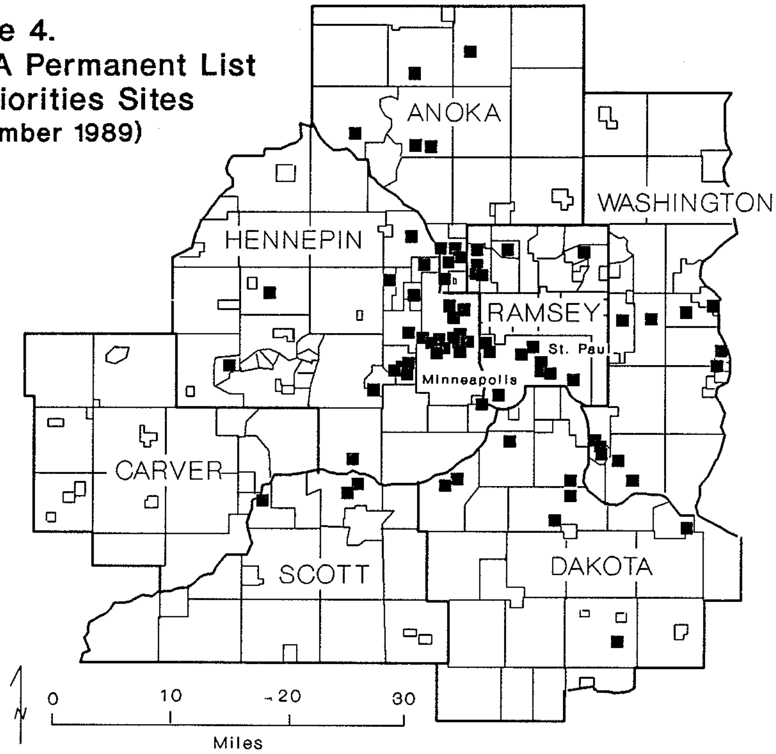
through the Metropolitan Area. Because of the hydraulic connection between surface and ground waters, USGS predicts that increasing groundwater demand to the full 650 mgd capacity (an unlikely scenario) would mean that flow to the major rivers would be decreased by about 225 cfs (145 mgd). Use at a level of 500 mgd would similarly decrease river flows by about 150 cfs (97 mgd). The Minneapolis Water Works, as well as the USGS, believes that most of the water which they withdrew from the river during the lowest flows in the summer of 1988 was groundwater-- this means that groundwater inflows likely support the flow of the river during a drought. The long-term plan will look at the ability of the groundwater system to sustain river flow during extreme water shortage situations.

Use of groundwater in the future must also consider the quality of the water being counted upon to provide an adequate supply. The latest Permanent List of Priority (PLP) sites for use of MPCA's Superfund money includes sites within the Metropolitan Area (Figure 4). Further sites of "suspected" contamination are included on MPCA's Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) list. A total of 176 sites of the approximately 400 sites in the statewide list are in the Metropolitan region; 55 of these are also on the PLP. Large and unknown instances of contamination through abandoned wells and leaking underground storage tanks add to the potential seriousness of the groundwater contamination problem.

The large number of contamination cases in the region have had a definite impact on the ability of municipal water suppliers to obtain clean water. For instance, the Twin Cities Army Ammunition Plant (TCAAP) contamination in Arden Hills and the Reilly Tar and Chemical spills in St. Louis Park have had far-reaching impacts on local and regional groundwater supplies. More recently, it appears as though the Minneapolis Water Works will not likely be able to obtain even moderate supplies of groundwater near its river intakes because of groundwater contamination in the vicinity. If the preliminary study results hold true, Minneapolis will not be able to use groundwater as a supplement to its surface water system at Fridley, unless the Water Works is willing to treat the contaminants in the groundwater. Other communities looking for additional sources of water might be faced with similar restrictions until all sources of contamination are removed and all contaminated aquifers reclaimed.

Monitoring efforts must continue on the movement of contaminants from known polluted sites and monitoring of ambient conditions should be focused on known and suspected pollution sites in order to track contamination and discover any new threats. This monitoring activity would also allow detection of increased downward movement in contaminants as a result of increased pumping from increased demands. The MPCA has received a grant from the Legislative Commission on Minnesota Resources (LCMR) to evaluate the current MPCA routine groundwater monitoring program to see what changes need to be made. The MPCA and the Minnesota Department of Agriculture (MDA) are also evaluating the impact of pesticides and fertilizer use on groundwater, as well as other detrimental nitrogen sources. The MDH is also putting together a wellhead protection program and working with several other agencies, including the Metropolitan Council, to define areas sensitive to groundwater contamination and to develop methods to assist local government units in their efforts to assure that the area's groundwater supply is kept clean.

Figure 4.
MPCA Permanent List
of Priorities Sites
(December 1989)



3. DROUGHT RESPONSE

NEEDS DURING A DROUGHT

The previous sections of this report have outlined the various uses of, and demands for, water in the Metropolitan Area and upstream. In order to assure adequate volumes of water to meet demand during a drought, critical needs have to be defined and a process has to be put in place to decrease withdrawals to these levels. The first step in this process is to determine which user(s) are impacted first as levels of available water drop.

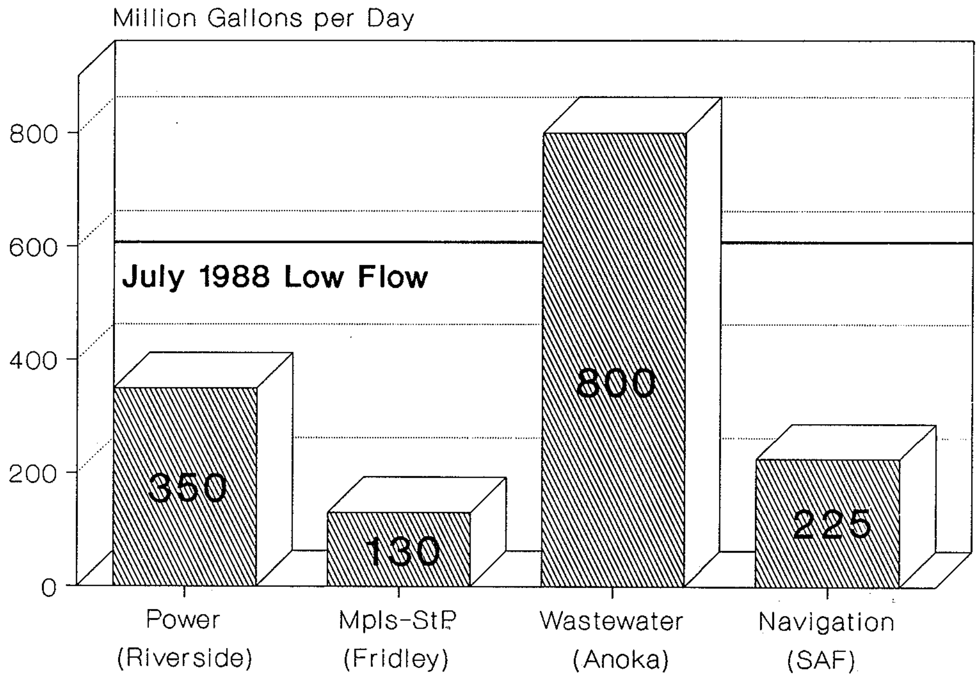
The situation that occurred in the summer of 1988 provides a good definition of how users are impacted. Figure 5 shows the various users in the Metropolitan Area and how they were impacted by dropping flows. The graphic portrays the situation at Anoka in late July 1988. The lowest flow that was recorded at Anoka was 842 cfs (544 mgd). An estimate of the summer 7Q10 flow at Anoka by the MWCC following the low flows of 1988 is 1,000 cfs. The first user impacted by low flows at Anoka is actually the MWCC at its Metro plant at Pig's Eye in St. Paul. The Metro plant uses water for wastewater assimilation based on meeting water quality requirements for the summer 7Q10 at St. Paul (lowered from 1,703 cfs prior to the 1988 low flows to the current 1,250 cfs). Assuming that the 7Q10 would occur at the same time at both Anoka and St. Paul, the MWCC would reach its "critical" flow level first, as seen in Figure 5. As discussed previously, the MWCC was able to overcome water quality problems at a flow as low as 752 cfs at St. Paul. However, for future planning purposes, the critical flow for MWCC should be consistent with its operating parameters and be kept at the 7Q10 level.

The next river user impacted, according to Figure 5, is NSP, which has two Mississippi River facilities--- the Riverside plant in Minneapolis and the High Bridge plant in St. Paul. The appropriation limits set at the Riverside and High Bridge plants are 543 cfs (351 mgd) and 490 cfs (316 mgd), respectively. Both of these plants are located on pooled reaches of the river, so low-flow impacts are not expected to be serious unless extremely low flows cause the pools into which the plants discharge to reach high temperatures, at which time the plants would begin to derate. Water consumption at each of these plants is approximately 1 cfs. NSP, as part of an overall conservation strategy, could urge its customers to reduce consumption so that maximum power production, and hence water use, is not needed. Impacts on the upstream NSP plants at Monticello and Sherco are discussed later in this section.

Proceeding through Figure 5, the next impacted use as flow drops would be the SAF lock, operated by the Corps of Engineers for navigation purposes. As noted previously, the Corps needs a flow into the lock of about 350 cfs (225 mgd) in order to maintain one lockage per hour. This figure is the "critical" flow to maintain conditions at a desirable level; the Corps notes, however, that it could reduce lockages below this level in an emergency.

The other parties most severely impacted by dropping river flow are the Minneapolis Water Works and the St. Paul Water Utility. Minneapolis' lowest use in 1988, after the imposition of mandatory

Figure 5. Mississippi River Uses
Summer 1988



conservation measures, was approximately 85 mgd (132 cfs). The Minneapolis Water Works believes that it could further reduce its demand in an emergency, but considers 85 mgd as its reasonable critical summer demand under all but extreme emergency conditions. St. Paul reduced its level of withdrawal to 45 mgd (70 cfs) in 1988. Although able to reduce this intake all the way to zero, it makes good resource sense for St. Paul to withdraw from the river as long as possible before going to its supplemental lake and groundwater supplies. For purposes of critical flow definition, St. Paul's critical flow will be defined as 45 mgd, with subsequent decreases all the way to zero as dictated by river flow. Until the emergency river flow levels are reached, however, St. Paul should use available river supplies and hold its supplemental sources at minimum maintenance withdrawals.

In summary, there are actually three levels of Mississippi River flow through the Metropolitan Area that should be considered. The first is the "water quality" (7Q10) flow required to maintain water quality standards below MWCC's Metro plant in St. Paul-- which is 1,250 cfs, approximately equal to an Anoka flow of 1,000 cfs. Maintaining this level of flow would mean that all subsequent Metropolitan Area surface water demands would also be met.

The second flow is reflective of a normal low-flow situation in which municipal withdrawals are at those attained in 1988 after water conservation programs were put into effect. This flow is required to assure adequate drinking water for the Minneapolis and St. Paul municipal water supplies; the added flow is also necessary to assure navigation and will be used to continually renew the pools into which the Riverside and High Bridge plants of NSP discharge heated water and supply the 2 cfs consumed by the plants. As noted above, the drinking water total flow would be Minneapolis' 85 mgd plus St. Paul's 45 mgd, for a total of 130 mgd (202 cfs). An additional volume for the NSP plants is not required beyond the 2 cfs consumed, since the plants can withdraw water from standing river pools and discharge it until temperature conditions warrant plant phase-down. The final increment is the 225 mgd (350 cfs) required to continue a minimum level of navigation. This volume of flow will also serve to renew the pools into which NSP's plants discharge.

The total amount of flow required at Anoka under this scenario is then 357 mgd (554 cfs). At this flow level, it is questionable whether the MWCC would be able to maintain water quality standards by aerating its effluent in the same manner as it did in 1988. The impact of a flow this low depends upon the operating conditions at the Metro plant, as well as the amount of flow entering the Mississippi River at its confluence with the Minnesota River. The Minnesota River water would most likely be of poor quality and would add to the quality problems in the Mississippi River.

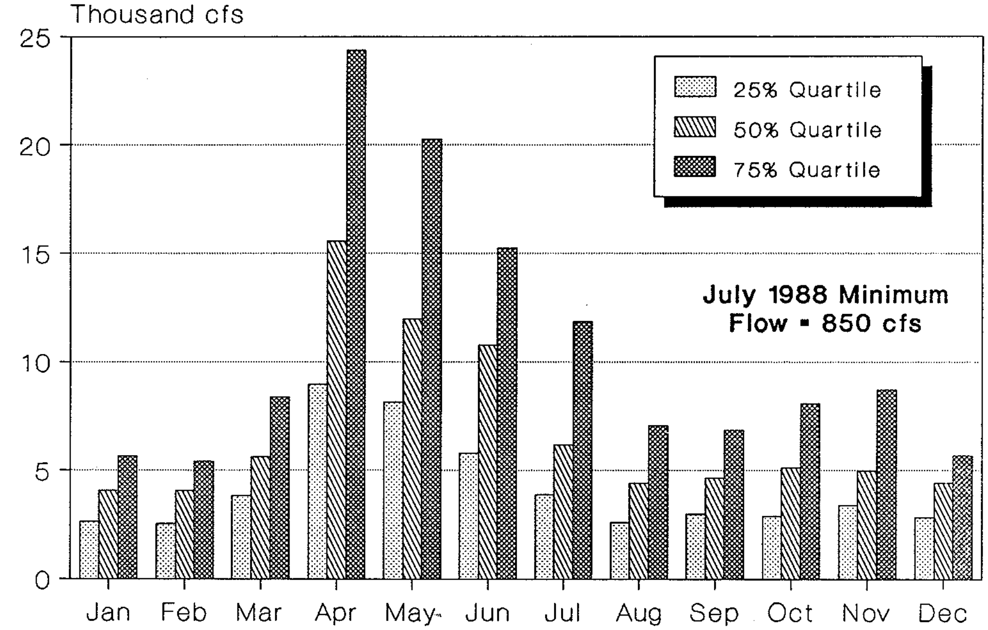
The third flow scenario represents an emergency situation in which serious volume shortages exist on the river. Under this scenario, Minneapolis would still have to obtain its water from the river, but St. Paul could switch to its supplemental sources after ascertaining that surplus flows are not available from the river. Navigation on the river would be significantly reduced or delayed based upon the lockage capacity available at seriously reduced flows. The Corps' District Engineer would manage the lock operation based on available flow and emergency water demand conditions, and could suspend all lockages if he determines a need to do so. NSP would need to make up power lost from derating the Riverside and possibly High Bridge plants from its own system or from purchases. The MWCC would continue its aeration, but there would be no guarantee that water quality standards would be maintained at this extremely low level of flow. The emergency, critical flow under this final scenario would be very low, with an absolute need to meet only Minneapolis' demand of 85 mgd (131 cfs).

For purposes of this report, the second level of flow will be considered as "critical" and the third level as "emergency" since the likelihood of ever reaching a flow as low as 85 mgd into the Metropolitan Area is remote. The "critical" level of flow (357 mgd or 554 cfs), however, is quite possible and should be planned for. This will be the basis for definition of user actions in a matrix included in the Institutional Aspects section of this report.

Figure 6 is a compilation of the monthly USGS flow data for the gauging station at Anoka from 1931 to 1989. The graph shows monthly low-flows that can be expected 25 percent, 50 percent (median) and 75 percent of the time at Anoka. Lowest overall flows occur during the winter, but since demand is low at this time, supply shortages are usually not critical. Flows during the peak demand and low flow portion of the summer are usually sufficient to meet demand. The 25 percent quartile flows during July and August are 3,894 cfs and 2,615 cfs, respectively. This far surpasses the "critical" flow requirement of 554 cfs; thus, it is very likely that most of the time there will be no problem meeting critical flow levels. Long-term plans should, however, take into account the rare years in which extremes are encountered.

Flow levels on the Minnesota and St. Croix Rivers have not been addressed because the

Figure 6. Mississippi R. at Anoka
Monthly Flow - 1931 to 1989



Data from USGS

major uses of these rivers are wastewater assimilation, which is regulated by the MPCA, and recreation, which is a primary use of the St. Croix River at any level of flow. The MWCC is required to maintain water quality standards on these rivers to the 7Q10 level (282 cfs at Shakopee and 1,110 cfs at Stillwater), the same as on the Mississippi River.

Flow upstream of the Metropolitan Area must also be considered, since it is intimately related to downstream uses. The primary demand upstream is for power plant cooling purposes at the Monticello and Sherco plants of NSP. The same "plug" or incremental volume of water that cools the water at Sherco can be used to cool Monticello, four miles downstream. Again, it is emphasized that these two plants provide a large portion of NSP's demand and they can be cooled only by the amount of water passing by as run-of-the-river flow. Although Sherco withdraws only 67 cfs for cooling, the minimum flow required to keep the intakes submerged and operational is 250 cfs (162 mgd). The cooling situation at Monticello, however, requires more water, with NSP allowed to take up to 645 cfs (417 mgd) but only up to 75 percent of river flow. That means that flows less than 860 cfs (555 mgd) result in cooling tower recirculation to maintain permit withdrawal and temperature conditions. Reductions in the amount of power that can be generated as withdrawals decrease depends upon ambient conditions in the river. In the summer of 1988, the combined water constraints, with the lowest flow at 640 cfs at Monticello, caused NSP to use only 70 percent of its generating capacity and to purchase additional power from MAPP. As with Sherco, a minimum flow of 250 cfs is required to keep the Monticello intakes submerged. Under the normal operating plan of the Corps of Engineers, the low-flow release from the Headwaters Reservoirs is 270 cfs. However, not all of this water will reach the NSP plants because of upstream withdrawals, evaporation and infiltration. Other sources of inflow to the river include groundwater seepage, other lake discharges and small tributary flows. For power production at these two facilities, "critical" flow would be anything less than 860 cfs, when Monticello has to begin phasing down to meet permit requirements. "Emergency" flow would be anything less than 250 cfs, when both Sherco and Monticello would be forced to close. At flows less than 860 cfs, NSP, depending upon demand, might have to begin purchase of power from the MAPP system at a cost higher than NSP could produce it.

All other users of the Mississippi River upstream of the Metropolitan Area consume small volumes of water. All of these demands should be met by upstream low-flow sources. All of the small hydropower and water supply dam operators should be coordinated by the DNR, the FERC (through permits) and the Corps of Engineers in order to assure that their operations do not negatively impact each other and downstream users. For example, NSP has noted flow decreases from operation of an upstream dam arrive at just the time that NSP needs peak flow to cool its facilities. Coordination of operating plans could help to smooth out flows and avoid adverse impacts.

Users of water in the Headwaters area are primarily those relying upon stable water levels in the reservoirs. These users are generally satisfied with the low-flow operation of the dams, as spelled-out in the low-flow plan. Discussions with the Mississippi Headwaters Board, the resort community, the Chippewa Indian Bands and interested citizens and businesses indicate that users of water in this region are financially and culturally reliant upon stable conditions in the reservoir system. These residents acquire their livelihood from the water resource and are justifiably upset when downstream water users look to additional releases without visible attempts to conserve water or seek alternative supplies within their own area. It is for this reason that the matrix of user actions that appears in the next section mandates conservation programs by downstream users even before a request for release is contemplated. Any additional release beyond the normal Corps of Engineers' low-flow plan should be considered only in an emergency and only after conservation programs and other sources of supplemental water supply are considered.

INSTITUTIONAL ASPECTS

In order to provide a defined sequence of actions that would be undertaken by Mississippi River users during periods of reduced river flow, a formalized matrix must be developed and adopted by each of the parties involved. The basic framework was put together by the DNR and several parties in response to the Governor's Twin Cities Water Supply Task Force. This matrix forms the basis of the short-term plan, prepared mainly to respond to water shortages on the Mississippi River prior to the adoption of a long-term plan. Table 6 itemizes the response by six parties that use water, regulate water usage or coordinate activities on the river. Response actions are "triggered" by various flows at Anoka for a 72 hour period. This table differs from the 1989 DNR drought response plan on five counts: one, the first trigger level was changed to the median monthly flow to make the trigger more seasonally accurate; two, the Mississippi Headwaters Board was added to the matrix; three, the lowest trigger level was changed from 850 cfs to 750 cfs; four, more narrative was added in several entries to clarify actions; and five, the DNR action at the lowest flow level was changed from preparing a request for water release from the Headwaters Reservoirs to an evaluation of alternative sources of water, including the reservoirs, but not limited to them. This last point allows the DNR and the Governor to evaluate existing and expected flow and demand conditions before reviewing alternative sources. This action also recognizes that a series of conservation actions must precede any request for a Headwaters release and that it is strictly an emergency supplement.

The movement from median monthly flow to 750 cfs allows for a graduated approach to action instead of a sudden emergency response in reaction to events. The first level of flow is only an advisory that we are moving towards drier conditions. It alerts all matrix participants that flow has dropped to the lower half of the spectrum and that water shortages are possible if climatic conditions do not provide adequate moisture. The demand values contained in the matrix are goals that would hopefully be achieved through instituting the conservation plans called for.

The second level of action occurs at 2,000 cfs, when we move into the realm of low-flow conditions. The level of alertness increases and the various users begin to think about conservation and water quality assurance procedures. The next levels at 1,200 and 1,000 cfs trigger further conservation action, which includes the need for communication among users and customers. The final action level is 750 cfs. A flow this low would trigger mandatory conservation actions by the major users and would lead the Drought Task Force to consider alternative sources of water supply, including, but not limited to, additional Headwaters Reservoir system releases. This situation precedes an emergency, so emergency actions could still be planned and undertaken before serious difficulties result. The lowest trigger flow is still about 200 cfs above "critical" conditions and over 400 cfs above "emergency" conditions. The trigger levels presented in the matrix are above those of the 1930s (602 cfs, Sept. 10, 1934), and 1976 (529 cfs, inadvertently caused by automatic gate, Aug. 29, 1976), and slightly below the lowest flow of 1988 (842 cfs, July 30).

The matrix also calls for the establishment of a formally constituted Drought Task Force that would advise the DNR on drought response actions. The Headwaters Board and the Metropolitan Council are suggested additions to the existing agencies that advised the DNR in the preparation of its 1989 Drought Contingency Plan.

The method for formal adoption of the Drought Response Plan (Table 6) should be decided upon by the legislature. The most feasible options appear to be legislation requiring the parties to adopt such a plan or a charge by the legislature for the parties to resolve among themselves how best to accomplish acceptance of the plan. Each of the parties included on the matrix has reviewed the framework and agreed that it represents a set of actions they are able to implement. However, a formalized set of actions is required so that all parties know their responsibilities and the actions they are expected to undertake during a water shortage.

Absent from the matrix is the Corps of Engineers, which operates under federal law. The Corps has repeatedly stated that any actions it undertakes relative to the operation of the Headwaters Reservoir structures or the river itself are done in cooperation with, and not dictated by, the state. This means that even in extreme

Table 6. Drought Response Plan

		72 Hour Flow at Anoka			
Participant	Median Monthly Flow*	2000 cfs	1200 cfs	1000 cfs	750 cfs
DNR - Division of Waters	Monitor flows including tributaries; notify affected parties in matrix that river flows have dropped below median for month	Intensify flow monitoring and commence low flow predictions; initiate awareness program among users; convene meeting of Drought Task Force* to develop strategy	Continue flow monitoring and predictions; begin intensive public information program; meet with Drought Task Force to implement strategy	Continue all activities with emphasis on prediction of flow and movement toward critical" flow; explore need to limit appropriations	Continue all activities; evaluate the need for upstream supplements and other alternatives based on conditions and future outlook
Minneapolis Water Works	Verify that flows have dropped below average for summer conditions	Continue normal use while alert to low flow potential	Institute voluntary** conservation program in order to reduce demand from river; begin coordination with St. Paul to optimize river withdrawals	Institute sprinkling restrictions** and reduce demand to 85 mgd	Institute mandatory** conservation program and reduce demand to 75 mgd; work with Drought Task Force to define critical supply needs
St. Paul Water Utility	Verify that flows have dropped below average for summer conditions; in anticipation of low flows, begin to pump surplus river flow into reservoir system	Continue normal use while alert to low flow potential	Institute voluntary** conservation program in order to reduce demand from river; begin coordination with Minneapolis to optimize river withdrawals	Institute sprinkling restrictions** and reduce demand to 56 mgd; begin consideration of shift from river source to reservoir system and groundwater supplements as required to optimize use of river	Continue optimizing river versus supplemental source use; institute mandatory** conservation program and reduce demand to 45 mgd; work with Drought Task Force to define critical supply needs
Metropolitan Waste Control Commission (MWCC)	Maintain treatment levels to assure compliance with water quality standards; begin aeration protocol at flows <7,000 cfs	Maintain treatment levels to assure compliance with water quality standards; continue aeration protocol	Continue program from 2,000 cfs level	Continue program from 2,000 cfs level	Continue program from 2,000 cfs level

Table 6 (continued). Drought Response Plan

Northern States Power (NSP)	Withdrawals as specified by permit conditions; begin public energy conservation program	Withdrawals as specified by permit conditions; continue public conservation program	Withdrawals as specified by permit conditions; as dictated by electrical demand: -interrupt oil customers -obtain power from most reliable and economic sources (includes purchases)	Withdrawals as specified by permit conditions; continue program from 1200 cfs level; as dictated by electrical demand: -implement water savings programs inside plants -reduce water appropriation rates at Monticello	Withdrawals as specified by permit conditions; respond to energy demand by implementing voluntary and emergency measures to conserve energy and keep plants operating at as high a level as possible; continue activities from previous flow levels
Mississippi Headwaters Board	Verify that flows have dropped below average for summer conditions	Begin contacts with headwaters interests in anticipation of low flows; serve as information liason between upstream interests and Drought Task Force	Continue in liason position	Continue in liason position	Continue in liason position

* From USGS data (cfs); subject to annual revision:

January - 4080	July - 6173
February - 4069	August - 4416
March - 5624	September - 4666
April - 15560	October - 5137
May - 11990	November - 4971
June - 10770	December - 4419

* The Drought Task Force is an officially constitued DNR advisory committee comprised of representatives of DNR-Division of Waters, NSP, St. Paul Water Utility, Minneapolis Water Works, Metropolitan Council, Mississippi Headwaters Board, MWCC and MPCA. Coordination with the Corps of Engineers is also assumed.

** Voluntary conservation would typically involve a request by the supplier for its customers to limit the discretionary use of water. Sprinkling restrictions could very from an odd-even system of use to a total ban. Mandatory conservation would likely include a ban on all outside and discretionary uses of water, including possible limits on industrial/commercial uses.

conditions the Corps will not necessarily rule in favor of the state if a request for release is made, especially if its evaluation shows that an increase above the agreed upon level of 270 cfs is likely to cause a negative impact on one of their priority users in the Headwaters area. Also, the Corps of Engineers decision-making process might be interrupted by court action if a dispute arises, thus lessening the possibility of the Metro Area's ever receiving water from the Headwaters system.

In its draft 1989 low-flow review, the Corps has stated a need to undertake several institutional actions to respond better to the state's needs during a drought. These actions include better interagency coordination, an internal drought management team and an improved public information program. The Corps said it could also assist in an emergency by decreasing or suspending lockages, or by artificial aeration through Corps-operated dams.

Related to the drought response matrix is the requirement in Minnesota Statutes, Chapter 105.417 subd.5 that all surface water appropriators prepare contingency plans that spell out their response to a water supply shortage. The DNR reports that-- except for NSP and the St. Paul Water Utility which have their own contingency plans-- most surface water users have not prepared these plans. Instead most users have signed a statement attached to the DNR permit that they will agree with DNR's decisions in the event of future water shortages. The DNR, though, has not been able to dedicate the personnel to promote the preparation of these plans, but anticipates more attention to this in the future. Additionally, the legislature should consider the extension of this requirement to all large-scale users, including users of ground water, and provide adequate resources to the DNR to implement the program. Expanding Ch. 105 to include groundwater users will put the Metropolitan Area in a position of preparedness, unlike during the two droughts of 1976 and 1988.

The drought plan in Table 6 does not address action by users not withdrawing water from the Mississippi River. The recommended legislative action for drought contingency plans for all large users would cover municipal and commercial/industrial users of groundwater. However, until Chapter 105 is amended, if seen fit by the legislature, municipal, industrial and commercial users of groundwater should prepare their own plans. Municipal water suppliers should include the means that they will use to notify customers of a water conservation effort. Similarly, industrial and commercial should prepare contingency plans for operation with less water should the necessity arise.

4. RECOMMENDATIONS

SHORT-TERM DROUGHT RESPONSE

1. The approach outlined in this report to the legislature should be followed by all affected parties until a long-term water supply plan is developed and adopted for the Metropolitan Area.

2. To the extent possible, excess water flowing in the Mississippi River should be used as a primary source of water supply. The Minneapolis Water Works should continue its endeavor to locate a supplemental source of water because of uncertainties in the quality of the Mississippi River. In preparing a long-term water supply plan for the region, the Metropolitan Council should evaluate the feasibility of moving towards a regionally-planned, locally-operated, water supply system that relies more on surplus surface water. Groundwater should be used judiciously and supplement surface water supplies when surpluses are not available. The long-term water supply plan should define the conditions under which "surplus" flows exist and examine alternative methods of using this surplus.

3. Major water users in the Metropolitan Area should first adopt a conservation approach to water use before looking for supplemental sources of water from outside of the region. Specifically, the matrix of response actions contained in Table 6 should be adopted and followed by the users at the respective trigger flows. Adoption of the plan by the appropriate parties should be mandated by the legislature. Municipal, industrial and commercial users not relying on the Mississippi River should prepare their own contingency plans for the conservation of water.

4. The Corps of Engineers and the DNR should formulate a cooperative arrangement with all of the operators of water control structures on, or adjacent to, the Mississippi River.

5. A critical flow level of 554 cfs (357 mgd) should be maintained at Anoka in order to meet the needs of surface water users in the Metropolitan Area, assuming they have begun conservation efforts. Attainment of this level of flow in the matrix (Table 6) will trigger the consideration of alternative sources of water, including a supplemental release from the Headwaters Reservoir system.

6. The state of Minnesota through the DNR, and the region through the Metropolitan Council should continue efforts to coordinate drought response with the Corps of Engineers.

7. The Corps of Engineers and the DNR should proceed with their cooperative study of the in-stream flow needs of the Mississippi River and its tributaries. The MWCC and the MPCA should be involved in the evaluation in order to account for wastewater impacts on the river.

8. The Minnesota Department of Health (MDH), with the help of MPCA and the DNR, should study options for the reuse and reinjection of water from such sources as water treatment pump-outs, once-through air-conditioning, and industrial non-contact cooling water. Agency policy allowing certain controlled water reuse and reinjection should be considered, based upon the findings of the MDH study.

LEGISLATIVE ACTIONS

9. The legislature should consider legislation requiring the adoption of the major elements of the short-term drought response plan outlined in Table 6.

10. A state drought management authority should be established in the State of Minnesota to respond to drought-related emergencies and to prepare a statewide framework for drought response. The DNR is a logical choice because of its existing regulatory authorities. If the DNR is given expanded drought-response authority, a formal state advisory group or standing drought task force should be established, consisting at least of the MPCA, the Metropolitan Council, the MWCC, the Mississippi Headwaters Board, NSP, and the cities of Minneapolis and St. Paul. This advisory committee would be expected to consult with the Corps of Engineers on matters pertaining to the Mississippi River. The drought management authority should establish a process for dealing with drought statewide and be given adequate resources to properly monitor the water resource inside and outside of the Metropolitan Area.

11. Minnesota Statutes, Chapter 105.417, should be expanded to include all major water users of both surface water and groundwater. No new appropriation permits should be issued by the DNR unless a contingency plan is prepared by the user. A time limit should be established within which all existing permits will be reissued with the contingency plan requirement applied. The DNR should review its policy on allowing users to "accept the consequences" in lieu of preparing a contingency plan and the MDH should require a DNR approved contingency plan before issuing well approvals.

LONG-TERM WATER SUPPLY PLAN

12. Alternative and emergency sources of water supply for the Metropolitan Area, including those sources evaluated in previous studies, should be re-evaluated on their social, environmental, economic and political impacts/relevance in order to update feasibility.

13. The long-term plan should evaluate the results of the latest USGS estimates of available groundwater and adjust the figures to represent the additional capacity lost to contamination. The plan should also define what level of withdrawal would be considered "optimal".

14. Following the second recommendation above, the plan should evaluate the long-term feasibility of developing a regionally planned water supply system that would, among other things, stress a more efficient use of surplus surface water and a shift from the unplanned use of groundwater; evaluate the feasibility of interconnecting municipal water supply systems in order to accommodate this shift in water use and provide emergency back-up for most suppliers, and examine how problems caused by the mixing of surface water and groundwater could be overcome; determine methods available to store and transfer surface water during periods of surplus river flow; and evaluate institutional arrangements and financial resources needed to undertake a regionally-planned supply system.

15. The economic implications of supplying a limited commodity (water) during a period of shortage should be examined. Among implications that need to be reviewed are how the cost of alternative supplies would be shared among users; how a system incorporating priority uses with the

users' ability to pay and the need to keep the cost of water low could work; and how demand could be held down by raising the price of water.

16. Responsibilities of agencies planning water use and supply for the Metro Area, Greater Minnesota and state water planning activities should be clarified, with particular attention to those activities in the upper Mississippi River basin.

17. A water education program should be developed with a focus on "growth managers"-- planners and decision-makers who guide the growth and development of the region. Public awareness efforts should also be the focus of educational programs carried out by both government agencies and water suppliers.

18. A detailed plan that aims to balance water availability with demand should be prepared, using statistics on the likelihood of obtaining water from various sources under differing climatic and demand conditions. In cooperation with the Corps of Engineers, the Metropolitan Council will continue to project the demand for water as the Metropolitan Area grows.

19. Proposed changes in the Federal Safe Drinking Water Act should be evaluated for their impact on the development of surface water and groundwater supplies. Specifically, the cost implications of treating one source versus the other should be examined.

20. The Metropolitan Council should collect and distribute information on effective water conservation techniques available to domestic, industrial and commercial users. It should also consider methods for implementing conservation of water in the region, including introduction through a mandatory state building code.

21. The Metropolitan Council should work with the MWCC and the MPCA to assure that a maximum cooperative effort is made to maintain good water quality in receiving streams during periods of extreme low flow.

22. Municipal water suppliers should be surveyed to determine the price they charge for water, the amount of commercial/industrial use of municipal water and the occurrence of well problems.

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