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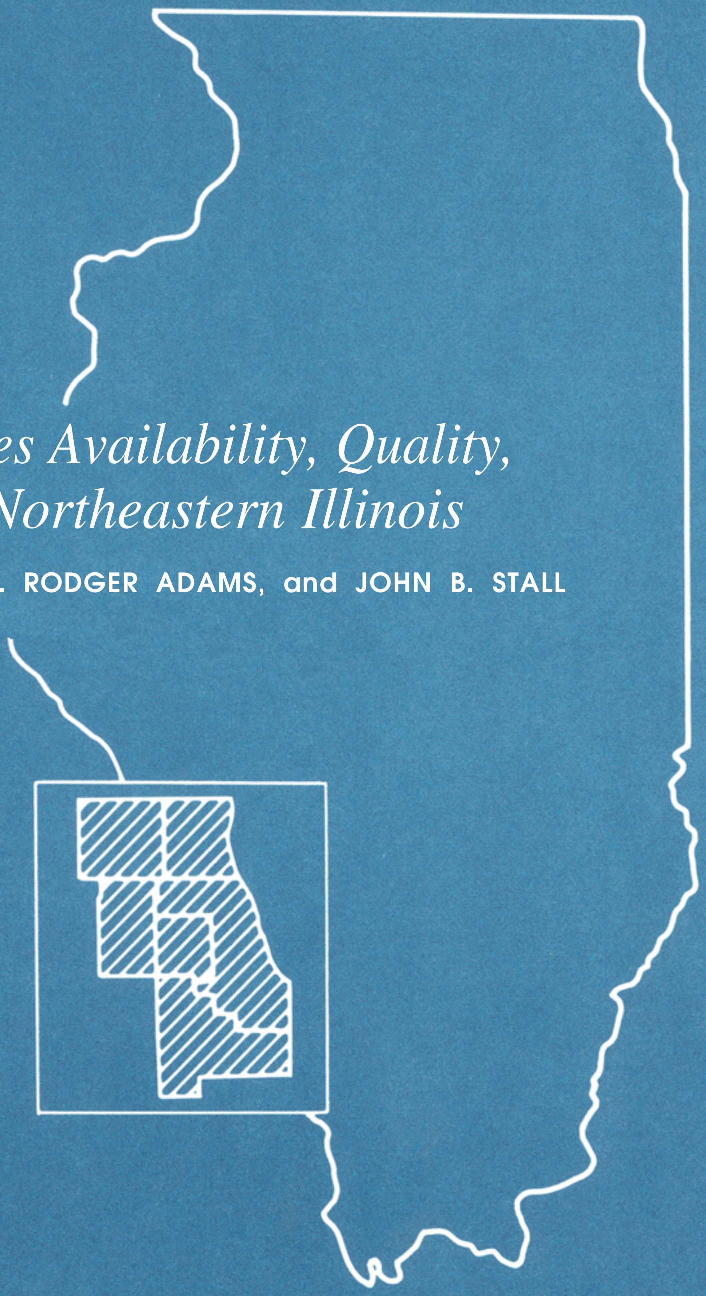
STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

Water Resources Availability, Quality, and Cost in Northeastern Illinois

by RICHARD J. SCHICHT, J. RODGER ADAMS, and JOHN B. STALL



ILLINOIS STATE WATER SURVEY
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by RICHARD J. SCHICHT, J. RODGER ADAMS, and JOHN B. STALL

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Reference: Schicht, Richard J., J. Rodger Adams, and John B. Stall. Water Resources Availability, Quality, and Cost in Northeastern Illinois. Illinois State Water Survey, Urbana, Report of Investigation 83, 1976.

Indexing Terms: Alternative costs, alternative planning, aquifer development, artificial recharge, computer model, groundwater, groundwater mining, Lake Michigan, mineral quality, reservoir yield, surface water availability, water costs, water quality, water supply, water use.

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ABSTRACT

This report summarizes extensive studies of the water resources of northeastern Illinois. This 3700-square-mile metropolitan-industrial area includes Cook, Du Page, Kane, McHenry, Lake, and Will Counties with a population of seven million persons.

Water resources for the area consist of Lake Michigan water, surface water, and groundwater resources. Because the use of Lake Michigan water is limited by the U.S. Supreme Court and the once favorable groundwater resources in the deep sandstone are being overdeveloped, future water shortages are expected. Available groundwater and surface water resources in addition to Lake Michigan were estimated by township and compared with projected future water demands for 1980-2010 to determine the amount and location of deficits.

Alternative sources to meet the specific shortages were studied and compared, where possible by cost. Alternatives studied include purchase of lake water from the city of Chicago, use of water from the Kankakee and Fox Rivers, transfer of groundwater from surplus areas, construction of reservoirs, desalting brackish groundwater, artificial recharge of aquifers, precipitation augmentation, and shifts in water use in connection with the Chicago Tunnel and Reservoir Plan. Extensive water quality data also were summarized for the water resources of the area.

Water shortages, depending on resource use schemes, may approach 200 million gallons per day by the year 2000. Possibilities for meeting these needs are described as a guide to allocation of Lake Michigan water and future planning for water resources.

SUMMARY

Northeastern Illinois as defined in this report includes the counties of Cook, Du Page, Kane, McHenry, Lake, and Will. It is the most densely populated and heavily industrialized area in Illinois. Because it is one of the most favorable groundwater areas in the state and diversion from Lake Michigan for domestic water supply has been adequate, only local problems of water supply have existed. Water supply problems are expected to increase because of limitations placed on the use of Lake Michigan water by the U.S. Supreme Court. As a result of these limitations, increases in water use must be largely supplied from groundwater, or by reallocating the present uses of Lake Michigan water.

Groundwater Resources

Groundwater resources in the area are developed 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, called the deep sandstone aquifer, of which the Ironton-Galesville and Glenwood-St. Peter sandstones are the most productive formations
4) The Mt. Simon aquifer, consisting of sandstones of the Mt. Simon and lower Eau Claire Formations of Cambrian age

Shallow Aquifers. Approximately 50 percent of the area is underlain by sand and gravel aquifers. Groundwater pumpage from sand and gravel aquifers was 35.3 million gallons per day (mgd) in 1974.

Most of the bedrock surface is formed by shallow dolomite aquifers that consist of Silurian rocks in most of the area but are dolomites of Maquoketa, and Galena-

Platteville Formations in the western part. High yielding wells in the shallow dolomite aquifers are concentrated in the Silurian dolomite. Although yields of wells in the Silurian are inconsistent, well yields exceed 500 gallons per minute (gpm) in many areas. Pumpage from the Silurian dolomite was 103.4 mgd in 1974.

Recharge to the sand and gravel aquifers is derived locally from precipitation. Recharge to the Silurian rocks is from vertical leakage through the glacial drift which is in turn recharged from precipitation.

The potential yield of the sand and gravel and shallow dolomite aquifers is estimated to be about 500 mgd. The potential yield is defined as the maximum amount of groundwater that can be developed from a reasonable number of wells and well fields without creating critical water levels or exceeding recharge. Methods used in evaluating the potential yield of the shallow aquifers are described in this report.

Deep Sandstone Aquifer. The deep sandstone aquifer is encountered at an average depth of about 500 feet below land surface. It has an average thickness of 1000 feet, and is composed chiefly of sandstones and dolomites. Yields of wells are dependable and generally exceed 700 gpm. The practical sustained yield with the present distribution of pumpage is estimated to be 46 mgd. Although present pumpage exceeds the practical sustained yield, there are tremendous quantities of water in storage in the deep sandstone aquifer that can sustain pumpage before critical pumping levels (the top of the Ironton-Galesville sandstone) are reached.

The recharge area for the deep sandstone aquifer is in the western part of the region. Some recharge also occurs from vertical leakage through the overlying and underlying confining beds.

The upper formations of the deep sandstone aquifer are being dewatered in the major pumping centers. Nonpumping levels declined at an average rate of 11 feet per year for the 4-year period November 1971 to November 1975. Pumpage from deep wells was 154.9 mgd in 1974. This includes pumpage from wells that are also open to the Mt. Simon.

Mt. Simon Aquifer. The Mt. Simon aquifer, consisting of sandstones of the Mt. Simon and lower Eau Claire Formations, lies beneath the deep sandstone aquifer and is separated from it by shale beds of the Eau Claire Formation. Many high capacity wells penetrate the upper 200 to 300 feet of the Mt. Simon aquifer.

The practical sustained yield for potable water from the Mt. Simon aquifer is estimated to be 14 mgd. The recharge area for the Mt. Simon is in southeast Wisconsin. Although there are tremendous quantities of water in storage in the Mt. Simon, the water quality deteriorates with depth limiting the quantity of potable water that can be taken out of storage. Water quality problems have been experienced in a number of wells that are finished in the Mt. Simon.

Future Water Demands

Future demands for groundwater and for Lake Michigan water were estimated by means of relationships between population and per capita consumption and between manufacturing employment and per capita consumption. Population and employment data were furnished by the Northeastern Illinois Planning Commission. Groundwater demands were estimated for each political township for 1980, 1985, 1990, 2000, and 2010. Estimated demands increase from 337.1 mgd in 1980 to 521.8 mgd in 2010.

Lake Michigan demand projections were made for 1980, 1990, and 2000 for townships in which communities presently withdraw water from Lake Michigan or are supplied by the city of Chicago or other municipal water supply systems withdrawing water from the lake. Demand projections were also made for Chicago. Estimated demands increase from 1771 mgd in 1980 to 1844 mgd in 2000.

Groundwater Deficiencies

The projected water demands for areas dependent upon groundwater as a source of water supply were compared with groundwater availability to define *water deficit areas.* Two approaches in developing the groundwater resource were considered. The first approach limits groundwater withdrawals from both the deep and shallow aquifers to the maximum rate of natural groundwater recharge that can be induced by pumping. In the first approach water demands in excess of groundwater recharge increase from about 75 mgd in 1980 to 200 mgd in 2010.

The second approach also limits groundwater withdrawals from the shallow aquifers to the amount of recharge, but allows water to be 'mined' (withdrawals in excess of recharge) from the deep sandstone aquifer. Because there are tremendous quantities of water in storage in the deep sandstone aquifer, mining can continue at accelerating rates before predetermined critical water levels are reached. Critical water levels occur when pumping levels reach the top of the Ironton-Galesville sandstone, the most productive formation in the deep sandstone aquifer. Predictions of the year when pumping levels reach the top of the Ironton-Galesville sandstone were made with the aid of a digital computer aquifer model.

Three mining schemes in the second approach were studied. In scheme 1, withdrawals are allowed to increase until pumping levels reach the top of the Ironton-Galesville sandstone. When pumping levels reach the top of the sandstone, withdrawals are gradually reduced to maintain a constant water level. Critical water levels under this scheme are first reached in 1995 when deficiencies total about 7 mgd. By 2010 deficiencies total 91 mgd.

Scheme 2 is similar except that when pumping water levels reach the top of the sandstone, withdrawals from the sandstone in that township are stopped. Under this scheme deficiencies increase from 45 mgd in 1995 to 123 mgd by the year 2010.

The third scheme maintains withdrawals at the 1980 rate. Under this scheme deficiencies increase from about 16 mgd in 1985 to 117 mgd in 2010.

The cost of raw and treated groundwater produced in quantities sufficient, in most cases, to meet the projected groundwater demand to 2000 was estimated for the first groundwater mining scheme. Costs were estimated for 35 townships with demands greater than 1.0 mgd. For the year 2000, costs for treated groundwater ranged from 34 to 50.1¢/1000 gallons (in 1974 dollars).

Alternatives to Groundwater

Water supply alternatives can be separated into two categories. The first includes alternatives for which costs can be estimated, and the second, those alternatives for which costs cannot be estimated because of insufficient data on operating costs. For most alternatives, costs were estimated for quantities of water needed to supply the deficit water under the no-mining approach.

Purchase Water from Chicago. Costs for meeting all water supply deficits under the no-mining approach with treated water purchased from the city of Chicago were estimated on the basis of purchasing water at 38¢/1000 gallons and transmitting the water from the boundary of the area now supplied with Chicago water to the center of the deficit township. The costs of transmitting water by separate pipelines to each deficit township were estimated. A more realistic approach would be to group deficit townships. For example, the cost of supplying water under a cooperative plan to 10 deficit townships with deficits ranging from 0.7 to 8.9 mgd in the year 2000 averaged 49¢/1000 gallons. The cost for one township in this group was reduced from 112 ¢/1000 gallons for the cost of a separate pipeline to 70¢/1000 gallons for the cooperative plan.

Because some of the possible solutions to water supply problems in northeastern Illinois might mean that a particular city could be using groundwater and Lake Michigan water at the same time, special problems could arise if these waters are mixed or commingled. It was concluded that commingling of waters can be carried out satisfactorily with proper management of chemicals and other factors.

Use Kankakee River Water. The Kankakee River is considered an important alternative for water supply in Will and southern Cook Counties. Water Survey cost estimates range from 43.7¢/1000 gallons for 18.4 mgd in 1980 to 33.4¢/1000 gallons for 59.6 mgd in 2000.

Use Fox River Water. If off-channel storage is provided, the flow in the Fox River is sufficient to meet the total water supply demands of 73.5 mgd in 2000 for the communities along the Fox River from Algonquin to Aurora. The average cost of supplying the 73.5 mgd was 26.9¢/l000 gallons.

The use of the Fox River as a public water supply appears technically feasible and economically reasonable. Questions of treatment and storage costs need to be resolved, however.

Transfer Surplus Groundwater. Transfer of groundwater developed from shallow aquifers from townships with surplus groundwater to deficit townships under the no-mining approach was considered as a feasible alternative. Schemes of transfer were considered for Lake, McHenry, and Will Counties. In Will County, in 2000, the cost of transferring water to five townships with deficits of 2.7 to 5.3 mgd ranged from 42 to 51¢/1000 gallons. In Lake and McHenry Counties, in 2000, the cost of transferring water to six townships with deficits of 0.2 to 4.5 mgd ranged from 44 to 85¢/1000 gallons.

The transfer of deep sandstone water from townships with non-critical water levels to townships with critical water levels was considered. It was recommended that computer studies should be made before a particular plan is adopted to determine the effect of redistributed pumpage on water levels.

Build Reservoirs. Potential reservoir sites in Cook, Du Page, Grundy, Kane, Kendall, McHenry, and Will Counties were evaluated as possible sources of water for water supply. Ten sites were identified as feasible for construction. Total net yield for the 10 sites is 28 mgd for half capacity during a 40-year drought. Unit costs of treated water range from 46 to 138¢/1000 gallons. Transmission costs were not included in the unit costs.

Desalt Mt. Simon Water. Desalting brackish water from the Mt. Simon aquifer is an expensive alternative. Water could probably be developed and desalted at 166 to 208¢ 1000 gallons for a 1 mgd plant and at 231 to 277¢/1000 gallons for a 5 mgd plant. Because of the many problems involved, a pilot installation would be needed to evaluate. the costs and problems that accompany the desalting process.

Modify Precipitation. Augmentation of precipitation over Lake Michigan was considered to increase the amount of water available from Lake Michigan. A 10 to 20 percent increase in precipitation during October, November, and December is considered feasible. This would result in a 640 to 1280 mgd increase in average daily flow which could be used for water supply in northeastern Illinois. The total benefit-to-cost ratio of precipitation augmentation is estimated to be 2 to 1 or greater.

Recharge Aquifers Artificially. Artificial recharge of the deep sandstone and shallow aquifers is considered as an important alternative and could supply a large part of the deficits predicted under the no-mining approach. Costs of developing water by artificial recharge are not available because of lack of experience in operating artificial recharge installations.

Shift Use of Diverted Lake Water. The Chicago Tunnel and Reservoir Plan (TARP), which is summarized in this report, could have a bearing on the use of water resources in northeastern Illinois by reducing the amount of diverted Lake Michigan water used for treated sewage dilution.

Water Quality

Groundwater quality data from analyses made from 1965 through 1974 for each township were summarized for this report. A tabulation showing the number of communities in each county that exceed given concentrations of selected chemical constituents is given.

Mineral quality of surface water at six Illinois State Water Survey sampling stations is discussed. Iron, manganese, and nitrate concentrations exceeded given water supply standards in varying degree at all six sampling stations. The total dissolved solids standard was exceeded at four of the six stations.

Data published by the Illinois Environmental Protection Agency for 1974 on dissolved oxygen concentrations and fecal coliform counts for five sampling stations are summarized. It was concluded from the published data that there are presently insufficient data available with which to characterize in detail the biological quality of the surface waters.

INTRODUCTION

Northeastern Illinois is a 3714-square-mile area with a population of about seven million people. It includes the counties of Cook, Du Page, Kane, McHenry, Lake, and Will. Water supplies in the area are presently from either Lake Michigan or groundwater developments.

Northeastern Illinois is one of the most favorable groundwater areas in the state. It is underlain at depths of 500 feet or more by sandstone aquifers that have been prolific sources of water for over 100 years. At lesser depths the area is underlain by sand and gravel deposits and creviced dolomite that locally are excellent sources of groundwater. Although there is controversy surrounding the diversion of Lake Michigan water, diversion has been adequate for the domestic water supply. The adequacy of water supplies in the area have facilitated extensive urban and industrial growth.

Since its inception in 1895, the Illinois State Water Survey has collected data on water resources in northeastern Illinois. During World War II, because of intense industrial activity, the demand on groundwater particularly from the deep sandstone aquifers revealed potential water supply problems. At that time the Water Survey established an intensive data collection and study program. The results of the program have been published in numerous Water Survey reports that are included in the References at the end of this report.

Because diversion of Lake Michigan water is near the limitations decided by the U.S. Supreme Court and groundwater is being overdeveloped in part of the area, the expected increase in water demand makes it certain that serious water shortages can be expected in the near future.

Purpose

This report, with certain modifications, is essentially the testimony given at hearings conducted in 1975 and 1976 by the Illinois Division of Water Resources on the allocation of Lake Michigan diversion water. The main purpose of the various studies prepared for this testimony was to determine the adequacy of surface water (other than Lake Michigan) and groundwater to meet projected water demands.

Included in this report are costs of developing surface and groundwater supplies, cost of providing Lake Michigan water from the city of Chicago, and a summary of water quality data. Also considered are various alternative sources of water including the feasibility of artificial recharge and the feasibility of precipitation augmentation over Lake Michigan. The Chicago Tunnel and Reservoir Plan is summarized. The expected problems with commingling of Lake Michigan water with groundwater are also included.

The report entered as testimony for the hearings on allocation of Lake Michigan diversion water was requested by the Illinois Division of Water Resources. Events leading to the 1975-1976 hearings are summarized below to provide background for understanding the need for allocation hearings.

Background

In 1900 the Metropolitan Sanitary District of Greater Chicago completed the construction of a drainage canal connecting the south branch of the Chicago River with the Des Plaines River at Lockport. By deepening the Chicago River and reversing its flow, the Sanitary District had caused water to flow from Lake Michigan through the Chicago River and the Canal into the Des Plaines River and ultimately into the Mississippi River. Although the canal facilitated navigation, its primary purpose was to provide for discharge of the sewage of the Sanitary District via a stream that would *not* carry it into Lake Michigan, the source for Chicago's domestic water supply.

Since 1900 several states have contested the legality of this diversion of lake water by the State of Illinois and its political subdivisions. The objections have been on the grounds that water levels in the Great Lakes are lowered by the diversion, thereby impinging upon the water rights of the other basin states.

The most recent intervention was in 1958 when the plaintiffs (states surrounding the Great Lakes) filed an application for a reopening and amendment of the Supreme Court decree of April 21, 1930, which provided:

1) By July 1, 1930, diversion reduction to 6500 cfs
2) By December 31, 1935, diversion reduced to 5000 cfs
3) By December 31, 1938, unless cause could be shown otherwise, diversion would be limited to 1500 cfs

Although domestic water supply withdrawals from the lake and subsequent diversion of the effluent into the canal were not included in the decree, the Court made it clear that such domestic withdrawals were not to be considered as being free from future limitations.

The 1930 Rivers and Harbors Act provided for navigation of the Illinois Waterway, and established 3200 cfs as the total diversion necessary to sustain inland navigational needs. The act incorporated a 1500 cfs direct rate prescribed by the Court for 1938, leaving 1700 cfs to be accounted for by other means, such as wastewater effluent, thus implicitly limiting the amount of water that could be diverted via domestic water withdrawals to 1700 cfs.

In their suit for reopening, the plaintiff states requested modifications to the 1930 decree and improved surveillance over diversion. The State of Illinois countered by filing a suit of its own on behalf of the Elmhurst–Villa Park–Lombard Water Commission, which at that time was seeking to obtain 25 to 30 cfs of lake water.

The Supreme Court reopened the case in 1959, consolidated both suits, and appointed Albert B. Maris as Special Master to resolve the issues. The final report of the Special Master was received by the Court in 1966. The following summarizes the more important conclusions reached in the report and in the Court decision that followed. Judge Maris concluded that:

10. Necessary domestic use by riparian States is the use of water of the Great Lakes having first priority.

11. The State of Illinois is, however, under the duty of employing all those means which are practicable and reasonably available to it for conserving its own water resources for domestic use in its Northeastern Metropolitan Region before seeking to take additional water from Lake Michigan for such use.

Judge Maris' decree stated:

4. The State of Illinois may make application for . . . the diversion of additional water from Lake Michigan for domestic use when and if the reasonable needs of the Northeastern Illinois Metropolitan Region . . . for water cannot be met from the water resources available to the region, including both ground and surface water and the water authorized by Act of Congress and permitted by this decree to be diverted from Lake Michigan,

and if it further appears that all feasible means reasonably available to the State of Illinois . . . have been employed to improve the water quality of the Sanitary and Ship Canal

and to conserve and manage the water resources of the region and the use of water therein in accordance with the best modern scientific knowledge and engineering practice.

The Supreme Court assigned responsibility for allocating lake water to the State of Illinois. The state has delegated this function to the Division of Water Resources.

It is expected that the testimony report will aid in making decisions on the allocation of Lake Michigan diversion water. It was decided to publish the testimony material as a Water Survey Report of Investigation because of the limited number of copies of the testimony prepared for the hearings and the Water Survey's policy of publishing the results of water resource studies.

Acknowledgments

This study was conducted under the general supervision of Dr. William C. Ackermann, Chief of the Illinois State Water Survey, and the direct supervision of John B. Stall, Head of the Hydrology Section. A number of Water Survey personnel assisted. Thomas A. Prickett gave instructions on the use of the digital computer model for the deep sandstone aquifer. Adrian Visocky made the groundwater cost computations and wrote the 'least cost' study. Robert H. Harmeson prepared the sections on the mineral and biological quality of surface water. Robert Sinclair provided IBM printouts for the section on groundwater quality data. Robert T. Sasman and his staff at the Water Survey's Warrenville office provided data on groundwater levels and pumpage. T. E. Larson wrote the section on commingling waters. Nani G. Bhowmik helped compile the data on potential reservoirs. E. E. Hill assisted in data tabulation. John W. Brother supervised the preparation of the illustrations. Mrs. Patricia A. Motherway and Mrs. J. Loreena Ivens edited the manuscript and Ms. Suzi L. O'Connor prepared the camera-ready copy.

Part 1. Supply and Demand

GROUNDWATER AVAILABILITY

Aquifer Systems

The groundwater resources in northeastern Illinois have been described in detail in numerous Illinois State Water Survey and State Geological Survey reports. The more pertinent information from these was used here in summarizing the groundwater resources of the area.

According to Suter et al. (1959), groundwater resources in the six-county area are developed 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, of which the Ironton–Galesville and Glenwood–St. Peter sandstones are the most productive single formations
4) The Mt. Simon aquifer, consisting of the sandstone of the Mt. Simon and lower Eau Claire Formations (Elmhurst Member) of Cambrian age

The geologic column and aquifer descriptions are given in figure 1. In this report the Cambrian–Ordovician aquifer is referred to as the deep sandstone aquifer, and the Cambrian–Ordovician and Mt. Simon aquifers are collectively referred to as the deep aquifers.

Deep Sandstone Aquifer

As shown in figure 1, the deep sandstone aquifer consists in descending order of the Galena–Platteville dolomite, Glenwood–St. Peter sandstone, and Prairie du Chien Series of Ordovician age; and the Eminence–Potosi dolomite, Franconia Formation, and Ironton–Galesville sandstone of Cambrian age.

The deep sandstone aquifer is encountered at an average depth of about 500 feet below the land surface. It has an average thickness of 1000 feet and is composed chiefly of sandstones and dolomites. It dips to the southeast, being found at a higher elevation in the northwest part of the area than in the southeast part. For example, the Galena–Platteville dolomite, the uppermost formation in the aquifer, is encountered at an elevation of about 700 feet above msl (300 feet below land surface) in the northwestern part of the area and about 100 feet below msl (800 feet below land surface) in the southeastern part. Wells penetrating the entire thickness of the deep sandstone would increase in depth from northwest to southeast from about 1200 feet to 1900 feet.

Available data indicate that on a regional basis, the entire sequence of strata, from the top of the Galena–Platteville dolomite to the top of the shale beds of the Eau Claire Formation, essentially behave as one aquifer. The Maquoketa Formation above the Galena–Platteville dolomite acts as a barrier between the Silurian age dolomites and the deep sandstone in addition to confining the deep sandstone aquifer under leaky artesian conditions. The deep sandstone is effectively separated from the fairly permeable Mt. Simon aquifer by relatively impermeable beds of the Eau Claire Formation.

Recharge to the deep sandstone aquifer occurs in parts of McHenry, Boone, Kane, and DeKalb Counties where the Maquoketa Formation contains appreciable dolomite, is relatively thin or may be completely removed by erosion. Recharge in these areas occurs from precipitation that falls locally and moves vertically through the glacial drift to the deep sandstone formation. In most parts of the area the Maquoketa Formation is relatively impervious and retards the vertical movement of water to the underlying formations. However, a significant quantity of water does move vertically through the Maquoketa Formation to the deep sandstone aquifer. There is evidence that some water from the Mt. Simon aquifer moves upward through the Eau Claire Formation into the deep sandstone aquifer.

Practical Sustained Yield

Included in the report by Suter et al. (1959) was a quantitative evaluation of the practical sustained yield of the deep sandstone aquifer. The evaluation was modified in subsequent reports by Walton (1960; 1964a; 1964b). The following discussion on practical sustained yield is from Walton (1964a).

Computations made with a mathematical model, taking into consideration gravity drainage of upper units of the Cambrian–Ordovician aquifer, indicate that if the distribution of pumpage remains the same as in 1958 and the amount of pumpage increases to 46 mgd and then remains the same, nonpumping levels in most pumping centers will eventually decline to positions about 200 feet above the top of the Ironton–Galesville sandstone.

Pumping levels in wells, if the present rates of pumping from individual wells are maintained, will eventually stabilize at critical levels within a few feet of the top of the Ironton–Galesville Sandstone. Upper units of the Cambrian–Ordovician aquifer will be partially dewatered and the coefficient of transmissivity and yields of deep sandstone wells will decrease about 26 percent.

SYSTEM	SERIES	GROUP OR FORMATION	GRAPHIC LOG	THICKNESS (FEET)	DESCRIPTION	WATER YIELDING PROPERTIES	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	Yields of wells variable, some well yields greater than 1000 gpm	Glacial drift aquifers
PENNSYLVANIAN				0 - 175	Shale; sandstones, fine grained; limestone; coal; clay	Generally not water yielding	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	Yields of wells variable, some well yields greater than 1000 gpm	
	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+		Generally not water yielding, acts as barrier between shallow and deep aquifers	
	CHAMPLAINIAN	Galena Platteville		150 - 350+	Dolomite, cherty; sandy at base; limestone; shale partings	Water yielding where not capped by shales	Cambrian-Ordovician aquifer
		Glenwood St. Peter		75 - 650	Sandstone, fine to coarse grained; shale at top; locally cherty red shale at base	Estimated transmissivity 15 percent that of Cambrian-Ordovician aquifer	
	CANADIAN	Prairie du Chien		0 - 340	Dolomite, sandy, cherty, interbedded with sandstone	Estimated transmissivity 35 percent that of Cambrian-Ordovician aquifer	
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	Estimated transmissivity 50 percent that of Cambrian-Ordovician aquifer	
		Eau Claire		235 - 450	Shale and siltstone, dolomitic, glauconitic; sandstone, dolomitic, glauconitic; dolomite, sandy	Generally not water yielding, acts as barrier between Ironton-Galesville and Mt. Simon	
		Mt. Simon		2000±	Sandstone, coarse grained, white, red in lower half; lenses of shale and siltstone, red, micaceous	Moderate amounts of water, permeability between that of Glenwood-St. Peter and Ironton-Galesville, water quality problem with depth of penetration	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.

(from Hughes et al., 1966)

Figure 1. Geologic column and aquifer description of northeastern Illinois

The practical sustained yield of the Cambrian–Ordovician aquifer is, therefore, estimated to be about 46 mgd (Suter et al., 1959). The practical sustained yield is here defined as *a maximum amount of water that can be continuously withdrawn from existing pumping centers without eventually dewatering the most productive water-yielding formation, the Ironton–Galesville Sandstone, or exceeding recharge.*

When water levels stabilize and water is no longer taken from storage within the aquifer, about 31 mgd will be derived from *recharge areas west* of the border of the Maquoketa Formation, about 12 mgd will be derived from *downward vertical leakage* through the Maquoketa Formation, and about 3 mgd will be derived from *upward vertical leakage* through the Eau Claire Formation.

It is estimated that the recharge area west of the border of the Maquoketa Formation affecting water level declines in the Chicago region is about 1200 square miles. Very little is known about the quantity of water that can be induced to enter the aquifer in recharge areas. The recharge rate in 1958 for the Cambrian–Ordovician aquifer in one area west of the border of the Maquoketa Formation was estimated to be about 21,000 gallons per day per square mile (gpd/sq mi) by Walton (1962).

It is estimated that water could be induced to infiltrate to the Cambrian–Ordovician aquifer at the rate of 42,000 gpd/sq mi. This estimate is based on the thickness and character of the overlying deposits, vertical hydraulic gradients that can be developed, and data on recharge rates for other bedrock aquifers in northeastern Illinois. If the maximum recharge rate is 42,000 gpd/sq mi (about 2.5 percent of precipitation) then recharge west of the border of the Maquoketa Formation cannot exceed about 50 mgd. The maximum amount of water that can be continuously withdrawn from existing pumping centers considering available drawdown is 46 mgd.

Thus, the practical sustained yield of the Cambrian–Ordovician aquifer with the present distribution of pumping centers is limited, *not* by the rate of replenishment in recharge areas, *but by the rate at which water can move eastward through the aquifer from recharge areas.*

The practical sustained yield of the Cambrian–Ordovician aquifer can be increased about 19 mgd to about 65 mgd by:

- Increasing the number of pumping centers
- Shifting centers of pumping to the west
- Spacing wells at greater distances

The practical sustained yield with an ideally uniform and wide distribution of pumping centers is limited by the low recharge rate and not by the coefficient of transmissibility. The maximum amount of recharge by vertical leakage through the Maquoketa Formation is about 12 mgd and the maximum amount of recharge west of the border of the Maquoketa Formation is about 50 mgd.

According to Suter et al. (1959), the total thickness of the middle and upper Eau Claire units which separate the Mt. Simon and Cambrian–Ordovician aquifers averages about 350 feet. On the basis of data given by Walton (1960), the average coefficient of vertical permeability of the Eau Claire Formation is estimated to be about 0.00003 gpd/sq ft and the average head differential between the Mt. Simon and Cambrian–Ordovician aquifers was about 75 feet in the Chicago region in 1960.

Computations made with the data given above and a form of Darcy's law indicate that leakage through the Eau Claire Formation within the Chicago region was less than 1 mgd in 1960. The average artesian pressure differential between the Mt. Simon and Cambrian–Ordovician aquifers in the Chicago region depends in part upon withdrawals from the Mt. Simon aquifer. It is possible that the average head differential could be increased to 300 feet by full development of the practical sustained yield of the Cambrian–Ordovician aquifer, in which case recharge by leakage through the Eau Claire Formation would be about 3 mgd.

Therefore, the practical sustained yield with any possible scheme of development *cannot exceed about 65 mgd* (12 + 50 + 3). It is probable that 65 mgd could be obtained by shifting the Elmhurst pumping center about 10 miles west and by adding 2 new pumping centers, one near the center of Lake County and one near the center of McHenry County.

Although the practical sustained yield of the deep sandstone aquifer is not great, there are tremendous quantities of water in storage. The average thickness of the deep sandstone aquifer above the top of the Ironton–Galesville is great. If we assume a specific yield of 0.05, this part of the aquifer contains about 3.5×10^{13} gallons of water in the six-county area.

Well Yields. Yields of deep sandstone wells were discussed in detail by Walton and Csallany (1962). Deep sandstone wells generally have yields exceeding 700 gpm.

Decline of Artesian Pressure

According to Suter et al. (1959), in 1864 the artesian pressure in the deep sandstone aquifer was sufficient to cause wells to flow in many parts of the Chicago–Joliet–Fox Valley area. From 1864 to 1958 the artesian pressure at Chicago declined about 660 feet, about 7.1 feet per year. Since 1958 the Water Survey has published five circulars on water level declines and pumpage in deep wells in the Chicago region. The Circular (C) numbers and the years reported are: C79, 1959; C83, 1960; C85, 1961; C94, 1962-1966; and C113, 1966-1971.

In recent years, nonpumping water levels in the six-county area have declined at an average rate of 9 feet per year for the 5-year period beginning in late fall 1966 to late fall 1971, and 11 feet per year for the 4-year period from late fall 1971 to late fall 1975. Table 1 gives the average individual county decline for these periods.

The most recent piezometric surface map is for October 1975 (figure 2). The deepest cones of depression were centered near Des Plaines, Elmhurst, Summit, and Joliet. Nonpumping levels were more than 100 feet below mean sea level in the Des Plaines, Elmhurst, and Joliet pumping centers or more than 750 feet below land surface.

The 1975 piezometric surface was compared with the elevation of the tops of the Galena–Platteville dolomite and the Glenwood–St. Peter Sandstone (from Suter et al., 1959) at various pumping centers. The amount of dewatering is shown in table 2.

Water level changes for the period 1971–1975 are shown in figure 3. Declines greater than 150 feet were recorded near the Du Page–Cook County line. Declines from 100 to 150 feet were recorded in numerous areas.

In addition to the piezometric surface and water-level decline maps, hydrographs of individual wells are available for wells at Chicago, Summit, Des Plaines, Villa Park, Elmhurst, Bensenville, Aurora, Geneva, Elgin, Lake Bluff, Zion, and Joliet. These may be requested from the Illinois State Water Survey.

Deep Aquifer Pumpage

Estimated pumpage from deep wells for 1974 by township and by use is given in tables 3 through 9. Domestic pumpage is not included in the tables. Pumpage from deep

Table 1. Decline in Nonpumping Water Levels in Northeastern Illinois

County	*Average decline (feet per year) 1966-1971*	*1971-1975*
Cook	9	11
Du Page	10	13
Kane	10	9
Lake	14	10
McHenry	5	6
Will	8	14

Table 2. Portions of Upper Deep Sandstone Formations Dewatered

Pumping center	*Formations*
Aurora	More than ½ the Galena–Platteville
Elgin	More than ½ the Glanea–Platteville
Joliet	Nearly all the Galena–Platteville
Summit	More than 2/3 the Galena–Platteville
Des Plaines	All of Galena–Platteville and upper part of Glenwood–St. Peter
Elmhurst	All of Galena–Platteville and upper part of Glenwood–St. Peter
Naperville	More than 2/3 the Galena–Platteville

Table 3. Groundwater Pumpage in Suburban Cook County, 1974

(Pumpage in millions of gallons per day)

	Public				*Industrial*				*Totals*			
Township and range	*Sand and gravel*	*Shallow dolomite*	*Deep sand-stone*	*Total*	*Sand and gravel*	*Shallow dolomite*	*Deep sand-stone*	*Total*	*Sand and gravel*	*Shallow dolomite*	*Deep sand-stone*	*Total pumpage*
42N9E		0.566		0.566						0.566		0.566
42N10E	2.069	0.098	4.153	6.320	0.015	0.120	0.100	0.235	2.084	0.218	4.253	6.555
42N11E		0.760	10.510	11.270	0.020	0.195	0.035	0.250	0.020	0.955	10.545	11.520
42N12E		0.201	1.716	1.917	0.020	0.034	1.047	1.101	0.020	0.235	2.763	3.018
42N13E		0.010		0.010		0.010		0.010		0.020		0.020
41N9E	1.809	0.256	1.421	3.486	0.005	0.120		0.125	1.814	0.376	1.421	3.611
41N10E	0.802	3.422	3.653	7.877	0.065	0.075		0.140	0.867	3.497	3.653	8.017
41N11E		0.216	9.038	9.254		0.127	0.045	0.172		0.343	9.083	9.426
41N12E		0.010	3.660	3.670		0.010	0.100	0.110		0.020	3.760	3.789
41N13E						0.020	0.556	0.576		0.020	0.556	0.576
41N14E												
40N12E		0.022		0.022		0.166	1.199	1.365		0.188	1.199	1.387
39N12E		0.017	2.961	2.978		0.917	0.786	1.703		0.934	3.747	4.681
39N13E						0.006	1.024	1.030		0.006	1.024	1.030
38N12E		3.580	1.857	5.437		1.089	3.392	4.481		4.669	5.249	9.918
38N13E		0.008		0.008		0.035	2.708	2.743		0.043	2.708	2.751
37N11E		0.033	0.683	0.716	0.045	0.100	0.219	0.364	0.045	0.133	0.902	1.080
37N12E		0.085	0.253	0.338		0.233		0.233		0.318	0.253	0.571
37N13E		0.015		0.015		0.128	0.025	0.153		0.143	0.025	0.168
37N14&15E						0.005	0.625	0.630		0.005	0.625	0.630
36N12E		1.649	0.219	1.868		0.111		0.111		1.760	0.219	1.979
36N13E		2.917	2.191	5.108		0.125	0.080	0.205		3.042	2.271	5.313
37N14&15E		0.501	0.505	1.006		2.303	0.025	2.328		2.804	0.530	3.334
35N13E		4.860	0.787	5.647		0.219		0.219		5.079	0.787	5.866
35N19&15E		8.423	3.013	11.436		1.474	0.488	1.962		9.897	3.501	13.398
Totals	4.680	27.649	46.620	78.949	0.170	7.622	12.454	20.246	4.850	35.271	59.074	99.195

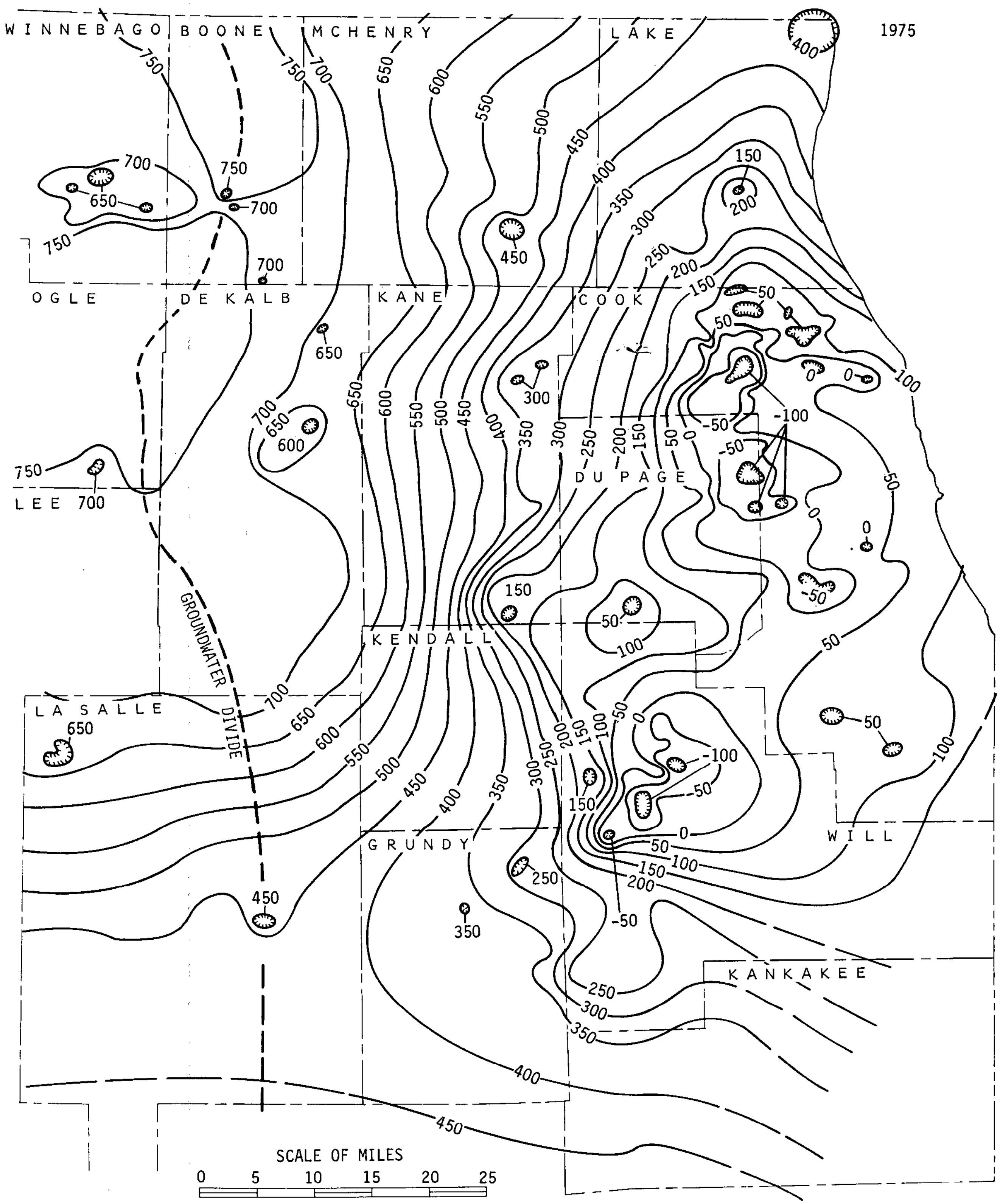

Figure 2. Elevation of piezometric surface of deep sandstone aquifer, October 1975

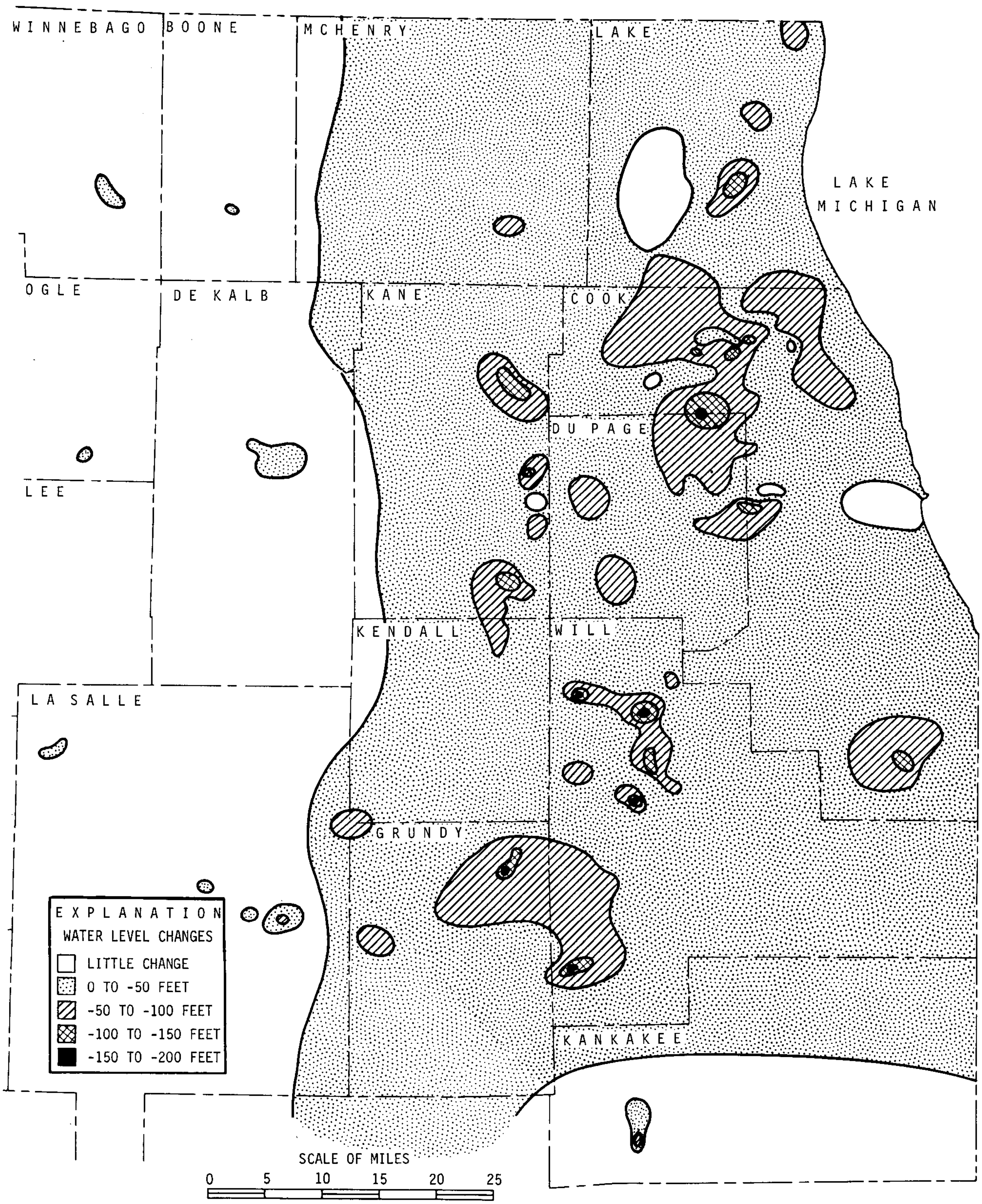

Figure 3. Water level declines in deep wells, 1971-1975

Table 4. Groundwater Pumpage in Du Page County, 1974

(Pumpage in millions of gallons per day)

	Public				*Industrial*				*Totals*			
Township and range	*Sand and gravel*	*Shallow dolomite*	*Deep sand-stone*	*Total*	*Sand and gravel*	*Shallow dolomite*	*Deep sand-stone*	*Total*	*Sand and gravel*	*Shallow dolomite*	*Deep sand-stone*	*Total pumpage*
40N9E		0.150		0.150		0.675		0.675		0.825		0.825
40N10E	0.241	3.651	0.347	4.239	0.045	0.172	0.025	0.242	0.286	3.823	0.372	4.481
40N10E	2.420	1.787	4.608	8.815		0.335	0.040	0.375	2.420	2.122	4.648	9.190
39N9E		0.750	1.330	2.080		0.164		0.164		0.914	1.330	2.244
39N10E		7.722		7.722		0.288	0.011	0.299		7.983	0.011	7.994
39N11E	0.002	2.575	10.344	12.921	0.015	1.472	0.460	1.947	0.017	4.047	10.804	14.868
38N9E		2.040	0.209	2.249	0.020	0.441	0.015	0.476	0.020	2.481	0.224	2.725
38N10E		4.086	0.660	4.746		0.188		0.188		4.274	0.660	4.934
38N11E												
37N11E		7.586	1.135	8.721		1.238		1.238		8.824	1.135	9.959
Totals	2.663	30.320	18.633	51.616	0.080	4.973	0.551	5.604	2.743	35.293	19.184	57.220

Table 5. Groundwater Pumpage in Kane County, 1974

(Pumpage in millions of gallons per day)

	Public				*Industrial*				*Totals*			
Township and range	*Sand and gravel*	*Shallow dolomite*	*Deep sand-stone*	*Total*	*Sand and gravel*	*Shallow dolomite*	*Deep sand-stone*	*Total*	*Sand and gravel*	*Shallow dolomite*	*Deep sand-stone*	*Total pumpage*
42N6E			0.197	0.197		0.105	0.010	0.115		0.105	0.207	0.312
42N7E												
42N8E	3.446	0.011	0.447	3.904	0.110	0.055	0.513	0.678	3.556	0.066	0.960	4.582
41N6E			0.085	0.085			0.001	0.001			0.086	0.086
41N7E	0.005		0.005						0.005			0.005
41N8E	0.412	0.013	8.457	8.882	0.336	0.664	0.049	1.049	0.748	0.677	8.506	9.931
40N6E	0.055			0.055		0.001		0.001	0.055	0.001		0.056
40N7E			0.049	0.049	0.003			0.003	0.003		0.049	0.052
40N8E	1.206	0.008	1.765	2.979	0.020	0.123	0.415	0.558	1.226	0.131	2.180	3.537
39N6E			0.005	0.005	0.010			0.010	0.010		0.005	0.015
39N7E	0.058		0.045	0.103	0.015		0.274	0.289	0.073		0.319	0.392
39N8E		0.033	3.564	3.597		0.216	1.025	1.241		0.249	4.589	4.838
38N6E						0.003		0.003		0.003		0.003
38N7E	0.085	0.005	1.395	1.485		0.002		0.002	0.085	0.007	1.395	1.487
38N8E	0.084	0.258	10.923	11.265		1.258	0.389	1.647	0.084	1.516	11.312	12.912
Totals	5.351	0.328	26.932	32.611	0.494	2.427	2.676	5.597	5.845	2.755	29.608	38.208

wells totaled 154.9 mgd in 1974. Pumpage from deep wells by county for 1960, 1970, and 1974 are given in table 10.

It should be noted that pumpage from deep wells in addition to pumpage from the deep sandstone includes pumpage from wells open to both the Silurian dolomite and Mt. Simon aquifer. A discussion of the percent of the total deep well pumpage from the dolomite and Mt. Simon is included in the section *Balancing Groundwater Supply and Demand.*

Mt. Simon Aquifer

Many high capacity deep wells penetrate the upper 200 to 300 feet of the Mt. Simon aquifer to obtain part of their yields. It was estimated in 1974 that 59 wells finished in the Mt. Simon aquifer were in use. Twenty-one wells that had been open to the Mt. Simon at one time and were plugged above the top of the Mt. Simon were in use in 1974. Wells not in use included 47 open to the Mt. Simon and 65 plugged. The number of Mt. Simon wells can be compared with the total number of deep wells, 886, as presently recorded at the Water Survey's Warrenville office.

Advantages of drilling into the Mt. Simon aquifer are higher well yields and higher pumping levels. Hydrostatic heads in the Mt. Simon are reported to be more than 50 feet higher than heads in the overlying deep sandstone aquifer. It was estimated by Walton and Csallany (1962) that for each 200 feet of penetration into the Mt. Simon an increase in specific capacity (yield in gallons per minute per foot of drawdown, gpm/ft) of 1.8 gpm/ft would result. If a typical specific capacity of a well finished in the deep sandstone is 9 gpm/ft, drilling 200 feet into the Mt. Simon would

Table 6. Groundwater Pumpage in Lake County, 1974

(Pumpage in millions of gallons per day)

Township and range	Public: Sand and gravel	Public: Shallow dolomite	Public: Deep sand-stone	Public: Total	Industrial: Sand and gravel	Industrial: Shallow dolomite	Industrial: Deep sand-stone	Industrial: Total	Totals: Sand and gravel	Totals: Shallow dolomite	Totals: Deep sand-stone	Total pumpage
46N9E	0.092	0.006		0.098	0.090			0.090	0.182	0.006		0.188
46N10E	0.634			0.634	0.095	0.040		0.135	0.729	0.040		0.769
46N11E						0.005		0.005		0.005		0.005
46N12E	0.077	0.027	0.126	0.230	0.004	0.002		0.006	0.081	0.029	0.126	0.236
45N9E	0.319	0.002		0.321	0.279		0.050	0.329	0.598	0.002	0.050	0.650
45N10E	0.372	0.923	0.459	1.754		0.067	0.100	0.167	0.372	0.990	0.559	1.921
45N11E	0.268	0.008	0.653	0.929	0.046	0.020	0.065	0.131	0.314	0.028	0.718	1.060
45N12E		0.030	0.030	0.060	0.050	0.045		0.095	0.050	0.075	0.030	0.155
44N9E	0.041	0.398		0.439	0.004	0.002		0.006	0.045	0.400		0.445
44N10E	0.606	0.121	0.403	1.130	0.010	0.028		0.038	0.616	0.149	0.403	1.168
44N11E	0.013	1.398	1.949	3.360	0.254	0.149	0.115	0.518	0.267	1.547	2.064	3.878
44N12E	0.005	0.017	0.007	0.029	0.287	0.124	0.705	1.116	0.292	0.141	0.712	1.145
43N9E	0.699	0.014		0.713	0.273	0.109		0.382	0.972	0.123		1.095
43N10E		0.322	0.630	0.952	0.025	0.040	0.025	0.090	0.025	0.362	0.655	1.042
43N11E	0.150	0.182	0.905	1.237	0.126	0.040	0.015	0.181	0.276	0.222	0.920	1.418
43N12E			0.171	0.171		0.005	0.601	0.606		0.005	0.772	0.777
Totals	3.276	3.448	5.333	12.057	1.543	0.676	1.676	3.895	4.819	4.124	7.009	15.952

Table 7. Groundwater Pumpage in McHenry County, 1974

(Pumpage in millions of gallons per day)

Township and range	Public: Sand and gravel	Public: Shallow dolomite	Public: Deep sand-stone	Public: Total	Industrial: Sand and gravel	Industrial: Shallow dolomite	Industrial: Deep sand-stone	Industrial: Total	Totals: Sand and gravel	Totals: Shallow dolomite	Totals: Deep sand-stone	Total pumpage
46N5E	0.751			0.751			0.205	0.205	0.751		0.205	0.956
46N6E	0.005			0.005					0.005			0.005
46N7E	0.197			0.197					0.197			0.197
46N8&9E	0.080			0.080	0.605			0.605	0.685			0.685
45N5E					0.016			0.016	0.016			0.016
45N6E		0.003		0.003	0.045	0.005	0.030	0.080	0.045	0.008	0.030	0.083
45N7E	1.975			1.975					1.975			1.975
45N8&9E	1.191			1.451	0.030	0.098	0.703	0.831	1.221	0.358	0.703	2.282
44N5E	0.542	0.001		0.543	0.015		0.121	0.136	0.557	0.001	0.121	0.679
44N6E					0.092			0.092	0.092			0.092
44N7E	0.888	0.005		0.893	0.053	0.010		0.063	0.941	0.015		0.956
44N8&9E	0.079	0.109	0.535	0.723	0.339	0.102		0.441	0.418	0.211	0.535	1.164
43N5E							0.001	0.001			0.001	0.001
43N6E	0.102			0.102					0.102			0.102
43N7E	0.312	0.010		0.322	0.058			0.058	0.370	0.010		0.380
43N8&9E	0.302	0.640	2.031	2.973		0.060	0.050	0.110	0.302	0.700	2.081	3.083
Totals	6.424	1.028	2.566	10.018	1.253	0.275	1.110	2.638	7.677	1.303	3.676	12.656

theoretically result in obtaining a specific capacity of 10.8 gpm/ft.

Walton and Csallany estimated that the average permeability of the Mt. Simon aquifer is about 16 gpd/sq ft, or about one-half that of the average permeability of the Ironton–Galesville sandstone.

Walton (1964b) estimated that the practical sustained yield of the Mt. Simon is 14 mgd. The recharge area for the Mt. Simon aquifer is in southeastern Wisconsin (Illinois State Water Survey, 1973).

An important consideration in developing the Mt. Simon aquifer as a water supply is the *water quality.* According to Suter et al. (1959) the primary characteristic of the quality of water from the Mt. Simon aquifer is its rapid increase in chloride concentration with depth of penetration or lower elevation. Table 11 shows the results of analyses of water samples collected from a proposed waste disposal well near West Chicago in Du Page County.

According to Suter et al, with increasing penetration below an elevation of 1275 feet below sea level, greater quantities of water with high chloride content and high hardness are permitted to enter a well. Because the rocks

Table 8. Groundwater Pumpage in Will County, 1974

(Pumpage in millions of gallons per day)

Township and range	Public: Sand and gravel	Public: Shallow dolomite	Public: Deep sand-stone	Public: Total	Industrial: Sand and gravel	Industrial: Shallow dolomite	Industrial: Deep sand-stone	Industrial: Total	Totals: Sand and gravel	Totals: Shallow dolomite	Totals: Deep sand-stone	Totals: Total pumpage
37N9E						0.003		0.003		0.003		0.003
37N10E		2.347	0.696	3.043		0.047	0.457	0.504		2.394	1.153	3.547
36N9E		0.231	0.526	0.757		0.050		0.005		0.281	0.526	0.807
36N10E		0.704	2.690	3.394		0.267	0.553	0.820		0.971	3.243	4.214
36N11E	1.118	0.118	0.768	2.004		0.200		0.200	1.118	0.318	0.768	2.204
35N9E		0.022	1.946	1.968		0.081	0.270	0.351		0.103	2.216	2.319
35N10E		0.330	5.374	5.704		0.136	6.372	6.508		0.466	11.746	12.212
35N11E	1.214	0.484	1.904	3.602		0.030		0.030	1.214	0.514	1.904	3.632
35N12&13E		1.078		1.078		0.020		0.020		1.098		1.098
34N9E	0.010	0.005	0.010	0.025		0.010	6.277	6.287	0.010	0.015	6.287	6.312
34N10E		0.059		0.059			0.305	0.305		0.059	0.305	0.364
34N11E		0.148		0.148	0.010			0.010	0.010	0.148		0.158
34N12E						0.032		0.032		0.032		0.032
34N13E		0.801		0.801		0.211		0.211		1.012		1.012
34N14&15E		0.433		0.433	0.030	0.281	0.005	0.316	0.030	0.714	0.005	0.749
33N9E		0.002	0.450	0.452			0.300	0.300		0.002	0.750	0.752
33N10E						0.005	0.534	0.539		0.005	0.534	0.539
33N11E												
33N12E		0.299		0.299		0.010		0.010		0.309		0.309
33N13E						0.020		0.020		0.020		0.020
33N14&15E		0.200		0.200		0.026		0.026		0.226		0.226
32N9E		0.020	0.255	0.275			0.005	0.005		0.020	0.260	0.280
32N10E			0.003	0.003							0.003	0.003
Totals	2.342	7.281	14.622	24.245	0.040	1.429	15.078	16.547	2.382	8.710	29.700	40.792

Table 9. Summary of Groundwater Pumpage in Northeast Illinois, 1974

(Pumpage in millions of gallons per day)

County	Public: Sand and gravel	Public: Shallow dolomite	Public: Deep sand-stone	Public: Total	Industrial: Sand and gravel	Industrial: Shallow dolomite	Industrial: Deep sand-stone	Industrial: Total	Totals: Sand and gravel	Totals: Shallow dolomite	Totals: Deep sand-stone	Totals: Total pumpage
Cook, Suburban	4.680	27.649	46.620	78.949	0.170	7.622	12.454	20.246	4.850	35.271	59.074	99.195
Cook, Chicago						0.006	3.904	3.910		0.006	3.904	3.910
DuPage	2.663	30.320	18.633	51.616	0.080	4.973	0.551	5.604	2.743	35.293	19.184	57.220
Kane	5.351	0.328	26.932	32.611	0.494	2.427	2.676	5.597	5.845	2.755	29.608	38.208
Lake	3.276	3.448	5.333	12.057	1.543	0.676	1.676	3.895	4.819	4.124	7.009	15.952
McHenry	6.424	1.028	2.566	10.018	1.253	0.275	1.110	2.638	7.677	1.303	3.676	12.656
Will	2.342	7.281	14.622	24.245	0.040	1.429	15.078	16.547	2.382	8.710	29.700	40.792
Totals	24.736	70.054	114.706	209.496	3.580	17.408	37.449	58.437	28.316	87.462	152.155	267.933

dip to the southeast, the top of the Mt. Simon aquifer is at an elevation below 1275 feet below sea level in a large part of Will County and in southeastern Cook County. Wells that would withdraw water from the Mt. Simon in this area would commonly yield water too salty for ordinary use. Caution should also be exercised in drilling wells into the Mt. Simon above this area. Water quality problems have been experienced in many Mt. Simon wells, as evidenced by the number of wells plugged above the top of the Mt. Simon.

Suter et al. estimated that about 17 percent of the water withdrawn from deep wells was derived from the Mt. Simon aquifer. On the basis of that percentage, about 26 mgd was derived from the Mt. Simon in 1974. Additional data collected by the Survey are presently being studied to validate the percentage given by Suter et al. For a more detailed discussion on contribution from the Mt. Simon, see the section *Balancing Groundwater Supply and Demand.*

The feasibility of desalting water from the Mt. Simon aquifer was considered in Illinois State Water Survey (1973). This report is summarized in the section *Desalting Brackish Water from the Mt. Simon Aquifer.* Illinois State Water Survey (1973) is an excellent reference on the hydrology and water quality of the Mt. Simon aquifer.

Table 10. Groundwater Pumpage from Deep Wells

(Pumpage in millions of gallons per day)

County	*1960 **	*1970**	*1974*
Cook	41.11	58.16	62.98
Du Page	9.09	15.50	19.18
Kane	21.99	27.91	29.61
Lake	1.97	5.97	7.01
McHenry	1.93	3 .00	3.68
Will	17.72	27.11	29.70
Total	93.81	137.65	152.16
Estimated domestic pumpage			2.74
			154.90

*From Sasman et al. (1974)

Shallow Dolomite Aquifers

The shallow dolomite aquifers consist of Silurian rocks in most of the area and dolomites of Maquoketa and Galena-Platteville Formations in the western part of the area. Discussion of the shallow dolomite aquifers will be limited to the Silurian dolomite since in northeastern Illinois high yielding wells for public and industrial use are concentrated in the Silurian dolomite.

Geohydrology

The geohydrology of the Silurian dolomite was studied in detail for Du Page County (Zeizel et al., 1962) and at Libertyville-Mundelein, Chicago Heights-Park Forest, and La Grange-Western Springs (Prickett et al., 1964).

The bedrock surface in most of the Chicago region is formed by Silurian rocks. The thickness of the rocks increases from less than 50 feet in McHenry, Kane, and Kendall Counties to more than 450 feet in southeastern Will County. Where valleys occur in the bedrock, the Silurian rocks have been deeply eroded and are thin.

The Silurian rocks are mainly dolomites and are silty at the base. They are divided into the Alexandrian Series below and the Niagaran Series above *(see figure 1).* Areas where the Alexandrian .Series forms the bedrock surface are small compared with the areas where the Niagaran Series is the uppermost bedrock.

Groundwater in the Silurian rocks occurs in joints, fissures, solution cavities, and other openings. The water-yielding openings are irregularly distributed both vertically and horizontally. Available geohydrologic data indicate that the rocks contain numerous openings which extend for considerable distances and are interconnected on an area1 basis. The upper parts of the rocks are much more permeable than the lower parts. The Nigaran and Alexandrian Series have about the same average productivity in areas where the units are the uppermost bedrock.

Recharge to these Silurian rocks is derived locally, mostly from vertical leakage through the glacial drift or other unconsolidated deposits which are in turn recharged from precipitation. Water occurs in these rocks mainly under leaky artesian conditions.

Shallow dolomite wells in northeastern Illinois range in depth from 15 to 450 feet. Well-bore diameters ranging from 6 to 12 inches at the bottom are common. Yields of wells are variable but exceed 500 gpm in many areas.

Pumpage and Well Yields

Pumpage from the shallow dolomite wells is largely concentrated in Du Page, Cook, and Lake Counties. Large quantities of water are pumped from wells owned by Chicago Heights, Downers Grove, Flossmoor, Glen Ellyn, Hinsdale, Homewood, La Grange, Libertyville, Lisle, Naperville, Orland Park, Park Forest, Wauconda, Westmont, Wheaton, Woodridge, and other municipalities. Pumpage from the Silurian dolomite for 1960, 1970, and 1974 is given in table 12.

The productivity of dolomite is very inconsistent. It is impossible to predict the yield of a well before drilling because a ‘dry’ hole could be drilled at any location.

Data from over 700 well production tests were studied in northeastern Illinois by Csallany and Walton (1963). The well production tests consisted of pumping a well at a con-

Table 11. Analyses of Water from Mt. Simon Well near West Chicago, Du Page County

(Chemical constituents in milligrams per liter)

*Aquifer penetration * (ft)*	*TDM*	*Cl*	*SO_4*	*Alkalinity ($CaCO_3$)*	*Hardness ($CaCO_3$)*	*Fe*
450	620	88	39	284	202	
738	4,076	2,150	224	204	1,370	44
1238	33,070	19,500	770	196	13,200	44
2038	79,3 30	47,500	1177	124	29,200	37
2138	80,100	48,000	1154	88	29,800	85
2190	81,780	50,500	1133	84	28,900	129

*Analyses are for point samples collected at these depths below the top of the Mt. Simon.

stant rate and frequently measuring the drawdown in the pumped well. Specific capacities (yield in gallons per minute per foot of drawdown) from the well production tests were adjusted for well losses and to a common radius and pumping period. Frequency graphs for specific capacity per foot of aquifer penetration were constructed as described by Zeizel et al. (1962). The frequency graphs indicate that the productivity of the Silurian rocks is greater in areas where sands and gravels directly overlie and are in hydraulic connection with the dolomite. Also, the productivity increases as the thickness of sand and gravel increases. The productivity of the Silurian rocks is greater in bedrock uplands than it is in bedrock valleys.

A map showing yields of shallow dolomite wells was prepared by Csallany and Walton (1963). The map, modified by Water Survey hydrologists for northeastern Illinois, is shown in figure 4. The probable well yields were estimated from specific capacity data, water level data, and aquifer thickness.

Sand and Gravel Aquifers

Approximately 50 percent of the area is underlain by sand and gravel aquifers (Northeastern Illinois Planning Commission, 1966). According to Prickett et al. (1964), fairly extensive surficial sand and gravel deposits are found in parts of Lake, McHenry, Kane, Du Page, and Will Counties. Buried sand and gravel deposits are widely scattered in McHenry and Kane Counties, western Lake County, northwestern Cook and Du Page Counties, and central Will County.

The chances of penetrating continuous water-yielding beds of considerable thickness are better within bedrock valleys than in bedrock uplands. However, bedrock valleys in Lake, Cook, and Du Page Counties that slope eastward toward Lake Michigan are generally filled with fine sediment.

Prickett et al. also stated that because of irregularity of occurrence, sand and gravel aquifers are more difficult to locate than bedrock aquifers. In addition, sand and gravel aquifers are more difficult to develop than bedrock aquifers because the installation of a screen is required to control the entrance of sand and gravel into a production well. However, sand and gravel aquifers are more readily recharged, and often are more permeable than bedrock aquifers.

As with the Silurian dolomite aquifer, it is impossible to predict the yield of a sand and gravel well without actually drilling and performing a well test. An intensive test drilling program is usually required to locate high capacity wells and well fields.

A number of Geological Survey and Water Survey publications are available to aid in locating promising areas for test drilling for large supplies from sand and gravel aquifers. They include Hackett and McComas (1969), Larsen (1973), and Zeizel et al. (1962).

The Geological Survey has been conducting a controlled test drilling program in northeastern Illinois to aid in locating sand and gravel aquifers in the glacial drift. The results of the test drilling program have been summarized in their Environmental Geology Notes series (Larsen and Lynd, 1965; Lund, 1965a, 1965b, 1966a, 1966b; Reed, 1972, 1975).

In addition to providing published reports the Water Survey and Geological Survey can provide assistance in planning and conducting test drilling and aquifer testing programs.

Pumpage and Well Yields

Municipalities that obtain all or part of their supplies from sand and gravel wells include Streamwood, Bartlett, Schaumberg, Hoffman Estates, Palatine, Itasca in Cook County; Addison in Du Page County; Elgin, Carpentersville, and East Dundee in Kane County; Barrington, Lincolnshire, Mundelein, Fox Lake, Round Lake, Lake Villa, and Antioch in Lake County; Union, Huntley, Cary, Marengo, Woodstock, McHenry, Harvard, and Hebron in McHenry County; and Joliet in Will County. Pumpage from sand and gravel aquifers for 1960, 1970, and 1974 is given in table 13.

Table 12. Groundwater Pumpage from Silurian Dolomite Wells

(Pumpage in millions of gallons per day)

County	*1960**	*1970**	*1974*
Cook	29.69	36.35	35.28
Du Page	20.21	33.92	35.29
Kane	2.63	3.37	2.76
Lake	5.28	6.06	4.12
McHenry	2.38	2.64	1.30
Will	6.92	8.37	8.71
Total	67.11	90.71	87.46
Estimated domestic pumpage			15.94
			103.40

*From Sasman et al. (1974)

Table 13. Groundwater Pumpage from Sand and Gravel Wells

(Pumpage in millions of gallons per day)

County	*1960**	*1970**	*1974*
Cook	1.11	3.68	4.85
Du Page	0.56	2.33	2.74
Kane	3.91	6.19	5.85
Lake	5.15	6.92	4.82
McHenry	6.39	9.34	7.68
Will	4.86	2.92	2.38
Total	21.98	31.38	28.32
Estimated domestic pumpage			6.99
			35.31

*From Sasman et al. (1974)

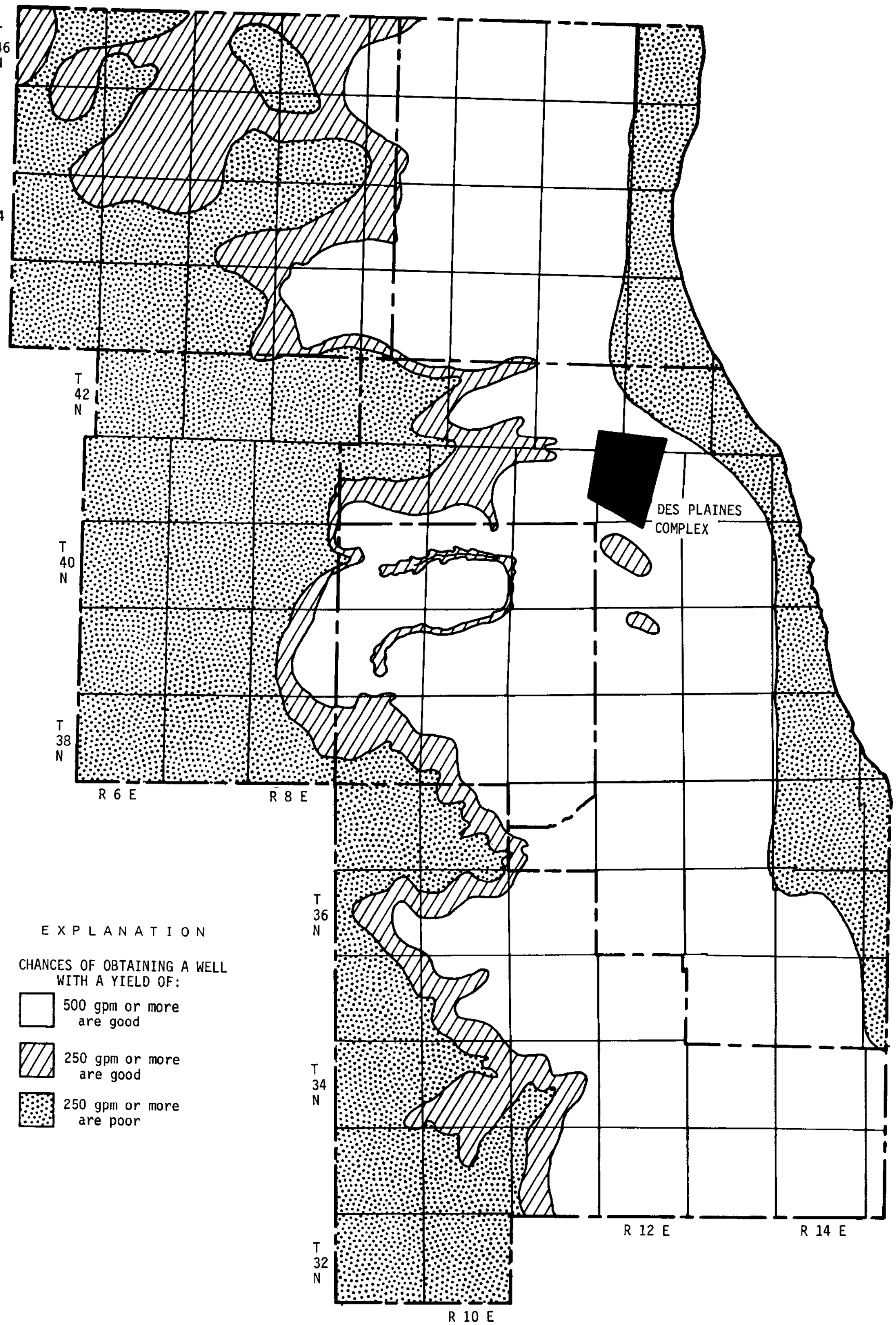

Figure 4. Estimated yields of shallow dolomite wells

A map showing the estimated yield of wells in sand and gravel aquifers was prepared for *Water for Illinois, a Plan for Action* (1967) from available data, and is shown in figure 5. The map indicates general areas where conditions are especially favorable for drilling wells with large yields, but test drilling is required to locate specific wells.

Potential Yields of Shallow Aquifers and Methods of Evaluation

The potential yield is defined as the maximum amount of groundwater that can be developed from a reasonable number of wells and well fields without creating critical water levels or exceeding, recharge. The potential yields of sand and gravel and the shallow dolomite aquifers were estimated from maps prepared by the Water Survey showing recharge rates (figures 6-9). Potential yield by township is given later in tables 19 through 24.

Withdrawals from shallow aquifers in Du Page County in 1974, 41.91 mgd, are already near the county potential yield of 44.40 mgd. The withdrawal figure includes estimated domestic pumpage.

Methods of evaluating the potential yields call for maps and cross sections showing the 1) sequence, structure, general characteristics, location, thickness, and areal extent of shallow dolomite aquifers; 2) the thickness and general characteristics of the glacial drift; and 3) the locations and general characteristics of basal, interbedded, and surficial sand and gravel aquifers. These were prepared from geologic data and jointly studied by the Water Survey and Geological Survey.

Shallow Dolomite Aquifers

The rates of recharge under heavy pumping conditions from vertical leakage of water through the glacial drift to the shallow aquifers in the Chicago region were estimated by flow-net analysis of piezometric surface maps and studies of past records of pumpage and water levels. Areas of diversion of production wells in seven pumping centers (Woodstock, Libertyville-Mundelein, Chicago Heights, La Grange, West Chicago, Wheaton, and Downers Grove-Hinsdale areas) were delineated and pumpage and water level graphs were compared to show that recharge has in the past balanced discharge.

Recharge rates computed by taking into consideration the vertical permeability and thickness of confining beds and the head loss associated with the vertical leakage of water were related to geologic controls. A map showing estimated recharge rates for the shallow dolomite aquifers in the Chicago region was prepared on the basis of the regional geologic maps, studies made in the seven pumping centers mentioned above, and water level data.

Statistical analysis of specific capacity data for more than 800 wells in northern Illinois provided a basis for determining the role of individual shallow dolomite aquifers or formations as contributors of water, and the relationships between yields of wells and geohydrologic controls. Probable ranges in specific capacities and yields of wells in undeveloped areas were estimated on the basis of specific-capacity data, aquifer thickness and areal geology maps, and water level data.

A map showing areas of diversion of existing shallow dolomite wells in the Chicago region was prepared from a pumpage inventory for 1962 and computed recharge rates. Undeveloped areas outside areas of diversion where heavy well development is possible were delineated. The practical sustained yields of existing pumping centers were estimated. Pumping and water level data describing the response of the shallow dolomite aquifers to heavy pumping were studied to determine what effect, if any, the inconsistency of the shallow dolomite aquifers has on the regional response of the aquifers to development.

The potential yields of the shallow dolomite aquifers in each of the six counties in the Chicago region were estimated from maps showing recharge rates and probable yields of wells. In most cases the potential yield of an area was simply the product of the area and the recharge rate. In some cases the potential yield was limited by the probable yields of wells.

Glacial Drift Aquifers

Glacial drift aquifers were segregated into two categories, complementary and supplementary, depending upon whether or not pumping from the glacial drift aquifers will reduce recharge to and, therefore, the potential yield of the shallow dolomite aquifers. In areas where shaly dolomite and shale beds in the shallow dolomite aquifers retard recharge to shallow dolomite wells, the potential yield of sand and gravel aquifers supplement the potential yield of the shallow dolomite aquifers.

Rates of recharge to basal and interbedded sand and gravel aquifers were assumed to be equal to the rates of recharge to the shallow dolomite aquifers in areas where shaly dolomite or shale beds do not retard the vertical movement of water. The rate of recharge to the surficial sand and gravel deposits was estimated on the basis of recent studies at Taylorville and East St. Louis, and the streamflow studies in Illinois.

Available specific-capacity data for wells in glacial drift aquifers in the Chicago region were studied to appraise the yields of sand and gravel wells. Areas of diversion of existing wells in the glacial drift aquifers were outlined on the basis of pumpage records and recharge rates. Undeveloped areas outside areas of diversion were delineated. Pumpage and water level records for heavily pumped areas were studied to determine the response of glacial drift aquifers. to development. The practical sustained yields of existing pumping centers were estimated.

The potential yield of the glacial drift aquifers in each

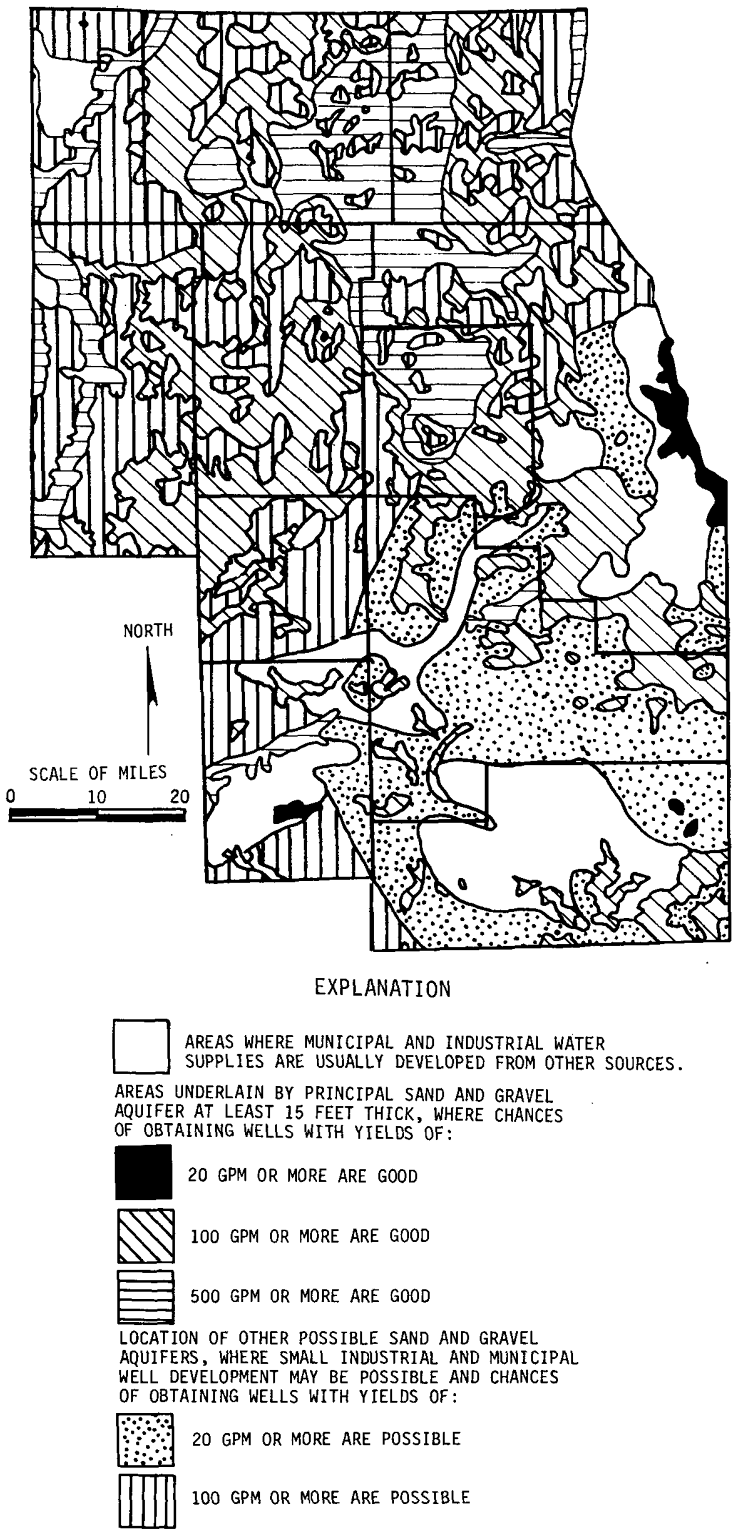

Figure 5. Estimated yields of walls in sand and gravel aquifers
(from Water for Illinois, a Plan for Action, 1967)

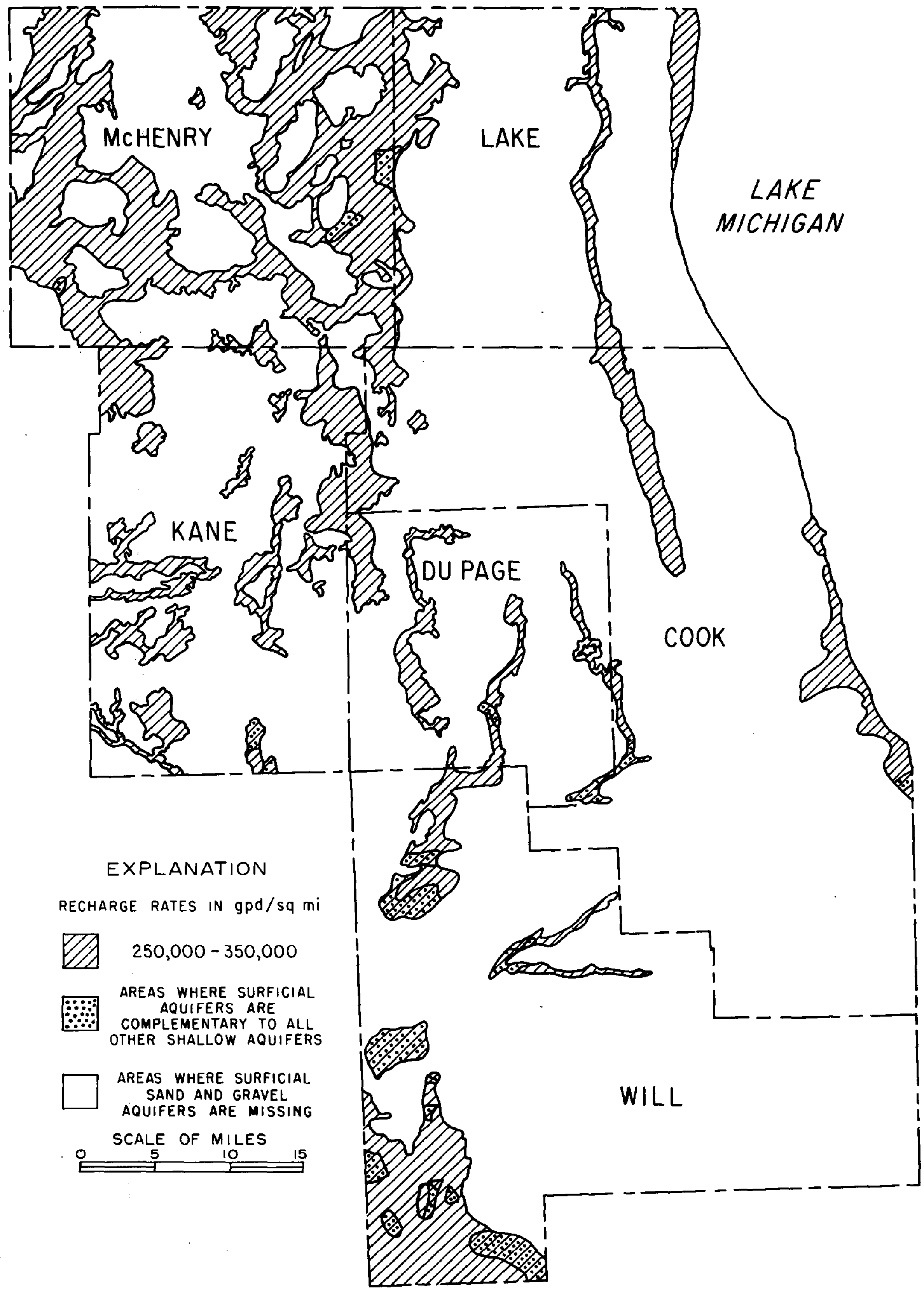

Figure 6. Recharge rates for surficial sand and gravel aquifers

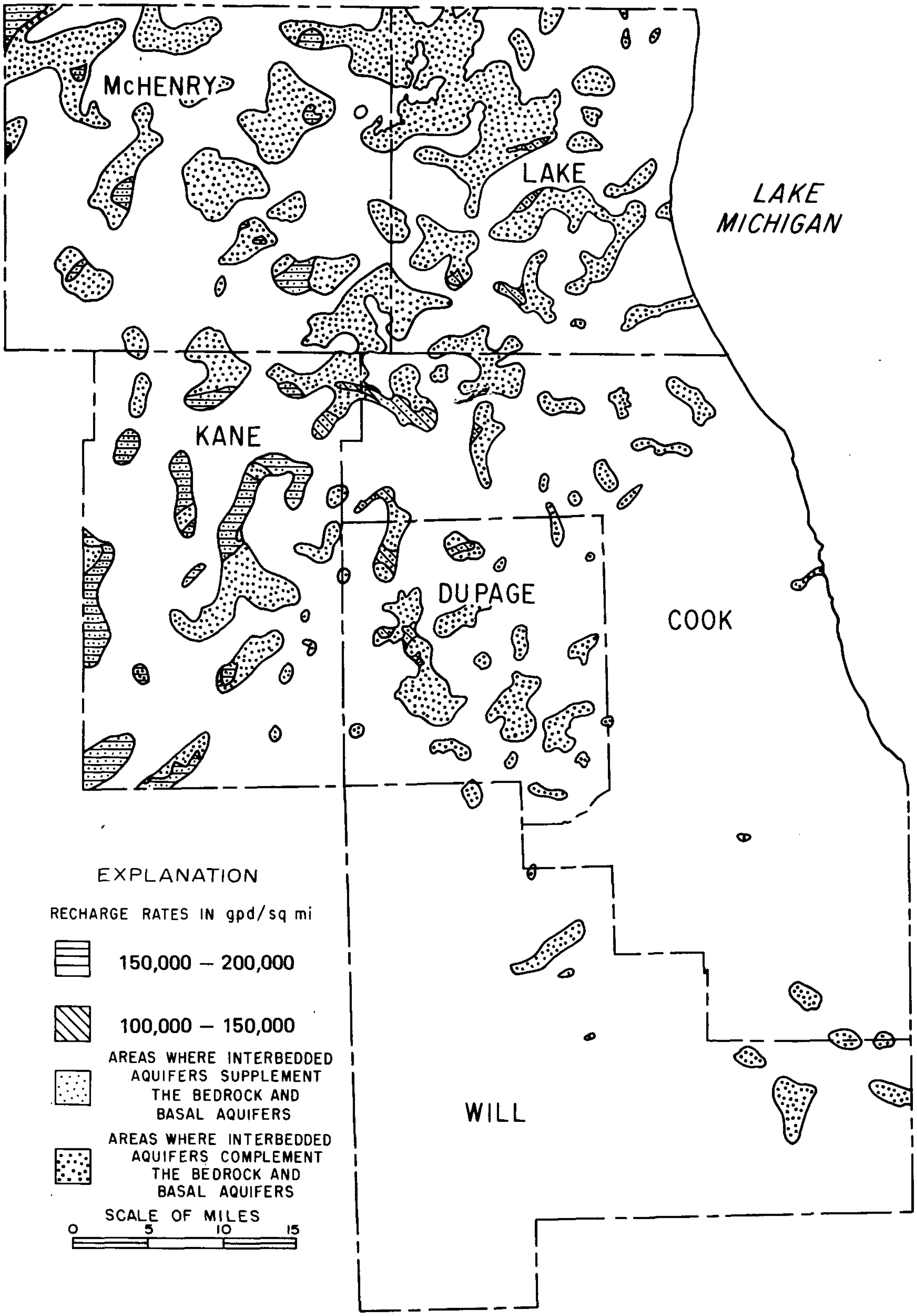

Figure 7. Recharge rates for interbedded sand and gravel aquifers

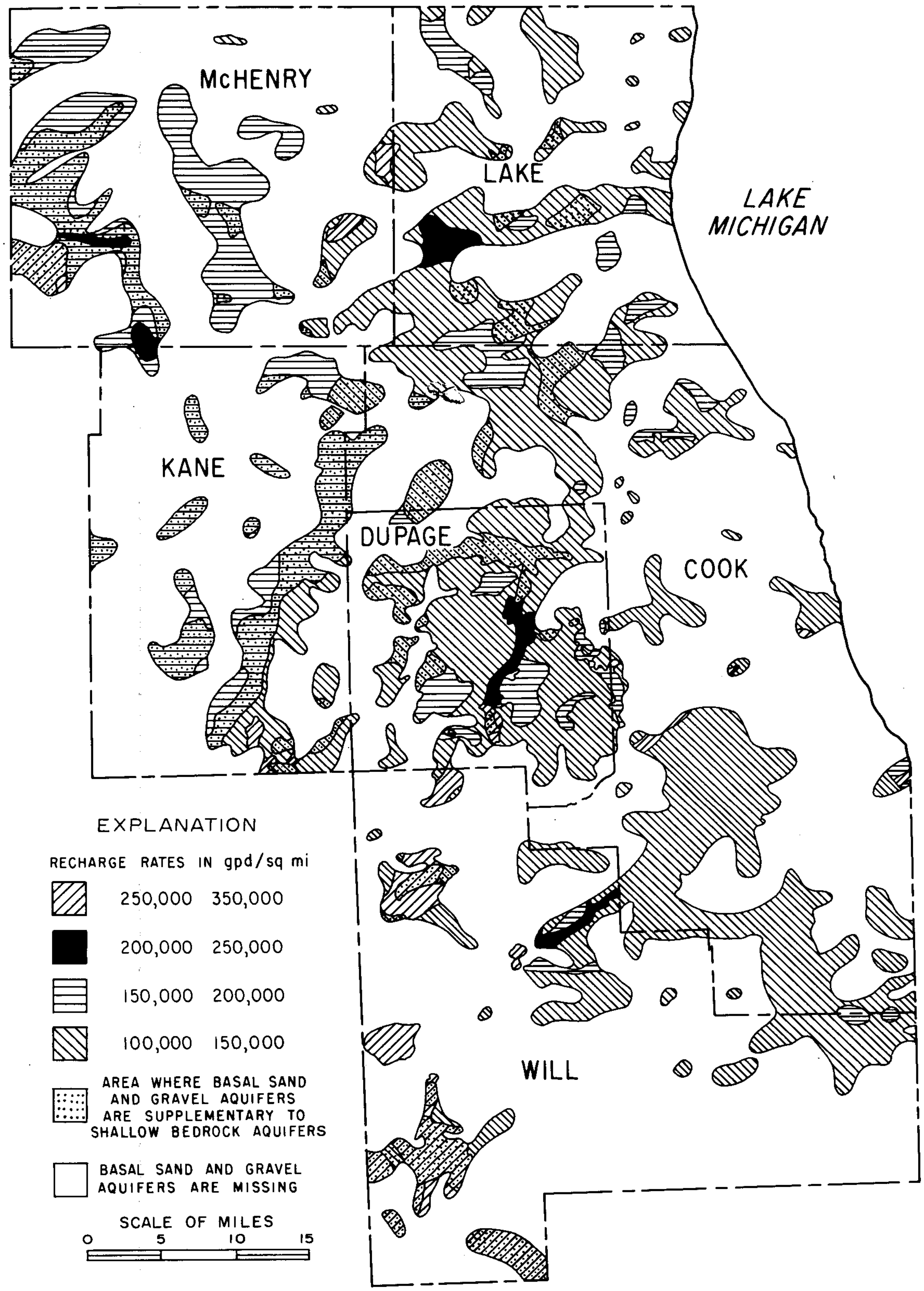

Figure 8. Recharge rates for basal sand and gravel aquifers

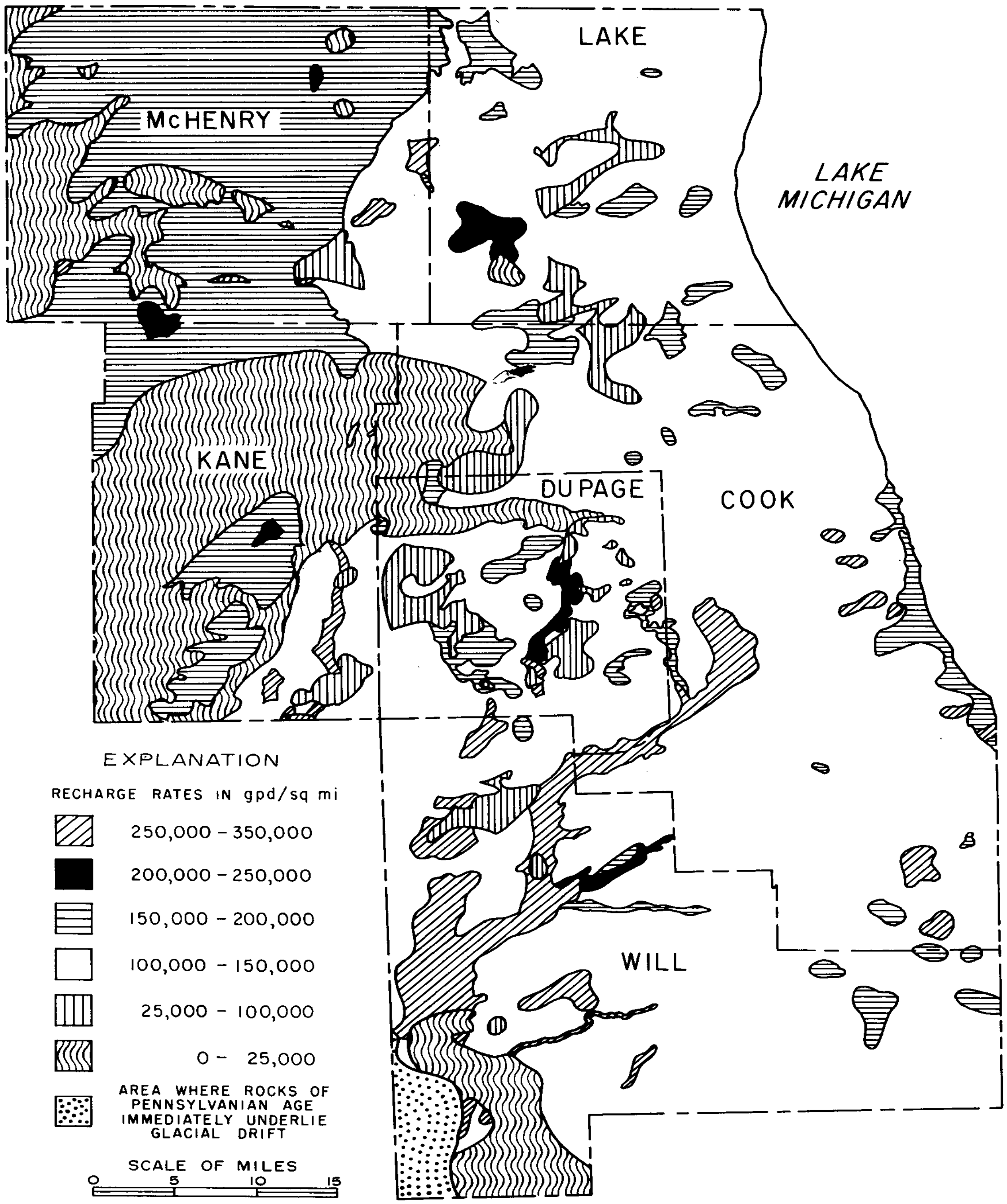

Figure 9. Recharge rates for shallow bedrock aquifers

of the six counties in the Chicago region were estimated from recharge rate maps and data on the yields of existing sand and gravel wells.

Total Potential Yield

The total potential yield of shallow aquifers was estimated by assuming full development of the shallow dolomite aquifers and supplemental development of the glacial drift aquifers. In many areas the opposite may be advantageous – that is, *full development of glacial drift aquifers* and *supplemental development* of shallow dolomite aquifers. Thus, it is possible to obtain more water from the glacial drift aquifers and correspondingly less water from the shallow dolomite aquifers.

The potential yields of the shallow aquifers in each of the six counties in the Chicago region are summarized in table 14.

Methods used in evaluating the potential yield of shallow aquifers; hydrologic maps and cross sections; hydraulic data for wells, aquifers, and confining beds; water level and pumpage data; and streamflow data are described in detail in numerous reports listed in the References.

Table 14. Estimated Potential Yield of Shallow Aquifers in the Chicago Region*

(*(in millions of gallons per day)*

County	*Glacial drift aquifers*	*Shallow dolomite aquifers*	*Total*
Lake	5	50	55
McHenry	27	85	112
Cook	7	101	108
Du Page	5	39	44
Kane	21	36	57
Will	10	121	131
Total	75	432	507

* Based on all available geohydrologic data as of September 1,1963

GROUNDWATER DEMAND PROJECTIONS, 1980-2010

Source of Data

Schicht and Moench (1971) determined water demands in the Chicago region dependent upon groundwater, to make comparisons with groundwater availability and thus to define water deficit areas. Future groundwater demands were estimated from relationships found between population and per capita consumption and between manufacturing employment and per capita consumption. Population and manufacturing employment projections were determined by the Northeastern Illinois Planning Commission (NIPC).

However, the projections of population and manufacturing employment were recently revised downward by NIPC, so it was necessary to revise water demands and to make new comparisons with groundwater availability. Table 15 shows the comparison of the population projections by county used by Schicht and Moench (1971) and the revised estimates. The adjusted township population forecasts are from NIPC (1974). In addition, unpublished population forecasts for 1985 and 2010 and unpublished data on manufacturing employment were provided by NIPC.

Demand Related to Population

Recent data on water consumption and the number of people served by each public water supply system in the study area were collected. Schicht and Moench (1971) had used the water consumption-population relationship for suburban Cook County (groundwater and lake water supplies) for the entire study area because it was believed that most of the factors affecting water consumption were included.

However, because a study on estimating future lake water demands showed that communities supplied by Lake Michigan water had a considerably higher per capita consumption than communities in Cook County supplied by groundwater, it was decided to relate water consumption and population for different county and source combinations.

Regression analyses for eight different combinations of water source and county (table 16) were made. Combinations were limited to eight because of small sample size. After plotting the data on log-probability paper and log-log paper it was decided that for better statistical results a log-log transformation of the data was needed. The form of the equation was

$$y = ax^b \qquad (1)$$

where

y = dependent variable (water consumption, mgd)
x = independent variable (population)

As shown in table 16 correlation coefficients ranged from 0.909 to 0.950 and the standard error of estimate ranged from 0.145 to 0.201.

Table 15. Comparison of Population Projections

County	1980 Revised	1980 Circular 101	1990 Revised	1990 Circular 101
Cook, suburban	2,504,600	2,706,000	2,761,300	3,137,000
Du Page	619,800	700,000	782,800	946,500
Kane	312,600	332,040	410,100	438,530
Lake	496,200	541,550	634,800	716,540
McHenry	147,500	142,100	186,700	202,120
Will	351,300	336,000	456,600	487,700

County	2000 Revised	2000 Circular 101	2010 Revised	2010 Circular 101
Cook, suburban	3,028,000	3,479,000	3,142,900	3,960,100
Du Page	930,000	1,162,000	971,200	1,389,000
Kane	479,000	578,030	525,700	739,100
Lake	720,000	949,400	797,000	1,241,000
McHenry	247,000	294,425	289,500	425,950
Will	550,000	704,850	617,700	1,024,500

Table 16. Results of Regression Analyses Relating Water Consumption and Population

Counties	*Source*	*Sample size*	*Correlation coefficient*	*Standard error of estimate*
All six	Lake and groundwater	193	0.940	0.165
All six	Groundwater	111	0.931	0.170
Cook	Groundwater	46	0.909	0.167
Cook, Du Page	Groundwater	67	0.928	0.145
Cook	Lake	73	0.949	0.150
Cook, Lake	Lake	82	0.950	0.149
Du Page, Kane, Lake, McHenry, Will	Groundwater	65	0.938	0.173
Kane, Lake, McHenry, Will	Groundwater	44	0.918	0.201

Results of the regression analyses are shown graphically in figures 10-13. For Cook and Du Page Counties the relationship between water consumption and population for communities in those counties was used to project groundwater demands (figure 12). Figure 13 shows the relationship used for Kane, Lake, McHenry, and Will Counties.

Projections of municipal demands for townships were made from the relationships shown in figures 12 and 13 and township population Projections. The lines shown in figures 12 and 13 were extended to 165,000 population and 154,100 population, respectively, the maximum projected township populations to use only groundwater. There are several townships in Cook and Lake Counties with municipalities that use *either* Lake Michigan water or groundwater, and a few municipalities that use *both* lake and groundwater. It was assumed that municipalities presently using groundwater would continue to do so to the year 2010. The projected population dependent upon groundwater was determined in these townships by estimating 1970 population dependent upon groundwater and projecting it proportionally to NIPC township projections.

Demand Related to Manufacturing Employment

It was noted by Schicht and Moench (1971) that in areas where manufacturing employment was large in relation to the population, per capita water consumption was much higher. Relationships between the percent of population employed in a manufacturing category and per capita consumption for townships are shown graphically in figure 14.

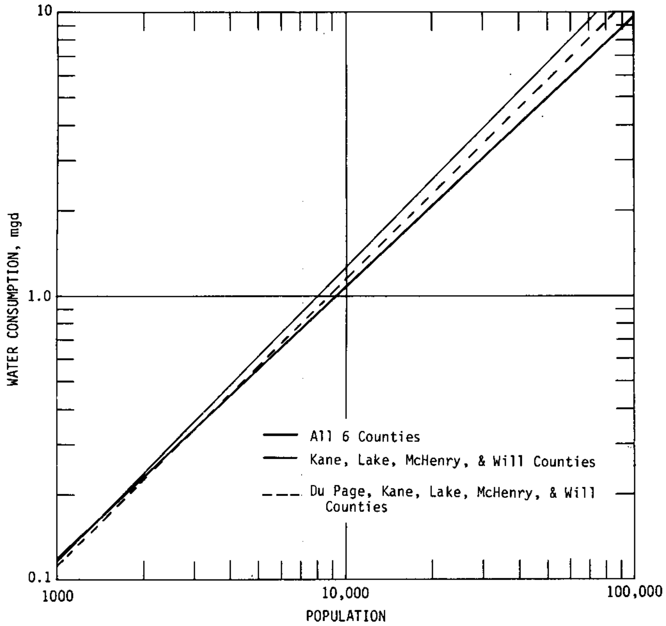

Figure 10. Relationship between groundwater consumption and population

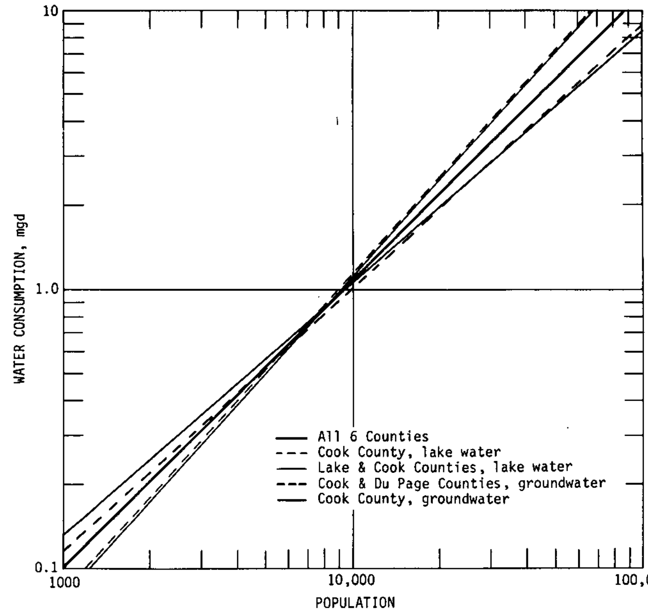

Figure 11. Relationship between groundwater and lake water consumption and population

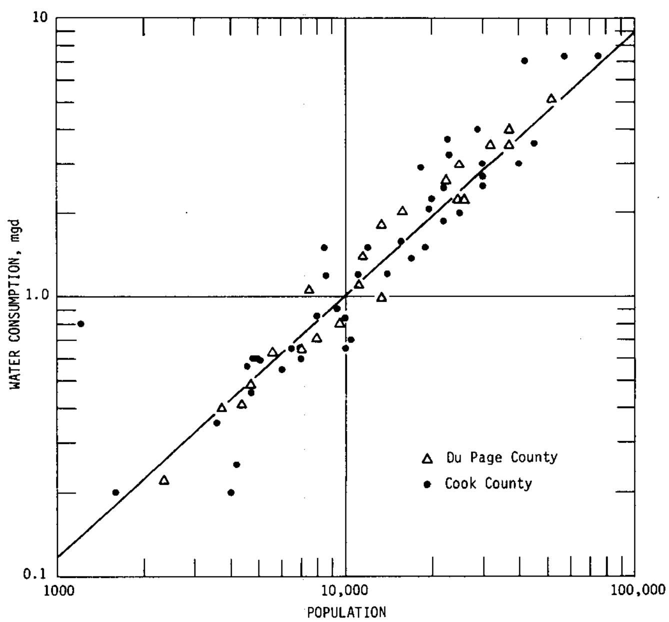

Figure 12. Relationship between groundwater consumption and population for communities using groundwater in Du Page and Cook Counties

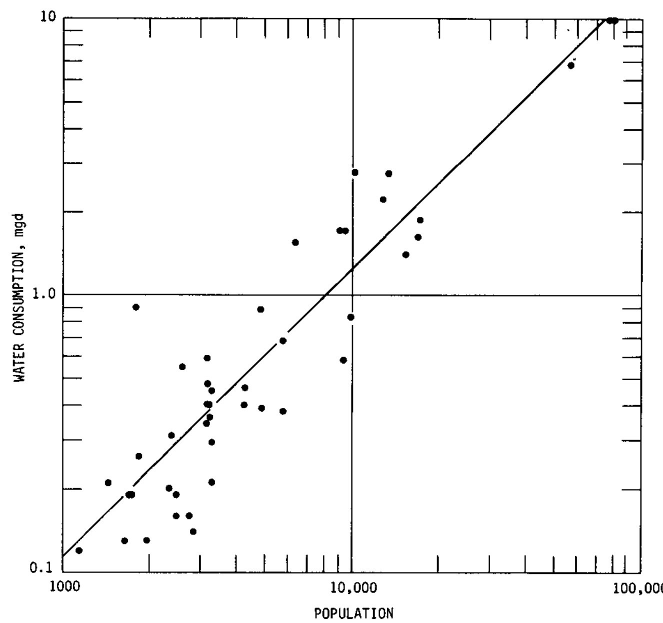

Figure 13. Relationship between groundwater consumption and population for communities using groundwater in Kane, Lake, McHenry, and Will Counties

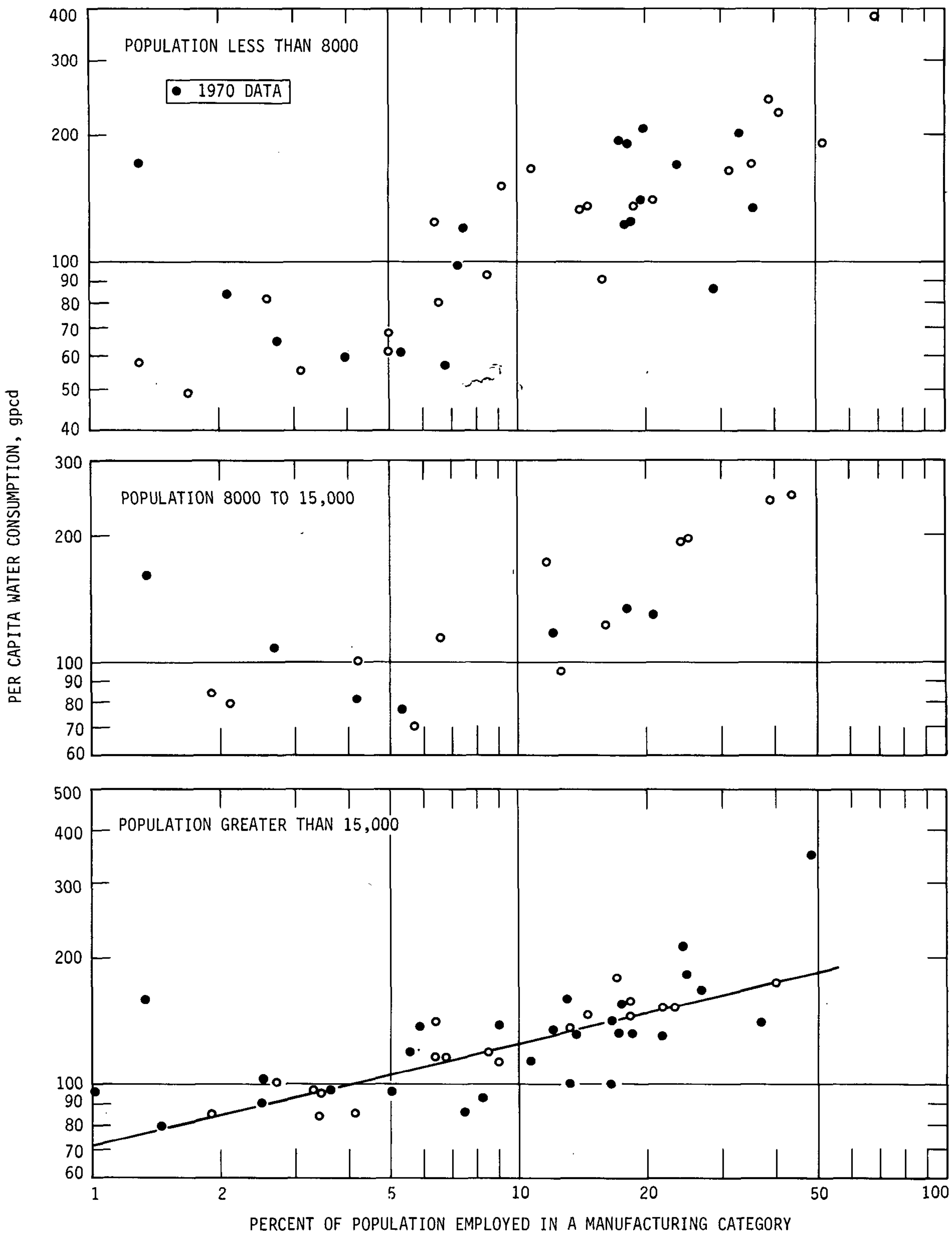

Figure 14. Relationship between manufacturing employment and per capita water consumption for townships according to population

Table 17. Groundwater Demand Projections by County
(in millions of gallons per day)

County	1970*	1980	1985	1990	2000	2010
Cook	98.2	116.9	124.5	133.3	146.4	155.5
Du Page	51.8	67.1	74.6	81.3	97.2	101.8
Kane	37.5	44.6	50.1	58.9	70.6	76.4
Lake	19.0	29.3	34.5	39.6	47.9	55.3
McHenry	15.0	20.5	22.9	25.0	32.8	38.9
Will	38.4	58.7	65.6	72.4	84.8	93.9
Total	259.9	337.1	372.2	410.5	479.7	521.8

* From Sasman et al. (1974)

Additional data on township manufacturing employment (not available to Schicht and Moench) from NIPC and on water consumption were available for 1970. The additional data are also plotted on figure 14. The data were segregated into townships with average community populations less than 8000, 8000 to 15,000, and greater than 15,000. Per capita water consumption was obtained by dividing combined industrial and municipal pumpage by estimated population served by public water supply systems.

The relationships shown in figure 14 and projected manufacturing employment and population from NIPC were used to project water demands. These demands were used if they were greater than the demands estimated from the relationship described earlier for population and consumption.

Other Considerations

Where one community dominates the township population, such as Elgin and Joliet in townships 22 and 88, municipal demand projections were estimated in a manner similar to that used by Roberts et al. (1970). Township population and water consumption for 1970 were plotted on the appropriate graph (figure 12 or 13) and a line was drawn through the point parallel to the line shown on the graph. The new line was extended to the projected population for 1980, 1990, and 2000. Municipal water demand was determined from the new relationship.

Significant groundwater withdrawals for industrial use were recorded in some of the townships where municipalities were supplied by lake water. Industrial groundwater demands in these townships were projected on the basis of previous use trends.

Projections of groundwater demands for individual domestic supplies were made for each township. They were based on estimates of rural population density per square mile and a per capita water consumption of 50 gpd. Projections, although relatively small, are included in the total demand.

From trends of livestock and poultry water use, these water demands were assumed to be negligible for the projection.

Demand Summary

As shown in table 17, groundwater demands for the region are projected to increase from 337.1 mgd in 1980 to 479.7 mgd in 2000. According to Sasman et al. (1974), actual groundwater withdrawals in 1970 were 259.9 mgd.

County summaries of population, percent of population employed in a manufacturing category, and groundwater demand projections for townships using only groundwater are given in table 18.

As noted earlier, per capita consumption is in general related to manufacturing employment and the relationships shown in figures 12 and 13. However, the highest per capita consumption in gallons per capita per day (gpcd) is in Will County, where it ranges from 177.6 gpcd in 1980 to 160.0 gpcd in 2000, although the percent of the population employed in a manufacturing category in Will County is not high (9.3 percent in 1980 and 6.8 percent in 2000). The high per capita consumption is attributed to two factors. High industrial pumpage in one township, 6.8 mgd in 1973, could not be related to percent of the township population employed in a manufacturing category. Pumpage in this township was projected on the basis of the previous pumpage trend and is considerably greater than pumpage that would have been determined from the relationship in figure 14. In addition, one township reported high institutional pumpage that could not be related to township population. The institutional pumpage was also projected from the previous trend.

Projected groundwater demands for 1980-2010 are given in tables 19-24 for Cook, Du Page, Kane, Lake, McHenry, and Will Counties.

Table 18. County Summaries of Population and Groundwater Demand Projections for Townships Using Only Groundwater

	Cook, suburban	*Du Page*	*Kane*	*Lake*	*McHenry*	*Will*
1980						
Population *	715,900	619,800	302,100	190,700	127,700	322,100
Manufacturing employment (percent)**	7.3	5.4	13.4	8.0	13.8	9.3
Groundwater demand (mgd)†	80.5	67.1	44.1	25.7	19.5	57.2
Per capita water consumption (gpcd)	112.4	108.3	146.0	134.8	152.7	177.6
1990						
Population*	871,400	782,800	397,700	275,000	166,100	425,500
Manufacturing employment (percent)**	6.5	4.7	10.5	6.1	11.0	7.3
Groundwater demand (mgd)†	96.2	81.3	58.4	35.6	24.0	70.7
Per capita water consumption (gpcd)	110.4	103.9	146.8	129.5	144.5	166.2
2000						
Population*	1,044,000	930,000	466,400	333,400	225,400	521,200
Manufacturing employment (percent)**	5.8	4.8	10.3	6.3	9.3	6.8
Groundwater demand (mgd)†	109.2	97.2	70.4	43.9	31.7	83.4
Per capita water consumption (gpcd)	104.5	104.5	150.9	131.8	140.6	160.0

*Population served by public groundwater systems
**Percent of population employed in a manufacturing category
†Does not include groundwater demands by individual domestic supplies

PROJECTED LAKE WATER DEMANDS, 1980-2000

Basis for Projections

Lake water demand projections were made for townships in which communities presently withdraw water from Lake Michigan or are supplied by the city of Chicago or other municipal water supply systems withdrawing water from the lake. Demand projections for 1980, 1990, and 2000 are summarized in table 25. Lake water demands by communities presently using lake water will exceed the 1700 cfs understood to be the part of the diversion for water supply by 71 cfs in 1980, 112 cfs in 1990, and 144 cfs in 2000. In 1970 lake water demands exceeded the 1700 cfs by 13 cfs, but the actual diversion was less than 1700 cfs since some north shore communities in Lake County were returning their effluent to the lake. By 1980 this effluent, with the exception of industrial cooling water, will not be returned to the lake because of pollution control regulations.

The demand projections were made on the basis of relationships between water consumption and population for municipalities using Lake Michigan water (figure 11) and between water consumption and manufacturing employment (figure 14). The method used to make demand projections was described in the preceding section.

Projected demands for the city of Chicago were based on the city's average daily consumption for the period 1969-1973 shown in table 26 and rounded off to the nearest 10. (Consumption for 1974 was not available at the time this report was written.)

Lake Water Demands

Because the city of Chicago's population is projected to decline only slightly (table 27) according to the population forecasts provided by NIPC, water demand by the city of Chicago is not forecast to increase.

Estimates were made of the population of the suburban communities using Lake water from township population forecasts provided by NIPC to compare per capita con-

Table 19. Groundwater Demands in Cook County, 1980-2010

(in millions of gallons per day)

Township	B_1*	B_2**	*1980*	*1985*	*1990*	*2000*	*2010*
48	4.25	0	1.21	1.73	2.14	3.30	3.80
49	4.83	0.76	10.21	11.35	12.24	12.50	13.12
50	4.69	3.46	15.20	15.64	15.90	16.50	17.99
51	2.48	0.76	2.00	2.00	2.00	2.00	2.00
52	0.50	0	0	0	0	0	0
53	2.76	0.18	5.60	6.90	9.00	10.50	11.20
54	3.00	0.23	8.10	9.40	10.50	13.50	14.60
55	3.57	4.61	13.15	13.63	14.01	14.11	16.07
56	4.34	2.58	3.50	3.50	3.50	3.50	3.50
57	2.60	0.56	2.00	2.00	2.00	2.00	2.00
58	0.70	0	0	0	0	0	0
59	5.12	0.51	1.30	1.30	1.30	1.30	1.30
60	5.39	2.52	7.00	7.00	7.00	7.00	7.00
61	4.88	0	0	0	0	0	0
62	7.32	2.02	10.60	10.70	10.80	10.80	10.80
63	4.55	0.80	3.00	3.00	3.00	3.00	3.00
64	3.79	0.45	1.20	1.35	1.50	1.76	2.84
65	4.69	0.19	0	0	0	0	0
66	4.57	0.02	0	0	0	0	0
67	1.92	0.11	0.80	0.80	0.80	0.80	0.80
68	4.55	0	4.43	5.04	6.84	11.60	12.00
69	4.75	0.75	1.20	1.45	1.70	1.80	1.90
70	4.31	0.20	5.00	5.00	5.00	5.00	5.00
71	4.57	0	5.90	7.00	8.00	8.30	8.60
72	6.68	1.42	15.54	15.70	16.05	17.16	17.96
City of Chicago †		1.75	2.50	2.50	2.50	2.50	2.50
Total	100.81	22.13	116.94	124.49	133.28	146.43	155.48

*B_1 = Potential yield of shallow aquifers
**B_2 = Practical sustained yield of Cambrian–Ordovician aquifer
†Not included in total

Table 20. Groundwater Demands in Du Page County, 1980-2010

(in millions of gallons per day)

Township	B_1*	B_2**	*1980*	*1985*	*1990*	*2000*	*2010*
73	4.16	0.05	1.00	1.40	1.80	2.64	3.29
74	3.97	0.05	6.70	7.55	8.40	11.00	11.35
75	4.37	1.44	12.10	13.31	14.50	16.20	16.45
76	4.05	0.39	3.30	3.98	4.60	5.98	6.47
77	5.09	0.10	8.00	8.70	9.40	10.50	11.20
78	4.90	4.02	14.50	15.00	15.50	16.00	16.53
79	4.90	0.03	3.00	4.24	4.80	10.20	11.20
80	5.73	0.01	7.70	8.75	9.80	10.71	10.93
81	7.23	0	10.80	11.65	12.50	14.00	14.42
Total	44.40	6.09	67.10	74.58	81.30	97.23	101.84

*B_1 = Potential yield of shallow aquifers
**B_2 = Practical sustained yield of Cambrian-Ordovician aquifer

sumption during 1970 with per capita consumption based on projected population and projected water demands (table 28).

Lake water demand projections were made for Cook County townships 51, 52, 56, 57, 58, 59, 60, 61, 62, 63 65, 66, 67, 69, and 70 shown in figure 15. Groundwater is

Table 21. Groundwater Demands in Kane County, 1980-2010

(in millions of gallons per day)

Township	B_1 *	B_2 **	*1980*	*1985*	*1990*	*2000*	*2010*
17	1.09	0.10	0.45	0.48	0.58	0.64	0.70
18	0.73	0	0.22	0.27	0.33	0.73	0.80
19	2.08	0.54	5.40	6.70	7.60	8.70	9.80
20	0.48	0.06	0.17	0.21	0.22	0.25	0.25
21	1.36	0	0.10	0.16	0.20	0.52	0.60
22	2.42	4.33	11.80	13.00	15.20	19.00	19.80
23	2.38	0	0.24	0.26	0.28	0.30	0.33
24	0.74	0	0.17	0.35	0.45	0.85	1.24
25	3.95	1.76	4.20	4.52	5.90	6.80	7.00
26	1.70	0.01	0.07	0.12	0.16	0.25	0.29
27	1.21	0.25	0.63	0.86	1.35	2.21	3.12
28	5.32	2.26	5.50	6.00	7.50	8.50	9.00
29	2.11	0	0.16	0.19	0.22	0.26	0.27
30	0.81	0	0.47	0.79	1.05	1.54	2.00
31	4.44	6.70	15.00	16.20	17.90	20.00	21.20
Total	30.82	16.01	44.58	50.11	58.94	70.55	76.40

*B_1 = Potential yield of shallow aquifers
**B_2 = Practical sustained yield of Cambrian-Ordovician aquifer

Table 22. Groundwater Demands in Lake County, 1980-2010

(in millions of gallons per day)

Township	B_1 *	B_2 **	*1980*	*1985*	*1990*	*2000*	*2010*
32	6.39	0	1.74	2.00	2.20	2.58	3.00
33	3.29	0	0.98	1.33	1.42	2.23	3.10
34	4.04	0.01	0.36	0.42	0.50	0.59	0.69
35	1.29	0.03	0	0	0	0	0
36	4.06	0	1.80	2.00	2.17	2.28	2.40
37	2.98	0.08	3.65	4.70	5.90	7.60	9.10
38	4.51	0.10	3.46	3.78	4.10	4.44	5.00
39	1.07	0.06	0	0	0	0	0
40	3.90	0	1.42	1.45	1.52	1.56	1.75
41	4.70	0	2.06	2.49	2.89	3.30	4.06
42	4.69	0.38	5.48	6.40	7.60	9.20	10.60
43	0.59	0.11	1.00	1.00	1.00	1.00	1.00
44	3.39	0	2.09	2.32	2.66	2.84	2.99
45	4.36	0.12	2.24	2.87	3.51	4.67	5.80
46	4.38	0.06	2.33	3.00	3.47	4.94	5.10
47	0.97	0.05	0.70	0.70	0.70	0.70	0.70
Total	54.61	1.00	29.31	34.46	39.64	47.93	55.29

*B_1 = Potential yield of shallow aquifers
**B_2 = Practical sustained yield of Cambrian-Ordovician aquifer

used by industry in all but one of the townships. Lake water demands were adjusted by subtracting projected self-supplied industrial groundwater demands from lake water demands estimated from township population and manufacturing employment.

Also, significant groundwater pumpage for municipal use was reported in four of the above townships. Municipalities presently using groundwater were assumed to continue using groundwater to the year 2000, so the population dependent upon groundwater was subtracted from the township total population. This adjusted population was then used to estimate township lake water demand

Lake water demand projections were made for Lake County townships 35, 39, 43, and 47 shown in figure 15. It was assumed that all municipal use would be met by lake water in these townships. Adjustments were made for self-supplied industrial use.

Table 23. Groundwater Demands in McHenry County, 1980-2010

(in millions of gallons per day)

Township	B_1 *	B_2 **	*1980*	*1985*	*1990*	*2000*	*2010*
1	6.14	0.21	1.13	1.16	1.24	1.28	1.40
2	5.82	0	0.08	0.10	0.10	0.15	0.16
3	6.54	0	0.21	0.22	0.23	0.26	0.27
4	9.02	0	0.64	0.78	0.83	1.20	1.17
5	2.96	0	0.67	0.76	0.84	0.97	1.12
6	0.33	0	0.18	0.19	0.20	0.23	0.24
7	7.08	0	0.59	0.68	0.72	0.82	0.93
8	10.10	0.14	3.84	4.41	4.97	6.86	8.50
9	4.01	0.02	1.07	1.09	1.11	1.19	2.00
10	5.64	0	0.13	0.15	0.16	0.18	0.21
11	6.41	0	2.15	2.28	2.36	3.66	4.05
12	9.86	0.19	2.27	2.60	2.89	3.75	4.54
13	1.48	0	0.09	0.10	0.12	0.14	0.16
14	6.31	0	0.26	0.28	0.29	0.32	0.32
15	6.83	0	1.06	1.12	1.16	1.26	1.35
16	7.95	0.44	6.10	7.00	7.80	10.50	12.50
Total	96.48	1.00	20.47	22.92	25.02	32.77	38.92

*B_1 = Potential yield of shallow aquifers
**B_2 = Practical sustained yield of Cambrian-Ordovician aquifer

Table 24. Groundwater Demands in Will County, 1980-2010

(in millions of gallons per day)

Township	B_1 *	B_2 **	*1980*	*1985*	*1990*	*2000*	*2010*
82	5.08	0	0.36	0.46	0.55	0.78	0.93
83	6.25	0.15	6.26	7.19	8.08	9.59	10.10
84	6.38	0.14	2.15	2.60	3.10	3.80	4.50
85	5.51	1.23	7.20	7.80	8.30	9.40	10.00
86	5.09	0.57	0.94	1.26	1.54	2.40	3.23
87	7.81	0.15	1.82	2.54	3.43	4.63	5.44
88	7.00	5.21	15.50	16.00	16.50	17.50	18.20
89	4.99	0.47	6.50	7.30	8.20	9.80	11.00
90	4.74	0	1.71	2.34	2.91	3.70	4.60
91	7.47	2.37	7.50	7.50	7.50	7.50	7.50
92	5.62	0.11	0.24	0.25	0.27	0.31	0.34
93	5.02	0	0.24	0.29	0.31	0.37	0.42
94	5.60	0	0.05	0.05	0.06	0.10	0.14
95	4.82	0	3.30	4.60	5.90	8.20	10.00
96	5.85	0	2.32	2.64	2.80	3.46	4.00
97	5.09	0.34	0.84	0.87	0.93	0.99	1.02
98	3.83	0.22	0.04	0.05	0.06	0.08	0.13
99	4.83	0	0.05	0.05	0.06	0.08	0.12
100	4.60	0	0.59	0.61	0.65	0.70	0.72
101	4.61	0	0.05	0.05	0.06	0.13	0.15
102	5.60	0	0.31	0.35	0.35	0.43	0.45
103	6.54	0.05	0.38	0.39	0.40	0.42	0.42
104	6.69	0	0.36	0.40	0.42	0.47	0.52
Total	128.02	11.01	58.71	65.59	72.38	84.84	93.93

*B_1 = Potential yield of shallow aquifers
**B_2 = Practical sustained yield of Cambrian-Ordovician aquifer

Table 25. Water Demands by Communities Presently Using Lake Michigan Water

(in millions of gallons per day)

	1970 use	*Projected demands 1980*	*1990*	*2000*
City of Chicago	867	860	860	860
Cook County, suburban	209	248	265	281
Lake County	31*	37*	46*	51*
Total	1107	1145	1171	1192
(cfs)	1713	1771	1812	1844

*Does not include industrial cooling water that will be returned to lake

Table 26. Average Daily Consumption for Chicago 1969-1973

(in millions of gallons per day)

1969	*1970*	*1971*	*1972*	*1973*
862	867	859	840	860

Table 27. Population Forecasts for City of Chicago

1970	*1980*	*1990*	*2000*
3,369,359*	3,229,000	3,225,700	3,210,000

*1970 federal census

Table 28. Summaries of Population and Lake Water Demand Projections

	Cook County, suburban	*Lake County*
1970		
Population	1,425,000	221,098
Water demand (mgd)	209	31
Per capita water consumption (gpcd)	147	140
1980		
Population	1,639,000	258,000
Water demand (mgd)	248	37
Per capita water consumption (gpcd)	151	143
1990		
Population	1,742,000	314,000
Water demand (mgd)	265	46
Per capita water consumption (gpcd)	152	146
2000		
Population	1,817,000	340,000
Water demand (mgd)	281	51
Per capita water consumption (gpcd)	155	150

BALANCING GROUNDWATER SUPPLY AND DEMAND

Data Used

Comparisons between water demand projections and groundwater availability were made for *no-mining* and *mining* concepts. The no-mining concept limits groundwater availability to the potential yield of the shallow aquifers and the practical sustained yield of the deep aquifers. The potential yield of the shallow aquifers was estimated from the groundwater recharge maps in figures 6–9. Potential yield and practical sustained yield by township were given in tables 19–24.

It should be noted that the total potential yield for the six-county area given in tables 19–24 is about 455 mgd. The total potential yield given in table 14 is 507 mgd. Potential yields given in tables 19–24 were reduced for certain townships to account for extremely low well yields. In these townships it would be impractical to develop the groundwater potential.

Schicht and Moench (1971) estimated the practical sustained yield of the deep aquifers for each township by reducing the recorded 1968 pumpage proportionally so that the total county pumpage would not exceed the county practical sustained yield given by Walton (1964b).

According to Walton the total practical sustained yield of the deep aquifers is 60 mgd, and was determined for each of the six counties as follows: Cook, 25; Du Page, 6; Kane, 16; Lake, l; McHenry, 1; and Will, 11 mgd.

The practical sustained yield total given in tables 19–24 is slightly less than the total given above. Because increases in deep aquifer pumpage have been recorded in Grundy and Kendall Counties during the past few years, part of the 60 mgd given above was assigned to those two counties and does not appear in tables 19–24.

No-Mining Concept

Comparisons between groundwater demand projections and groundwater availability for the no-mining concept were made for each township for the years 1980, 1985, 1990, 2000, and 2010. Deficiencies are shown in figures 16–20. Total groundwater deficiencies increase from about 75 mgd in 1980 to 200 mgd in 2010.

Mining Concept

An alternative to limiting pumpage from the deep aquifers to the practical sustained yield is continued mining of the deep sandstone aquifer at rates which will meet the projected deficits. A digital computer model described below was used to study the effects of increased groundwater withdrawals on water levels in the deep sandstone aquifer to determine areas where water levels may decline to critical levels. Critical levels are defined as being reached when pumping levels are at the top of the most productive formation in the deep sandstone aquifer, the Ironton–Galesville sandstone.

If the Ironton–Galesville Formation is dewatered, yields of wells will decline significantly. In all cases in which mining of the water stored in the aquifer takes place, the pumping water levels are not permitted to drop below the top of the Ironton–Galesville. When a pumping water level reaches this elevation, the discharge available from the pumping center will be reduced as the surrounding water levels continue to decline.

Digital Computer Model

In the past, prediction of water level fluctuations in the deep sandstone aquifer due to changes in pumpage was accomplished with a simplified model aquifer and a mathematical model (Walton, 1962). The model aquifer used by Walton to simulate aquifer response to pumpage was a semi-infinite rectilinear strip of sandstones and dolomites 84 miles wide and 1000 feet thick. The model aquifer was bounded by a recharge boundary 47 miles west of Chicago and by two intersecting barrier boundaries 37 miles east and 60 miles south of Chicago, and was overlain by a confining bed consisting mostly of shale averaging 200 feet thick. The aquifer transmissivity and storage coefficient used in the model were 17,000 gpd/ft and 0.00035, respectively. The vertical permeability assigned to the confining bed was 0.00005 gpd/sq ft. The type of modeling used by Walton was linear in nature and had been highly successful until recently.

In recent years extensive groundwater development has taken place to the extent that, in certain areas of the Chicago region, dewatering of the aquifer is beginning to occur. As this happens, the aquifer response to development becomes nonlinear. This is because a conversion from artesian to water table conditions takes place, a reduction of the saturated thickness of the aquifer occurs, the flow of water changes from two to three dimensions, and the leakage rates across confining beds reach maximum values. Thus, as dewatering of the aquifer becomes more prevalent, the simplified linear model becomes less valid for predicting aquifer response.

A digital computer model was developed by Prickett and Lonnquist (1971) to improve on Walton's method for predicting water level declines for projected future groundwater development. The assumption that the aquifer is bounded by two intersecting right angle boundaries 37 miles east and 60 miles south of Chicago was also used in the digital model. The recharge boundary, however, was replaced by a more realistic recharge area beginning about 54 miles west of Chicago. Other aspects of the model are briefly discussed below.

A 100 by 100 variable size grid was used to discretize the aquifer. In the area where groundwater demands are the greatest, the grid spacing is 1 mile. In the more distant areas, the grid spacing is 2 miles.

The model aquifer is assumed to be 1025 feet thick with a transmissivity of 17,000 gpd/ft. The top of the aquifer is assumed to be at a uniform elevation of 699 feet above mean sea level west of a line about 1 mile east of the western boundary of McHenry County. East of this line the top of the aquifer slopes downward at a rate of 13 feet per mile. The bottom formation, the Ironton–Galesville sandstone, is assumed to be 175 feet thick and to have a transmissivity of 8500 gpd/ft, or half the aquifer transmissivity.

There are some limitations of the model results. The datum for relating drawdowns and the aquifer is elevation 700 above mean sea level. This is an approximation of the average elevation of the piezometric surface in 1864. The top of the aquifer is represented by two straight line segments. Locally the actual top of the aquifer is irregular, so there can be differences between model and field elevations at a given point. This caution also applies to the elevation of the top of the Ironton–Galesville Formation.

The thicknesses of the aquifer and its several formations are all taken to be uniform at average values in the model. The transmissivities are also average values for the aquifer and for each formation. The storage coefficient is assumed to be 0.0005 for confined conditions and 0.005 for water table conditions in regions where the piezometric surface is below the top of the aquifer. The effective well radius in the computer model is about 1100 feet for a 1 mile grid. The drawdowns are not corrected for this well radius effect.

Pumpage from the aquifer is aggregated by township and location at one grid node near the township pumping centroid. Eighty-one pumping nodes are used in the model to represent the distribution of water withdrawal.

Prickett and Lonnquist compared actual aquifer response to pumpage with the digitally simulated response for the period 1860 to 1960 and found agreement was good. They

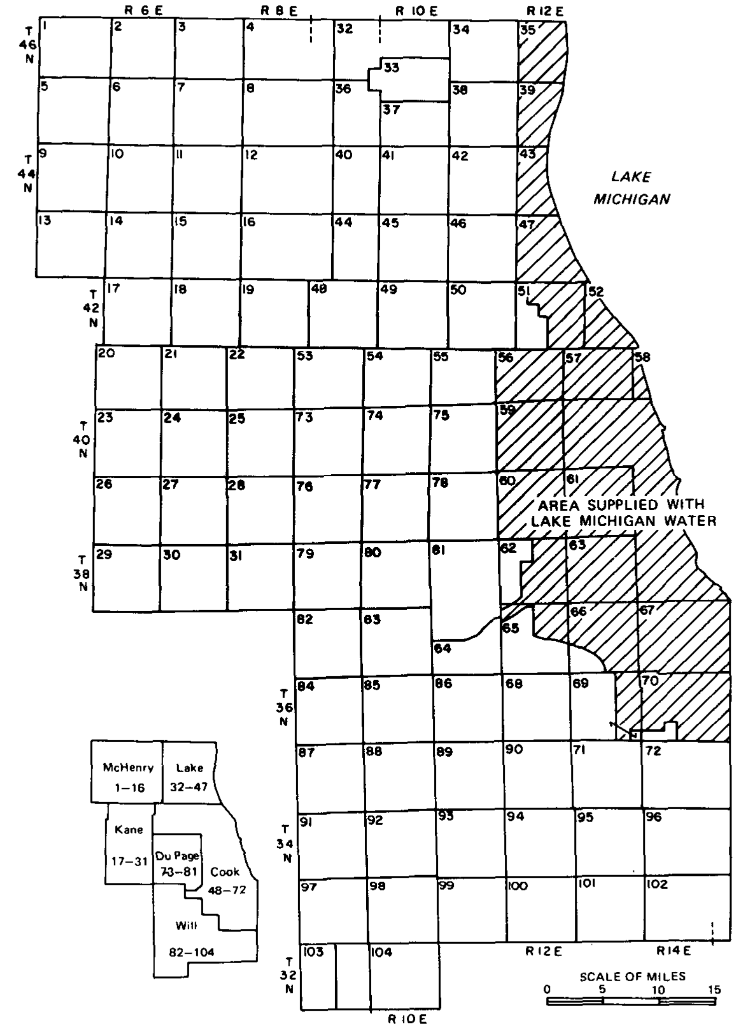

Figure 15. Townships either totally or partially supplied by Lake Michigan water

also stated, however, the use of the model in predicting future water level declines is somewhat in question since massive dewatering of the deep sandstone has not yet occurred. The model should be further validated as more of the aquifer is dewatered.

Projected Deep Sandstone Pumpage

It should be emphasized that the mining concept considers only water in storage in the deep sandstone aquifer. There are large quantities of potable water in storage in the Mt. Simon aquifer. However, attempts to mine Mt. Simon water would induce a poorer quality of water to migrate toward wells. Water quality and effects of pumping Mt. Simon water are described by the Illinois State Water Survey (1973). The shallow aquifers are too thin to allow mining for a lengthy period.

It should be noted that present pumpage from deep wells includes pumpage from wells open to both the deep sandstone aquifer and the Mt. Simon aquifer, and to wells open to both the shallow dolomite and the deep sandstone. In addition, many deep wells are faultily cased through the shallow dolomite. Leakage down the well bore from the shallow dolomite may be appreciable in these cases.

According to Suter et al. (1959), about 33.3 mgd or 43 percent of the total amount of 76 mgd pumped from deep wells in 1958 was derived from the shallow dolomite and the Mt. Simon aquifer. Suter et al. estimated further, on the basis of an inventory of well construction and studies of water quality, that in 1958 about 20.5 mgd was derived from the shallow dolomite and 12.8 mgd was obtained from the Mt. Simon aquifer. Leakage from the shallow dolomite into deep wells remains fairly constant after the artesian pressure in the Cambrian-Ordovician aquifer declines below the base of the Silurian age dolomite.

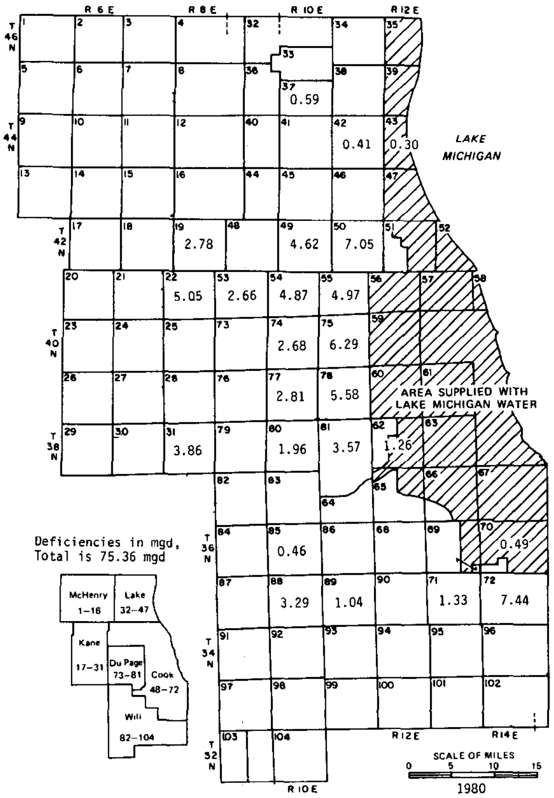

Figure 16. Water demands in 1980 in excess of groundwater available from natural recharge

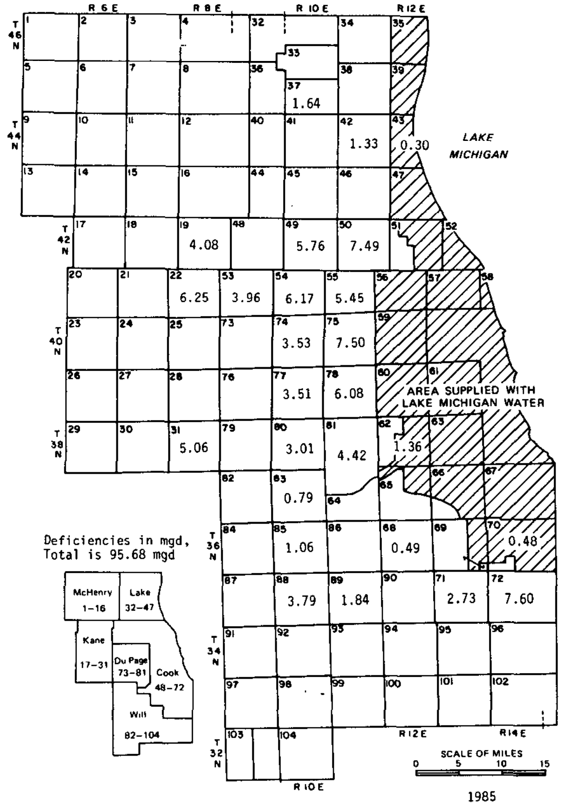

Figure 17. Water demands in 1985 in excess of groundwater available from natural recharge

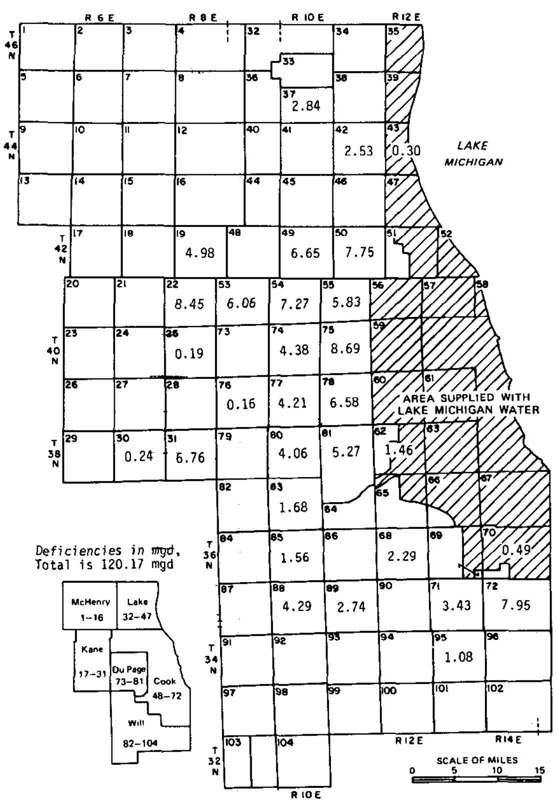

Figure 18. Water demands in 1990 in excess of groundwater available from natural recharge

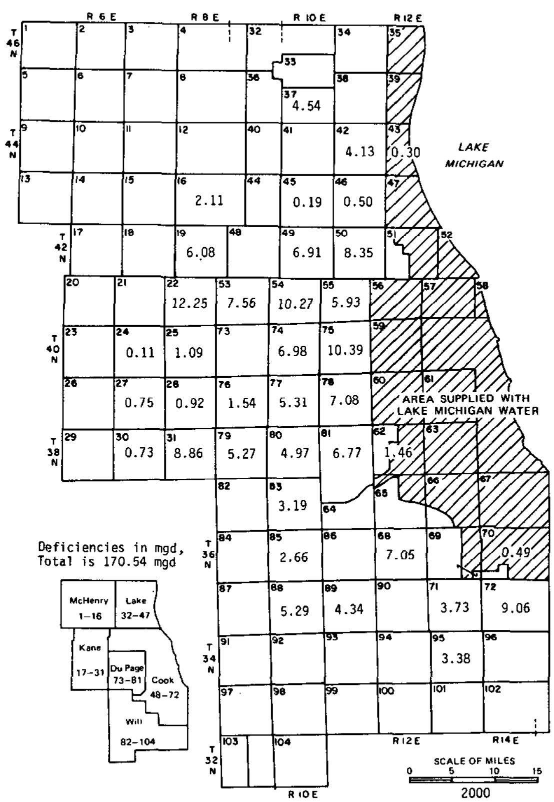

Figure 19. Water demands in 2000 in excess of groundwater available from natural recharge

Because the deep sandstone piezometric surface is below the base of the Silurian in major pumping centers, and has been since 1958, it is likely that the deep well pumpage estimated by Suter et al. (20.5 mgd) as derived from the Silurian dolomite will not increase appreciably.

An inventory of deep wells in 1974 indicated that 59 wells finished in the Mt. Simon were in use. Pumpage from these wells in 1974 averaged 25 mgd. It is reasonable to assume that one-third of the 25 mgd (8.3 mgd) is from the Mt. Simon. Twenty-one deep wells that had been open to the Mt. Simon at one time and then plugged above the top of the Mt. Simon were in use in 1974. There is evidence to indicate that some of these plugs were not effective in sealing off the Mt. Simon. Thus, it seems reasonable that in 1974 an upper limit of 10 mgd was derived from the Mt. Simon.

According to Sasman et al. (1973), pumpage in the Chicago region from deep wells increased from 128.5 mgd in 1966 to 144.5 mgd in 1971. The 1974 tabulation was 154.9 mgd.

With 20.5 mgd as the pumpage derived from the Silurian dolomite and 10 mgd as that derived from the Mt. Simon, pumpage from the deep sandstone aquifer in 1974 was 124.4 mgd. Projected deep sandstone pumpage is given in table 29.

The Water Survey is presently investigating the contribution to deep well pumpage from the Silurian dolomite-and the Mt. Simon aquifer on the basis of data collected since Suter et al. (1959). Preliminary results indicate that the percent contribution from the Silurian dolomite is considerably less than reported by Suter et al. However, because considerable dewatering of the Cambrian-Ordovician aquifer has taken place since 1959, it is difficult to separate the Mt. Simon contribution from the effects of dewatering.

The contribution from the Mt. Simon aquifer in this study was accounted for by reducing the projected deep aquifer pumpage by the estimated practical sustained yield (14 mgd) of the Mt. Simon given by Walton (1964b).

Pumpage from the deep sandstone aquifer for the mining concept was estimated for each township in the following manner.

- It was assumed that deep sandstone pumpage would continue at the 1974 rate even if there was a surplus of shallow aquifer water available.
- After the potential yield of the township shallow aquifer was developed, further increase in demand would be provided from the deep sandstone.

The above approach in estimating deep sandstone pumpage differs from that used by Moench and Visocky (1971). They assumed that the deep sandstone pumpage would continue at the practical sustained rate until the potential of the shallow dolomite was utilized. Deep sandstone pumpage would then increase to balance demand. A comparison

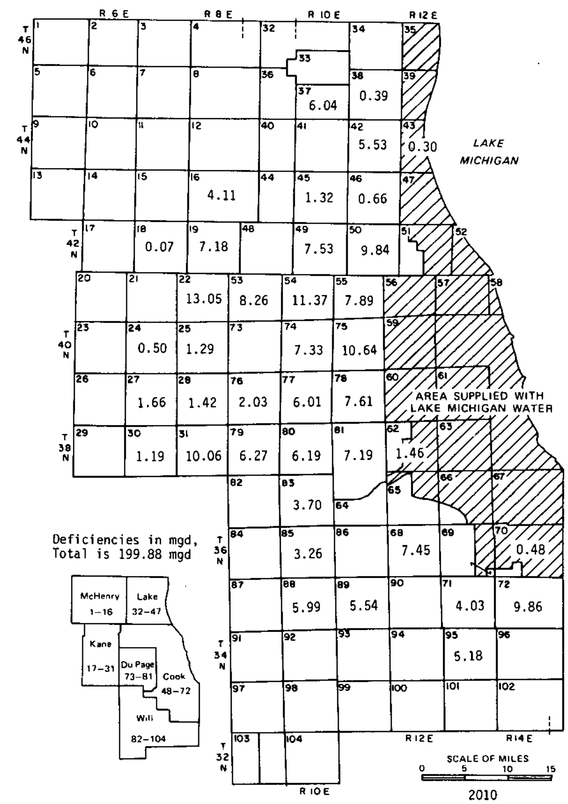

Figure 20. Water demands in 2010 in excess of groundwater available from natural recharge

Table 29. Projected Pumpage from the Deep Sandstone Aquifer in Northeastern Illinois

(Pumpage in millions of gallons per day)

	1980	*1990*	*2000*
Moench and Visocky (1971) for 6 counties	121	196	284
Current			
For 6 counties	143	186	232
For Kendall and Grundy Counties	11	13	15
For 8 counties	154	199	247

of current projected deep sandstone pumpage with that estimated by Moench and Visocky (1971) was shown in table 29.

Mining Schemes

Three schemes for continued mining of the deep sandstone aquifer from 1980 to 2010 were considered and evaluated. Two of the plans anticipate mining at increasing rates as the projected water supply demands increase with time.

In scheme 1, pumping at a pumping node continues at the projected rate until the pumping water level reaches the top of the Ironton–Galesville Formation. From the time this critical condition is reached, the pumping water level is fixed at the top of the Ironton–Galesville and the pumping rate is reduced to the gradient flow rate into that node. As the water levels continue to decline in the vicinity of one node, the flow rate to the node will decline.

In scheme 2, when the water level reaches the top of the Ironton–Galesville at a pumping node, the pumping rate is set and held at zero. The water level at this node and in its vicinity then increases with time.

In scheme 3, the pumping rates are held equal to the demand projected for 1980. This scheme limits the rate of mining throughout the region, but results in widely distributed water supply deficiencies as early as 1985.

Scheme 1 uses stored groundwater in the aquifer to meet demands, and mines the water as rapidly as required. Scheme 2 protects the continued transmission capability of the aquifer and allows other townships to continue pumping somewhat longer than in scheme 1. The need for water from other sources is immediate and equal to the demand when critical levels are reached in a township. In schemes 1 and 3 gradual incremental water supply deficiencies are developed. Scheme 3 results in incremental deficiencies by 1985 in a number of townships. Critical conditions are delayed and only four townships have had water levels decline to the Ironton–Galesville by 2010.

Schemes 1 and 2 result in one or two townships having pumping levels that become critical by 1995. Scheme 2 does delay critical conditions in some townships near those which have become critical and have stopped pumping. In scheme 1 by 2010, critical pumping levels have been reached and pumping rates have been reduced in 15 townships. In scheme 2 critical pumping levels have been reached by 2010 in 11 townships.

By 2010, the model indicates that several townships have pumping water levels less than 100 feet above the top of the Ironton–Galesville. As long as the total pumping rate from the deep sandstone aquifer exceeds the practical sustained yield, decline of water levels and reduction of pumpage will continue in the years after 2010.

Township water deficiencies for the three mining schemes are shown in figures 21–32. Total deficiencies for northeastern Illinois and the total number of deficient townships for each scheme are summarized below.

Year	*Scheme 1*	*Scheme 2*	*Scheme 3*
Total deficiencies (mgd)			
1985			16.1
1990			39.7
1995	6.9	45.0	
2000	35.9	88.8	84.2
2005	61.6	99.9	
2010	90.5	123.1	116.7
Total number of deficient townships			
1985			20
1990			24
1995	4	4	
2000	9	7	33
2005	12	8	
2010	15	11	36

Scheme 1 allows greater quantities of water to be taken out of storage, thus requiring less water from alternative sources. Deficiencies are more concentrated under scheme 2 which may result in a more efficient distribution system for alternative sources. Deficiencies are greatest and most widespread under scheme 3.

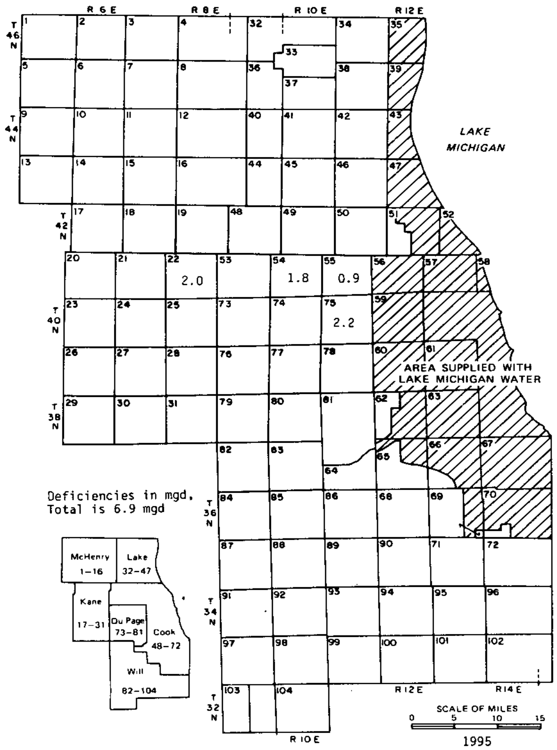

Figure 21. Water demands in 1995 in excess of groundwater available from natural recharge and mining (scheme 1)

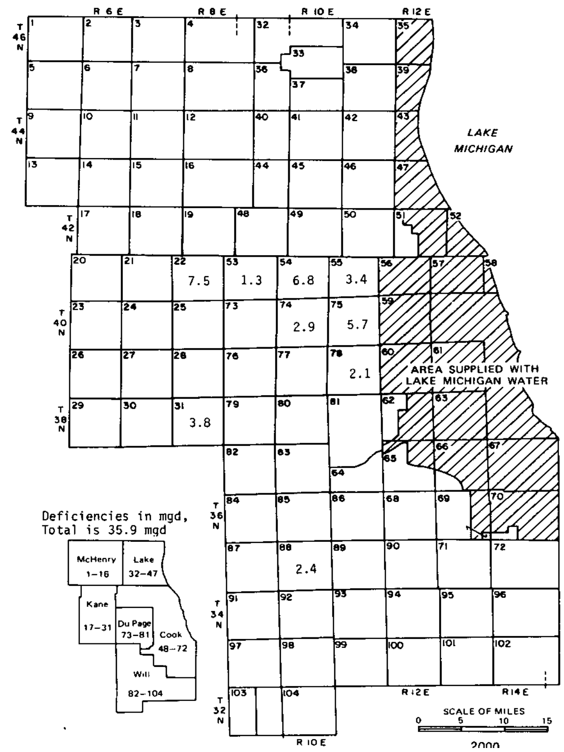

Figure 22. Water demands in 2000 in excess of groundwater available from natural recharge and mining (scheme 1)

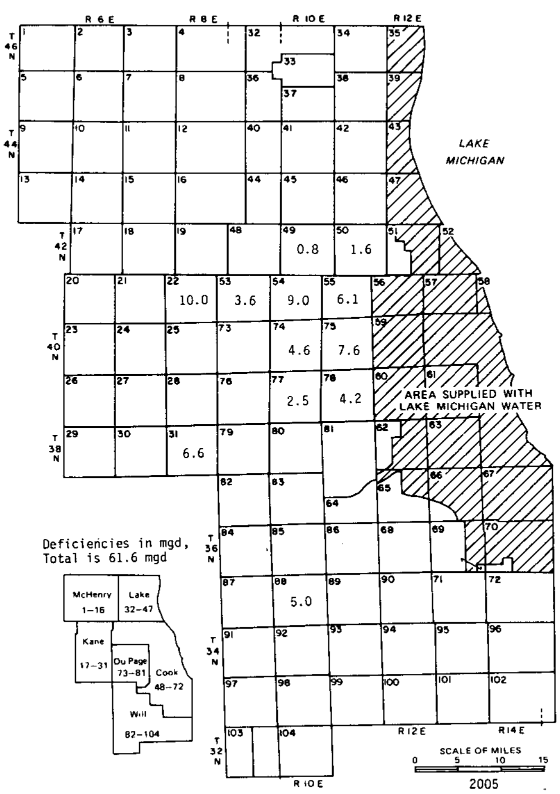

Figure 23. Water demands in 2005 in excess of groundwater available from natural recharge and mining (scheme 1)

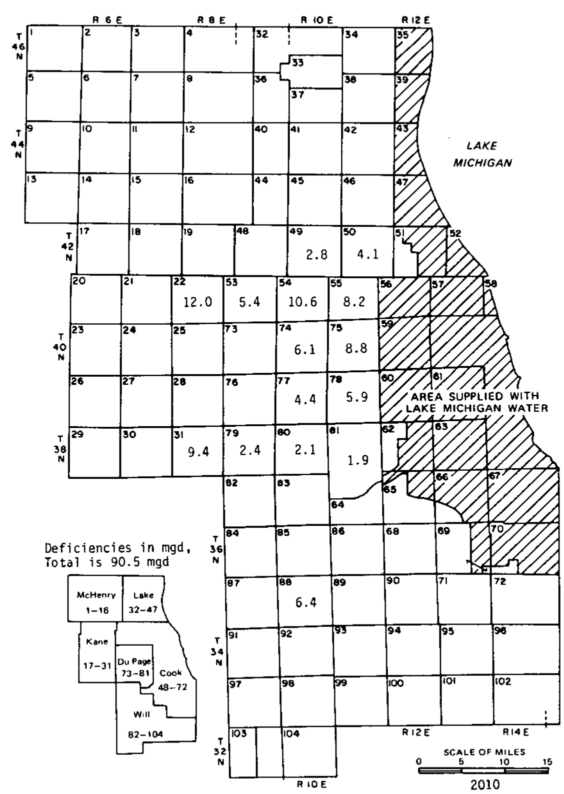

Figure 24. Water demands in 2010 in excess of groundwater available from natural recharge and mining (scheme 1)

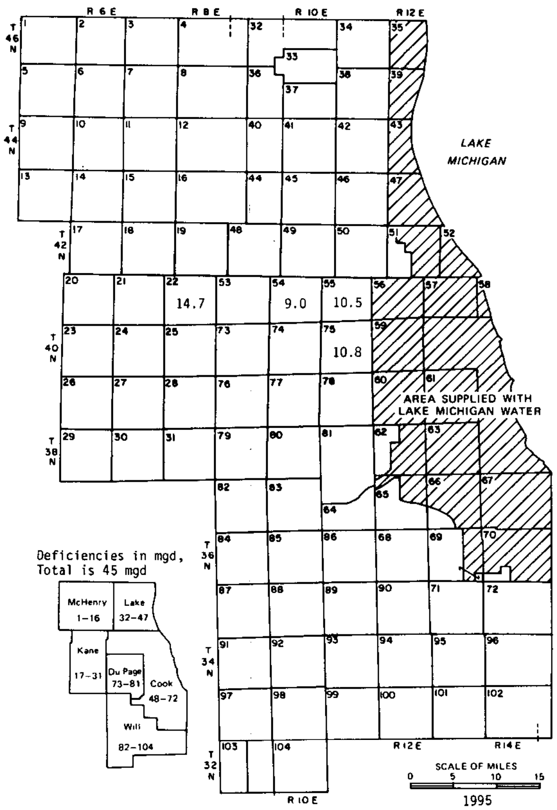

Figure 25. Water demands in 1995 in excess of groundwater available from natural recharge and mining (scheme 2)

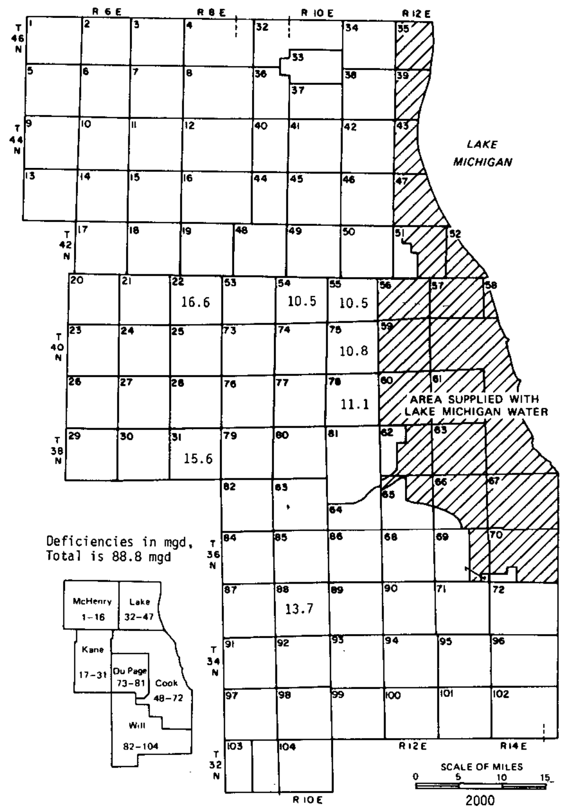

Figure 26. Water demands in 2000 in excess of groundwater available from natural recharge and mining (scheme 2)

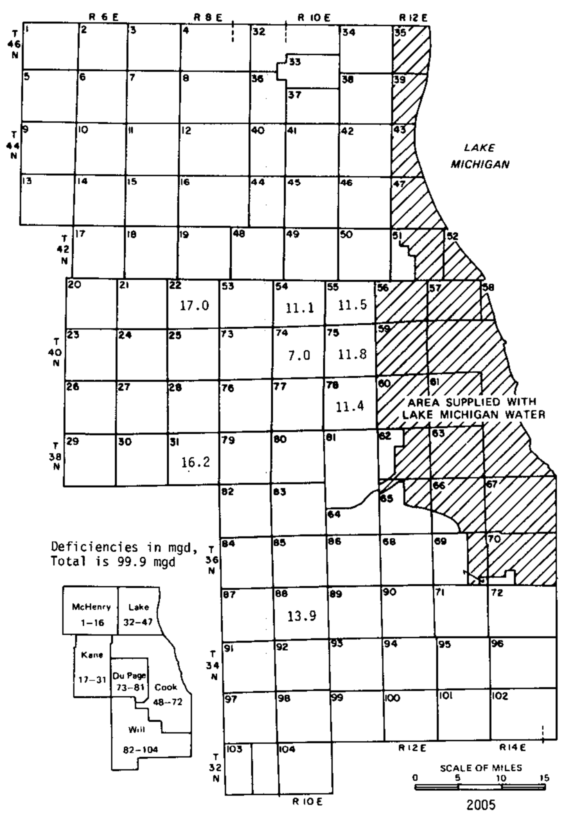

Figure 27. Water demands in 2005 in excess of groundwater available from natural recharge and mining (scheme 2)

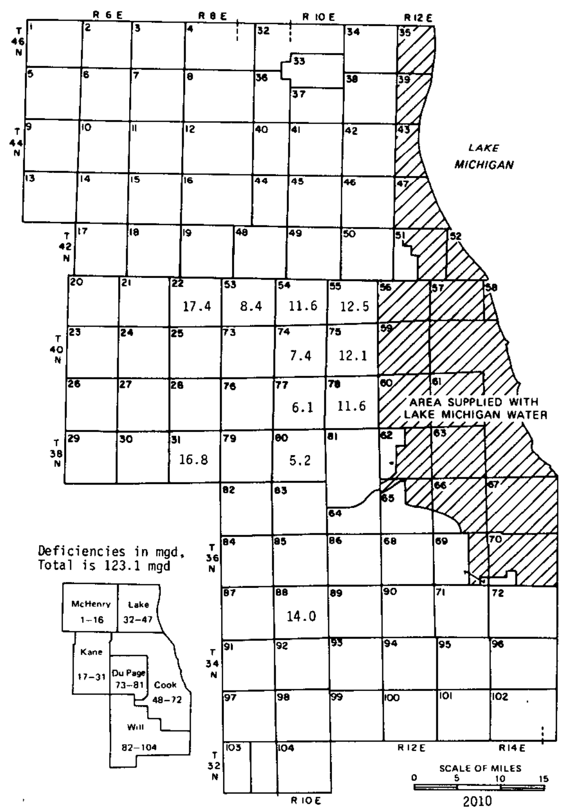

Figure 28. Water demands in 2010 in excess of groundwater available from natural recharge and mining (scheme 2)

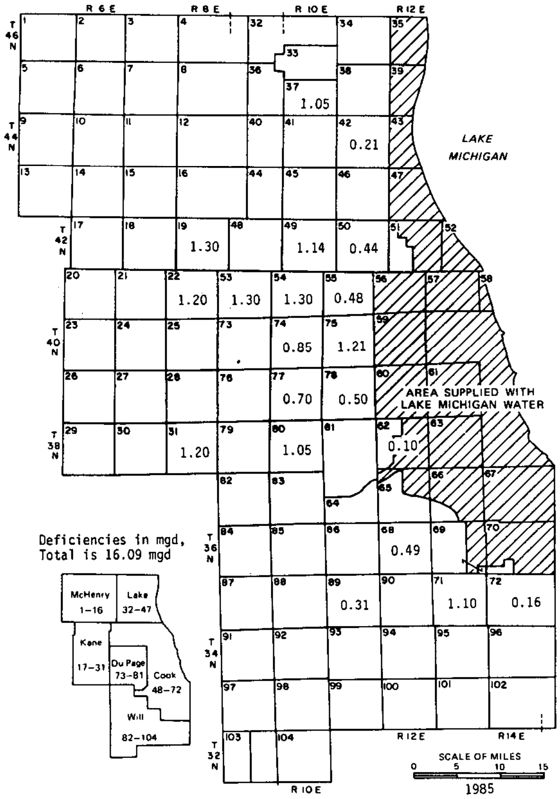

Figure 29. Water demands in 1985 in excess of groundwater available from natural recharge and mining limited to 1980 pumpags (scheme 3)

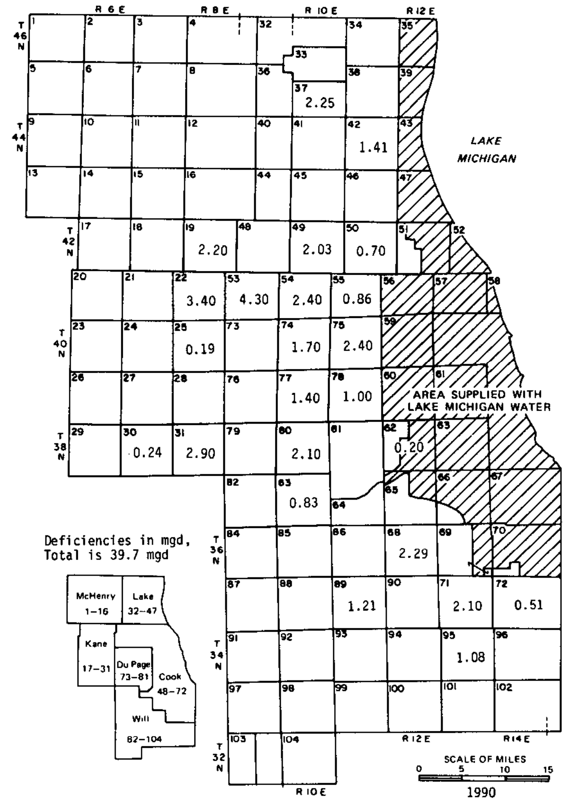

Figure 30. Water demands in 1990 in excess of groundwater available from natural recharge and mining limited to 1980 pumpage (scheme 3)

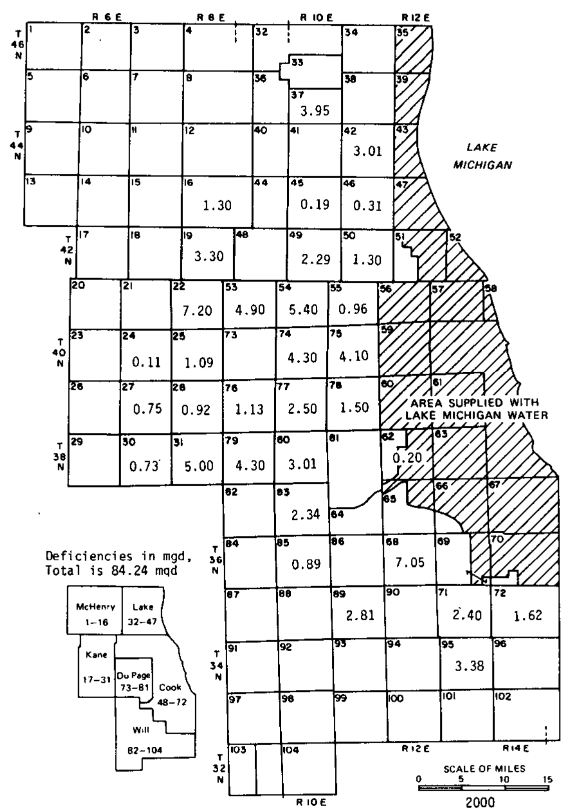

Figure 31. Water demands in 2000 in excess of groundwater available from natural recharge and mining limited to 1980 pumpage (scheme 3)

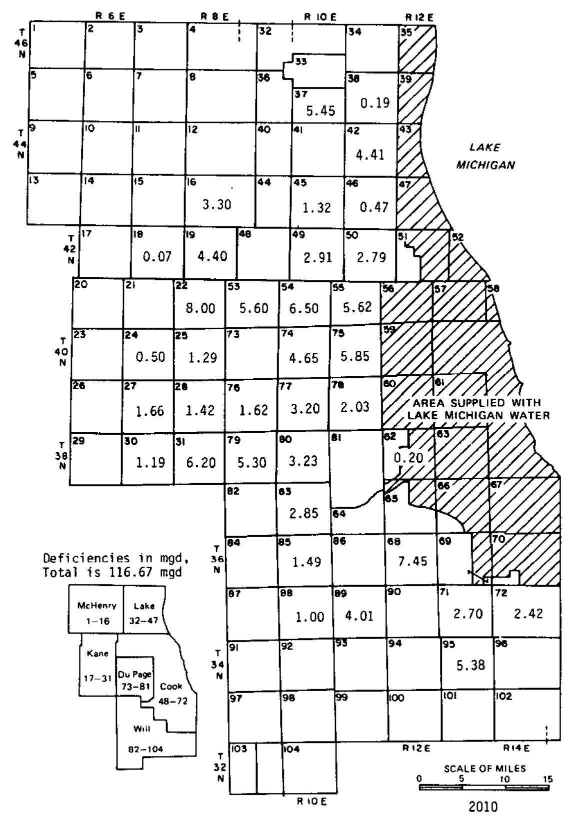

Figure 32. Water demands in 2010 in excess of groundwater available from natural recharge and mining limited to 1980 pumpaga (scheme 3)

Part 2. Meeting Future Demands

LEAST COST STUDY OF FUTURE GROUNDWATER DEVELOPMENT

Assumptions

Cost estimates for future groundwater development were made within the framework of the following assumptions. Demands were to be satisfied by using the cheapest available groundwater source within each township. Three such sources were generally available: 1) sand and gravel, 2) Silurian dolomite, and 3) deep sandstone. Sources 1 and 2 are referred to as shallow aquifers, and source 3 is called the deep sandstone aquifer.

Pumpage from the shallow aquifers was limited to their potential yield, while that from the deep sandstone was increased until pumping levels reached the top of the Ironton-Galesville Formation of the deep sandstone, at which time pumpage was reduced to prevent further water level declines (mining approach, scheme 1).

Pumping lifts for the shallow aquifers were assumed to be constant with time (steady-state), while those for the deep sandstone were assumed to continuously decline with time. Deep sandstone pumping lifts were determined by use of a digital simulation model (Prickett, 1969).

Costs were estimated only for those townships with demands greater than 1 mgd.

Treatment costs were considered separately, since it was assumed that waters from all three sources would be blended and treated as one source.

Costs were adjusted to 1974 dollars and included operations, maintenance, and repair expenses as well as capital expenses (amortized at 8 percent interest over the expected service life of each cost component). Costs were computed on both a yearly and unit (¢/1000 gallons) basis.

Cost Components of Raw Water

Raw water costs include those of wells, pumps, and electricity (pumping costs). Well and pump costs were determined from equations presented by Gibb and Sanderson (1969) and adjusted to 1974 prices *(First Quarterly Cost Roundup,* 1974). Treatment costs were determined by adjusting cost equations of Moench and Visocky (1971) to 1974 prices according to the *Handy-Whitman Index of Water Utility Construction Costs* (1975).

Wells

Average well depths and yields for each aquifer in each township were determined from data on file and reports of the Illinois State Water Survey. Average well yields were used to determine the number of wells required for shallow pumpage. Deep sandstone wells were assumed capable of developing 1 mgd each. To allow for peaking and standby, the number of wells for the two sources was increased by 50 and 20 percent, respectively (a multiplier of 1.8).

Annual costs of wells were obtained by amortizing the capital costs at 8 percent interest over their expected service life. A service life of 50 years was assumed for Silurian and deep sandstone wells, whereas sand and gravel wells were expected to last 25 years.

Capital costs in dollars per well for each source are:

$$\text{Sand and gravel cost} = 1346\ d^{0.408}$$

$$\text{Silurian dolomite cost} = 1.66\ d^{1.45}$$

$$\text{Deep sandstone cost} = 0.057\ d^{1.87}$$

where d is the well depth in feet. Annual costs were obtained by multiplying the cost equations by the appropriate capital recovery factor (0.0937 for sand and gravel and 0.0817 for both Silurian and deep sandstone wells).

In addition to capital costs, it was assumed that Silurian dolomite wells would require an additional cost for rehabilitation (acidizing) once every 25 years. Such costs for wells with yields of 100, 200, 300, 400, and 500 gpm were estimated to be $750, $1500, $2250, $3000, and $3750, respectively. This resulted in additional annual costs of $70, $140, $210, $280, and $350, respectively, for each Silurian well required.

Pumps

A cost formula for submersible pumps presented by Gibb and Sanderson (1969) was adjusted to 1974 prices and used to estimate pump costs. Well yields and pumping lifts for each source were used in applying their formula. Lifts for shallow aquifers were determined by adding 100 feet to calculated pumping levels (in order to raise water to storage tanks). Those for the deep sandstone were computed with the digital computer model (Prickett, 1969). In order to allow for the additional cost of switches, wiring, etc., the cost for each pump was multiplied by a factor of 1.5. The resulting cost equation in dollars per pump is:

$$\text{Pump cost} = 16.718\ Q^{0.541} H^{0.658}$$

where Q is pumpage in gpm and H is lift in feet. Annual costs were obtained by amortizing capital costs over an assumed 10-year pump service life (capital recovery factor of 0.149).

Electricity

The cost of electrical energy for pumping water to an elevation of 100 feet above ground was computed at a flat rate of 1.14¢ per kilowatt-hour (Commonwealth Edison rate schedule). Annual electrical costs were determined by applying the above rate and a wire-to-water efficiency of 50 percent as described in Illinois State Water Survey Technical Letter 9 (1968b). Annual electrical costs in dollars for each source was computed as:

Annual cost = 0.03755 QH

where Q is total pumpage in gpm and H is lift in feet. This relationship is illustrated in figure 33 for unit pumpages of 1 mgd.

The total raw water cost for each township was calculated as the sum of the component costs for all sources utilized.

Treatment Costs

Moench and Visocky (1971) reported earlier studies made of capital costs and operation, maintenance, and repair (OM&R) costs for water treatment plants. Cost equations from that report were adjusted to 1974 prices and used to estimate treatment costs for each township. It was assumed that raw water from all sources would be blended and receive the same amount of treatment. It was also assumed that two treatment plants would be used for pumpages exceeding 1 mgd.

Figure 34 shows the annual investment costs for treatment plants based on amortizing capital costs at 8 percent interest over the expected 25-year plant service life. For pumpages greater than 1 mgd the annual investment cost is expressed as:

$$\text{Annual cost} = 98{,}643(Qf/2)^{0.625}$$

where Qf is the future demand in mgd 20 years hence (2000 demand was used in all cases except those where such demand was reduced; in such cases the 1990 demand was used for Qf).

Figure 35 shows the annual operations, maintenance, and repair costs for treatment plants versus the quantity of water treated. For pumpages greater than 1 mgd this cost is expressed as:

$$\text{Annual OM\&R cost} = 266{,}600(Q/2)^{0.666}$$

where Q is the current pumpage (amount of water to be treated) in mgd.

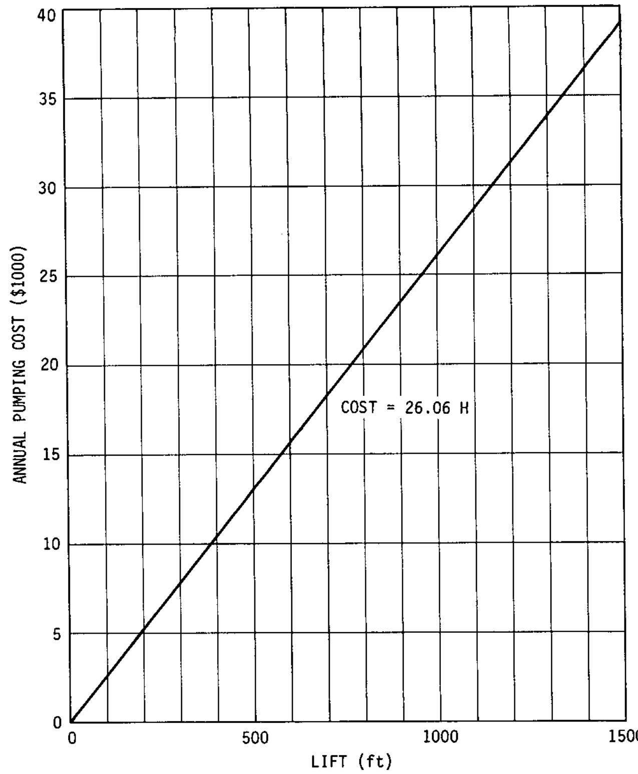

Figure 33. Annual pumping cost per mgd versus lift

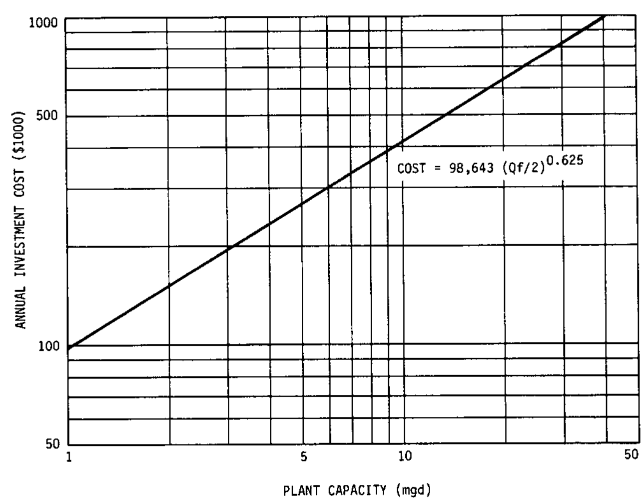

Figure 34. Annual investment costs of treatment plants versus plant capacity

Unit costs (¢/1000 gal) of raw and treated groundwater are summarized for the years 1980, 1985, 1990, and 2000 in tables 30–33.

Table 30. Least Costs of Raw and Treated Groundwater, 1980

(Costs in ¢/1000 gallons)

Township	Demand (mgd)	Raw Shallow	Raw Deep	Raw Combined	Treated
McHenry County					
16	6.10	4.2	7.3	4.8	42.5
Kane County					
19	5.40	3.5	7.2	5.8	44.5
22	11.80	4.4	9.2	8.2	36.5
25	4.20	5.6	8.4	6.8	49.1
28	5.50	5.0	7.4	6.0	44.2
31	15.00	3.9	9.5	7.8	33.5
Lake County					
37	3.65	3.8	7.7	4.5	51.4
38	3.46	3.9	11.4	4.6	47.8
42	5.48	3.5	7.0	4.5	43.4
45	2.24	4.6	27.6	5.8	61.4
46	2.33	3.8	12.9	4.8	59.9
Cook County					
48	1.21	8.0	0	8.0	81.7
49	10.21	7.3	10.6	9.1	38.6
50	15.20	5.7	10.4	8.9	34.1
53	5.60	7.1	8.8	7.9	47.4
54	8.10	6.4	9.8	8.5	40.8
55	13.15	6.4	10.9	9.7	36.1
62	10.60	4.4	9.9	6.1	34.4
68	4.43	4.1	0	4.1	50.4
71	5.90	3.6	10.7	5.2	41.8
72	15.54	4.0	10.6	7.8	32.8
Du Page County					
73	1.00	3.2	53.8	3.8	81.9
74	6.70	3.1	6.5	4.5	38.8
75	12.10	2.8	10.6	7.8	35.5
76	3.30	3.6	9.6	5.1	52.2
77	8.00	3.4	10.8	6.0	38.6
78	14.50	3.2	11.3	8.6	34.2
79	3.00	3.3	7.8	4.8	61.6
80	7.70	3.5	9.2	5.5	38.8
81	10.80	3.7	10.6	6.1	35.3
Will County					
83	6.26	5.1	9.7	5.8	42.2
85	7.20	4.3	10.0	6.7	40.4
88	15.50	4.2	12.5	10.6	34.4
89	6.50	4.6	11.2	6.6	42.4
95	3.30	4.3	0	4.3	54.9

Table 31. Least Costs of Raw and Treated Groundwater, 1985

(Costs in ¢/1000 gallons)

Township	Demand (mgd)	Raw Shallow	Raw Deep	Raw Combined	Treated
McHenry County					
16	7.00	4.4	7.3	5.0	40.0
Kane County					
19	6.70	3.5	8.8	7.1	41.6
22	13.00	4.4	10.7	9.5	36.4
25	4.52	5.6	9.0	7.0	47.6
28	6.00	4.8	8.0	6.0	42.4
31	16.20	3.9	10.4	8.6	33.3
Lake County					
37	4.70	3.8	6.2	4.7	45.4
38	3.78	3.8	11.9	4.4	45.7
42	6.40	3.5	7.1	4.7	40.4
45	2.87	4.6	28.7	5.6	54.0
46	3.00	3.9	14.6	5.0	52.7
Cook County					
48	1.73	8.0	0	8.0	67.7
49	11.35	7.3	11.6	9.8	37.7
50	15.64	5.7	11.9	10.0	34.8
53	6.90	7.1	9.1	8.3	43.5
54	9.40	6.4	12.1	10.3	40.1
55	13.63	6.4	12.5	10.9	36.8
62	10.70	4.4	10.5	6.3	34.4
68	5.04	4.1	13.9	5.2	48.1
71	7.00	3.6	11.4	6.3	39.8
72	15.70	4.0	12.6	9.0	33.8
Du Page County					
73	1.40	3.6	55.6	5.5	69.6
74	7.55	3.1	11.7	7.2	39.4
75	13.31	2.8	12.9	9.6	36.0
76	3.98	3.4	9.6	5.0	47.5
77	8.70	3.4	11.7	6.8	37.9
78	15.00	3.2	12.5	9.4	34.7
79	4.24	3.3	8.9	5.0	51.0
80	8.75	3.5	10.4	6.4	37.6
81	11.65	3.7	12.0	7.0	35.1
Will County					
83	7.19	5.1	10.1	6.1	39.9
85	7.80	3.8	9.9	6.3	38.6
88	16.00	4.4	12.9	11.0	34.5
89	7.30	4.7	11.2	7.0	40.7
95	4.60	4.3	15.3	5.6	47.4

WATER SUPPLY ALTERNATIVES

Limits of Comparisons

The water supply alternatives to groundwater that were studied can be separated into two categories — those for which costs can be estimated, and those for which costs cannot be estimated because of insufficient operating cost data. For most alternatives, costs were estimated for quantities of water needed to supply groundwater deficits under the no-mining approach. The costs for groundwater development estimated in the preceding 'least cost' study were for the mining approach, scheme 1, and cannot be compared with the alternatives discussed here. Further, the costs

Table 32. Least Costs of Raw and Treated Groundwater, 1990

(Costs in ¢/1000 gallons)

Township	Demand (mgd)	Raw Shallow	Raw Deep	Raw Combined	Treated
McHenry County					
16	7.80	4.3	8.8	5.3	38.3
Kane County					
19	7.60	3.5	9.6	7.9	40.2
22	15.20	4.4	12.2	11.0	35.9
25	5.90	4.3	9.7	6.1	41.3
28	7.50	4.8	8.6	5.9	38.3
31	17.90	3.9	11.3	9.5	33.0
Lake County					
37	5.90	3.8	7.9	5.8	41.8
38	4.10	4.0	12.6	4.6	44.2
42	7.60	3.6	8.7	5.6	38.2
45	3.51	4.6	29.9	5.5	48.8
46	3.47	4.0	13.8	5.0	49.0
Cook County					
48	2.14	7.6	0	7.6	60.6
49	12.24	7.3	12.7	10.6	37.5
50	15.90	5.7	12.6	10.6	35.2
53	9.00	7.1	11.6	10.2	40.8
54	10.50	6.4	13.8	11.7	39.9
55	14.01	6.4	13.9	12.0	37.6
62	10.80	4.4	11.9	6.8	34.8
68	6.84	4.0	11.3	6.5	42.6
71	8.00	3.6	12.6	7.5	38.7
72	16.05	4.0	13.3	9.4	34.1
Du Page County					
73	1.80	3.6	57.7	5.1	60.8
74	8.40	3.1	12.8	8.2	38.7
75	14.50	2.8	14.3	10.8	36.1
76	4.60	3.4	9.9	5.7	45.0
77	9.40	3.4	12.7	7.6	37.5
78	15.50	3.2	13.9	10.5	35.3
79	4.80	3.4	10.0	5.4	48.3
80	9.80	3.5	11.7	7.5	36.8
81	12.50	3.7	12.7	7.7	34.8
Will County					
83	8.08	5.1	11.7	6.6	38.4
85	8.30	3.8	10.4	6.4	37.7
88	16.50	4.4	13.9	11.8	34.9
89	8.20	4.6	11.6	7.4	39.0
95	5.90	4.3	10.9	5.5	42.0

Table 33. Least Costs of Raw and Treated Groundwater, 2000

(Costs in ¢/1000 gallons)

Township	Demand (mgd)	Raw Shallow	Raw Deep	Raw Combined	Treated
McHenry County					
16	10.50	4.5	9.7	5.8	34.0
Kane County					
19	8.70	3.5	12.0	9.9	40.0
22	19.00	4.4	15.0	12.9	40.8
25	6.80	4.3	10.9	7.0	39.8
28	8.50	4.7	10.8	7.0	37.4
31	20.00	3.9	14.7	11.6	35.9
Lake County					
37	7.60	3.8	8.9	6.9	38.5
38	4.44	3.8	13.7	4.5	42.5
42	9.20	3.6	9.0	6.2	35.8
45	4.67	4.5	19.1	5.5	42.8
46	4.94	3.8	11.5	4.7	41.3
Cook County					
48	3.30	7.5	0	7.5	49.6
49	12.50	7.3	14.4	11.7	38.3
50	16.50	5.7	15.0	12.3	36.5
53	10.50	7.1	15.6	13.3	41.6
54	13.50	6.4	16.3	12.0	47.2
55	14.11	6.4	16.0	12.2	44.6
62	10.80	4.4	13.4	7.3	35.3
68	11.60	4.0	14.3	10.3	37.6
71	8.30	3.6	13.4	8.0	38.6
72	17.16	4.0	14.3	10.3	34.1
Du Page County					
73	2.64	3.5	62.1	4.6	50.1
74	11.00	3.2	17.3	10.0	40.5
75	16.20	2.8	16.6	10.2	41.8
76	5.98	3.4	13.0	10.7	42.5
77	10.50	3.4	15.9	9.8	38.1
78	16.00	3.2	16.6	12.5	37.0
79	10.20	3.3	12.6	7.8	36.3
80	10.71	3.5	14.8	9.5	37.6
81	14.00	3.7	15.5	9.6	35.2
Will County					
83	9.59	5.1	12.5	7.7	36.8
85	9.40	4.3	12.2	7.6	36.9
88	17.50	4.3	16.2	13.4	36.9
89	9.80	4.6	13.7	9.0	38.0
95	8.20	4.3	13.6	8.1	38.9

developed for alternatives are only for comparisons between the different water supply alternatives in this report. Included in the cost estimates are treatment costs to obtain a quality of water comparable to Lake Michigan water.

Alternatives discussed are:

- Purchase of Lake Michigan water from the city of Chicago
- Use of Kankakee River water in Will and southern Cook Counties
- Use of Fox River water in Kane County
- Transfer of groundwater from shallow aquifers in Will, Lake, and McHenry Counties
- Transfer of groundwater from the deep sandstone aquifer
- Use of potential reservoirs
- Desalting brackish water from the Mt. Simon aquifer
- Artificial recharge of deep sandstone aquifer
- Artificial recharge of shallow aquifers
- Precipitation augmentation over Lake Michigan
- Shift in use of diverted Lake Michigan water with TARP

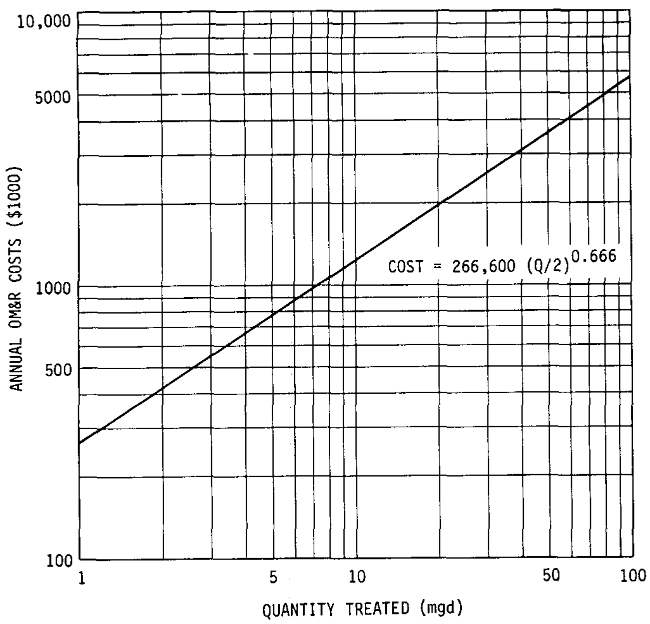

Figure 35. Annual operation, maintenance, and repair costs of treatment plants versus quantity treated

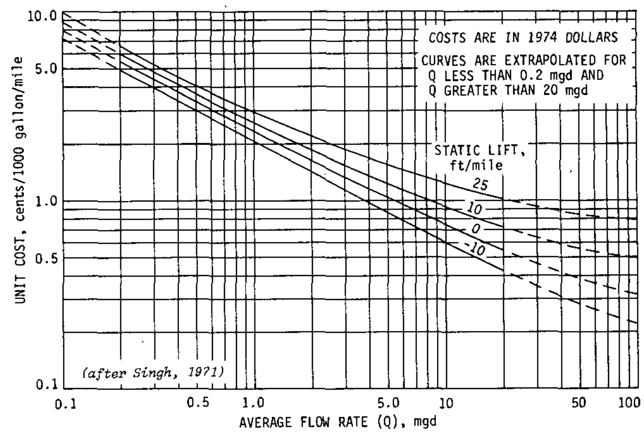

Figure 36. Unit costs of transporting water

Lake Michigan Water Purchased from City of Chicago

The cost of Lake Michigan water purchased from the city of Chicago and transmitted to deficient townships was estimated. The deficits to be supplied are those estimated from the groundwater no-mining approach. The total cost to a township is the sum of the water price from the city of Chicago and the cost of transport from the boundary of the area currently serviced by Chicago to the center of the deficient township.

There are many opportunities for cooperation and shared pipelines and rights-of-way. The deficient townships in Lake County could obtain Lake Michigan water from supply systems directly east. Another possibility exists in Kane County, where the three most westerly townships with deficiencies could obtain water in cooperation with the adjacent townships to the east. The southern two tiers of townships with deficits in Kane and Du Page Counties could develop a common transmission line along the township line between T38N and T39N. A county-wide water supply system for Du Page County could be beneficial.

In all cases several conditions are assumed and similar procedures are followed. The assumptions are:

1) The transmission lines are of minimum length from the nearest point on the boundary of the area now supplied with Chicago water to the center of each township. For the alternate case in Lake County the starting point is on the boundary of the area currently supplied with Lake Michigan water. For the 10-township case in Kane and Du Page Counties, the transmission line is on the townline with perpendicular spur lines to the center of each township. Right-of-way availability may result in other alignments, but the length of pipeline and elevation difference will be similar.
2) The price of water from Chicago is 38¢/1000 gallons, the current charge to municipalities now using Chicago water within the boundaries of the Metropolitan Sanitary District.
3) Elevations used are average values for each township.
4) The quantities of water to be met by importing Chicago water are the deficits under the groundwater no-mining approach.
5) Water transport costs are estimated from figure 36 which is adapted from Singh (1971). The costs are given in cents per 1000 gallons per mile in 1974 money. For average flows over 20 mgd or under 0.2 mgd, the curves are extrapolated.

The groundwater deficiencies for the condition of no-mining of the deep sandstone water are shown in figure 37. Townships with demands exceeding the locally available supply are concentrated in suburban Cook County, in Du Page County, along the Fox River in Kane County, and in the vicinity of Joliet in Will County. The total amount of water demand in excess of local supplies is 76.7 mgd in 1980 and 169.5 mgd in 2000.

Total costs for meeting these water supply deficiencies in 1980 and 2000 are shown in figure 38 for each deficient township. In 1980 total costs range from 38 to 81¢/1000 gallons. The two townships with no transport cost are in Cook County areas now using some Chicago water. Unit costs of transporting water increase with distance, static lift, and decreasing quantity.

In 2000 total costs range from 38 to 258.6¢/1000 gallons. For townships with deficiencies of 1 mgd or greater, total costs range from 38 to 85 cents. For townships which

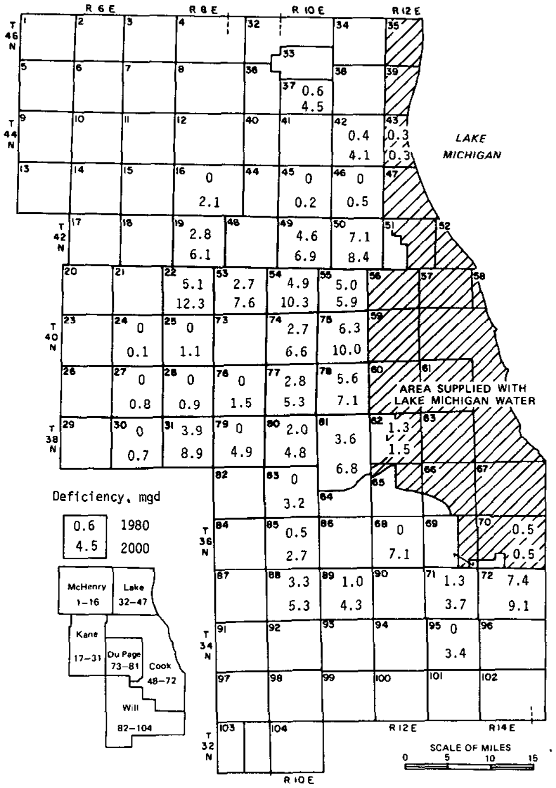

Figure 37. Water demands in excess of groundwater available from natural recharge

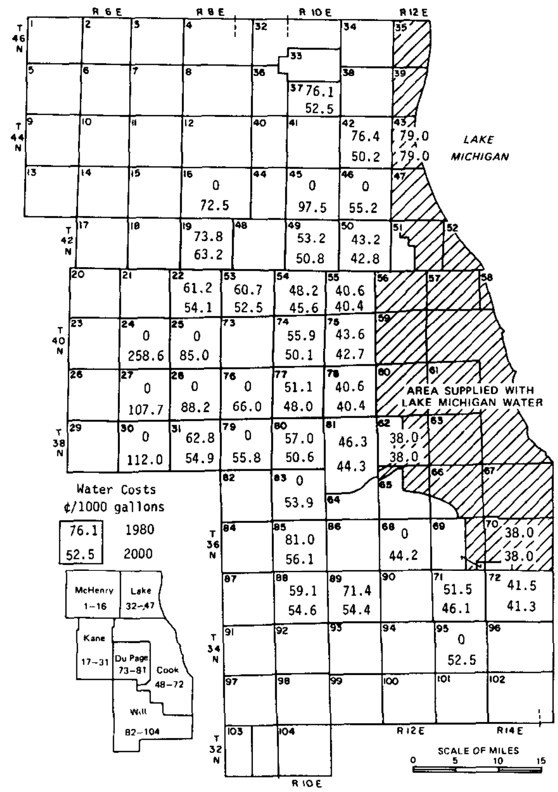

Figure 38. Cost of meeting water supply deficiencies with water purchased from the city of Chicago

had deficiencies in 1980, the reduced total cost in 2000 results from economy of scale in transport costs. For example, deficiencies for township 22 increased from 5.1 to 12.3 mgd with a resultant decline in costs from 61.2 to 54.1¢/1000 gallons. The amount of economy of scale depends on the percent increase in deficiency and the distance from the Chicago service area.

The five deficient townships in Lake County in 2000 have two alternate sources of water. Water could be obtained from existing Lake Michigan supplies in Lake County. Shallow groundwater is also available in Lake County and could be transferred from surplus to deficient townships. The shallow groundwater transfer is discussed in another section of this study. Costs of Lake Michigan water purchased from Lake County water supply systems is not known. Depending on costs, either of these alternatives, Chicago water or some combination, may be most economical for meeting the local water supply deficiencies in Lake County.

In 2000 the three townships with the highest unit costs for meeting water supply deficiencies are in Kane County. Township 24 has a very small deficiency as well as the long distance to transport water from Chicago. Cooperation with the township immediately east of each of these three townships would reduce the transport cost substantially. Approximate calculations show a possible reduction in total costs of 33, 12, and 29 percent for townships 24, 27, and 30, respectively.

Possibilities of large scale cooperative systems for making up the water supply deficiencies exist in northwestern Cook, Du Page, Kane, and Will Counties. As an example of such a system, the 10 deficient townships in T38N and T39N in Kane and Du Page Counties were considered. A transmission pipeline is assumed to be located along the line between T38N and T39N. In 2000, this line extends from the east line of Du Page County to the east-west center of townships 27 and 30 in Kane County. From a point on the east-west center of each pair of townships feeder mains extend north and south to the center of each township.

Total cooperative and individual costs for supplying the five deficient townships in 1980 are shown in table 34. At the time of this study, the transmission main ends at the east-west center of township 31. The cooperative and individual systems yield essentially the same average cost, 50¢/1000 gallons, in 1980.

In 2000, all 10 townships are deficient. The total costs are given in table 35. At this time the combined system is less costly. The average unit cost for the cooperative scheme is 48.5¢/1000 gallons, or 4 percent lower than the average for individual transmission systems. On a township by township basis, the combined system results in extremes

Table 34. Kane-Du Page County Cooperative Plan, 1980

County	Township	Deficit (mgd)	Total cost (¢/1000 gal) Cooperative	Individual
Kane	31	3.9	58.1	62.8
Du Page	77	2.8	50.2	51.1
	78	5.6	42.8	40.6
	80	2.0	49.9	57.0
	81	3.6	46.5	46.3
Average			49.8	50.1

Table 35. Kane-Du Page County Cooperative Plan, 2000

County	Township	Deficit (mgd)	Total cost (¢/1000 gal) Cooperative	Individual
Kane	27	0.8	70.8	107.7
	28	0.9	58.3	88.2
	30	0.7	69.8	112.0
	31	8.9	52.9	54.9
Du Page	76	1.5	52.4	66.0
	77	5.3	46.6	48.0
	78	7.1	42.2	40.4
	79	4.9	49.4	55.8
	80	4.8	46.0	50.6
	81	6.8	44.7	44.3
Average			48.5	52.5

of a cost reduction of 38 percent in township 30 but a cost increase of 4 percent in township 78. Costs are reduced substantially in townships 27, 28, 30, 76, 79, and 80. Moderate cost reductions occur for townships 31 and 77. The cost to township 81 increases slightly.

Commingling of Lake Michigan Water with Groundwater

There are several suburban public water supplies that commingle Chicago water with groundwater.

At Riverside, when Chicago water was used to supplement the supply, problems with corrosion in domestic galvanized steel pipe were, in 1963, reported to be severe with 25 to 30 year old installations, especially at threaded joints, but not with 50 year or over installations. New installations were reported to have 'pinhole attack.' Copper services were reported to be unaffected. Until a year or so ago, about 25 percent of the supply was from Lake Michigan. Currently, only about 5 percent of the supply is from Lake Michigan and the corrosion problem is reported to be minimized.

Lyons also commingles a water similar to that of Riverside with Chicago water, but the mixing takes place in a common reservoir before pumping into the distribution system. It is reported that no corrosion problem has developed during the last 25 years.

During the last 5 years, Hickory Hills has mixed about 33 percent Chicago water with partially softened well water with a total mineral content of 600 mg/l. The Chicago water, well water, and softened well water is mixed in a common reservoir before pumping into the distribution system at separate points. No scale or corrosion problem has been observed.

The Riverside well water is rather highly mineralized (825 mg/l) with a hardness of 300 mg/l and alkalinity 325 mg/l. The pH is 7.1 and temperature 61.2F. No dissolved oxygen is present. Chicago water has a mineral content of about 165 mg/l with hardness 130 mg/l and alkalinity 105 mg/l. The pH ranges from 7.9 to 8.2 and the temperature from 75 to 35F. Dissolved oxygen ranges from 8 to 13 mg/l. Water from the wells and from Chicago enters the distribution system at separate points and the mixing zone varies with relative pressure and demand.

Theoretically, the chemistry of commingling waters is complicated by the relative concentrations of the calcium and particularly the alkalinity through shifts in equilibrium of the carbon dioxide-bicarbonate-carbonate species with changes in pH, temperature, and mineral content.

The water may be oversaturated or undersaturated, or both, with different mixed proportions. Oversaturation tends to cause slight scaling, and undersaturation to cause corrosion. Oxygen tends to accelerate corrosion if the water is undersaturated, especially with higher mineral concentrations. Higher temperatures tend to cause scaling, and lower temperatures to cause undersaturation.

Experience in the suburbs that blend Lake Michigan water with well water appears to suggest that blending should be done in a common mixing basin, or the well water should be treated for a pH, hardness, and alkalinity similar to that of the lake water. Computer calculations can predict *tendencies* for scaling or corrosion by different proportions of water mixed together, but the problem of developing mathematical relationships is very time consuming and still leaves a judgment factor on the effect of introducing dissolved oxygen to the system.

Kankakee River

The Kankakee River near Wilmington is within approximately 20 miles of the Joliet area where new sources of water supply may be required in the near future. The U.S. Geological Survey (USGS) gaging station near Wilmington shows the following daily flow characteristics for the Kankakee River. The mean daily flow is 2500 mgd. The median daily flow is 1470 mgd. Low flow records show discharge greater than 320 mgd for 99 percent of the time, and discharge greater than 240 mgd for 99.9 percent of the time. The lowest daily flow of record is 175 mgd. The lowest instantaneous flow is 132 mgd. The water quality of the Kankakee River (Harmeson and Larson, 1969; Harmeson et al., 1973) is similar to some of the groundwater now being used. Kankakee River water could be treated to obtain water of a quality comparable to Lake Michigan water.

In 1964, the Stanley Engineering Company issued the *Lower Des Plaines Valley Water Resources Study.* Costs of independently obtained Lake Michigan water were found to be somewhat higher than water from the Kankakee River. However, the cost of softening was not included in the Stanley Engineering cost estimates. Water was to be furnished to Joliet, Lockport, and Lemont in Will County, and to Orland Park and Tinley Park in Cook County. Groundwater supplies would be continued, but would be supplemented by surface water. By 2014, the final year considered, 82.5 mgd of a total use of 120 mgd would be from surface water.

In 1972 a report, *Preliminary Engineering Report on Kankakee River Water Supply System for Public Water Commission of Frankfort, Joliet, Lockport, Mokena, New Lennox, Rockdale, and Romeoville,* was prepared by Consoer, Townsend & Associates.

In addition to service to the commission cities, called case I, two extensions of service were considered. Case II included water supply for Park Forest and Chicago Heights. Case III added Bolingbrook to case II. The ultimate development in 2020 was for mean daily demands of 52, 69, and 87 mgd for cases I, II, and III (figure 39), respectively. The system provided water treatment including softening in a plant near the Kankakee River in the vicinity of Custer Park. Transmission mains were provided to deliver water to each town being served. The treatment and transmission facilities were designed for maximum daily flows of 84, 115, and 150 mgd for cases I, II, and III, respectively.

Both of these reports presented estimated prices for water. The Consoer, Townsend & Associates' report gives prices only for 1980 and 1985 so these were extrapolated to obtain an estimate for 2000. All prices were adjusted to 1974 values with a composite index based on Handy-Whitman Index numbers. The composite index is a sum made up of two-thirds large treatment plant and one-third transmission mains. This is based on capital cost figures in the report by Consoer, Townsend & Associates.

Independent cost estimates were made by the Illinois State Water Survey by methods discussed in Technical Letters 7, 9, and 11, Reprint 170 (Singh, 1971), and Circular 102 (Moench and Visocky, 1971). These were made for the three cases in the Consoer, Townsend & Associates' plan for the years 1980 and 2000. Because their design was based on maximum daily flows, the Water Survey costs were extended to this design discharge in addition to mean daily flows.

Cost estimates at 1974 levels are shown in table 36 for both engineering reports and the Water Survey estimates for water needs. In 1980 and in 2000, the Stanley figures are similar to Water Survey figures for mean daily flow design. The Consoer, Townsend & Associates prices for

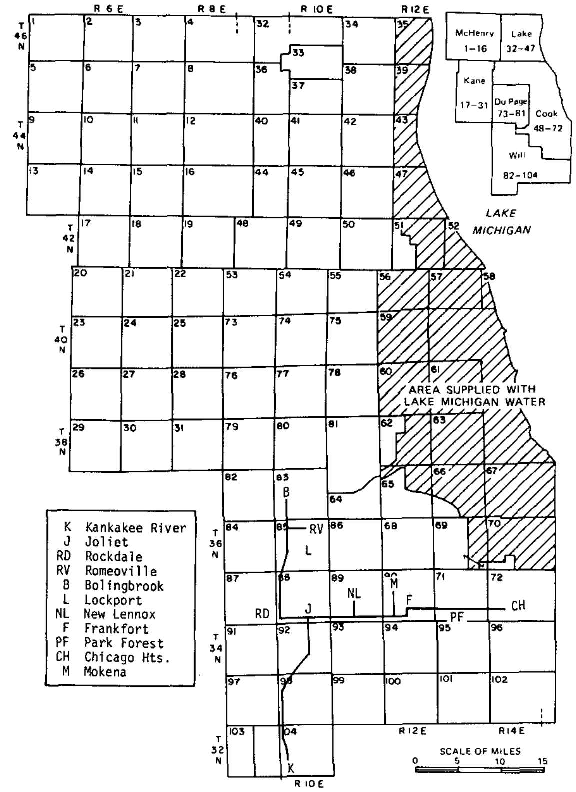

Figure 39. Pipeline system for Joliet area public water commission, case III

1980 and those extrapolated for 2000 are considerably higher than Water Survey prices for a design based on the same maximum daily flows. The most likely reason is treatment cost. Consoer, Townsend & Associates designed for softening to 90 mg/l hardness, plus filtration and disinfection. The Water Survey treatment costs are not clearly identified with particular treatment processes though softening to 130 mg/l hardness (hardness of Lake Michigan water) is intended.

In November 1975, a report to the city of Joliet (*Water Resources of Northeast Illinois,* 1975) recommended development of groundwater resources to meet water supply demands through 2010.

For meeting the water supply deficiencies in Will and southern Cook Counties, the Kankakee River is a feasible alternative to continued mining of the deep sandstone aquifer. The cost of transferring shallow aquifer water for this area is discussed in a subsequent section.

Fox River

The flow in the Fox River at Algonquin, if off-channel storage is made available, is sufficient to meet the total water supply demands in townships along the river from Algon-

Table 36. Cost Estimates for Kankakee River Water

Study	1980 Design Q (mgd)	1980 Water (¢/1000 gal)	2000 Design Q (mgd)	2000 Water (¢/1000 gal)
A. Stanley, mean daily	15.0	44.5	51.8	28.9
B. Consoer, Townsend & Associates, maximum daily				
Case I	28.5	90.5	54.7	62.8
Case II	47.6	74.0	79.3	55.6
Case III	58.1	72.6	102.8	51.5
C. State Water Survey, mean daily				
Case I	18.4	43.7	33.8	35.6
Case II	29.3	40.9	47.8	34.6
Case III	34.5	39.6	59.6	33.4
D. State Water Survey, maximum daily				
Case I	28.5	58.4	54.7	48.3
Case II	47.6	55.7	79.3	47.3
Case III	58.1	57.8	102.8	49.1

quin to Aurora in 2000. Near Algonquin, according to USGS gaging station records, the Fox River has a mean daily flow of 492 mgd and a median daily flow of 318 mgd. Low flow records show discharge greater than 103 mgd for 90 percent of the time, discharge greater than 36 mgd for 99 percent of the time, and discharge greater than 16 mgd for 99.9 percent of the time. The lowest daily flow of record is 12 mgd.

The mineral quality of the Fox River water is similar to the quality of the water in the shallow aquifers (Harmeson et al., 1973). The water can be treated to obtain water of mineral quality similar to Lake Michigan water.

The biological quality is poor, especially during low flow periods, because of sewage effluents discharged to the river. Since there are several sewage treatment plants below Algonquin, the water from the Fox River would be obtained from an intake at Algonquin. Special control systems or treatment processes may be required to assure a finished water of adequate biological quality at all times.

Because the state water quality standards designate the Fox River for 'domestic and food processing water supply,' an improved water quality can be expected in the future. Further discussions of the Fox River as a water supply source are in NIPC Technical Reports No. 4 and No. 8 (Northern Illinois Planning Commission, 1966, 1974). A recent engineering report (Black and Veatch, 1975) for the city of Elgin noted that Fox River water quality is as good as, or better than, the quality of surface waters which are being used for water supply elsewhere in Illinois. Conventional treatment was considered to be sufficient to produce a safe, potable water from the Fox River.

In this report, six case studies of supplying water to communities along the Fox River are described. Assumptions and methods used in determining quantities of water and costs are given below. Several areas of uncertainty are discussed.

Assumptions and Methods of Analysis

1) Transmission lines are of minimum length between the centers of townships. Land surface elevations are average values for each township. Right-of-way availability may result in other alignments, but the length of pipeline and elevation difference will be similar.
2) Water transport costs were estimated with information adapted from Singh (1971) and adjusted to 1974 dollars. For average flow rates over 20 mgd, Singh's results were extrapolated.
3) Treatment costs were obtained from Moench and Visocky (1971), and adjusted to 1974 dollars. Treatment takes place in the source township to benefit from economy of scale.
4) The quantities of water to be obtained from the Fox River were based on estimates made in the section on Groundwater Demand Projections, 1980–2010. The series A cases were planned to meet the deficits obtained from the no-mining approach (figures 16 and 19). The series B cases were planned to meet the total projected water supply demands (table 21).
5) Systems were planned to furnish the required quantity of water during a drought with a return period of 25 years while maintaining the 7-day 10-year low flow (33 mgd or 51 cfs) in the river. Off-channel storage is necessary to meet flow requirements during periods of low streamflow.
6) Storage volumes were determined by use of the 25-year low flow mass curve and the appropriate demand mass line. The reservoir was assumed to be full at the beginning of the drought period and empty at the end of the drought. The reservoir was sized for the volume needed in 2000. Provision for net evaporation was determined by methods described by Roberts and Stall (1967). Reservoir locations were obtained from

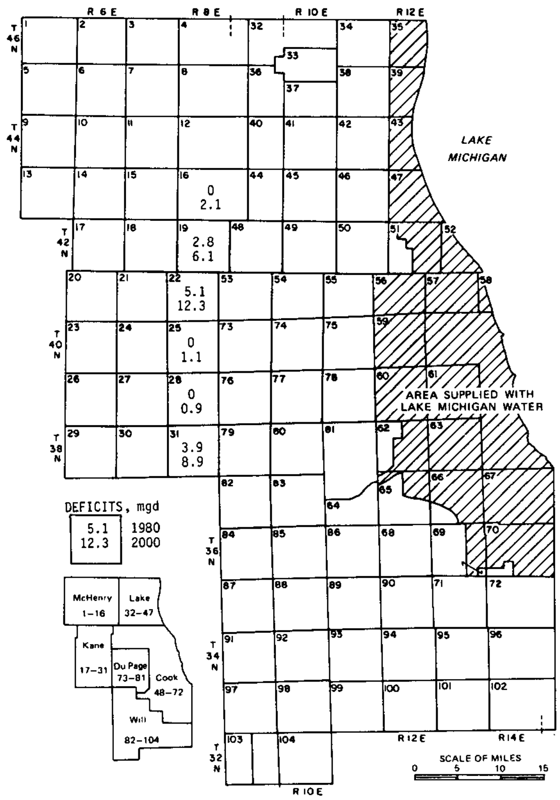

Figure 40. Water supply deficits along the Fox River in 1980 and 2000

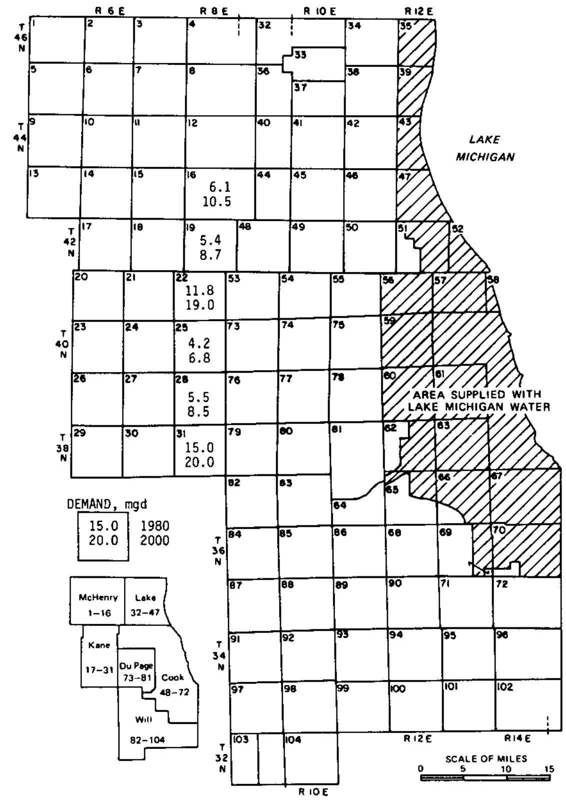

Figure 41. Water supply demands along the Fox River in 1980 and 2000

Dawes and Terstriep (1967), or from study of USGS topographic maps.

7) Cost of pumping water from the river to the storage reservoir was based on a static lift of 75 feet, 1 mile of pipeline, and annual costs to fill the reservoir during the time that the river flow is high enough to provide water for storage. Only the power cost was affected by the partial-year operation.
8) Costs were adjusted to 1974 values with the Handy-Whitman Index (1975).

Case Studies

Six case studies that include three different combinations of townships and two levels of water supply were considered. The water supply deficiencies under the no-mining concept are shown in figure 40 for the six townships along the Fox River from Algonquin to Aurora. The total water supply demands for these townships are given in figure 41. The projections are for 1980 and 2000.

The cases in which only the deficits are met by using river water are labeled A. The cases in which the total demand is met from river water are labeled B. Cases labeled I are for Elgin township (township 22) only. Cases labeled II include all six townships. Cases labeled III include five townships excluding Aurora township (township 31).

Flow rates for each case are shown in table 37. In 1980 the amount of water to be obtained from the river ranges from 5.1 mgd for case I A to 48.0 mgd for case II B. In 2000 the range of flows required is from 12.3 to 73.5 mgd for case I A and II B, respectively. The effect of maintaining the 7-day 10-year low flow of 33 mgd is very significant. This flow is 31 percent of the total for case II B in 2000 and is 87 percent of the total for case I A in 1980.

The cost of furnishing water to fill the projected deficiencies or the total demands includes water treatment, transportation to the townships, storage for protection against drought, and pumping to the storage reservoir. Costs of each of these were estimated and then combined to obtain total costs to each township and the average cost for each of the six cases in both 1980 and 2000.

The mineral quality of Fox River water is similar to much of the groundwater being used. For example, Fox River water has a median hardness of 318 mg/l compared with 132 mg/l for Lake Michigan, 300 mg/l for water from the Cambrian-Ordovician aquifer, or 440 mg/l for shallow aquifer water. Treatment costs are estimated for a finished water with hardness equal to that of Lake Michigan water. To obtain the maximum advantage from economy of scale the treatment plant is placed near Algonquin where the intake would be located. In computing the 1980 costs, the

Table 37. Water Supply Quantities to be Obtained from the Fox River

	Case					
	I A	*II A*	*III A*	*I B*	*II B*	*III B*
1980						
Q, mgd	5.1	11.8	7.9	11.8	48.0	33.0
Q+33, mgd	38.1	44.8	40.9	44.8	81.0	66.0
Q+51, cfs	59.0	69.3	63.2	69.3	125.0	102.0
2000						
Q, mgd	12.3	31.4	22.5	19.0	73.5	53.5
Q+33, mgd	45.3	64.4	55.5	52.0	106.5	86.5
Q+51, cfs	70.0	99.5	85.8	80.5	165.0	134.0

Notes: 1) I is Elgin township (22)
II is all six townships (16, 19, 22, 25, 28, 31)
III is all townships except Aurora (16, 19, 22, 25, 28)
2) A = meeting deficits only
B = meeting total demand
3) 7-day 10-year low flow is 33 mgd or 51 cfs

Table 38. Estimated Treatment Costs for a Finished Water with Hardness Equal to That of Lake Michigan

(Costs in ¢/1000 gallons)

	Case					
	I A	*II A*	*III A*	*I B*	*II B*	*III B*
1980	40.7	31.0	36.3	28.2	18.0	20.7
2000	25.8	18.7	21.0	22.2	14.0	15.6

Note: A = meeting deficits only; B = meeting total demand

capacity required in 2000 is considered, but for 2000 no allowance for future capacity is made.

Treatment costs are given in table 38 for all cases in 1980 and 2000. Economy of scale is evident with costs ranging from 40.7¢/1000 gallons for the 5.1 mgd of case I A in 1980 to 14¢/1000 gallons for the 73.5 mgd of case II B in 2000. The effect of providing for increased future capacity is shown by case I B, 1980, and case II A, 1980. The cost for case I B is about 28 cents with a future capacity of 19 mgd or 1.6 times the 1980 capacity. The cost for case II A is 31 cents with a future capacity of 31.4 mgd or 2.6 times the 1980 capacity.

The cost of transporting water depends on the pipeline length, the elevation difference between the ends of the pipeline, and the flow rate. The unit cost increases with longer distance and higher lift and decreases with higher flow rate. For cases II and III the pipeline from each township to the next is figured separately because the flow rate changes at each township which receives water from the transmission system. For case I transport costs will be significant if the intake or intake and treatment plant are located near Algonquin but will be small if the intake and treatment facilities are near Elgin. Transport costs for each township are shown in table 39. The transport cost for

Table 39. Estimated Transport Costs for Five Townships

(Costs in ¢/1000 gallons)

	Dundee 19	*Elgin 22*	*St. Charles 25*	*Geneva-Batavia 28*	*Aurora 31*
1980					
Case I A		12.5			
Case II A	4.2	9.2			28.5
Case III A	5.0	11.2			
Case I B		8.7			
Case II B	2.5	5.1	7.6	10.5	13.9
Case III B	3.0	6.2	10.0	15.5	
2000					
Case I A		8.2			
Case II A	2.8	5.9	9.5	13.6	17.9
Case III A	3.3	7.1	15.9	29.7	
Case I B		7.2			
Case II B	2.2	4.5	6.6	9.1	12.1
Case III B	2.5	5.2	8.2	12.6	

Note: A = meeting deficits only; B = meeting total demand

township 16, Algonquin, is zero because the intake and treatment plant are there in cases II and III.

The mass curve showing the volume of water passing the gage at Algonquin as a function of time for a drought or low-flow year with a return period of 25 years is shown in figure 42. Mass curves are also shown for average and 10-year low-flow conditions. The draft mass lines for cases I B, II B, and III B in 2000 are also shown. The maximum difference in ordinate between the draft line and the flow mass curve is the required storage volume in cfs-days. Note that some stored water is needed even in average flow years. The demand rate includes the 7-day 10-year low flow of 51 cfs which would be the minimum flow in the river. A drought more severe than the once in 25-year annual drought

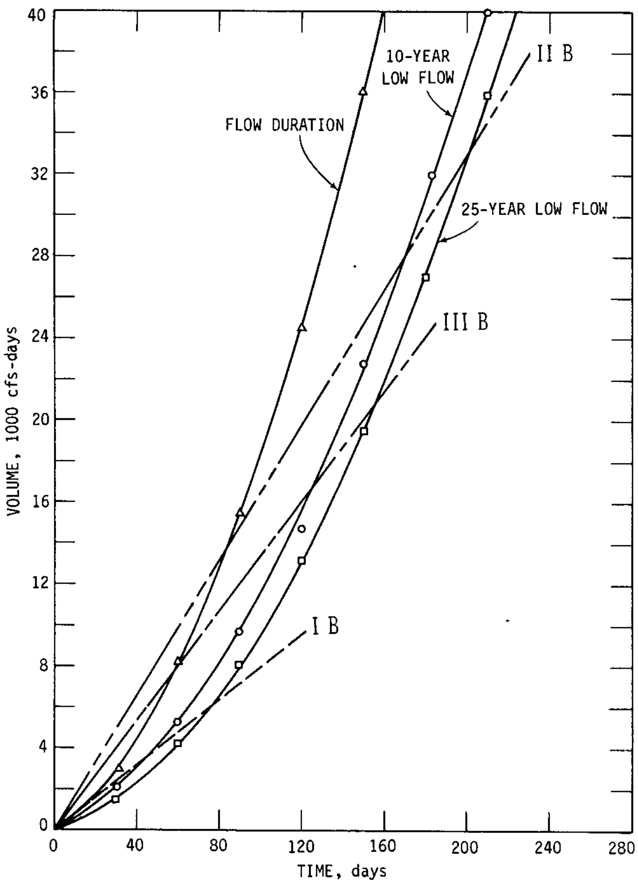

Figure 42. Fox River flow and water supply mass curves

would result in lower flow in the river or a water supply deficiency.

The storage volume required in each case to provide the water supply and maintain the 7-day 10-year low flow during the 25-year low flow is given in table 40. A simple second degree equation was found to fit the 25-year low flow mass curve within about 200 cfs-days and was used to compute the volume. required and the length of time the stored water would be needed. The volume calculation is more easily obtained by this method than it is by graphically finding the point on the flow mass curve which has a slope equal to the draft rate. Evaporation was computed for the net 25-year evaporation during the time the reservoir would be needed. Costs were computed by methods given by Dawes and Wathne (1968). Land was assumed to cost $5000 per acre. Annual costs were computed on the basis of an 8 percent interest rate and a 50-year amortization period.

The location and type of reservoir site had a major effect on the cost of development. A potential reservoir site with a maximum capacity of 11,200 acre-feet is located in Section 33, T43N, R8E, Township 16, Algonquin. Two smaller reservoir sites are on the same tributary. Dawes and Terstriep (1967) show site Kane 1 having a volume of 774 acre-feet and site McHenry 6 having a volume of 1620 acre-feet. All three sites are well formed and are relatively deep with considerably smaller surface areas than given by the relation used by Dawes and Wathne (1968). In case II B an additional reservoir would be needed. Because of the uncertainties, the costs given in table 40 are based on the relations given by Dawes and Wathne even though a natural site would probably be more economical than an off-channel structure. Off-channel sites are possible in Sections 26 and 35, T43N, R8E for all cases and in Sections 2, 26, and 35 of T42N, R8E, for case I, Elgin only. Land cost is also very hard to predict and could easily differ by a factor of two from the $5000 per acre used.

The reservoir will have to be filled by pumping during times when the discharge in the river exceeds the demand

Table 40. Reservoir Capacities and Costs

	Case					
	I A	*II A*	*III A*	*I B*	*II B*	*III B*
Reservoir construction						
V, acre-feet	1260	3870	2470	2105	14,490	8630
A, acres	110	290	190	170	910	580
C, $1000/year	137.0	305.5	216.5	195.5	821.0	554.0
1980, ¢/1000 gallons	7.4	7.1	7.5	4.5	4.7	4.6
2000, ¢/1000 gallons	3.1	2.7	2.6	2.8	3.1	2.8
Pumping to reservoir						
t_d, days emptying	60	104	82	76	203	156
t, days filling	305	261	283	289	162	209
1980, ¢/1000 gallons	1.0	1.0	1.0	0.6	1.1	0.8
2000, ¢/1000 gallons	0.4	0.4	0.4	0.4	0.7	0.5
Total storage costs, ¢/1000 gallons						
1980	8.4	8.1	8.5	5.1	5.8	5.4
2000	3.5	3.3	3.0	3.2	3.8	3.3

Table 41. Estimated Cost Summary-Case I, Elgin Only

(Costs in ¢/1000 gallons)

	A	B
1980		
Storage	8.4	5.1
Treatment	40.7	28.2
Transport	12.5	8.7
Total	61.6	42.0
2000		
Storage	3.5	3.2
Treatment	25.8	22.2
Transport	8.2	7.2
Total	37.5	32.6

and minimum flow requirements. The pumping schedule would have to be determined from actual flow records. A preliminary calculation for case II B by the detailed method in Singh (1971) produced results lower than those obtained by a simple adaptation of the generalized transmission costs. This simpler method was used and is described here.

The volume to fill the reservoir and the number of days which would be available for pumping during the 25-year drought are known. The pumping rate to fill the reservoir is calculated from these data, and the transmission cost is calculated with an assumed static lift of 75 feet and a pipeline length of 1 mile. This cost is for the water pumped into the reservoir and is multiplied by the ratio of the water supply use rate to the pumping rate to obtain the cost increment per 1000 gallons of the actual amount of water used per year. These costs and the total cost to provide storage are included in table 40.

No economy of scale is obtained. In fact, in the year 2000 case II B has the highest unit cost associated with the largest storage volume. The higher unit costs in 1980 are due to the partial use of the storage facility designed for the conditions in 2000.

With the costs of the several items tabulated, the total cost of supplying water to each deficient township for each case can be obtained. The total costs are presented in tables 41, 42, and 43 for cases I, II, and III, respectively. Table 44 contains average costs for each case and percentages of the total average cost for storage and treatment facilities. In table 44, the economy of scale is evident in the lower costs for cases II and III compared with case I, and in the lower cost for case B compared with case A. In 2000 the average costs for case II and case III are essentially the same.

Table 42. Estimated Cost Summary-Case II, All Townships

(Costs in ¢/1000 gallons)

	1980				*2000*			
	A Storage = 8.1 Treatment = 31.0		*B* Storage = 5.8 Treatment = 18.0		*A* storage = 3.3 Treatment = 18.7		*B* Storage = 3.8 Treatment = 14.0	
Township	*Transport*	*Total*	*Transport*	*Total*	*Transport*	*Total*	*Transport*	*Total*
16			0	23.8	0	22.0	0	17.8
19	4.2	43.3	2.5	26.3	2.8	24.8	2.2	20.0
22	9.2	48.3	5.1	28.9	5.9	27.9	4.5	22.3
25			7.6	31.4	9.5	31.5	6.6	24.4
28			10.5	34.3	13.6	35.6	9.1	26.9
31	28.5	67.6	13.9	37.7	17.9	39.9	12.1	29.9

Table 43. Estimated Cost Summary-Case III, All Townships Except Aurora

(Costs in ¢/1000 gallons)

	1980				*2000*			
	A Storage = 8.5 Treatment = 36.3		*B* Storage = 5.4 Treatment = 20.7		*A* Storage = 3.0 Treatment = 21.0		*B* Storage = 3.3 Treatment = 15.6	
Township	*Transport*	*Total*	*Transport*	*Total*	*Transport*	*Total*	*Transport*	*Total*
16			0	26.1	0	24.0	0	18.9
19	5.0	49.8	3.0	29.1	3.3	27.3	2.5	21.4
22	11.2	56.0	6.2	32.3	7.1	31.1	5.2	24.1
25			10.0	36.1	15.9	39.9	8.2	27.1
28			15.5	41.6	29.7	53.7	12.6	31.5

Table 44. Average Total Costs and Percentages of Costs for Storage and Treatment

	Case					
	I A	*II A*	*III A*	*I B*	*II B*	*III B*
1980						
Average cost, ¢/1000 gallons	61.6	53.5	53.8	42.0	31.5	32.7
% storage	13.6	15.1	15.8	12.1	18.4	16.5
% treatment	66.1	57.9	67.5	67.1	57.1	63.3
2000						
Average cost, ¢/1000 gallons	37.5	30.7	30.8	32.6	24.2	24.2
% storage	9.3	10.8	9.7	9.8	15.7	13.6
% treatment	68.8	60.9	68.2	68.1	57.9	64.5

Storage costs are a relatively constant portion of the cost ranging from 12.1 to 18.4 percent in 1980, and from 9.3 to 15.7 percent in 2000. Treatment costs are the single largest part of the total cost ranging from 57.1 to 67.5 percent in 1980 and from 57.9 to 68.8 percent in 2000. Separating transport costs is useful only for the average since this cost is different for each township. On the average, transport costs range from 16.7 to 27.0 percent of the average cost in 1980 and from 21.9 to 28.3 percent of the average cost in 2000.

For case I serving Elgin township only, the unit cost is higher to this township than for either case II or III. Economy of scale is a more significant factor than transport distance or storage volume in the cost of water.

For case II supplying water to townships 19, 22, and 31 in 1980 and all six townships in 2000, the costs to each township are lower than for case III which excludes Aurora (township 31). Distance affects the cost to each township as treatment and storage are common for the entire system. The costs to townships 25 and 28 are high in case III because of the small quantity of water required, but do not appreciably affect the average cost. In case II, though township 31 has a large water demand, the location at the far end of the pipeline keeps the average cost from being reduced.

In 1980 the unit cost of water to a township ranges from 23.8¢/1000 gallons for township 16 (case II B) to 67.6¢/1000 gallons for township 31 (case II A). In 2000 the range of unit costs is from 17.8¢/1000 gallons for township 16 (case II B) to 53.7¢/1000 gallons for township 28 (case III A).

Areas of Uncertainty

Raw water quality, reservoir cost, and cost of water from alternative sources are major factors to be considered in deciding on use of Fox River water for municipal water supply.

Water quality in the Fox River is a problem because of the sewage effluents discharged to the river. Within Illinois the amount of effluent discharged to the Fox above Algonquin is relatively small. Approximately one half of the 50 cfs increase in the 7-day 10-year low flow between Algonquin and Aurora is due to sewage effluents. The intake structure should be located above the point at which the drain from Crystal Lake enters the Fox River.

The biological quality as indicated by a typical coliform count of 6000 per 100 ml is not good at Algonquin. Special treatment may be required to assure safe treated water. Much higher coliform densities have been obtained at times. The variability of water quality can require special care in process control of special processes to assure uniform quality in the finished water. The storage reservoir required for water supply during periods of low streamflow may have an effect (unknown) on quality of the stored water.

Because of the uncertain quality of the raw water, the treatment costs could be significantly higher than those obtained. Since treatment costs amount to nearly two-thirds of the total cost, increased treatment requirements will result in substantial increases in the total cost of water.

The cost of reservoirs is another uncertainty. Land costs are a large part of the reservoir cost in a developed area and could easily be significantly different from the $5000 per acre figure used. Relocations of roads, utilities, and houses are important factors in reservoir location. There are a few buildings and two black top roads within the largest site.

The geology is also important, and the location and extent of sand or gravel deposits can affect the cost of the structure or can make a site not feasible because of excessive leakage. If an off-channel reservoir is built by excavation and diking, the construction costs could be much higher. There are locations that appear suitable on the topographic maps, but the geology can affect the economics of a site. Since storage costs are no more than 18 percent of the average cost, doubling storage costs increases the total cost by less than 20 percent.

Several alternate or combination plans for meeting the projected water supply needs in the Fox River Valley are possible. Of the two choices considered, meeting the deficiencies under the no-mining concept may be more economical than meeting the total demands with river water. Some combination of surface water and groundwater supply is reasonable, but the most economical scheme must be determined by detailed analysis. For instance, river water could be used when available in sufficient quantity and groundwater could be used during periods of low streamflow. The cases in which only the deficiencies were met assume continued development of shallow aquifers. In 1970 pumpage from shallow aquifers was 25 percent of the total pumpage in Kane County.

In case III, Aurora might find Kankakee River water obtained from the Joliet area public water commission to be an alternate source of water. Economic or water quality considerations may make water purchased from Chicago a feasible supply. Importing groundwater, particularly from shallow aquifers, may be practical for some of the area, e.g., Algonquin to Elgin.

Use of the Fox River as a public water supply appears technically feasible and economically reasonable on preliminary investigation. Questions of treatment and storage costs, finished water quality, various alternate sources, and combined or conjunctive use of several sources need to be resolved before proceeding past this preliminary study stage.

Black and Veatch (1975) recommended the development of 16 mgd daily maximum flow rate water supply from the Fox River to satisfy two-thirds of the 1995 demand for the city of Elgin. Two alternate systems were investigated and were found to be more expensive. Their proposed project costs cannot be compared with the cost figures in this study, because Black and Veatch include distribution system improvements and total water system operations in their cost estimates.

Transfer of Groundwater from Shallow Aquifers

Will, Lake, and McHenry Counties are used as examples for estimating costs of transfer of surplus shallow groundwater. Groundwater from the shallow aquifers is readily available in these counties for transfer to townships with projected water supply deficiencies under the groundwater no-mining approach.

Will County

There is sufficient shallow groundwater available in Will County to meet projected deficiencies in Will County and in the two southern townships in Cook County. Costs of this source were compared with costs of systems using Kankakee River water or water purchased from the city of Chicago.

Assumptions used in determining the costs are:

1) The transmission lines are of minimum length from the center of the source township to the center of the deficient township.
2) Elevations used are average values for each township.
3) Water transport costs are estimated with information from Singh (1971) and adjusted to 1974 dollars.
4) Well capacity and depth are those used by Moench and Visocky (1971). In townships where well capacities are less than 250 gpm (3 wells per mgd) the shallow groundwater is assumed to be developed only for local use. Raw water costs are based on those given by Moench and Visocky (1971), adjusted to 1974 dollars.
5) Treatment costs were estimated from Moench and Visocky (1971) and adjusted to 1974 dollars. Treatment of shallow groundwater takes place in the deficient township to benefit from economy of scale.

The water supply deficiencies for 1980 and 2000 in Will County are given in figure 43. Also given is shallow groundwater surplus in 2000 for townships which meet the requirement on capacity of individual wells. Deficiencies total 4.8 mgd in 1980 and 18.9 mgd in 2000 while the surplus in 2000 is 34.2 mgd.

Although well yields in township 84 are only about 175 gpm, not meeting criterion 4, township 84 could be considered a future source for townships 83, 85, or 88.

In 1980 the deficient area is in the Joliet vicinity (townships 85, 88, and 89). Township 85 could obtain water from township 84, 86, or 93. Township 89 could obtain

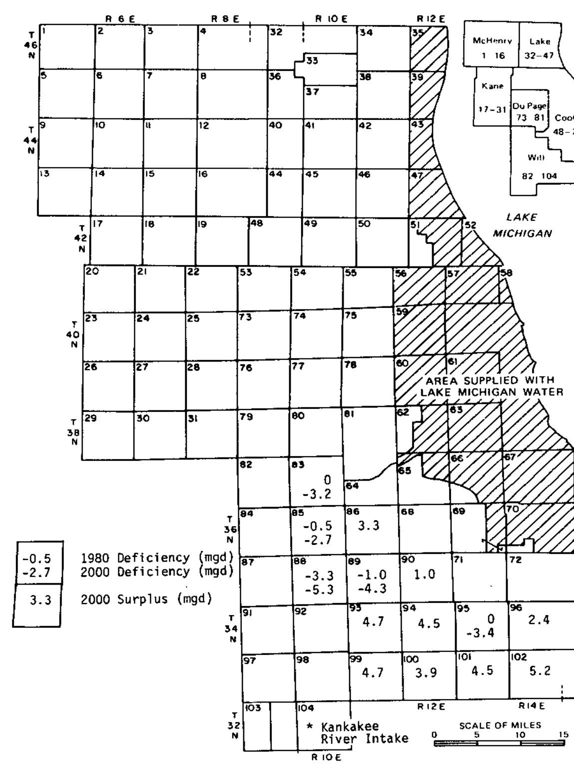

Figure 43. Townships with water supply deficiencies or surplus shallow groundwater in Will County

Table 45. Surplus Townships Assigned to Supply Deficient Townships

Deficient township	*Deficiency (mgd)*	*Source township*
1980		
85	0.5	93
88	3.3	93
89	1.0	94
2000		
83	3.2	86
85	2.7	93
88	5.3	93,99*
89	4.3	94
95	3.4	101

*2.0 mgd from township 93;
3.3 mgd from township 99

water from 90, 93, or 94. Township 88 could obtain water from 93, 94, or 99. Future needs must be considered because longer distances and multiple sources will be required to satisfy the deficiencies in 2000. No single source township can meet the deficiency in township 88 in 2000.

Surplus townships were assigned to supply deficient townships as listed in table 45. Additional source townships will be required after 2000 if demand increases at the rate indicated for the 1980 to 2000 period.

Combined transmission lines are feasible by 2000, at least for townships 85, 88, and 89, but have little or no cost benefit and will not be discussed in conjunction with groundwater.

Costs with the plan for importing water from the shallow dolomite aquifer were compared with those for using the Kankakee River and Lake Michigan water imported from the city of Chicago.

Costs for the Kankakee River alternative given previously (table 36) had to be revised to provide cost estimates which are comparable with the township costs. For direct comparison, the cost of water from the Kankakee River includes treatment near the source, transport direct from the source location shown in figure 43 to the center of township 88 with further transmission lines from township 88 to townships 83, 85, and 89, and a separate transmission line from the river to township 95.

Costs of the several schemes for 1980 are shown in figure 44 and table 46. Figure 44 gives the costs for importing Lake Michigan water purchased from Chicago, Kankakee River water, and shallow dolomite water from nearby townships. In 1980 the shallow groundwater is least expensive. In township 88, Chicago water will cost 54 percent more than shallow groundwater. Table 46 gives treatment costs and transport costs as well as total costs. Treatment costs are at least 58 percent of the total cost for Kankakee River water. This high treatment cost is caused by provision for future capacity requirements. For individual townships, economy of scale and distance from source have the greatest

Table 46. Will County Water Supply Deficits, 1980 and 2000

(Costs in ¢/1000 gallons)

	Townships				
	83	*85*	*88*	*89*	*95*
1980					
Deficit, mgd	0	0.5	3.3	1.0	0
Demand, mgd	6.3	7.2	15.5	6.5	3.8
Treatment cost		33.7	25.2	35.9	
Raw water cost, source		4.3	4.4	4.0	
Transport cost		40.3	8.9	18.2	
Shallow dolomite water cost		78.3	38.5	58.1	
Water from Chicago		81.0	59.1	71.4	
Kankakee River water*		87.1	67.5	83.8	
2000					
Deficit, mgd	3.2	2.7	5.3	4.3	3.4
Demand, mgd	9.6	9.4	17.5	9.8	8.2
Treatment cost	29.2	29.4	23.7	29.0	30.8
Raw water cost, source	4.3	4.3	4.4	4.0	3.9
Transport cost	10.1	16.8	14.3	8.6	8.0
Shallow dolomite water cost	43.6	50.5	42.4	41.6	42.7
Water from Chicago	53.9	56.1	54.6	54.4	52.5
Kankakee River water**	48.9	39.2	33.4	42.1	54.1

*Includes treatment cost of 50.3¢/1000 gallons and provision for expansion to meet deficits in 2000 in all 5 townships
**Includes treatment cost of 23.1¢/1000 gallons

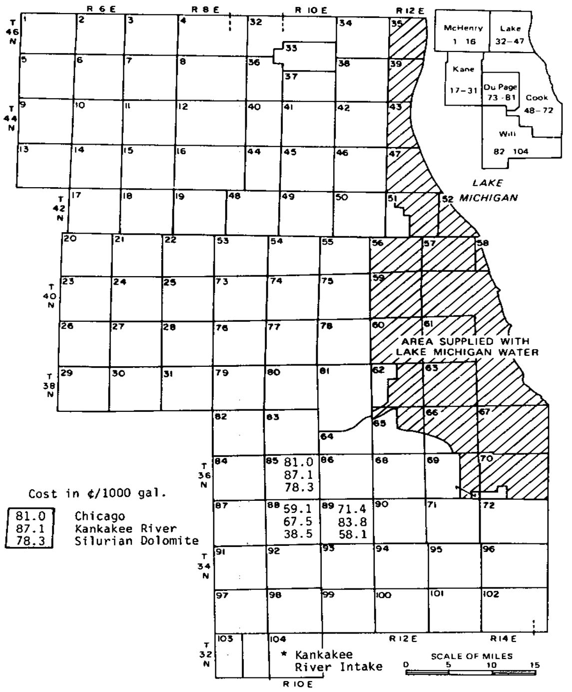

Figure 44. Cost of meeting water supply deficiencies in Will County in 1980

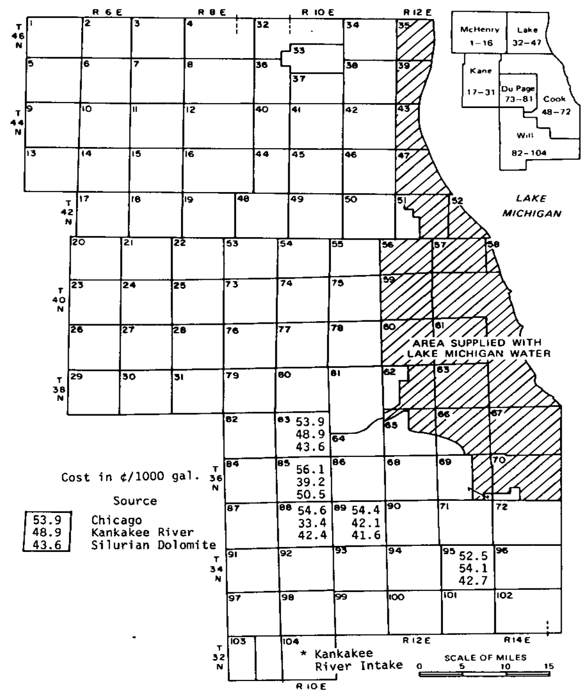

Figure 45. Cost of meeting water supply deficiencies in 2000

effect on the unit cost of supplying water to satisfy the projected demand.

Table 46 and figure 45 give cost figures for meeting the deficiencies in 2000. Purchasing water from Chicago is most costly for all townships except 95. For townships 83 and 95, which did not have deficiencies in 1980, imported groundwater from the shallow dolomite aquifer is least costly. Kankakee River water is clearly least costly in townships 85 and 88. In township 89, groundwater and Kankakee River water are essentially equal in cost.

A scheme using Kankakee River water for townships 85, 88, and 89 and groundwater for townships 83 and 95 can result in a further reduction in average cost.

Each scheme for meeting projected water supply deficiencies has unique features that make comparison difficult. The groundwater systems rely on treatment at the deficient township to benefit from economy of scale. Because the total demand increases less than the deficiencies, provision for future capacity has less effect on 1980 treatment costs for the groundwater than for Kankakee River water. The single treatment plant for the Kankakee River system has a lower treatment cost in 2000, but is increased substantially in 1980 by provision for expansion.

Transport costs are directly affected by the distance from the source to the use area. Because straight line distances were used here, actual system design will probably increase pipeline lengths. Changed relations between transport distances can change the cost comparison in a detailed analysis.

The cost estimates in the section on using Kankakee River water illustrate the variations between several different estimates, all based on transmission lines different from those in this section.

Water supply deficiencies for Will County can be met at reasonable cost by transfer of groundwater from the shallow aquifers. An intensive test drilling program is required to locate high capacity wells. Regional planning and implementing are required for orderly, least cost development in the entire region. Other sources of imported water, particularly the Kankakee River, also provide feasible alternatives.

Lake and McHenry Counties

Lake and McHenry Counties by 2000 have six townships with projected water supply deficiencies under the groundwater no-mining approach. Surplus groundwater from the shallow aquifers is available in these two counties. Assumptions and methods used to estimate the costs of meeting deficiencies by transfer of shallow groundwater are the same as those used in the Will County study of groundwater transfer.

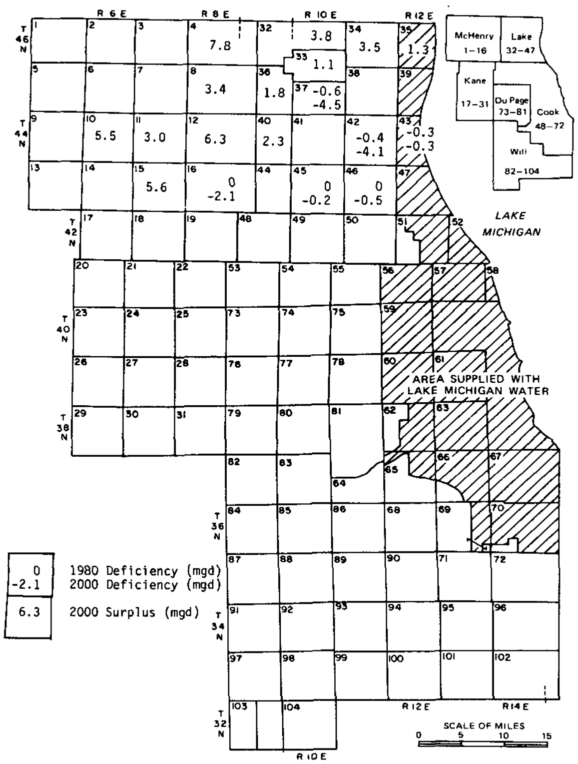

Figure 46. Townships with water supply deficiencies or surplus shallow groundwater in McHenry and Lake Counties

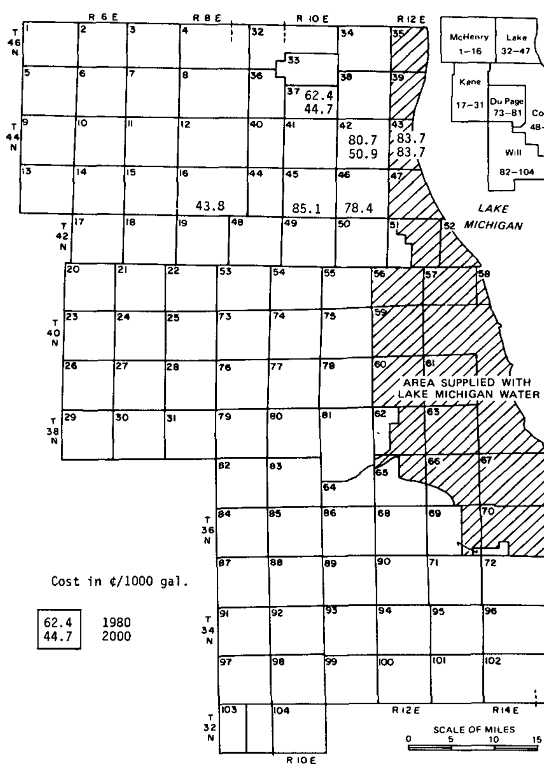

Figure 47. Cost of meeting water supply deficiencies with imported shallow groundwater in Lake and McHenry Counties for 1980 and 2000

The water supply deficiencies for 1980 and 2000 are shown in figure 46. Also shown is shallow groundwater surplus in 2000 for townships which meet the requirement of minimum well yields of 250 gpm. Most of the surplus water is in the shallow dolomite aquifer though some water is available in the sand and gravel aquifers. Because well and pumping costs are similar in most townships, the source of transferred groundwater is not identified. If there is a substantial difference, the higher cost water is assumed to be transferred. Deficiencies total 1.3 mgd in 1980 and 11.7 mgd in 2000 while the surplus in 2000 is 45.4 mgd.

Selection of supply townships in 1980 depends on conditions expected in 2000. By 2000 townships 37 and 42 will need to import water from two source townships. Surplus townships were assigned to supply deficient townships as listed in table 47. Transmission lines are direct from the center of a source township to the center of the deficient township. The opportunity for combined transmission lines exists for township 37 in 2000 and for townships 45 and 56 in 2000. Because of uncertainty about the exact alignment of transmission lines, the combined pipelines are not located.

The total costs of meeting water supply deficiencies in 1980 and 2000 are shown in figure 47. The cost of raw

Table 47. Deficient and Source Townships in Lake and McHenry Counties

Deficient township	*Deficiency (mgd)*		*Source township*
1980			
37	0.6		33
42	0.4		40
43.	0.3		35
2000			
16	2.1		12
37	4.5	1.1 mgd	33
		3.4 mgd	32
42	4.1	1.6 mgd	40
		2.5 mgd	34
43	0.3		35
45	0.2		40
46	0.5		40

water at the source township is generally less than 10 percent of the total cost. In 1980 total costs range from 62.4 to 80.7¢/1000 gallons. Treatment costs range from 48 to 76 percent of the total cost. Transport costs in 1980 range from 19 to 47 percent of the total. In 2000 total costs range from 43.8 to 85.1¢/1000 gallons. In 2000 treatment costs range from 44 to 71 percent of the total while transport costs range from 19 to 52 percent of the total.

All costs are based on generalized functions and are subject to modification in specific design situations. Water supply deficiencies projected for Lake and McHenry Counties can be met at reasonable cost by transfer of groundwater from the shallow aquifers. Costs of Lake Michigan water purchased from Chicago, as was shown in figure 38, indicate that in townships closest to the city of Chicago, lake water is more economical. Cost of lake water purchased from Lake County systems is not known.

Transfer of Groundwater from the Deep Sandstone Aquifer

Under the groundwater mining concept, pumping water levels become critical in some townships. This results in reduced water availability from the deep sandstone and a deficiency in water supply in the affected townships. However, substantial volumes of water remain in storage in the deep sandstone in nearby townships (called source townships) and can be mined at accelerated rates to meet the water supply demands in the deficient townships. This will increase the rate of water level decline in the townships used as sources. Any township which is predicted to become critical cannot be used as a source.

The capital costs of transmission lines and wells require a reasonably long useful life. Thus, source townships that can be mined for a period greater than 20 years should be chosen. In addition source townships should be chosen so that accelerated mining will have only very minor effects on water levels in deficient townships.

The cost of importing deep sandstone water has been investigated by Beaver (1974). He used the water supply deficiencies projected by Moench and Visocky (1971), the digital computer model of the deep sandstone aquifer (Prickett and Lonnquist, 1971), and pipeline transport cost data by Singh (1971) to determine the cost of meeting the projected deficiencies. Because of the revised deficiency projections given in this report, Beaver's results cannot be applied directly. However, the import of deep sandstone water increased the cost of raw water 35 to 45 percent. Applying the 45 percent increase to the combined raw water costs in tables 30–33 for the nine townships deficient in 2000 (figure 22) increases costs between 3.5 and 6.0¢/1000 gallons. With treatment at the deficient township for maximum economy of scale, this is a 10 to 15 percent increase in the cost of water to these townships in 2000.

The cost of importing water is directly proportional to the distance from source to deficient township, so the current model prediction of nine instead of two deficient townships in 2000 as predicted by Beaver probably means longer transport distances and thus higher percentage increases in water costs for using imported deep sandstone

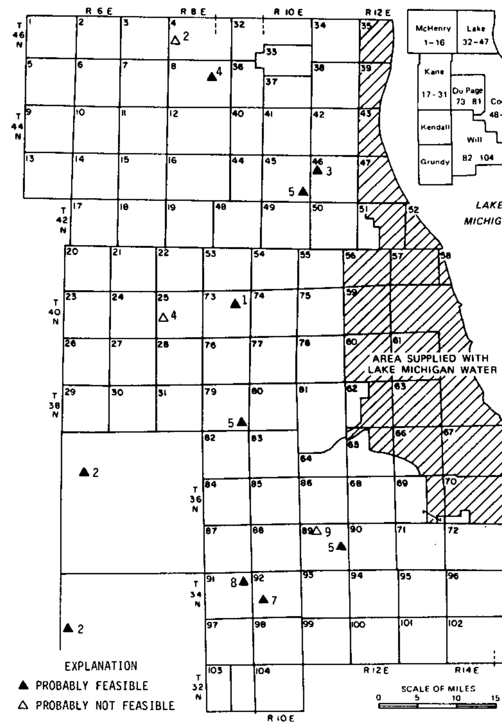

Figure 48. Potential reservoir sites in northeast Illinois

water. Because of the interrelation of all pumping under the mining concept, further computer studies should be made to determine the effect of redistributed pumpage on water levels and on the time to dewater the aquifer to the top of the Ironton–Galesville sandstone before a particular plan for transfer of deep sandstone water is adopted.

Potential Reservoirs in Northeast Illinois

Reservoir Sites

Potential reservoir sites numbering 115 in all 23 counties of the northern one-fourth of Illinois were described in Dawes and Terstriep (1967). This earlier information has been updated, re-evaluated, and is presented here for eight counties in northeastern Illinois — Cook, Du Page, Grundy, Kane, Kendall, Lake, McHenry, and Will Counties.

Table 48 gives the location, capacity, surface area, drainage area, and other physical facts on 13 potential reservoir sites in northeastern Illinois. In 1974, a field inspection of each of these sites showed 10 sites generally as being physically feasible and 3 sites probably not feasible. The locations of the sites are shown on figure 48.

The net yields available for water supply during a drought having a recurrence interval of 40 years are given in table 48. These yield values assume that the *full capacity* of the reservoir is dedicated to water supply, and that the reservoir is emptied during the drought. Also shown are

Table 48. Potential Reservoir Sites in Northeastern Illinois

County & site number	Location of site	Pool area (acres)	Storage (ac-ft)	Storage (mil gal)	Drainage area (sq mi)	Net yield (mgd) during 40-yr drought: Full capacity	Net yield (mgd) during 40-yr drought: Half capacity	Construction cost ($ mil)	Land cost ($ per ac)	Land cost ($ mil)	1974 total cost ($ mil)
	Feasible sites, map symbol ▲										
Cook	none										
Du Page											
1	W. Br. Du Page River SE ¼ SE ¼ 10 T40N, R9E	850	8500	2700	19.2	5.2	2.4	2.5	4290	5.5	8.0
5	Spring Brook NE ¼ SW ¼ 36 T38N, R9E	415	3570	1163	9.3	2.8	1.4	1.5	4290	2.6	4.1
Grundy											
2	Long Point Creek SE ¼ SE ¼ 7 T33N, R6E	210	3500	1140	9.0	2.6	1.6	1.5	1085	0.6	2.1
Kendall											
2	Little Rock Creek SE ¼ 33 T37N, R6E	345	5750	1874	34.0	8.1	5.6	2.0	1340	1.2	3.2
Lake											
3	Indian Creek SE ¼ 7 T43N, R11E	470	4385	1429	18.6	3.0	1.2	1.7	3310	2.4	4.1
5	Buffalo Creek S ¼ NE ¼ 25 T43N, R10E	560	5970	1945	7.4	2.3	1.4	2.0	3310	3.1	5.1
McHenry											
4	Trib. Fox River SE ¼, NE ¼ 14 T45N, R8E	125	1412	460	4.4	1.7	1.4	0.9	1555	0.4	1.3
Will											
5	Hickory Creek SW ¼ SE ¼ 13 T35N, R11E	580	5025	1637	40.0	9.9	6.1	1.9	1540	1.2	3.1
7	Jackson Creek SW ¼ SE ¼ 17 T34N, R10E	255	2040	665	44.7	6.8	4.4	1.1	1540	0.6	1.7
8	Cedar Creek SW ¼ SW ¼ 1 T34N, R9E	145	2115	689	13.1	3.5	2.5	1.2	1540	0.6	1.8
Totals for 10 feasible reservoirs							28.0				34.5
	Sites probably not feasible, due to leakage, map symbol △										
Kane											
4	Ferson Creek NE ¼ NE ¼ 19 T40N, R8E	1229	14748	4805	47.0	10.6	5.6	3.3	1810	3.8	7.1
McHenry											
2	Nippersink Creek SW ¼ NW ¼ 18 T46N, R7E	1280	8960	1919	21.6	8.5	7.3	2.5	1555	2.1	4.6
Will											
9	Spring Creek E ½ NE ¼ 5 T35N, R11E	627	7524	2452	14.0	5.5	4.2	2.3	1540	1.8	4.1

net yields for the same recurrence interval assuming that only *half of the capacity* of the reservoir is used for water supply, and the reservoir is only half emptied during a drought. This means that fish life can survive, and recreational use of the reservoir can continue during the drought. All reservoir yields were calculated with methods described by Stall (1964).

For the 10 reservoirs considered feasible, the net yield during a 40-year drought, using half of the reservoirs, is 28 mgd. This can be considered a reasonable evaluation of this total resource.

General Conditions

These counties have a limited number of sites because of limited topographic relief, and a few have geologic conditions that indicate leakage and stability problems or insufficient impervious material available for constructing an earth dam. Rainfall in the area averages 32 to 34 inches; runoff varies from 8 to 9 inches, or about 25 percent of the annual rainfall. All of the area is heavily populated with numerous man-made obstructions which make reservoir construction difficult. High land values make reservoir construction expensive.

A considerable concern with surface water reservoir construction in this area is that pollution will occur, and that sediment and debris will accumulate in a reservoir. It is questionable whether low-capacity surface water reservoirs of the type which can be built in northeastern Illinois can provide a safe, dependable, and easily treatable water supply.

In this part of Illinois the drainage system has been encroached upon and overloaded to the point that major flooding occurs often. Building a surface water reservoir in such a drainage system would not in itself increase the flooding, but would make adequate reservoir design difficult in order to pass the flood flow.

Reservoir Construction Cost

Table 48 shows the estimated 1974 construction costs for each of the 13 potential reservoirs. The basic approach to development of these costs, and the various elements of cost in reservoir construction were described by Dawes and Wathne (1968). Their equation was:

$$P_c = C_1 C + C_2 L_a k$$

where

P_c = total project cost in 1964 dollars

C_1 = 1.25, a combined constant accounting for engineering and legal services (15 percent of C) plus contingencies (10 percent of C)

$C = 4287\ S^{0.54}$, the construction cost (S = storage capacity in acre-feet)

C_2 = 1.50, total required land area, 50 percent more area than needed for normal surface area of pool

$L_a = 0.23\ S^{0.87}$ the required lake area

k = land cost expressed in dollars per acre

This equation was based on data for reservoirs constructed in Illinois between 1946 and 1964 that were collected from consulting engineers, private and municipal water utilities, and state and federal agencies. The project cost used is the sum of the cost of construction, engineering and legal services, contingencies, and land. The term 'construction cost' in the analysis encompasses costs of land clearing, dam and spillway construction, and relocations. Engineering and legal services were added as a fixed 15 percent of construction cost. Contingencies were added as 10 percent of the construction cost. The amount of land required for a project was determined to be 50 percent more than the actual normal surface area of the pool. Construction costs and land costs were adjusted to 1974 dollars by use of the Handy-Whitman Index.

Unit Costs of Water

Costs of treated water at each of the 10 feasible reservoir sites were computed to provide a basis for comparing water from reservoirs with other possible sources of water supply. The reservoir costs are assumed to be amortized over 50 years at 8 percent interest. The capital recovery factor for this time and interest rate is 0.08174. Multiplying the project cost by this factor yields an annual cost which is then divided by the volume of water used in a year to obtain a unit cost in ¢/1000 gallons. The net yield at half capacity during a 40-year drought is assumed to be the amount of water available. This is the unit cost of raw water at the site and is given in table 49.

Annual treatment costs are obtained in 1974 dollars by an updated version of the relations in Moench and Visocky (1971). The equation, with no provision for future demand, is:

$$C_T = 99.1(Q/2)^{0.625} + 266.6(Q/2)^{0.666}$$

where

C_T = annual cost of treatment, in thousands of dollars

Q = mean daily demand, in mgd

No provision for future demand is made because the development of a reservoir for water supply is assumed to be at design capacity.

Costs of treatment and total costs are also presented in table 49. Water supply from these reservoirs is rather costly. Raw water costs range from 8.7¢/1000 gallons at Will County site 7 to 81.6¢/1000 gallons at Lake County site 5. Treatment costs for the supply quantities obtainable from these reservoirs range from 34.1 at Will County site 5 to 59.8¢/1000 gallons at Lake County site 3. Total costs of treated water vary from 45.5¢/1000 gallons at Will County site 5 to 138.3¢/1000 gallons at Lake County site 5.

Table 49. Unit Costs of Water from Potential Reservoir Sites

County & site number	*Net yield (mgd) half capacity 40-year drought*	*Raw water cost (¢/1000 gal)*	*Treatment cost (¢/1000 gal)*	*Total cost (¢/1000 gal)*
Du Page				
1	2.4	74.7	47.0	121.7
5	1.4	65.6	56.7	122.3
Grundy				
2	1.6	29.4	54.1	83.5
Kendall				
2	2.0	35.8	50.1	85.9
Lake				
3	1.2	76.5	59.8	136.3
5	1.4	81.6	56.7	138.3
McHenry				
4	1.4	20.8	56.7	77.5
Will				
5	6.1	11.4	34.1	45.5
7	4.4	8.7	38.2	46.9
8	2.5	16.1	46.4	62.5

Desalting Brackish Water from the Mt. Simon Aquifer

A report describing the feasibility of developing and desalting large quantities of brackish water stored in the very deep Mt. Simon sandstone as an alternative to aid in meeting projected water deficits for the Chicago region was published in 1973. The report, *Feasibility Study on Desalting Brackish Water from the Mt. Simon Aquifer in Northeastern Illinois,* was prepared by the Water Survey and Hittman Associates, Columbia, Maryland, and was funded in part by the Department of the Interior, Office of Saline Water. Hittman Associates, under subcontract to the Water Survey, carried out the feasibility study of the technical and economic aspects related to the desalting of the brackish water. The report is summarized here.

The Mt. Simon aquifer is found at depths of 1500 to 1900 feet below ground surface and consists of fine- to coarse-grained sandstone. Many wells penetrate the upper 200 to 300 feet of the aquifer which generally contains potable water in the northern two-thirds of northeastern Illinois. It was estimated in 1971 that of the 151 mgd pumped from deep wells, 26 mgd was contributed by the Mt. Simon. Deteriorating mineral quality has been reported in many of these wells. Below the 200 to 300 foot level, the total dissolved minerals increase gradually with depth to almost 90,000 mg/l at the bottom of the aquifer. Chlorides increase to about 50,000 mg/l. The mineral quality varies with location as well as depth.

Groundwater in the aquifer occurs under artesian conditions. Hydrostatic heads in the Mt. Simon are reported to be more than 50 feet higher than heads in the overlying Cambrian-Ordovician aquifer. Groundwater movement is downdip from the recharge area in southeastern Wisconsin southward. On the basis of available core analyses and well tests, the average transmissivity and storage coefficient were estimated to be 10,000 gpd/sq ft and 0.0004 respectively. The ratio of vertical to horizontal permeability is 0.5.

The yields of wells and the mineral quality of water withdrawn from wells are dependent primarily upon aquifer hydraulic properties and water quality-depth relationships. The Mt. Simon aquifer was modeled from existing data so that the hydraulic properties and the quality-depth profile could be determined for any given well field location. The flow in the Mt. Simon model was simulated by digital computer analysis to enable predictions of water quality and well field yields. A separate computer program was written to predict pH values.

Analyses made indicated that the mineral concentration of water withdrawn from the Mt. Simon wells increases rapidly at first and then at gradually slower rates similar to drawdowns within a pumped well. The ultimate mineral concentration of the water withdrawn will depend not only on the well location but its depth of penetration. In a multiple-well system the ultimate concentration would also depend upon spacing and total pumpage.

Desalting plants with capacities of 1, 5, and 10 mgd were selected for study. The eastern part of Du Page County, an area of projected water deficiency, was selected as a site for the desalting plants. To aid in plant design, predictions of water quality of the Mt. Simon feedwater for different well field schemes were made by computer analysis. The important characteristics of the feedwater are its high hardness, high concentration of iron, and large amount of total dissolved minerals. For example, water from a well penetrating 50 percent of the Mt. Simon contains 40,000 mg/l TDM, exceeding seawater which has 35,000 mg/l TDM.

Five different desalting processes were considered: ion exchange, electrodialysis, reverse osmosis, distillation, and freezing. The number of wells, each pumping at a rate of 1 mgd, needed to ultimately supply the desalting plants varied from 3 wells (including standby) to supply a 1 mgd plant to 54 wells (including standbys) to supply a 10 mgd plant. Well penetrations into the aquifer were 20, 31, and 50 percent. Well fields were from 4 to 7 miles from the desalting plants.

The ion exchange process was rejected because the high salinity water incurs a very high chemical cost. The electrodialysis process was rejected because the cost for electric power was prohibitive. The reverse osmosis process was applied only for 1 mgd plants with feedwater from wells with 20 to 50 percent aquifer penetration.

From evaluation of several methods, brine disposal by injection through wells open to the lower Mt. Simon aquifer was selected. Depending upon the size of desalting plant and the desalting process, from 2 to 42 wells (including standbys) were required for disposal. Injection sites were at distances of less than 1 mile to 4 miles from desalting plants.

Costs of producing water for the 1 mgd reverse osmosis plants ranged from 132.9¢/1000 gallons for water from wells with 50 percent aquifer penetration to 136.4¢/1000 gallons for 20 percent penetrating wells. Costs of producing water for the 1 mgd freezing plants ranged from 138.6¢/1000 gallons for water from wells with 50 percent penetration to 142.1¢/1000 gallons for water from wells with 20 percent penetration. Costs of producing water for the 5 mgd distillation plants averaged 184.6¢/1000 gallons. Costs of desalting water by the freezing process for the 5 and 10 mgd plants were not estimated since the freezing process is still under development and it is difficult to estimate costs for plants larger than 1 mgd.

The costs of desalting water are much higher than those for other water supply alternatives but become more competitive when used *in conjunction* with the available fresh groundwater. The cost to one area in the region was estimated to be 74¢/1000 gallons for a 15 mgd combined supply, in which 11 mgd was available from conventional groundwater sources and 4 mgd was supplied from a desalting plant.

Although there are tremendous quantities of water stored in the Mt. Simon aquifer, problems expected in desalting and brine disposal limit the use of the resource.

The difficulties in desalting the Mt. Simon aquifer water are:

1) The feedwater salinity will change greatly during the 30-year operation and thus the water flow rate and concentration ratio will vary accordingly. The design and operation of a desalting plant with such large variations will pose some challenging problems.
2) The high content of Ca^{+5} and SO_4^{-2} increases the scale-forming tendency and thus puts limitations on the recovery ratio.
3) The high Fe^{+3} and Mn^{+2} concentrations require special procedures to prevent the formation of precipitates.

Because of all the difficulties expected, a bench scale or pilot plant study would be necessary to obtain data to be used as a guideline for the construction of future plants.

Disposing of the large quantities of brine by injection may have a harmful effect on the quality of water being withdrawn from existing wells open to both the Cambrian-Ordovician and Mt. Simon aquifers. Any injection scheme should be approached with extreme caution.

Costs of producing water adjusted to 1974 dollars are probably 1.25 to 1.5 greater than the costs previously given. Cost ranges adjusted to 1974 dollars are as follows:

(Costs in ¢/1000 gallons)

	1 mgd reverse osmosis plant	*1 mgd freezing plant*	*5 mgd distillation plant*
50 percent penetrating wells	166 to 199	173 to 208	231 to 277
20 percent penetrating wells	171 to 205	178 to 213	

Artificial Recharge of the Deep Sandstone Aquifer

Artificial recharge is receiving strong consideration as a remedial measure for water supply deficiencies in the Chicago region. The deep sandstone aquifer has been considered as one of the better opportunities for artificial recharge. There are advantages in recharging the deep sandstone aquifer. The aquifer is uniform in permeability and thickness throughout the region so artificial recharge installations can be located to serve specific areas. Continued withdrawals from the aquifer will create considerable storage volume.

Since the deep sandstone aquifer is deeply buried, it will be necessary to recharge the aquifer through wells. One source of recharge water suggested is effluent that meets drinking water quality standards from tertiary treatment plants. According to Jones and Heil (1967) one of the potential markets for the effluent is for artificial recharge.

Because clogging of recharge injection wells has been reported by many investigators, the Water Survey conducted laboratory studies to determine some of the problems that may arise from recharging sewage effluent into the deep sandstone aquifer. A laboratory study in which sewage effluent from a secondary treatment plant was treated and recharged through formation cores of the deep sandstone aquifer was recently completed (Schicht and Risk, 1974). The study concluded that it may be feasible to inject treated effluent into the deep sandstone aquifer at realistic rates (500 to 1000 gpm) with a very high quality effluent.

The best results were obtained with an effluent having concentrations of total suspended solids less than 1 mg/l. Frequent well rehabilitation by pumping or surging or other means would be necessary to maintain injection capacity. Chlorination and pH modification of the effluent would be required.

One problem with using tertiary treated effluent as recharge water is that it may involve direct use of the treated wastewater. The Eminence Potosi dolomite, one of the more productive formations in the deep sandstone aquifer, is sufficiently creviced that wastewater could migrate to a nearby public water supply production well without further water polishing by the aquifer. Direct use of treated wastewaters for public water supply is not an acceptable practice. It is believed that current technology is not sufficiently advanced to permit direct use of treated wastewater as a source of public water supply.

One source of recharge water that could be considered is treated Lake Michigan water. Water at the western ends of Chicago's four major water supply tunnels, produced during off peak water production periods, could be used for recharge.

Also studied was the effect on piezometric levels in the deep sandstone aquifer of recharging 1000 gpm by a single injection well at each site. The locations of the four major pumping stations at the western ends of the major tunnels relative to the piezometric surface of the deep sandstone in October 1974 are shown in figure 49. The artificial recharge sites are located from 6 to 10 miles east of the deep cones of depression in western Cook County.

To show the general direction of groundwater movement, flow paths (figure 49) were drawn from each recharge site to the center of the appropriate cone of depression. Piezometric profiles along the flow paths after 1 and 5 years of recharging were constructed by adding the resultant head buildup (figure 50) to the estimated 1975 piezometric levels. The resultant piezometric profiles are shown in figures 51-54. The profiles do not include the effects of future water-level declines.

The main initial advantage of recharge will be to reduce pumping lifts. For example, at a distance of 5 miles from the recharge well at the Mayfair pumping station pumping lifts after 1 and 5 years of recharge would be reduced about 33 and 75 feet, respectively. Since the actual groundwater velocity is low, averaging about 0.5 foot per day within a mile of the recharge well and about 0.1 foot per day near the cones of depression, it would be many years before recharge water would reach the centers of the cones of depression.

The 4000 gpm scheme (5.8 mgd) described above is only a small part of the approximately 150 mgd being withdrawn from deep wells. If mining of the deep sandstone aquifer continues, withdrawals from deep wells may be two times greater than present withdrawals by the year 2000. An extensive network of recharge wells would be required to recharge meaningful quantities of water. The cost of a network of injection wells and transmission lines would be sub-

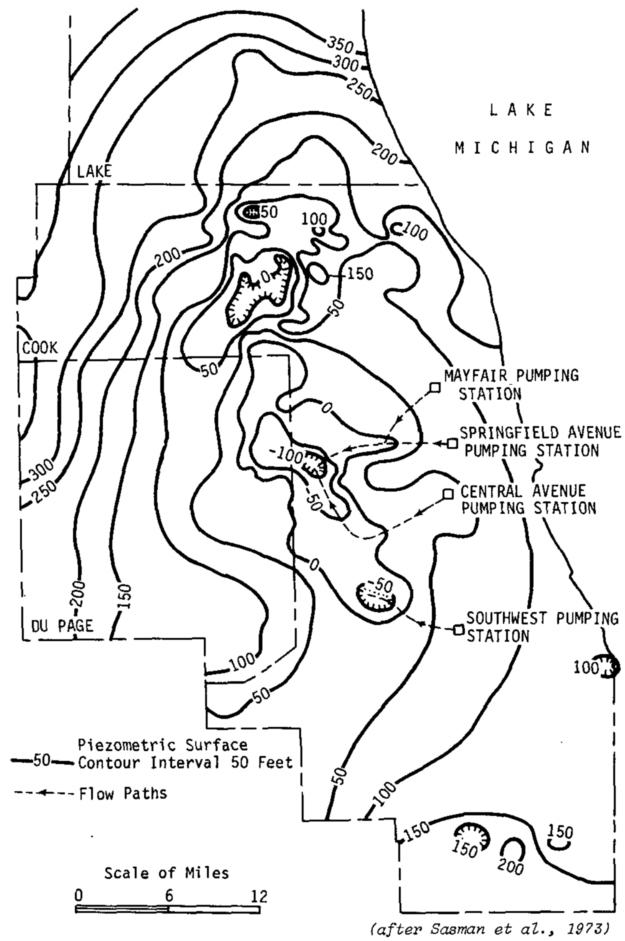

Figure 49. Elevation of piezometric surface of Cambrian-Ordovician aquifer (deep sandstone), October 1971

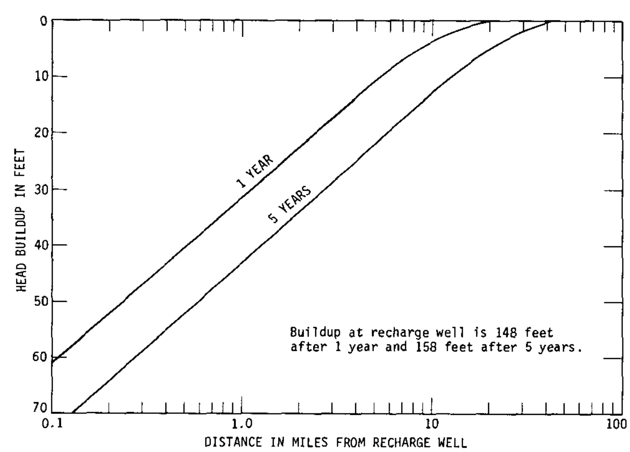

Figure 50. Piezometric head buildup in the deep sandstone aquifer for 1000 gpm recharge rate

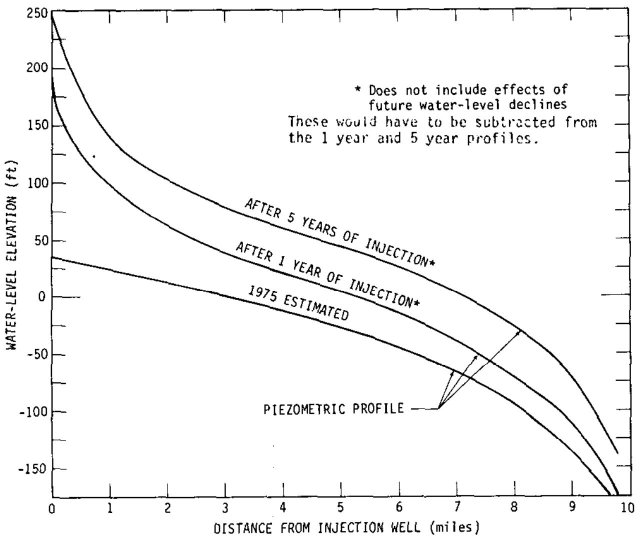

Figure 51. Piezometric profiles, Mayfair pumping station

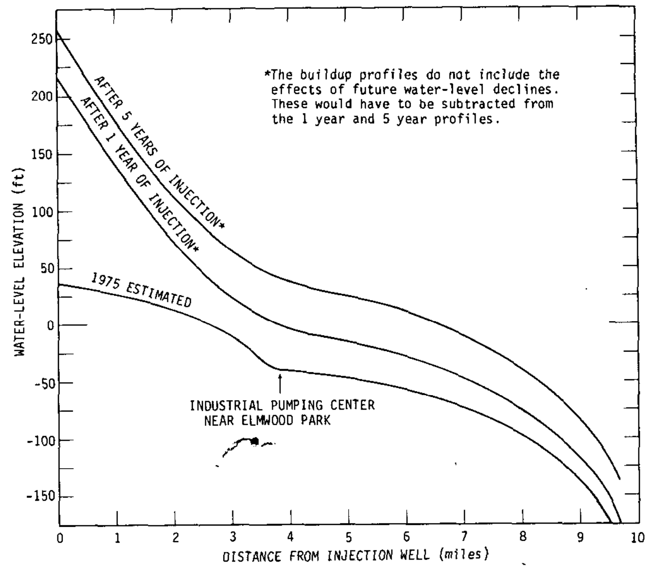

Figure 52. Piezometric profiles, Springfield Avenue pumping station

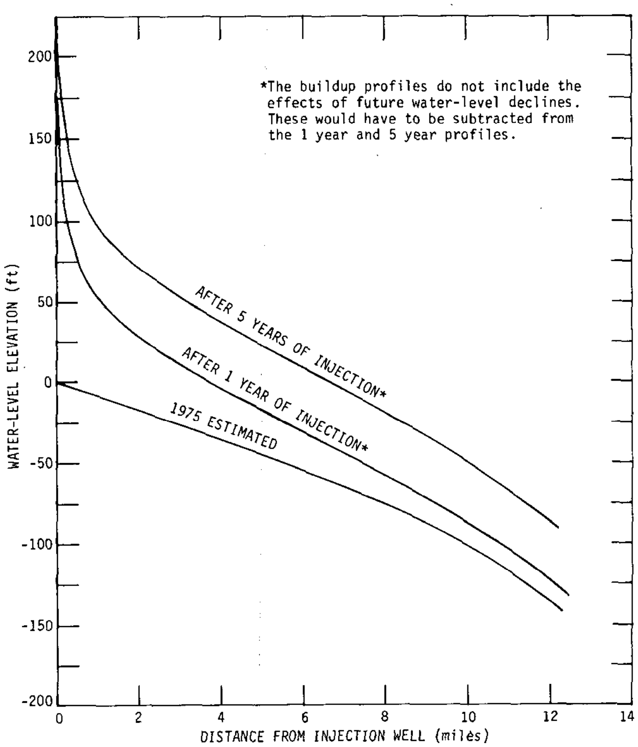

Figure 53. Piezometric profiles, Central Park Avenue pumping station

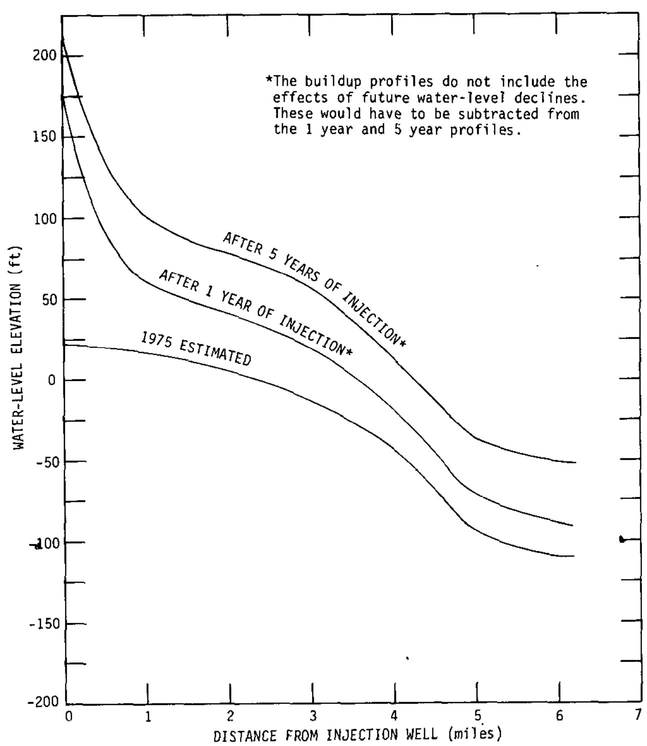

Figure 54. Piezometric profiles, Southwest pumping station

stantial. It may be possible to reduce costs by using existing production wells for recharge purposes.

With the present use of allowable lake diversion for sewage dilution and water supply, the quantities of treated lake water available for recharge is small. Increased diversion during periods of high lake levels is a possibility. If the cost of an intensive recharge program was estimated and found to be not prohibitive, the deep sandstone aquifer could be used as a reservoir to store treated lake water diverted from Lake Michigan during periods of high lake levels. Water could then be withdrawn from wells when lake diversion was reduced to its present limits during periods of normal or low lake levels.

In summary, artificial recharge of the deep sandstone aquifer with treated lake water is believed to be technically feasible. A study should be made to estimate the cost of an intensive recharge program. If the estimated cost is reasonable, it is recommended that a pilot project be considered to determine some of the problems that may arise during injection.

Artificial Recharge of the Shallow Aquifers

Recharge into the shallow aquifers (shallow sands and gravels and shallow dolomites) has been discussed by NIPC (1966). The sources of water for artificial recharge considered in that report were high flow in surface streams, water that has been used for cooling, certain industrial wastewaters, and treated domestic sewage. The pit method was considered mainly because of the experience and success with the pit recharge operation at Peoria (Suter and Harmeson, 1960). Areas where the pit method of artificial recharge is potentially favorable were determined for the planning commission report on the basis of data from the State Geological and Water Surveys. These areas were limited to reaches of major streams in the region. It was estimated that a potential of 121 mgd could be recharged.

A study for Park Forest–Chicago Heights by McDonald and Sasman (1967) indicated that artificial recharge to the Silurian dolomite aquifer, the source of water supply in that area, is feasible. They gave main consideration to the pit method of artificial recharge. Pits generally have higher infiltration rates than land flooding operations, require a smaller surface area, and have lower operating costs than other artificial recharge methods.

McDonald and Sasman discussed three principal criteria to develop satisfactory pit recharge installations in northeastern Illinois. First, there must be a well defined cone of depression in the water-level surface of the aquifer under consideration. It is not practical to attempt to recharge an aquifer that is not partially dewatered or to dewater an aquifer solely for recharge purposes.

Second, there must be a surficial sand and gravel deposit in the area, which may be either the aquifer itself or a surficial deposit hydrologically connected to a buried sand and gravel or shallow dolomite aquifer. Surficial deposits are defined as those at least 15 feet thick and within 10 feet of the ground surface. For recharge purposes, at least 15 feet of deposit should be below the bottom of the recharge source stream. Recharge of untreated water directly to bedrock aquifers is not recommended.

The third criterion is that there must be a perennial stream with a minimum average flow of 1 cfs in the immediate vicinity of the aquifer to be recharged, to serve as a recharge source. For streams with a wide range in discharge volume, some method of flow control may make it possible to insure a minimum sustained discharge of at least 1 cfs for an 8-month period per year.

McDonald and Sasman made preliminary investigations to identify nine areas in northeastern Illinois which appeared to satisfy the three criteria necessary for artificial groundwater recharge. These areas are shown in figure 55 and described in table 50.

Artificial Recharge Estimates

The three prime requisites for successful artificial recharge of aquifers are the existence of a suitable geologic environment, an adequate supply of recharge water of suitable quality, and adequate open space. Suitable geologic environments are briefly described as:

1) Permeable sand and gravel deposits present at shallow depths immediately overlying permeable dolomite bedrock. Pumped wells developed in the shallow dolomite to create storage for recharge water. Recharge is effected by spreading basins. The basin size is largely dependent upon vertical permeability of the filter bed and hydraulic gradients that can be developed by pumping.
2) Permeable sand and gravel deposits with sufficient thickness and available drawdown so that large capacity wells can be developed. Recharge is by pits or channels excavated into the sand and gravel. (Pit and channel size would be largely dependent upon permeability and hydraulic gradients that can be developed by pumping.) Where these sand and gravel deposits directly overlie bedrock, artificial recharge may also benefit wells finished in shallow dolomite.

Areas favorable for artificial recharge of the shallow sands and gravels in northeastern Illinois, as shown by Anderson (1960), appear in figure 56. The areas indicated on the map as most favorable, generally favorable, possibly favorable, and unfavorable are described below. They are based on the following required specifications:

- *Aquifer minimum thickness of 20 feet with 15 feet below stream surface*
- *Median grain size of 0.3 mm or medium sand having permeability in excess of 500 gpd/sq ft*

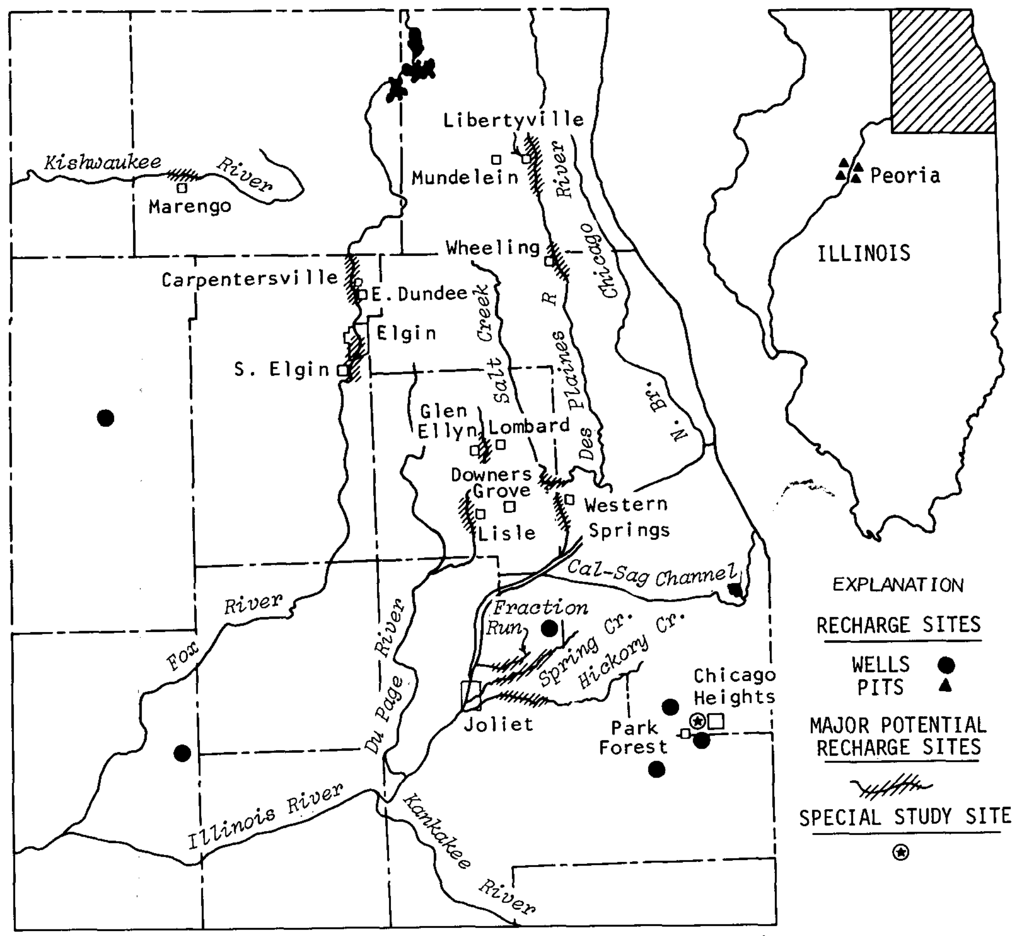

Figure 55. Groundwatar recharge sites in northeastern Illinois

Table 50. Potential Artificial Groundwater Recharge Areas in Northeastern Illinois*

Potential recharge area	*County*	*Recharge source*	*Aquifer*
Joliet–Hadley Valley	Will	Spring and Hickory Creek	Sand and gravel
Libertyville–Mundelein	Lake	Des Plaines River	Sand and gravel; dolomite
Western Springs–Hinsdale	Du Page Cook	Salt Creek	Sand and gravel; dolomite
Glen Ellyn–Lombard	Du Page	East Branch Du Page River	Sand and gravel; dolomite
Wheeling	Cook	Des Plaines River	Sand and gravel; dolomite
East Dundee–Carpentersville	Kane	Fox River	Sand and gravel
Elgin–South Elgin	Kane	Fox River	Sand and gravel
Marengo	McHenry	Kishwaukee River	Sand and gravel
Lisle–Downers Grove	Du Page	East Branch Du Page River	Sand and gravel dolomite

*from McDonald and Sasman, 1967

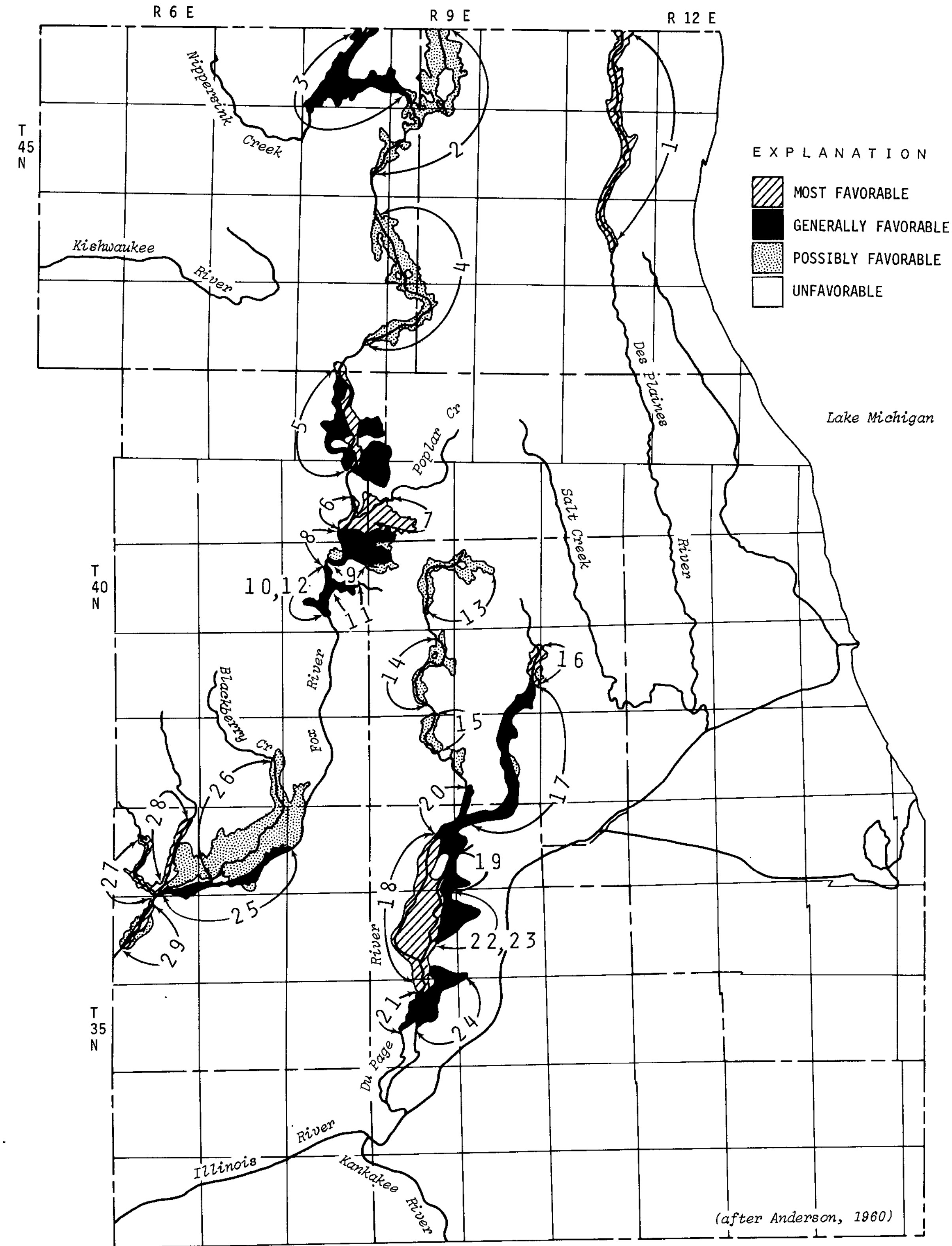

Figure 56. Artificial recharge sites in shallow sand and gravel aquifers along major streams

- *Minimum surface area of 370 acres with 0.25-mile minimum width*

Most Favorable: Areas underlain by sand and gravel deposits meeting the required specifications.

Generally Favorable: Areas underlain by sand and gravel deposits having known local variations in thickness or texture which may restrict or eliminate their consideration in terms of the required specifications.

Possibly Favorable: Areas underlain by sand or gravel deposits whose thickness is largely or entirely unknown, but which otherwise meet the required specifications.

Unfavorable: Areas lacking sand or gravel deposits which meet the required specifications.

Areas along streams were selected because of their proximity to an adequate supply of recharge water. There are other areas in northeastern Illinois that would meet the required specifications for artificial recharge to shallow sand and gravel aquifers but not a known adequate supply of water.

Without information on aquifer hydraulic properties and aquifer areal extent and thickness only rough estimates can be made of potential artificial recharge. Estimates of shallow aquifer recharge potential were made by determining pumping rates that would be required to dewater a reasonable volume of the aquifer for a 6-month period. It was assumed that an adequate supply of surface water would be available for the remaining 6 months to sustain pumpage. The following assumptions were made to determine the artificial recharge potential for the areas shown in figure 55.

1) Aquifer thickness 30 feet
2) Water table conditions
3) Long-term storage coefficient 0.1
4) Saturated aquifer thickness 20 feet
5) During artificial recharge period be able to maintain near saturated aquifer conditions
6) Pump from aquifer storage for 6 months
7) Recover one-sixth of water in storage

On the basis of the above assumptions and the dimensions of the areas shown in figure 56 (aquifer width was based on a reasonable distance from the stream), estimates of rates of groundwater capable of being withdrawn for a 6-month period were made and are given in table 51. If conditions given in the list of assumptions could be met, 194.1 mgd could be withdrawn for a 6-month period in most favorable areas, 162.3 mgd in generally favorable areas, and 174.2 mgd in possibly favorable areas.

On the basis of the above assumptions and an assumed aquifer permeability of 1000 gpd/sq ft, a typical well yield would be low, about 100 gpm. Higher well yields would be possible in areas with greater aquifer thickness and higher aquifer permeability. If well yields are low, 100 gpm or less, a large number of wells would be required to develop the aquifer potential to create storage for artificial recharge water.

It is impossible with the present limited knowledge on aquifer properties to make reasonably accurate estimates of the aquifer potential for artificial recharge. An intensive test drilling and aquifer testing program would be needed to locate the most favorable artificial recharge sites and to design artificial recharge systems. In 1973 the Water Survey (Schicht, 1973), assisted by the State Geological Survey, prepared an artificial recharge proposal for the city of Naperville at their request. A summary of that proposal included in this report outlines the steps required to obtain data for an artificial recharge installation. The system cannot be designed until test drilling, aquifer testing, water quality, and streamflow evaluation programs are made.

Streamflow Availability

The USGS duration tables of daily discharges for seven gaging stations in northeastern Illinois were studied to compare shallow aquifer recharge potential with streamflow availability. For this report it was decided to select the flow that is equaled or exceeded 50 percent of the time during the year of the lowest flow for a recent selected period of record to compare with aquifer recharge potential, as shown in table 52. The 50 percent flow for a year of low flow gives an indication of the adequacy of stream water as a source of recharge water.

Table 53 compares the aquifer recharge potential along the stream reach in the vicinity of the gaging station with the 50 percent flow at the gaging station. The 50 percent flow is less than the aquifer potential along stream reaches 1, 7, 26, and 13. As would be expected, there is sufficient flow in the Fox and Du Page Rivers for large artificial recharge systems.

Summary

Artificial recharge does not provide an additional source of water, but a transfer from a surface water source to a groundwater source. The groundwater reservoir when depleted by pumping offers storage for surface water for subsequent use. A well-designed artificial recharge system can improve the quality of water used in artificial recharge.

Shallow sand and gravel aquifers along major streams were considered for artificial recharge and were subdivided into the following classifications: most favorable, generally favorable, possibly favorable, and unfavorable. The aquifer artificial recharge potential is great, 194.1 mgd for the areas classified as most favorable. Streamflow is a limiting factor in many areas.

Although artificial recharge can be an important alternative to conventional groundwater supplies, considerable effort is needed in test drilling and aquifer testing to locate specific artificial recharge sites. A pilot artificial recharge

Table 51. Estimated Aquifer Potential Rates for a 6-Month Pumping Period for Artificial Recharge Areas

(in millions of gallons per day)

Location numbers	*Location*	*Most favorable*	*Generally favorable*	*Possibly favorable*
1	Des Plaines River, Lake County	36.1		
2	FoxRiver, Lake and McHenry Counties			59.3
3	North Branch and Nippersink Creek, McHenry County		48.6	
4	Fox River, McHenry and Lake Counties			41.7
5	Fox River, north of Elgin in Kane County	22.2		
6	Fox River, south of Elgin in Kane County	4.6		
7	Poplar Creek, Kane and Cook Counties	9.7		
8	Fox River, south of Elgin, Kane County		5.4	
9	Brewster Creek		3.9	
10	Fox River, north of St. Charles, Kane County		5.5	
11	Norton Creek		2.3	
12	Ferson Creek		0.5	
13	West Branch Du Page, northern Du Page County			16.1
14	West Branch Du Page, near West Chicago, Du Page County			17.3
15	West Branch Du Page, vicinity of Warrenville and Naperville, Du Page County			5.1
16	East Branch Du Page, vicinity of Glen Ellyn and Lombard, Du Page County	5.8		
17	Remainder of East Branch, Du Page and Will Counties		38.2	
18	Main Branch, Du Page River, Will County	74.1		
19	Lily Cache Creek, Will County		7.7	
20	Lower East Branch, Upper Main Branch, Du Page and Will Counties		6.9	
21	Lower Main Branch, Du Page River, Will County		8.1	
22	Lily Cache Creek, Will County	17.3		
23	Mink Creek, Will County		15.1	
24	Rock Run, Will County	6.2		
25	Fox River, Kendall County		20.1	
26	Blackberry Creek, Kane and Kendall Counties			34.7
27	Little Rock Creek, Kendall County	5.6		
28	Big Rock Creek, Kendall County	9.3		
29	Fox River, Kendall County	3.2		
	Total	194.1	162.3	174.2

installation is needed to determine the cost of operation and possible technical problems in the operation of the installation.

Artificial Recharge Proposal for City of Naperville

The city of Naperville in Du Page County indicated an interest in funding a pilot study on artificial recharge of the shallow aquifers in that area. Wells finished in the Silurian dolomite and in the deep sandstone aquifers are the present source of water for Naperville.

The Water Survey prepared a proposal (Schicht, 1973) for such a pilot study in 1973, since the demonstration of a successful artificial recharge project could do much to encourage artificial recharge as a viable alternative to continued mining.

The proposal outlined steps to be taken in developing an artificial recharge study and estimated the cost of the study. The most important part of the study would be the test drilling program. It should be emphasized that artificial recharge may not be possible in large enough quantities to be attractive. To offset this the *test drilling program can be planned to locate additional production wells* in the dolomite or sand and gravel to serve Naperville's growing water demands.

The three prime requisites for artificial recharge of aquifers included the existence of a suitable geologic environment as described in the previous section, an adequate supply of recharge water of suitable quality, and adequate open space.

The procedure suggested for conducting an artificial recharge pilot study in the shallow aquifers is as follows:

1) From the regional studies (Anderson, 1960; Landon

Table 52. Fifty Percent Flow during Year of Lowest Flow for Selected Period of Record

(Flow in millions of gallons per day)

Gaging station	*Selected period of record*	*Year of lowest flow*	*50% flow*
Des Plaines River near Gurnee	1946-1958, 1969-1971	1956	9.2
Fox River at Algonquin	1954-1971	1963	400
Poplar Creek at Elgin	1952-1971	1963	2.0
Ferson Creek near St. Charles	1962-1971	1964	3.8
Blackberry Creek near Yorkville	1961-1971	1963	13.9
West Branch Du Page River near West Chicago	1962-1971	1963	3.1
Du Page River at Shorewood	1941-1971	1963	112

Table 53. Aquifer Potential Compared with Fifty Percent Flow

(in millions of gallons per day)

Gaging station	*Stream reach*	*50% flow*	*Aquifer potential*	*Aquifer classification*
Des Plaines River near Gurnee	1	9.2	36.1	Most favorable
Fox River at Algonquin	5	400	22.2	Most favorable
Poplar Creek at Elgin	7	2.0	9.7	Most favorable
Ferson Creek near St. Charles	12	3.8	0.5	Generally favorable
Blackberry Creek near Yorkville	26	13.9	34.7	Possibly favorable
West Branch Du Page River near West Chicago	13	3.1	16.1	Possibly favorable
Du Page River at Shorewood	21	112	8.1	Generally favorable

et al., 1965; Hackett, 1968; and Zeizel et al., 1962), open space considerations, and water availability, select the most promising sites for artificial recharge.

2) From available streamflow records, determine water availability.
3) Start water quality monitoring program to determine suitability of water for artificial recharge.
4) Conduct planned test drilling program to define the geologic environment.
5) Conduct aquifer pumping tests to determine aquifer and confining bed properties.
6) Drill production well or wells.
7) Predetermine pumping schedule to allow maximum underground storage during artificial recharge season.
8) Establish long-term hydrologic observation network.
9) Design artificial recharge installation.

These steps are discussed in more detail in subsequent sections.

Selection of Area for Study

The areas favorable for artificial recharge in the vicinity of Naperville are shown in figure 57. The streams were selected by the Water Survey on the basis of their adequacy of flow and water quality. The areas shown in figure 57 as most favorable for artificial recharge met the required specifications outlined in the previous section (page 67).

The areas in figure 57 indicated as generally favorable are areas underlain by sand and gravel deposits having known local variations in thickness or texture which may restrict or eliminate their consideration in terms of the required specifications.

The possibly favorable areas are underlain by sand or gravel deposits whose thickness is largely or entirely unknown, but which otherwise meet the required specifications.

The area to be considered initially as an artificial recharge site is the reach along the West Branch in Section 11, T38N, R9E.

Recharge Water Availability

The West and East Branches of the Du Page River are considered as prime sources of recharge water. There are two streamgages established on the East Branch and three on the West Branch, as described in table 54.

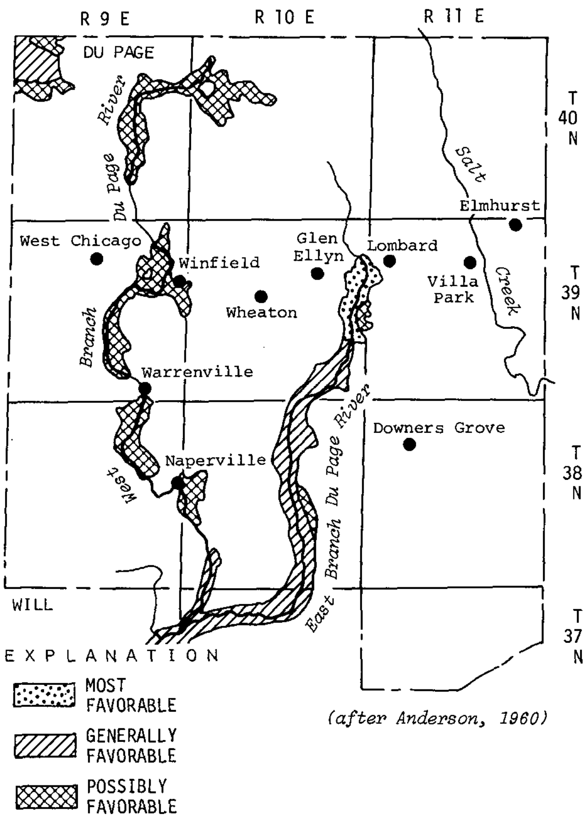

Figure 57. Suggested areas for artificial recharge investigations

The periods of record are long enough and the streamgages are strategically located so that flow duration curves can be synthesized for any point near Naperville on either Branch. Flow duration curves constructed for the period of record for gages 2 and 3 indicate there is sufficient flow at least 60 percent of the time for artificial recharge at the site selected in Section 11.

Water Quality Monitoring Program

A water quality monitoring program should be established on the West Branch and eventually on the East Branch Du Page River to determine the suitability of the water for artificial recharge. It was recommended that samples be collected weekly for analysis at the West Branch near Ogden Avenue. More frequent sampling may be desirable during periods when the river is in flood stage.

It was recommended that analyses be made of the following: turbidity, temperature, total dissolved minerals, hardness, iron, manganese, chloride, sulfate, nitrate, heavy metals, BOD, COD, and bacterial counts.

Field Testing Program

A tentative test drilling program was planned from discussions with Dr. John Kempton, Dr. George Hughes, and Philip Reed, of the State Geological Survey. Initially it was recommended that three test holes be drilled in Section 11, T38N, R9E, the site selected for the first artificial recharge investigation. Suggested locations for the three test holes are:

1) 2000 ft E, 2500 ft N, SW Cor (east of Cress Creek Subdivision)
2) 2250 ft E, 500 ft S, NW Cor (west of Saddle Dam)
3) 250 ft E, 1000 ft S, NW Cor (McDowell Grove)

It was recommended that formation samples be collected at 5 foot intervals and a minimum of 3 split-spoon samples be collected. The test holes should be continued into bed-

Table 54. Du Page River Sources of Recharge

Stream	*Gage number*	*Location*	*Date installed*	*Drainage area (sq mi)*	*Agency*
West Branch	1	State Highway 64	July 1961	27.5	USGS
West Branch	2	Near Warrenville Road	October 1968	88.5	USGS
West Branch *	3	Washington Street	October 1959	131.6	Water Survey, Division of Water Resources
East Branch *	4	West Maple Avenue	October 1959	50.3	Water Survey, Division of Water Resources
East Branch*	5	Washington Street	October 1959	72.3	Water Survey, Division of Water Resources

*Discontinued October 1974

rock with the glacial drift materials cased out and a short production test (2 hours) in the dolomite be conducted at each site.

If the results of the test drilling indicate a favorable geologic environment for artificial recharge, a more intensive test drilling program should be conducted. Nine additional test holes were recommended.

If the results of the test drilling indicate an unfavorable geologic environment, areas south of Naperville along the West Branch and East Branch should be investigated.

An aquifer test consisting of pumping a test production well at a constant rate for 24 hours and frequently measuring water levels in observation wells should be conducted in the vicinity of the most suitable artificial recharge site. The purpose of the test would be to determine aquifer and confining bed hydraulic properties to aid in designing production wells and artificial recharge installations. The test production well and observation well design would be based on the geologic exploration.

Production well design would be based on the results of the aquifer tests and the geologic exploration.

It is expected that water would be artificially recharged primarily during the late winter and spring months when the river stage is high and water temperatures are low. Pumping from the groundwater reservoir should be planned so that maximum groundwater storage is available at the start of the recharge season.

An hydrologic observation network for determining the response of water levels in the aquifer to long-term pumping, recharge from precipitation, and recharge from the West Branch (if the artificial recharge installation is to be located adjacent to the river) is important in the final design of the artificial recharge installation. Groundwater pumpage from the well or well-field, groundwater levels in a minimum of three observation wells, soil moisture above the water table at several locations, and precipitation should all be accurately measured. The final hydrologic observation network design depends on the test drilling and aquifer testing program.

The artificial recharge installation can be designed on the basis of the geologic and hydrologic data and the performance of the well field.

Cost Summary

The total estimated cost (1975 dollars) of test drilling, aquifer testing, and the hydrologic observation network is $52,300, as indicated in table 55. This does not include the final production well or wells, land acquisition, easement costs, the artificial recharge installation, or a part-time

Table 55. Cost Estimates

	Item	*Estimated cost**
1	Three initial test holes – 8 inches in diameter (average drift thickness 70 feet, test holes completed to 50 feet into bedrock, logged with gamma ray or electric logger, 3 split spoons per hole)	$12,000
2	Three 2-hour pumping tests on each of the above test holes	3,000
3	Nine additional test holes (average drift thickness 70 feet, three split spoons per hole, samples at 5 foot intervals)	14,400
4	Mineral and bacteriological analyses	Made by Water Survey and City, no charge**
5	A 10-inch production test well, 120-feet deep	5,000
6	Three 4-inch observation wells averaging 120 feet in depth, finished 50 feet into dolomite	6,000
7	Three 4-inch observation wells averaging 70 feet in depth, finished in sand and gravel	5,100
8	A 28-hour well production test	4,400
9	Production well or wells	Cost not included
10	Hydrologic observation network	
	a) recording raingage	400
	b) three continuous water level recorders	1,500
	c) neutron soil moisture detector	Can be borrowed from Water Survey
	d) soil moisture probe pipe	500
	Total for network	2,400
11	Artificial recharge installation	Cost not included

*Based on 1975 prices
**No charge unless City includes partial salary for laboratory technician

hydrologic technician. The study can be phased over a 2- or 3-year period as indicated below.

Two-year study (1975 dollars)
First year: Items 1, 2, and 3 – Estimated cost $29,400
Second year: Items 4, 5, 6, 7, 8, 9, and 10 – Estimated cost $22,900

Three-year study (1975 dollars)
First year: Items 1 and 2 – Estimated cost $15,000
Second year: Items 3 and 10 – Estimated cost $16,800
Third year: Items 4, 5, 6, 7, 8, and 9 – Estimated cost $20,500

The division of responsibility for the various tasks is indicated in table 56.

Additional Comments

The main emphasis in the proposal was on exploring the possibilities of artificial recharge northwest of Naperville since this was an area in which city officials had indicated it would be desirable to develop an additional groundwater supply. If this area does not meet criteria for artificial recharge, the next area suggested for investigation would be in the vicinity of the confluence of the East and West Branches. This is in an area not contemplated for immediate water resource development. In addition to water from the streams, the high quality effluent from a new wastewater treatment plant (now constructed) would be available as a source of recharge water in this area.

Table 56. Suggested Responsibilities for Task Performance

Task	*Suggested responsibilities*
Preliminary report	Water Survey (completed)
Plan test drilling program	Geological Survey, Naperville
Contract for drilling test holes	City
Water quality monitoring program	
a) collection of samples	City
b) mineral analyses	Water Survey
c) bacteriological analyses	City
Streamflow study to determine recharge water availability	Water Survey
Supervision of test drilling program and geologic interpretation	Geological Survey
Contract for production test well or wells, observation wells, and aquifer pumping tests	City
Aquifer test supervision and interpretation of results	Water Survey
Production well design	Water Survey
Contract for production well	City
Establish hydrologic observation network	Water Survey, Geological Survey, City
Determine pumping schedule	Water Survey, City
Review task performances to design artificial recharge installation	Water Survey, Geological Survey, City

Precipitation Augmentation over Lake Michigan

Lake Michigan is a primary source of water in northeastern Illinois. The current usage for water supply, navigation, and water quality control approximates the 3200 cfs which the U.S. Supreme Court has allowed to be diverted from Lake Michigan. If Illinois were to undertake a precipitation augmentation program over the lake, the incremental volume of water added to Lake Michigan as rainfall or snowfall would presumably be available for diversion as water supply in Illinois.

The idea of seeding clouds with silver iodide or other artificial nuclei to increase rainfall was first suggested as being scientifically feasible about 1950. After more than two decades of research, cloud seeding for precipitation enhancement has not developed to an all-purpose science having provable, controllable results. It is believed, however, in 1976 that under suitable atmospheric conditions, precipitation can be increased at selected times and places. Precipitation enhancement is being practiced regularly at places in the western United States.

In 1973 a state law titled *The Weather Modification Control Act* was passed in Illinois. It states that weather modification can produce economic benefit to the people of Illinois; that its use and development should be encouraged; that in order to minimize adverse effects, it should be controlled. A state permit is required before any activities can be carried out.

Figure 58 shows the amount of water that moves through the hydrologic cycle for Illinois. The large arrow across the top shows that 2000 billion gallons of water vapor daily passes over Illinois. Of this, the total annual rainfall or precipitation falling on Illinois is equivalent to only 1000 billion gallons per day (bgd) or 5 percent of the water in the atmosphere. Nearly half of this precipitation, 44 bgd, evaporates from land and water surfaces and is lost to the atmosphere by evaporation.

The purpose of rainfall augmentation is to tap the atmospheric water which leaves Illinois each day. Changnon (1973) describes the possibilities of doing this. While a precipitation enhancement program is conceived to remove an additional amount of water from this enormous supply, that which remains is still so great as to be more than adequate to supply normal rainfall to areas outside the region selected for seeding.

Stout and Ackermann (1974) have investigated the

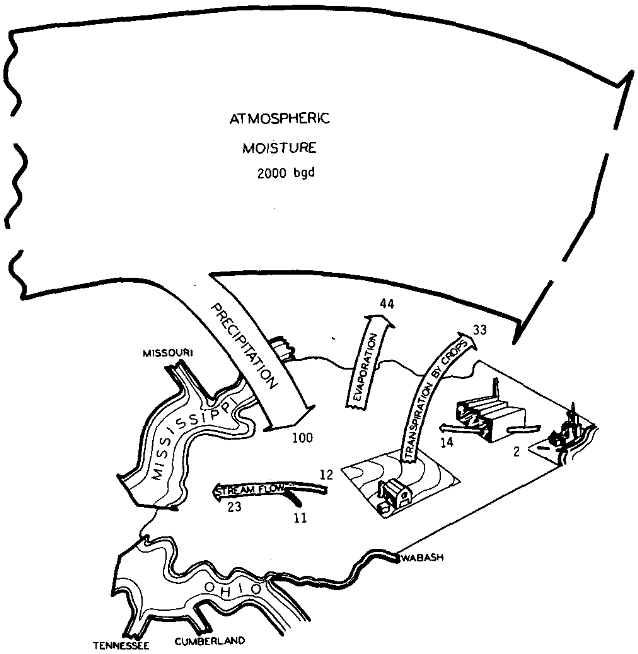

Figure 58. Hydrologic cycle for Illinois

specific hydrologic and economic feasibility of increasing precipitation over Lake Michigan. Climatic conditions in the fall and early winter are the most suitable for cloud seeding over the lake. During the fall season, the Lake Michigan water body is much warmer than the air, evaporation is high, and heavy cloud systems are often present over the lake. Consequently during this season it is considered feasible to increase precipitation by 10 to 20 percent over the lake by cloud seeding. This could be done by introducing artificial nuclei either by aircraft or by generators on the ground.

Increased water in the Great Lakes affects navigation, downstream power generation, and lake shore property, as well as water supply. The economic effect on lake shore property is negative except in periods of very low water levels. The value of water for water supply is uncertain in comparison with its value for power and navigation. Also, if water is diverted from the lakes for water supply, it is not available for power or navigation purposes. There are questions concerning the correlation between years of high or low precipitation and lake levels, and the time to reach a new 'equilibrium condition' if precipitation is increased. The following is a preliminary discussion of this alternative for increased water supply to northeastern Illinois.

In the report by Stout and Ackermann (1974), 10 and 20 percent increases in precipitation during October, November, and December were considered. Jones and Meredith (1972) compiled data on the hydrology and climatology of the Great Lakes. Precipitation during the October-December period ranged from 2.4 to 11.5 inches and averaged 6.4 inches during the period from 1946 to 1965. If precipitation were increased by 10 percent over the entire lake area of 22,400 square miles, the daily flow increase would range from 240 to 1150 mgd, with an average of 640 mgd. A 20 percent increase would yield from 480 to 2300 mgd with an average of 1280 mgd.

The projected water supply deficiency in northeastern Illinois, based on meeting demands with groundwater available from natural recharge (see figure 19), is 170 mgd in 2000. If water for water supply is arbitrarily valued at 0.5 ¢/1000 gallons, this 170 mgd has an annual value of $310,000. Stout and Ackermann (1974) found a nearly linear relation between increased precipitation and economic benefits. Table 57 was prepared from their report, but it does not include a factor for inflation.

The first two lines in table 57 are without any use of the increased volume of water for water supply. The last two lines include diversion of 170 mgd for water supply in northeastern Illinois. The power, navigation, and shore property effects are assumed to be a linear function of the increased water levels.

Stout and Ackermann (1974) gave a cost of $500,000 per year for a cloud seeding program. If all costs and benefits are affected similarly by inflation, the benefit-cost ratio of about 2 to 1 for a 20 percent increase in precipitation would remain valid. This indicates that precipitation augmentation is economically feasible. However, political questions have not been treated and the stochastic nature of both precipitation and lake levels has not been considered.

Chicago Tunnel and Reservoir Plan (TARP)

The Metropolitan Sanitary District of Greater Chicago (MSDGC), in cooperation with the Chicago Department of Public Works, has developed the "Chicago Tunnel and Reservoir Plan" as a major project to reduce flooding and surface water pollution in the Chicago area. The principal objects to be accomplished are: 1) preventing storm water runoff in the Chicago River from entering Lake Michigan, 2) eliminating (except under very severe conditions) basement and viaduct flooding, and 3) treating all of the discharge from the combined sanitary and storm sewers before it enters the Illinois Waterway drainage system in order to meet stream water quality standards. The Chicago Tunnel and Reservoir Plan (TARP) is the result of many years of study

Table 57. Benefits of Precipitation Augmentation, 1950-1966

(in millions of dollars)

Precipitation increase	*Power*	*Navigation*	*Shore property*	*Water supply*	*Total*
10%	1.1	0.2	–0.7	0	0.6
20%	2.2	0.3	–1.5	0	1.0
10%	0.8	0.2	–0.5	0.3	0.8
20%	1.9	0.2	–1.3	0.3	1.1

of the problems involved and various programs proposed to reduce these problems.

TARP affects the storage, treatment, and subsequent discharge of storm water runoff. It may affect the amount of water diverted from Lake Michigan for dilution of treated storm water effluents. The storage of this runoff water also makes conceivable the use of this water. These two factors illustrate that TARP would have a considerable bearing on the total water resources of northeastern Illinois.

In 1968 a system of deep tunnels was first proposed in a report by the Bauer Engineering Co. and the Harza Engineering Co. of Chicago. A specific plan was described in *Summary of Technical Reports* published in 1972 by the state, Cook County, MSDGC, and Chicago. The plan was summarized in January 1975 in the MSDGC Overview Report (1975) and in October 1975 by the U.S. Army Corpe of Engineers (1975). A popular booklet "How to Bottle Rainstorms" (MSDGC, 1974) describes the project. The following discussion was prepared from these publications.

About 120 miles of conveyance tunnels would be constructed. These tunnels would collect the flow from 640 sewer overflow points in a 375-square-mile area served by MSDGC. The tunnel locations are shown in figure 59. The tunnels would vary from 15 to 72 feet in diameter and would be excavated in the Silurian dolomite bedrock at depths from 150 to 300 feet below ground level.

Water would be delivered to the deep tunnels by hundreds of vertical drop shafts, illustrated schematically in figure 60. The drop shafts would have a split vertical shaft, one side for water and the other side for air. The center dividing wall would have slots which would cause air to be blown into the falling water. This would reduce the impact when the air-water mixture reaches the bottom.

Surface storage reservoirs would be constructed at three locations shown on figure 59 – at McCook near the MSDGC West-Southwest Plant, at Thornton near the Calumet Plant, and near the O'Hare Plant. The storage capacity at O'Hare would be 2700 acre-feet, and at Thornton 39,000 acre-feet. Storage within the conveyance tunnels would be 9400 acre-feet.

The largest surface storage reservoir would be at McCook as shown in figures 59 and 61. It would be about 2.5 miles long, divided into three sections and located in the northeast part of the McCook quarry where limestone is now being mined. The excavated rock would be stockpiled at the quarry and eventually would be incorporated into the sale of limestone aggregate. A cross section of the proposed McCook reservoir is shown in figure 62. It would be about 320 feet deep, 1250 feet wide, and would hold about 56,000 acre-feet (that expected for the maximum recorded storm) at a water surface elevation 100 feet below ground surface. It would hold 82,000 acre-feet if filled to the ground surface. In order to control odors, floating aerators would be used to pump air into the water in the reservoirs. For three years, solids would be allowed to collect in the reservoir, then they would be dredged out for disposal elsewhere.

The deep tunnels would collect and store water during and after rainstorms. This water, from combined sewer overflows would be pumped into the surface reservoirs in about three days. For the maximum recorded storm event, the water would be held in the reservoir up to 50 days. It would be emptied by pumping the water into the sewage treatment plant during off-peak hours at a rate the plant can treat, which is 1.5 times the dry-weather flow to the plant. After treatment, of course, the plant effluent would be discharged into the Sanitary and Ship Canal.

The water would receive primary and secondary treatment and chlorination before being discharged to the waterway.

Construction of the 35 projects in the TARP plan would require 10 years or more. The construction costs at December 1974 prices are summarized as:

Tunnels and shafts	$852,600,000
Collecting structures	72,575,000
Pumping stations	69,986,000
Reservoirs	401,100,000
Total construction costs	$1,396,261,000

Addition of the technical services costs and land costs increases the total to $1,521,608,000. Each project cost estimate includes excavation, spoil management, concrete lining, aquifer protection, etc.

Additional costs to agencies other than the MSDGC associated with the project but not listed as part of TARP are: widening the Chicago Sanitary and Ship Canal from 160 to 225 feet from Lockport to Cal-Sag Canal, U.S. Army Corps of Engineers, $97,705,000; and upgrading local combined sewers, local governments, $600,000,000. Total of these additional costs would be $697,705,000.

The Corps of Engineers has provided the cost of TARP and related costs (at June 1975 price levels) for the 375-square-mile combined sewer area shown in table 58. The capital costs include 25 percent for contingencies.

The total construction cost of $4.97 billion is equal to about $1000 per person for those persons living in the region.

In addition to the benefits of pollution and flood control, the tunnel and reservoir plan would make available a source of water that could be used for some industrial water supplies. Studies would be necessary to determine the quality and quantity of the water, as well as the market potential. One major disadvantage would be the need for a separate distribution system. The state and federal Environmental Protection Agencies, as well as the American Water Works Association, are opposed to the direct recycling of sanitary treatment plant effluent into a public water supply.

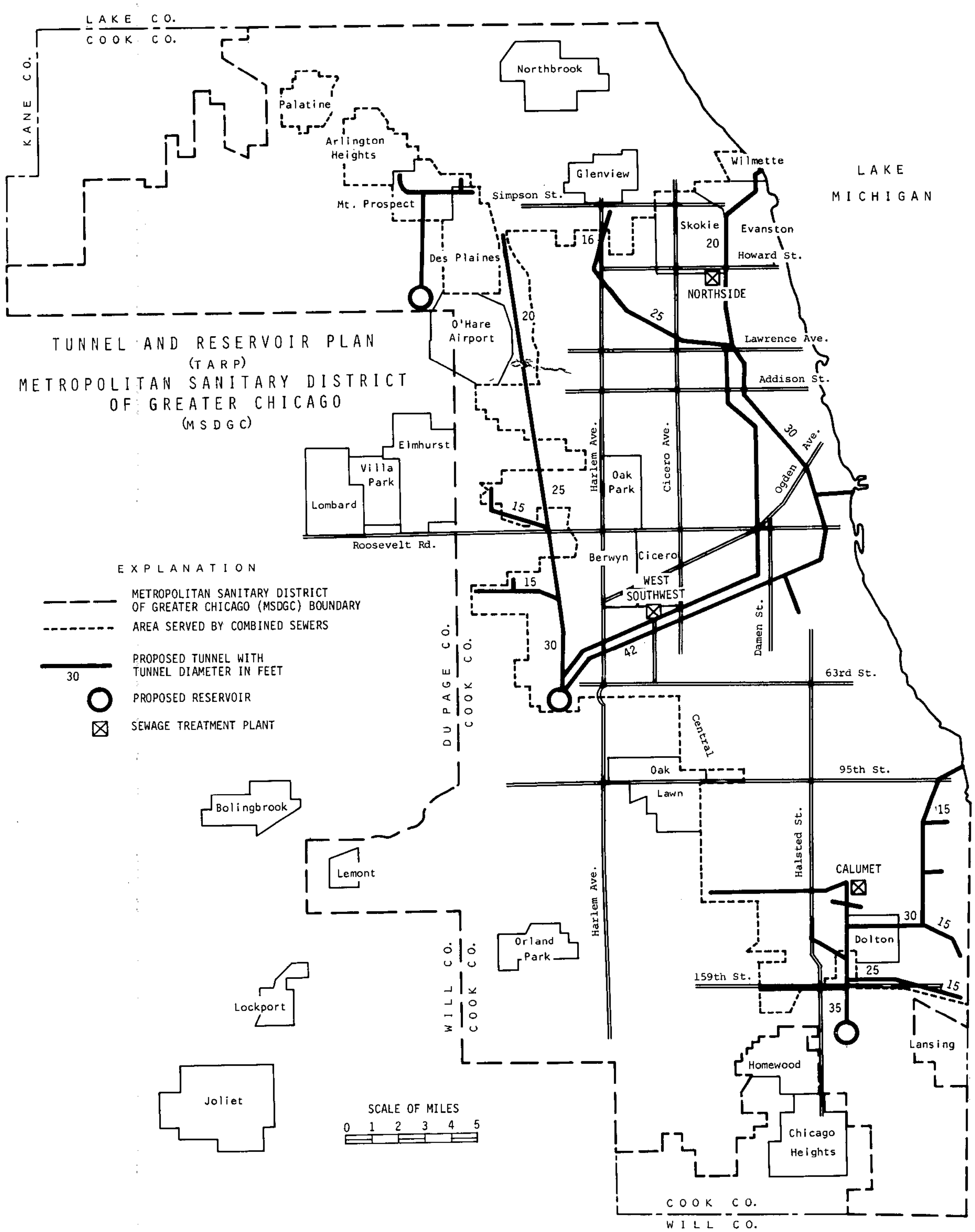

Figure 59. Layout of Chicago Tunnel and Reservoir Plan (TARP)

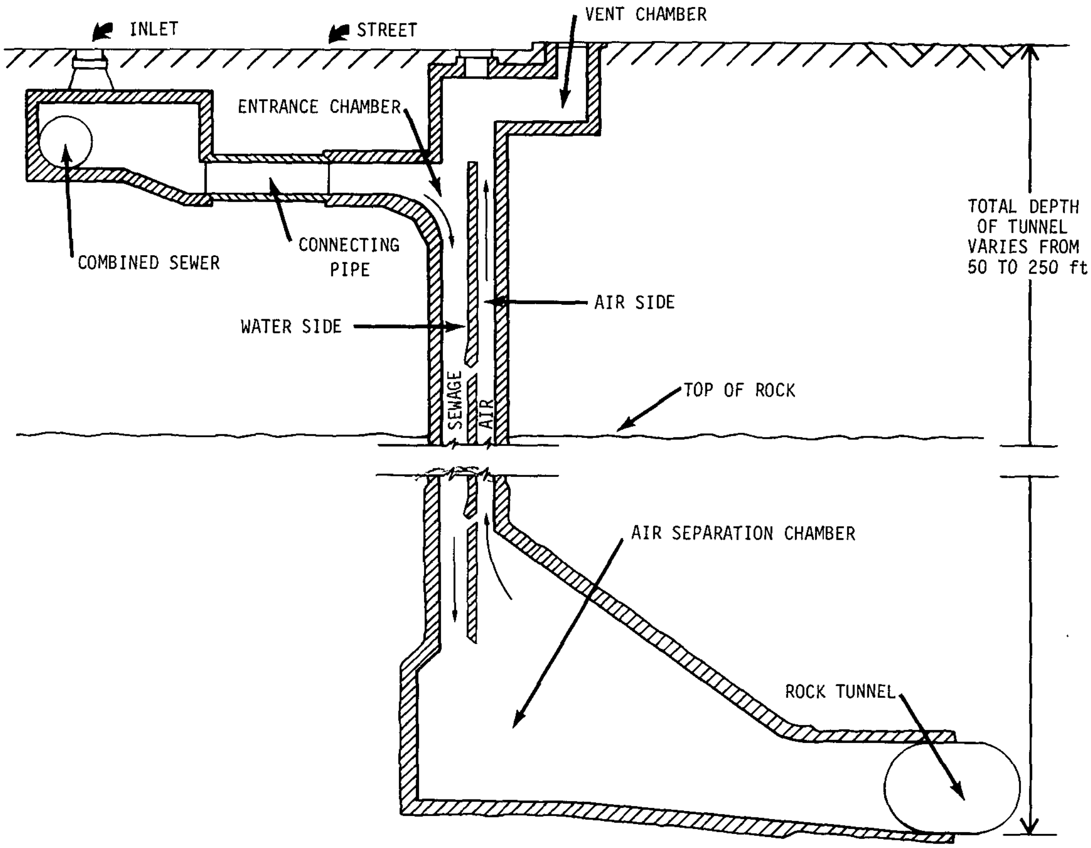

Figure 60. Cross section of vertical drop shaft

A pilot tunnel project was completed in 1974. This consists of a 13-foot diameter tunnel, approximately 3 miles long in the McCook area. The stored water from the tunnel is pumped through an interceptor sewer to the West Southwest Treatment Plant. No program for reuse of this water has been developed. Existing plans by MSDGC and Chicago do not include considerations for reuse of treated sewage effluent other than for dilution and low-flow augmentation.

WATER QUALITY

Groundwater Quality Data

In this report only a brief summary of groundwater quality data is presented. Extensive data on groundwater quality are available in the Water Survey files. Broad discussion of the data is beyond the scope of this report. Interpretation of groundwater quality data in northeastern Illinois is included in Suter et al. (1959). Water quality of the Mt. Simon aquifer is discussed in detail in Illinois State Water Survey (1973).

Groundwater quality data from Water Survey chemical analyses made after January 1, 1965, were separated into two sets of IBM printouts for inclusion in the testimony presented at the Lake Michigan water diversion allocation hearings (Water Resources of Northeast Illinois, 1976). The first set listed individual chemical analyses and pertinent physical data such as locations, aquifers, and well depths. The chemical constituents included in the printout were alkalinity, calcium, chloride, fluoride, hardness, iron, magnesium, manganese, ammonium, nitrate, sulfate, total dissolved minerals, and zinc.

The second set of IBM printouts summarized groundwater quality for each township by aquifer type. Included were the mean, median, maximum, and minimum values for each chemical constituent for each township for which chemical

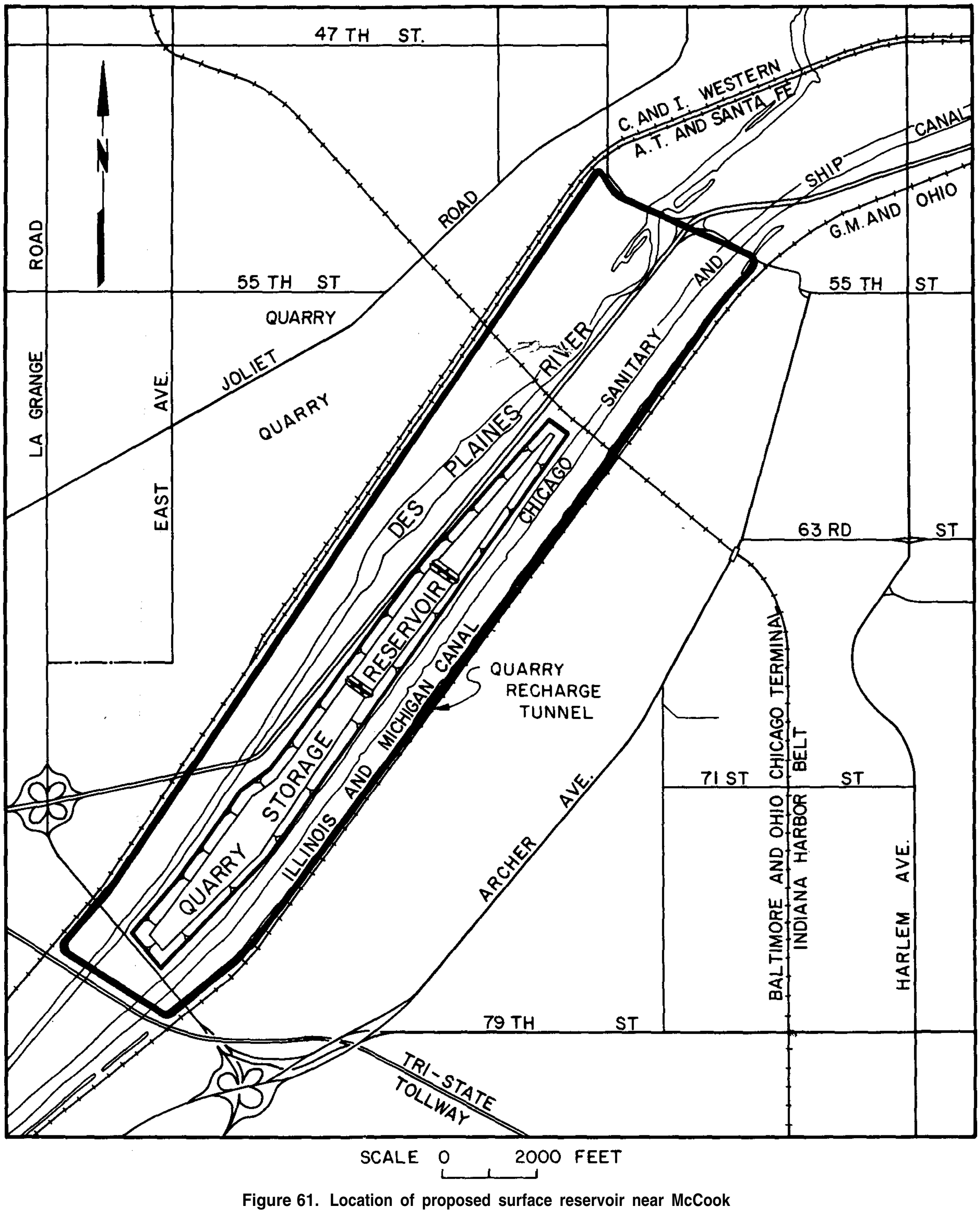

Figure 61. Location of proposed surface reservoir near McCook

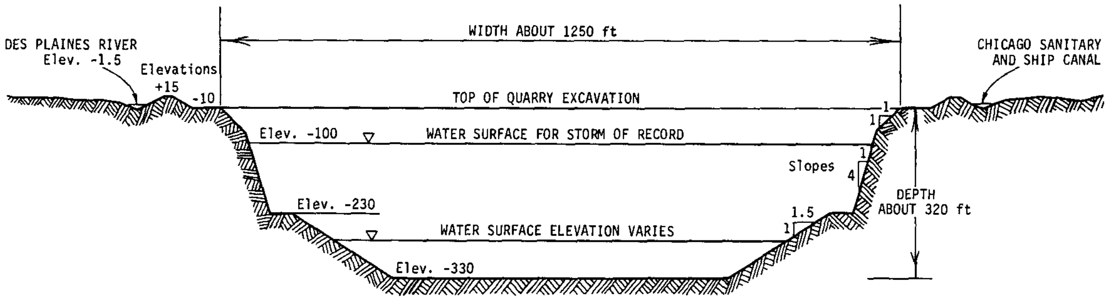

Figure 62. Cross section of proposed surface reservoir near McCook

Table 58. Corps of Engineers Estimated Costs for TARP and Related Expenditures

Item	*Capital ($ billion)*	*Annual OPR&M ($ million)*
Upgrading sewers	1.31	2.6
Tunnel and reservoir system	1.85	17.5
Upgrading interceptors and treatment plants	0.93	27.5
Sludge management	0.13	8.2
Appurtenant works, dredging, pump stations, etc.	0.21	0.3
Engineering and design	0.27	
Administration	0.27	
Total	4.97	56.1

analyses are available. Also included, when a sufficient number of analyses were available, was the range in concentration for each chemical constituent, the concentrations that are equaled or exceeded in 10 percent of the analyses, and the concentrations that are equaled or exceeded in 90 percent of the analyses.

The median and 10 to 90 percent range for selected chemical constituents for each aquifer for townships in which chemical analyses are available are summarized in tables 59, 60, and 61. Hardness and iron were included in the tables since treatment costs given in this report include hardness reduction and iron removal. Chlorides were included because high chloride concentrations in the shallow aquifers may be indicative of road salt pollution. In the deep aquifers high chlorides may be indicative of upward intrusion of brackish water from the Mt. Simon aquifer into deep wells. Total dissolved minerals were included because a high total dissolved mineral concentration may indicate that the water requires other than conventional treatment to meet water quality standards.

It should be apparent that when two analyses are listed, the value given in the median column is a mean. When only one analysis is listed, the value is the actual value of the chemical constituent.

Included in the testimony was a tabulation showing that raw groundwater used for public water supplies has a high content of several chemical constituents. The selected constituents and the number of public water supplies for each county that exceed given concentrations are given in table 62.

Mineral Quality of Surface Water

The Water Survey, in cooperation with the U.S. Geological Survey collects samples at approximately monthly intervals from selected points on various streams within the state. Data were available for the period 1971 to 1975, for six stations in northeastern Illinois. The streams and sampling stations used were: Coon Creek near Riley, Kankakee River at Momence, Fox River at Algonquin and at Batavia, Des Plaines River at Des Plaines, and Du Page River near Shorewood.

The available data for these stations were analyzed and various statistics were generated which are useful to the evaluation of surface water quality in these streams. The sets of ranked data and generated statistics for these six stations, as well as additional analyses of data from earlier sampling periods were included in Water Resources of Northeast Illinois (1976).

The data from the 1971–1975 sampling period were analyzed and compared with the Illinois Pollution Control Board's *General Standards and Public and Food Processing Water Supply Standards* (Illinois Pollution Control Board, Rules and Regulations, Chapter 3: Water Pollution, Part II, Sections 203 and 204.) Criteria given in the recently published U.S. Environmental Protection Agency *Water Quality Criteria for Domestic Supplies* were also considered. Table 63 lists these standards and criteria for several parameters.

Comparison of the 1971–1975 data with the standards listed demonstrates that the standards for iron, manganese, and nitrate were exceeded in varying degrees at all six sampling stations. The total dissolved solids standard was exceeded at Riley on Coon Creek, at Des Plaines on the Des Plaines River, at Shorewood on the Du Page River, and at Algonquin on the Fox River. Table 64 shows which standards were exceeded at the six stations during 1971–1975, the values of the standards, and percentiles exceeding the standards.

Table 59. Summary of Chemical Quality of Water from Sand and Gravel Wells

(Chemical constituents in milligrams per liter)

Township	Number of observations	Chlorides Median	Chlorides Range 10%	Chlorides Range 90%	Hardness Median	Hardness Range 10%	Hardness Range 90%	Iron Median	Iron Range 10%	Iron Range 90%	Total dissolved minerals Median	Total dissolved minerals Range 10%	Total dissolved minerals Range 90%
32N9E	2	39.0			710.0			8.05			1012.5		
32N10E	1	56.0			560.0			0.50			776.0		
35N11E	3	5.0			450.0			1.10			634.0		
36N10E	1	26.0			612.0			0.00			700.0		
36N11E	2	5.0			532.0			0.65			690.0		
37N11E	1	10.0			430.0			0.30			533.0		
38N7E	4	7.0			388.0			2.00			407.5		
38N8E	4	16.0			451.0			0.30			488.5		
38N12E	1	17.0			580.0			4.20			1331.0		
39N7E	1	2.0			260.0			0.50			350.0		
39N9E	2	36.0			406.0			0.34			556.0		
40N6E	3	1.0			264.0			0.10			289.0		
40N7E	5	3.0			360.0			1.50			489.0		
40N8E	5	3.0			376.0			0.70			441.0		
40N9E	2	49.0			516.0			3.10			588.5		
40N10E	5	9.0			484.0			0.80			663.0		
40N11E	15	17.0	5.0	96.4	530.0	426.4	736.0	2.0	0.06	6.16	661.0	495.8	905.4
40N12E	1	8.0			354.0			0.10			752.0		
41N8E	4	25.0			338.0			1.35			370.0		
41N9E	17	9.5	1.7	45.2	432.0	273.6	711.5	1.30	0.18	3.76	500.0	398.3	900.8
41N10E	17	3.0	0.00	7.20	332.0	257.4	447.4	1.00	0.08	2.96	511.0	412.4	802.0
42N6E	1	6.0			272.0			0.10			335.0		
42N7E	1	0.0			220.0			1.10			296.0		
42N8E	13	8.0	0.40	23.60	400.0	307.2	456.0	0.90	0.00	12.68	452.0	400.2	567.8
42N9E	3	8.0			432.0			0.50			516.0		
42N10E	11	2.0	0.20	6.00	376.0	314.4	891.2	0.20	0.00	1.64	648.0	453.4	1520.8
42N11E	3	11.0			318.0			0.30			418.0		
43N5E	20	22.0	6.70	210.5	437.0	324.8	647.0	0.10	0.00	1.29	507.5	347.9	937.3
43N6E	12	16.5	0.30	45.7	363.0	254.2	441.0	0.50	0.00	4.05	435.5	306.1	549.2
43N7E	3	20.0			500.0			0.20			533.0		
43N8E	11	11.0	0.40	36.0	352.0	187.6	414.4	0.70	0.00	4.36	414.0	324.2	482.6
43N9E	13	10.0	3.20	95.6	444.0	369.6	707.4	0.60	0.08	1.24	513.0	429.2	915.4
43N10E	9	6.0	1.00	8.00	605.0	202.0	710.0	0.20	0.20	0.30	1144.0	290.0	1232.0
43N11E	16	50.0	13.5	109.1	897.5	454.0	2496.0	2.30	0.00	21.40	1375.5	631.0	3250.3
44N5E	19	27.0	6.00	63.0	366.0	268.0	448.0	0.00	0.00	1.10	477.0	329.0	575.0
44N6E	6	12.5			384.0			2.10			445.5		
44N7E	5	7.5			352.0			0.80			412.0		
44N8E	14	9.5	0.00	120.0	344.0	208.0	563.0	0.50	0.00	2.10	420.0	248.8	726.8
44N9E	9	4.0	0.00	14.0	400.0	172.0	436.0	0.80	0.40	2.00	430.0	312.0	459.0
44N10E	6	3.5			330.0			0.05			673.0		
44N11E	5	7.0			388.0			2.20			733.0		
44N12E	1	8.0			152.0			0.00			440.0		
45N5E	2	28.5			454.4			2.55			544.5		
45N6E	2	1.0			308.0			1.95			383.0		
45N7E	5	3.0			328.0			0.85			360.0		
45N8E	7	16.0			406.0			1.70			470.0		
45N9E	14	4.0	0.50	13.5	392.0	278.0	437.5	1.40	0.15	2.25	432.5	313.5	502.0
45N10E	9	3.0	0.00	6.0	244.0	181.0	336.0	0.40	0.00	0.80	360.0	330.0	498.0
45N11E	5	6.0			238.0			0.30			434.0		
45N12E	3	2.0			112.0			0.60			239.0		
46N5E	8	19.5			399.0			1.50			444.5		
46N6E	3	0.0			158.0			0.90			356.0		
46N7E	1	0.0			132.0			4.80			218.0		
46N8E	6	2.0			344.0			0.25			373.5		
46N9E	5	5.0			330.5			0.40			361.0		
46N10E	4	4.5			216.0			0.55			364.0		
46N11E	1	23.0			68.0			5.40			359.0		
46N12E	11	6.0	4.20	38.00	238.0	104.4	664.0	0.40	0.02	1.12	347.0	285.0	835.6

Table 60. Summary of Chemical Quality of Water from Shallow Dolomite Wells

(Chemical constituents in milligrams per liter)

Township	Number of observations	Chlorides' Median	Chlorides' Range 10%	Chlorides' Range 90%	Hardness Median	Hardness Range 10%	Hardness Range 90%	Iron Median	Iron Range 10%	Iron Range 90%	Total dissolved minerals Median	Total dissolved minerals Range 10%	Total dissolved minerals Range 90%
32N9E	6	45.0			49.0			0.05			708.5		
32N10E	4	170.0			175.0			0.05			1091.5		
33N9E	6	112.0			46.0			0.05			1035.0		
33N10E	1	112.0			14.0			0.60			1120.0		
33N12E	7	4.0			869.5			0.80			1407.0		
33N13E	2	4.5			531.0			1.15			784.0		
33N14E	3	2.0			544.0			0.40			852.5		
33N15E	1	3.0			132.0			0.00			361.0		
34N10E	1	6.0			260.0			0.60			390.0		
34N11E	2	9.5			450.0			0.00			555.0		
34N13E	18	1.5	1.0	5.7	469.0	389.9	661.5	0.71	0.28	7.50	566.5	437.2	902.3
34N14E	25	4.0	1.0	34.0	408.0	364.0	488.0	0.40	0.10	1.68	457.5	400.0	621.0
34N15E	2	5.0			471.0			0.15			672.0		
35N9E	9	115.0			410.0			0.05			531.0		
35N10E	21	17.0	3.0	100.6	512.0	416.8	1242.0	0.10	0.00	1.78	624.0	520.2	1516.4
35N11E	13	3.0	0.00	95.2	588.0	488.8	946.0	1.00	0.00	3.20	665.0	550.6	1407.2
35N12E	12	2.5	0.30	16.4	543.5	389.2	938.0	0.80	0.13	2.76	663.0	489.5	1261.4
35N13E	41	5.0	3.0	50.2	600.0	496.8	928.8	0.50	0.10	2.38	861.0	664.2	1188.8
35N14E	72	30.0	4.0	129.8	600.0	441.2	1063.1	0.77	0.20	1.97	812.0	531.2	1460.8
35N15E	5	7.0			36.0			1.10			617.0		
36N9E	8	17.0			390.5			0.25			471.0		
36N10E	11	23.0	11.6	114.0	476.0	384.0	690.6	0.50	0.00	3.28	590.0	476.8	821.2
36N11E	12	3.0	0.30	45.2	526.0	364.8	981.0	1.10	0.23	5.03	639.5	390.5	1286.9
36N12E	20	3.0	1.00	50.0	506.0	374.0	830.0	0.75	0.10	2.28	667.5	441.2	1114.4
36N13E	30	4.0	1.00	42.9	485.5	416.6	689.8	0.75	0.10	2.73	666.0	501.8	901.5
36N14E	11	120.0	4.80	428.0	672.0	63.2	866.0	0.70	0.19	7.48	1033.0	350.4	1697.8
36N15E	3	68.0			136.0			21.00			456.0		
37N9E	2	23.0			471.0			0.15			561.5		
37N10E	19	21.0	4.00	49.0	442.0	352.0	530.0	0.60	0.00	1.50	555.0	423.0	683.0
37N11E	4	44.0			486.0			0.90			631.0		
37N12E	3	2.0			548.0			0.80			594.0		
37N13E	3	38.0			780.0			0.50			1197.0		
37N14E	5	33.0			134.0			0.70			443.0		
37N15E	2	221.0			404.5			3.50			1223.0		
38N5E	1	7.0			340.0			0.50			472.0		
38N7E	7	8.0			500.0			0.60			561.0		
38N8E	20	4.0	0.10	41.4	400.0	75.2	536.8	0.70	0.01	2.20	502.0	342.0	637.0
38N9E	25	11.0	3.00	41.2	380.0	274.8	446.8	0.30	0.10	1.94	460.0	374.4	550.2
38N10E	50	37.0	11.00	82.9	441.0	380.4	591.8	0.20		1.90	554.0	444.6	768.1
38N11E	71	15.0	2.20	65.8	523.0	463.8	706.8	1.20	0.10	2.30	682.0	558.2	945.6
38N12E	129	230.0	23.0	810.0	840.0	595.0		1.80	0.50	7.00	1431.5	876.7	2099.6
38N13E	1	35.0			128.0			0.00			352.0		
38N14E	1	18.0			56.0			0.10			167.0		
39N7E	1	11.0			574.0			9.60			613.0		
39N8E	3	6.0			360.0			0.90			452.0		
39N9E	25	23.0	4.6	73.2	428.0	336.0	653.5	0.60	0.20	2.60	519.0	393.2	824.8
39N10E	38	21.5	7.8	61.0	426.0	203.2	576.8	0.86	0.10	1.30	575.0	472.2	752.8
39N11E	31	36.0	5.2	164.0	610.0	460.8	889.2	1.45	0.20	3.92	721.0	567.4	1221.6
39N12E	18	58.5	40.6	79.7	705.0	464.0	752.0	1.50	0.79	3.48	905.0	653.8	994.30
40N6E	1	3.00			196.0			0.80			321.0		
4ON7E	2	2.5			314.0			1.75			363.0		
40N8E	6	9.5			365.0			0.20			441.0		
40N9E	3	7.0			380.0			0.00			456.0		
40N10E	29	8.0	0.90	95.2	330.0	113.8	488.2	0.90	0.10	4.20	480.0	410.0	914.0
40N11E	23	10.0	5.0	28.8	482.5	389.1	725.5	0.80	0.14	2.84	678.0	449.0	1185.7
40N12E	7	14.0			350.0			0.30			587.0		
4ON13E	3	16.0			24.0			1.00			206.0		
41N6E	2	0.50			305.0			4.95			421.0		
41N8E	25	17.0	3.00	18.5	337.0	295.2	374.8	0.45	0.00	2.86	404.0	356.6	445.2
41N9E	5	10.0			458.0			2.10			512.0		
41N10E	27	4.0	0.80	13.6	350.0	213.6	544.0	0.60	0.20	2.68	703.0	455.2	903.8
41N11E	3	15.0			463.0			0.50			720.0		
41N13E	1	3850.0			5800.0			20.00			6849.0		

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Table 60. (Concluded)

Township	Number of observations	Chlorides			Hardness			Iron			Total dissolved minerals		
		Median	Range 10%	Range 90%	Median	Range 10%	Range 90%	Median	Range 10%	Range 90%	Median	Range 10%	Range 90%
42N7E	3	1.0			352.0			3.40			567.0		
42N8E	7	3.0			368.0			1.00			402.0		
42N9E	7	7.0			366.0			0.20			468.0		
42N10E	13	2.0	2.0	47.4	416.0	340.0	448.8	0.30	0.08	1.64	734.0	682.0	766.0
42N11E	9	16.0	6.0	40.0	347.0	182.0	821.0	0.30	0.10	0.70	570.0	482.0	1236.0
42N12E	8	8.0			216.0			0.25			439.0		
43N5E	1	96.0			464.0			1.40			485.0		
43N6E	6	1.0			315.0			1.05			368.5		
43N7E	3	4.0			27.0			0.40			390.0		
43N8E	14	5.0	2.0	35.5	302.0	112.5	393.0	0.45	0.10	2.00	386.0	325.0	474.5
43N9E	3	3.0			287.0			0.00			406.0		
43N10E	16	5.5	1.7	12.9	710.0	323.2	922.0	0.20	0.00	1.67	1147.5	489.4	1579.4
43N11E	12	10.0	5.3	24.0	446.0	263.2	501.4	0.10	0.00	5.60	952.5	531.8	1127.0
43N12E	2	2.5			306.0			0.50			636.5		
44N5E	3	1.0			402.0			1.80			439.0		
44N6E	1	0.0			274.0			1.40			439.0		
44N7E	2	2.50			155.0			0.95			362.0		
44N8E	6	4.0			249.0			2.40			305.0		
44N9E	4	6.5			388.0			0.45			436.5		
44N10E	3	5.0			329.0			0.10			687.5		
44N11E	33	12.0	4.0	24.0	386.0	290.4	433.6	0.20	0.04	0.78	705.0	574.4	822.0
44N12E	4	14.5			164.0			0.50			448.0		
45N6E	1	1.0			344.0			2.10			435.0		
45N7E	2	57.5			248.0			0.50			442.0		
45N8E	1	2.0			260.0			0.70			310.0		
45N9E	3	1.0			292.0			0.25			330.0		
45N10E	11	5.0	4.0	10.8	160.0	140.8	332.8	0.01	0.00	1.24	390.0	314.0	459.6
45N11E	3	8.0			170.0			0.30			368.0		
45N12E	2	366.0			103.0			0.325			1402.5		
46N5E	1	2.0			352.0			2.10			393.0		
46N6E	3	0.0			272.0			4.10			419.0		
46N7E	1	10.0			456.0			0.00			604.0		
46N10E	3	9.0			21.0			1.40			222.0		
46N11E	1	7.0			52.0			0.00			224.0		
46N12E	3	14.0			84.0			0.05			426.0		

Table 61. Summary of Chemical Quality of Water from Sandstone Wells

(Chemical constituents in milligrams per liter)

Township	Number of observations	Chlorides			Hardness			Iron			Total dissolved minerals		
		Median	Range 10%	Range 90%	Median	Range 10%	Range 90%	Median	Range 10%	Range 90%	Median	Range 10%	Range 90%
32N9E	4	266.0			392.0			0.10			1210.5		
32N10E	3	292.0			416.0			0.80			1441.0		
33N9E	6	250.0			411.0			0.15			1116.5		
34N9E	6	84.5			265.0			0.65			640.0		
34N10E	2	39.0			261.0			0.15			532.5		
35N9E	8	29.0			209.0			0.15			504.0		
35N10E	9	91.0	32.0	130.0	300.0	108.0	508.0	0.30	0.00	0.70	610.0	516.0	685.0
35N11E	1	6.0			548.0			2.30			794.0		
35N13E	3	165.0			568.0			0.20			1276.0		
35N14E	19	260.0	13.0	340.0	744.0	428.0	840.0	0.80	0.10	1.60	1770.0	558.0	1994.0
35N15E	1	345.0			860.0			0.90			2121.0		
36N9E	3	14.0			220.0			0.10			365.0		
36N10E	19	36.0	8.0	134.0	238.0	136.0	744.0	0.10	0.00	1.30	536.0	413.0	865.0
36N12E	2	216.5			445.0			0.30			1042.5		
36N13E	10	95.5	3.0	205.5	477.0	464.3	707.4	0.30	0.0	1.28	919.0	487.3	1560.2
36N14E	7	275.0			748.0			0.40			1750.0		
37N10E	6	30.0			226.5			0.20			455.0		
37N11E	9	100.0	1.0	140.0	176.0	140.0	600.0	0.40	0.00	4.80	618.0	440.0	860.0
37N12E	2	73.5			275.0			0.10			460.5		
37N13E	1	13.0			544.0			0.40			732.0		
37N14E	3	230.0			750.0			0.40			1676.0		

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Table 61. (Concluded)

Township	Number of observations	Chlorides Median	Chlorides Range 10%	Chlorides Range 90%	Hardness Median	Hardness Range 10%	Hardness Range 90%	Iron Median	Iron Range 10%	Iron Range 90%	Total dissolved minerals Median	Total dissolved minerals Range 10%	Total dissolved minerals Range 90%
38N7E	4	6.0			254.0			0.20			338.5		
38N8E	49	16.0	6.0	330.0	248.0	227.0	356.0	0.30	0.00	2.30	386.0	333.0	896.0
38N9E	4	15.0			259.0			0.55			449.5		
38N10E	2	17.5			274.0			0.30			460.5		
38N11E	9	23.0	18.0	50.0	280.0	260.0	488.0	0.30	0.10	3.10	527.0	445.0	628.0
38N12E	21	80.0	26.0	138.0	296.0	191.2	510.4	0.30	0.00	2.42	632.0	482.6	878.0
38N13E	5	116.0			424.0			0.30			1008.0		
38N14E	5	585.0			710.0			0.50			1983.0		
39N7E	2	6.0			234.0			0.15			335.0		
39N8E	13	17.0	4.0	69.6	230.0	217.6	256.0	0.10	0.00	0.50	335.0	306.8	406.4
39N9E	8	14.0			287.0			0.20			403.5		
39N10E	1	25.0			220.0			0.10			490.0		
39N11E	17	24.0	16.0	187.6	284.0	204.0	344.0	0.30	0.08	2.0	497.0	409.6	793.2
39N12E	62	47.5	29.0	288.0	310.0	142.6	668.0	0.40	0.10	2.5	671.0	479.3	948.5
39N13E	4	156.0			400.0			0.25			845.5		
39N14E	2	247.5			725.0			1.00			1483.5		
40N6E	1	27.0			440.0			0.10			533.0		
40N7E	4	2.5			227.5			0.05			318.5		
40N8E	19	18.0	4.0	450.0	296.0	234.0	502.0	0.30	0.00	1.50	429.0	313.0	1062.0
40N10E	4	14.5			293.0			0.20			637.5		
40N11E	27	25.0	10.8	34.2	324.0	245.6	350.8	0.10	0.00	1.38	540.0	398.0	604.6
40N12E	5	32.0			426.0			0.30			704.0		
40N13E	2	190.0			428.0			0.40			1059.5		
41N6E	1	2.0			292.0			0.50			356.0		
41N7E	2	1.5			225.0			0.35			332.5		
41N8E	17	10.0	3.0	68.8	252.0	236.8	434.0	0.10	0.00	0.52	333.0	271.4	572.8
41N9E	5	5.0			192.0			0.00			334.0		
41N10E	17	7.0	3.0	17.6	242.0	227.1	282.7	0.40	0.00	1.54	374.0	300.8	486.8
41N11E	30	21.5	13.0	31.8	321.0	249.0	471.0	0.25	0.03	1.46	508.0	395.5	669.8
41N12E	13	42.0	13.2	1909.0	338.0	281.2	444.2	0.30	0.10	1.76	575.0	466.9	1170.0
41N13E	4	38.5			404.0			0.40			742.5		
42N6E	1	3.0			243.0			0.10			246.0		
42N8E	7	4.0			242.0			0.10			328.0		
42N10E	26	11.0	6.0	18.3	263.0	233.8	323.6	0.30	0.00	1.22	403.5	341.7	525.1
42N11E	40	16.5	11.0	32.9	288.0	258.4	346.9	0.30	0.10	0.80	448.0	401.2	626.6
42N12E	22	29.0	17.3	49.6	364.0	322.4	383.1	0.40	0.00	1.31	609.5	498.3	715.9
43N5E	1	12.0			198.0			1.20			273.0		
43N8E	13	3.0	0.40	12.0	220.0	198.6	324.0	0.10	0.00	1.49	288.0	252.2	379.2
43N10E	10	9.0	8.0	18.5	260.0	182.0	302.0	0.10	0.01	0.39	358.0	326.7	495.1
43N11E	6	28.5			320.0			0.60			564.0		
43N12E	5	17.0			356.0			0.50			553.0		
44N6E	1	0.0			338.0			4.30			396.0		
44N8E	5	3.0			236.0			0.10			311.0		
44N9E	1	15.0			234.0			0.20			337.0		
44N10E	3	9.0			276.0			0.00			394.0		
44N11E	14	20.5	5.5	92.5	300.0	222.8	330.8	0.35	0.05	0.70	448.0	349.5	723.0
44N12E	1	15.0			376.0			0.60			554.0		
45N8E	3	1.0			216.0			0.10			268.0		
45N9E	3	5.0			247.0			0.20			336.0		
45N10E	6	6.0			242.0			0.65			325.5		
45N11E	9	10.0			306.0			0.90			432.0		
45N12E	3	19.0			348.0			1.20			530.0		
46N12E	3	9.0			388.0			0.60			533.0		

Depending on the intended use of these streams, some of the noted excesses might have more significant effects than others. For instance, iron and manganese can be reduced to acceptable levels in finished, or treated, water in domestic supplies if adequate treatment methods are employed. From the viewpoint of the consumer, the effects of excessive iron and manganese concentrations are probably more economic than physiologic. On the other hand, high nitrate and total dissolved solids concentrations are more apt to cause health problems and are much more costly and difficult to remove.

Biological Quality of Surface Water

Data on dissolved oxygen concentrations and fecal coliform counts were taken from the Illinois Environmental Protection Agency's *Water Quality Network – 1974 – Summary of Data.* These are shown in table 65 and are for loca-

Table 62. Number of Public Water Supplies That Exceed Given Concentrations for Selected Chemical Constituents

Constituent	*Given concentration (mg/l)*	*Cook*	*Du Page*	*Kane*	*Lake*	*McHenry*	*Will*
Iron	0.8	47	38	21	16	25	21
Chloride	250	11	2	2	0	0	1
Sulfate	250	22	11	0	9	1	9
Total dissolved minerals	1000	20	7	2	5	0	4
Fluoride	1.5	11	8	3	1	4	8
Nitrate	45	0	0	0	0	0	0
Manganese	0.1	12	15	4	6	6	11
Ammonia	0.5	36	28	18	21	15	22
Zinc	7.5	0	0	0	0	0	0

Table 63. IPCB Standards and USEPA Water Quality Criteria

(Chemical constituents in milligrams per liter)

Parameter	*IPCB* General standards	*IPCB* Water supply and food processing	*USEPA* Water quality criteria
Iron	1.0	0.3	0.3
Manganese	1.0	0.05	0.05
Ammonium	1.5		
Fluoride	1.4		
Boron	1.0		
Nitrate		10.0	10.0
Chloride	500	250	
Sulfate	500	250	
Total dissolved solids	1000	500	
Barium	5.0	1.0	
Cadmium	0.05	0.01	0.01
Chromium	1.05		0.05
Copper	0.02		1.0
Lead	0.1	0.05	0.05
Nickel	1.0		0.1
Zinc	1.0		
Temperature (degrees F)	90 (April to November) 60 (December to March)		

tions near five of the six stations for which there were mineral quality analyses from 1971 to 1975.

It should be noted that the largest number of analyses at any of the five stations was nine (at Du Page River-Shorewood). This paucity of data diminishes considerably their usefulness for evaluation of bacteriological quality. Rule 203 (9d) of the IPCB Rules and Regulations states that "Dissolved oxygen shall not be less than 6.0 mg/l during at least 16 hours of any 24-hour period, nor less than 5.0 mg/l at any time." Rule 203(g) states "Based on a minimum of five samples taken over not more than a 30-day period, fecal coliforms shall not exceed a geometric mean of 200 per 100 ml, nor shall more than 10% of the samples during any 30-day period exceed 400 per 100 ml."

Comparing the data with these two rules demonstrates that there are presently insufficient data available with which to make a reasonably accurate evaluation of biological quality, and points to the need for obtaining additional data if such evaluations are deemed necessary.

Table 64. Standards Exceeded in Northeastern Illinois Streams

(Standards in milligrams per liter)

Stream station	*Standard value*		*Percentile exceeding standard*	*Percentile value*	*Total number of observations*
Coon Creek at Riley	Iron	0.3	10	0.4	49
	Manganese	0.05	50	0.08	49
	Nitrate	10.0	50	18.7	49
	Total dissolved solids	500			
Kankakee River at Momence	Iron	0.3	10	0.61	50
	Manganese	0.05	10	0.06	50
	Nitrate	10.0	90	15.4	50
Des Plaines River at Des Plaines	Iron	0.3	10	0.4	49
	Manganese	0.05	50	0.1	49
	Nitrate	10.0	90	17.6	49
	Total dissolved solids	500	90	78.9	49
Du Page River near Shorewood	Iron	0.3	10	0.4	49
	Manganese	0.05	50	0.09	49
	Nitrate	10.0	10	14.9	49
	Total dissolved solids	500	10	497	49
			50	695	
Fox River at Algonquin	Iron	0.3	50	0.7	49
	Manganese	0.05	50	0.05	49
			90	0.1	
	Nitrate	10.1	90	10.8	49
	Total dissolved solids	500	90	512	49
Fox River at Batavia	Iron	0.3	10	0.36	45
	Manganese	0.05	50	0.07	45
	Nitrate	10.0	90	10.2	45

Table 65. Summary of IEPA Data, 1974

Station and location	*Field dissolved oxygen, mg/l**					*Fecal coliform – number/100***				
	Number of analyses	*Max*	*Min*	*Mean*	*Median*	*Number of analyses*	*Max*	*Min*	*Mean*	*Median*
Fox River, (Route 62, Algonquin Road Bridge)	6	17.9	4.7	11.4	11.5	6	200	10	62	100
Fox River, (Route 64, Main Street Bridge, St. Charles)	7	14.1	9.2	12.0	12.0	7	600	30	178	200
Des Plaines River, (Route 62, Oakton Street Bridge)	8	13.0	6.3	10.0	10.3	8	62,000	1100	6380	5500
Kankakee River, (Route 17, Bridge 4 miles east of Kankakee)	8	11.8	6.9	9.2	9.2	8	200,000	100	688	410
Du Page River, (Township Road Bridge, 1 mile south of Shorewood)	9	13.5	7.7	11.3	11.8	9	5,200	100	607	400

*IPCB rule is not less than 5.0 mg/l at any time
**IPCB rule is a geometric mean not exceeding 200/100 ml for five samples in a 30-day period
NOTE: Mean values are arithmetic mean except for fecal coliform which is geometric

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