Illinois Institute of Natural Resources

State Water Survey Division

ADEQUACY AND ECONOMICS OF WATER SUPPLY IN NORTHEASTERN ILLINOIS: PROPOSED GROUNDWATER AND REGIONAL SURFACE WATER SYSTEMS, 1985 - 2010

by

Krishan P. Singh and J. Rodger Adams

Urbana, Illinois
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SUMMARY

This three-year study was a cooperative effort between the State Water Survey and the Division of Water Resources. Its purpose is to plan for the optimal use of the available groundwater and surface water resources in northeastern Illinois for an adequate and dependable water supply to all towns in Cook, Du Page, Kane, Lake, McHenry, and Will Counties in future years up to 2010. Information on municipal water demands, inventory of existing wells, estimates of well depths and capacities for each aquifer in the townships comprising the six counties, and cost functions (in July 1976 dollars) for the several components of water supply systems were developed during the first year. In the second year, the study focused on refining the cost functions, developing costs for meeting radioactivity standards for drinking water, determining the cost and adequacy of groundwater to meet municipal water demands through 2010, assessing the availability of river water, investigating the feasibility of conjunctive use of groundwater and surface water, and analyzing various combinations of towns (without adequate groundwater supply from shallow aquifers) that six regional supply systems can serve with water from the rivers, Lake Michigan, or Chicago. During the third year, the cost functions were updated to July 1980 dollars, the costs of groundwater supply and the six regional supply systems were recomputed with the updated cost functions, and at least one water supply system was dynamically optimized for each of the six regional systems analyzed the previous year.

Equations to predict water demands from a town's population and manufacturing employment were developed for each of the six counties. Future water demands were projected using the appropriate equation with a multiplier to account for each town's variation from the average regression equation. The total projected water demand increases from 1272 mgd in 1980 to 1360 mgd in 2010 for the 273 towns in northeastern Illinois. About 300,000 people live in rural areas and can obtain groundwater from individual or subdivision wells. This use totals between 20 and 30 mgd in the six counties. The self-supplied industrial water is about 45 mgd, out of which about 37 mgd is pumped from the deep sandstone wells.

The potential yield of the shallow aquifers, Silurian dolomite and sand and gravel, is between 450 and 495 mgd, depending on whether the Silurian dolomite or the sand and gravel is the aquifer selected for primary development. The deep sandstone aquifer has a practical sustained yield of 46 to 65 mgd. Water supplies of up to 32 mgd from the Fox River and up to 100 mgd from the Kankakee River can be developed if reservoir

storage is provided to meet demands, wholly or partially, during periods of low river flow. The 3200 cfs diversion from Lake Michigan was fully accounted for in 1970 by public water supply, storm runoff, and diversions into the Sanitary and Ship Canal. Implementation of instream aeration by 1985 and completion of phase I of the Tunnel and Reservoir Plan in 1986 will make additional water available to meet public water demands.

Cost functions, in terms of July 1980 dollars, were developed for wells, well pumps, reservoirs, water treatment, pipelines, and pipeline pumping stations. The pumping capacity in the pipeline conveyance networks was designed to meet 1.8 times the average demand. Any extra storage needed to meet hourly demand variations will be provided by the user entities or towns according to their particular needs. The increase in cost of water treatment to reduce radioactivity was derived because water from many deep sandstone wells contains alpha radioactivity above the permissible limit. Groundwater costs were computed for the 177 towns which do not presently use water from Lake Michigan or the city of Chicago. These costs include wells and pumps, water treatment, and conveyance to one or two distribution storage facilities.

Six regional systems to meet the water demands of towns with inadequate shallow groundwater supplies were investigated. Preliminary analyses considered a wide range of system configurations, with considerable overlap of some systems. Conjunctive use of groundwater was a key part of the Fox River system and an option on other systems. At least one of the configurations for each system was selected for optimization over the period from 1985 to 2010. The configurations were selected on the basis of the preliminary analyses and discussions with Division of Water Resources staff. Costs were computed with 0 and 5% inflation rates beginning in July 1980 to determine the effect of inflation on the optimal system design. Capital requirements include capital expenditures, capitalized interest during construction, and 20% for contingencies. An interest rate of 8% was used.

The optimal systems and their 2010 demands are: Lake County system supplying 17 towns, 27.80 mgd; Southern Cook County system supplying 8 towns, 19.98 mgd; Du Page County system supplying 19 towns, 77.55 mgd; Northwestern Cook County system supplying 14 towns, 61.59 mgd; Fox River system supplying 8 towns, 35.61 mgd; and Kankakee River system supply 10 towns, 25.33 mgd. Except for the Fox River system, conjunctive use is not economical. Directly supplied industries will continue to use 35 to 40 mgd of groundwater from the deep sandstone aquifer. With the use of groundwater from the shallow aquifer and the regional surface water supply systems outlined in this report, municipal use of groundwater from the deep sandstone aquifer will be between 20 and 35 mgd. Thus, the total use of water from the deep sandstone aquifer may be between 55 and 75 mgd. The total demand to be met from Lake Michigan increases from 1190 mgd in 1985 to 1213 mgd in 2010. Assuming the completion of phase I of the Tunnel and Reservoir Plan in 1986, there is enough Lake Michigan water available to meet these demands.

INTRODUCTION

Northeastern Illinois comprises six counties (Cook, DuPage, Kane, McHenry, Lake, and Will) with a population of about 7 million and a land area of 3714 square miles. Municipal and industrial water supplies are presently obtained from either Lake Michigan or groundwater.

Northeastern Illinois is one of the most favorable areas in the state for groundwater development. It is underlain at depths of 500 feet or more by sandstone aquifers that have been used for water supply for over 100 years. At lesser depths, the area is underlain by sand and gravel and creviced dolomite aquifers that are good local sources of groundwater. Water from Lake Michigan is used by about 100 towns including Chicago. The Fox and Kankakee Rivers are potential sources of water for municipal use.

Background

Since the beginning of diversion in 1900, several states have contested the legality of the diversion of lake water for navigation, sewage dilution, and water supply by the State of Illinois and its political subdivisions. On June 12, 1967, the U.S. Supreme Court entered a decree which enjoins the State of Illinois from diverting water from Lake Michigan in excess of an annual average flow of 3200 cubic feet per second (cfs) or 2068 million gallons per day (mgd), and requires the state to apportion the flow among its political subdivisions for domestic use and direct diversion into the Sanitary and Ship Canal. The Division of Water Resources (DOWR), Illinois Department of Transportation, held hearings in Chicago during 1975 and 1976 to obtain information about the available water resources and projected water demands of the towns and other applicants for an allocation of Lake Michigan water. The Division of Water Resources (1977) issued an allocation of the 3200 cfs in 1977 as a result of these hearings.

The State Water Survey presented testimony on the adequacy of surface waters other than Lake Michigan, and groundwater to meet water demands on a township basis. This testimony was published as Report of Investigation 83 (Schicht, Adams, and Stall, 1976). Groundwater demands were estimated with population and manufacturing employment data provided by the Northeastern Illinois Planning Commission (NIPC) in 1974. Water demand and the unit cost in 1974 dollars of groundwater were computed for each township outside of Chicago. Unit costs of water supply from the Fox and Kankakee Rivers, groundwater from shallow aquifers in nearby townships, and Lake Michigan water purchased from the city of Chicago were given as alternatives to local groundwater development. Other water sources including artifical recharge, precipitation augmentation over Lake Michigan, and reduction in direct diversion as a result of the Tunnel and Reservoir Plan (TARP) were also considered. The report included a summary of water quality data and a discussion of the problems with commingling Lake Michigan water and groundwater. Townships in which groundwater availability from the deep sandstone aquifer was predicted to drop significantly by 2010 were identified.

Preliminary analyses of regional systems supplying lake or river water were conducted by Keifer and Associates (1977a). Individual town water demands were computed from 1980 to 2010 and compared with local groundwater resources. Technical planning policies, based on those proposed by NIPC (1974), were used to select towns (unable to meet projected water demands with groundwater only) for each of the regional supply systems. The Fox and Kankakee River water supply systems as well as the Lake Michigan water supply systems were proposed. The costs were calculated in 1976 dollars and included provision for engineering and contingencies.

Three-Year Study Plan

A system study was conceived in July 1976 for optimal development and use of the available groundwater and surface water resources to ensure an adequate and dependable water supply to all the users in the six counties in future years up to 2010. The study is a cooperative effort between the Division of Water Resources and the State Water Survey. The broad objectives achieved in each of the three years of the study plan are given below.

The first year was spent developing data inputs such as municipal water requirements from 1980 through 2010; inventorying existing wells in sand and gravel, dolomite, and deep sandstone aquifers; and estimating expected well capacities and depths in the various townships making up the six counties. Cost functions for wells, pumps, water treatment plants, and water transport were developed for use in economic analyses of alternative water supplies.

Investigations in the second year focused on: 1) refinement of cost functions and development of costs for meeting standards for radioactivity in drinking water; 2) the adequacy of groundwater for meeting water demands through 2010 and the associated costs; 3) availability of water from the Fox, DuPage, and Kankakee Rivers; 4) the optimal combinations of towns that can be served with water from the rivers, Lake Michigan, or the city of Chicago; 5) the size and cost of reservoirs required by the river water supply systems; 6) the feasibility of conjunctive use of groundwater and surface water.

The third-year study produced dynamically optimized systems to meet water demands from 1985 to 2010 for each of the six regional systems investigated during the previous year. Water demands were computed with town populations revised by NIPC to be compatible with the projected county populations developed by the Illinois Bureau of the Budget (IBOB) in 1977. Costs were computed in July 1980 dollars and include contingencies, interest, and inflation factors.

Project Highlights

The information in this final report is a concise description of the investigations conducted throughout the three-year project. Highlights from each subject investigated are presented here to give the reader a quick overview and to allow him the option of delving directly into the sections of immediate interest.

Water Demands

Water use, population, and manufacturing employment data for 1970 were used to develop water demand predictor equations for each of the six counties. In all cases, the multiple correlation coefficient was greater than 0.992. Town water demands for future years were projected using the appropriate regression equation and a multiplier to account for each town's variation from the average relation. The populations used are in agreement with the IBOB 1977 county population projections. The total water demand of the 273 towns in the six counties increases from 1272 mgd in 1980 to 1360 mgd in 2010.

Water Availability

The water resources of the area include groundwater in several aquifers and surface water in rivers and Lake Michigan.

Groundwater. The potential yield of the shallow aquifers, both sand and gravel and Silurian dolomite, were determined. Potential yield in each township was computed with primary development of either the sand and gravel or the dolomite aquifer. Twenty-two townships were identified in which the potential yield is significantly higher with primary development of sand and gravel aquifer. The total potential yield of the shallow aquifers is between 450 and 495 mgd, depending on the aquifer selected for primary development in each township.

River Water. The quantity and quality of water available from the DuPage, Fox, and Kankakee Rivers have been assessed for their possible development as sources of water supply. Curves have been developed delineating the relation between river flow, frequency, and deficit duration in months, for each of the three rivers. For developing a supply of about 32 mgd from the Fox River at Algonquin, the deficit duration in months varies from 1.8 to 3.9 months with drought recurrence intervals varying from 10 to 40 years. From the Kankakee River at Wilmington, about 100 mgd supply can be developed with deficit duration varying from 1.6 to 4.1 months.

About 6 to 9 mgd can be developed from the DuPage River. The DuPage River has not been considered as a supply source because of poor water quality, small quantity, and local opposition to such use.

Lake Water. The Lake Michigan diversion of 3200 cfs was fully accounted for in 1970 by public water supply, lockage and leakage, navigation make-up water (it equals the difference between the amount of water released from the Canal at Lockport in anticipation of a storm and the actual run-off from that storm, if the actual runoff is less than that expected), discretionary diversion, and storm runoff. This implies that no water is available to meet increased future demands of current users or for allocation to new users. However, with partial implementation of instream aeration in 1979, discretionary diversion has been somewhat reduced. The completion of TARP phase I in 1986 will reduce discretionary diversion and navigation makeup water by 287 cfs. Presumably this 387 cfs (250 mgd) will be available to meet public water supply demands. If the present request to change the storm runoff accounting procedure is accepted by the U.S. Supreme Court, 150 cfs or more could be available for other purposes such as public water supply (Keifer, 1977b). The reduction in projected future population by the IBOB in 1977 has lowered the future water demand projections.

Cost of System Components

The main components of a regional system are 1) the raw water supply from well fields or withdrawal from a river or lake, 2) the treatment plant, and 3) the pipeline network for delivering water to a central point in each town on the system. Each of these components requires cost functions for its various subcomponents. These cost functions were developed in terms of July 1980 dollars by projecting the trends indicated by Handy-Whitman Indexes (Whitman-Requardt, 1978). The increase in treatment cost to reduce radioactivity in groundwater from the deep sandstone aquifer to the permissible level and the increase in disposal cost of the resulting sludge or brine containing radioactivity were also derived.

Capital requirements include capital expenditures with or without inflation, interest during construction, and 20% for contingencies. Operation, maintenance, and repair (OM&R) costs are computed for each system component with or without inflation. An interest rate of 8% is assumed. Costs for the optimal systems are computed for both 0 and 5% annual inflation rates.

Cost of Groundwater

The unit cost of developing local groundwater supplies to meet the 2010 demand of each of the 177 user entities, not using water from Lake Michigan or the city of Chicago, was computed in July 1980 dollars. The required number of wells was calculated on the basis of meeting 1.5 times the average demand, pumping 18 hours per day, and considering the highest capacity well as a standby. The cheaper of the lime-soda or ion-exchange softening was considered for the treatment plant. The cost of water at the well was calculated on a township basis using the potential yield and average well depth and capacity in that township. New wells in the deep sandstone aquifer were considered only where present or future water demands could not be met from the shallow aquifers alone.

Regional Systems

Six regional systems providing surface water to user entities, mostly with inadequate shallow aquifer resources, were investigated. These supply systems are: Lake County, southern Cook County, DuPage County, northwestern Cook County, Fox River, and Kankakee River. Preliminary analyses considered a wide range of system configurations, serving from a small to a large number of towns, and with considerable overlap of some configurations for three of the six systems. Conjunctive use of groundwater was a key part of the Fox River system, and it was considered as an option on several other systems with towns which have or can develop shallow aquifer well fields. The unit costs, towns served, and system demands indicate the more economical system configurations as well as the economic feasibility of using surface water resources with or without conjunctive use of groundwater.

One or more of the system configurations for each of the six regional systems were selected for optimization over the 25-year period from 1985 to 2010. The selected configurations were identified as desirable by the preliminary analyses, the Division of Water Resources, or the county officials. Staged construction of treatment plants and pipeline pumping capacity was included in these analyses. Costs were computed with 0 and 5% inflation rates, effective July 1980, to assess the effect of inflation on the optimal system design. The final choice between direct supply of water from Lake Michigan and purchase of water from the city of Chicago for four of the six systems will depend on the price charged by Chicago.

Acknowledgments

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MUNICIPAL WATER REQUIREMENTS

Various municipalities in the six-county region satisfy residential, commercial, and industrial water demands from groundwater and/or Lake Michigan water (water pumped directly from the lake, or treated water purchased from the city of Chicago). Water use is measured at the treatment plant for directly diverted lake water or at the master meters installed on the inflow lines from the supplier. Well water use is generally measured at the well head or at the water treatment plant. Therefore, the average daily pumpage or use throughout the year, in million gallons per day (mgd), generally refers to the raw water entering the treatment plant (with the exception of towns using treated water from the city of Chicago) and includes the actual domestic, commercial, and industrial water use, water used in firefighting and public purposes such as for fountains and parks, and water lost in the treatment plant and through leakage in the distribution system. Unaccounted-for water equals the amount of water pumped or entering the treatment plant minus the amount of water actually used or billed on the basis of metered supplies. The unaccounted-for water as a percent of total water pumped varies; the higher the percentage the more inefficient the water system. A figure of 10 to 15 percent or less is deemed to be satisfactory (Howe, 1971; Keller, 1976). Cost of leak detection surveys and remedial measures to effect a reduction of about 10 in the percent unaccounted-for water is usually compensated by savings on water over a 6-month period. The higher the percent unaccounted-for water, the more pressing and economical are the remedial measures to bring it within acceptable limits.

Most of the towns have a computerized billing system and they can get information on total water billed and pumped in a year by a small change in the computer program. Some of the towns may be doing so already. Such information not only keeps the water authorities informed about their system's efficiency but also leads to better management and use of the limited water resources of the region.

Water Use

The following sources of data were used to determine the average water use in the year 1970 for 214 towns in the six counties.

1) Opinion and Order: In the Matter of Lake Michigan Water Allocation, LMO 77-1. Division of Water Resources, Illinois Department of Transportation, April 1977.
2) Public water supply data sheets from the Division of Public Water Supplies, Illinois Environmental Protection Agency.
3) Sanitary engineering surveys by the Cook County Department of Public Health.
4) State Water Survey files.
5) Northeastern Illinois Planning Commission reports.

6) Telephone inquiries.

The number of towns per county for which water use data were developed is:

County	*Towns*
Cook	118
DuPage	20
Kane	16
Lake	28
McHenry	14
Will	18
Total	214

Town Populations

The population for the 214 towns was taken from the United States Census of Population 1970: Illinois, published by the Bureau of Census, U.S. Department of Commerce.

Manufacturing Employment

The Illinois Manufacturers Directory, 1971, was used to aggregate the manufacturing employment listed under various industries for each of the 214 towns. These figures were generally in the same range as developed by NIPC from the county totals, though there were some significant differences for a small number of towns.

Data Modifications

Some examples of data modifications, carried out before performing statistical analyses, are:

1) North Chicago (Lake County) water use, excluding water supplied to the Great Lakes Naval Training Center, was 3.57 mgd during the year 1970 for a population of 18,000.
2) Industrial employment for Northlake (Cook - DuPage Counties) does not include some 11,600 employees of GTE Automatic Electric which according to 1974 IEPA uses only 0.1 mgd from the town's water supply.
3) Water use for Lemont (Cook County) does not include water supplied to Argonne National Laboratory and the industrial employment also excludes 5,000 shown in the Illinois Manufacturers Directory for the laboratory.
4) Hebron (McHenry County), 1970 population of 781, used 0.17 mgd in 1970 but 0.1 mgd was used by the Kenosha Meat Packing Company with 150 employees. These employees and 0.1 mgd were excluded from the total employees and water use.

5) Woodstock (McHenry County), 1970 population of 10,226, used 2.40 mgd in 1970 but 1.0 mgd was used by the Woodstock Die Casting Company. This use was treated in the same manner as for Hebron.

Water Use, Population, and Employment Relationships

The following two models were tested to assess the relative impact of manufacturing employment, I, on the water use, Q, of a town with the 1970 population, P.

$$Q = a\,P^{\alpha}(I/P)^{\beta} \tag{1}$$

and

$$Q = a\,P^{\alpha+\beta\,(I/P)} \tag{2}$$

in which Q is the average water use in mgd (recorded at the water treatment plant) over the year; P is the population from the 1970 census; I is the manufacturing employment from the 1971 Illinois Manufacturers Directory, a is a coefficient, and a and $ are exponents. The second model was found to be superior to the first because equation 1 implies a constant multiplier for a given I/P ratio irrespective of the magnitude of P. It is believed that water use increases with increase in P for a given value of I/P according to equation 2.

The results of multiple regressions for each of the six counties are given in table 1. Equation 2 was transformed to equation 3 for conducting regression analyses:

$$\log_{10}Q = \log_{10}a + \alpha\,\log_{10}P + \beta\,(I/P\,\log_{10}P) \tag{3}$$

Four towns were dropped from a total of 118 in Cook County because the per capita water use was much higher than the others. These were Glencoe, Rosemont, Stickney, and Winnetka. Similarly, Lake Forest and Highland Park were dropped from the 28 towns in Lake County.

Table 1. Regression Parameters with Model: $Q = a\,P^{\alpha+\beta(I/p)}$

County	*Number of towns*	$a \times 10^4$	α	β	*R*
Cook	114	0.5508	1.0546	0.0845	0.9948
DuPage	20	0.6073	1.0396	0.1106	0.9938
Kane	16	0.5012	1.0486	0.1667	0.9960
Lake	26	0.4129	1.0721	0.1682	0.9947
McHenry	14	0.3860	1.0890	0.1137	0.9924
Will	18	0.5036	1.0397	0.1660	0.9943
	208				

Note: R = multiple correlation coefficient

Development of Multipliers

A list was prepared of the 273 user entities or towns in the six counties. Many of the towns added to the 214 used in the regression analyses had partially developed water supply systems in 1970 or the development took place later. The water use data for the added towns was estimated for the year 1970 assuming fully developed supplies.

The 1970 water use for each of the 273 user entities (with the exception of Chicago) was computed with the applicable model parameters in the table and the P and I data. The ratio of actual 1970 Q to that computed according to the model is designated as multiplier K. It reflects the variation of water use from the average relation depending on the particular use and system characteristics of a particular town.

Estimated Future Water Requirements

NIPC (1976) had prepared projections of manufacturing employment, I_n, and population for the years 1970, 1980, 1985, 1990, 2000, and 2010 for all towns in northeastern Illinois. The manufacturing employment figures were developed from the county to the township to the town level. The following procedure was used to compute the manufacturing employment, I, in future years from the corresponding NIPC values:

1) If I (1970) = 0
   let $I(t) = I_n(t)$; t represents the years 1980 through 2010

2) If I (1970) $\neq$ 0 and I_n (1970) = 0
   let $I(t) = I(1970) + I_n(t)$

3) If I (1970) $\neq$ 0 and I_n (1970) $\neq$ 0
   let $I(t) = I_n(t) \times I_n(1970)/I(1970)$

The future water requirement, in mgd, was computed from

$$Q_t = K\ a\ P^{\alpha+\beta(I/P)} \tag{4}$$

in which P and I refer to future estimates of population and manufacturing employment.

The Illinois Bureau of the Budget (IB0B) revised its population projections in 1977. The 1976 NIPC populations are in general agreement with 1976 IBOB figures, but are up to 12 percent higher than the 1977 IB0B estimates. These population projections, in millions, for the six-county area are:

	1980	*1990*	*2000*	*2010*
IBOB (1976)	7.248	7.935	8.882	8.933
NIPC (1976)	7.435	8.205	8.925	
IBOB (1977)	7.091	7.394	7.980	8.267

The 1970 census population was 6.995 million and the census bureau estimate for 1975 was 7.015 million. The State Water Survey (SWS) requested the Division of Water Resources for revision of NIPC estimates so the county population projections would agree with those of the IBOB 1977. The old and new total populations, in millions, for the 273 towns are:

	1980	*1990*	*2000*	*2010*
SWS Interim Report (1977)	7.157	8.006	8.700	9.144
NIPC (1978)	6.837	7.157	7.766	7.968

The difference of 0.25 to 0.30 million in IBOB (1977) and NIPC (1978) figures is the result of the IBOB total being for six counties and the NIPC total being for 273 user entities or towns.

The new populations were used with the original manufacturing employment data to generate new water demands for the 273 towns. Use of the original manufacturing employment results in slightly higher estimates of water demand for the towns with lowered population estimates. The use of the same manufacturing employment implies that the industrial activity is not affected by a small decrease in projected population. The original and revised water demands, in mgd, for the 273 towns as well as 1976 NIPC demands are:

	1980	*1990*	*2000*	*2010*
NIPC (1976)	1380.5	1501.4	1598.8	1664.9
SWS Interim Report (1977)	1312.8	1400.3	1477.8	1527.4
SWS New (final report)	1272.1	1295.0	1336.7	1360.3

Part of the difference between the NIPC 1976 and SWS 1977 demands can be attributed to the inclusion of some of the self-supplied industrial water use (46.3 mgd in 1970) in its demand projections by NIPC. The remaining difference is caused by the use of different water demand functions. No allowance has been made for any reduction in water use from possible water conservation measures. The K factor, 1970 water use, and projected water demands for each of the 273 user entities are listed in table 2.

Some Water Conservation Measures

Measures that will aid in the reduction of water waste are: good accounting of water pumped and actually used; satisfactory operation, maintenance, and repair of the water supply system; a savings oriented water rate structure; and the use of water saving devices in new and rehabilitated developments.

Unaccounted-for Water

An effort was made to explain the variation in unaccounted-for water reported by more than 100 towns in Cook County (Division of Water Resources, 1977). Generally, towns with moderate-to-large water use

Table 2. Estimated Water Demands in mgd for Selected Years

No.	Town name	K factor	1970	1980	1985	1990	2000	2010	
				Cook County					
1	Alsip	1.050	1.20	2.22	2.25	2.29	2.42	2.46	
2	Arlington Heights	.971	6.57	7.95	8.05	8.14	8.41	8.61	
3	Barrington	.871	1.15	1.47	1.60	1.70	2.17	2.23	
4	Barrington Hills	.870	.20	.27	.30	.34	.47	.47	
5	Bedford Park	1.000	10.00	10.30	10.30	10.30	10.30	10.30	
6	Bellwood	1.047	3.10	3.04	3.04	3.04	3.02	3.03	
7	Berkeley	1.002	.58	.64	.69	.69	.70	.70	
8	Berwyn	1.131	6.00	5.65	5.61	5.55	5.31	5.31	
9	Blue Island	1.139	3.00	2.78	2.85	2.90	3.08	3.16	
10	Bridgeview	1.092	1.40	1.80	1.93	2.05	2.44	2.45	
11	Broadview	1.091	1.80	1.78	1.80	1.79	1.77	1.77	
12	Brookfield	1.177	2.33	2.46	2.43	2.40	2.30	2.30	
13	Buffalo Grove	.913	1.01	2.35	2.46	2.57	2.97	3.11	
14	Burbank - S. Stickney	.797	2.30	2.34	2.37	2.39	2.50	2.50	
15	Burnham	1.057	.34	.40	.42	.44	.52	.52	
16	Calumet City	1.077	3.50	4.57	4.64	4.71	4.96	4.96	
17	Calumet Park	1.033	.95	1.26	1.24	1.22	1.14	1.14	
18	Central Stickney S.D.	.909	.20	.20	.20	.20	.20	.20	
19	Chicago	1.000	825.00	814.00	805.00	797.00	759.00	759.00	*
20	Chicago Heights	1.026	5.73	5.65	5.65	5.64	5.62	5.74	
21	Chicago Ridge	.830	.75	1.41	1.41	1.40	1.39	1.44	
22	Cicero	1.022	14.41	14.20	14.13	14.06	15.11	15.16	
23	Country Club Hills	.988	.61	1.61	1.70	1.78	2.07	2.14	
24	Countryside	.987	.26	.55	.57	.59	.67	.69	
25	Crestwood	1.002	.49	.95	.99	1.03	1.16	1.18	
26	Des Plaines	.929	7.10	7.35	7.59	7.55	8.08	8.36	
27	Dixmoor	1.047	.44	.52	.53	.54	.58	.60	
28	Dolton	1.095	3.00	3.26	3.31	3.36	3.58	3.60	
29	E. Chicago Heights	1.026	.45	.62	.65	.68	.81	.84	
30	East Hazelcrest	.891	.14	.16	.16	.16	.18	.19	
31	Elk Grove Village	.878	3.70	5.27	5.64	6.00	7.23	7.51	
32	Elmwood Park	1.104	2.80	2.85	2.78	2.73	2.49	2.49	
33	Evanston	1.116	10.80	10.60	10.53	10.43	10.03	10.03	
34	Evergreen Park	1.017	2.50	2.43	2.40	2.37	2.25	2.25	
35	Flossmoor	1.402	.99	1.08	1.13	1.17	1.36	1.36	
36	Forest Park	1.123	1.80	1.83	1.84	1.85	1.86	1.86	
37	Forest View	1.051	.14	.18	.18	.18	.17	.17	
38	Franklin Park	.931	4.80	4.97	4.99	5.02	5.05	5.08	
39	Garden Homes S.D.	.886	.14	.14	.14	.14	.14	.14	
40	Glencoe	1.973	1.90	1.85	1.85	1.85	1.85	1.85	
41	Glenview	.985	2.64	3.44	3.46	3.47	3.55	3.59	
42	Glenwood	1.050	.70	1.37	1.56	1.75	2.50	2.59	
43	Golf	1.094	.04	.04	.04	.04	.04	.04	
44	Hanover Park	.887	.98	3.13	3.26	3.39	3.92	3.92	
45	Harvey	1.234	5.00	4.83	4.90	4.97	5.21	5.39	
46	Harwood Heights	.960	.95	1.01	1.00	.99	.94	.94	

Continued on next page

Table 2. Continued

No.	Town name	K factor	1970	1980	1985	1990	2000	2010
			Cook County (continued)					
47	Hazel Crest	.943	.90	1.42	1.44	1.46	1.52	1.55
48	Hickory Hills	.903	1.10	1.31	1.31	1.31	1.31	1.32
49	Hillside	.953	.90	.95	.94	.93	.91	.91
50	Hodgkins	.955	.19	.18	.20	.22	.30	.30
51	Hoffman Estates	.945	2.00	3.62	3.85	4.07	4.94	4.95
52	Hometown	.834	.50	.43	.44	.43	.40	.40
53	Homewood	.938	1.70	1.89	1.98	2.07	2.43	2.49
54	Indian Head Park	1.097	.04	.28	.29	.29	.32	.33
55	Inverness	.940	.13	.22	.27	.30	.45	.46
56	Justice	.823	.75	.82	.89	.95	1.20	1.25
57	Kenilworth	1.453	.37	.43	.43	.41	.40	.40
58	LaGrange	1.057	1.78	1.80	1.84	1.86	1.96	1.96
59	LaGrange Highland S.D.	1.339	.55	.75	.75	.76	.76	.81
60	LaGrange Park	.958	1.45	1.30	1.28	1.27	1.21	1.21
61	Lansing	.999	2.57	3.26	3.34	3.40	3.66	3.75
62	Lemont	1.024	.59	.80	1.07	1.34	2.34	2.57
63	Leydon Twp. Service	.939	1.00	1.00	1.00	1.00	1.00	1.00
64	Lincolnwood	.994	2.33	2.57	2.55	2.53	2.46	2.46
65	Lynwood	1.073	.09	.10	.13	.16	.28	.30
66	Lyons	1.088	1.35	1.28	1.30	1.32	1.37	1.37
67	Markham	.845	1.27	1.35	1.49	1.62	2.18	2.27
68	Matteson	1.134	.55	.89	1.06	1.23	1.89	1.96
69	Maywood	1.047	3.28	3.06	3.07	3.08	3.13	3.13
70	McCook	1.000	5.20	5.40	5.40	5.40	5.40	5.40
71	Melrose Park	.953	6.60	6.94	7.02	7.02	7.02	7.02
72	Merrionette Park	.878	.17	.22	.22	.22	.20	.20
73	Midlothian	.854	1.30	1.16	1.20	1.22	1.34	1.38
74	Morton Grove	.843	4.06	4.17	4.14	4.12	4.01	4.01
75	Mount Prospect	.899	3.30	5.30	5.31	5.32	5.36	5.49
76	Niles	.934	4.34	4.33	4.37	4.41	4.54	4.60
77	Norridge	.916	1.50	1.61	1.58	1.56	1.48	1.48
78	Northbrook	1.001	3.00	3.67	3.81	3.95	4.44	4.55
79	Northfield	1.173	.62	.68	.73	.78	.96	.99
80	Northlake	1.079	1.63	1.47	1.45	1.44	1.38	1.40
81	North Riverside	1.128	.85	.81	.81	.81	.80	.80
82	Oak Forest	.945	1.59	2.32	2.34	2.36	2.43	2.49
83	Oak Lawn	.920	5.65	6.31	6.24	6.15	5.82	5.82
84	Oak Park	.977	6.20	5.98	5.93	5.87	5.63	5.63
85	Olympia Fields	.936	.28	.35	.41	.45	.64	.67
86	Orland Park	.902	.55	1.88	2.35	2.82	4.61	5.38
87	Palatine	1.119	3.10	4.31	4.64	4.94	6.15	6.17
88	Palos Heights	.974	.88	1.09	1.11	1.13	1.22	1.22
89	Palos Hills	.982	.58	1.76	1.81	1.86	2.05	2.05
90	Palos Park	.989	.28	.30	.31	.32	.34	.34

Continued on next page

Table 2. Continued

No.	Town name	K factor	1970	1980	1985	1990	2000	2010
			Cook County (continued)					
91	Park Forest	.809	2.45	2.99	3.00	3.00	3.01	3.02
92	Park Ridge	1.187	5.00	5.31	5.28	5.24	5.08	5.19
93	Phoenix	.807	.25	.29	.29	.29	.28	.29
94	Posen	.876	.43	.41	.47	.52	.74	.76
95	Prospect Heights	.867	1.07	.77	.80	.82	.89	.92
96	Richton Park	1.013	.22	1.08	1.25	1.41	2.06	2.15
97	Riverdale	1.218	2.30	2.18	2.21	2.21	2.23	2.29
98	River Forest	1.196	1.50	1.50	1.48	1.46	1.38	1.38
99	River Grove	.955	1.50	1.56	1.56	1.55	1.52	1.52
100	Riverside	.899	.94	.93	.93	.92	.90	.90
101	Robbins	1.255	1.10	1.01	1.02	1.02	1.06	1.08
102	Rolling Meadows	.986	2.10	2.33	2.40	2.46	2.70	2.77
103	Rosemont	2.564	1.37	1.34	1.34	1.32	1.30	1.30
104	Sauk Village	.895	.60	.99	1.04	1.09	1.28	1.33
105	Schaumburg	.908	1.94	6.22	6.79	7.35	9.30	9.67
106	Schiller Park	1.083	1.90	1.90	1.89	1.88	1.82	1.82
107	Skokie	1.159	12.00	12.12	11.99	11.86	11.35	11.28
108	South Barrington	1.137	.03	.08	.15	.21	.46	.51
109	S. Chicago Heights	.984	.45	.40	.40	.40	.41	.43
110	South Holland	1.007	2.35	2.91	2.98	3.04	3.31	3.33
111	Stickney	2.494	1.50	1.69	1.69	1.69	1.71	1.74
112	Stone Park	1.043	.43	.39	.39	.39	.38	.38
113	Streamwood	.934	1.60	2.53	2.80	3.06	4.07	4.23
114	Summit	1.074	1.35	1.15	1.14	1.13	1.09	1.09
115	Thornton	1.063	.38	.37	.43	.48	.68	.71
116	Tinley Park	.983	1.15	2.87	3.17	3.47	4.60	5.10
117	Waycinden	1.310	.30	.34	.36	.38	.47	.49
118	Westchester	1.272	2.44	2.43	2.42	2.41	2.36	2.36
119	Western Springs	.938	1.05	1.25	1.25	1.25	1.24	1.27
120	Westhaven	.828	.03	.19	.29	.38	.76	.90
121	Wheeling	.860	1.43	2.30	2.37	2.44	2.70	2.76
122	Willow Springs	.857	.25	.30	.34	.39	.58	.59
123	Wilmette	.852	2.80	2.91	2.88	2.86	2.78	2.80
124	Winnetka	1.904	2.50	2.77	2.76	2.74	2.64	2.64
125	Worth	.865	.96	.97	.98	.98	1.00	1.00
			DuPage County					
126	Addison	.903	2.65	3.47	3.70	3.93	4.82	5.19
127	Arrowhead	1.140	.11	.11	.11	.11	.15	.16
128	Bartlett	.676	.32	.82	1.02	1.21	1.97	2.17
129	Bensenville	1.064	1.61	1.80	1.86	1.92	2.16	2.21
130	Bloomingdale	.879	.22	1.10	1.32	1.53	2.38	2.57

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Table 2. Continued

No.	Town name	K factor	1970	1980	1985	1990	2000	2010
			DuPage County (continued)					
131	Burr Ridge	.562	.12	.18	.23	.28	.49	.51
132	Butterfield	1.056	.31	.33	.34	.34	.40	.44
133	Carol Stream	.991	.65	1.50	1.75	2.01	3.01	3.17
134	Clarendon Hills	1.145	.68	.85	.85	.85	.86	.86
135	Country Club Highlands	1.422	.09	.13	.13	.13	.14	.15
136	Darien	1.228	.86	1.56	1.86	2.17	3.39	3.47
137	Downers Grove	.998	3.60	4.65	5.20	5.73	7.73	7.93
138	Elmhurst	.892	5.25	4.80	4.96	5.12	5.68	5.89
139	Glendale Heights	.959	.97	1.96	2.19	2.40	3.29	3.37
140	Glen Ellyn	1.220	2.50	3.11	3.29	3.45	3.94	4.12
141	Hinsdale	1.161	2.07	2.30	2.41	2.50	2.88	2.95
142	Itasca	1.041	.53	1.06	1.17	1.25	1.61	1.79
143	Lisle	.584	.28	.63	.81	.99	1.70	1.75
144	Lombard	1.007	3.37	3.57	3.91	4.21	5.40	5.53
145	Lombard Heights	.795	.09	.11	.15	.19	.19	.19
146	Naperville	.991	2.75	4.71	5.65	6.54	10.78	11.55
147	Oak Brook Area	2.370	1.37	1.94	2.10	2.23	2.76	2.79
148	Oakbrook Terrace	1.033	.10	.19	.27	.34	.63	.63
149	Roselle	.405	.40	.89	.98	1.01	1.45	1.61
150	Valley View	1.001	.19	.20	.21	.22	.22	.24
151	Villa Park	.943	2.30	2.06	2.12	2.17	2.32	2.39
152	Warrenville	.600	.20	.27	.35	.42	.72	.76
153	Wayne	.660	.05	.07	.08	.10	.18	.19
154	West Chicago	1.123	1.20	1.85	2.18	2.47	3.68	4.08
155	Westmont	.955	.72	1.31	1.43	1.56	2.04	2.08
156	Wheaton	1.052	3.10	4.52	4.87	5.21	6.57	6.82
157	Willowbrook	.838	.09	.29	.36	.44	.73	.75
158	Winfield	1.066	.39	.50	.58	.66	.93	1.01
159	Wood Dale	.866	.69	1.03	1.15	1.25	1.67	1.74
160	Woodridge	.961	.93	2.18	2.30	2.42	2.91	2.95
			Kane County					
161	Aurora	.792	9.61	10.29 .	11.03	11.73	14.95	15.66
162	Batavia	1.151	1.19	1.64	1.74	1.83	2.26	2.53
163	Burlington	1.111	.04	.04	.05	.05	.07	.09
164	Carpentersville	1.001	2.22	2.56	2.69	2.80	3.48	3.73
165	East Dundee	1.145	.32	.36	.40	.44	.57	.61
166	Elburn	1.222	.11	.19	.24	.27	.43	.50
167	Elgin	.932	6.59	7.75	8.24	8.69	10.82	11.86
168	Geneva	1.139	1.50	1.69	1.78	1.87	2.20	2.28
169	Gilberts	.936	.03	.03	.05	.06	.13	.15
170	Hampshire	.837	.14	.18	.23	.25	.39	.42
171	Maple Park	.810	.04	.04	.05	.05	.07	.07
172	Montgomery & B. Hill	1.136	1.10	1.19	1.39	1.63	1.87	1.97

Continued on next page

Table 2. Continued

No.	Town name	K factor	1970	1980	1985	1990	2000	2010
	Kane County (continued]							
173	North Aurora	1.226	.48	.58	.66	.73	1.03	1.09
174	Pingree Grove	.892	.01	.01	.01	.01	.02	.02
175	St. Charles	1.008	2.03	2.47	2.70	2.90	3.89	4.37
176	Sleepy Hollow	.803	.10	.13	.14	.15	.21	.23
177	South Elgin	.915	.36	.49	.56	.63	.90	.94
178	Sugar Grove	.903	.08	.13	.15	.16	.23	.25
179	Valley View	.484	.06	.08	.09	.09	.11	.12
180	West Dundee	1.631	.40	.49	.53	.57	.74	.80
	Lake County							
181	Antioch	1.269	.48	.64	.71	.76	.99	1.11
182	Bannockburn	1.225	.04	.17	.18	.18	.19	.20
183	Deerfield	.967	1.97	2.06	2.08	2.09	2.15	2.19
184	Deer Park	1.252	.07	.09	.11	.12	.18	.21
185	Delmar Woods	1.070	.02	.02	.02	.02	.02	.02
186	Fox Lake	.906	.32	.48	.54	.60	.82	.85
187	Glehbrook Countryside	1.318	.08	.15	.15	.15	.15	.15
188	Grayslake	.964	.48	.58	.69	.79	1.18	1.32
189	Green Oaks	1.151	.05	.12	.15	.16	.24	.27
190	Gurnee	.977	.35	.66	.79	.92	1.48	1.71
191	Hainesville	1.193	.01	.02	.06	.08	.20	.25
192	Hawthorn Woods	.945	.06	.09	.10	.11	.17	.19
193	Highland Park	1.661	4.97	5.08	5.15	5.20	5.37	5.49
194	Highwood	1.121	.43	.44	.48	.52	.68	.68
195	Indian Creek	1.198	.02	.02	.02	.02	.03	.03
196	Island Lake	.995	.14	.20	.22	.24	.29	.31
197	Kildeer	1.182	.05	.13	.15	.16	.22	.24
198	Knollwood - Rondout	3.296	.20	.30	.37	.45	.60	.65
199	Lake Barrington	1.374	.03	.54	.61	.66	.92	.98
200	Lake Bluff	1.062	.47	.47	.60	.66	.87	.91
201	Lake Forest	1.676	2.19	2.22	2.41	2.59	3.31	3.54
202	Lake Villa	1.006	.08	.08	.10	.11	.16	.18
203	Lake Zurich	.980	.52	.98	1.15	1.30	1.92	2.17
204	Libertyville	.944	1.80	2.46	2.66	2.83	3.82	4.23
205	Lincolnshire	1.436	.29	.52	.54	.55	.64	.67
206	Lindenhurst	.820	.19	.38	.41	.43	.53	.57
207	Long Grove	1.215	.10	.18	.19	.20	.25	.28
208	Mettawa	1.131	.02	.02	.03	.03	.05	.07
209	Mundelein	.982	1.66	2.05	2.21	2.34	3.05	3.35
210	North Barrington	1.425	.14	.24	.25	.26	.34	.38
211	North Chicago	1.386	8.87	8.06	8.18	8.27	8.76	8.98
212	Old Mill Creek	1.023	.01	.01	.01	.01	.01	.01
213	Park City	.567	.12	.23	.23	.22	.21	.23
214	Riverwoods	.907	.10	.16	.19	.20	.27	.29

Continued on next page

Table 2. Continued

No.	Town name	K factor	1970	1980	1985	1990	2000	2010
			Lake County (continued)					
215	Round Lake	1.088	.15	.38	.55	.66	1.27	1.51
216	Round Lake Beach	.981	.45	1.42	1.47	1.52	1.63	1.83
217	Round Lake Heights	1.529	.12	.15	.16	.16	.20	.25
218	Round Lake Park	1.937	.45	.71	.81	.89	1.28	1.44
219	Third Lake	.831	.01	.01	.02	.02	.02	.02
220	Tower Lakes	1.034	.06	.09	.10	.10	.11	.12
221	Vernon Hills	.972	.07	.55	.67	.80	1.30	1.46
222	Wadsworth	1.154	.06	.09	.10	.11	.13	.14
223	Wauconda	.803	.36	.41	.45	.48	.61	.66
224	Waukegan	1.145	9.30	9.70	10.19	10.69	12.68	13.10
225	Wildwood - Gages Lake	.818	.40	.52	.57	.62	.71	.86
226	Winthrop Harbor	.848	.31	.29	.39	.49	.88	.97
227	Zion	.980	1.57	1.67	1.81	1.96	2.51	2.81
			McHenry County					
228	Algonquin	1.216	.39	.57	.69	.80	1.24	1.32
229	Cary	1.142	.50	.63	.84	1.05	1.91	2.21
230	Crystal Lake	.776	1.51	2.13	2.49	2.85	4.34	5.01
231	Fox River Grove	1.106	.20	.24	.29	.34	.54	.58
232	Harvard	.970	.68	.73	.75	.78	.89	.94
233	Hebron	1.078	.17	.18	.19	.19	.20	.20
234	Huntley	1.153	.17	.22	.22	.22	.21	.22
235	Lake in the Hills	.818	.21	.45	.47	.48	.53	.61
236	Lakemoor	.978	.06	.08	.08	.08	.07	.08
237	Lakewood	1.099	.06	.13	.14	.15	.18	.19
238	Marengo	.903	.42	.43	.45	.47	.54	.57
239	McCullom Lake	1.137	.07	.09	.10	.11	.14	.15
240	McHenry	1.059	.80	1.26	1.62	1.94	3.39	4.09
241	McHenry Shores	1.142	.04	.11	.15	.20	.40	.49
242	Oakwood Hills	1.258	.04	.12	.13	.13	.14	.17
243	Richmond	.833	.10	.15	.15	.16	.19	.19
244	Spring Grove	.769	.03	.05	.05	.05	.07	.08
245	Sunnyside	.835	.02	.03	.11	.20	.56	.67
246	Sunrise Ridge	.894	.03	.02	.02	.02	.02	.02
247	Union	1.110	.06	.08	.08	.08	.08	.09
248	Woodstock	1.163	2.40	2.69	2.93	3.15	4.05	4.31
			Will County					
249	Arbury Hills	1.249	.10	.12	.13	.13	.17	.23
250	Beecher	1.171	.15	.17	.19	.21	.30	.31
251	Bolingbrook	1.151	.60	3.94	4.20	4.46	5.49	5.65
252	Braidwood	.941	.16	.25	.25	.25	.25	.25

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Table 2. Concluded

No.	Town name	K factor	1970	1980	1985	1990	2000	2010
				Will County (continued)				
253	Channahon	1.377	.14	.65	.69	.72	.87	.92
254	Crest Hill	1.114	.60	.86	.88	.90	.98	1.03
255	Crete	.865	.30	.38	.46	.55	.88	.98
256	Elwood	1.051	.06	.08	.08	.08	.08	.08
257	Frankfort	1.074	.25	.47	.57	.65	1.04	1.22
258	Godley	1.320	.02	.03	.03	.03	.03	.03
259	Joliet	1.056	10.40	9.90	10.67	11.41	14.57	15.81
260	Lockport	.767	.75	1.00	1.08	1.15	1.45	1.73
261	Manhattan	1.046	.11	.17	.19	.20	.23	.25
262	Mokena	.852	.10	.22	.33	.43	.87	1.05
263	Monee	.810	.06	.08	.11	.13	.23	.32
264	New Lenox	.952	.20	.43	.59	.76	1.49	1.77
265	Park Forest South	1.297	.19	.90	1.17	1.44	2.52	2.74
266	Peotone	1.061	.24	.28	.29	.29	.31	.33
267	Plainfield	1.207	.40	.51	.56	.62	.82	.87
268	Rockdale	1.414	.29	.35	.37	.37	.41	.44
269	Romeoville	.960	.96	1.49	1.58	1.67	2.03	2.08
270	Shorewood	1.101	.14	.38	.44	.51	.75	.84
271	Steger	1.101	.70	.93	.96	.98	1.07	1.17
272	Symerton	1.049	.01	.01	.01	.01	.01	.01
273	Wilmington	.991	.38	.46	.49	.52	.64	.68

*Chicago reported a water use of 867 mgd in 1970. Keifer & Associates are using demands of about 840 mgd for Chicago from 1980 to 2010 in a current study for the Division of Water Resources.

reported a greater percent of unaccounted-for water than those with lower water use. Plausible reasons are older systems and absence of leak detection surveys followed by remedial measures. It is imperative that all municipalities keep monthly and yearly records of water pumped to the treatment plant and that billed to the customers, so that an excessive unaccounted-for water problem may be recognized and rectified.

Water Rate Structure

The water rate structure in most of the towns has a decreasing charge with an increase in consumption, a vestige of the principle of the economy of scale when resources are plentiful. Excessive water use not only increases the cost of extra water, but also increases the volume entering the wastewater treatment plants, necessitating plant expansions and higher operation, maintenance, and repair costs. The increase in effluent from wastewater plants may require advanced treatment because of a reduction in the dilution ratio based on the 7-day 10-year low flow in the area streams. Water rate structure should be based on the consideration of limited resources and other externalities in order to foster an optimal use of water for domestic, commercial, and industrial purposes.

Miscellaneous

Residential water metering programs need to be actively pursued in the city of Chicago and some other towns with moderate-to-large water use. Generally, a savings of 10 to 20 percent in water use can be effected by metering. Use of water saving devices in new or rehabilitated developments may reduce the household water use by 10 to 20 percent. This may result in lower water bills for homeowners, but will not significantly reduce the cost of water supply. Conservation measures may increase the adequacy of a water system designed for 2010 to say 2025 or 2040. For instance, excluding Chicago, the new demand projections increase from 458.1 mgd in 1980 to 601.3 mgd in 2010. This is an increase of about 5 mgd per year. A 10 percent reduction in the 2010 demand is 60 mgd which is equivalent to 12 years of growth at 5 mgd per year. Thus the positive effects of conservation are saving the resource for future use and postponing the need for new sources of water and expanded conveyance systems and treatment plants.

POTENTIAL YIELD OF SHALLOW GROUNDWATER AQUIFERS

In 1966, the Water Survey estimated the potential yield of the shallow groundwater aquifers in the six-county region to be 507 mgd (NIPC, 1966). Moench and Visocky (1971) revised the yield estimate to 445 mgd using all the data available at that time. Estimates of the potential yield by townships (Schicht et al., 1976) add up to 455 mgd. The difference between the 1966 and the 1971 estimates is largely caused by a reduction in the yield in the western part of the area where the Maquoketa shale is the uppermost bedrock and by the elimination of the potential yield for the areas with extremely low well yields. The small difference between 1971 and 1976 estimates is caused by a greater detail of computation and smaller and more numerous subareas used in the 1976 study.

The exact location and extent of the sand and gravel aquifer are not known. The areal extent and thickness of the Silurian dolomite aquifer are better known, but information on the distribution of water-bearing cracks, crevices, and solution channels is lacking. Recharge is generally adequate to provide the projected yield on a regional basis, but some test drilling may be necessary to locate and to design an adequate and economical well field. The well yields may vary by a factor of 10 or more (Csallany and Walton, 1963). Either a suitable test-drilling program or drilling 2 to 3 times the required number of well holes may be needed to locate sufficiently high capacity wells.

The distribution of the Silurian dolomite aquifer over the area is well known. On the other hand, the sand and gravel aquifer covers only certain parts of the area and its local areal distribution needs to be verified. More drawdown is available in the dolomite aquifer. Because of these and some other considerations, the potential yield estimates made in the past were based on the assumption of developing first the dolomite aquifer and then the sand and gravel. The data compiled on shallow aquifer wells in present use indicate greater development of sand and gravel in some townships (with Silurian dolomite either missing or thin) than that estimated with dolomite as the primary aquifer. Primary development of dolomite assumes maximum possible recharge to the Silurian dolomite and hence maximum withdrawal from it. With the primary development of dolomite, recharge first meets the recharge requirements of the dolomite aquifer, and the balance, if any, is available for pumping from the sand and gravel aquifer. If the sand and gravel aquifer is selected for primary development, recharge to the dolomite is limited to the amount that cannot be practically developed from the sand and gravel aquifer. Detailed computations were carried out to estimate the yields with sand and gravel aquifers as the primary source. The information on the yields computed from the two bases should help in optimal use of the groundwater resource.

It is not practical to develop groundwater well fields in the four cross-hatched townships shown in figure 1 because they are completely urbanized. Fifteen more townships are almost completely urbanized and full development of their groundwater potential is doubtful. All of these townships

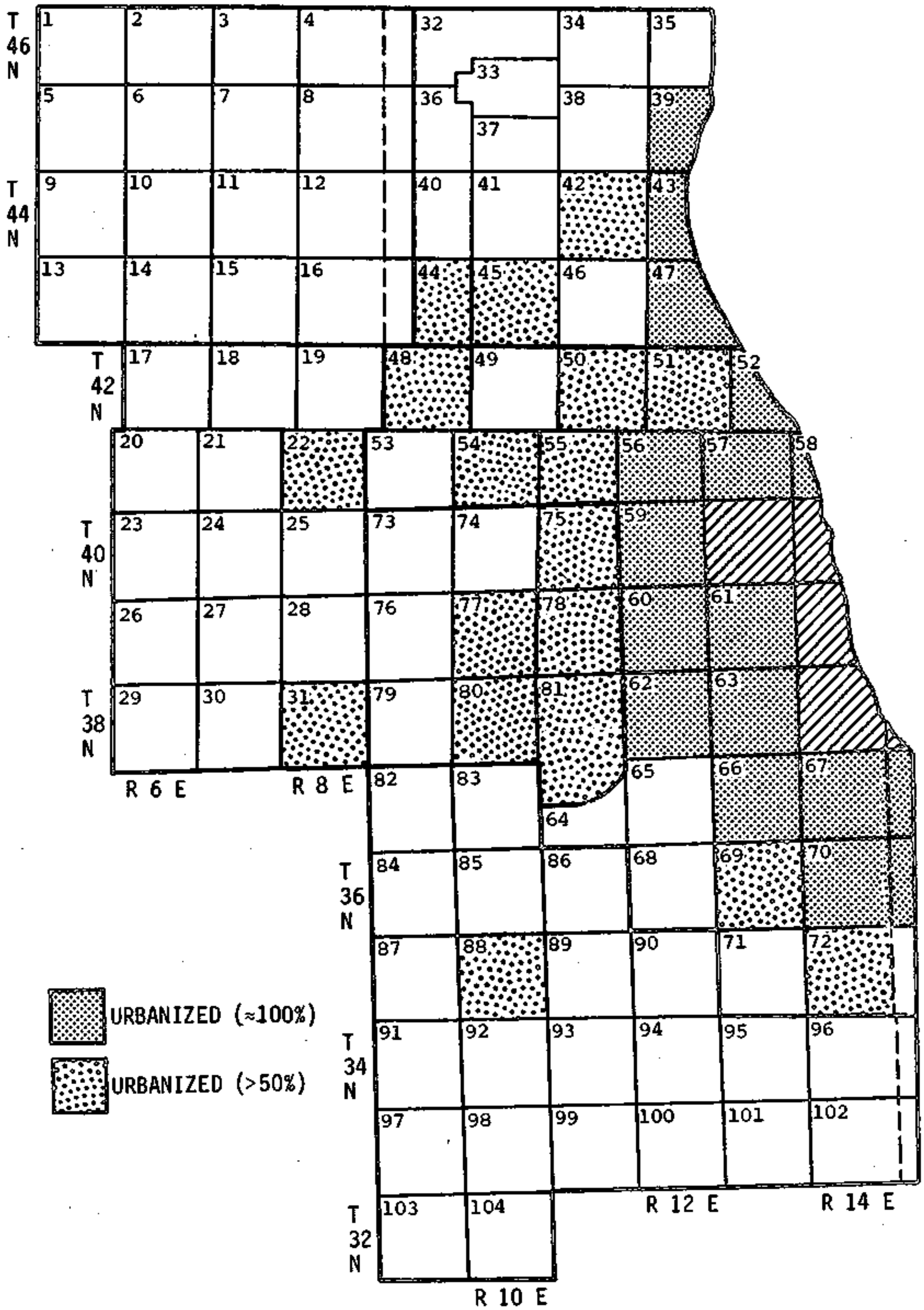

Figure 1. Location map and urbanized townships

receive water from Lake Michigan, either directly or through Chicago. An additional 18 townships are more than 50 percent urbanized and optimal development of well fields therein will pose some problems and difficulties. Some of these townships have already developed their potential yield. Various townships, shown in figure 1, have been so labelled by a perusal of the 1979 Illinois Highway Map.

Potential Yields

The potential yield of an aquifer 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 (Schicht et al., 1976). The potential yield of an aquifer is less than the groundwater recharge which equals the product of the recharge rate and the area. No well field can be devised which will divert all of the recharge into the pumping cones. Development of an aquifer for water supply may reduce groundwater contribution to the surface streams (thus reducing their base flow) and groundwater flow to other areas of the aquifer.

Dolomite as the Primary Aquifer

The shallow aquifer potential for the six-county area was estimated with the Silurian dolomite as the primary aquifer (Moench and Visocky, 1971; Schicht et al., 1976). The sand and gravel aquifers in the glacial drift were considered complementary to the dolomite where their development would reduce recharge to the dolomite. In such areas, the shallow aquifer potential yield equals the potential yield of the dolomite aquifer. In areas where shales or shaly dolomites are present in the upper portion of the dolomite aquifer and limit the recharge rate to it, the yield from the sand and gravel supplements that from the dolomite. The potential yield of the shallow aquifers was computed with the maps showing recharge rates to and areal distribution of these aquifers. A sample computation for a township is given in table 3A. The C factor, generally 1.0 for dolomite and 0.5 for sand and gravel, is based on well-field data and represents the fraction of recharge that may be diverted into the pumping cones. The values of C used in computing potential yields were taken from Circular 102 (Moench and Visocky, 1971). Figure 2 shows the distribution of the various aquifers.

The water that is not diverted into the pumping cones leaves the aquifer as lateral outflow or baseflow to the streams. Column 3 in table 3A is the probable recharge rate which depends on the thickness, vertical permeability, and head in the overlying glacial till or shale. In the sample township, 5.6 sq mi of dolomite has a very low recharge rate. This can be caused by the absence of the upper Silurian (Niagaran) formation or by the presence of a shale layer as the uppermost bedrock. For the township under consideration, it is caused by the absence of the upper Silurian dolomite. Column 4 shows the recharge passed through the sand and gravel aquifer to assure the maximum recharge rate to the dolomite. The interbedded and basal sand and gravel aquifers are tabulated only where they overlie dolomite with

Table 3. Sample Computation of Potential Yield of Shallow Groundwater Aquifer (Township: No. 11, T44N R7E, Dorr; McHenry County)

A. With Primary Development of the Silurian Dolomite

Aquifer	*Area (sq mi)*	*Recharge (mgd/sq mi)* In	Out	Net	*C*	*Potential yield (mgd)*
Dolomite	5.6	0.012		0.012	1.0	0.067
	30.4	0.175		0.175	1.0	5.320
Sand and gravel						
Basal	4.4	0.175	0.012	0.163	0.5	0.359
Interbedded	0.4	0.175	0.012	0.163	0.5	0.033
Surficial	10.0	0.300	0.175	0.125	0.5	0.625
Totals						
Dolomite						5.387
Sand and gravel						1.017
Shallow aquifer						6.404

B. With Primary Development in Sand and Gravel

Sequence	*Line*	*Aquifer*	*Area (sq mi)*	*Recharge (mgd/sq mi)*	*C*	*Potential yield (mgd)*
a	1	S	10.0	0.300	0.5	1.500
	2	I+S	6.0	0.150	0.5	0.450
	3	B+S	1.7	0.150	0.5	0.128
	4	B+I+S	2.5	0.075	0.5	0.094
	5	D+S	2.3	0.150	1.0	0.345
	6	D+I+S	3.5	0.075	1.0	0.262
	7	D+B+S	1.7	0.075	1.0	0.128
	8	D+B+I+S	2.5	0.038	1.0	0.094
b	9	I	11.5	0.175	0.5	1.006
	10	B+I	9.5	0.088	0.5	0.418
	11	D+I	2.0	0.088	1.0	0.175
	12	D+B+I	9.5	0.044	1.0	0.418
c	13	B	6.0	0.175	0.5	0.525
	14	D+B	6.0	0.012	1.0	0.072
d	15	D	8.5	0.175	1.0	1.488
		∑S	10.0			1.500
		∑I	17.5			1.456
		∑B	19.7			1.165
		∑D	36.0			2.982
Sand and gravel = ∑S+∑I+∑B						4.121
Dolomite ∑D						2.982
						7.103

Note: S= surficial; I= interbedded; B= basal sand and gravel; and D = dolomite aquifer

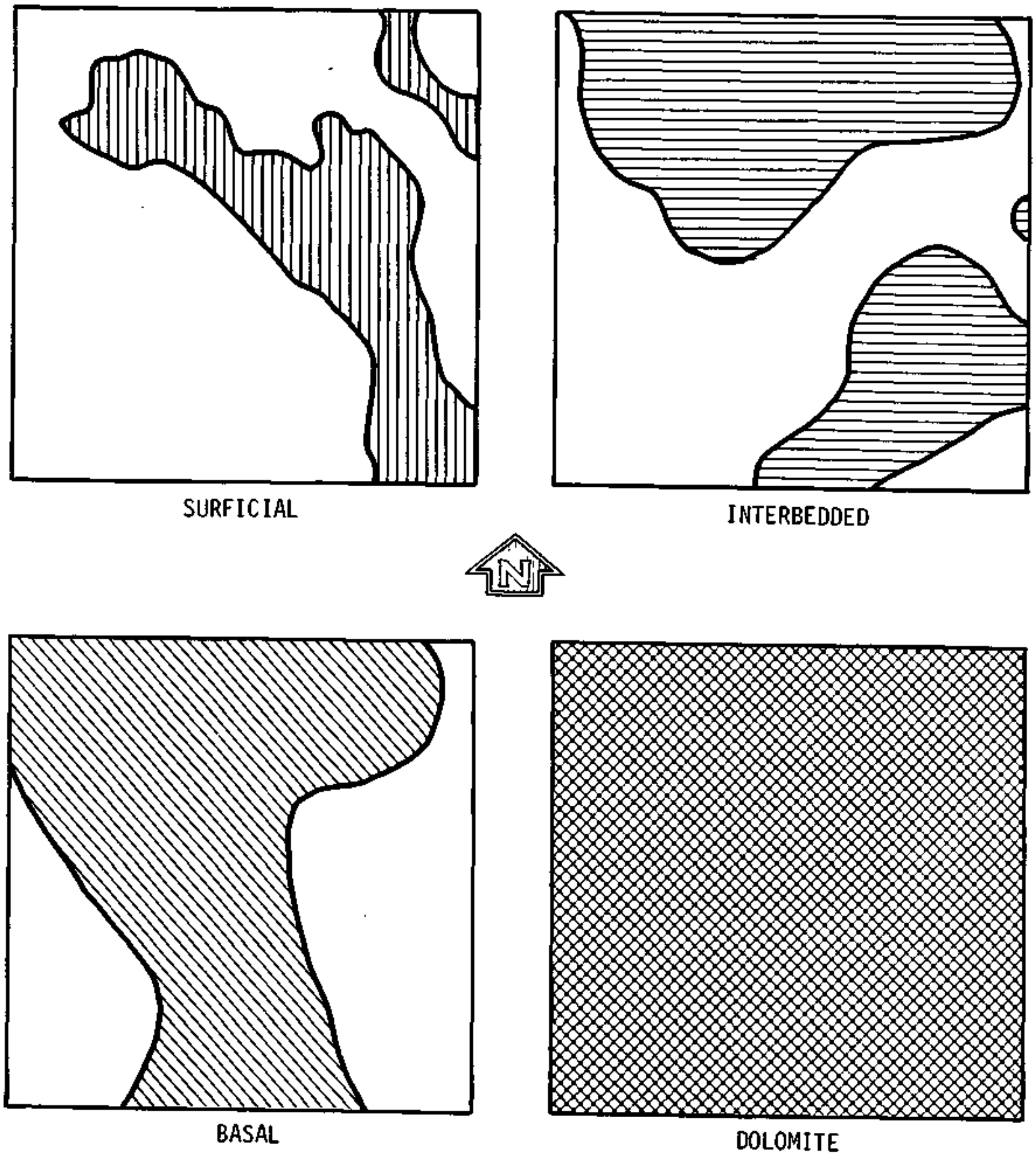

Figure 2. Distribution of surficial, interbedded, and basal sand and gravel; and dolomite aquifers in Dorr township, No. 11, T14N, R7E

a recharge rate less than that for the overlying interbedded or basal aquifer. Everywhere else, the interbedded or basal sand and gravel has the same recharge rate as the dolomite and the net recharge to these aquifers is zero. Column 5 shows the net recharge rate to the aquifers. The sand and gravel aquifers have a useable potential yield only where they have a net recharge rate when primary development of the dolomite aquifer is considered.

The yield computations were made in this fashion for all the townships. The potential yield for the shallow aquifer as well as the component yields for the dolomite and sand and gravel with the primary development in the Silurian dolomite are given in figure 3.

Sand and Gravel as the Primary Aquifer

In Woodstock in McHenry County and in the Hadley Valley aquifer in Will County, much larger quantities of groundwater are developed from sand and gravel aquifers than indicated with dolomite as the primary source. To accommodate these differences and to assess the effect of using sand and gravel for primary development, the potential yields for all the townships in the six-county area were calculated. The maps delineating surficial, interbedded, and basal sand and gravel aquifers and their appropriate recharge rates were used. The recharge rates generally decrease downward because of rather low permeability of the glacial till. The recharge rate to the next underlying aquifer was assumed to be one-half that of the aquifer under consideration. The distribution of shallow aquifers in Dorr township is shown in figure 2. The yield computation for this township is given in table 3B.

The potential yield is computed for each aquifer layer or unit starting from the uppermost. In sequence 'a' (all combinations of units with surficial sand and gravel) in table 3B, one-half of the recharge to the surficial aquifer contributes to the potential yield of that aquifer and one-half is passed on to the next lower unit — interbedded, basal, or dolomite. Recharge to the succeeding unit is one-half of that to the preceding unit. In the dolomite, the entire recharge to the dolomite is considered developable. It may be stressed that a relatively less permeable till or shale can limit the recharge rates to the lower aquifers. The dolomite recharge rate in column 5 and line 14 under sequence 'c' (basal sand and gravel) is 0.012 mgd per square mile instead of one-half of 0.175 because of the absence of the upper dolomite as mentioned earlier. Since the maximum potential yield is derived from the sand and gravel aquifers, the total area of each aquifer unit is accounted for in this scheme.

The potential yield for this township is 6.404 mgd with dolomite as the primary and 7.103 mgd with sand and gravel as the primary. However, the sand and gravel contribution changes from 1.017 to 4.121 mgd. Where surficial sand and gravel is present over a large part of the area, there is a significant increase in shallow aquifer potential yield. The increased development possibility in the sand and gravel aquifer decreases recharge to the dolomite and hence its yield. The potential yield estimates with primary development in sand and gravel are given in figure 4.

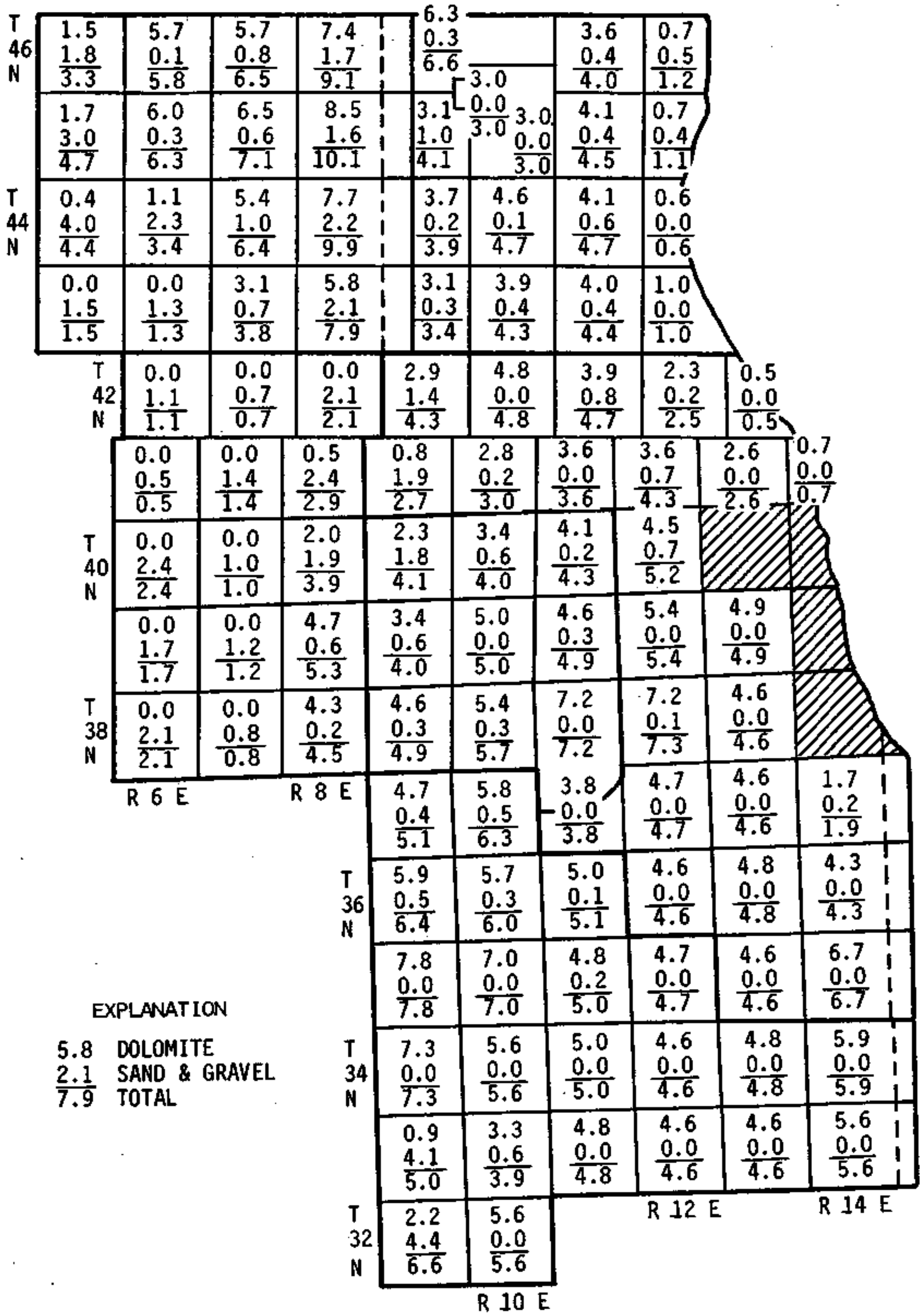

Figure 3. Potential yield, in mgd, of shallow aquifers with primary development of Silurian dolomite

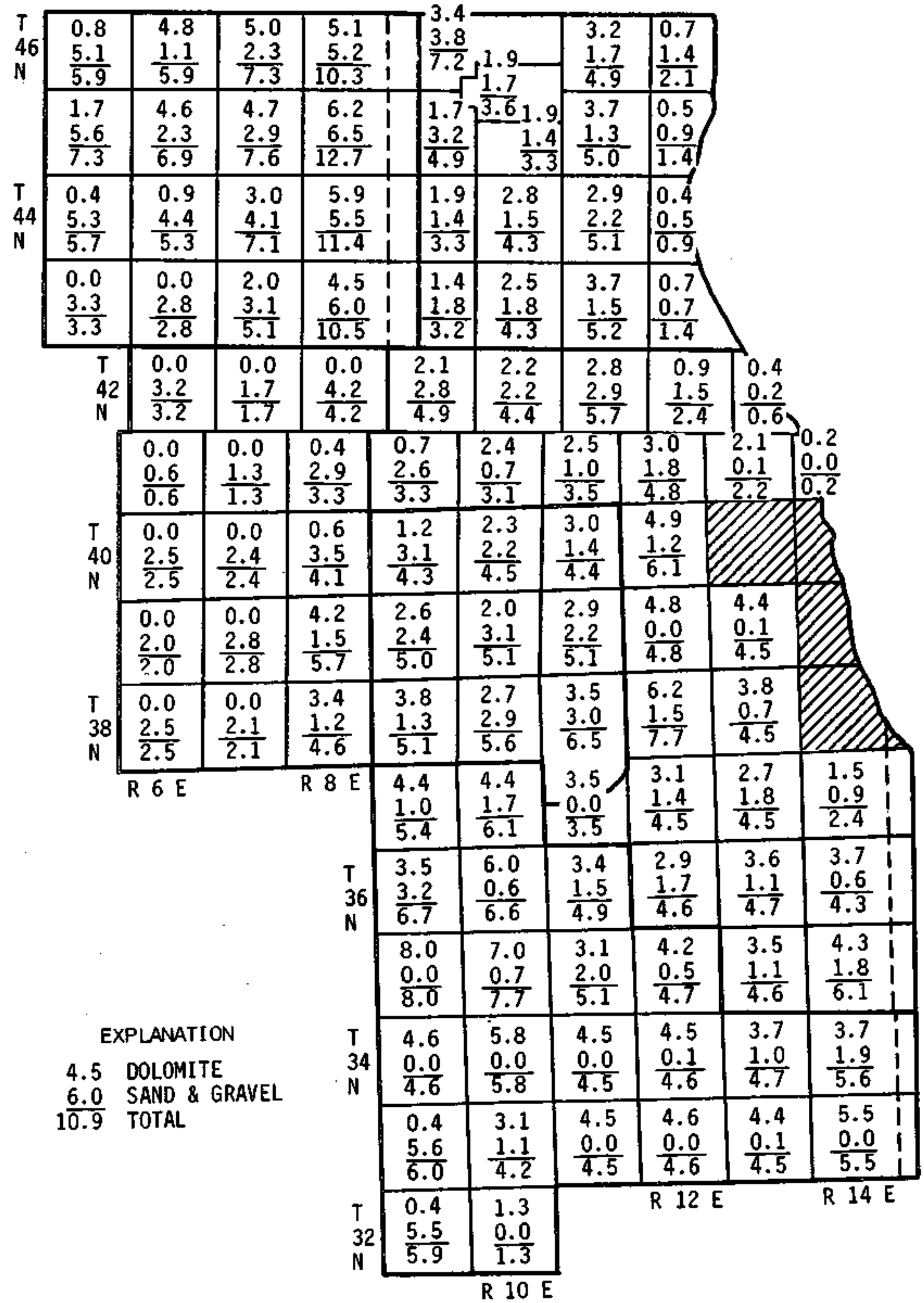

Figure 4. Potential yield, in mgd, of shallow aquifers with primary development of sand and gravel

Table 4. Shallow Groundwater Aquifer Potential with Primary Development in Silurian Dolomite or Sand and Gravel

	Potential yield with primary development in					
	Dolomite			*Sand and gravel*		
County	*S&G*	*D*	*Total*	*S&G*	*D*	*Total*
Cook*	6.2	95.0	101.2	30.7	72.2	102.9
Du Page	4.0	40.0	44.0	21.6	24.0	45.6
Kane	20.0	11.5	31.5	34.4	8.6	43.0
Lake	5.0	49.4	54.4	26.8	33.7	60.5
McHenry	24.9	66.4	91.3	65.5	49.6	115.1
Will	12.3	116.2	128.5	33.4	95.0	128.4
Total	72.4	378.5	450.9	212.4	283.1	495.5

*The 4 townships cross hatched in figure 1 are excluded from potential yield calculations.

Note: S&G = sand and gravel; D = dolomite aquifer

Comparison of Yields

Shallow aquifer potential for each of the six counties considering primary development in the Silurian dolomite or the sand and gravel aquifer is given in table 4. The potential yield with either development is practically the same for Cook, Du Page, and Will counties. When sand and gravel is considered as the primary aquifer, an increase in potential yield of 11.5, 6.1, and 23.8 mgd is indicated for the Kane, Lake, and McHenry county, respectively. The increase is mostly attributed to a decreased amount of lateral outflow from the sand and gravel aquifers and the development of large surficial aquifers with high recharge rates. The magnitude of this increase depends on the areal extent of the surficial sand and gravel aquifers, and the absence of the upper Silurian dolomite or the presence of shales overlying the dolomite.

The relative importance of sand and gravel and dolomite aquifers differs with the selection of one or the other for primary development. For primary development in sand and gravel aquifers, their potential of 212.4 mgd is about 3 times the yield of 72.4 mgd with dolomite as the primary aquifer. The dolomite aquifer potential with its primary development is 378.5 mgd compared with 283.1 mgd when sand and gravel is considered the primary aquifer. There are 22 townships showing 1.0 mgd or more increase in potential yield with the primary development in sand and gravel; their total increase is 35.8 mgd. Similarly, 37 townships show an increase of 0.5 mgd or more, with a total of 45.8 mgd.

The choice of aquifer, sand and gravel or dolomite, for primary development will be determined by the technical feasibility and the economics of resource use. The groundwater resource forms an integral part of any regional optimization scheme. A choice will be made for each community as to whether the primary development of one or the other shallow aquifer will be optimal.

Sand and gravel aquifer development may be economical where it increases yields significantly and where limited test drilling is needed for delineation of the aquifer. In other areas, as well as in areas where sand and gravel aquifer cannot support high yield wells, the primary development of the dolomite aquifer will be more desirable.

Effect of Urbanization on Potential Yields

Figure 1 shows that there are 15 townships that are almost fully urbanized and are served with Lake Michigan water, directly or through Chicago. If they are excluded from development of shallow aquifers, the potential yield will be reduced by 49.1 mgd with dolomite as the primary aquifer and 51.1 mgd with sand and gravel as the primary aquifer. The development of sand and gravel aquifers may not be feasible in these townships, but it should be possible to develop the dolomite aquifer in some of them. Because of the uncertainity about the areal extent, thickness, and transmissivity of the sand and gravel aquifers, a test drilling program is a prerequisite to design a suitable well field. This type of drilling program is impractical in heavily built-up areas. It may be of interest to note that only 2.1 mgd is contributed by a sand and gravel aquifer out of a total of 49.1 mgd with the primary development in the dolomite aquifer.

The potential yield includes current pumpage so that the amount of water available for future development is the difference between the potential yield and the present pumpage.

AVAILABILITY OF WATER FROM FOX, DU PAGE, AND KANKAKEE RIVERS

The quantity and quality of water available from the Fox, Du Page, and Kankakee River in northeastern Illinois were investigated to assess the potential of these sources for water supply. The gaging stations, the drainage areas, the 7-day 10-year low flows ($Q_{7,10}$), and the years of daily flow data used are:

River	*Gaging station*	*Drainage area (sq mi)*	*$Q_{7,10}$ (cfs)*	*Record used*
Fox	at Algonquin	1,403	51	1924-1972
	at Dayton	2,642	198	1924-1972
Du Page	at Shorewood	324	45	1941-1972
Kankakee	at Wilmington	5,150	450	1934-1972

The 7-day 10-year low flow values (Singh and Stall, 1973) apply to the 1970 condition of effluents discharged to the receiving stream.

Low Flow Statistics

The 7-, 15-, and 31-day low flows for the months of January through December for each year of the flow record at the four gaging stations were computed with the use of the daily flow data stored on DISK and a computer program specifically prepared for this purpose. The 31-day low flow in any month could have 0 to 15 days in the preceding or succeeding month. Similarly, the 15- and 7-day low flow could have 0 to 7 and 0 to 3 days in the preceding or succeeding month, respectively. The low flows in each year were adjusted for the effluent flow condition in 1970 for which the $Q_{7,10}$ values hold. Curves of relation were developed for the effluent discharge to the stream during dry weather conditions versus the calendar year, for each of the towns above the 4 gaging stations. There were 4 towns above Algonquin, 20 towns above Dayton, 22 towns above Shorewood, and 3 towns above Wilmington. The sum of these effluents entering the Fox, Du Page, and Kankakee River above the gaging stations of interest are plotted in figure 5 with respect to time. The low flow in a particular year was adjusted by adding to it the difference between the 1970 effluents and the effluents for the year under consideration. For example, the 1950 low flow adjustment for the Fox River at Dayton equals 54.12 - 26.11, or 28.01 cfs.

Flow-Deficit-Duration Frequency

From the adjusted 7-, 15-, and 31-day low flows during January to December for each year of the flow record, deficit durations at different levels of flow were tabulated at the four gaging stations. As an example, a part of the information covering years 1961 through 1970 for the 31-day low flows in the Fox River at Algonquin is shown in table 5 which shows the month and the middle of the 31-day low flow period when the flow was less than the desired flow. Deficit durations at different recurrence intervals

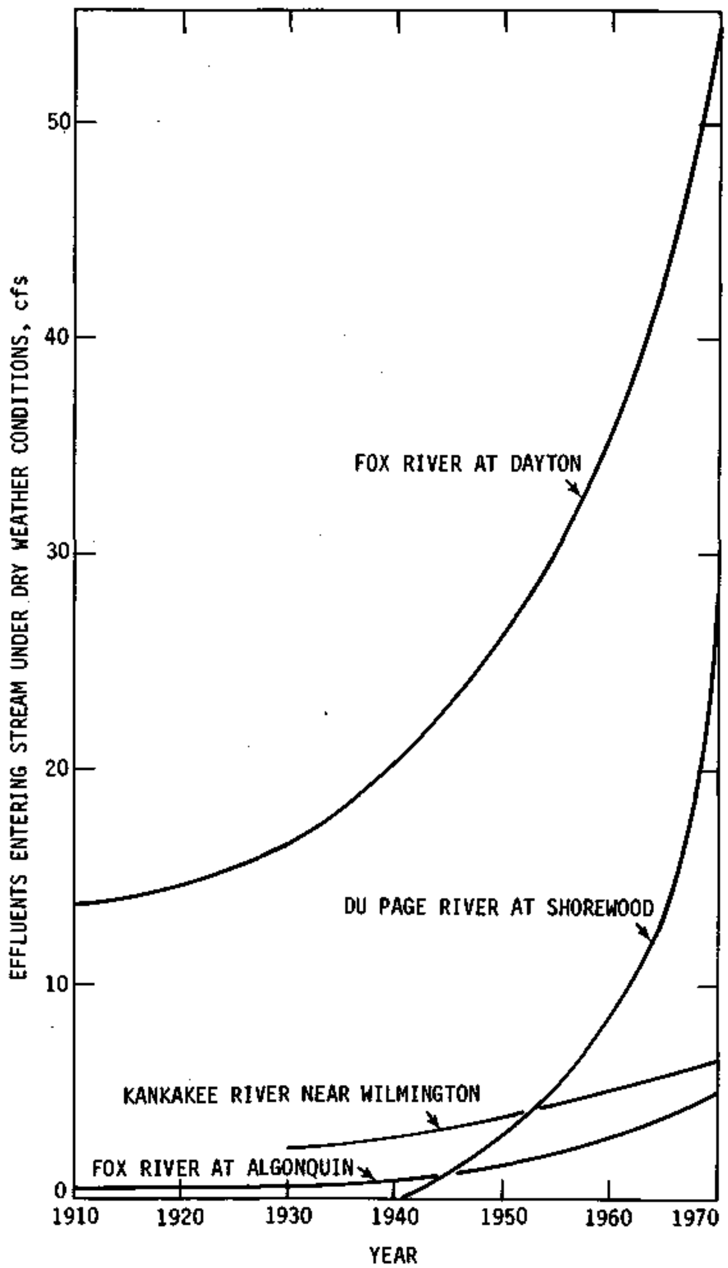

Figure 5. Effluents entering the Fox, Du Page, and Kankakee Rivers upstream of the gaging stations

Table 5. Nonavailability of Water from the Fox River at Algonquin
(from 31-day low flow information)

Year	M or D	Water available in cfs is less than 125	150	175
1963	M	8,9,10	7,8,9,10,12	6,7,8,9,10,12
	D	27,3,16	18,27,3,16,31	30,18,27,3,16,31
1964	M	10	1,8,9,10	1,8,9,10
	D	18	4,30,7,18	4,30,7,18
1965	M	7	7	6,7
	D	16	16	30,16
1966	M	9	9,10	9,10
	D	27	27,1	27,1

Notes: 1) M denotes the month. D denotes the date of the middle of the 31-day period, in the month on the preceding line.
2) 100 cfs is available in any month. More than 175 cfs is available at all times in years 1961, 1962, and 1967-1970.

Table 6. Available Flow, Deficit Duration, and Recurrence Interval Information

Available flow (cfs)	(mgd)	Deficit durations in months recurrence intervals (years) of 10	20	30	40
Fox River at Algonquin					
9	5.8	0.6	1.3	1.8	2.1
19	12.3	0.8	1.7	2.2	2.5
29	18.7	1.2	2.0	2.5	3.0
39	25.2	1.5	2.3	2.9	3.4
49	31.7	1.8	2.7	3.3	3.9
Fox River at Dayton					
22	14.2	0.7	1.4	1.7	2.1
42	27.1	1.2	1.9	2.4	2.8
62	40.1	1.5	2.3	2.9	3.9
82	53.0	2.0	2.8	3.8	5.0
Du Page River at Shorewood					
5	3.2	0.9	2.2	2.8	3.0
10	6.5	2.5	3.2	3.6	3.9
15	9.7	4.0	4.3	4.6	4.8
Kankakee River at Wilmington					
50	32.3	0.5	1.1	1.4	1.7
100	64.6	1.2	1.7	2.4	3.1
150	97.0	1.6	2.6	3.5	4.1
200	129.3	2.0	3.5	4.4	5.0

Note: Above deficit durations may be increased by one-half month to allow flow variations within the deficit duration.

for each of the selected flow levels were determined from deficit duration versus probability graphs. The final information is presented in figures 6 and 7.

Availability of Water

It is assumed that no withdrawals from the river for water supply purposes will be made when the flow is equal to or less than the 7-day 10-year low flow. River flow in excess of the $Q_{7,10}$ can be pumped for water supply as needed. Usually, this pumpage will not vary considerably over the year. Availability of flow in cfs and in mgd and the associated deficit durations in months for recurrence intervals of 10 to 40 years are given in table 6. For a 40-year drought, the deficit duration lies usually between mid-June and mid-October at Algonquin, between mid-May and mid-October at Dayton for the Fox, and between mid-September and mid-January for the Du Page and Kankakee Rivers.

Water Quality

The Water Survey has data for numerous water quality parameters stored in readily accessible computer storage from samples of surface and groundwater taken all over the state. The data for the Fox River at Algonquin and at Dayton, Du Page River at Shorewood, and Kankakee River at Wilmington were printed out separately by months -- January through December. The means and standard deviations for each of the 12 months at a gaging station were computed for the following parameters: iron (Fe), manganese (Mn), calcium (Ca), magnesium (Mg), strontium (Sr), sodium (Na), potassium (Ka), ammonium (NH_4), barium (Ba), copper (Cu), lead (Pb), lithium (Li), nickel (Ni), zinc (Zn), phosphates (PO_4), silica (SiO_2), fluoride (F), boron (B), nitrate (NO_3), chloride (Cl), sulphates (SO_4), alkalinity, and hardness. Water quality information developed is shown in table 7 for 5 parameters: NO_3, Fe, PO_4, NH_4, and hardness. Quality of water is such that it can be treated by conventional means. Fox River water quality at Algonquin is better than at Dayton. Kankakee River water is of good quality. Du Page River water is inferior in quality to both Fox and Kankakee waters.

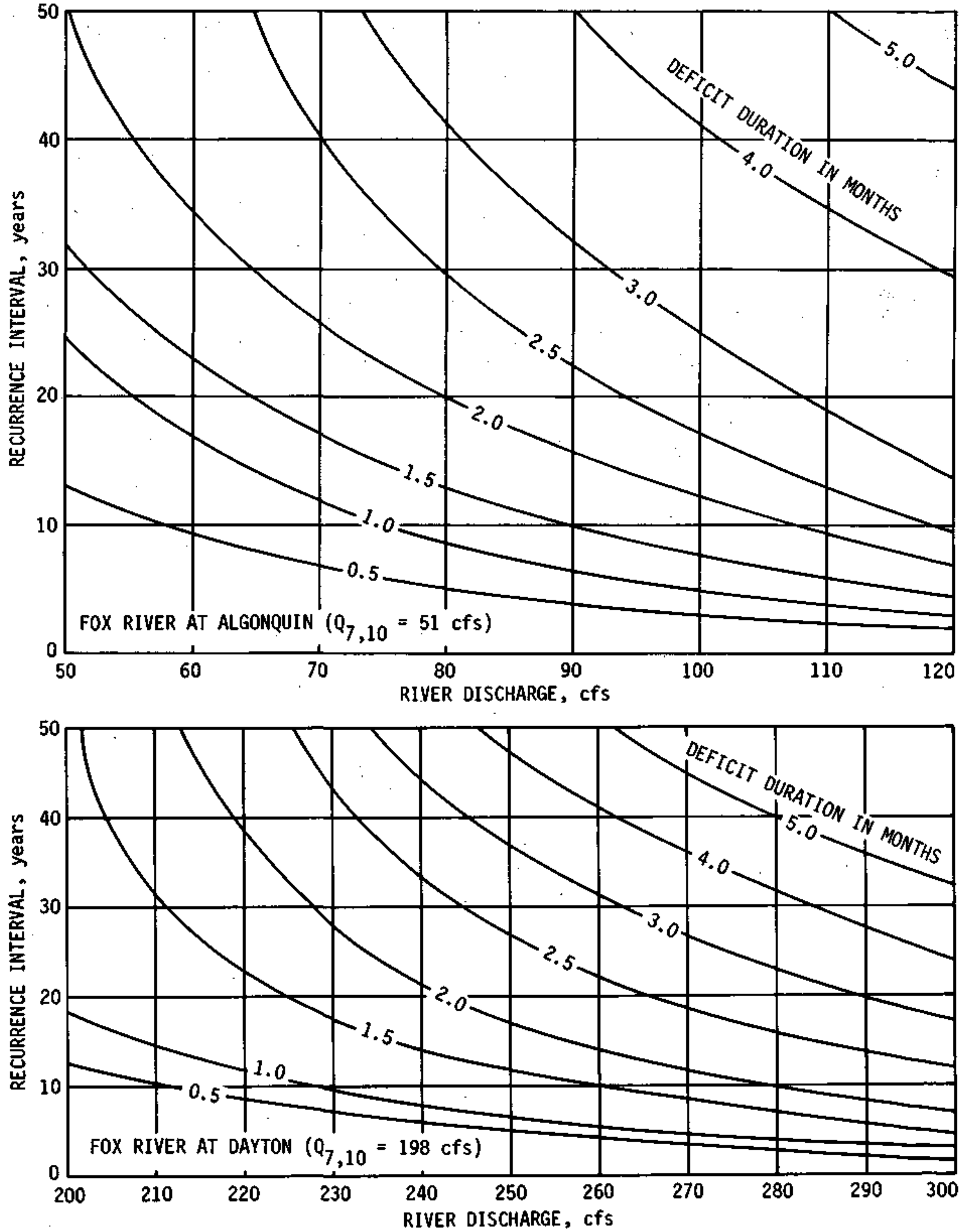

Figure 6. Duration and frequency of flow deficiency in the Fox River at Algonquin and at Dayton

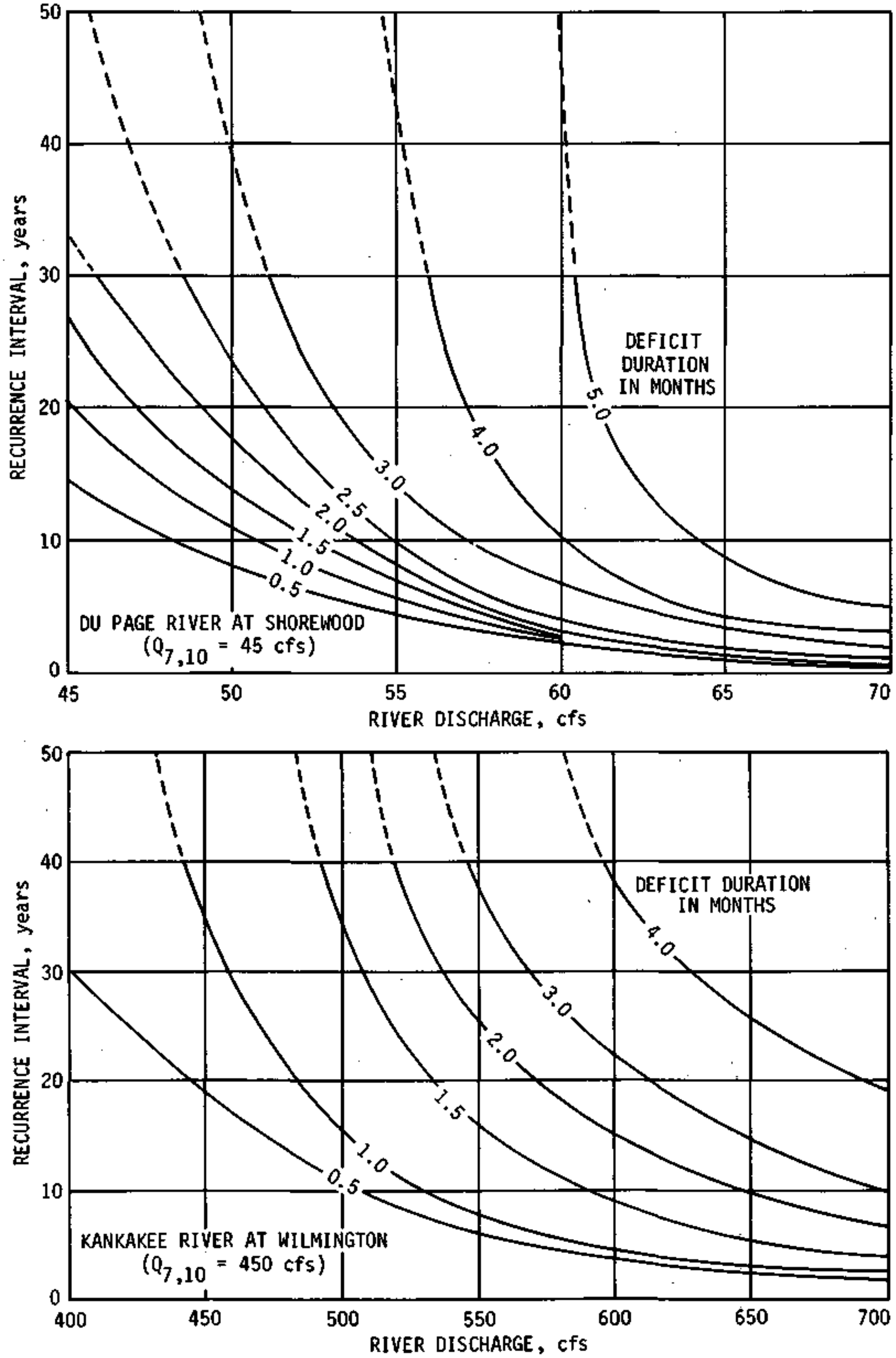

Figure 7. Duration and frequency of flow deficiency in the Du Page River at Shorewood and the Kankakee River at Wilmington

Table 7. Quality of Water in Fox, Du Page, and Kankakee Rivers
(Concentration in mg/l)

Month	*Nitrate*		*Iron*		*Phosphate*		*Ammonium*		*Hardness*	
	Range	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*
Fox River at Algonquin										
Jan.	4.7-25.0	9.2	0.1-1.3	0.4	0.6-5.1	1.6	0.0-2.2	0.5	311-440	381
Feb.	3.3-16.4	9.1	0.1-0.5	0.3	0.4-2.2	1.3	0.0-2.4	0.6	272-408	358
Mar.	4.1-13.3	8.3	0.1-0.9	0.5	0.3-2.8	1.1	0.0-1.6	0.4	232-442	306
Apr.	0.7-16.6	6.2	0.4-2.7	1.1	0.5-1.6	0.8	0.0-0.7	0.2	195-392	306
May	0.5-17.0	3.8	0.4-3.0	1.2	0.1-5.9	1.1	0.0-2.0	0.3	270-357	315
June	1.2-10.3	4.5	0.6-1.4	0.9	0.3-2.7	0.8	0.0-1.9	0.4	278-344	312
July	1.2-9.2	4.3	0.2-2.4	1.2	0.3-1.0	0.7	0.0-0.9	0.3	252-336	313
Aug.	1.1-10.6	4.3	0.9-2.7	1.4	0.6-2.2	1.2	0.0-2.2	0.3	244-334	308
Sep.	0.4-8.2	3.4	0.3-3.8	1.2	0.6-2.1	1.2	0.0-0.7	0.2	238-352	304
Oct.	0.0-9.4	4.2	0.4-2.4	0.9	0.4-3.0	1.2	0.0-0.6	0.1	276-420	323
Nov.	0.5-14.3	5.6	0.2-2.7	0.7	0.4-3.0	1.2	0.0-0.6	0.2	300-366	327
Dec.	0.9-10.8	5.4	0.2-1.5	0.4	0.3-2.1	0.9	0.0-1.6	0.3	306-402	348
Fox River at Dayton										
Jan.	7.1-18.9	12.7	0.3-1.4	0.7			0.0-0.0	0.0	227-411	311
Feb.	3.4-16.6	9.3	0.2-0.7	0.4			0.0-0.1	0.0	146-452	322
Mar.	4.4-15.5	8.3	0.3-2.8	1.4			0.0-0.1	0.0	211-366	299
Apr.	5.1-30.0	12.1	0.9-1.3	1.1			0.0-0.1	0.0	261-332	298
May	1.9-17.4	9.4	0.8-2.9	1.5			0.0-0.1	0.0	312-351	331
June	3.0-13.5	8.9	0.4-4.9	2.4			0.0-0.1	0.0	306-342	323
July	3.4-8.3	6.1	1.0-2.7	2.0			0.0-0.1	0.1	278-342	309
Aug.	3.7-10.1	6.7	1.0-4.5	2.0			0.0-0.1	0.0	278-325	298
Sep.	5.4-9.6	6.6	1.0-3.7	2.0			0.0-0.1	0.1	249-349	300
Oct.	3.3-12.1	8.3	0.9-2.4	1.4			0.0-0.1	0.0	297-360	334
Nov.	0.4-11.9	6.4	0.6-5.6	2.1			0.0-0.4	0.1	309-388	343
Dec.	1.8-9.6	6.4	0.1-0.5	0.3			0.0-0.6	0.1	340-391	364
Du Page River at Shorewood										
Jan.	10.5-22.0	17.6	0.1-8.0	2.0	1.8-6.1	3.7	0.2-4.8	2.0	206-558	395
Feb.	18.3-38.5	18.3	0.1-11.0	2.3	0.1-10.2	3.4	0.0-10.1	1.9	146-554	375
Mar.	8.9-27.2	18.8	0.3-11.5	2.0	0.9-3.1	1.9	0.0-1.8	0.7	154-412	361
Apr.	9.1-30.8	20.5	0.3-15.0	2.8	1.6-2.4	2.1	0.0-0.8	0.3	274-432	386
May	3.3-25.4	16.7	0.2-5.7	1.8	1.4-5.0	2.7	0.0-1.9	0.4	296-459	389
June	0.2-33.1	18.8	0.2-7.3	3.1	2.2-4.2	3.3	0.0-0.3	0.1	324-456	399
July	3.5-21.0	12.1	0.3-2.8	1.0	2.9-4.6	3.7	0.0-0.2	0.1	378-454	419
Aug.	2.2-20.1	10.5	0.2-4.6	1.4	2.4-5.4	4.3	0.0-4.3	0.6	360-467	409
Sep.	0.5-21.3	11.5	0.4-2.7	1.0	3.3-6.9	5.1	0.1-1.9	0.5	326-454	387
Oct.	0.2-23.3	12.2	0.1-2.9	0.9	2.8-8.2	5.4	0.0-0.8	0.2	314-464	417
Nov.	3.4-25.3	17.0	0.3-2.3	0.7	1.7-10.8	6.1	0.0-3.5	0.7	397-460	433
Dec.	11.0-25.8	17.9	0.1-4.3	1.0	1.5-11.9	5.2	0.0-5.6	1.8	332-546	422
Kankakee River at Wilmington										
Jan.	3.6-16.1	8.7	0.2-1.5	0.6		0.1	0.0-0.1	0.1	188-389	322
Feb.	1.4-24.1	12.6	1.4-2.5	1.9		0.6	0.0-0.2	0.1	111-286	226
Mar.	3.9-19.8	8.8	0.4-4.2	1.6		0.2	0.0-0.1	0.0	291-334	317
Apr.	4.7-19.3	13.9	0.8-5.9	2.6		0.7	0.0-0.1	0.1	275-328	299
May	2.5-10.0	6.7	0.9-3.3	1.5		0.4	0.0-0.0	0.0	311-331	323
June	3.8-36.1	15.7	0.4-10.0	3.6		0.1	0.0-0.1	0.0	295-328	313
July	5.7-23.9	9.5	0.5-4.6	1.9		0.2	0.0-0.1	0.0	249-332	295
Aug.	3.1-8.6	5.4	0.6-2.7	1.4		0.3	0.0-0.3	0.1	279-316	296
Sep.	1.0-9.0	3.4	0.5-3.7	1.3		0.3	0.0-0.0	0.0	187-352	302
Oct.	0.0-11.8	3.4	0.3-1.9	0.7		0.0	0.0-0.1	0.1	279-333	308
Nov.	1.1-6.9	3.7	0.3-2.2	0.8		0.0	0.0-0.2	0.1	296-350	325
Dec.	2.3-9.4	5.9	0.2-0.6	0.4		0.1	0.0-0.0	0.0	309-455	368

COST FUNCTIONS FOR WATER SUPPLY SYSTEM COMPONENTS

Cost functions for pipelines, pumping stations, wells, well pumps, reservoirs, intake structures, and water treatment plants, in terms of July 1980 dollars, have been used to develop the cost of water supply systems. These cost functions for construction and operation, maintenance, and repair (OM&R) are intended for use in planning and system studies. The economically feasible water supply systems selected from these studies will require detailed engineering design and cost estimates.

The Handy-Whitman Index (HWI) of Water Utility Construction Costs (Whitman et al, 1978) was used to convert the cost functions in terms of July 1976 dollars given in the Interim Reports of 1977 and 1978 to July 1980 dollars. From 1980 to 2010 the annual inflation rate is assumed to be either 0 or 5 percent. Inflation after 1980 is accounted for in the computer programs developed for system-staging details and unit cost of water from year to year. Land costs for reservoirs and for acquiring rights-of-way for pipelines are adjusted to July 1980 dollars by using Farmland Index Numbers (FIN) given by Reiss (1978). The HWI and FIN have been extrapolated to July 1980 from the indexes and numbers available in 1978.

Capital requirements in 1985 include, in July 1980 dollars, capital outlays, interest charges during construction, added costs due to inflation from 1980 to 1985 on account of construction over a period of 2 to 5 years, and contingency costs. The contingency cost has been taken at 20 percent of the capital expenditure and interest and inflation costs. The 20 percent comprises 12 percent for engineering, 5 percent for unforeseen items, and 3 percent for bond floatation. Interest and inflation during construction depend on the construction schedules which are specified for each system component. The 1985 capital cost is converted to an annual cost by means of a capital recovery factor (CRF) which is given by:

$$CRF = i/[1-(1+i)^{-n}] \tag{5}$$

in which i is the interest rate in decimal fraction and n is the amortization period in years. The amortization period, capital recovery factor, and cost indexes in July 1976 and July 1980 are given in table 8 for each system component.

Operation, maintenance, and repair (OM&R) costs have been estimated in July 1980 dollars for each system component. Electric power costs are computed with the Commonwealth Edison Company rate schedule (applicable from October 14, 1977) for municipal use. The schedule is;

For the first 100,000 kwh/month	2.45¢/kwh
For all over 100,000 kwh/month	1.99¢/kwh

Table 8. Construction Cost Parameters

System component	Amortization period (years)	CRF	Index values Actual July 2976	Estimated July 1980
1. Wells				
a. Sand and gravel	25	0.0937	404	536
b. Dolomite or sandstone	50	0.0817	404	536
2. Well pumps	10	0.1490	388	503
3. Reservoirs				
a. Land	50	0.0817	717	1227
b. Construction	50	0.0817	388	500
c. Intake structures	50	0.0817	388	500
4. Conveyance systems				
a. Pipelines	50	0.0817	357	455
b. Pumping stations	30	0.0888	404	536
5. Treatment plants	30	0.0888	402	533

Note: Index values give HWI for all components except land for which they represent FIN.

The 2.45¢/kwh rate for the first 100,000 kwh in a month assumes a monthly power variation small enough to obtain a 10 percent load factor discount. Annual electric charges are calculated from the monthly kwh and applicable electric rate, summed over the 12 months in a year.

Wells and Pumps

The cost of constructing a well depends on the type of aquifer, the need for a well screen and/or gravel pack, and the diameter and depth of the well. The diameter of a well depends on the expected well capacity and the size of the pump required. Well diameters for various pumping rates or well capacities (Smith 1961) used in Illinois are:

Pumping rate (gpm)	125	300	600	1200
Well diameter (inches)	6	8	10	12

For intermediate pumping capacities, the larger diameter is used.

The cost of a pump includes the pump and motor, their installation, electrical wiring, meters, connections, etc. The two types of pumping installations in use are the vertical turbine pump and the submersible turbine pump. The choice of one or the other depends on the preferences of the engineering consultant, well driller, and the municipal authorities who are guided by their past experience. From data on the wells drilled over the last 70 years in northeastern Illinois, the useful life of a well in a sand and gravel aquifer can be taken as 25 years and in Silurian dolomite and deep sandstone aquifers as 50 years. Well pumps are assumed to have a useful life of 10 years with normal operation and maintenance.

Gibb and Sanderson (1969) presented equations for computing well costs in sand and gravel, dolomite, and deep sandstone aquifers for several ranges of well diameters. The well costs for the specified ranges are a function of the well depth alone; the coefficient and the exponent in the equations vary with the well diameter and the type of aquifer. A preliminary analysis indicated that the fixed cost as a percent of total well cost is considerable in the case of sand and gravel wells, but that it is less with dolomite wells and least with deep sandstone wells. An effort was made to derive three general cost equations, one for each aquifer, from which a well cost could be determined. It is recognized that the cost of a particular well may differ from that given by the developed equations because of site access or local geologic conditions. Normal well development and pumping test costs are included. Shooting and associated bailing and retesting would increase the cost of a well requiring special development. Cost data were collected for wells drilled and well pumps installed in northeastern Illinois between 1974 and early 1978 to check the cost functions in the 1977 Interim Report. Adequate information was obtained for 4 gravel-packed wells in sand and gravel, 5 wells in Silurian dolomite, and 10 wells in the deep sandstone aquifer. Similar data were also obtained for 4 well pumps in the shallow aquifers (sand and gravel or Silurian dolomite) and for 6 well pumps in the deep sandstone aquifer. Analysis of these data yielded the multipliers listed below which need to be applied to the cost functions in the 1977 Interim Report.

	Multiplier
Sand and gravel wells	1.2
Silurian dolomite wells	1.5
Deep sandstone wells	1.4
Shallow aquifer well pumps	1.1
Deep sandstone well pumps	2.0

These multipliers are included in the final cost equations for wells and well pumps.

Well Costs

Wells are assumed to be constructed and well pumps installed in one year, for example from July 1984 to June 1985. The cost of a gravel-packed well, WC_{sg}, in the sand and gravel aquifer is given by

$$WC_{sg} = 7320 + 465D + 9.3d\ D \tag{6}$$

in which WC is the well cost in July 1980 dollars, D = bottom casing diameter in inches, and d = well depth in feet. The cost of a well in the Silurian dolomite, WC_{sd}, is

$$WC_{sd} = 1150 + 520\ x + (0.23 + 0.050\ x)\ d^{1.83} \tag{7}$$

in which x = D - 6 and D = bottom bore hole diameter in inches. In computing deep sandstone well costs, the well diameters for pumping rates of 350, 700, and 1000 gpm have been taken as 10, 12, and 15 inches, respectively. The cost of a deep sandstone well, WC_{ds}, is given by

$$WC_{ds} = (4400 + 0.066\ d^{1.95})\ (D/10)^{1.35} \tag{8}$$

Well Pump Costs

Installed costs of vertical turbine pumps (line-shaft) and submersible turbine pumps, including motors and electrical appurtenances, are given by Gibb and Sanderson (1969) in terms of 1966 dollars. Singh et al. (1972) added $800, 1964 prices, for a pump enclosure to the cost of vertical turbine pumps. In July 1980 dollars the cost functions for well pumps in shallow aquifers including motor, electrical equipment, and installation are:

$$PC_{tp} = 2920 + 23.9\ Q^{0.45}\ H^{0.64} \tag{9}$$

$$PC_{sp} = 18.6\ Q^{0.54}\ H^{0.66} \tag{10}$$

in which PC is the pump cost and subscripts tp and sp denote vertical turbine and submersible turbine, respectively; Q and H are the pump capacity in gpm and total dynamic head in feet, respectively. Total head is obtained by adding 25 feet to the pumping lift to furnish raw groundwater to a treatment plant or a transmission line. Any additional head required would be considered under the cost of transporting water.

The pumping lift for shallow aquifers is determined from ground surface elevation, static water level, and drawdown. The less expensive type of pump is assumed in computing the cost of shallow groundwater. Submersible turbine pumps are cheaper if less than 20 horsepower is required. Deep sandstone wells are mostly high capacity and have high pumping heads. Vertical turbine pumps will be more economical for such wells. The cost of vertical turbine pumps, in dollars, for deep sandstone wells, PC_{ds}, is

$$PC_{ds} = 5300 + 43.5\ Q^{0.45}\ H^{0.64} \tag{11}$$

The pumping head in the deep sandstone aquifer is determined from pumping levels obtained from the digital computer model of that aquifer.

Annual Operation Costs

The annual cost of electricity for pumping is obtained with the electric power cost schedule and the annual electric consumption which is given by:

$$kwh = 1147.6\ Q\ H/E \quad (12)$$

where Q is the average pumping rate in mgd, and E is the annual average efficiency taken as 0.6. The annual operation, maintenance, and repair cost for a municipal well field in July 1980 dollars is given by:

$$OM\&R = 305 + 230\ NW \quad (13)$$

in which NW = number of wells.

In addition, costs are incurred for rehabilitation of dolomite wells. A dolomite well generally needs rehabilitation by acidizing once every 25 years on the average (Schicht et al., 1976). An addition of $1.20 per gpm of well capacity is made to the OM&R cost to allow for the rehabilitation cost incurred once over the 50-year useful life of a dolomite well.

Reservoir Costs

The reservoir storage, S, is designed to meet 1.2 times the average yearly demand in mgd during a 40-year drought and the evaporation and leakage loss (taken as 1.5 times the evaporation during the critical drought duration). The reservoir water surface area, A, in acres is obtained from (Dawes and Wathne, 1968)

$$A = 0.23\ S^{0.87} \quad (14)$$

where S is in acre-feet. Area acquired for the reservoir, embankments, and access roads will be 1.5 times A. An intake structure will be constructed in the river for pumping water to the reservoir.

Reservoir Cost

The reservoir construction cost, RC, following the expression given by Dawes and Wathne (1968), in July 1980 dollars is

$$RC = 26{,}400\ S^{0.54} + 1.5\ (LC)\ A \quad (15)$$

in which LC is the land cost in dollars per acre. Construction is assumed to occur between July 1980 and June 1985 according to this schedule: 0.05, 0.20, 0.35, 0.30, and 0.10 from the first to the fifth year. Land is assumed to be purchased during the second half of 1980.

Intake Structure Cost

Singh et al. (1972) gave an expression for the cost of a reservoir or river intake structure. The construction cost of an intake structure, IC, in 1980 dollars is

$$IC = 78,000 + 7800\ Q \quad (16)$$

in which Q is the average withdrawal in mgd. The intake structure is assumed to be built in 1984-1985.

OM&R Cost

Annual operation, maintenance, and repair cost for a reservoir and intake structure, in 1980 dollars is computed from

$$OM\&R = 26,600 + 0.015\ (RC + IC) \quad (17)$$

Water Conveyance System

Water will be conveyed by a network of pipelines from the source, whether groundwater or surface water, to the user towns or entities. The conveyance network will have pumping stations to keep the pressure in the system between 25 and 300 feet of water. The pipeline will be optimal in the sense that the unit cost of conveyance will be minimum. It will be adequate to meet the varying water demand expressed in terms of the demand factor (ratio of the demand to the average demand) and the fraction of time a factor is to be met. Additional storage to meet hourly demand variations will be provided by each town according to its particular needs.

Factor	*Fraction of time*	*Product*
1.8	0.01	0.018
1.7	0.02	0.034
1.6	0.03	0.048
1.5	0.04	0.060
1.4	0.05	0.070
1.3	0.07	0.091
1.2	0.08	0.096
1.1	0.09	0.099
1.0	0.10	0.100
0.9	0.12	0.108
0.8	0.15	0.120
0.7	0.12	0.084
0.6	0.12	0.072
	1.00	1.000

Six components of conveyance cost (Singh, 1971) are: 1) pipeline construction cost, 2) pipeline maintenance cost, 3) easement cost, 4) pumping station cost, 5) pumping cost, and 6) pumping station OM&R cost. Conveyance pipeline systems are assumed to be constructed between July 1980 and June 1985 according to the schedule: 0.05, 0.20, 0.35, 0.30, and 0.10 from the first to the fifth year. Pipelines for local groundwater collection systems are assumed to be constructed in 1984-1985. Study of some recent engineering reports on water supply for northeastern Illinois indicated the need for increasing the cost of pipeline construction. Such an increase is dependent on the depth at which pipe is to be laid, drainage, road and highway crossings, extra costs involved in directing and routing traffic, limited easements and workspace in and around medium to large size towns, number of other utility lines to be crossed, any breaking of pavements, etc. The increase in cost is achieved by the use of a multiplier, which varies from 1.0 to 2.0. It is 3.0 for underwater pipelines to intakes in Lake Michigan.

Pipeline Construction Cost, C_1

The cost C_1 in dollars is obtained from

$$C_1 = 5750\ M\ L\ D^{1.2} \tag{18}$$

in which L is length in miles, D is inside pipe diameter in inches, and M is a multiplier.

Pipeline OM&R, C_2

Annual pipeline operation, maintenance, and repair cost in dollars is given by

$$C_2 = 27\ D\ L \tag{19}$$

Easement Cost, C_3

The easement cost in dollars of the right-of-way lands for the pipelines is given by

$$C_3 = 10{,}700\ L \tag{20}$$

Pumping Station Cost, C_4

The construction of a pump station complete with installation of pumps in July 1980 dollars is

$$C_4 = 57{,}300\ h_{max}/300 + 427\ HP_{max} \tag{21}$$

in which h_{max} equals maximum head at 1.8 times the average flow and HP_{max} is the maximum installed horsepower.

Annual Energy Cost, C_5

The annual cost of energy depends on the horsepower actually expended (varying with the varying pumpage demand) integrated over the year.

The annual energy cost, C_5, is the product of the annual kwh and the appropriate value from the rate schedule.

Pump Station OM&R, C_6

This cost includes oiling, painting, routine checking, servicing, and repairs to or renewal of worn-out parts. The annual cost in dollars is

$$C_6 = 3520 + 26\ (HP_{max})^{1.05} \tag{22}$$

Water Treatment

Water treatment costs in two recent regional studies of northeastern Illinois (Schicht et al., 1976; Keifer, 1977a) were based on the cost functions in State Water Survey Technical Letter 11 (ISWS, 1968) and Circular 102 (Moench and Visocky, 1971). The unit treatment costs developed in this study considered the information from these publications together with that from three others (Howson, 1962; USEPA, 1977: and Volkert, 1974).

Because hardness of water, concentration of suspended solids, and other water quality parameters vary with the source of water, water treatment requirements are considered for the average raw water quality from each source. Lake Michigan water will be treated by coagulation, sedimentation, filtration, and disinfection. The water from the Fox and Kankakee Rivers will not only be similarly treated but also softened to the hardness of Lake Michigan water, treated for iron removal when necessary, and disinfected. Typical values of hardness for river and groundwater (Harmeson et al., 1973; and NIPC, 1966) are 325 and 425 mg/l. Thus, hardness removal of 200 and 300 mg/l will be required for raw river and groundwater on the basis of 125 mg/l hardness in the treated lake water. In a few townships where groundwater has hardness considerably higher than the average, the treatment cost can be modified to reflect the additional cost of chemicals to soften the water to 125 mg/l hardness. The extra costs involved if radioactivity in the groundwater from the deep sandstone aquifer exceeds permissible limits is given in the section on radioactivity.

Treatment plants are assumed to be built in 3 years according to the schedule: 0.1, 0.5, and 0.4 in the first to the third year. Construction costs are based on building a plant with a capacity 1.5 times the average demand. The 3-year construction schedule may run from July 1982 to June 1985.

Cost data from several sources were used to derive satisfactory cost functions. Technical Letter 11 (ISWS, 1968), a USEPA manual (1977), and a report by Keifer and Associates (1977a) were used to derive the treatment costs for Lake Michigan. Howson (1962) and Volkert (1974) suggested adjustments to the cost of filtration plants to account for the added cost of softening river water. The OM&R costs for treating river water were adjusted to be consistent with the OM&R costs for lime-soda softening of groundwater. Groundwater treatment costs were developed from Howson (1962), USEPA (1977), and Keifer (1977a).

Lake Michigan Water

The curves for capital, OM&R, and total unit costs in figure 8 include coagulation, sedimentation, rapid sand filtration, and disinfection. Unit costs for plants with capacities over 100 mgd are assumed to equal those for a 100 mgd plant. The following sample calculation illustrates the derivation of the total cost curve and the method of obtaining annual and construction costs from the unit cost.

Consider a 20 mgd average supply from Lake Michigan
Maximum plant capacity = 30 mgd
Unit capital cost = 11.0 ¢/1000 gal (for a 30 mgd plant)
Annual capital cost, $ = [(11.0 × 30 × 1000 × 365.2)/100] = 1,205,160
Capital cost = 1,205,160/0.088 = $13,572,000 (not including contingencies or interest during construction)
Unit OM&R cost = 7.4¢/1000 gal
Annual OM&R cost, $ = [(7.4 × 20 × 1000 × 365.2)/100] = 540,496
Total annual cost, $ = 1,745,656
Total unit cost = [(1,745,656 × 100)/(20 × 1000 × 365.2)] = 23.9¢/1000 gal

River Water

Softening by the lime-soda process is required in addition to coagulation, sedimentation, filtration, and disinfection. The hardness is about 325 mg/l as compared with 125 mg/l for Lake Michigan water. Construction costs were increased 10 percent over those for Lake Michigan water. The OM&R costs were based on adding about 10 cents per thousand gallons to the OM&R costs for Lake Michigan water and then adjusting costs for plant capacities under 10 mgd to be consistent with the OM&R costs for lime-soda plants treating groundwater. The unit costs of treating river water are given in figure 9.

Groundwater

The groundwater will be softened to 125 mg/l hardness. About two-thirds of the towns using groundwater have iron concentrations in raw water exceeding 0.8 mg/l (Schicht et al., 1976); the drinking water standard specifies a maximum of 0.3 mg/l of iron in treated water. The lime-soda softening process removes iron. Iron removal can also be achieved by ion exchange and diatomaceous earth filtration. The costs for ion exchange softening include oxidation and diatomaceous earth filtration, in addition to softening and disinfection. Unit cost curves for both softening processes are shown in figure 10. For plant capacities less than 5 mgd, ion exchange softening is less costly than lime-soda softening. Above 5 mgd

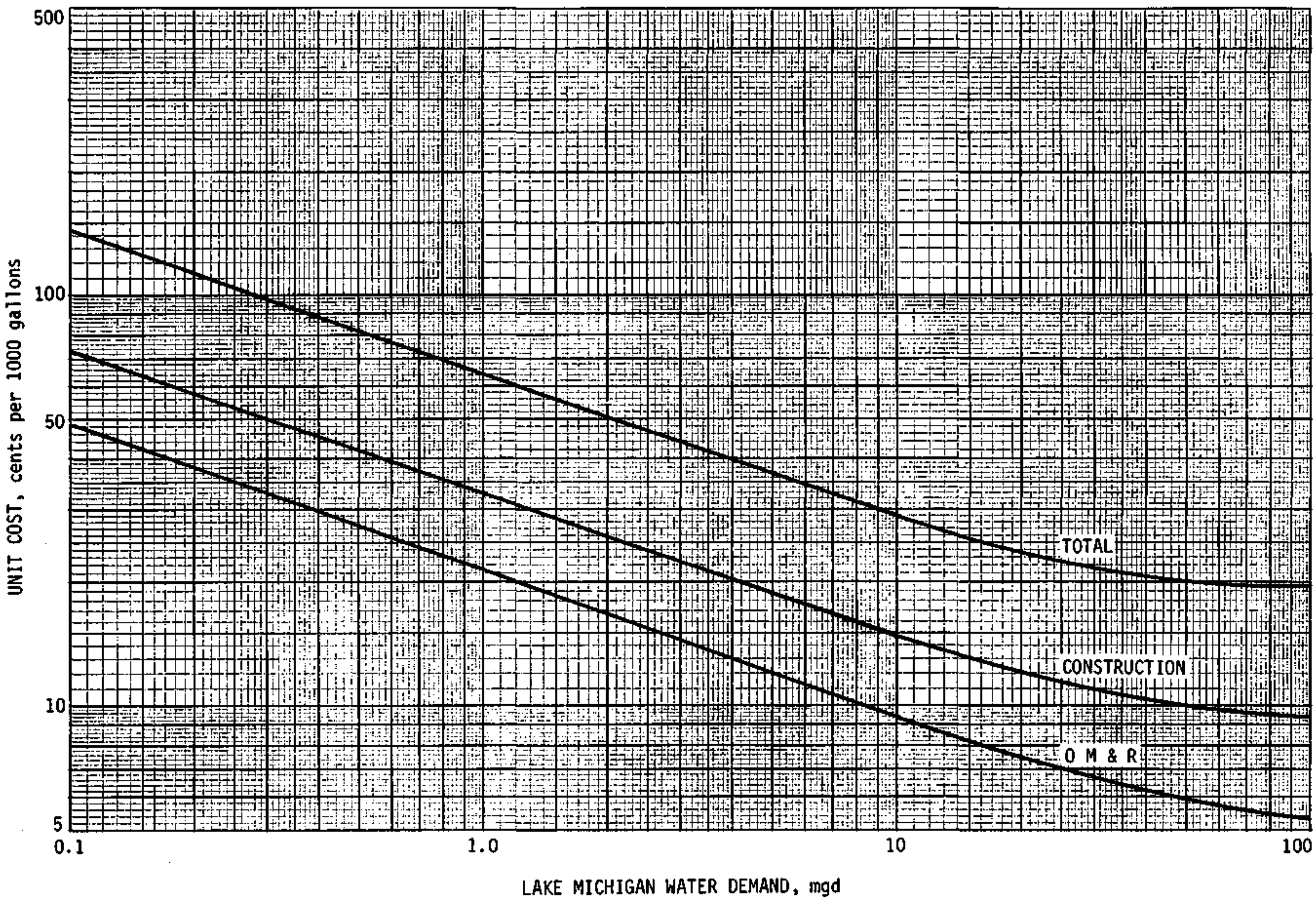

Figure 8. Lake Michigan water treatment costs in July 1980 dollars

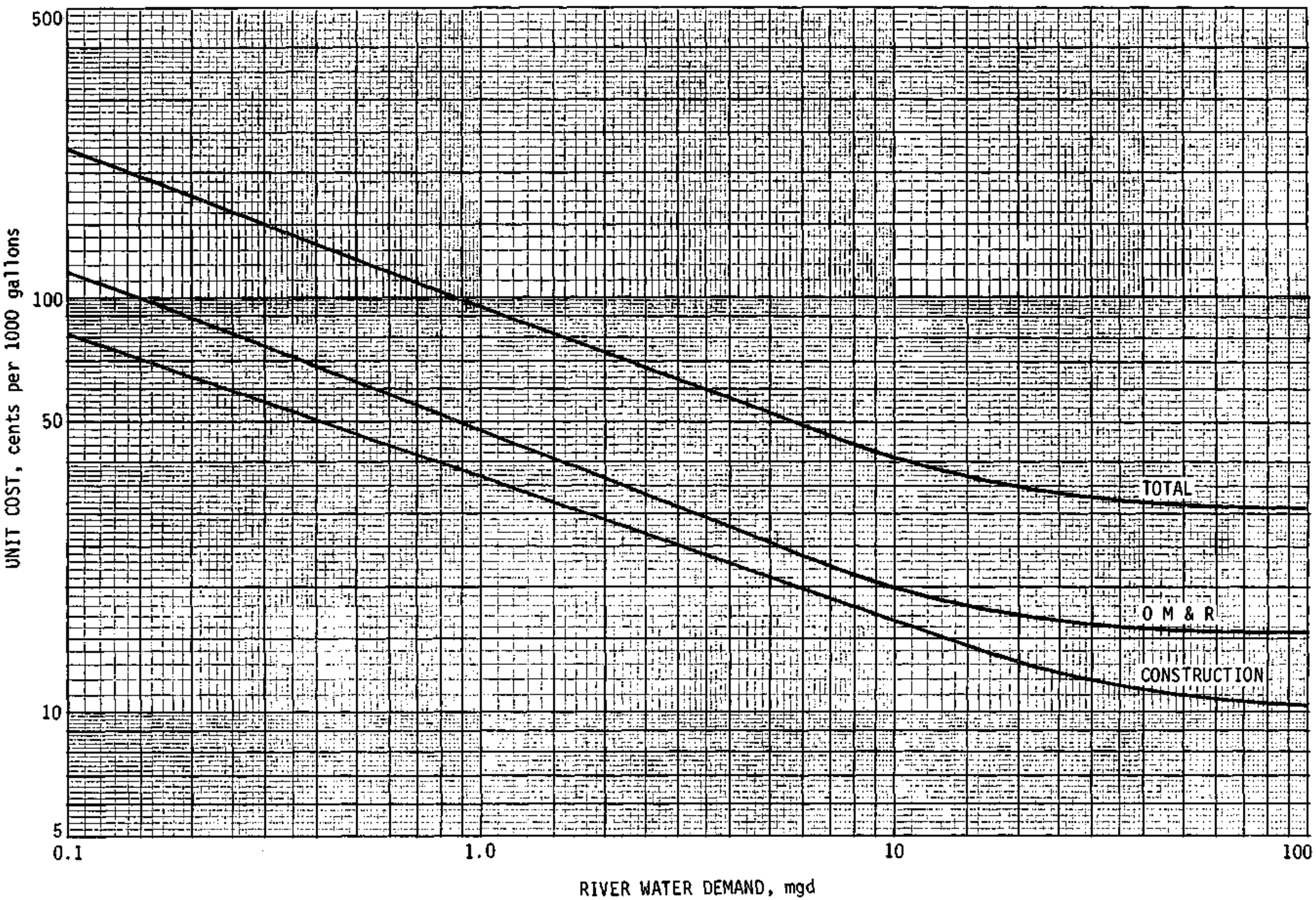

Figure 9. River water treatment costs in July 1980 dollars

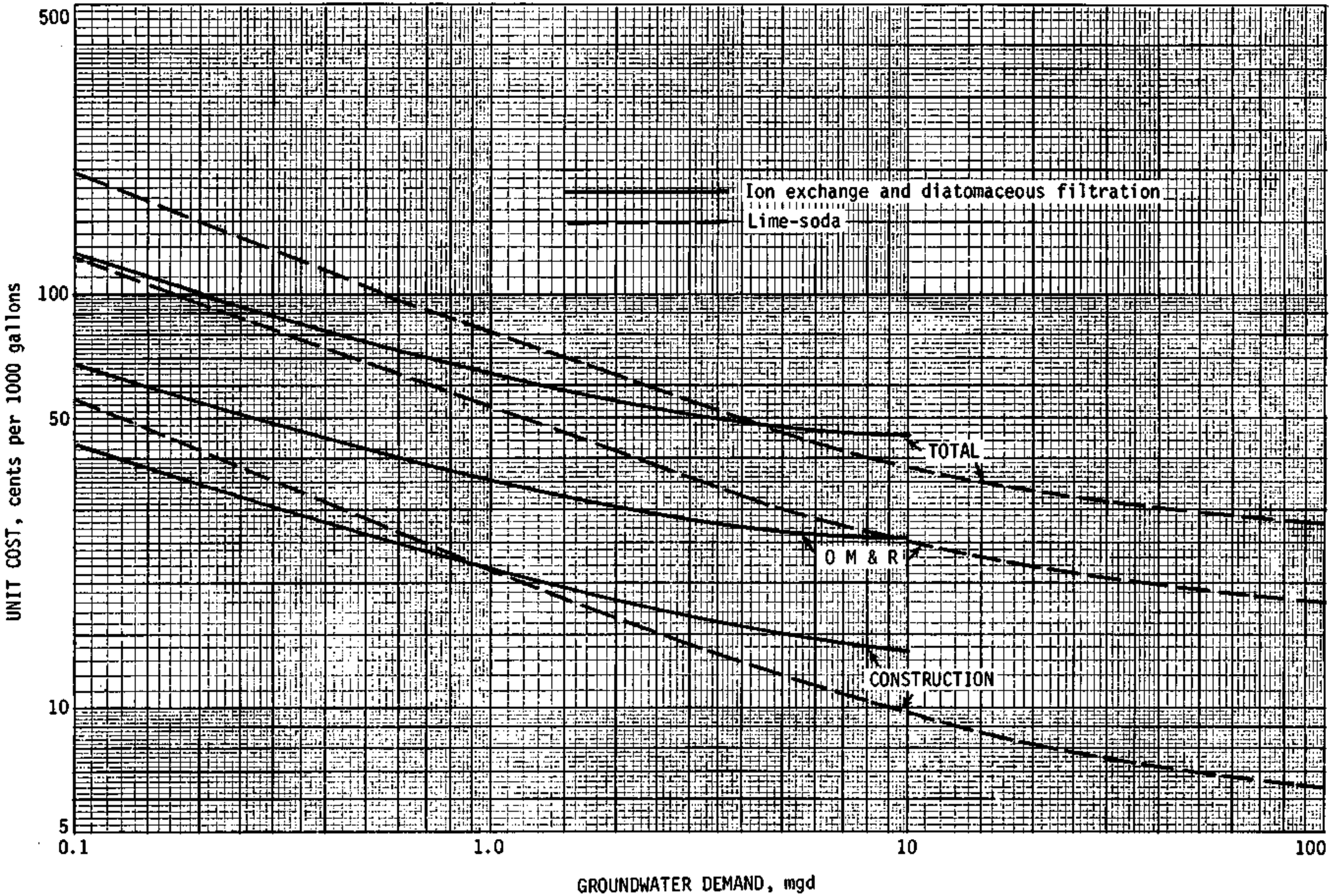

Figure 10. Groundwater treatment costs in July 1980 dollars

capacity, lime-soda treatment becomes progressively more economical as the plant size increases. The ion exchange cost curves are drawn up to 10 mgd. For larger ion exchange plants, more treatment units are added, but there is no economy of scale,

Generally, groundwater supplies in northeastern Illinois are not treated for hardness removal in the municipal treatment plants. Home softening of water, usually that portion which goes through the water heater, is common and it is achieved with individual ion exchange units. Considering the useful life of these units as 10 to 15 years, Howson (1962) gave a total unit cost estimate which is 130 to 160¢/1000 gal of water softened in terms of 1961 dollars. Staackmann and Agardy (1977) give a relation between home softening cost and hardness removal. The cost works out to 105¢/1000 gal in July 1980 dollars with 300mg/l hardness removal for a household using an average of 450 gallons per day. However, this cost is based on a 30-year life of the home softening units. With a life of 10 to 15 years as used by Howson, the unit cost would be close to $2.00. These estimates can be compared with the total cost curves in figure 10.

RADIOACTIVITY AND INCREASE IN TREATMENT COSTS

The Illinois Pollution Control Board adopted radiological standards for alpha particle activity and monitoring requirements on August 24, 1978, in line with the National Interim Primary Drinking Water Regulations. Some of these are given below.

> "Maximum allowable concentrations for radium-226, radium-228, and gross alpha particle radioactivity are: 5 pCi/1 for combined radium-226 and radium-228 and 15 pCi/1 for gross alpha particle activity (excluding radon and uranium)."

> "A gross alpha particle activity measurement may be substituted for the required radium-226 and radium-228 analysis, provided that the measured gross alpha particle activity does not exceed 5 pCi/1 at a confidence level of 95 percent (1.65σ where σ is the standard deviation of the net counting rate of the sample). In localities where radium-228 may be present in drinking water, radium-226 and/or radium-228 analyses may be required by the agency (Illinois Environmental Protection Agency) when the gross alpha particle activity exceeds 2 pCi/1."

> "When the gross alpha particle activity exceeds 5 pCi/1, the same or an equivalent sample shall be analyzed for radium-226. If the concentration of radium exceeds 3 pCi/1, the same or an equivalent sample shall be analyzed for radium-228."

> "If the gross beta particle activity exceeds 50 pCi/1, an analysis of the sample must be performed to identify the major radioactive constituents present and the appropriate organ and total body doses shall be calculated to determine compliance with Rule 304 C2."

Radioactivity in surface water (Lake Michigan and the Fox, DuPage, and Kankakee Rivers) is very low. It is higher in the water from sand and gravel and Silurian dolomite aquifers but still lower than the permissible limit. However, the radioactivity in water from the deep sandstone aquifer exceeds the standard over a significant portion of northeastern Illinois. It is believed to be caused by leaching of radium from radium-bearing rock strata in the deep sandstone aquifer.

Radioactivity in Groundwater

The State Water Survey has records of laboratory tests on groundwater samples from shallow and deep wells in northeastern Illinois. The radioactivity data from the tests conducted during the years 1971-1976 were compiled for all townships for gross alpha and beta particle activity. Sample size and values of mean and range are given in table 9. There were no data for the townships that are not listed.

Table 9. Radioactivity in Groundwater

Twp NO.	α β	Sand and gravel n	mean	range	Silurian dolomite n	mean	range	Deep sandstone n	mean	range
McHenry County										
1	α	2	2.4	0.9-3.8						
	β	2	7.9	6.7-9.0						
3	α	3	0.3	0.0-1.0						
	β	3	0.3	0.0-1.0						
4	α	5	0.2	0.0-1.0	3	0.0				
	β	5	2.1	0.5-4.3	3	1.2	0.5-2.0			
8	α	5	0.6	0.0-1.7	6	0.9	0.0-2.2			
	β	5	2.3	1.6-3.0	6	3.7	0.0-8.5			
9	α	4	1.1	0.2-1.4						
	β	4	1.8	0.0-3.5						
11	α	9	0.3	0.0-0.9						
	β	9	2.7	0.0-4.1						
12	α	6	0.6	0.0-1.3						
	β	6	0.8	0.0-3.0						
14	α	5	0.1	0.0-0.2	1	1.6				
	β	5	2.0	1.0-4.0	1	8.6				
15	α	5	1.5	0.0-2.6						
	β	5	3.7	1.9-4.2						
16	α	11	1.0	0.0-3.5	8	0.7	0.0-1.8	13	8.8	1.0-21.8
	β	11	2.7	0.0-9.8	8	2.4	1.0-5.0	13	13.0	0.6-27.1
Kane County										
17	α							4	5.8	1.0-12.1
	β							4	11.0	3.0-17.0
19	α	13	0.4	0.0-1.0				6	8.5	2.0-15.6
	β	13	1.7	0.0-3.6				6	15.4	9.0-25.9
20	α							4	10.5	2.2-19.4
	β							4	13.4	5.0-22.0
22	α	19	0.7	0.0-1.8				7	11.0	7.8-16.7
	β	19	1.4	0.0-5.0				7	19.1	15.9-23.9
23	α	3	0.3	0.0-0.8						
	β	3	2.8	0.3-4.5						
25	α	7	0.6	0.0-1.5				4	14.5	8.0-30.6
	β	7	2.0	0.0-4.5				4	24.0	18.0-34.8
27	α	1	1.0					4	17.0	11.0-24.7
	β	1	14.0					4	26.2	16.0-33.0
28	α							24	18.6	5.4-34.9
	β							24	28.1	15.0-40.1
30	α	4	1.8	0.0-3.3						
	β	5	3.7	0.0-5.3						
31	α							37	13.6	4.0-38.6
	β							37	25.2	12.0-71.0
Lake County										
32	α	9	0.7	0.0-2.0						
	B	9	2.2	0.8-3.0						
33	α	11	0.5	0.0-1.4						
	B	11	1.5	0.5-3.0						

Continued on next page

Table 9. Continued

Twp No.	*α β*	*Sand and gravel* *n*	*mean*	*range*	*Silurian dolomite* *n*	*mean*	*range*	*Deep sandstone* *n*	*mean*	*range*
Lake County (Continued)										
35	α	4	1.2	0.0-2.4	2	1.1	0.0-2.2	2	34.6	33.2-36.0
	β	4	2.4	1.0-3.5	2	1.6	0.0-3.2	2	36.7	34.6-38.7
36	α	4	0.7	0.0-1.4						
	β	4	3.6	1.0-7.0						
37	α	4	0.6	0.0-2.2	13	0.7	0.1-1.9	2	37.0	32.1-41.8
	β	4	5.0	1.0-6.7	13	1.9	0.0-4.8	2	31.0	29.3-32.8
38	α	8	0.3	0.0-1.0				4	18.1	7.3-39.1
	β	7	2.2	1.0-5.2				4	22.6	12.6-34.3
40	α	7	0.1	0.0-0.5	6	0.9	0.0-1.5	1	19.3	
	β	7	1.8	0.0-3.0	6	2.5	0.0-4.0	1	23.3	
41	α	2	1.8	0.0-3.6	1	1.9		4	9.0	3.0-20.1
	β	2	1.0	0.6-1.3	1	2.7		4	16.6	11.0-24.5
42	α	3	0.6	0.0-1.3	7	0.1	0.0-0.6	3	25.4	10.0-43.6
	β	3	2.7	0.0-5.0	7	2.3	1.1-4.2	3	27.9	19.1-38.7
44	α	3	0.8	0.0-2.0						
	β	3	2.5	1.5-3.1						
45	α				4	0.1	0.0-0.4	2	4.5	4.0- 5.0
	β				4	1.4	0.0-3.0	2	15.0	15.0-15.0
46	α	3	1.1	0.3-1.9	5	0.8	0.0-3.3			
	β	3	2.5	0.6-5.8	5	2.1	0.0-5.5			
Cook County										
48	α				8	0.9	0.1-1.6			
	β				8	2.8	1.0-7.1			
49	α	6	1.8	0.0-4.7				12	10.5	0.0-31.7
	β	6	3.4	2.3-6.2				12	21.4	2.3-45.8
50	α				1	2.2		29	13.9	3.1-31.3
	β				1	1.1		29	27.4	6.9-48.1
51	α							3	13.9	6.4-19.7
	β							3	24.8	17.7-29.0
53	α	4	0.1	0.0-0.4	9	0.8	0.0-2.0	6	11.4	3.3-22.7
	β	4	1.2	0.7-2.1	9	2.3	0.0-9.2	6	16.9	2.9-31.9
54	α				9	1.3	0.0- 3.8	9	20.5	10.8-44.0
	β				9	6.9	1.7-15.0	9	28.2	10.6-47.0
55	α	1	0.2		9	1.0	0.0- 4.0	25	8.3	0.6-17.5
	β	1	4.1		9	5.2	3.0-17.6	25	19.3	0.6-33.3
56	α							6	3.1	1.2- 4.8
	β							6	12.9	9.9-18.2
60	α				9	1.5	0.0- 4.7	11	9.3	1.0-22.0
	β				9	3.4	0.0- 9.5	11	19.2	1.0-31.2
62	α				15	2.5	1.0- 8.1			
	β				15	5.4	0.0-14.4			
64	α				2	2.3	0.4- 4.1	4	21.0	9.1-44.7
	β				2	6.5	3.2- 9.7	4	29.6	13.0-38.8

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Table 9. Continued

Tup No.	α β	Sand and gravel n	mean	range	Silurian dolomite n	mean	range	Deep sandstone n	mean	range
Cook County (Continued)										
68	α				8	0.8	0.0- 2.2	2	34.7	28.0-41.3
	β				8	4.0	0.0- 6.2	2	48.6	44.5-52.6
70	α							6	33.8	4.1-80.0
	β							6	46.4	22.2-81.6
71	α				20	1.4	0.0- 4.7			
	β				20	7.2	0.0-13.0			
72	α				50	1.6	0.0- 5.0	17	31.2	0.8-86.0
	β				50	7.8	0.8-15.3	17	39.7	1.0-83.7
DuPage County										
74	α	1	1.2		25	1.1	0.0- 4.3	3	15.4	3.0-33.1
	β	1	3.6		25	3.9	1.0- 7.2	3	26.9	17.0-35.8
75	α	8	1.1	0.0- 3.0	19	1.5	0.0- 4.0	10	23.6	5.1-46.5
	β	8	4.2	1.0- 8.4	19	3.6	0.0- 6.1	10	29.0	13.1-45.5
76	α				8	2.0	0.8- 3.5	12	26.4	0.0-92.3
	β				8	6.6	0.0-16.1	12	28.3	3.0-64.0
77	α				27	1.0	0.0- 2.2			
	β				27	5.5	0.7- 9.9			
78	α	2	2.5	2.0- 3.0	8	2.0	0.9- 4.2	22	15.7	1.0-47.6
	β	2	2.4	1.5- 3.2	8	6.8	0.0- 9.0	22	24.5	1.0-43.1
79	α				18	2.2	0.4- 5.5	5	14.3	6.4-22.8
	β				18	3.5	0.0- 6.7	5	27.1	17.5-32.3
80	α				21	2.4	0.2- 5.8			
	β				21	5.6	0.0-13.8			
81	α				51	1.7	0.0- 5.3	3	16.6	5.2-27.3
	β				51	4.9	0.0-14.6	3	23.4	11.9-30.5
Will County										
83	α				3	11.9	4.0-26.6	13	1.8	0.0- 4.2
	β				3	21.1	14.0-32.3	13	4.2	0.0-12.2
84	α				3	20.0	3.0-42.5	1	8.3	
	β				3	26.6	17.0-34.9	1	26.8	
85	α				9	22.4	4.0-42.0	10	1.7	0.0- 5.3
	β				9	29.0	7.0-48.1	12	4.8	0.6- 8.6
87	α				7	12.2	3.0-23.0	3	2.9	0.2- 4.9
	β				7	20.9	9.0-30.5	4	11.5	0.0-22.4
88	α				3	21.2	8.2-40.4	7	1.8	0.0- 3.5
	β				3	22.8	6.7-48.1	7	6.8	2.0-14.0
89	α							4	2.2	0.0- 4.2
	β							4	10.5	1.0-18.5
90	α							7	1.5	0.0- 4.0
	β							8	6.0	4.0-10.6

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Table 9. Concluded

Twp No.	α β	Sand and gravel n	mean	range	Silurian dolomite n	mean	range	Deep sandstone n	mean	range
Will County (Continued)										
92	α				3	1.2	0.0- 2.7			
	β				3	3.2	2.0- 4.5			
93	α				2	2.5	1.0- 4.0			
	β				2	2.8	1.0- 4.6			
95	α				8	1.1	0.1- 4.0			
	β				8	4.8	1.4- 9.0			
96	α				7	2.1	0.0- 4.5			
	β				7	4.2	2.7- 5.8			
97	α							5	23.9	2.4-51.7
	β							5	30.4	9.5-49.3
100	α				6	1.2	0.0- 2.9			
	β				6	8.0	0.0-11.6			
102	α				1	2.5				
	β				1	5.9				
103	α							2	22.3	11.0-33.6
	β							2	36.5	26.0-47.0

α is gross alpha particle activity in pCi/1
β is gross beta particle activity in pCi/1
n is the number of samples tested

The activity varies over a wide range, indicating nonstandardized testing and inherent variability. Different activity levels may be obtained if a sample is tested at different times after collection. It seems that under equilibrium conditions the combined radium-226 and radium-228 concentration is about one-third of gross alpha particle activity, but this proportion varies with the source characteristics and testing procedures.

Sand and Gravel

Mean gross alpha activity varies from 0.1-2.5 and maximum values range from 0.2-4.7 pCi/1 for 33 townships. The values are much lower than the maximum allowable. The maximum beta activity observed is less than 10 except it is 14 for one out of a total of 182 samples.

Silurian Dolomite

Mean gross alpha activity varies from 0.0 to 2.9 and maximum values range from 0.0 to 8.1 pCi/1 for 43 townships. These values are much lower than the standard. The maximum observed beta activity is 22.4 in a total of 449 samples.

Deep Sandstone

Mean gross alpha activity varies from 3.1 to 37.0 and maximum values range from 4.8 to 92.3 pCi/1 for 41 townships. Some low values are caused by wells being open to the dolomite aquifer also. The maximum beta activity observed is 83.7 pCi/1 in a total of 338 samples.

Costs of Radium Removal

The maximum contaminant level for radium-226 and radium-228 alpha emitters is 5 pCi/1. The reduction to 5 pCi/1 or lower can be achieved either by lime-soda softening or ion-exchange. The groundwater treatment costs with lime-soda and ion-exchange have already been derived on the basis of reducing hardness from 425 to 125 mg/l. This hardness removal is accompanied by certain radium removal which may or may not be sufficient to meet the standards. Any extra costs involved pursuant to achieving the standard are discussed below.

Lime-Soda Softening Plants

Radium removal in lime-soda plants is given by the equation (Singley et al., 1977)

$$f_H = (f_R)^{2.86} \tag{23}$$

in which f_H = hardness removal fraction and f_R = radium (Ra) removal fraction.

In the case of groundwater from the deep sandstone aquifer

$$f_H = (425 - 125)/425 = 0.706 \quad (24)$$

$$f_R = (0.706)^{0.35} = 0.885 \quad (25)$$

For 5 pCi/1 in finished water, the radium in raw water equals 5/(1 - 0.885) or 44 pCi/1. For Ra less than 44 pCi/1, no increase in hardness removal or treatment cost is needed.

With a residual hardness of 75 mg/1 (which is about the practical limit for lime-soda softening), raw water with 76 pCi/1 can be treated to contain no more than 5 pCi/1. Increased chemical costs per 100 mg/1 of hardness removal are about 3¢/1000 gal (Singh and Adams, 1977 Interim Report). For a residual hardness of 75 mg/1, the increase in hardness removed is 50 mg/1. This would increase the treatment cost 1.5¢/1000 gal for treating groundwater with Ra up to 76 pCi/1.

The radium is concentrated in the sludge produced in the treatment process. The increase in the cost of water treatment due to disposal of this sludge is shown in figure 11 for a raw water hardness of 300 mg/1. This is adopted from Singley et al. (1977) and assumes sludge disposal by gravity thickening followed by landfill. For raw water with Ra of 5 pCi/1 or less, the cost of sludge disposal is assumed to be included in the treatment cost in figure 11. The increase in cost for other levels of hardness in raw water, AC(H), can be obtained from

$$\Delta C(H) = (1 + 0.4\ (H - 300)/300)\ \Delta C(300) \quad (26)$$

in which AC = cost increment in ¢/1000 gal, and H = hardness in mg/1. Some values for Ra = 25 pCi/1 and H = 425 mg/1 are:

Q, mgd	1	3	10
ΔC(300)	7.3	4.9	3.0
ΔC(425)	8.5	5.7	3.6

Ion-Exchange Plants

According to Singley et al. (1977), the removal of radium by ion-exchange softening is similar to removal of calcium and magnesium, and the removal efficiency can be assumed to be 95 percent for design calculations. The desired hardness (125 mg/1) or radium (5 pCi/1) or lower in the finished water is obtained by blending unsoftened water with the softened water. For raw water hardness of 425 mg/1, the treated fraction passing through the ion-exchange unit is 0.743 of the total. It can reduce 17 pCi/1 to 5 pCi/1. For Ra higher than 17 pCi/1 in the raw water, the treated fraction, f , needs to be higher. It is given by:

$$f_T = (R - 5)/0.95R \quad (27)$$

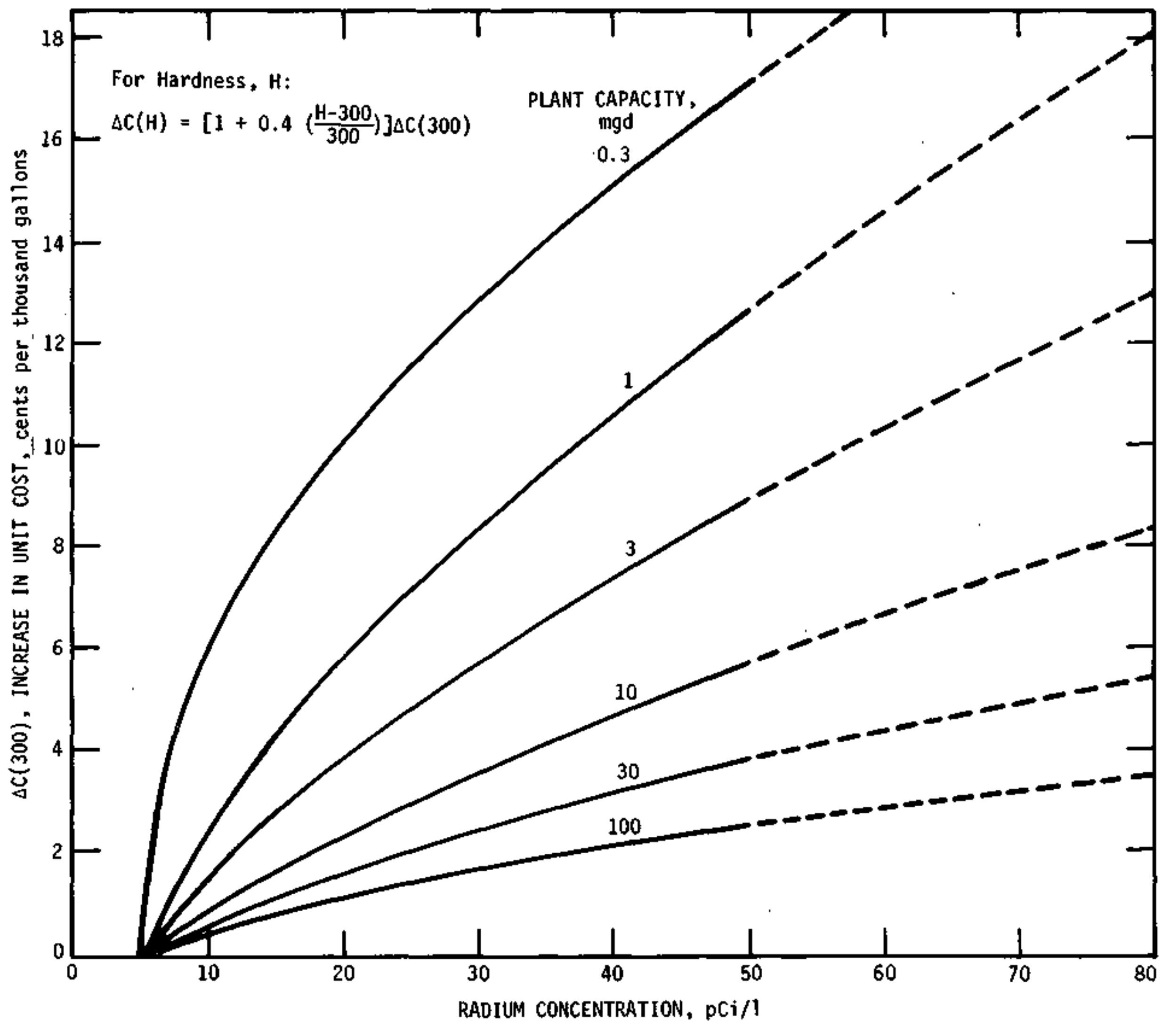

Figure 11. Increase in cost of lime-soda treatment for disposal of radioactive sludge

in which R denotes the concentration of Ra in raw water in pCi/1. The increase in treatment cost is obtained by the following procedure.

1) Capacity of plant = $Q \times f_T/0.743$; Q = water supply in mgd
2) Find the unit cost, U_b, from figure 10 for the plant capacity obtained in 1)
3) Find the unit cost, U_Q, from figure 10 for a plant with capacity Q
4) Increase in cost over U_Q in ¢/1000 gal

$$= (U_b \times f_T/0.743 - U_Q)$$
$$= (U' - U_Q)$$

in which U_b is the unit cost as determined in step 2. Hardness in the finished water will be less than 125 mg/l. The values of U' and U_Q for a range of Ra and Q are given below.

Ra (pCi/l)	f_T	Q = 1 mgd U'	Q = 1 mgd U_Q	Q = 3 mgd U'	Q = 3 mgd U_Q	Q = 8 mgd U'	Q = 8 mgd U_Q
17	0.743	64.0	64.0	51.0	51.0	46.0	46.0
25	0.842	72.5	64.0	57.8	51.0	52.1	46.0
50	0.947	81.6	64.0	65.0	51.0	58.6	46.0
75	0.982	84.6	64.0	67.4	51.0	60.8	46.0

The increase in cost of water treatment due to disposal of radioactive sludge can be obtained from figure 12 which is based on the work of Singley et al.(1977).

Design Value of Radium Concentration

The methodology for estimating the increase in treatment cost and sludge disposal cost is based on reducing combined radium-226 and radium-228 concentration to 5 pCi/1 or lower. The test values are for gross alpha particle activity (including radium but excluding radon and uranium). Because of unstandardized testing, considerable variability in gross alpha activity in groundwater from deep sandstone within a township, and the possibility of a greater portion of alpha activity attributable to radium, the radium concentration used for computing deep sandstone groundwater treatment cost varied from about 50 to 80 percent of the maximum value of gross alpha activity. The alpha activity values attributable to radium in townships with existing or potential groundwater development from deep sandstone wells are given on the following page.

Twp	Ra (pCi/l)	Twp	Ra (pCi/l)	Twp	Ra (pCi/l)	Twp	Ra (pCi/l)
12	14	40	21	62	24	79	20
16	14	41	35	64	30	80	20
17	8	42	35	68	38	81	22
19	11	45	5	69	40	83	20
20	14	46	25	70	40	84	30
22	14	48	18	71	40	85	32
25	20	49	18	72	40	87	20
27	20	50	24	73	21	88	20
28	24	53	17	74	24	91	30
31	22	54	32	75	32	98	34
36	30	55	14	76	25	103	34
37	38	57	17	77	30		
38	27	60	14	78	25		

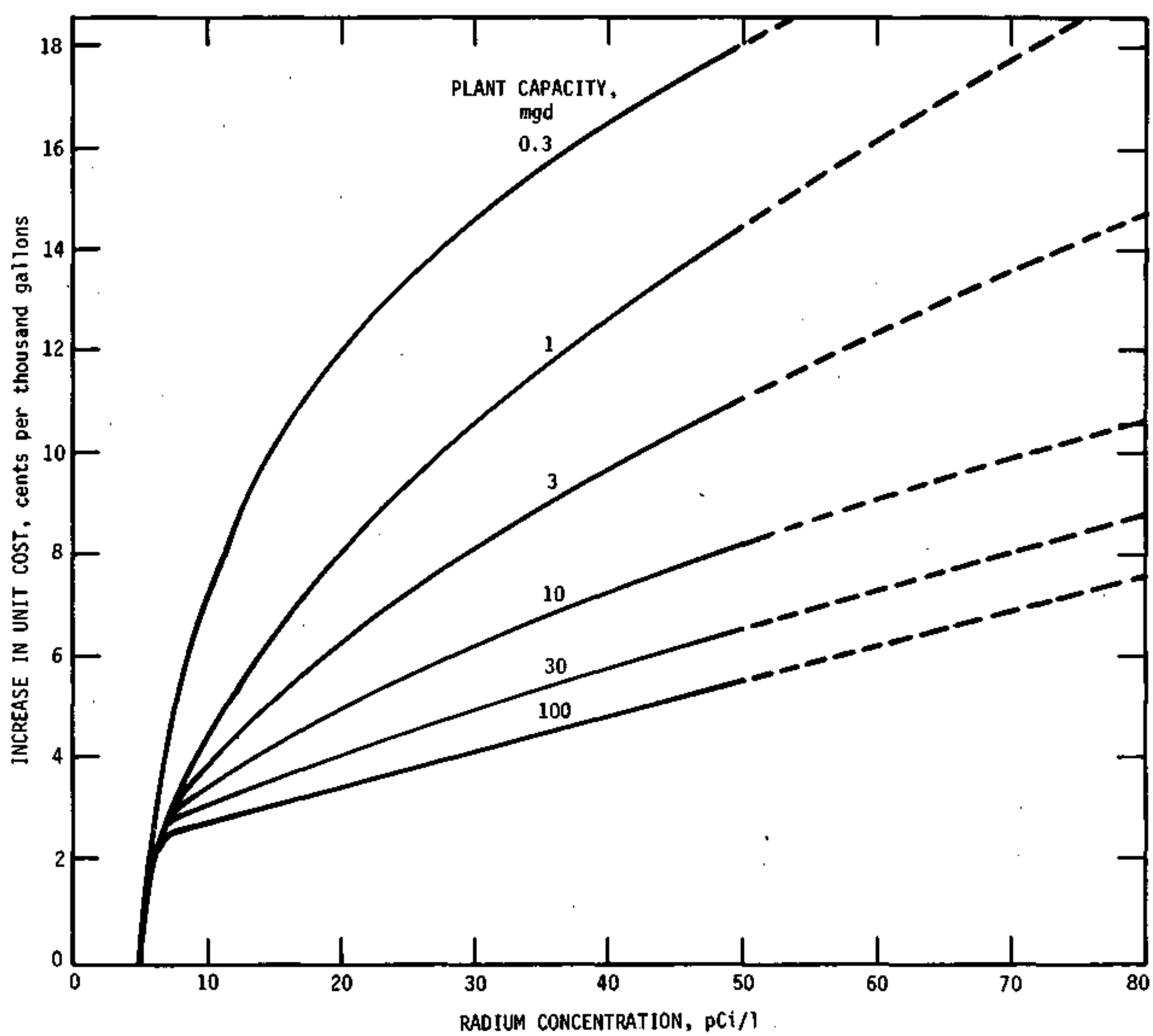

Figure 12. Increase in cost of ion exchange treatment for disposal of radioactive brine

GROUNDWATER AVAILABILITY AND COST

Groundwater resources in the area are developed from the shallow and deep aquifers. The shallow aquifers include the sand and gravel aquifers underlying about 50 percent of the area, the dolomite aquifers consisting of Silurian rocks in most of the area, and the Maquoketa and Galena-Platteville Formations in the western part of the study area. High yielding wells in the shallow dolomite aquifers are concentrated in the Silurian dolomite. The potential yield of the shallow aquifers is between 450 and 495 mgd, depending on which aquifer is considered for primary development. The deep sandstone aquifer with an average thickness of 1000 feet lies at an average depth of 500 feet below the land surface. Well yields are dependable and the potential of the aquifer is variously rated at 46 to 65 mgd depending on the distribution of pumping centers. The Mt. Simon aquifer underlies the deep sandstone and is separated from it by shaley beds of the Eau Claire Formation. The practical sustained yield for potable water from this aquifer is estimated at 14 mgd (Schicht et al., 1976). Water quality problems have been experienced in a number of wells that are finished in the Mt. Simon.

Well Capacities and Depths

Information on the capacity and depth of a well in shallow and deep aquifers is needed to estimate the well costs. Such information has been developed for sand and gravel, Silurian dolomite, and deep sandstone (Cambrian-Ordovician) aquifers. Both existing municipal wells and available hydrogeologic data have been used to determine average values of well capacity and depth in each township.

Municipal Wells

The State Water Survey well files and groundwater supply bulletins (Woller and Sanderson, 1976; Woller and Gibb, 1976) were used to delineate the distribution of active municipal wells in the three aquifers: sand and gravel, dolomite, and sandstone. The information developed was used in the system program for defining the desired economical development of groundwater aquifers from a matrix of well depths, capacities, and potential aquifer yields for all the townships in the area. When these data were compiled in 1977, there were 737 active municipal wells. There were 115 wells in the sand and gravel aquifer, 352 wells in the Silurian dolomite, and 270 wells in the deep sandstone.

Industrial Wells

Data in respect to location of wells, aquifer, and water pumped are collected regularly by the Warrenville office of the State Water Survey. Information on these industrial wells was also stored on the computer. The average pumpage from these wells is rather low, usually much lower than the well yield. The 1970 total pumpage from the 243 industrial wells was 46.3 mgd. There were 26 sand and gravel wells, 63 Silurian dolomite wells, and 154 deep sandstone wells. The pumpage for the year 1976 was 45.0 mgd, a slight decrease from that in 1970. Pumpage from the sand and gravel aquifer was about 1 mgd in Lake and McHenry Counties and about 0.5 mgd in Kane County. Between 1 and 2 mgd were pumped from the Silurian dolomite in each county, except in Lake and McHenry where pumpage was less than 0.1 mgd. Deep sandstone pumpage was about 18 mgd in Cook County, 15 mgd in Will County, and 1 mgd each in the other four counties.

Sand and Gravel Aquifers

The average thickness of the glacial drift in a township yields the first estimate of the well depth in the township. The State Geological Survey has been conducting a controlled test-drilling program in north-eastern Illinois to aid in locating sand and gravel aquifers in the glacial drift. The results of the program have been summarized in their Environmental Geology Notes series. These series and other information (Suter et al., 1959) were analyzed in estimating the well depths.

The sand and gravel aquifer occurs as a surficial, interbedded, or basal aquifer. The well depth depends on the unit or units which are penetrated for developing the water supply. In townships where existing municipal well depths differ considerably from the drift thickness, an average value was used. The average well depths developed for each town-ship are shown in figure 13. Where potential yield is zero with primary development of the sand and gravel aquifer, no well capacity and depth values are given. Many other townships will have these values as zero with primary development in the Silurian dolomite aquifer.

Estimates of average well capacities, in gallons per minute (gpm), were developed from available information (Schicht et al., 1976) on the existing municipal wells. The rated capacity of the pumps on the municipal wells seems to be of the same order as the long-term well yield if there is minimal interference from the nearby wells and if the aquifer is not limited in areal extent. The pump rating is usually based on the results of an 8- to 24-hour well pumping test. Records of actual pumping rates, pumping durations, and volumes of water pumped are not readily available. These limitations have been considered in estimating average well capacities from the well and glacial geology data. The well capacities are taken as one-half of those given in figure 13 for the 70 or more townships in which Silurian dolomite may be the primary aquifer to be developed.

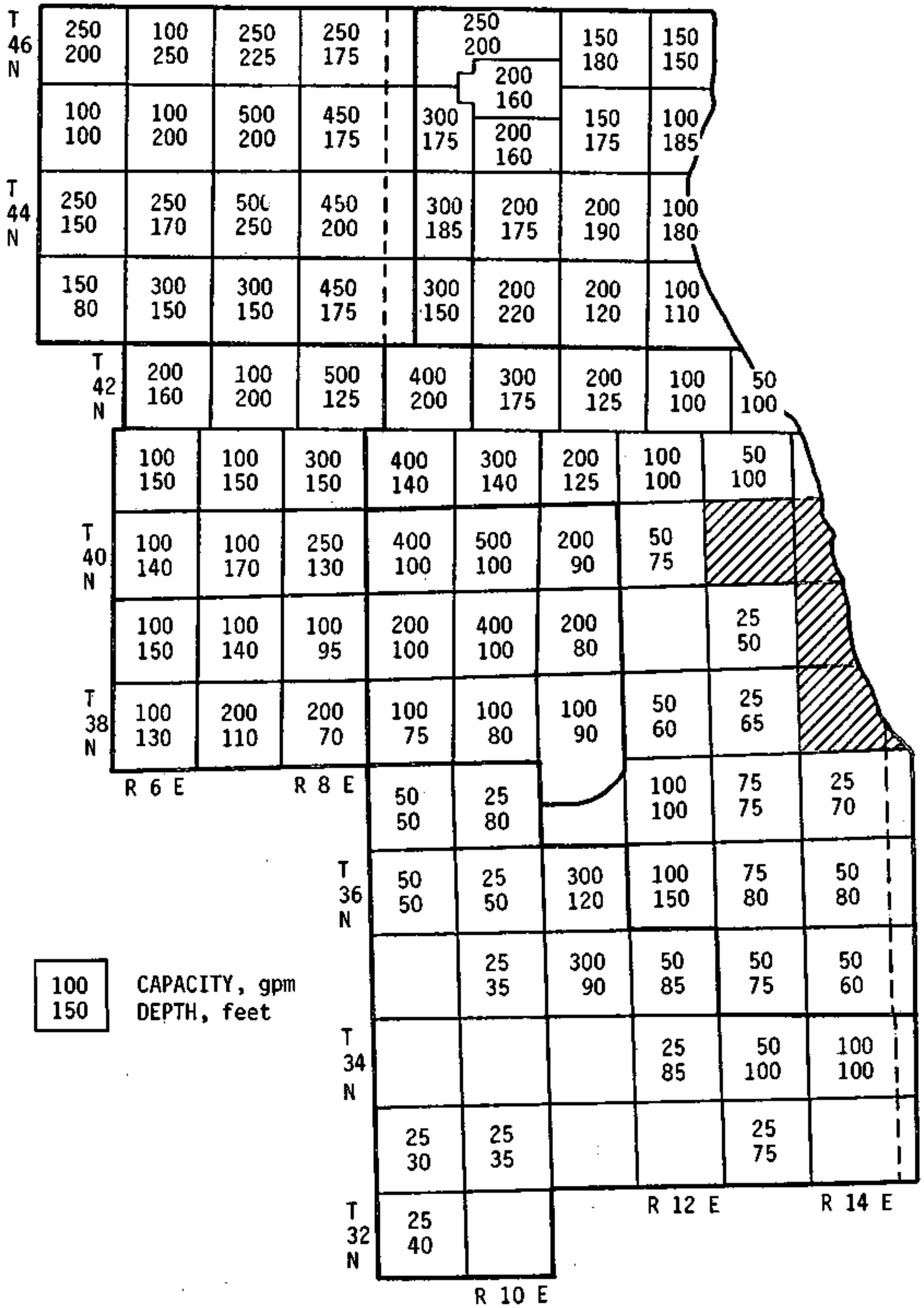

Figure 13. Average capacity and depth of wells in sand and gravel aquifers

Silurian Dolomite

The bedrock surface in most of the six-county area is formed by Silurian dolomite; the thickness increases from less than 50 feet in McHenry and Kane Counties to 450 feet or more in southeastern Will County. The geohydrology of the Silurian dolomite has been studied in detail by the State Geological and Water Surveys. Average well depths based on the past studies were developed for each township. Where average depths of existing municipal wells differed from the developed values, both depth values were used in computing the average depth. The final values are given in figure 14. The Maquoketa shale is the uppermost bedrock in 13 townships in McHenry and Kane Counties. Since no Silurian dolomite overlies the shale formation, depths are not given for these townships. The specific capacity (the flow rate per foot of drawdown) decreases with increase in penetration into the Silurian dolomite. Thus, in many cases, a well of less than maximum depth may be practical and economical.

Groundwater in the Silurian dolomite occurs in joints, fissures, solution cavities, and other openings. These openings are very irregularly distributed both vertically and horizontally. Available geohydrologic data indicate that the dolomite contains numerous openings which extend for considerable distances and are interconnected on an areal basis. Expected well capacities were calculated from specific capacity data (Csallany and Walton, 1963) and available drawdown data from Water Survey files. The rated capacities from the existing municipal wells were considered in the final computations. The well capacities in gpm are given in figure 14. If the sand and gravel is the primary aquifer to be developed, the dolomite well capacities are taken as three-fourths of those shown in figure 14.

It may be stressed that the well capacities are average capacities and that the dolomite well capacities are quite variable. The probability of drilling a low capacity well is recognized, but the use of average capacity is acceptable in regional optimization studies, allowing for drilling of some extra holes which cannot be economically developed.

Deep Sandstone

The deep sandstone aquifer consists of the Galena-Platteville dolomite, Glenwood-St. Peter sandstone, and Prairie du Chien Series of Ordovician age; Eminence-Potosi dolomite, Franconia Formation, and Ironton-Galesville sandstone of Cambrian age. The aquifer begins at about 500 feet below the land surface and has an average thickness of 1000 feet. The Ironton-Galesville sandstone has the highest transmissivity and any new wells will penetrate this formation to develop the maximum capacity. The depths estimated for each township from available geologic and well information are shown in figure 15. No data were available for township 97 through 104; however, extrapolated well depths are shown in italics.

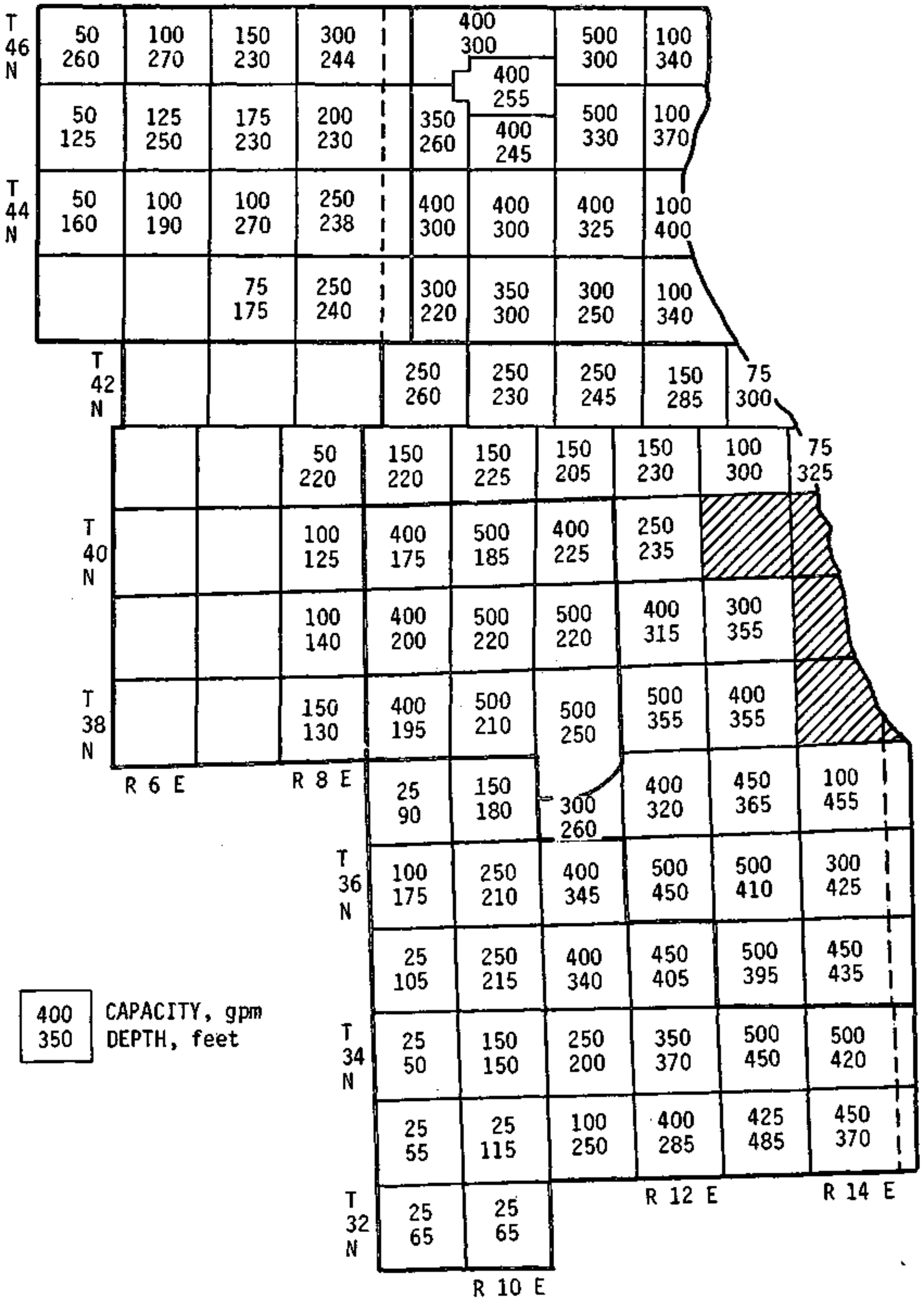

Figure 14. Average capacity and depth of wells in the Silurian dolomite aquifer

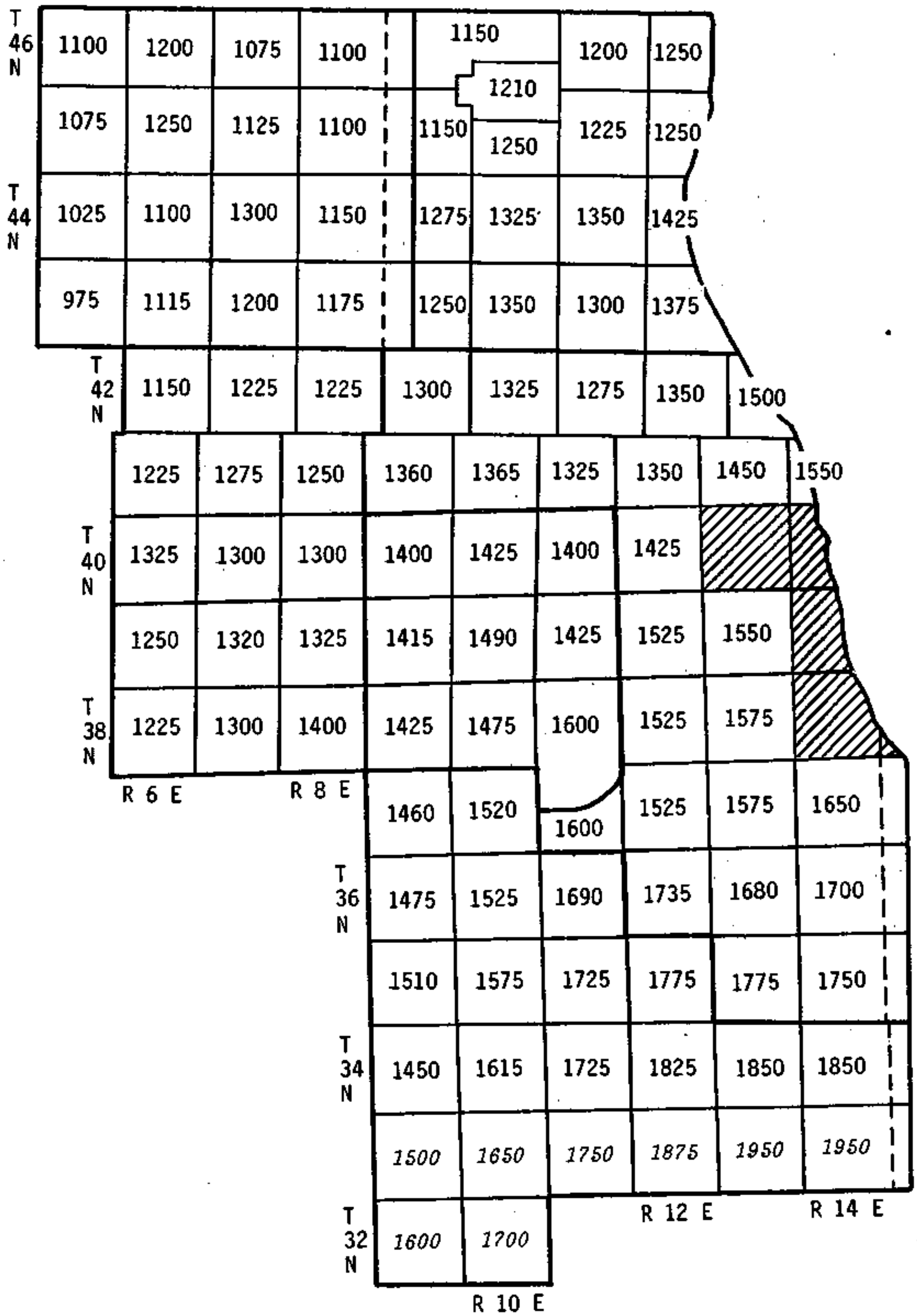

Figure 15. Average depth of wells, in feet, in the deep sandstone aquifer

Existing municipal well data indicate that wells with a capacity of 1 mgd or more can be developed in the deep sandstone aquifer throughout the region. Walton and Csallany (1962) give a detailed discussion of well capacities in this aquifer. Development of any new wells may be considered only in areas west or north of the existing pumping centers in eastern Kane, Cook, DuPage, and Will Counties. This is the area of relatively lower well depths and higher piezometric levels so that the cost of development and operation would be lower than in the area already developed.

Unit Cost of Groundwater

Unit costs of raw water from the sand and gravel and Silurian dolomite aquifers for each of the townships have been derived considering primary development in one aquifer or the other. Unit cost of raw water from the deep sandstone aquifer was also calculated for each township with pumpage from the deep sandstone. Out of the 273 user entities or towns, 177 were not served with water from Lake Michigan in 1976. The distribution of the towns by county is:

County	*Number of towns not served from lake*	*Total*
Cook	40	125
DuPage	35	35
Kane	20	20
Lake	36	47
McHenry	21	21
Will	25	25
	177	273

The existing wells in each of 177 towns were located on 7½ minute quadrangle maps. Any extra supply capacity needed to meet the 2010 demand was met by locating new wells in shallow aquifers within the constraint of their potential yield, and the remaining unmet capacity by locating new wells in the deep sandstone aquifer considering no constraint on the potential yield of that aquifer. A computer program was developed to calculate the unit cost of treated groundwater for each of the 177 towns.

Raw Water From Shallow Aquifers

A computer program was developed for computing unit cost of raw groundwater from sand and gravel and dolomite aquifers with primary development in one aquifer or the other. The program methodology is described below.

1) Potential yield for the two conditions of primary development, depth of well, capacity of well, static water level in each of the two aquifers, glacial drift thickness, depth of well

penetration in dolomite, specific capacity of sand and gravel aquifer, and specific capacity per foot of penetration in the dolomite aquifer were stored for each of the 104 townships in a matrix form on the DISK, With primary development in sand and gravel, the dolomite well capacity was adjusted to 75 percent, and with primary development in dolomite the sand-and-gravel well capacity was adjusted to 50 percent of the normal capacity.

2) The adjusted capacity of a sand-and-gravel well was modified, if so warranted, according to the following constraints;

   a) If SWL $\geq$ DSG; capacity = 0

   b) If drawdown $\leq$ 0.5 (DSG - SWL); capacity equals adjusted capacity

   c) If drawdown > 0.5 (DSG - SWL); capacity = 0.5 (DSG-SWL) $\times$ specific capacity

   in which SWL and DSG denote the depth of the static water level and of the sand-and-gravel well below ground level, respectively, and drawdown equals adjusted capacity divided by the specific capacity.

3) The adjusted capacity of a dolomite well was modified, if so warranted, according to the following constraints:

   a) If SWL $\geq$ (GDT + 0.25 PD); capacity = 0

   b) If drawdown $\leq$ [(GDT - SWL) + 0.25 PD]; capacity equals adjusted capacity

   c) For drawdown > [(GDT - SWL) + 0.25 PD]; then, capacity = [(GDT - SWL) + 0.25 PD] $\times$ specific capacity per foot of penetration $\times$ depth of penetration in dolomite

      in which GDT and PD denote the glacial drift thickness and the depth of penetration of the well in dolomite. The drawdown was computed from the adjusted well capacity divided by the product of the depth of penetration, PD, and the specific capacity per foot of penetration.

4) The number of wells to develop the potential yield equals the potential yield divided by the safe yield of a well in comparable units. The safe yield is 75 percent of the well capacity and is based on pumping 18 hours per day. The number of wells is increased by 50 percent to meet up to 1.5 times the average yearly demand during heavy demand periods. One standby well is allowed if the number of wells is equal to or less than 3, otherwise 2 standby wells are added to obtain the total number of wells, N_{wt}.

5) The cost in dollars of one well is computed by the equations given in the section on cost functions. The total well cost is obtained by multiplying N_{wt} by the cost of a well.

6) Costs of both vertical and submersible turbine pumps are calculated with the equations given in the section on cost functions. The least cost pump is considered for installation. The total pump cost equals N_{wt} times the cost of one pump.

7) The electric power cost is computed as described in the section on cost functions. The pumping rate, Q, is taken as the aquifer potential yield in mgd and the total dynamic head, H, is taken as static water level plus drawdown plus 25 feet.

8) Annual capital costs are obtained by multiplying the capital costs by the appropriate capital recovery factors for wells and well pumps. The total annual cost is the sum of annual costs for wells, pumps, and the annual OM&R cost for a well field. Annual OM&R cost of a well field is given in the section on cost functions.

9) The unit cost, UC, of raw water at the well field is

   UC in ¢/1000 gal = (Total annual cost in dollars)/(3652 Q)

   with Q equal to the township potential yield of the aquifer in mgd. Raw water costs and potential yields are given in table 10.

Raw Water from Deep Sandstone Aquifer

The cost of wells and vertical turbine pumps are computed by the equations in the section on cost functions. Well capacities are assumed to be 0.5 mgd (350 gpm), 1.0 mgd (700 gpm), or 1.4 mgd (1000 gpm) depending on the 2010 township pumpage from the deep sandstone aquifer. The heads used for calculating pump and electrical costs were obtained from the 2010 drawdowns produced by the computer model of the deep sandstone aquifer. Historical pumping patterns have resulted in pumping heads that vary throughout the region. The pumping schedules used from 1980 to 2010 were estimates of the deep pumpage required to meet all increased demands from groundwater. The number of wells is sufficient to meet 1.5 times the average demand, pumping 75 percent of the time with one well as standby. Table 11 gives the unit costs of raw water at the deep wells for the 52 townships in which there are towns or user entities that are partially or wholly dependent on this source.

Unit Cost of Groundwater Supply to Towns

There are 177 towns or user entities in the six-county area meeting their water requirements from shallow and deep groundwater aquifers.

Table 10. Raw Water Unit Cost, U_{sg} and U_d, in ¢/1000 gal., for Wells in Sand and Gravel and Silurian Dolomite Aquifers

	Sand & Gravel as Primary				Silurian Dolomite as Primary			
Twp	Sand & Gravel		Dolomite		Sand & Gravel		Dolomite	
No.	PY	U_{sg}	PY	U_d	PY	U_{sg}	PY	U_d
1	5.15	7.81	0.83	24.07	1.79	11.84	1.45	23.85
2	1.06	15.94	4.84	15.92	0.08	39.10	5.74	15.80
3	2.32	8.42	4.97	12.72	0.80	13.20	5.74	12.64
4	5.15	7.48	5.14	11.80	1.67	11.53	7.35	11.62
5	5.60	11.20	1.70	15.93	2.96	19.93	1.73	15.92
6	2.32	14.14	4.59	11.04	0.33	29.20	5.99	10.40
7	2.95	5.87	4.71	12.43	0.58	8.94	6.50	12.23
8	6.50	5.77	6.23	12.70	1.63	9.13	8.47	12.57
9	5.34	6.00	0.37	21.34	4.01	9.20	0.36	21.76
10	4.41	7.49	0.94	16.36	2.26	11.41	1.13	16.00
11	4.12	6.50	2.98	16.83	1.02	10.42	5.39	16.53
12	5.53	6.21	5.93	11.63	2.17	9.22	7.70	11.58
13	3.30	8.87	0.00		1.48	14.04	0.00	
14	2.76	6.57	0.00		1.30	11.49	0.00	
15	3.10	6.03	1.95	13.25	0.69	11.56	3.07	12.94
16	6.01	5.90	4.48	11.62	2.13	9.08	5.82	11.52
17	3.18	8.83	0.00		1.09	13.94	0.00	
18	1.68	14.40	0.00		0.73	26.47	0.00	
19	4.18	5.04	0.00		2.08	7.40	0.00	
20	0.56	14.28	0.00		0.48	24.96	0.00	
21	1.35	13.07	0.00		1.36	22.65	0.00	
22	2.88	6.14	0.41	18.85	2.42	9.98	0.47	16.45
23	2.49	12.48	0.00		2.38	21.79	0.00	
24	2.42	13.23	0.00		1.03	23.97	0.00	
25	3.50	6.84	0.58	15.06	1.94	10.25	2.01	14.48
26	2.00	12.79	0.00		1.70	22.82	0.00	
27	2.76	12.66	0.00		1.21	22.59	0.00	
28	1.46	11.57	4.17	10.53	0.60	20.72	4.73	10.51
29	2.49	12.23	0.00		2.11	21.52	0.00	
30	2.15	7.78	0.00		0.81	12.91	0.00	
31	1.24	7.29	3.42	9.31	0.17	12.96	4.27	9.29
32	3.82	8.04	3.37	7.16	0.34	14.56	6.34	6.98
33	1.68	9.58	1.86	7.57	0.02	40.20	2.95	7.61
34	1.67	12.05	3.24	7.22	0.41	20.03	3.63	7.17
35	1.39	11.29	0.73	12.83	0.55	18.74	0.74	11.27

Continued on next page

Table 10. Continued

	Sand & Gravel as Primary				*Silurian Dolomite as Primary*			
Twp	*Sand & Gravel*		*Dolomite*		*Sand & Gravel*		*Dolomite*	
No.	*PY*	U_{sg}	*PY*	U_d	*PY*	U_{sg}	*PY*	U_d
36	3.18	7.17	1.65	8.70	0.98	12.96	3.08	8.72
37	1.39	9.56	1.88	7.53	0.03	28.34	2.98	7.57
38	1.28	12.12	3.67	7.30	0.36	20.54	4.15	6.73
39	0.89	15.21	0.54	14.83	0.42	26.88	0.65	12.41
40	1.39	7.84	1.93	7.09	0.21	11.34	3.69	6.93
41	1.53	10.86	2.76	8.17	0.08	27.24	4.63	8.01
42	2.20	9.74	2.90	7.21	0.55	15.65	4.14	7.07
43	0.51	16.48	0.42	15.00	0.00		0.59	12.81
44	1.84	8.14	1.36	9.09	0.27	13.52	3.13	8.51
45	1.83	10.99	2.45	8.53	0.42	17.96	3.94	8.38
46	1.49	9.10	3.70	7.24	0.40	14.87	3.98	6.86
47	0.72	12.90	0.72	13.04	0.00		0.97	10.63
48	2.80	11.79	2.09	12.56	1.39	12.32	2.86	12.36
49	2.21	11.47	2.24	14.29	0.04	33.43	4.80	13.91
50	2.88	12.02	2.77	8.70	0.77	13.90	3.92	8.36
51	1.51	16.87	0.89	10.19	0.23	26.30	2.26	9.33
52	0.19	27.16	0.44	14.59	0.00		0.50	12.92
53	2.60	12.52	0.71	11.36	1.93	12.66	0.83	11.37
54	0.70	14.73	2.42	9.92	0.20	17.00	2.80	10.48
55	1.04	12.47	2.47	9.02	0.00	0.00	3.57	9.57
56	1.78	21.79	3.04	9.29	0.70	22.96	3.64	9.68
57	0.12	25.29	2.07	11.33	0.00		2.60	9.74
58	0.04	37.81	0.16	17.58	0.00		0.70	12.30
59	1.24	19.35	4.94	8.09	0.67	34.36	4.45	8.12
60	0.00		4.79	9.15	0.00		5.36	9.17
61	0.15	130.59	4.43	8.36	0.00		4.88	7.49
62	1.49	171.77	6.16	7.75	0.13	178.55	7.19	7.52
63	0.72	33.85	3.77	7.60	0.00		4.55	7.54
64	0.00		3.48	8.11	0.00		3.79	8.03
65	1.42	42.93	3.13	7.53	0.00		4.69	7.18
66	1.76	13.56	2.74	6.72	0.00		4.57	5.83
67	0.94	34.96	1.51	15.21	0.23	67.62	1.69	12.53
68	1.67	13.97	2.86	7.82	0.00		4.55	6.59
69	1.13	14.20	3.59	6.96	0.00		4.75	6.08
70	0.58	20.59	3.75	8.51	0.00		4.31	7.11
71	1.09	19.81	3.48	6.87	0.00		4.57	6.04
72	1.81	43.75	4.33	7.82	0.00		6.68	6.63
73	3.06	5.65	1.21	5.88	1.84	8.06	2.32	5.60
74	2.17	5.36	2.28	5.25	0.61	7.11	3.36	4.78
75	1.45	7.62	3.01	4.45	0.24	12.50	4.14	4.46

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Table 10. Concluded

Twp No.	Sand & Gravel as Primary: Sand & Gravel PY	U_{sg}	Dolomite PY	U_d	Silurian Dolomite as Primary: Sand & Gravel PY	U_{sg}	Dolomite PY	U_d
76	2.42	8.44	2.58	5.69	0.61	13.89	3.44	5.39
77	3.09	5.69	1.98	5.76	0.04	26.29	5.05	4.85
78	2.24	7.47	2.90	5.03	0.28	13.56	4.62	4.41
79	1.29	11.53	3.84	5.17	0.28	22.13	4.63	5.12
80	2.90	11.80	2.66	5.50	0.34	22.65	5.39	4.77
81	3.04	12.68	3.54	6.22	0.03	32.63	7.23	5.22
82	0.97	17.92	4.41	16.13	0.35	33.19	4.73	14.01
83	1.68	34.04	4.36	7.38	0.46	65.91	5.79	7.50
84	3.16	16.35	3.53	7.74	0.46	31.52	5.88	6.81
85	0.56	32.23	5.96	6.70	0.25	60.44	5.71	6.49
86	1.46	6.65	3.44	7.13	0.08	14.04	5.01	7.09
87	0.00		8.00	18.20	0.00		7.81	18.19
88	0.73	54.49	7.01	6.60	0.04	75.93	6.96	6.64
89	2.03	5.89	3.08	6.80	0.21	8.90	4.78	6.55
90	0.51	21.98	4.21	8.05	0.05	39.46	4.69	7.05
91	0.00		4.59	59.27	0.00		7.30	59.23
92	0.00		5.81	6.62	0.00		5.62	6.66
93	0.00		4.55	6.52	0.00		5.02	6.28
94	0.07	47.22	4.47	7.00	0.00		4.60	7.14
95	1.00	19.34	3.67	7.50	0.00		4.82	6.57
96	1.91	11.29	3.66	7.46	0.00		5.85	6.49
97	5.61	27.99	0.44	24.86	4.14	53.03	0.95	24.55
98	1.14	30.00	3.15	16.49	0.58	55.90	3.26	13.58
99	0.00		4.49	9.16	0.00		4.83	7.86
100	0.00		4.59	6.15	0.00		4.60	6.00
101	0.06	38.87	4.43	8.77	0.00		4.61	7.67
102	0.00		5.52	7.11	0.00		5.60	6.45
103	5.53	29.72	0.44	30.91	4.38	56.01	2.17	30.31
104	0.00		1.28	100.15	0.00		5.64	100.00

PY = Potential yield in mgd

Table 11. Raw Water Unit Cost, U , in ¢/1000 gal, for Wells in the Deep Sandstone Aquifer

Twp No.	U_{ss}	*Twp No.*	U_{ss}
16	22.9	61	29.5
17	25.9	62	32.1
19	23.6	64	37.2
20	52.3	68	27.9
22	25.1	69	25.9
25	20.4	70	27.9
27	26.8	71	27.5
28	34.6	72	26.3
31	25.1	73	31.1
35	19.9	74	29.6
36	25.7	75	28.3
37	17.4	76	28.5
38	21.8	77	30.1
40	42.2	78	29.2
41	23.5	79	28.7
42	20.5	80	28.7
45	28.5	81	31.5
46	31.5	83	29.0
48	27.6	84	27.7
49	27.6	85	26.8
50	27.0	87	28.2
53	27.2	88	24.2
54	27.5	91	23.8
55	27.8	97	31.0
60	26.8	103	31.8

Because water withdrawal from the deep aquifer greatly exceeds its long-term yield, piezometric levels have been falling at an increasing rate over the last 50 years. In order to devise a framework for considering which towns need to be given priority in furnishing water from Lake Michigan and regional rivers, the ability of shallow aquifers to help meet the 2010 demands was investigated. Where sufficient supplies could not be developed from the shallow aquifers, the balance was provided by the deep wells. The unit costs and problems associated with disposal of the radio-active sludges from the treatment of deep sandstone water as well as the falling piezometric levels are some of the factors guiding the size and feasibility of regional and subregional systems of alternate surface water supplies.

The existing shallow and deep wells have been updated to the year 1978 for each of the 177 towns and were located on 7½ minute quandrangle maps. Any new shallow and deep wells needed to meet the 2010 demand are also indicated. Total well capacities are sufficient to meet 1.5 times the new 2010 demands (see section on potential yield of shallow aquifers) assuming that wells are pumped for 18 hours per day and that adequate provision is made for standby wells. The number of treatment plants and their location for a town were decided on the basis of existing ground or elevated storage facilities and the town size. The average distance of the new wells to the nearest treatment plant was estimated. The economics of providing one or two treatment plants was investigated for the towns where more than one treatment plant was indicated.

Computer Program

A computer program was developed to obtain the unit cost of treated groundwater supply to meet the 2010 demand. The basic data input to the program, in addition to the cost functions in July 1980 dollars for water transport and treatment, are as follows.

Town number: as per table 2.

Total well capacity: for wells in sand and gravel, dolomite and deep aquifers, in mgd (zero for aquifer with no wells).

Unit raw water costs: of water from sand and gravel, dolomite, and sandstone aquifers, in ¢/1000 gal (zero for aquifer with no wells).

2010 demand in mgd.

Number of new wells.

Average capacity of new wells, in mgd.

Number of treatment plants.

Average distance in miles of the new wells from the treatment plant(s).

Capacity of first treatment plant in mgd (equals 1.5 times the average demand it meets).

Alpha radium radioactivity in water from shallow wells, in pCi/1.

Deficiency: equals 2010 demand minus groundwater supply, zero in this program.

Effective pipe cost multiplier: for pipe network in and around the town to allow for increased construction cost in urban areas.

Alpha radium radioactivity in deep water, in pCi/1.

The following information is provided if there is more than one treatment plant:

Capacity of the second treatment plant equals 1.5 times the sum of the 2010 demand and one standby well capacity, minus the capacity of the first treatment plant.

Distance between the two treatment plants in miles.

Amount of water to be conveyed, in mgd, from one plant location to the other if a single treatment plant is constructed.

Various steps in the computer program developed for calculating the groundwater costs are:

1) Compute weighted unit raw water cost from the three raw water costs and the respective total well capacity in each aquifer.

2) Compute overall increase in weighted unit cost because of carrying water from the new wells to the treatment plant(s). Annual cost of water transport is obtained by a computer subroutine which calculates the optimal pipe diameter with use of the cost functions for water conveyance. Increase in weighted unit cost is given by

$$\text{Increase} = \frac{\text{Annual cost in dollars}}{3652 \times (\text{2010 demand, in mgd})} \quad ¢/1000 \text{ gal}$$

3) If deep aquifer is a source of water supply, compute equivalent alpha radium radioactivity by weighting radioactivity in shallow and deep aquifers with their respective proportions of total capacity.

4) Compute treatment cost in ¢/1000 gal according to the following procedure:

   a) Treatment costs are obtained for both ion exchange and lime-soda process. The cheaper one is selected and the cost printed out.

   b) A matrix each for the unit capital and the OM&R costs as a function of average demand for the two processes is stored in the computer.

   c) Plant capacity is 1.5 times the average demand served. The unit capital cost is obtained by logarithmic interpolation and multiplied by 1.5 to reflect the unit capital cost on the average use basis.

   d) Unit OM&R cost is obtained by logarithmic interpolation. The capacity for the OM&R equals average demand, or the plant capacity divided by 1.5.

   e) Extra treatment cost for achieving reduction in radioactivity to the standard, if needed, is computed via a subroutine based on the methodology described under 'Radioactivity and Increase in Treatment Costs' in this report.

f) Two matrices of extra sludge disposal cost, one for lime-soda and the other for ion-exchange process, are stored in the computer. Appropriate cost is obtained by interpolation. It is zero if radioactivity is 5 pCi/1 or less.

g) Unit treatment cost is the sum of unit capital, OM&R, radioactivity reduction, and sludge costs.

5) If there is more than one plant, the treatment cost is computed for both plants and printed under the heading 'Using Approach 1'.

6) Costs of treatment and transmission of water from one plant location to the other are included in determining the unit cost for a single treatment plant (capacity equals 1.5 times the 2010 demand) and it is printed under the heading 'Using Approach 2'.

7) Weighted unit treatment cost for two plants is obtained from

$$\text{Unit cost} = \frac{U_1 \times C_1 + U_2 \times C_2}{C}$$

in which U_1 and U_2 are unit treatment costs for plant with capacity C_1 and C_2 and C is the capacity of a single plant.

8) Total cost of groundwater supply equals the sum of the weighted raw water cost, increase in cost because of transporting water from new wells, and smaller of the treatment costs with one or two plants.

Cost of Groundwater Supply

A typical computer output for Bartlett (number 128) is shown in table 12. Such information was developed for all the 177 towns in the six-county area. The unit costs in ¢/1000 gal are given in table 13. Also included are some alternate schemes for developing supplies from shallow aquifers for some towns at the expense of other towns which are relatively more dependent on the deep aquifer for their water supply.

Information by county on the 2010 demand, the total capacity of wells in each of the three aquifers as well as in the three aquifers combined, and the use factor, which signifies the average use of these capacities, are given below. The use factor is the 2010 demand divided by the combined well capacity. The capacity is about 2.5 times the average use because of the requirement of being able to meet 1.5 times the average demand and the need for standby wells to meet emergencies. The average proportional withdrawal from each aquifer is given in parentheses.

Use Factors for 177 Entities in Table 13 (alternates not considered)

County	2010 demand (mgd)	Well capacity, mgd: Sand & Gravel	Dolomite	Deep sandstone	Total	Factor
Cook	107.22	16.29	53.85	201.46	271.60	0.39
DuPage	93.82	7.59	62.67	152.71	222.97	0.42
Kane	47.69	31.74	1.00	84.78	117.52	0.41
Lake	29.81	14.50	30.80	40.60	85.90	0.35
McHenry	22.17	40.39	6.04	8.53	54.96	0.40
Will	40.74	7.13	61.02	38.67	106.82	0.38
	341.45	117.64	215.38	526.75	859.77	0.42
		(46.72)	(85.54)	(209.19)		

Table 12. Typical Information Printout on Groundwater Costs

Entity Number 128

	Sand & Gravel	*Dolomite*	*Deep sandstone*
Total well capacity, mgd	2.01	2.35	1.51
Unit raw water cost, ¢/1000 gal	8.06	5.60	31.10

New wells = 2 Capacity/Well =0.53 mgd
Number of plants = 2 Average distance from new wells = 0.50 mi
Alpha radioactivity: Shallow water = 1.6 Deep water = 21.0
Effective pipe cost multiplier = 1.60
Plant 1 capacity = 1.72 mgd Plant 2 capacity = 2.40 mgd
Equivalent capacity of a single plant = 3.255 mgd

Weighted raw water cost	13.00 ¢/1000 gal
Increase in cost due to new wells	1.64 ¢/1000 gal
Using Approach 1	
Treatment cost, 1st plant (ion exchange)	72.20 ¢/1000 gal
Treatment cost, 2nd plant (ion exchange)	66.14 ¢/1000 gal
Using Approach 2	
Treatment cost, single plant (ion exchange)	63.32 ¢/1000 gal
Transmission cost between plants	13.87 ¢/1000 gal

Results

Treatment cost considering 2 plants	85.86 ¢/1000 gal
Treatment cost considering 1 plant	77.19 ¢/1000 gal
Total groundwater cost	91.83 ¢/1000 gal

2010 demand =2.17 mgd

Table 13. Water Supply from Groundwater Aquifers

No.	Town	Pop.	2010 demand (mgd)	Q_{well} (total) S&G	D	SS	Total	Q_{well} (new required) S&G	D	SS	Total	Unit cost (¢/1000 gal)	Pipeline cost factor
	Cook County												
2	Arlington Heights	50	8.61			20.58	20.58					82.95	1.8
3	Barrington	48	2.23	3.83	2.44		6.27	0.30			0.30	73.57	1.6
4	Barrington Hills	48	0.47		1.28		1.28		1.28		1.28	118.63	1.4
6	Bellwood	60	3.03			9.07	9.07					101.46	1.8
13	Buffalo Grove	50	3.11		0.29	7.52	7.81			0.47	0.47	94.62	1.8
20	Chicago Heights	72	5.74		4.76	8.16	12.92			4.84	4.84	96.05	2.0
23	Country Club Hills	69	2.14		5.73		5.73		0.75		0.75	69.10	1.6
29	East Chicago Heights	72	0.84		0.42	2.90	3.32			2.90	2.90	127.81	1.6
31	Elk Grove Village	55	7.51	1.58		15.12	16.70					85.06	1.9
35	Flossmoor	71	1.36		0.45	3.09	3.54			0.92	0.92	116.07	1.7
42	Glenwood	72	2.59		0.16	7.21	7.37			3.60	3.60	108.00	1.7
44	Hanover Park	53	3.92		0.29	9.42	9.71			2.40	2.40	85.38	1.8
51	Hoffman Estates	54	4.95	0.58	0.63	10.14	11.35			0.44	0.44	81.70	1.7
53	Homewood	69	2.49		3.66	3.52	7.18					109.78	1.8
54	Indian Head Park	62	0.33		2.58		2.58					102.64	1.5
55	Inverness	49	0.46	0.86		0.50	1.36			0.50	0.50	110.82	1.5
58	LaGrange	62	1.96		4.94		4.94		0.76		0.76	72.58	1.7
59	LaGrange HSD	62	0.81		2.49		2.49		0.19		0.19	85.75	1.6
62	Lemont	64	2.57		3.74	3.89	7.63		2.88		2.88	100.22	1.5
65	Lynwood	72	0.30		0.61	1.44	2.05		0.54		0.54	149.01	1.4
68	Matteson	71	1.96		1.13	3.12	4.25			3.12	3.12	106.30	1.6
75	Mt. Prospect	50	5.49		0.43	16.28	16.71					86.46	1.8
85	Olympia Fields	71	0.67		0.29	2.40	2.69			2.40	2.40	139.68	1.5
86	Orland Park	68	5.38		5.14	6.98	12.12			5.64	5.64	75.76	1.8
87	Palatine	49	6.17	2.09	0.39	11.61	14.09			3.57	3.57	85.80	1.8
90	Palos Park	65	0.34		1.02		1.02		1.02		1.02	114.65	1.5
91	Park Forest	71	3.02		2.02	4.48	6.50			4.48	4.48	97.70	1.7
95	Prospect Heights	50	0.92	Included in Mount Prospect (75)									
96	Richton Park	71	2.15		0.46	4.08	4.54			4.08	4.08	111.11	1.6
102	Rolling Meadows	49	2.77			8.00	8.00					110.45	1.8
104	Sauk Village	72	1.33		0.78	2.85	3.63			2.85	2.85	114.69	1.6
105	Schaumburg	54	9.67	2.83		18.59	21.42			11.04	11.04	78.93	1.8
108	S. Barrington	48	0.51			2.04	2.04			2.04	2.04	128.78	1.4
109	S. Chicago Heights	72	0.43		0.53	0.84	1.37			0.34	0.34	131.04	1.5
113	Streamwood	53	4.23	4.52		6.12	10.64			3.96	3.96	77.86	1.8
115	Thornton	70	0.71		0.58	1.72	2.30		0.58		0.58	125.71	1.5
117	Waycinden	55	0.49		0.18	2.30	2.48					119.55	1.5
119	Western Springs	62	1.27		1.08	3.17	4.25					103.30	1.7
120	Westhaven	68	0.90		2.25		2.25		2.25		2.25	92.43	1.5
121	Wheeling	50	2.76		3.10	4.32	7.42		1.65		1.65	85.46	1.7
			107.22	16.29	53.85	201.46	271.60	0.30	11.90	59.59	71.79		
	Cook County Alternate												
20	Chicago Heights	72	5.74			12.52	12.52			9.20	9.20	112.47	2.0
29	E. Chicago Heights	72	0.84		2.24		2.24		2.24		2.24	88.45	1.6
42	Glenwood	72	2.59			6.76	6.76			3.81	3.81	108.71	1.7
65	Lynwood	72	0.30		1.20		1.20		1.20		1.20	116.83	1.4
104	Sauk Village	72	1.33		3.25		3.25		3.25		3.25	85.38	1.6
109	S. Chicago Heights	72	0.43		1.32		1.32		1.32		1.32	106.71	1.5
115	Thornton	70	0.71		1.80		1.80		1.80		1.80	96.99	1.5
			11.94	0.00	9.81	19.28	29.09	0.00	9.81	13.01	22.82		
	DuPage County												
126	Addison	75	5.19		7.81	4.24	12.05			4.24	4.24	85.50	1.8
127	Arrowhead	77	0.16		0.58		0.58					122.27	1.3
128	Bartlett	73	2.17	2.01	2.35	1.51	5.87		1.06		1.06	91.83	1.6
129	Bensenville	75	2.21			6.18	6.18			0.54	0.54	107.27	1.7
130	Bloomingdale	74	2.57		0.65	6.23	6.88			3.42	3.42	99.90	1.6
131	Burr Ridge	81	0.51		0.54	0.60	1.14			0.60	0.60	114.39	1.5
132	Butterfield	77	0.44		1.32		1.32		1.32		1.32	100.04	1.6
133	Carol Stream	74	3.17		2.88	4.92	7.80			2.04	2.04	97.31	1.5
134	Clarendon Hills	81	0.86		0.67	2.78	3.45			1.05	1.05	113.11	1.7
135	Country Club Highlands	75	0.15		0.42		0.42		0.14		0.14	128.66	1.4
136	Darien	81	3.47		0.66	7.74	8.40			6.30	6.30	97.83	1.7
137	Downers Grove	81	7.93		4.12	12.33	16.45			12.33	12.33	90.14	2.0
138	Elmhurst	78	5.89		0.86	12.86	13.72			2.28	2.28	99.22	2.0
139	Glendale Heights	74	3.37		4.68	3.21	7.89			3.21	3.21	89.45	1.6
140	Glen Ellyn	77	4.12		2.67	4.68	7.35			4.68	4.68	95.48	1.8

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Table 13. Continued

No.	Town	Twp.	2010 demand (mgd)	Q_{well} (total) S&G	D	SS	Total	Q_{well} (new required) S&G	D	SS	Total	Unit cost (¢/1000 gal)	Pipeline cost factor
	DuPage County (continued)												
141	Hinsdale	81	2.95		3.43	2.96	6.39			2.96	2.96	80.77	1.8
142	Itasca	75	1.79	1.05	1.70	1.90	4.65			1.90	1.90	88.12	1.6
143	Lisle	80	1.75		3.09	1.02	4.11			1.02	1.02	77.92	1.6
144	Lombard	78	5.72		1.54	10.97	12.51			4.20	4.20	99.92	2.0
145	Lombard Heights		included in Lombard (144)										
146	Naperville	79	11.55		3.34	21.96	25.30			16.92	16.92	79.90	1.8
147	Oakbrook Area	78	2.79		0.72	6.89	7.61					117.54	1.6
148	Oakbrook Terrace	78	0.63			2.54	2.54			2.54	2.54	136.28	1.6
149	Roselle	74	1.61	1.58	2.01	1.44	5.03					86.84	1.6
150	Valley View	77	0.24		1.46		1.46					109.22	1.4
151	Villa Park	78	2.39		0.58	5.54	6.12			0.99	0.99	112.80	1.8
152	Warrenville	76	0.76	2.17			2.17		0.76		0.76	84.68	1.4
153	Wayne	73	0.19	0.78			0.78	0.78			0.78	125.45	1.1
154	West Chicago	76	4.08			9.63	9.63			5.12	5.12	104.41	1.7
155	Westmont	81	2.08		1.97	3.22	5.19			1.88	1.88	90.61	1.6
156	Wheaton	77	6.82		4.00	8.34	12.34			8.34	8.34	91.43	1.8
157	Willowbrook	81	0.75		0.29	2.35	2.64			0.91	0.91	120.33	1.6
158	Winfield	76	1.01		3.33		3.33		0.56		0.56	77.65	1.4
159	Wood Dale	75	1.74		2.95	2.27	5.22					84.55	1.6
160	Woodridge	80	2.95		2.05	4.40	6.45			4.40	4.40	86.43	1.6
			93.82	7.59	62.67	152.71	222.97	0.78	3.84	89.33	93.95		
	DuPage County Alternate												
131	Burr Ridge	81	0.51		2.15		2.15					89.80	1.5
134	Clarendon Hills	81	0.86		2.90		2.90		0.21		0.21	80.63	1.7
136	Darien	81	3.47			8.39	8.39			6.95	6.95	101.22	1.7
141	Hinsdale	81	2.95			7.08	7.08			7.08	7.08	106.30	1.8
142	Itasca	75	1.79	1.05	3.59		4.64		1.89		1.89	73.55	1.6
143	Lisle	80	1.75		10.31		10.31					68.55	1.6
148	Oakbrook Terrace	78	0.63		1.92		1.92		1.92		1.92	95.19	1.6
149	Roselle	74	1.61	1.58	2.91		4.49		0.90		0.90	72.39	1.5
155	Westmont	81	2.08		6.55	1.44	7.99					72.46	1.6
157	Willowbrook	81	0.75		1.51	1.44	2.95		0.64		0.64	104.23	1.6
160	Woodridge	80	2.95		7.54		7.54		1.40		1.40	62.76	1.6
			19.35	2.63	39.38	18.35	60.36	0.00	6.96	14.03	20.99		
	Kane County												
161	Aurora	31	15.66	1.01		31.35	32.36			8.89	8.89	76.73	2.0
162	Batavia	28	2.53			6.95	6.95			2.06	2.06	127.37	1.8
163	Burlington	20	0.09	0.19		0.39	0.58	0.12			0.12	196.59	1.3
164	Carpentersville	19	3.73	11.52			11.52					59.00	1.7
165	East Dundee	19	0.61	2.54			2.54	0.46			0.46	88.51	1.5
166	Elburn	27	0.50	1.04		0.43	1.47	0.78			0.78	121.42	1.2
167	Elgin	22	11.86	1.57		24.32	25.89			2.14	2.14	77.15	2.0
168	Geneva	28	2.28			6.14	6.14			0.40	0.40	135.97	1.8
169	Gilberts	18	0.15	0.44			0.44	0.44			0.44	171.26	1.2
170	Hampshire	17	0.42	0.88		0.40	1.28	0.40			0.40	107.92	1.2
171	Maple Park	23	0.07	0.29			0.29	0.04			0.04	166.98	1.3
172	Montgomery & B. Hill	31	1.97	0.75	1.00	3.69	5.44	0.46			0.46	87.72	1.3
173	North Aurora	31	1.09	0.14		3.50	3.64	0.14			0.14	133.07	1.8
174	Pingree Grove	18&21	0.02	0.08			0.08	0.08			0.08	408.01	1.1
175	St. Charles	25	4.37	4.37		6.17	10.54	2.64		0.70	3.34	85.68	1.7
176	Sleepy Hollow	19	0.23	1.20			1.20	0.26			0.26	116.48	1.6
177	South Elgin	22	0.94	2.40			2.40	1.17			1.17	95.52	1.7
178	Sugar Grove	30	0.25	1.24			1.24	0.44			0.44	119.66	1.1
179	Valley View	25	0.12	0.48			0.48	0.48			0.48	152.57	1.6
180	West Dundee	19	0.80	1.60		1.44	3.04	0.88			0.88	96.37	1.7
			47.69	31.74	1.00	84.78	117.52	8.79	0.00	14.19	22.98		
	Lake County												
181	Antioch	32	1.11	2.35	0.90		3.25		0.90		0.90	80.07	1.5
184	Deer Park	45	0.21		0.66		0.66		0.66		0.66	129.22	1.3
186	Fox Lake	36	0.85	2.04		0.35	2.39	0.24			0.24	127.41	1.6
188	Grayslake	37	1.32		0.58	2.92	3.50			1.56	1.56	106.34	1.6
189	Green Oaks	42	0.27		1.10		1.10		1.10		1.10	113.96	1.2

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Table 13. Continued

			2010 demand	Q_{well} (total)				Q_{well} (new required)				Unit cost (¢/1000	Pipeline cost
No.	Town	Twp.	(mgd)	S&G	D	SS	Total	S&G	D	SS	Total	gal)	factor
						Lake County (continued)							
190	Gurnee	38	1.71		2.72	2.16	4.88		2.72		2.72	103.94	1.3
191	Hainsville	37	0.25		1.02		1.02		1.02		1.02	122.20	1.3
192	Hawthorn Woods	45	0.19		0.61		0.61					120.01	1.3
195	Indian Creek	46	0.03	0.28			0.28	0.28			0.28	203.17	1.3
196	Island Lake	40	0.31	0.72		0.43	1.15					121.80	1.3
197	Kildeer	45	0.24		0.72		0.72		0.72		0.72	123.52	1.3
198	Knollwood	42	0.65			2.62	2.62			2.62	2.62	128.72	1.3
199	Lake Barrington	44	0.98	1.97		1.08	3.05	1.05			1.05	88.64	1.3
202	Lake Villa	33	0.18	0.79			0.79					122.93	1.3
203	Lake Zurich	45	2.17		1.74	4.06	5.80			1.90	1.90	93.69	1.5
204	Libertyville	42	4.23		3.49	6.09	9.58			3.48	3.48	74.10	1.6
205	Lincolnshire	46	0.67	0.72		2.24	2.96					118.30	1.5
206	Lindenhurst	33	0.57	0.87	0.74		1.61		0.74		0.74	94.87	1.4
207	Long Grove	46	0.28		0.84		0.84		0.84		0.84	113.02	1.2
208	Mettawa	42	0.07		0.38		0.38		0.38		0.38	168.25	1.2
209	Mundelein	41	3.35	1.43	2.02	4.50	7.95		1.68		1.68	84.91	1.6
210	North Barrington	44	0.38		1.14		1.14	1.14			1.14	109.65	1.4
212	Old Mill Creek	34	0.01	0.28			0.28	0.28			0.28	266.66	1.1
213	Park City	38	0.23		0.94		0.94		0.94		0.94	126.88	1.5
214	Riverwoods	46	0.29		0.58	0.58	1.16		0.58		0.58	135.73	1.5
215	Round Lake	37	1.51		3.05	0.63	3.68		2.45		2.45	108.29	1.4
216	Round Lake Beach	37	1.83	0.27	3.40	0.98	4.65		2.40		2.40	106.13	1.6
217	Round Lake Heights	37	0.25		1.02		1.02		1.02		1.02	125.57	1.2
218	Round Lake Park	37	1.44		1.11	2.46	3.57			2.46	2.46	101.75	1.6
219	Third Lake	38	0.02	0.20			0.20	0.20			0.20	230.90	1.3
220	Tower Lake	44	0.12	0.59			0.59	0.14			0.14	141.58	1.3
221	Vernon Hills	46	1.46	0.11	0.90	4.18	5.19					104.09	1.2
222	Wadsworth	34	0.14	0.33			0.33	0.33			0.33	147.08	1.2
223	Wauconda	40	0.66		1.01	1.44	2.45		0.14		0.14	104.30	1.4
225	Wilwood Gages	37	0.86	0.47		2.20	2.67			0.54	0.54	111.83	1.6
226	Winthrop Harbor	35	0.97	1.08	0.13	1.68	2.89	0.88		0.74	1.62	106.53	1.5
			29.81	14.50	30.80	40.60	85.90	4.54	18.29	13.30	36.13		
					McHenry County								
228	Algonquin	16	1.32	1.50	0.22	1.50	3:22	1.22			1.22	103.23	1.6
229	Cary	16	2.21	3.67	0.14	1.28	5.09	3.24			3.24	100.07	1.4
230	Crystal Lake	12&16	5.20	6.29	0.50	5.47	12.26	6.00			6.00	83.22	1.6
231	Fox River Grove	16	0.58		1.61		1.61		0.72		0.72	97.12	1.3
232	Harvard	1	0.94	2.74			2.74	1.16			1.16	97.93	1.4
233	Hebron	2	0.20	1.01			1.01					125.97	1.0
234	Huntley	15	0.22	0.68			0.68					113.09	1.0
235	Lake in the Hills	16	0.61	0.58	0.78	0.28	1.64	0.34			0.34	96.61	1.6
236	Lakemoor	8&12	0.08		0.32		0.32					163.80	1.1
237	Lakewood	15	(0.19) included in Crystal Lake (230)										
238	Marengo	9	0.57	1.73			1.73					88.14	1.2
239	McCullom Lake	8	(0.15) included in McHenry (240)										
240	McHenry	8	4.24	8.85	0.52		9.37	5.85			5.85	83.49	1.6
241	McHenry Shores	12	0.49	0.19	0.98		1.17		0.90		0.90	102.31	1.2
242	Oakwood Hills	12	0.17		0.70		0.70		0.70		0.70	133.94	1.2
243	Richmond	4	0.19	0.83			0.83	0.18			0.18	123.91	1.1
244	Spring Grove	4	0.08	0.32			0.32	0.32			0.32	156.54	1.0
245	Sunnyside	8	0.67	1.32	0.05		1.37	1.32			1.32	93.20	1.4
246	Sunrise Ridge Subd.	7	(0.02) Subdivision										
247	Union	14	0.09	0.60	0.22		0.82					146.34	1.0
248	Woodstock	11	4.31	10.08			10.08	1.00			1.00	61.87	1.6
			22.17	40.39	6.04	8.53	54.96	20.63	2.32	0.00	22.95		
					Will County								
249	Arbury Hills	90	0.23		1.30		1.30		0.14		0.14	115.32	1.2
250	Beecher	102	0.31		1.21		1.21		0.08		0.08	105.66	1.3
251	Bolingbrook	83	5.65		13.74		13.74		7.20		7.20	72.16	1.5
252	Braidwood	103	0.25			0.78	0.78			0.28	0.28	163.80	1.3
253	Channahon	91	0.92			2.76	2.76			2.76	2.76	122.36	1.3
254	Crest Hill	85	0.98		2.01	0.43	2.44		0.87		0.87	114.30	1.6
255	Crete	96	0.98		2.93		2.93		1.28		1.28	86.35	1.5
256	Elwood	92	0.08		0.35		0.35					147.43	1.2
257	Frankfort	90	1.22		4.94		4.94					74.99	1.3
258	Godley	103	0.03	0.09			0.09	0.09			0.09	202.09	1.2

Concluded on next page

Table 13. Concluded

No.	Town	Twp.	2010 demand (mgd)	Q_{well} (total) S&G	Q_{well} (total) D	Q_{well} (total) SS	Q_{well} (total) Total	Q_{well} (new required) S&G	Q_{well} (new required) D	Q_{well} (new required) SS	Q_{well} (new required) Total	Unit cost (¢/1000 gal)	Pipeline cost factor
						Will County (continued)							
259	Joliet	88	15.81	7.04	5.80	19.43	32.27		5.80	2.00	7.80	81.72	1.9
260	Lockport	85	1.73		1.29	3.38	4.67		0.57		0.57	119.48	1.6
261	Manhattan	93	0.25		0.91		0.91		0.15		0.15	112.00	1.3
262	Mokena	90	1.05		3.21		3.21		1.77		1.77	81.30	1.3
263	Monee	95	0.32		1.80		1.80					102.52	1.3
264	New Lenox	89	1.77		3.98		3.98		3.12		3.12	77.58	1.4
265	Park Forest South	95	2.74		6.93		6.93		2.10		2.10	66.99	1.2
266	Peotone	100	0.33		3.24		3.24					101.12	1.3
267	Plainfield	84	0.87		0.84	2.01	2.85		0.84		0.84	118.74	1.3
268	Rockdale	88	0.44			1.60	1.60			0.88	0.88	131.86	1.6
269	Romeoville	83	2.08		3.08	2.81	5.89		0.64		0.64	83.54	1.5
270	Shorewood	87	0.84		0.16	2.87	3.03			2.52	2.52	119.19	1.3
271	Steger	96	1.17		3.26		3.26		1.14		1.14	77.82	1.5
272	Symerton	98	0.01		0.04		0.04		0.04		0.04	240.29	1.2
273	Wilmington	97	0.68			2.60	2.60					133.35	1.2
			40.74	7.13	61.02	38.67	106.82	0.09	25.74	8.44	34.27		

Existing Lake Michigan users not included in Cook and Lake County.

REGIONAL SUPPLY SYSTEMS: PRELIMINARY STUDIES

There are 273 towns or entities (table 2) in the six counties and 96 of them are already served with water from Lake Michigan directly or through the city of Chicago. The availability of groundwater from shallow sand and gravel and dolomite aquifers as well as from deep aquifers has been investigated for the remaining 177 towns. Table 13 indicates that 85 of the 177 entities can meet their water demands up to the year 2010 from the shallow aquifers. Thus, 92 entities need other sources of water supply if the lowering of water levels in the deep wells is to be mitigated and if the safe yield of the deep sandstone aquifer is not to be exceeded. The locations of these 92 entities suggest 6 regional systems as shown in figure 16. The location and size of these regional systems have been determined from the criteria of financial and technical feasibility, compactness, and existing railroads and major highways.

A number of system configurations were examined for each regional system. Each system configuration is designed to meet water demands for a certain number of towns, though the number and mix varies from one configuration to the other. The system costs were calculated with the cost functions, described earlier in this report, applicable to the system components designed for the 2010 demands. Unit cost of water for each system has been computed for the 2010 demand assuming no inflation. The unit cost and system demand information can help the decision maker to choose the desired configuration taking into consideration the preferences of the towns to be served, taxing base and bonding requirements, and any allowed use of deep sandstone wells for some towns. In some of the system configurations, towns with sufficient groundwater from shallow aquifers but either within the system boundary or close to it, have been included in the system to determine whether it will be economical for these towns to have an independent groundwater supply or a supply from a regional system if sufficient water is available to the system from another source.

The six regional supply systems (shown as A through F in figure 16) analyzed are: 1) Lake County, 2) southern Cook County, 3) Du Page County, 4) northwestern Cook County, 5) Fox River supply for Kane County, and 6) Kankakee River supply for Will and Du Page Counties. Details of system configurations, water demands, conjunctive use, and annual and unit costs are given for each of these systems.

Water From Lake Michigan for Lake County

Out of the 47 user entities or towns listed in table 2 for Lake County, a total of 11 is currently meeting water demands with water from Lake Michigan. Two others, Gurnee and Winthrop Harbor, have been allocated some Lake Michigan water for the years 1979 through 1980. The towns that cannot meet future water demands from shallow aquifers alone are listed in table 14 along with their 2010 demand. The capacity of shallow and deep aquifer wells to meet the 2010 demand from groundwater alone is also included. Numbers in parentheses indicate the existing capacity. The needed total capacity of wells is 2.3 to 4 times the 2010 demand because of these assumptions: 18 hours a day pumping of the wells, maximum demand equals 1.5 times the average demand, and the requirement for standby wells.

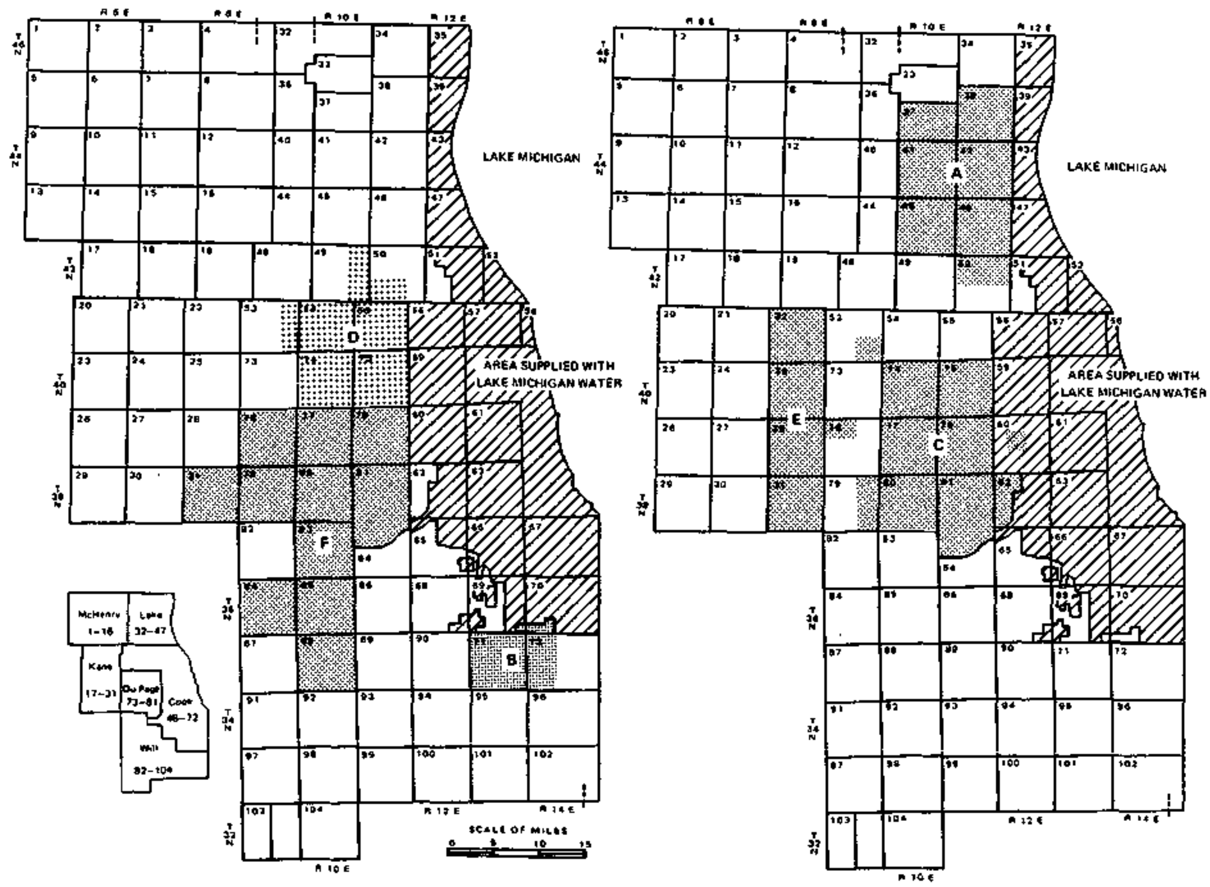


Figure 16. Location map for the six regional systems, A through F

Table 14. Lake County Supply System: 2010 Demands and Well Capacities

No.	Town	2010 demand mgd	Capacity of wells (mgd) Shallow		Deep	
186	Fox Lake	0.85	2.04	(1.80)	0.35	(0.35)
188	Grayslake	1.32	0.58	(0.58)	2.92	(1.36)
190	Gurnee	1.71	2.72	(-)	2.16	(2.16)
198	Knollwood	0.65	-	(-)	2.62	(-)
203	Lake Zurich	2.17	1.74	(1.74)	4.06	(2.16)
204	Libertyville	4.23	3.49	(3.49)	6.09	(2.61)
205	Lincolnshire	0.67	0.72	(0.72)	2.24	(2.24)
209	Mundelein	3.35	3.45	(1.77)	4.50	(4.50)
214	Riverwoods	0.29	0.58	(-)	0.58	(0.58)
215	Round Lake	1.51	3.05	(0.60)	0.63	(0.63)
218	Round Lake Park	1.44	1.11	(1.11)	2.46	(-)
223	Wauconda	0.66	1.01	(0.87)	1.44	(1.44)
225	Wildwood Gages	0.86	0.47	(0.47)	2.20	(1.66)
226	Winthrop Harbor	0.97	1.21	(0.33)	1.68	(0.94)

Fox Lake and Wauconda can meet their 2010 requirements from shallow aquifers and use the existing deep wells only in emergency during high demand periods when a shallow-aquifer well breaks down. Winthrop Harbor is scheduled to get water from the plant supplying Zion. The remaining user entities will need water from Lake Michigan if pumpage from the deep aquifer is to be reduced. A supply system serving these entities passes so close to Hainesville, Hawthorn Woods, Round Lake Beach, and Vernon Hills that these towns may be economically served from the system serving the 11 towns. The system configuration is shown in figure 17. Buffalo Grove and Wheeling in Cook County have also been added to the system because of their close proximity.

Lake County Lake Michigan System

The 17 towns on this system and their 2010 demands are given in table 15. Unit cost in 0/1000 gal was obtained with a computer program which considered the cost of intake in Lake Michigan and submerged pipeline from there to the shore, the capital and OM&R costs of a coagulation-filtration plant, and the pipeline and pumping costs through the pipeline network to the user entities. System demands and unit costs for 10 system configurations are given in table 15 and are summarized below.

	Total demand (mgd)	*Unit cost (¢/1000 gal)*
17 towns	27.80	63.08
13 towns (excluding Hainesville, Hawthorn Woods, Round Lake Beach, and Vernon Hills)	24.07	65.21

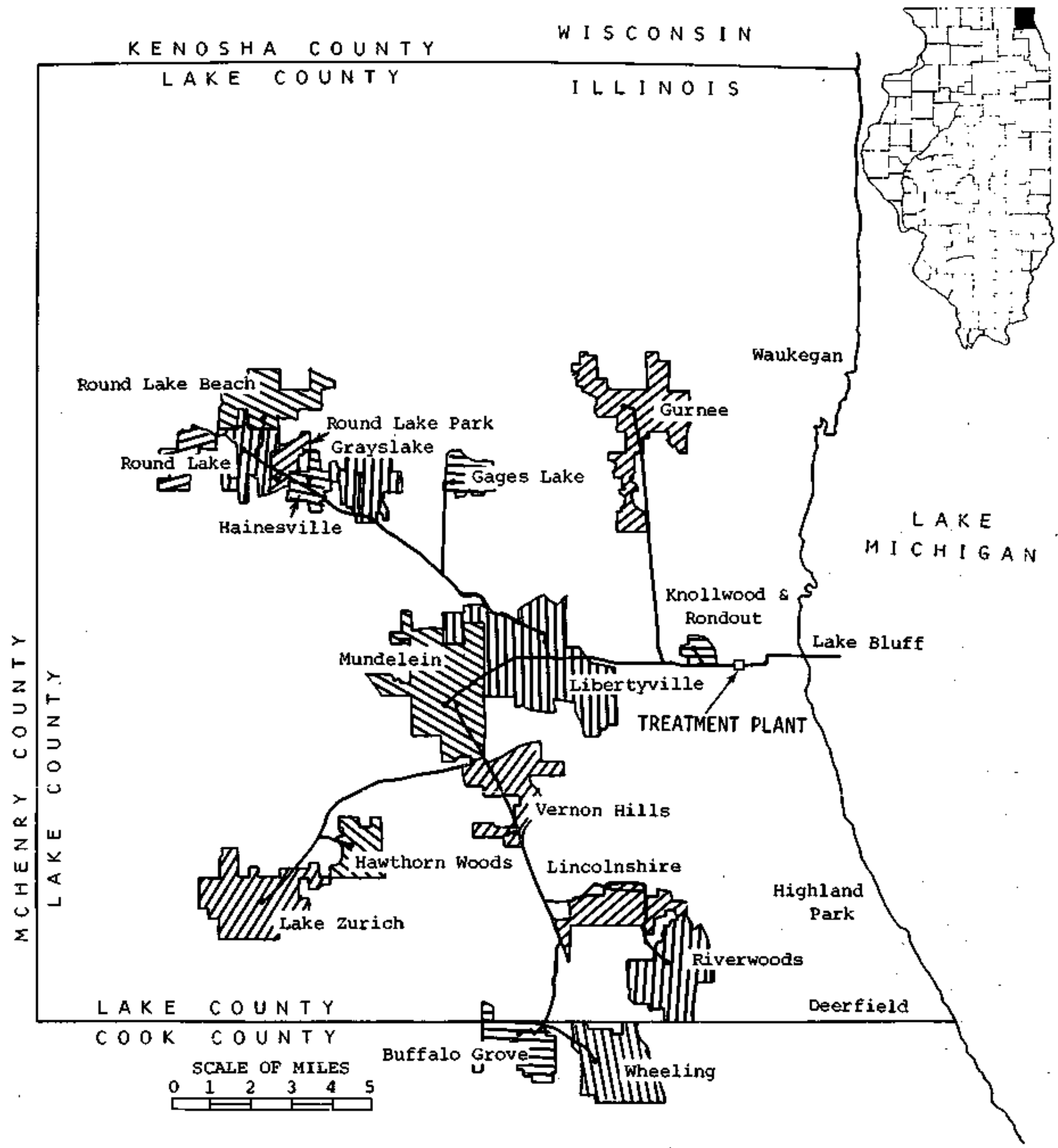


Figure 17. Lake County supply system

Table 15. Lake County Supply Systems

No.	Town	2010 demand (mgd)	System number (towns served marked by x) 1	2	3	4	5	6	7	8	9	10
13	Buffalo Grove	3.11	x	x	x	x	x				x	x
121	Wheeling	2.76	x	x	x	x	x				x	x
188	Grayslake	1.32	x	x	x	x	x	x	x	x	x	x
190	Gurnee	1.71	x	x	x	x	x	x	x	x		x
191	Hainesville	0.25	x		x	x	x	x	x	x	x	x
192	Hawthorn Woods	0.19	x		x						x	x
198	Knollwood	0.65	x	x	x	x	x	x	x	x	x	x
203	Lake Zurich	2.17	x	x	x	x	x	x			x	x
204	Libertyville	4.23	x	x	x	x	x	x	x	x	x	x
205	Lincolnshire	0.67	x	x		x					x	x
209	Mundelein	3.35	x	x	x	x	x	x	x	x	x	x
214	Riverwoods	0.29	x	x		x					x	x
215	Round Lake	1.51	x	x	x	x	x	x	x	x	x	x
216	Round Lake Beach	1.83	x		x	x	x	x	x	x	x	
218	Round Lake Park	1.44	x	x	x	x	x	x	x	x	x	x
221	Vernon Hills	1.46	x		x	x	x	x	x		x	x
225	Wildwood Gages	0.86	x	x	x	x	x	x	x	x	x	x
	System demand, mgd		27.80	24.07	26.84	27.61	26.65	20.78	18.61	17.15	26.09	25.97
	System cost, ¢/1000 gal		63.08	65.21	62.84	63.10	62.90	64.57	63.40	63.74	63.49	63.95

Lake County Lake Michigan Supplemental System

Most of the towns on the system have some groundwater available from wells in shallow aquifers. The demand that can be met from them is prorated on the basis of the ratio of shallow-aquifer-well capacity to total shallow-and-deep-aquifer-well capacity. The remaining demand can be supplemented by conveying water from Lake Michigan through the conveyance network. Thus, there are 13 towns on the system and all have supplemental demands less than the 2010 demand except Knollwood which has no shallow wells. The system demand totals 15.63 mgd with a unit cost of 76.21 ¢/1000 gal (table 16).

Comparative Unit Costs.

Unit costs and annual costs for serving the 17 towns with complete and supplemental systems have been computed considering both no treatment and full treatment of groundwater from shallow aquifers. At present, the groundwater is mostly chlorinated and polyphosphates added to keep iron in suspension. Costs with various options for the two systems are given below.

Lake County System (table 15)

System No.	*System demand (mgd)*	*Unit cost (¢/1000 gal)*	*Annual cost (thousand dollars)*
17 towns	27.80	63.80	6404
13 towns	24.07	65.21	5732
4 towns (GW)*	3.73	107.12	1459
4 towns (GW)†	3.73	16.34	223
17 towns (13+4*)	27.80	70.83	7191
17 towns (13+4†)	27.80	58.66	5955

Lake County Supplemental System (table 16)

	System demand (mgd)	*Unit cost (¢/1000 gal)*	*Annual cost (thousand dollars)*
13 towns (Lake)	15.63	76.21	4350
16 towns (GW)*	12.17	94.08	4181
16 towns (GW)†	12.17	7.87	350
17 towns with GW*	27.80	84.03	8531
17 towns with GW†	27.80	46.29	4706

Note: † No treatment costs included
* Full treatment costs included

In case the groundwater will have to be fully treated (cheaper than doing so by individual home softening units), the following alternatives need to be considered.

Water supply from Lake Michigan only	$6,404,000/yr
Lake supply for 13 towns and 4 towns on GW	$7,191,000/yr
Lake supply with supplemental groundwater	$8,531,000/yr

Table 16. Lake County Lake Michigan Supplemental System

		2010 demand (mgd) met by		Groundwater unit costs (¢/1000 gal)		
No.	*Town*	*SG&D*	*Lake*	*SG&D*	*SG&D**	*T.†*
13	Buffalo Grove	0.12	2.99	8.36	136.33	94.62
121	Wheeling	1.16	1.60	8.36	78.27	85.46
188	Grayslake	0.22	1.10	7.53	113.93	106.34
190	Gurnee	0.95	0.76	6.73	97.10	103.94
191	Hainesville	0.25	-	7.53	122.20	122.20
192	Hawthorn Woods	0.19	-	8.38	120.01	120.01
198	Knollwood	-	0.65	-	-	128.72
203	Lake Zurich	0.65	1.52	8.38	89.30	93.69
204	Libertyville	1.54	2.69	7.21	71.21	74.10
205	Lincolnshire	0.16	0.51	9.10	125.73	118.30
209	Mundelein	1.45	1.90	9.28	75.59	84.91
214	Riverwoods	0.14	0.15	6.86	135.27	135.73
215	Round Lake	1.25	0.26	7.53	103.13	108.29
216	Round Lake Beach	1.83	-	7.68	106.13	106.13
218	Round Lake Park	0.65	0.79	7.53	88.37	101.75
221	Vernon Hills	1.46	-	7.53	104.09	104.09
225	Wildwood Gages	0.15	0.71	9.56	120.56	111.83
		12.17	15.63			

Lake system unit cost 76.21 ¢/1000 gal

Notes:

SG&D = Unit cost in ¢/1000 gal for raw water from SG&D wells; it does not include the cost of chlorination, polyphosphate, or any other treatment.

SG&D* = Unit cost in ¢/1000 gal if water from shallow aquifer is to be fully treated; SG&D wells for a town are served by one treatment plant.

T.† = Unit cost in ¢/1000 gal when 2010 demand is met by wells in shallow as well as deep aquifers.

Southern Cook County Supply System

Fourteen towns were considered for inclusion in a single system using 1) groundwater collected locally and from southeastern Will County, 2) water purchased from the city of Chicago, or 3) water obtained directly from Lake Michigan. Most of the towns have wells in the Silurian dolomite aquifer- All of these wells cannot be pumped at the same time because the total well capacity far exceeds the aquifer potential yield. The Silurian dolomite is being dewatered at East Chicago with substantial reduction in well yields.

Country Club Hills presently uses water from the Silurian dolomite aquifer and can develop adequate supply from this source. Thornton is using water from the deep sandstone aquifer and it can shift to the shallow dolomite aquifer for new wells and use the deep wells as standby. Lynwood, Sauk Village, and East Chicago Heights are distant from the proposed conveyance system. Lynwood presently has deep wells and can shift to shallow dolomite wells by 2010. Sauk Village and East Chicago Heights are using water from the Silurian dolomite and can further develop this source to meet 2010 demands. The existing dolomite well capacity for South Chicago Heights is nearly adequate to meet the 2010 demand. The development of dolomite wells for Lynwood, Sauk Village, East Chicago Heights, and South Chicago Heights depends on the reduction in usage of the shallow aquifer by Homewood, Chicago Heights, Matteson, and Park Forest. The eight remaining towns, their 2010 demands, and well capacities needed to meet those demands from shallow and deep aquifers, are given in table 17. Only the Silurian dolomite potential that can be developed for each town is given under the shallow wells. The 2010 demand for the eight towns is 19.98 mgd.

Table 17. Southern Cook County Supply System: 2010 Demands and Well Capacities

No.	*Town*	*2010 demand (mgd)*	*Capacity of wells (mgd) Shallow*	*Deep*
20	Chicago Heights	5.74	4.76 (4.76)	8.16 (3.32)
35	Flossmoor	1.36	0.45 (0.45)	3.09 (2.17)
42	Glenwood	2.59	0.16 (0.16)	7.21 (3.61)
53	Homewood	2.49	3.66 (3.66)	3.52 (3.52)
68	Matteson	1.96	1.13 (1.13)	3.12 (-)
85	Olympia Fields	0.67	0.29 (0.29)	2.40 (-)
91	Park Forest	3.02	2.02 (2.02)	4.48 (-)
96	Richton Park	2.15	0.46 (0.46)	4.08 (-)

Note: Existing well capacities are in parentheses.

Groundwater Supply System

The eight towns on the system have existing wells with a total capacity of 12.93 mgd in the Silurian dolomite and 12.62 mgd in the deep sandstone. Deep well pumpage is reduced to avoid critical pumping levels. Silurian dolomite pumpage is reduced to assure adequate supply for the towns not on the system. Six townships in Will County (numbers 93, 94, 96, 100, 101, and 102) have about 24 mgd groundwater available from the Silurian dolomite aquifer after meeting local 2010 demands.

Groundwater from Existing Local Wells. Eleven dolomite wells out of 18 dolomite and sandstone wells are considered for the groundwater collection system. These wells can provide a maximum capacity of 11.12 mgd and an average supply of 7.41 mgd for unit costs of 17.4 ¢/1000 gal for the collection system and 6.0 ¢/1000 gal for wells and well pumping. The wells are distributed among the towns with 2 in Flossmoor, 2 in Homewood, 3 in Matteson, and 4 in Park Forest. The 7.41 mgd is about 60 percent of the 1970 pumpage and about 87 percent of the 2010 projected demand for the eight towns. Deep well pumpage will be eliminated and dolomite well pumpage will be reduced to assure adequate supply for towns not on the system. The collection system is shown in figure 18.

Water from Southeastern Will County. As many as 49 wells are needed to develop the 24 mgd available in southeastern Will County. A system of 34 wells is used to deliver an average of 14.24 mgd from townships 94, 96, 100, 101, and 102. The system is designed to develop water from the Silurian dolomite aquifer in these townships and to permit the towns of Beecher, Crete, Peotone, and Steger to meet their 2010 water demands from the same aquifer. The proposed well field and collection system are shown in figure 19. The water can be collected and piped to a point along the Illinois Central-Gulf Railroad tracks and State Highway 50 near the northeast corner of Sec. 5, T33N, R13E (township 101) for transport to the treatment plant which can be located in the NE¼ of Sec. 3, T34N, R13E (township 95). The pipeline network is optimized to deliver an average flow of 14.24 mgd with a ± 50% variation. The unit cost to deliver the water from the wells to the treatment plant is 31.9 ¢/1000 gal. The wells and well pumping cost is 6.8 ¢/1000 gal.

Treatment and Distribution of Groundwater. The 2010 system demand is 19.98 mgd. The local and Will County groundwater collection systems have a combined capacity of 21.65 mgd. Unit conveyance costs are adjusted assuming the annual capital costs remain as calculated and annual operating costs are proportional to the actual flow rate. Treatment cost is for lime-soda softening of 19.98 mgd. The treated water is distributed to the user entities by the conveyance network shown in figure 18. The distribution system generally runs parallel to the local groundwater collection system. Annual and unit costs are given in table 18.

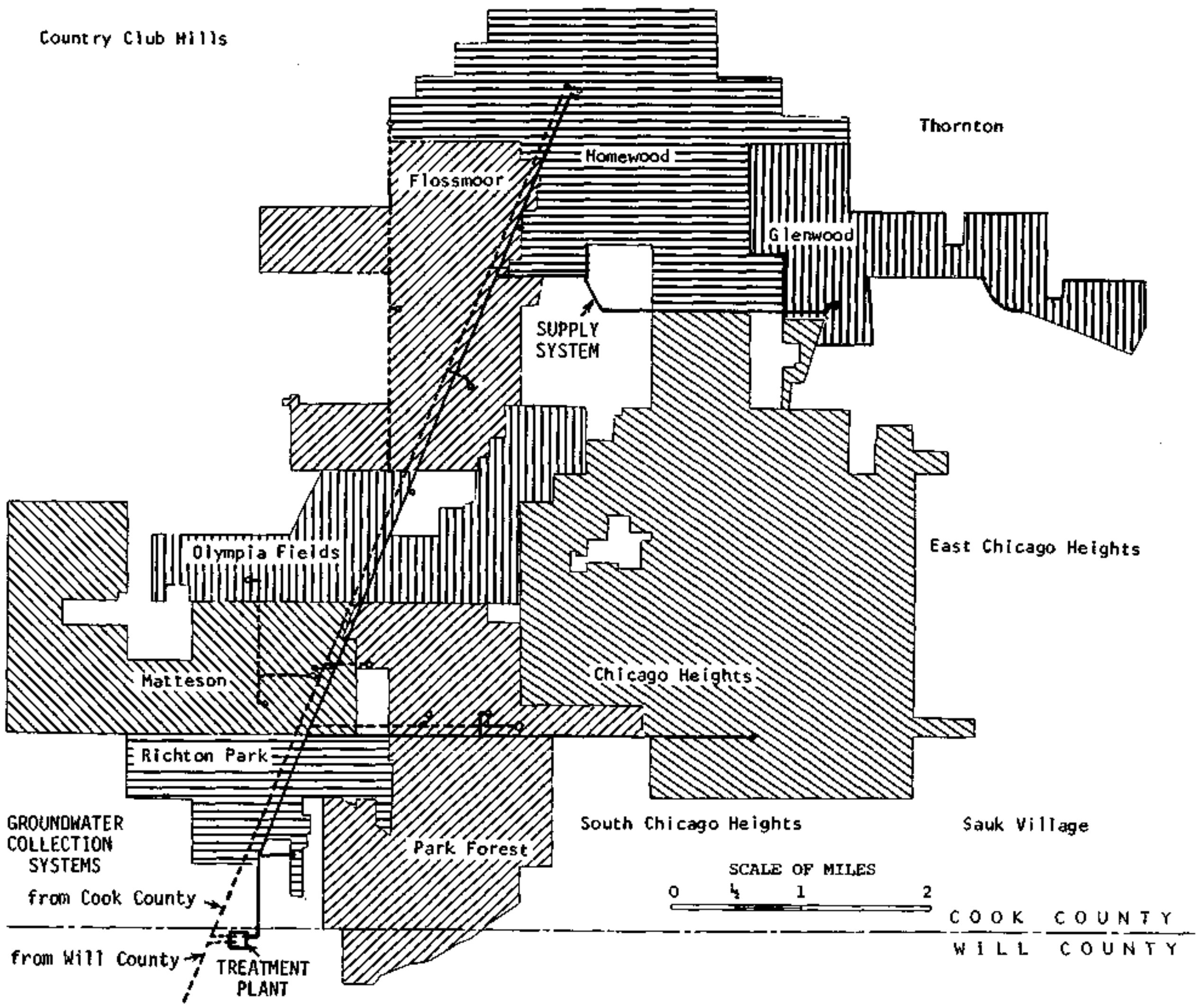


Figure 18. Southern Cook County supply system and pipeline network for collection of groundwater from existing wells

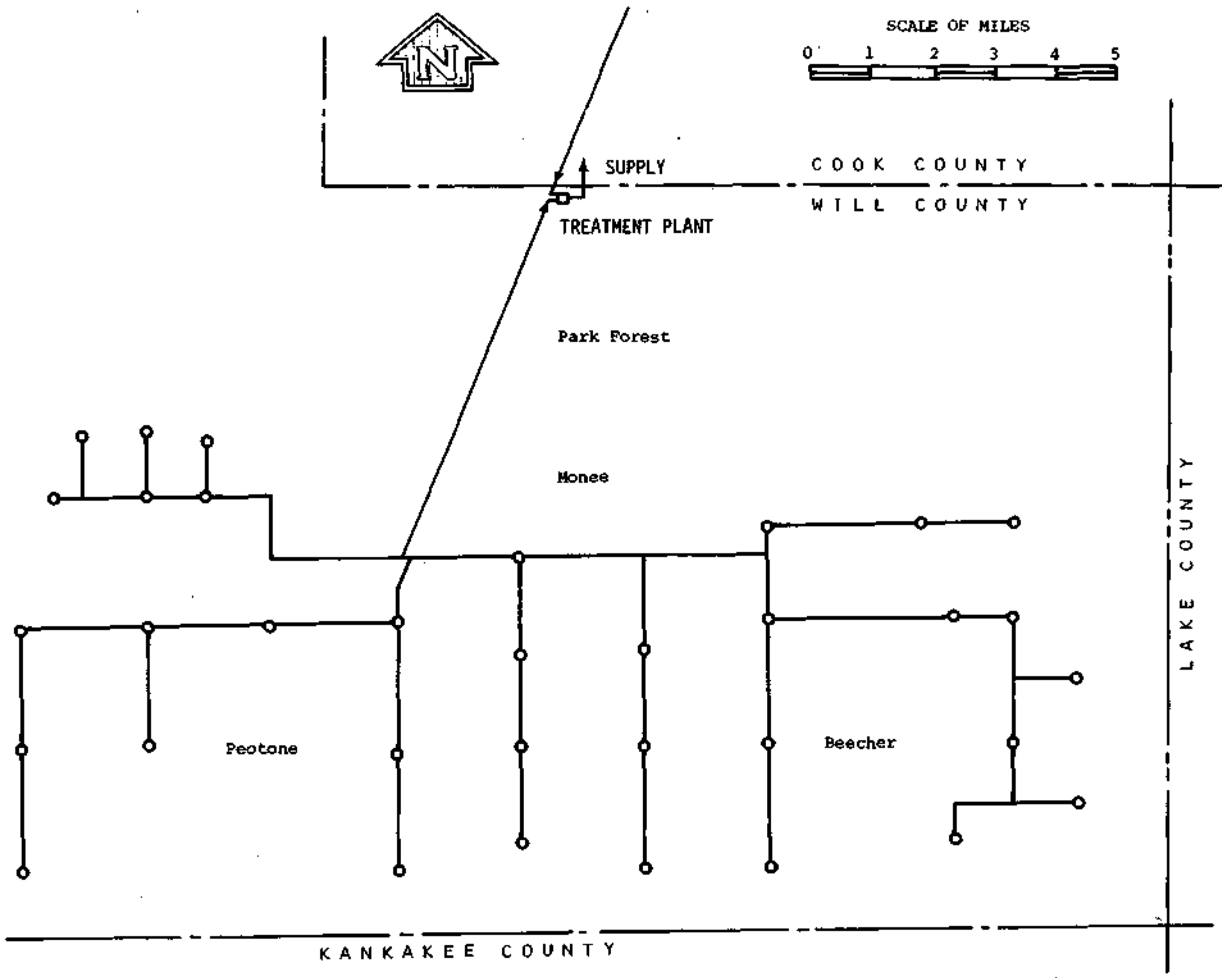


Figure 19. Pipeline network for collection of groundwater from southeastern Will County

Table 18. Cost of Groundwater Supply to the Southern Cook County System

System element	*Annual cost (thousand dollars)*	*Unit cost (¢/1000 gal)*
Will County groundwater collection, 13.14 mgd		
Raw water	328	6.84
Conveyance to treatment plant	1636	34.10
Cook County groundwater collection, 6.84 mgd		
Raw water	151	6.04
Conveyance to treatment plant	457	18.30
Total groundwater collection, 19.98 mgd		
Raw water	479	6.56
Conveyance to treatment plant	2093	28.68
Treatment (lime-soda process)	2718	37.25
Conveyance to user entities	900	12.34
Total	6190	84.83

Water Supply from Chicago

Purchase of treated Lake Michigan water from the city of Chicago is an alternate means of supplying these eight towns. The price for water purchased from Chicago is to be negotiated, so an alternative cost will be computed in comparison with groundwater and direct lake supply costs. The pickup point for a Chicago supply is taken at 130th Street and the Illinois Central-Gulf tracks, just west of S. Indiana Avenue. Three supply system configurations were investigated and the one shown in figure 20 was the least-cost layout. The total conveyance system cost is $1,949,000 per year or 26.70 ¢/1000 gal.

Water Supply from Lake Michigan

A 2-mile lake intake pipeline and a 10-mile pipeline to the location proposed for getting water from the city of Chicago are needed to bring lake water to the supply system serving the eight towns. The intake will be about 2 miles northeast of the existing Chicago South Filtration Plant. The pipeline follows 76th Street to Stony Island Avenue, travels south along Stony Island Avenue to the Calumet Expressway, and follows the expressway to the treatment plant which will be located near the intersection of 130th Street

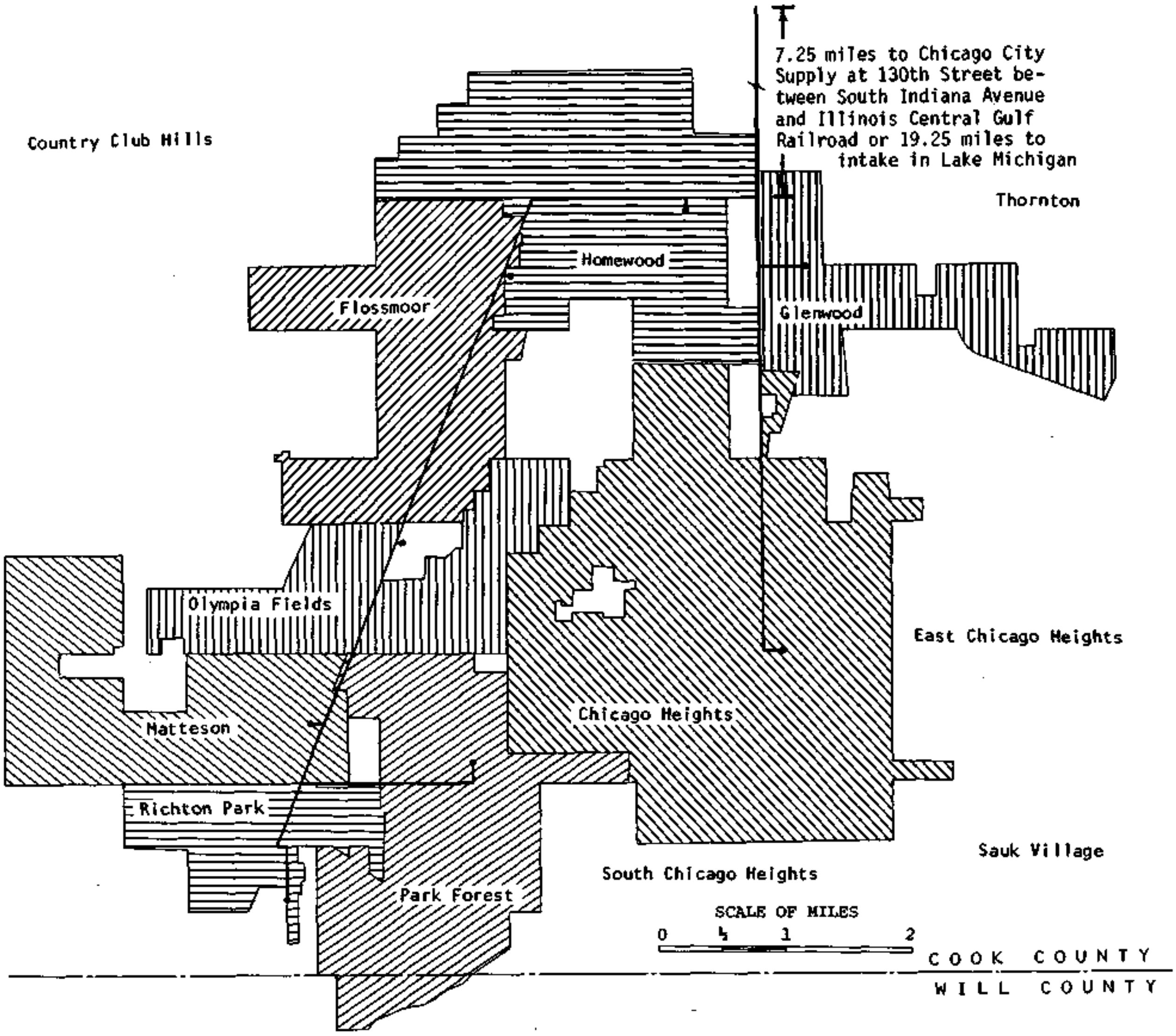


Figure 20. Southern Cook County supply system with water from the city of Chicago or Lake Michigan

and the expressway. The finished water pipeline goes west along 130th Street to the Illinois Central-Gulf right-of-way. From there on the supply system is the same as that with water from the city of Chicago. Pipeline cost multipliers have been taken as 3.0 for the lake intake pipeline, and 2.5 for the pipeline to the treatment plant.

Annual costs for this system are $4,067,000 for intake and water transport to the user towns and $2,131,000 for treatment. Corresponding unit costs are 55.73 and 29.21 ¢/1000 gal. Thus, the total unit cost becomes 84.94 ¢/1000 gal. This compares with a unit cost of 84.83 ¢/1000 gal for the groundwater supply system. Thus, if the negotiated 2010 unit price of water purchased from Chicago (assuming system costs in 1980 dollars) is less than 58¢/1000 gal, water from Chicago would be the least costly supply option.

Du Page County Supply System

Du Page County has a projected 2010 demand of 94 mgd. The shallow aquifers, mostly the Silurian dolomite, have a potential yield of about 45 mgd. The county's share of the deep sandstone practical sustained yield is about 6 mgd. If the remaining 43 mgd is obtained by mining the deep sandstone aquifer, critical pumping levels and reduced well yields are predicted by the year 2004 in the six central and eastern townships. Twenty-three of the 35 Du Page County towns listed in table 13 are considered for inclusion on a system supplying either water purchased from the city of Chicago or water obtained independently from Lake Michigan. Hanover Park and Streamwood in Cook County are considered on the system. Bellwood and Western Springs, also in Cook County, are included because this is the closest lake water supply system. Itasca and Roselle in Du Page County are included because they are close to the system network, although they can develop shallow aquifer supplies under the alternate scheme (table 13) at a unit cost of 73.6 and 72.4 ¢/1000 gal, respectively. These 27 towns (23 in Du Page and 4 in Cook County) are listed as 25 user entities in table 19 combining Lombard Heights with Lombard and Oakbrook Terrace with Oak Brook. Six towns in Du Page County (Bartlett, Burr Ridge, Wayne, West Chicago, Woodridge, and Willowbrook) are not included in this system because Bartlett, Wayne, and West Chicago are distant from the system limits and Burr Ridge, Woodridge, and Willowbrook can meet their demand from the Silurian dolomite aquifer with supplemental use of deep sandstone wells during maximum demand periods.

The towns served by the system, their 2010 demands, and the capacity of shallow and deep wells to meet these demands are given in table 19. The capacity for shallow wells has been reduced, if needed, so that the total well capacity in a township approximates the potential yield of the shallow aquifer in that township.

Water Supply from Chicago

Treated water will be purchased from the city of Chicago to serve the towns on the system. The purchase price at the city boundary is to be negotiated. The supply point is on the boundary between Chicago and Oak Park, at the intersection of Austin and Washington Boulevards. The water conveyance network and towns served are shown in figure 21. The towns served,

Table 19. Du Page County Supply System: 2010 Demands and Well Capacities

No.	Town	2010 demand (mgd)	Capacity of wells (mgd) Shallow		Veep	
6	Bellwood	3.03		(-)	9.07	(9.07)
44	Hanover Park	3.92	0.29	(0.29)	9.42	(7.02)
113	Streamwood	4.23	4.52	(4.52)	6.12	(2.16)
119	Western Springs	1.27	1.08	(1.08)	3.17	(3.17)
126	Addison	5.19	3.91	(3.91)	4.24	(-)
129	Bensenville	2.21		(-)	6.18	(5.64)
130	Bloomingdale	2.57	0.65	(0.65)	6.23	(2.81)
133	Carol Stream	3.17	2.88	(2.88)	4.92	(2.88)
134	Clarendon Hills	0.86	0.67	(0.67)	2.78	(1.73)
136	Darien	3.47	0.66	(0.66)	7.74	(1.44)
137	Downers Grove	7.93	4.12	(4.12)	12.33	(-)
138	Elmhurst	5.89	0.86	(0.86)	12.86	(10.58)
139	Glendale Heights	3.37	4.68	(4.68)	3.21	(-)
140	Glen Ellyn	4.12	2.67	(2.67)	4.68	(-)
141	Hinsdale	2.95	3.43	(3.43)	2.96	(-)
142	Itasca*	1.79	4.64	(2.75)	-	(-)
143	Lisle	1.75	3.09	(3.09)	1.02	(-)
144	Lombard & Lombard Heights	5.72	1.54	(1.54)	10.97	(6.77)
146	Naperville	11.55	3.34	(3.34)	21.96	(5.04)
147	Oak Brook & Oakbrook Terrace	3.42	0.72	(0.72)	9.43	(9.43)
149	Roselle*	1.61	4.49	(3.59)	-	(-)
151	Villa Park	2.39	0.58	(0.58)	5.54	(4.55)
155	Westmont	2.08	1.97	(1.97)	3.22	(1.34)
156	Wheaton	6.82	4.00	(4.00)	8.34	(-)
159	Wood Dale	1.74	2.95	(2.95)	2.27	(2.27)

*'Alternate' well capacities for independent groundwater supply.

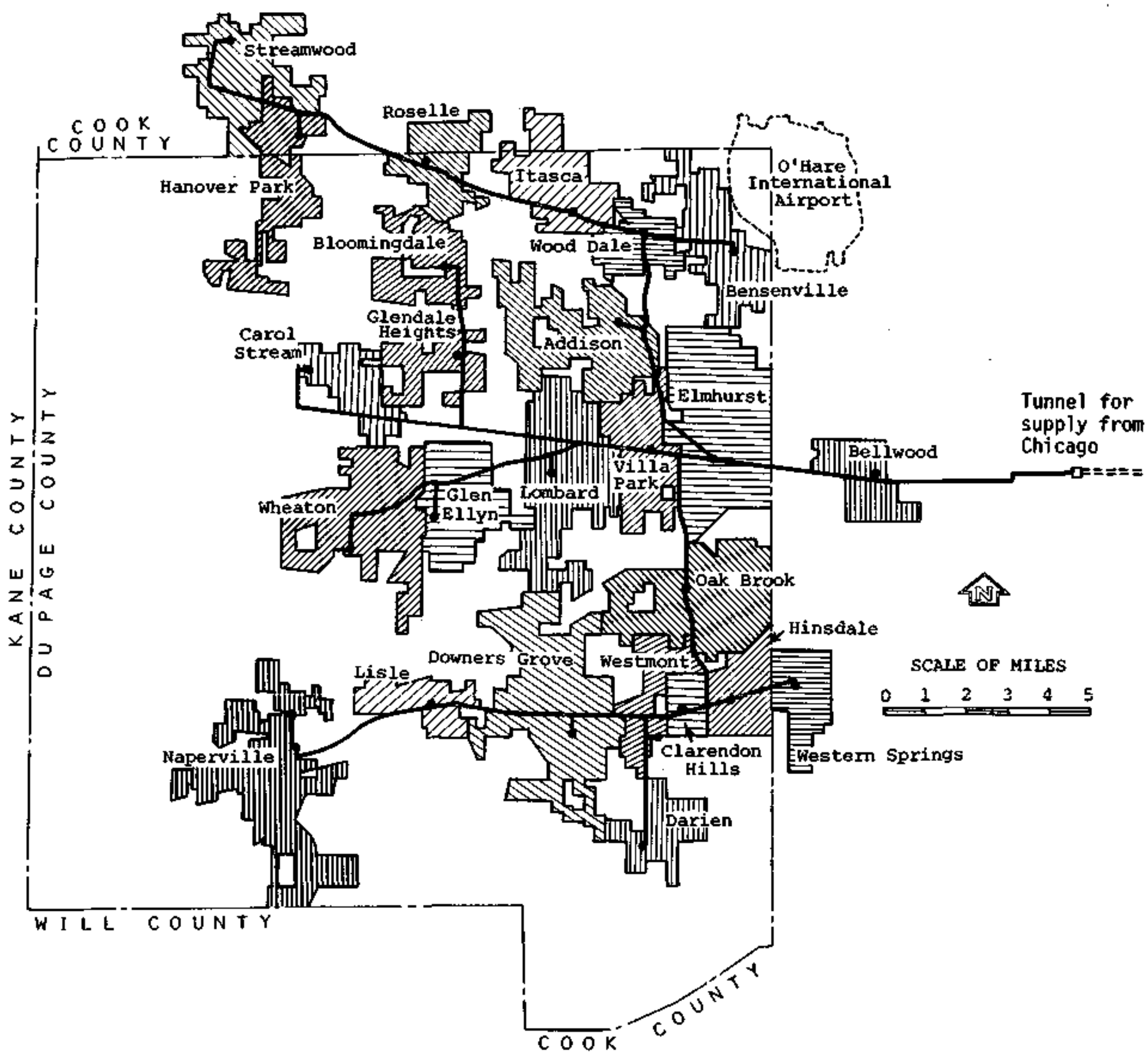


Figure 21. Du Page County supply system with water from the city of Chicago

their 2010 demands, and annual and unit costs of conveyance for the 7 system variations investigated are given in table 20. System demands range from 44.20 to 93.05 mgd. unit cost of transmitting water from the Chicago city limit to the system users varies from 26.73 to 29.46 ¢/1000 gal. The seven system variations listed were selected to provide comparative costs for different size systems as well as for comparing these costs with costs from the northwestern Cook County system and the Kankakee River water system.

Water from Chicago and Shallow Aquifers

All towns except Bellwood and Bensenville have existing shallow wells. The demand that can be met from these wells in a town is taken as the 2010 demand times the shallow-well capacity, divided by the total shallow-and-deep-well capacity to fully meet the 2010 demand. The remaining demand is met by the water purchased from the city of Chicago. The 10 towns which can obtain more than 1 mgd from shallow wells are listed in table 21A. The demands met by the groundwater and the system, and unit costs of raw and treated water are also included in the table. Table 21B lists the Chicago water and groundwater supplies, annual costs, and unit costs for each of the 7 system variations with conjunctive use of shallow groundwater and Chicago water. The range of unit costs for treated groundwater plus conveyance of water purchased from Chicago is 34.86 to 42.66 ¢/1000 gal.

Water from Lake Michigan

A system which includes laying an intake in Lake Michigan, transporting raw water to the treatment plant, and carrying treated water to user entities via a pipeline network has been investigated as a possible alternative to using treated water from the city of Chicago. The 1-mile pipeline intake extends into the lake near the Lake-Cook County line. A raw water pumping station on the lake shore pumps the water to the treatment plant near the Des Plaines River, Illinois 58, and the Chicago and Northwestern Railroad (C&NW) tracks (De Leuw, Cather & Company, 1972). The pipeline extends west along Lake-Cook County Road to the C&NW tracks, and continues along the railroad in a southwesterly direction to the treatment plant. The main, carrying treated water, follows the C&NW and connects with the service system as shown in figure 22. Pipeline cost multipliers of 3.0 and 2.0 have been used for the lake intake pipeline and raw water transmission main, respectively. Cost information is given in table 22. Unit cost ranges from 64.50 to 76.55 ¢/1000 gal for the 7 systems. Conjunctive use of Lake Michigan water and shallow groundwater is considered under the same conditions as conjunctive use of Chicago water and groundwater. Relevant costs are given in table 22. Total unit costs range from 69.10 to 79.69 ¢/1000 gal.

Comparative Unit Costs

Total unit costs for the four sources of supply for this system are given in table 23 for the 7 system configurations. The difference in unit cost between the systems for Lake Michigan water and those for conveyance of water purchased from Chicago is the alternative price for the Chicago water. Without conjunctive use of groundwater, this alternative price varies

Table 20. Du Page County Supply System with Water from the City of Chicago

No.	Town	2010 demand (mgd)	System number (towns served marked by x) 1	2	3	4	5	6	7
6	Bellwood	3.03	x	x	x	x	x	x	x
44	Hanover Park	3.92	x		x			x	
113	Streamwood	4.23	x		x			x	
119	Western Springs	1.27	x	x		x	x	x	x
126	Addison	5.19	x		x			x	x
129	Bensenville	2.21	x		x			x	
130	Bloomingdale	2.57	x		x			x	x
133	Carol Stream	3.17	x		x	x		x	x
134	Clarendon Hills	0.86	x	x		x	x	x	x
136	Darien	3.47	x	x		x	x		x
137	Downers Grove	7.93	x	x		x	x		x
138	Elmhurst	5.89	x	x	x	x	x	x	x
139	Glendale Heights	3.37	x		x	x		x	x
140	Glen Ellyn	4.12	x	x	x	x		x	x
141	Hinsdale	2.95	x	x		x	x	x	x
142	Itasca	1.79	x		x			x	
143	Lisle	1.75	x	x		x	x		x
144	Lombard & Lombard Heights	5.72	x	x	x	x		x	x
146	Naperville	11.55	x	x		x	x		x
147	Oak Brook & Oakbrook Terrace	3.42	x	x		x	x	x	x
149	Roselle	1.61	x		x			x	
151	Villa Park	2.39	x	x	x	x		x	x
155	Westmont	2.08	x	x		x	x		x
156	Wheaton	6.82	x	x	x	x		x	x
159	Wood Dale	1.74	x		x			x	
	System demand, mgd		93.05	63.25	57.77	69.79	44.20	66.27	77.55
	Annual cost of water conveyance, thousand of dollars		9469	6175	6215	6929	4572	6906	7635
	Unit cost of water conveyance, ¢/1000 gal		27.87	26.73	29.46	27.19	28.32	28.53	26.96

Table 21. Du Page County Supply System with Conjunctive Use of Shallow Groundwater and Water from the City of Chicago

A. Towns with more than 1 mgd shallow groundwater available

No.	*Town*	*2010 demands (mgd) met by system*	*SGW*	*Unit costs (¢/1000 gal) SGW*	*SGWT*	*SDGWT*
113	Streamwood	2.43	1.80	12.52	75.94	77.86
126	Addison	1.83	3.36	4.46	62.23	85.50
137	Downers Grove	5.94	1.99	5.22	68.73	90.14
140	Glen Ellyn	2.62	1.50	4.85	70.44	95.48
141	Hinsdale	1.37	1.58	5.22	69.79	80.77
142	Itasca	-	1.79	7.53	70.46	88.12
143	Lisle	0.43	1.32	4.77	70.53	77.92
146	Naperville	10.03	1.52	5.12	71.56	79.90
149	Roselle	-	1.61	5.80	67.33	86.84
156	Wheaton	4.61	2.21	4.85	65.34	91.43

SGW = raw shallow groundwater
SGWT = treated shallow groundwater
SDGWT = treated shallow and deep groundwater to meet 2010 demand

B. Overall costs with conjunctive use

Item	*System number* 1	2	3	4	5	6	7
Chicago water supply, mgd	74.37	53.13	45.50	59.67	37.79	52.42	64.07
Groundwater supply, mgd	18.68	10.12	12.27	10.12	6.41	13.85	13.48
Annual costs, thousand of dollars							
Treated groundwater	4,672	2,553	3,713	2,553	1,639	4,115	3,316
Transport of Chicago water	8,282	5,521	5,287	6,320	4,191	5,895	6,806
Total	12,954	8,074	9,000	8,873	5,830	10,010	10,122
Unit cost, ¢/1000 gal (does not include purchase cost of water from Chicago)	38.12	34.95	42.66	34.86	36.12	41.36	35.74

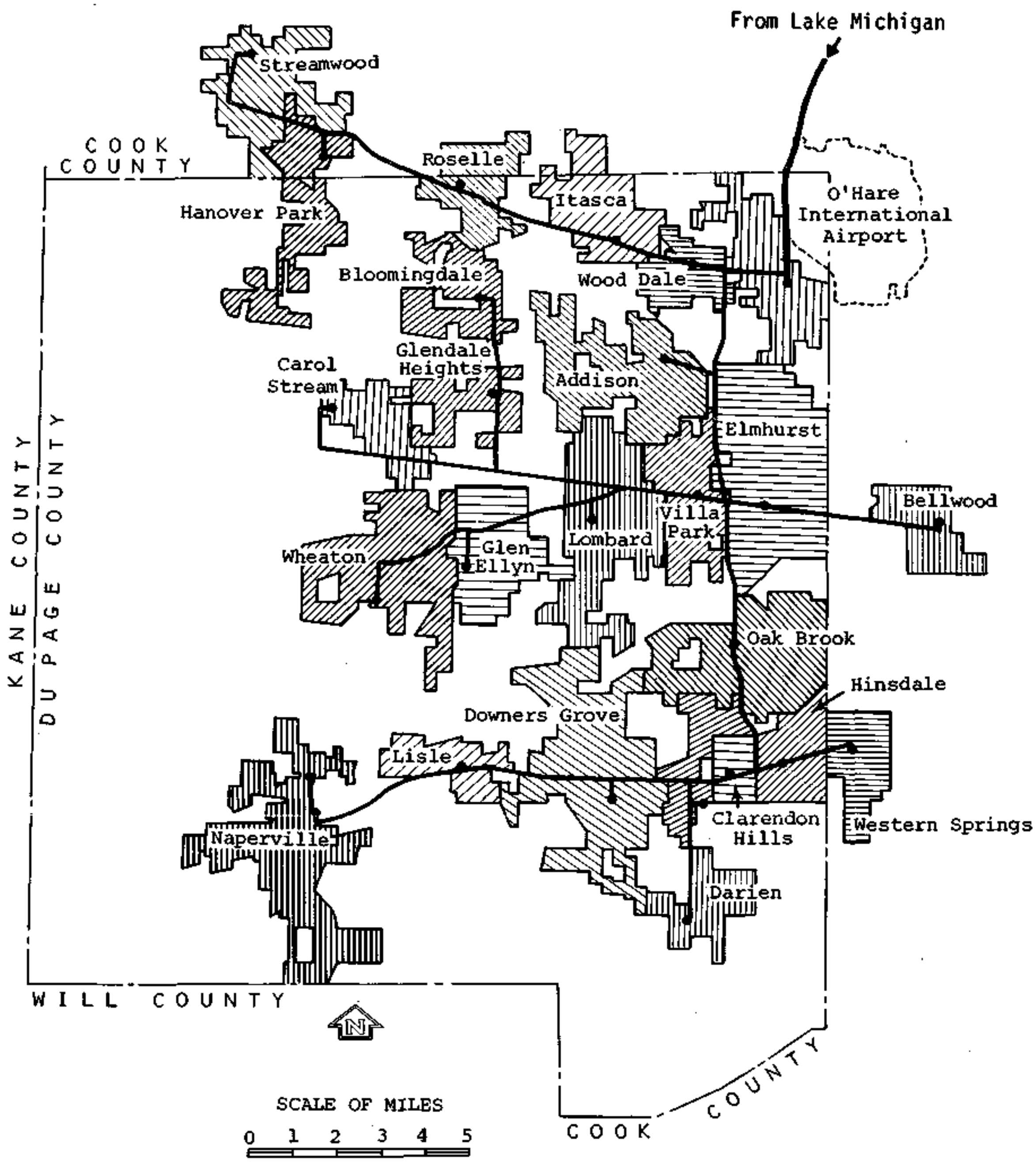


Figure 22. Du Page County supply system with water from Lake Michigan

Table 22. Du Page County Supply System with Water from Lake Michigan

Item	System number 1	2	3	4	5	6	7
Water from Lake Michigan							
System demand, mgd	93.05	63.25	57.77	69.79	44.20	66.27	77.55
Annual cost, thousand dollars							
Transmission	13,864	10,703	9,221	11,714	8,295	10,270	12,426
Treatment	8,053	5,557	5,123	6,090	4,062	5,795	6,747
Total	21,917	16,260	14,344	17,804	12,357	16,065	19,173
Unit cost, ¢/1000 gal	64.50	70.39	67.99	69.85	76.55	66.38	67.70
Water from Lake Michigan and shallow groundwater							
Lake water supply, mgd	74.37	53.13	45.50	59.67	37.79	52.42	64.07
Groundwater supply, mgd	18.68	10.12	12.27	10.12	6.41	13.85	13.48
Annual cost, thousand dollars							
Treated groundwater	4,672	2,553	3,713	2,553	1,639	4,115	3,316
Lake water	18,809	14,402	12,248	15,976	11,224	13,738	16,855
Total	23,481	16,955	15,961	18,529	12,863	17,853	20,171
Unit cost, ¢/1000 gal	69.10	73.40	75.65	72.80	79.69	73.77	71.22

Table 23. Comparative and Alternative Unit Costs of Water Supply for Du Page County

	Unit cost in ¢/1000 gal for system						
	1	2	3	4	5	6	7
Lake water only							
Direct lake supply	64.50	70.39	67.99	69.85	76.55	66.38	67.70
Purchased water from Chicago	27.87	26.73	29.46	27.19	28.32	28.53	26.96
Alternative unit purchase cost of Chicago water	36.63	43.66	38.53	42.66	48.23	37.85	40.74
Conjunctive use of lake water and shallow groundwater							
Groundwater and lake water costs	69.10	73.40	75.65	72.80	79.69	73.77	71.22
Groundwater cost and conveyance costs of Chicago water	38.12	34.95	42.66	34.86	36.12	41.36	35.74
*Alternative unit purchase cost of Chicago water	38.76	45.77	41.89	44.31	50.96	40.96	42.94

*This cost is obtained as explained below for system 1

Water from lake = 74.37 mgd
Annual cost = $18,809,000

Water from Chicago = 74.37 mgd
Annual conveyance cost = $8,282,000

Alternative unit purchase cost of Chicago water

$$= \frac{18{,}809{,}000 - 8{,}282{,}000}{74.37 \times 365.2 \times 1000} \times 100$$

$$= 38.76 ¢/1000 \text{ gal}$$

from 36.63 to 48.23 ¢/1000 gal. With conjunctive use of shallow groundwater the alternative price of Chicago water varies from 38.76 to 50.96 ¢/1000 gal. If the negotiated 2010 unit cost of water from Chicago (assuming system costs in 1980 dollars) is less than the alternative cost, it will be economical to supply the system with Chicago water.

Northwestern Cook County Supply System

There are 26 towns or user entities in northwestern Cook County and northern Du Page County. Sixteen towns are in townships 48, 49, 50, 53, 54, and 55 of Cook County and 10 towns in townships 73, 74, and 75 of Du Page County. Towns of Barrington, Barrington Hills, South Barrington, Inverness, and Waycinden have or can develop adequate supply from groundwater aquifers, and Buffalo Grove and Wheeling have already been considered on the Lake County system. Exclusion of these 7 towns makes the transmission pipe network more compact. Bartlett and Wayne in Du Page County can develop adequate supplies, mostly from shallow aquifers. The remaining 17 towns are considered on the supply system with supply from the city of Chicago just east of O'Hare International Airport. These towns are listed in table 24 together with their 2010 demands and the capacity of shallow and deep wells to meet these demands. Existing capacity from these wells is given in parentheses. The capacity for shallow wells has been reduced if needed so that the total well capacity in a township approximates the potential yield of the sand and gravel and/or dolomite aquifers in that township. The towns of

Table 24. Northwestern Cook County System
2010 Demands and Well Capacities

No.	Town	2010 demand (mgd)	Capacity of Wells (mgd) Shallow		Deep	
2	Arlington Heights	8.61	-	(-)	20.58	(20.58)
31	Elk Grove Village	7.51	1.58	(1.58)	15.12	(15.12)
44	Hanover Park	3.92	0.29	(0.29)	9.42	(7.02)
51	Hoffman Estates	4.95	1.21	(1.21)	10.14	(9.70)
75	Mt. Prospect and Prospect Heights (#95)	6.41	0.43	(0.43)	16.28	(16.28)
87	Palatine	6.17	2.48	(2.48)	11.61	(8.04)
102	Rolling Meadows	2.77	-	(-)	8.00	(8.00)
105	Schaumburg	9.67	2.83	(2.83)	18.59	(7.55)
113	Streamwood	4.23	4.52	(4.52)	6.12	(2.16)
126	Addison	5.19	7.81	(7.81)	4.24	(-)
129	Bensenville	2.21	-	(-)	6.18	(5.64)
130	Bloomingdale	2.57	0.65	(0.65)	6.23	(2.81)
133	Carol Stream	3.17	2.88	(2.88)	4.92	(2.88)
139	Glendale Heights	3.37	4.68	(4.68)	3.21	(-)
142	Itasca	1.79	4.64	(2.75)	-	(-)
149	Roselle	1.61	4.49	(3.59)	-	(-)
159	Wood Dale	1.74	2.95	(2.95)	2.27	(2.27)

Note: Capacity of wells for Itasca and Roselle is given on the basis of alternate scheme (table 13)

Itasca and Roselle have been considered on the system because they lie close to the system network. They can develop shallow aquifers for meeting their demands under the alternate scheme (table 13) at a cost of 73.6 and 72.4 ¢/1000 gal, respectively.

Water Supply from Chicago

Treated water will be obtained from the city of Chicago for a negotiated price just east of O'Hare International Airport (figure 23). The northern and southern parts of the system network carry water to the service area. These parts can be considered as independent subsystems. The towns served, their 2010 demands, and annual and unit costs for 5 of the 20 system variations investigated are given in table 25. System demands range from 46.09 to 75.89 mgd. Unit cost of transmitting water from Chicago supply point to the system users varies from 23.92 to 26.05 ¢/1000 gal. System 2 and 4 differ from 1 and 3 in excluding Itasca and Roselle from the respective systems.

Water from Lake Michigan

A system which includes laying an intake in Lake Michigan, transporting raw water to the treatment plant, and carrying treated water to user entities via a pipeline network has been investigated as a possible alternative to using treated water from the city of Chicago. The 1-mile pipeline intake extends into the lake near the Lake-Cook County line. A raw water pumping station on the lake shore pumps the water to the treatment plant near the Des Plaines River, Illinois 58, and the Chicago and Northwestern Railroad (C&NW) tracks (De Leuw, Cather & Company, 1972). The locations of the raw water pipeline and treatment plant are the same as for the Du Page County system. The supply system pipeline network is shown in figure 24. Pipeline cost multipliers of 3.0 and 2.0 have been used for the lake intake pipeline and raw water transmission main, respectively. Cost information is given in table 25. Unit cost ranges from 60.59 to 62.28 ¢/1000 gal for the 5 systems. This is 35.42 to 36.91 ¢/1000 gal more than the conveyance cost of water from Chicago, and is, thus, the alternative price of Chicago water.

Conjunctive Use of Groundwater from the Shallow Aquifers

Most of the towns served by the system have some wells in the shallow aquifers. The demand that can be met from this source equals the 2010 demand multiplied by the shallow-well capacity and divided by the shallow-and-deep-well capacity. The remaining demand can be met from the system carrying water from the city of Chicago, or directly from Lake Michigan. Only those towns which can obtain more than 1 mgd from shallow wells are considered for the conjunctive use of surface and groundwater and these are listed in table 26A. Also included are the demands met by groundwater and the system, and unit costs of raw shallow groundwater (SGW), treated shallow groundwater (SGWT), and treated shallow and deep groundwater (SDGWT) to meet the 2010 demand. Annual costs for conveyance of water from Chicago, treated shallow groundwater, and the overall unit cost for each of the 5 systems is given in table 26B. The annual costs and overall unit costs for conjunctive use of treated shallow groundwater and directly supplied treated Lake Michigan water

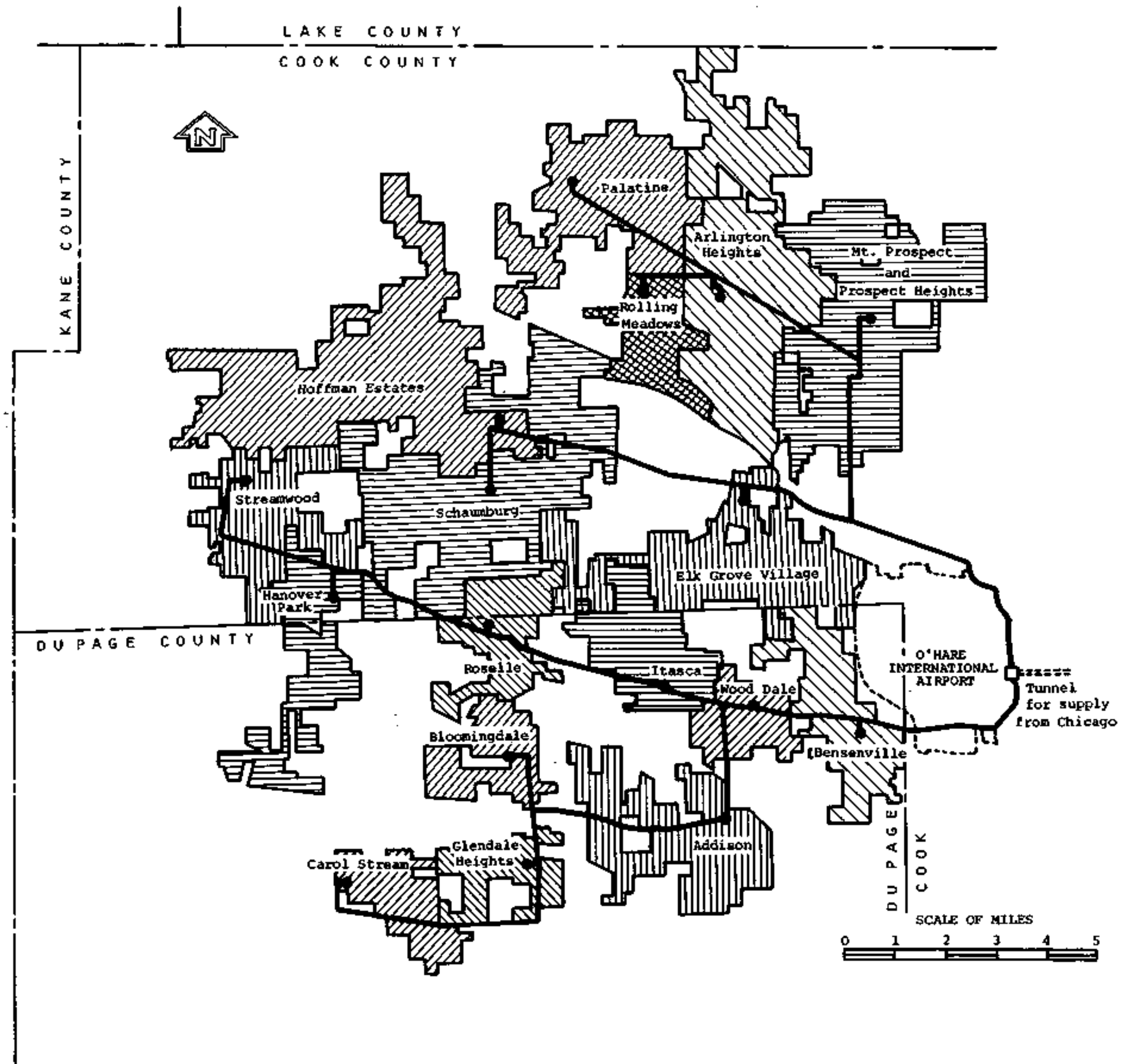


Figure 23. Northwestern Cook County supply system with water from the city of Chicago

Table 25. Northwest Cook County Supply System

No.	Town	2010 demand (mgd)	System number (towns served marked by x) 1	2	3	4	5
2	Arlington Heights	8.61	x	x	x	x	x
31	Elk Grove Village	7.51	x	x	x	x	x
44	Hanover Park	3.92	x	x	x	x	
51	Hoffman Estates	4.95	x	x	x	x	x
75	Mt. Prospect & Prospect Heights	6.41	x	x	x	x	x
87	Palatine	6.17	x	x	x	x	x
102	Rolling Meadows	2.77	x	x	x	x	x
105	Schaumburg	9.67	x	x	x	x	x
113	Streamwood	4.23	x	x	x	x	
126	Addison	5.19	x	x			
129	Bensenville	2.21	x	x	x	x	
130	Bloomingdale	2.57	x	x			
133	Carol Stream	3.17	x	x			
139	Glendale Heights	3.37	x	x			
142	Itasca	1.79	x		x		
149	Roselle	1.61	x		x		
159	Wood Dale	1.74	x	x	x	x	
	System demand, mgd		75.89	72.49	61.59	58.19	46.09
	Water Conveyance from Chicago						
	Annual cost in thousand dollars		6,975	6,827	5,705	5,536	4,026
	Unit cost, ¢/1000 gal		25.17	25.79	25.36	26.05	23.92
	Water from Lake Michigan						
	Annual cost in thousand dollars						
	Water transport		10,186	9,932	8,366	8,079	6,027
	Water treatment		6,607	6,319	5,426	5,157	4,211
	Total		16,793	16,251	13,792	13,236	10,238
	Total unit cost, ¢/1000 gal		60.59	61.39	61.32	62.28	60.83
	Alternative Unit Purchase Cost of Water from Chicago		35.42	35.60	35.96	36.23	36.91

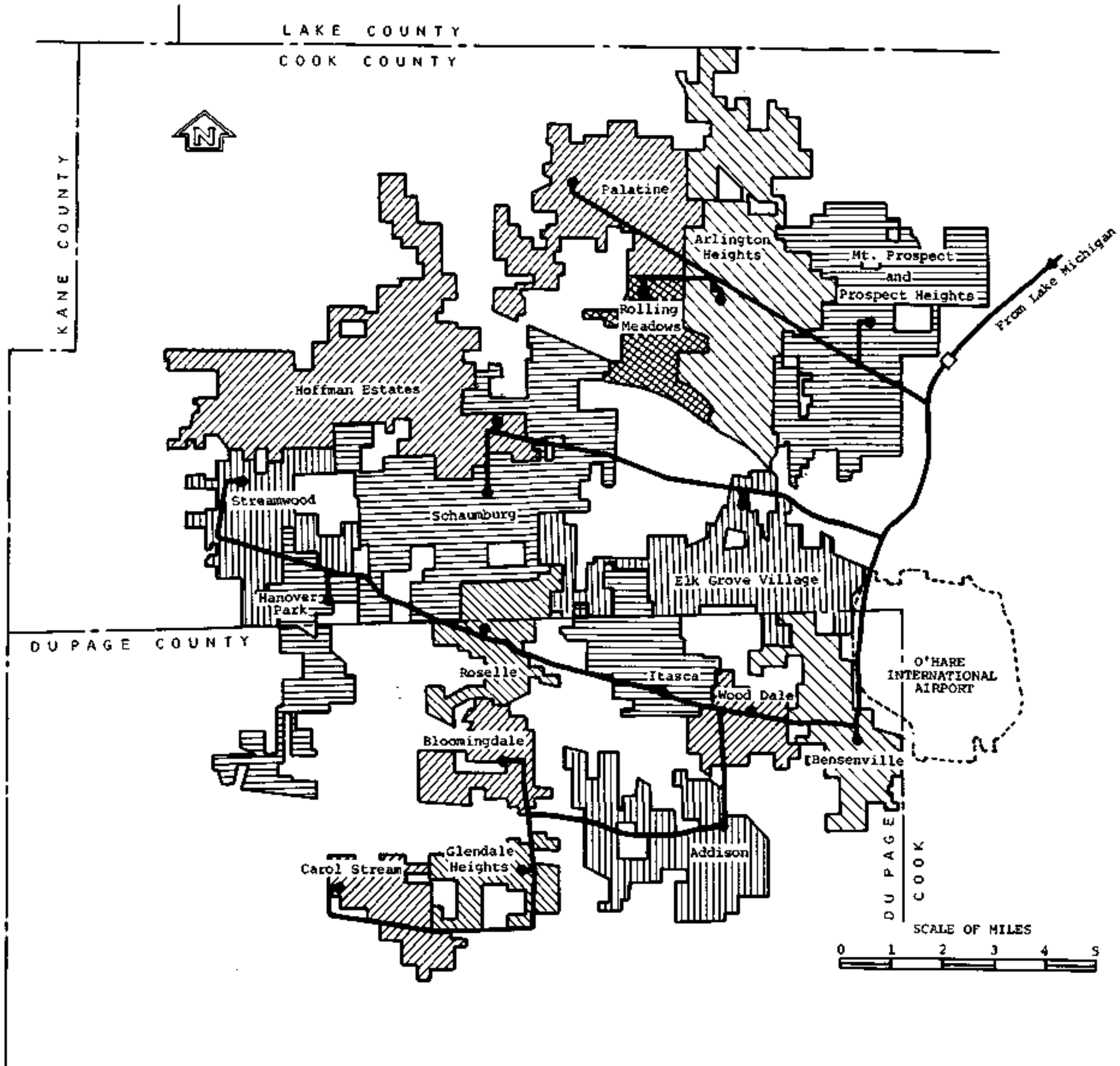


Figure 24. Northwestern Cook County supply system with water from Lake Michigan

Table 26. Groundwater and Overall Unit Costs with Conjunctive Use of Groundwater

A. Groundwater use and unit costs

No.	Town	2010 demand met by System	2010 demand met by GW	Unit cost (¢/1000 gal) SGW	Unit cost (¢/1000 gal) SGWT	Unit cost (¢/1000 gal) SDGWT
87	Palatine	5.08	1.09	11.91	82.32	85.80
105	Schaumburg	8.39	1.28	14.73	86.57	78.93
113	Streamwood	2.43	1.80	12.52	75.94	77.86
126	Addison	1.83	3.36	4.46	62.23	85.50
142	Itasca	-	1.79	7.53	70.46	88.12
14 9	Roselle	-	1.61	5.80	67.33	86.84

GW = groundwater from shallow aquifer
SGW = raw shallow groundwater
SGWT = treated shallow groundwater
SDGWT = treated shallow and deep groundwater to meet 2010 demand

B. Costs with conjunctive use

Item	System number 1	2	3	4	5
Water from system, mgd	64.96	64.96	54.02	54.02	43.72
Groundwater supply, mgd	10.93	7.53	7.57	4.17	2.37
2010 demand, mgd	75.89	72.49	61.59	58.19	46.09
Annual cost in thousand dollars					
Conveyance of water from Chicago	6389	6389	5199	5195	3880
Treated groundwater	2852	1995	2088	1232	732
Total	9241	8384	7287	6427	4612
Overall unit cost in ¢/1000 gal	33.34	31.67	32.40	30.24	27.40
Annual cost in thousand dollars					
Lake Michigan water	14,900	14,900	12,399	12,397	9,837
Treated groundwater	2,852	1,995	2,088	1,232	732
Total	17,752	16,895	14,487	13,629	10,569
Overall unit cost in ¢/1000 gal	64.06	63.82	64.41	64.13	62.79
Alternative purchase price of water from Chicago in ¢/1000 gal	35.88	35.89	36.50	36.51	37.31

are also given in table 26B. The difference between the unit cost for directly supplied lake water and the unit cost for conveyance of water from Chicago is the alternative price for water purchased from Chicago. This price varies from 35.88 to 37.31 ¢/1000 gal (37.31 = (9837-3880) × 1000/(3652 × 43.72)).

Fox River Water for Kane County

Nine out of the 20 towns or user entities in Kane County, listed in table 13, can meet their 2010 demand from sand and gravel aquifers. The remaining 11 towns, two of the 9 towns (South Elgin and Valley View which are very close to any proposed Fox River water supply system), and West Chicago in Du Page County are listed in table 27 with their 2010 demand and capacity of shallow and deep wells to meet that demand. Numbers in parentheses indicate the existing capacity.

The small towns of Burlington, Elburn, and Hampshire are at a considerable distance from the Fox River and can meet their 2010 demand from the shallow aquifer, using the deep wells as a standby. Montgomery and Boulder Hill are south of Aurora and the supply system from the Fox River may at the most extend to Aurora. West Dundee is north of the proposed river intake and can meet the 2010 demand from the sand and gravel aquifer, with deep wells as a standby. West Chicago in Du Page County is included because it is closer to the Fox River than to either Lake Michigan or the Kankakee River. The system configuration serving 8 towns in the valley and West Chicago is shown in figure 25.

Table 27. Fox River Supply System 2010 Demands and Well Capacities

No.	*Town*	*2010 demand (mgd)*	*Capacity of wells (mgd)* *Shallow*		*Deep*	
161	Aurora	15.66	1.01	(1.01)	31.35	(22.46)
162	Batavia	2.53		(-)	6.95	(4.89)
163	Burlington	0.09	0.19	(0.07)	0.39	(0.39)
166	Elburn	0.50	1.04	(0.26)	0.43	(0.43)
167	Elgin	11.86	1.57	(1.57)	24.32	(22.18)
168	Geneva	2.28		(-)	6.14	(5.74)
170	Hampshire	0.42	0.88	(0.48)	0.40	(0.40)
172	Montgomery & B. Hill	1.97	1.75	(1.29)	3.69	(3.69)
173	North Aurora	1.09	0.14	(-)	3.50	(3.50)
175	St. Charles	4.37	4.37	(1.73)	6.17	(5.47)
177	South Elgin	0.94	2.40	(1.23)	-	(-)
179	Valley View	0.12	0.40	(-)	-	(-)
180	West Dundee	0.80	1.60	(0.72)	1.44	(1.44)
154	West Chicago	4.08	-	(-)	9.63	(4.51)

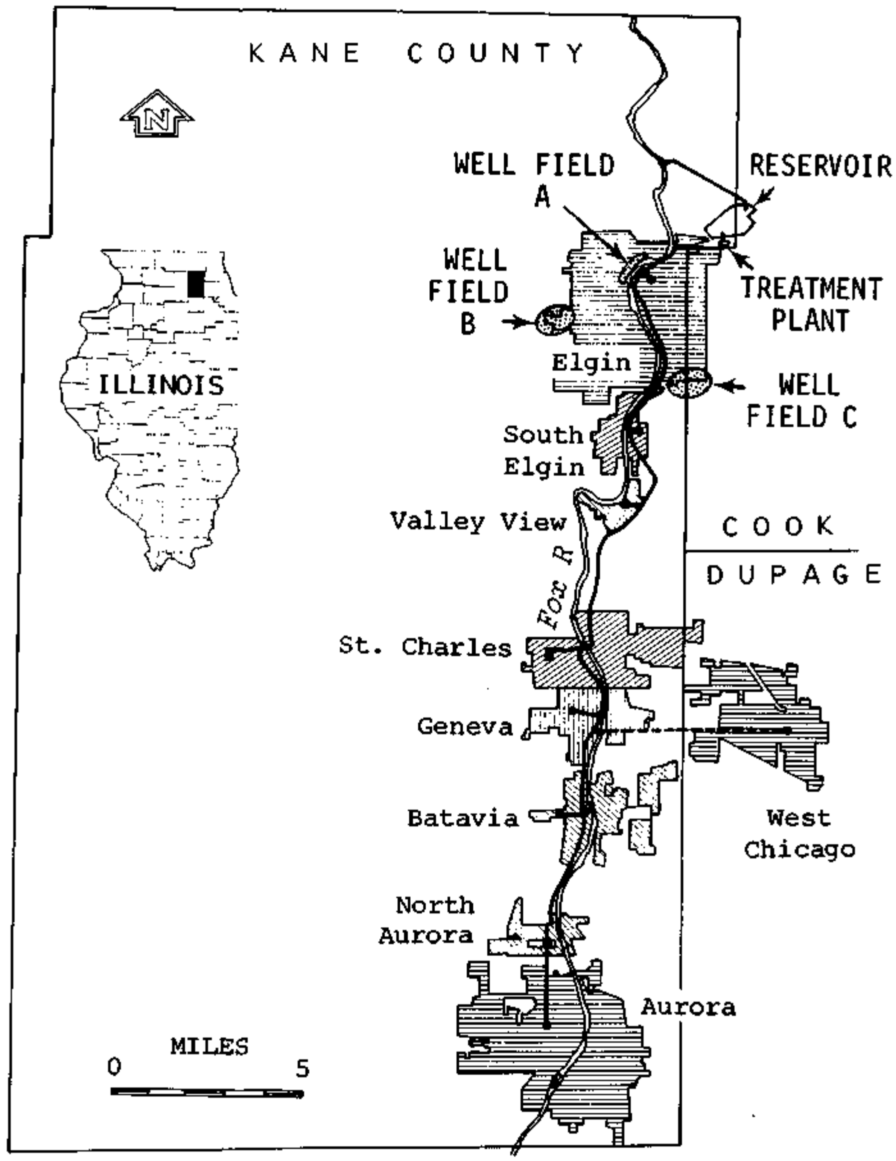


Figure 25. Fox River Valley supply system

Water from the Fox River

The proposed intake is located near the Illinois 72 bridge over the river between East Dundee and West Dundee, about 6 miles downstream of the USGS gaging station at Algonquin. No water for water supply will be withdrawn from the river when the flow is equal to or less than 51 cfs (or 33 mgd), the 7-day 10-year low flow. Available daily flow at Algonquin has been considered to apply at the intake 6 miles downstream because the drainage area above the intake is only 17 sq mi more than that of 1403 sq mi at Algonquin. Information on the duration and frequency of flow deficiency is given in the section on Availability of Water from Fox, Du Page, and Kankakee Rivers. The deficit duration in months is shown in figure 26 for meeting water supply demands up to 50 mgd, as a function of deficit recurrence intervals of 5, 10, 20, 30, and 40 years. The area below the curve for a given recurrence interval from zero to a selected water demand is the storage volume required for that demand and recurrence interval.

The storage required for a 40-year drought was adjusted for evaporation and leakage from the reservoir by adding a volume equal to 1.5 times the evaporation loss. Net evaporation loss, E, in feet for the duration shown in figure 26 for a 40-year drought is obtained by averaging the values for Rockford and Chicago (Roberts and Stall, 1967). Because the water surface area in a reservoir decreases with declining water level, the evaporation loss, V_e, in acre-feet is calculated from

$$V_e = 0.7 \; A \; E$$

in which A is the water surface area of the reservoir at normal pool level, in acres. The provision for losses increases the storage by about 9 percent. Reservoir costs were determined with the cost equations in the section on cost functions.

The probability of river water being unavailable for various durations and three water supply demands, 10, 30, and 50 mgd, is shown in figure 27. Data points are obtained from figure 26 for recurrence intervals of 5, 10, 20, 30, and 40 years, which correspond to nonexceedance probabilities of 0.2, 0.1, 0.05, 0.033, and 0.025, respectively. The deficit duration is assumed to be equal to the value at 0.025 for probabilities less than 0.025. The deficit duration is assumed to decrease linearly from its value at 0.2 to zero at probability 1.0. The area under each curve yields the average deficit duration in months over a long period of years.

Water demand, mgd	10	20	30	40	50
Average deficit duration					
in months	0.36	0.55	0.79	1.08	1.44
as percent of a year	3.00	4.60	6.60	9.00	12.00

The system capability needed during a drought will probably be in the range of 20 to 50 mgd. If groundwater from deep wells is used to augment the reservoir storage during deficit periods, it may also be used to cover any period of high turbidity in river water, a chemical spill pollution episode, and some pumping to keep the wells and groundwater collection system in good working order. Thus, groundwater pumping at an average of 15 percent of a year will be used when conjunctive groundwater use is contemplated to help tide over deficit periods.

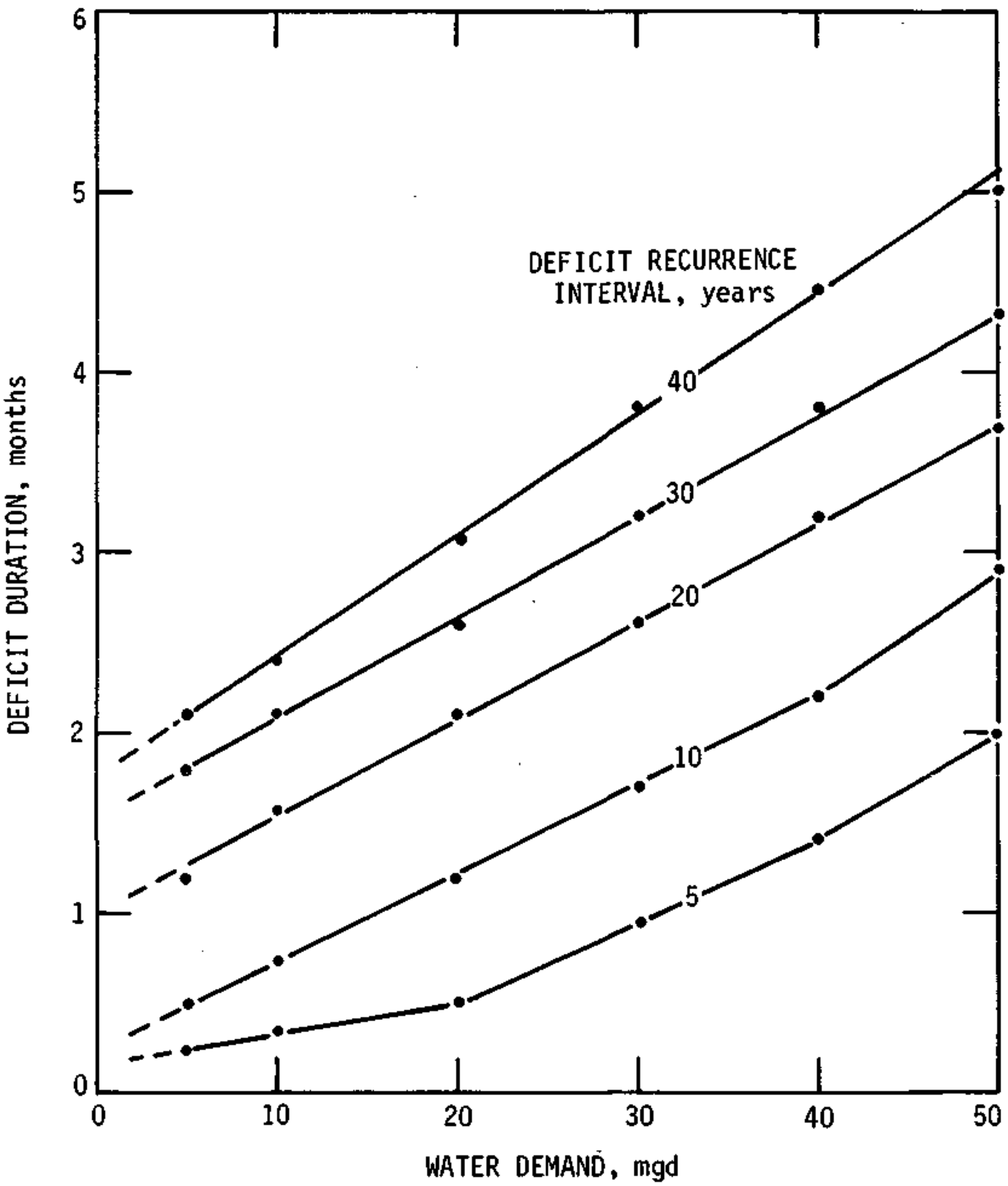


Figure 26. Deficit duration as a function of water demand and deficit recurrence interval for the Fox River at Algonquin

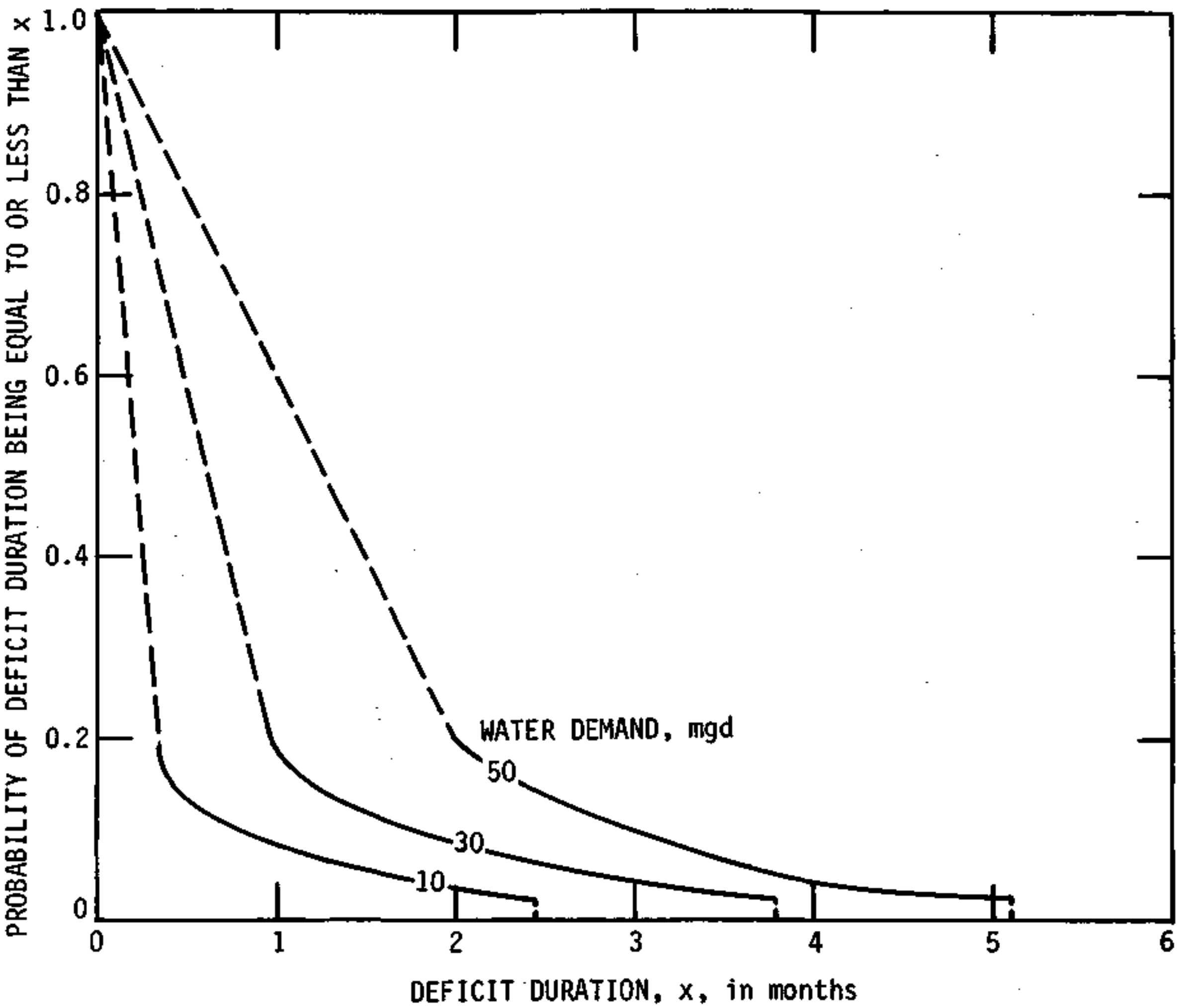


Figure 27. Deficit durations and associated probabilities for meeting three water demands

Groundwater Collection System and Cost

The city of Elgin has 13 deep sandstone wells with a total capacity of 22.18 mgd, or an average of 1.64 mgd per well. Concentrations of total dissolved solids and hardness in the Fox River and the deep sandstone aquifer water are not much different. Iron content is lower in the groundwater but alpha radioactivity is much higher than in the river water. The treatment and sludge disposal costs may be slightly increased with the conjunctive use of groundwater.

The water from the deep wells can be used to supplement the river withdrawals during periods of low river flow and in emergencies. The location of wells and the collection system to transport groundwater to the storage reservoir are shown in figure 28. Costs are computed for 5 groundwater collection systems, from 8 wells yielding 8.14 mgd to 17 wells yielding 19.60 mgd. In all cases, one well is considered a standby. The relevant cost data are given in table 28. The energy cost is obtained by multiplying the annual energy cost by 0.15 to account for pumpage over an average 15 percent of the time. Annual capital costs of wells and collection system (consisting of pipelines and suitable pumping facilities) are not adjusted because the entire system is to be amortized irrespective of the percent time it is operated. Additional wells are needed for the two large systems, numbers 4 and 5 in table 28, and these are indicated in figure 28 as wells number 13-16.

Table 28. Annual Cost of Groundwater Collection System

	System number				
Item	*1*	*2*	*3*	*4*	*5*
System capacity, mgd	8.14	11.02	14.40	17.00	19.60
Number of wells	8	10	13	15	17
Well number	1-6, 10,12	1-6, 9-12	1-12,17	1-14,17	1-17
Annual cost in thousands of dollars					
Wells	128.6	160.7	208.9	241.0	273.0
*Energy (wells)	28.5	38.3	49.8	58.6	67.4
Collection system	366.3	487.2	629.1	731.4	833.6
*Energy (collection)	7.1	9.0	11.3	13.6	15.9
Total system	530.5	695.2	899.1	1044.6	1189.9

*Energy costs are for pumping wells and conveying water through the collection system, assuming system use at an average 15 percent of the year.

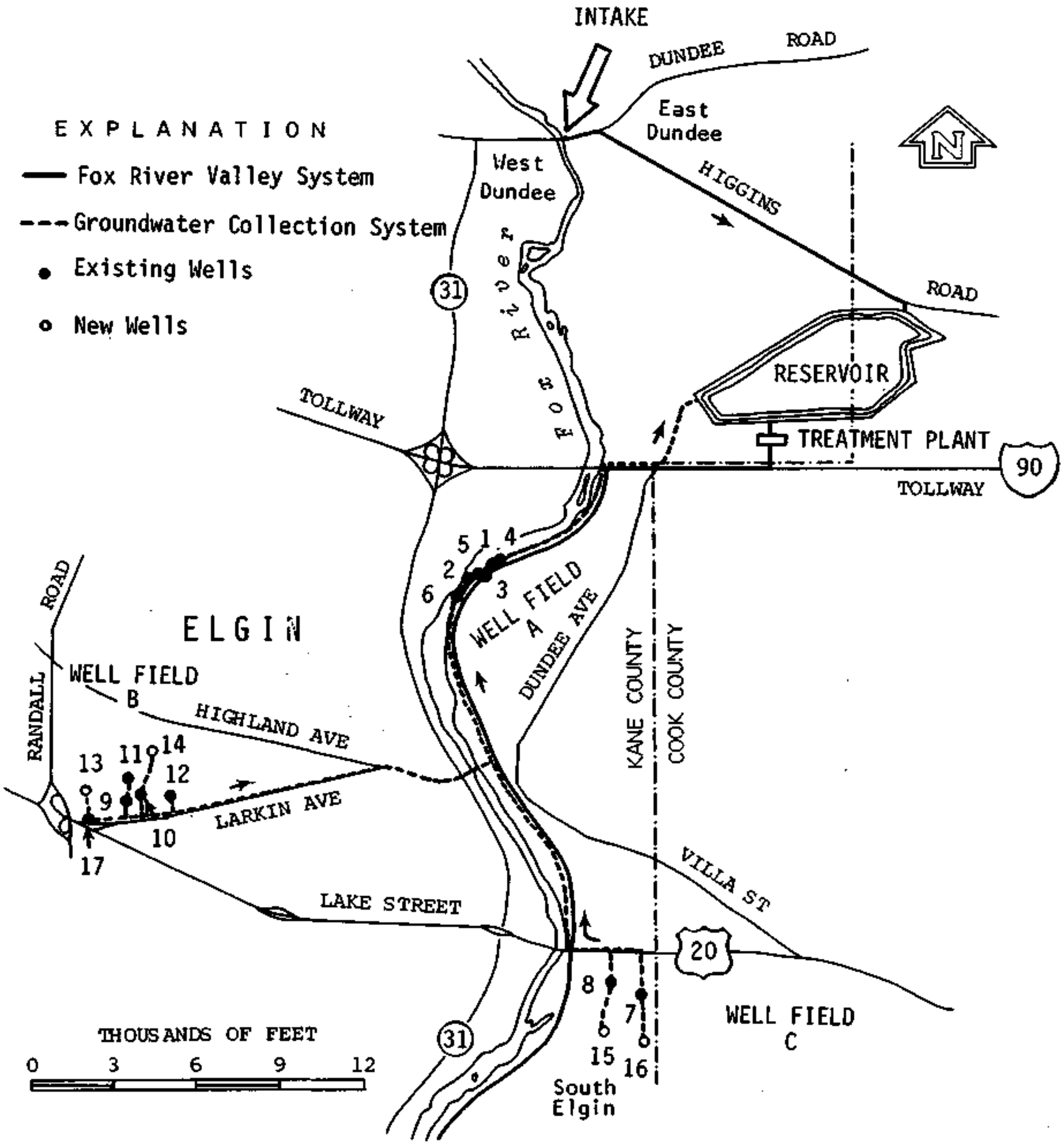


Figure 28. Location of wells and groundwater collection system

Fox River Valley System

Two systems have been considered: Fox River as the single supply source, and Fox River with conjunctive use of groundwater during deficit months.

Fox River as the Single Supply Source. The nine towns on this system and their 2010 demands are given in table 29. Nine system variations, towns served, and system demands are also included. A study of water use during the deficit period, usually between June and October, showed the average monthly demand in mgd not to exceed 1.2 times the average for the year. For each of the systems, the storage required to provide 1.2 times the average yearly demand rate over the 40-year deficit duration, the annual costs of storage, lime-soda treatment, and transmission (includes pipeline and pumping costs of the conveyance system), and the total annual and unit costs are given in table 29. The unit costs, 87.35 to 92.74 ¢/1000 gal, are quite close for the listed system configurations. The system demands range from 19.95 to 38.85 mgd. Reservoir storage capacities vary from 6,200 to 15,800 ac-ft and the reservoir surface area from 460 to 1,030 acres. Scarcity of large areas for constructing high capacity reservoirs within a reasonable distance of Elgin would probably limit the 'river only system' capacity to 28 mgd or less.

Fox River with Conjunctive Use of Groundwater. The deep sandstone well fields in and around Elgin can be used to supplement the reservoir storage when full demand cannot be met from the Fox River. This will reduce the storage required because groundwater will be pumped into the reservoir during low withdrawals from the river. Practical sustained yield estimates (Schicht, Adams, and Stall, 1976) assign 4.3 mgd to the Elgin area. About 28 mgd groundwater can be pumped for 15 percent of the time to equal an annual rate of 4.3 mgd. Groundwater pumpages of 14.40, 17.00, and 19.60 mgd were used to supplement river water in each of the 9 systems investigated with the Fox River as the single supply source.

In addition to the direct cost of the reservoir and groundwater collection system, two adjustments in the transmission and treatment costs were made in evaluating the system cost with conjunctive use of groundwater. One was the reduction in pumping cost for lifting river water into the reservoir during periods of low withdrawals. The other was the increased treatment cost to reduce alpha radioactivity in groundwater to the acceptable limit.

For computing the increase in treatment and sludge disposal cost, a value of 14 pCi/1 was used for alpha radioactivity. No increase in the use of chemicals occurs at this level and the treatment cost by the lime-soda process remains unchanged. However, there is an incremental cost for sludge disposal. It depends on the relative proportion of groundwater in the water to be treated. An average of 60 percent deep-aquifer water is considered during the conjunctive use period.

Table 30 is arranged in 3 sections for the 3 groundwater supply rates of 14.40, 17.00, and 19.60 mgd. Annual cost common to these sections for systems 1 through 9 includes the cost of treatment, distribution network,

Table 29. Fox River Valley System Costs
(Fox River as the Single Supply Source)

No.	Town	2010 Demand (mgd)	System number (towns served marked by x) 1	2	3	4	5	6	7	8	9
161	Aurora	15.66		x	x*		x*		x	x*	
162	Batavia	2.53	x	x	x	x	x	x	x	x	x
167	Elgin	11.86	x	x	x	x	x	x	x	x	x
168	Geneva	2.28	x	x	x	x	x	x	x	x	x
173	N. Aurora	1.09	x	x	x	x	x	x	x	x	x
175	St. Charles	4.37	x	x	x	x	x	x†	x†	x†	x†
177	S. Elgin	0.94	x	x	x	x	x	x	x		
179	Valley View	0.12	x	x	x	x	x	x	x	x	x
154	W. Chicago	4.08				x	x				x
System demand, mgd			23.19	38.85	32.15	27.27	36.23	19.95	35.61	27.97	23.09
Reservoir storage, ac-ft			7,600	15,800	12,100	9,500	14,400	6,200	13,900	9,900	7,600
Reservoir area, acres			500	1,030	820	660	950	460	930	690	550
Annual cost in thousands of dollars											
Storage			1,733	3,075	2,491	2,061	2,857	1,481	2,779	2,128	1,733
Treatment			3,387	5,266	4,457	3,880	4,946	2,989	4,872	3,963	3,374
Transmission			2,278	4,060	3,442	2,870	3,940	2,013	3,822	3,145	2,584
Total			7,398	12,401	10,390	8,811	11,743	6,483	11,473	9,236	7,691
Unit cost, ¢/1000 gal			87.35	87.40	88.49	88.47	88.75	88.98	88.22	92.74	91.21

Notes: * System supplies only 8.96 mgd to Aurora.

† System supplies 1.13 mgd to St. Charles, rest of demand can be met from groundwater from shallow aquifers.

Table 30. Fox River Valley System Costs
(Fox River with conjunctive use of groundwater)

Item	*System number* 1	2	3	4	5	6	7	8	9
System demand, mgd	23.19	38.85	32.15	27.27	36.23	19.95	35.61	27.97	23.09
Design flow, mgd	27.83	46.62	38.58	32.72	43.48	23.94	42.73	33.56	27.71
Annual common costs in thousands of dollars									
Treatment	3,387	5,266	4,457	3,880	4,996	2,989	4,872	3,963	3,374
Conveyance	2,278	4,060	3,442	2,870	3,940	2,013	3,822	3,145	2,584
Sludge disposal	7	9	8	7	8	6	8	7	7
Pumping credit	-19	-32	-26	-23	-29	-16	-29	-23	-19
Total	5,653	9,303	7,881	6,734	8,915	4,992	8,673	7,092	5,946
1) 14.40 mgd groundwater									
Reservoir storage, ac-ft	3,100	9,300	6,300	4,400	8,100	2,100	7,800	4,700	3,000
Reservoir area, acres	250	650	460	340	580	180	560	360	240
Annual costs in thousands of dollars									
Storage	877	2,027	1,500	1,141	1,821	659	1,768	1,199	856
Groundwater system	899	899	899	899	899	899	899	899	899
Common cost	5,653	9,303	7,881	6,734	8,915	4,992	8,673	7,092	5,946
Total	7,429	12,229	10,280	8,774	11,635	6,550	11,340	9,190	7,701
Unit cost in ¢/1000 gal	87.72	86.19	87.56	88.10	87.94	89.90	87.20	89.97	91.33

Concluded on next page

Table 30. Concluded

Item	System number 1	2	3	4	5	6	7	8	9
2) <u>17.00 mgd groundwater</u>									
Reservoir storage, ac-ft	2,400	8,300	5,400	3,600	7,100	1,500	6,900	4,000	2,400
Reservoir area, acres	200	590	410	290	520	130	500	310	200
Annual costs in thousands of dollars									
Storage	726	1,855	1,333	981	1,644	518	1,608	1,062	726
Groundwater system	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045	1,045
Common cost	5,653	9,303	7,881	6,734	8,915	4,992	8,673	7,092	5,946
Total	7,424	12,203	10,259	8,760	11,604	6,555	11,326	9,199	7,717
Unit cost in ¢/1000 gal	87.66	86.01	87.38	87.96	87.70	89.97	87.09	90.06	91.52
3) <u>19.60 mgd groundwater</u>									
Storage, ac-ft	1,800	7,300	4,600	3,000	6,200	1,100*	5,900	3,200	1,800
Reservoir area, acres	160	530	350	240	460	100	440	260	160
Annual costs in thousands of dollars									
Storage	590	1,680	1,180	856	1,481	416	1,426	898	590
Groundwater system	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190
Common cost	5,653	9,303	7,881	6,734	8,915	4,992	8,673	7,092	5,946
Total	7,433	12,173	10,251	8,780	11,586	6,598	11,289	9,180	7,726
Unit cost in ¢/1000 gal	87.77	85.80	87.31	88.16	87.57	90.56	86.81	89.87	91.62

* Minimum storage equals 15 days of design flow.

Design flow during drought equals 1.2 times the system demand.

extra sludge disposal cost, and credit for not pumping river water during drought periods. The common cost is added to the annual cost and unit cost for each section. Reservoir storage and reservoir area required for each of the 9 systems and 3 groundwater supply rates are also given in table 30. The unit costs range from 85.80 to 91.62 ¢/1000 gal. Comparative minimum cost systems are:

	System demand (mgd)	Fox River Storage (ac-ft)	Fox River Unit cost (¢/1000 gal)	Fox River and groundwater Storage (ac-ft)	Fox River and groundwater Groundwater (mgd)	Fox River and groundwater Unit cost (¢/1000 gal)
1	23.19	7,600	87.35	2,400	17.00	87.66
2	38.85	15,800	87.40	7,300	19.60	85.80
3	32.15	12,100	88.49	4,600	19.60	87.31
4	27.27	9,500	88.47	3,600	17.00	87.96
5	36.23	14,400	88.75	6,200	19.60	87.57
6	19.95	6,200	88.98	2,100	14.40	89.90
7	35.61	13,900	88.22	5,900	19.60	86.91
8	27.97	9,900	92.74	3,200	19.60	89.87
9	23.09	7,600	91.21	3,000	14.40	91.33

Selection of one or the other system will depend largely on the availability and cost of area for the storage reservoir and on the number of towns to be served by the Fox River Valley system, with or without conjunctive use of groundwater during low river flow periods.

Kankakee River Water for Will and Du Page Counties

Water from the Kankakee River is considered for 23 towns or user entities in western Will County, central and southern Du Page County, and for Aurora in Kane County. The towns of Channahon and Shorewood can meet their combined water demand of 1.81 mgd from wells in the deep sandstone aquifer, or they can be easily supplied from any proposed Kankakee River supply system. The towns of Woodridge, Warrenville, Willowbrook, and Burr Ridge in Du Page County can develop adequate groundwater supplies (mostly from the shallow aquifers) and are not considered a part of the system. Winfield and Clarendon Hills have been included in some system configurations when the conveyance network passed through or close to these towns. In Will County, the towns of Romeoville, Plainfield, Crest Hill, and Rockdale have been considered on the system because of their proximity to the network. Up to 23 towns can be served by the system. These are listed in table 31, together with their 2010 water demand and capacity of shallow and deep wells to meet these demands. Existing well capacities are given in parentheses. Many towns have more wells drilled in Silurian dolomite but the aquifer potential is such that not all wells can be pumped at their design capacity. The maximum that would be available has been assumed in such cases.

Intense present and increased future demands on the deep sandstone aquifer will cause critical pumping levels and reduced well capacities before 2010 in Joliet, Aurora, and many towns in southeastern Du Page County.

Table 31. Towns in System Service Area

No.	Town	2010 demand (mgd)	Shallow			
134	Clarendon Hills	0.86	0.67	(0.67)	2.78	(1.73)
136	Darien	3.47	0.66	(0.66)	7.74	(1.44)
137	Downers Grove	7.93	4.12	(4.12)	12.33	(-)
138	Elmhurst	5.89	0.86	(0.86)	12.86	(10.58)
140	Glen Ellyn	4.12	2.67	(2.67)	4.68	(-)
141	Hinsdale	2.95	3.43	(3.43)	2.96	(-)
143	Lisle	1.75	3.09	(3.09)	1.02	(-)
*144	Lombard	5.72	1.54	(1.54)	10.97	(6.77)
146	Naperville	11.55	3.34	(3.34)	21.96	(5.04)
147	Oak Brook & Oakbrook Terrace	3.42	0.72	(0.72)	9.43	(6.89)
151	Villa Park	2.39	0.58	(0.58)	5.54	(4.55)
154	West Chicago	4.08	-	(-)	9.63	(4.51)
155	Westmont	2.08	1.97	(1.97)	3.22	(1.34)
156	Wheaton	6.82	4.00	(4.00)	8.34	(-)
158	Winfield	1.01	3.33	(2.77)	-	(-)
161	Aurora	15.66	1.01	(1.01)	31.35	(22.46)
251	Bolingbrook	5.65	13.74	(6.54)	-	(-)
254	Crest Hill	0.98	2.01	(1.14)	0.43	(0.43)
259	Joliet	15.81	12.84	(7.04)	19.43	(17.43)
260	Lockport	1.73	1.29	(0.72)	3.38	(3.38)
267	Plainfield	0.87	0.84	(-)	2.01	(2.01)
268	Rockdale	0.44	-	(-)	1.60	(0.72)
269	Romeoville	2.08	3.08	(2.44)	2.81	(2.81)

* Includes water demand for Lombard Heights (No. 145)

The Kankakee River may be used as a supply source to resolve this impending problem. The supply system configuration is shown in figure 29.

Water from the Kankakee River

Off-channel storage is needed to meet water supply demands when these cannot be met from the river during low flow periods. The best site available is just south of the Kankakee River and west of I-55. The reservoir location suggests that dam and intake structure be located about 0.5 mile downstream of the I-55 bridge. The dam, intake, reservoir, and treatment plant are shown in figure 29. The river intake will be 4 miles below Wilmington and 6 miles above the confluence with the Des Plaines to form Illinois River. The pool from the Dresden Island Dam extends to about 2.5 miles downstream of the intake site. A dam about 8 feet high and 600 feet long at the site is estimated to cost $1,000,000, providing a pool for the intake structure and instream storage of about 900 ac-ft.

Off-channel storage has been calculated for two conditions. The first condition considers withdrawing water from the river even at the expense of reducing flow below the dam (6 miles to Illinois River) to less than the 7-day 10-year low flow. An off-channel storage of 1.2 times the average system demand for a month is considered adequate to meet emergencies such as chemical spills, repairs to dam, and extremely low river flow, as well as to meet any high system demand during periods of low flow. Under the second condition, water may be withdrawn from the river only to the extent the flow exceeds the 7-day 10-year low flow of 450 cfs at Wilmington. The storage requirements are determined with the methodology detailed earlier for the Fox River water for Kane County. The curves exhibiting the relation between deficit duration and supplies to be developed for drought recurrence intervals varying from 10 to 40 years are shown in figure 30.

Kankakee River System

Many different system configurations were analyzed with respect to total system demand and unit cost with the computer program developed for this purpose. Fifteen typical system variations have been chosen to cover the range of system demand as well as the range of area served. The towns served by each of these systems are listed in table 32. System demand in mgd, annual cost, unit cost in ¢/1000 gal, and storage requirements are also given in table 32.

The reservoir storage volume and surface area needed for systems 1 through 15 for the two conditions (one month storage to meet 1.2 times the system demand, and storage to meet a 40-yr drought episode) are given in table 32. Storage requirements range from 1,800 to 10,100 ac-ft for one month supply and from 2,300 to 28,800 ac-ft for supply during a 40-yr drought. The corresponding reservoir areas range from 160 to 700, and 190 to 1,740 acres, respectively. The topographic maps indicate that it may be possible to develop a reservoir with a maximum area of about 2,000 acres. Unit cost for the first condition varies from 79.16 to 89.90, and for the second condition it varies from 82.56 to 92.38 ¢/1000 gal.

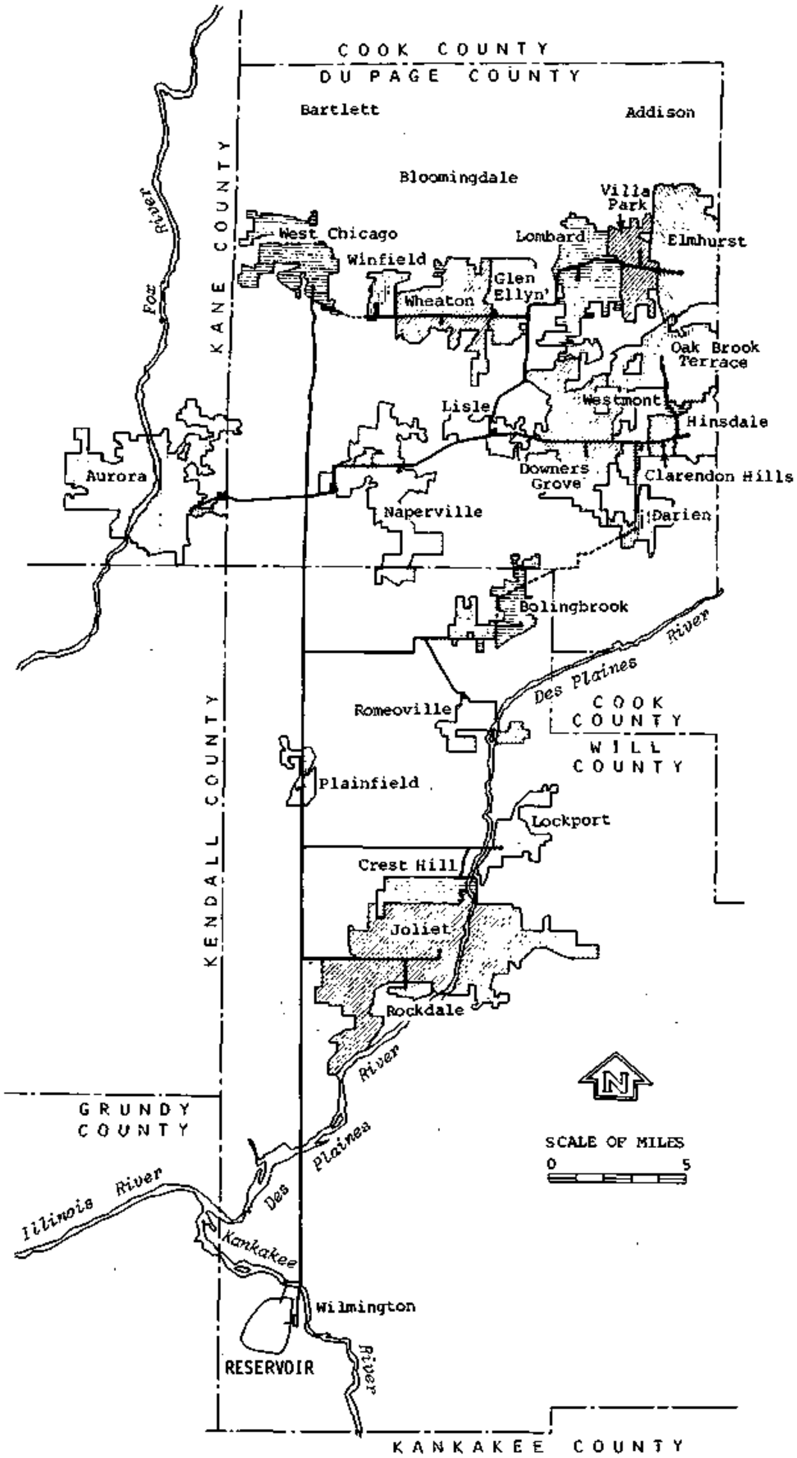


Figure 29. Kankakee River supply system

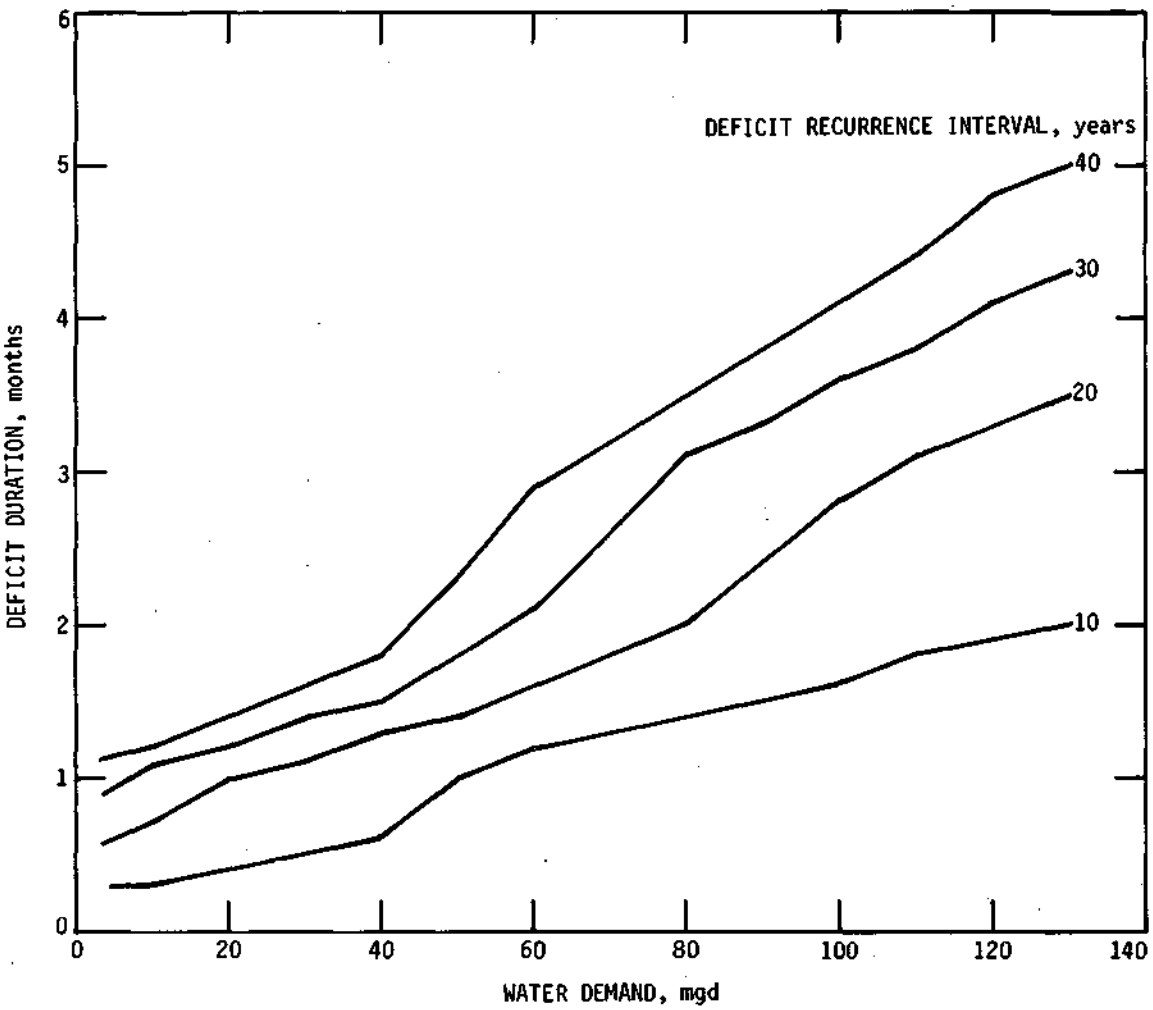


Figure 30. Deficit duration as a function of water demand and deficit recurrence interval for the Kankakee River at Wilmington

Table 32. Kankakee River System

No.	Town	2010 demand (mgd)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			System number (towns served marked by x)														
134	Clarendon Hills	0.86				x								x	x	x	
136	Darien	3.47			x*	x						x*	x	x	x	x	x
137	Downers Grove	7.93				x					x		x	x	x	x	x
138	Elmhurst	5.89													x	x	
140	Glen Ellyn	4.12				x									x	x	x
141	Hinsdale	2.95				x								x	x	x	
143	Lisle	1.75											x	x	x	x	x
144	Lombard	5.72													x	x	x
146	Naperville	11.55			x		x	x	x	x	x	x	x	x	x	x	x
147	Oak Brook+	3.42				x								x	x	x	
151	Villa Park	2.39													x	x	
154	W. Chicago	4.08			x			x	x	x	x	x				x	x
155	Westmont	2.08				x							x	x	x	x	x
156	Wheaton	6.82													x	x	x
158	Winfield	1.01														x	x
161	Aurora	15.66					x	x	x	x	x	x	x	x			x
251	Bolingbrook	5.65		x	x	x	x	x	x	x	x	x	x	x	x	x	x
254	Crest Hill	1.03		x	x				x	x		x		x	x	x	x
259	Joliet	15.81	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
260	Lockport	1.73		x	x				x	x		x		x	x	x	x
267	Plainfield	0.87		x	x				x	x		x		x	x	x	x
268	Rockdale	0.44	x	x	x	x			x	x		x		x	x	x	x
269	Romeoville	2.08		x	x					x		x		x	x	x	x
System demand, mgd			16.25	27.61	46.71	46.73	48.67	52.75	56.82	58.90	60.68	62.37	63.90	77.28	86.56	91.65	91.80

*Darien served via Bolingbrook (pipeline shown dashed in figure 29)

+Includes Oakbrook Terrace

	System number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. One month storage															
Reservoir storage, ac-ft	1,800	3,100	5,200	5,200	5,400	5,800	6,300	6,500	6,700	6,900	7,100	8,500	9,600	10,100	10,100
Reservoir area, acres	160	250	390	390	410	430	460	480	490	500	520	600	670	700	700
Annual cost in thousands of dollars															
Storage	408	586	838	838	861	905	960	981	1,003	1,024	1,045	1,190	1,299	1,348	1,348
Treatment	2,534	3,920	6,238	6,241	6,479	6,977	7,471	7,726	7,943	8,149	8,335	10,032	11,221	11,872	11,891
Conveyance	1,939	4,097	7,094	8,264	6,866	7,615	8,141	8,400	8,869	8,859	9,246	11,120	13,261	14,462	13,750
Total	4,881	8,603	14,170	15,343	14,206	15,497	16,572	17,107	17,815	18,032	18,626	22,342	25,781	27,682	13,750
Unit cost in ¢/1000 gal	82.25	85.32	83.07	89.90	79.92	80.44	79.86	79.53	80.39	79.17	79.82	79.16	81.56	82.71	80.50
B. 40-year drought storage															
Reservoir storage, ac-ft	2,300	4,300	9,200	9,200	9,900	11,300	12,800	13,600	14,300	15,000	15,600	21,600	26,100	28,700	28,800
Reservoir area, acres	190	330	650	650	690	770	860	910	950	990	1,020	1,260	1,600	1,740	1,740
Annual cost in thousands of dollars															
Storage	480	734	1,260	1,260	1,329	1,463	1,604	1,677	1,741	1,803	1,857	2,369	2,733	2,938	2,946
Treatment	2,534	3,920	6,238	6,241	6,479	6.977	7,471	7,726	7,943	8,149	8,335	10,032	11,221	11,872	11,891
Conveyance	1,939	4,097	7,094	8,264	6,866	7,615	8,141	8,400	8,869	8,859	9,246	11,120	13,261	14,462	13,750
Total	4,953	8,751	14,592	15,765	14,674	16,055	17,216	17,803	18,553	18,811	19,438	23,521	27,215	29,272	28,587
Unit cost in ¢/1000 gal	83.46	86.79	85.54	92.38	82.56	83.34	82.97	82.77	83.72	82.59	83.30	83.34	86.09	87.46	85.27

Kankakee River and Shallow Groundwater

Most of the towns on the system have some wells in the shallow dolomite aquifer. The demand that can be met from them is obtained by multiplying the 2010 demand with shallow-aquifer-well capacity and dividing the product by the total shallow-and-deep-well capacity (table 33). The remaining demand can be met from the Kankakee River if deep wells are not to be used.

The portion of the 2010 demand that can be met from the shallow wells and that to be supplied by the Kankakee River are given in table 33 for all the 23 towns. The towns of Rockdale, West Chicago, and Aurora have no shallow wells and, therefore, no shallow groundwater supply. Winfield and Bolingbrook can meet their 2010 demands from the shallow aquifer alone. Unit groundwater costs are given in table 33 for 3 cases: 1) raw groundwater at the well (includes well and pumping costs), 2) treated groundwater including cost of conveyance to the treatment plant, and 3) treated shallow and deep groundwater for meeting the 2010 demand. Cost of raw groundwater from shallow wells ranges from 4.41 to 7.50, of treated shallow groundwater from 65.34 to 122.02, and of treated shallow and deep aquifer water from 72.16 to 131.86 ¢/1000 gal.

System costs and reservoir storage, area, and costs are given in table 34 for the 15 systems when shallow groundwater is used to supplement river water supply. The storage and area requirements are given both for one month's demand and the 40-yr drought. To provide adequate storage for the one month supply at 1.2 times the average system demand, the reservoir storage and area vary from 1100 to 7300 ac-ft and 100 to 530 acres, respectively. If storage is provided to meet water demand equal to 1.2 times the system demand during the 40-yr drought, the reservoir storage and area range from 1,400 to 16,400 ac-ft, and 130 to 1,070 acres, respectively.

Total unit costs for the 15 systems with Kankakee River and shallow groundwater are given in table 34 for the two storage conditions: 1.2 times the 1-month system demand and 40-yr drought demand, and considering groundwater with and without treatment. The following inferences are drawn from the tabulated information.

1) Conjunctive use systems with no lime-soda or ion-exchange softening of groundwater are the cheapest but the finished water will have greater hardness than the Lake Michigan water.
2) 'Kankakee River only* systems are slightly cheaper than the conjunctive use systems when groundwater is fully treated and 1-month storage is provided. Most of the systems have a total cost between 79 to 85 and 82 to 87 ¢/1000 gal with 1-month and 40-yr drought storage, respectively (table 32).
3) Most of the conjunctive use systems with full treatment range in total cost from 80 to 87 and 83 to 88 ¢/1000 gal with 1-month and 40-yr drought storage, respectively.
4) The change in annual cost with a change of 1 ¢/1000 gal in the unit cost is given below for certain demands:

Demand, mgd	20	40	60	80	100
Annual cost, $	73,040	146,080	219,120	292,160	365,200

Table 33. Kankakee River System and Groundwater from Shallow Aquifers

Town No.	*Town*	*2010 demand (mgd) met by*		*Unit cost ¢/1000 gal)*		
		System	*GW*	*SGW*	*SGWT*	*SDGWT*
134	Clarendon Hills	0.69	0.17	5.22	122.02	113.11
136	Darien	3.20	0.27	5.22	107.32	97.83
137	Downers Grove	5.94	1.99	5.22	68.20	90.14
138	Elmhurst	5.50	0.39	4.41	93.31	99.22
140	Glen Ellyn	2.62	1.50	4.85	69.90	95.48
141	Hinsdale	1.37	1.58	5.22	69.79	80.77
143	Lisle	0.43	1.32	4.77	70.53	77.92
144	Lombard	5.02	0.70	4.41	81.17	99.92
146	Naperville	10.03	1.52	5.12	71.02	79.90
147	Oak Brook & Oakbrook Terrace	3.18	0.24	4.41	104.99	120.99
151	Villa Park	2.16	0.23	4.41	105.62	112.80
154	West Chicago	4.08	-	-	-	104.41
155	Westmont	1.29	0.79	5.22	79.61	90.61
156	Wheaton	4.61	2.21	4.85	65.34	91.43
158	Winfield	-	1.01	5.39	77.65	77.65
161	Aurora	15.66	-	-	-	76.73
251	Bolingbrook	-	5.65	7.50	72.16	72.16
254	Crest Hill	0.17	0.86	6.49	86.84	114.30
259	Joliet	9.52	6.29	6.43	68.64	81.72
260	Lockport	1.25	0.48	6.49	92.00	119.48
267	Plainfield	0.61	0.26	6.81	114.71	118.74
268	Rockdale	0.44	-	-	-	131.86
269	Romeoville	0.99	1.09	7.50	74.91	83.54

GW = shallow groundwater
SGW = raw shallow groundwater
SGWT = treated shallow groundwater
SDGWT = treated shallow and deep groundwater to meet 2010 demand

Table 34. Kankakee River System Costs with Shallow Groundwater

	System number														
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
River supply, mgd	9.96	12.98	30.29	28.25	35.21	39.29	A1.76	42.75	45.23	45.95	46.07	54.77	59.02	63.10	65.86
Groundwater supply, mgd	6.29	14.63	16.42	18.48	13.46	13.46	15.06	16.15	15.45	16.42	17.83	22.51	27.54	28.55	25.94
System demand, mgd	16.25	27.61	46.71	46.73	48.67	52.75	56.82	58.90	60.68	62.37	63.90	77.28	86.56	91.65	91.80
Common elements (annual costs in thousands of dollars)															
Treatment	1,736	2,120	4,237	3,996	4,824	5,321	5,627	5,750	6,056	6,144	6,160	7,222	7,740	8,238	8,574
Conveyance	1,461	2,440	5,587	6,118	5,519	6,270	6,694	6,960	7,309	7,420	7,425	8,996	10,605	11,707	11,292
Total	3,197	4,560	9,824	10,114	10,343	11,591	12,321	12,710	13,365	13,564	13,585	16,218	18,345	19,945	19,866
Reservoirs															
1-month storage, ac-ft	1,100	1,400	3,300	3,100	3,900	4,300	4,600	4,700	5,000	5,100	5,100	6,100	6,500	7,000	7,300
Reservoir area, acres	100	130	260	250	310	330	350	360	380	390	390	450	480	510	530
Annual cost in 1000 $	298	347	612	586	686	734	769	781	815	827	827	938	981	1,035	1,066
40-year drought storage, ac-ft	1,400	1,800	4,900	4,400	5,900	7,000	7,700	8,000	8,700	8,900	9,100	12,000	13,700	15,300	16,400
Reservoir area, acres	130	160	370	340	440	510	550	570	620	630	640	810	910	1,010	1,070
Annual cost in 1000 $	347	408	804	746	916	1,035	1,108	1,139	1,210	1,230	1,250	1,529	1,686	1,830	1,927
River water and untreated groundwater (annual cost in thousands of dollars)															
Annual cost of groundwater	148	360	392	424	331	331	357	386	369	392	412	505	607	627	595
Total annual cost with 1-month storage	3,643	5,267	10,828	11,124	11,360	12,656	13,447	13,877	14,549	14,783	14,824	17,661	19,933	21,607	21,527
Unit cost in ¢/1000 gal	61.39	52.24	63.48	65.18	63.91	65.70	64.80	64.51	65.65	64.90	63.52	62.58	63.06	64.56	64.21
Total annual cost with 40-year drought storage	3,692	5,328	11,020	11,284	11,590	12,957	13,786	14,235	14,944	15,186	15,247	18,252	20,638	22,402	22,388
Unit cost in ¢/1000 gal	62.21	52.84	64.60	66.12	65.21	67.26	66.44	66.18	67.44	66.67	65.34	64.67	65.29	66.93	66.78
River water and treated groundwater (annual cost in thousands of dollars)															
Annual cost of groundwater	1,577	3,891	4,391	4,850	3,460	3,460	3,987	4,285	3,956	4,391	4,291	6,027	7,429	7,715	6,861
Total anual cost with 1-month storage	5,072	8,798	14,827	15,550	14,489	15,785	17,077	17,776	18,136	18,782	18,703	23,183	26,755	28,695	27,793
Unit cost in ¢/1000 gal	85.47	87.25	86.92	91.12	81.52	81.94	82.30	82.64	81.84	82.46	80.15	82.14	84.64	85.73	82.90
Total annual cost with 40-year drought storage	5,121	8,859	15,019	15,710	14,719	16,086	17,416	18,134	18,531	19,185	19,125	23,774	27,460	29,490	28,654
Unit cost in ¢/1000 gal	86.29	87.86	88.04	92.06	82.81	83.50	83.93	84.30	83.62	84.23	81.96	84.24	86.87	88.11	85.47

The selection of a system or systems for further study (staging and optimization) will depend on the amount of water which can be withdrawn from the Kankakee River, the required storage volume depending on whether the 7-day 10-year low flow below the intake up to the Illinois River (a distance of 6 miles) is to be maintained, the feasibility of constructing a reservoir with adequate storage, the. allocation of Lake Michigan water to eastern Du Page County, and the conjunctive use of the shallow aquifer potential yield.

OPTIMAL REGIONAL SUPPLY SYSTEMS

A number of system configurations have been considered for each of the six regional supply systems and these have been described in the last section. The towns served, annual and unit costs of supplying water to meet the 2010 demands, and the layout of the conveyance pipelines are given for each configuration investigated. An economical design for a given system can be found by dynamically optimizing the components to meet the water demands over the period from 1985 through 2010. This involves consideration of component staging, inflation, construction schedules, etc.

One or more of the system configurations for each regional supply system were selected for optimization after discussions with the Division of Water Resources staff and county representatives. The selected systems are considered to be in operation by July 1985. System demands are computed at 5-year intervals over the period 1985 to 2010. Annual and unit costs of water for the years 1985, 1990, 1995, 2000, 2005, and 2010 illustrate the effect of increase in demand and inflation on these costs.

Costs are computed with the equations in the section on cost functions. Inflation rates of 0 and 5% and an interest rate of 8% have been used in the cost calculations. Staged construction was investigated for treatment plants and conveyance system pumping equipment. Pipelines, reservoirs, wells, and pumping stations are assumed to be completed by July 1985. Accumulated capital costs in 1985 are developed for each system and include construction costs (with 0 or 5% inflation), interest accrued on construction expenditures until 1985, and contingencies at 20% of capital expenditures as well as interest thereon. The optimization studies indicate that staging of treatment plant capacity in 1995 is economical for some systems. The additional capital cost of the increased plant capacity is given separately and not included in the 1985 accumulated capital cost. A treatment plant is assumed to have a maximum, capacity of 1.5 times the average system demand. Thus, a 10 mgd plant will have a maximum capacity of 15 mgd. Pipelines and pumping stations are optimized to meet demands varying from 0.6 to 1.8 times the average demand over a year as indicated in the description of conveyance system components in the section on cost functions. Pump stations are assumed to be built by 1985 to accommodate the pumping equipment required in 2010. Pumping equipment capacity and horsepower will be increased at 5-year intervals as required to meet increased demands.

Lake County Supply System

Water demands for 17 towns which may be supplied with Lake Michigan water are given in table 35A. Five of these towns (Hainesville, Hawthorn Woods, Round Lake, Round Lake Beach, and Vernon Hills) can meet their water demands from shallow aquifers. Two supply systems, A and B, have been selected for optimization. System A serves all 17 towns with Lake Michigan water. System B supplies lake water to the 12 towns that cannot meet their 2010 demands with shallow groundwater. The intake in Lake Michigan is 1 mile from shore near the town of Lake Bluff.

Table 35. Lake County System Water Demands

A. Water demands

Town	Average water demand in mgd in year					
	1985	1990	1995	2000	2005	2010
Buffalo Grove*	2.46	2.57	2.77	2.97	3.04	3.11
Grayslake	.69	.79	.99	1.18	1.25	1.32
Gurnee	.79	.92	1.20	1.48	1.60	1.71
Hainesville	.06	.08	.14	.20	.23	.25
Hawthorn Woods	.10	.11	.14	.17	.18	.19
Knollwood	.37	.45	.53	.60	.63	.65
Lake Zurich	1.15	1.30	1.61	1.92	2.05	2.17
Libertyville	2.66	2.83	3.33	3.82	4.03	4.23
Lincolnshire	.54	.55	.60	.64	.66	.67
Mundelein	2.21	2.34	2.70	3.05	3.20	3.35
Riverwoods	.19	.20	.24	.27	.28	.29
Round Lake	.55	.66	.97	1.27	1.39	1.51
Round Lake Beach	1.47	1.52	1.58	1.63	1.73	1.83
Round Lake Park	.81	.89	1.09	1.28	1.36	1.44
Vernon Hills	.67	.80	1.05	1.30	1.38	1.46
Wheeling*	2.37	2.44	2.57	2.70	2.73	2.76
Wildwood Gages	.57	.62	.67	.71	.79	.86

*Buffalo Grove and Wheeling are in Cook County

B. System demands

	System demand in mgd vn year					
	1985	1990	1995	2000	2005	2010
System 'A' serves all 17 towns	17.66	19.07	22.18	25.19	26.53	27.80
System 'B' serves 12 towns (does not include Hainesville, Hawthorn Woods, Round Lake, Round Lake Beach, and Vernon Hills)	14.81	15.90	18.30	20.62	21.62	22.56

System A

Pipeline length, static head, construction cost multiplier, and diameter are shown on the schematic plan given in figure 31 (see figure 17 for a system map). Capital requirements are: conveyance system, $32,842,000; treatment plant, $19,421,000; and total $52,263,000 with 0% inflation. This is with a 22.18 mgd plant built by 1985. An additional plant of 5.62 mgd capacity is needed by 1995 at an additional cost of $7,174,000. With 5% inflation, the 1985 capital requirements are: conveyance system, $39,618,000; treatment plant (27.80 mgd), $28,809,000; and total, $68,427,000. Unit costs of the conveyance system, treatment, and total system are given in table 36 for both 0 and 5% inflation rates. Total system unit costs vary from 65.6 to 83.9 ¢/1000 gal with 0% inflation and from 102.4 to 121.1 ¢/1000 gal with 5% inflation. The installed horsepower for each pumping station is given in table 37 as an example of the increase in pumping power requirements with time.

System B

Pipeline length, static head, construction cost multiplier, and diameter are given on figure 32. With 0% inflation, capital requirements in 1985 are: conveyance system, $28,183,000; an 18.30 mgd treatment plant, $16,678,000; and total, $44,861,000. A 4.26 mgd treatment plant addition will be required in 1995 at a cost of $5,992,000. With 5% inflation, capital requirements in 1985 are: conveyance system, $33,764,000; a 22.56 mgd treatment plant, $24,266,000; and total, $58,030,000. Total installed horsepower varies from 3721 in 1985 to 7504 in 2010 with 0% inflation and from 3400 in 1985 to 6572 in 2010 with 5% inflation. Unit costs are given in table 38. Total system unit costs vary from 68.7 to 86.1 ¢/1000 gal with 0% inflation and from 105.1 to 123.9 ¢/1000 gal with 5% inflation.

Comparative Unit Costs

Unit costs in ¢/1000 gal of raw and treated locally developed shallow groundwater in 2010 as given in table 16 for self-sufficient towns are: Hainesville, 7.5 and 122.2; Hawthorn Woods, 8.4 and 120.0; Round Lake, 7.5 and 103.1; Round Lake Beach, 7.7 and 106.1; and Vernon Hills, 7.5 and 104.1. The marginal cost of supplying these five towns with Lake Michigan water is obtained from the unit costs for Lake County systems A and B. As an example, the marginal cost of supplying 2.85 mgd more water with system A than with system B in 1985 with 0% inflation is:

$$[(83.9 \times 17.66) - (86.1 \times 14.81)]/2.85 = 72.5 \text{ ¢/1000 gal}$$

The marginal cost of lake water is then compared with the weighted average cost of locally supplied groundwater. Marginal and groundwater costs are given in table 39. The marginal cost of supplying Lake Michigan water to these 5 towns is about one-half the cost of individual community groundwater supplies, if the groundwater is softened to a finished water hardness equal to that of Lake Michigan water. If the groundwater is not softened, but chlorinated and treated with flouride and polyphosphate, it would be more economical for these towns to use groundwater.

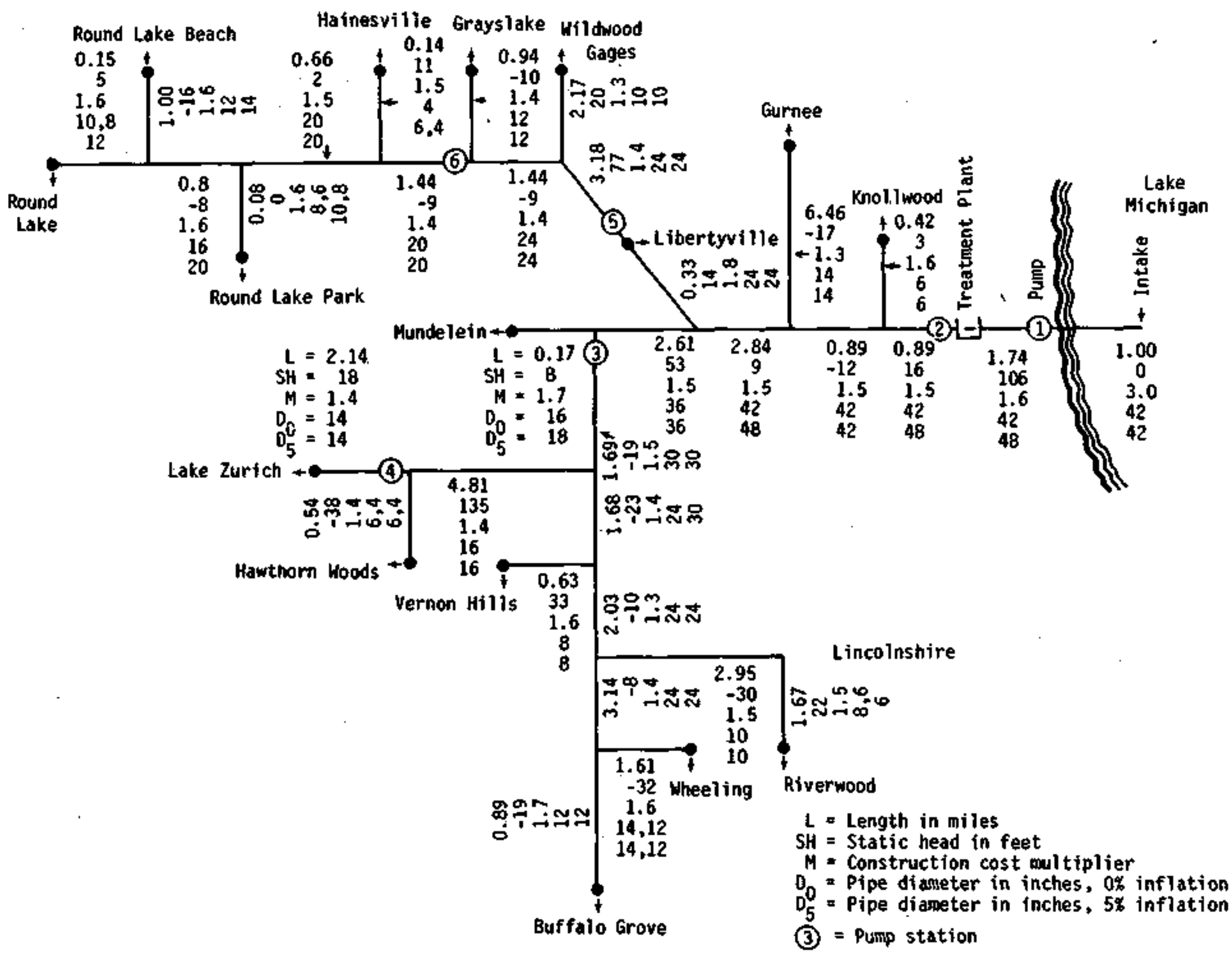


Figure 31. Lake County supply system A

Table 36. Unit Cost of Water: Lake County System A
(Interest rate 8%)

System components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
	Unit cost in ¢/1000 gal in the year					
A. With inflation rate of 0%						
Conveyance system						
Capital	42.1	39.1	33.9	30.1	28.7	27.5
OM&R	6.6	6.7	7.0	7.5	7.7	8.0
Total	48.7	45.8	40.9	37.6	36.4	35.5
Treatment plant						
Capital	26.7	24.8	29.2	25.7	24.4	23.3
OM&R	8.5	8.0	7.9	7.3	7.0	6.8
Total	35.2	32.8	37.1	33.0	31.4	30.1
Total system						
Capital	68.8	63.9	63.1	55.8	53.1	50.8
OM&R	15.1	14.7	14.9	14.8	14.7	14.8
Total	83.9	78.6	78.0	70.6	67.8	65.6
B. With inflation rate of 5%						
Conveyance system						
Capital	50.7	47.2	41.0	36.7	35.2	34.1
OM&R	8.1	10.6	13.9	18.5	24.3	32.2
Total	58.8	57.8	54.9	55.2	59.5	66.3
Treatment plant						
Capital	39.7	36.7	31.6	27.8	26.4	25.2
OM&R	11.8	14.3	16.5	19.4	23.9	29.6
Total	51.5	51.0	48.1	47.2	50.3	54.8
Total system						
Capital	90.4	83.9	72.6	64.5	61.6	59.3
OM&R	19.9	24.9	30.4	37.9	48.2	61.8
Total	110.3	108.8	103.0	102.4	109.8	121.1

Table 37. Increase in Total Installed Horsepower With Time: Lake County System A

Pump station number	Installed horsepower needed in year 1985	1990	1995	2000	2005	2010
With inflation rate of 0%						
1	1,563	1,728	2,103	2,545	2,755	2,966
2	1,563	1,771	2,291	2,915	3,220	3,531
3	684	772	992	1,257	1,377	1,500
4	42	54	85	128	149	172
5	284	333	439	570	699	837
6	57	74	143	231	274	325
Total	4,193	4,732	6,053	7,646	8,474	9,331
With inflation rate of 5%						
1	1,493	1,641	1,966	2,332	2,501	2,683
2	1,402	1,597	2,016	2,474	2,710	3,154
3	689	768	992	1,274	1,395	1,445
4	42	54	85	128	149	170
5	292	330	439	581	711	795
6	0	9	46	110	124	144
Total	3,918	4,399	5,544	6,899	7,590	8,391

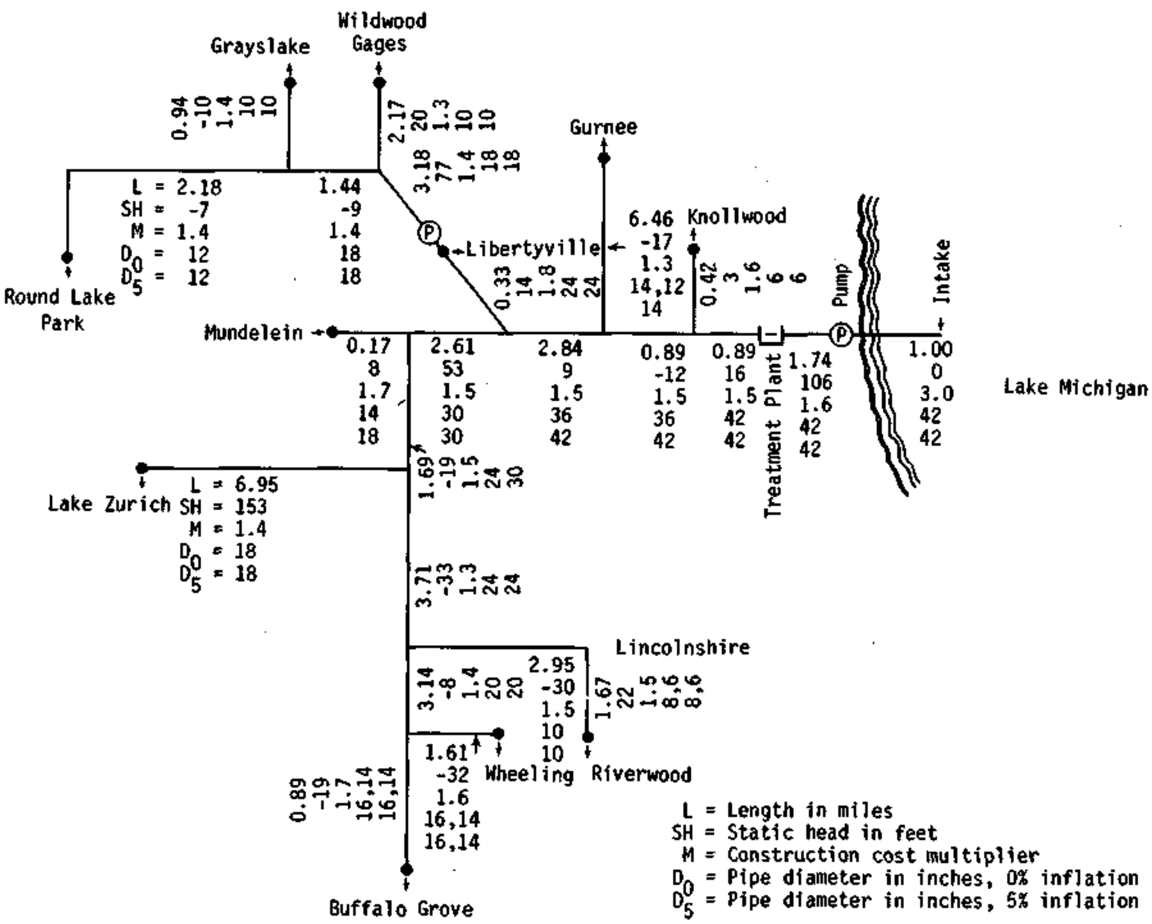


Figure 32. Lake County supply system B

Table 38. Unit Cost of Water: Lake County System B
(Interest rate 8%)

System components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
	Unit cost in ¢/1000 gal in the year					
A. With inflation rate of 0%						
Conveyance system						
Capital	43.0	40.2	35.1	31.4	30.1	28.9
OM&R	6.9	7.0	7.3	7.6	7.8	8.1
Total	49.9	47.2	42.4	39.0	37.9	37.0
Treatment plant						
Capital	27.4	25.5	30.1	26.7	25.5	24.5
OM&R	8.8	8.4	8.3	7.7	7.4	7.2
Total	36.2	33.9	38.4	34.4	32.9	31.7
Total system						
Capital	70.4	65.7	65.2	58.1	55.6	53.4
OM&R	15.7	15.4	15.6	15.3	15.2	15.3
Total	86.1	81.1	80.8	73.4	70.8	68.7
B. With inflation rate of 5%						
Conveyance system						
Capital	51.5	48.1	42.2	37.9	36.5	35.3
OM&R	8.3	10.7	14.0	18.3	23.9	31.2
Total	59.8	58.8	56.2	56.2	60.4	66.5
Treatment plant						
Capital	39.8	37.1	32.3	28.6	27.3	26.1
OM&R	12.3	14.9	17.2	20.3	25.2	31.3
Total	52.1	52.0	49.5	48.9	52.5	57.4
Total system						
Capital	91.3	85.2	74.5	66.5	63.8	61.4
OM&R	20.6	25.6	31.2	38.6	49.1	62.5
Total	111.9	110.8	105.7	105.1	112.9	123.9

Table 39. Marginal and Groundwater Costs of Water Supply to Hainesville, Hawthorn Woods, Round Lake, Round Lake Beach, and Vernon Hills

System	*Item*	*Inflation rate, %*	*Unit cost in ¢/1000 gal in year*					
			1985	*1990*	*1995*	*2000*	*2005*	*2010*
A	Q_A, mgd		17.66	19.07	22.18	25.19	26.53	27.80
B	Q_B, mgd		14.81	15.90	18.30	20.62	21.62	22.56
	(Q_A-Q_B), mgd		2.85	3.17	3.88	4.57	4.91	5.24
A	Unit cost	0	83.9	78.6	78.0	70.6	67.8	65.6
B	Unit cost	0	86.1	81.1	80.8	73.4	70.8	68.7
	Marginal cost	0	72.5	66.1	64.8	58.0	54.6	52.3
	Groundwater cost	0	158.7	147.4	128.9	116.4	111.5	107.4
A	Unit cost	5	110.3	108.8	103.3	102.4	109.8	121.1
B	Unit cost	5	111.9	110.8	105.7	105.1	112.9	123.9
	Marginal cost	5	102.0	98.8	-92.0	90.2	96.1	109.0
	Groundwater cost	5	202.6	204.2	201.5	211.9	239.3	277.3

Southern Cook County Supply System

Eight towns are supplied with water from Lake Michigan and their water demands for the years 1985, 1990, 1995, 2000, 2005, and 2010 are in table 40. Costs are computed for a supply system obtaining water from Lake Michigan and for a system conveying water purchased from the city of Chicago to these eight towns. Relatively poor water quality and questions about intercounty transfer of groundwater make an alternative groundwater supply from local wells and from wells in the Silurian dolomite aquifer in Will County undesirable. Thus, such a supply system is not considered for optimization.

Supply from Lake Michigan

This supply system will have an intake structure 2 miles northeast from 67th Street and the lake shore where a raw water pumping station will be located. The pipeline will follow 67th Street west to Stony Island Avenue, go south along Stony Island Avenue to the Calumet Expressway, and follow the expressway to the treatment plant which will be located near 130th Street and the Calumet Expressway. From there, the pipeline will go west along 130th Street to the Illinois Central Gulf right-of-way, follow the railroad tracks south to Halsted Street, and go along this street to the vicinity of the eight towns on the system. This conveyance system with pipeline length, static head, pipeline cost multiplier, and diameter is shown schematically in figure 33 (see figure 20 for a system map).

Table 40. Southern Cook County System Demands

Town	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
	Average water demand in mgd in year					
Chicago Heights	5.65	5.64	5.63	5.62	5.68	5.74
Flossmoor	1.13	1.17	1.27	1.36	1.36	1.36
Glenwood	1.56	1.75	2.13	2.50	2.55	2.59
Homewood	1.98	2.07	2.25	2.43	2.46	2.49
Matteson	1.06	1.23	1.56	1.89	1.93	1.96
Olympia Fields	0.41	0.45	0.55	0.64	0.66	0.67
Park Forest	3.00	3.00	3.01	3.01	3.02	3.02
Richton Park	1.25	1.41	1.74	2.06	2.11	2.15
Total	16.04	16.72	18.14	19.51	19.77	19.98

With 0% inflation, the capital requirements in 1985 are: conveyance system, $42,929,000; treatment plant, $17,862,000; and total, $60,791,000. With 5% inflation, the 1985 capital requirements are: conveyance system, $50,419,000; treatment plant, $22,009,000; and total, $72,428,000. The total installed horsepower increases from 4014 in 1985 to 6708 in 2010 for 0% inflation, and from 3901 in 1985 to 6621 in 2010 with 5% inflation. Unit costs for conveyance, treatment, and the total system are given in table 41. The 2010 unit cost is 85.9 ¢/1000 gal with 0% inflation and 150.6 ¢/1000 gal with 5% inflation.

Supply from the City of Chicago

The water will be purchased from the city of Chicago for a negotiated unit cost and will be picked up at 130th Street and the Illinois Central Gulf tracks, just west of S. Indiana Avenue. The pipeline length, static head, construction cost multiplier, and diameter are shown in figure 34. The conveyance system capital requirements in 1985 are $19,873,000 with 0% inflation, and $23,463,000 with 5% inflation. The total installed horsepower increases from 2196 in 1985 to 3502 in 2010 for 0% inflation and from 2092 in 1985 to 3415 in 2010 for 5% inflation. Unit costs of conveyance are given in Table 42. The 2010 unit conveyance costs are 27.0 and 45.2 ¢/1000 gal with 0 and 5% inflation, respectively. The negotiated unit cost of water from the city of Chicago will be added to the unit conveyance costs to obtain the total unit costs.

Comparative Unit Costs

Total system unit cost for the Lake Michigan supply system as well as the unit conveyance cost for the water purchased from Chicago are shown in figure 35A for 0% inflation rate. The difference in the two unit costs, in ¢/1000 gal, varies from 71.0 in 1985 to 58.9 in 2010. This difference indicates the alternative cost of water from the city of Chicago. Total system unit cost for the Lake Michigan supply system as well as the unit conveyance cost for the water purchased from Chicago is shown in figure 35B for 5% inflation rate.

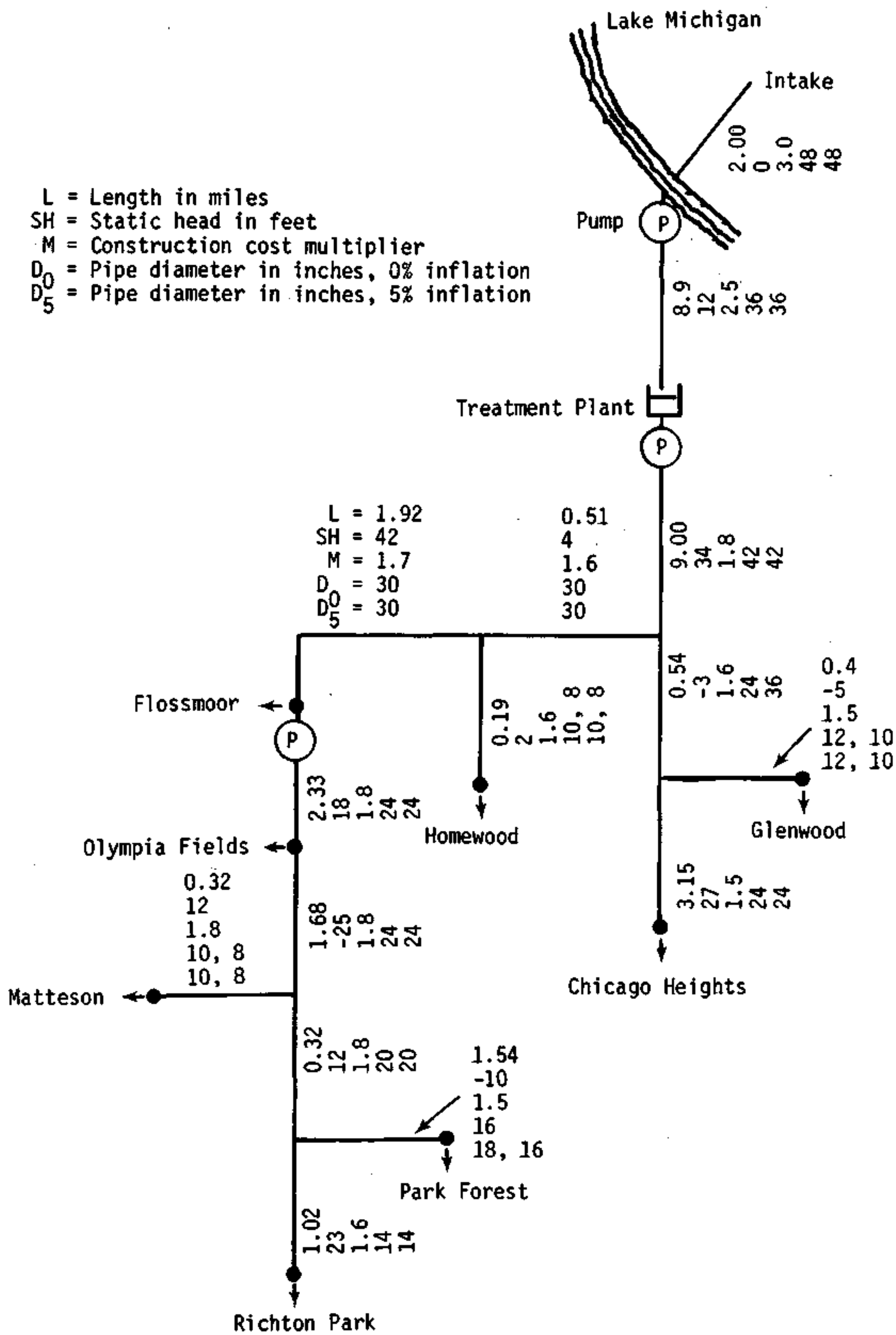


Figure 33. Southern Cook County supply system with water from Lake Michigan

Table 41. Unit Cost of Water: Southern Cook System, Supply from Lake Michigan (Interest rate 8%)

System components	*Unit cost in ¢/1000 gal in the year* 1985	1990	1995	2000	2005	2010
A. With inflation rate of 0%						
Conveyance system						
Capital	60.3	57.9	53.6	50.0	49.4	48.9
OM&R	6.6	6.7	7.1	7.6	7.7	7.8
Total	66.9	64.6	60.7	57.6	57.1	56.7
Treatment plant						
Capital	27.1	26.0	24.0	22.3	22.0	21.7
OM&R	8.6	8.4	7.9	7.6	7.5	7.5
Total	35.7	34.4	31.9	29.9	29.5	29.2
Total system						
Capital	87.4	83.9	77.6	72.3	71.4	70.6
OM&R	15.2	15.1	15.0	15.2	15.2	15.3
Total	102.6	99.0	92.6	87.5	86.6	85.9
B. With inflation rate of 5%						
Conveyance system						
Capital	70.8	68.1	63.2	59.3	58.7	58.2
OM&R	8.2	10.7	14.6	20.0	25.8	33.3
Total	79.0	78.8	77.8	79.3	84.5	91.5
Treatment plant						
Capital	33.4	32.0	29.5	27.4	27.1	26.8
OM&R	11.0	13.7	16.5	20.1	25.4	32.3
Total	44.4	45.7	46.0	47.5	52.5	59.1
Total system						
Capital	104.2	100.1	92.7	86.7	85.8	85.0
OM&R	19.2	24.4	31.1	40.1	51.2	65.6
Total	123.4	124.5	123.8	126.8	137.0	150.6

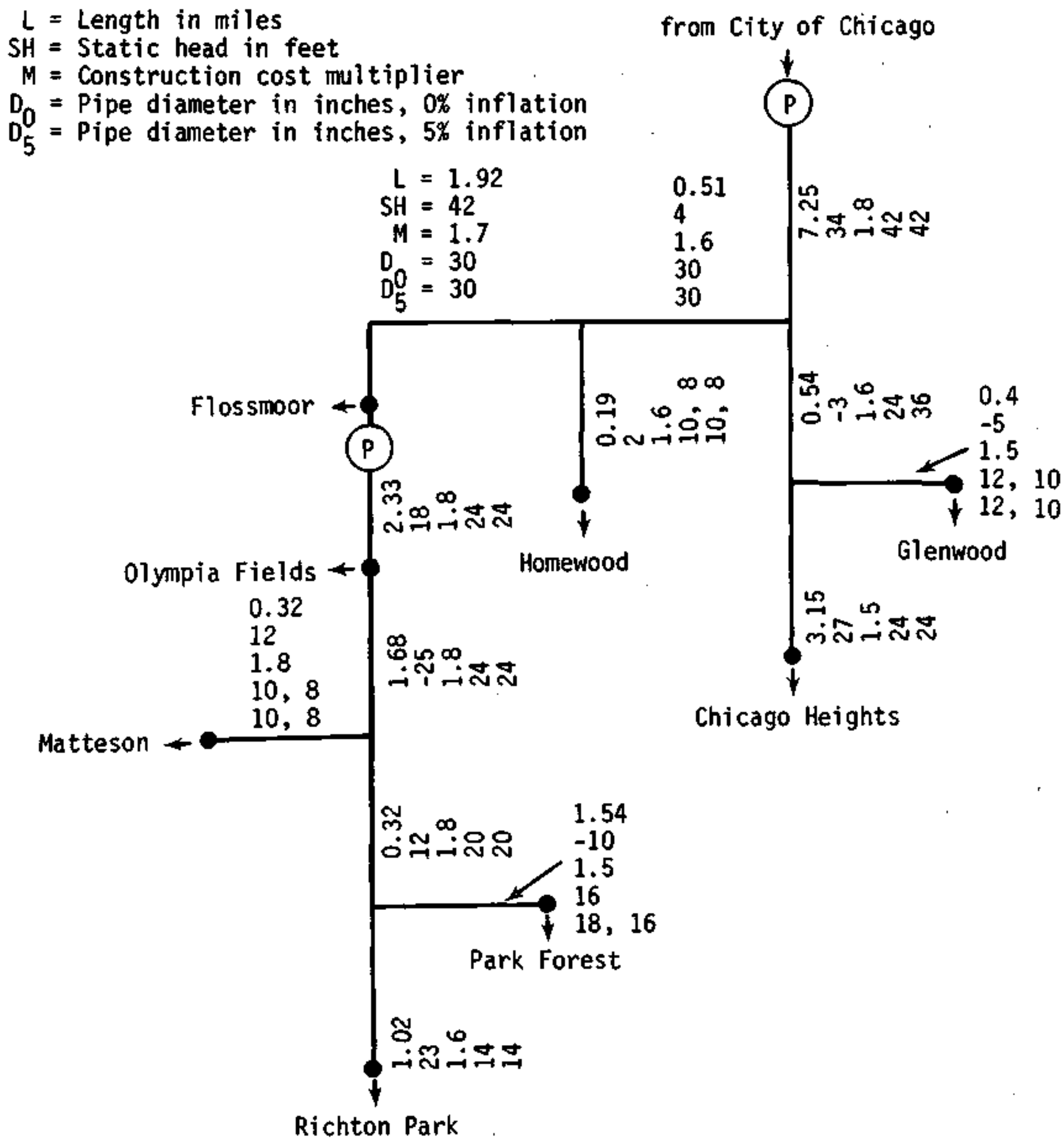


Figure 34. Southern Cook County supply system with water from the city of Chicago

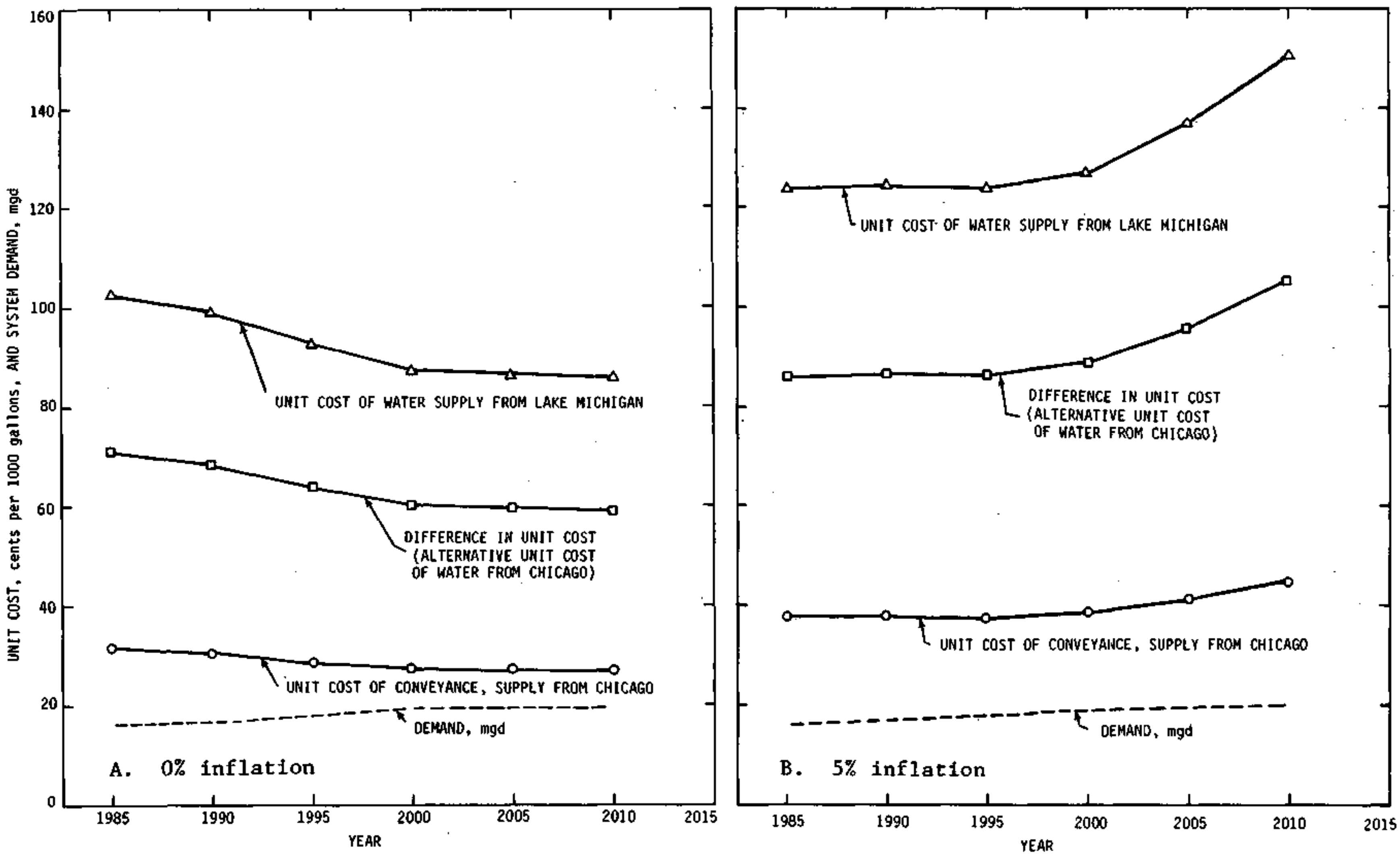


Figure 35. Unit cost of water supply for the Southern Cook County supply system

Table 42. Unit Cost of Water: Southern Cook System, Supply from Chicago (Interest rate 8%)

System components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
	Unit cost in ¢/1000 gal in the year					
A. With inflation rate of 0%						
Conveyance system						
Capital	27.9	26.9	24.8	23.2	22.9	22.7
OM&R	3.7	3.8	4.0	4.2	4.2	4.3
Total	31.6	30.7	28.8	27.4	27.1	27.0
B. With inflation rate of 5%						
Conveyance system						
Capital	33.0	31.7	29.4	27.6	27.4	27.1
OM&R	4.6	6.0	8.0	10.8	14.1	18.1
Total	37.6	37.7	37.4	38.4	41.5	45.2

The difference in the two unit costs, in ¢/1000 gal, varies from 85.9 in 1985 to 105.4 in 2010. This difference indicates the alternative cost of water from the city of Chicago. If the negotiated unit cost of water from Chicago is less than the alternative cost, it will be economical to supply the 8 towns with Chicago water.

Du Page County Supply System

Nineteen towns are supplied with water from Lake Michigan. Water demands for the years 1985, 1990, 1995, 2000, 2005, and 2010 are given in table 43. Costs are computed for a supply system obtaining water from Lake Michigan and for a system conveying water purchased from the city of Chicago to the user towns. Costs are not computed for a system with conjunctive use of existing shallow groundwater supplies. Water quality and corrosion problems require treatment of groundwater and blending with lake water before pumping into the distribution system. Towns may retain shallow wells for emergency use, but this is not considered in system design. The system which is optimized is number 7 in table 20.

Supply from Lake Michigan

The 1-mile long intake extends into the lake near the Lake-Cook County line. A raw water pumping station on the lake shore pumps the water to the treatment plant near the Des Plaines River, Illinois 58, and the Chicago and Northwestern Railroad (C&NW) tracks (De Leuw, Cather & Company, 1972). The pipeline extends west along Lake-Cook County Road to the C&NW tracks, and continues along the railroad in a southwesterly direction to the treatment plant. The main, carrying treated water, follows the C&NW and connects with the service system south of Bensenville. Pipeline length, static head, construction cost multiplier, diameter, and pump station locations are shown on the schematic plan in figure 36 (see figure 22 for a system map). With 0% inflation, the 1985 capital requirements are: conveyance system, $117,936,000;

Table 43. Du Page County Supply System Demands

Town	Average water demand in mgd in year 1985	1990	1995	2000	2005	2010
Addison	3.70	3.93	4.38	4.82	5.01	5.19
Bellwood	3.04	3.04	3.03	3.02	3.03	3.03
Bloomingdale	1.32	1.53	1.96	2.38	2.48	2.57
Carol Stream	1.75	2.01	2.51	3.01	3.09	3.17
Clarendon Hills	0.85	0.85	0.86	0.86	0.86	0.86
Darien	1.86	2.17	2.78	3.39	3.43	3.47
Downers Grove	5.20	5.73	6.73	7.73	7.83	7.93
Elmhurst	4.96	5.12	5.40	5.68	5.79	5.89
Glendale Heights	2.19	2.40	2.85	3.29	3.33	3.37
Glen Ellyn	3.29	3.45	3.70	3.94	4.03	4.12
Hinsdale	2.41	2.50	2.69	2.88	2.92	2.95
Lisle	0.81	0.99	1.35	1.70	1.73	1.75
Lombard & Lombard Heights	4.06	4.40	5.00	5.59	5.66	5.72
Naperville	5.65	6.54	8.66	10.78	11.17	11.55
Oak Brook & Oakbrook Terrace	2.37	2.57	2.98	3.39	3.41	3.42
Villa Park	2.12	2.17	2.25	2.32	2.36	2.39
Wheaton	4.87	5.21	5.89	6.57	6.70	6.82
Western Springs	1.25	1.25	1.25	1.24	1.26	1.27
Westmont	1.43	1.56	1.80	2.04	2.06	2.08
Total	53.13	57.42	66.07	74.63	76.15	77.55

66.07 mgd treatment plant, $49,422,000; and total, $167,358,000. Treatment plant capacity will be increased by 11.48 mgd in 1995 at a capital cost of $11,518,000. With 5% inflation, the 1985 capital requirements are: conveyance system, $142,918,000; 77.55 mgd treatment plant, $71,311,000; and total, $214,229,000. Installed horsepower increases from 13,532 in 1985 to 33,024 in 2010 for 0% inflation and from 12,039 in 1985 to 27,978 in 2010 for 5% inflation. Unit costs of conveyance, treatment, and the total system are given in table 44 for both 0 and 5% inflation rates. Total system unit costs range from 70.4 to 86.5 ¢/1000 gal with 0% inflation and from 104.2 to 127.6 ¢/1000 gal with 5% inflation.

Water Supply from Chicago

Treated Lake Michigan water will be purchased from the city of Chicago to serve the towns on the system. The supply point is on the boundary between Chicago and Oak Park, at the intersection of Austin and Washington Blvds. The water transport network and pipeline length, static head, construction cost multiplier, and diameter are shown in figure 37 (see figure 21 for a system map). Capital requirements in 1985 are $70,788,000 for 0% inflation and $87,001,000 for 5% inflation. The installed horsepower increases from 8724 in 1985 to 22,488 in 2010 for 0% inflation and from 7729 in 1985 to 18,169 in 2010 for 5% inflation. The unit cost of conveyance is given in table 45. The unit cost of conveyance from Chicago to the system varies from 28.5 to 34.8 ¢/1000 gal with 0% inflation and from 40.5 to 51.6 with 5%

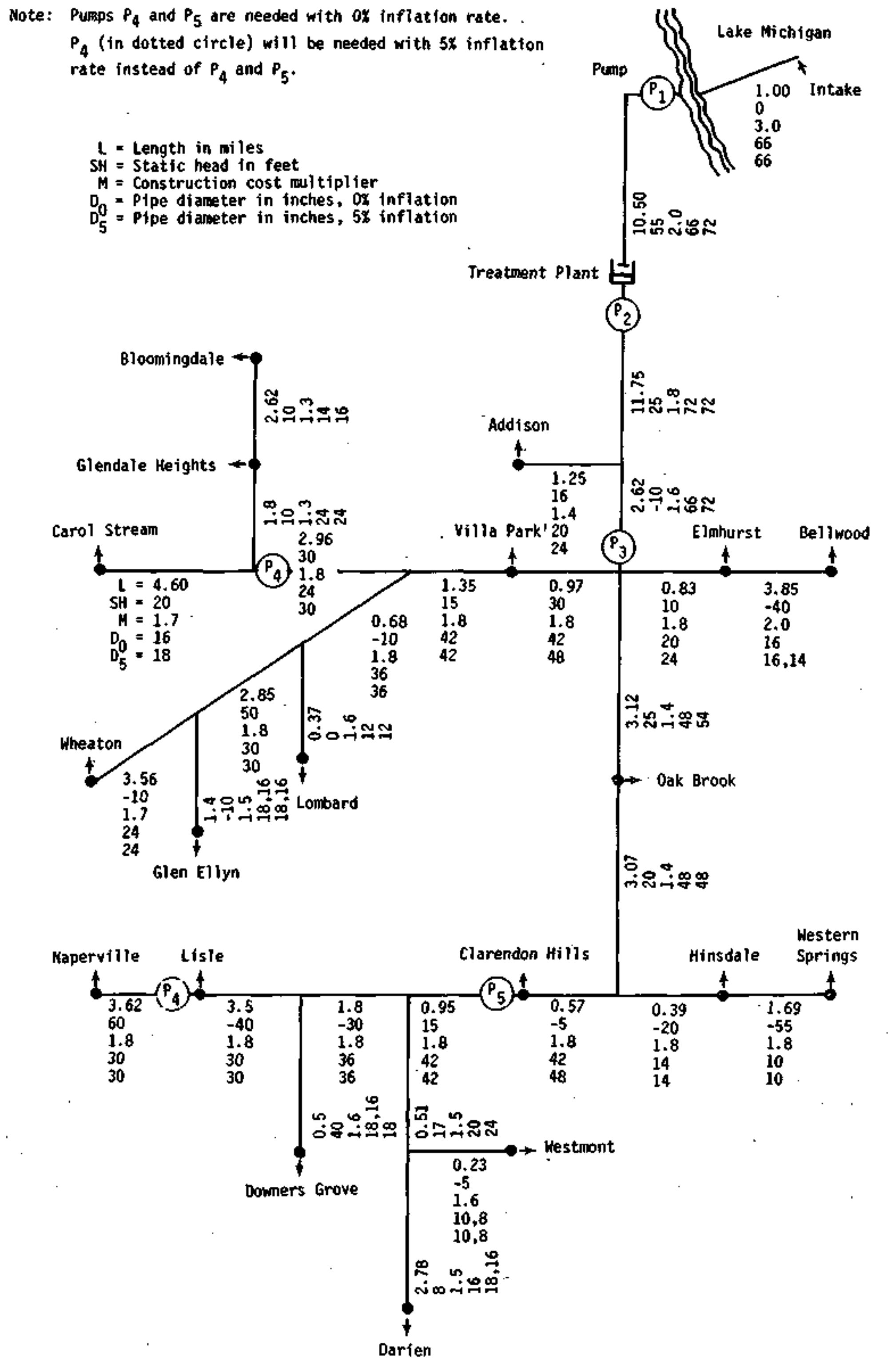


Figure 36. Du Page County supply system with water from Lake Michigan

Table 44. Unit Cost of Water: Du Page County System, Lake Michigan Supply (Interest rate 8%)

System components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
	Unit cost in ¢/1000 gal in the year					
A. With inflation rate of 0%						
Conveyance system						
Capital	50.6	47.3	41.5	37.2	36.5	35.9
OM&R	6.7	7.0	8.0	9.2	9.5	9.7
Total	57.3	54.3	49.5	46.4	46.0	45.6
Treatment plant						
Capital	22.8	21.1	22.7	20.1	19.7	19.3
OM&R	6.4	6.1	6.0	5.6	5.5	5.5
Total	29.2	27.2	28.7	25.7	25.2	24.8
Total system						
Capital	73.4	68.4	64.2	57.3	56.2	55.2
OM&R	13.1	13.1	14.0	14.8	15.0	15.2
Total	86.5	81.5	78.2	72.1	71.2	70.4
B. With inflation rate of 5%						
Conveyance system						
Capital	61.2	57.0	50.3	45.5	44.8	44.2
OM&R	8.0	10.6	14.9	21.7	28.4	37.1
Total	69.2	67.6	65.2	67.2	73.2	81.3
Treatment plant						
Capital	32.9	30.4	26.5	23.5	23.0	22.6
OM&R	8.8	10.7	12.5	14.9	18.8	23.7
Total	41.7	41.1	39.0	38.4	41.8	46.3
Total system						
Capital	94.1	87.4	76.8	69.0	67.8	66.8
OM&R	16.8	21.3	27.4	36.6	47.2	60.8
Total	110.9	108.7	104.2	105.6	115.0	127.6

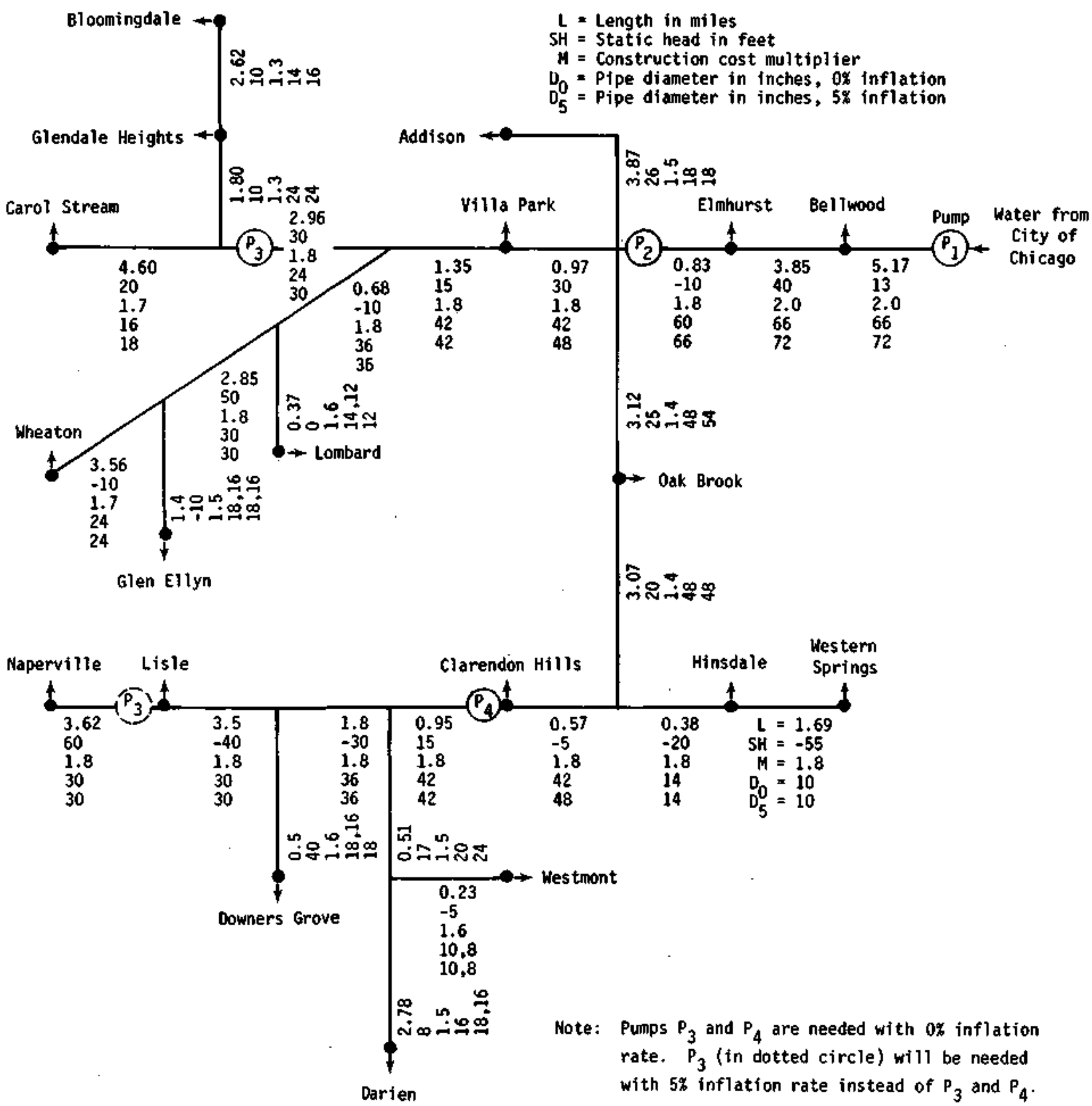


Figure 37. Du Page County supply system with water from the city of Chicago

Table 45. Unit Cost of Water: Du Page County System, Supply from Chicago (Interest rate 8%)

System components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
	Unit cost in ¢/1000 gal in the year					
A. With inflation rate of 0%						
Conveyance system						
Capital	30.4	28.6	25.1	22.5	22.1	21.8
OM&R	4.4	4.7	5.4	6.3	6.5	6.7
Total	34.8	33.3	30.5	28.8	28.6	28.5
B. With inflation rate 5%						
Conveyance system						
Capital	37.3	34.7	30.7	27.8	27.4	27.1
OM&R	5.3	7.0	9.8	14.4	18.7	24.5
Total	42.6	41.7	40.5	42.2	46.1	51.6

inflation. The negotiated unit cost of water purchased from the city of Chicago will be added to the unit conveyance costs to obtain the total unit costs.

Comparative Unit Costs

Total system unit cost for the Lake Michigan supply system as well as the unit conveyance cost for the water purchased from the city of Chicago is shown in figure 38A for 0% inflation rate. The difference in the. two unit costs in ¢/1000 gal (varies from 51.7 in 1985 to 41.9 in 2010) indicates the alternative cost for water from the city of Chicago. Total system unit cost for the Lake Michigan supply system as well as the unit conveyance cost for the water purchased from Chicago is shown in figure 38B for 5% inflation rate. The difference in the two unit costs in ¢/1000 gal (varies from a minimum of 63.4 in 2000 to a maximum of 76.0 in 2010) indicates the alternative cost for water from the city of Chicago. If the negotiated unit cost of water from Chicago is less than the alternative cost, it will be economical to supply the 19 towns with Chicago water.

Northwestern Cook County Supply System

Fourteen towns in northern Du Page and northwestern Cook Counties are supplied with water from Lake Michigan. Water demands for the years 1985, 1990, 1995, 2000, 2005, and 2010 are in table 46. Costs are computed for a supply system obtaining water from Lake Michigan and for a system conveying water purchased from the city of Chicago to the user towns. Costs are not computed for a system with conjunctive use of existing shallow groundwater supplies. Water quality and corrosion problems require treatment of groundwater and blending with lake water before pumping into the distribution network. Towns may retain shallow wells for emergency use, but this is not

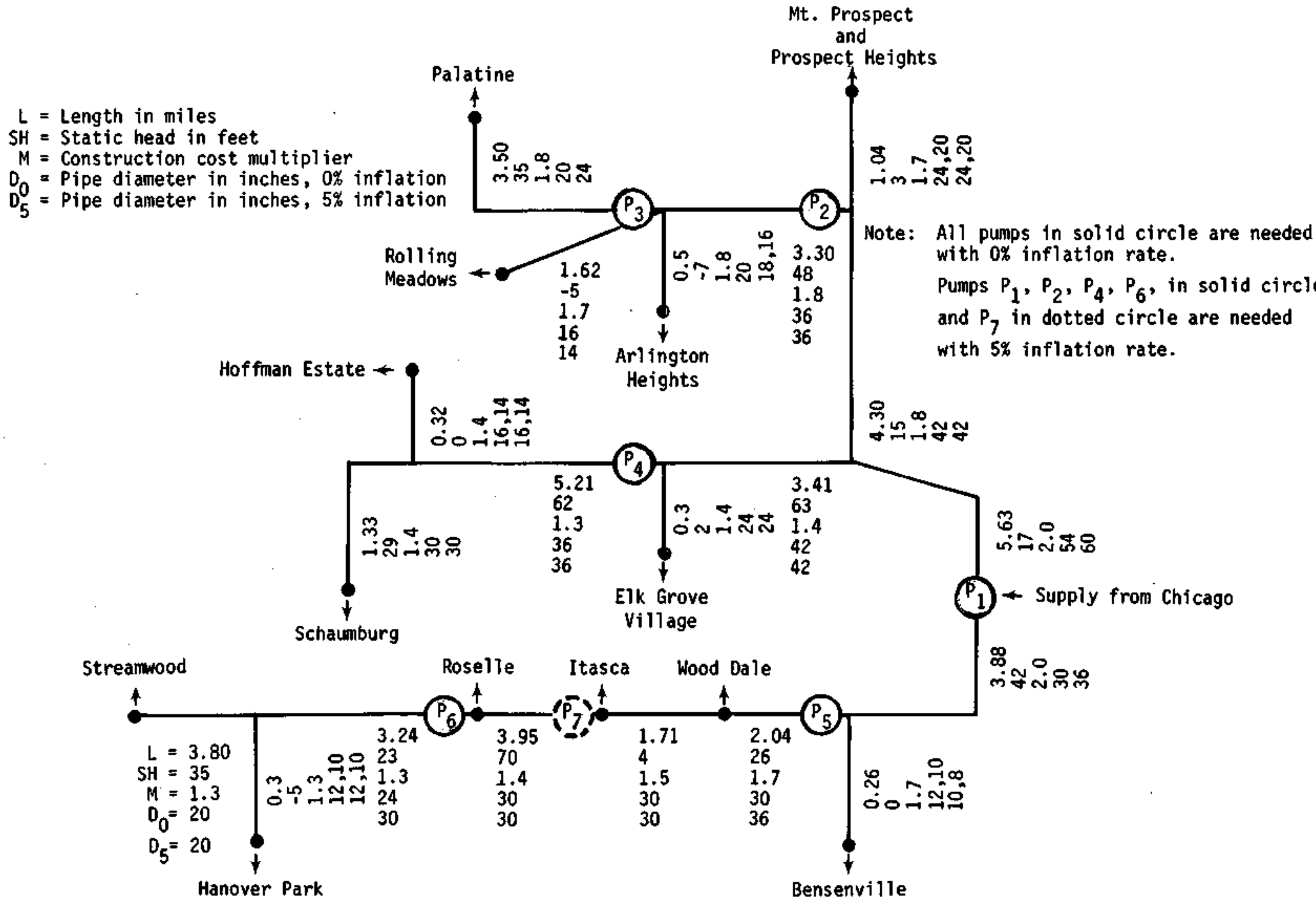


Figure 40. Northwestern Cook County supply system with water from the city of Chicago

Table 46. Northwestern Cook County System Demands

Town	Average water demand in mgd in year 1985	1990	1995	2000	2005	2010
Arlington Heights	8.05	8.14	8.28	8.41	8.51	8.61
Bensenville	1.86	1.92	2.04	2.16	2.19	2.21
Elk Grove Village	5.64	6.00	6.62	7.23	7.37	7.51
Hanover Park	3.26	3.39	3.66	3.92	3.92	3.92
Hoffman Estates	3.85	4.07	4.51	4.94	4.95	4.95
Itasca	1.17	1.25	1.43	1.61	1.70	1.79
Mount Prospect	5.31	5.32	5.34	5.36	5.43	5.49
Palatine	4.64	4.94	5.55	6.15	6.16	6.17
Prospect Heights	0.80	0.82	0.86	0.89	0.91	0.92
Boiling Meadows	2.40	2.46	2.58	2.70	2.74	2.77
Roselle	0.98	1.01	1.23	1.45	1.53	1.61
Schaumburg	6.79	7.35	8.33	9.30	9.49	9.67
Streamwood	2.80	3.06	3.57	4.07	4.15	4.23
Wood Dale	1.15	1.25	1.46	1.67	1.71	1.74
Total	48.70	50.98	55.46	59.86	60.76	61.59

considered in system design. Itasca and Roselle may obtain their 2010 demand from shallow aquifers for about 73 ¢/1000 gal. The optimized system is number 3 in table 25.

Supply from Lake Michigan

The intake, raw water pipeline, and treatment plant are located close to similar elements for the Du Page County supply system. Pipeline length, static head, construction cost multiplier, diameter, and pump station locations are shown on the schematic plan in figure 39 (see figure 24 for a system map). With 0% inflation, the 1985 capital requirements are: conveyance system, $78,061,000; 55.46 mgd treatment plant, $42,583,000; and total, $120,644,000. An additional 6.13 mgd capacity of treatment will be built by 1995 at a capital cost of $7,591,000. With 5% inflation, the 1985 capital requirements are: conveyance system, $95,149,000; 61.59 mgd treatment plant, $57,680,000; and total, $152,829,000. The installed horsepower increases from 13,183 in 1985 to 22,263 in 2010 for 0% inflation and from 11,482 in 1985 to 18,587 in 2010 for 5% inflation. Unit costs of conveyance, treatment, and the total system are given in table 47 for both 0 and 5% inflation rates. Total system unit costs range from 63.2 to 70.7 ¢/1000 gal with 0% inflation and from 89.3 to 115.0 ¢/1000 gal with 5% inflation.

Water Supply from Chicago

Treated Lake Michigan water will be purchased from the city of Chicago to serve the towns on the system. The supply point is just east of O'Hare International Airport. Northern and southern branches of the transmission system carry water to the service area. The water transport network and pipeline data are shown in figure 40 (see figure 23 for a system map).

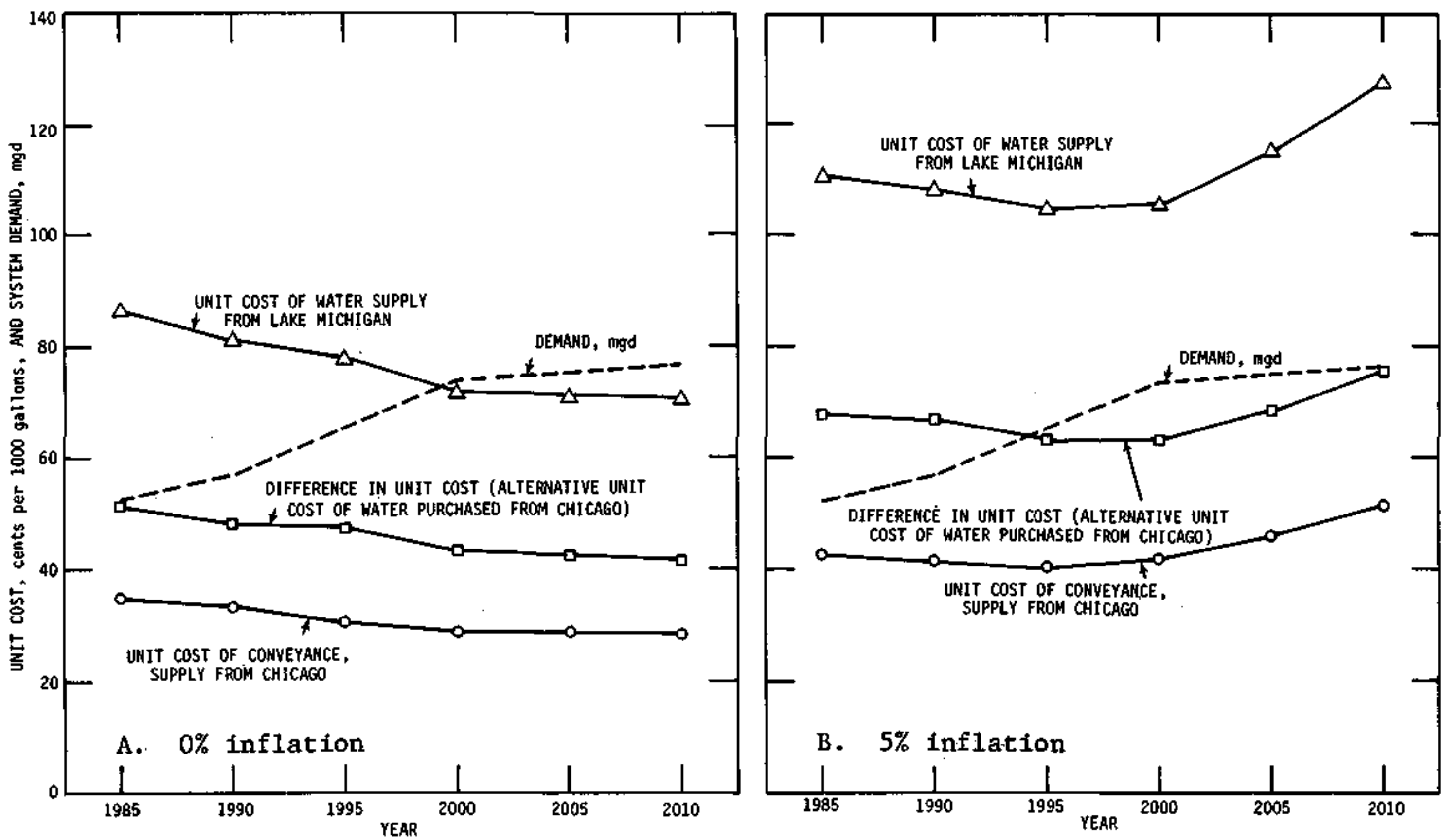


Figure 38. Unit cost of water supply for the Du Page County supply system

Table 47. Unit Cost of Water: Northwestern Cook County System, Supply from Lake Michigan (Interest rate 8%)

System components	*Unit cost in ¢/1000 gal in the year* 1985	1990	1995	2000	2005	2010
A. With inflation rate of 0%						
Conveyance system						
Capital	36.3	34.8	32.2	30.0	29.7	29.3
OM&R	6.9	7.1	7.6	8.2	8.3	8.4
Total	43.2	41.9	39.8	38.2	38.0	37.7
Treatment plant						
Capital	21.3	20.4	22.0	20.4	20.1	19.9
OM&R	6.2	6.0	6.0	5.7	5.7	5.6
Total	27.5	26.4	28.0	26.1	25.8	25.5
Total system						
Capital	57.6	55.2	54.2	50.4	49.8	49.2
OM&R	13.1	13.1	13.6	13.9	14.0	14.0
Total	70.7	68.3	67.8	64.3	63.8	63.2
B. With inflation rate of 5%						
Conveyance system						
Capital	44.2	42.4	39.2	36.9	36.4	36.1
OM&R	8.6	10.5	14.2	19.1	24.7	31.8
Total	52.2	52.9	53.4	56.0	61.1	67.9
Treatment plant						
Capital	28.8	27.5	25.3	23.4	23.1	22.7
OM&R	8.3	10.3	12.5	15.2	19.2	24.4
Total	37.1	37.8	37.8	38.6	42.3	47.1
Total system						
Capital	73.0	69.9	64.5	60.3	59.5	58.8
OM&R	16.3	20.8	26.7	34.3	43.9	56.2
Total	89.3	90.7	91.2	94.6	103.4	115.0

Capital requirements in 1985 are $53,721,000 with 0% inflation and $65,811,000 with 5% inflation. The total installed horsepower increases from 8695 in 1985 to 14,770 in 2010 with 0% inflation and from 7554 in 1985 to 12,192 in 2010 with 5% inflation. The unit cost of conveyance is given in table 48. The unit cost of conveyance from Chicago to the system varies from 25.8 to 29.6 ¢/1000 gal with 0% inflation and from 35.9 to 46.0 with 5% inflation. The negotiated unit cost of water purchased from the city of Chicago will be added to the unit conveyance costs to obtain the total unit costs.

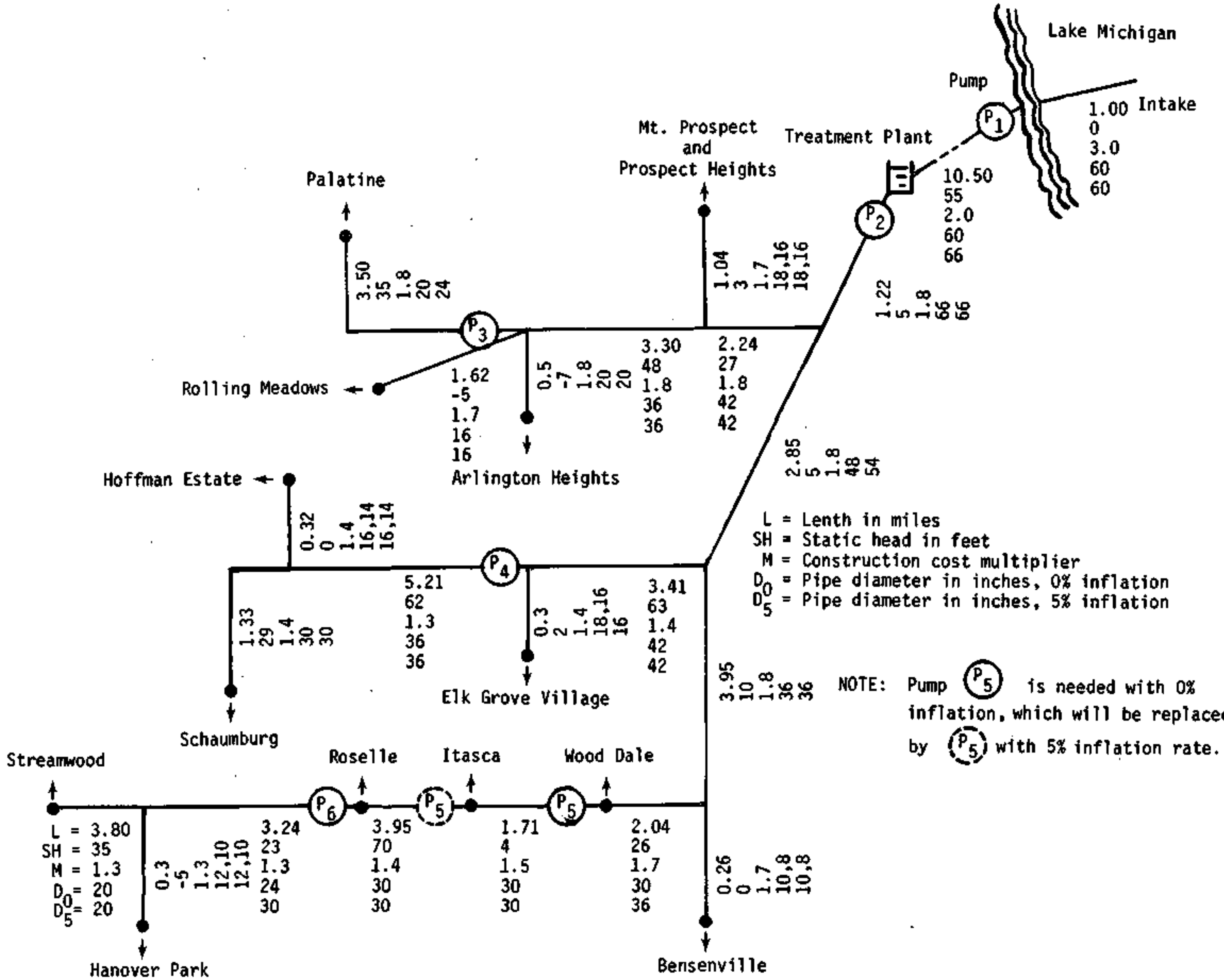


Figure 39. Northwestern Cook County supply system with water from Lake Michigan

Table 48. Unit Cost of Water: Northwestern Cook County System, System Supply from Chicago (Interest rate 8%)

System Components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
	Unit cost in ¢/1000 gal in the year					
A. With inflation rate of 0%						
Conveyance system						
Capital	25.0	23.9	22.2	20.7	20.4	20.1
OM&R	4.6	4.8	5.1	5.5	5.6	5.7
Total	29.6	28.7	27.3	26.2	26.0	25.8
B. With inflation rate of 5%						
Conveyance system						
Capital	30.5	29.3	27.1	25.4	25.2	24.8
OM&R	5.4	7.0	9.5	12.8	16.4	21.2
Total	35.9	36.3	36.6	38.2	41.6	46.0

Comparative Unit Costs

Total system unit cost for the Lake Michigan supply system as well as the unit conveyance cost for the water purchased from Chicago is shown in figure 41A for 0% inflation rate. The difference in the two unit costs in ¢/1000 gal (varies from minimum of 41.1 in 1985 to 37.4 in 2010) indicates the alternative cost of water from the city of Chicago.

Total system unit cost for the Lake Michigan supply system as well as the unit conveyance cost for the water purchased from Chicago is shown in figure 41B for 5% inflation rate. The difference in the two unit costs in ¢/1000 gal (varies from minimum of 53.4 in 1985 to 69.0 in 2010) indicates the alternative cost of water from the city of Chicago.

If the negotiated unit cost of water from Chicago is less than the alternative cost, it will be economical to supply the 14 towns with Chicago water. A long-term contract for the purchase of Chicago water is required to make this comparison over the system design period from 1985 to 2010.

Advisability of a Single Intake, Raw Water Pipeline, and Treatment Plant

Since the Lake Michigan intake, raw water transmission pipeline, and treatment plant are in the identical locations for the northwestern Cook and Du Page County supply systems, common raw water conveyance and water treatment facilities are possible. System and combined water demands are given in table 49 for Du Page and northwestern Cook supply systems. Unit costs for raw water conveyance are given in table 49A. With 0% inflation the combined conveyance system has a unit cost which is 4.1 and 3.1 ¢/1000 gal less than the weighted average of the separate systems in 1985 and 2010, respectively. This represents a cost saving of about $1,500,000 per year. The installed horsepower is about 7% less for the single system. Diameter of the 1-mile long lake intake line is 60 inches for northwestern Cook, 66 inches for

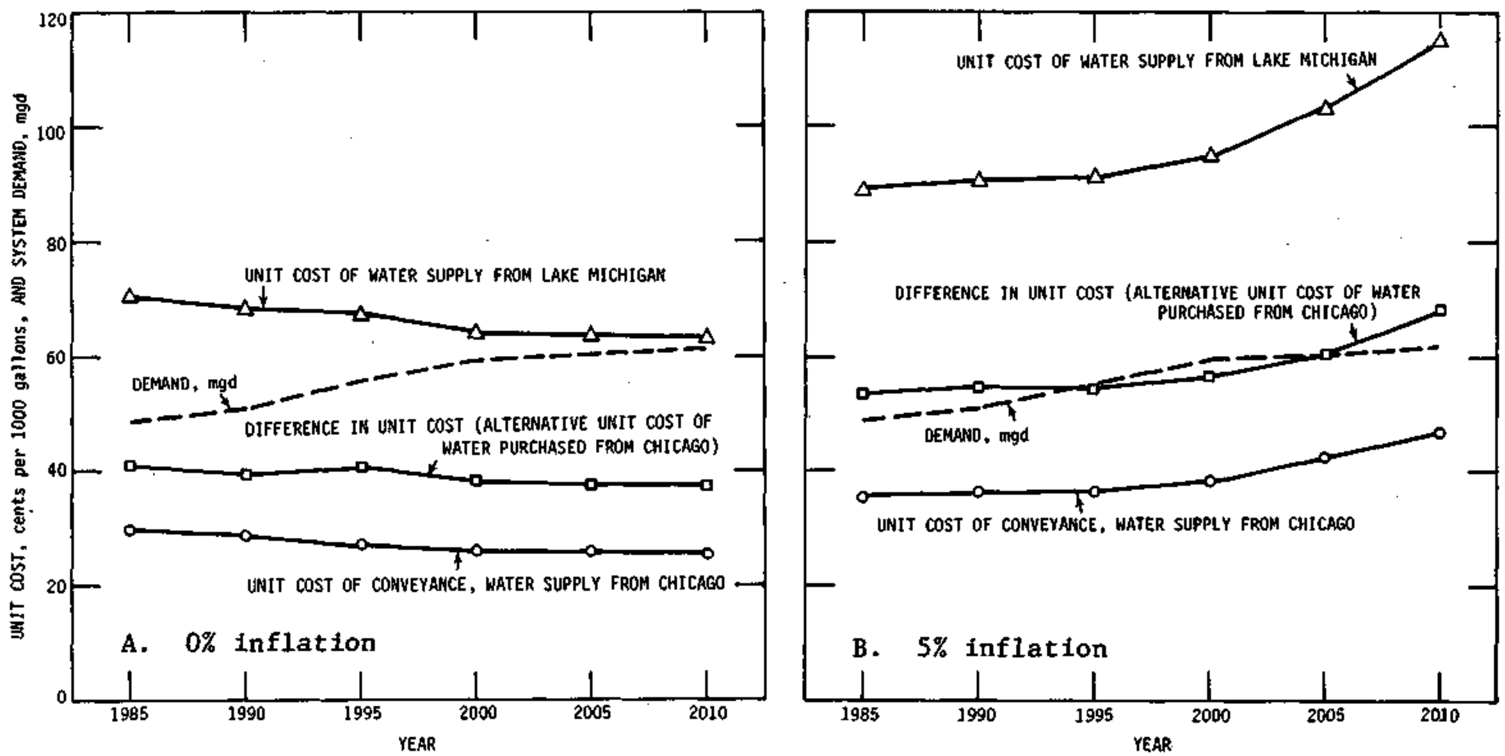


Figure 41. Unit cost of water for the northwestern Cook County supply system

Table 49. Unit Cost of Raw Water Conveyance and Water Treatment

System	*Item*	*Inflation rate, %*	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
A. Raw water conveyance								
Du Page	Q, mgd	-	53.13	57.42	66.07	74.63	76.15	77.55
NW Cook	Q, mgd	-	48.70	50.98	55.46	59.86	60.76	61.59
	Combined Q, mgd	-	101.83	108.40	121.53	134.49	136.91	139.14
Du Page	Unit cost	0	17.6	16.6	15.2	14.2	14.1	14.0
NW Cook	Unit cost	0	17.4	16.9	16.0	15.4	15.3	15.2
	Average unit cost	0	17.5	16.7	15.6	14.7	14.6	14.5
	Combined unit cost	0	13.4	12.9	12.1	11.6	11.5	11.4
Du Page	Unit cost	5	21.4	20.9	20.2	20.6	22.3	24.7
NW Cook	Unit cost	5	21.1	21.2	21.2	22.0	23.8	26.3
	Average unit cost	5	21.3	21.0	20.7	21.2	23.0	25.4
	Combined unit cost	5	15.9	16.2	16.7	18.2	20.4	23.3
B. Treatment								
Du Page	Unit cost	0	29.2	27.2	28.7	25.7	25.2	24.8
NW Cook	Unit cost	0	27.5	26.4	28.0	26.1	25.8	25.5
	Average unit cost	0	28.4	26.8	28.4	25.9	25.5	25.1
	Combined unit cost	0	27.7	26.2	27.3	24.9	24.5	24.2
Du Page	Unit cost	5	36.2	35.9	43.7	42.6	45.9	50.3
NW Cook	Unit cost	5	37.1	37.8	37.8	38.6	42.3	47.1
	Average unit cost	5	36.6	36.8	41.0	40.8	44.3	48.9
	Combined unit cost	5	34.4	34.5	40.9	40.6	44.0	48.3
C. Total								
D + NWC	Unit cost	0	45.9	43.5	44.0	40.6	40.1	39.6
	Combined unit cost	0	41.1	39.1	39.4	36.5	36.0	35.6
D + NWC	Unit cost	5	57.9	57.8	61.7	62.0	67.3	74.3
	Combined unit cost	5	50.3	50.7	57.6	58.8	64.4	71.6

D stands for Du Page and NWC for Northwestern Cook supply systems.

Du Page, and 84 inches for the single pipeline. With 5% inflation, the raw water line has 66 inches diameter for the northwestern Cook, 72 inches diameter for the Du Page, and 84 inches for the single pipeline.

Unit costs of water treatment are given in table 49B. With 0% annual inflation, the single treatment plant has unit costs between 0.6 and 1.0 ¢/1000 gal less than the weighted average unit cost of treatment in two separate plants. Total unit cost for conveyance plus treatment are given in

49C. With 0% inflation, the single system is less costly by 4.8 ¢/1000 gal in 1985 and 4.0 ¢/1000 gal in 2010. The corresponding annual savings are $1,800,000 in 1985 and $2,000,000 in 2010. Table 49 also includes costs for 5% inflation. The single conveyance system and treatment plant are more economical in this case, too. Economics favors the construction and operation of single raw water intake, transmission line, and treatment plant to deliver finished water to the northwestern Cook and Du Page County supply systems.

If twin pipelines are built to provide flexibility to repair a pipeline or meet emergencies, the costs are very similar to those for separate systems because most of the savings are made on the conveyance system. The single system requires cooperation in planning, design, and construction of the two supply systems.

Fox River Supply System

Eight towns in the Fox River Valley can be served from a system withdrawing water from the Fox River. The water will be pumped to a storage reservoir, treated by lime-soda softening, and delivered to the towns through a conveyance system. Because sufficient water cannot be withdrawn from the river during low flows, the reservoir storage will be used to meet the demands during low flow periods of short duration. The available water supply during long low flow periods can be augmented by pumping water from the deep sandstone wells in and around Elgin. A pipeline system for collecting this groundwater and conveying it to the reservoir is an integral part of the Fox River system. The 8 towns and their demands are given in table 50.

Table 50. Fox River System Water Demands

	Average water demand in mgd in year					
Town	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
Aurora[1]	11.03	11.73	13.34	14.95	15.30	15.66
Batavia	1.74	1.83	2.04	2.26	2.40	2.53
Elgin	8.24	8.69	9.76	10.82	11.34	11.86
Geneva	1.78	1.87	2.04	2.20	2.24	2.28
North Aurora	0.66	0.73	0.88	1.03	1.06	1.09
St. Charles[2]	-	-	0.16	0.65	0.89	1.13
South Elgin[3]	0.56	0.63	0.76	0.90	0.92	0.94
Valley View	0.09	0.09	0.10	0.11	0.12	0.12
System A total	24.10	25.57	29.08	32.92	34.27	35.61
System B total	16.84	18.24	21.62	25.32	26.65	27.97

[1]For system B, Aurora used 6.70 mgd from existing deep wells.

[2]St. Charles can develop 3.24 mgd from existing shallow and deep wells.

[3]For system B, South Elgin meets its demand from shallow wells.

To keep the system demand low, because of limited availability of river water and lack of large areas for suitable reservoir sites, the town of St. Charles is assumed to develop up to 3.24 mgd from shallow and deep wells. At least 70% of the water is from the shallow wells. Aurora has the largest demand of the 8 towns and uses about 45% of the system demand. The practical sustained yield of the deep sandstone aquifer at Aurora is estimated to be 6.7 mgd. South Elgin can meet its demand by developing groundwater from shallow aquifers at a unit cost of 95.5 ¢/1000 gal. Valley View can develop a shallow aquifer supply at a cost of 152.6 ¢/1000 gal. Thus, two systems were selected for optimization: A, which serves all 8 towns; and B, which serves 7 towns. System B does not supply South Elgin and supplies Aurora the balance of its demand above the 6.7 mgd available from the deep sandstone aquifer. Systems A and B correspond respectively to system configurations 7 and 8 in table 30.

On a long-term average the deep sandstone wells near Elgin will be needed about 10% of the year, but an allowance of 15% use has been made. The average barium concentration is 6.6 mg/l from the available well-test data. Considering its dilution with river water in the reservoir and the softening of mixed water by lime-soda process (which reduces barium concentration), the barium concentration in the treated water may be about 1.0 mg/l during a 40-year drought. The permissible concentration under present safe drinking water standards is 1 mg/l. For lesser drought events, the concentration will be lower because of less use of groundwater from the deep sandstone aquifer.

Fox River System A

This system includes a 5900 ac-ft reservoir with a surface area of 440 acres. The groundwater collection system consists of 13 existing and 4 new deep wells, with a safe yield of 19.60 mgd. The capital required in 1985 is given in table 51. With 0% inflation a 29.08 mgd treatment plant is built by

Table 51. Accumulated Capital Costs in 1985:
Fox River System A

System Components	*1985 Capital cost in millions of dollars, with inflation rate of* 0%	5%
Conveyance system	35.464	42.415
Reservoir		
Structure	6.306	6.880
Land	13.286	13.286
Total	19.592	20.166
Treatment plant	26.689	38.839
Groundwater collection system	7.075	8.380
New wells and pumps	0.965	1.232
Total	89.785	111.032

1985. A 6.53 mgd capacity addition will be built by 1995 for $8,701,000. With 5% inflation a 35.61 mgd capacity plant is built by 1985. The installed horsepower in the conveyance system increases from 4124 in 1985 to 9942 in 2010 with 0% inflation and from 3901 in 1985 to 9078 in 2010 with 5% inflation. Component and system unit costs are given in table 52. Total system unit costs in 2010 are 91.3 and 179.2 ¢/1000 gal with 0 and 5% inflation, respectively. Pipeline length, static head, cost multiplier, and diameter are given in figure 42 for both the conveyance and groundwater collection systems (see figures 25 and 28 for system maps).

Fox River System B

The reservoir needed for this system has a volume of 5300 ac-ft and a surface area of 400 acres. The groundwater collection system consists of 11 existing wells, with a safe yield of 12.52 mgd. Pipeline length, static head, construction cost multiplier, and diameter are given in figure 43 for both conveyance and groundwater collection systems. The capital required in 1985 is given in table 53. Installed horsepower for the conveyance system increases from 2768 in 1985 to 8983 in 2010 with 0% inflation and from 2557 in 1985 to 7870 in 2010 with 5% inflation. Unit costs are given in table 54. The total system unit cost in 2010 is 95.9 ¢/1000 gal with 0% inflation and 186.7 ¢/1000 gal with 5% inflation.

Feasibility of Shallow Groundwater for Aurora

An area south of Sugar Grove and 6 miles west of Aurora has been explored for developing water from sand and gravel aquifers. About 4 mgd can be developed from the sand and gravel aquifer in a bedrock valley. A system of 9 wells, a collection network, treatment plant, and pipeline conveying 4 mgd to Aurora can be built for a total capital cost of $9,629,000 in 1985

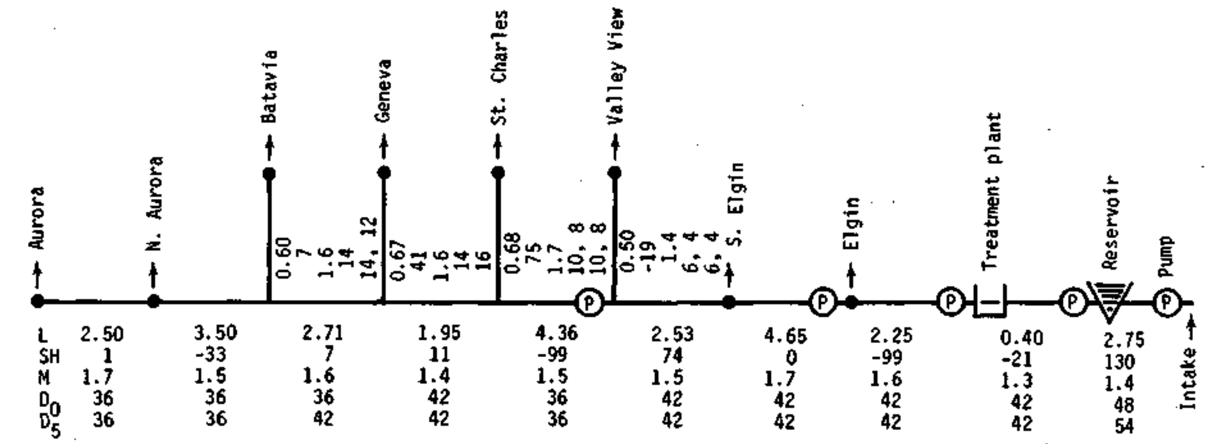
Table 53. Accumulated Capital Costs in 1985
Fox River System B

System Components	*1985 Capital cost in millions of dollars, with inflation rate of* 0%	5%
Conveyance system	28.496	34.680
Reservoir		
Structure	5.858	6.397
Land	12.078	12.078
Total	17.936	18.475
Treatment plant[1]	20.919	31.849
Groundwater collection system	4.553	5.343
Total	71.904	90.347

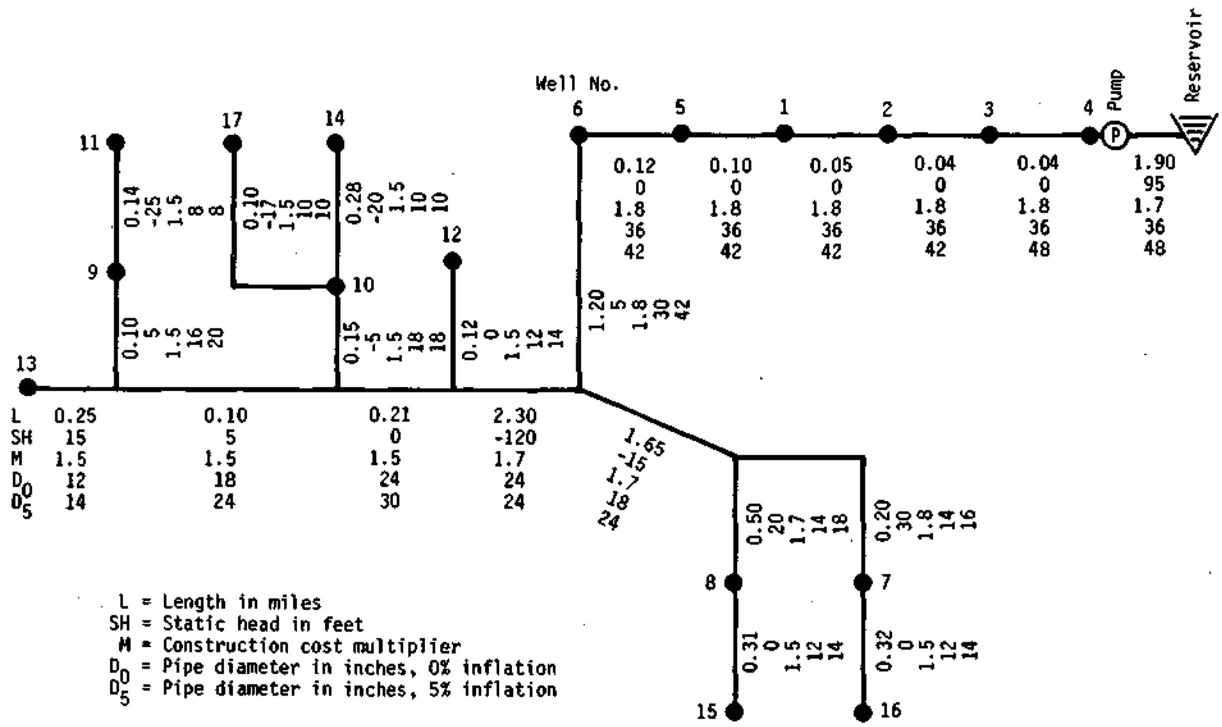
[1]21.62 mgd plant to meet 1995 demand built by 1985; another plant with 6.35 mgd capacity to be added by 1995 for $8,701,000 with 0% inflation. With 5% inflation, a 27.97 mgd capacity plant is built by 1985.

Table 52. Unit Cost of Water: Fox River System A

	0% inflation						*5% inflation*					
	Unit cost in ¢/1000 gal in the year						*Unit cost in ¢/1000 gal in the year*					
System components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
Conveyance system												
Capital	33.3	31.4	27.9	24.8	24.0	23.1	39.8	37.5	33.0	29.2	28.0	27.0
OM&R	4.3	4.5	4.9	5.6	5.8	6.0	5.3	7.2	10.0	14.7	19.3	25.2
Total	37.6	35.9	32.8	30.4	29.8	29.1	45.1	44.7	43.0	43.9	47.3	52.2
Reservoir												
Capital	18.2	17.1	15.1	13.3	12.8	12.3	18.7	17.6	15.5	13.7	13.2	12.7
OM&R	2.3	2.2	1.9	1.7	1.6	1.6	3.0	3.6	4.0	4.5	5.6	6.9
Total	20.5	19.3	17.0	15.0	14.4	13.9	21.7	21.2	19.5	18.2	18.8	19.6
Treatment plant												
Capital	27.0	25.4	29.6	26.2	25.1	24.2	39.2	36.9	32.5	28.7	27.6	26.5
OM&R	18.1	17.5	17.9	16.6	16.3	15.9	25.7	31.5	37.2	44.1	55.1	68.9
Total	45.1	42.9	47.5	42.8	41.4	40.1	64.9	68.4	69.7	72.8	82.7	95.4
Groundwater collection												
Capital	6.6	6.2	5.4	4.8	4.6	4.5	7.8	7.4	6.5	5.7	5.5	5.3
OM&R	0.4	0.4	0.4	0.3	0.3	0.3	0.6	0.7	0.8	0.9	1.1	1.3
Total	7.0	6.6	5.8	5.1	4.9	4.8	8.4	8.1	7.3	6.6	6.6	6.6
Well fields												
Capital	4.3	4.0	3.5	3.1	3.0	2.9	4.6	4.3	3.8	3.3	3.2	3.1
OM&R	0.8	0.8	0.7	0.6	0.6	0.5	1.0	1.2	1.4	1.5	1.9	2.3
Total	5.1	4.8	4.2	3.7	3.6	3.4	5.6	5.5	5.2	4.8	5.1	5.4
Total system												
Capital	89.4	84.1	81.5	72.2	69.5	67.0	110.1	103.7	91.3	80.6	77.5	74.6
OM&R	25.9	25.4	25.8	24.8	24.6	24.3	35.6	44.2	53.4	65.7	83.0	104.6
Total	115.3	109.5	107.3	97.0	94.1	91.3	145.7	147.9	144.7	146.3	160.5	179.2



a. Conveyance system



b. Groundwater collection system

Figure 42. Fox River supply system A

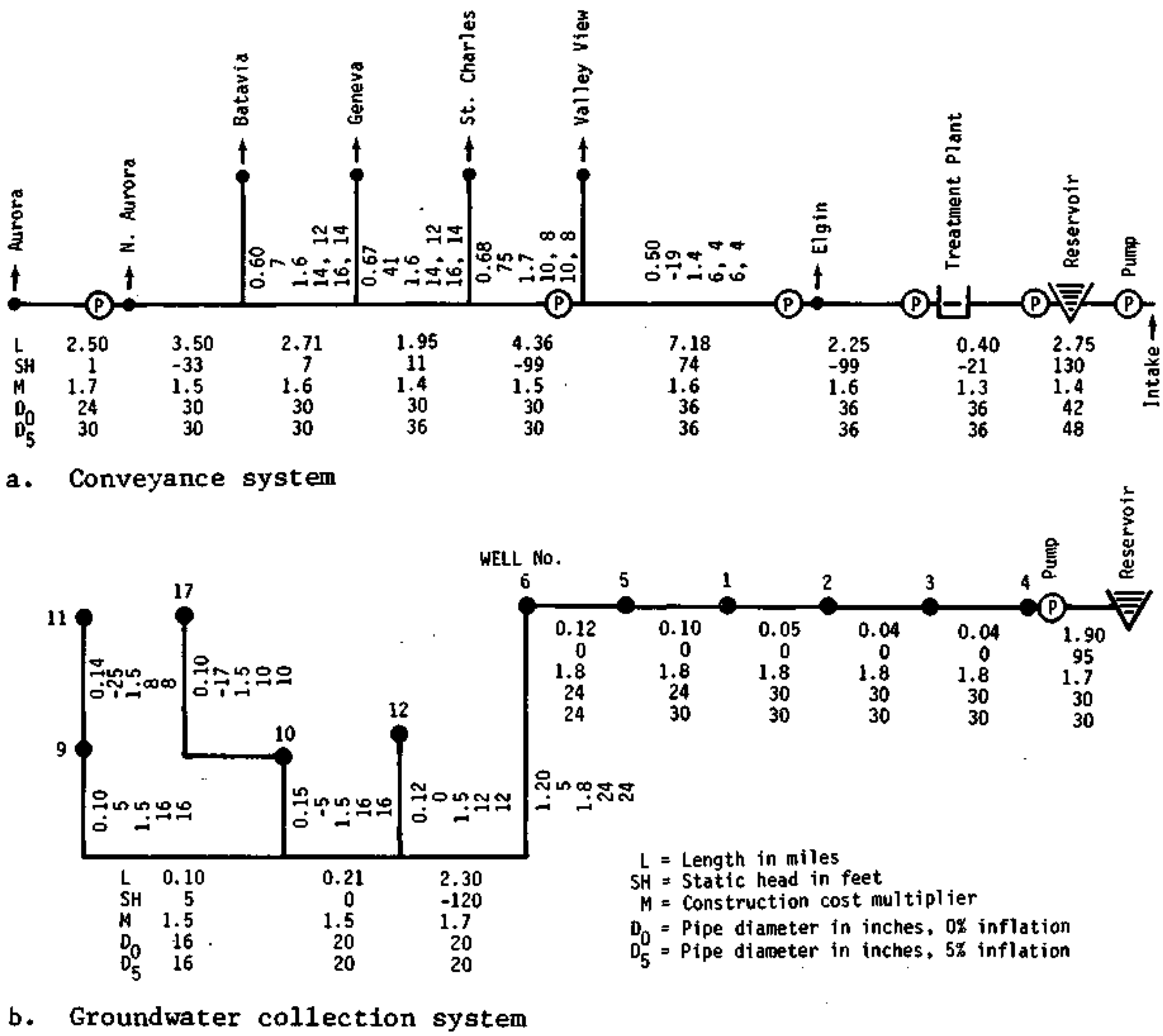


Figure 43. Fox River supply system B

Table 54. Unit Cost of Water: Fox River System B

System components	0% inflation						5% inflation					
	Unit cost in ¢/1000 gal in the year						Unit cost in ¢/1000 gal in the year					
	1985	1990	1995	2000	2005	2010	1985	1990	1995	2000	2005	2010
Conveyance system												
Capital	38.8	35.9	30.2	25.7	24.5	23.4	46.6	43.1	36.4	31.0	29.4	28.0
OM&R	4.7	4.9	5.8	7.2	7.6	7.8	4.6	7.4	10.3	15.9	21.0	28.1
Total	43.5	40.8	36.0	32.9	32.1	31.2	51.2	50.5	46.7	46.9	50.4	56.1
Reservoir												
Capital	23.8	22.0	18.6	15.9	15.1	14.3	24.5	22.7	19.1	16.3	15.5	14.8
OM&R	3.1	2.9	2.4	2.1	2.0	1.9	4.0	4.6	5.0	5.5	6.6	8.0
Total	26.9	24.9	21.0	18.0	17.1	16.2	28.5	27.3	24.1	21.8	22.1	22.8
Treatment plant												
Capital	30.2	27.9	33.1	28.3	26.9	25.6	46.0	42.5	35.8	30.6	29.1	27.7
OM&R	19.6	18.7	19.1	17.3	16.8	16.3	28.5	34.5	39.5	45.9	56.8	70.5
Total	49.8	46.6	52.2	45.6	43.7	41.9	74.5	77.0	75.3	76.5	85.9	98.2
Groundwater collection												
Capital	6.1	5.6	4.7	4.0	3.8	3.6	7.1	6.6	5.6	4.7	4.5	4.3
OM&R	0.4	0.4	0.3	0.3	0.3	0.3	0.6	0.6	0.7	0.8	1.0	1.1
Total	6.5	6.0	5.0	4.3	4.1	3.9	7.7	7.2	6.3	5.5	5.5	5.4
Well fields												
Capital	3.8	3.5	2.9	2.5	2.4	2.3	3.8	3.5	2.9	2.5	2.4	2.3
OM&R	0.7	0.7	0.6	0.5	0.5	0.4	0.9	1.1	1.2	1.3	1.6	1.9
Total	4.5	4.2	3.5	3.0	2.9	2.7	4.7	4.6	4.1	3.8	4.0	4.2
Total system												
Capital	102.7	94.9	89.5	76.4	72.7	69.2	128.0	118.4	99.8	85.1	80.9	77.1
OM&R	28.5	27.6	28.2	27.4	27.2	26.7	38.6	48.2	56.7	69.4	87.0	109.6
Total	131.2	122.5	117.7	103.8	99.9	95.9	166.6	166.6	156.5	154.5	167.9	186.7

with 0% inflation. The unit cost of 92.2 ¢/1000 gal is higher than the 78 ¢/1000 gal cost of treated deep sandstone water at Aurora and the 75 to 78 ¢/1000 gal marginal cost of supplying water to Aurora from the Fox River system. With 5% inflation, shallow groundwater is still the most expensive supply option for Aurora. In addition, importing shallow water, especially from Kendall County, is legally and politically uncertain. If only the portion of the aquifer in Kane County is developed, the potential yield is 2 mgd and Sugar Grove, as well as rural residents near the well field, would probably have serious objections. Thus, importing shallow groundwater to meet a part of Aurora water demand appears to be impractical.

Kankakee River Supply System

Fifteen system configurations serving 2 to 23 user entities with 9.96 to 91.80 mgd of Kankakee River water are given in the section on preliminary studies of regional supply systems. From discussions with Division of Water Resources and Will County personnel, it was decided to 1) keep the Kankakee River systems entirely within Will County, 2) optimize moderate sized systems, and 3) locate the river intake upstream of the existing dam in the Kankakee River at Wilmington. Locating the intake upstream from the dam at Wilmington eliminates the need to build a new diversion structure. Since Wilmington has considered using the river for water supply, this town will be included on the system. Channahon and Shorewood, as well as Plainfield, are considered for inclusion on the system because they are dependent on deep wells for water supply. Frankfort, Mokena, and New Lenox can meet their 2010 demands with water from the Silurian dolomite aquifer. However, this water is highly mineralized and the Kankakee River is the nearest source of better quality water.

Three systems, A, B, and C, which supply 4, 7, or 10 towns are considered for optimization. Town and system demands for the years 1985, 1990, 1995, 2000, 2005, and 2010 are given in table 55. Supply systems with the Kankakee River as the only source are indicated by subscript 1, and systems with Kankakee River water and 6 mgd of groundwater from the Hadley Valley sand and gravel aquifer are indicated by subscript 2. The 6 mgd of groundwater from the Hadley Valley aquifer will be treated so that it is chemically compatible with the Kankakee River water with which it will be commingled in the Joliet distribution system. Pipeline length, static head, cost multiplier, and diameter are shown in figure 44 for this groundwater system. Wells 1 to 5 are new wells as recommended in Water Survey Report of Investigation 47 (Prickett et al., 1964). The other 5 wells (numbers 10 to 14) are existing wells, owned by the city of Joliet. With 0% inflation, the capital requirements in 1985 for the groundwater system are: wells and pumps, $224,000; collection system, $4,026,000; treatment plant, $4,863,000; and total, $9,113,000. With 5% inflation, the 1985 capital requirements are: wells and pumps, $286,000; collection system, $4,696,000; treatment plant, $5,992,000; and total, $10,974,000. The unit cost of this groundwater is given in table 56 for 0 and 5% inflation rates.

Table 55. Kankakee River System Water Demands

A. Water demands

	Demand in mgd in year					
Town	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
Channahon	0.69	0.72	0.80	0.87	0.90	0.92
Frankfort	0.57	0.65	0.85	1.04	1.13	1.22
Joliet	10.67	11.41	12.99	14.57	15.19	15.81
Lockport	1.08	1.15	1.30	1.45	1.59	1.73
Mokena	0.33	0.43	0.65	0.87	0.96	1.05
New Lenox	0.59	0.76	1.12	1.49	1.63	1.77
Plainfleld	0.56	0.62	0.72	0.82	0.85	0.87
Rockdale	0.37	0.37	0.39	0.41	0.43	0.44
Shorewood	0.44	0.51	0.63	0.75	0.80	0.84
Wilmington	0.49	0.52	0.58	0.64	0.66	0.68

B. System demands

System A serves Joliet, Lockport, Rockdale, and Wilmington						
A_1	12.61	13.45	15.26	17.07	17.87	18.66
A_2	6.61	7.45	9.26	11.07	11.87	12.66
System B serves Channahon, Plainfield, and Shorewood in addition to system A towns						
B_1	14.30	15.30	17.41	19.51	20.42	21.29
B_2	8.30	9.30	11.41	13.51	14.42	15.29
System C serves Frankfort, Mokena, and New Lenox in addition to system B towns						
C_1	15.79	17.14	20.03	22.91	24.14	25.33
C_2	9.79	11.14	14.03	16.91	18.14	19.33

Subscript 1 denotes systems supplied entirely from the Kankakee River.

Subscript 2 denotes systems with 6 mgd shallow groundwater from Joliet area.

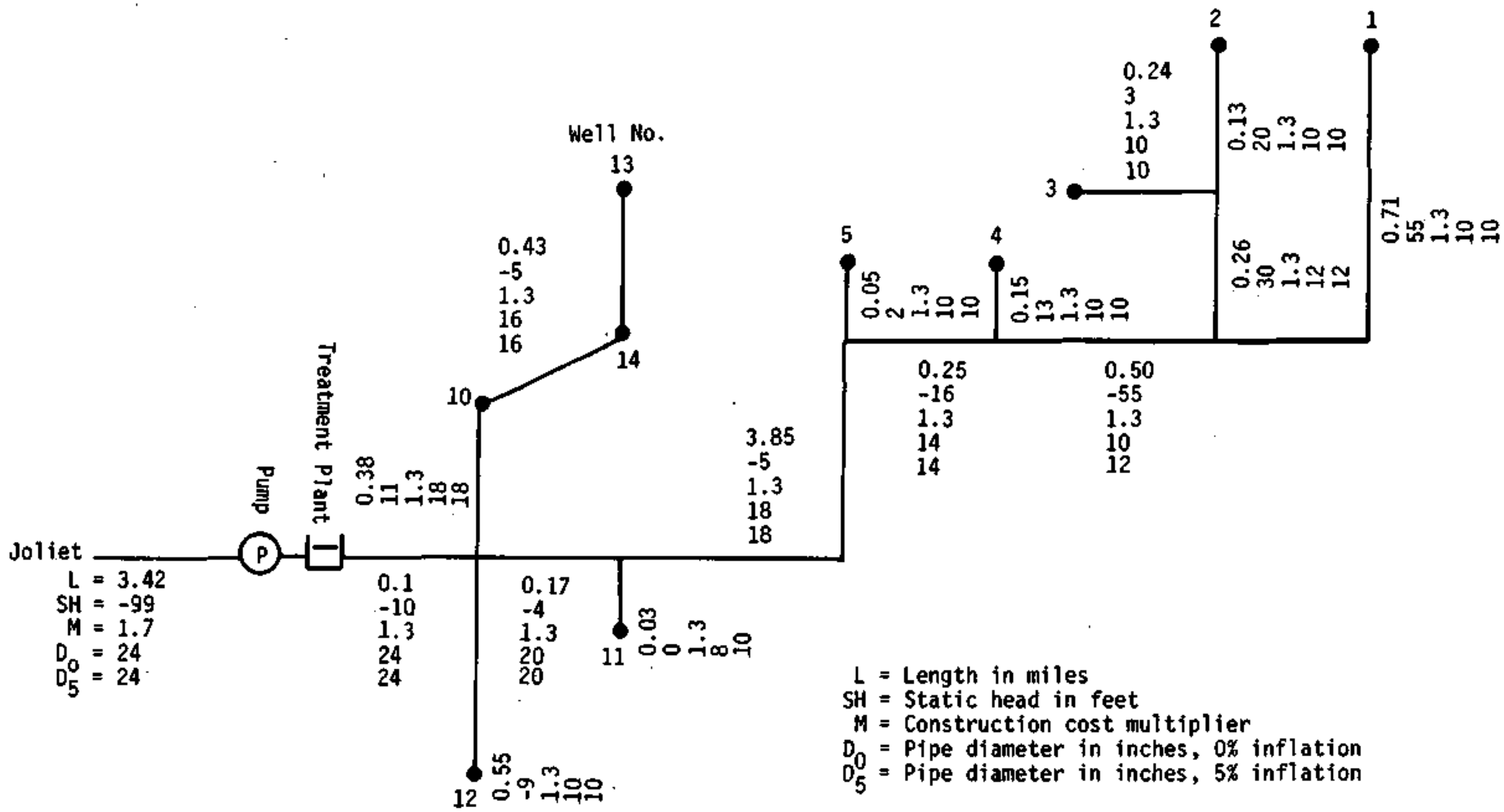


Figure 44. Groundwater collection system for the Hadley Valley wells

Table 56. Unit Cost in 0/1000 gal of 6 mgd of Groundwater from the Hadley Valley for Joliet

	Unit cost in ¢/1000 gal in the year					
	1985	*1990*	*1995*	*2000*	*2005*	*2010*
A. 0% inflation						
Groundwater collection						
Capital	15.0	15.0	15.0	15.0	15.0	15.0
OM&R	0.8	0.8	0.8	0.8	0.8	0.8
Total	15.8	15.8	15.8	15.8	15.8	15.8
Well fields						
Capital	1.9	1.9	1.9	1.9	1.9	1.9
OM&R	0.9	0.9	0.9	0.9	0.9	0.9
Total	2.8	2.8	2.8	2.8	2.8	2.8
Groundwater treatment						
Capital	19.7	19.7	19.7	19.7	19.7	19.7
OM&R	28.7	28.7	28.7	28.7	28.7	28.7
Total	48.4	48.4	48.4	48.4	48.4	48.4
Total						
Capital	36.6	36.6	36.6	36.6	36.6	36.6
OM&R	30.4	30.4	30.4	30.4	30.4	30.4
Total	67.0	67.0	67.0	67.0	67.0	67.0
B. 5% inflation						
Groundwater collection						
Capital	17.5	17.5	17.5	17.5	17.5	17.5
OM&R	1.1	1.4	1.7	2.2	2.8	3.6
Total	18.6	18.9	19.2	19.7	20.3	21.1
Well fields						
Capital	2.5	2.5	2.5	2.5	2.5	2.5
OM&R	1.3	1.7	2.2	2.7	3.5	4.5
Total	3.8	4.2	4.7	5.2	6.0	7.0
Groundwater treatment						
Capital	24.3	24.3	24.3	24.3	24.3	24.3
OM&R	36.6	46.7	59.7	76.1	97.2	124.0
Total	60.9	71.0	84.0	100.4	121.5	148.3
Total						
Capital	44.3	44.3	44.3	44.3	44.3	44.3
OM&R	39.0	49.8	63.6	81.0	103.5	132.1
Total	83.3	94.1	107.9	125.3	147.8	176.4

The water from the Kankakee River will be pumped from an intake structure upstream of the dam at Wilmington to a reservoir to provide storage for meeting 1.2 times the average demand during low river flow periods. The treatment plant will be adjacent to the reservoir. From the treatment plant the water transmission main follows Illinois Route 53 to Interstate 80 in the southern part of Joliet. From there the water is transported along state or federal highways to one delivery point in each town. A separate transmission main will connect with the Wilmington water distribution system.

System A

Systems A_1 and A_2 serve Joliet, Lockport, Rockdale, and Wilmington. Kankakee River water requirements range from 12.61 to 18.66 mgd for A_1 and from 6.61 to 12.66 mgd for A_2 over the period 1985 to 2010. Pipeline length, static head, cost multiplier, and diameter are shown for both the water collection and conveyance systems in figure 45. The reservoir storage and surface area for system A_1 are 2270 ac-ft and 190 acres and for system A_2 they are 1540 ac-ft and 140 acres, respectively. Capital requirements are given in table 57A for system A_1 and in table 57B for system A_2. Unit costs of each component of the system are in table 58 for system A_1 and in table 59 for system A_2. The unit costs for the total system in table 59 (as well as in similar tables for systems B_2 and C_2) are weighted sums of the costs of river water and groundwater. For example, with 0% inflation, the total unit cost in 1985 is computed as:

$$[(154.4 \times 6.61) + (67.0 \times 6.00)]/(6.61 + 6.00) = 112.8 \text{ ¢/1000 gal}$$

From 1985 to 2010 the installed horsepower increases from 2151 to 5972 for system A_1 with 0% inflation, from 1248 to 3115 for system A_1 with 5% inflation, from 1019 to 4580 for system A_2 with 0% inflation, and from 921 to 3976 for system A_2 with 5% inflation.

System B

Systems B_1 and B_2 serve 7 towns including Channahon, Plainfield, and Shorewood as well as the 4 towns served by systems A_1 and A_2. Total river water demands vary from 14.30 to 21.29 for system B_1 and from 8.30 to 15.29 mgd for system B_2 over the period 1985 to 2010. Channahon, Plainfield, and Shorewood will use local groundwater, mostly from the deep sandstone aquifer, if they are not on the Kankakee River supply system. Pipeline length, static head, construction cost multiplier, and diameter for systems B_1 and B_2 are given in figure 46. The reservoir storage and surface area for system B_1 are 2590 ac-ft and 210 acres and for system B_2 they are 1860 ac-ft and 160 acres, respectively. The capital required in 1985 for systems B_1 and B_2 is given in table 60. Unit costs are given in table 61 for system B_1 and in table 62 for system B_2. From 1985 to 2010 the installed horsepower increases from 1757 to 4927 for system B_1 with 0% inflation, from 1683 to 4771 for system B_1 with 5% inflation, from 1179 to 4890 for system B_2 with 0% inflation, and from 1096 to 4710 for system B_2 with 5% inflation.

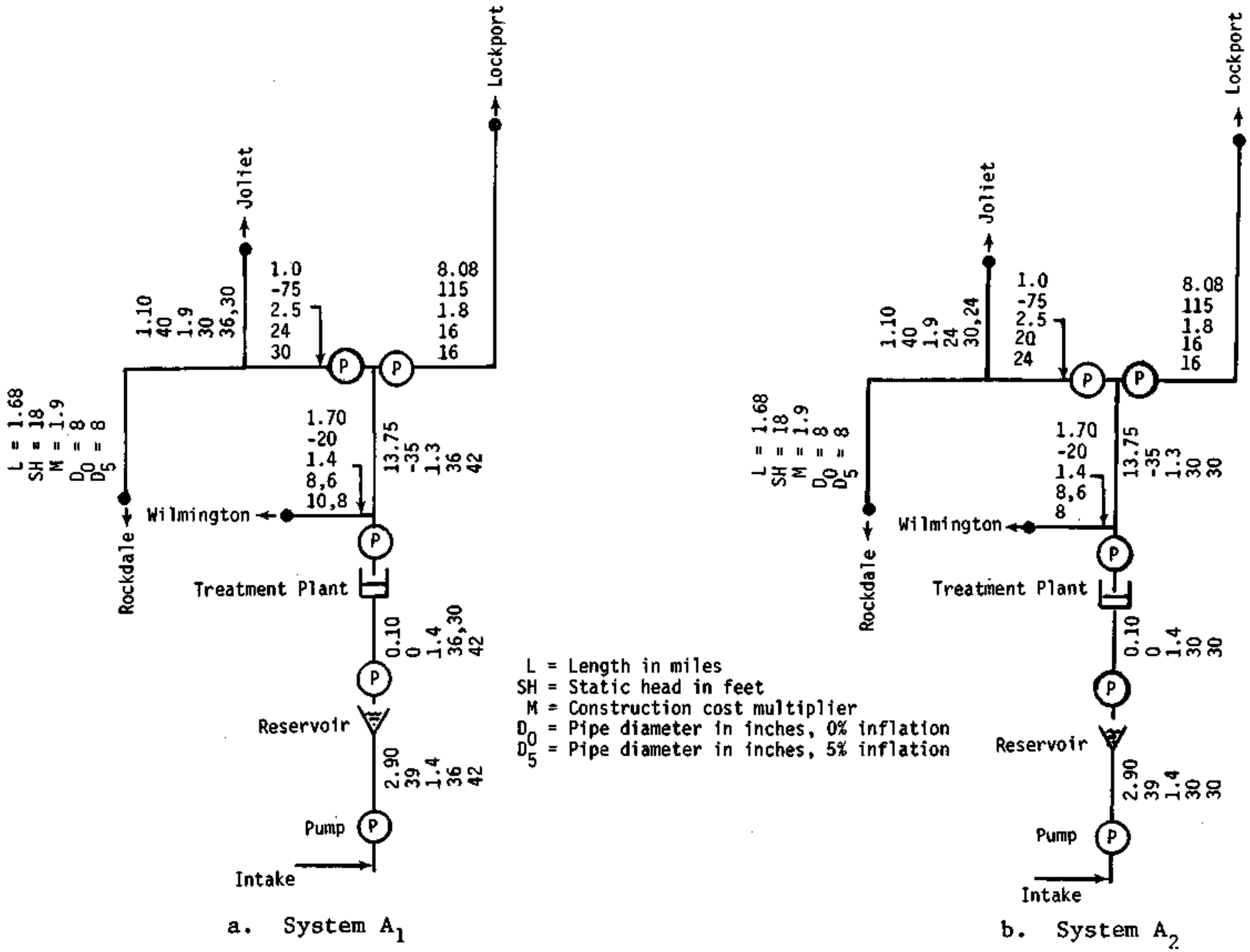


Figure 45. Kankakee River conveyance systems A

Table 57. Accumulated Capital Costs in 1985: Kankakee River Systems A_1 and A_2

System Components	1985 Capital cost, in millions of dollars, with inflation rate of 0%	5%
A. System A_1		
Conveyance system	22.352	28.835
Reservoir		
Structure	3.328	3.799
Land	2.887	2.887
Total	6.215	6.686
Treatment plant[1]	15.918	22.951
Total	44.485	58.472
B. System A_2		
Conveyance system	18.602	22.139
Reservoir		
Structure	2.638	3.018
Land	2.060	2.060
Total	4.698	5.078
Treatment plant[2]	11.038	16.950
Groundwater system	9.113	10.974
Total	43.451	55.141

Notes:

[1] 15.26 mgd plant to meet 1995 demand built by 1985; another plant with 3.40 mgd supply capacity to be added by 1995 at a cost of $5.693 million with 0% inflation rate. With 5% inflation, an 18.66 mgd supply capacity plant is built by 1985.

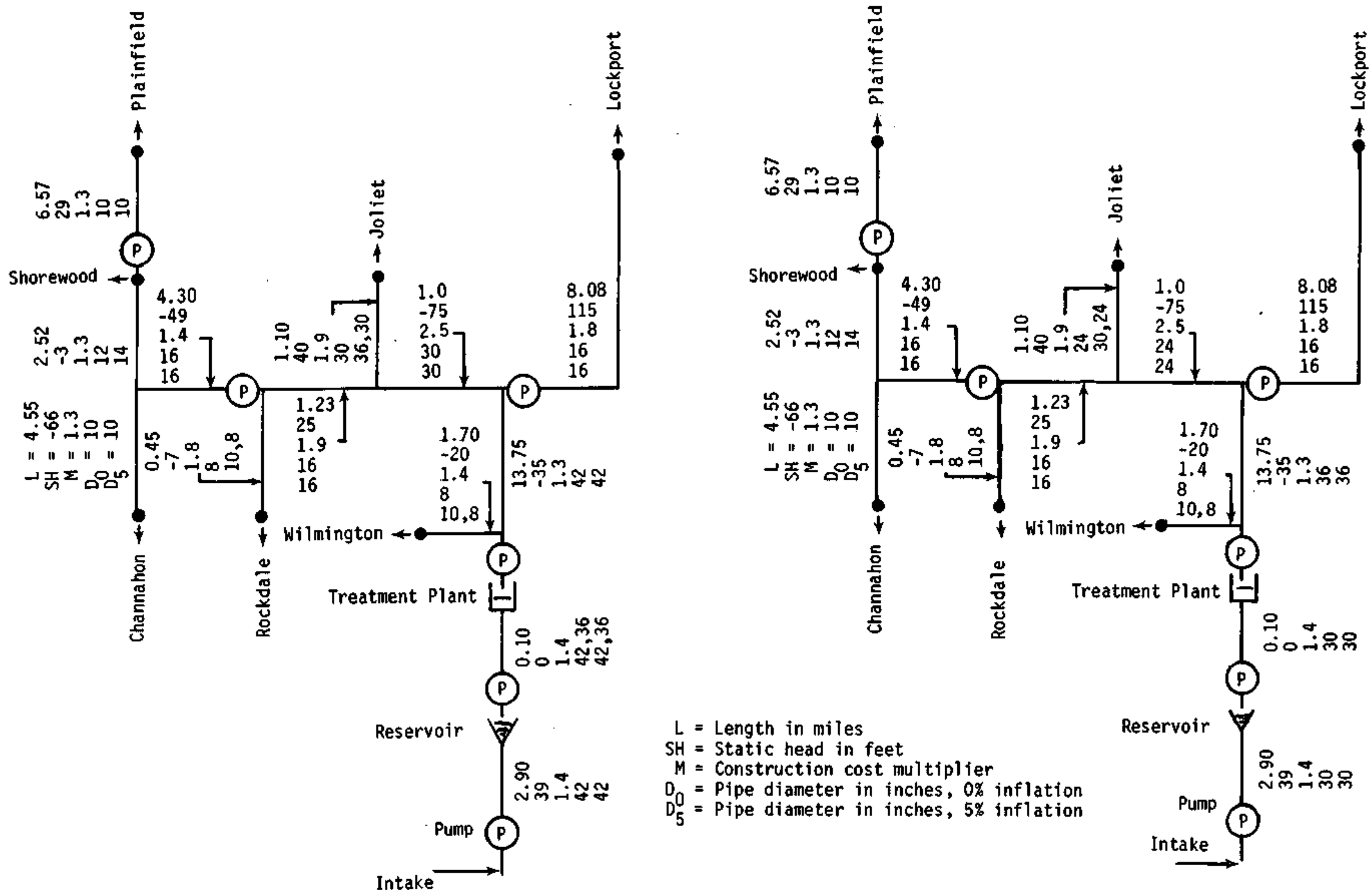
[2] 9.26 mgd plant to meet 1995 demand built by 1985; another plant with 3.40 mgd supply capacity to be added by 1995 at a cost of $5.693 million with 0% inflation rate. With 5% inflation a 12.66 mgd supply capacity plant is built by 1985.

Table 58. Unit Cost of Water: Kankakee River System A_1
(Interest rate 8%)

System components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
	Unit cost in ¢/1000 gal in the year					
A. With inflation rate of 0%						
Coveyance system						
Capital	40.0	37.7	33.4	30.6	29.3	28.2
OM&R	4.4	4.6	5.3	6.0	6.3	6.7
Total	44.4	42.3	38.7	36.6	35.6	34.9
Reservoir						
Capital	11.0	10.3	9.1	8.1	7.8	7.5
OM&R	2.6	2.5	2.2	2.0	1.8	1.7
Total	13.6	12.8	11.3	10.1	9.6	9.2
Treatment plant						
Capital	30.7	28.8	34.4	30.8	29.4	28.2
OM&R	20.1	19.3	19.5	18.2	17.7	17.3
Total	50.8	48.1	53.9	49.0	47.1	45.5
Total system						
Capital	81.7	76.8	76.9	69.5	66.5	63.9
OM&R	27.1	26.4	27.0	26.2	25.8	25.7
Total	108.8	103.2	103.9	95.7	92.3	89.6
B. With inflation rate of 5%						
Conveyance system						
Capital	51.5	48.3	42.8	38.6	37.2	35.9
OM&R	4.0	5.2	7.0	9.7	13.0	17.3
Total	55.5	53.5	49.8	48.3	50.2	53.2
Reservoir						
Capital	11.9	11.1	9.8	8.8	8.4	8.0
OM&R	3.5	4.2	4.7	5.4	6.6	8.1
Total	15.4	15.3	14.5	14.2	15.0	16.1
Treatment plant						
Capital	44.3	41.5	36.6	32.7	31.2	29.9
OM&R	28.1	34.4	40.5	48.3	59.9	74.6
Total	72.4	75.9	77.1	81.0	91.1	104.5
Total system						
Capital	107.7	100.9	89.2	80.1	76.8	73.8
OM&R	35.6	43.8	52.2	63.4	79.5	100.0
Total	143.3	144.7	141.4	143.5	156.3	173.8

Table 59. Unit Cost of Water: Kankakee River System A_2

System components	*0% inflation*						*5% inflation*					
	Unit coat in ¢/1000 gal in the year						*Unit cost in ¢/1000 gal in the year*					
	1985	*1990*	*1995*	*2000*	*2005*	*2010*	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
Conveyance system												
Capital	63.5	56.5	45.7	39.3	36.9	34.8	75.6	67.3	54.7	46.7	44.7	42.8
OM&R	5.0	5.2	5.6	6.7	7.2	7.8	6.0	8.1	10.9	16.5	22.1	30.0
Total	68.5	61.7	51.3	46.0	44.1	42.6	81.6	75.4	65.6	63.2	66.8	72.8
Reservoir												
Capital	15.9	14.1	11.4	9.5	9.1	8.7	17.2	15.3	12.3	10.3	9.6	9.0
OM&R	4.0	3.6	3.2	2.4	2.0	1.7	5.4	6.2	6.3	6.8	8.0	9.6
Total	19.9	17.7	14.6	11.9	11.1	10.4	22.6	21.5	18.6	17.1	17.6	18.6
Treatment plant												
Capital	40.6	36.0	43.9	36.8	34.3	32.1	62.4	55.3	44.5	37.2	34.7	32.6
OM&R	25.4	23.3	22.6	20.1	19.2	18.5	37.2	43.4	47.1	53.3	65.2	80.0
Total	66.0	59.3	66.5	56.9	53.5	50.6	99.6	98.7	91.6	90.5	99.9	112.6
Total, river water												
Capital	120.0	106.6	101.0	85.6	80.3	75.6	155.2	137.9	111.5	94.2	89.0	84.4
OM&R	34.4	32.1	31.4	29.2	28.4	28.0	48.6	57.7	64.3	76.6	95.3	119.6
Total	154.4	138.7	132.4	114.8	108.7	103.6	203.8	195.6	175.8	170.8	184.3	204.0
Total, groundwater												
Capital	36.6	36.6	36.6	36.6	36.6	36.6	44.3	44.3	44.3	44.3	44.3	44.3
OM&R	30.4	30.4	30.4	30.4	30.4	30.4	39.0	49.8	63.6	81.0	103.5	132.1
Total	67.0	67.0	67.0	67.0	67.0	67.0	83.3	94.1	107.9	125.3	147.8	176.4
Total system												
Capital	80.3	75.4	75.7	68.4	65.6	63.1	102.4	96.1	85.1	76.7	74.0	71.5
OM&R	32.5	31.3	31.0	29.6	29.1	28.8	44.0	54.2	64.0	78.1	98.1	123.6
Total	112.8	106.7	106.7	98.0	94.7	91.9	146.4	150.3	149.1	154.8	172.1	195.1



a. System B_1 b. System B_2

Figure 46. Kankakee River conveyance systems B

Table 60. Accumulated Capital Costs in 1985
Kankakee River Systems B_1 and B_2

System Components	*1985 Capital cost, in millions of dollars, with inflation vote of* 0%	5%
A. System B_1		
Conveyance system	29.825	35.181
Reservoir		
Structure	3.647	4.114
Land	3.237	3.237
Total	6.884	7.351
Treatment plant[1]	17.645	25.452
Total	54.354	67.984
B. System B_2		
Conveyance system	25.947	30.598
Reservoir		
Structure	2.951	3.374
Land	2.427	2.427
Total	5.378	5.801
Treatment plant[2]	12.731	19.643
Groundwater system	9.113	10.974
Total	53.169	67.016

Notes:

[1]17.41 mgd plant to meet 1995 demand built by 1985; another plant with 3.88 mgd supply capacity to be added by 1995 at a cost of $6.203 million with 0% inflation rate. With 5% inflation a 21.29 mgd supply capacity is built by 1985.

[2]11.41 mgd plant to meet 1995 demand built by 1985; another plant with 3.88 mgd supply capacity to be added by 1995 at a cost of $6.203 million with 0% inflation rate. With 5% inflation, a 15.29 mgd supply capacity plant is built in 1985.

Table 61. Unit Cost of Water: Kankakee River System B_1

System components	*Unit cost in ¢/1000 gal in the year* 1985	1990	1995	2000	2005	2010
A. Inflation rate of 0%						
Conveyance system						
Capital	47.0	44.0	38.9	34.9	33.4	32.2
OM&R	3.6	3.8	4.2	4.7	4.9	5.2
Total	50.6	47.8	43.1	39.6	38.3	37.4
Reservoir						
Capital	12.5	11.7	10.3	9.2	8.7	8.4
OM&R	2.8	2.6	2.3	2.0	2.0	1.9
Total	15.3	14.3	12.6	11.2	10.7	10.3
Treatment plant						
Capital	30.0	28.1	33.3	29.7	28.4	27.2
OM&R	19.7	18.9	19.1	17.8	17.4	16.9
Total	49.7	47.0	52.4	47.5	45.8	44.1
Total system						
Capital	89.5	83.8	82.5	73.8	70.5	67.8
OM&R	26.1	25.3	25.6	24.5	24.3	24.0
Total	115.6	109.1	108.1	98.3	94.8	91.8
B. Inflation rate of 5%						
Conveyance system						
Capital	55.4	51.9	46.0	41.6	40.1	38.8
OM&R	4.5	6.0	8.5	12.3	16.4	22.0
Total	59.9	57.9	54.5	53.9	56.5	60.8
Reservoir						
Capital	13.4	12.5	11.0	9.8	9.4	9.0
OM&R	3.8	4.5	5.0	5.7	7.0	8.6
Total	17.2	17.0	16.0	15.5	16.4	17.6
Treatment plant						
Capital	43.3	40.5	35.6	31.7	30.3	29.1
OM&R	27.6	33.8	39.6	47.3	58.8	73.2
Total	70.9	74.3	75.2	79.0	89.1	102.3
Total system						
Capital	112.1	104.9	92.6	83.1	79.8	76.9
OM&R	35.9	44.3	53.1	65.3	82.2	103.8
Total	148.0	149.2	145.7	148.4	162.0	180.7

Table 62. Unit Cost of Water: Kankakee River System B_2

System components	0% inflation: Unit cost in ¢/1000 gal in the year 1985	1990	1995	2000	2005	2010	5% inflation: Unit cost in ¢/1000 gal in the year 1985	1990	1995	2000	2005	2010
Conveyance system												
Capital	70.5	63.0	51.7	44.0	41.4	39.2	83.1	74.4	61.3	52.7	49.9	47.8
OM&R	4.8	4.8	5.2	6.1	6.5	7.0	5.8	7.6	10.8	16.0	21.7	29.5
Total	75.3	67.8	56.9	50.1	47.9	46.2	88.9	82.0	72.1	68.7	71.6	77.3
Reservoir												
Capital	14.5	12.9	10.5	8.9	8.3	7.9	15.6	14.0	11.4	9.6	9.0	8.5
OM&R	3.5	3.2	2.6	2.2	2.0	1.9	4.8	5.5	5.7	6.1	7.3	8.8
Total	18.0	16.1	13.1	11.1	10.3	9.8	20.4	19.5	17.1	15.7	16.3	17.3
Treatment plant												
Capital	37.3	33.3	40.4	34.1	31.9	30.1	57.6	51.4	41.9	35.4	33.1	31.2
OM&R	23.4	21.6	21.4	19.3	18.5	17.9	34.3	40.2	44.5	51.1	62.7	77.2
Total	60.7	54.9	61.8	53.4	50.4	48.0	91.9	91.6	86.4	86.5	95.8	108.4
Total, river water												
Capital	122.3	109.2	102.6	87.0	81.6	77.2	156.3	139.8	114.6	97.7	92.0	87.5
OM&R	31.7	29.6	29.2	27.6	27.0	26.8	44.9	53.3	61.0	73.2	91.7	115.5
Total	154.0	138.8	131.8	114.6	108.6	104.0	201.2	193.1	175.6	170.9	183.7	203.0
Total, groundwater												
Capital	36.6	36.6	36.6	36.6	36.6	36.6	44.3	44.3	44.3	44.3	44.3	44.3
OM&R	30.4	30.4	30.4	30.4	30.4	30.4	39.0	49.8	63.6	81.0	103.5	132.1
Total	67.0	67.0	67.0	67.0	67.0	67.0	83.3	94.1	107.9	125.3	147.8	176.4
Total system												
Capital	86.3	80.7	79.9	71.5	68.4	65.8	109.3	102.3	90.4	81.3	78.0	75.3
OM&R	31.2	29.9	29.6	28.5	28.0	27.8	42.4	51.9	61.9	75.6	95.2	120.2
Total	117.5	110.6	109.5	100.0	96.4	93.6	151.7	154.2	152.3	156.9	173.2	195.5

System C

Systems C_1 and C_2 supply 10 towns including Frankfort, Mokena, and New Lenox as well as the 7 towns on systems B_1 and B_2. Total river water demand ranges from 15.79 to 25.33 mgd for system C_1 and from 9.79 to 19.33 mgd for system C_2 over the period 1985 to 2010. Frankfort, Mokena, and New Lenox will obtain their water supply from the Silurian dolomite aquifer if they are not on the Kankakee River system. Pipeline data for systems C_1 and C_2 are given in figure 47. The reservoir storage and surface area for system C_1 are 3080 ac-ft and 250 acres and for system C_2 they are 2350 ac-ft and 200 acres, respectively. The capital required in 1985 for systems C_1 and C_2 is given in table 63. Unit costs are given for system C_1 in table 64 and for system C_2 in table 65. From 1985 to 2010 the installed horsepower increases from 2317 to 7790 for system C_1 with 0% inflation, from 2151 to 7272 for system C_1 with 5% inflation, from 1574 to 7518 for system C_2 with 0% inflation, and from 1431 to 6919 for system C_2 with 5% inflation.

Comparative unit costs

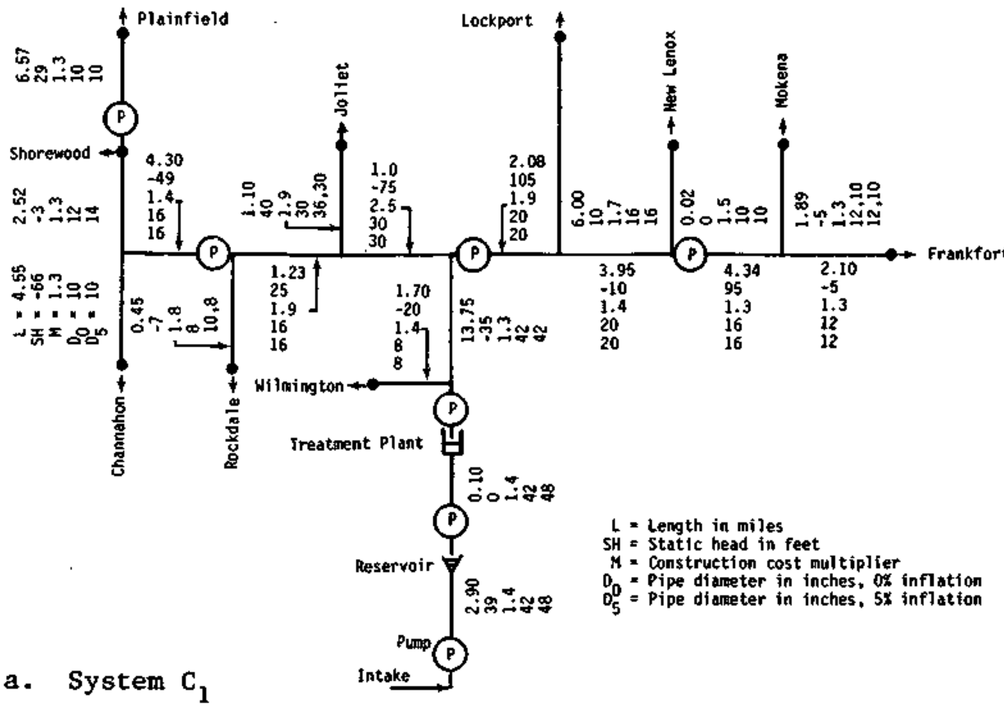
Total system unit costs are summarized in table 66 for each system and with both 0 and 5% inflation rates. Comparison of subscript 1 with subscript 2 for systems A, B, and C shows that the unit cost of the subscript 1 system is lower than the unit cost of the same system with subscript 2 in all three cases. The unit cost difference is between 1 and 4 ¢/1000 gal with 0% inflation and between 3 and 21 ¢/1000 gal with 5% inflation. Thus, economics supports the construction of a system using the Kankakee River as the only source of supply over a system with conjunctive use of the Hadley Valley groundwater and river water.

The marginal cost of providing water to additional towns can be used to choose the more economical system: A_1 or B_1, A_2 or B_2, B_1 or C_1, B_2 or C_2. The marginal cost of supplying water to the additional towns is compared with the weighted average cost of local groundwater supplies for these towns. The first part of table 66A and 66B gives the system demands and the increase in demand between the smaller and larger system. Marginal cost computations are best explained by a sample calculation. The marginal cost of supplying 1.69 mgd more water in system B_1 than is supplied in system A_1 for 0% inflation in 1985 is:

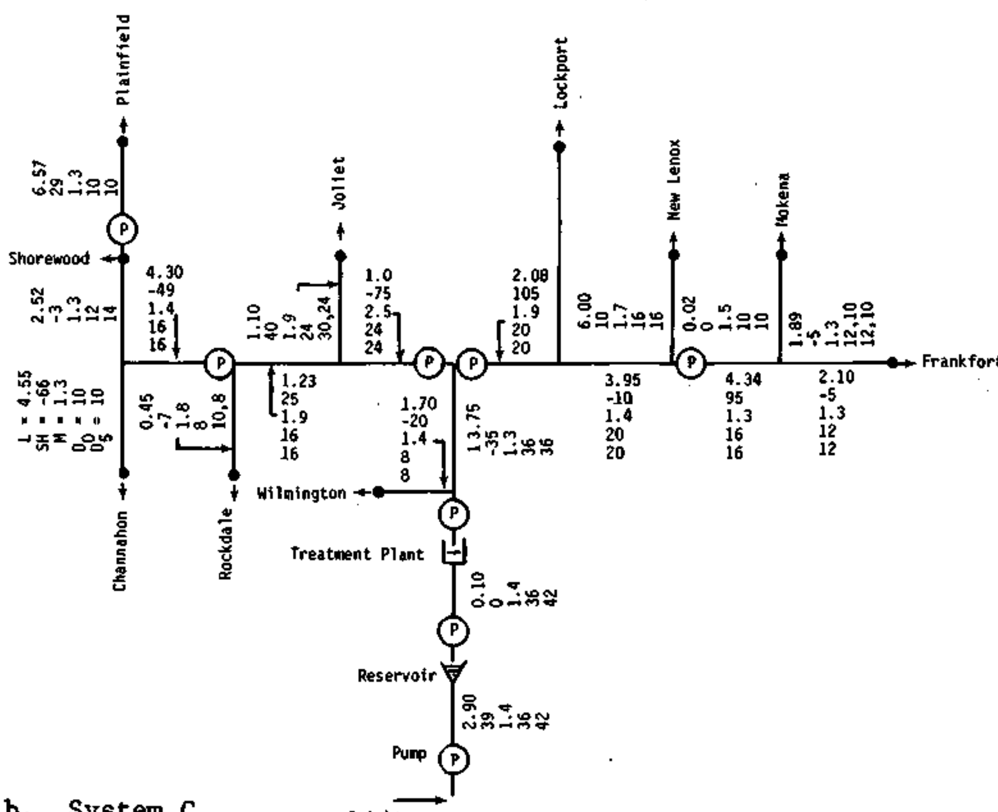
$$[(115.6 \times 14.30) - (108.8 \times 12.61)]/1.69 = 166.3 \text{ ¢/1000 gal}$$

The marginal cost of supplying Channahon, Plainfield, and Shorewood (with B_1 instead of A_1, or B_2 instead of A_2) is less than the alternative cost of local groundwater supplies. Thus, it will be economical to supply these three towns from system B_1 because the unit cost of water from B_1 is less than that from B_2.

The marginal cost of supplying water to Frankfort, Mokena, and New Lenox is lower in the first half and higher in the second half of the 25-year period than the alternative cost with 0% inflation; but is higher in the first half and lower in the second half than the alternative cost with 5% inflation.



a. System C_1



b. System C_2

Figure 47. Kankakee River conveyance systems C

Table 63. Accumulated Capital Costs in 1985: Kankakee River System C_1 and C_2

System Components	*1985 Capital cost, in millions of dollars, with inflation rate of* 0%	5%
A. System C_1		
Conveyance system	35.239	41.966
Reservoir		
Structure	4.012	4.571
Land	3.764	3.764
Total	7.776	8.335
Treatment plant[1]	19.687	29.357
Total	62.702	79.658
B. System C_2		
Conveyance system	31.536	37.592
Reservoir		
Structure	3.399	3.879
Land	2.975	2.975
Total	6.374	6.854
Treatment plant[2]	14.907	23.592
Groundwater system	9.113	10.974
Total	61.930	79.012

Notes:

[1]20.03 mgd plant to meet 1995 demand built by 1985; another plant with 5.30 mgd supply capacity to be added by 1995 at a cost of $7.597 million with 0% inflation rate. With 5% inflation, a 25.33 mgd supply capacity plant is built by 1985.

[2]14.03 mgd plant to meet 1995 demand built by 1985; another plant with 5.30 mgd supply capacity to be added by 1995 at a cost of $7.597 million with 0% inflation rate. With 5% inflation, a 19.33 mgd supply capacity plant is built by 1985.

Table 64. Unit Cost of Water: Kankakee River System C_1

System components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
	Unit cost in ¢/1000 gal in the year					
A. Inflation rate of 0%						
Conveyance system						
Capital	50.4	46.5	40.1	35.3	33.7	32.3
OM&R	4.2	4.5	5.1	5.9	6.3	6.7
Total	54.6	51.0	45.2	41.2	40.0	39.0
Reservoir						
Capital	13.2	12.2	10.4	9.1	8.6	8.2
OM&R	2.9	2.6	2.3	2.0	1.9	1.8
Total	16.1	14.8	12.7	11.1	10.5	10.0
Treatment plant						
Capital	30.3	27.9	33.1	29.0	27.5	26.2
OM&R	19.7	18.7	19.0	17.5	17.0	16.5
Total	50.0	46.6	52.1	46.5	44.5	42.7
Total system						
Capital	93.9	86.6	83.6	73.4	69.8	66.7
OM&R	26.8	25.8	26.4	25.4	25.2	25.0
Total	120.7	112.4	110.0	98.8	95.0	91.7
B. Inflation rate of 5%						
Conveyance system						
Capital	60.0	55.4	48.0	42.7	41.0	39.7
OM&R	5.2	7.0	10.2	15.0	20.4	27.7
Total	65.2	62.4	58.2	57.7	61.4	67.4
Reservoir						
Capital	14.1	13.0	11.1	9.7	9.2	8.8
OM&R	3.9	4.6	5.0	5.6	6.8	8.2
Total	18.0	17.6	16.1	15.3	16.0	17.0
Treatment plant						
Capital	45.2	41.7	35.6	31.2	29.6	28.2
OM&R	28.3	34.2	39.5	46.5	57.6	71.5
Total	73.5	75.9	75.1	77.7	87.2	99.7
Total system						
Capital	119.3	110.1	94.7	83.6	79.8	76.7
OM&R	37.4	45.8	54.7	67.1	84.8	107.4
Total	156.7	155.9	149.4	150.7	164.6	184.1

Table 65. Unit Cost of Water: Kankakee River System C_2

	0% inflation						5% inflation					
	Unit cost in ¢/1000 gal in the year						*Unit cost in ¢/1000 gal in the year*					
System components	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*	*1985*	*1990*	*1995*	*2000*	*2005*	*2010*
Conveyance system												
Capital	72.7	64.1	51.3	43.0	40.5	38.3	86.6	76.4	61.4	52.1	49.8	47.7
OM&R	5.3	5.4	6.1	7.3	7.8	8.4	6.4	8.4	12.2	18.3	25.2	34.4
Total	78.0	69.5	57.4	50.3	48.3	46.7	93.0	84.8	73.6	70.4	75.0	82.1
Reservoir												
Capital	14.6	12.8	10.2	8.4	7.9	7.4	15.7	13.8	11.0	9.1	8.5	8.0
OM&R	3.4	3.0	2.4	2.0	1.8	1.7	4.6	5.2	5.2	5.5	6.6	7.9
Total	18.0	15.8	12.6	10.4	9.7	9.1	20.3	19.0	16.2	14.6	15.1	15.9
Treatment plant												
Capital	37.0	32.5	39.0	32.4	30.2	28.3	58.6	51.5	40.9	33.9	31.6	29.7
OM&R	22.8	20.9	20.9	18.6	17.8	17.2	34.1	39.7	43.5	49.3	60.3	74.2
Total	59.8	53.4	59.9	51.0	48.0	45.5	92.7	91.2	84.4	83.2	91.9	103.9
Total, river water												
Capital	124.3	109.4	100.5	83.8	78.6	74.0	160.9	141.7	113.3	95.1	89.9	85.4
OM&R	31.5	29.3	29.4	27.9	27.4	27.3	45.1	53.3	60.9	73.1	92.1	116.5
Total	155.8	138.7	129.9	111.7	106.0	101.3	206.0	195.0	174.2	168.2	182.0	201.9
Total, groundwater												
Capital	36.6	36.6	36.6	36.6	36.6	36.6	44.3	44.3	44.3	44.3	44.3	44.3
OM&R	30.4	30.4	30.4	30.4	30.4	30.4	39.0	49.8	63.6	81.0	103.5	132.1
Total	67.0	67.0	67.0	67.0	67.0	67.0	83.3	94.1	107.9	125.3	147.8	176.4
Total system												
Capital	91.0	83.9	81.4	71.4	68.2	65.1	116.6	107.6	92.6	81.8	78.6	75.7
OM&R	31.1	29.7	29.7	28.6	28.1	28.0	42.8	52.1	61.7	75.2	94.9	120.2
Total	122.1	113.6	111.1	100.0	96.3	93.1	159.4	159.7	154.3	157.0	173.5	195.9

Table 66. Marginal and Alternative Unit Costs of Water Supply

A. Systems A and B (marginal and alternative costs of supplying Channahon, Plainfield, and Shorewood)

System	*Item*	*Inflation rate, %*	*Unit cost in ¢/1000 gal in year* *1985*	*1990*	*1995*	*2000*	*2005*	*2010*
A	Q_A, mgd	-	12.61	13.45	15.26	17.07	17.87	18.66
B	Q_B, mgd	-	14.30	15.30	17.41	19.51	20.42	21.29
	(Q_B-Q_A), mgd	-	1.69	1.85	2.15	2.44	2.55	2.63
A_1	Unit cost	0	108.8	103.2	103.9	95.7	92.3	89.6
B_1	Unit cost	0	115.6	109.1	108.1	98.3	94.8	91.8
	Marginal cost	0	166.3	152.0	137.9	116.5	112.3	107.4
A_2	Unit cost	0	112.8	106.7	106.7	98.0	94.7	91.9
B_2	Unit cost	0	117.5	110.6	109.5	100.0	96.4	93.6
	Marginal cost	0	152.6	139.0	129.4	114.0	108.3	105.7
	Alternative cost	0	171.6	159.1	140.3	127.2	122.8	120.2
A_1	Unit cost	5	143.3	144.7	141.4	143.5	156.3	173.8
B_1	Unit cost	5	148.0	149.2	145.8	148.4	162.0	180.7
	Marginal cost	5	183.1	181.9	177.0	182.7	201.9	229.7
A_2	Unit cost	5	146.4	150.3	149.1	154.8	172.1	195.1
B_2	Unit cost	5	151.7	154.2	152.3	156.9	173.2	195.5
	Marginal cost	5	191.2	182.6	175.0	171.6	180.9	198.3
	Alternative cost	5	216.1	220.9	221.9	228.9	258.0	298.1

Notes:

Subscript 1 denotes systems supplied entirely from the Kankakee River.

Subscript 2 denotes systems with 6 mgd shallow groundwater from the Joliet area.

Alternative cost is the cost of a local supply of water from the deep sandstone aquifer for Channahon, Plainfield, and Shorewood.

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Table 66. Concluded

B. Systems B anc C (marginal and alternative costs of supplying Frankfort, Mokena, and New Lenox)

System	Item	Inflation rate, %	Unit cost in ¢/1000 gal in year 1985	1990	1995	2000	2005	2010
B	Q_B, mgd	-	14.30	15.30	17.41	19.51	20.42	21.29
C	Q_C, mgd	-	15.79	17.14	20.03	22.91	24.14	25.33
	(Q_C-Q_B), mgd	-	1.49	1.84	2.62	3.40	3.72	4.04
B_1	Unit cost	0	115.6	109.1	108.1	98.3	94.8	91.8
C_1	Unit cost	0	120.7	112.4	110.0	98.8	95.0	91.7
	Marginal cost	0	169.6	139.8	122.6	101.7	96.1	91.2
B_2	Unit cost	0	117.5	110.6	109.5	100.0	96.4	93.6
C_2	Unit cost	0	122.1	113.6	111.1	100.0	96.3	93.1
	Marginal cost	0	166.2	138.5	121.7	100.0	95.8	91.1
	Alternative cost	0	182.5	151.0	111.0	89.3	83.0	77.8
B_1	Unit cost	5	148.0	149.2	145.8	148.4	162.0	180.7
C_1	Unit cost	5	156.7	155.9	149.4	150.7	164.6	184.1
	Marginal cost	5	240.2	211.6	173.3	163.9	178.9	202.0
B_2	Unit cost	5	151.7	154.2	152.3	156.9	173.2	195.5
C_2	Unit cost	5	159.4	159.7	154.3	157.0	173.5	195.9
	Marginal cost	5	233.3	205.4	167.6	157.6	175.1	198.0
	Alternative cost	5	228.3	210.9	177.4	168.3	185.9	210.2

Notes:

Subscript 1 denotes systems supplied entirely from the Kankakee River.

Subscript 2 denotes systems with 6 mgd shallow groundwater from the Joliet area.

Alternative cost is the cost of a local supply of water from the Silurian dolomite aquifer for Frankfort, Mokena, and New Lenox.

There is not much difference when present worths are calculated over the 25-year period. Thus, inclusion of these three towns will depend on the expediency of increased supply from the Kankakee River, abandonment of existing dolomite wells, and the agreement between all the towns to be served by the system.

Economic considerations indicate construction of system B_1 which supplies Kankakee River water to Channahon, Joliet, Lockport, Plainfield, Rockdale, Shorewood, and Wilmington for unit costs which decrease from 115.6 ¢/1000 gal in 1985 to 91.8 ¢/1000 gal in 2010 with 0% inflation. With 5% inflation, the 1985 cost is 148.0 ¢/1000 gal and the 2010 cost is 180.7 ¢/1000 gal. Economic considerations do not determine whether or not the towns of Frankfort, Mokena, and New Lenox should be supplied from the Kankakee River. Water quality requirements may have a significant influence in this decision. Recent Illinois EPA reports list the following water quality parameters for these towns.

		Concentration of constituent in mg/l		
Town	*Year*	*Hardness*	*TDM*	*Iron*
Frankfort	1977	568	620	1.1
Mokena	1977	641	760	1.2
New Lenox	1978	935	1358	1.2

The dolomite aquifer water is highly mineralized, especially at New Lenox which has total dissolved minerals exceeding the 1000 mg/l standard for drinking water. Reverse osmosis is a treatment method to reduce the total mineral content of water. Including chemical costs, estimates from USEPA data yield unit costs with 0% inflation of about 93 ¢/1000 gal for a 1 mgd and 83 ¢/1000 gal for a 2 mgd plant. These unit costs are 10 to 15 ¢/1000 gal more than the unit costs for ion-exchange softening. If reduction in total dissolved minerals is required to meet drinking water standards, economics will probably support construction of system C_1 to supply Kankakee River water to all the 10 towns.

SYSTEMS SUMMARY

Six systems have been developed to furnish surface water to towns with inadequate groundwater resources. Two of the systems use river water and four of the systems use Lake Michigan water, either obtained directly or purchased from the city of Chicago. Preliminary studies of each system considered a wide range of service area, conjunctive use of shallow groundwater, and various sources of water. The unit costs of furnishing water to meet the 2010 demands for a number of configurations for each system were useful in selecting one or more configurations for optimization over the period 1985 to 2010. Information from the Division of Water Resources staff and county representatives was also used in the selection process.

Staged construction of treatment plants, incremental installation of pumping equipment in the system pumping stations, and increase of water demand with time have been considered in system optimization. An interest rate of 8% and inflation rates of either 0 or 5% have been assumed. The construction of reservoirs, intake structures, pipelines, pump station buildings, and well fields has been scheduled so that system operation can begin in July 1985. If inflation is neglected, staging of treatment plant capacity is indicated for most of the systems. With an inflation rate of 5%, staging of treatment plant capacity is not indicated. The diameter of some pipelines in the conveyance networks is one size larger with 5% inflation than with 0% inflation, and the installed horsepower is lower with inflation than without inflation. All cost functions for the system components and subcomponents are in terms of July 1980 dollars.- Inflation in the costs applies to expenditures incurred after that time. The optimal system configurations, for each of the six systems, correspond to one or more of the configurations included in the preliminary studies with the exception of the Kankakee River supply system. Comparison of the unit costs of water supply for the optimal system and the preliminary system with the same configuration can be used as a guide to estimate the unit cost of water for optimal systems corresponding to other configurations in the preliminary study. Unit costs for the case with 0% inflation are given in the following summaries of the six systems. System demands and unit costs are used to show the variation in system capacity and water supply cost for the years 1985 and 2010.

Lake County Supply System

Water from Lake Michigan is supplied to 17 towns, including Buffalo Grove and Wheeling in Cook County. The system demand increases from 17.66 mgd in 1985 to 27.80 mgd in 2010 with corresponding unit costs of 83.9 and 65.6 ¢/1000 gal. Five towns (Hainesville, Hawthorn Woods, Round Lake, Round Lake Beach and Vernon Hills) can develop groundwater from the shallow aquifers to meet their demands, which total 2.85 mgd in 1985 and 5.24 mgd in 2010, at corresponding unit costs of 158.7 and 107.4 ¢/1000 gal. The system demand for the 12 towns that cannot meet their demands by developing the shallow aquifers increases from 14.81 mgd in 1985 to 22.56 mgd in 2010, and the corresponding unit costs are 86.1 and 68.7 ¢/1000 gal. The marginal cost (obtained from the unit costs of supplying 12 towns and 17 towns) of supplying lake water to the five towns is about one-half the cost of groundwater supply for these towns. Thus, the system serving 17 towns is more economical.

Southern Cook County Supply System

This system supplies eight towns with Lake Michigan water and has a demand which increases from 16.04 mgd in 1985 to 19.98 mgd in 2010. The system developing groundwater from the Silurian dolomite (both local and imported from Will County) was not considered for optimization. The unit cost, in ¢/1000 gal, of water supplied directly from Lake Michigan decreases from 102.6 in 1985 to 85.9 in 2010. The unit cost, in ¢/1000 gal, for conveyance of water purchased from Chicago decreases from 31.6 in 1985 to 27.0 in 2010. The difference, in ¢/1000 gal, between the unit costs for the two methods of supply is 71.0 in 1985 and 58.9 in 2010. This difference is the alternative unit cost of water from Chicago. If the negotiated price of water from Chicago is less than the alternative cost, the system will be more economically supplied by purchasing water from Chicago.

Du Page County Supply System

Nineteen towns, including Bellwood and Western Springs in Cook County, are supplied with water from Lake Michigan or with water purchased from Chicago. The system demand increases from 53.13 mgd in 1985 to 77.55 mgd in 2010. Conjunctive use of shallow groundwater, which is available in some towns in small quantities, was not considered because it is more expensive than water from the system. The unit cost, in ¢/1000 gal, of supplying Lake Michigan water is 86.5 in 1985 and 70.4 in 2010. The corresponding unit costs of conveying water from the city of Chicago to the system towns are 34.8 and 28.5. The difference, in ¢/1000 gal, between the unit costs for the two methods of supply varies from 51.7 in 1985 to 41.9 in 2010. This difference is the alternative unit cost of water from Chicago. If the negotiated price of water from Chicago is less than the alternative cost, the system with water purchased from Chicago will be more economical.

Northwestern Cook County Supply System

Fourteen towns in northern Du Page County and northwestern Cook County are supplied with water from Lake Michigan or purchased from Chicago to meet system demands which increase from 48.70 mgd in 1985 to 61.59 mgd in 2010. Conjunctive use of shallow groundwater was not considered as part of optimal systems for the same reasons as stated for the Du Page County system. The unit cost, in ¢/1000 gal, of supplying Lake Michigan water is 70.7 in 1985 and 63.2 in 2010. The corresponding unit costs of conveying water from Chicago to the system towns are 29.6 and 25.8 ¢/1000 gal. The difference, in ¢/1000 gal, between the unit costs for the two supply methods is 41.1 in 1985 and 37.4 in 2010. This difference is the alternative unit cost of water from Chicago. If the negotiated price of water from Chicago is less than the alternative cost, the system with water purchased from Chicago will be more economical.

Since the locations of the Lake Michigan intake, raw water transmission pipeline, and treatment plant are identical for the Du Page County and northwestern Cook County supply systems, joint raw water and treatment facilities are possible. The demand for the combined system increases from 101.83 mgd in 1985 to 139.14 mgd in 2010. The weighted unit costs, in ¢/1000 gal, for conveying raw water from Lake Michigan to the treatment plants in separate pipelines are 17.5 in 1985 and 14.5 in 2010, and the corresponding unit costs of conveyance in a single pipeline are 13.4 and 11.4 ¢/1000 gal . Thus, a single intake and raw water pipeline is 4.1 to 3.1 ¢/1000 gal less costly than two separate raw water systems. Similarly, the weighted unit costs of treatment in separate plants are 28.4 and 25.1 ¢/1000 gal, and the corresponding unit costs with a single treatment plant are 27.7 and 24.2 ¢/1000 gal. A single treatment plant is less costly than two separate treatment plants by 0.7 to 0.9 ¢/1000 gal. The conveyance networks which convey water from the treatment plant to the user towns will be separate for the two systems.

Fox River Supply System

This system withdraws water from the Fox River, pumps it to a storage reservoir, augments the water stored in the reservoir with groundwater collected from wells in the deep sandstone aquifer during periods of low flow in the river, treats water withdrawn from the reservoir, and conveys it to a central location in each of the eight user towns in the Fox River Valley. St. Charles is assumed to develop up to 3.24 mgd of groundwater from shallow and deep wells and will be supplied with water from the system when its demand exceeds 3.24 mgd. Aurora is assumed either to be fully supplied from the system or to augment its supply from the system with 6.7 mgd of groundwater from the deep sandstone aquifer. South Elgin can be supplied from the system because of its proximity to the system, or it can develop an adequate supply from the shallow aquifers. Valley View is also very close to the system network and is included because the unit cost of developing a supply from the shallow aquifers will be 152.6 ¢/1000 gal. The possibility of shallow groundwater transfer from an area south of Sugar Grove to augment Aurora's supply was evaluated and determined to be infeasible.

Two systems were optimized considering full or partial supply for Aurora and including or excluding South Elgin. System A serves eight towns with a system demand of 24.10 mgd in 1985 and 35.61 mgd in 2010. A 5950 acre-feet (ac-ft) reservoir with a surface area of 440 acres is required to store water withdrawn from the river. The groundwater collection system, with 17 wells in the deep sandstone aquifer, has a capacity of 19.60 mgd. It will be used to augment the reservoir storage during periods of low flow in the river. Groundwater is expected to be used less than 15% of the time as a long-term average. Total unit costs, in ¢/1000 gal, are 115.3 in 1985 and 91.3 in 2010.

System B does not supply South Elgin but it supplies Aurora with water to meet its demand in excess of 6.7 mgd. A 5300 ac-ft reservoir with a surface area of 400 acres is required. Groundwater is collected from 11 wells in the deep sandstone aquifer with a safe yeild of 12.52 mgd. Total system unit costs, in ¢/1000 gal, are 131.2 in 1985 and 95.9 in 2010.

Kankakee River Supply System

From discussions with the Division of Water Resources and Will County personnel, it was decided to 1) serve towns in Will County only, 2) optimize three moderate-sized systems not considered in the preliminary analyses, and 3) locate the intake upstream of the existing dam at Wilmington. The basic system includes Joliet, Lockport, Rockdale, and Wilmington. Channahon, Plainfield, and Shorewood have been considered because they are dependent on deep wells for water supply. Frankfort, Mokena, and New Lenox have also been considered because groundwater from the Silurian dolomite aquifer is highly mineralized in these towns.

System A serves Joliet, Lockport, Rockdale, and Wilmington, and the system demand increases from 12.61 mgd in 1985 to 18.66 mgd in 2010. System B serves Channahon, Plainfield, and Shorewood in addition to the four towns served by system A, and its demand increases from 14.30 mgd in 1985 to 21.29 mgd in 2010. System C serves Frankfort, Mokena, and New Lenox in addition to the seven towns served by system B, its demand increasing from 15.79 mgd in 1985 to 25.33 mgd in 2010. Development of 6 mgd from the Hadley Valley aquifer for use in Joliet was an option on each of the three systems. The system demands decrease by 6 mgd with this option.

For all three systems, the system using the Kankakee River as the only source was less costly than the system with conjunctive use of groundwater and river water. Comparison of the marginal cost of supplying river water and the unit cost of groundwater for Channahon, Plainfield, and Shorewood indicates that system B is more economical than system A. Similar comparisons for Frankfort, Mokena, and New Lenox do not show a clear choice between systems B and C. Inclusion of these three towns on the system will depend on the expediency of increased supply from the Kankakee River, abandonment of existing dolomite wells, concerns about groundwater quality, and agreement of all towns to be served by the system.

Economic considerations appear to indicate construction of system B, which supplies Kankakee River water to Channahon, Joliet, Lockport, Plainfield, Rockdale, Shorewood, and Wilmington for a unit cost, in ¢/1000 gal, of 115.6 in 1985 and 91.8 in 2010.

Availability of Lake Michigan Water

The towns on systems with Lake Michigan or Chicago as the source and the towns currently using lake water together with some other towns in Cook County are considered as potential candidates for water supply from the lake. This is the maximum demand since the systems may not include all the proposed towns. Lake water demands by county for current users and proposed systems are given in table 67. The current users have less demand in 2010 than in 1985 due to the projected decrease in water demand for Chicago. The towns served by the proposed systems, with water either obtained directly from Lake Michigan or purchased from Chicago, have a sufficient increase in demand to increase the total water demand on the lake.

Table 67. Lake Michigan Water for Public Water Supply

	1985		*2010*	
	mgd	*ofs*	*mgd*	*ofs*
Current Users				
Chicago[1]	805.00	1245.34	759.00	1174.17
Cook County[2]	217.50	336.47	228.40	353.33
Lake County	31.64	48.95	39.04	60.39
Subtotal	1054.14	1630.76	1026.44	1587.89
New Users[3]				
Cook County	68.70	106.28	84.39	130.55
Lake County	12.83	19.85	21.93	33.93
Du Page County	54.00	83.54	80.60	124.69
Subtotal	135.53	209.67	186.92	289.17
Total water supply demand	1189.67	1840.43	1213.36	1877.06

Notes:

[1]Chicago demands computed using NIPC per capita consumption and population projections.

[2]Some users not currently on lake water and not on the systems are also included.

[3]Maximum size systems without conjunctive use are considered with demands totaled by county.

Conjunctive use of up to 42.69 mgd or 66.04 cfs of groundwater is possible (Cook County deep sandstone users could use 10.40 mgd and shallow groundwater use in the proposed systems could be 32.29 mgd). Conjunctive use of groundwater will decrease the total water supply demand by about 43 mgd. However, the groundwater costs if water is to be treated and the problems with commingling of groundwater and lake water will have to be considered.

Table 68 shows water supply and other uses with allocations as given in the Division of Water Resources LMO 77-1 (1977). Water quality improvement is the goal of the discretionary diversion. From 1980 to 1985, instream aeration is assumed. Phase one of the deep tunnel plan (TARP I) is scheduled for completion in 1986. The column labeled 1985 with TARP I assumes other uses at 1985 levels, but navigation makeup and discretionary diversion at 1986 levels. The difference between the allowed diversion of 3200 cfs and the total of water supply demands and other allocations is the amount of diversion that can be used to balance the storm runoff and provide water for other purposes. The 686 cfs available for storm runoff in 1985 without TARP I has been exceeded 15 years in the 100-year period (Keifer, 1977b). After the completion of TARP I, there is sufficient water available for all requirements including the maximum annual runoff of 795 cfs or the highest 5-year moving average of 816 cfs computed by Keifer (1977b).

Table 68. Projected Use of Lake Michigan Diversion, in cfs

	1985 Without TARP I	1985 With TARP I	2010 With TARP I
Water supply	1840.43	1840.43	1877.06
Metropolitan Sanitary District of Greater Chicago (MSDGC)			
1) Lockage, leakage, and navigation makeup	309.20	241.20	252.00
2) Discretionary diversion	320.00	101.00[1]	101.00
Steel mill recycling makeup	19.55	19.55	19.55
North Shore Sanitary District	14.75	14.75	17.00
Other allocations[2]	10.45	10.45	10.45
Total allocation and demands	2514.38	2227.38	2277.06
Water available for storm runoff and other purposes	685.62	972.62	922.94

Notes:

[1]Completion of TARP I is scheduled for 1986. Navigation makeup and discretionary diversion are reduced by TARP I. Instream aeration is assumed. TARP II is projected for completion in 1995. This would eliminate discretionary diversion and navigation makeup of 101 and 10 cfs, respectively.

[2]Glenview NAS, Great Lakes NTC, Illinois Beach St. Park, Loyola Medical Center, Madden MHC, and V.A. Hines Hospital.

Conjunctive use of groundwater by towns on the supply systems can reduce lake water demands by about 66 cfs. Although TARP II has an estimated completion date of 1995, it is not needed to assure adequate water for public water supply in the study period ending in 2010. It will eliminate all discretionary diversion and navigation makeup, thus freeing about 111 cfs for other uses.

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APPENDIX

SYSTEM COST DIFFERENCES FROM OTHER REPORTS

When the Division of Water Resources staff reviewed this report, they expressed their concern about substantial differences between the unit costs of water supply herein and those in a draft of a new report by Keifer and Associates. These differences were discussed at a meeting in Chicago. Keifer's new study uses cost functions which are essentially the same as those used in this report for various components of water supply systems. The differences in unit costs are largely due to the following variations in methodology.

1) Keifer uses 33% of the construction cost for contingency, engineering, and bond flotation costs. This report uses about 23% of construction costs (20% of construction cost and capitalized interest) for these items. A brief review of four other engineering reports found this factor to vary from 12.8 to 29.6%.

2) Capitalized interest is taken as 32% of construction cost by Keifer. In this report the factor for capitalized interest is about 20% for pipeline, 10% for treatment plants, and 8% for pumping stations; with construction scheduled over 5, 3, and 2 years, respectively.

3) Staged construction of some system components reduced unit costs in this report as compared with unit costs with no staging. Keifer does not consider staged construction.

4) The annual capital cost of pipelines is based on ammortization periods of 50 years in this report and 30 years in Keifer's study.

5) Keifer applies a 20% contingency factor to operation, maintenance, and repair costs, but this report does not include such a factor.

6) This report considers design period from 1985 to 2010 whereas Keifer uses 1985 to 2020. His ratio of 2020 to 1985 water demands is much higher than the ratio of 2010 and 1985 demands in this report. This increases his 1985 unit water cost because of less utilization of the system designed for a much higher demands.

The data on the contingency, engineering, and bond flotation cost factors and an example of unit cost computations for the northwestern Cook County supply system are given here for the reader's information.

Contingency, Engineering, and Bond Flotation

The information listed in table A for typical values of the factors for contingency, engineering, and bond flotation costs is taken from the following reports.

1. Clark, Dietz, Painter & Associates, 1963, "Report on the Feasibility of Rend Lake Intercity Water System."

2. Clark, Dietz, Painter & Associates, 1964, "Preliminary Report of the Rend Lake Intercity Water System, Phase II--Water Treatment Facilities."

3. De Leuw, Cather & Company, 1972, "Report on Lake Michigan Water Supply for the Elmhurst-Villa Park-Lombard Water Commission."

4. Consoer, Townsend & Associates, 1972, "Preliminary Engineering Report on Kankakee River Water Supply System for Public Water Commission of Frankfort, Joliet, Lockport, Mokena, New Lenox, Rockdale, and Romeoville."

5. Keifer & Associates, Inc., 1977, "Regional Water Supply: A Planning Study for Northeastern Illinois."

6. Illinois State Water Survey, 1980, "Adequacy and Economics of Water Supply in Northeastern Illinois: Proposed Groundwater and Regional Surface Water Systems, 1985-2010."

Example System Unit Cost Computation

The northwestern Cook County supply system in this report serves 14 towns with a system demand of 48.70 mgd in 1980 and 61.59 mgd in 2010. The capital costs, annual costs, and unit cost of water in 1985 are tabulated in table B. The cost functions in this report are used in the methodologies of this report and Keifer.

Table A. Percentages of Construction Cost for Contingencies Engineering, and Bond Flotation

Report number	*Year*	*Construction Cost, $*	*Cont., %*	*Eng., %*	*Bonds, %*	*Total, %*
1	1963	6,430,000	5.0	7.0	1.2	13.2
		7,430,000	5.0	7.0	1.2	13.2
		8,350,000	5.0	6.9	1.6	13.5
2	1964	10,260,000	4.0	6.4	2.4	12.8
3	1972	40,640,000	13.9	8.5	4.7	27.1
		54,210,000	14.1	8.0	4.7	26.8
		48,400,000	14.6	8.1	4.8	27.5
		27,000,000	15.0	9.8	4.8	29.6
4	1972	25,620,000	10.2	6.7	3.1	20.0
		33,300,000	10.3	6.3	3.0	19.6
		37,100,000	10.3	6.1	3.0	19.3
5	1977	-	20.0	10.0	3.0	33.0
6	1980	-	5.0	12.0	3.0	20.0*

Cont. = contingencies, Eng. - engineering, Bonds = bond flotation

*This percentage is taken on construction cost plus capitalized interest. The percentage based on construction cost alone is 23% which may be considered to be 10% contingencies, 10% engineering, and 3% bond flotation.

Table B. Comparison of Costs in 1985 for Northwestern Cook County Supply Systems with Water From Lake Michigan

Item	By ISWS Method Capacity, mgd	Factor	Amount, million $	By Keifer's Method Capacity, mgd	Factor	Amount, million $
I. Capital Costs						
A. Pipeline const.	61.59	-	46.890	61.59	-	46.890
Capitalized interest		0.197	9.238		0.320	15.005
Cont., Eng. & Bond		0.200[1]	11.226		0.330	15.474
Total			67.354			77.369
B. Pump station const.	*	-	8.255	61.59	-	9.742
Capitalized interest		0.080	0.660		0.320	3.117
Cont., Eng. & Bond		0.200[2]	1.782		0.330	3.215
Total			10.697			16.074
C. Treatment plant const.	55.46	-	32.319	61.59	-	35.529
Capitalized interest		0.098	3.167		0.320	11.369
Cont., Eng. & Bond		0.200[3]	7.097		0.330	11.725
Total			42.583			58.623
Capital required in 1985			120.644			152.066
II. Annual Costs						
A. Capital costs						
Pipeline		0.0817	5.503		0.0888	6.870
Pump station		0.0888	0.950		0.0888	1.427
Treatment plant		0.0888	3.781		0.0888	5.206
Total			10.234			13.503
B. Operation, Maintenance & Repair						
Pipeline			0.102			0.122
Pump station			0.541			1.105
Electricity			0.581			0.581
Treatment plant			1.103			1.387
Total			2.327			3.195
Total Annual Cost			12.561			16.698
Unit cost in ¢/1000 gal (48.70 mgd in 1985)			70.7			93.9[5]

*Pump station is built for 2010 demand, but pumping equipment has an installed horsepower of 13,183 in 1985 and 22,263 in 2010.

Notes:

[1]Applied to construction cost plus capitalized interest; equivalent to 23.9% on construction cost alone.

[2]Equivalent to 21.6% on construction cost.

[3]Equivalent to 22.0% on construction cost.

[4]Keifer applied 20% contingency factor to OM&R costs.

[5]Keifer extends the planning period to 2020 and uses higher system demands in their new report. The ratio of water demands in 2010 and 1985 is 1.26 in this report. The ratio of water demands in 2020 and 1985 is 1.58 in Keifer's new report and would result in a 2985 unit cost of about 120 ¢/1000 gal.