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IMPACT OF LAKE MICHIGAN ALLOCATIONS ON THE CAMBRIAN-ORDOVICIAN AQUIFER SYSTEM

by

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ABSTRACT

Overpumping of the Cambrian-Ordovician aquifer in the Chicago area has caused severe water level declines in portions of Cook, DuPage, Kane, and Will Counties. Recent changes in the accounting procedure involved in diversion of Lake Michigan water have released more water for public supplies. As communities currently withdrawing water from deep wells receive allocations of Lake Michigan water, deep pumpage will decrease in those areas and water levels will partially recover. Major cones of depression will shift southward to Joliet and westward to the Fox River communities north of Aurora. Critically low water levels caused by pumpage in these areas will result in a loss of as much as 19% of pumping capacity by the year 2020. Despite lake allocations, deep pumpage will grow again and will still exceed the practical sustained yield (65 mgd) of the aquifer. Continued growth in Wisconsin pumpage will also contribute an estimated additional decline of about 80 feet near the state line between 1980 and 2020.

INTRODUCTION

Purpose and Scope

Within the eight-county northeastern Illinois area (Cook, DuPage, Grundy, Kane, Kendall, Lake, McHenry, and Will Counties) the Cambrian-Ordovician (deep sandstone) aquifer has been a reliable water supply for public and industrial use for many years. However, as this area has grown — particularly in the last 20 years — and pumpage has increased, water levels within the aquifer system have declined drastically near centers of major withdrawals, and their associated cones of depression have been enlarged, affecting large portions of Cook, DuPage and Will Counties.

To mitigate the continuing depletion of this resource, the state has assessed various alternatives for meeting projected water demands (Singh and Adams, 1980; Schicht et al., 1976; Beaver, 1974; Illinois State Water Survey and Hittman Associates, 1973; Moench and Visocky, 1971; Schicht and Moench, 1971). Inherent in all of these studies is the assumption that water levels will not be allowed to decline below the top of the Ironton-Galesville sandstone — the most productive unit of the Cambrian-Ordovician aquifer. If the Ironton-Galesville sandstone is dewatered, yields of wells will decrease drastically.

Recent changes in the accounting procedure involved in diversion of Lake Michigan water allow more water to be made available for public water supply. Eighty-six public water systems that currently rely on groundwater have received an allocation of lake water. Many of these systems currently use water from the Cambrian-Ordovician aquifer. One of the goals of the Illinois Department of Transportation's program for the allocation of Lake Michigan water, which is also the goal of Illinois state statutes pertaining to allocation, is to reduce withdrawals from the deep aquifer. In the interest of planning to meet anticipated water demands of the year 2020, it is important to assess the impact of reduced withdrawals regionally and to identify areas where critically low water levels can be anticipated as a result of continued pumpage.

This study utilizes a digital computer model of the Cambrian-Ordovician aquifer to predict the effect of anticipated pumping schedules on groundwater levels throughout the area simulated by the model. The scope of the study was divided into the following tasks:

1) Identify communities supplied by deep aquifer pumpage in the study area. This task relied on information from the State Water Survey files as well as the Illinois Water Inventory Program at the Water Survey.

2) Calculate water demands for the years 1980-2020 and compute deep aquifer withdrawals based on Lake Michigan allocations and water demand projections. This task was performed by the Illinois Department of Transportation, using 1980 water use data from the Illinois Water Inventory Program and water demand models for the study area.

3) Identify current industrial deep pumpage in the study area and determine projected usage. A telephone survey of approximately 65 industries was conducted in which anticipated deep water demands for the decades between 1980 and 2020 were determined. It was necessary to mail a small number of follow-up requests to complete the survey.

4) Assess the current conditions in the deep aquifer system. Outline the extent and severity of water level declines caused by groundwater withdrawals since the 1860's. Data used were from a mass water level measurement made by the State Water Survey in October and November 1980 (Sasman et al., 1982) and from a piezometric surface map constructed by Suter et al. (1959) for pre-development conditions.

5) Verify the aquifer model. The digital computer model has been used successfully in the past to predict aquifer response to various pumping schemes. In several areas of heavy groundwater withdrawals, however, severe dewatering of the Galena-Platteville Formation and sometimes even the St. Peter Sandstone has occurred, resulting in a conversion from artesian to water-table conditions. Because the model had previously been verified only under artesian conditions, a new calibration was necessary.

6) Use the model to:
    a) Predict water levels based on current and projected water levels through 2020

b) Identify when and where problems (critical water levels) will occur
c) Project when/if the practical sustained yield will be attained under reduced withdrawal schemes
d) Determine the impact of reduced groundwater withdrawals on water levels in southern Wisconsin

An additional task, which was not included in the original proposal of study, but was determined later to have an important bearing on the study, was to estimate the current and future impact of Wisconsin pumpage on water levels in Illinois. Fetter (1981) has shown that drawdowns in Illinois due to groundwater withdrawals in Wisconsin are substantial and will continue to increase. A simple analytical model and Fetter's projected Wisconsin deep pumpages were used to estimate future impacts in Illinois.

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GROUNDWATER AVAILABILITY AND DEVELOPMENT

Geohydrology

The groundwater resources of northeastern Illinois have been described in numerous reports of the Illinois State Water Survey and State Geological Survey. The most comprehensive early work by Suter et al. (1959) summarizes these resources as coming from four aquifer systems:

1) Sand and gravel deposits in the glacial drift

2) Shallow dolomite formations, mainly of Silurian age

3) The Cambrian-Ordovician aquifer (often referred to as the deep sandstone aquifer), of which the Ironton-Galesville and Glenwood-St. Peter sandstone are the most productive individual units

4) The Mt. Simon aquifer, consisting of sandstones of the Mt. Simon Formation and the Elmhurst member of the lower Eau Claire Formations of Cambrian age

The descriptions of the various geohydrologic units and their relationships to one another are given in figure 1. As seen, the Cambrian-Ordovician aquifer consists, in descending order, of the Galena-Platteville dolomite, Glenwood-St. Peter sandstone, and Prairie du Chien Formation of Ordovician age; and the Eminence-Potosi dolomite, Franconia Formation, and Ironton-Galesville sandstone of Cambrian age. The aquifer is confined between the Maquoketa Formation at the top, which separates it from the shallow dolomite aquifer, and the Eau Claire Formation at the bottom, which separates it from the Elmhurst-Mt. Simon aquifer below.

The aquifer is encountered at an average depth of 500 feet and averages about 1000 feet in thickness. It dips to the southeast, so that the Galena-Platteville dolomite, the uppermost unit, is encountered at an elevation of about 700 feet above mean sea level in the northwestern part of the study area and about 100 feet below mean sea level in the southeastern part. Wells penetrating the entire thickness of the aquifer range in depth from 1200 feet in the northwest to 1900 feet in the southeast.

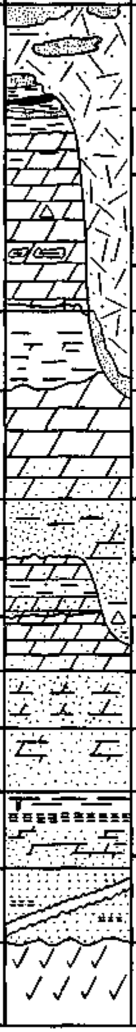
The Glenwood-St. Peter sandstone is present throughout the study area and averages about 200 feet in thickness, although locally it may exceed 600 feet in thickness. This sandstone generally yields less than 200 gallons per minute (gpm) to wells in the Chicago area and is the second most productive unit of the Cambrian-Ordovician aquifer.

The most productive single unit of the aquifer is the Ironton-Galesville sandstone which is found throughout the study area. This sandstone is generally between 150 and 200 feet thick. Most high-capacity deep wells are finished in this unit and obtain a major portion of their yield from it.

Many wells finished in the Ironton-Galesville sandstone are open throughout most of the Cambrian-Ordovician aquifer and are cased only opposite sections which cave or have particular water quality problems. On a regional basis, therefore, the entire sequence of units behaves as one aquifer.

The primary recharge areas for the Cambrian-Ordovician aquifer are the areas where the Galena-Platteville dolomite is the uppermost bedrock formation: Boone, DeKalb, Kane, Kendall, and McHenry Counties, and southeastern Wisconsin. In these primary recharge areas, the aquifer receives water from the overlying glacial deposits which, in turn, are recharged directly from precipitation. In the Chicago region the aquifer receives water by lateral movement from the recharge areas and also to a lesser extent by vertical leakage through the Maquoketa Formation.

Suter et al. (1959) estimated that the practical sustained yield of the Cambrian-Ordovician aquifer in the Chicago area was 46 million gallons per day (mgd). The practical yield is the amount of water that can be withdrawn without eventually dewatering the Ironton-Galesville sandstone or exceeding recharge. Walton (1964) estimated that the maximum amount of



SYSTEM	SERIES	GROUP OR FORMATION	GRAPHIC LOG	THICKNESS (FEET)	DESCRIPTION	AQUIFERS
QUATERNARY	PLEISTOCENE			0 - 400+	Unconsolidated ice - and water-laid deposits, pebbly clay (till), silt, sand and gravel, generally discontinuous and interbedded; alluvial silts and sands commonly present along streams	Glacial drift aquifers
PENNSYLVANIAN				0 - 175	Shale; sandstones, fine grained; limestone; coal; clay	Shallow bedrock aquifers
MISSISSIPPIAN DEVONIAN *						
SILURIAN	NIAGARAN			0 - 400+	Dolomite, very pure to very silty, cherty; shale partings; thin shales and argillaceous beds frequently present in lower parts of Silurian dolomite.	
	ALEXANDRIAN			0 - 165	Upper and middle units - shale, light gray to green, plastic to brittle, some dolomite, silty; dolomite, mostly silty, argillaceous; minor limestone Lower unit - shale, dark gray, black, brown, plastic to brittle; some dolomite in upper part; silty, argillaceous.	
ORDOVICIAN	CINCINNATIAN	Maquoketa		0 - 250+		
	CHAMPLAINIAN	Galena Platteville		150 - 350+	Dolomite, cherty; sandy at base; limestone; shale partings.	Cambrian-Ordovician aquifer
		Glenwood St. Peter		75 - 650	Sandstone, fine to coarse grained; shale at top; locally cherty red shale at base.	
	CANADIAN	Prairie du Chien		0 - 340	Dolomite, sandy, cherty, interbedded with sandstone.	
CAMBRIAN	CROIXAN	Eminence Potosi		0 - 225	Dolomite, white, fine grained sandy at base; drusy quartz.	
		Franconia		45 - 175	Sandstone, dolomite, and shale, glauconitic, green to red, micaceous.	
		Ironton Galesville		103 - 275	Sandstone, fine to medium grained, well sorted, upper part dolomitic	
		Eau Claire		235 - 450	Shale and siltstone, dolomitic, glauconitic; sandstone, dolomitic, glauconitic; dolomite, sandy	
		Mt. Simon		2000±	Sandstone, coarse grained, white, red in lower half; lenses of shale and siltstone, red, micaceous.	Mt. Simon aquifer
PRECAMBRIAN					Not penetrated by wells in Chicago area. Nearby wells encounter red or gray granite or similar rocks.	

* Mississippian rocks present in Des Plaines Disturbance.
Devonian rocks present as crevice fillings in Silurian rocks.

after Hughes et al. (1966)

Figure 1. Geologic column and aquifer descriptions of northeastern Illinois

recharge could be increased to about 65 mgd if the number of pumping centers was increased over the number in 1959, pumping centers were shifted to the west to increase flow gradients, and well spacing was increased.

Fetter (1981) estimated that the practical sustained yield of the Cambrian-Ordovician aquifer in southeastern Wisconsin was 34 mgd.

Increase of Groundwater Pumpage

Records indicate that the first deep well in northern Illinois was drilled in Chicago in 1864. The artesian pressure at the time was high enough to cause the well to flow at a rate of 150 gpm or about 200,000 gallons per day. By 1900 a considerable number of municipal and industrial wells were tapping the Cambrian-Ordovician aquifer and pumpage is estimated to have been 23.2 mgd. During the next half century pumpage increased by nearly 1 mgd each year, and by 1955 it had reached 75.6 mgd. Pumpage then sharply increased at a rate of 4.6 mgd per year and reached a peak of 186.2 mgd in 1979 (Sasman et al., 1982). Pumpage in 1980 totaled 183.7 mgd. Of this total, 141.9 mgd was withdrawn for public water supplies, 34.0 mgd for industrial use, and 7.8 mgd for rural domestic use.

Data presented by Fetter (1981) indicate that pumpage in southeastern Wisconsin exceeded the practical sustained yield there by the late 1970's.

It should be noted that in the past, and to a lesser extent at present, pumpage from deep wells in northeastern Illinois has included pumpage from wells known to be open to both the Cambrian-Ordovician aquifer and the Mt. Simon aquifer, and from wells open to both the shallow dolomite and the Cambrian-Ordovician (Schicht et al., 1976). In addition, many deep wells were improperly cased through the shallow dolomite, and leakage down the well bore may have been significant. Suter et al. (1959) estimated the contributions to deep pumpage from these outside sources to be as much as 43% of the total in 1958. It is known that many wells formerly open to the Mt. Simon sandstone have been plugged in that unit because of deteriorating water quality. As discussed in the section on the aquifer model, outside contributions by 1975 may have declined to about 14% of the total withdrawals.

Water Level Decline

According to Suter et al. (1959), the artesian pressure in the Cambrian-Ordovician aquifer in 1864 was sufficient tq cause wells to flow in the Chicago-Joliet-Fox Valley area. From 1864 to 1958 water levels declined about 660 feet at Chicago — a rate of about 7.1 feet per year. By 1971 declines had increased to about 9 feet per year so that by 1980 total declines were over 900 feet in parts of northern Cook and northeastern DuPage Counties. In major pumping centers at Aurora, Elgin, and Joliet and in eastern DuPage County and northern and western Cook County, dewatering of the uppermost units of the aquifer was substantial, as shown in table 1.

Table 1. Portions of Deep Aquifer Dewatered in 1980

Pumping center	Formations dewatered
Aurora	More than 2/3 of the Galena-Platteville
Elgin	More than 2/3 of the Galena-Platteville
E. DuPage-W. Cook Co.	All of Galena-Platteville and less than 1/4 of the Glenwood-St. Peter
Joliet	All of Galena-Platteville and nearly 1/4 of the Glenwood-St. Peter
N. Cook Co.	All of Galena-Platteville and more than 1/3 of the Glenwood-St. Peter

The piezometric surface of the Cambrian-Ordovician aquifer in the fall of 1980 is shown in figure 2. The major pumping centers are outlined by the -100 foot elevation contours. As shown by the shape of the piezometric surface, groundwater movement toward these major pumping centers is primarily from the north and west, and to a lesser extent from the south and southwest.

EFFECT OF ALLOCATION ON PROJECTED DEEP GROUNDWATER DEMANDS

The Illinois Department of Transportation, Division of Water Resources, which has been charged with administering the Lake Michigan water allocation program, determined the available allocations for each applicant by considering the population of the area to be served, projected population, current and projected per capita consumption within the area, nature and extent of industrial uses, municipal and hydrant uses, implementation of conservation practices, and reduction of unaccounted-for flows as required by the rules. Table 2 lists current and projected deep pumpages for communities within the study area which have been using deep wells in the past, as well as the effects of allocation on these pumpages. Many of these communities have received an allocation for Lake Michigan water. However, more than 40 communities expect to continue pumping from deep wells, including Joliet and several Fox River Valley communities. The projected public water demands from deep wells in 2020 are estimated to be' about 78.5 mgd. This figure includes the communities listed in table 2 as well as several additional small subdivisions.

At least 75 non-public supplies (industries and utilities) will also continue to pump water from deep wells. A telephone survey of these consumers was made in order to estimate their anticipated future water pumpages. Most non-public consumers anticipated level or reduced consumption because of water conservation plans. Nonetheless, by 2020 these supplies are expected to pump 29.8 mgd.

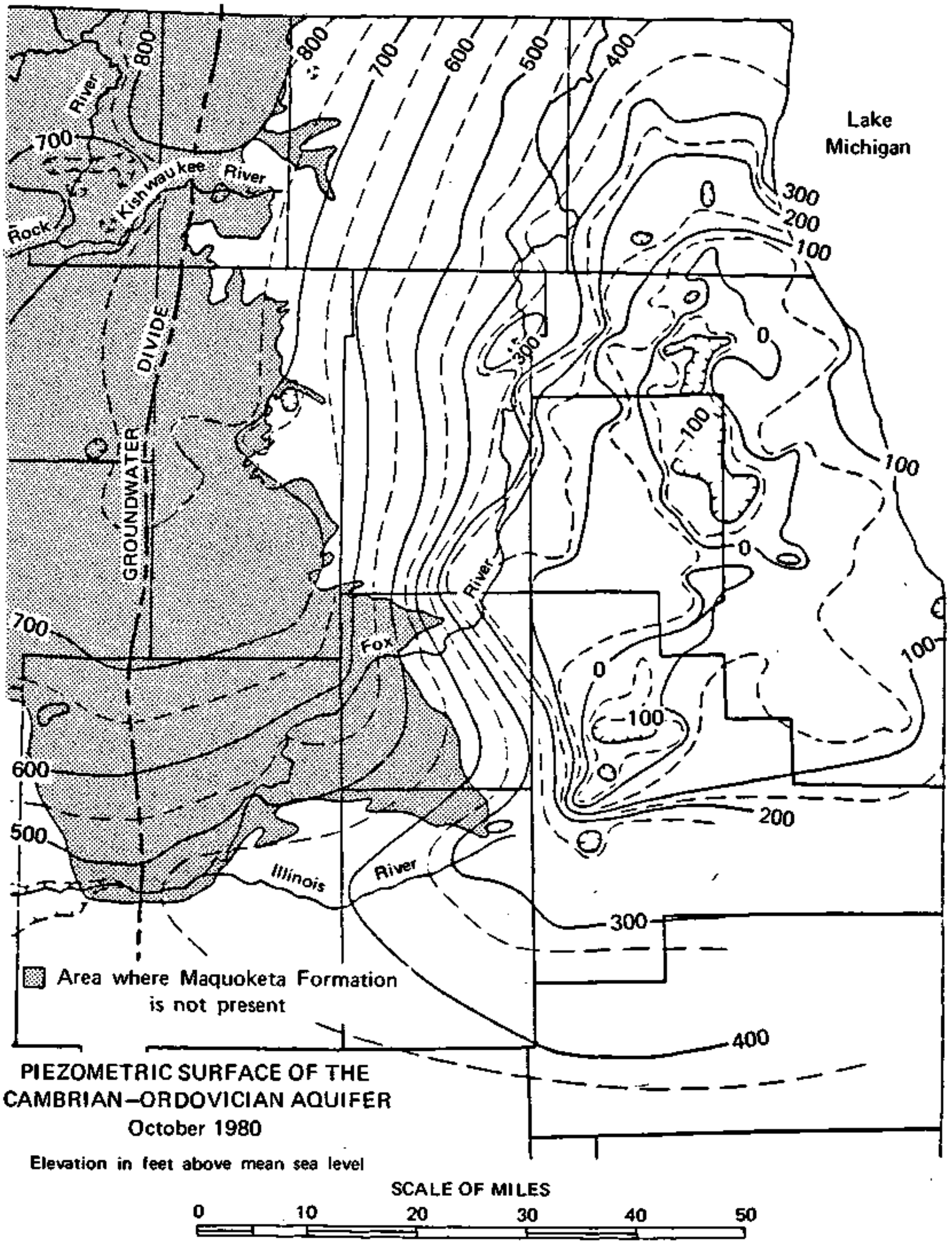


Figure 2. Piezometrio surface of Cambrian-Ordovician aquifer, fall 1980

Table 2. Projected Pumpages from Public Water Supply Deep Wells

Supply	1980	1985	1990	2000	2010	2020	Predicted connection to L. Michigan	End of deep pumpage
	Current and projected deep pumpage (mgd)							
<u>Cook County</u>								
Arlington Heights	7.94	8.35	0	0	0	0	1985	1986
Bartlett	0.52	0.67	0.76	0.92	0.94	0.98	-	-
Bellwood	3.27	3.97	3.78	3.63	3.66	3.82	-	-
Buffalo Grove	0.69	2.58	0	0	0	0	1985	1986
Chicago Heights	1.46	0	0	0	0	0	1984	1985
Citizens Utilities Co.								
Chicago Sub.	1.76	1.96	0	0	0	0	1985	1986
Fernway	0.34	0	0	0	0	0	1982	1985
Waycinden	0.58	0.56	0	0	0	0	1985	1986
DesPlaines	0.86	0	0	0	0	0	existing	
Domestic Utilities Co.	2.29	0	0	0	0	0	1982	1985
East Chicago Heights	0.24	0.76	0.84	1.07	1.11	1.15	-	-
Elk Grove Village	5.12	6.91	0	0	0	0	1985	1986
Ferndale Heights	1.38	0	0	0	0	0	1984	1985
Flossmoor	0.89	0	0	0	0	0	1984	1985
Glenview	0*	0	0	0	0	0	existing	-
Glenwood	1.30	0	0	0	0	0	1984	1985
Hanover Park	2.14	2.43	0	0	0	0	1985	1990
Hickory Hills	0.44	0	0	0	0	0	existing	-
Hillside	0	0	0	0	0	0	-	-
Hoffman Estates	2.56	3.40	0	0	0	0	1985	1986
Homewood	1.86	0	0	0	0	0	1984	1985
LaGrange	0**	0	0	0	0	0	1983	1984
Lemont	0.71	0.48	0	0	0	0	1986	1990
Lynwood	0.26	0	0	0	0	0	1981	1985
Lyons	0.80	0	0	0	0	0	1981	1985
Mt. Prospect	4.62	2.39	0	0	0	0	1984	1986
Orland Park	0.42	0	0	0	0	0.	1983	1984
Palatine	2.40	0	0	0	0	0	1984	1985
Riverside	0.83	0	0	0	0	0	1982	1983
Rolling Meadows	2.63	2.82	0	0	0	0	1985	1986
Schaumburg	3.56	3.39	0	0	0	0	1985	1990
South Chicago Heights	0.80	0.80	0.83	0.87	0.91	0.95	-	-

Table 2. Continued

	Current and projected deep pumpage (mgd)						Predicted connection	End of deep
Supply	1980	1985	1990	2000	2010	2020	to L. Michigan	pumpage
Cook County (continued)								
Streamwood	0.45	0.43	0	0	0	0	1988	1990
Thornton	0.36	0	0	0	0	0	1982	1983
Western Springs	1.15	1.20	1.30	1.30	1.30	1.40	-	-
Wheeling	1.40	0	0	0	0	0	1983	1985
DuPage County								
Bensenville	2.64	2.55	0	0	0	0	1988	1990
Blooraingdale	0.98	1.65	0	0	0	0	1988	1990
Carol Stream	0.35	0.64	0	0	0	0	1988	1990
Clarendon Hills	0.55	0.63	0	0	0	0	1988	1990
Darien	0.37	<0.01	0	0	0	0	1988	1990
Elmhurst	4.93	5.70	0	0	0	0	1987	1988
Lombard	4.07	4.07	0	0	0	0	1988	1989
Naperville	2.48	2.78	0	0	0	0	1988	1989
Oakbrook	2.90	4.33	0	0	0	0	1987	1988
Roselle	0.16	0.38	0	0	0	0	1987	1988
Villa Park	1.59	1.77	0	0	0	0	1987	1988
West Chicago	1.77	2.18	0	0	0	0	1989	1990
Westmont	1.31	0.62	0	0	0	0	1987	1988
Willowbrook	0.44	0.46	0	0	0	0	1988	1990
Wooddale	0.37	0.51	0	0	0	0	1987	1988
Grundy County								
Braceville	0.02	0.02	0.02	0.02	0.02	0.02	-	-
Coal City	0.40	0.40	0.40	0.40	0.40	0.40	-	-
Diamond	0.07	0.07	0.07	0.07	0.07	0.07	-	-
Eileen	0.04	0.04	0.04	0.04	0.04	0.04	-	-
Gardner	0.10	0.11	0.11	0.12	0.13	0.14	-	-
Kinsman	0.03	0.03	0.03	0.03	0.03	0.03	-	-
Minooka	0.18	0.21	0.26	0.33	0.41	0.49	-	-
Morris	0.86	1.10	1.28	1.70	1.85	2.00	-	-
Ridgecrest	0.03	0.03	0.03	0.03	0.03	0.03	-	-
South Wilmington	0.09	0.09	0.09	0.09	0.09	0.09	-	-

Table 2. Continued

Supply	Current and projected deep pumpage (mgd) 1980	1985	1990	2000	2010	2020	Predicted connection to L. Michigan	End of deep pumpage
Kane County								
Aurora	9.86	12.24	14.49	0	0	0	1990	19.95
Batavia	1.47	1.86	2.04	2.47	2.80	2.94		
Burlington	0.04	0.04	0.04	0.04	0.04	0.04	-	-
Elburn	0.10	0.19	0.23	0.37	0.43	0.49	-	-
Elgin	9.14	4.86	5.30	6.64	7.10	7.45	-	-
Elgin State Hospital	0.27	0.27	0.27	0.27	0.27	0.27	-	-
Geneva	1.80	2.06	2.52	2.97	3.20	3.33	-	-
Hampshire	0.25	0.36	0.43	0.68	0.73	0.76	-	-
Ill. Youth Center	0.12	0.12	0.12	0.12	0.12	0.12	-	-
Montgomery	1.73	1.77	0.82	0	0	0	1995	2000
North Aurora	0.99	1.22	0	0	0	0	1989	1990
St. Charles	2.24	3.54	4.11	5.75	6.34	6.86	-	-
West Dundee	0.40	0.55	0.61	0.80	0.87	0.94	-	-
Kendall County								
Newark	0.07	0.07	0.07	0.07	0.07	0.07	-	-
Oswego	0.39	0.32	0.34	0.38	0.42	0.46	-	-
Yorkville	0.40	0.44	0.48	0.55	0.62	0.70	-	-
Lake County								
Grayslake	0.23	0.33	0	0	0	0	1985	1988
Gurnee	0.46	0.36	0	0	0	0	1985	1987
Ill. Beach State Park	0.21	0.21	0.21	0.21	0.21	0.21	-	-
Lake Zurich	0.98	1.51	1.79	2.25	2.53	2.80	-	-
Libertyville	1.08	1.71	0	0	0	0	1981	1986
Lincolnshire	0.69	0	0	0	0	0	1981	1982
Mundelein	1.46	1.53	0	0	0	0	1986	1987
Round Lake	0.24	0.36	0.47	0.92	1.10	1.27	-	-
Round Lake Beach	0.94	1.03	0	0	0	0	1987	1988
Vernon Hills	1.06	1.14	0	0	0	0	1986	1987
Wildwood-Gages Lake	0.48	0.59	0	0	0	0	1987	1988
Winthrop Harbor	0.25	0	0	0	0	0	existing	-

Table 2. Concluded

Supply	Current and projected deep pumpage (mgd) 1980	1985	1990	2000	2010	2020	Predicted connection to L. Michigan	End of deep pumpage
McHenry County								
Algonquin	0.20	0.81	0.97	1.54	1.63	1.70	-	-
Cary	0.65	1.07	1.39	2.67	3.03	3.41	-	-
Crystal Lake	2.03	2.85	3.40	4.92	5.43	5.84	-	-
Lake-in-the-Hills	0.18	0.18	0.18	0.18	0.18	0.18	-	-
Will County								
Braidwood	0.32	0.33	0.34	0.35	0.36	0.37	-	-
Ill. Pen.-Joliet	0.13	0.13	0.13	0.13	0.13	6.13	-	-
Ill. Pen.-Statesville	0.87	0.90	0.90	0.90	0.90	0.90	-	-
Joliet	10.16	13.71	14.50	15.72	16.62	17.59	-	-
Lockport	1.15	1.29	1.44	1.63	1.84	2.13	-	-
Plainfield	0.61	0.65	0.74	1.08	1.14	1.18	-	-
Rockdale	0.38	0.54	0.55	0.63	0.68	0.70	-	-
Romeoville	1.08	2.36	2.57	2.78	2.92	2.97	-	-
Wilmington	0.54	0.66	0.73	0.95	1.02	1.08	-	-
TOTAL	138.41	137.84	71.49	68.59	73.62	78.50		

*Glenview completed switch from deep wells in 1980

**LaGrange currently meeting its demand with shallow supplies.

Table 3 lists the total public and non-public groundwater pumpage expected in each township of the study area through the year 2020. The Joliet area (T.35N., R.10E.) with 21 mgd and the Crystal Lake area (T.43N., R.8E.) at nearly 11 mgd will be the largest groundwater pumping centers by 2020.

AQUIFER MODEL

Description

Walton (1962) described an idealized mathematical model of the Cambrian-Ordovician aquifer which had been developed to predict water level response to pumpage and to estimate the practical sustained yield of the aquifer (Suter et al., 1959). The model aquifer was a semi-infinite rectilinear strip of sandstones and dolomites 84 miles wide and 1000 feet thick. The model was bounded by a recharge boundary 47 miles west of Chicago and by two intersecting barrier boundaries 37 miles east and 67 miles south of Chicago.

On the basis of the results of 63 aquifer tests and other studies, the storage coefficient and transmissivity of the aquifer and the coefficient of vertical hydraulic conductivity of the Maquoketa Formation were found to be fairly uniform throughout large areas of northeastern Illinois, and Walton applied uniform values of these three parameters to the model: 0.00035, 17,000 gpd/ft, and 0.0005 gpd/sq ft, respectively. This model was linear in response and proved highly useful.

As pumpages increased dramatically in the Chicago region, however, dewatering began to occur and drawdown response became nonlinear. As a result, the original mathematical model could no longer be relied on to predict drawdowns in these areas accurately. Prickett and Lonnquist (1971) developed a digital computer model to improve on Walton's method for predicting water level response to deep pumpage.

The digital model developed by Prickett and Lonnquist included the two barrier boundaries, 37 miles to the east and 67 miles to the south of Chicago, used by Walton. The recharge boundary was set at about 54 miles to the west of Chicago to correspond to the subcrop of the Galena-Platteville dolomite. As water levels decline below the top of the Galena-Platteville dolomite, a conversion to water-table conditions takes place. Prickett and Lonnquist (1971) originally assigned a water-table storage coefficient of 0.05 for use when the conversion from artesian to water-table conditions occurred. They cautioned, however, that as further dewatering took place the water-table storage coefficient should be investigated and the model further verified. This will be discussed in the section on model calibration.

Physically the model uses a 100 by 100 variable-size finite-difference grid to provide a detailed area of interest around the major pumping centers and yet avoid the use of an excessive number of nodes (see figure 3). The grid interval in the area of detailed interest (I = 35 to 85 and J = 35 to 85) is one mile per node. Elsewhere the grid interval is

Table 3. Projected. Deep Pumpage From Public and Industrial Wells

		Current and projected deep pumpage (mgd)					
		1980	1985	1990	2000	2010	2020
Cook County							
T35N	R13E	0.89	0	0	0	0	0
	14E	4.13	1.57	1.67	1.94	2.02	2.10
	15E	0.26	0	0	0	0	0
36N	12E	0.68	0	0	0	0	0
	13E	0	0	0	0	0	0
	14E	2.08	0	0	0	0	0
	15E	0	0	0	0	0	0
37N	11E	1.03	0.88	0.40	0.40	0.40	0.40
	12E	0.44	0	0	0	0	0
	13E	0	0	0	0	0	0
	14E	0	0	0	0	0	0
	15E	0	0	0	0	0	0
38N	12E	5.29	4.54	4.59	4.64	4.64	4.74
	13E	1.97	1.94	1.94	1.94	1.94	1.94
	14E	0.72	0.46	0.46	0.46	0.46	0.46
	15E	0	0	0	0	0	0
39N	12E	3.99	4.19	4.00	3.85	3.88	4.04
	13E	0.11	0.09	0.07	0.07	0.07	0.07
	14E	0.09	0.12	0.12	0.12	0.12	0.12
40N	12E	1.62	1.62	1.06	0.77	0.77	0.77
	13E	0	0	0	0	0	0
	14E	0	0	0	0	0	0
41N	9E	3.10	3.53	0.76	0.92	0.94	0.98
	10E	6.11	4.07	0	0	0	0
	11E	5.70	1.49	0	0	0	0
	12E	3.16	0	0	0	0	0
	13E	0.51	0.51	0.51	0.51	0.51	0.51
	14E	0	0	0	0	0	0
42N	9E	0	0	0	0	0	0
	10E	6.46	0.61	0.05	0.05	0.05	0.05
	11E	16.45	2.57	0.03	0.03	0.03	0.03
	12E	0.57	0.57	0.57	0.57	0.57	0.57
	13E	0	0	0	0	0	0
DuPage County							
T37N	R11E	0.44	0.44	0.44	0.44	0.44	0.44
38N	9E	0	0	0	0	0	0
	10E	2.48	2.78	0	0	0	0
	11E	2.67	1.71	0	0	0	0
39N	9E	1.77	2.18	0	0	0	0
	10E	0	0	0	0	0	0
	11E	13.66	10.53	0.22	0.26	0.26	0.26
40N	9E	0.20	0.20	0.20	0.14	0.14	0.14
	10E	1.49	2.52	0	0	0	0
	11E	3.01	2.86	0	0	0	0

Table 3. Continued

		Current and projected deep pumpage (mgd)					
		1980	1985	1990	2000	2010	2020
Grundy County							
T31N	R6E	0.03	0.03	0.03	0.03	0.03	0.03
	7E	0	0	0	0	0	0
	8E	0.10	0.10	0.10	0.10	0.10	0.10
32N	6E	0	0	0	0	0	0
	7E	0	0	0	0	0	0
	8E	0.42	0.40	0.40	0.40	0.40	0.40
33N	6E	1.01	1.01	1.01	1.01	1.01	1.01
	7E	0.87	1.11	1.29	1.71	1.86	2.01
	8E	1.02	0.91	0.80	0.13	0.13	0.13
34N	6E	0	0	0	0	0	0
	7E	0.03	0.03	0.03	0.03	0.03	0.03
	8E	7.22	8.05	8.89	8.97	8.92	9.00
Kane County							
T38N	R6E	0	0	0	0	0	0
	7E	0	0	0	0	0	0
	8E	12.67	15.32	15.40	0.09	0.09	0.09
39N	6E	0	0	0	0	0	0
	7E	0.39	0.46	0.50	0.63	0.70	0.75
	8E	3.31	3.96	4.59	5.47	6.03	6.30
40N	6E	0	0	0	0	0	0
	7E	0	0	0	0	0	0
	8E	2.35	3.66	4.22	5.86	6.46	6.98
41N	6E	0.04	0.04	0.04	0.04	0.04	0.04
	7E	0	0	0	0	0	0
	8E	7.58	5.13	5.57	6.91	7.37	7.72
42N	6E	0.25	0.36	0.43	0.68	0.73	0.76
	7E	0	0	0	0	0	0
	8E	0.40	0.55	0.61	0.80	0.87	0.94
Kendall County							
T35N	R6E	0.07	0.07	0.07	0.07	0.07	0.07
	7E	0	0	0	0	0	0
	8E	0	0	0	0	0	0
36N	6E	0	0	0	0	0	0
	7E	0.02	0.02	0.02	0.02	0.02	0.02
	8E	0	0	0	0	0	0
37N	6E	0	0	0	0	0	0
	7E	0.40	0.44	0.48	0.55	0.62	0.70
	8E	1.14	0.94	0.96	1.00	1.04	1.08
Lake County							
T43N	R 9E	0	0	0	0	0	0
	10E	0.98	1.51	1.79	2.25	2.53	2.80

Table 3. Continued

		Current and projected deep pumpage (mgd)					
		1980	1985	1990	2000	2010	2020
Lake County (cont'd)							
	11E	0.28	0	0	0	0	0
	12E	0.64	0.64	0.64	0.64	0.64	0.64
44N	9E	0	0	0	0	0	0
	10E	1.46	0.62	0	0	0	0
	11E	2.22	0.82	0	0	0	0
	12E	0	0	0	0	0	0
45E	9E	0.40	0.40	0.40	0.80	0.80	0.80
	10E	1.47	1.22	0.51	0.96	1.14	1.30
	11E	1.04	0.64	0.18	0.26	0.26	0.26
	12E	0	0	0	0	0	0
46N	9E	0	0	0	0	0	0
	10E	0	0	0	0	0	0
	11E	0	0	0	0	0	0
	12E	0.26	0.21	0.21	0.21	0.21	0.21
McHenry County							
T43N	R5E	0	0	0	0	0	0
	6E	0	0	0	0	0	0
	7E	0	0	0	0	0	0
	8E	2.87	4.72	5.77	9.13	10.08	10.95
44N	5E	0.11	0.11	0.11	0.11	0.11	0.11
	6E	0	0	0	0	0	0
	7E	0	0	0	0	0	0
	8E	0	0	0	0	0	0
45N	5E	0	0	0	0	0	0
	6E	0	0	0	0	0	0
	7E	0	0	0	0	0	0
	8E	0.78	0.78	0.78	0.78	0.78	0.78
46N	5E	0.14	0.14	0.14	0.14	0.14	0.14
	6E	0	0	0	0	0	0
	7E	0	0	0	0	0	0
	8E	0.18	0.18	0.18	0.18	0.18	0.18
Will County							
T32N	R 9E	0.37	0.36	0.37	0.38	0.39	0.40
	10E	0	0	0	0	0	0
33N	9E	0.54	0.66	0.73	0.95	1.02	1.08
	10E	0.18	0.18	0.18	0.18	0.18	0.18
	11E	0	0	0	0	0	0
	12E	0	0	0	0	0	0
	13E	0	0	0	0	0	0
	14E	0	0	0	0	0	0
	15E	0	0	0	0	0	0
34N	9E	3.19	3.32	3.46	3.22	2.96	3.08
	10E	0.32	0.32	0.32	0.32	0.32	0.32
	11E	0	0	0	0	0	0

Table 3. Concluded

		Current and projected deep pumpage (mgd)					
		1980	1985	1990	2000	2010	2020
Will County (cont'd)							
	12E	0	0	0	0	0	0
	13E	0	0	0	0	0	0
	14E	0	0	0	0	0	0
	15E	0	0	0	0	0	0
35N	9E	0.34	0.34	0.34	0.34	0.34	0.34
	10E	14.25	17.85	18.55	19.85	20.79	21.00
	11E	0	0	0	0	0	0
	12E	0	0	0	0	0	0
36N	9E	0.61	0.65	0.74	1.08	1.14	1.18
	10E	2.60	2.75	2.90	3.09	3.29	3.59
	11E	0	0	0	0	0	0
37N	9E	0	0	0	0	0	0
	10E	1.28	2.56	2.77	2.98	3.12	3.17
TOTAL		166.64	135.57	103.59	99.44	104.20	108.29

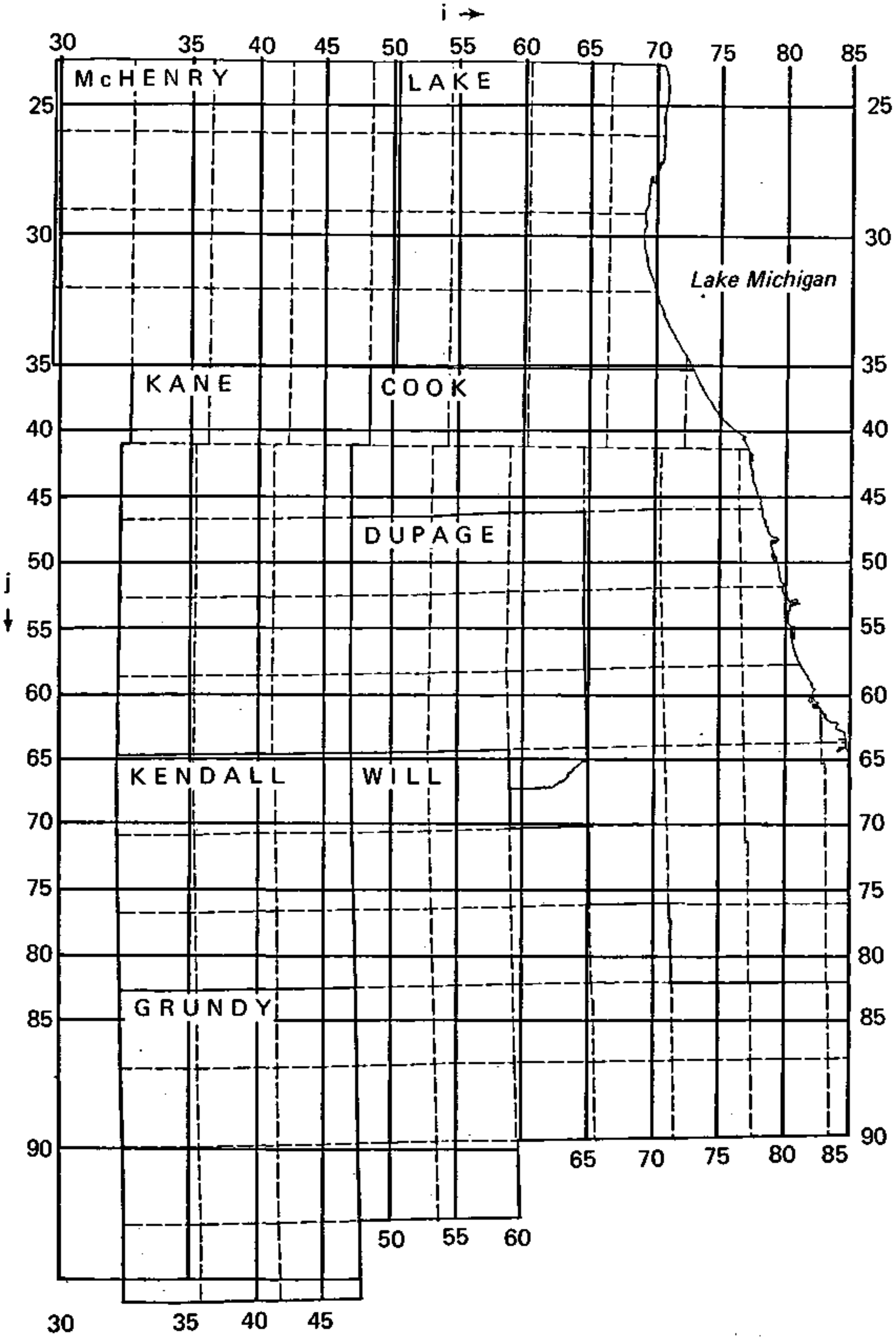


Figure 3. Model grid system in study area

two miles per node. The computer program for the Chicago area model has been described in detail by Prickett and Lonnquist (1971). A later modification by Schicht et al. (1976) allows water levels to decline to the top of the Ironton-Galesville sandstone but does not allow further declines below this critical level. Pumpages at these critical nodes are reduced in order to allow water levels to remain at the top of that formation.

Schicht et al. (1976) point out some limitations of the model. The model uses uniform average values of aquifer properties (it is basically a regional model) and with a node spacing of one mile in the area of detailed interest, the effective radius of those nodes is about 1100 feet (drawdowns are not corrected for this well radius effect). These limitations do not impose severe constraints on the usefulness of the model results, however, since pumping nodes simulate pumpages from their vicinity concentrated at those nodes and are generally not meant to model individual wells.

Pumpage at a given model node is held constant for a five-year period and then changed to a new five-year pumping rate for the next simulation. For the calibration runs (1970-1975 and 1975-1980) and the prediction runs (1980 to 2020), 112 pumping nodes were simulated.

Calibration

The validity of the Chicago area model was checked through a comparison of measured drawdowns with predicted values. In 1975 and 1980 water levels were measured in several hundred deep wells in northeastern Illinois (Sasman et al., 1977 and 1982). From piezometric maps presented in these reports and from estimated pre-development water levels (Suter et al., 1959) maps were constructed showing drawdown from pre-development (1864) to 1975 and 1980. These maps were then corrected for the effects of Wisconsin deep pumpage (discussed in the following section), since the model does not include pumping centers outside of Illinois.

Simulation runs were made for the period 1970-1975 and the results were compared with the adjusted drawdowns for 1975. Calibration of the model included adjusting pumpages at pumping centers known to have a contribution of water from the Mt. Simon Formation and adjusting the water-table storage coefficient conversion. A simulation of the period 1975-1980 was then conducted using minor additional adjustments in the water-table storage coefficient.

Several methods of comparison were used in testing the accuracy of the model. One method was to construct maps of predicted 1975 and 1980 drawdowns and to compare them visually with the previously constructed maps of drawdown corrected for Wisconsin effects — a qualitative procedure. A more quantitative approach was to compare predicted versus observed drawdowns at regular intervals within the area of detailed interest. These two methods assessed the accuracy of the model on a regional basis. A third and also quantitative approach was to compare predicted versus observed drawdowns at pumping nodes, which tested the accuracy of the model within major cones of depression.

A comparison of drawdowns corrected for the effects of Wisconsin pumpage (figure 4a) and drawdowns predicted by the model (figure 4b) for the year 1980 shows that in general the drawdown configuration predicted by the model agrees well with that of the corrected drawdown map. The model tends to overestimate drawdowns slightly in the area of northern Cook and northeastern DuPage Counties and to underestimate drawdowns in the Joliet area. A second set of maps comparing corrected versus predicted drawdowns by 1975 showed a similar closeness of agreement.

Drawdowns predicted by the model for 1975 and 1980 were compared with drawdowns corrected for Wisconsin pumpage at regular intervals in the area of detailed interest. Drawdowns predicted for 1980 showed an average error of +10.8% and an average range of errors of ±14.3%. This means that while the average of the absolute values of errors was 14.3%, the model had an overall error of +10.8% in the area of detailed interest. The average error in predicted drawdowns for 1975 was -5.1%, while the average of absolute values of error for that year was 8.8%.

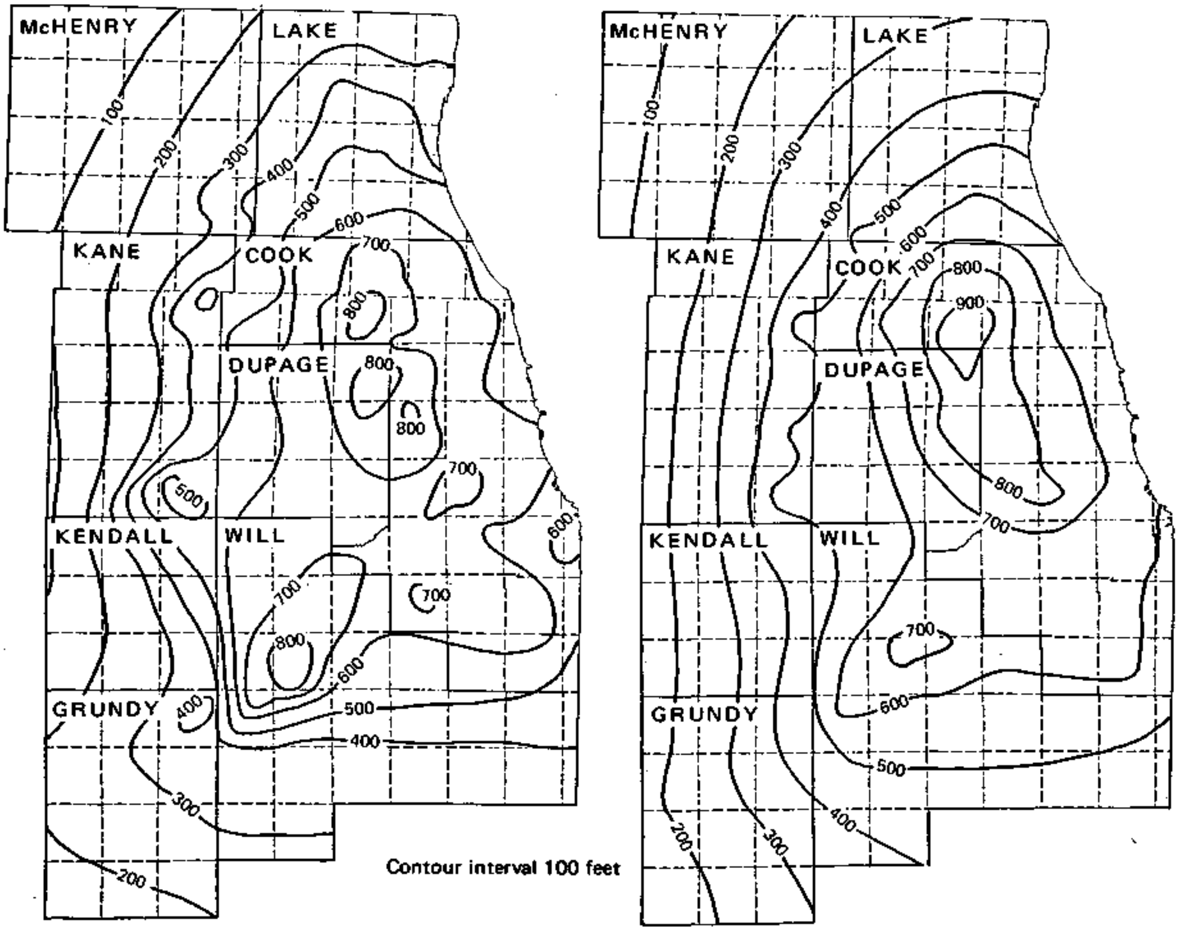
Predicted drawdowns were also tested at 27 major pumping nodes for 1980 and at 25 pumping nodes for 1975. For 1980 the overall average error at major pumping nodes was +13.6% while the average of the absolute error values was 16.2%. For 1975 the overall error was +6.0% and the average absolute error was 9.8%.

The results of the verification runs of the digital model indicated that, in general, the model simulated conditions on a regional basis fairly closely through 1980 and that it could be expected to predict the effects of future pumpage schemes with approximately the same accuracy as shown in the calibration (errors of 10 to 14%).

Effect of Wisconsin Pumpage

Fetter (1981) summarized the results of a computer model study of the Cambrian-Ordovician aquifer in southeastern Wisconsin and northeastern Illinois. The model was able to separate the effects of Wisconsin pumpages from those in Illinois, and Fetter presented distance-drawdown graphs and tabulated drawdowns at selected locations for the years 1973 and 1990. The Chicago model used in this report does not model Wisconsin pumpages, but the Fetter report allowed this author to estimate the effects of Wisconsin pumpage for the calibration years 1975 and 1980 and also for the prediction years 1985, 1990, 2000, 2010, and 2020.

An analytical model was derived for use in estimating the effects of future Wisconsin pumpages in Illinois. Average transmissivity and artesian storage coefficient values of 17,000 gpd/ft and 0.0002, respectively, were used in the model, along with a leakage coefficient of 3.0 x 10^{-7} gpd/cu ft used by Fetter (1981). To simplify computations of distance-drawdown, Wisconsin pumpages were concentrated at Milwaukee, the major pumping center in that state. Pumpage at the Milwaukee pumping center was adjusted until drawdowns at selected sites matched those given by Fetter. In the period 1963-1973 the total deep pumpage in southeastern Wisconsin averaged 28.3 mgd, and drawdown at the Illinois-Wisconsin border along the Lake County line was approximately 94 feet, according to Fetter. When



a. Drawdowns to 1980 corrected for Wisconsin pumpage b. Drawdowns to 1980 predicted by Chicago Model

Figure 4. Drawdowns to 1980, a) corrected for Wisconsin pumpage and b) predicted by Chicago model

pumpage at Milwaukee was adjusted to 25.7 mgd, or about 91% of the total pumpage for southeastern Wisconsin, drawdown at the state line also was predicted by the analytical model to be 94 feet. Predicted effects of future Wisconsin pumpages were derived by assuming a multiplier of 0.91 times the projected Wisconsin withdrawals and applying the resultant effective pumpage at Milwaukee to the analytical model. Estimated drawdowns at selected sites for 1980 and for future years are given in table 4.

Table 4. Drawdown in Feet Due to Wisconsin Deep Pumpages

Location	1980	1985	1990	2000	2010	2020
State Line	115	130	139	165	180	195
T.42N, R.11E (Arlington Hts)	65	87	96	129	149	170
T.39N, R.11E (Elmhurst)	42	65	75	108	130	150
T.41N, R.8E (Elgin)	52	76	86	120	140	162
T.38N, R.8E (Aurora)	32	47	53	83	105	125
T.35N, R.10E (Joliet)	20	34	41	68	90	110
Wisconsin pumpage (mgd) (after Fetter, 1981)	39	45	51	60	69*	78*

*Extrapolated from Fetter's data

EFFECT OF FUTURE PUMPAGES

Full Utilization of Allocation

Following the calibration runs for 1975 and 1980, the Chicago model was used to predict water level declines for the period 1980 to 2020 (figures 5 through 9), on the assumption of full utilization of the present allocation of lake water. Pumpage input to the model was in most cases accomplished by assigning a single node to a township and selecting the node whose location best approximated the center of pumpage. In five townships (T.35N., R. 10E.; T.38N., R.12E.; T.39N., R.11E; T.42N., R.11E; and T.43N., R.8E.) pumpages were assigned from three to six nodes, depending on the density of pumping centers.

Pumpages were not corrected for possible contributions from wells open to the Mt. Simon aquifer; it was assumed that all such wells would be phased out due to deteriorating water quality. Since pumpages are entered into the model as five-year constant-rate averages, withdrawals which were phased out during a shorter period of time were pro-rated over five years. During the 1980-1985 period, sixteen such withdrawals were phased out. An additional 37 withdrawals were phased out during the period 1985-1990. In the 1990-1995 and 1995-2000 periods, one withdrawal each was phased out.

Figures 5 through 9, described below, do not include the effects of future Wisconsin pumpages. These effects, shown in table 4 for selected sites, would represent additional drawdowns which can be expected in the 1980-2020 period.

1980-1985

The predicted water level decline by the year 1985 is shown in figure 5. Drawdown contours were observed to have a configuration quite similar to that in 1980 (figure 4a). Deep pumping centers that were apparent in 1980 in northern Cook and northeastern Dupage Counties deepened, and the 700-foot drawdown contour merged with the one in north-central Will County. Total model pumpage for the 1980-1985 period averaged 166.6 mgd, nearly 17% higher than for the 1975-1980 period, despite the initiation of pumpage phaseouts due to lake water allocations.

1985-1990

Total demand for the 1985-1990 period declined to 135.6 mgd. Heavy, concentrated demand in the Aurora area (T. 38N, R. 8E), however, caused water levels to reach critical stages at the top of the Ironton-Galesville Formation, and the model automatically reduced pumpage at that node by nearly 13% (from 15.32 mgd to 13.36 mgd). It is conceivable that contributions from wells still open to the Mt. Simon sandstone at that time could make up for the reduction in yield from the Cambrian-Ordovician aquifer. The drawdown configuration for 1990 (shown in figure 6) changed noticeably from 1985. The deep cone of depression in northern Cook County did not appear, since water levels there had begun recovery due to the lake allocation. Instead, the most prominent cone of depression in the area now appeared in eastern Dupage County. The cone at Aurora was much more apparent than formerly, as were the 800-foot contour in Will County and the 700-foot contour in eastern Kane County.

1990-1995

The most notable feature of the 1990-1995 model run is the continued declining production at the Aurora pumping center because of critical water levels. The model reduced pumpage' there from the demand Q of 15.4 mgd to 10.18 mgd, nearly a 34% reduction.

1995-2000

During the period 1995-2000 the average water demand in the model area was 94.6 mgd, a reduction of 30% from the 1985-1990 period. No critical water levels were predicted at any of the pumping centers for this period. By this time the anticipated pumpage reduction due to allocations at Aurora had taken place, and the recovery of water levels had eliminated the cone of depression, as shown in figure 7. Smaller cones of depression farther north along the Fox Valley began to appear instead. The dominant cone of depression in the year 2000 was in the Joliet area, and a smaller cone began to appear in northeastern Grundy County. The cone of depression formerly centered in eastern Dupage County also shifted to western Cook County and became about 100 feet shallower. The 700- and 800-foot drawdown contours shifted westward into Kane County and southwestward into Kendall and Grundy Counties.

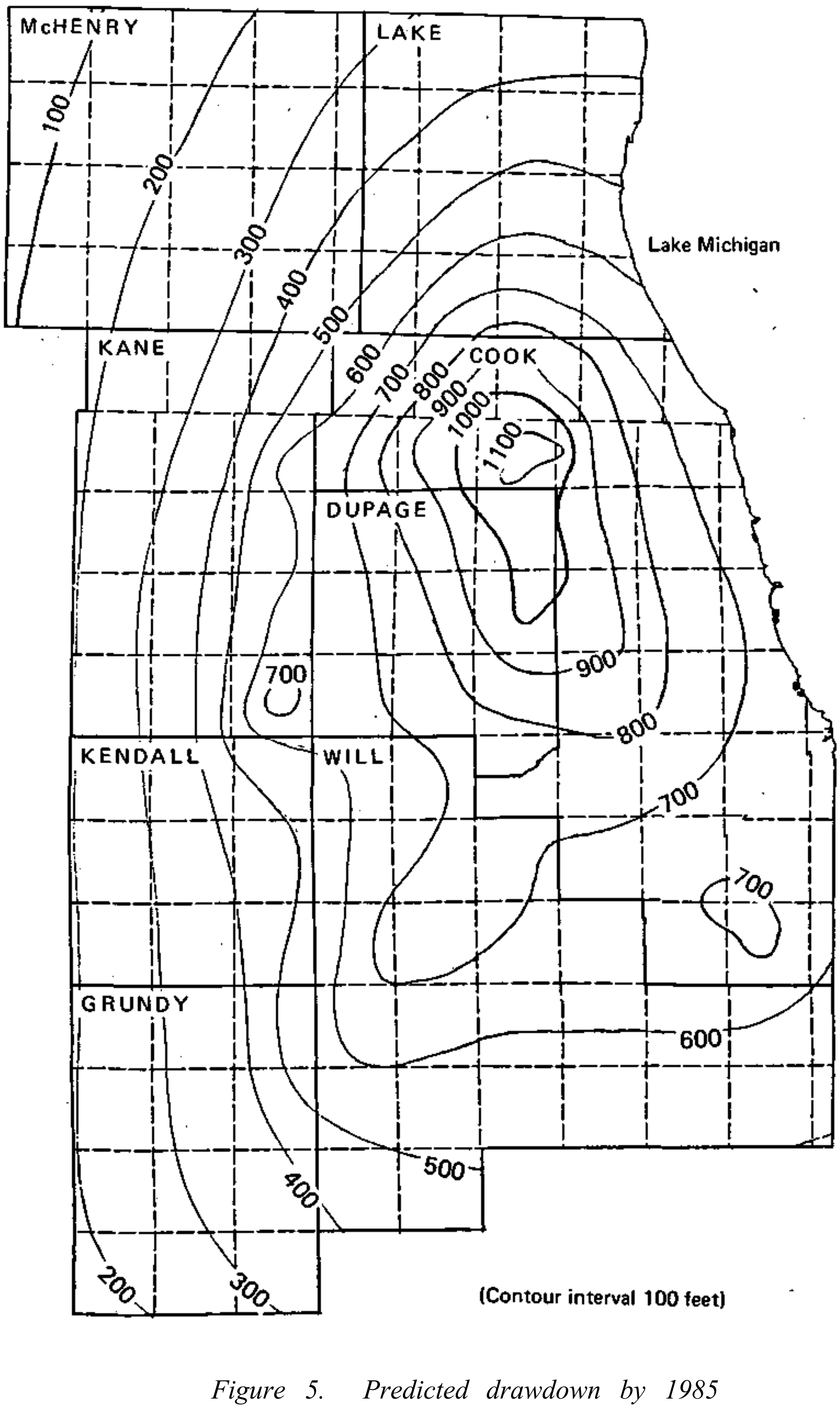


Figure 5. Predicted drawdown by 1985

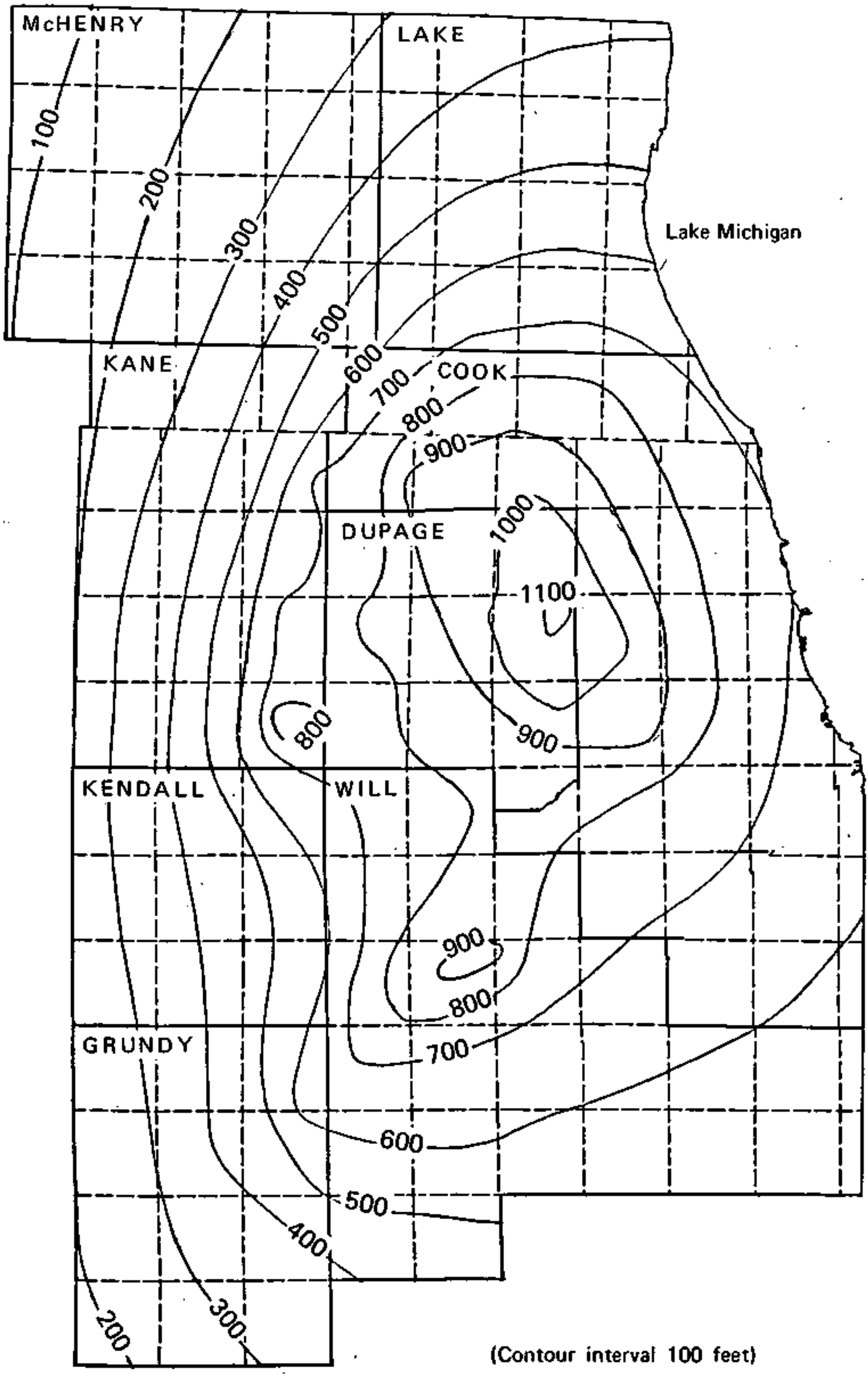


Figure 6. Predicted drawdown by 1990

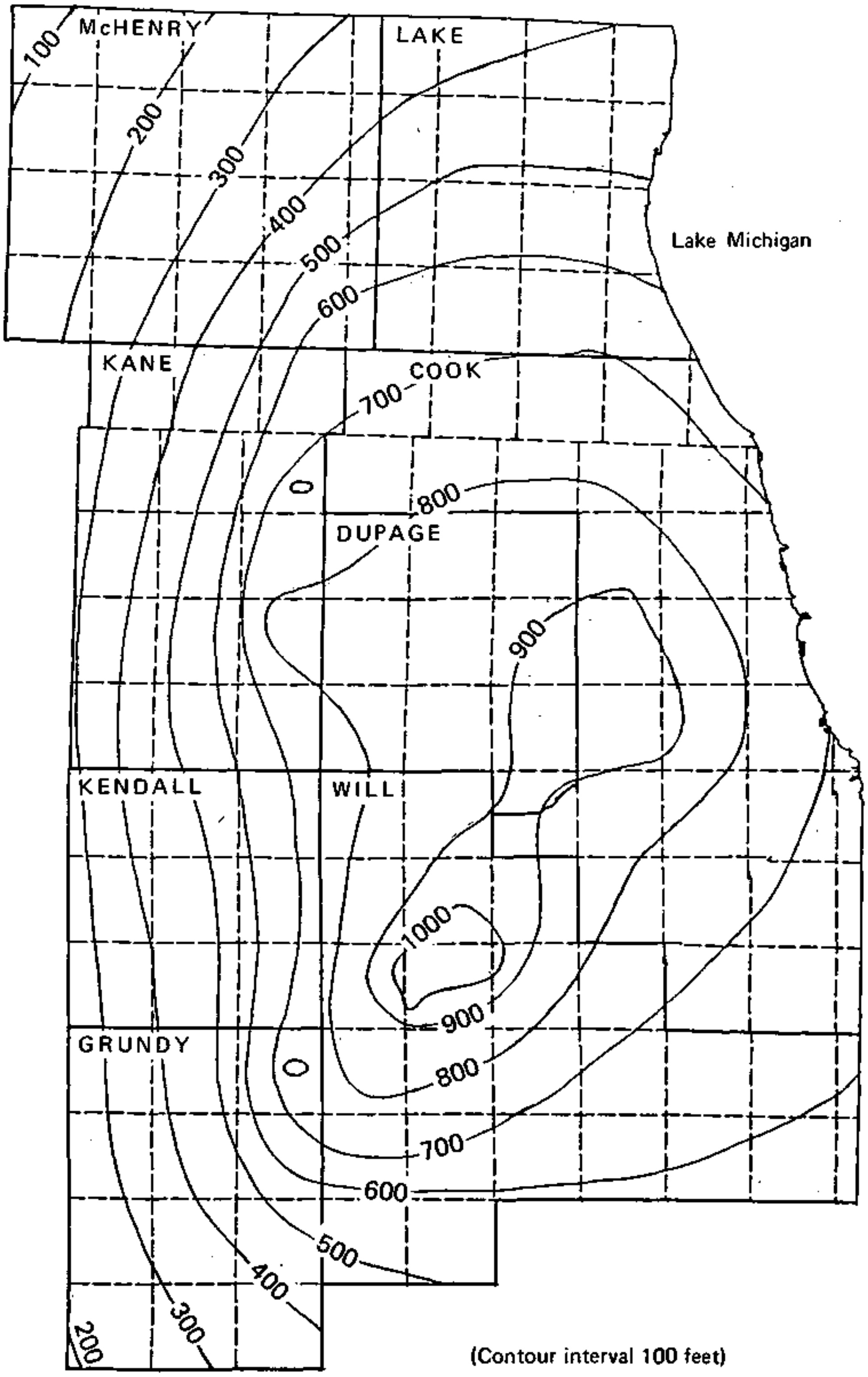


Figure 7. Predicted drawdown by 2000

2000–2005

Total pumping demand in the 2000-2005 period averaged 99.4 mgd. The most significant event predicted by the model was a critical pumping node in the Joliet area. Demand was reduced by slightly less than 2% at that node and by only 0.5% for the entire Joliet area. Pumpage in the area is represented by five pumping nodes.

2005–2010

Total demand Q for the period 2005-2010 increased to 101.8 mgd. The critical water level at one of the five Joliet nodes continued and the model reduced demand at that node from 6.23 mgd to 5.39 mgd, a reduction of about 13%. Overall pumpage at the five Joliet nodes was reduced by slightly over 4%. As shown in figure 8, the Joliet pumping center remained the dominant cone of depression by 2010, with the deepening cone in the Batavia-St. Charles area becoming more apparent. The regional cone continued to recover in the former deep areas of northern Cook and northeastern DuPage Counties, but its areal enlargement was evident even in southeastern McHenry County. A steep west-to-east contour gradient is a striking feature of the drawdown map in Kane and Kendall Counties. The small cone of depression in northeastern Grundy County deepened by 2010 and became part of the larger Joliet cone.

2010–2015

Total demand Q for the 2010-2015 period increased to 104.2 mgd. The model predicted that a second pumping node in the Joliet area would experience critical water levels by 2015 and reduced the pumpage at two nodes from 9.89 mgd to 7.24 mgd. This amounted to an overall reduction of 12.8% in the five-node Joliet pumping center.

2015–2020

The demand Q for the last period modeled in the study, 2015-2020, increased to 105.8 mgd. During this period the model predicted that five pumping nodes would reach critically low water levels. Two nodes which had earlier reached critical levels at Joliet remained that way during 2015-2020, and total pumpage in the five-node Joliet area was reduced by 18.9% from 20.47 to 16.6 mgd. The St. Charles pumping node experienced a critical water level, and demand there was reduced from 6.72 to 6.50 mgd, a reduction of about 3%. At nearby Batavia, the model Q also was reduced about 3%, from 6.17 to 5.99 mgd. It was predicted that the large industrial pumping center in northeastern Grundy County would lose about 3% of its pumping capacity, declining from 8.96 to 8.70 mgd.

Figure 9 shows the predicted drawdown map for the year 2020. The Joliet pumping center remained the dominant cone of depression, merging with the nearby northeastern Grundy County pumping center. Other major pumping centers were observable at Elgin and St. Charles-Batavia. A small pumping center at Crystal Lake became clearly distinguishable. The influence of the Fox Valley pumping centers on water levels in the northern

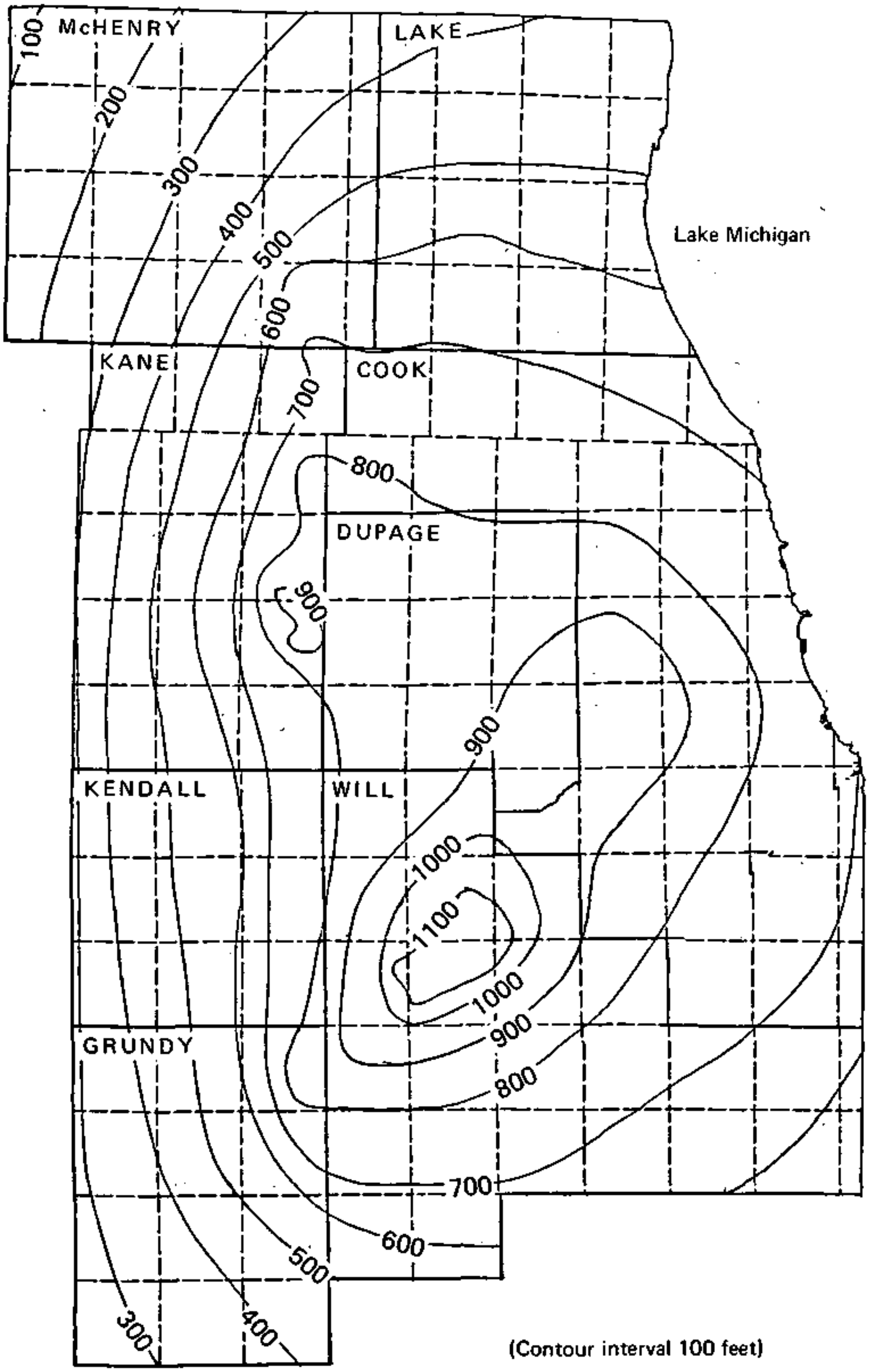


Figure 8. Predicted drawdown by 2010

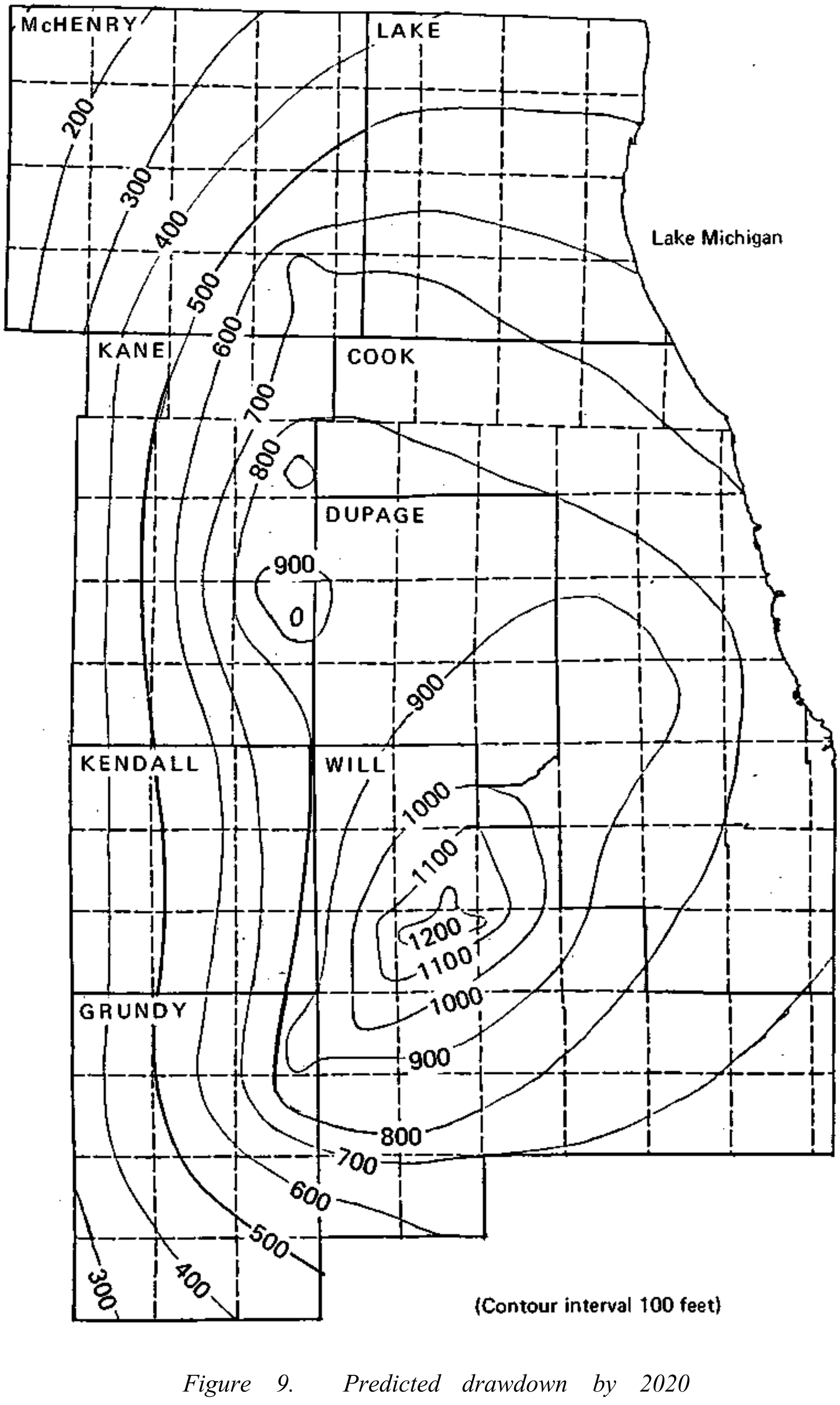


Figure 9. Predicted drawdown by 2020

part of the area was apparent, as the 700-foot contour extended into southern Lake County. The steep west-to-east gradient remained unchanged along the western edge of the study area.

Along the Wisconsin border, water level declines since 1864 exceeded 400 feet in Lake County and varied from 100 feet, at the western end of the McHenry County-Wisconsin border, to 400 feet at the eastern end of that border. Total declines along the border between 1980 and 2020 varied from 50' feet at the northwestern corner of McHenry County to about 130 feet in the middle of the Lake County-Wisconsin line.

Recovery at former cones of depression was impressive also. In the Arlington Heights area in northern Cook County, water levels were approximately 300 feet higher in 2020 than they were in 1985, and in the Elmhurst area, a recovery of about 100 feet was observed from 1985 to 2020.

Figure 10 shows the anticipated piezometric surface map in 2020. The map was prepared by adding anticipated drawdowns caused by Wisconsin pumpage to figure 9 and converting the total drawdowns into water level elevations.

Non-Utilization of Allocation

In order to appreciate, in a quantitative way, the significant impact of the lake allocation, an additional set of computer runs was made in which deep sandstone wells continued to supply water demands beyond 1980 (a scenario of zero utilization of the allocation). It was expected that under such a pumping scheme many more pumping nodes would experience critical water levels and reduced pumping capacities. Pumpages were modeled for the period 1980-2005. Additional runs were deemed unnecessary, since the impact of zero utilization was already quite evident by the year 2005.

1980-1985

As in the full utilization runs, no critical levels were experienced during this period. Total pumpage in the model was 167.5 mgd.

1985-1990

During this period total withdrawals in the model were 195.5 mgd. As found previously, the Aurora pumping node experienced critical water levels and also a similar reduction in pumping capacity (nearly 13%). In addition, however, six other pumping nodes also had reduced capacities (table 5), ranging from nearly 10% to just under 28%.

1990-1995

Total model pumpage in this period reached 214.7 mgd. All of the pumping nodes that had lost capacity in the previous five-year period indicated much more severe reductions, ranging from 35 to 65%. An additional pumping node — representing wells at Arlington Heights, Wheeling, and Buffalo Grove — experienced a loss of capacity of less than 5%.

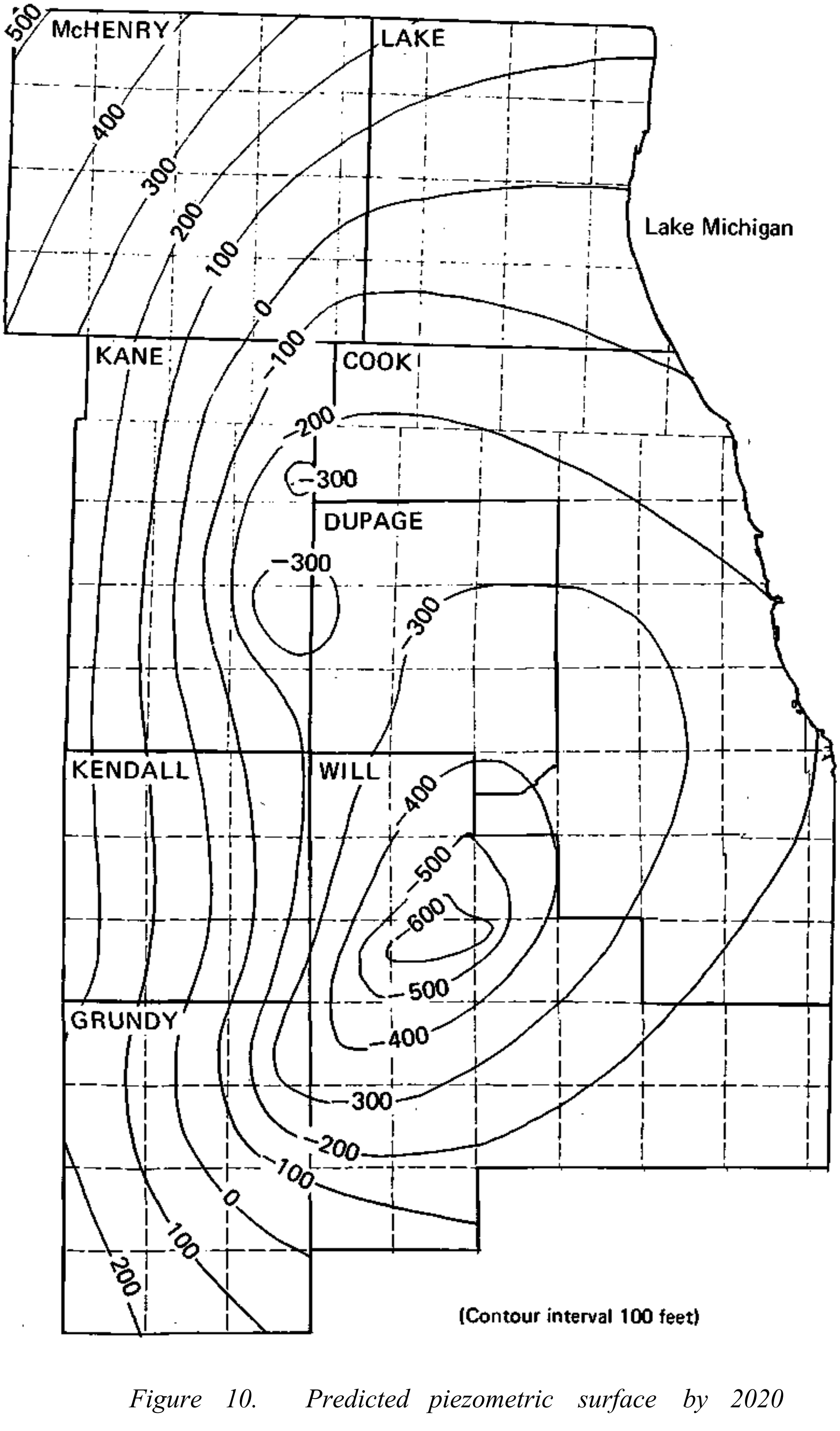


Figure 10. Predicted piezometric surface by 2020

Table 5. Reductions in Pumping Capacity between 1985 and 1990

Pumping node	Demand Q (mgd)	% reduction
Arlington Heights	4.96	27.8
Arlington Hts.-Mt. Prospect	4.47	19.6
Aurora*	15.32	12.8
Elk Grove	7.54	15.5
Elmhurst-Lombard-Oakbrook-Villa Park	6.97	11.2
Hoffman Estates-Schaumburg	6.79	9.6
Palatine-Rolling Meadows	9.03	21.0

*Also experienced reduced capacity in full-utilization pumpage scheme

Table 6. Reductions in Pumping Capacity between 1995 and 2000

Pumping Node	Demand Q (mgd)	% reductions
Arlington Heights	5.16	75.2
Arlington Hts.-Mt. Prospect	4.82	77.1
Arlington Hts.-Wheeling-Buffalo Grove	7.54	32.2
Aurora*	21.10	67.6
Bensenville-Wooddale	3.43	13.1
Bloomingdale-Carol Stream-Roselle	3.83	5.8
Domestic Utilities	3.30	2.1
Elk Grove	8.70	92.4
Elmhurst-Lombard-Oakbrook-Villa Park*	7.56	75.1
Hanover Park-Streamwood-Bartlett	4.52	4.9
Hoffman Estates-Schaumburg	8.91	70.9
Lombard	2.13	31.4
Lombard	1.59	14.4
Mt. Prospect	2.37	5.7
Oakbrook	2.46	4.5
Oakbrook-Villa Park*	3.42	9.6
Palatine-Rolling Meadows	10.30	74.4

*Also experienced reduced capacity in full-utilization pumpage scheme

1995-2000

With pumpage exceeding 233 mgd, the number of pumping nodes showing critical pumping levels and reduced capacities rose to 17. Reductions ranged from 2% to over 92% of capacity (table 6).

2000-2005

Total pumpage during this period increased to 251.5 mgd, and, as a result, reductions in pumping capacity were widespread and severe (table 7). The model predicted that 24 pumping nodes would reach critical water levels and suffer reductions in pumping capacity of 85 mgd — a third of the demand total pumpage! It was evident (as seen in table 7) that continued pumpage under a non-utilization scenario would result in pumping reductions at additional nodes and nearly total loss of capacity at several of the nodes. For this reason, additional model runs were deemed unwarranted.

Table 7. Reductions in Pumping Capacity between 2000 arid 2005

Pumping node	Demand Q (mgd)	% reductions
Arlington Heights	5.26	91.1
Arlington Hts.-Mt. Prospect	4.94	95.5
Arlington Hts.-Wheeling-Buffalo Grove	8.40	57.0
Aurora*	24.07	82.6
Batavia-Geneva*	5.47	14.6
Bensenville-Wooddale	3.64	45.9
Bloomingdale-Carol Stream-Roselle	4.50	60.2
Clarendon Hills-Westmont-Willowbrook	3.32	3.3
Domestic Utilities	3.50	19.7
Elgin	6.91	7.1
Elk Grove	9.21	100
Elmhurst-Lombard-Oakbrook-Villa Park*	7.85	95.9
Hanover Park-Streamwood-Bartlett	4.82	39.6
Hoffman Estates-Schaumburg	9.72	91.8
Joliet*	6.08	3.6
Lombard*	2.31	42.8
Lombard	1.73	29.5
Mt. Prospect	2.45	35.1
Naperville*	5.45	20.0
Oakbrook*	2.60	30.8
Oakbrook-Villa Park*	3.58	64.2
Palatine-Rolling Meadows	10.80	86.4
St. Charles	5.86	7.8
West Chicago*	4.33	23.2

*Also experienced reduced capacity in full-utilization pumpage scheme

SUMMARY AND CONCLUSIONS

The Cambrian-Ordovician aquifer has been a plentiful source of water for northeastern Illinois and southeastern Wisconsin since the 1860's. Unfortunately, pumpage began to exceed the practical sustained yield in northeastern Illinois in the late 1950's and in southeastern Wisconsin by the late 1970's. As a result, water levels have declined over 900 feet in some areas.

Allocations of Lake Michigan water will relieve many of the deep pumping lifts in the current major pumping centers of northern and western Cook County and northeastern DuPage County. As communities presently allocated lake water shut off their deep wells, recovery of water levels will occur. However, the regional cone of depression will continue to spread outward into the western counties and to the south. Pumping centers will shift to Joliet and to Fox River Valley.

Model runs made with projected pumpages for the period 1980-2020 indicate that five pumping centers will eventually experience critically low water levels and that well field production will decline by as much as 34% (see table 8). It is not the purpose of this report to be precise about the exact percentages of decline in well field production; the overall accuracy of the model does not allow that degree of certainty. What is perhaps the most useful outcome of the study are the predictions that, with the implementation of the lake allocation plan, a major shift in pumping cones of depression will almost certainly occur regionally, and that critically low water levels are likely to occur at several locations such as Joliet, Batavia, and St. Charles. Given the additional drawdown which the effect of Wisconsin pumpages will superpose on the piezometric surface of the study area, additional areas — especially larger pumping centers closer to Wisconsin such as Elgin or Crystal Lake — might also experience severe declines in water levels and reduced well production.

Table 8. Pumping Centers with Critical Water Levels

Pumping center	Earliest critical year	Reduction in pumpage by 2020 (%)
Aurora	1990	33.9*
Batavia	2020	2.9
Joliet	2005**	18.9
NE Grundy Co.	2020	2.9
St. Charles	2020	3.3

*Aurora's Lake Michigan allocation would be put into effect by 1995, eliminating deep pumpage

**The model predicted that one of Joliet's five pumping nodes will reach critical levels in 2005, and a second will reach critical levels in 2015

The study also indicates that — even with full implementation of Lake Michigan allocations — projected demands still exceed the practical sustained yield of the aquifer (65 mgd). Pumpages are anticipated to be at least 65% in excess of this amount in 2020. For this reason, although substantial recovery will be observed in some areas of DuPage and Cook Counties, the regional enlargement of the cone of depression will continue and the effects will be observed in southern Wisconsin (as much as 130 feet of additional decline over 1980 effects). Supplemental trial computer runs have confirmed the 65 mgd estimate of Walton (1964) for the practical sustained yield and have indicated that when this level of withdrawal is attained, water levels recover over an extended period of time near major pumping nodes but reach equilibrium elsewhere within 10 years.

On the other hand, projected Wisconsin pumpage effects will also be observed, especially in the northern portion of the study area. It is estimated that, compared with 1980 effects, as much as 80 feet of additional drawdown will occur near the state line in Illinois by the year 2020 because of anticipated deep pumpages in Wisconsin.

As significant as the effects of full-utilization pumping schemes proved to be, model runs of zero-utilization schemes clearly indicated that severe and widespread effects would be observed much sooner and that some pumping nodes would lose nearly all of their current pumping capacity by the year 2005. Reductions in pumping capacity would total 85 mgd or one-third of the total deep sandstone pumpage.

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