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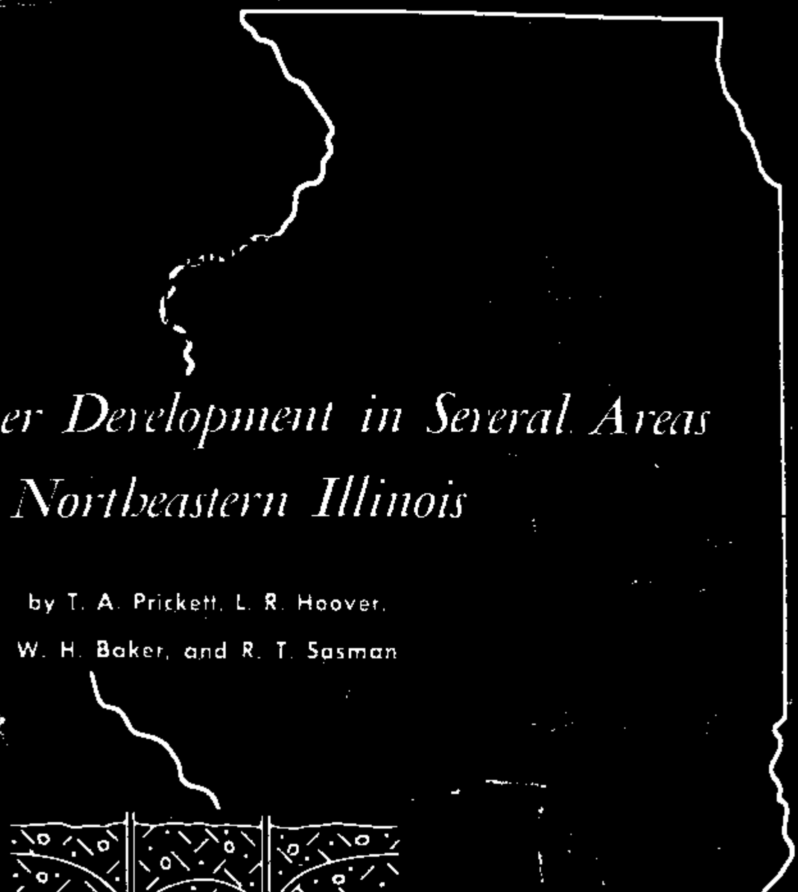

Ground-Water Development in Several Areas of Northeastern Illinois

by T. A. Prickett, L. R. Hoover, W. H. Baker, and R. T. Sasman

ILLINOIS STATE WATER SURVEY
URBANA
1964

REPORT OF INVESTIGATION 47

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URBANA

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Ground-Water Development in Several Areas of Northeastern Illinois

by T. A. Prickett, L. R. Hoover, W. H. Baker, and R. T. Sasman

ABSTRACT

In many parts of northeastern Illinois ground water is obtained for municipal, institutional, commercial, and industrial supplies from shallow dolomite and glacial sand and gravel aquifers. The dolomite aquifer of Silurian age has a large areal extent covering two-thirds of northeastern Illinois; the sand and gravel aquifers are often thin and limited in areal extent. Case histories of the development of the dolomite aquifer in three areas and sand and gravel aquifers in two areas are presented in detail in this report. Complex aquifer conditions arc simulated with simplified model aquifers. Model aquifers and existing ground-water formulas are used to evaluate the practical sustained yields of well fields und aquifers in the Hadlcy Valley area near Joliet, Woodstock area, Libertyville area, Chicago Heights area, and LaGrange area.

Available data on specific capacities of individual wells and of pumping centers at locations outside these five areas indicate that large quantities of water are being successfully obtained from shallow dolomite and sand and gravel aquifers throughout most of northeastern Illinois.

SUMMARY

The aquifer in the *Hadley Valley area* northeast of Joliet is a semi-infinite strip of sand and gravel approximately 2 miles wide and 60 feet thick. Dolomite with some permeability bounds the aquifer on the sides and bottom. The aquifer is overlain by fine-grained materials (confining bed) averaging 30 feet thick. The coefficients of transmissibility of the aquifer, 186,000 gallons per day per foot (gpd/ft), and vertical permeability of the confining bed, 1.02 gallons per day per square foot (gpd/sq ft), are high. The aquifer is recharged at an average rate of 300,000 gallons per day per square mile (gpd/sq mi) directly from precipitation and from the induced infiltration of water in Spring Creek which transects the Hadley Valley area.

Computations made with a model aquifer and a mathematical model indicate that the practical sustained yield of the existing well field containing five wells is about 4 million gallons per day (mgd) or about 0.7 mgd more than the average pumping rate recorded in 1961. The potential yield of the part of the aquifer within or near the drainage basin of Spring Creek is estimated to be about 6.5 mgd and probably can be developed from a 10-well system. This system consists of the five existing wells and five additional wells spaced in a northeasterly direction about 1000 feet apart with the first well about 2 miles northeast of the existing well field.

The most heavily pumped aquifer in the *Woodstock area* is a layer of sand and gravel with a large areal extent and 50 feet thick. Dolomite with some permeability bounds the aquifer on the bottom, The aquifer is overlain by clayey materials (confining bed) averaging 80 feet thick. The coefficients of transmissibility and storage of the aquifer are 57,000 gpd/ft and 0.00034, respectively; the coefficient of vertical permeability of the confining bed is 0.012 gpd/sq ft. The aquifer was recharged in 1962 by the vertical leakage of water through the confining bed at an average rate of 125,000 gpd/sq mi. Water is also obtained from multi-aquifer wells penetrating the above-mentioned aquifer, an aquifer of limited areal extent interbedded in the confining bed, and a shallow aquifer averaging 30 feet thick above the confining bed.

Computations made with well-production data and a mathematical model indicate that the practical sustained yield of the two existing municipal well fields containing seven wells is about 5.5 mgd, or about 3.7 mgd more than the average pumping rate recorded in 1962.

The most heavily pumped aquifer in the *Libertyville area* is the Silurian dolomite aquifer which averages 150 feet in thickness. The aquifer is overlain by clayey materials of glacial origin (confining bed) averaging 175 feet thick. The coefficient of transmissibility of the Silurian dolomite aquifer locally varies considerably but on an areal basis averages about 10,000 gpd/ft; the coefficient of vertical permeability of the confining bed is 0.009 gpd/sq ft. The dolomite aquifer was recharged in 1962 by vertical leakage of water through the confining bed at an average rate of 52,000 gpd/sq mi.

Water is also obtained from wells in thin sand and gravel aquifers of limited areal extent interbedded in or occurring at the base of the confining bed. The coefficient of tranmissibility of sand and gravel aquifers in the Libertyville area varies considerably but averages about 25,000 gpd/ft. The municipal water supply for Libertyville is obtained from the Silurian dolomite aquifer, and most of the water pumped at Mundelein is from sand and gravel aquifers.

Computations made with well-production data, estimated recharge rates, and records of past pumpage and water-level decline indicate that the practical sustained yield of the two existing well fields containing 15 wells at Libertyville and Mundelein is about 4 mgd, or about 2 mgd more than the average pumping rate in 1962.

The most heavily pumped aquifer in the *Chicago Heights area* is the Silurian dolomite aquifer which averages 400 feet in thickness. The aquifer is overlain by materials of glacial origin (confining bed) averaging 35 feet thick. Because of close spacing of wells and well fields, and heavy pumpage at Chicago Heights, extensive dewatering of upper portions of the aquifer has taken place. The coefficient of transmissibility of the Silurian dolomite aquifer averages about 65,000 gpd/ft in areas where no dewatering has taken place; the coefficient of transmissibility in areas where extensive dewatering of the dolomite has taken place averages about 22,000 gpd/ft. The gravity yield of the upper portion of the Silurian dolomite aquifer is about 0.03; the coefficient of permeability of the confining bed is 0.011 gpd/sq ft. The dolomite aquifer was recharged in 1962 by vertical leakage of water through the confining bed at an average rate of 225,000 gpd/sq mi.

Computations made with well-production data, estimated recharge rates, and records of past pumpage and water-level declines indicate that the practical sustained yield of the two existing well fields containing 22 wells at Chicago Heights and Park Forest is about 15 mgd, or about 7 mgd more than the average pumping rate in 1962.

The most heavily pumped aquifer in the *LaGrange area* is the Silurian dolomite aquifer which averages about 250 feet in thickness. Unconsolidated material of glacial origin (confining bed) averaging 40 feet in thickness overlies the aquifer. Because of heavy pumpage from rock quarries and well fields in the vicinity of LaGrange, extensive dewatering of upper portions of the aquifer has taken place. The coefficient of transmissibility of the Silurian dolomite aquifer averages 100,000 gpd/ft in areas where dewatering has not occurred; in areas where extensive dewatering has taken place, the coefficient of transmissibility has been reduced to about 30,000 gpd/ft. The coefficient of vertical permeability of the confining bed is 0.008 gpd/sq ft. The dolomite aquifer was recharged in 1962 by vertical leakage of water through the confining bed at an average rate of 160,000 gpd/sq mi.

Computations involving well-production data, estimated recharge rates, pumpage and water-level records, and the hydraulic properties of the aquifer indicate that the practical sustained yield of the two existing well fields containing six wells at LaGrange and Western Springs is about 5 mgd, or about twice the average pumping rate in 1962.

INTRODUCTION

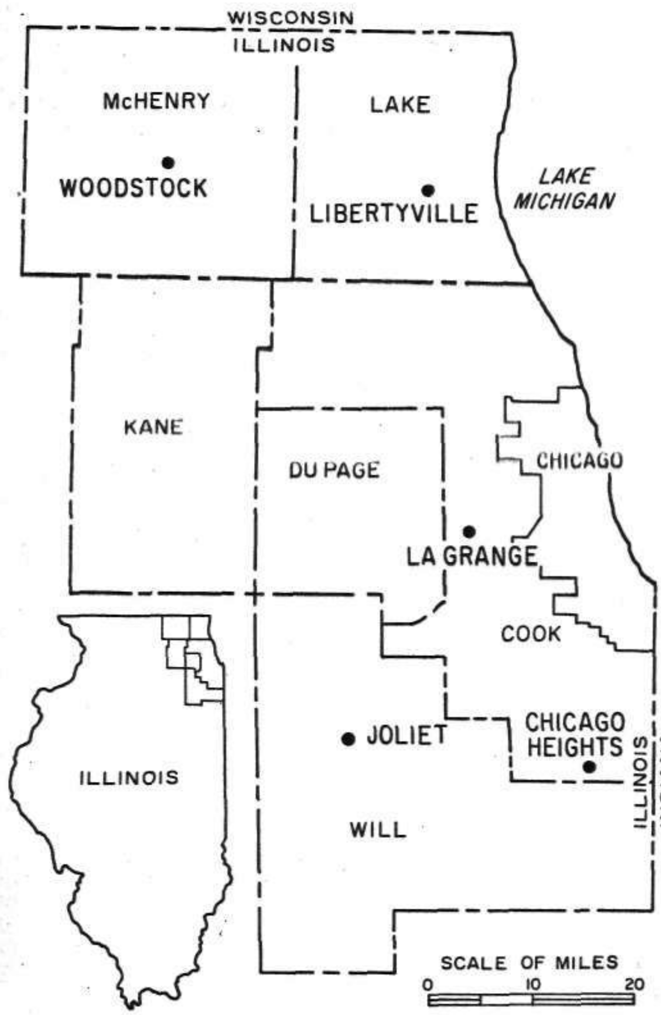
Records of experience in ground-water development are important sources of hydrologic data. Actual performance data studies in relation to geohydrologic theory can be a guide to sound evaluation of untapped aquifers and to proper design of ground-water systems. Case histories of ground-water development in five areas in northeastern Illinois are presented in this report to facilitate the future planning and management of ground-water supplies.

Ground-water resources in northeastern Illinois are developed in part from two aquifer systems: 1) Dolomite aquifers of Silurian age, and 2) sand and gravel aquifers of glacial origin. The Silurian dolomite aquifer is encountered commonly at depths less than 300 feet. Most of the bedrock surface beneath the glacial drift in the eastern two-thirds of northeastern Illinois is formed by the Silurian dolomite aquifer. The thickness of the Silurian dolomite aquifer increases from less than 50 feet in the western part to more than 450 feet in the southeastern part

Ground water in the Silurian dolomite aquifer occurs in joints, fissures, and solution cavities. The water-bearing openings are irregularly distributed both vertically and horizontally, and the yields of shallow dolomite wells vary greatly from place to place. Available geohydrologic data suggest that on a regional basis the dolomite aquifer is permeated by numerous fractures and crevices which extend for considerable distances and are interconnected. The Silurian dolomite aquifer receives water from overlying glacial deposits. The potential yield of the Silurian dolomite aquifer far exceeds the present withdrawal.

Unconsolidated deposits, mainly glacial drift, ranging in thickness from a foot or less to more than 400 feet, overlie the bedrock in northeastern Illinois. Ground water in the drift is obtained mainly from thin sands and gravels that occur as surficial deposits or, more commonly, as deposits underlying or interbedded with glacial till. Large supplies of ground water are often encountered in sand and gravel at the base of the drift, directly above bedrock. The chances of penetrating continuous water-bearing beds of considerable thickness are often better within bedrock valleys than in bedrock uplands. Sand and gravel aquifers are more readily recharged than bedrock aquifers, and commonly are more permeable than bedrock aquifers. The potential yield of sand and gravel aquifers is considerably larger than present withdrawals.

The Silurian dolomite and sand and gravel aquifers are connected hydrologically. These aquifers are commonly



Figuro 1. location of Joliet, Woodstock, Chicago Heights, Libertyvilie, and LaGrange

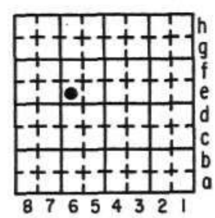
overlain by deposits of till that contain a high percentage of silt and clay and have a low permeability. In most areas, recharge to the aquifers is derived from vertical leakage of ground water through the till.

The practical sustained yields of the Silurian dolomite aquifer at Libertyvilie, Chicago Heights, and LaGrange, and sand and gravel aquifers near Joliet and at Woodstock (see figure 1), are evaluated in this report. Available information concerning geographic, climatic, and geologic features of study areas are given to serve as a background for interpretation of records. The practical sustained yield is defined here as the maximum amount of water that can be continuously withdrawn without eventually lowering water levels to critical stages within the dolomite or below tops of screens in production wells, or without exceeding recharge.

In some cases complex aquifer conditions are simulated with simplified model aquifers. Geohydrologic boundaries are assumed to be straight-line demarcations and are given mathematical expression by means of the image-well theory. The hydraulic properties of the aquifer and overlying confining beds are considered mathematically by using ground-water formulas. Records of past pumpage and water levels are Used to establish the validity of this mechanism to describe the response of aquifers to pumping, to predict the effects of future ground-water development, and to estimate the practical sustained yield of aquifers and existing well fields.

Well-Numbering System

The well-numbering system used in this report in based on the location of the well, and used the township, range, and section for identification. The well number consists of five parts: county abbreviation, township, range, section, and coordinate* within the section, Sections are divided into rows of ⅛-mile squares. Each ⅛-mile square contains 10 acres and corresponds to a quarter of a quarter of a quarter section. A normal section of 1 square mile contains eight rows of ⅛-mile squares; an odd-sized section contains more or fewer rows. Rows are numbered from east to west and lettered from south to north as shown in the diagram.



Will County
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Section 5

The number of the well shown is WIL 35N10E-5.6e. Where there is more than one well in a 10-acre square they are identified by arabic numbers after the lower-case letter in the well number.

Any number assigned to a well by the owner is shown in parentheses after the location well number. Directional titles used by the owner are indicated by (N) for North Well, etc.; a Test Well is indicated by (T). In the listing of wells owned by municipalities, the place-name is followed by V, T, or C in parentheses to indicate whether it is a village, town, or city.

The abbreviations for counties discussed in this report are:

Cook	COK	Lake	LKE
DuPage	DUP	McHenry	MCH
Kane	KNE	WiU	WIL
Kendall	KEN		

Acknowledgments

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HADLEY VALLEY AREA NEAR JOLIET

Water for municipal use at Joliet is obtained in part from wells in a shallow sand and gravel aquifer contained in a buried bedrock valley northeast of the city. Large quantities of water have been withdrawn since 1951 without critically depleting the aquifer in the well-field area. In fact, available data indicate that the potential yield of the sand and gravel aquifer is greater than present withdrawals, and that there are undeveloped areas available for future well-field expansion.

Since 1951, when the aquifer was first tapped by the city of Joliet, the average daily withdrawal from a five-well system has been about 3.7 mgd. Exploitation of groundwater resources caused a local water-level decline averaging about 8 feet within a 1-mile radius of the municipal well field. Under heavy pumping conditions, recharge has balanced discharge, and water levels have stabilized rapidly after changes in pumpage.

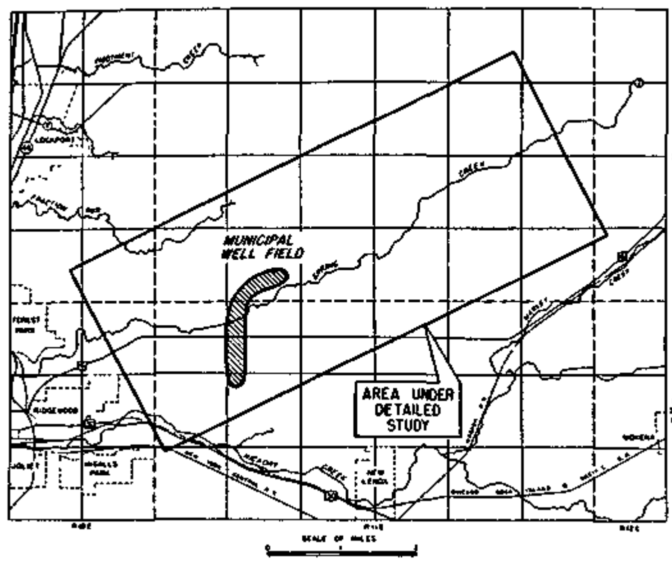

Figure 2. Location of Hadley Valley area and municipal well field near Joliet

Geography and Climate

Joliet, the county seat of Will County, is in northeastern Illinois about 25 miles soudiwest of Chicago. Detailed study was confined to a rectangular area, hereafter referred to as the "Hadley Valley area," of about 20 square miles northeast of Joliet in T35N, T36N, R10E, R11E, and R12E, as shown in figure 2. The area is between 87° 51' and 88° 03' west longitude and between 41° 31' and 41° 36' north latitude and is about 4 miles northeast of the center of Joliet.

The Hadley Valley area lies near the center of the physiographic Central Lowland Province, a glaciated lowland that stretches from the Appalachian Plateau on the east to the Great Plains of Kansas, Nebraska, and the Dakotas on the west. The Hadley Valley area is located in the Wheaton Morainal Country subdivision of the Central Lowland Province. The topography is characterized by hills, broad parallel morainic ridges, and swamps on the flood plain of Spring Creek. The elevation pf the land surface declines from about 790 feet on a ridge in the northwestern part to about 570 feet in the valley of Spring Creek where it crosses the soudiwest border of the area, thus giving a maximum relief of about 220 feet.

Drainage is largely southeastward to Spring Creek which flows in a course near the center of the area, as shown in figure 2. Fraction Run drains a small portion of the area towards the DesPlaines River; the southwestern corner is drained to Hickory Creek.

The Hadley Valley area lies in the north temperate zone. Its climate is characterized by warm summers and moderately cold winters. Graphs of annual and mean monthly precipitation at Joliet are given in figure 3. Most of the precipitation data were collected at the Illinois State Penitentiary at Joliet; records collected at the Army Corps of Engineers' weather station at Brandon Road Dam approximately ½ mile south of Joliet were used to fill missing records at Joliet

According to available data the mean annual precipitation is 34.25 inches. On the average, the months of greatest precipitation are April, May, June, August, and September, each having more than 3.5 inches; February is the month of least precipitation, having less tiian 2 inches.

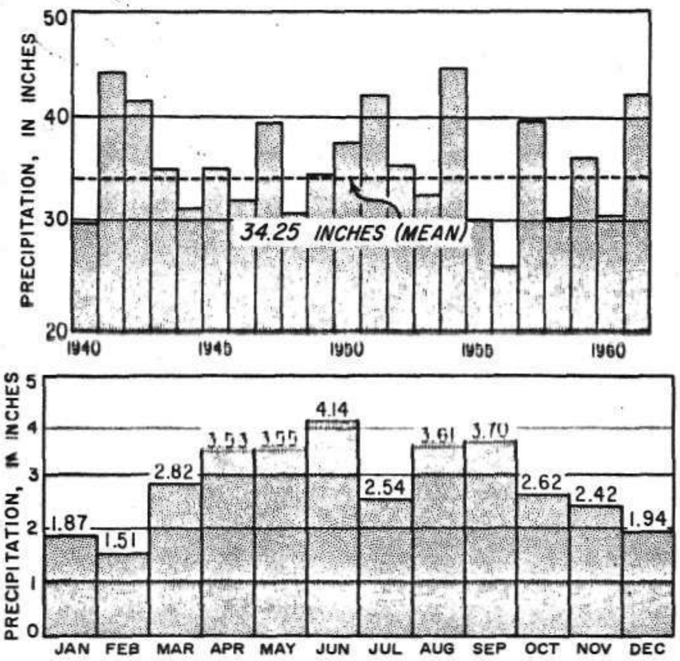

Figure 3. Annual and mean monthly precipitation at Joliot

The annual maximum precipitation amounts occurring on an average of once in 5 and once in 50 years are 38 and 47 inches respectively; annual minimum amounts expected for the same intervals are 29 and 23 inches respectively. Amounts are based on data given in the Adas of Illinois Resources, Section 1 (1958).

The mean annual snowfall is 30 inches, and the area averages about 42 days witii 1 inch or more and 24 days with 3 inches or more of ground snow cover.

Based on records collected at the Illinois State Penitentiary the mean annual temperature is 49.1° F. June, July, and August are the hottest months with mean temperatures of 69.0° F, 73.3° F, and 71.3° F respectively; January is the coldest month with a mean temperature of 23.8° F. The mean length of the growing season is about 165 days.

Geology

For a detailed discussion of the geology in the Joliet area the reader is referred to Horberg and Emery (1943) and Suter et al. (1959). Most of the following section is based on these two reports.

The area east of Joliet is covered largely witii glacial drift which seldom exceeds 100 feet in thickness. The bedrock immediately beneath the glacial drift is mainly dolomite of Silurian age. Silurian rocks commonly exceed 250 feet in thickness, except where they have been deeply eroded as in buried bedrock valleys, and yield moderate amounts of water to wells. Large deposits of water-yielding sand and gravel are scarce in the glacial drift. They occur chiefly in existing or buried valleys, and as lenticular and discontinuous layers. The glacial drift is more than 100 feet thick and contains thick deposits of sand and gravel in a deeply buried valley which extends northeast from Joliet for a distance of at least 10 miles (Horberg and Emery, 1943).

A contour map showing the topography of the bedrock surface east of Joliet is shown in figure 4. Most features of the bedrock topography were previously delineated, named, and discussed by Horberg and Emery (1943) and Horberg (1950). Two large bedrock valleys extend northeastward from Joliet and roughly coincide with the present valleys of Spring Creek and Hickory Creek. These two bedrock valleys are connected by a third short bedrock valley about 2 miles east of Forest Park. An island-like upland is surrounded by the bedrock valleys and rises 100 feet above their floors. The channels of the bedrock valleys are about 1 mile wide, have relatively steep walls, and average 100 feet in depth. The buried valley beneath Spring Creek and the connecting buried valley are collectively called Hadley Valley (see Horberg and Emery, 1943).

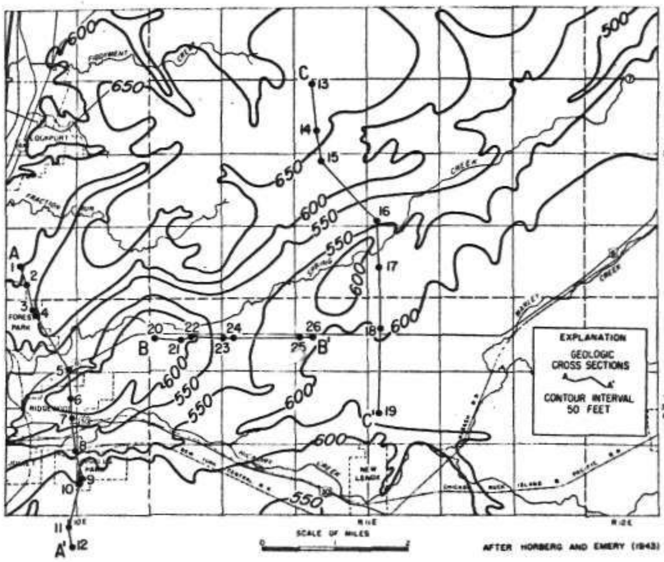

Figure 4. Bedrock topography east of Joliot

Cross sections in figure 5 illustrate the nature of the glacial drift east of Joliet. The fill in the Hadley Valley area contains a large proportion of sand and gravel. At places the lower part of the fill contains material of finer grain than that in the upper part. The sand and gravel is commonly overlain by deposits of till (confining bed) that contain a high percentage of silt and clay. Till deposits are missing in many places in the present valley of Spring Creek and Hickory Creek. The glacial drift which nearly fills Hadley Valley may be Illinoian in age (Horberg and Potter, 1955).

The map of the saturated tiiickness of sand and gravel (figure 6) shows that the aquifer exceeds 100 feet in tiiickness in the vicinity and east of the municipal well field. Thicknesses exceeding 60 feet occur in a belt

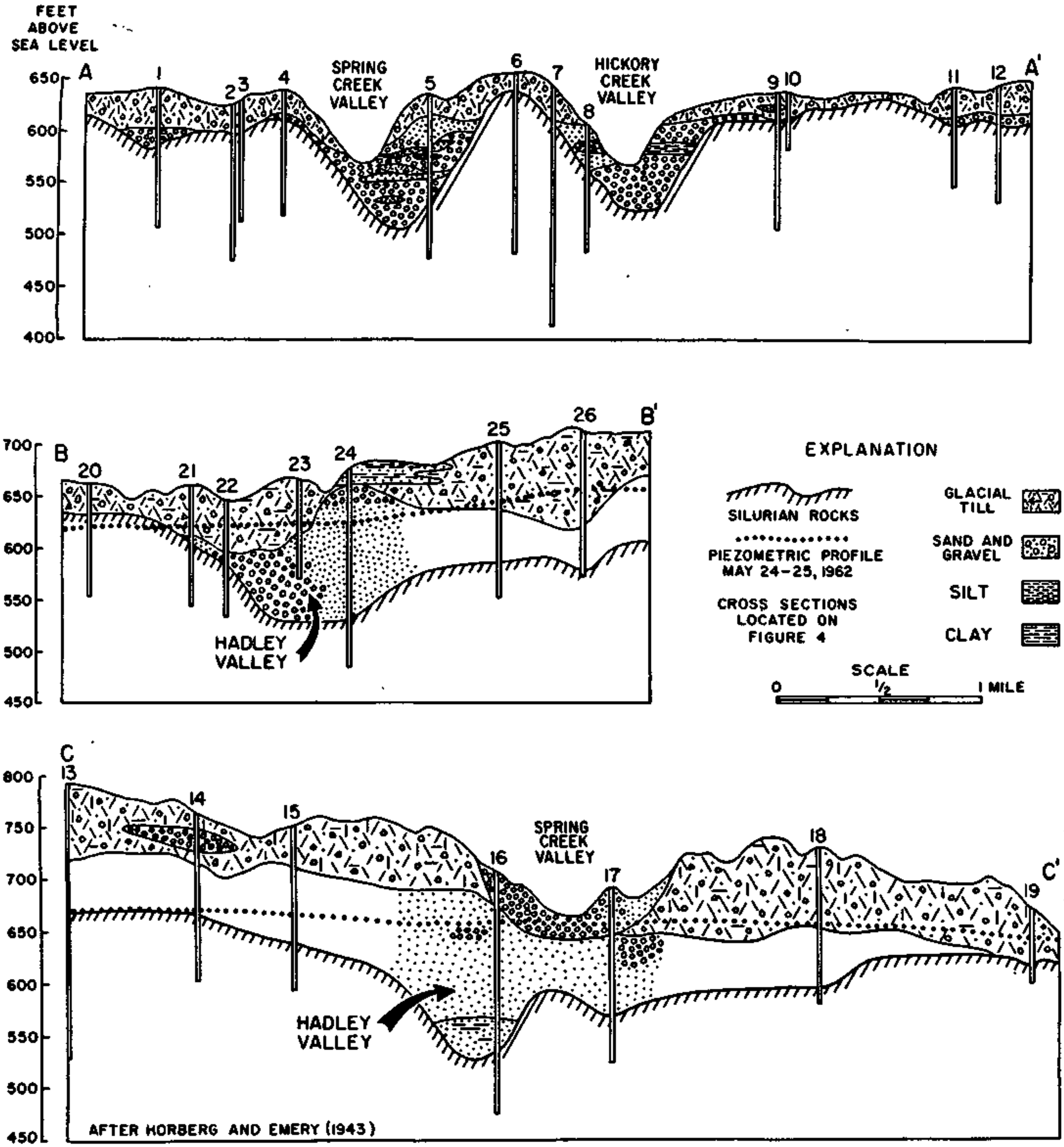

Figure 5. Cross tactions of glacial drift and piezometric profiles east of Joliet

averaging ¾ mile in width. The thickness lines more or less parallel bedrock-surface contours. The map shows that the sand and gravel deposits range in width from about ¾ to 3 miles and trend southwest to northeast.

Logs of selected wells and test holes in the Hadley Valley area are given in table 1; the locations of wells and test holes for which geologic data are available are shown in figure 7. Records of wells and test holes appear in table 2.

Occurrence of Ground *Water*

The sand and gravel deposits in the Hadley Valley area consist of fragments of rock rounded by wear and deposited by glacial melt waters. Ground water occurs in the irregular spaces, or interstices, that exist between the rock fragments, or grains. Ground water in the Silurian rocks occurs in joints, fissures, and solution cavities.

Table 1. Logs of Selected Wells and Test Holes in Hadley Valley Area

Well number	Type of record	Formation	Thickness (ft)	Depth (ft)
WIL—				
35N10E–				
1.3h	drillers log	soil	20	20
		sand, coarse	41	61
		till	30	91
		gravel	4	95
		sand, coarse	8	103
		dolomite	—	135
35N11E–				
5.4g	drillers log	soil and clay	10	10
		sand and gravel, clayey	10	20
		sand and gravel, cemented	20	40
		sand and gravel, coarse	20	60
		fine sand	10	70
		sand and gravel, clean	13	83
		muddy clay, soft, till	22	105
		sand and gravel, some till	7	112
		sand and gravel, clean	13	125
		sand and gravel, clay seams	10	135
		limestone	—	140
5.6d	drillers log	soil and clay	20	20
		till	40	60
		gravel	55	115
		till	15	130
		sand	5	135
		gravel	10	145
		dolomite	—	250
5.7dl	drillers log	soil and clay	25	25
		gravel, clayey	10	35
		gravel	10	45
		clay	2	47
		gravel	—	90
5.7h2	drillers log	soil and clay	8	8
		gravel	8	16
		sand and gravel	12	28
		sand	62	90
		gravel	—	112.5
5.8a	drillers log	soil	15	15
		till	44	59
		sand	31	90
		till	20	110
		sand	17	127
		till	6	133
		dolomite	—	143
6.3h	drillers log	soil	20	20
		till	24	44
		sand and gravel	31	75
		sand	25	100
		till, sandy	5	105
		gravel	10	115
		till, gravelly	26	141
		dolomite	—	160
7.6g	drillers log	soil and clay	25	25
		sand and gravel	20	45
		silt	5	50
		gravel	25	75
		dolomite	10	85
		gravel	5	90
		dolomite	—	210
7.7d	drillers log	soil	10	10
		till	5	15
		sand	10	25
		till	25	50
		till, gravelly	5	55
		limestone	2	57
		till	3	60
		dolomite	—	110
7.8a	drillers log	soil	3	3
		gravel, silty	22	25
		sand	15	40
		gravel	10	50
		sand	10	60
		gravel	15	75
		sand	5	80
		gravel	20	100
		dolomite	—	114
8.5e	drillers log	soil and clay	19	19
		till	44	63
		gravel	12	75
		sand, fine, and gravel	11	86
		gravel	10	96
		dolomite	—	125
8.8h2	drillers log	no record	6	6
		sand	18	24
		clay	25	49
		gravel	—	83
36N11E–				
27.3c	drillers log	till	43	43
		gravel	33	76
		sand	29	105
		till, silty	27	132
		till, sandy	11	143
		gravel	13	156
		dolomite	—	175
31.8b2	drillers log	soil and clay	12	12
		sand and gravel	33	45
		fine sand	37	82
		clay with gravel	6	88
		gravel, clayey	10	98
		limestone	—	103
32.2c	drillers log	soil	10	10
		till	20	30
		gravel	7	37
		till	8	45
		gravel	45	90
		sand	23	113
		gravel	2	115
		till	15	130
		dolomite	—	140
32.3cl	drillers log	soil	1	1
		blue clay and boulders	39	40
		boulders	30	70
		fine sand	40	110
		cemented gravel	2	112
		blue clay	—	113
32.4al	drillers log	no record	25	25
		gravelly blue clay	5	30
		gravel with large rocks	5	35
		hard packed gravel	20	55
		gravel	15	70
		loose gravel	—	95

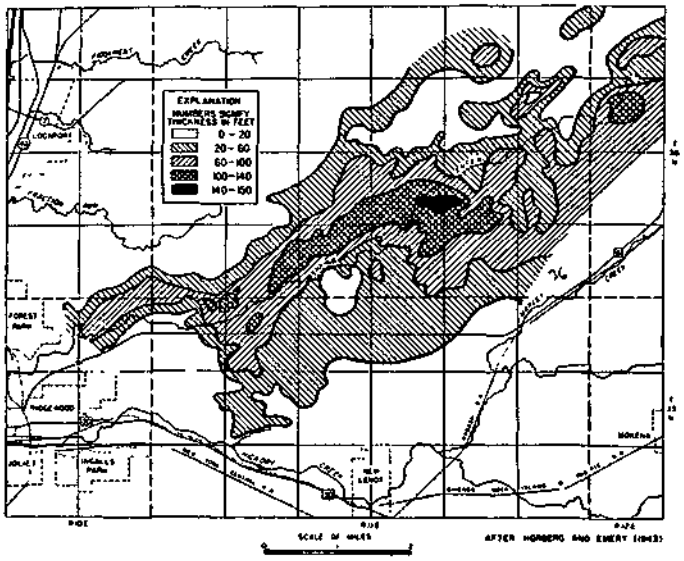

Figure 6. Saturated thickness of sand and gravel deposits in Hadley Valley area

The sand and gravel aquifer and the dolomite are overlain by till or other fine-grained deposits (confining bed) which impede or retard the vertical movement of ground water and confine the water in the formations under artesian pressure. Vertical leakage dirough the confining bed is possible and water is said to occur under leaky artesian conditions. The surface to which water will rise under these conditions, as defined by water levels in a number of wells, is the piezometric surface.

Hydraulic Properties of Aquifer and Confining Bed

The principal hydraulic properties of an aquifer and its confining bed influencing water-level decline and the yields of wells are the coefficients of permeability or transmissibility, storage, and vertical permeability.

Table 2. Records of Selected Wells and Test Holes in Hadley Valley Area

Well number	Year drilled	Depth *(ft)*	Casing depth *(ft)*	Casing diam *(in)*	Screen length *(ft)*	Screen diam. (in)	Pumping rate *(gpm)*	Specific capacity *(gpm/ft)*
WIL—								
35N10E-								
1.3h(T5)*	1945	98.5	88.5	6	10	6	180	2.4
35N11E-								
5.6d(T8)*	1945	111	81	6	30	6	345	26.5
5.7dl(2)	1950	90	60	18	30	18	699	21.8
5.7h2(l)	1950	103	63	18	40	18	1280	42.7
5.8a(T9)*	1946	88	58	6	30	6	184	38.8
6.3h(T6)*	1946	92	71	6	21	6	270	7.1
7.8a(T2)*	1945	97.5	76.5	6	21	6	180	6.8
8.8h2(3)	1950	83	58	18	25	18	1209	51.5
36N11E-								
27.3c*	1943	75	61	6	14	6	310	6.2
31.8b2*	1949	95	85	6	10	6	—	—
32.2c (T7)*	1946	97	67	6	30	6	300	27.3
32.3cl(4)	1950	112.5	72.5	18	40	18	1130	51.3
32.4al(5)	1950	95	60	18	35	18	1029	21.7

***** *Casing and screen removed after aquifer tests*

The capacity of a formation to transmit ground water is expressed by the coefficient of transmissibility, *T*, which is defined as the rate of flow of water in gallons per day, through a vertical strip of the aquifer 1 foot wide and extending the full saturated thickness under a hydraulic gradient of 100 percent (1 foot per foot) at the prevailing temperature of the water. The coefficient of transmissibility is the product of the saturated thickness of the aquifer, *m*, and the coefficient of permeability, *P*, which is defined as the rate of flow of water in gallons per day, dirough a cross-sectional area of 1 square foot of the aquifer under a hydraulic gradient of 100 percent at the prevailing temperature of the water. The storage properties of an aquifer are expressed by the coefficient of storage, which is defined as the volume of water released from storage per unit surface area of the aquifer per unit change in the water level.

The rate of vertical leakage of ground water dirough a confining bed in response to a given vertical hydraulic gradient is dependent upon the vertical permeability of the confining bed. The coefficient of vertical permeability, *P'*, is defined as the rate of vertical flow of water, in gallons per day, through a horizontal cross-sectional area of 1 square foot of the confining bed under a hydraulic gradient of 1 foot per foot at the prevailing temperature of the water.

Aquifer Tests

The hydraulic properties of an aquifer and its confining bed may be determined by means of aquifer tests, where the effect of pumping a well at a known constant rate is measured in the pumped well and at observation wells penetrating the aquifer. Graphs of drawdown versus time after pumping started, and/or drawdown versus distance from the pumped well, are used to solve equations which express the relation between the coefficients of transmissibil-

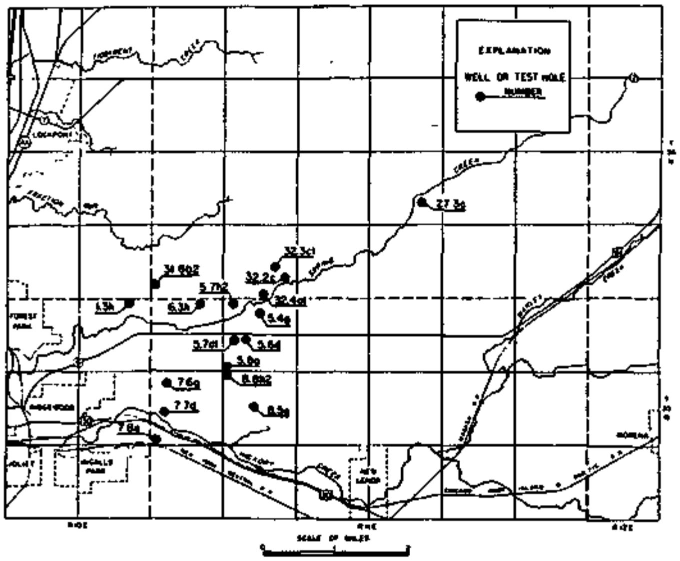

Figure 7. Location of (elected wells and test holes in Hadley Valley area

ity, vertical permeability and storage, and the lowering of water levels in the vicinity of a pumped well.

The data collected during aquifer tests can be analyzed by means of the leaky artesian formula (Hantush and Jacob, 1955) which can be expressed by the following relation:

$$s = (114.6Q/T)\ W(u,r/B) \qquad (1)$$

where;

$$W(u,r/B) = \int_u^{\infty} (1/u)\ \exp\ (-u - r^2/4B^2u)\ du$$

$$u = 2693r^2S/Tt \qquad (2)$$

and

$$r/B = r/\sqrt{T/(P'/m')} \qquad (3)$$

s = drawdown in observation well, in ft
r = distance from pumped well to observation well, in ft
Q = discharge, in gpm
t = time after pumping started, in min
T = coefficient of transmissibility of aquifer, in gpd/ft
S = coefficient of storage of aquifer, fraction
p' = vertical permeability of confining bed, in gpd/sq ft
m' = saturated thickness of confining bed through which leakage occurs, in ft

Several controlled aquifer tests were made in 1950; the pumping rates during two of the tests were constant for about 17 hours, and the data for these two tests were analyzed to determine hydraulic properties. These tests were made by Consoer, Townsend and Associates, consulting engineers, and Layne-Western Company, well contractors.

An aquifer test (test 1) was made September 8 and 9, 1950. The effects of pumping well 32.3cl were measured

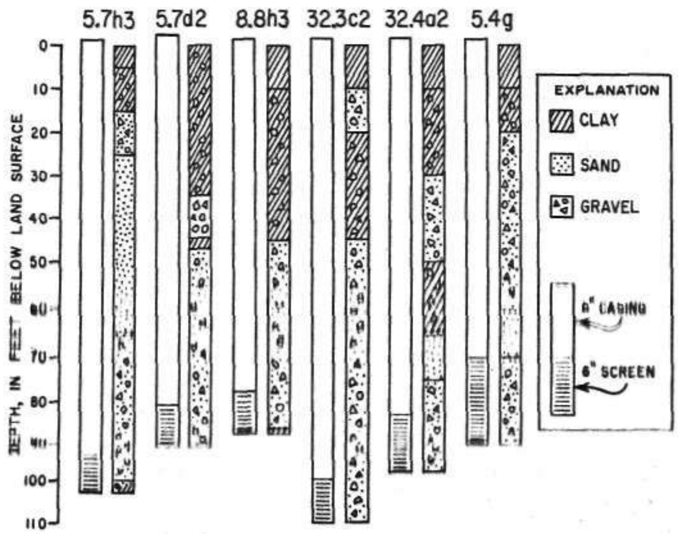

Figure 9 Generalized construction features and logs of observation wells in Hadley Valley area

in the pumped well and in observation wells 32.3c2, 32.4a2, 5.4g, 5.7h3, 5.7d2, and 8.8h3. The locations of the wells used during the test are shown in figure 8; logs of the observation wells are given in figure 9. Pumping was continuous for about 17 hours at a constant rate of 1130 gpm.

Test 2 was made August 21 and 22, 1950. The effects of pumping well 32.4a1 were measured in the pumped well and in observation wells 32.4a2, 5.4g, 5.7h3, 5.7d2, and 8.8h3. Pumping was continuous for about 18 hours at a constant rate of 1018 gpm. The locations of the wells used during the test are shown in figure 8; logs of the observation wells are given in figure 9.

Drawdowns in the pumped and observation wells were determined by comparing water levels measured before pumping started with water levels measured during the pumping period. Drawdowns at the ends of the test are

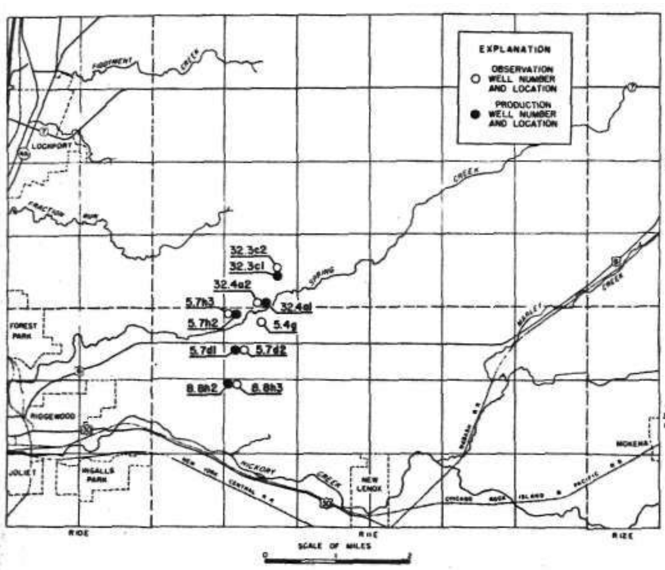

Figure 8. Location of wells used in aquifer torts in Hadley Valley area

Table 3. Distance-Drawdown Data for Aquifer Tests in Hadley Valley Area

Well number	Distance from pumped well (*ft*)	Drawdown for pumping period of 1000 min (*ft*)
Test 1		
WIL—		
36N11E-		
32.3cl		**22.00**
32.3c2	**17.5**	**13.80**
32.4a2	**1770**	**0.77**
35N11E-		
5.4g	**3220**	**0.35**
5.7h3	**3810**	**0.26**
5.7d2	**5390**	**0.19**
8.8h3	**7950**	**0.09**
Test 2		
MIL—		
36N11E-		
32.4al		**47.00**
32.4a2	**18.5**	**12.50**
35N11E-		
5.4g	**1690**	**0.67**
5.7h3	**2100**	**0.74**
5.7d2	**3640**	**0.33**
8.8h3	**6260**	**0.16**

given in table 3. Drawdowns in observation wells were plotted against time on logarithmic paper. The time-drawdown field data graphs for well 32.4a2 (test 1) and well 5.7h3 (test 2) are given, as examples, in figure 10.

Time-drawdown field data graphs were superposed on the family of nonsteady-state leaky artesian type curves (Walton, 1960). The type curves found to be analogous to the time-drawdown field data graphs were noted. The time-drawdown field data graphs were matched to type curves, and equations 1, 2, and 3 were used to compute hydraulic properties as illustrated in figure 10. The average computed coefficients of transmissibility, permeability, storage, leakage *(P'/m')*, and vertical permeability are 186,000 gpd/ft, 3100 gpd/sq ft, 0.0015, 0.034 gpd/cu ft, and 1.02 gpd/sq ft, respectively. As indicated by the theoretical distance-drawdown curve shown in figure 11, the aquifer tests sampled an area of the aquifer having a radius of roughly 10,000 feet. The coefficients computed from the results of the tests represent the average hydraulic properties of the aquifer and confining bed within that area of influence. A comparison of the coefficients computed from test data with the hydraulic properties of other aquifers and confining beds in Illinois given by Walton (1960), indicates that 1) the coefficients of transmissibility and permeability of the aquifer in Hadley Valley are moderately high; 2) the coefficient of storage of the aquifer in

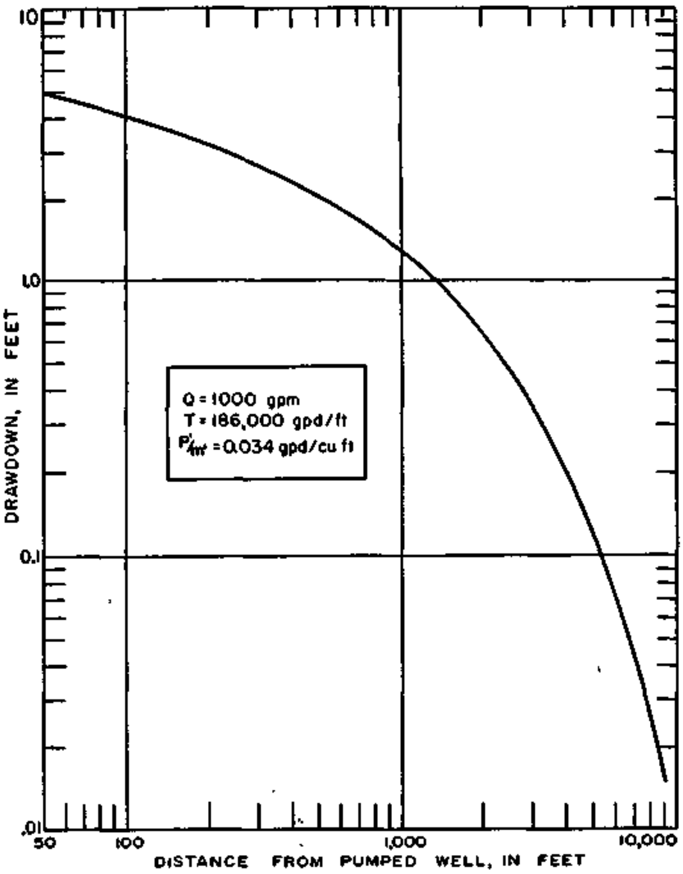

Figure 11. Theoretical distance-drawdown graph for aquifer tests in Hadley Valley area

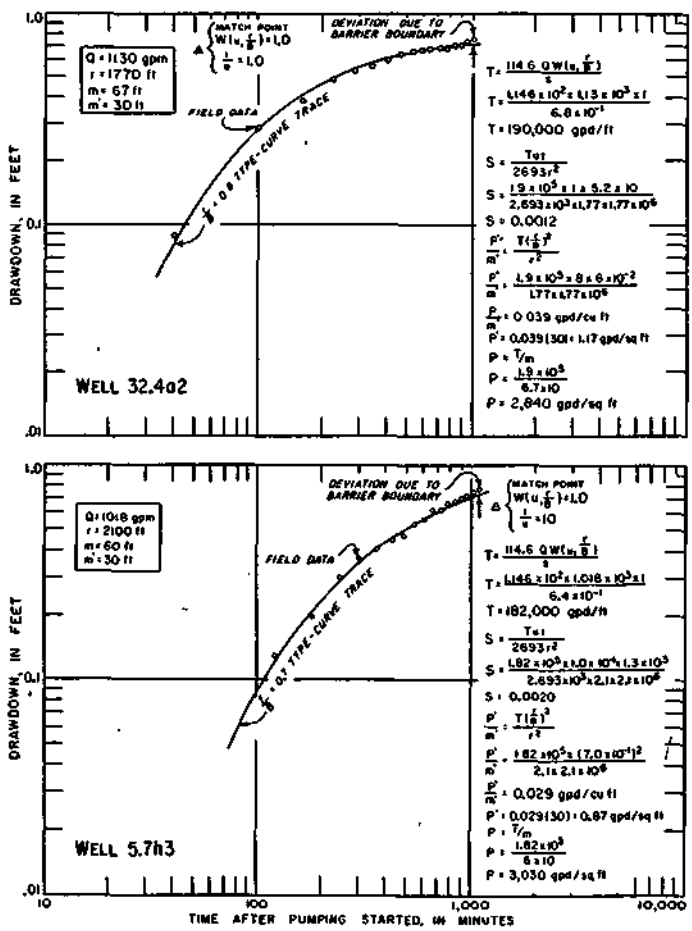

Figure 10. Time-drawdown graphs for two wolls in Hadley Valley area

Hadley Valley is high; 3) the vertical permeability of the confining bed in Hadley Valley is high. The high coefficients of storage and vertical permeability suggest that recharge will have little difficulty reaching the aquifer.

Leakage during the short-term aquifer tests lowered the water table very little, and the confining bed was not appreciably drained. However, as a consequence of prolonged heavy pumping during the summer and fall months when recharge to the water table is small, the confining bed will be partially drained and leakage will not keep up with discharge as it did during the aquifer tests. Computations of long-term drawdown must take into consideration the draining of the confining bed. The coefficient of storage of the confining bed cannot be computed from test data.

The time-drawdown field data deviate slightly from type curve traces towards the ends of the tests as time-rates of drawdown increase. As shown in figures 5 and 6 the aquifer is bounded on the north, south, and southwest by dolomite which is much less permeable than the sand and gravel. The dolomite delimits the aquifer and acts as barrier boundaries. The barrier boundaries distort cones of depression and increase drawdown in wells. Thus, the increase in the time-rate of drawdown after about 800 minutes of pumping is attributed to the effects of the barrier boundary north of wells 32.3cl and 32.4al.

Rough estimates of the coefficient of transmissibility were made with specific-capacity data for existing production wells. Available specific-capacity data were adjusted for the effects of partial penetration and well loss (see Walton, 1962). Coefficients of transmissibility were then computed with the following equation:

$$Q/s = T/[264 \log (Tt/2693 r_w^2 S) - 65.5] \qquad (4)$$

where:

Q/s = specific capacity of well adjusted for effects of partial penetration and well loss, in gpm/ft
T = coefficient of transmissibility, in gpd/ft
S = coefficient of storage, fraction
r_w = nominal radius of well, in ft
t = pumping period, in min

The coefficient of storage computed from the aquifer tests was used in computations. The coefficients of transmissibility estimated with specific-capacity data for wells 32.3cl and 32.4al are within a few percent of the average coefficient of transmissibility computed from aquifer-test data.

Theoretical Effects of Pumping

Pumping from wells in the aquifer has a fairly widespread effect on water levels. The nonequilibrium formula (Theis, 1935), the coefficient of transmissibility of the aquifer determined from the results of the aquifer test, and the estimated long-term coefficient of storage of the confining bed were used to evaluate the magnitude of interference between wells, and to compute the theoretical decline in the piezometric surface at any distance from a pumped well and within any length of time after pumping started.

Figure 12 shows the amount of interference that will occur at distances of 100 feet to 60,000 feet from a well pumping continuously at 695 gpm or 1 mgd for periods of 90 days, 6 months, and 2 years. The drawdowns given occur at equal distances from the pumped well in all directions. The graphs assume that all the water pumped is withdrawn from storage in the confining bed and that the aquifer is infinite in areal extent. The aquifer in the Hadley Valley area is bounded by barrier boundaries; therefore, actual drawdowns are greater than those shown in figure 12.

The drawdown is appreciable several thousands of feet from the pumped well. For example, the drawdown at a distance of 5000 feet is about 1 foot for a pumping period of 6 months. The theoretical drawdown is directly proportional to the pumping rate. If the pumping rate is 347 gpm instead of 695 gpm the drawdown would be one-half that shown in figure 12.

Geohydrologic Boundaries of Aquifer

The graphs in figure 12 were constructed assuming an aquifer of infinite extent However, geologic conditions limit the extent of the aquifer. As shown in figures 5 and

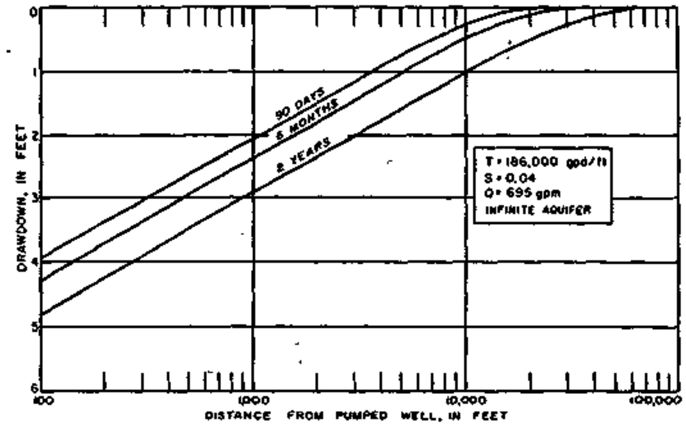

Figure 12. Graph of theoretical distance-drawdown for aquifer similar to that in Hadley Valley area

6 the sand and gravel deposits are bounded on the north, southwest, and south by dolomite. Based on specific-capacity data, the average coefficient of transmissibility of the dolomite is only about 20 percent as great as the average coefficient of transmissibility of the sand and gravel. Thus, the dolomite delimits the aquifer and acts as barrier boundaries. The barrier boundaries distort cones of depression and increase drawdown in wells.

By treating the boundaries as straight-line demarcations, the image-well theory described by Ferris (1959) can be used to evaluate the influence of the barrier boundaries on the regional effects of pumping.

The image-well theory as applied to barrier boundaries may be stated as follows: The effect of a barrier boundary on the drawdown in a well, as a result of pumping from another well, is the same as though the aquifer were infinite and a similar discharging well were located across the real boundary, on a line at right angles to, and at the same distance from, the boundary as the real pumping well. Thus, an imaginary hydraulic system of a well and its image counterpart in an infinite aquifer satisfies the actual barrier boundary conditions.

The arrangement of the three barrier boundaries is such mat the north and south boundaries are for practical purposes parallel to each other. These two boundaries are intersected at right angles by a barrier boundary soudiwest of the municipal well field. The image-well system for the aquifer situation is shown in figure 13. The fact that the dolomite has some permeability was taken into consideration by using only a limited number of discharging image wells associated with the barrier boundaries, thus decreasing the adverse effect of the barrier boundaries and allowing for some movement of water through the dolomite into the aquifer. The soudiwest boundary actually is only a partial boundary (see figure 6). The effect of the partial boundary was imitated by slightly increasing the distance between the production wells and the barrier boundary.

Figure 14 shows the effects of the barrier boundaries on the drawdown in well 5.4g as the result of pumping well 32.2cl at a constant rate of 900 gpm for 180 days.

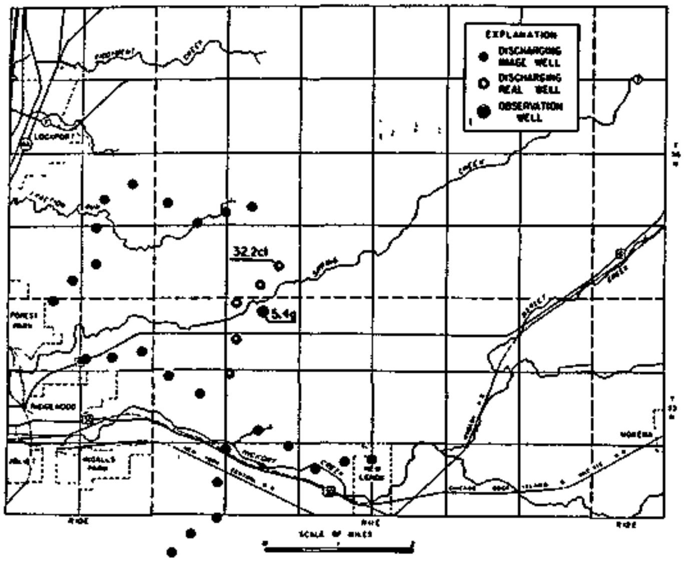

Figure 13. Plan of image-well system for aquifer in Hadley Valley area

Construction Features and Yields of Wells

The production wells were drilled by the conventional rotary and reverse rotary methods during 1949 and 1950. They range in depth from 83 to 112 feet. The construction features of the wells are basically the same; only the lengths of casing and screen differ from well to well. The case history of the drilling of well 8.8h2 will illustrate construction features. During the construction of well 8.8h2, a 48-inch diameter hole was excavated with an orange peel bucket to a depth of 25 feet and a 48-inch diameter casing was installed in the hole. A 36-inch diameter hole was then drilled to a depth of 51 feet with a reverse rotary rig, and 36-inch diameter casing was set from the ground surface to a depth of 51 feet A 36-inch hole was then drilled to the finished depth of 83 feet, and a No. 6 Layne brass shutter screen, 18 inches in diameter and 25 feet long, was set at the bottom of the well. Eighteen-inch diameter casing was set from the top of the screen to the ground surface. The annulus between the 18-inch diameter screen and casing and 36-inch diameter hole and casing was filled with 1/16- and 1/8-inch gravel. The annulus between the 36-inch casing and the 48-inch casing was grouted with concrete. The construction features of the production wells are illustrated in figure 15 and the well locations are shown in figure 16.

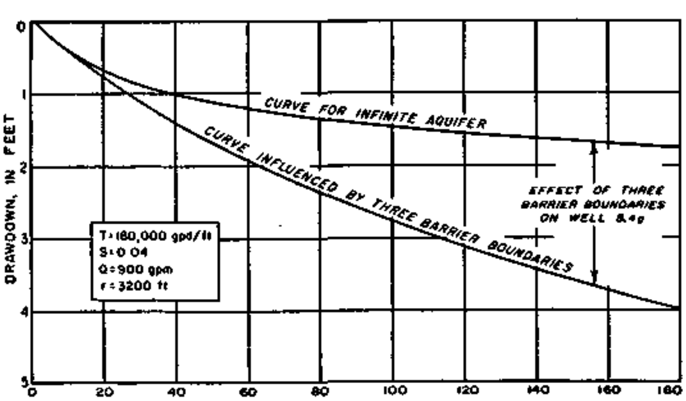

Figure 14. Graph of theoretical time-drawdown considering barrier boundaries for aquifer in Hadley Valley area

The production wells were tested after completion to determine their yields. They were tested again in April 1962 to ascertain whether or not yields had decreased during the last 10 years. The results of the well-production tests are summarized in table 4.

The yield of a well may be expressed in terms of its specific capacity. The specific capacity of a well is defined

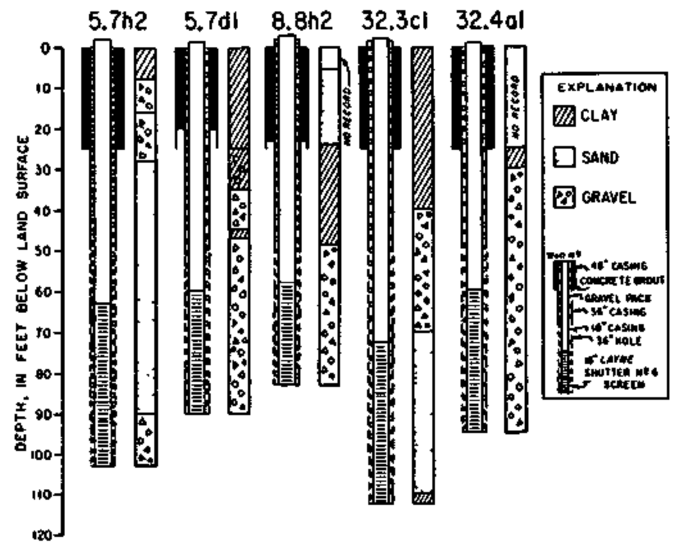

Figure 15. Generalized construction features and logs of production wells in Hadley Valley area

Table 4. Yields of Sand and Gravel Wells
in Hadley Valley Area

Well number	Length of screen (ft)	Thicknen of aquifer (ft)	Percent of penetration	Date of test	Length of test (min)	Pumping rate (gpm)	Draw-down (ft)	Specific capacity (gpm/ft)
WIL—								
35N11E-								
5.7dl	30	46	65	5/11/50	30	305	13.5	22.6
					30	433	19.5	22.2
					30	699	32.0	21.8
				1/11/62	10	625	24.2	25.8
5.7h2	40	100	40	6/21/50	20	717	14.0	51.2
					20	950	19.0	50.2
					20	1023	22.0	46.6
					20	1148	25.0	45.8
					20	1280	30.0	42.7
				1/11/62	10	400	26.0	15.4
8.8h2	25	41	61	8/14/50	20	421	6.0	70.2
					20	618	10.0	61.8
					20	805	13.5	59.6
					20	1007	18.5	54.4
					20	1209	23.5	51.5
				1/11/62	10	750	10.1	74.3
36N11E-								
32.3cl	40	70	57	9/8/50	40	458	8.0	57.4
					30	1130	22.0	51.3
				1/11/62	10	800	44.9	17.8
32.4al	35	67	52	8/21/50	60	805	35.0	23.0
					60	967	43.0	22.5
					60	1029	47.5	21.7
				5/21/62	10	780	38.2	20.4

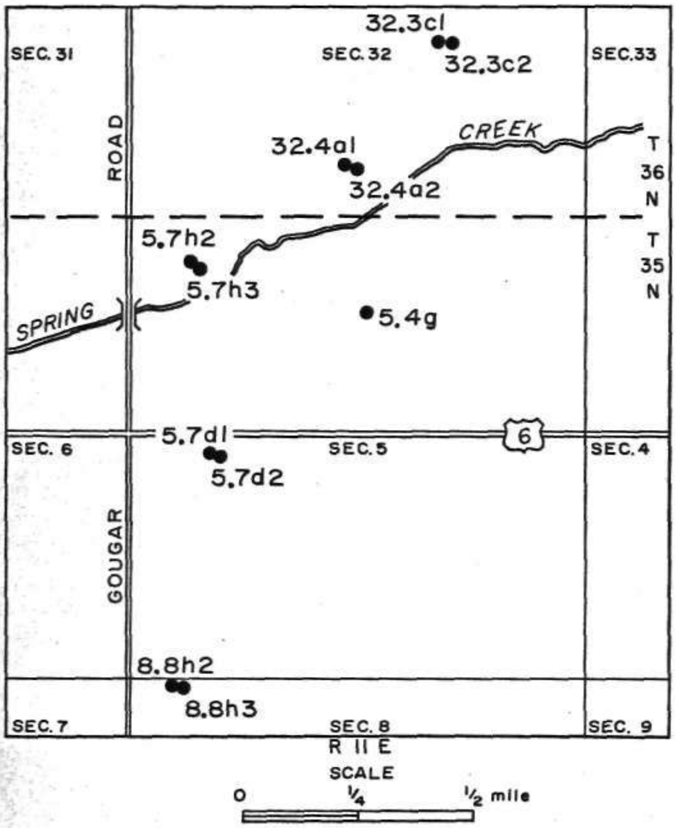

Figure 16. location of production and observation walls in Hadloy Valloy area

as the yield of the well in gallons per minute per foot of drawdown (gpm/ft) for a stated pumping period and rate. The specific capacity decreases witii the length of the pumping period until water levels stabilize because the drawdown continually increases with time until equilibrium conditions prevail. In wells having appreciable well loss, the specific capacity decreases with an increase in the pumping rate. Well loss is the head loss or drawdown due to the turbulent flow of water as it enters the screen and flows upward through the well.

Well loss may be represented approximately by the following relationship (Jacob, 1946a):

$$s_w = CQ^2 \tag{5}$$

where:

s_w = well loss, in ft

C = well-loss constant, in sec^2/ft^5

Q = rate of pumping, in cubic feet per second (cfs)

The value of C may be estimated from the data collected during a "step-drawdown" test by using the equation given below (see Jacob, 1946a). In a step-drawdown test the well is operated during three successive periods at constant fractions of full capacity.

For steps 1 and 2

$$C = \frac{(\Delta s_2/\Delta Q_2) - (\Delta s_1/\Delta Q_1)}{\Delta Q_1 + \Delta Q_2} \tag{6}$$

For steps 2 and 3

$$C = \frac{(\Delta s_3/\Delta Q_3) - (\Delta s_2/\Delta Q_2)}{\Delta Q_2 + \Delta Q_3} \tag{7}$$

where:

the Δs terms represent increments of drawdown produced by each increase *(AQ)* in the rate of pumping. The commonly used dimensions of *As* and *AQ* are feet and cubic feet per second, respectively.

The production wells are not screened opposite the entire saturated thickness of the aquifer and are said to partially penetrate die aquifer. The partial penetration of a well increases the drawdown in a well because some of the water that enters the well must percolate downward from the part of the aquifer above the screen. Water percolating vertically as well as horizontally to a well moves a greater distance than if it had percolated only horizontally, and thus more drawdown occurs than would have occurred if the well had completely penetrated the aquifer.

The drawdown due to the effects of partial penetration may be approximated with the following equation (see Muskat, 1946);

$$s_p = s\left[\left\{1/\alpha\left[1+7\sqrt{r_w/2m\alpha}\cos(\pi\alpha/2)\right]\right\}-1\right] \tag{8}$$

where:

s = drawdown for full penetration, in ft

s_p = drawdown due to effects of partial penetration, in ft

r_w = nominal radius of well, in ft

a = ratio of screen length and saturated thickness of aquifer

m = saturated thickness of aquifer, in ft

The specific capacities of the production wells range from 15.4 to 74.3 gpm/ft. A comparison of the specific capacities in 1950 and in 1962 indicates that the yields of wells 5.7dl, 8.8h2, and 32.4al have not reduced witii use, and the yields of wells 5.7h2 and 32.3cl have decreased during the last 10 years.

After completion of the wells, step-drawdown tests were made. Several of the wells were unstable during the tests, and the data could not be used to determine well-loss constants C. Values of C of 2.0 and 1.0 were computed for wells 8.8h2 and 5.7dl, respectively.

Silurian rocks below the glacial drift in the Hadley Valley area yield appreciable amounts of water to wells. The productivity of the dolomite is very inconsistent and the yields of dolomite wells vary gready from place to place. During the period 1945 to 1961, well-production tests were made on five dolomite wells near the Hadley Valley area. The results of the tests are summarized in table 5. Specific capacities of the wells range from 5.3 to 57.2 gpm/ft and average 22 gpm/ft indicating that the dolomite is permeated by numerous openings. A dolomite well in Pilcher Park near well 8.8h2 has been flowing at a moderate rate for about 35 years.

Table 5. Yields of. Dolomite Wells **in Vicinity** of Hadley Valley Area

Well number	Diam. *(in)*	Depth *(ft)*	Depth of penetration *(ft)*	Year of test	Length of test *(hr)*	Pumping rate *(gpm)*	Drawdown *(ft)*	Specific capacity *(gpm/ft)*
WIL—								
35N10E-								
11.5e	**8**	**277**	**185**	**1945**	**-**	**80**	**15**	**5.3**
35N11E-								
7.7a	**7**	**145**	**55**	**1956**	**2**	**200**	**8**	**25.0**
21.2b2	**12**	**325**	**225**	**1961**	**8**	**302**	**41**	**7.4**
35N12E-								
8.6c	**8**	**220**	**—**	**1958**	**-**	**475**	**31**	**15.3**
36N11E-								
11.1g	**12**	**485**	**—**	**1957**	**5**	**400**	**7**	**57.2**

Ground-Water Withdrawals

Although the five sand and gravel wells were completed during the summer months of 1950, large withdrawals of ground water did not start until early in 1952 as shown in figure 17. Small amounts of water were pumped during May, June, and July of 1951 at a maximum rate of about 0.5 mgd. Pumpage increased during the period 1952 through 1953 and reached a peak of 5.4 mgd in December 1953. As the result of the heavy withdrawals, water levels in domestic wells in the vicinity of the well field declined, and well owners started to file complaints against the city. Pumpage was greatly reduced during February, March, and April of 1954 to allow recovery of water levels in domestic wells. However, pumpage increased to over 5.0 mgd during the last half of 1954. Two other sharp decreases in ground-water withdrawal occurred during 1955 as shown in figure 17. From 1956 through 1961, pumpage has been generally greatest during the summer months and least during the winter months. The maximum average monthly rate of ground-water withdrawal, about 5.9 mgd, was recorded for August 1957.

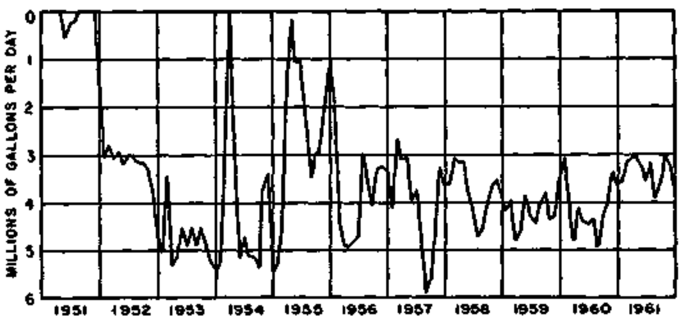

Figure 17. Average monthly pumpage from Kind and gravel aquifer in Hadley Valley area, 1951-1961

Rates of pumpage for individual wells are shown in figure 18. The amounts of ground water withdrawn from individual wells during the period 1951 through 1961 and pump data are given in table 6. About 57 percent of the total pumpage was withdrawn from wells 8.8h2 and 32.3c1; well 32.3cl is the most heavily pumped well. In general,

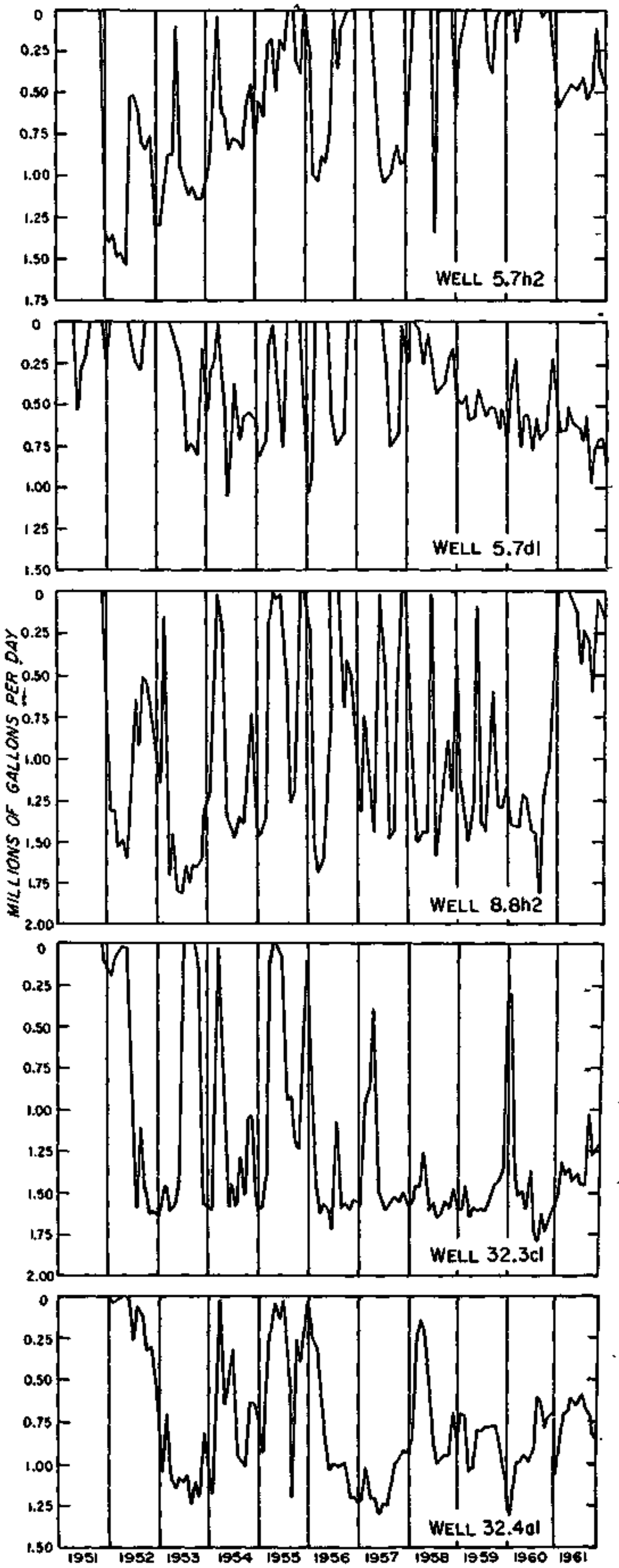

figure 18. Average monthly pumpage from five wells in Hadley Valley area, 1951-1961

Table 6. Distribution of Ground-Water Withdrawals from Sand and Gravel Wells in Hadley Valley Area, 1951-1961

Well number	Total pumpage, 1951-1961 (*bil gal*)	Motor horse-power	Pump rating capacity/head (*gpm*)/(*ft*)	Pump setting (*ft below land surface*)
WIL—				
35N11E–				
5.7d1	1.41		600/100	70
5.7h2	1.75	50	1000/100	80
8.8h2	3.36	50	1000/126	75
36N11E–				
32.3c1	4.46	50	1000/120	100
32.4a1	2.69		900/105	80
Total	13.67			

individual well-pumpage graphs show a yearly cycle; withdrawals are greatest in the summer and least in the winter.

As shown in figure 19, total ground-water withdrawal varied greatly during the period 1952 to 1955 but was fairly uniform from 1956 to 1961. A maximum average annual pumpage of 4.75 mgd was recorded in 1953; except for the first year of operation, a minimum average annual pumpage of 2.20 mgd was recorded in 1955. From 1956 through 1961 average annual pumpage was 3.75 mgd. In 1961 total ground-water withdrawal averaged 3.30 mgd.

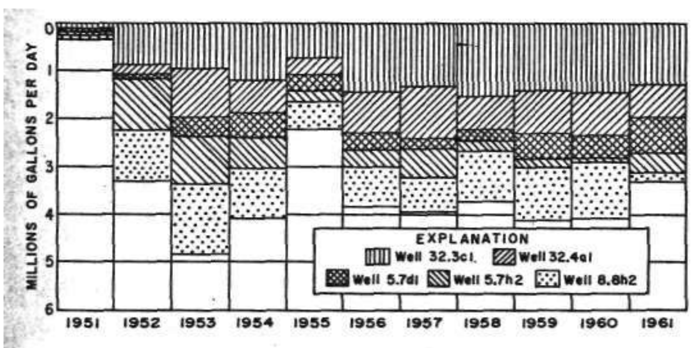

Figure 19. Average annual pumpage from sand and gravel aquifer in Hadley Valley area, 1951-1961, subdivided by well

Ground-water withdrawals from dolomite within a 2-mile radius of the municipal well field are summarized in table 7. None of these ground-water withdrawals is from wells within the area of diversion of the well field.

Table 7. Ground-Water Withdrawals from Dolomite in Vicinity of Hadley Valley Area

Well number	Owner	Pumpage in 1960 (*mgd*)
WIL—		
35N11E-		
7.3d	Pilcher Park	0.150
7.7a	Cherry Hill Sbd.	0.010
17.8g	N. Ill. Gas Go.	0.010

Fluctuations of Water Levels and Their Significance

A recording gage was installed on well 5.7d2 in May 1954; prior to May 1954 water levels in the well were periodically measured with a steel tape. The location of the well is shown in figure 16. Water-level fluctuations in the well during 1959, a year of near normal precipitation, are shown in figure 20. Ground-water withdrawals were fairly constant during the year, thus the large rise in water levels starting in April cannot be attributed to a reduction in pumpage but is the result of recharge from precipitation. Water levels rose, or the rate of water-level decline decreased, during portions of every month except January and December following periods of precipitation, indicating that some ground-water recharge occurred in most months of the year. Water levels start to rise shortly after periods of rainfall, suggesting that the aquifer is readily recharged from precipitation. Ground-water recharge is greatest in spring months of heavy rainfall and least in summer and fall months. Many ordinary summer rains have little or no effect on water levels. In general, maximum water levels are recorded in June and July after the major recharge season; minimum water levels occur during the late fall or winter after the heavy pumping season.

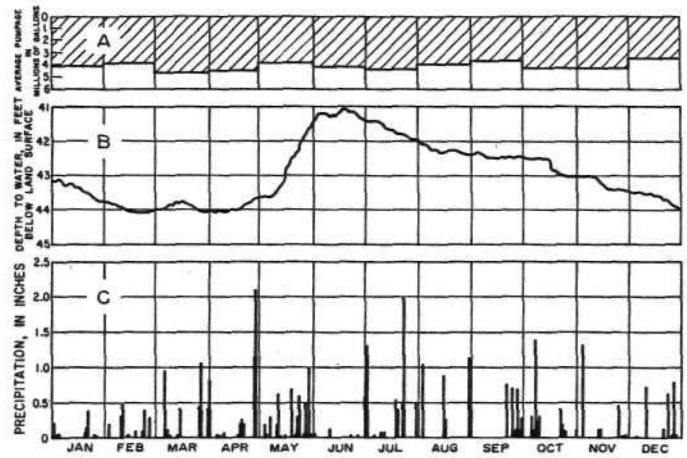

Figure 20. Ground-water pumpage (A), daily water levels in well 5.7d2 (B), and daily precipitation (C) during 19S9 in Hadley Valley area

Water-level fluctuations in well 5.7d2, 1950 through 1961, are shown in figure 21. Water levels in the well are affected to a great degree by pumpage from nearby well 5.7dl but are also influenced by changes in pumping rates

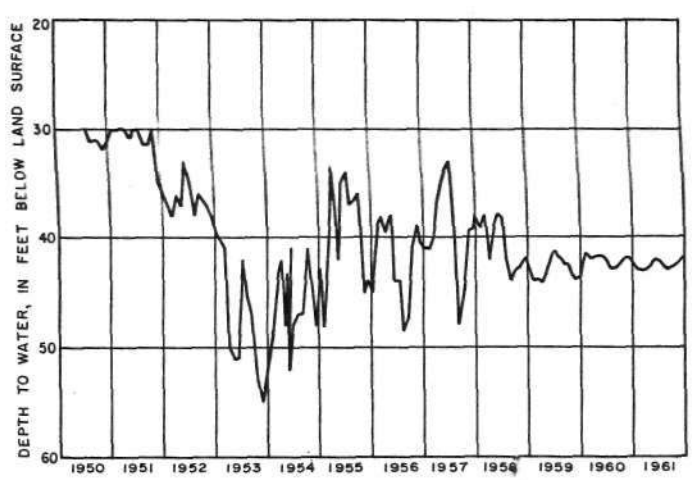

Figure 21. Water levels in well 5.7d2 in Hadley Valley area, 1950-1961

of the other four production wells and recharge from precipitation. The trend of water levels in well 5.7d2 is generally parallel to the trend of the pumpage graph in figure 17. Prior to development, water levels fluctuated in response to natural conditions of discharge and recharge; the range of change in water levels, less than 3 feet, was small. After development, water levels fluctuated to a greater extent, more than 14 feet in short periods of time, chiefly in response to changes in pumpage. It was necessary for water levels to decline permanently to stages below those recorded in 1950 in order that hydraulic gradients could be established toward production wells. However, no serious continuing downward trend in water levels has resulted from development. Water levels were at the same stage, about 42 feet below land surface, in March 1953 and in December 1961, indicating that water pumped from 1953 through 1961 was replenished in full.

Although precipitation was far below normal in 1956 and pumpage averaged 3.8 mgd, water levels did not decline to critical stages. The minimum water level in 1956 was only 6 feet lower than water levels recorded in 1960, when precipitation was nearly normal and pumpage was slightly greater than it was in 1956. Water taken from storage within me aquifer during years of below-normal precipitation was replaced during the years of normal and above-normal precipitation. During the period from 1958 through 1961 when pumpage was fairly uniform, water levels stabilized at an average stage of about 42 feet below land surface, suggesting that recharge balanced discharge.

A recording gage was in operation on well 5.4g during the period from 1950 through 1953. Figure 22 shows a hydrograph of water levels in the well. Water-level fluctuations before development and the effects of municipal pumpage are apparent. Well 5.4g is farther from produc-

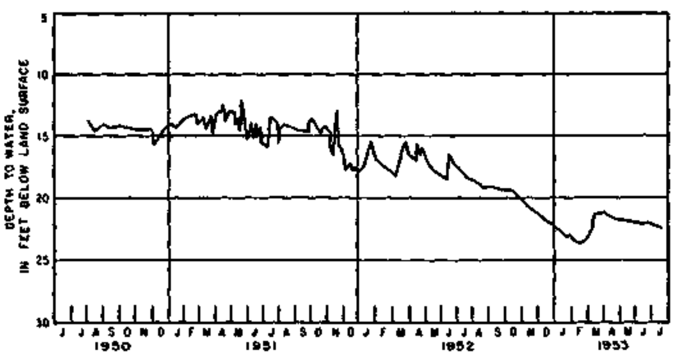

Figure 22. Water levels in wall 5.4g in Hadley Valley area, 1950-1953

tion wells than is well 5.7d2 (see figure 16). In general, the trend of water levels in well 5.4g parallels the trend of water levels in well 5.7d2. The drawdown due to development is less in well 5.4g than in well 5.7d2, however, because of the relative distances to production wells. Water levels in well 5.4g declined about 8 feet during the period 1950 through 1953, whereas water levels in well 5.7d2 declined about 22 feet during the same period.

Both nonpumping and pumping levels in production wells were measured periodically prior to and after development. Nonpumping level hydrographs for the five production wells are shown in figure 23. Although the water levels vary considerably from time to time because of shifts in

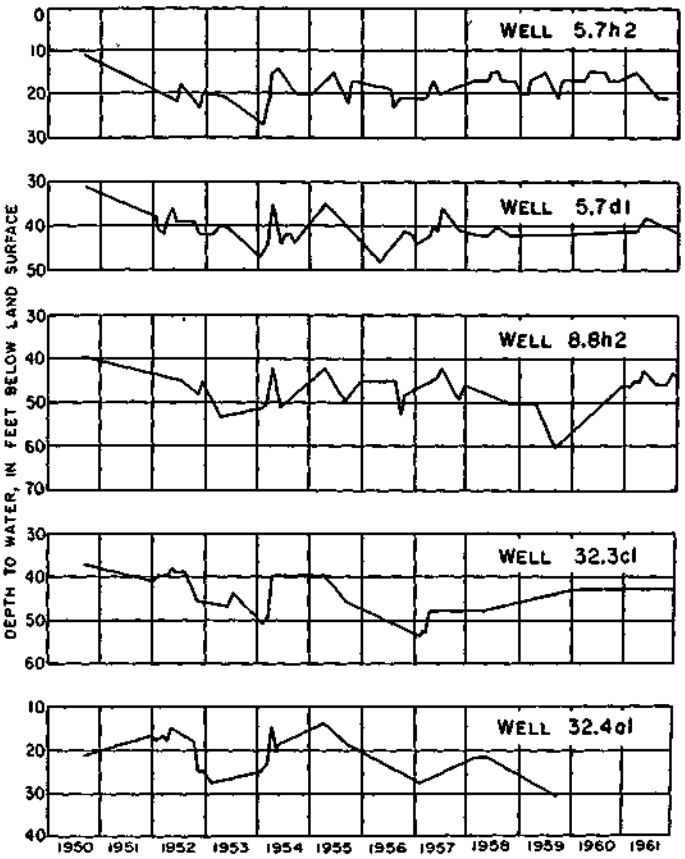

Figure 23. Nonpumping levels in five wells in Hadley Valley area, 1950-1961

pumpage from one well to the other and changes in total pumpage, the hydrographs show no continuous decline in water levels. Pumping levels in the production wells are shown in figure 24. Pumping levels have been below tops of screens for long periods of time in all wells but well 5.7h2. Exposing screens to air often accelerates the rate of clogging of screen openings and is undesirable. The hydrographs in figure 24 suggest that present pumping rates in some wells are excessive.

A comparison of hydrographs in figures 23 and 24 and pumpage graphs in figure 18 indicates that in general water-level decline is proportional to the rate of pumpage. Average water-level declines in wells plotted against corresponding average rates of pumpage in the well field are shown in figure 25. The data are somewhat scattered, but the consistent relationship between decline and pumpage is apparent. Approximately 380,000 gpd were obtained with each foot of decline. The consistent relationship between decline and pumpage and the fact mat water level stabilize after each increase in pumpage indicate that in the past recharge has balanced withdrawal.

Configuration of Piezometric Surface of Aquifer

Prior to development, the piezometric surface of the aquifer was very near the surface in the flood plain of Spring Creek and fairly high under the surrounding uplands. Data on water levels in wells prior to development given in table 8 suggest that the piezometric surface was a subdued replica of the topography, and the general direction of movement of ground water was from uplands towards the streams draining the area. Ground-water divides roughly coincided with surface-water divides. The piezometric surface sloped from an estimated elevation of about 675 feet in the northeast part of the area to about 600 feet in the southwest part. The average slope of the piezometric surface was about 17 feet per mile, and the slope ranged from 3 to 35 feet per mile. The slope was greatest near Spring Creek in the southwest part of the area.

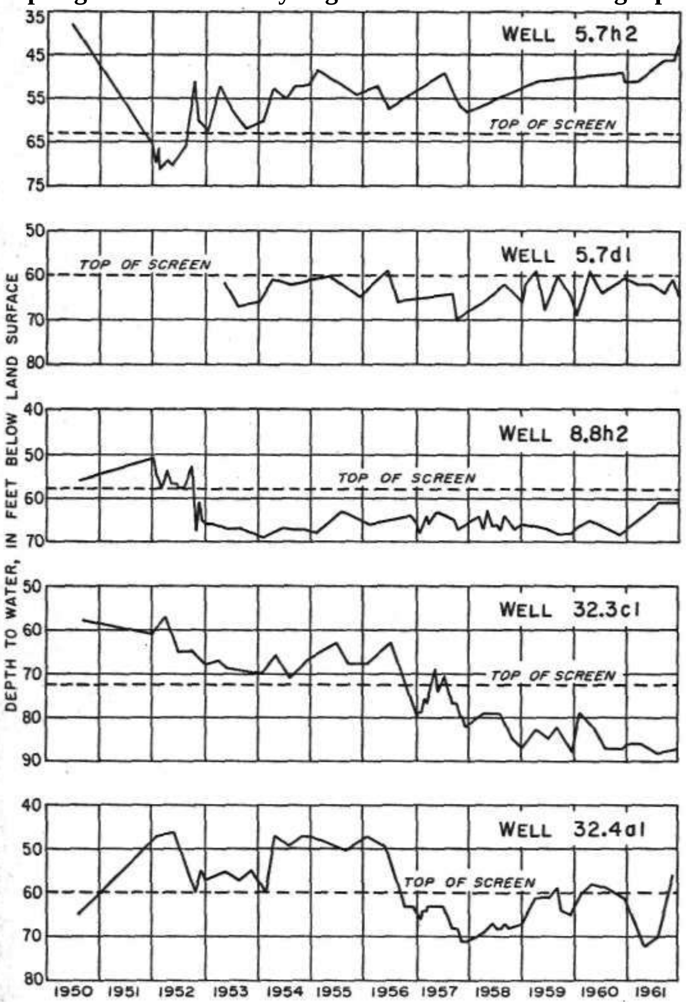

Figure 24. Pumping levels in five wells in Hadley Valley area, 1950-1961

The approximate piezometric surface of the aquifer after development is shown in figure 26. The map was prepared from water-level measurements in table 8, made on May 24 and 25, 1962. The altitudes of the land surface at the wells were determined by means of altimeters. There are few wells in the area in the aquifer; most domestic wells are open in the dolomite below the aquifer. The aquifer and the dolomite have slightly different heads at the same location (see wells 32.4el and 32.4e2 in table 8). It was not practical to map the piezometric surface using only the few available wells in the aquifer; water-level data for wells in the dolomite were used to augment data for wells in the aquifer. On the basis of measured water levels in a few closely spaced wells drilled to different depths, it is considered probable that the piezometric surfaces of the aquifer and the dolomite are, in general, very similar. Accordingly, it is believed that the contours on figure 26 show the approximate directions of movement of ground water, the average hydraulic gradients of the piezometric surface, and the area of diversion of pumping in the aquifer.

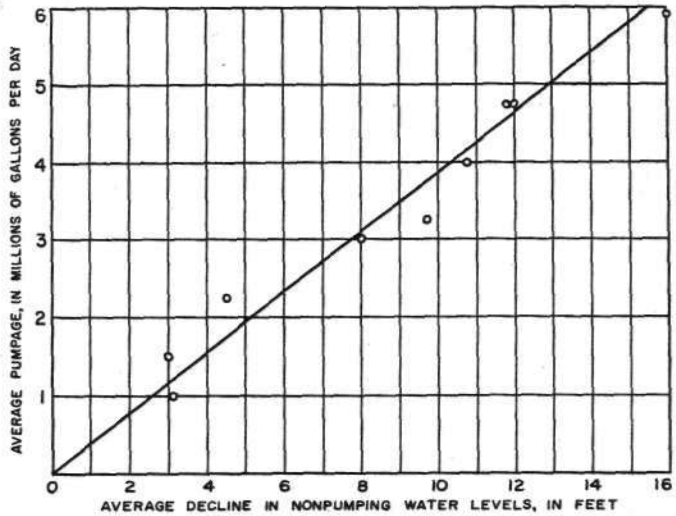

Figure 25. Relation between average pumpage and decline in water levels in Hadley Valley area

There are no well-defined cones of depression in the area. Pumping has considerably reduced natural discharge of ground water to Spring Creek and has warped contours upstream. Most of the ground water which under natural

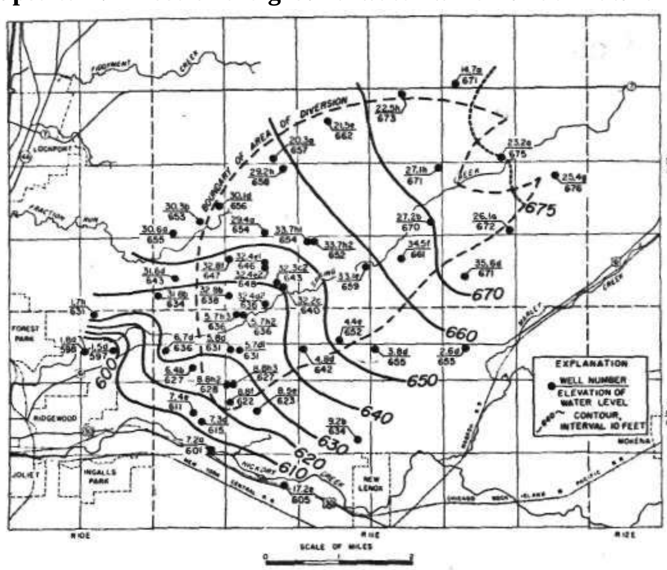

Figure 26. Approximate elevation of piezometric surface in Hadley Valley area, May 24-25, 1942

Table 8. Water Levels in Wells in Hadley Valley Area

Well number	Owner	Depth (ft)	Aquifer*	Land surface elevation (ft above MSL)	Depth to water (ft)	Date measured	Water level elevation (ft above MSL)
WIL—							
35N10E–							
1.5d	St. Cyrits Cmty.	103	dol	621	23.77	5/25/62	597.23
1.7h	E. Blum	75	dol	645	14.44	5/25/62	630.56
1.8d	—	30	s&g	615	17.42	5/25/62	597.58
35N11E–							
2.6d	G. Yapp	85	dol	720	65.29	5/24/62	654.71
2.7e	W. Warwick	125	dol	725	62	1948	663
3.8d	Haven Motel	180	dol	731	74.71	5/24/62	656.29
4.4e	—	318	dol	728	75.66	5/25/62	652.34
4.8d	Lynk Schl.	150	dol	700	58.00	5/25/62	642.00
5.4g	M. Moore	97	s&g	658	18	1950	640
5.7dl(2)	Joliet (C)	90	s&g	668.38	31	1950	637
5.7dl(2)	Joliet (C)	90	s&g	668.38	37.0	5/24/62	631.4
5.7h2(1)	Joliet (C)	103	s&g	649.78	11	1950	639
5.7h2(1)	Joliet (C)	103	s&g	649.78	14.0	5/24/62	635.78
5.7h3	Joliet (C)	103	s&g	649.78	14.0	5/24/62	635.78
5.8d	H. Kemp	57	s&g	665	33.87	5/25/62	631.13
6.4b	Joliet Pump Shop	180	dol	677	49.82	5/25/62	627.18
6.7d	Mr. Ellis	140	dol	665	29.50	5/21/62	635.50
7.2a	Joliet Pk. Dist.	300	dol	608	6.54	5/25/62	601.46
7.3d	Joliet Pk. Dist.	205	dol	610	+5.00	5/25/62	615
7.4e	Mr. Hoberg	205	dol	610	+1.00	5/25/62	611
8.2b	D. Henning	185	dol	685	40	1949	645
8.5e	Dr. G. Woodruff	125	dol	673	50.50	5/25/62	622.50
8.8f	Dr. G. Woodruff	240	dol	676	53.80	5/25/62	622.20
8.8h2(3)	Joliet (C)	83	s&g	673.63	40	1950	634
8.8h2(3)	Joliet (C)	83	s&g	673.63	45.5	5/24/62	628.1
8.8h3	Joliet (C)	86	s&g	673.63	47.29	5/24/62	626.71
9.1b1	H. Henning	144	dol	685	50	1951	635
9.2b	—	130	dol	680	45.80	4/11/62	634.20
9.5a	C. Krapp	200	dol	655	8	1948	647
10.7b	C. Luther	111	dol	695	52	1950	643
10.7c	Trieble	150	dol	680	43	1948	637
17.2e	—	100	dol	620	15.00	4/11/62	605.00
36N11E–							
14.7a	A. Welter	205	dol	754	83.43	5/24/62	670.57
19.3h1	J. M. Zick	120	dol	735	60	1952	675
19.3h2	J. Loughlin	205	dol	735	89	1952	646
20.3a	R. Burch	154	dol	735	78.20	5/24/62	656.80
21.5e	Homer Cong. Church	—	dol	778	116.14	5/24/62	661.86
22.5h	—	220	dol	770	96.75	4/25/62	673.25
23.2a	Mrs. Garrabrant	180	dol	700	25.48	5/24/62	674.52
25.4g	R. Jordan	150	dol	748	71.54	5/24/62	676.46
25.7g	S. Swartz	167	dol	705	45	1949	660
26.1a	F. Lauffer	204	dol	745	72.60	5/24/62	672.40
27.1h	A. Southwick	200	dol	729	57.66	5/24/62	671.34
27.2b	Will County	—	—	681	11.02	5/25/62	669.98
29.2h	R. Burch	200	dol	733	74.57	5/24/62	658.43
29.4a	F. Loucks	130	dol	715	61.25	5/21/62	653.75
30.1d	R. Cagwin	200	dol	740	83.87	5/25/62	656.13
30.3b	M. J. Cagwin	205	dol	715	61.90	5/25/62	653.10
30.6a	M. J. Cagwin	200	dol	712	57.00	5/25/62	655.00
31.6d	B. Cagwin	100	dol	681	38.36	5/25/62	642.64
31.8b2	Joliet (C)	86	s&g	641	6.51	5/24/62	634.49
32.2c	Joliet (C)	97	s&g	665	24.89	5/24/62	640.11
32.3c1	Joliet (C)	—	s&g	688.25	37	1950	651
32.3c2	Joliet (C)	115	s&g	688.25	45.20	5/24/62	643.05
32.4a1	Joliet (C)	—	s&g	662.20	21	1950	641
32.4a2	Joliet (C)	94	s&g	662.20	26.45	5/24/62	635.75
32.4e1	B. Buck	90	s&g	705	59.19	5/24/62	645.81
32.4e2	B. Buck	205	dol	708	60.00	4/4/62	648.00
32.8b	P. Warren	101	s&g	698	60.35	5/24/62	637.65
32.8f	P. Warren	90	dol	682	35.16	5/24/62	646.84
33.1e	E. Anderson	250	dol	679	19.83	5/24/62	659.17
33.7h1	Mr. Reiter	80	s&g	725	70.86	5/25/62	654.14
33.7h2	Mr. Reiter	180	dol	725	72.64	5/25/62	652.36
34.5f	Hadley Schl.	125	s&g	690	29.5	5/24/62	660.5
35.6d	D. Davis	125	s&g	762	91.47	5/24/62	670.53

**Abbreviations: dol=dolomite, s&g=sand and gravel* conditions discharged into Spring Creek in the reach between gaging station 4 and 6 (see figure 30) is now diverted into production wells. Ground water still discharges into' Spring Creek above gaging station 6 and below gaging station 3. Pumping displaced the 650-foot contour about 1 mile northeast of its original position. Withdrawals by the city have also moved the 640-foot contour approximately 1 mile from its estimated original position. Water levels near Spring Creek between gaging stations 4 and 6 are probably a few feet below the bed of the creek.

Flow lines were drawn at right angles to the piezometric-surface contours from production wells up gradient to define the area (area of diversion) within which the general movement of ground water is toward production wells as shown in figure 26. As measured from figure 26, the area of diversion is 11 square miles. Ground-water movement outside the area of diversion is towards Spring Creek and other streams and scattered pumping centers beyond the Hadley Valley area.

The piezometric-surface map was compared with water-level data for the period prior to development, and water-level changes were computed. The greatest declines occurred in the immediate vicinity of the production wells and averaged about 8 feet. Water levels about 1 mile from production wells and in the area of diversion of pumping have declined on the average about 2 feet. The average decline of water levels with the area of diversion is about 5 feet.

Streamflow and Ground-Water Runoff

Streamflow records for a gaging station on Spring Creek, at the Benton Street Bridge in Joliet about 4 miles southeast of the municipal well field, are available for the period 1926 through 1933. The drainage area of Spring Creek above the station is 19.7 square miles and is shown in figure 27. Daily discharges, expressed in cubic feet per

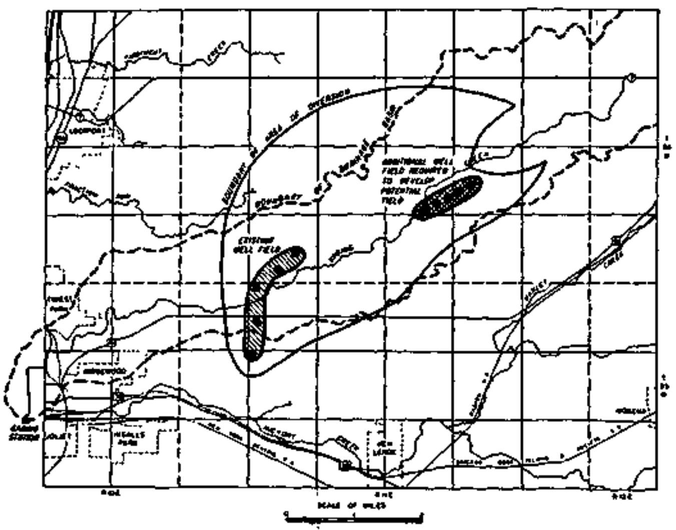

Figure 27. Drainage basin of Spring Creek and area of diversion in Hadley Valley area

second per square mile (cfs/sq mi), obtained from U. S. Geological Survey Water Supply Papers, were tabulated in order of magnitude, and frequencies were computed. Values of discharge were then plotted against percent of time on logarithmic probability paper, and a flow-duration curve was constructed as shown in figure 28. A discharge

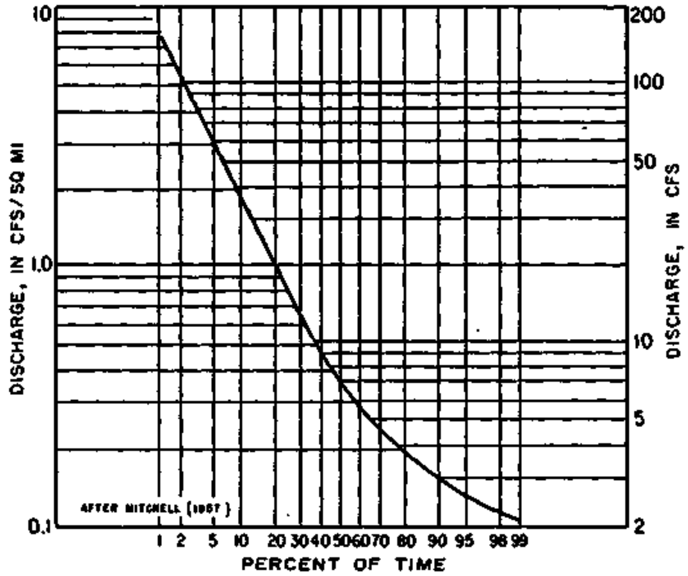

Figure 28. Flow-duration curvo for Spring Crook in Hadioy Valley area

equal to or greater than about 7 cfs or 4.5 mgd was recorded 50 percent of the time. Daily streamflow during 1932, a year of near normal precipitation, is shown graphically in figure 29; streamflow was often less than 4

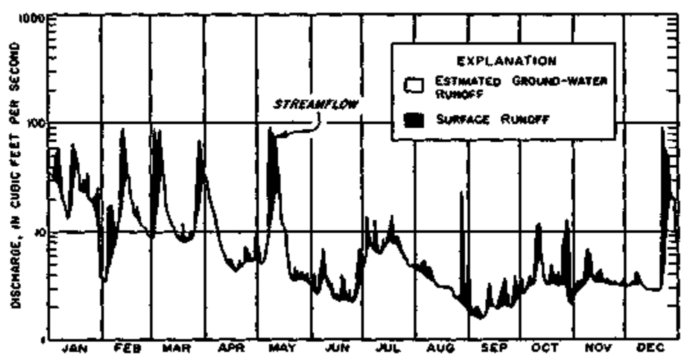

Figure 29. Streamflow at gaging station on Spring Crook in Hadley Valloy area, 1932

cfs or 2.6 mgd during summer and fall months, and exceeded 80 cfs or 52 mgd for short periods during winter and spring months. Unfortunately annual precipitation at Joliet was near or above normal during the entire period of streamflow record; streamflow during extended dry periods has not been measured.

Ground-water runoff to Spring Creek was estimated with streamflow hydrograph separation methods oudined by Linsley, Kohler, and Paulhus (1958). Daily ground-water runoff during 1932 was plotted beneath the streamflow hydrograph for 1932, and a line was drawn connecting points to describe the ground-wafer runoff hydrograph in figure 29. The shaded areas between streamflow and ground-water runoff hydrographs represent surface runoff. Ground-water runoff averaged about 5.78 inches of precipitation over the basin or about 275,000 gpd/sq mi and was about 69 percent of streamflow and 18 percent of precipitation. Ground-water runoff averaged about 476,000 gpd/sq mi during 1927 when precipitation at Joliet was 47.49 inches, and much above normal. Based on streamflow records for other drainage basins (see Schicht and Walton, 1961), it is probable that ground-water runoff during a year of much below normal precipitation averages about 135,000 gpd/sq mi.

Recharge to Aquifer

The source of recharge to the aquifer is precipitation. Ground-water recharge is greatest in spring months of heavy rainfall and least in the summer, fall, and winter months. Only a small fraction of the annual precipitation seeps downward to the water table. A large proportion of the precipitation runs off to streams or is discharged by evapotranspiration without reaching the aquifer.

The rate of recharge to the aquifer can be estimated with the piezometric-surface map and past records of pumpage and water levels. Comparisons of pumpage and water-level graphs indicate that in general water-level declines are directly proportional to pumping rates, and within a relatively short time after each increase in pumpage the area of diversion, which had expanded in proportion to pumpage and water levels, had stabilized. Thus, recharge balanced discharge, and the average recharge rate to the aquifer is the quotient of the average pumping rate and the area of diversion. The area of diversion of pumping was delineated as explained earlier and is shown in figure 26; pumpage data are given in figure 17. Computations with data from figures 17 and 26 show that the average recharge rate to the aquifer in 1961 was about 300,000 gpd/sq mi.

The aquifer is not recharged entirely by the percolation of precipitation to the water table. Recharge to the aquifer by induced infiltration of surface water occurs because the piezometric surface is below stream level and the stream bed and surficial deposits in the flood plain of Spring Creek have some permeability. The stream bed is only a few feet wide and is silted; streamflow during much of the time is low. Very little recharge from Spring Creek occurs during periods of low flow. However, at high flood-stream stages the flood plain is inundated and fairly large amounts of recharge by induced infiltration occur for short periods of time. The average rate of recharge from stream flow was computed as the difference of the average recharge rate to the aquifer and the amount of ground-water runoff diverted into cones of depression.

Ground-water runoff to Spring Creek under natural conditions was estimated to average about 275,000 gpd/sq mi earlier in this report. Not all ground-water runoff can be diverted into cones of depression because even under heavy pumping conditions there is some shallow lateral as well as deeper vertical movement of ground water in the surficial deposits. Precipitation and therefore recharge is unevenly distributed throughout the year, and there are periods of time during the wet spring months when recharge temporarily exceeds the rate of vertical movement of water. Based on studies in DuPage County (Zeizel et al., 1962) it is estimated that about 75 percent of ground-water runoff is diverted into existing cones of depression. The rate of recharge directly from precipitation is therefore about 200,000 gpd/sq mi based on the average ground-water runoff and the 75 percent factor. The average rate of recharge from streamflow was computed to be about 100,000 gpd/sq mi by subtracting the rate of recharge directly from precipitation from the average rate of recharge to the aquifer.

Earlier in this report ground-water runoff was estimated to average about 135,000 gpd/sq mi during years of greatly below normal precipitation. It is probable that recharge from streamflow will be less than 100,000 gpd/sq mi during dry periods. Based on the ratio of ground-water runoff during years of normal precipitation (275,000 gpd/sq mi) and ground-water runoff during dry years (135,000 gpd/sq mi) it is probable that recharge from streamflow may average about 50,000 gpd/sq mi during dry years. It is estimated that the average rate of the recharge to the aquifer during dry periods is about 185,000 gpd/sq mi.

Recharge from the flow in Spring Creek was determined along two reaches of the stream by measuring the water lost between successive gaging stations. Discharge measurements were made on April 26, 1962, at the stations listed in table 9 and shown in figure 30. Seepage losses ranged from 0.07 mgd or 58,000 gpd per acre of stream bed between stations 4 and 5 to 0.32 mgd or 175,000 gpd per*

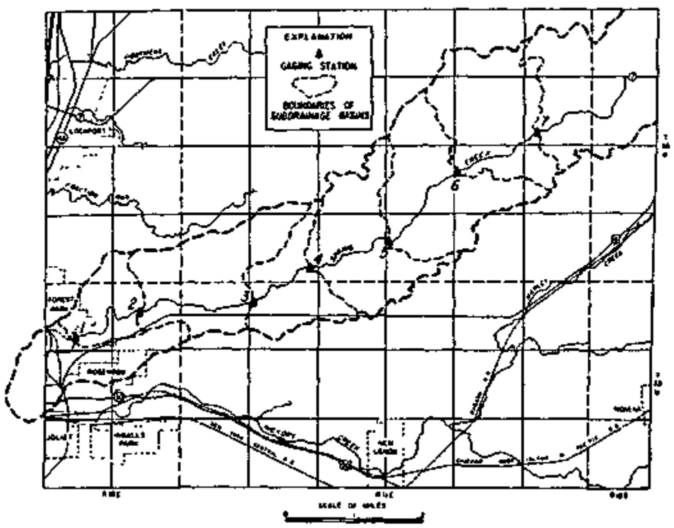

Figure 30. Location of partial record stream-gaging stations in Hadley Valley area

Table 9. Streamflow Measurements for Spring Creek near Joliet

Gaging station number	Discharge (cfs)	Discharge (mgd)	Loss of flow between stations (mgd)	Percent of flow infiltrated	Infiltration rate (gpd/acre)	Average depth of water in stream (ft)
1	5.16	3.59				0.65
2	3.47	2.41				0.70
3	1.30	0.90				0.73
4	1.11	0.77	0.07	8	58,000	1.02
5	1.21	0.84				0.35
6	1.67	1.16	0.32	29	175,000	0.60
7	0.75	0.52				1.05

acre of stream bed between stations 5 and 6; Spring Creek was effluent between stations 1 and 4 and 6 and 7. The infiltration rates were measured during a period of low streamflow. They are probably far greater when the flow in Spring Creek is high.

Model Aquifer and Mathematical Model

The results of geologic and hydrologic studies indicate that it is possible to simulate complex aquifer conditions in the Hadley Valley area with an idealized model aquifer. The model aquifer is a semi-infinite rectilinear strip of sand and gravel 2 miles wide, 60 feet thick, overlain by a confining bed 30 feet thick, and bounded on the sides and bottom by dolomite. The orientation of the model aquifer in relation to the Hadley Valley area is shown in figure 31. Based on aquifer-test data the average coefficient of transmissibility of the model aquifer is 186,000 gpd/ft. Under heavy pumping conditions, part of the confining bed is dewatered. The coefficient of storage of the confining bed cannot be determined from available aquifer-test data. The model aquifer and records of past pumpage and water-level decline were used to estimate the coefficient of storage.

The water-level decline at well 5.4g for the period

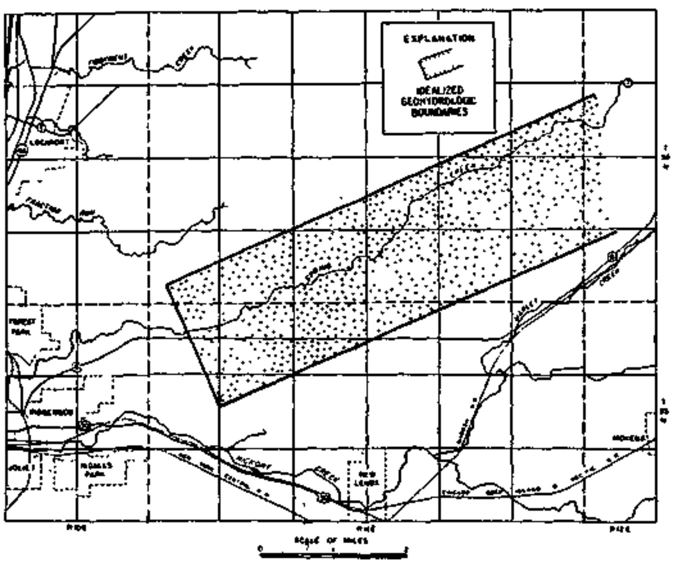

Figure 31. Orientation of model aquifer for Hadley Valley area

October 15, 1952 to February 1, 1953 was computed using- the model aquifer, the calculated coefficient of transmissibility, the image-well system in figure 13, the nonequilibrium formula, estimated pumpage data, and several assumed values of the coefficient of storage of the confining bed. Computed declines were then compared with the actual decline (see figure 22) and that coefficient of storage which gave a computed decline equal to the actual decline was assigned to the confining bed.

Production wells, well 5.4g, and the barrier boundaries were drawn to scale on a map, and the image wells associated with the geohydrologic boundaries were located. The distances between well 5.4g, production wells, and image wells were scaled from the map. The water-level decline in well 5.4g resulting from an increase in total pumpage of 1.9 mgd (see figure 17) was determined using the nonequilibrium formula to compute the effects of real and image wells. Very little recharge to the aquifer occurred during the period October 15, 1952 to February 1, 1953, and water levels were not influenced appreciably by recharge. All the water withdrawn from wells was for practical purposes taken from storage within the confining bed.

The actual decline in well 5.4g from figure 22 is 3.33 feet. A water-level decline of 3.25 feet was computed by using a coefficient of storage of 0.04; the coefficient of storage of the confining bed is therefore estimated to be 0.04. Thus, the effects of three barrier boundaries and gravity drainage of the confining bed on the response of the aquifer to development of wells can be simulated by using the model aquifer mentioned earlier and a coefficient of storage of 0.04.

A semilogarithmic distance-drawdown graph based on coefficients of transmissibility and storage of 186,000 gpd/ft and 0.04 respectively was constructed to provide a rapid means for determining the effects of real and image wells associated with the model aquifer. The map showing location of production wells, well 5.4g, and image wells and the distance-drawdown graph constitute the mathematical model (see Walton and Walker, 1961) for the Hadley Valley area.

The matiiematical model is based on a particular combination of aquifer boundaries and properties. There are probably other matiiematical models involving several slightly different combinations of parameters which would also duplicate aquifer conditions. It is recognized that the analytical method of analysis described above provides only approximate answers on a bulk basis. However, the close agreement between computed and actual declines indicates that the model aquifer and mathematical model closely describe the geohydrologic conditions of the Hadley Valley area. It is reasonable to assume that the model aquifer and matiiematical model may be used to predict with reasonable accuracy the practical sustained yield of the existing well field and the potential yield of the aquifer.

Practical Sustained Yield of Existing Well Field and Potential Yield of Aquifer

The model aquifer was used to 'determine the maximum amount of water that can be continuously pumped from the existing well field without eventually lowering water levels to critical stages below tops of screens. The effects of recharge were simulated by using a pumping period of 6 months to construct the distance-drawdown graph of the mathematical model. Inspection of water-level hydrographs shows that during many summer and fall months recharge to the water table is very small and water levels would decline almost without interruption if pumping rates were held constant. The aquifer generally receives appreciable recharge starting in the late fall months and the recession of water levels normally ceases after a period of decline averaging 6 months in duration. Providing discharge does not exceed recharge, maximum drawdowns will be observed at the end of a 6-month pumping period. Thus, the use of a 6-month pumping period to construct the distance-drawdown graph of the mathematical model assumes that recharge balances discharge and provides a means of estimating maximum drawdowns.

To test the validity of the mathematical model with a time factor of 3 months, the drawdown in well 5.7d2 during the period November 1952 through January 1953 for a pumping rate of 1.9 mgd was computed and compared with the actual drawdown (see figure 21). The computed decline, 3.30 feet, is within 3 percent of the actual decline, 3.20 feet. Computations made with the mathematical model indicate that the practical sustained yield of the existing five-well system is about 4 mgd or about 0.7 mgd more than the average rate of pumpage in 1961.

It has been estimated that the average rate of recharge to the aquifer is 300,000 gpd/sq mi. This average includes recharge direcdy from precipitation and by induced infiltration of surface water. The area of diversion, 11 sq mi, in 1961 (see figure 27) covered less than half of the drainage basin of Spring Greek. Thus, only part of the available ground-water resources of the Spring Creek drainage basin have been developed. Considering the part of the Spring Creek drainage basin outside and northeast of the area of diversion and the fact that the present area of diversion spreads beyond the boundaries of the basin, the potential yield of the aquifer is estimated to be about 6.5 mgd based on a recharge rate of 300,000 gpd/sq mi. A 6.5 mgd water supply can be obtained from a reasonable number of wells in the Hadley Valley area.

Computations made with the mathematical model indicate that 6.5 mgd can be obtained from a 10-well system, consisting of the existing five-well system and five additional wells spaced about 1000 feet apart in a well field about 2 miles northeast of the existing well field as shown in figure 27. The additional wells are spaced upstream from the existing well field toward the part of the drainage basin of Spring Creek which was unaffected in 1961 by pumping. The five additional wells are located in the thickest part of the aquifer and are spaced at distances from the existing well field great enough so that the interference between the two well fields will be small and less than 3 feet.

Considerable study, based in large part on mechanical analyses of the samples of materials obtained during drilling of test wells at the sites of the new wells, must be made before production wells are designed. Mechanical analyses of the samples of materials obtained from well 27.3c (see figure 32) indicate that 12-inch diameter gravel-pack wells averaging 80 feet deep may be required.

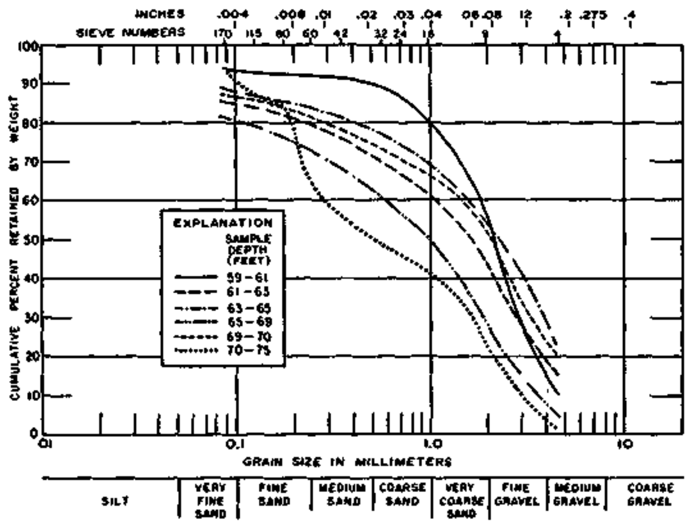

Figure 32. Mechanical analyses of samples from well 274c in Hadley Valley area

Full development of the potential yield of the aquifer will result in a much greater area of influence of pumping than existed in 1961. Water levels in most of the drainage basin above the existing well field and some areas outside the drainage basin will be affected by pumping. As large amounts of water are pumped from storage in the aquifer in dry periods some shallow domestic wells in or near the upper reaches of the drainage basin near the well fields may go dry. The effects of the development of an additional well field on domestic wells may be estimated from data on measured drawdowns in the vicinity of the existing well field.

Water for municipal use at Woodstock is obtained locally from wells in sand and gravel aquifers. The most heavily pumped aquifer averaging 50 feet thick is encountered at an average depth of 170 feet below land surface, and is recharged by the vertical leakage of water through 80 feet of overlying clayey materials. A shallow sand and gravel aquifer averaging 30 feet thick is the source bed for the deeply buried aquifer. Some water is withdrawn from an aquifer interbedded in the clayey materials immediately above the most heavily pumped aquifer and the shallow aquifer through multi-aquifer wells.

Since 1921, when the deeply buried aquifer was first tapped for the municipal water supply, the average daily withdrawal steadily increased from 250,000 gallons to 1.8 million gallons in 1962. Continual increases in pumpage caused a general water-level decline, and in 1962 water levels in closely spaced production wells in the deeply buried aquifer receded to near critical stages. As a result, a new municipal well field was developed northeast of town.

Geography and Climate

Woodstock is located in the central part of McHenry County in northeastern Illinois, about 50 miles northwest of Chicago, as shown in the inset in figure 33. The Woodstock area is a rectangle of about 56 square miles in T44N, T45N, R6E, and R7E, and is between 88° 20' and 88° 30' west longitude, and between 42° 15' and 42° 25' north latitude.

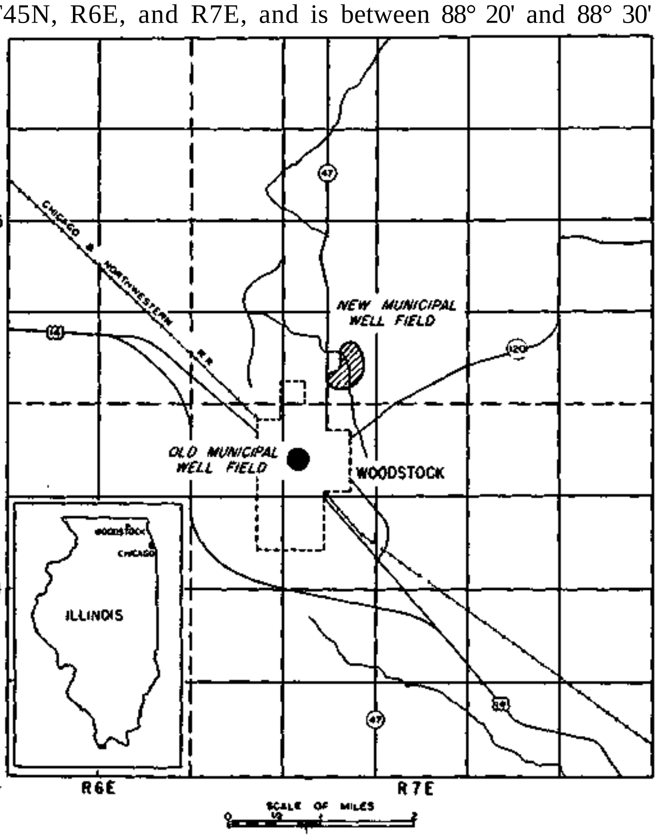

Figure 33. Location of pumping centers in Woodstock area

The Woodstock area is located in the Wheaton Morainal Country subdivision of the Central Lowland Physiographic Province. The topography is characterized by hills, broad parallel morainic ridges, and swamps. The elevation of the land surface declines from 1020 feet on a ridge just west of Woodstock to about 800 feet in the valley of Boone Creek near the eastern border of the Woodstock area, thus giving a maximum relief of about 220 feet.

Drainage is in three directions: Nippersink Creek drains the northern part of the Woodstock area, Boone Creek drains the eastern part, and the North Branch of the Kishwaukee River drains the south and west parts.

Graphs of annual and mean monthly precipitation given in figures 34 and 35 were compiled from precipitation data collected by the U. S. Weather Bureau at Marengo about 9 miles southwest of Woodstock. According to records for the period 1927-1961, the mean annual precipitation is 32.12 inches. On the average, the months of greatest precipitation are May and June, each having more than 3.5 inches; February is the month of least precipitation, having less than 1.5 inches.

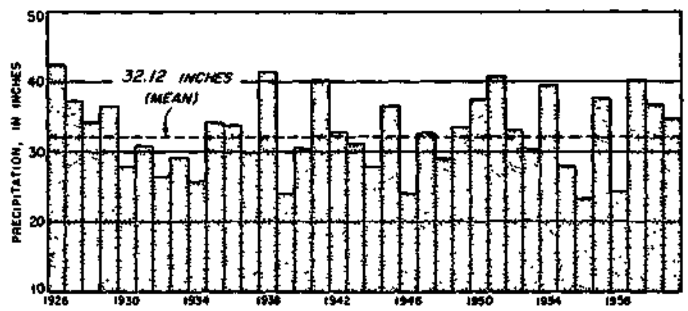

Figure 34. Annual precipitation at Marengo

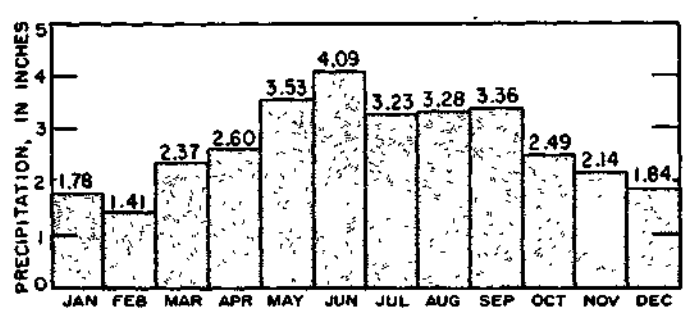

Figure 35. Mean monthly precipitation at Marengo

A large part of northern Illinois including the Woodstock area experienced a severe drought beginning early in 1930. For the period 1930 through 1935, cumulative deficiency of precipitation at Woodstock was about 21 inches. Recharge from precipitation was much below normal during the dry years, and large quantities of water were taken from storage within shallow deposits to balance ground-water discharge to streams and the atmosphere.

The annual maximum precipitation amounts occurring on an average of once in 5 and once in 50 years are 37 and 45 inches respectively; annual minimum amounts expected for the same intervals are 26 and 22 inches respectively. Amounts are based on data given in the Atlas of Illinois Resources, Section 1 (1958).

The mean annual snowfall is 30 inches, and the area averages about 48 days with 1 inch or more and about 29 days with 3 inches or more of ground snow cover.

Based on records collected by the U. S. Weather Bureau at Marengo, the mean annual temperature is 48.6° F: June, July, and August are the hottest months with mean temperatures of 69.1° F, 73.9° F, and 71.9° F, respectively. January is the coldest month with a mean temperature of 22.9° F. The mean length of the growing season is about 165 days.

Geology

For a detailed discussion of the geology in the Woodstock area the reader is referred to Suter et al. (1959) and Horberg (1950). The following section is based largely upon these two reports.

The Woodstock area is covered with glacial drift which is frequently more than 200 feet thick.. The bedrock immediately beneath the glacial drift is mainly dolomite of the Alexandrian Series of Silurian age. In a narrow belt averaging about 1 mile wide south and east of Woodstock it is largely shale of the Maquoketa Formation of Ordovician age. The glacial drift contains thick and extensive deposits of sand and gravel in two zones, near the surface (upper aquifer) and immediately above bedrock (lower aquifer). The upper and lower aquifers exceed 30 feet in thickness at many places and are separated by clayey materials (confining bed) commonly exceeding 75 feet in thickness.

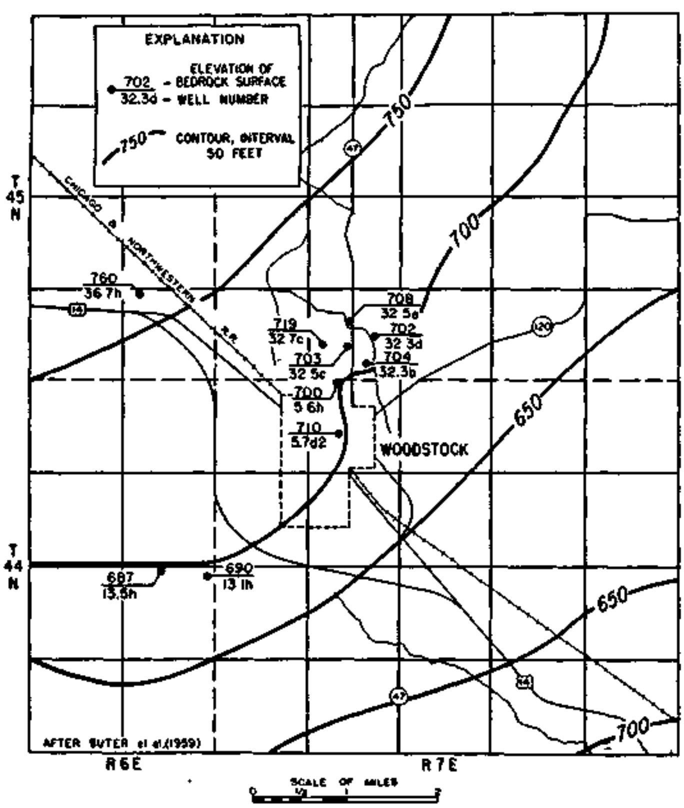

Figure 36. Bedrock topography of **Woodstock area**

A contour map showing the topography of the bedrock surface is shown in figure 36. Features of the bedrock topography were previously discussed by Suter et al. (1959). A bedrock valley extends northeastward across the southern part of the Woodstock area. The channel of the bedrock valley, roughly delineated by 650-foot contours, is more than 1½ miles wide in most places, has walls of moderate to low relief, and averages about 50 feet in depth. The bedrock surface at Woodstock slopes southeastward toward the channel of the bedrock valley and has an average elevation of 700 feet.

Except in small areas south and east of Woodstock in the vicinity of the channel of the bedrock valley, the bedrock surface beneath the glacial drift is formed by rocks of the Alexandrian Series as shown in figure 37. The Alexandrian

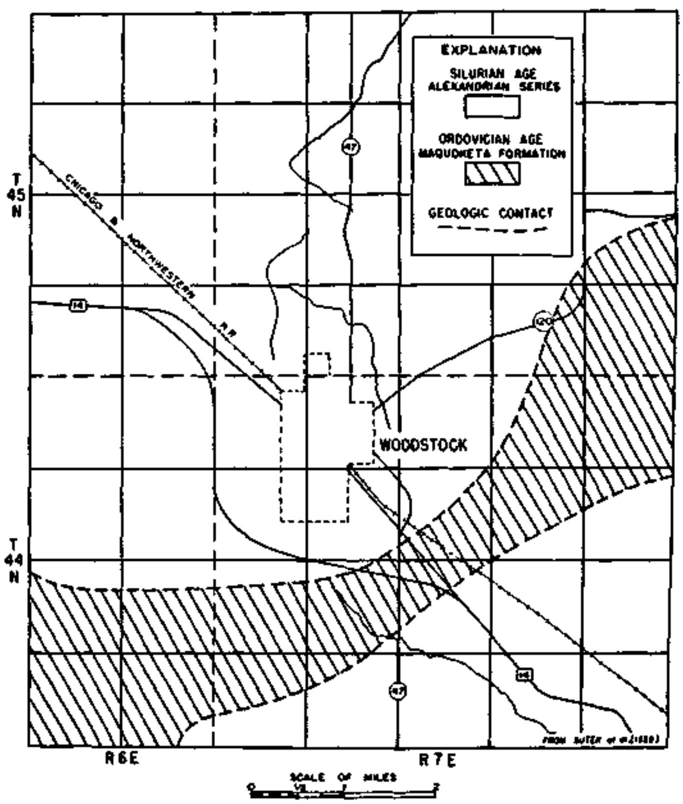

Figure 37. Bedrock geology of Woodstock area

Series is composed chiefly of dolomite; shale and argillaceous dolomite beds occur near the base. The thickness of the Alexandrian Series commonly exceeds 50 feet and averages 42 feet. The Maquoketa Formation is the uppermost bedrock beneath the glacial drift in a narrow band coinciding with the deeper portions of the buried bedrock valley. It has an average thickness of 175 feet, exceeds 150 feet in thickness in most parts of the Woodstock area, and consists largely of shale.

The cross section in figure 38 illustrates in general the nature of the unconsolidated deposits above bedrock. The

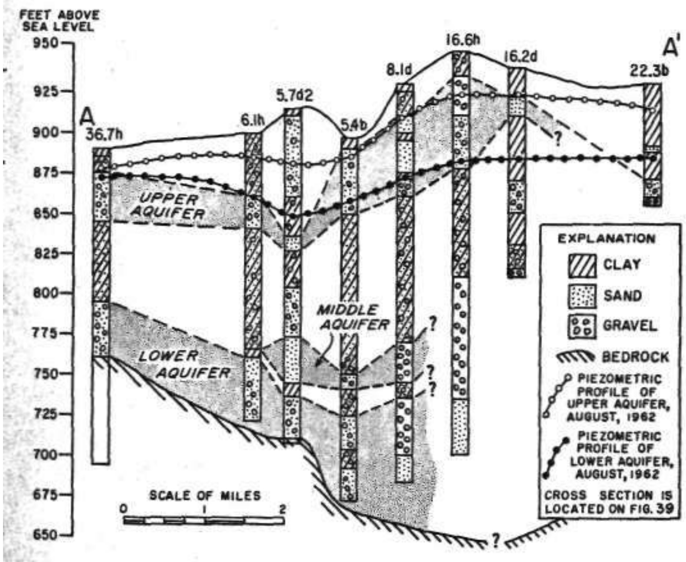

Figure 38. Cross section of glacial drift and piezometric profiles in Woodstock area

unconsolidated deposits are mostly glacial drift, and increase in diickness from 150 feet in the northwestern part of the Woodstock area to more than 300 feet southeast of Woodstock as shown in figure 39. The entire diickness of

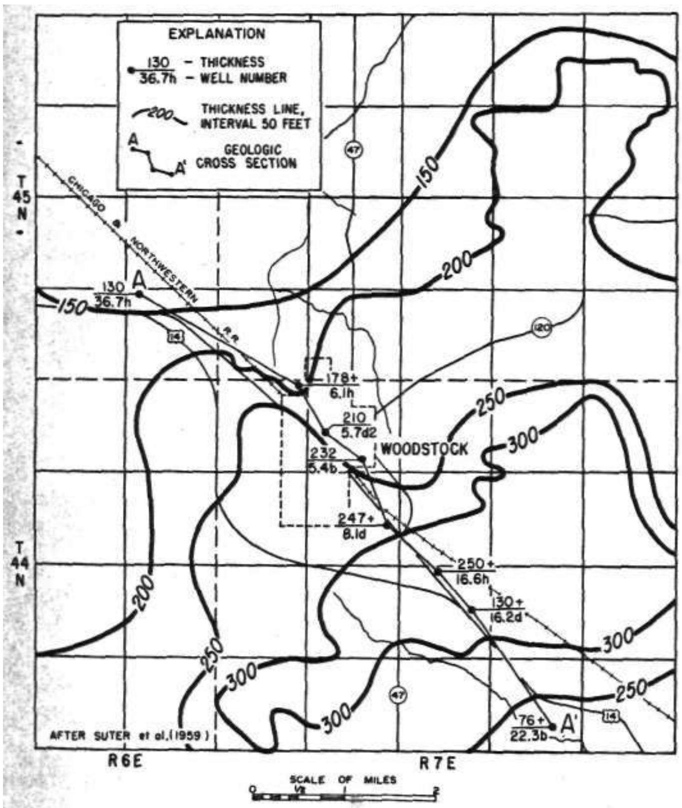

Figure 39. Thickness of unconsolidated deposits overlying the bedrock in Woodsteck area

the unconsolidated deposits has been penetrated in only 10 wells located mostly at Woodstock. The thickness in other areas is based on regional bedrock surface maps. The glacial drift consists largely of deposits of till that contain a high percentage of silt and clay.

Logs of wells show that widely distributed and permeable sand and gravel are found in two major zones within the glacial drift; near the surface and immediately above bedrock. Sand and gravel are encountered at many places at shallow depths, as shown in figure 38. The thickness of this zone, the "upper aquifer," is variable but averages 30 feet. Data are not sufficient to delineate the boundaries of the upper aquifer, but available information suggests that the upper aquifer has a large areal extent in the Woodstock area. Large supplies of sand and gravel have been mined from several gravel pits in the upper aquifer.

Medium- to coarse-grained sand and gravel occur at the base of the glacial drift over most of the Woodstock area. The thickness of this zone, the "lower aquifer," is variable but averages 50 feet except in the vicinity of the channel of the buried bedrock valley southeast of Woodstock. The lower aquifer is interbedded with lenses of clay and changes in character from place to place. Based on the regional bedrock surface map and logs of a few wells which do not completely penetrate the glacial drift, the thickness of the lower aquifer increases from about 50 feet at Woodstock to more than 150 feet in the channel of the buried bedrock valley southeast of Woodstock. Logs of wells and other geologic data suggest that the materials of the lower aquifer may be predominantly fine-grained in the vicinity of the buried bedrock channel. The fine-grained character of the lower aquifer southeast of Woodstock may make development of high-capacity wells difficult or impossible. Additional subsurface information is needed to determine the diickness and character of the glacial drift especially in the vicinity of the channel of the buried bedrock valley. Mechanical (particle-size) analyses of samples of the materials obtained from test wells show that the lower aquifer is corn-

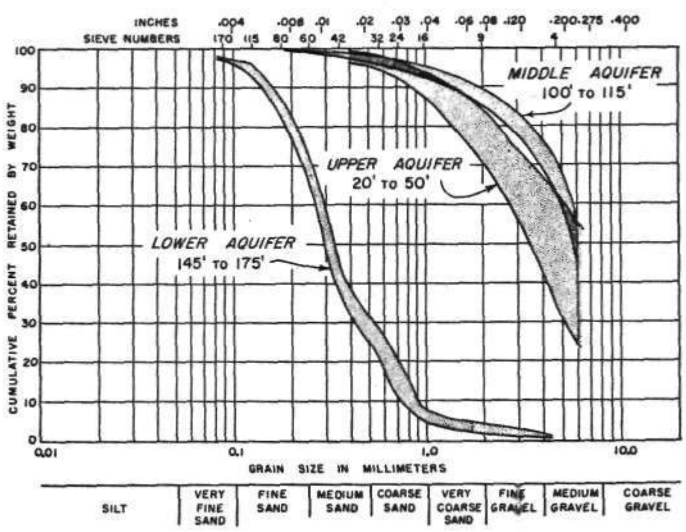

Figure 40. Mechanical analyses of samples for well in Woodstock area

Table 10. Logs of Selected Wells and Test Holes in Woodstock Area

Well number	Type of record	Formation	Thickness (ft)	Depth (ft)
MCH–44N6E–13.3h	drillers log	clay	140	140
		hardpan	12	152
		sand	10	162
		clay and sand	36	198
		black hardpan	12	210
		limestone	10	220
		Cincinnati shale	50	270
		limestone	—	300
44N7E–2.3e	drillers log	clay	5	5
		gravel	23	28
		sand	37	65
		pink clay	42	107
		brown clay	52	159
		sand and gravel	1	160
5.1h	*SS 35092	till	20	20
		sand and gravel	20	40
		till	10	50
		gravel	25	75
		till	20	95
		gravel	25	120
		till	5	125
		gravel	10	135
		sand and gravel	15	150
5.4b	drillers log	fill	5	5
		black soil	2	7
		dirty sand and boulders	41	48
		sand and clay	97	145
		clay and boulders	2	147
		sand and boulders	8	155
		dirty sand and clay	14	169
		sand, clay and boulders	4	173
		gravel, sand and boulders	21	194
		sand, clay and boulders	11	205
		sand, gravel, clay streaks	12	217
		sand, gravel and boulders	9	226
5.6h	SS 35323	top soil	1	1
		yellow clay, gravel embedded	7	8
		gray clay	2	10
		granite boulders	2	12
		sandy clay	45	57
		gravelly clay, streaks of sand	62	119
		brown peat and wood	7	126
		reddish gravelly clay	3	129
		gray fine sand	3	132
		grey fine sand to medium gravel	4	136
		tight fine sand, some clay	5	141
		gray fine sand to medium gravel	16	157
		gray clay	2	159
		sand, gravel, streaks of clay	9	168
		reddish clay	3	171
		fine gray sand and gravel	3	174
		clay with streaks of sand	4	178
		broken limestone	10	188
		solid limestone	2	190
44N7E–(Cont'd) 5.7d2	drillers log	cinders and sand	4	4
		sand and boulders	50	54
		clay and boulders	24	78
		sand	9	87
		clay and boulders	25	112
		sand and gravel	28	140
		clay and boulders	2	142
		fine sand	12	154
		clay	3	157
		coarse sand	5	162
		clay	4	166
		fine sand	5	171
		clay	7	178
		gravel	13	191
		clay	6	197
		gravel and sand	9	206
6.1h	SS 34932	till	40	40
		sand and gravel	20	60
		till	75	135
		peat	5	140
		sand	10	150
		gravel and sand	129	179
8.1d	SS 34983	black soil	5	5
		till	10	15
		till	5	20
		sand	10	30
		till	5	35
		sand	20	55
		till	5	60
		gravel	10	70
		till	25	95
		till	65	160
		gravel	25	185
		till	10	195
		gravel	35	230
		sand	17	247
8.3g	SS 34991	till	10	10
		sand	35	45
		gravel	15	60
		till	35	95
		gravel and sand	10	105
		till	50	155
		gravel	20	175
		till	35	210
		gravel	15	225
		till	14	239
9.6h	drillers log	black dirt	2	2
		yellow clay	23	25
		sand	10	35
		blue clay	35	70
		sand and gravel	—	73
9.2b	drillers log	clay	12	12
		gravel	10	22
		clay and sand	30	52
		hardpan	10	62
		sand	26	88
		hardpan	20	108
		gravel and sand	14	122
		water gravel	—	125
16.2d	drillers log	clay	18	18
		sand	12	30
		blue clay	40	70
		sand and gravel	20	90
		clay	20	110
		hardpan	15	125
		gravel	5	130

** SS refers to sample set number of State Geological Survey*

Table 10 (Continued)

Well number	Type of record	Formation	Thickness (ft)	Depth (ft)
MCH— 44N7E–(Cont'd)				
16.6h	SS 25432	till	15	15
		gravel	25	40
		sand and gravel	33	73
		till, sand and gravel	45	118
		gravel, sand, silt	22	140
		sandstone, gravel	50	190
		gravel	25	215
		sand	35	250
17.1h	drillers log	fill	4	4
		clay and stone	17	21
		sand	9	30
		clay and sand	153	183
		sand	68	251
		black rock	29	280
		shale	10	290
22.3b	drillers log	pit	38	38
		sand and gravel	4	42
		blue clay	16	58
		sand and gravel	12	70
		gravel	6	76
23.7h	drillers log	top soil	21	21
		gravel	49	70
		gravel and red clay	72	142
		gravel	—	142
45N6E– 23.5c	drillers log	pit	45	45
		sand	85	130
		red clay	31	161
		sand and gravel	4	165
		rock	35	200
45N7E– 22.7b	drillers log	gravel	20	20
		sand	15	35
		blue clay	60	95
		sand	6	101
31.4c	drillers log	brown clay	15	15
		red clay	185	200
		gravel	25	225
32.7c	SS 35322	top soil	0	1
		yellow silty clay with streaks of gray sand and gray clay	1	7
45N7E–(Cont'd) 32.7c		gray sandy clay	7	31
		gray fine sand to coarse gravel	31	43
		reddish sandy clay, gravel embedded	43	118
		reddish clay with streaks of fine sand	118	123
		gray tight fine to coarse sand	123	130
		reddish soft sandy clay	130	134
		gray fine sand	134	138
		gray soft sandy clay	138	141
		tight gray fine sand to medium gravel occasional streak of clay	141	152
		gray clay	152	154
		tight fine sand to medium gravel	154	158
		gray tight fine sand to coarse gravel	158	164
		boulders and limestone chips at 166' lost circulation	164	171
		solid limestone	172	176 TD
33.7c	drillers log	pit	34	34
		sand and clay	31	65
		blue clay	15	80
		hardpan	8	88
		sand and clay	123	211
		sand and gravel	6	217
		rock	—	230
34.2f	drillers log	pit	35	35
		sand and gravel	50	85
		blue clay	15	100
		sand	18	118
		water gravel	—	120
35.5c	drillers log	clay and sand	18	18
		hard gravel and sand	112	130
		clay and sand	13	143
		gravel	3	146
36.7h	drillers log	clay	5	5
		clay and gravel	10	15
		sand and gravel	30	45
		sand	50	95
		sand and gravel	34	129
		lime rock	67	196

posed mainly of medium to very coarse sand. Mechanical analyses of samples for well 32.3b are given in figure 40 to illustrate the grain-size distribution of the lower aquifer.

The upper and lower aquifers are separated by a confining bed of sandy and silty clay and gravel that is relatively impermeable, and averages 80 feet in thickness. The confining bed is interbedded with permeable sand and gravel deposits (middle aquifer, see figure 38) of limited areal extent The thickness of the middle aquifer is variable but at places exceeds 10 feet.

Logs of selected wells and test holes for which geologic data are available are given in table 10. The locations of wells and test holes are shown in figure 41.

Occurrence of *Ground Water*

Ground water in the upper aquifer occurs under leaky artesian and water-table conditions. Leaky artesian conditions exist where till or other fine-grained deposits overlie the upper aquifer and impede or retard the vertical movement of ground water, thus confining the water in the upper aquifer under artesian pressure. Under leaky artesian conditions, water levels in wells rise above the top of the upper aquifer to stages within the fine-grained deposits. Water-table conditions exist at places where the water table is within the upper aquifer and water is unconfined.

Ground water in the middle and lower aquifers occurs

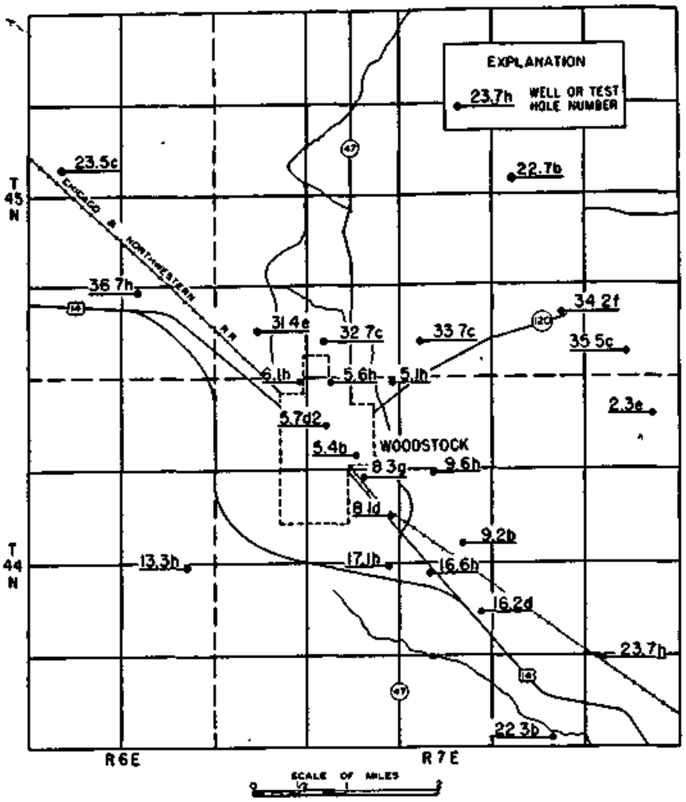

Figure 41. Location of selected wells and test holes in **Woodstock area**

under leaky artesian conditions. The surface to which water will rise under these conditions, as defined by water levels in a number of wells, is the piezometric surface. Artesian pressure in lowland areas north of Woodstock is sufficient to cause wells in the lower aquifer to flow. The head above land surface in flowing wells seldom exceeds a few feet; the discharge of most flowing wells is small and generally less than 5 gpm.

Hydraulic Properties of Aquifers and Their Confining Beds

Aquifer Tesfs

During the period 1920 to 1962, six aquifer tests were made to determine the hydraulic properties of the upper, middle, and lower aquifers, and of the confining bed between the middle and lower aquifers. Three of these tests were made at the old municipal well field and three at the new municipal well field.

The modified nonequilibrium formula (Cooper and Jacob, 1946) was used to analyze data for tests in the old municipal well field as illustrated in figure 42. The com-

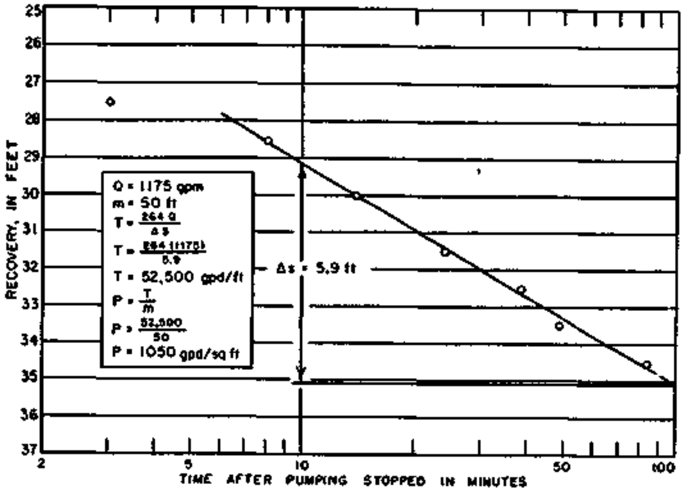

Figure 42. Time-recovery graph for well 5.7d3 at **Woodstock**

puted values of the coefficients of transmissibility and permeability pertain to the lower aquifer. Estimates of the hydraulic properties of the lower aquifer were also made

Table 11. Coefficients of Transmissibility, Permeability, Storage, and Leakage for Aquifers and Confining Bed at Woodstock

Well number	Date	Length of test (*hr*)	Pumping rate (*gpm*)	Method of analysis*	Specific capacity (*gpm/ft*)	Coefficient of transmissibility (*gpd/ft*)	Coefficient of permeability (*gpd/sq ft*)	Coefficient of storage	Leakage coefficient (*gpd/cu ft*)
MCH—44N7E–									
5.7d1	2/4/21	10	680	SC	27.2	47,000	940		
5.7d2	1/6/21	4	885	T-D	36.0	61,000	1220		
5.7d3	9/8/39	1.5	1175	T-D	34.1	52,500	1050		
32.3c2	9/19-22/61	69	1043	T-D		56,800	1140	0.00028	5.5×10^{-6}
32.2b, 32.2c, 32.3c2, 32.3c3, 32.4b, and 32.4c2	9/19-22/61	69	1043	D-D		59,800	1190		5.1×10^{-6}
32.2b	9/19-22/61	69	1043	T-D		53,200	1070	0.00053	5.7×10^{-6}
32.2c	9/19-22/61	69	1043	T-D		55,000	1100	0.00017	3.2×10^{-6}
32.3c3	9/19-22/61	69	1043	T-D		59,900	1200	0.00036	2.9×10^{-6}
32.4b	9/19-22/61	69	1043	T-D		57,000	1140	0.00030	5.7×10^{-6}
32.4c2	9/19-22/61	69	1043	T-D		56,000	1120	0.00027	3.8×10^{-6}
32.4c1	10/60	12	1043	SC	104	170,000	8500		
32.3e1	5/61	12	1020	SC	213	200,000	6600		

**SC=specific capacity; T-D=time-drawdown; D-D=distance-drawdown* by substituting specific-capacity data, a coefficient of storage of 0.0003, and well-construction data in the modified nonequilibrium formula. Specific-capacity data were adjusted for the effects of partial penetration and well loss before they were used to determine the coefficient of transmissibility. A summary of the coefficients of transmissibility and permeability obtained from the three tests in the old municipal well field is given in table 11. The coefficient of storage cannot be determined from aquifer test data for the old municipal well field because observation wells were not available during the tests.

A controlled aquifer test (test 4) was conducted by Layne-Western Company in the new municipal well field located about 1 mile northeast of the old municipal well field. The aquifer test was made September 19-22, 1961. The effects of pumping well 32.3cl were measured in the pumped well and in observation wells 32.2b, 32.2c, 32.3c2, 32.3c3, 32.4b, and 32.4c2. The locations of the wells used during the test are shown in figure 43; logs of the wells are given in figure 44. The wells have 6-inch casings and

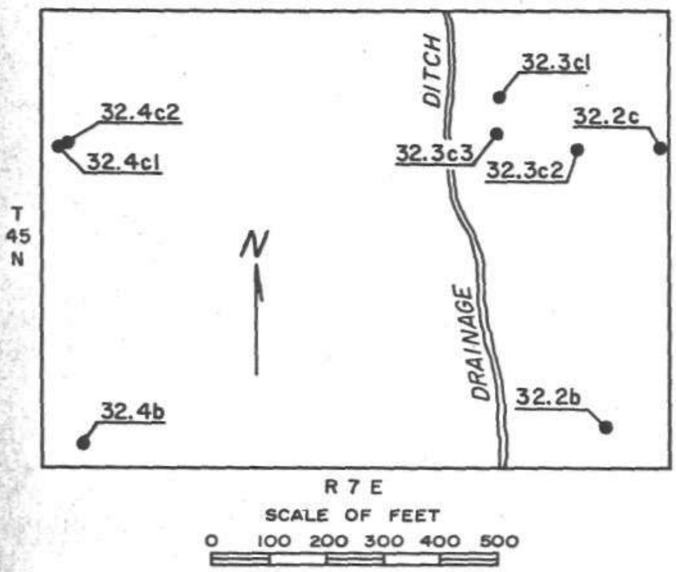

Figure 43. Location of wells used in aquifer tests at Woodstock

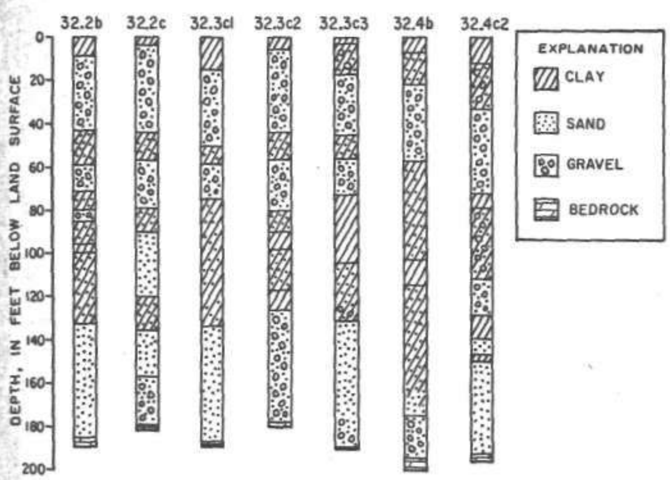

Figure 44. Generalized graphic logs of walls usad in aquifer last 4 at Woodstock

are screened in the lower 20 feet of glacial deposits. Pumping was started at noon on September 19 and was continued for a period of 69 hours at a constant rate of 1043 gpm.

Drawdowns were plotted against time on logarithmic paper. The time-drawdown field data graph for observation well 32.3c2 is given as an example in figure 45. The graph was superposed on the family of leaky artesian type curves; the data closely follow the r/B=0.05 type curve and were matched to that curve. Match-point coordinates and a r/B value of 0.05 were substituted into the leaky artesian formula to compute coefficients of transmissibility and storage of the aquifer, and the leakage coefficient of the confining bed. Computations for well 32.3c2 are given in figure 45.

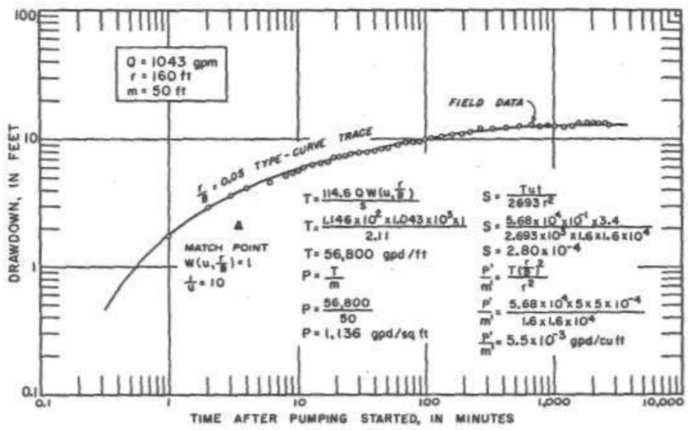

Figure 45. Time-drawdown graph for wall 32.3c2 at Woodstock

Drawdowns in observation wells 32.2b, 32.2c, 32.3c2, 32.3c3, 32.4b, and 32.4c2, measured at a time 1000 minutes after pumping started when steady-state conditions prevailed, were plotted on logarithmic paper against the distances from the respective observation wells to the pumped well, to describe a distance-drawdown field data curve (a portion of the profile of the cone of depression). The steady-state leaky artesian type curve was matched to the distance-drawdown field data curve, and match-point coordinates were substituted in the steady-state leaky artesian formula (Jacob, 1946b) given below:

$$s = [229\, Q\, K_o(r/B)]/T \qquad (9)$$

where:

$$r/B = r/\sqrt{T/(P'/m')} \qquad (10)$$

s = drawdown in observation well, in ft
r = distance from pumped well to observation well, in ft
Q = discharge, in gpm
T = coefficient of transmissibility, in gpd/ft
P' = coefficient of vertical permeability of confining bed, in gpd/sq ft
m' = saturated thickness of confining bed through which leakage occurs, in ft
K_o = modified Bessel function of the second kind of zero order

Computations are given in figure 46.

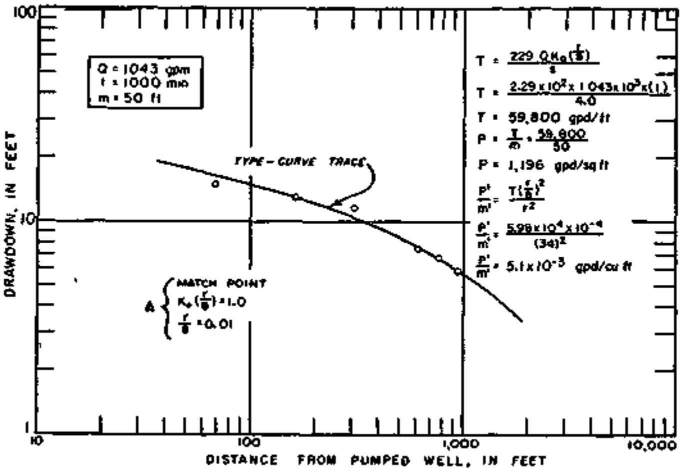

Figure 46. Distance-drawdown graph for aquifer test 4 at Woodstock

The average coefficients of transmissibility, permeability, storage, and leakage *(P'/m')* computed from data for aquifer test 4 are 57,000 gpd/ft, 1140 gpd/sq ft, 0.00034, and 5.5 x 10^{-3} gpd/cu ft, respectively. The effective thickness of the confining bed during the period of the pumping test is unknown. Permeable sand and gravel deposits (middle aquifer) occur at places near the base of the thick confining bed separating the upper and lower aquifer. The leakage coefficient computed from test data applies to the thin fine-grained deposits immediately overlying the lower aquifer and separating the lower aquifer from the middle aquifer interbedded in the thick confining bed. The leakage coefficient does not apply to the entire thickness of materials between the upper and lower aquifers. As indicated by the distance-drawdown curve in figure 46, the 69-hour test sampled an area of the lower sand and gravel aquifer having a radius of roughly 10,000 feet. The coefficients computed from the results of test 4 represent the average hydraulic properties of the lower aquifer and its associated confining bed within that large cone of depression.

An aquifer test (test 5) was made on well 32.4cl in the new municipal well field on October 25, 1960. Pumping was carried on for 12 hours and 5 minutes at a constant rate of 1043 gpm. The effects of pumping well 32.4c1 were measured in the pumped well and in observation well 32.4c2. The locations of the wells used during the test are shown in figure 43. The pumped well is screened in two zones. The upper zone is the middle aquifer interbedded in the confining bed separating the upper and lower aquifers. The lower zone is the lower aquifer. The observation well was screened only in the lower aquifer. Drawdowns observed in observation well 32.4c2 were plotted on semi-log paper versus time after pumping started, as shown in figure 47.

Based on the results of aquifer test 4, the coefficient of transmissibility of the lower aquifer is 57,000 gpd/ft. A straight line was fitted to the time-drawdown data. for well 32.4c2; the slope of the straight line, Δs, and a *T* value of 57,000 gpd/ft were substituted into the modified nonequilibrium formula to determine the amount of water withdrawn from the lower aquifer. Computations given in figure 47 indicate that, of the 1043 gpm pumped from well 32.4cl, 708 gpm were from the lower aquifer and 335 gpm were from the middle aquifer. The time-rate of drawdown was constant throughout most of the test, suggesting that geohydrologic boundaries were not encountered by the cone of depression and that the lower aquifer has a large areal extent.

The specific capacity of well 32.4cl for a pumping period of 8 hours and a pumping rate of 1043 gpm is 104 gpm/ft. The specific capacity and a coefficient of storage of 0.0003 were substituted into the modified nonequilibrium formula to determine the coefficient of transmissibility of a single aquifer which would behave in the same manner as the

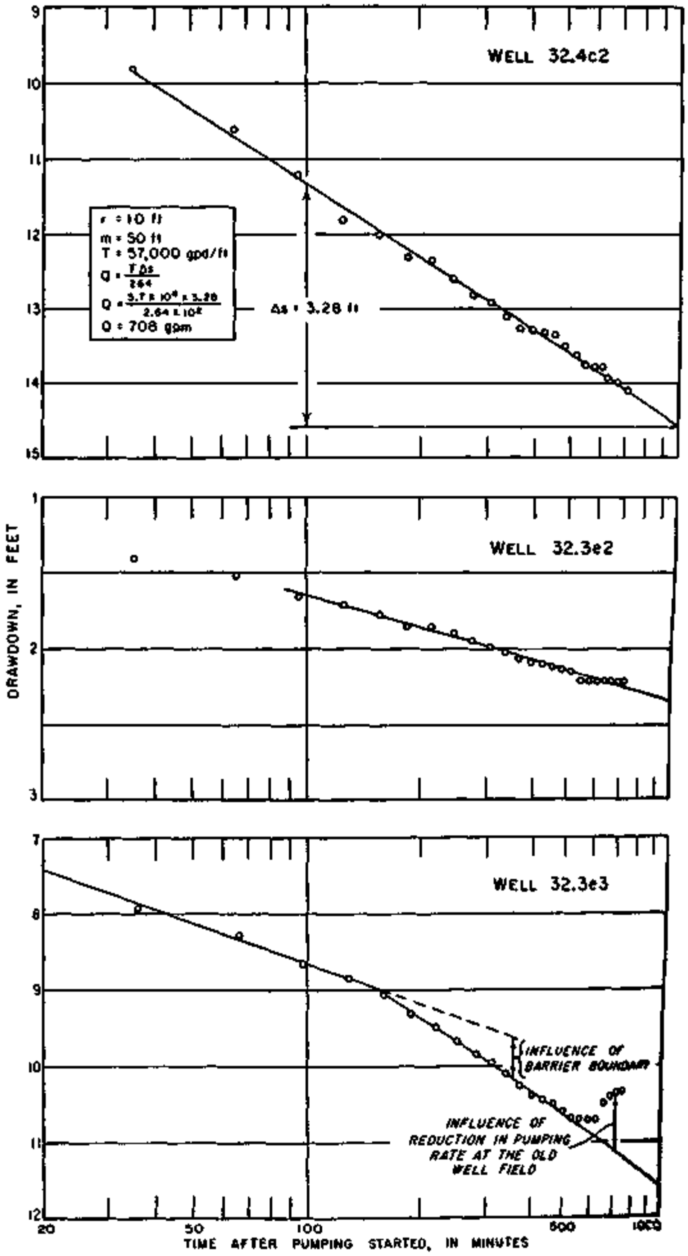

Figure 47. Time-drawdown graphs for three wells at Woodstock.

aquifers open to well 32.4cl. The computed coefficient of transmissibility is 227,000 gpd/ft. The coefficient of transmissibility of the lower aquifer (57,000 gpd/ft) was subtracted from the computed *T* to determine the coefficient of transmissibility of the middle aquifer interbedded in the confining bed above the lower aquifer. Based on specific-capacity data, the coefficients of transmissibility and permeability of the middle aquifer are 170,000 gpd/ft and 8500 gpd/sq ft, respectively.

An aquifer test (test 6) was made on well 32.3el on May 2, 1961 in the new municipal well field. Pumping was continuous for 12 hours and 5 minutes at a constant rate of 1022 gpm. The effects of pumping well 32.3el were measured in the pumped well and in observation wells 32.3e2 and 32.3e3, both 10 feet from the pumped well. (See figure 54 for the location of well 32.3el and figure 55 for its generalized construction features and log.)

Well 32.3el is screened in two zones. The lower zone is the middle aquifer; the upper zone is the upper aquifer. Observation wells 32.3e2 and 32.3e3 are screened in only the upper and middle aquifer, respectively.

The time-drawdown graph for well 32.3e2 in figure 47 indicates that the upper aquifer has a fairly large areal extent because the time-rate of drawdown was constant throughout most of the test. The time-drawdown graph for well 32.3e3 in figure 47 suggests that the middle aquifer is limited in areal extent and that the hydraulic connection between the middle aquifer and the lower aquifer is good. After 150 minutes the time-rate of drawdown increased because of the effects of a barrier boundary. After about 510 minutes water levels recovered due to the reduction of pumpage from wells in the old municipal well field about 5000 feet from well 32.3e3. The wells in the old municipal well field are screened only in the lower aquifer.

A comparison of the mechanical analyses of samples for the upper aquifer, middle aquifer, and lower aquifer shown in figure 40 indicates that the upper and middle aquifers are much more permeable than the lower aquifer. The specific capacity of well 32.3el for a pumping period of 12 hours and a pumping rate of 1022 gpm is 213 gpm/ft. The specific capacity and a water-table coefficient of storage were substituted into the modified nonequilibrium formula to determine the coefficient of transmissibility of a single aquifer which would behave in the same manner as the two aquifers open to well 32.3el. The computed coefficient of transmissibility is 370,000 gpd/ft. The coefficient of the middle aquifer (170,000 gpd/ft) determined from data for test 5 was subtracted from the computed coefficient of transmissibility to determine the coefficient of transmissibility of the upper aquifer. Based on specific-capacity data, the coefficients of transmissibility and permeability of the upper aquifer are 200,000 gpd/ft and 6600 gpd/sq ft, respectively.

A summary of the hydraulic properties obtained with aquifer test data is given In table 11. The coefficients of transmissibility and permeability for the upper and middle aquifers are much greater than those for the lower aquifer. The high leakage coefficient for the thin confining bed between the lower and middle aquifers indicates that the hydraulic connection between these two aquifers is good.

Theoretical Effects of Pumping

Pumping from wells in the lower aquifer has a fairly widespread effect on water levels. The leaky artesian formula, the coefficients of transmissibility and storage of the lower aquifer, and the coefficient of vertical permeability (see "Recharge to Aquifers") of the confining bed between the upper and lower aquifers were used to evaluate the magnitude of interference between wells and well fields.

Figure 48 shows the amount of interference that will

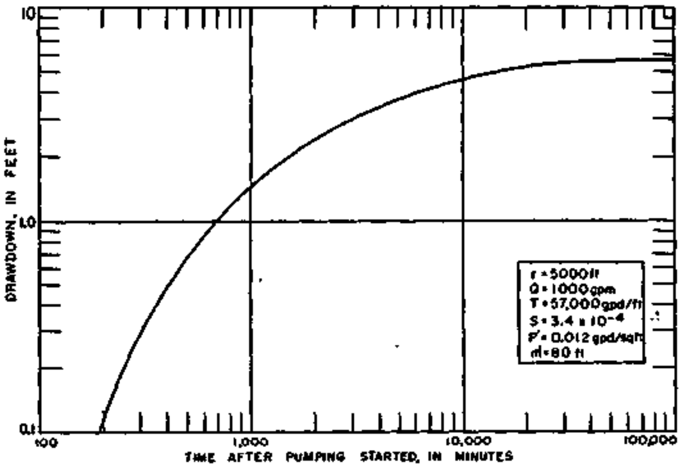

Figure 48. Graph of theoretical time-drawdown for lower aquifer at Woodstock

occur at a distance of 5000 feet from a well pumping continuously at 1000 gpm for pumping periods ranging from 190 to 100,000 minutes. The distance between the old municipal well field and the new municipal well field is 5000 feet. Figure 48 shows, for example, that for a pumping rate of 1000 gpm, maximum interference between the old and new municipal well fields will be about 6 feet. About 98 percent of the interference occurs approximately 14 days after pumping starts.

Ground-Water Withdrawals

The first municipal wells at Woodstock were constructed during the period 1894-1907. Three deep sandstone wells were drilled, and these supplied the city with water until 1912. Because of a threatened water shortage in 1912, two sand and gravel wells were drilled. The sand and gravel and deep sandstone wells were all abandoned in 1921 when production capacities of the wells decreased. During 1920 and 1921, two sand and gravel wells were drilled. In 1921 about 250,000 gpd were pumped from these two wells to satisfy the municipal water demands.

Figure 49 shows estimated withdrawal rates, 1921-1962. Very few records of pumpage are available for years prior to 1952. The graph was constructed by piecing together fragments of information on pumpage found in published reports and in the files of the State Water Survey, by taking

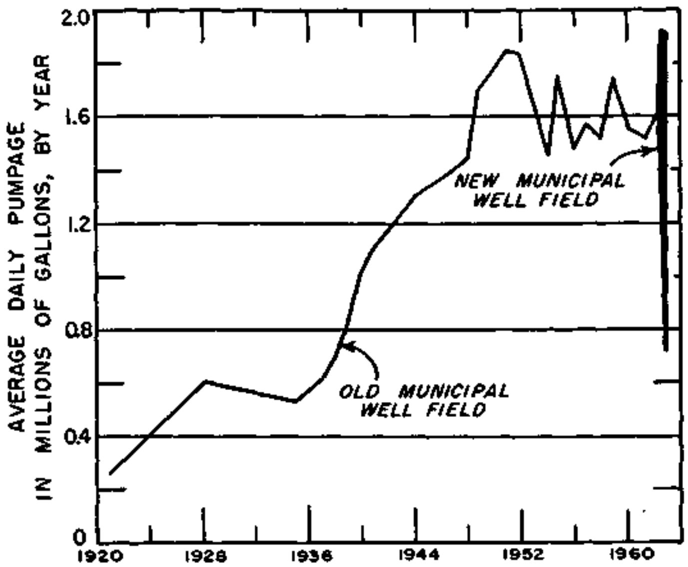

Figure 49. Ground-water pumpage from sand and gravel aquifers at Woodstock, 1921-1962

into consideration population growth, number of services, and revenues derived by the city from the sale of the water.

As shown in figure 49, municipal water use has steadily increased since 1921 as the city has grown in population from 5523 to 8897 people. In 1960 approximately 1,550,000 gpd were required to fulfill industrial, commercial, and domestic water demands. Total per capita consumption increased from 45 gpd per person in 1921 to nearly 175 gpd per person in 1960.

Records of monthly pumpage at the old municipal well field were started in 1952 and are illustrated in figure 50.

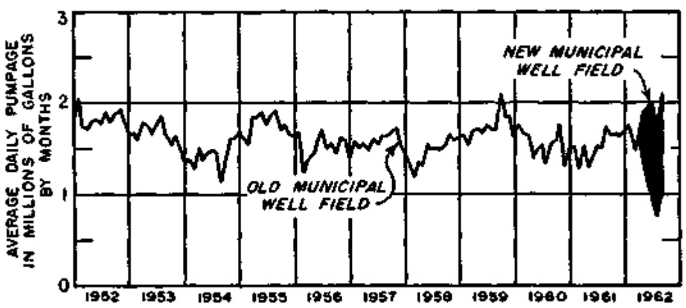

Figure 50. Ground-water pumpage from sand and gravel aquifers at Woodstock, 1952-1962

No records of individual well pumpage are available. Water use generally is greatest in the summer months and least in the winter months. A maximum pumping rate of 2.1 mgd was recorded during September 1959 and a minimum pumping rate of 1.15 mgd was recorded during July 1954.

Until April 1962 all water for the municipal water supply was pumped from wells in the old municipal well field. As water levels declined to near critical stages in the old municipal well field and the yields of individual sand and gravel wells decreased, undeveloped portions of the lower aquifer away from the center of pumpage were explored for an additional source of water. In 1960 a test drilling program was started and in 1961 three new sand and gravel wells, 32.3cl, 32.3el, and 32.4cl, were constructed about 1 mile northeast of the old well field as shown in figure 33. In April 1962 the new municipal well field was placed in service.

Pumpage data for the individual wells in the new well field have been recorded on a monthly basis and are illustrated in figure 51. The total pumpage from the new municipal well field is distributed about equally to each

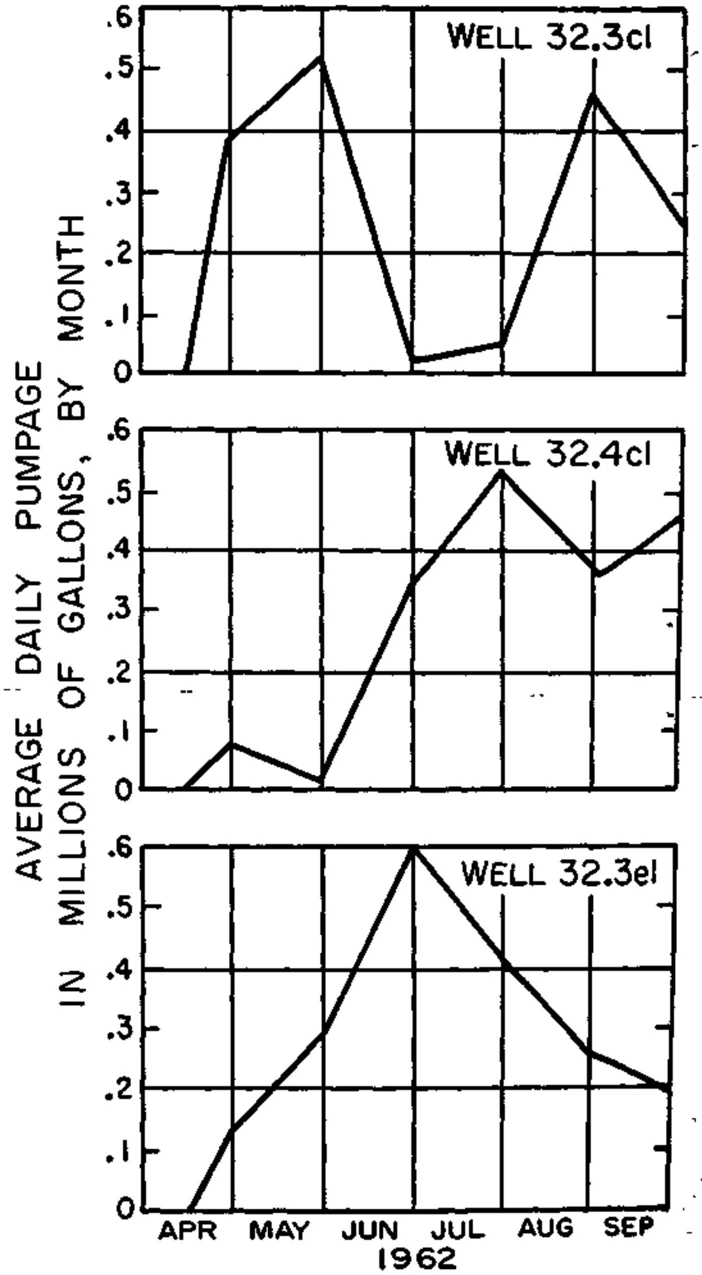

Figure 51. Graphs of average daily pumpage in three wells in new municipal well field at Woodstock

well. The pumping schedule is based on a three-month cycle; each well produces the bulk of the pumpage once every three months. This is the pumping schedule which the water superintendent intends using in the future.

After wells in the new municipal well field were placed in service, the wells in the old municipal well field were operated only to supply Electric Auto-Lite, the principal industry at Woodstock. Auto-Lite uses treated city water for most of its water supply, but maintains a private sand and gravel well (well 5.7d5) for domestic demands. Well 5.7d5 pumps an average of 100,000 gpd and is located about 500 feet southeast of well 5.7d3.

Construction Features and Yields of Wells

The construction features of the four production wells in the old municipal well field are illustrated in figure 52;

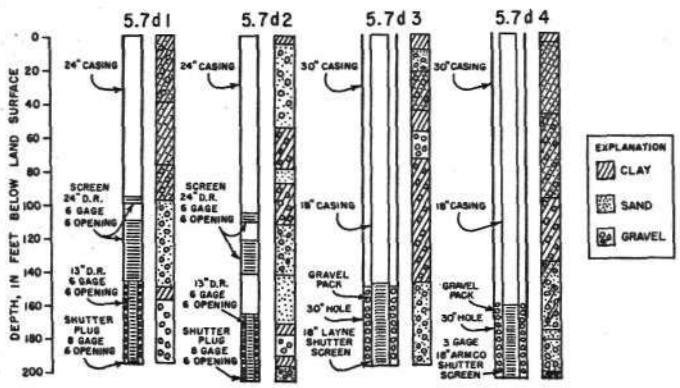

Figure 52. Generalized construction feature* and logs of production walk in old municipal well field at Woodstock

locations of the wells are shown in figure 53. Wells 5.7dl and 5.7d2 were drilled by the cable tool method in 1921 and are 196 feet and 206 feet deep, respectively. Both wells are artificial pack wells and are screened in several zones. Wells 5.7d3 and 5.7d4 were drilled by the cable tool method in 1939 and 1948, respectively, and are very similar in construction. Both wells are artificial pack wells having 30-inch outer casings, 18-inch inner casings, and 18-inch shutter screens in one zone.

Upon completion the production wells were tested to determine their yields. The production wells were also tested in 1962 to ascertain whether or not yields had decreased during tiieir use. The results of the well-production tests are summarized in table 12.

The specific capacities of the production wells in 1962 ranged from 13.3 to 16.7 gpm/ft. A comparison of the specific capacities recorded upon completion of the wells and measured in 1962 indicates that the yields of wells 5.7dl, 5.7d2, and 5.7d3 have decreased during tiieir use and the yield of well 5.7d4 has increased.

The three production wells in the new municipal well field are located about 1 mile northeast of the old well field and are shown in figure 54. The wells were drilled

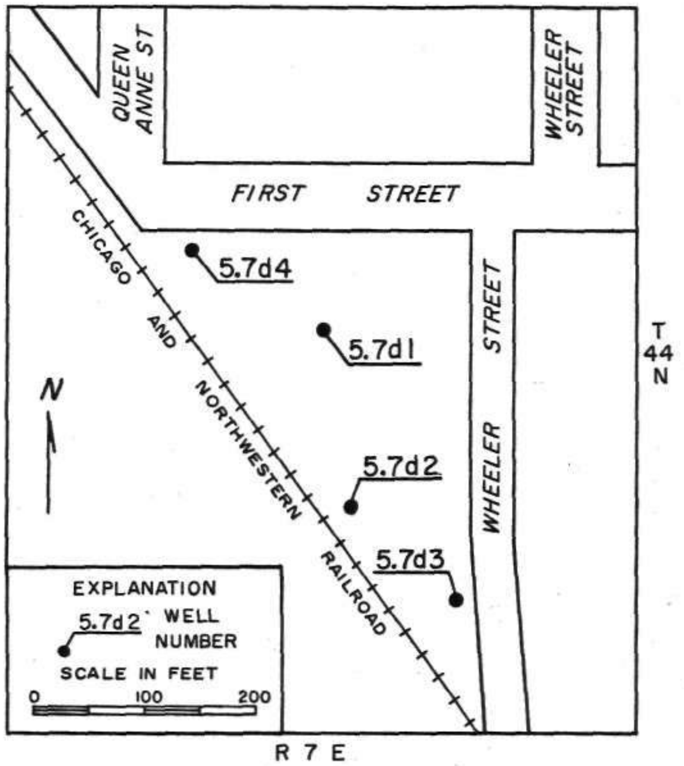

Figure 53. Wall locations in old municipal well field at Woodstock

by the rotary process during 1960 and 1961. They range in depth from 114 to 192 feet. The construction features of the wells are basically the same; only the lengths of casings and screens differ from well to well.

The case history of the drilling of well 32.3c1 will illustrate construction features. During the construction of well 32.3cl, a 34-inch diameter hole was drilled to a depth of 189 feet. A No. 8 Layne shutter screen, 12 inches in diameter and 50 feet long, was set at the bottom of the well. Twelve-inch diameter casing was set from the top of the screen to 4 feet below land surface. A pitless adapter 4 feet long was placed on the top of the casing to bring the well up to land surface. Forty-one tons of Muscatine size 0 gravel were placed in the annular space between the 34-inch hole and the 12-inch screen, to serve

Table 12. Yields; of Sand and Gravel Wells in Municipal Well Fields at Woodstock

Well number	Year of test	Length of test (*min*)	Pump-ing rate (*gpm*)	Draw-down (*ft*)	Specific capacity (*gpm/ft*)
MCH—					
44N7E-					
5.7dl	1921	80	659	34	19.4
5.7d2	1921	75	866	38	22.8
5.7d3	1939	90	1440	68	21.2
5.7d4	1948	—	1000	94	10.7
5.7dl	1962	60	1050	79	13.3
5.7d2	1962	60	800	48	16.7
5.7d3	1962	20	1050	71	14.9
5.7d4	1962	20	1050	79	13.3
45N7E-					
32.3cl	1960	720	1043	26	40.1
32.3el	1961	720	1022	4.8	213.0
32.4cl	1960	720	1043	10	104.3

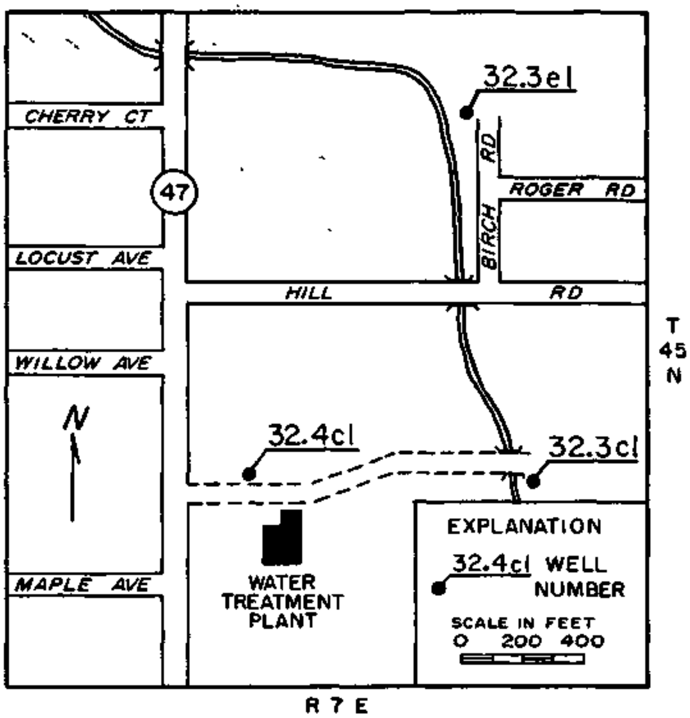

Figure 54. Wall locations in new municipal well field at Woodstock

as an artificial pack. The remaining annular space was filled with sand up to 19 feet below land surface. Cement was placed in the annular space from 19 feet below land surface to 5 feet below land surface. The remaining space was filled with fill dirt to the existing grade. The construction features of the production wells in the new municipal well field are illustrated in figure 55.

Fluctuations of Water Levels and Their Significance

Both nonpumping and pumping levels of water in production wells were measured periodically after development. Unfortunately, very little data are available on water

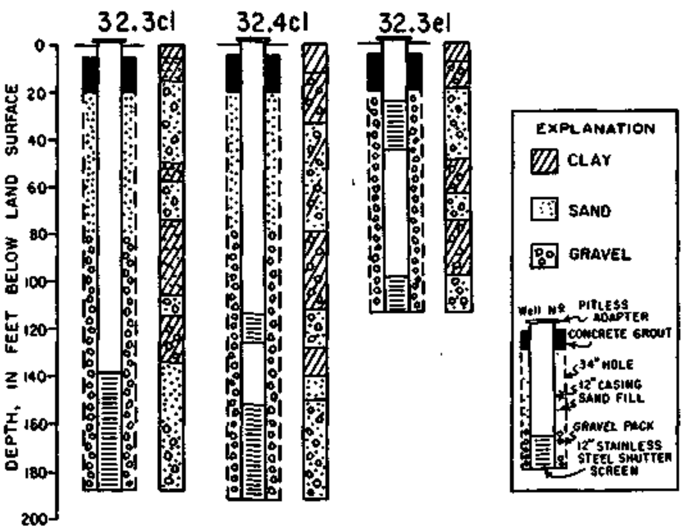

Figure 55. Generalized construction features and logs of production wells in new municipal well field at Woodstock

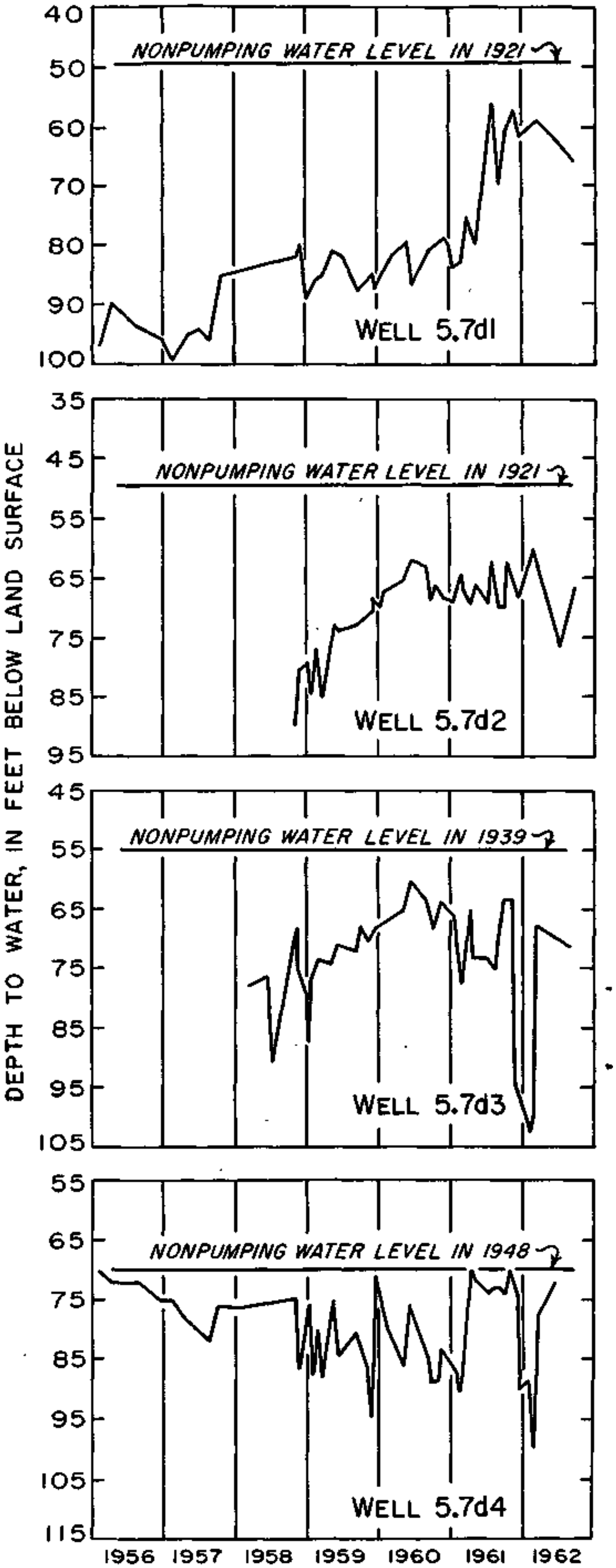

Figure 56. Nonpumping levels in wells at Woodstock, 1956-1962

levels prior to 1956. Hydrographs of nonpumping levels for the four production wells in the old municipal well field (1956-1962) are shown in figure 56. Although the water levels vary considerably from time to time because of shifts in pumpage from one well to the other and changes in total pumpage, the hydrographs show no continuous decline in water levels.

Wells 5.7dl and 5.7d2 show definite recovery trends in 1961 and 1959, respectively. The recovery is attributed to the recent practice of shifting pumpage from wells 5.7dl and 5.7d2 to wells 5.7d3 and 5.7d4, thereby reducing the amount of interference between production wells. Water levels in well 5.7d4 were at the same stage, about 40 feet below land surface, in 1948 and in 1961, indicating that water pumped from 1948 through 1961 was replenished in full.

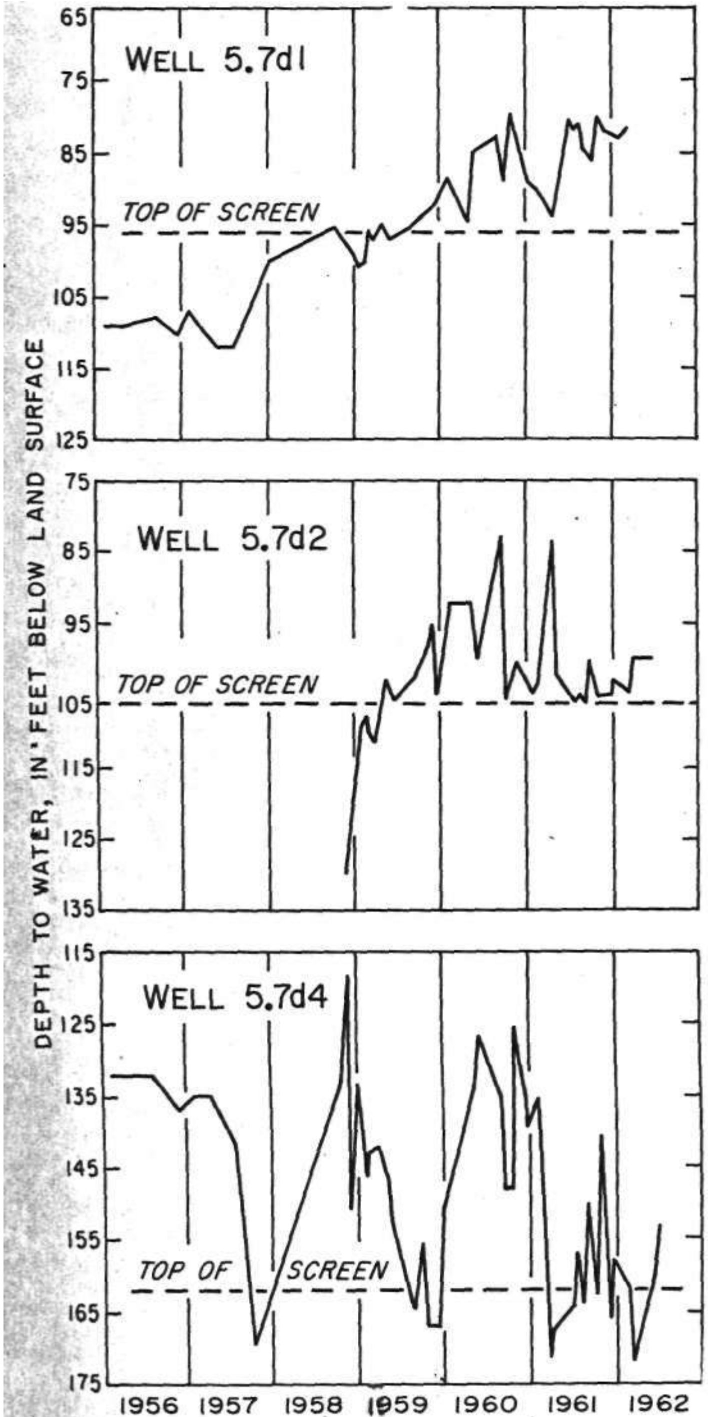

Figure 57. Pumping levels in wells in Woodstock, 1956-1962

Pumping levels in production wells in the old municipal well field are shown in figure 57. Prior to 1959, pumping levels were below tops of screens in wells 5.7d1, 5.7d2 and 5.7d3. Exposing screens to air is not desirable because it often accelerates the rate at which the screen openings clog. Since 1959 the pumping levels in wells 5.7dl and 5.7d2 have recovered in general to stages above tops of screens because pumpage was shifted to wells 5.7d3 and 5.7d4, and total pumpage from wells in the old municipal well field was reduced.

A comparison of water-level hydrographs and pumpage graphs indicates that in general water-level decline is proportional to the rate of pumpage. Average water-level declines in wells plotted against corresponding average rates of pumpage in the old municipal well field are shown in figure 58. Although the data are somewhat scattered, a consistent relationship between decline and pumpage is apparent. Approximately 60,000 gpd were obtained with each foot of decline. The consistent relationship between decline and pumpage and the stabilization of water levels after each increase of pumpage indicate that in the past recharge has balanced withdrawal.

Water-level data for wells in the new municipal well field are given in table 13. Water-level trends cannot be determined from the short-term records.

Configuration of Piezometric Surface of Aquifers

Prior to development, the piezometric surfaces of the middle and lower aquifers were near the land surface in the northern half of the Woodstock area, and fairly high under the surrounding uplands to the south and east. Data on water levels in wells prior to development suggest that the piezometric surfaces of the middle and lower aquifers were subdued replicas of the topography, and the general

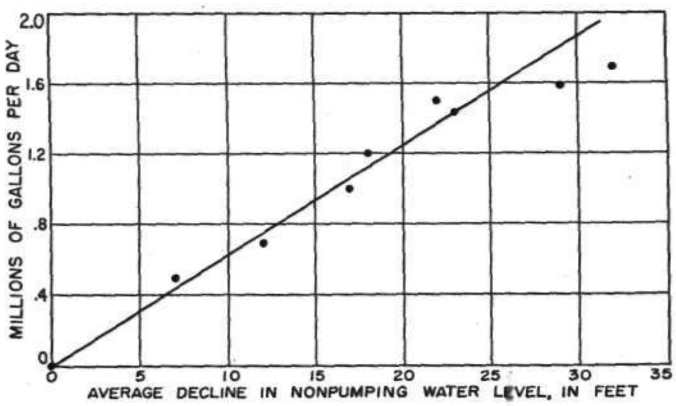

Figure 58. Rotation between averago pumping rate and docline of water levels in old municipal well field at Woodstock

Table 13. Water-Level Data for New Municipal Well Field at Woodstock

Well number	Month 1962	Water levels (ft below land surface) nonpumping	pumping
MCH—45N7E-			
32.3cl	Apr	31	43
	May	31	43
	Jun	31	44
	Jul	31	43
	Aug	29	43
	Sep	28	41
32.4c1	Apr	27	42
	May	27	42
	Jun	27	42
	Jul	27	42
	Aug	30	43
	Sep	33	44
32.3el	Apr	28	31
	May	26	31
	Jun	26	31
	Jul	26	31
	Aug	26	31
	Sep	28	33

movement of ground water was from the uplands towards the streams draining the area. Ground-water divides coincided roughly with topographic divides.

The approximate piezometric surface of the lower aquifer after development is shown in figure 59. The map was prepared from water-level measurements in table 14 made during the latter part of August and the early part of September 1962. The majority of observation wells in the

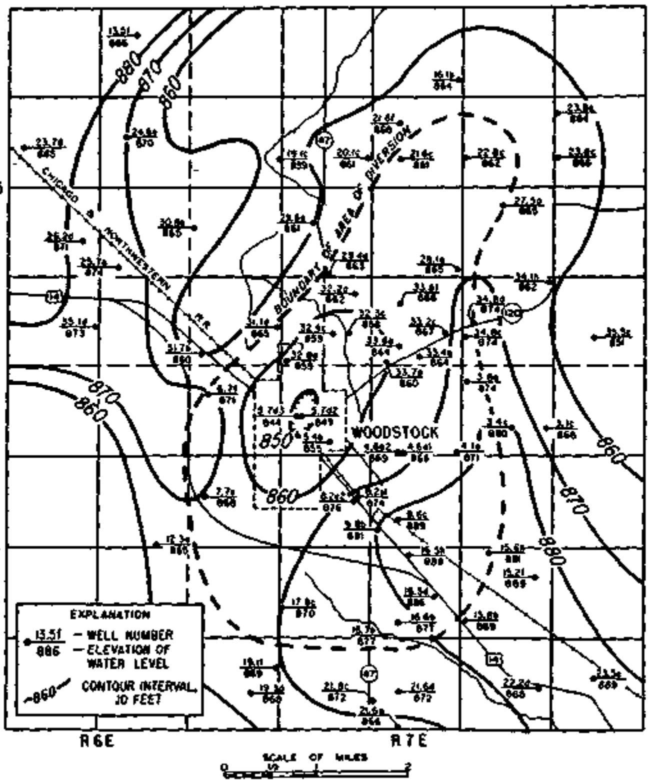

Figure 59. Approximate elevation of piezometric surface of lower aquifer in Woodstock area, August-September, 1962

Table 14. Water-Level Data for Wells in Lower Aquifer in Woodstock Area

Well number	Owner	Depth (ft)	Land surface elev. (ft) above MSL)	Depth to water (ft)	Date measured	Water level elev. above (ft MSL)
MCH-44N7E-						
3.8g	C. Geschke	85	898	24.36	9/6/62	874
3.1c	M. Peterson	150	955	85.16	9/6/62	868
3.4c	J. Hummeland	116	921	40.56	9/6/62	880
4.6a1	B. Burgess	228	895	28.54	9/6/62	866
4.6a2		62	893	23.80	9/6/62	869
5.4b	R. O. Andrew	226	898	42.58	8/9/62	855
5.7d	Electric Auto-Lite	204	905	56	7/3/62	849
6.7f	B. Frank	211	1007	135.88	9/6/62	871
7.7e	Torgeson	237	953	84.83	8/23/62	868
7.d1(1)	Woodstock (C)	196	915	66	9/7/62	849
7.d2(2)	Woodstock (C)	207	915	66	9/7/62	849
7.d3(3)	Woodstock (C)	198	915	71	9/7/62	844
7.d4(4)	Woodstock (C)	205	915	66	9/7/62	849
8.2el	I. J. Lewis	175	952	78	9/6/62	874
8.2e2	J. Bates	110	938	62.15	9/6/62	876
9.6c	McHenry Co. Serv.	75	945	56.02	7/26/62	889
9.8b	M. Mueller	150	952	70.50	7/26/62	881
15.6h	L. Shaw	232	962	81.06	7/26/62	881
15.8b	P. Roach	130	925	36.32	9/7/62	889
15.2f	J. W. Clarke	160	950	61.09	9/7/62	889
16.5hl	Morton Salt	150	975	82	11/5/60	893
16.5h2	Morton Salt	231	975	87	11/5/60	888
16.6b	Horst	189	926	49.42	8/22/62	877
16.3d	R. Nehls	80	940	54.12	8/21/62	886
17.8c	G. H. Eddy	212	960	90	8/22/62	870
19.1f	Savings & Loan	185	945	76.10	8/22/62	869
19.3d	Unzner	185	935	67.18	8/24/62	868
21.7f	H. Morgan	200	930	61.00	8/21/62	869
21.6a	T. Fuchs	185	947	81.30	9/6/62	866
21.8c	C. Ziller	182	941	68.60	8/22/62	872
21.6d	None	174	930	58.37	8/21/62	872
22.2d	A. Kesteleyn	230	930	42.33	9/7/62	888
23.5e	S. D. Hurley	155	941	52.31	9/7/62	889
30.8e	R. C. H. Vass	165	905	66.48	9/4/62	839
45N6E-						
13.5f	J. Eggum	175	970	83.73	9/5/62	886
23.7d	G. Halderman	125	920	35.04	9/5/62	885
26.4e	N. Britz	194	950	80.30	9/5/62	870
2'5.7al	P. Hinner	198	885	11.15	7/27/62	874
25.7a2	P. Hinner	200	885	11	7/27/62	874
26.2d	F. Raffel	107	887	16.43	9/5/62	871
45N7E-						
16.1b	H. Betilinski	120	915	51.49	9/5/62	864
19.1c	J. McConnell	95	867	5.82	9/6/62	861
20.1c	A. Larson, Jr.	80	895	32.49	9/6/62	863
21.6f	Meckier	190	903	35.19	9/6/62	868
21.6c	C. Mavis	165	902	41	1959	861
22.8c2	None	190	925	58.89	9/5/62	866
23.8g	C. Lethen	125	913	48.95	9/5/62	864
27.5g	Volmer	100	890	25.29	9/6/62	865
29.6e	R. Larson	85	873	12.95	9/6/62	873
29.4a	Schoenberger	197	890	26.99	9/6/62	863
30.8e	Dettning Bros.	60	887	21.51	9/6/62	865
31.1d	E. Foster	70	891	26.30	8/24/62	865
31.7b	M. DiPirro	195	925	64.63	9/6/62	860
32.3c1(5)	Woodstock (C)	189	886	28	9/6/62	858
32.4c1(6)	Woodstock (C)	192.5	892	33	9/6/62	859
32.3e1(7)	Woodstock (C)	114	890	28	9/6/62	862
32.2g	Kauffman	131	892	29.64	9/6/62	862
32.8a	L. J. Clarke	140	898	39	1953	859
33.6f	Robinson	105	888	22	1962	866
33.7a	W. Ahrens	77	883	23.08	9/6/62	860
33.4a	Dr. J. B. Palenski	80	887	23.09	9/6/62	864
33.2c	I. Epple	200	912	44.89	8/7/62	867
34.8c	I. Epple	100	906	31.59	9/6/62	874
34.8d	I. Epple	105	912	38.02	9/6/62	874
34.1h	E. Given	225	910	48.39	8/7/62	865

Woodstock area are open in the lower aquifer; however, many wells are open in the middle aquifer interbedded in the confining bed above the lower aquifer. The middle and lower aquifers have slightly different water levels at the same location (for example, see wells 8.2el and 8.2e2 in table 14). The piezometric surface could not be mapped using only the available water-level data for the lower aquifer; water-level data for wells in the middle aquifer were used to augment data for wells in the lower aquifer. On the basis of measured water levels in a few closely spaced wells drilled to different depths, it is probable that the piezometric surfaces of the middle and lower aquifers are in general very similar. Accordingly, it is believed that the contours, on figure 59 can be used to determine the approximate directions of movement of ground water, the average hydraulic gradients of the piezometric surface, and the area of diversion of pumping in the lower aquifer.

A pronounced cone of depression is centered at the old municipal well field. A ground-water ridge occurs southeast of Woodstock and a ground-water trough exists north of Woodstock. Pumping has reduced natural discharge of ground water to the shallow aquifer norm of Woodstock. Contours are warped around the new municipal well field. As shown in figure 59 ground-water movement is in all directions toward well fields or topographic lowlands.

Flow lines were drawn at right angles to the piezometric surface contours from production wells up gradient to define the area of diversion. As measured from figure 59, the area of diversion is 15 square miles.

The piezometric surface map of the lower aquifer was compared with water-level data for the period prior to development, and water-level changes were computed. The greatest declines in the piezometric surface occurred in the immediate vicinity of the old municipal well field and averaged about 20 feet. In 1959 prior to the reduction in pumpage at the old municipal well the piezometric surface averaged about 30 feet below the piezometric surface prior to development.

Data on water levels in the upper aquifer are given in table 15. The piezometric surface of the upper aquifer more closely resembles the topography than does the piezometric surface of the lower aquifer. The piezometric surface of the upper aquifer is at most places at a higher elevation man the piezometric surface of the lower aquifer.

Table 15. Water-Level Data for Upper Aquifer in Woodstock Area

WeU number	Owner	Depth *(ft)*	Land surface elev. *(ft above MSL)*	Depth to water *(ft)*	Date measured	Water level elev. *(ft above MSL)*
MCH—44N6E-						
1.5c	**Camp Kiawassa**	**45**	**920**	**5.15**	**9/7/62**	**915**
11.1d	**Weigel**	**60**	**955**	**15**	**8/23/62**	**940**
44N7E-						
4.1a	**W. D. Young**	**54**	**920**	**49.2**	**1959**	**871**
6.6c	**Allen**	**62**	**991**	**29.29**	**8/23/62**	**961**
6.5h	**Burmeister**	**40**	**925**	**10.05**	**8/24/62**	**915**
7.2b	**F. Draffkorn**	**83**	**940**	**24**	**1962**	**916**
7.7al	**S. J. Kaisor**	**49**	**975**	**27.20**	**8/21/62**	**948**
7.4g	**Hoerbert**	**35**	**940**	**19.50**	**8/22/62**	**920**
8.2c	**Phelan**	**35**	**930**	**14.15**	**8/21/62**	**916**
8.2g	**E. Sweetland**	**20**	**915**	**8.62**	**8/21/62**	**906**
9.8g	**Tilicke**	**60**	**912**	**16.35**	**8/21/62**	**896**
9.8d	**G.&H. Mfg.**	**20**	**930**	**2.69**	**8/21/62**	**927**
15.7h			**925**	**0.00**	**9/17/62**	**925**
17.8c	**J. C. Heisler**	**55**	**930**	**5.33**	**9/22/62**	**925**
17.8d	**L. Eddy**	**80**	**960**	**27.67**	**8/22/62**	**932**
45N6E-						
35.1d	**L. Burlingham**	**47**	**950**	**76.63**	**8/23/62**	**873**
36.1d	**Gillies**	**50**	**915**	**21.60**	**8/24/62**	**893**
45N7E-						
19.3a	**Pratt**	**56**	**890**	**5**	**9/6/62**	**885**
22.8cl	**Workman**	**50**	**900**	**38.42**	**9/6/62**	**862**
28.1a	**D. Michelatti**	**28**	**888**	**23**	**1961**	**865**
33.6b	**Thomson Flowers**	**30**	**885**	**21.50**	**9/6/62**	**864**

Recharge to Aquifers

Recharge to aquifers in the Woodstock area occurs locally as vertical leakage of water through deposits and has precipitation as its source. A large proportion of precipitation runs off to streams or is discharged by evapotranspiration without reaching aquifers. Some precipitation reaches the water table and becomes ground water. Part of the water stored temporarily in the upper aquifer moves downward tiirough the confining bed and into the middle and lower aquifers. Vertical movement is possible because of the large differentials in head between the water table in the upper aquifer and the piezometric surfaces of the middle and lower aquifers.

The water level in shallow (10 to 50 feet deep) dug or bored wells fluctuates through a wide range in response to above or below normal precipitation; in drought years some shallow wells go dry. However, water stored in the duck confining bed is available to the middle and lower aquifers so that drought periods have little influence on water levels in the middle and lower aquifers.

The quantity of leakage (recharge) tiirough the confining bed varies from place to place and is primarily controlled by the vertical permeability and thickness of the confining bed and the difference between the piezometric surfaces of the upper and lower aquifers. Comparisons of pumpage and water-level graphs indicate that water-level declines are directly proportional to pumping rates, and within a short time after each increase in pumpage, water levels stabilize. Thus, recharge balanced discharge and the quantity of leakage in 1962 was equal to the average pumping rate in 1962, or about 1.86 mgd.

The rate of recharge to the lower aquifer expressed in gpd/sq mi can be estimated from the piezometric surface map in figure 59 and the quantity of leakage. The quotient of the quantity of leakage (recharge) and the area of diversion is the rate of recharge. The area of diversion is about 15 square miles, therefore the recharge rate to the lower aquifer was about 125,000 gpd/sq mi in 1962.

The rate of recharge may be expressed mathematically by the following form of Darcy's law:

$$Q_c/A_c = 2.8\text{x}10^7\ (P'/m')\ \Delta h \qquad (11)$$

where:

Q_c/A_c = recharge rate, in gpd/sq mi
Q_c = leakage (recharge) through confining bed, in gpd
A_c = area of diversion, in sq mi
P' = vertical permeability of confining bed, in gpd/sq ft
m' = saturated thickness of confining bed, in ft
Δh = difference between the head in the aquifer and in the source bed above the confining bed, in ft

As shown in equation 11, the recharge rate varies with the vertical head loss (Ah) associated with leakage of water through the confining bed. The average vertical head loss in August 1962 was computed to be about 30 feet by comparing the piezometric surface map for the lower aquifer with water-level data for the upper aquifer (source bed for the lower aquifer). The average recharge rate per unit area per foot of head loss is about 4200 gpd/sq mi/ft.

The dependence of recharge rate per unit area upon vertical head loss is not constant but varies in value with changes in the elevation of the piezometric surface of the lower aquifer. As the piezometric surface declines, the vertical head loss increases, and the recharge rate per unit area increases. The recharge rate per unit area is directly proportional to the vertical head loss, and is at a maximum when the piezometric surface is at the top of the lower aquifer, provided the head in the upper aquifer remains fairly constant.

The recharge rate per unit area is valid for only one average vertical head loss. On the other hand, the recharge rate per unit area per foot of head loss remains constant so long as the saturated thickness and vertical permeability of the confining bed does not change. Thus, the recharge rate per unit area per foot of head loss is much more meaningful than the recharge rate per unit area. The recharge rate per unit area per foot of head loss (P'/m') is the leakage coefficient of the confining bed.

Vertical Permeability of Confining Bed

Equation 11 may be rewritten as

$$P' = Q_c m'/2.8\text{x}10^7\ \Delta h\ A_c \qquad (12)$$

Thus, the vertical permeability of the confining bed between the upper and lower aquifers may be computed by multiplying the recharge rate per unit area per foot of head loss $(Q_c/\Delta h\ A_c)$ by the saturated thickness of the confining bed. Based on available well logs, the average saturated diickness of the confining bed within the area of diversion is 80 feet. A coefficient of vertical permeability of 0.012 gpd/sq ft was computed by substituting appropriate data in equation 12. The coefficient of vertical permeability based on the piezometric surface map applies to the average hydraulic property of the entire diickness of the confining bed between the middle and lower aquifers.

Model Aquifer and Mathematical Model

The results of geologic and hydrologic studies indicate that it is possible to simulate complex aquifer conditions in the Woodstock area with idealized model aquifers. The model aquifer for the lower aquifer shown in figure 60 is

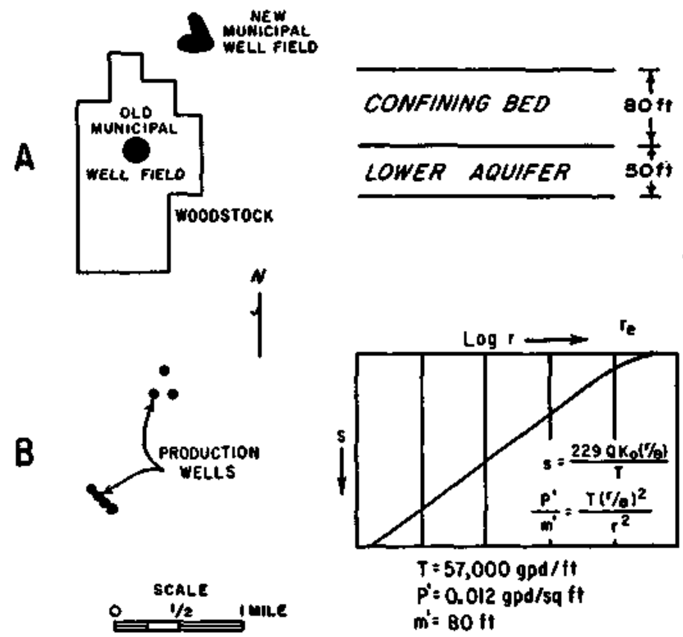

Figure 60. Modal aquifer (A) and mathematical modal (B) for lower aquifer at Woodstock

a layer of sand and gravel extending beyond the virtual radius of the cone of depression, 50 feet thick, overlain by a confining bed 80 feet thick, and bounded on the bottom by relatively impermeable material. Based on aquifer-test data the average coefficients of transmissibility and storage of the model aquifer are 57,000 gpd/ft and 3.4 x 10"*, respectively. The average coefficient of vertical permeability of the confining bed of the model aquifer was computed to be 0.012 gpd/sq ft by flow-net analysis of the piezometric surface of the lower aquifer, vertical head loss data, geologic data, and pumpage data.

A distance-drawdown graph (figure 61) based on the hydraulic properties of the model aquifer was prepared for use in determining components of drawdown associated with development of the lower aquifer. The map showing the location of existing production wells and the distance-drawdown graph constitute the mathematical model for the Woodstock area.

Records of past pumpage and water levels were used to test the assumed model aquifer against past performance of the real aquifer, and thereby establish the validity of the matiiematical model to estimate the practical sustained

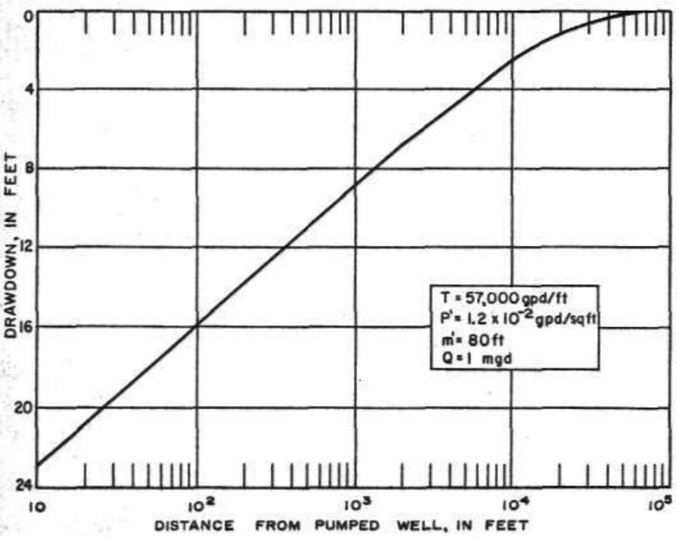

Figure 61. Theoretical distance-drawdown graph for lower aquifer at Woodstock

yield of the lower aquifer. The water-level decline in well 5.7d2 from 1921 to September 1961 was computed using the mathematical model and estimated pumpage data. The computed decline was then compared with the actual drawdown. During the month of September 1961, well 5.7d2 was pumped infrequently and the drawdown observed in the well was mosdy due to the effects of pumpage from other production wells in the old municipal well field. Ground-water withdrawals from the old municipal well field during September 1961 averaged 1.65 mgd. The actual water-level decline in well 5.7d2 was 21.00 feet; a water-level decline of 22.90 feet was computed with the mathematical model. The computed water-level decline is within 9 percent of the actual drawdown.

The mathematical model is based on a particular combination of aquifer properties and dimensions. There are probably other mathematical models involving several slightly different combinations of parameters which would also duplicate aquifer conditions. It is recognized that the analytical method of analysis described above provides only approximate answers on a bulk basis. However, the close agreement between computed and actual declines indicates that the model aquifer and madiematical model closely describe the geohydrologic conditions of the lower aquifer in the Woodstock area. It is reasonable to assume that the model aquifer and madiematical model may be used to predict with reasonable accuracy the practical sustained yield of the existing wells in the lower aquifer.

Available data concerning the hydraulic properties of the upper and middle aquifers are not sufficient to permit preparation of a model aquifer and madiematical model for those aquifers.

Practical Sustained Yield of Existing Well Fields

The model aquifer and madiematical model were used to determine the maximum amount of water that can be continuously withdrawn from existing wells screened in the lower aquifer at Woodstock without eventually lowering water levels to critical stages below tops of screens, or exceeding recharge. Computations indicate that the practical sustained yield of wells in the old municipal well field is about 2.4 mgd or about 0.9 mgd more than the average annual rate of pumpage in 1961.

Computations based on the madiematical model for the lower aquifer and available well-production data indicate that the practical sustained yield of multi-aquifer wells in the new municipal well field is about 3 mgd. Of the 3 mgd, ¼ mgd is derived from the upper aquifer, ¾ mgd is derived from the middle aquifer, and 2 mgd is derived from the lower aquifer. Interference between old and new municipal well fields, effects of partial penetration of production wells, and well losses in production wells were considered in computations.

The pumping rate schedule used in computing practical sustained yields is given in the following table.

Well number	Average daily pumping rate (mgd)
MCH 44N7E-5.7dl	0.60
5.7d2	0.60
5.7d3	0.60
5.7d4	0.60
MCH 45N7E-32.3cl	1.25
32.4cl	1.00
32.3el	0.75

The practical sustained yield can be developed by use of other pumping rate schedules such as pumping wells 5.7d3 and 5.7d4 at rates of about 1.2 mgd each and discontinuing use of wells 5.7dl and 5.7d2 in the old municipal well field. However, an even distribution of withdrawals from wells in the old municipal well field is more desirable.

In order to increase the amount of recharge to the middle and lower aquifers from the 1962 rate of 1.86 mgd to the practical sustained yield of 5.4 mgd, the product ΔhA_e must increase to a value 2.9 times the value of ΔAhA_c in 1962. Thus, full development of the practical sustained yield will be accompanied by large increases in the area of diversion and vertical head loss.

LIBERTYVILLE AREA

Water for municipal use at Libertyville and Mundelein is obtained locally from wells, in deeply buried dolomite and sand and gravel aquifers. Since 1905 the average daily withdrawal for the two municipal water supplies steadily increased from 50,000 gallons to 2.14 million gallons in 1962. Continual increases in pumpage caused water levels to decline about 85 feet at Libertyville and about 60 feet at Mundelein. Water levels in dolomite wells are not yet at critical stages at Libertyville; pumping levels in sand and gravel wells at Mundelein, however, were below tops of screens in 1962. Available data indicate that the dolomite aquifer is capable of yielding more water than is being withdrawn at present.

Geography and Climate

The Libertyville area is rectangular in shape and includes about 260 square miles in central Lake County, as shown in figure 62. It is bounded on the east by Lake Michigan

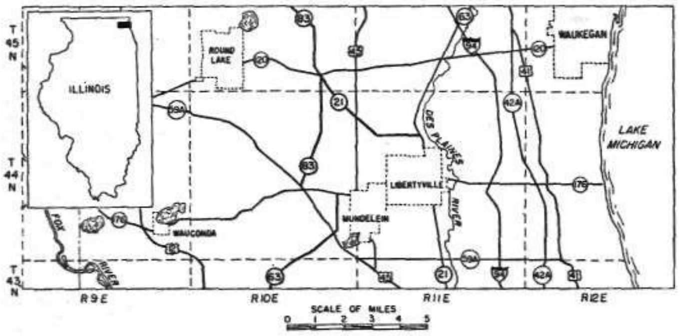

Figure 62. Location of Libertyville area

and on the west by the Fox River, and is between 42° 23' and 42° 13' north latitude, and between 88° 15' and 88° 50' west longitude.

Libertyville and Mundelein are in the eastern section of the area (T44N, R11E). State highways 63 and 176 and U.S. 45 pass through the cities as do several railroads.

The Libertyville area lies in the Central Lowland Physiographic Province. The land surface is characterized by hilly topography, broad parallel morainic ridges, lakes, and swamps. Drainage is mainly to the DesPlaines River and Lake Michigan in the eastern part of the area, and to the Fox River and several lakes in the west.

The elevation of the land surface declines from about 900 feet on a ridge 6 miles southwest of Libertyville to about 580 feet along the shore of Lake Michigan, and to about 730 feet in the valley of the Fox River. Maximum relief is about 320 feet.

Graphs of annual and mean monthly precipitation in the Libertyville area given in figures 63 and 64 were compiled from precipitation data collected by the U. S. Weather Bureau at Waukegan (1923-1961). According to these

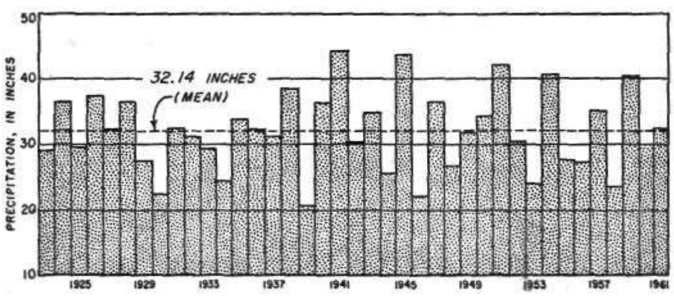

Figure 63. Annual precipitation at Waukegan

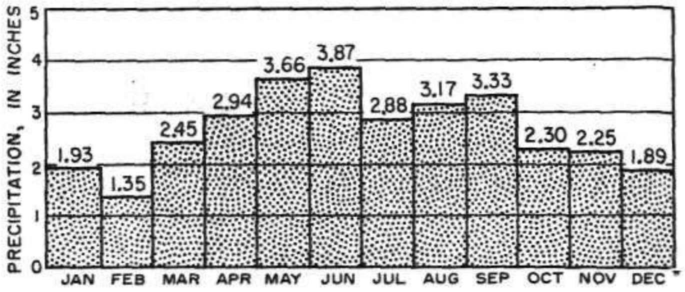

Figure 64. Mean monthly precipitation at Waukegan

records the mean annual precipitation is 32.14 inches. On" the average, the months of greatest precipitation are May, June, August, and September, each having more than 3.0 inches; February is the month of least precipitation, having less than 1.5 inches.

The annual maximum precipitation amounts occurring on an average of once in 5 and once in 50 years are 36 and 43 inches respectively; annual minimum amounts expected for the same intervals are 27 and 21 inches respectively. Amounts are based on data given in the Adas of Illinois Resources, Section 1 (1958).

The mean annual snowfall is 31 inches, and the area averages about 46 days with 1 inch or more and about 26 days with 3 inches or more of ground snow cover.

Based on records collected by the U. S. Weatiier Bureau at Waukegan, the mean annual temperature is 48.7° F. June, July, and August are the hottest months with mean temperatures of 67.3° F, 72.8° F, and 71.6° F respectively; January is the coldest month with a mean temperature of 24.8° F. The mean length of the growing season is 165 days.

Geology

For a detailed discussion of the geology in the Libertyville area the reader is referred to Suter et al. (1959) and Horberg (1950). The following section is based largely upon these two reports.

The Libertyville area is covered mostly with glacial drift which commonly exceeds 200 feet in thickness. The bedrock immediately underlying the glacial drift is mainly dolomite of the Niagaran Series of Silurian age. In the western part of the area the Niagaran Series has been removed by erosion, and dolomite of the Alexandrian Series of Silurian age is the uppermost bedrock. Immediately above the bedrock, the glacial drift contains a thick and fairly extensive deposit of sand and gravel which commonly exceeds 20 feet in thickness. The remainder of the glacial drift is mainly composed of clayey materials (confining bed) and commonly exceeds 175 feet in thickness. Lenses of sand and gravel are intercalated in the confining bed.

A contour map showing the topography of the bedrock surface is shown in figure 65. Features of the bedrock topography were previously discussed by Suter et al. (1959). A bedrock valley extends northeastward across the center

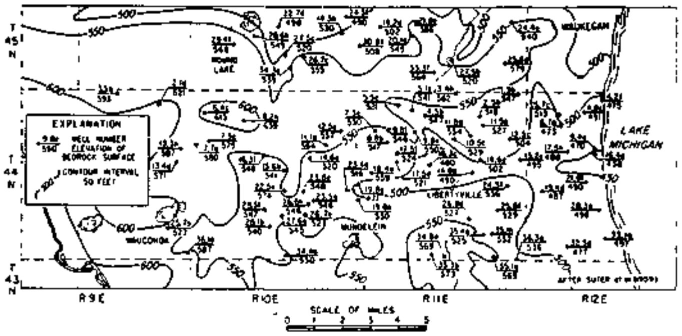

Figure 65. Bedrock topography of Libertyville area

of the Libertyville area. The channel of the bedrock valley exceeds a mile in width in most places, has walls of moderate relief, and averages about 50 feet in depth.

Except in the western part of the Libertyville area, the bedrock surface beneath the glacial drift is formed by rocks of the Niagaran Series as shown in figure 66. The

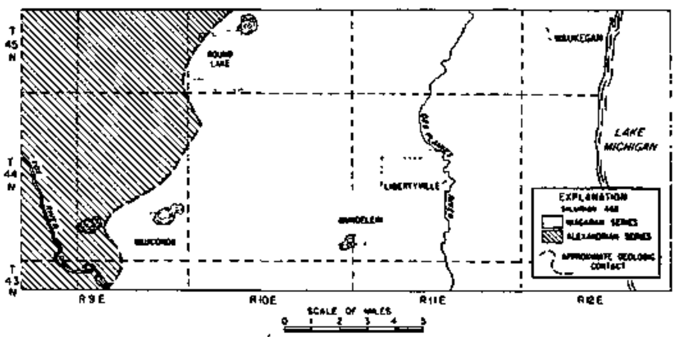

Figure 66. Bedrock geology of Libertyville area

Niagaran Series is composed chiefly of dolomite, although shaly dolomite beds occur at the base. The Niagaran Series in the Libertyville area is relatively more argillaceous than the same series in other parts of northeastern Illinois. The thickness of the Niagaran Series varies, but averages about 60 feet and generally increases from the Niagaran-Alexandrian contact toward the southeastern part of the Libertyville area. The Alexandrian Series is composed chiefly of dolomite; shale and argillaceous dolomite beds occur near the base. The thickness of the Alexandrian Series commonly exceeds 75 feet and averages about 90 feet.

A map showing the thickness of the Silurian rocks is given in figure 67. The diickness of the Silurian rocks in-

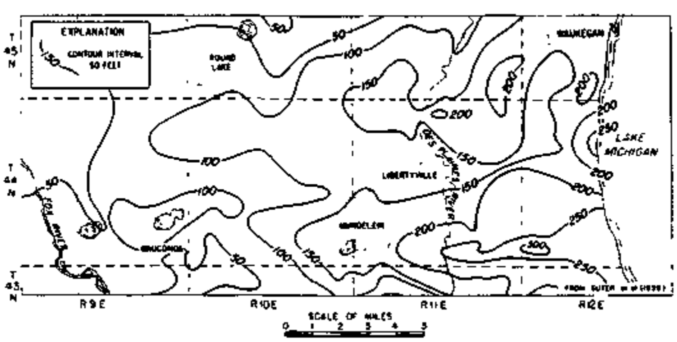

Figure 67. Thickness of Silurian rocks in libertyville area

creases from less than 50 feet in the western part to over 300 feet in the southeastern corner of the Libertyville area.

The cross section in figure 68 illustrates in general the nature of the unconsolidated deposits above bedrock. The

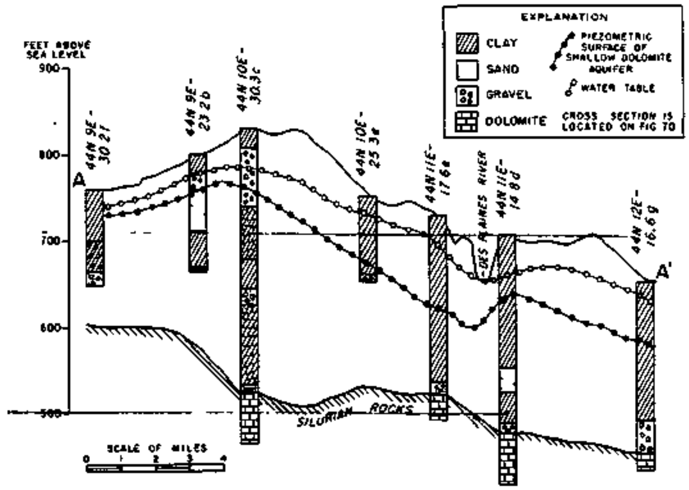

Figure 68. Cross section of glacial drift and piezometric profiles in Libertyville area

unconsolidated deposits are mainly glacial drift, and increase in thickness from less than 100 feet southeast of Libertyville to over 300 feet in the western part of the Libertyville area, as shown on figure 69. The glacial drift

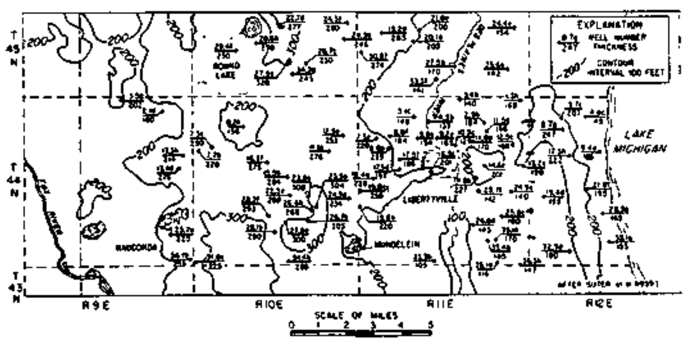

Figure 69. Thickness of unconsolidated deposits overlying bedrock in Libertyville area

consists largely of deposits of till that contain a high percentage of silt and clay.

Logs of wells show that permeable sand and gravel deposits are found in numerous zones within the glacial drift. Sand and gravel occur at the base of the glacial drift over most of the Libertyville area. The thickness of this zone is variable but averages 20 feet except in the vicinity of the channel of the buried bedrock valley near the center of the Libertyville area. Based on logs of a few wells which completely penetrate the glacial drift, the diickness of this basal sand and gravel deposit increases in the vicinity of the bedrock valley and commonly exceeds 40 feet. Geologic data suggest that the materials of the basal sand and gravel deposit may be predominandy fine-grained in the vicinity of the buried bedrock valley, a characteristic that would make development of high capacity wells diffi-

Table 16. Logs of Selected Wells and Test Holes in Libertyville Area

Well number	Formation	Thickness (ft)	Depth (ft)
LKE—			
43N11E–			
9.3f	clay	60	60
	sand and gravel, some clay	20	80
	clay	16	96
	sand and gravel	11	107
	clay	12	119
	rock	—	119
44N9E–			
14.4h	clay	116	116
	clay and boulders	10	126
	clay	74	200
	sand and gravel	15	310
23.2b	clay	22	22
	gravel	18	40
	gray sand	48	88
	clay	41	129
	sand and gravel	5	134
36.4d	drift	200	200
	gravel	27	227
	rock	—	227
44N10E–			
8.2g	clay	57	57
	sand	18	75
	clay	60	135
	gravel	21	156
	rock	—	262
17.4f	clay	23	23
	gravel	20	43
	clay	91	134
	gravel	10	144
25.3e	clay	90	90
	sand and gravel	7	97
30.3c	clay	26	26
	gravel	64	90
	quicksand	62	152
	clay	28	180
	sand and gravel	18	198
	clay and sand	90	288
	sand and gravel	10	298
	bedrock	—	358
44N11E–			
4.7f	clay	80	80
	sand	5	85
	clay	30	115
	gravel	16	131
	rock	—	143
9.8e	clay	60	60
	sand	30	90
	clay	60	150
	gravel	4	154
	rock	—	178
10.8h	clay	54	54
	sand	18	72
	hardpan	6	78
	sand	23	101
	hardpan	27	128
	gravel	2	130
	rock	—	141
11.8d	clay	130	130
	sand and gravel	40	170
	rock	—	200
14.8d	clay	150	150
	quicksand	30	180
	clay	36	216
	gravel	11	227
	rock	—	285
17.6e	clay	200	200
	gravel	14	214
	rock	—	235
24.5f	clay	35	35
	sand	20	55
	mud and gravel	10	65
	sand	10	75
	mud and gravel	20	95
	mud	15	110
	sand, mud and gravel	20	130
	gravel	12	142
	rock	—	—
25.8f	clay	155	155
	gravel	3	158
	rock	—	177
26.8d	clay	100	100
	gravel	45	145
	rock	—	165
32.7d	clay	185	185
	gravel and clay	5	190
	sand and gravel	2	192
35.4h	clay	120	120
	sand	65	185
	rock	—	1600
44N12E–			
7.4f	clay	140	140
	gritty sand	45	185
	gravel	2	187
16.6g	clay	160	160
	gravel	44	204
	rock	—	204
45N10E–			
26.3c	clay	226	226
	fine sand	3	229
	rock	—	233
30.1f	clay	160	160
	fine sand	50	210
	clay	10	220
	gravel	5	225
45N11E–			
21.8a	clay	140	140
	clay and sand	50	190
	gravel	10	200
	rock	—	204
26.2e	clay	74	74
	sandy clay	14	88
	clay	61	149
	clay and gravel	22	171
	sand and gravel	4	175
	rock	—	177
30.6e	clay	180	180
	quicksand	70	250
	gravel	15	265
	rock	—	285
MCH—			
44N9E–			
30.2f	clay	60	60
	clay and gravel	35	95
	gravel and sand	17	112

cult or impossible. Additional subsurface information is needed to determine the thickness and character of the glacial drift especially in the vicinity of the buried bedrock valley.

Relatively impermeable deposits (confining bed) consisting of sandy and silty clay and gravel overlies the basal sand and gravel deposits. The thickness of these clayey materials varies considerably but averages about 175 feet. Deposits of permeable sand and gravel of limited areal extent are interbedded in the confining bed. Many wells in the Libertyville area penetrate these interbedded sand and gravel aquifers and supply moderate quantities of water. Logs of wells and other geologic data suggest that interbedded sand and gravel aquifers are found at most places; however, extensive test drilling is needed in order to locate deposits large enough in areal extent to support heavy pumpage.

Drillers logs of selected wells and test holes for which geologic data are available are given in table 16. The locations of the wells and test holes are shown in figure 70.

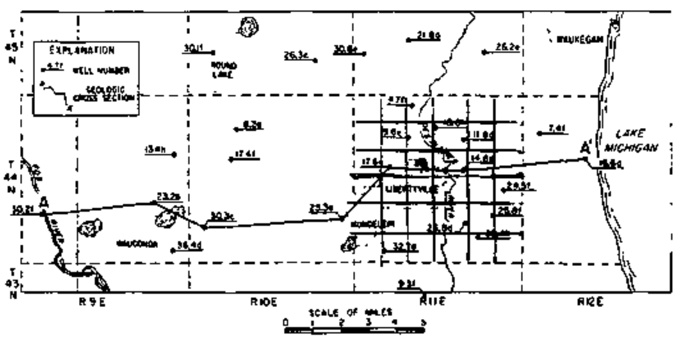

Figure 70. Location of selected wells and test holes in libertyville area

Occurrence of Ground *Water*

Ground water in the Silurian dolomite aquifer occurs in joints, fissures, fractures, solution cavities, and other openings. The water-yielding openings are irregularly distributed, both vertically and horizontally. The conformable piezometric surface and available geohydrologic data suggest that the dolomite aquifer is permeated by numerous openings which extend for considerable distances and are interconnected on an areal basis. The weathered zone of the upper part of the dolomite aquifer has a relatively high permeability; the Niagaran Series is generally more permeable than the Alexandrian Series. Suter et al. (1959) state that among the many factors that may be responsible for the inconsistent productivity of the Silurian dolomite aquifer are:

1. Differences in development of solution zones with respect to bedrock topography.
2. Differences in depth of ground-water circulation. For example, shallow impermeable shales in a given dolomite area may limit solution downcutting and promote extensive enlargement of channels in the soluble rock above.
3. Differences in permeability of the overlying drift.
4. Differences in solubility of the various dolomite units.

Leaky artesian conditions exist where till or other fine-grained deposits overlie the Silurian dolomite aquifer and impede or retard the vertical movement of ground water, thus confining the water in the Silurian dolomite aquifer under artesian pressure. Under leaky artesian conditions, water levels in wells rise above the top of the Silurian dolomite aquifer to stages within the fine-grained deposits.

Ground water in the glacial drift is obtained mainly from sand and gravel aquifers underlying or interbedded with glacial till. Because of their irregularity of occurrence, glacial drift aquifers are often more difficult to locate than bedrock aquifers. The difficulties are compensated for in part by lower costs of drilling and pumping, often by water that is cooler or of better quality, and at some places by greater yields. The ground water in the sand and gravel aquifers in the Libertyville area occurs under leaky artesian conditions.

Water-Yielding Properties of Aquifers

Silurian Dolomite Aquifer

During the period 1929-1961, well-production tests were made by water well contractors and the State Water Survey on more than 80 dolomite wells in and near the Libertyville area. The well-production tests consisted of pumping a well at a constant rate and frequently measuring the drawdown in the production well. Drawdowns were measured usually with an airline or electric dropline; rates of pumping were measured by means of a circular orifice at the end of the pump-discharge pipe.

The results of the tests are summarized in table 17. The lengths of tests range from 1 to 24 hours and average 8 hours. Pumping rates range from 10 to 740 gpm. Diameters of inner casings range from 4.5 to 12 inches and the average radius of inner casings averages about 1/3 foot.

Unfortunately, very few step-drawdown tests were made in the Libertyville area. Values of well loss were estimated for all wells based on the results of studies made on 40 step tests on dolomite wells in northeastern Illinois (Csallany and Walton, 1963). Well losses were subtracted from observed drawdowns, and specific capacities adjusted for well losses were computed.

Several values of t and r_w, and a coefficient of storage of 0.0003, were substituted into the nonequilibrium equation to determine the relationships between specific capacity and the coefficient of transmissibility for various values of r_w^2/t, and results are shown in figure 71. This graph, specific capacities adjusted for well losses, and data concerning the lengths of tests and radii of wells in table 17 were used to estimate theoretical coefficients of transmissibility of the Silurian dolomite aquifer in the vicinities of the

Table 17. Specific-Capacity Data for Dolomite Wells in Libertyville Area

Well number	Owner	Depth (ft)	Diam. (in)	Penetration (ft)	Year drilled	Year of test	Length of test (hr)	Non-pumping level (ft)	Pumping rate (gpm)	Drawdown (ft)	Unadjusted		Adjusted		Estimated coefficient of transmissibility (gpd/ft)
											specific capacity (gpm/ft)	specific capacity per foot of penetration (gpm/ft²)	specific capacity (gpm/ft)	specific capacity per foot of penetration (gpm/ft²)	
LKE—															
43N9E–															
13	E. Sayewski	247	4.5	100	1934	1934	5	75	16	20	0.81	0.008	0.83	0.008	1,500
13.6b	G. Greswell	252	6	40	1933	1933	24	50	30	80	0.38	0.009	0.41	0.010	900
22	I. Bates	207	6	39	——	——	—	38	50	7	7.15	0.183	7.60	0.195	13,000
25.3d	Valenti	310	10	71	1958	1958	7	112	740	3	247.00	3.480	426.00	6.000	1,000,000
25.7a	Elm Construction Co.	310	10	71	1958	1958	3	119	716	2	358.00	5.180	568.00	8.000	1,300,000
26.1e	M. McDoo	247	6	15	1937	1937	4	82	40	3	13.35	0.890	13.95	0.931	24,000
36.1h	Pure Oil, Barrington	305	10	85	1945	1945	12	84	665	9.5	70.00	0.825	137.00	1.620	310,000
43N10E–															
6.6a	Albani Real Est.	330	6	43	1956	1958	8	135	240	35	6.85	0.159	9.95	0.232	13,000
7	Wm. Rueffer	274	4.5	10	1941	1941	8	90	16	13	1.23	0.125	1.27	0.127	21,000
7.3h (3)	Mt. St. Joseph (V)	400	10	112	1949	1949	8	106	113	67	1.69	0.015	2.12	0.019	2,000
18.5c	C. E. Johnson	278	6	11	1941	1941	24	101	40	9	4.45	0.404	4.72	0.428	8,700
20.2e (3)	Lake Zurich (V)	443	6	143	1949	1949	1	40	135.5	3	13.31	0.093	13.92	0.098	23,000
20.6h (2)	Lake Zurich (V)	421	10	149	1951	1951	1.5	108	396	7	56.60	0.380	82.00	0.550	150,000
24.5e	G. Reed	197	6	30	1939	1939	2	45	10	20	0.50	0.017	0.51	0.017	700
25	C. H. Parson	192	6	17	1940	1941	14	33	40	15	2.67	0.057	2.86	0.170	5,000
25	L. Schaufler	211	6	17	1937	1937	4	46	40	14	2.86	0.163	3.06	0.180	5,500
26	R. L. Huszaah	202	6	9	1934	1944	—	8	35	14	2.50	0.278	2.65	0.295	4,100
28	Kopp Farm	350	6	81	1958	1958	5	110	100	2	50.00	0.617	55.50	0.685	120,000
43N11E–															
6.7g	Towner Sbd.	280	6	39	1957	1957	—	85	50	75	0.67	0.017	0.75	0.019	1,100
8.2f	Vernon Hills, Inc.	190	6	17	1961	1961	24	74	50	38	1.32	0.078	1.46	0.086	3,200
15.5f	J. D. Allen	162	6	44	1941	1941	16	38	15	7	2.14	0.049	2.20	0.050	4,100
35.3d	Wm. Johnson	350	—	230	1938	1957	24	53	236	44	5.36	0.023	7.94	0.035	13,000
35.6c	Chevy Chase CCb	280	—	160	1938	1958	24	53	236	44	5.37	0.034	8.33	0.052	14,000
43N12E–															
19.1c	W. Wecker	228	6	18	1935	1935	8	68	25	32	0.78	0.043	0.82	0.045	1,400
19.1h	H. E. LeRoy	275	6	81	1940	1940	10	30	75	10	7.50	0.093	8.27	0.012	16,000
31.6f	Ill. Toll Hwy. Comm.	330	6	115	1958	1958	21	63	30	3	10.00	0.087	10.23	0.090	20,000
44N9E–															
21.6b	Island Lake (V)	182	4.5	20	1940	1940	8	50	20	50	0.40	0.020	0.42	0.021	900
26.1c1 (1)	Wauconda (V)	231	8	13	1939	1939	8	39	210	20	10.50	0.807	13.85	1.065	27,000
26.1c2 (2)	Wauconda (V)	257	12	31	1939	1939	8	36	318	44	7.23	0.233	11.20	0.362	20,000
26.3b (3)	Wauconda (V)	325	12	32	1957	1957	8	25	287	155	1.85	0.058	4.00	0.125	5,500
44N10E–															
24.3d2	Mundelein (V)	270	6	37	1954	1954	—	64	183	13	14.05	0.380	17.45	0.474	32,000
24.3d	A. T. McIntosh & Co	264	12	31	——	——	—	80	350	143	2.45	0.079	5.80	0.187	10,000
24.3e1	Loch Lomond Sbd.	358	8	91	1953	1953	—	71	60	10	6.00	0.066	6.70	0.074	11,000
24.3e2	A. T. McIntosh & Co.	270	6	39	1954	1954	—	64	183	13.5	13.60	0.348	13.90	0.357	24,000
30.3c	M. J. Boyle	358	12	60	1944	1944	8	—	330	20	16.50	0.276	25.50	0.425	47,000
32.6c	Wm. M. Paris	351	6	5	1942	1942	8	135	25	2	12.50	2.500	12.90	2.580	24,000
44N11E–															
8 (1)	Leesley Nursery	252	8	81	——	1929	9	20	60	19	3.16	0.039	3.48	0.043	6,000
8	Leesley Nursery	255	8	90	1956	1959	—	40	100	70	1.43	0.016	1.75	0.019	2,600
9.2d	E. J. Burns (Sbd.)	168	12	46	1954	1954	—	14	115	75	1.53	0.033	1.80	0.039	2,600
10.3b	B. Cooper	242	6	79	1959	1959	24	47	125	93	1.35	0.017	1.75	0.022	
11.4b	E. P. Doerr	260	6	50	1959	1959	8	77	226	36	6.27	0.125	8.89	0.177	17,000
14.7c	Casey	342	6	104	1941	1941	4	60	35	80	0.44	0.004	0.49	0.005	1,000
14.8d	Farm	301	6	74	1940	1940	4	67	30	28	1.07	0.014	1.14	0.015	2,000
16.1b1 (6)	Libertyville (V)	297	6	99	1955	1958	8	53	200	24	8.34	0.086	11.00	0.131	25,000
16.1b2 (7)	Libertyville (V)	300	6	102	1955	1955	6	33	630	152	4.15	0.041	5.25	0.052	8,700
16.2c (1)	Libertyville (V)	251	—	64	1929	1958	—	96	300	57	5.26	0.082	8.92	0.140	15,000
16.3c (8)	Libertyville (V)	320	8	120	1961	1961	8	95	247	40	6.20	0.052	8.00	0.067	15,000
16.3c4 (4)	Libertyville (V)	240	8	40	1921	——	5	—	70	35	2.00	0.050	2.28	0.057	3,500
16.3e1 (3)	Libertyville (V)	287	12	115	1947	1947	3	15	330	37	8.90	0.078	14.90	0.130	24,000
16.3e2 (4)	Libertyville (V)	286	6	129	1946	1958	—	20	150	14	10.70	0.083	12.85	0.100	20,000
16.4d (5)	Libertyville (V)	227	12	71	1951	1951	1.8	39	305	13	23.60	0.332	33.30	0.470	55,000
19.8a2 (2)	Mundelein (V)	285	12	46	1930	1930	—	64	120	57	2.11	0.046	2.64	0.057	4,100
19.2a (3)	Mundelein (V)	213	10	1	1946	1946	6	90	125	60	2.08	2.080	2.63	2.630	4,000
28.2f (3)	I. Florsheim	178	10	9	1935	1935	24	37	100	27	3.71	0.412	4.35	0.483	8,000
31.5e	E. J. & E. RR	215	5	25	1959	1961	3	73	55	34	1.62	0.065	1.80	0.072	3,000
32.2a	Cuneo, Inc.	231	6	51	1954	1954	—	50	50	140	0.36	0.007	0.46	0.009	600
32.2a	Cuneo, Inc.	231	6	51	1954	1954	—	50	130	128	1.02	0.020	1.38	0.027	2,000
36.3d	A. A. Gilchrist	222	4.5	17	1941	1941	4	50	10	4	2.50	0.147	2.54	0.150	4,500
44N12E–															
6	Abbott Lab	270	8	113	1952	1952	—	44	30	88	0.34	0.003	0.37	0.003	500
9 (1)	Great Lakes Hosp.	200	—	20	——	——	9	25	110	35	3.15	0.158	3.78	0.189	6,000
16	T. H. Donnelly	201	8	12	1936	1936	10	40	55	55	1.00	0.083	1.12	0.093	3,500
21	C. Olmstead	295	8	125	1937	1937	3	55	25	120	0.21	——	0.23	0.002	400
45N9E–															
1.1a	Fox Lane Hills Sbd.	383	—	111	1954	1954	—	60	30	140	0.21	0.002	0.24	0.002	300
23 (2)	Wooster Lake Co.	200	—	8	——	1932	1	30	70	2	35.00	4.370	37.20	4.650	70,000
23.3c	E. Ross	265	6	65	1947	1947	—	40	40	10	4.00	0.062	4.20	0.065	6,800
45N10E–															
12	A. Hallman	235	4.5	9	1939	1939	6	45	10	10	1.00	0.112	1.02	0.114	1,700
12.2e (1)	L. Hennier	265	4	15	1951	1951	—	60	10	5	2.00	0.199	7.20	0.248	12,000
16	Shorewood Ridge Water Co	314	6	81	1952	1952	—	45	200	81	2.47	0.031	3.66	0.045	6,000
16.4a	L. B. Harris	278	6	40	1952	1952	—	45	128	20	6.40	0.160	7.70	0.193	13,000
16.5a (1)	Shorewood Ridge Water Co.	342	12	54	1947	1948	23	41	100	158	0.63	0.012	0.79	0.015	1,300
19.1a	Public Service Co. of N. Ill.	267	—	57	1953	1953	—	35	25	27	0.93	0.016	1.11	0.020	1,200
28.6h (3)	Round Lake Park	313	10	53	1944	1944	8	46	100	74	1.35	0.025	1.67	0.032	2,800
27.5c	Grays Lake (V)	337	12	87	1958	1958	8	80	442	145	3.05	0.035	9.82	0.113	17,000
28.6h1 (1)	Boysen Water Co.	279	6	29	1939	1939	6	46	150	26	5.78	0.199	7.20	0.248	15,000
28.6h2 (3)	Boysen Water Co.	313	10	53	1944	1944	8	46	100	54	1.85	0.035	2.25	0.043	5,000
29.4f (1)	Round Lake (V)	350	6	120	1914	1945	1.5	40	175	10	17.50	0.146	21.00	0.175	40,000
29.5h (2)	Round Lake (V)	359	10	133	1945	1945	7.5	51	288	107	2.66	0.020	5.10	0.038	10,000
45N11E–															
2.1b (2)	Waukegan C'tryside Sbd.	285	6	75	1957	1957	—	25	22	175	0.13	0.002	0.14	0.002	200
MCH—															
44N9E–															
20.2f	Island Lake (V)	190	4.5	20	1941	1941	8	70	10	40	0.25	0.012	0.26	0.013	500

test sites. Specific capacities adjusted for well losses were then further adjusted to a common radius and pumping period, based on estimated coefficients of transmissibility and the graphs in figure 71. The average radius (4 inches) and pumping period (8 hours) based on data in table 17 were used as the bases (see base line in figure 71).

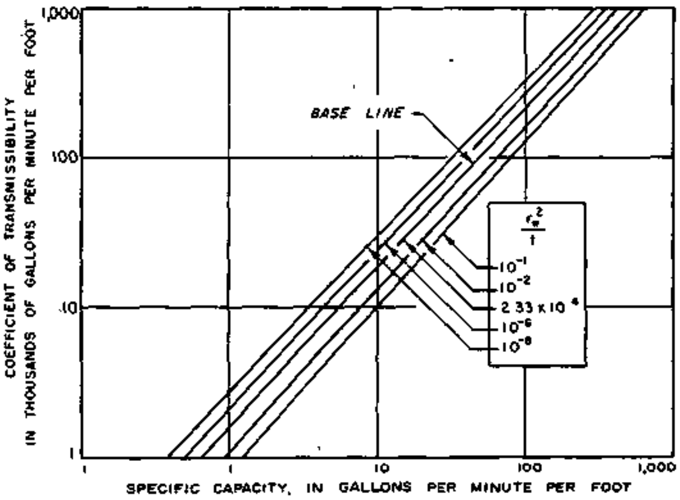

Figure 71. Coefficient of transmissibility versus specific capacity for several values of well radius and pumping period

No great accuracy is inferred for the adjusted specific capacities or computed coefficients of transmissibility because they are based on estimated well-loss constants; however, they come much closer to describing the relative yields of wells than do the observed specific capacities based on pumping rates, pumping periods, and radii which vary from well to well. Based on the average adjusted specific capacity in table 17, the coefficient of transmissibility of the Silurian dolomite aquifer averages about 10,000 gpd/ft in the Libertyville area.

In general, the specific capacity of a dolomite well increases with the depth of penetration; the upper part of the Silurian dolomite aquifer is usually the most productive, however. The total depths of penetration of wells into dolomite were determined from well logs and sample studies of drill cuttings, and are given in table 17. Adjusted specific capacities were divided by the total depths of penetration to obtain the adjusted specific capacities per foot of penetration in table 17.

Wells were divided into two categories, those which penetrate less than 33 percent of the Silurian age rocks and those which penetrate more than 33 percent of the Silurian age rocks. Adjusted specific capacities per foot of penetration for wells in the two categories were tabulated in order of magnitude, and frequencies were computed by the Kimball (1946) method. Values of specific capacity per foot of penetration were then plotted against percent of wells on logarithmic probability paper as shown in figure 72.

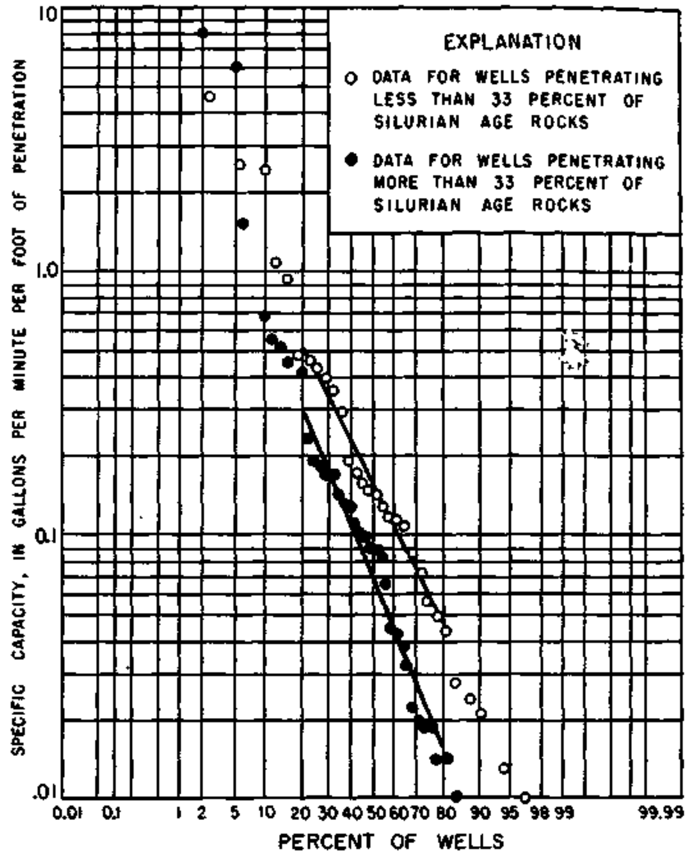

Figure 72. Specific-capacity frequency graphs for dolomite wells in libertyville area

Specific capacities per foot of penetration decrease as depths of wells increase, indicating that the upper part of the Silurian dolomite aquifer is more productive than the lower part.

Glacial Drift Aquifers

Numerous rural and residential water supplies, but only a few municipal, commercial, and industrial supplies, are obtained from glacial drift aquifers. The largest development of sand and gravel aquifers is at Mundelein, and the village has one sand and gravel well that is capable of producing 750 gpm. Data for municipal and industrial wells obtaining water from glacial drift aquifers in the Libertyville area are given in table 18. This tabulation indicates that the specific capacity of sand and gravel wells ranges from 1.0 to 47.4 gpm/ft and averages about 14 gpm/ft. The average depth and diameter of wells are 140 feet and 10 inches, respectively, and the average thickness of the aquifer at well sites is 40 feet. Of the 33 wells listed only two were not equipped with screens. The average length of screen used in the 31 screened wells is 15 feet. Specific-capacity data in table 18 indicate that the coefficient of transmissibility of the sand and gravel aquifers in the Libertyville area ranges between 2000 and 90,000 gpd/ft and averages 25,000 gpd/ft.

Table 18. Specific-Capacity Data for Wells in Glacial Drift Aquifers in Libertyville Area

Well number	Owner	Depth (ft)	Diam. (in)	Screen length (ft)	Screen diam. (in)	Thickness of aquifer (ft)	Date of test	Non-pumping level (ft)	Pumping rate (gpm)	Draw-down (ft)	Specific capacity (gpm/ft)
LKE—											
43N9E–											
36.3f	Jewel Tea Co.	163	30	30	—	—	1953	78	520	14	37.1
36.6e	Kendall Co.	112	12	15	12	14	1962	81	343	16.5	20.8
43N10E–											
20.6h	Lake Zurich (V)	214	10	no screen		—	1921	95	100	20	5.0
24.1a	Twin Orchard CCb.	136.5	10	15	10	17	1958	18	644	50	12.9
43N11E–											
15.2c	Do-Mor Day Camp	55	6	30	6	33	1961	9	44	8	5.5
19.8h	G. W. Traer	190	12	17	12	90	1948	42	127	13	9.8
44N9E–											
21.8b	Island Lake Water Co.	116	10	24	10	—	1946	29	425	11	38.5
21.7f	Island Lake Water Co.	95	8	11	8	—	1960	16	360	21	17.1
44N10E–											
24.3g	Mundelein (V)	140	12	24	12	30	1954	69	800	21	38.1
24.1g	Mundelein (V)	165	20	20	20	15	1959	104	1000	44	23.0
44N11E–											
10.5c	Green Valley Bldrs.	36	5	4	5	12	1958	19	80	9.5	8.4
11.5d	Oak Grove Schl.	99	6	—	—	26	1957	45	25	6	4.2
16.1a	Foulds Milling	202	8	14	8	190	1945	7	275	84.5	3.3
19.3b	Mundelein (V)	106	12	20	20	—	1955	56	500	19	26.3
21.7f	Libertyville (V)	83	—	30	—	30	1935	28	380	14	27.1
22.4d	M. Dall	34	6	6	6	15	1941	7	75	8	9.4
30.6c1	Mundelein (V)	200	6	8	6	—	1949	47	103	45	2.3
30.6c2	Mundelein (V)	194	8	20	8	24	1951	50	138	105	1.3
45N9E–											
1.2h	Fox Lake Hills Sbd.	130	8	15	8	15	1954	16	290	76	3.8
1.4a	Fox Lake Hills Sbd.	126	10	10	10	—	1954	38	600	30	20.0
9.1g	Fox Lake (V)	135	16	16	15	45	1941	36	284	4	75.8
15.5c1	Hilldale Manor Sbd.	123	6	15	6	—	1954	67	253	20	12.7
15.5c2	Hilldale Manor Sbd.	123	8	16.75	8	—	1954	72	281	17	16.5
45N10E–											
2.7h	Lindenhurst (V)	165	8	16	8	16	1961	52	300	36	8.4
17.7h	Round Lk. Beach (V)	174	12	20	12	21	1948	49	500	52	9.6
18.2f	Round Lk. Beach (V)	215	8	6	8	16	1947	50	75	75	1.0
21.5h	Shorewood Sbd.	253	4.5	no screen		73	1942	30	10	10	1.0
45N11E–											
7.6b	Hoag Farm	145	12	25	12	110	1949	31.5	289	77	3.8
31.5h	Wildwood Sbd.	145	6	12	6	12	1950	95	53	23	1.9
31.4h	Wildwood Sbd.	173	6	14	6	—	1952	108	201	6	33.5
33.8h	B. K. Evans	151	8	4	6	5	1940	65	100	10	10.0
MCH—											
44N9E–											
20.2f	Island Lake Water Co.	122	8	10	8	107	1954	24	75	50	1.5

Probable Yields of Dolomite Wells

Because the productivity of the Silurian dolomite aquifer is inconsistent, it is impossible to predict with a high degree of accuracy the yield of a well before drilling at any location. Probable range of yields of wells can be estimated from the frequency graphs in figure 72 and data on the thickness of the Silurian dolomite aquifer. Probable specific capacities of wells in figure 73 were estimated as the product of the specific capacity per foot of penetration measured in 50 percent of the existing wells (see figure 72) and aquifer thickness (see figure 67). Specific capacities equal to or less than 10 gpm/ft can be expected in large areas in the western part of the Libertyville area where the thickness of the Silurian dolomite aquifer is less than 150 feet. Specific capacities equal to or less than 15 gpm/ft can be expected in areas in the eastern part of the Libertyville area where the thickness of the dolomite of Silurian age commonly exceeds 150 feet.

Probable specific capacities were in turn multiplied by available drawdowns based on water-level data (see figure

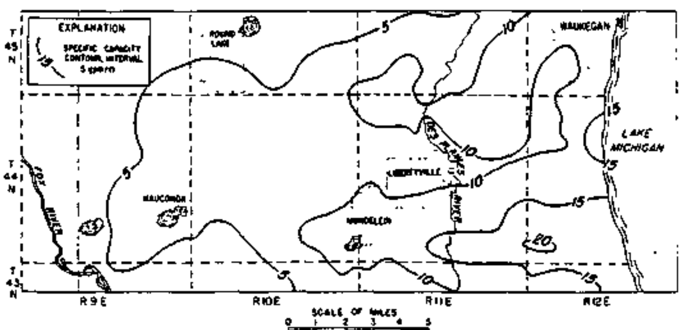

Figure 73. Estimated specific capacities of wells in Silurian dolomite aquifer in libertyville area

85) to estimate the probable yields of wells. Nonpumping levels were limited to the top of the Silurian dolomite aquifer.

The probable range of yields of dolomite wells is shown in figure 74. It is possible to drill what is essentially a dry

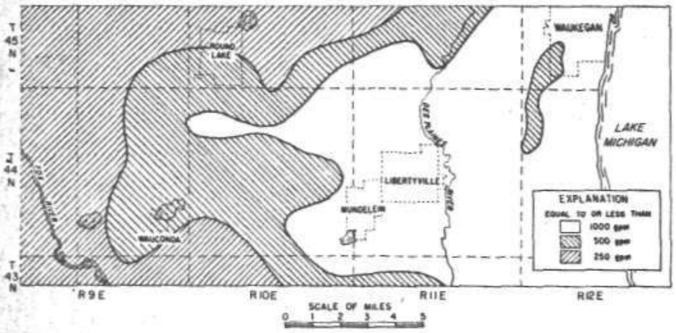

Figure 74. Estimated yields of wells in Silurian dolomite aquifer in Libertyville area

hole at any location. Based on data for 50 percent of existing wells, however, the chances of obtaining a well with a yield of 500 gpm or more are good except in the western part of the Libertyville area where the Silurian rocks are thin. Thus, the yield of the Silurian dolomite aquifer is probably high enough to support heavy industrial or municipal well development in all but a small part of the Libertyville area.

For design purposes, the reader may wish to base the computation of the probable yield of a well on a specific capacity with a particular frequency other than 50 percent. In this event the probable yield indicated in figure 74 is multiplied by the ratio of the specific capacity with the selected frequency (see figure 72) and the specific capacity with a 50 percent frequency.

Construction Features of Wells and Pumps

The production wells located at Libertyville and Mundelein serve as examples of the usual type of well installations

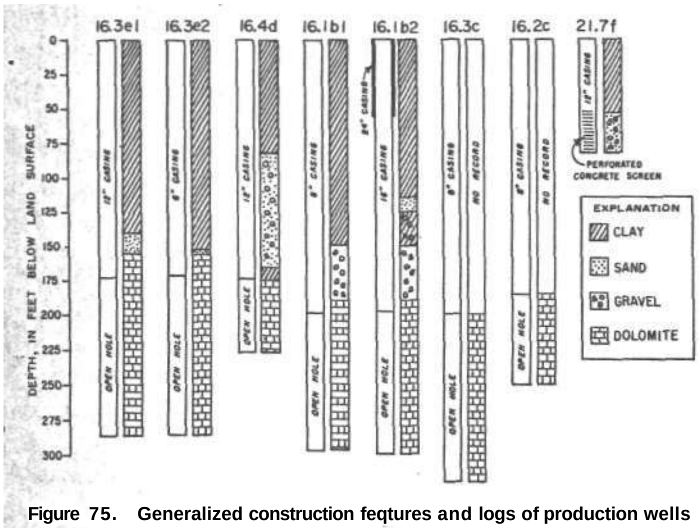

Figure 75. Generalized construction feqtures and logs of production wells at Libertyville

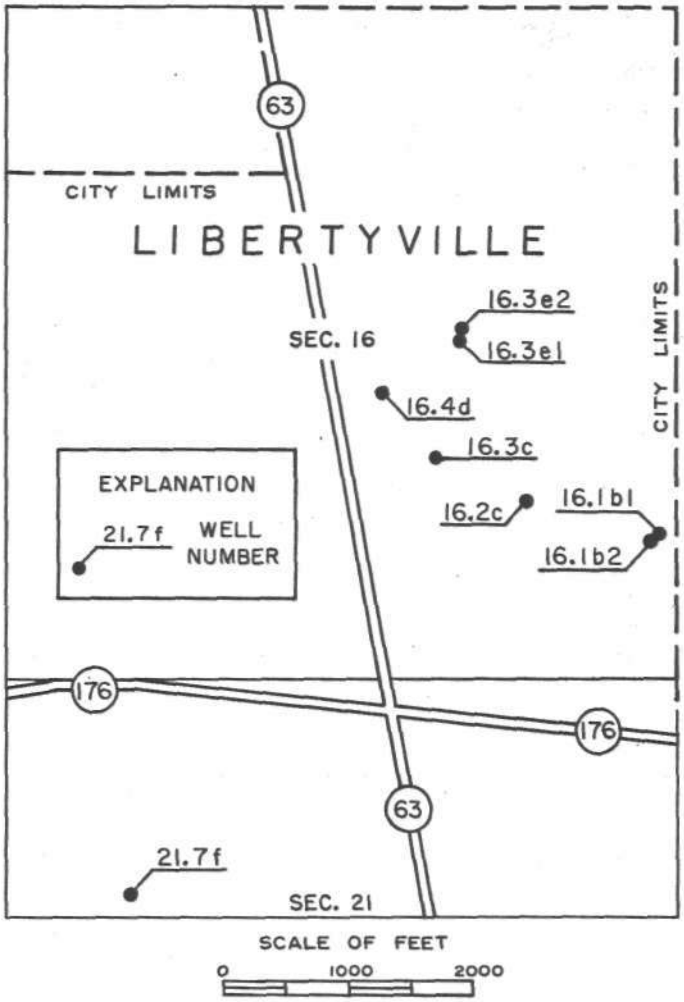

Figure 76. Location of production wells at Libertyville

found in the Libertyville area and are described in detail below. The construction features of the eight existing production wells at Libertyville are illustrated in figure 75; locations of the wells are shown in figure 76. Dolomite

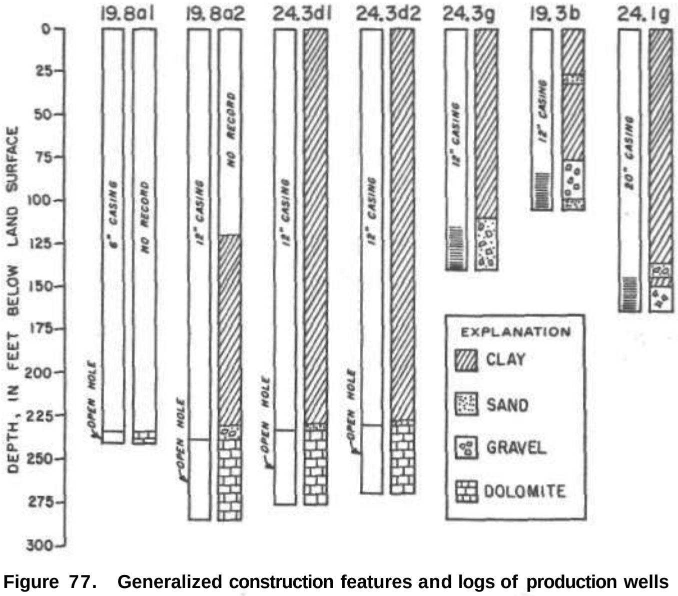

Figure 77. Generalized construction features and logs of production wells at Mundelein

[illegible] Silurian rocks.

The construction features of the Mundelein wells are shown" in figure 77; the locations of these production wells are shown in figure 78. The four wells penetrating the

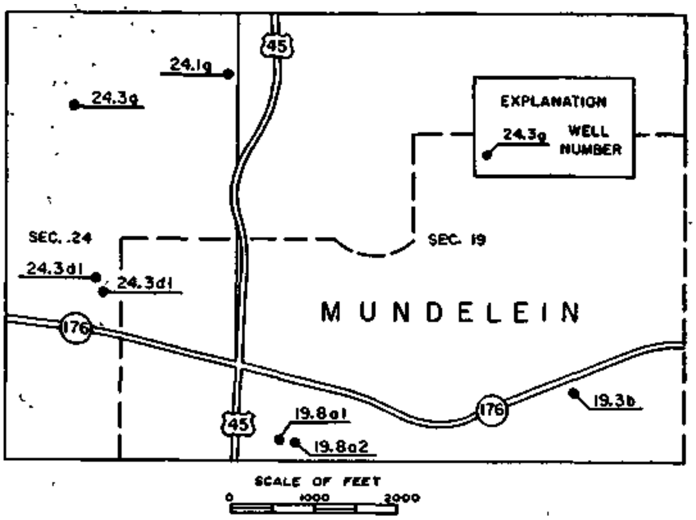

figure 78. location of production wells at Mundelein

Silurian dolomite aquifer at Mundelein range in depth from 241 to 285 feet and penetrate only the upper part of the Silurian rocks. The three sand and gravel wells are natural pack wells and range in depth from 106 to 165 feet. No data are available on the slot size of screen openings.

Pumps in wells in the Silurian dolomite aquifer at Libertyville and Mundelein are powered by 7.5 to 75 horsepower electric motors. The number of bowl stages ranges from 4 to 25. Column pipes have lengths ranging from 100 to 260 feet and. diameters ranging from 4 to 8 inches. Details on pump installations at Libertyville and Mundelein are given in table 19.

Table 19. Description of Pumps in Wells at Libertyville and Mundelein

Well number	Pump rating capacity/head (gpm) / (ft)	Number of stages	Column pipe length (ft)	Column pipe diam. (in)	Motor horsepower
LKE—					
44N10E-					
24. 1g	700/468	9	141	10	125
24.3dl	280/350	11	220	6	40
24.3d2	100/217	22	170	4	15
24.3g	700/250	5	111	8	50
44N11E-					
16.1bl	200/380	4	220	4	30
16.1b2	700/290	6	260	8	75
16.2c	300/230	8	200	6	25
16.3c	240/139	—	—	—	25
16.3el	325/200	12	100	6	20
16.3e2	150/241	23	130	4	15
16.4d	500/225	6	140	8	40
19.3b	500/217	6	80	8	40
19.8al	70/270	25	150	4	7.5
19.8a2	190/280	12	175	8	30
21.7f	400/190	9	73	7	30

[illegible]

[illegible] in figure 79. Data in table 20 indicate that of the total

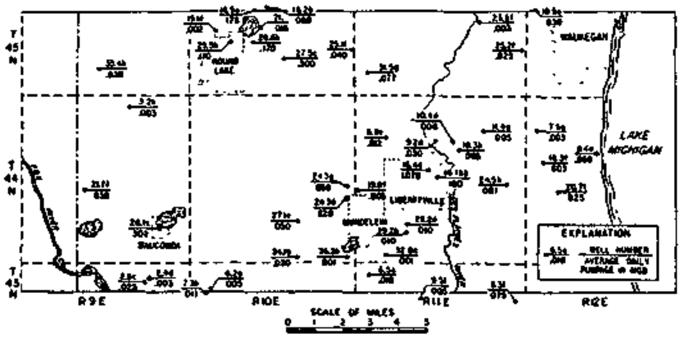

figure 79. Distribution of pumpage from shallow aquifers in libertyville area, 1962

water pumped from wells in 1962, 63 percent was derived from the Silurian dolomite aquifer and 37 percent from glacial drift aquifers. In 1962 withdrawals for public water-supply systems amounted to 41 percent of the total pumpage; industrial pumpage was 12 percent of the total; and domestic pumpage was about 47 percent of the total.

Table 20. Distribution of Pumpage from Wells in Libertyville Area, Subdivided by Source and Use, 1962

Use	Pumpage from glacial drift aquifers (mgd)	Pumpage from Silurian dolomite aquifer (mgd)	Total pumpage (mgd)
Public	1.069	2.580	3.649
Industrial	.829	.203	1.032
Domestic	1.410	2.830	4.240
Total	3.308	5.613	8.921

Public use data are. classified in this report according to three main categories: 1) *public,* including municipal, subdivisions, and institutional; 2) *industrial,* including commercial, industrial, golf courses, irrigation, and cemeteries; and 3) *domestic,* including rural farm and rural nonfarm.

Most water-supply systems furnish water for several types of use. For example, a public supply commonly includes water used for drinking and other domestic uses, manufacturing processes, and lawn sprinkling. Industrial supplies may also be used in part for drinking and other domestic uses. No attempt has been made to determine the final use of water within categories. Any water pumped by a municipality is called a public supply, regardless of its use.

The reliability of pumpage data varies greatly. Municipal pumpage is nearly always metered in cities and large villages, but many small villages and subdivisions operate without meters. Only a few of the larger industries meter their supplies. Pumpage data for municipalities and some of the larger industries are systematically recorded. Pumpage from farm wells and individual residential wells is estimated on the basis of detailed use surveys. For these

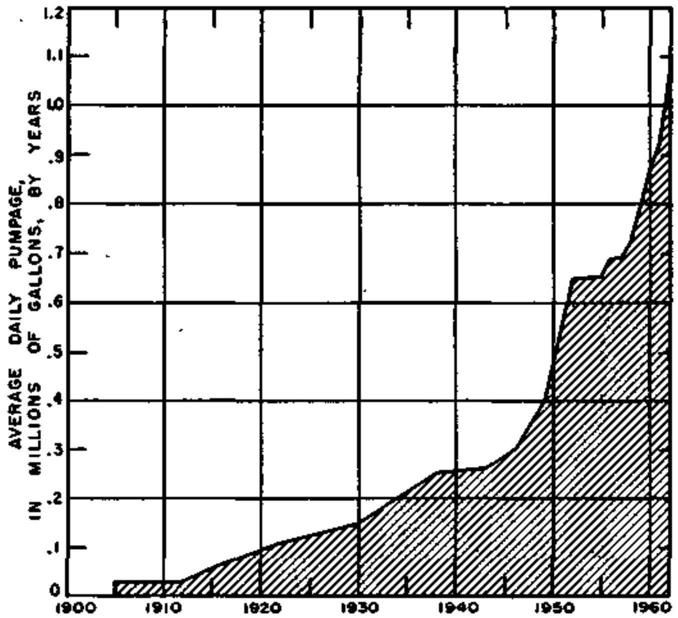

Figure 80. Estimated ground-water pumpage at Libertyville, 1905-1962

reasons it is often difficult to estimate pumpage precisely.

The village limits of Libertyville and Mundelein and immediately surrounding areas constitute the areas of greatest ground-water withdrawals in the Libertyville area. Pumpage data show that the municipal use of water was about the same (1 mgd) in Libertyville and Mundelein in 1962.

Pumpage at Libertyville has grown at an accelerating rate since the original installation of a water supply system in 1905. The pumpage in 1905 was about 30,000 gpd and increased to about 290,000 gpd in 1945 at an annual rate of increase of 6500 gpd/yr. This rate increased to 47,000 gpd/yr after 1945 and in 1962 the daily pumpage amounted to 1,070,000 gpd (see figure 80).

Prior to 1936 the majority of the water pumped at Libertyville was from glacial drift aquifers. After 1936 when sand and gravel wells were abandoned, the municipal water supply was obtained from dolomite wells.

Mundelein installed a water supply in 1915 when the demand was almost 20,000 gpd. Pumpage increased to about 200,000 gpd in 1950, having grown at a rate of 5000 gpd/yr. After 1950 pumpage greatly accelerated, reaching 1,070,000 gpd by 1962 (see figure 81). During the period 1950 to 1962 the annual increase in pumpage exceeded 72,000 gpd/yr. This rapid increase may in part be explained by the addition of the Loch Lomond Subdivision to the municipal water supply system; Mundelein purchased the wells and distribution system of the subdivision in 1956.

Prior to 1954, all water supplied to Mundelein consumers was obtained from wells penetrating the Silurian dolomite aquifer. During the period 1954-1957, pumpage from sand and gravel wells gradually increased in glacial drift aquifers as shown in figure 82. In 1957, 66 percent of the water was obtained from glacial drift aquifers and 34 percent from the Silurian dolomite aquifer. In 1962, 20 percent or 220,000 gpd was derived from the Silurian dolomite

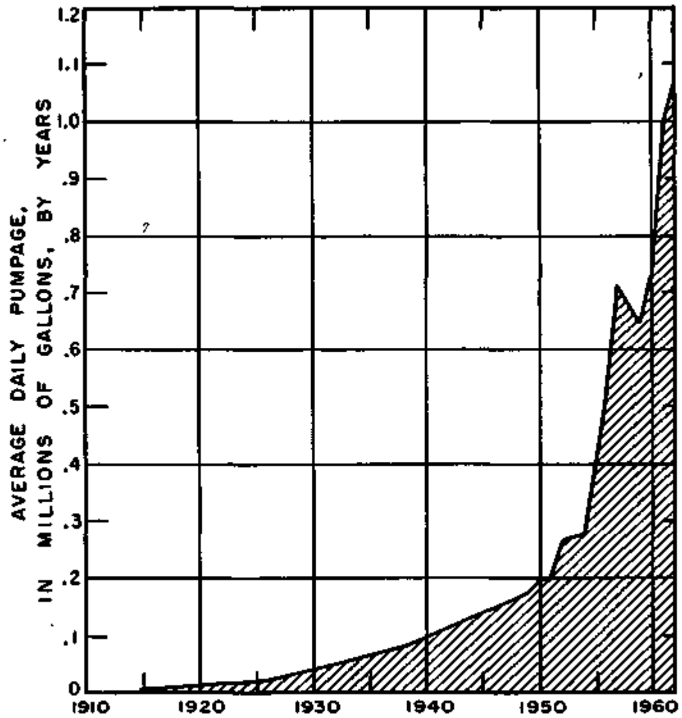

figure 81. Total ground-water pumpage from aquifers at Mundelein, 1915-1962

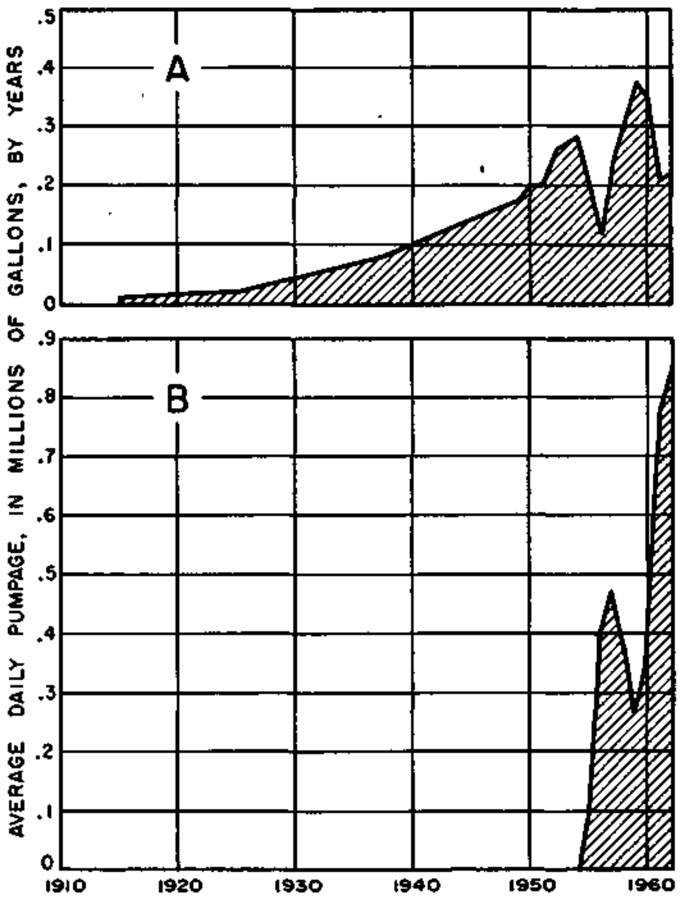

Figure 82. Ground-watsr pumpage from Silurian dolomite aquifer (A) and from sand and gravsl aquifers (B) at Mundelein, 1915-1961

aquifer and 80 percent or 850,000 gpd from glacial drift aquifers.

Leakage through *Maquoketa Formation*

In many instances pumpage is not the only withdrawal from the dolomite aquifer. In the Libertyville area a vertical hydraulic gradient prevails which allows the downward movement of water through the Maquoketa Formation. The Maquoketa Formation of Ordovician age is largely shale and is the confining bed between shallow aquifers and the heavily pumped Cambrian-Ordovician Aquifer in northeastern Illinois. In 1962 the piezometric surface of the Cambrian-Ordovician Aquifer was, on the average, 200 feet below the water table in the Libertyville [illegible] through the Maquoketa Formation was appreciable under the influence of large differentials in head between shallow deposits and the Cambrian-Ordovician Aquifer. The quantity of leakage through the Maquoketa Formation can be computed from the following form of Darcy's law:

$$Q_c = (P'/m')\Delta h\, A_c \qquad (13)$$

where:

Q_c = leakage through Maquoketa Formation, in gpd

P' = vertical permeability of Maquoketa Formation, in gpd/sq ft

m' = saturated thickness of Maquoketa Formation, in ft

A_c = area of Maquoketa Formation through which leakage occurs, in sq ft

Δh = difference between the head in the Cambrian-Ordovician Aquifer and the head in shallow deposits, in ft

Based on data given by Walton (1960), the average vertical permeability of the Maquoketa Formation in the Libertyville area is estimated to be about 0.00005 gpd/sq ft. The area of Maquoketa Formation tiirough which leakage occurs is about 260 square miles. The average Δh was determined to be about 200 feet; the average thickness of the Maquoketa Formation is about 200 feet. Substitution of these data into equation 13 indicates that the leakage tiirough the Maquoketa Formation with the Libertyville area was about 0.37 mgd in 1962.

Fluctuations of Water Levels and Their Significance

Water-level measurements were made infrequently in several wells in the Libertyville area between 1917 and 1962. Changes in water levels shown in figure 83 are indicative of conditions in general at Libertyville. It should be emphasized that water levels in figure 83 are nonpumping levels.

The average elevation of the piezometric surface at Libertyville in 1917 was probably about 675 feet, and flow-

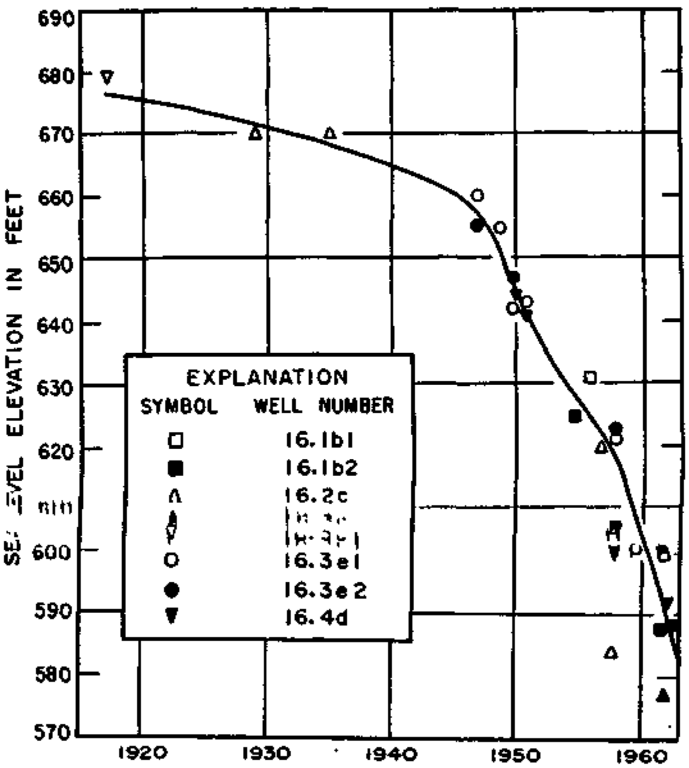

figure 83. Water levels in walls at Libertyville, 1917-1962

ing wells existed in the vicinity. By 1950 water levels had declined in response to continual withdrawals of water to an average elevation of 645 feet. Thus, in a period of 33 years, water levels declined 30 feet or at an average rate of about 0.9 foot per year. As the result of continual increases in pumpage, water levels declined from an average elevation of 645 feet in 1950 to an average elevation of 590 feet in 1962. The average rate and total decline of water levels, 1950 tiirough 1962, were 4.6 feet per year and 55 feet, respectively.

A comparison of the water-level hydrograph shown in figure 83 and the pumpage graph shown in figure 80 indicates tiiat in general water-level decline has been proportional to the rate of pumpage. Average water-level declines in wells plotted against corresponding average rates of pumpage at Libertyville are shown in figure 84. The consistent relationship between decline and pumpage is apparent. Approximately 12,000 gpd were obtained with each foot of decline. The consistent relationship between decline and pumpage indicates that in the past recharge has balanced discharge. If pumpage is kept constant, water levels decline at a decreasing rate with time and eventually stabilize at a stage lower than that measured prior to pumping. Water levels do not stabilize but continue to decline if pumpage constantly increases. Pumpage in the past at Libertyville has not remained constant but has increased almost without interruption, as shown in figure 80; as a result, water levels have never stabilized but have declined continuously throughout the period of development.

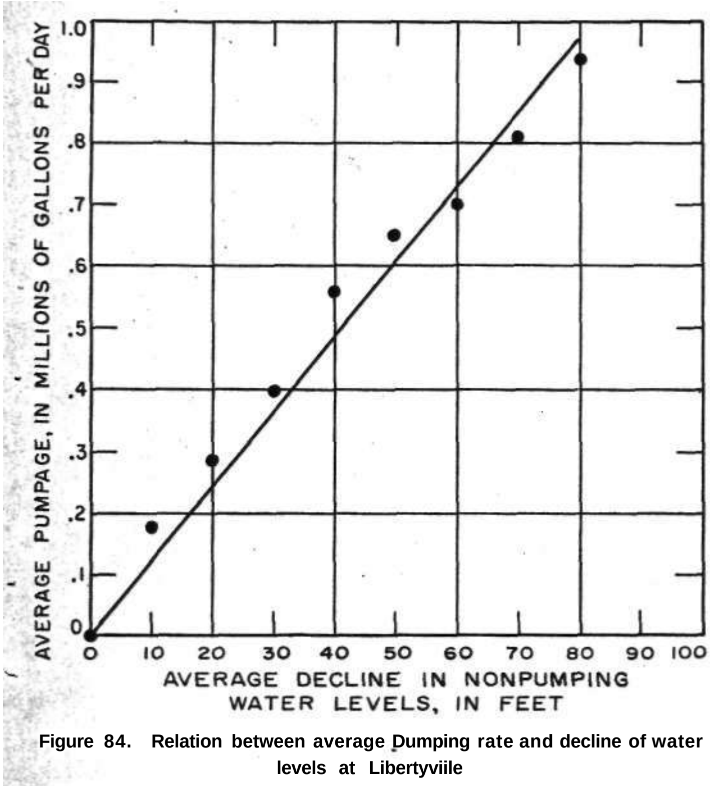

Figure 84. Relation between average pumping rate and decline of water levels at Libertyviile

Nonpumping levels in wells at Mundelein were measured with less frequency than wells at Libertyviile; available water-level data are summarized in table 21. Water-level trends cannot be determined from the short-term records.

Table 22 lists pumping levels in wells at Libertyviile and Mundelein. Pumping-level measurements were made at infrequent intervals. Pumping levels in sand and gravel wells 19.3b and 24.1g at Mundelein were below tops of

Table 21. Nonpumping Levels in Wells at Mundelein

Well number	Date measured	Depth to water (ft below measuring point)
LKE—		
44N10E-		
24.1g	1959	104
24.1g	1960	114
24.1g	1961	115
24.1g	1962	120
24.3d1	1954	82
24.3dl	1960	95
24.3dl	1961	98
24.3dl	1962	100
24.3d2	1954	91
24.3d2	1961	79
24.3d2	1962	89
24.3g	1954	69
24.3g	1959	90
24.3g	1960	92
24.3g	1961	87
24.3g	1962	95
44N11E-		
19.3b	1955	56
19.3b	1961	70
19.3b	1962	75
19.6a	1946	90
19.8al	1915	40
19.8al	1926	40
19.8al	1961	110
19.8a2	1930	64

Table 22. Pumping Levels in Wells at Libertyviile and Mundelein

WeU number	Date measured	Pumping rate (gpm)	Depth to water (ft below measuring point)
LKE—			
44N10E-			
24.1g	1962	750	148
24.3dl	1961	320	175
24.3d2	1962	110	107
24.3g	1962	460	109
44N11E-			
16.1bl	1955	728	170
16.1b2	1955	630	188
16.3c	1961	247	135
16.3el	1962	300	95
16.3e2	1962	150	95
16.4d	1958	500	105
19.3b	1962	200	92

screens in 1962; pumping levels in dolomite wells at Libertyviile averaged about 60 feet above the top of the dolomite aquifer in 1962.

Configuration of Piezometric Surface of Aquifers

In order to determine areas of recharge and discharge and directions of ground-water movement in the Silurian dolomite aquifer, a piezometric surface map was made (figure 85). Data on nonpumping levels in table 23 were used to prepare the map.

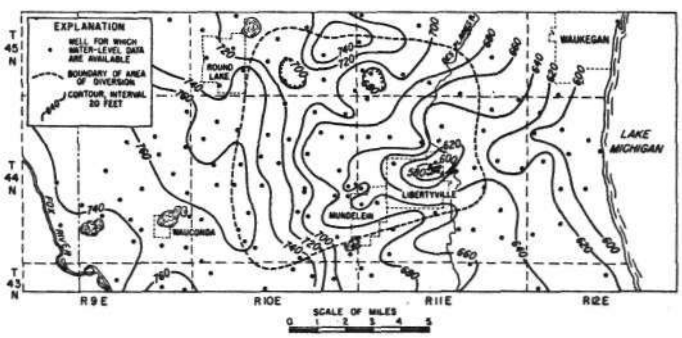

Figure 85. Piezometric surface of Silurian dolomite aquifer in Libertyviile area, July-August 1962

The piezometric surface map in figure 85 represents the elevation to which water will rise in a well completed in the Silurian dolomite aquifer, and does not usually coincide with the position of the water table in shallow sand and gravel aquifers. The map was prepared from water-level measurements made mostly during the months of July and August 1962. The majority of observation wells shown on the map are open in the Silurian dolomite aquifer; however, some wells are open to deeply buried sand and gravel deposits above the Silurian dolomite aquifer. The Silurian dolomite aquifer and deeply buried sand and gravel aquifers have slightly different water levels at the same location (for example, see wells LKE 44N10E-23.8e and LKE 44N10E-23.8f in table 23). The piezometric surface could not be mapped using only the available water-level data for the Silurian dolomite aquifer; water-

Table 23. Water-Level Data for Wells in Silurian Dolomite Aquifer and in Deeply Buried Sand and Gravel Aquifers in Libertyville Area

Well number	Owner	Depth (ft)	Aquifer	Depth to water (ft below measuring point)	Land surface elevation (ft above MSL)	Water level elevation (ft above MSL)	Date measured
LKE—							
43N9E–							
1.3a	R. A. Gillis	265	s&g	94.7	856	761	8/14/62
2.1b	A. R. Rein	166	s&g	24.8	790	765	7/5/62
3.6d	C. Schleifer	200	dol	30.7	765	734	7/30/62
43N10E–							
1.8d	Rogers	—	s&g	70.7	775	704	8/13/62
2.6e	O. Ohenauf	320	s&g	37.5	781	743	8/10/62
3.3g	D. J. Hodges	300	—	82.4	825	743	7/10/62
4.3a	R. J. Kreuser	—	s&g	140.7	885	744	7/10/62
6.3f	R. Rieke	300	s&g	109.8	865	755	7/24/62
8.3g	E. Mahachek	—	—	123	873	750	7/5/62
24.1b	Twin Orchard CCb.	136	s&g	9	740	731	3/29/62
43N11E–							
3.1h	G. Brown	139	dol	22.8	686	663	8/16/62
6.5e	Towner Sbd.	180	dol	39	728	689	4/26/62
6.8g	Diamond Lake Schl.	234	s&g	69.18	760	691	2/8/62
8.3f	Vernon Hills Sbd.	150	s&g	30	715	685	4/26/62
43N12E–							
4.2e	Barat College	71	dol	67.6	695	627	8/20/62
6.5a	Fisher	—	dol	35.1	677	642	8/17/62
16.2h	Old Elm Golf Club	184	dol	27.14	650	623	8/17/62
44N9E–							
1.2d	J. Hoffman	212	s&g	56.44	820	764	6/21/62
3.2f	B. Schmidt	200	s&g	25.7	788	762	6/26/62
9.2h	E. L. Fisher	—	s&g	28.6	784	755	6/27/62
10.3c	W. Chandler	170	s&g	21	776	755	6/26/62
11.3e	Natural gas pipeline	280	s&g	27.2	792	765	6/25/62
12.2b2	W. Roney	160	s&g	42.3	805	763	7/17/62
13.6b	D. Lexow	150	s&g	42.7	810	767	7/13/62
14.2h	K. Sorlie	150	s&g	49.8	812	762	7/18/62
16.1c	—	84	s&g	17.9	774	756	7/3/62
21.8a	J. Conigli	131	s&g	22.5	764	742	7/27/62
22.5c	J. Dowell	80	s&g	27.8	790	756	7/26/62
23.7f	R. Sanca	208	s&g	42	797	755	6/27/62
24.2e	M. Arendt	255	dol	75.4	839	764	7/31/62
24.3e	B. Jennings	190	s&g	28	795	767	7/12/62
25.1f	A. Christensen	142	s&g	44.0	800	756	7/31/62
26.7b	A. Daumke	220	s&g	23.5	772	742	7/26/62
27.2e	R. Norcross	160	s&g	35.8	782	746	7/27/62
28.2f	J. Filippo	178	s&g	13.3	749	736	6/29/62
34.1g	P. Piccolo	275	dol	13.8	750	736	7/3/62
35.1f	W. H. Bode	165	s&g	42.8	787	744	7/24/62
36.2e	J. Baska	230	s&g	19.2	789	770	7/6/62
44N10E–							
1.4c	Suhling	265	s&g	107.0	810	703	10/16/61
2.5d	G. Titus	335	dol	116.1	812	696	8/8/62
3.5f	F. Krene	254	dol	103.2	823	720	3/26/62
4.6h	V. Campbell	—	s&g	43.92	785	741	3/26/62
6.1a	A. Hartle	200	s&g	55.2	809	754	7/18/62
7.5d	R. Hartle	—	s&g	65.9	821	765	7/19/62
8.3g	Schroeder Nursery	200	s&g	41.85	792	750	6/21/62
9.2e	L. Behm	256	dol	75.53	811	735	10/9/61
10.4d	—	—	s&g	101.4	814	713	8/9/62
11.3f	G. Stode,	—	dol	145.18	822	677	10/16/61
12.5e	R. Meyer	265	dol	138.46	815	677	9/18/61
13.6c	V. Kahn	165	s&g	128.98	802	673	9/18/61
14.7h	H. Grabbe	205	s&g	174.67	853	678	9/26/61
15.7e	A. M. Wirtz	314	dol	99.90	825	725	10/9/61
16.4g	L. Itta	329	dol	73.9	812	738	7/18/62
17.2e	R. Kebro	151	s&g	41.2	802	761	7/18/62
18.2e	J. H. Betjmann	285	dol	40.1	800	760	7/13/62
19.1g	J. Epstein	—	s&g	62.6	825	762	8/1/62
20.4g	R. Bielewitz	200	s&g	52.3	813	761	7/12/62
21.4g	Fremont Schl.	300	dol	60.3	810	750	7/11/62
23.8e	B. Small	298	s&g	142.31	850	708	10/19/61
23.8f	M. Behm	304	dol	145.55	848	702	9/29/61

Table 23 (Continued)

Well number	Owner	Depth (ft)	Aquifer	Depth to water (ft below measuring point)	Land surface elevation (ft above MSL)	Water level elevation (ft above MSL)	Date measured
LKE—							
44N10E–(Cont'd)							
24.3d1	Mundelein (V)	276	dol	98	750	652	5/22/61
24.3d2	Mundelein (V)	270	dol	89	750	661	1/27/62
24.3g	Mundelein (V)	140	s&g	103	750	647	1/26/62
24.1g	Mundelein (V)	165	s&g	119	777	658	1/21/62
24.7d	E. Kingman	111	s&g	103.67	793	689	9/18/61
26.7f	A. S. Hanson	312	dol	142.53	825	682	3/26/62
27.2g	W. A. Singer	180	s&g	128.13	845	717	10/9/61
28.8g	A. Dahlquist	300	dol	48.5	810	762	7/20/62
29.3b	R. V. Jones	—	s&g	88.5	850	762	7/23/62
30.6e	C. Lochmoon	375	dol	53.0	810	757	7/23/62
31.6a	A. Niemic	285	s&g	98.8	850	751	7/24/62
32.1g	A. Mioriello	280	s&g	109.2	870	761	7/11/62
33.6e	E. M. Olsen	125	s&g	117.0	875	758	7/19/62
34.1b	Schwerman	300	s&g	63.2	808	745	8/14/62
35.7b	N. B. Heath	300	s&g	49.9	796	746	8/10/62
36.7h	G. Reimey	—	s&g	76.0	767	691	8/8/62
44N11E–							
1.3h	T. E. Wilson	185	dol	69.29	720	651	4/2/62
2.3e	R. E. Anlliser	85	s&g	57.2	705	648	5/21/62
5.3d	—	—	s&g	20.14	705	685	4/16/62
6.6h	Anderson	250	s&g	94.61	785	690	10/16/61
7.6e	G. Christienson	204	s&g	71.6	750	678	4/16/62
8.8e	Leesley Nursery	255	dol	34.13	710	676	4/16/62
9.2d	North Libertyville	168	dol	37.95	662	624	7/13/62
9.1h	J. V. Casey	150	s&g	39.41	672	633	4/16/62
9.7c	Cities Serv. Sta.	90	s&g	42.79	712	669	4/2/62
11.5g	Ascension Cmty.	160	s&g	68.29	695	627	3/29/62
13.2d	C. Vennett	178	s&g	98.00	715	617	4/19/62
14.1f	Atkinson Farm	110	s&g	78.00	695	617	4/19/62
14.8d	E. Harrison	200	s&g	61.70	696	634	4/20/62
15.5c	T. McFayden	180	s&g	23.58	648	624	4/20/62
16.1b1	Grocery Store Prod.	100	s&g	72.0	660	588	6/19/62
16.1b2	Grocery Store Prod.	90	s&g	63.0	658	595	6/19/62
16.3c	Libertyville (V)	320	dol	108	685	577	4/5/62
16.3e2	Libertyville (V)	286	dol	74	675	601	4/5/62
16.4d	Libertyville (V)	227	dol	98	690	592	4/5/62
16.1b1	Libertyville (V)	297	dol	70	658	588	4/5/62
16.1b2	Libertyville (V)	300	dol	70	658	588	4/5/62
16.3e1	Libertyville (V)	287	dol	74	675	601	4/5/62
17.7e	Quaker Oats Res. Fm.	180	dol	95.91	730	634	4/23/62
19.3b	Mundelein (V)	106	s&g	75	743	668	5/22/62
19.8a1	Mundelein (V)	242	dol	110	765	655	5/22/61
19.8a2	Mundelein (V)	285	dol	35	765	730	5/22/61
19.6a	Mundelein (V)	213	dol	90	765	675	5/22/61
19.8f1	St. Mary's of the Lake Sem.	300	dol	162	729	567	—
19.8f3	St. Mary's of the Lake Sem.	295	dol	77	740	663	2/5/62
22.5e	C. Shen	—	—	6.26	654	648	4/26/62
23.5f	R. L. Vachherm	65	s&g	54	705	651	11/5/61
25.8b	H. R. Vahnke	—	dol	43.40	692	649	4/26/62
26.8b	—	126	s&g	35.17	674	639	4/28/62
27.4b	—	—	dol	flowing	650	650	4/30/62
28.3g2	—	86	s&g	29.55	709	679	4/30/62
29.7b	R. P. Hillinger	96	s&g	52.48	740	688	4/30/62
30.6c1	Mundelein (V)	200	s&g	46.5	745	698	6/8/49
30.6c2	Mundelein (V)	194	s&g	50	780	730	3/1/51
31.6b	P. Baldino	75	s&g	30.85	752	721	5/3/62
32.8c	E.J.&E. RR	215	dol	63.27	728	665	3/19/62
36.8b	—	185	dol	40.5	688	647	8/16/62
44N12E–							
6.5d	Abbott Lab.	270	dol	68	690	622	8/9/62
7.7f	Pagoda Motel	162	s&g	85.12	694	599	7/13/62
8.7g	J. Wasniewski	180	s&g	122.4	715	593	8/9/62
9.4a	Shore Acres	285	dol	73.42	653	580	8/9/62
9.7d	Shore Acres CCb.	210	s&g	55.5	645	590	8/10/62
17.5h	H. E. Doney	350	dol	125	720	595	8/10/62
18.3f	Goodyear Tire & Rubber	144	s&g	50	680	630	1/7/62
20.7f	Natural Marble Co.	165	dol	58.74	668	609	8/13/62

Table 23 (Continued)

Well number	Owner	Depth (ft)	Aquifer	Depth to water (ft below measuring point)	Land surface elevation (ft above MSL)	Water level elevation (ft above MSL)	Date measured
LKE—							
44N12E–(Cont'd)							
21.8f	Lake Bluff (V)	498	dol	90.80	680	589	7/20/62
29.7d	C & NW RR	224	dol	41.42	675	634	8/13/62
30.7a	Le Wa Farm	175	dol	45.53	673	627	8/13/62
45N9E–							
24.7f	Gavin Schl.	180	dol	67.7	802	734	8/22/62
26.5b	F. O. Mark Trust	200	s&g	25.9	766	740	8/24/62
36.4e	D. Rowden	—	s&g	48.9	802	753	8/21/62
45N10E–							
14.5f	—	200	s&g	50.00	777	727	8/23/62
19.5c	H. Renner	—	s&g	45.8	779	733	8/22/62
20.3g	R. Below	—	dol	43.2	761	718	8/23/62
22.7a	F. Ruszkowski	250	s&g	86.2	800	714	8/3/62
23.7d	G. Halsey	200	s&g	66.5	783	717	8/23/62
26.2b	—	105	s&g	40.15	790	750	6/20/62
27.5c	Grays Lake (V)	337	dol	93	793	700	11/22/61
28.2b	Grays Lake Gelatin	275	dol	91.2	801	710	8/7/62
29.4f	C. Junge	160	dol	83.8	800	716	8/23/62
30.4c	V. A. Tascher	206	dol	42.9	770	727	8/21/62
32.1h	J. Writz	240	dol	49.2	790	741	6/20/62
32.8c2	H. Vanderspool	—	s&g	75.6	812	736	6/21/62
34.5e	W. Hintz	230	dol	109.3	795	686	8/7/62
35.2e	C. Stemler	250	s&g	86.6	793	707	8/1/62
36.1b	H. L. Milk Farm	260	s&g	124.37	811	687	10/16/61
45N11E–							
19.7h	E. Lohuck	225	s&g	75.15	790	715	8/23/62
21.8e	E. Huffhines	109	s&g	49.9	751	701	8/23/62
26.3d	L. Buraadt	175	dol	48	727	679	8/23/62
27.7f	—	140	s&g	48.63	697	648	8/24/62
30.3e	Peterson	360	dol	96.5	790	693	6/19/62
30.8h	J. S. Porto	226	s&g	33	778	745	8/3/62
31.7h	Wildwood Sbd.	145	s&g	130	816	684	11/20/61
31.5g	Wildwood Sbd.	173	s&g	145	810	665	11/20/61
32.4g	L. Bristol	115	s&g	64.7	768	703	6/19/62
33.4d	Serbian Monastery	70	s&g	26	705	679	6/18/62
34.4a2	E. S. Richardson	90	s&g	67.15	713	646	6/18/62
45N12E–							
32.8a	N. Shore Cmty.	168	s&g	101.50	711	609	8/9/62
MCH—							
44N9E–							
5.5g1	C. Fritzsche	198	s&g	15.3	766	751	6/28/62
5.5g2	C. Fritzsche	220	s&g	– 6.2	756	750	6/28/62
20.7h	A. Shustitsky	130	dol	14.9	755	740	7/27/62
29.6c	E. Kocmoud	140	s&g	63.7	795	731	7/27/62

level data for wells penetrating deeply buried sand and gravel aquifers were used to augment data for wells in the Silurian dolomite aquifer. On the basis of measured water levels in a few closely spaced wells drilled to different depths, it is probable mat the piezometric surfaces of the Silurian dolomite aquifer and deeply buried sand and gravel aquifers are in general very similar. Accordingly, it is believed that the contours on figure 85 can be used to determine the approximate directions of movement of ground water, the average hydraulic gradients of the piezometric surface, and the area of diversion of pumping in the Silurian dolomite aquifer.

A pronounced cone of depression is centered around Libertyville and Mundelein. Other cones of depression are present at Grays Lake and at Wildwood Subdivision in the north-central part of the Libertyville area. Ground-water movement is in all directions toward well fields or topographic lowlands.

Flow lines, paths followed by particles of water as they move through the aquifer in the direction of decreasing head, were drawn at right angles to the piezometric surface contours to define the area of diversion. As measured from figure 85, the area of diversion is about 58 square miles.

The piezometric surface map of the Silurian dolomite aquifer was compared with water-level data for the period prior to development, and water-level changes were computed. The greatest declines in the piezometric surface occurred in the immediate vicinity of Libertyville and averaged about 85 feet.

Data on water levels in shallow sand and gravel aquifers given in table 24 indicate that the piezometric surface of the shallow sand and gravel aquifers more closely resembles

Table 24. Water-Level Data for Wells in Shallow Sand and Gravel Aquifers in Libertyville Area

Well number	Owner	Depth (ft)	Depth to water (ft below measuring point)	Land surface elev (ft above MSL)	Water level elev. (ft above MSL)	Date measured
LKE—						
43N10E–						
4.7h	J. L. Smith	24	14.7	875	860	7/6/62
43N11E–						
4.1h	Daughters of Charity	50	16.1	677	661	8/16/62
5.8h	Diamond Lake Cmty.	32	11.70	722	710	4/30/62
5.6g	W. Martin	55	15.09	722	707	7/26/62
15.2c	Do-Mor Day Camp	55	9	650	641	6/11/62
15.4c	Dove	38	10.85	650	639	3/29/62
44N9E–						
2.1d	L. H. Wood	—	18.5	785	765	6/25/62
3.3e	J. McNally	30	5	790	785	6/25/62
10.3g	E. Kulin	60	15.4	780	765	6/26/62
12.2b1	W. Roney	60	21.2	805	784	7/17/62
15.2e	Fisher	60	8.8	772	763	8/15/62
33.7c	M. Snider	26	6	741	735	7/3/62
44N10E–						
30.4e	Ascension Cmty.	15	10.0	778	768	7/12/62
44N11E–						
12.5h	—	40	22.24	710	688	4/19/62
17.8e	C. Simmonds	23	4.30	740	736	4/16/62
28.3g1	Florsheim Estate	55	28.55	708	679	4/30/62
44N12E–						
18.5a	W. R. Winters	60	33.4	688	655	8/10/62
45N10E–						
32.8c1	H. Vanderspool	—	75.6	812	736	6/21/62
45N11E–						
34.4a1	E. S. Richardson	27	21.20	713	692	6/18/62
MCH—						
44N9E–						
8.6f	W. Krepel	40	27.5	765	725	6/29/62
17.3f	J. J. Morinich	65	10.9	755	744	8/15/62
18.1g	Holiday Hills Inc.	—	21.4	755	734	6/29/62

the topography than does the piezometric surface of the Silurian dolomite aquifer. The data also indicate that the piezometric surface of shallow sand and gravel aquifers is at most places at a higher elevation than the piezometric surface of the Silurian dolomite aquifer.

Coefficient of Transmissibility of Silurian Dolomite Aquifer at Libertyville

The coefficients of transmissibility determined from well-production data pertain to parts of the Silurian dolomite aquifer in the immediate vicinity of production wells and may not be representative of the regional coefficient of transmissibility of the Silurian dolomite aquifer. Flow-net analysis of the piezometric surface was made to determine the average coefficient of transmissibility of the part of the aquifer in the deep cone of depression at Libertyville. The area enclosed by the contour line having an elevation of 620 feet near Libertyville was selected for analysis (see figure 85).

From Darcy's equation

$$T = Q/IL \tag{14}$$

where:

T = coefficient of transmissibility, in gpd/ft
Q = discharge, in gpd
I = hydraulic gradient, in ft/mi
L = width of flow cross section, in mi

The quantity of water, Q, moving across the 620-foot contour line is equal to the total pumpage (1.25 mgd) from the Silurian dolomite aquifer in the Libertyville area minus the water taken from storage and derived from vertical leakage within the area enclosed by the 620-foot contour line. The amount of water taken from storage is very small; however, the amount of vertical leakage into the cone of depression was estimated to be about 40,000 gpd, on the basis of water-level data and the average recharge rate for the Libertyville area. Thus, Q is about 1.21 mgd. The hydraulic gradient, I, and the length of flow cross section, L, at the 620-foot contour line were scaled from figure 85. Computations made using the data mentioned above and equation 14 indicate that the average coefficient of transmissibility of the part of the Silurian dolomite aquifer within the Libertyville cone of depression is 9500 gpd/ft. This value compares favorably with the average coefficient of transmissibility computed from specific-capacity data.

Recharge to Aquifers

Recharge to aquifers in the Libertyville area occurs locally as vertical leakage of water through clayey deposits, and has precipitation as its source. Vertical movement is possible because of the large differentials in head between the water table in the shallow sand and gravel aquifers and the piezometric surface of the Silurian dolomite aquifer. The rate of recharge to the Silurian dolomite aquifer was estimated using the piezometric surface map and past records of pumpage and water levels.

The area of diversion of production wells in the Libertyville area was delineated with the piezometric surface map in figure 85. The water levels in the dolomite aquifer and overlying sand and gravel aquifers vary greatly from place to place and from time to time, mostly because of the shifting of pumpage from well to well and variations in total well field pumpage. At no location, however, is there any apparent continuous decline that cannot be explained by pumpage increases. Within a relatively short time after each increase in pumpage, recharge from vertical leakage through the glacial drift increased in proportion to pumpage as vertical hydraulic gradients became greater and the area of diversion expanded. Therefore, recharge to the Silurian dolomite aquifer and deeply buried sand and gravel aquifers within the area of diversion is equal to the total pumpage from these aquifers, or about 3 mgd in 1962.

The quotient of the quantity of leakage (recharge) and the area of diversion is the rate of recharge. The area of diversion is about 58 square miles; therefore, the recharge rate to the Silurian dolomite aquifer was about 52,000 gpd/sq mi in 1962.

Darcy's equation indicates that the recharge rate varies with the vertical head loss *(Ah)* associated with leakage of water through the confining bed. The average vertical head loss in 1962 was computed to be about 40 feet by comparing the piezometric surface map for the Silurian dolomite aquifer with water-level data for wells in shallow sand and gravel deposits (source bed for the Silurian dolomite aquifer). The average recharge rate taking into account head loss is about 1300 gpd/sq mi/ft. Data were not sufficient to evaluate the recharge rate for shallow sand and gravel aquifers.

Vertical Permeability of Confining Bed

Based on Darcy's equation, the vertical permeability of the confining bed between the shallow sand and gravel aquifers and the Silurian dolomite and deeply buried sand and gravel aquifers may be computed by multiplying . the recharge rate per unit area per foot of head loss $(Q_c/\Delta h\ A_c)$ by the saturated thickness of the confining bed. Based on available well logs, the average saturated thickness of the glacial drift confining bed within the area of diversion is about 200 feet. It is possible that shaly beds in the upper part of the Silurian dolomite aquifer may also retard vertical movement of water towards permeable zones within the dolomite aquifer. A coefficient of vertical permeability of 0.009 gpd/sq ft was computed by substituting appropriate data in Darcy's equation. The coefficient of vertical permeability based on the piezometric surface map applies to the entire thickness of the confining bed between the shallow sand and gravel aquifers and the Silurian dolomite and deeply-buried sand and gravel "aquifers.

Practical Sustained Yield of Existing Well Fields at Libertyville and Mundelein

Silurian Dolomite Aquifer

Because the Silurian dolomite aquifer is thick, deeply buried, and on a regional basis has moderate permeabilities and great areal extent, cones of depression of production wells can extend for considerable distances and available water resources can be developed with a reasonably small number of wells and well fields. There are large areas outside present areas of diversion that are not influenced by present pumpage, and water levels in dolomite wells are not at critical stages, suggesting that the practical sustained yield of the existing well fields is much greater than present withdrawals.

Areas influenced by pumping include sites where the Silurian dolomite aquifer yields very little water to individual wells. In addition, the piezometric surface map is regular in appearance and could be favorably compared to piezometric surface maps for uniform sand and gravel or sandstone aquifers. These facts indicate that the inconsistency of the Silurian dolomite aquifer has little effect on the regional response of the aquifer to pumping and should not seriously deter the full development of available ground-water resources.

In 1962 large parts of the Libertyville area were influenced by pumping from the Silurian dolomite aquifer. Many pumping centers are so closely spaced that individual cones of depression overlap and there is competition between pumping centers. Interference between pumping centers affects values of discharge and drawdown in individual wells. This situation is particularly apparent in the vicinity of Libertyville and Mundelein.

The pumping levels in dolomite wells in the area of diversion are well above the top of the Silurian dolomite aquifer, and there is available drawdown to support future pumpage increases. When nonpumping levels recede to stages below the top of the Silurian dolomite aquifer the yields of production wells will decrease and become critical for two reasons: 1) the aquifer will be partially dewatered, thus decreasing the coefficient of transmissibility; and 2) based on a recent study by Zeizel et al. (1962), well loss in dolomite wells increases at an accelerating rate when nonpumping levels recede to stages below the top of the Silurian dolomite aquifer. Therefore, the practical sustained yield of existing well fields is limited by available drawdown to the top of the Silurian dolomite aquifer.

Drawdowns available for future increases in pumpage were estimated for Libertyville and Mundelein from the piezometric surface and the bedrock topography maps. It was assumed that critical water levels will result if nonpumping levels are below the top of the Silurian dolomite aquifer. The amounts of water, in addition to withdrawals in 1962, that can be withdrawn from the Libertyville and Mundelein pumping centers without creating critical water-level conditions were estimated as the products of available drawdown and the average yield of the dolomite aquifer given in figure 73. Estimated additional withdrawals were added to pumping rates in 1962 to obtain the practical sustained yield of existing well fields.

Computations indicate that the practical sustained yield of the dolomite wells at Mundelein is about 1.3 mgd, or about 1.1 mgd more than the average annual rate of pumpage from wells in 1962. The practical sustained yield of existing dolomite wells at Libertyville is about 2.0 mgd, or about 1.0 mgd more than the average annual rate of pumpage from wells in 1962.

In order to increase the amount of recharge to the Silurian dolomite aquifer from the 1962 rate to the practical sustained yield, the product ΔhA_c must increase in direct proportion to the increase in pumpage. Thus, full development of the practical sustained yield will be accompanied by increases in the area of diversion and water-level lowering.

Glacial Drift Aquifer

Mundelein has three wells penetrating sand and gravel aquifers. The majority of ground-water withdrawals in 1962 at Mundelein were from these wells. Geologic and hydrologic data are not available to predict with a high degree of accuracy the practical sustained yield of these wells. However, based on pumping-level data in table 22 the practical sustained yield of these wells has already been exceeded. Pumping levels have been below tops of screens. Exposing screens to air often accelerates the rate of clogging of screen openings and is undesirable. Thus, present pumping rates are excessive in these wells, and the practical sustained yield is slightly less than the average annual rate of withdrawal in 1962. A reasonable estimate of the practical sustained yield of the three sand and gravel wells based upon 1962 water-level data and allowable drawdown to the tops of screens is 0.75 mgd.

CHICAGO HEIGHTS AREA

Water for municipal use in Chicago Heights and Park Forest is obtained locally from wells in a shallow dolomite aquifer. Since 1900 the average daily withdrawal from the two municipal water supplies steadily increased from 700,000 gallons to 7.84 million gallons in 1962. Continual increases in pumpage caused water levels to decline about 90 feet at Chicago Heights and about 30 feet at Park Forest. Water levels in dolomite wells are not yet at critical stages at Chicago Heights or Park Forest; however, water levels in dolomite wells in the immediate vicinity of Chicago Heights were below the top of the dolomite in 1962. Available data indicate that the dolomite aquifer is capable of yielding more water than is being withdrawn at present.

Geography and Climate

Chicago Heights is located in southeastern Cook County about 27 miles south of the Chicago loop. Detailed study was confined to a square area, hereafter referred to as "the Chicago Heights area," of about 150 square miles. The area is located in southern Cook County and eastern Will County, as shown in figure 86, and is between 87° 31' and 87° 45' west longitude and between 41° 20' and 41° 35' norm latitude.

Chicago Heights lies near the center of the area. Other cities and villages within the area are: East Chicago Heights, Crete, Flossmoor, Homewood, Steger, South Chicago Heights, Park Forest, Matteson, Richton • Park, Olympia Fields, Sauk Village, Glenwood, Thornton, and Monee. State highway 1 and U.S. 30 and 54 pass through the area as do the Illinois Central, the New York Central, and the Chicago and Eastern Illinois railroads.

The Chicago Heights area lies in the Central Lowland' Physiographic Province. The land surface is characterized by relatively flat terrain; extensive surface and subsurface drainage is necessary for development. The average land surface elevation declines from about 750 feet in the southern part of the Chicago Heights area to about 630 feet in the northeastern part.

Drainage is largely northeastward to tributaries of the Little Calumet River flowing in a course about 8 miles north of Chicago Heights. Butterfield Creek and a part of Thorn Creek drain the western portion of the area; Deer Creek and North Creek drain most of the eastern part of the area.

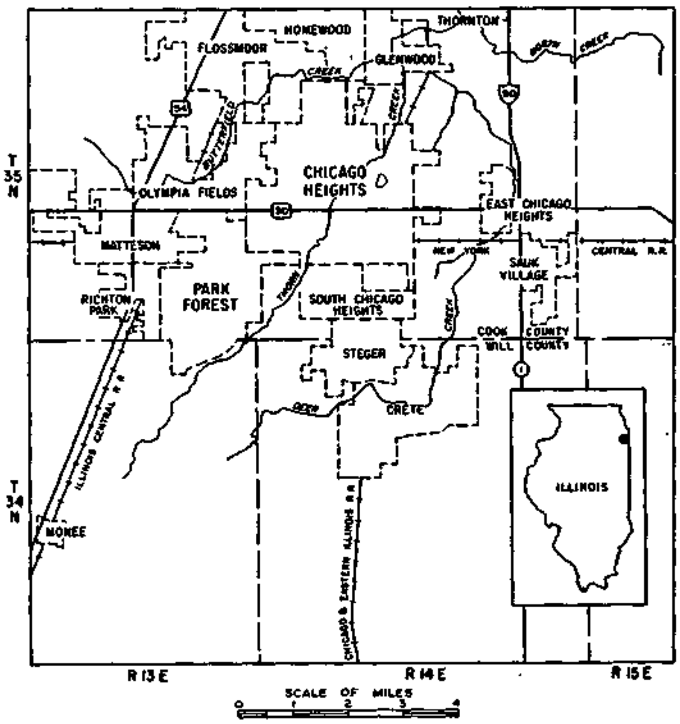

Figure 86. location of Chicago Heights *ana*

Graphs of annual and mean monthly precipitation given in figures 87 and 88 were compiled from precipitation data collected by the Corps of Engineers at Brandon Road Dam near Joliet, about 22 miles west of Chicago Heights. According to these records the mean annual precipitation is 33.65 inches. Oh the average, the months of greatest precipitation are May, June, and September, each having more than 3.5 inches; January, February, and December are the mondis of least precipitation, each having less than 2 inches.

The Chicago Heights area experienced a severe drought beginning in 1912. For the period 1912 through 1926, cumulative deficiency of precipitation at Chicago Heights was about 56 inches. Recharge from precipitation was much

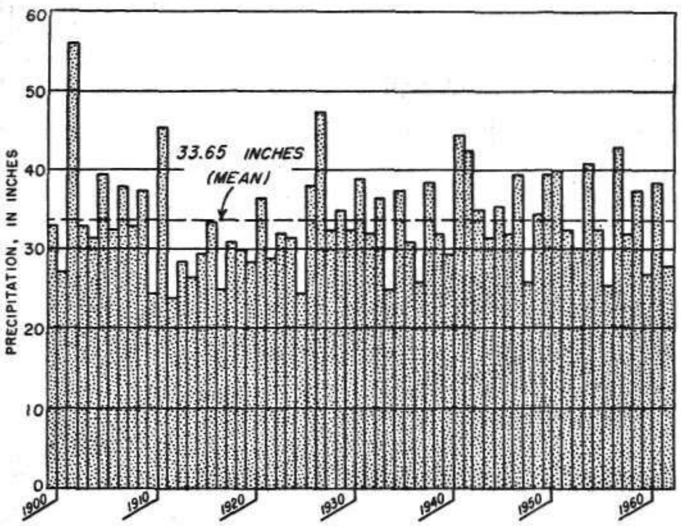

Figure 87. Annual precipitation near Joliet

below normal during the dry years, and large quantities of water were taken from storage within aquifers to balance ground-water discharge to streams and to the atmosphere and pumpage.

The annual maximum precipitation amounts occurring on an average of once in 5 and once in 50 years are 38 and 47 inches respectively; annual minimum amounts expected for the same intervals are 29 and 23 inches respectively. Amounts are based on data given in the Atlas of Illinois Resources, Section 1 (1958).

The mean annual snowfall is 30 inches, and the area averages about 42 days with 1 inch or more and about 24 days with 3 inches or more of ground snow cover.

Based on records collected by the U.S. Weather Bureau at Joliet, the mean annual temperature is 49.1° F. July and August are the hottest months with mean temperatures of 73.3° F and 71.3° F respectively; January is the coldest month with a mean temperature of 23.8° F. The mean length of the growing season is 165 days.

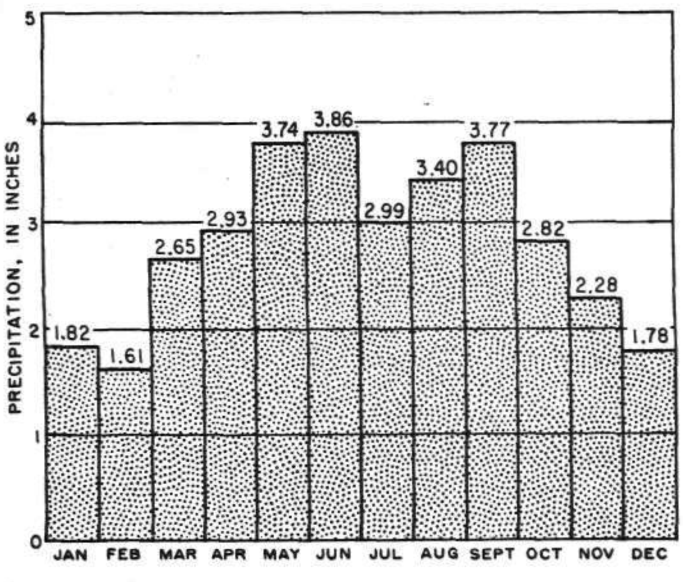

Figure 88. Mean monthly precipitation near Joliet

Geology

For a detailed discussion of the geology in the Chicago Heights area the reader is referred to Suter et al. (1959) and Horberg (1950). The following section is based largely upon these two reports.

The Chicago Heights area is covered mostly with glacial drift which varies in thickness from a few feet in the north-central part to more than 100 feet in the southern part as shown in figure 89. Numerous bedrock exposures are found

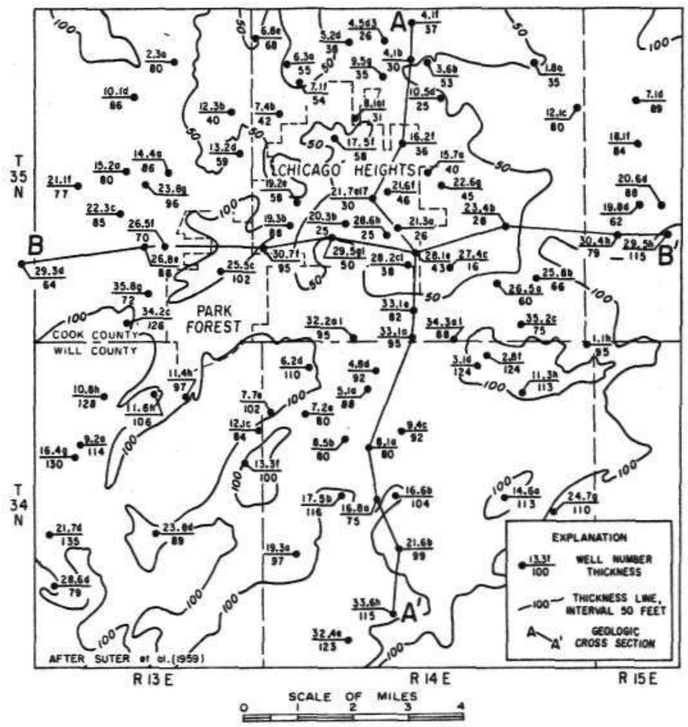

Figure 89. Thickness of unconsolidated deposits overlying bedrock in Chicago Heights area

northeast of Chicago Heights. Figure SO illustrates the nature of the unconsolidated deposits above bedrock. The glacial drift contains a thick and extensive deposit of sand and gravel immediately above the bedrock. The thickness of the sand and gravel deposit, often exceeding 25 feet, tends to increase with increasing drift thickness, thinning generally from the southwest to the northeast. The average thickness of the sand and gravel deposit ranges from about 15 feet in the northeastern part to about 40 feet in the southern part of the Chicago Heights area. Wells rarely terminate in this sand and gravel deposit, and no information is available on grain size distribution. Additional subsurface information is needed to determine the character and saturated thickness of these deposits.

Relatively impermeable deposits (confining bed) consisting of sandy and silty clay and gravel overlie the basal sand and gravel deposits. The thickness of these clayey materials varies considerably but often exceeds 25 feet.

Rocks of Silurian age form the bedrock surface throughout the Chicago Heights area. They are mainly dolomites, although shaly dolomite beds occur at the base. The Silurian rocks are divided into the Niagaran Series above

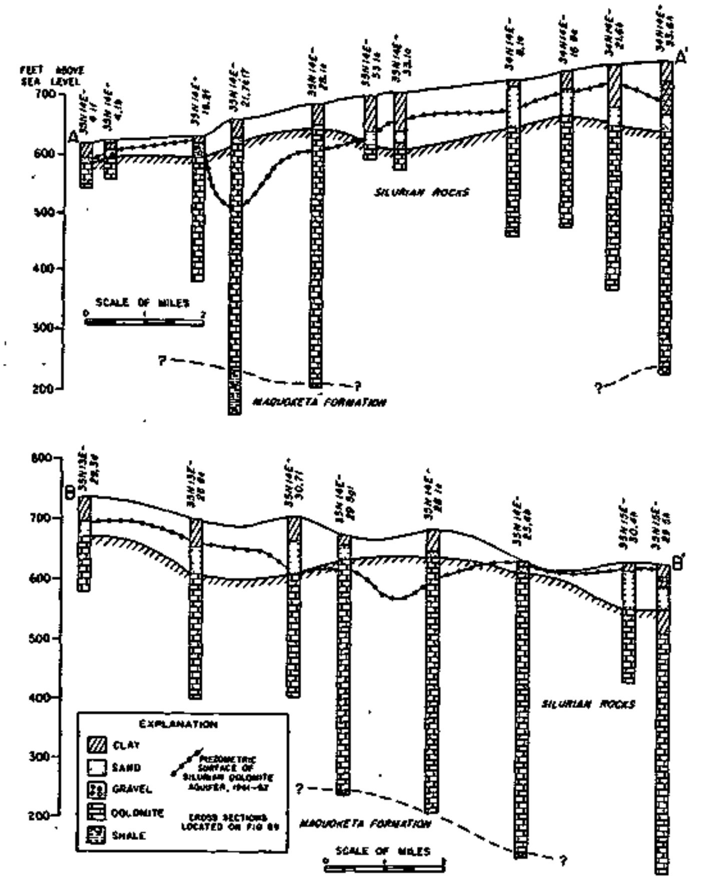

Figure 90. Cross sections A—A' and B—B' of glacial drift and Silurian dolomite aquifer in Chicago Heights area and piezometric profiles

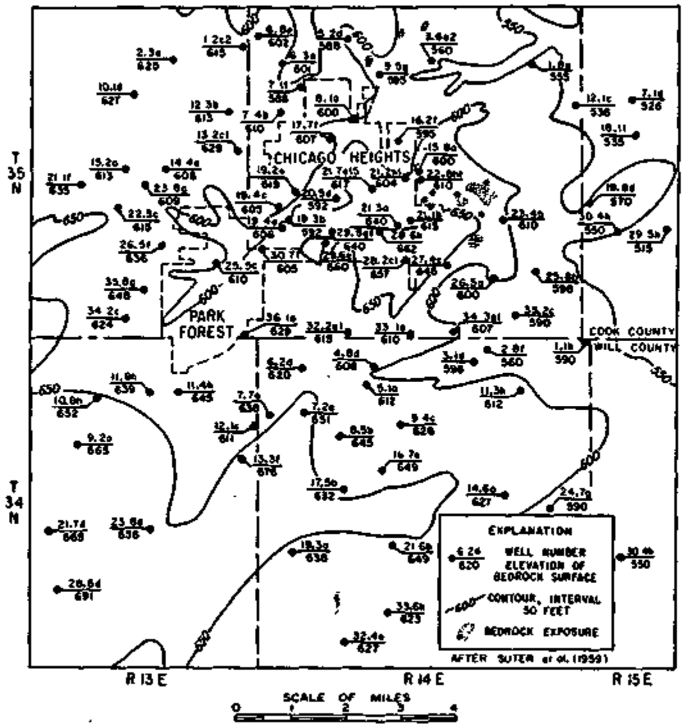

Figure 91. Bedrock topography of Chicago Heights area

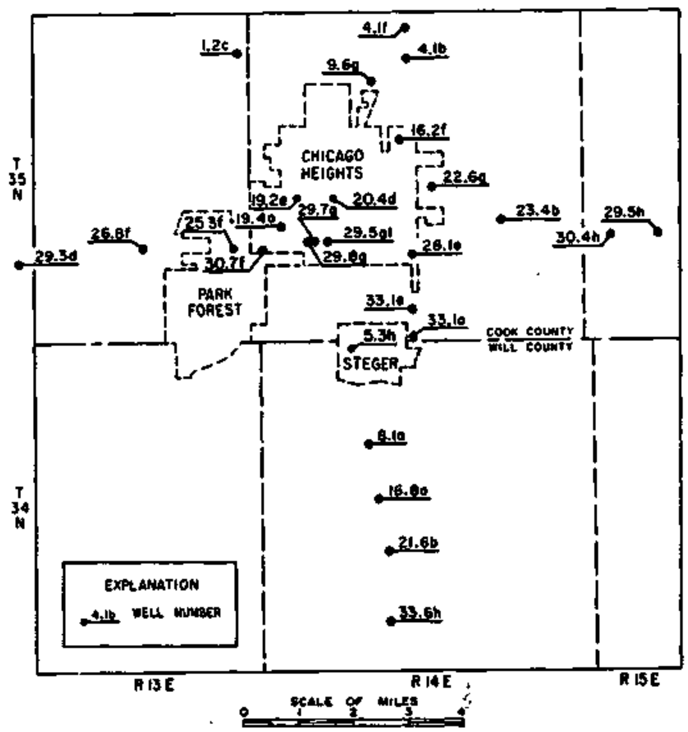

Figura 92. Location of selected wells and test holes in Chicago Heights area

and the Alexandrian Series below. Based on logs of a few wells that completely penetrate the Silurian rocks, the combined thickness of the Niagaran and Alexandrian Series is fairly uniform and averages about 400 feet. The Niagaran Series is white to light gray, finely to medium crystalline, compact dolomite with varying amounts of shale and argillaceous dolomite beds, and averages about 360 feet in diickness. The Alexandrian Series is relatively thin, averaging about 40 feet in diickness, and is composed chiefly of dolomite. Shale and argillaceous dolomite beds occur near the base.

A contour map showing the topography of the bedrock surface is shown in figure 91. Features of the bedrock topography were previously discussed by Suter et al. (1959). In general the bedrock surface slopes to the northeast toward Lake Michigan at an average rate of about 7 feet per mile. Chicago Heights is located on a bedrock upland; the maximum elevation of the bedrock surface at Chicago Heights reaches abo.ut 660 feet.

Logs of selected wells and test holes for which geologic data are available are given in table 25. The location of the wells and test holes is shown in figure 92.

Occurrence of Ground *Water*

Ground water in the Silurian dolomite aquifer occurs under leaky artesian and water-table conditions. Leaky artesian conditions exist at places where fine-grained deposits, which impede or retard the vertical movement of water, overlie the dolomite, and water in the aquifer is under artesian pressure. Under leaky artesian conditions, water rises in wells above the top of the aquifer to stages within the overlying fine-grained deposits.

Water-table conditions prevail at many places where bedrock outcrops and the upper surface of the zone of satura-

Table 25. Logs of Selected Wells and Test Holes in Chicago Heights Area

Well number	Formation	Thickness (ft)	Depth (ft)
WIL—34N14E–			
8.1a	sandy clay	12	12
	fine sand	68	80
	dolomite	80	160
	siltstone (dolomitic)	35	195
	dolomite	—	264
16.8a	clay	30	30
	sand	45	75
	dolomite	—	265
21.6b	soil and clay	70	70
	sand and gravel	30	100
	limestone	—	379
33.6h	soil	30	30
	sandy clay	55	85
	sand and gravel	30	115
	limestone	402	517
	shale	—	526
COK—35N13E–			
1.2c	Pleistocene Series		
	clay, gravel, and boulders	65	65
	Silurian System		
	Niagarian Series		
	lime and broken lime	23	88
	red and mixed shale	36	124
	lime rock	1	125
	red and mixed shale	23	148
	lime rock	12	160
	dolomite, light gray, pink, green, fine	85	245
	dolomite, white, fine	40	285
	dolomite, gray, fine	20	305
	dolomite, white, very fine	20	325
	dolomite, silty, fine	30	355
	Alexandrian Series		
	Kankakee Formation		
	dolomite, light buff, fine	15	370
	dolomite, buff, fine to medium	20	390
	dolomite cherty, buff, fine to medium	20	410
	Edgewood Formation		
	dolomite, silty, gray, very fine	45	455
	dolomite and shale, silty, gray	12	467 TD
26.8f	clay	46	46
	sand and gravel	42	88
	dolomite	—	300
29.3d	clay	40	40
	sand and gravel	24	64
	limestone	—	158
35N14E–			
4.1b	sand	5	5
	clay	10	15
	sand and gravel	15	30
	rock	—	64.5
4.1f	clay	27	27
	sand and gravel	10	37
	rock	—	77
9.6g	top soil	5	5
	clay, yellow	10	15
	clay, blue	5	20
	mud and gravel	10	30
	sand and gravel	5	35
COK—35N14E–			
9.6g (Cont'd)			
	gray lime, hard	20	55
	gray lime, soft	10	65
	gray lime, hard	15	80
	lime gray	25	105
	gray lime, soft	40	145
	gray lime, hard	45	190
	lime, light gray, soft	5	195
	lime, light gray, hard	—	220
16.2f	soil	10	10
	sand and gravel	26	36
	limestone	—	250
19.4a	soil	5	5
	shale, gray	30	35
	gravel	20	55
	gravel and sand	5	60
	sand	5	65
	broken lime, dark	5	70
	lime, dark and hard	15	85
	lime, sandy, dark, hard	10	95
	broken sandy dark medium lime	5	100
	lime, sandy, dark, hard	40	140
	lime, sandv, broken, dark	25	165
	lime, sandy, hard, lighter	35	200
	lime, dark gray, hard	15	215
	no record		220
	hard gray lime	5	225
	gray lime	5	230
	white lime, hard	10	240
	gray lime	10	250
	white lime, hard	20	270
	gray lime, hard	10	280
	sand, gray, lime, hard	20	300
	light brown lime	5	305
	white hard lime	15	320
	light gray lime, hard	35	355
	white lime, hard	30	390
	gray lime	10	400
	brown lime	5	405
	brown lime, medium hard	25	435
	brown lime, hard	10	440
	no record	—	450
22.6g	clay	20	20
	sandy clay	15	35
	sand and gravel	10	45
	limestone	—	200
23.4b	clay	10	10
	sand and gravel	10	20
	limestone	473	493
	shale	—	499
28.1e	soil and till	35	35
	gravel	8	43
	Niagaran dolomite	400	443
	Alexandrian dolomite	30	473
	Maquoketa shale	—	475
29.5g1	Pleistocene Series		
	till, brown, leached	5	5
	till, sandy, gravelly, yellowish buff to buff	25	30
	sand, silty, fine to medium; little gravel	20	50
	Silurian System		
	Niagaran Series		
	Port Byron-Racine Formation		
	dolomite, white to light gray, fine	45	95

Table 25 (Continued)

Well number	Formation	Thickness (ft)	Depth (ft)
COK—			
35N14E–			
29.5gl (Cont'd)			
	Waukseka Formation		
	dolomite, silty, grayish buff	25	120
	dolomite, very silty, buffish gray, grading to shale	20	140
	dolomite, silty, light grayish buff, fine	25	165
	dolomite, silty, buffish gray, fine	75	240
	dolomite, silty, grayish buff	25	265
	dolomite, slightly silty, buff, very fine	35	300
	Joliet Formation		
	dolomite, light buff to buff	25	325
	dolomite, silty, light grayish buff	20	345
	dolomite, light gray, fine to medium	30	375
	dolomite, slightly silty, grayish buff, fine	25	400
	Alexandrian Series		
	Kankakee Formation		
	dolomite, buff, little grayish buff	35	435
	Ordovician System		
	Cincinnatian Series		
	Maquoketa Formation		
	shale, gray, weak; little dolomite	—	439
29.7g	clay	40	40
	sand and gravel	21	61
	limestone	—	248
29.8g	clay	15	15
	sand	25	40
	Niagara dolomite	355	395
	Alexandrian dolomite	38	433
	Maquoketa shale	—	436
30.7f	clay	40	40
	sand and gravel	55	95
	Niagaran dolomite	205	300
33.1a	clay	67	67
	sand	20	87
	clay	8	95
	limestone	—	130
33.1e	clay	59	59
	sand and gravel	21	80
	silt	2	82
	limestone	—	107
35N15E–			
29.5h	clay	20	20
	sand	5	25
	clay	10	35
	sand	39	74
	clay	41	115
	dolomite	—	601
30.4h	clay	15	15
	sand and gravel	64	79
	dolomite	—	200

tion is in the dolomite, and at places within deep cones of depression where water levels in wells rise to stages within the dolomite and water is unconfined. Because water occurs most commonly under leaky artesian conditions in the Chicago Heights area, the surface to which water rises, as defined by water levels in wells, is hereafter called the piezometric surface.

Recharge within the area is from precipitation and from induced infiltration of surface water in small streams traversing the area. Only a fraction of the annual precipitation seeps downward through surficial materials and into the Silurian dolomite aquifer. Recharge by induced infiltration occurs at places where heavy pumping from wells has lowered the piezometric surface below the surface of streams.

Construction Features of Wells and Pumps

Wells drilled into the Silurian dolomite aquifer in the Chicago Heights area all have very similar construction features. The wells are usually cased through the unconsolidated deposits into the bedrock; almost all wells are grouted with concrete from land surface to bedrock. Generalized construction features and logs of selected production wells in the Chicago Heights area are shown in figure 93; locations of the wells are shown in figure 92.

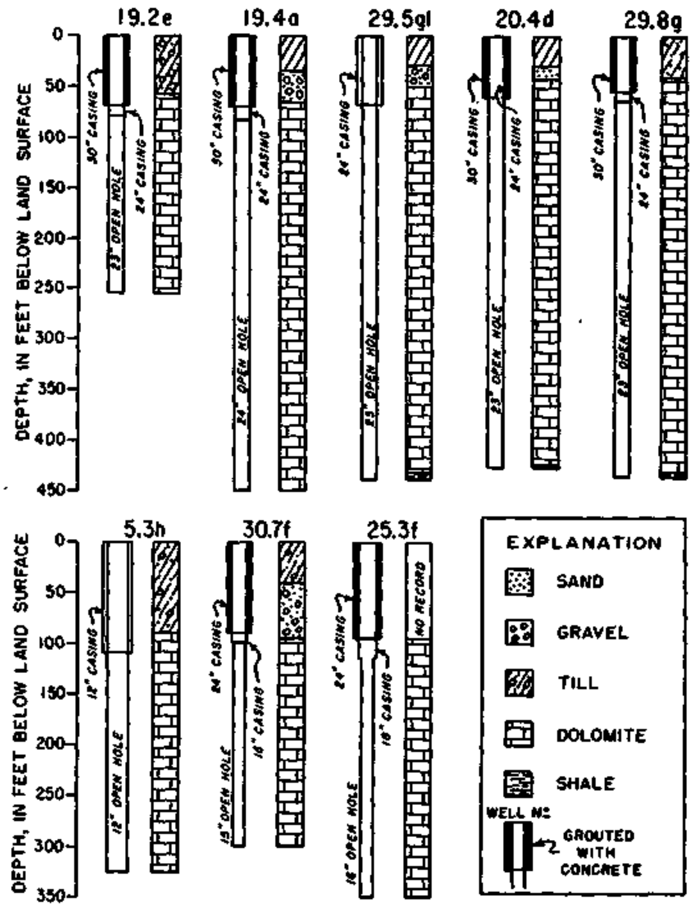

Figure 93. Generalized construction features and logs of selected production wells in Chicago Heights area

Because of the unusual diickness of the Silurian rocks in the Chicago Heights area, most wells do not penetrate the entire diickness of dolomite.

Casing diameters range in size from 8 to 33 inches and commonly exceed 24 inches. Bore-hole diameters are generally smaller at the bottom than at the top. Bore-hole diameters ranging from 8 to 33 inches at the top and reduced to 8 to 23 inches at the bottom are common. Details of construction features of selected wells are given in table 26.

Table 26. Construction Features of Selected Wells in Silurian Dolomite Aquifer in Chicago Heights Area

Depth (ft)	Bore-hole record depth (ft)	Bore-hole record diam. (in)	Casing record depth (ft)	Casing record diam. (in)
203	0-50	30	0-50	30
	50-58	24	0-58	24
	58-203	23		
270	0-71	33	+2-71	33
	71-80	24	+2-80	24
	80-270	23		
260	0-67	30	0-67	30
	67-78	24	0-78	24
	78-260	23		
152	0-152	10	0-85	10
351	0-105	12	0-105	12
	105-351	10.		
160	0-88	16	0-88	16
	88-160	14		
408	0-408	12	0-18	12
250	0-250	8	0-25	8
318	0-318	12	0-147	12
325	0-325	12	0-110	12
300	0-95	24	+ 0.5-95	24
	95-116	16	+ 1.5-116	16
300	0-97	24	+ 0.5-88	24
	97-300	15	+ 1.5-97	16
350	0-96	24	0-96	24
	96-117	18	1-117	18
	117-350	16		
345	0-90	24	0-90	24
	90-101	18	0-101	18
	101-345	17		
450	0-32	30	0-32	30
	32-450	20	0-67	20
450	0-30	30	0-74	30
	30-81	24	0-81	
	81-450	23.5		
427	0-60	30	0-60	30
	60-427	24	0-60	24
436	0-54	30	0-54	30
	54-63	24	0-63	24
	63-436	23.5		
406	0-50	30	0-50	30
	50-57	24	0-57	24
	57-406	23.5		

Pumps in wells in the Silurian dolomite aquifer with capacities equal to or greater than 1000 gpm are powered by 50 to 150 horsepower electric motors. Column pipes range in diameter from 5 to 10 inches and have lengths ranging from 60 to 400 feet. The number of bowl stages ranges from 2 to 27. Suction pipes have lengths ranging from 10 to 43 feet and diameters ranging from 5 to 10 inches. Details of selected pump installations are given in table 27.

Table 27. Description of Pumps in Selected Wells in Silurian Dolomite Aquifer in Chicago Heights Area

Horsepower	Pump rating capacity/head (gpm/ft)	Number of stages	Column pipe length (ft)	Column pipe diam. (in)	Suction pipe length (It)	Suction pipe diam. (in)
100	1500/185	3	160	10	—	—
75	550/300	8	213	8	—	—
100	1000/270	6	110	10	—	—
100	1200/206	4	160	7	20	7
100	1500/199	3	180	8	—	—
125	1500/226	3	210	10	—	—
60	1000/220	6	120	8	20	8
150	1400/—	6	300	8	20	6
125	1150/160	4	120	8	10	8
25	300/220	—	110	6	10	6
40	350/226	11	80	8	20	8
40	400/308	8	200	6	30	6
15	300/110	7	110	6	10	6
75	500/500	13	340	8	30	8
20	300/192	7	60	6	20	5
20	300/170	9	60	6	10	6
15	175/195	20	90	5	10	5
15	250/200	9	60	5	10	5
50	1000/—	2	80	10	—	—
50	900/—	4	100	8	10	8
75	1500/—	2	100	10	10	10
40	620/110	6	140	8	20	8
20	125/300	17	300	5	10	5
25	125/520	24	370	5	—	—
15	150/306	27	150	5	20	5
25	300/315	10	220	6	30	6
15	175/—	4	120	5	20	5
60	500/200	11	225	8	—	—
125	630/368	4	400	8	43	8
30	200/—	10	200	5	30	5

Ground-Water Withdrawals

Ground-water pumpage from the Silurian dolomite aquifer in the Chicago Heights area increased at a fairly uniform rate from 1890, when the first wells were drilled, until about 1940 when pumpage increased at an accelerating rate as shown in figure 94. During the 72-year period, 1890-1962, total pumpage increased from about 50,000 gpd to 15.4 mgd at an average rate of about 210,000 gpd/yr. Pumpage increased very rapidly, at an average rate of 400,000 gpd/yr, during the period 1940 to 1960.

The first industrial water supply in the Silurian dolomite aquifer was developed in 1890 by the American Manganese Company located in northeast Chicago Heights. Industrial pumpage has increased very slowly in comparison to public pumpage as shown in figure 94 and in 1962 was 2.8 mgd or about 18 percent of the water pumped from the Silurian

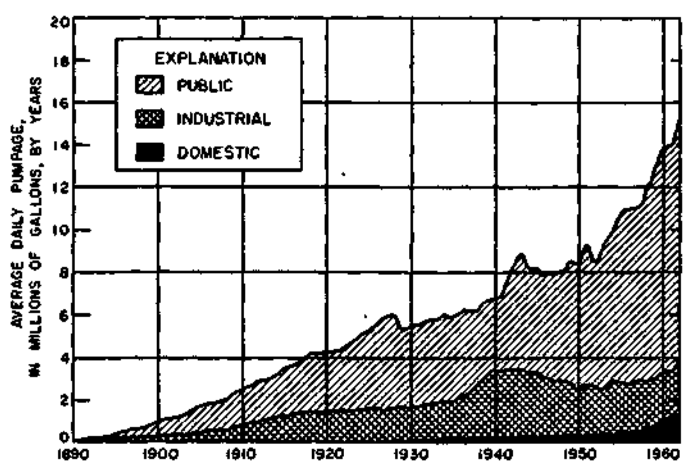

Figure 94. Estimated ground-water pumpage from Silurian dolomite aquifer in Chicago Heights area, 1890-1962

dolomite aquifer. Only a few industrial plants meter their pumpage, and in many cases pumpage was estimated on a basis of the number of hours the pump operates and the pump capacity.

The first public water-supply well was drilled in 1894 for the city of Chicago Heights. Public pumpage increased steadily, as shown in figure 94, and in 1962 was 11.6 mgd or about 75 percent of the water pumped from the Silurian dolomite aquifer. Records of public pumpage are fairly complete for the period 1939 to 1962; very few records of pumpage are available for years prior to 1939. The graph of public pumpage was constructed by piecing together fragments of information derived from many sources including files of the State Water Survey and published reports; by making evaluations based on the number of wells, their reported yields, and their time of construction; and by taking into account per capita consumption and population growth.

Domestic pumpage, including rural farm and rural non-farm use, was estimated by considering rural population as reported by the U.S. Bureau of the Census and per capita use. Domestic pumpage has always constituted a small percentage of total pumpage. Total domestic pumpage in 1962 was about 1.0 mgd or 7 percent of the total water withdrawal from the Silurian dolomite aquifer. Water for domestic use comes from small wells of low capacity that are widely distributed mainly in the southern part of the Chicago Heights area.

Distribution of pumpage in 1962 from the Silurian dolomite aquifer in the Chicago Heights area is shown in figure 95. The greatest concentration of pumpage in 1962 is located within about a 3-mile radius of Chicago Heights.

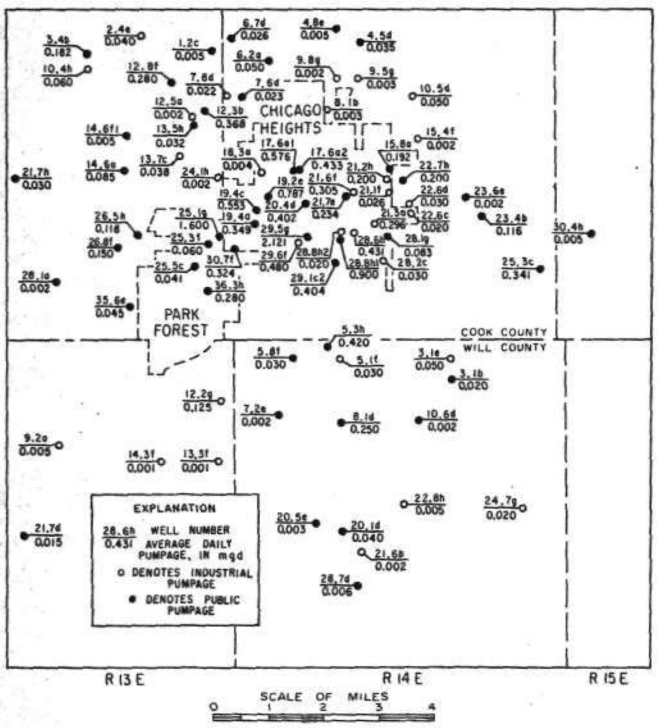

Figure 95. Distribution of pumpage from Silurian dolomite aquifer in Chicago Heights area, 1962

Total pumpage in this area in 1962 amounted to about 13.4 mgd Or 87 percent of the total water withdrawn from the Silurian dolomite aquifer in the entire Chicago Heights area.

The city of Chicago Heights has the largest single water-supply system in the Chicago Heights area. Ground-water pumpage from municipal wells at Chicago Heights amounted to about 5.5 mgd in 1962, as shown in figure 96,

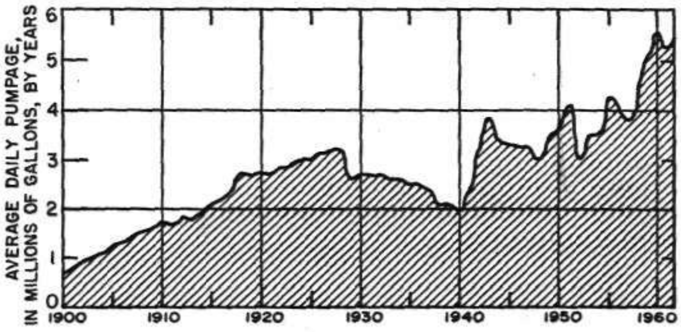

Figure 96. Estimated ground-water pumpage at Chicago Heights, 1900-1962

or about 36 percent of total pumpage in the Chicago Heights area. The variations in average annual pumpage in figure 96 are due to the greatly varying demands for municipal water by industries. The effect of the depression in the 1930's on pumpage is evident as well as the effect of World War II in the 1940's. Municipal pumpage at Chicago Heights has steadily increased since 1940 as the city has steadily grown in population from 22,461 to about 35,000 people. In 1962 approximately 5.5 mgd were required to fulfill industrial, commercial, and domestic de-

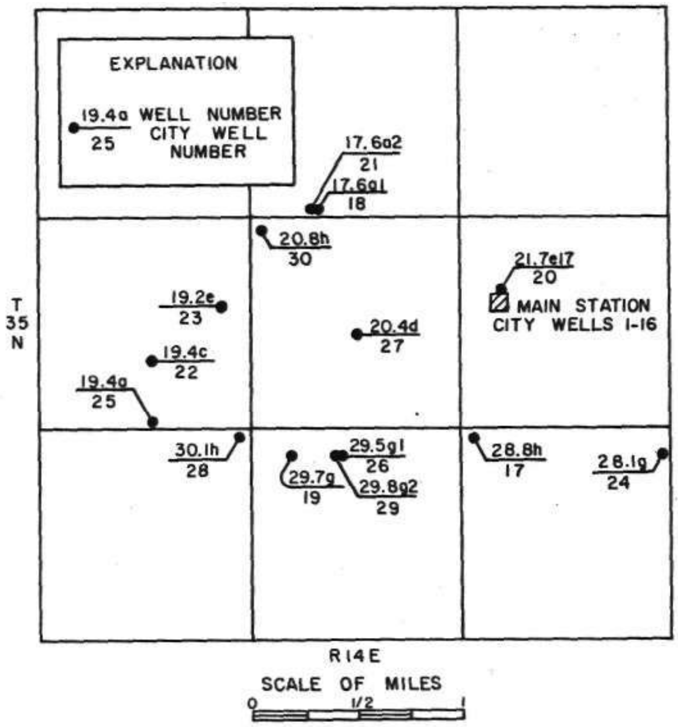

Figure 97. Location of municipal wells at Chicago Heights

mands. Total per capita consumption has increased from 90 gpd per person in 1940 to over 160 gpd per person in 1962.

Until 1941, nearly all water for the municipal water supply of Chicago Heights was pumped from a cluster of 16 wells located at the "main station" in the northeastern part of the city, as shown in figure 97. Because water levels declined to near-critical stages, wells were more widely spaced starting in 1941. Since 1941, 11 new municipal wells have been constructed and are located as shown in figure 97. The length of service of each municipal well is shown in figure 98. Development of new municipal wells at Chi-

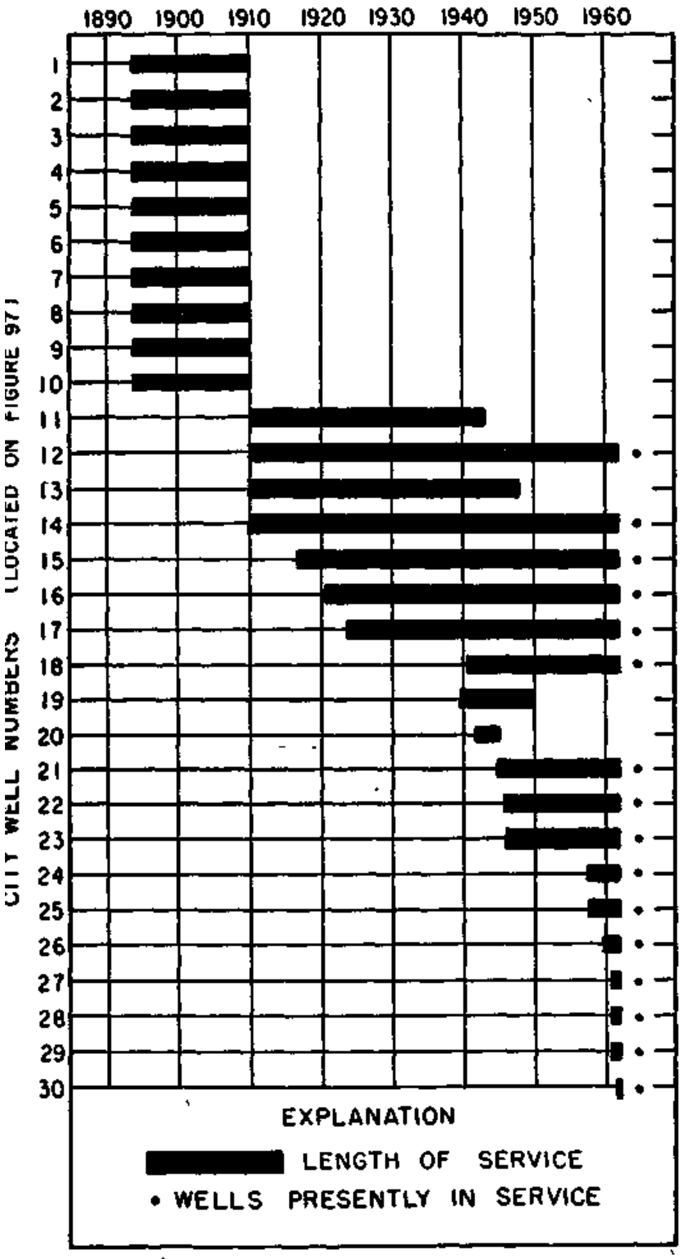

Figure 98. Length of service of municipal wells at Chicago Heights

cago Heights has been to the west and southwest of the main station due in part to the heavy industrial ground-water development east and northeast of the main station (see figure 95). High yielding wells have been obtained west and southwest of the main station.

Of all other municipalities in the Chicago Heights area, Park Forest is the only city with average water demands exceeding 500,000 gpd. The village of Park Forest is located west of the city of Chicago Heights as shown in figure 86, and had a population of about 30,000 people in 1960. All water pumped at Park Forest is for domestic and commercial uses; there is no industrial use. The locations of the individual village wells are shown in figure 99, and

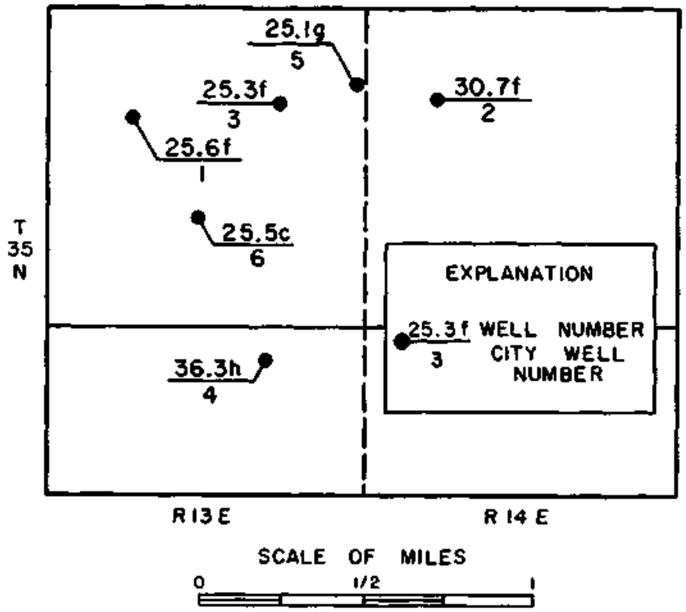

Figure 99. Location of municipal wells at Park Forest

the total pumpage growth curve for the village is shown in figure 100. Pumpage from the Silurian dolomite aquifer has increased steadily since 1947 at an average rate of about 150,000 gpd/yr.

Leakage through Maquoketa Formation

In 1962, the piezometric surface of the Cambrian-Ordovician Aquifer was several hundred feet below the water table throughout the Chicago Heights area, and downward movement of water through the Maquoketa Formation was appreciable under the influence of large differentials in head between shallow deposits and the Cambrian-Ordovician Aquifer. From this information and data given by Walton (1960), it is estimated that leakage through the Maquoketa Formation within the Chicago Heights area was about 250,000 gpd in 1962. Leakage through the Maquoketa Formation is derived mostly from storage within the Silurian dolomite aquifer.

A few deep sandstone wells in the Chicago Heights area are either uncased or faultily cased in the Silurian dolomite aquifer. Thus, a large portion of the water pumped from these deep sandstone wells is obtained from the Silurian

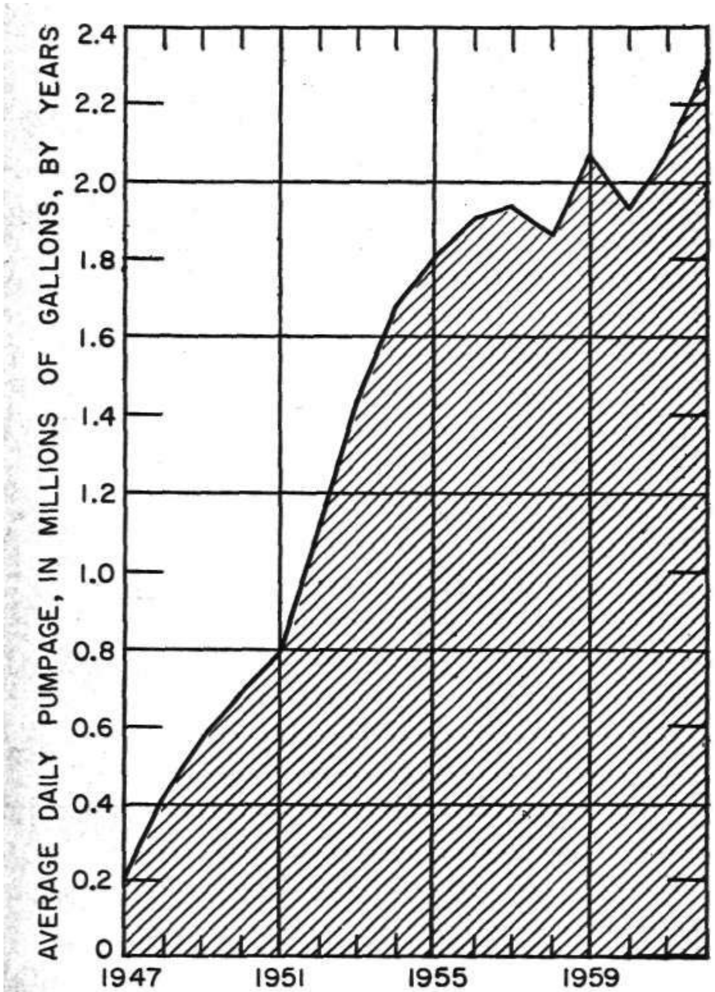

Figure 100. Estimated ground-water pumpage from Silurian dolomite aquifer at Park Forest, 1947-1962

dolomite aquifer. An example of one such well is WIL 35N14E-28.8hl, which is uncased in the Silurian dolomite aquifer as well as the Cambrian-Ordovician Aquifer. From water-level and well-construction data, it is estimated that 0.90 mgd was being withdrawn from the Silurian dolomite aquifer through deep sandstone wells in 1962. The pumpage graph shown in figure 94 includes withdrawals of this description.

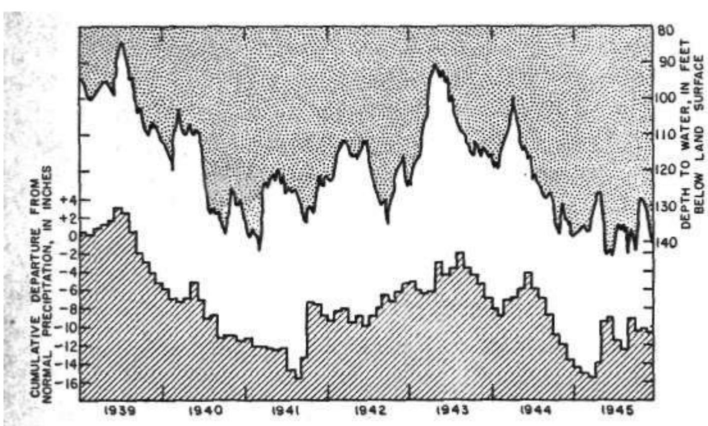

Figure 101. Water levels in well COK 35N14E-21.7el5 compared with departure from normal precipitation at Chicago Heights

Fluctuations of Water Levels and Their Significance

As illustrated by the graphs in figure 101, water levels in the Silurian dolomite aquifer respond readily to fluctuations in precipitation. Water levels in wells rise when precipitation is above normal and fall when precipitation is below normal. Superimposed upon the water-level variations due to precipitation are those due to pumpage. Recharge during wet periods, especially as the result of heavy spring rains, causes water levels to rise rapidly in wells. The close relation between water-level and precipitation changes suggests that precipitation has little difficulty in reaching the Silurian dolomite aquifer.

Water-level fluctuations in well 21.7el5, 1908 through 1961, are shown in figure 102. Water levels were at the same

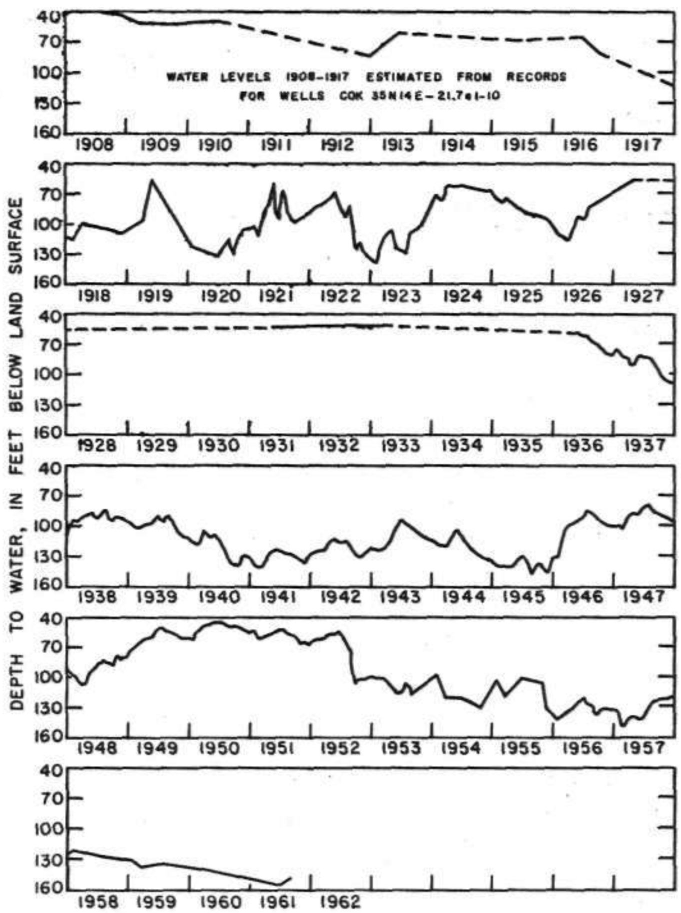

Figure 102. Water levels in well COK 35N14E-21.7el5 at Chicago Heights, 1908-1961

stage, about 55 feet below land surface, in June of 1910 and in June of 1952, indicating that water pumped from 1910 tiirough 1952 was replenished in full. Water taken from storage within the aquifer during years of below-normal precipitation was replenished during years of normal and above-normal precipitation.

Because total pumpage has steadily and greatly increased during recent years (see figure 96), water-levels in well 21.7el5 have continued to decline since 1952, despite the fact that pumpage has been more widely distributed at greater distances from the well.

Water-level data obtained mostly from Illinois State Water Survey Bulletin 40 (1950) for periods prior to heavy well development are summarized in table 28. A comparison of early water levels and water levels measured in 1961 and 1962 indicates that the artesian pressure of the Silurian dolomite aquifer has lowered more than 30 feet in many pumping centers, in response to heavy pumpage.

Table 28. Water-Level Declines in Wells in Silurian Dolomite Aquifer in Chicago Heights Area

Well number	Owner	Land surface elevation (ft above MSL)	Water level elevation (ft about MSL) date	eleva-tion	date	eleva-tion	Water level decline (ft)
WIL—34N14E-							
5.3h	Steger (V)	715	1910	685	1961	660	25
COK—35N13E-							
1.2c2	Flossmoor (V)	680	1926	634	1961	544	90
25.3f	Park Forest (V)	710	1948	669	1961	640	29
25.6f	Park Forest (V)	710	1947	680	1962	667	13
26.5h	Matteson (V)	707	1924	693	1961	674	19
35.6e	Richton Park (V)	733	1926	715	1961	696	37
35N14E-							
6.7d	Flossmoor (V)	667	1941	631	1961	619	12
7.8d	Flossmoor CCb.	652	1951	622	1961	592	30
19.2e	Chicago Hts. (C)	671	1946	651	1961	612	39
19.4c	Chicago Hts. (C)	675	1946	649	1961	624	25
21.3a3	Flintkote Co.	665	1946	559	1961	552	7
21.6f	Tile-tex Div.	648	1951	590	1961	508	82
21.7el5	Chicago Hts. (C)	657	1917	597	1961	507	90
30.7f	Park Forest (V)	701	1947	644	1962	614	30

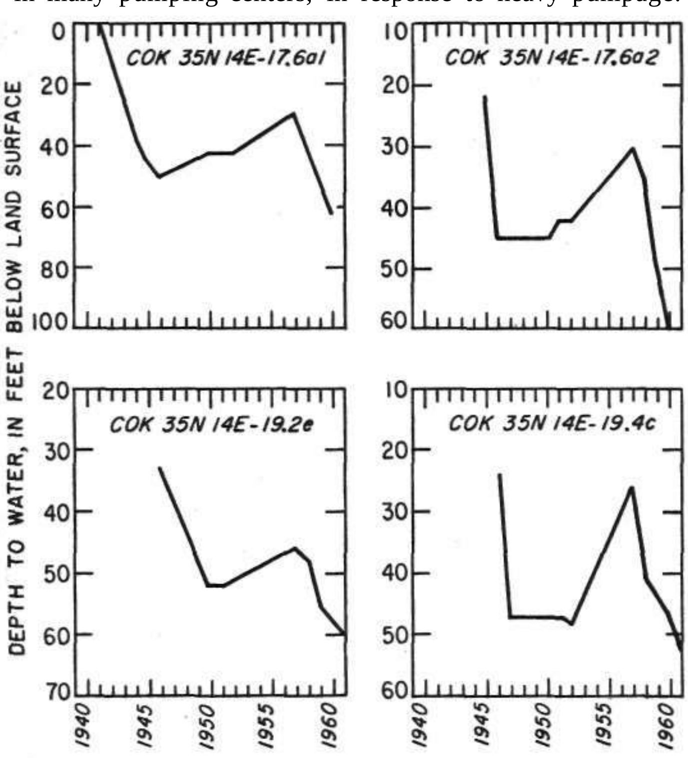

Figure 103. Water levels in wells in Silurian dolomite aquifer at Chicago Heights, 1940-1961

According to data in table 28, water-level declines range from 7 feet at the Flintkote Company to 90 feet at Chicago Heights, and average about 40 feet.

Water levels in several dolomite wells have been measured periodically since 1945. Hydrographs for dolomite wells at Chicago Heights and Park Forest are given in figures 103 and 104. The wells are municipal wells and are near centers of heavy pumpage.

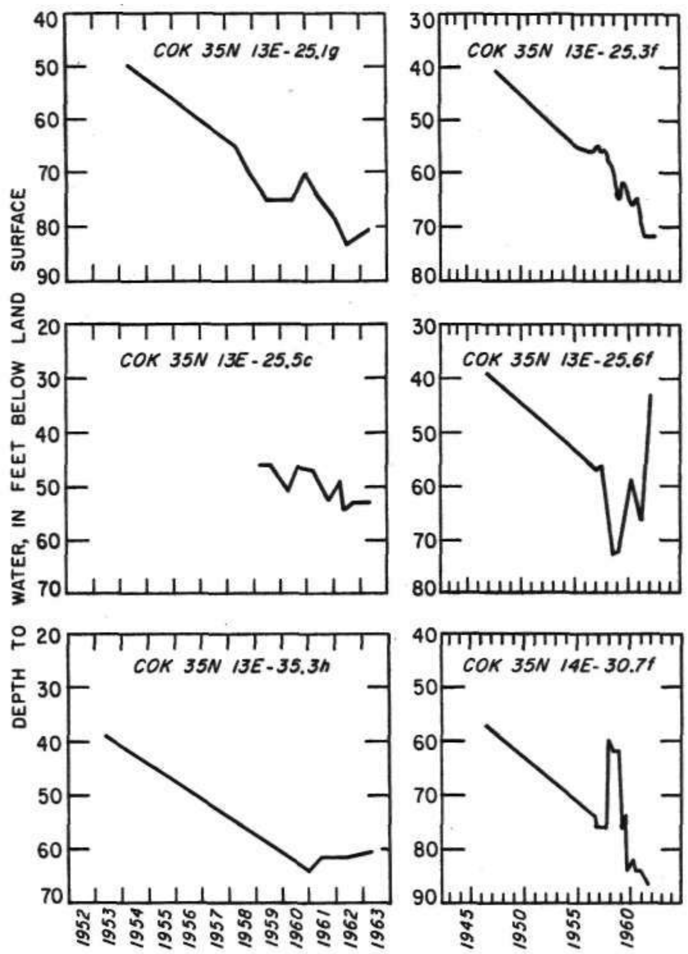

Figure 104. Water levels in wells in Silurian dolomite aquifer at Park Forest, 1945-1962

As a result of heavy pumping, the nonpumping levels in dolomite wells declined about 35 feet between 1940 and 1961 at Chicago Heights, or at an average rate of about 1.6 feet per year. The average rate of decline between 1957 and 1961 was about 5.0 feet per year, and the total decline during the same period averaged about 25 feet.

The average water-level decline in dolomite wells at Park Forest was about 25 feet between 1947 and 1962. The average rate of decline in the same 16-year period was about 1.6 feet per year.

A comparison of water-level hydrographs and pumpage graphs indicates that in general water-level declines are proportional to the pumpage rates. Although the water levels vary considerably from time to time because of shifts in pumpage in well fields and variations in recharge from

Table 29. Water-Level Data for Wells in Silurian Dolomite Aquifer in Chicago Heights Area

Well number	Owner	Depth (ft)	Land surface elevation (ft above MSL)	Depth to water (ft)	Date measured	Water level elevation (ft above MSL)
WIL—						
33N13E–						
3.2h	K. E. Hullenschmidt	—	757	46.60	11/30/62	710
34N13E–						
9.2a	Cardox Co.	404	777	65	10/8/62	712
11.4h	D. Nist	134	730	38	1/31/61	692
12.2g	Remington Arms Co. Inc.	405	753	57	12/11/61	696
13.3f	Woodhill Util. Co.	480	774	78	7/61	696
21.7d	Monee (V)	494	800	82	10/8/62	718
33.1e	Wilbur Wolkow	156	759	54	6/61	705
34.8h	Fred Jwietmeyer	167	794	77	6/61	717
34N14E–						
3.4b	W. K. Mitchell	105	717	47	9/11/62	670
4.1a	L. G. Offill	100	715	45	5/25/62	670
5.3h	Steger (V)	318	715	55	8/1/61	660
7.6a	Unknown	232	750	23	9/3/62	727
8.1d	Crete (V)	265	720	50	12/8/61	670
11.7b	Phil J. Hantab	100	720	48	9/11/62	672
12.3h	Robert Grigsby	100	710.80	57.60	9/11/62	653.20
16.7e	Arden Co.	265	730	46	3/23/62	684
19.4d	Richard Braun	60	756	34.45	11/28/62	721.55
20.1d2	Balmoral Heights	240	762	53.15	10/12/62	708.85
20.3f	Unknown	300	760	40	9/3/62	720
21.6b	Balmoral Jockey Club	379	755	36	3/23/62	719
22.8b	Milwaukee RR	60	723	9.65	11/28/62	713.35
24.7g	Sun Valley Sports Club	203	692	21	10/60	671
30.4b	Martin Koelling	100	773	54.30	11/28/62	718.70
32.4e	Harry Nilles	140	747	33	11/28/62	714
33.6h	Township Pub. Util. Co.	526	740	50	1/24/62	690
34N15E–						
6.5g	R. O. Echterling	160	665	38	1/62	627
COK—						
35N13E–						
1.2c2	Flossmoor (V)	467	682	138	9/21/61	544
2.3a	Flossmoor (V)	505	706	48	7/2/62	658
3.4b	Country Club Hills	382	731	85	1/29/62	646
8.2h	Ray Sickman	100	698	28.40	10/10/62	669.60
9.1c	Gustav Meyer	113	702	32.20	10/10/62	669.80
10.4h	H. and E. Sod Nursery	212	730	43	8/30/61	687
12.3b	Flossmoor (V)	250	655	36	7/18/61	619
12.8f	Flossmoor (V)	501	680	24	9/21/61	656
13.5h	Olympia Fields CCb.	332	668	55	10/11/61	613
14.6a	Olympia Fields (V)	270	712	47	10/3/61	665
14.6f	Rich Township H. S.	303	710	48	3/26/62	662
16.1f	Frieda Krumwiede	81	701	26.10	10/10/62	674.90
20.6e	Thomas Pleckham	110	713	28.80	10/8/62	684.20
21.7h	Pacesetter Homes Inc.	303	711	25	5/1/61	686
22.3b	Charles Barr	137	697	17	11/15/61	680
24.1h	Cull's Nursery	85	691	64.50	4/24/62	628
25.1g	Park Forest (V)	345	706	80	6/5/62	626
25.3f	Park Forest (V)	350	712	72	6/5/62	640
25.5c	Park Forest (V)	361	714	53	6/5/62	661
25.6f	Park Forest (V)	300	710	43	6/5/62	667
26.5h	Matteson (V)	282	709	35	10/3/61	674
26.8f	Matteson (V)	305	702	34	10/3/61	668
28.2a	Marvin Blume	100	728	37	10/5/62	691
28.8e	Elmer Dahlman	137	720	37	10/5/62	683
32.4h	Henry Bohlman	110	727	45	10/5/62	682
35.6e	Richton Park (V)	614	735	39	4/4/61	696
35.7b	Harry Reichert	137	730	38.60	10/8/62	691.40
36.1a	Forest Pres. Dist. of Cook Co.	600	712.5	58.93	8/14/62	653.6
36.3h	Park Forest (V)	345	715	61	10/16/61	654
35N14E–						
3.1a	W. Bakker	120	618.50	15.40		603.10
4.5d1	Glenwood Schl./Boys	130	617	20	9/16/61	597
4.5d3	Glenwood Schl./Boys	198	615	18	9/16/61	597
4.8e	Glenwood Manor	455	625	13	8/31/61	612
5.2e	Glenwood (V)	426	629	19	9/4/62	610
5.5h1	Homewood (V)	250	630	28	10/4/61	602
5.5h2	Homewood (V)	250	630	35	10/4/61	595
6.2b	Idlewild CCb.	320	645	60	10/17/61	585

Table 29 (Continued)

Well number	Owner	Depth (ft)	Land surface elevation (ft above MSL)	Depth to water (ft)	Date measured	Water level elevation (ft above MSL)
35N14E—(Cont'd)						
6.7d	Flossmoor (V)	351	665	46	9/21/61	619
7.1a	Ray Stelter	100	661	36	4/26/62	625
7.3e2	Nelson's Garden & Gift Shop		661	34	4/26/62	627
7.4h	Idlewild CCb.	90	644	27	10/17/61	617
7.8d	Flossmoor CCb.	402	652	60	10/11/61	592
8.1b	Olympia Greenhouse	100	634	6.80	4/23/62	627
8.1e	Brookwood Schl. Playground	51	632	10.30	4/23/62	622
9.5g	N. Illinois Gas Co.	220	630	15	2/21/63	615
9.8g	Holm's Greenhouse	85	631	10	4/16/62	621
10.5d	Glenwood CCb.	225	630	5	4/2/62	625
10.6e	Glenwood CCb.	269	626	10	4/2/62	616
11.2h	Harry De Bruin	65	610	14.60	6/15/62	595.40
12.3h	Paul Samash	200	613	20.70	6/28/62	592.30
12.8a	Anthony Garibaldi	129	645	26.17	10/16/62	619
13.5d	Manual Garcia	90	634	11.88	10/16/62	622.12
14.3d	Joe Jrevino	90	635	13.77	10/16/62	621
15.1e	Sora Rietveld	100	628.50	14.25	10/16/62	614.25
15.7a	Certainteed Prod. Corp.	440	636	65	3/8/62	571
15.8a2	Certainteed Prod. Corp.	240	638	90	8/31/61	548
16.2a	Victor Chemical	433	642	49	8/31/62	593
16.2f	Dawes Lab	250	632.5	6.35	5/21/62	626
17.6a1	Chicago Heights (C)	251	653	62	4/5/60	591
17.6a2	Chicago Heights (C)	203	652	62	4/5/60	590
18.2f	Edward Spaulding	60	659	44.80	4/24/62	614
18.3a	Chicago Heights CCb.	130	687	67	1960	620
19.2e	Chicago Heights (C)	260	672	60	5/3/61	612
19.4a	Chicago Heights (C)	450	682	56	10/3/61	626
19.4c	Chicago Heights (C)	270	677	53	9/29/61	624
20.4d	Chicago Heights (C)	427	643	42	3/11/61	601
21.1h1	Victor Chemical	252	639	50.80	8/31/61	588
21.2h1	Victor Chemical	433	642	45.60	8/31/61	596
21.3a3	Flintkote Co.	300	665	113	3/10/61	552
21.6f	Tile-Tex Div.	418	650	142	9/61	508
21.7e15	Chicago Heights (C)	450	657	150	9/21/61	507
22.8h1	Victor Chemical	250	642	45.60	8/31/61	596
23.6e	E. Chicago Heights (V)	510	668	17.3	4/19/62	651
24.1g	Mr. Sikma	125	632.70	12.20	9/17/62	620.50
25.3c	Indian Hills Util. Co.	470	652	24	6/14/61	628
25.4c	Indian Hills Util. Co.	474	652	25	6/14/61	627
26.5a	Charles O'Banion	103	657	10.50	5/24/62	647
27.4a	Mr. Milles		665	11	5/24/62	654
28.2c2	Triem Steel & Proc. Co.	475	695	80	2/21/63	615
28.6h	Ihland Steel Co.	426	687	199	2/6/62	488
28.8h1	Chicago Heights (C)	1800	677	185	9/29/61	492
29.5g1	Chicago Heights (C)	439	692	80	9/21/61	612
29.5g2	Chicago Heights (C)	436	688	72	11/13/61	616
29.6e2	Alco Products	222	708.5	92.73	8/14/62	616
29.6f2	Alco Products	248	704	87	8/6/62	617
30.1h	Chicago Heights (C)	413	684	59	9/29/61	625
30.7f	Park Forest (V)	300	702	87.7	5/21/62	614
32.2a1	Amer. Legion Post #521	205	704	49	3/27/62	655
34.6d	Frank Kozuch	108	680	18	5/24/62	662
35.6d	Paul Pankonien	122	678	24	5/25/62	654
35N15E–						
18.5d	Peter Jomgsma	80	631	10.56	10/16/62	620.44
30.4h	Lakewood Club	200	632	3	1/22/62	629
31.8f	Richard Abel	120	650	26.80	8/13/62	623
36N13E–						
26.8e	Country Club Hills	375	671	67	1/29/62	604
34.5e	Country Club Hills	387	681	21	1/29/62	660
34.7b	Country Club Hills	375	711	55	1/29/62	656
36.2h	Homewood (V)	455	655.30	32.95	1/19/62	622
36.8b	Homewood (V)	275	676	28.9	10/4/61	647
36N14E–						
30.7a	Calumet CCb.	500	647	33	5/18/62	614
30.8b	Calumet CCb.	412	642	29.87	10/4/61	612
31.4h	Surmas Restaurant	146	627	16.8	10/4/61	610
31.5d3	Homewood (V)	421	655	45	3/13/62	610
31.5h2	Homewood (V)	300	640	33.62	10/4/61	606
31.8d	Ravisloe CCb.	420	651	40	10/4/61	611
34.5h2	Thornton (V)	250	625	142	8/31/61	483

precipitation, the hydrographs show no permanent decline in water levels that cannot be explained by pumpage increases and short-term dry periods. The relation between water-level decline and pumpage suggests that recharge has balanced discharge in the past.

If pumpage is held constant, water levels will decline at a decreasing rate and eventually will stabilize at a stage lower than the stage measured prior to development. Water levels will fluctuate below and above this stage in response to below- and above-normal precipitation. Water will be taken from storage within the aquifer, and water levels will decline during periods of below-normal precipitation; storage of water will increase, and water levels will rise during periods of normal and above-normal precipitation.

Configuration of Piezomefric Surface of Aquifer

In order to determine the areas of recharge and discharge, and the directions of ground-water movement in the Silurian dolomite aquifer, a piezometric surface map was made (figure 105). Data on nonpumping levels in table 29 were used to prepare the map. The piezometric surface map represents the elevation to which water will rise in a well completed in the Silurian dolomite aquifer, and does not usually coincide with the position of the water table in shallow glacial-drift deposits.

As shown in figure 105, ground water in the Chicago Heights area moves in all directions from topographic uplands toward streams and well fields. Heavy concentration of pumpage from wells has produced cones of depressions in many parts of the Chicago Heights area. The piezometric surface map shows well-defined cones of depression at Chicago Heights and Flossmoor, and in the vicinity of the industrial complex northeast of Chicago Heights.

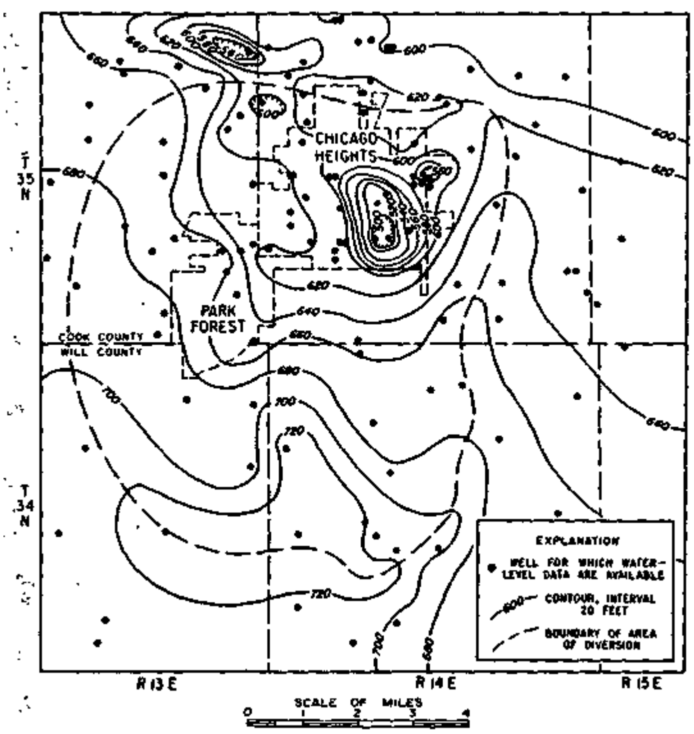

Figure 105. Piexometric surface of Wurian dolomite aquifer in Chicago Heights area, 1961-1962

Flow lines were drawn at right angles to the piezometric surface contours to define the area of diversion in the vicinity of Chicago Heights. The area of diversion as measured from figure 105 is about 60 square miles.

The piezometric surface map of the Silurian dolomite aquifer was compared with water-level data for the period prior to development, and water-level changes were computed. The greatest declines in the piezometric surface occurred in the immediate vicinity of Chicago Heights, and averaged about 100 feet.

The average slope of the piezometric surface in areas unaffected by pumpage is about 15 feet per mile. Gradients are much steeper and exceed 100 feet per mile near and within cones of depression.

Recharge to Aquifer

Recharge to the Silurian dolomite aquifer occurs locally, mosdy as vertical leakage of water through unconsolidated deposits, and has precipitation as its source. A large proportion of precipitation runs off to streams or is discharged into the atmosphere by evapotranspiration without reaching the aquifer. Some precipitation reaches the water table and becomes ground water. Part of the water stored temporarily in shallow deposits moves downward through the glacial drift and then into the Silurian dolomite aquifer.

The rate of recharge to the aquifer was estimated using the piezometric surface map and past records of pumpage and water levels. The area of diversion of pumping was delineated as explained earlier and is shown in figure 105; pumpage data are given in figure 94. Because recharge balances discharge, the average rate of recharge to the aquifer during 1961-1962 is the quotient of the average pumping rate and the area of diversion. Computations with data from figures 105 and 94 show that the average recharge rate to the Silurian dolomite aquifer in the Chicago Heights area was about 225,000 gpd/sq mi.

The aquifer is not recharged entirely by the direct percolation of precipitation to the water table. Some recharge to the aquifer by induced infiltration of surface water occurs because the piezometric surface is below stream levels and the stream beds have some permeability. In some cases the streams lie directly on the aquifer where bedrock outcrops east of Chicago Heights (see figure 91).

Darcy's equation indicates that the recharge rate varies with the vertical head loss (Δh) associated with leakage of water through materials. The average vertical head loss in 1961-62 was computed to be about 25 feet by comparing the piezometric surface map for the Silurian dolomite aquifer with water-level data for shallow deposits. The average recharge rate taking into accoung| head loss is about 9000 gpd/sq mi/ft.

Table 30. Specific-Capacity Data for Dolomite Wells in Chicago Heights Area

Well number	Owner	Depth (ft)	Diam. (in)	Penetration (ft)	Year drilled	Year of test	Length of test (hr)	Nonpumping level (ft)	Pumping rate (gpm)	Drawdown (ft)	Unadjusted: Specific capacity (gpm/ft)	Unadjusted: Specific capacity per foot of penetration (gpm/ft²)	Adjusted: Specific capacity (gpm/ft)	Adjusted: Specific capacity per foot of penetration (gpm/ft²)	Coefficient of transmissibility (gpd/ft)
WIL—															
34N13E-															
9.2a	Cardox Corp.	408	17	277	1945	1945	—	59	195	43	4 53	0.016	6.25	0.022	10,000
14.3f	Mall Airport	412	6	265	1957	1957	—	70	70	11	6.36	0.024	7.05	0.027	12,000
17	A. DeMuth	250	10	121	1958	1958	1	50	200	8	25.00	0.205	25.50	0.210	42,000
21.5d	Monee (V)	157	10	67	1913	1946	1	75	140	10	14 00	0.209	16.40	0.245	29,000
21.7c	Monee (V)	490	20	356	1960	1960	8	80	600	15	40.00	0.112	80.60	0.220	162,000
30	J. Koenig	200	8	120	1960	1960	—	28	80	22	3.64	0 030	4.12	0.034	6,500
34N14E-															
5.3h1	Steger (V)	318	12	171	1910	1946	2	43	350	4	87.66	0 513	118.00	0 691	240,000
5.3h2	Steger (V)	325	12	215	1935	1946	2	45	400	4	100.00	0.463	138.00	0.642	290,000
5.3h2	Steger (V)	325	12	215	1935	1942	1	31	300	2.5	120.00	0.560	150.00	0.698	310,000
7 6a	Meadwood Elem. Schl.	200	6	100	1960	1960	3.5	33	50	11	4.54	0 045	4.88	0.048	8,000
8 1a	Crete (V)	195	10	45	1903	1945	1	48	123	5	24.60	0.547	27.80	0.620	50,000
8 5h	Crete (V)	263	12	162	1955	1955	—	40	300	16	18.80	0.115	26 90	0.166	49,000
20.1d	Balmoral Heights Sbd.	246	6	140	1956	1956	8	50	60	40	1.50	0.011	1.68	0.012	2,500
20.4e	Balmoral Elem. Schl.	202	6	—	—	1960	4	33	100	20	5.00	—	6.25	—	12,500
21.6b	Lincoln Fields	379	16	—	1953	1953	1	32	508	10	50 80	—	86 20	—	172,000
24 8d	Sun Valley Sports Club	203	6	91	1960	1960	—	21	60	3	20.00	0.250	21.30	0.234	39,000
33.6b	Township Pub. Util.	526	14	404	—	1962	15	50	980	10	98.00	0 250	122.00	0.302	244,000
COK—															
35N13E-															
1.2a (1)	Flossmoor (V)	275	10	190	1939	1940.	—	47	300	38	7.90	0.042	11.50	0.061	23,000
1.2a (1)	Flossmoor (V)	275	10	190	1939	1945	.25	90	300	20	15.00	0.079	18.80	0.100	38,000
1.2c (3)	Flossmoor (V)	467	16	379	1941	1941	8	64	250	38	6.60	0.017	8.30	0 022	17,000
2 3a (6)	Flossmoor (V)	505	18-15	412	1962	1962	1	48	410	175	2.34	0.006	4.50	0 011	9,000
3 4b (4)	Country Club Hills	382	12	289	—	—	—	60	500	32	15.63	0.054	45.50	0.157	91,000
12.3b	Flossmoor (V)	250	12	207	1952	1952	—	7	544	52	10.45	0.051	36.30	0 175	73,000
12 4d	A Hrush	470	—	—	1923	—	—	30	75	195	0.38	—	1.00	—	2,000
12.8f (5)	Flossmoor (V)	500	11	408	1956	1956	7	40	450	47	9.57	0.023	18.00	0.044	36,000
13 (1)	Olympia Fields CCb.	370	10	—	—	—	—	18	500	3	167.00	—	207.00	—	414,000
13.7c (2)	Olympia Fields CCb.	187	15	—	1925	1925	—	1.5	650	7	93.00	—	116.00	—	232,000
14.6a (2)	Olympia Fields (V)	270	12	177	1958	1958	8	42	560	31	18.15	0.102	62.30	0.352	125,000
14.6f (2)	Rich Township H. S.	303	—	—	1960	1960	6	46	748	7 41	10 55	—	13.20	—	26,000
21.7h (1)	Glenridge Sbd.	303	16-12	218	—	1961	7.5	25	600	52	11.53	0.053	43.00	0.197	86,000
23 1h (1)	Olympia Fields (V)	169	10	—	1956	1956	4	17	380	4	95.00	—	210.00	—	420,000
23 2c (1)	Park Forest (V)	463	12	370	1950	1950	2.5	31	480	16	30.00	0.081	160 00	0.433	320,000
23.2c	Park Forest (V)	463	12	370	—	1950	—	33	500	15	33.30	0.090	166 00	0.450	332,000
25.1e (5)	Park Forest (V)	345	24-17	244	1953	1953	23	50	575	5	115.00	—	144.00	0.592	288,000
25.1g (6)	Park Forest (V)	361	16	—	1958	1958	7	46	1050	95	11.08	—	13.80	—	27,000
25.5f (3)	Park Forest (V)	350	24-16	133	1948	1948	15	41	645	19	33.90	0.146	42.00	0.316	84,000
25.5f (4)	Park Forest (V)	300	12	237	1952	1952	24	39	595	46	12.95	0 055	74.50	0.315	149,000
26.5h (1)	Matteson (V)	282	10	—	1914	1914	14	8	200	8	25.00	—	33.30	—	67,000
26.8f (2)	Matteson (V)	305	12	213	1956	1956	10	20	650	25	26 00	0.122	162.00	0.762	324,000
26.8f (2)	Matteson (V)	305	12	213	1956	1958	—	33	580	16	36 20	0 170	45 30	0 213	91,000
29.3d	Pub. Serv. Co. of N. Ill.	158	8	78	1948	1948	.75	27	71	2	35 50	0.456	38.50	0.494	77,000
29.3d	Pub. Serv Co. of N. Ill.	156	8	71	1948	1948	4	26	313	8.4	37.30	0.525	51.30	0.723	103,000
30.7f (2)	Park Forest (V)	300	15	203	1947	1947	3	57.5	1025	10	102 50	0.505	128.00	0 630	256,000
35.6e (1)	Richton Park	614	10	—	—	1961	2.5	39	250	8	3.13	—	3.90	—	7,800
36.1a	Indian Wood CCb.	300	12	227	1929	1929	10	10	250	20	12.50	0.055	18 50	0.082	37,000
36.3h (4)	Park Forest (V)	345	12	237	1952	1952	24	39	595	46	12.95	0.055	54.00	0.227	108,000
35N14E-															
3	Glenwood (V)	150	6	103	1946	1946	3	18	35	5	7 00	0.068	8.75	0.085	17,500
3.1g	Camp Thornton CCC	153	6	63	—	1939	—	14	25	11	2.28	0.036	2.85	0.045	5,800
4.8e (1)	Glenwood Manor	404	20-14	371	—	1961	3	12	160	106	1.51	0.004	1.90	0.005	3,800
4 8e (1)	Glenwood Manor	455	20-14	422	—	1961	6.75	12	175	185	1.06	0 003	1.20	0.003	2,400
5.2e (2)	Glenwood (V)	426	20-14	380	1962	1962	24	19	168	112	1.50	0.004	1.78	0.005	3,600
6 5b (2)	Flossmoor (V)	351	12-10	246	1928	1945	.25	40	420	20	21.00	0.085	38.50	0.156	77,000
6.2a (1)	Idlewild CCb.	277	8	—	1934	1960	1.5	25	243	58	4.20	—	5.00	—	10,000
6 2b (2)	Idlewild CCb	320	12	270	1960	1960	9 75	28	686	59	11.60	0.043	76.50	0.283	144,000
6.7h (2)	Homewood (V)	436	21	256	1945	1945	.25	35	350	242	1.45	0.006	1.80	0.007	3,600
7.5c	Flossmoor CCb.	280	12	230	1952	1952	—	12	280	6	46.70	0.203	90.50	0.393	181,000
7 5c	Flossmoor CCb.	280	12	230	1952	1952	3	12	517	20	25.80	0.112	101 00	0.440	202,000
9 6g	N. Ill. Gas Co.	220	12	182	1959	1959	1	10	160	11	14.55	0.080	18.20	0.100	36,000
9.6g	N. Ill. Gas Co.	220	12	182	1959	1959	1	10	350	34	10.30	0 057	19.50	0.107	40,000
15 8a1	Gold Seal Asphalt Co.	240	8	205	1946	1946	—	32	130	60	2.17	0.011	2.37	0.012	5,000
15 8a1 (3)	Gold Seal Asphalt Co.	240	8	205	1946	1946	—	32	30	—	—	—	—	—	—
15 8a1 (3)	Gold Seal Asphalt Co.	240	8	205	1946	1946	2	32	155	8	19.40	0.095	24.30	0.118	49,000
15.8a2	Gold Seal Asphalt Co.	309	8	246	1937	1946	—	63	130	56.5	2.30	0.009	2.88	0.011	6,000
15.8a2 (1)	Gold Seal Asphalt Co.	309	8	246	1937	1946	2	63	155	35	4.44	0.018	5.55	0.023	11,000
15.8a2	Gold Seal Asphalt Co.	309	8	241	1937	1947	2	68	73	13	5.61	0.023	9.12	0.038	18,000
15.8a2	Gold Seal Asphalt Co.	309	8	254	1937	1940	—	55	135	20	6.75	0.027	19.30	0 076	39,000
15.8a2	Gold Seal Asphalt Co.	309	8	254	1937	1940	—	55	170	25	6.82	0.027	8.50	0.034	17,000
15 8a2	Gold Seal Asphalt Co.	309	8	254	1937	1937	—	—	185	47	3.94	0.016	4.93	0.020	10,000
15.8a2	Gold Seal Asphalt Co.	309	8	269	1937	1955	—	40	82	56	1.46	0.005	2.16	0.008	4,000
15.8a2	Gold Seal Asphalt Co.	309	8	—	1937	1953	—	—	25	—	—	—	—	—	—
15.8a2	Gold Seal Asphalt Co.	309	8	243	1937	1953	—	66	120	24	5.00	0.021	20.00	0.084	40,000
15.8a3	Gold Seal Asphalt Co.	425	8	—	1953	1953	—	38	118	75	1.57	—	1.96	—	3,900
15.8a3	Gold Seal Asphalt Co.	425	8	—	1953	1955	—	40	375	160	2.34	—	2 93	—	6,000
15.8h	Gold Seal Asphalt Co.	205	8	170	1941	1946	2.5	25	92	87	1.06	0.006	12.25	0.722	25,000
15 8h	Gold Seal Asphalt Co.	205	8	165	1941	1946	13	40	222	75	2.96	0 018	3.70	0 023	7,000
15.8h	Gold Seal Asphalt Co.	205	8	133	1941	1953	—	72	120	16	7.50	0.056	24.00	0.117	48,000
15.7a	Certainteed Prod.	440	14-10	—	1962	1962	2	65	250	71	3.53	—	4.42	—	8,800
16 2a	Victor Chemical Co.	275	15	238	1941	1941	2.25	36.5	147	111	1 32	0.006	1.65	0.008	3,000
16.2a	Victor Chemical Co.	433	15	395	1941	1941	.75	37	145	275	0.53	0.001	0.66	0.002	1,000
16.2a	Victor Chemical Co.	433	15	395	1941	1947	24	37	130	178	0.73	0.002	1.05	0.003	2,000
16 2f	Alcoa Prod. Inc.	250	15	212	1957	1957	24	9	544	30	18.15	0.086	22.50	0.116	45,000
17	Chicago Heights (C)	330	—	228	—	1946	—	20	400	17	23.50	0.103	28.50	0 125	57,000
17 6a1 (18)	Chicago Heights (C)	251	24	196	1941	1941	—	—	1650	39	42.40	0.216	53.10	0.270	106,000
17.6a2 (21)	Chicago Heights (C)	203	23	145	1945	1945	14	22.0	1680	45.5	37.00	0.255	46.40	0.320	93,000
17.6a2 (21)	Chicago Heights (C)	203	23	145	1945	1948	0.3	26	1440	40	36.00	0.248	45.00	0.310	90,000
19.2e (23)	Chicago Heights (C)	260	23	202	1946	1956	—	33.5	1800	55	32.80	0.163	41.00	0.199	82,000

Table 30 (Continued)

Well number	Owner	Depth (ft)	Diam. (in)	Penetration (ft)	Year drilled	Year of test	Length of test (hr)	Non-pumping level (ft)	Pumping rate (gpm)	Drawdown (ft)	Unadjusted		Adjusted		Coefficient of transmissibility (gpd/ft)
											Specific capacity (gpm/ft)	Specific capacity per foot of penetration (gpm/ft²)	Specific capacity (gpm/ft)	Specific capacity per foot of penetration (gpm/ft²)	
COK—															
35N14E-(Cont'd)															
19.2e(23)	Chicago Heights (C)	260	23	202	1946	1946	23	33.5	1270	28	45.50	0.225	57.00	0.282	114,000
19.4c (22)	Chicago Heights (C)	270	23	190	1946	1946	1	26	1500	46	32.60	0.175	40.80	0.215	81,000
19.4a (25)	Chicago Heights (C)	450	24	168	1958	1959	1.5	50	1900	35	54.30	0.324	67.80	0.405	135,000
20	Lincoln-Dixie Theater	210	—	182	1938	1938	—	84	100	80	1.25	0.009	1.55	0.011	31,000
20	Lincoln-Dixie Theater	330	—	302	1938	1938	—	84	150	80	1.87	0.008	2.52	0.010	50,000
20	Lincoln-Dixie Theater	330	—	302	1938	1938	—	84	198	196	1.01	0.004	1.69	0.007	34,000
20.4d (27)	Chicago Heights (C)	427	30-24	365	1961	1961	8	42	580	202	2.87	0.008	3.60	0.010	7,200
21.7b	Diamond-Braiding Mills	200	12	—	1936	1936	—	110	440	14	31.40	—	—	—	—
21.7e15 (15)	Chicago Heights (C)	193	24	105	1917	1947	5	88	1000	27	37.10	0.353	46.30	0.453	93,000
21.1h (4)	Victor Chemical Co.	252	10	115	1945	1947	5	52	350	59	5.94	0.052	11.50	0.100	23,000
21.1h1 (6)	Victor Chemical Co.	250	10	213	1955	1955	—	102	70	78	0.90	0.006	5.38	0.036	11,000
21.1h1 (6)	Victor Chemical Co.	250	10	213	1955	1955	—	108	60	62	0.97	0.007	3.92	0 028	8,000
21.1h2 (7)	Victor Chemical Co.	—	—	—	1955	1955	—	110	130	60	2.17	—	—	—	—
21.2h (1)	Victor Chemical Co.	400	10	40	1909	1921	—	35	340	100	3.40	0.085	5.90	0.147	12,000
21.2h (1)	Victor Chemical Co.	400	10	40	1909	1923	—	70	300	135	2.22	0.056	4.45	0.111	9,000
21.2h (1)	Victor Chemical Co.	400	10	40	1909	1929	—	79	300	105	2.86	0.069	5.50	0.137	11,000
21.2h (1)	Victor Chemical Co.	400	10	40	1909	1930	—	79	105	260	0.40	0.010	0.56	0.014	1,200
21.2h (1)	Victor Chemical Co.	400	10	40	1909	1945	—	70	120	240	0.50	0.012	0.69	0.017	1,400
21.2h (1)	Victor Chemical Co.	400	10	40	1909	1945	—	40	100	—	—	—	—	—	—
21.2h (1)	Victor Chemical Co.	400	10	40	1909	1945	—	35	58	—	—	—	—	—	—
21.2h (1)	Victor Chemical Co.	400	10	40	1909	1945	—	35	123	—	—	—	—	—	—
21.2h (1)	Victor Chemical Co.	400	10	40	1909	1946	—	36	350	224	1.56	0.039	4.50	0.112	9,000
21.4a (3)	Flintkote Co.	300	18	274	1946	1946	4	106	325	100	3.25	0.017	4.07	0.015	8,100
21.4a (3)	Flintkote Co.	300	18	274	1946	1946	2	111	210	47	4.47	0.016	5.60	0.020	11,200
21.7e	Tile Tex Div.	416	17.3	306	1951	1951	2.8	58	510	19	26.80	0.088	35.60	0.116	71,000
22	Penn. Salt Mfg. Co.	215	16	193	1954	1954	3.5	6	88	26	3.39	0.018	3.46	0.018	7,000
22.8h (5)	Victor Chemical Co.	250	15	201	1956	1956	12	49	520	111	4.68	0.023	17.35	0.087	34,700
22.8h2 (10)	Victor Chemical Co.	250	15	155	1956	1956	—	95	500	65	7.70	0.050	20.50	0.132	41,000
22.8h3 (8)	Victor Chemical Co.	—	—	—	1955	1955	—	97	250	15	16.65	—	20.80	—	41,000
23.4b	E. Chicago Heights	499	16	419	1958	1958	6	5	135	82	1.65	0.004	2.05	0.005	4,100
23.4b	E. Chicago Heights	499	16	419	1958	1958	96	5	130	78	1.67	0.004	2.06	0.005	4,100
23.5a	E. Chicago Heights	510	12	452	1953	1953	2	13	110	67	1.65	0.004	2.00	0.004	4,000
23.5b	E. Chicago Heights	499	16	419	1958	1958	24	5	126	78	1.62	0.004	1.90	0 005	3,800
23.6e	E. Chicago Heights	510	12	453	1953	1953	—	13	200	187	1.07	0.002	1.34	0 003	2,700
25.3c	Sauk Village	474	12	396	1959	1959	11	27	1016	11	92.40	0.233	116.00	0.294	232,000
28	Inland Steel Co.	425	15	302	1953	1953	—	120	400	80	5.00	0.017	11.22	0.037	22,400
28.1g (24)	Chicago Heights (C)	450	19	383	1958	1960	3	15	500	181	2.76	0.007	33.00	0.009	66,000
28.1g (24)	Chicago Heights (C)	450	19	168	1958	1958	20	13	435	148	2.94	0.018	35.00	0.021	70,000
28.5h	Inland Steel Co.	332	8	132	1900	1900	—	—	450	48	9.38	0.071	20.00	0.151	40,000
28.5h	Inland Steel Co.	332	8	132	1900	1945	—	—	125	—	—	—	—	—	—
28.5h	Inland Steel Co.	332	8	132	1900	1945	—	—	183	—	—	—	—	—	—
28.5h	Inland Steel Co.	332	8	132	1900	1945	—	—	220	—	—	—	—	—	—
28.2c2 (2)	Triem Steel Prod. Co.	475	12-10	375	—	1961	4	32	155	184	0.84	0.002	0.92	0.002	1,800
29.5g1 (26)	Chicago Heights (C)	450	23	161	1960	1960	1.3	59	1500	21	71.50	0.445	89.50	0.556	180,000
29.5g1 (26)	Chicago Heights (C)	450	23	161	1960	1960	6	59	2000	33	60.60	0.376	76.00	0.473	152,000
29.5g1 (26)	Chicago Heights (C)	450	23	161	1960	1960	2.5	59	2000	31	64.60	0.400	81.00	0 503	162,000
29.1c	S. Chicago Heights	250	12	168	1956	1956	3	82	500	66	7.58	0.045	9.50	0.057	19,000
29.5e (1)	American Locomotive	222	10	160	1910	1945	—	—	300	—	—	—	—	—	—
29.5e (1)	American Locomotive	222	10	160	1910	1945	—	63	600	—	—	—	—	—	—
29.6e (3)	American Locomotive	222	12.3	174	1942	1942	3	56	690	0.2	3450.00	20.700	3470.00	20.900	—
29.6e (3)	American Locomotive	222	12.3	174	1942	1942	16.5	56	900	1.0	900.00	5.420	3210.00	19.350	—
29.6e (3)	American Locomotive	222	12.3	174	1942	1942	24	56	1150	2.1	549.00	3.300	3200 00	19.300	—
29.6f2 (6)	Alcoa Prod.	248	18-14	177	1959	1962	2.5	87	860	8	108.00	0.610	135.00	0.764	280,000
29.7f (3)	Alcoa Prod.	248	12	175	1959	1959	24	74	1000	1.0	1000.00	5.750	1250.00	7.150	—
30.1h (28)	Chicago Heights (C)	413	30-24	341	1961	1961	23.5	53	760	172	4.42	0.013	5.56	0.016	11,200
32.1a	Ex-Servicemen's Club	205	8	116	1953	1953	—	45	75	45	1.67	0.014	1.80	0.015	3,600
35N15E-															
20.6d	J. De Chico	304	8	211	1955	1955	4	9.5	220	26	8.45	0.040	10.00	0.047	20,000
30.4b (1)	McKesha Lakewood Club	200	8	114	—	1962	16	3	200	10	20.00	0.175	25.00	0.219	50,000
36N13E-															
22	Sherry Builders	455	16	371	1959	1959	1.5	27	350	118	2.97	0.008	5.85	0.016	11,800
22.6b	Willowick Estates	455	15	371	1959	1959	5	22	350	125	2.81	0.008	5.25	0.014	10,000
34.5e	Country Club Hills	387	12	304	1957	1957	10	14	700	40	17.50	0.058	21.90	0.072	43,800
34.7b	Country Club Hills	373	12	263	1956	1956	4	45	270	95	2.84	0.011	3.98	0.015	8,000
36N14E-															
19.5e	Coca-Cola Bottling Co.	280	15	216	1960	1960	7	50	140	110	1.27	0.006	1.55	0.007	3,100
23.2a	State Div. of Hwys.	250	6	152	1957	1957	24	36	14	36	0.39	0.003	0.50	0.003	1,000
30.7a	Calumet CCb.	500	12	418	1962	1962	5	39	300	172	1.75	0.004	2.30	0.006	4,600
31.5d (1)	Homewood (V)	252	10	182	1911	1946	72	77	285	39	7.32	0 040	9.17	0 050	18,400
31.5d (1)	Homewood (V)	252	10	182	1911	1923	1	26	170	22	7.74	0.042	9.00	0.050	18,000
31.5d (1)	Homewood (V)	252	10	182	1911	1945	—	34	245	134	1.80	0.010	2.20	0.012	4,400
31.5d (1)	Homewood (V)	252	10	182	1911	1943	—	34	345	120	28.75	0.158	30.00	0.165	60,000
31.5d3 (9)	Homewood (V)	421	24	348	1962	1962	9	45	490	85	5.78	0.017	7.25	0.021	14,600
31 (1-46)	Homewood (V)	460	6	351	—	1945	—	29	210	59	3.50	—	4.00	0.011	8.000
31.6h (3)	Homewood (V)	210	10	146	1922	1922	20	16	240	73	3.29	0.022	4.14	0.028	8,300
31.6h (3)	Homewood (V)	226	10	160	1946	1946	1.5	23	195	103	1.89	0.012	2.20	0.014	4,400
31.8d	Ravinsloe Golf Club	420	12	357	1953	1953	7	41	530	38	1.40	0.004	1.75	0.005	3,600
31.8d	Ravinsloe Golf Club	420	12	357	1953	1953	2	41	520	33	15.75	0.042	47.20	0.132	94,400
32	Washington Pk. Race Track	400	12	375	1946	1946	1	25	230	300	0.77	0.002	0.97	0.003	2,000
33.5f	Oak Lawn Cmty.	302	8	260	1946	1946	4	42	180	16	11.25	0.043	14.10	0.054	28,200
34.5d (1)	Thornton (V)	477	12	385	1923	1923	—	30	75	195	0.38	0.001	0.48	0.001	1,000
34.5d (1)	Thornton (V)	477	12	385	1923	1941	0.3	92	100	61	1.64	0.004	2.07	0.005	4,100
34.5h1 (2)	Thornton (V)	408	12	332	1928	1928	—	76	160	130	1.23	0.004	1.54	0.005	3,100
34.5h2 (3)	Thornton (V)	250	8	97	1943	1946	4	53	100	43	2.33	0.024	2.50	0.026	5,000
34.5h2 (3)	Thornton (V)	250	8	153	1943	1944	4	97	100	10	10.00	0.065	22.20	0.145	44,400
36.2h(1-46)	Homewood (V)	460	6	381	1940	1946	1	29	103	18	5.72	0.015	6.06	0.016	12,100
36N15E-															
23	Storage Bldg. Div. of Hwys.	250	—	—	1957	1957	24	36	14.4	38	0.38	—	—	—	—

Water-Yielding Properties of Silurian Dolomite Aquifer

Coefficient of Transmissibifity

During the period 1900-1962, well-production tests were made by water well contractors and the State Water Survey on more than 150 dolomite wells in the Chicago Heights area. The results of the tests are summarized in table 30. The lengths of tests range from 15 minutes to 96 hours and average 9 hours. Pumping rates range from 14 to 2000 gpm. Diameters of inner casings range from 6 to 30 inches, and the average radius of inner casings is about 0.5 foot.

Values of well loss were estimated for all wells based on data given by Csallany and Walton (1963). Well losses were subtracted from observed drawdowns, and specific capacities adjusted for well losses were computed. Rough estimates of the coefficient of transmissibility were made by substituting the adjusted specific capacity and individual well construction data from table 30 into the non-equilibrium formula.

Effects of Dewatering on *Yields* of *Dolomite Wells*

Because of the close spacing of wells and well fields and the heavy pumpage at Chicago Heights, extensive dewatering of upper portions of the Silurian dolomite aquifer has taken place. Thicknesses of dewatered dolomite were determined by comparing nonpumping levels in wells and the bedrock surface map, and are listed in table 31. A map showing thicknesses of dewatered dolomite was prepared with data for individual wells, the piezometric surface map,

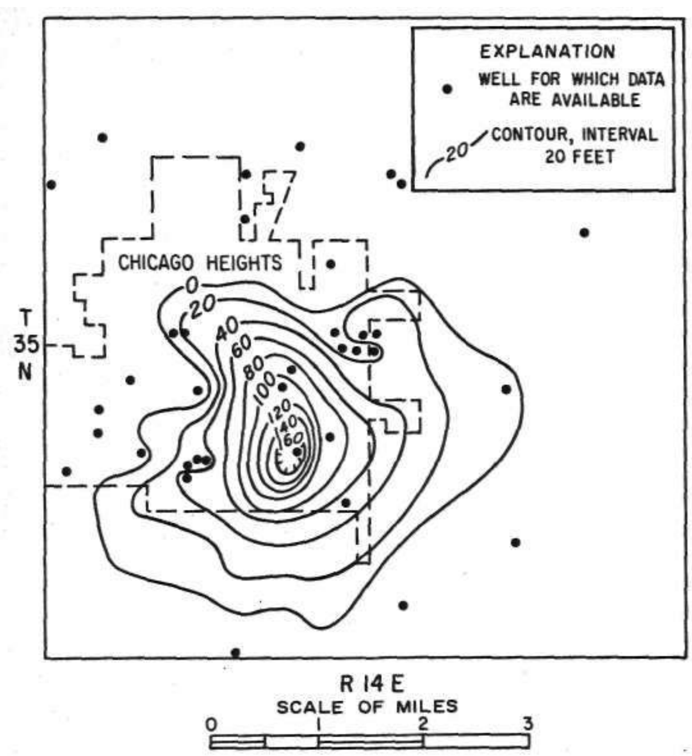

Figure 106. Thickness of dewatered Silurian dolomite aquifer at Chicago Heights

Table 31. Thickness of Dewatered Silurian **Dolomite** Aquifer at Chicago Heights

Well number	1962 . Nonpumping water level elevation (*ft above MSL)*	Elevation of bedrock surface (*ft above MSL)*	Thickness of dewatered dolomite at well site (*ft*)
COK— 35N14E-			
7.4h	617	606	none
8.1b	627	600	none
8.1e	622	606	none
9.5g	615	595	none
10.5d	625	605	none
10.6e	616	601	none
12.8a	619	613	none
15.7a	571	594	23
15.8a2	548	600	52
16.2a	593	604	11
16.2f	626	595	none
17.6al	591	611	20
17.6a2	590	611	21
19.2e	612	613	1
19.4a	626	606	**none**
19.4c	624	605	**none**
20.5d	601	592	**none**
21.1hl	588	600	12
21.2hl	596	604	8
21.3a3	552	640	88
21.6f	508	602	94
21.7el5	507	617	110
22.8hl	596	610	14
23.6e	651	667	16
26.5a	647	600	none
28.2c2	615	657	42
28.6h	488	662	174
29.5gl	612	**640**	28
29.5g2	616	648	32
29.6e2	616	666	50
29.6f2	617	642	25
30.1h	625	640	none
30.7f	614	605	none
32.2al	655	615	none
34.6d	662	630	none

and the bedrock topography map. As shown in figure 106 the area within which dewatering has taken place is about 9 square miles; the average thickness of dewatered dolomite is about 36 feet. The greatest thickness of dewatered dolomite is located around a group of wells owned by the Inland Steel Company and Chicago Heights, and exceeds 170 feet.

It has been shown by Walton and Neill (1963) and Zeizel et al. (1962) that the specific capacities per foot of penetration of dolomite wells decrease as the depths of wells increase, indicating that the upper part of the Silurian dolomite aquifer is much more productive than the lower part. To determine the magnitude of decreases in specific capacities of dolomite wells at Chicago Heights as the result of the dewatering of the uppermost productive portion of the Silurian dolomite aquifer, specific-capacity data for wells within and outside the area of dewatering were compared.

The total depths of penetration of wells into the dolomite were determined from well logs and are given in table 30. Adjusted specific capacities were divided by the total depth of penetration to obtain the adjusted specific capacities per foot of penetration in table 30.

Wells were segregated into two categories, depending upon whether they are located within or outside the area of dewatering shown in figure 106. Adjusted specific capacities per foot of penetration for wells in the two categories were tabulated in order of magnitude, and frequencies were computed by the Kimball (1946) method. Values of specific capacity per foot of penetration were then plotted against percent of wells on logarithmic probability paper as shown in figure 107.

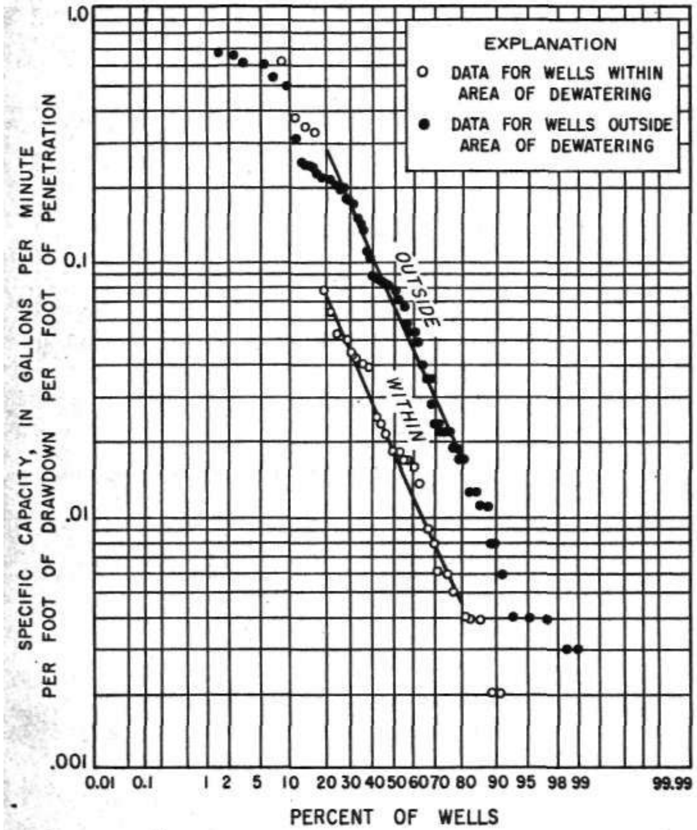

Figure 107. Specific-capacity frequency graphs for dolomite wells in Chicago Heights area

The frequency graphs indicate mat the specific capacities of wells within the area of dewatering are much less than the specific capacities of wells outside the area of dewatering. Based on the specific capacities with a frequency of 50 percent, it is estimated mat the specific capacities of wells within the area of dewatering have decreased an average of about 65 percent as the result of dewatering.

Specific-capacity data in table 30 indicate that the coefficient of transmissibility of the Silurian dolomite aquifer averages about 65,000 gpd/ft in areas where no dewatering of the dolomite has taken place; the coefficient of transmissibility in areas where extensive dewatering of the dolomite has taken place averages about 22,000 gpd/ft.

Gravity Yield of *Silurian Dolomite Aquifer*

Gravity yield (Rasmussen, and Andreasen, 1959) may be denned as the ratio of the volume of water mat deposits will yield by gravity drainage to the total volume of deposits drained during a given period of ground-water decline. The gravity yield of the upper portions of the Silurian dolomite aquifer can be estimated with data concerning dewatering at Chicago Heights.

A ground-water budget was prepared for the dewatered area at Chicago Heights. For a given period of time, pumpage is balanced by precipitation reaching the dolomite (ground-water recharge), subsurface flow of ground water into the area (underflow), and decrease in ground-water storage. This balance expresses a ground-water budget and may be stated as the following equation:

$$Q = R_g + U + \Delta S_g \tag{15}$$

where:

Q = pumpage, in cu ft
R_g = ground-water recharge, in cu ft
U = underflow, in cu ft
ΔS_g = decrease in ground-water storage, in cu ft

The average thickness of dolomite dewatered during an inventory period, AH, multiplied by the dewatered area, *Ad*, and the gravity yield, Y_g, of the dewatered portion of the Silurian dolomite aquifer is equal to the decrease in ground-water storage. Stated as an equation:

$$\Delta S_g = \Delta H\, A_d\, Y_g \tag{16}$$

where:

ASg = decrease in ground-water storage, in cu ft
AH = average thickness of dolomite dewatered, in ft
Ad = dewatered area, in sq ft
Yg = gravity yield, fraction

Figure 106 indicates that AH is 36 feet and A_d is 2.46 x 10^8 sq ft. A study of water-level data for wells within the area of dewatering shows that most of the dewatering occurred during the period 1950 to 1962. The inventory period selected for the ground-water budget was therefore 1950 to 1962.

The volume of water pumped from 1950 to 1962, *Q*, was about 7.8 x 10^8 cu ft, according to pumpage records. Based on estimated coefficients of transmissibility, hydraulic gradients of the piezometric surface in die vicinity of Chicago Heights, and Darcy's law, underflow was computed to be about 4.4 x 10^8 cu ft. Assuming an average recharge rate of 225,000 gpd/sq mi, ground-water recharge was estimated to be about 7.2 x 10^7 cu ft. Substitution of the above data into equation 15 results in the conclusion that during the period 1950-1962 about 2.68 x 10^8 cu ft or 2 billion gallons were taken from storage widiin the Silurian dolomite aquifer to balance pumpage.

The gravity yield was computed to be about 0.03 by substituting the decrease in ground-water storage, ΔS_9, and other data given earlier on AH and A_d in equation 16. The computed gravity yield is valid for inventory periods of several years, and is much greater than the gravity yield which would be computed for short inventory periods of several days or months.

Vertical Permeability of **Confining** *Bed*

Based on Darcy's law the vertical permeability of materials overlying producing zones in the Silurian dolomite aquifer may be computed by multiplying the recharge rate per unit area per foot of head loss $(Q_c/\Delta hA_c)$ by the average saturated thickness, *m'*, of the confining bed. Based on available well logs, the average saturated thickness of the glacial drift confining bed within the area of diversion is about 35 feet. It is probable that beds in the upper part of the Silurian dolomite aquifer also retard vertical movement of water towards producing zones within the aquifer. A coefficient of vertical permeability of 0.011 was computed by multiplying the recharge rate per unit area per foot of head loss by a thickness of 35 feet. It is probable that the computed coefficient of vertical permeability applies largely to glacial deposits overlying bedrock.

Probable Yields of Wells

Probable range of yields of wells can be estimated from the frequency graphs in figure 107 and data on the thickness of the Silurian dolomite aquifer. Probable specific capacities of wells were estimated as the product of the specific capacity per foot of penetration measured in 50 percent of the existing wells and aquifer thicknesses. Specific capacities equal to or less than 27 gpm/ft can be expected in all parts of the Chicago Heights area except where extensive dewatering has taken place. Specific capacities equal to or less than 7 gpm/ft can be expected in the areas where extensive dewatering of the uppermost productive portion of the Silurian dolomite aquifer has taken place.

Probable specific capacities were in turn multiplied by available drawdowns based on water-level data in figure 105 to estimate the probable yields of wells. Pumping levels were limited to depths below the top of the Silurian dolomite aquifer equal to 100 feet.

It is possible to drill what is essentially a dry hole at any location. Based on data for 50 percent of existing wells, however, the chances of obtaining a well with a yield of 750 gpm are good in the Chicago Heights area. In places where extensive dewatering has not taken place, wells which may yield over 1500 gpm are a good possibility.

Thus, the yield of the Silurian dolomite aquifer in the Chicago Heights area is high enough to support heavy industry or municipal well development in all parts of the area.

Practical Sustained Yield of Existing Well Fields at Chicago Heights and Park Forest

Because the Silurian dolomite aquifer is extremely thick, and on a regional basis has high to moderate permeabilities and great areal extent, areas of diversion of production wells can extend for considerable distances, and available water resources can be developed with a reasonably small number of wells and well fields. According to figure 105 and data on available drawdowns, the present area of diversion can be greatly increased by additional pumpage from existing pumping centers, indicating that the practical sustained yield of the existing well fields is much greater than present withdrawals. The inconsistency of production of wells in the Silurian dolomite aquifer has little effect on the regional response of the aquifer to pumping, and should not seriously deter full development of available ground-water resources.

The nonpumping levels in wells in the vicinity of the main station at Chicago Heights were below the top of the Silurian dolomite aquifer in 1962. The yields of production wells will continually decrease as more of the aquifer is dewatered. Declines in yield will probably become critical after one-half of the Silurian dolomite aquifer is dewatered. Therefore, available drawdown in the main station area at Chicago Heights is limited. However, in 1962 nonpumping levels were far from critical in many parts of the Chicago Heights and Park Forest area. Thus, the practical sustained yield of the existing well fields at Chicago Heights and Park Forest exceeds total withdrawals in 1962.

Data on the response of the Silurian dolomite aquifer to heavy pumping and on yields of existing production wells at Chicago Heights and Park Forest indicate that the practical sustained yield of existing well fields is limited by recharge; the capacity of the Silurian dolomite aquifer to transmit water to wells is far greater than the recharge rate.

The amounts of water, in addition to withdrawals in 1962, that can be withdrawn from the Chicago Heights and Park Forest pumping centers without creating critical water levels or exceeding recharge were estimated, taking into consideration recharge rate, hydraulic properties, and available drawdown.

Computations indicate that the practical sustained yield of existing wells at Chicago Heights and Park Forest is about 15 mgd, or about 1.9 times more man the average annual pumpage from existing wells in 1962.

In order to increase the amount of recharge to the Silurian dolomite aquifer from the 1962 rate to the practical sustained yield, the product ΔhA_c must increase in direct proportion to the increase in pumpage. Thus, full development of the practical sustained yield will be accompanied by large increases in the area of diversion and additional water-level declines.

Because recharge varies greatly from time to time as the result of variations in precipitation, as discussed earlier in this report, water will be taken from storage from the aquifer during extended dry periods and will be replenished during times of normal and above-normal precipitation. Computations based upon the estimated gravity yield (0.03) of the Silurian dolomite aquifer indicate that mere is enough water available in storage in the aquifer to balance pumpage in excess of pumpage at Chicago Heights and Park Forest during dry periods.

Water for municipal use at LaGrange and Western Springs is obtained locally from wells penetrating a shallow dolomite aquifer. Average daily demand from the two municipal systems has increased from 1.3 mgd in 1946 to 2.4 mgd in 1962. Continual pumpage increases caused water levels to decline about 70 feet at LaGrange and Western Springs. Water levels in dolomite wells are not yet at critical stages; however, water levels in the immediate vicinity of the municipal wells were below the top of the dolomite in 1962. Available data indicate mat the dolomite aquifer is capable of producing water at a greater rate than that of present withdrawals.

Geography and Climate

The LaGrange area comprises about 100 square miles in western Cook and southeastern DuPage Counties, as shown in figure 108. The LaGrange area is bounded on the east

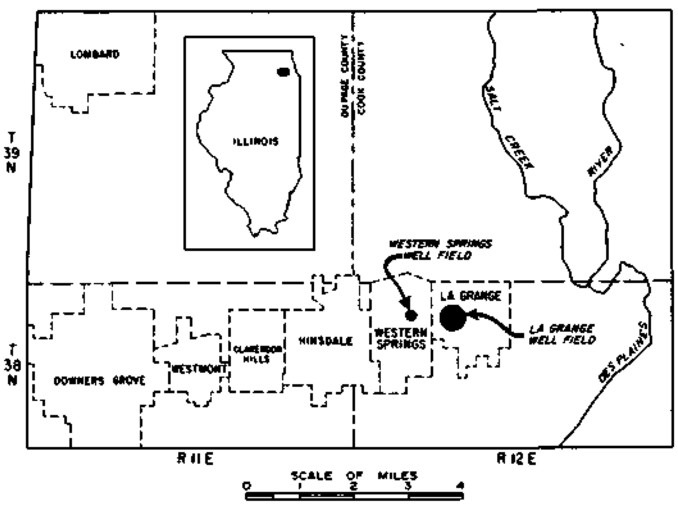

Figure 108. Location of study area and municipal wall fields at LaGrange and Western Springs

generally by the DesPlaines River and extends west through Downers Grove. The area is in T38N, T39N, R11E, and R12E, and is between 41° 52' and 41° 47' north latitude and between 88° 00' and 87° 48' west longitude. The city of LaGrange is in the southeastern part of the area. •

The LaGrange area is located in the Wheaton Morainal Country and the Chicago Lake Plain subdivisions of the Central Lowland Province. Two parallel morainic ridges cross the area from north to south. The Valparaiso moraine covers part of the area west of Hinsdale; the Tinley moraine trends southward through Western Springs in the center of the study area. The Valparaiso and Tinley moraines have ridge elevations of about 750 and 670 feet respectively. The land surface elevation declines from morainic ridges to an average of 620 feet on an extensive level plain in the northeast corner of the study area (Lake Chicago Plain).

Drainage is to the DesPlaines River either directly, as in the eastern portion of the area, or indirectly via tributaries. Salt Creek and Flag Creek, each a tributary to the DesPlaines River, drain the northern and southern sections respectively.

Figures 109 and 110 graphically illustrate the distribution of annual and mean monthly precipitation in the

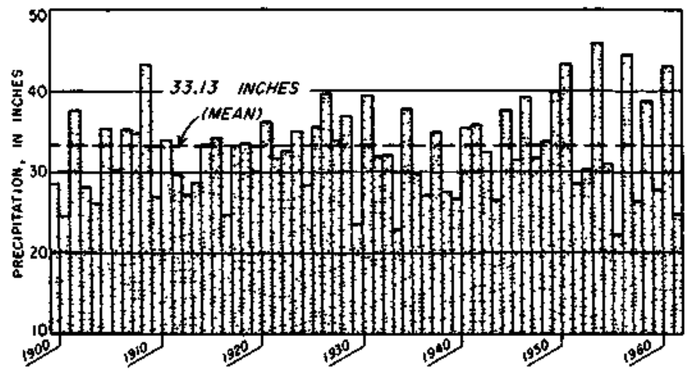

Figure 109. Annual precipitation at Chicago

LaGrange area. U. S. Weather Bureau data for Chicago (1900-1962) indicate the mean annual precipitation is 33.13 inches. On the average, June is the month of greatest precipitation, having more than 3.5 inches; the months of least precipitation are December, January, and February, each having less than 2.0 inches.

Rainfall deficiency is most apparent for the period 1936 to 1941. Cumulative deficiency of precipitation at LaGrange for this period was about 20 inches. Recharge from pre-

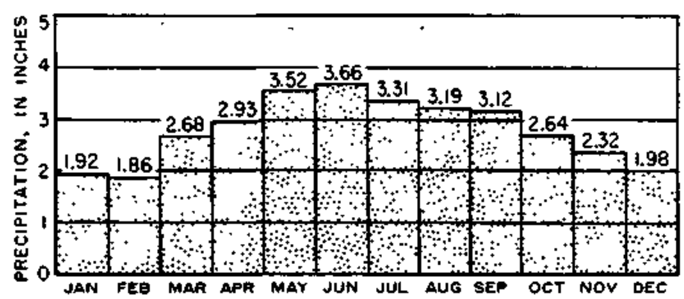

Figure 110. Mean menthly precipitation at Chicago

cipitation was below normal during these dry years, and large quantities of water were taken from storage within the aquifer to balance pumpage and discharge to streams and to the atmosphere.

The annual maximum precipitation amounts occurring on an average of once in 5 and once in 50 years are 38 and 47 inches respectively; annual minimum amounts expected for die same intervals are 29 and 23 inches respectively. Amounts are based on data given in the Atlas of Illinois Resources, Section 1 (1958).

The mean annual snowfall is 32 inches, and the area averages about 42 days with 1 inch or more and about 24 days with 3 inches or more of ground snow cover.

Based on records collected by the U. S. Weather Bureau at Chicago, the mean annual temperature is 49.8° F. June, July, and August are the hottest months, with mean temperatures of 68.0° F, 73.6° F, and 72.4° F respectively; January is the coldest month with a mean temperature of 25.0° F. The mean length of the growing season is 165 days.

Geology

For a detailed discussion of the geology in the LaGrange area the reader is referred to Suter et al. (1959) and Horberg (1950). The following section is based largely upon these two reports.

The LaGrange area is covered by glacial drift in all but a few locations where bedrock is exposed. The glacial drift is of variable thickness but averages about 50 feet thick in the Cook County part and about 100 feet thick in the DuPage County part of the LaGrange area as shown in figure 111. The basal part of the glacial drift directly

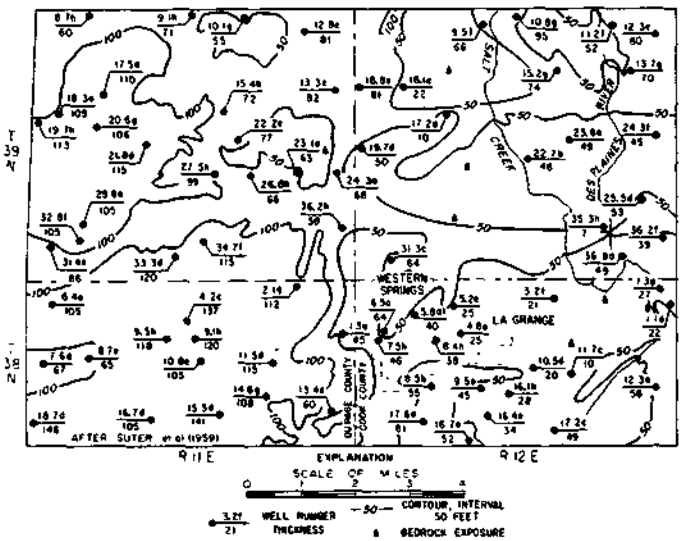

Figure 111. Thickness of unconsolidated deposits overlying bedrock in LaGrange area

overlying the bedrock contains a relatively extensive deposit of sand and gravel. The thickness of this basal unit is extremely variable, ranging from a foot or less to more than 50 feet. Generally, the deposit is thickest where the total drift thickness is greatest. The remainder of the glacial drift (confining bed) is mainly composed of clayey materials (till) with intercalated lenses and layers of sand and gravel. The thickness of these clayey deposits varies considerably but often exceeds 50 feet.

Silurian age rocks form the bedrock surface over the entire LaGrange area. The topography of the bedrock is shown by the contour map in figure 112. Features of the bedrock topography were previously discussed by Suter et al. (1959). A shallow bedrock valley trends eastward across the center of the area. The channel of the bedrock valley averages ½ mile in width, has walls of moderate relief, and averages 50 feet in depth. The bedrock surface elevation varies from 550 feet in the eastern part to 650 feet in the southwestern part of the area.

The Silurian rocks include the Alexandrian Series overlain by the Niagaran Series, and are underlain by the Maquoketa Formation of Ordovician age consisting largely of shale. Based on logs of wells that completely penetrate the Silurian rocks, the combined thickness of the Niagaran and Alexandrian Series is variable but generally increases from less than 150 feet in the northwestern part of the area to more than 350 feet in the southeastern part as shown in

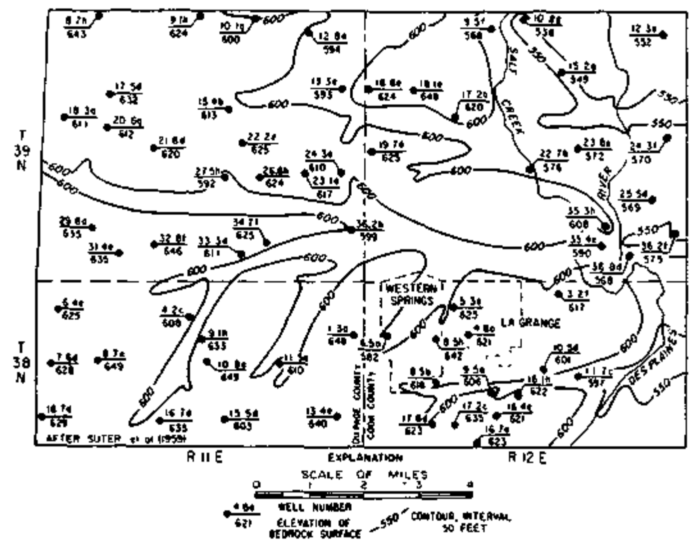

Figure 112. Bedrock topography of LaGrange area

figure 113. The rocks of the Niagaran Series range from clean dolomite to highly silty, argillaceous, and cherty dolomite with some thin shale beds, and contain reefs locally. The Alexandrian Series is composed chiefly of dolomite that increases in clastic content from the top of the series downward. Shale and argillaceous dolomite beds occur near the base of the series.

The cross section in figure 114 illustrates the character of the glacial drift and the nature of the bedrock. The

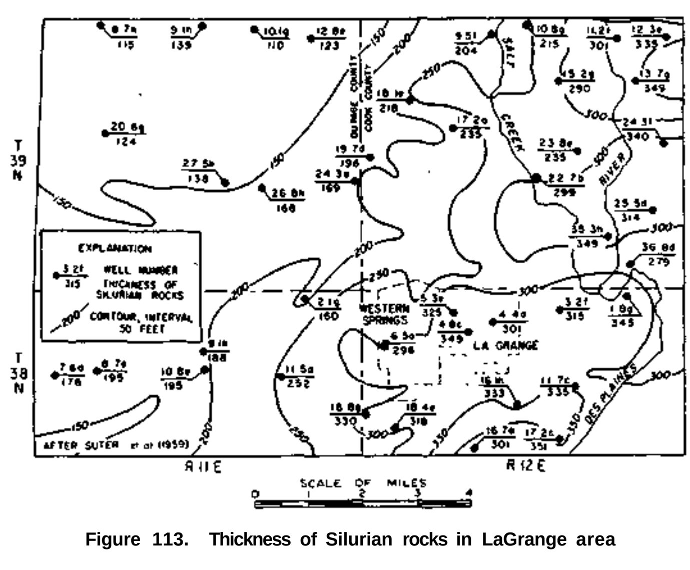

Figure 113. Thickness of Silurian rocks in LaGrange area

Table 32. Logs of Selected Wells and Test Holes in LaGrange Area

Well number	Type of record	Formation	Thickness (ft)	Depth (ft)
DUP—38N11E–				
2.1g	*SS 42074	yellow clay	8	8
		gray clay	17	25
		gravel and clay	26	51
		silty gravel	25	76
		coarse gravel and clay	4	80
		gravel and clay	32	112
		broken limestone	5	117
		hard gray lime	8	125
		gray lime	40	165
		white lime	23	188
		gray lime	35	223
		white lime	4	227
		gray lime	45	272
		green shale	2	274
		broken lime and shale	16	290
		hard and soft gray shale	21	311
4.1f	drillers log	soil	3	3
		yellow clay	46	49
		blue clay	69	118
		sand and gravel	12	130
		limestone	—	182
4.4f	SS 26960	till	50	50
		gravel	15	65
		till	5	70
		Niagaran dolomite	160	230
		Alexandrian dolomite	35	265
		Maquoketa shale	—	275
6.2h	drillers log	soil	2	2
		clay and gravel	35	37
		blue clay	84	121
		sand and gravel	14	135
		limestone	—	150
16.8e	drillers log	top soil	2	2
		yellow clay	18	20
		blue clay	40	60
		sandy blue clay	5	65
		blue clay	30	95
		sand and gravel	18	113
		limestone	—	140
18.7e	drillers log	soil	7	7
		yellow clay	10	17
		gravel	20	37
		sand	40	77
		sand and clay	30	107
		yellow gravel	20	127
		sand	18	145
		limestone	—	175
COK—38N12E–				
5.3e	drillers log	drift	25	25
		limestone	325	350
		shale	—	352
6.5a	drillers log	clay	36	36
		gravel	28	64
		broken stone	9	73
		limestone	287	360
		shale	114	474
		—	—	2046
9.5a	drillers log	fill	1.5	1.5
		black soil	1	2.5
		yellow clay	11.5	14
		blue clay	16	30
		gravel	10	40
		broken rock	5	45
		limestone	—	327
11.6c	SS 10746	Pleistocene Series		
		drift	10	10
		Silurian System		
		Niagaran Series		
		dolomite, white to light buff	75	85
		dolomite, cherty, glauconitic, buff	45	130
		dolomite, light gray to light buff	60	190
		dolomite, light buff, silty	28	218
		Alexandrian Series		
		Kankakee Formation		
		dolomite, white to buff, fine	47	265
		dolomite, cherty, glauconitic, buff	22	287
		dolomite, cherty, buff, brown, silty	23	310
		Edgewood Formation		
		dolomite, shaly, silty; shale	30	340
		dolomite, very shaly, gray, silty	20	360
		Ordovician System		
		Maquoketa Formation		
		shale, light gray, weak, little dolomite	5	365
17.6d	drillers log	clay	60	60
		clay and gravel	21	81
		broken limestone	9	90
		limestone	—	393
DUP—39N11E–				
18.3a	drillers log	soil	3	3
		clay and gravel	25	28
		gravel and sand	50	78
		sand	20	98
		fine sand	11	109
		limestone	—	147
22.2d	drillers log	soil	1	1
		yellow clay	11	12
		sand and gravel	30	42
		fine sand	38	80
		limestone	—	100
29.1d	SS 5561	soil	2	2
		yellow clay	20	22
		blue clay	50	72
		clay and stones	40	112
		hardpan	13	125
		limestone	—	174
COK—39N12E–				
9.5a	drillers log	clay	25	25
		gravel	15	40
		broken limestone	10	50
		limestone	198	248
		shale	—	472
12.3e	drillers log	sandy soil	15	15
		hardpan and gravel	25	40
		sand and gravel	15	55
		sandy clay	15	70
		limestone	395	410
		shale	165	575
		—	—	2072
18.8e	drillers log	black soil	1	1
		clay	30	31
		clay and gravel	30	61
		sand and gravel	20	81
		limestone	—	130

**SS refers to sample set number of State Geological Survey*

Table 32 (Continued)

Well number	Type of record	Formation	Thick-ness *(ft)*	Depth *(ft)*
COK—				
39N12E-	(Cont'd)			
24.3f	drillers log	drift	45	45
		lime, broken, white	5	50
		lime, broken, light	6	56
		lime, light	34	90
		shale, light	2	92
		lime, light	43	135
		lime, hard, light	95	230
		lime, very hard, light	20	250
		lime, hard, light	5	255
		lime, medium, light	8	263
		red broken lime; green shale	12	275
		red broken lime	5	280
		broken lime, green shale	2	282
		hard lime	3	285
		hard lime, light	39	324
		medium lime, light	4	328
		hard lime, light	22	350
		medium lime, gray	40	390
		gray lime and shale	10	400
		gray shale	3	403
31.3c	SS 1792	yellow clay	12	12
		blue clay	43	55
		gravel	9	64
		limestone	49	113
34.8a	drillers log	fill	4.5	4.5
		sandy yellow clay	6.5	11.0
		brown sand	1	12.0
		stony gray clay	21	33.0
		limestone	5.5	38.5
35.4e	drillers log	black soil	2.5	2.5
		yellow clay	4	6.5
		yellow clay and sand	2	8.5
		blue clay	7.5	16
		sand and boulders	5.5	21.5
		limestone	—	22
36.2f	drillers log	fill	5	5
		stony clay	19	24
		silty clay	15	39
		limestone	—	45

general slope of the bedrock as well as the slope of the land surface is towards the east. The glacial drift thins eastward; the Silurian rocks also increase in thickness to

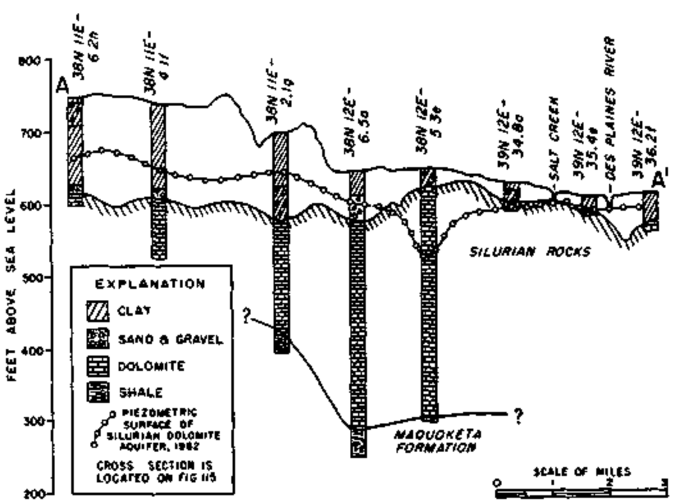

Figure 114. Geologic cross section and piezometric profile of Silurian dolomite aquifer in LaGrange area

the east. Where the glacial drift is thinnest, basal sand and gravel deposits are very thin or missing.

Logs of selected wells and test holes in the LaGrange area are given in table 32; locations of wells and test holes are shown in figure 115.

Occurrence of Ground Water

Ground-water withdrawals in the LaGrange area are chiefly from the Silurian dolomite aquifer. Ground water in the dolomite aquifer occurs in joints, fissures, and solution cavities, which are irregularly distributed both areally and with respect to depth. The yields of wells vary greatly from place to place. The weathered upper zone of the

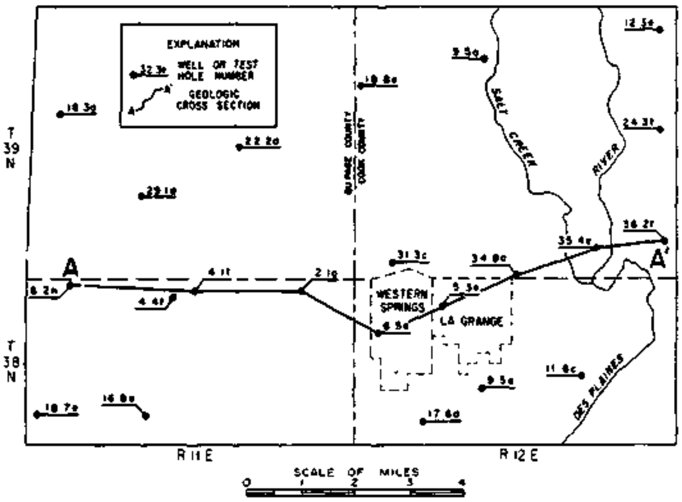

Figure 115. Locations of selected wells and test holes in LaGrange area

Niagaran Series generally has a higher permeability than other zones of the Silurian dolomite aquifer.

Ground water in the Silurian dolomite aquifer occurs under both leaky artesian and water-table conditions. Leaky artesian conditions exist at places where fine-grained material overlies the aquifer and impedes the vertical movement of water, thus confining water in the aquifer under artesian pressure. Water-table conditions prevail at many places where the upper surface of the water table is in the dolomite within deep cones of depression created by heavy pumping and water is unconfined. Because water occurs most commonly under leaky artesian conditions in the LaGrange area, the surface to which water rises, as defined by water levels in wells, is hereafter called the piezometric surface.

Ground water is also obtained from glacial deposits of sand and gravel in which water occurs chiefly under leaky artesian conditions. Most sand and gravel wells are scattered in DuPage County, and only small amounts of water are withdrawn for domestic use.

Construction Features of Wells and Pumps

The construction features of six municipal wells in service in 1962 at LaGrange and Western Springs illustrate the type c- well installation commonly found in the LaGrange area. The construction features and logs of these large capacity wells are shown in figure 116; locations of the wells are shown in figure 117.

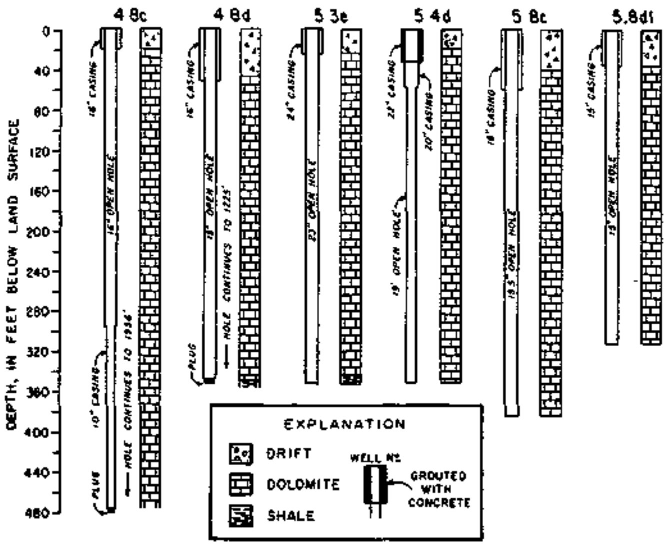

Figure 116. Generalized construction features and logs of production wells at LaGrange and Western Springs

These wells, ranging in depth from 317 to 475 feet, completely penetrate the Silurian rocks. Wells 4.8d and 4.8c, constructed between 1889 and 1908, were originally drilled to depths of 1225 and 1956 feet respectively. Well 4.8d was plugged at a depth of about 350 feet in 1957; well 4.8c was plugged with a cement grout at a depth of 475 feet in 1956. The plugs were installed at the base of the Silurian rocks. After wells were plugged, water levels rose about 80 feet, indicating that a large head differential exists between the Silurian dolomite aquifer and the Cambrian-Ordovician Aquifer (see Suter et al., 1959) underlying the Maquoketa Formation. The wells are from 15 to 24 inches in diameter and are all cased to the top of or just into the dolomite. Casing lengths range from 27 to 60 feet. Well 5.4d has a 22-inch casing and a 20-inch liner; the annulus between the casings contains cement grout.

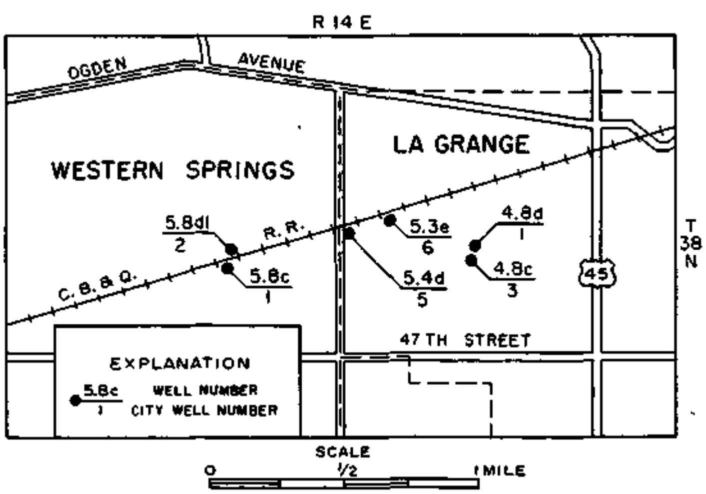

Figure 117. Location of production wells at LaGrange and Western Springs

Pumps in wells at LaGrange and Western Springs are powered by 40 to 125 horsepower electric motors. Pump settings range from 160 to 312 feet. The number of bowl stages ranges from 5 to 7. Column pipes have 8-inch diameters. Details on pump installations at LaGrange and Western Springs are given in table 33.

Table 33. Description of Pumps in Selected Wells at LaGrange and Western Springs

Well number	Pump rating capacity/head (*gpm*)/(*ft*)	Number of bowl stages	Column pipe length (*ft*)	Column pipe diam. (*in*)	Motor horsepower
COK—38N12E-					
4.8d	1000/825	7	312	8	125
4.8c	1000/—	6	260	8	100
5.4d	700/325	5	295	8	75
5.3e	800/225	5	200	8	75
5.8c	500/135	6	160	8	40
5.8dl	500/135	6	160	7	40

Ground-Water Withdrawals

Ground-water supplies for public, industrial, and domestic uses are obtained mainly from the Silurian dolomite aquifer in the LaGrange area. Areal distribution of ground-water withdrawals is shown in figure 118.

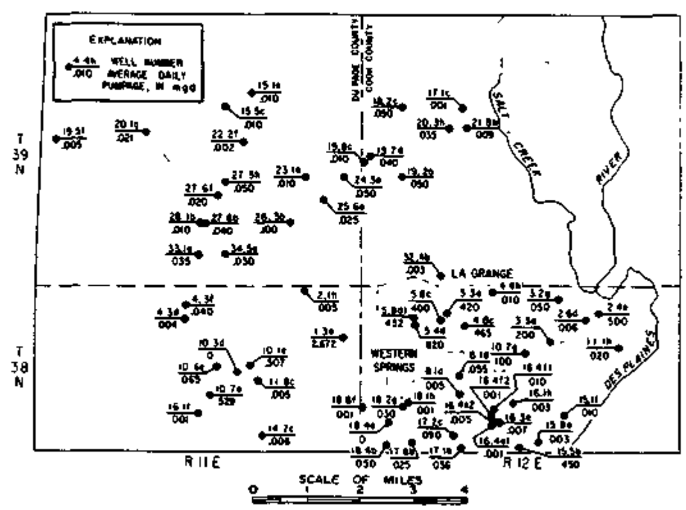

Figure 118. Distribution of pumpage from Silurian dolomite aquifer in LaGrange area, 1962

A municipal ground-water supply was installed at LaGrange in 1889. Water was obtained from a well penetrating the Cambrian-Ordovician Aquifer. Three additional wells tapping the Cambrian-Ordovician Aquifer were constructed in 1890, 1908, and 1928. Wells 5.3e and 5.4d were drilled in 1947 and 1949 respectively and terminate in the Silurian dolomite aquifer (see figure 116). Two of the original deep sandstone wells were abondoned about 1945 and 1955; wells 4.8c and 4.8d were plugged at the base of the Silurian dolomite in 1957 and 1956 respectively (see figure 116). Therefore, prior to 1947 the water was pumped from deep sandstone wells; between 1947 and 1957 water was pumped from both deep sandstone and Silurian dolomite wells; after 1957 all water was pumped from Silurian dolomite wells.

Pumpage from the Silurian dolomite aquifer at LaGrange during 1962 averaged about 1.6 mgd. Average yearly pumpage grew from 0.9 mgd in 1947 to 1.6 mgd in 1959 at an annual rate of increase of about 40,000 gpd/yr. Ground-water withdrawals reached a peak of about 2.2 mgd in June 1959 at LaGrange. Fluctuations in ground-water withdrawals for the period 1947 to 1962 at LaGrange are shown in figure 119.

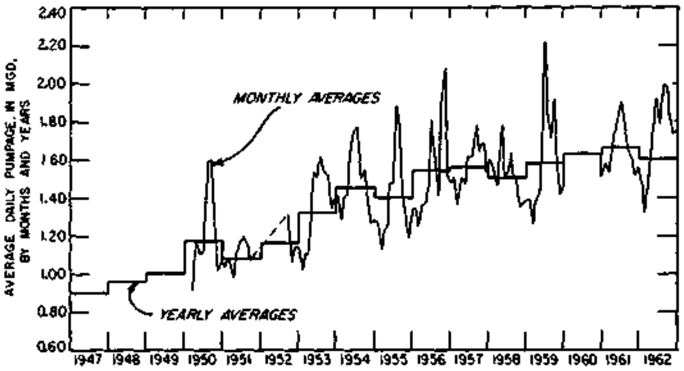

Figure 119. Estimated ground-water pumpage from Silurian dolomite aquifer at LaGrange, 1947-1962

Prior to 1924 Western Springs obtained its water supply from wells penetrating the Cambrian-Ordovician Aquifer. Pumpage from the Silurian dolomite aquifer was started in 1924. Silurian dolomite wells 5.8c and 5.8dl were drilled in 1924 and 1930 respectively. Average daily pumpage from dolomite wells increased from 0.17 mgd in 1924 to about 0.7 mgd in 1955 at an average annual rate of 17,500 gpd/yr. Figure 120 shows the growth of ground-water

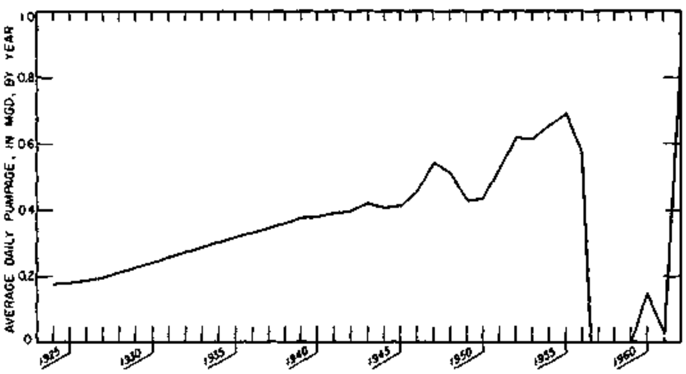

Figure 120. Estimated ground-water pumpage from Silurian dolomite aquifer at Western Springs, 1924-1962

pumpage at Western Springs. In 1956 a deep sandstone well was drilled and put into service at Western Springs. For a period of about 5 years this well furnished most of the municipal water supply. After 1961 the water demand was again obtained from wells in the Silurian dolomite aquifer. Peak ground-water withdrawal at Western Springs amounted to more than 800,000 gpd and occurred in 1962.

Table 34 shows the figures for 1962 of pumpage from wells in the LaGrange area.

Table 34. Distribution of Pumpage from Wells in LaGrange Area, Subdivided by Use, 1962

Use	Average pumpage (mgd)	Percent of total pumpage
Public	6 73	**66**
Industrial	2.14	**20**
Domestic	1.41	**14**
Total	10.29	100

Leakage through Maquoketa Formation

Leakage of ground water from Silurian rocks through the Maquoketa Formation in the LaGrange area occurs under the influence of large differentials in head between shallow deposits and the Cambrian-Ordovician Aquifer. The average vertical permeability of the Maquoketa Formation is about 0.0005 gpd/sq ft (Walton, 1960). The average head differential was computed by comparing the piezometric map for the Cambrian-Ordovician Aquifer (see Sasman et al., 1962) and the piezometric surface map for the Silurian dolomite aquifer.

Substitution of appropriate data in Darcy's law indicates that the leakage through the Maquoketa Formation within the LaGrange area was about 350,000 gpd in 1962.

Fluctuations of Water Levels and Their Significance

As illustrated by the hydrograph for well DUP 39N11E-24.2g in figure 121, water levels in the Silurian dolomite

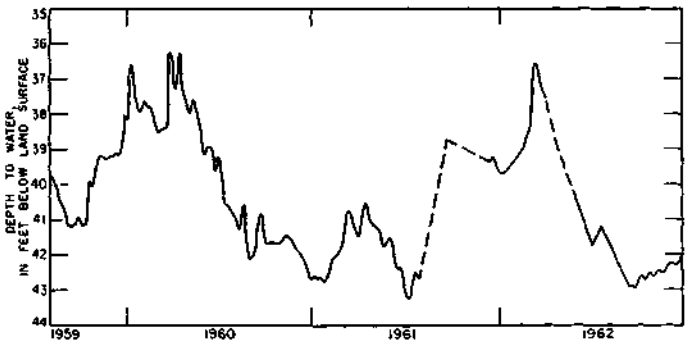

Figure 121. Water levels in well DUP 39N11E-24.2g, 1959-1962

aquifer generally recede in late spring, summer, and early fall when discharge of ground water to streams and to the atmosphere and from wells is greater than recharge from precipitation. Water levels begin to recover in wells late in the fall when pumping rates and evapotranspiration decrease and conditions are favorable for the infiltration of rainfall, first to replenish surface deposits and later to percolate to the Silurian dolomite aquifer. The rise in water levels is especially pronounced during wet spring months, when the ground-water reservoir receives most of its annual recharge. Maximum and minimum annual water levels are recorded at different times of the year depending primarily upon climatic and pumping conditions.

Water-level measurements were made infrequently in several wells in the LaGrange area between 1924 and 1963. Changes in water levels shown in figures 122 and 123 are

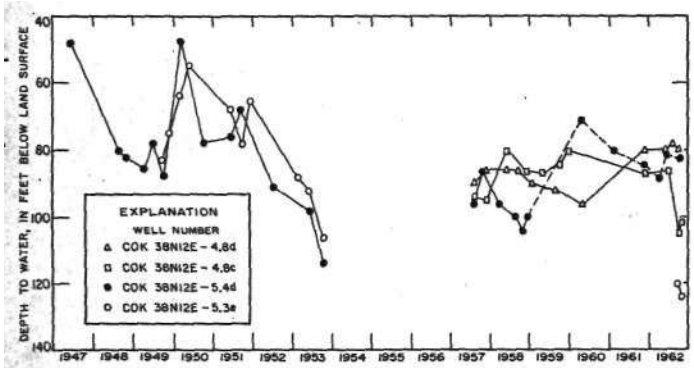

Figure 122. Water levels in walls at LaGrange, 1947-1962

indicative of conditions in general at LaGrange and Western Springs respectively. It should be emphasized that water levels in figures 122 and 123 are nonpumping levels. Although water levels vary considerably from time to time because of shifts in pumpage from one well to another and changes in total well-field pumpage, the hydrographs

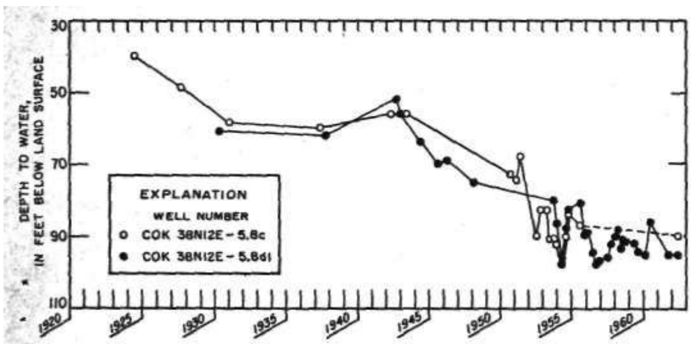

Figure 123. Water levels in wells at Western Springs, 1924-1962

show no continuous decline that cannot be explained by pumpage changes.

The average elevation of the piezometric surface at LaGrange and Western Springs in 1924 was probably about 630 feet. By 1962 water levels had declined in response to withdrawals of water to an average elevation of 560 feet Thus, in a period of 38 years, water levels declined 70 feet or at an average rate of about 1.9 feet per year; however, water levels in wells at LaGrange and Western Springs have generally stabilized since 1957.

A comparison of water-level hydrographs and pumpage graphs indicates that in general water-level decline is proportional to the rate of pumpage. Average water-level declines in wells plotted against corresponding average pumpage rates in the LaGrange municipal well field are shown in figure 124. The data are somewhat scattered; however, a consistent relationship between decline and pumpage is apparent. Approximately 41,000 gpd were

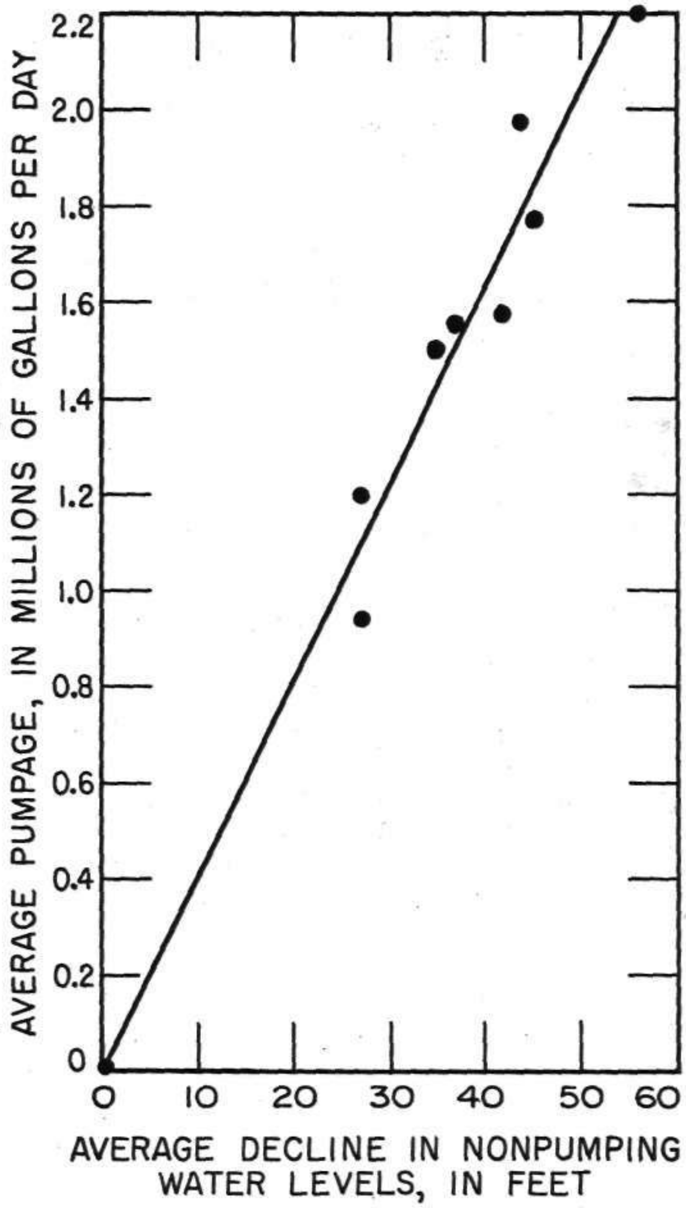

Figure 124. Relation between average pumping rate and decline of water levels at LaGrange

obtained with each foot of decline. The consistent relationship between decline and pumpage and the fact that water levels have generally stabilized shortly after each pumpage increase indicate that in the past recharge has balanced withdrawals.

Configuration of Piezometric Surface of Aquifer

In order to determine areas of recharge and discharge and directions of ground-water movement in the Silurian dolomite aquifer, a piezometric surface map was made (figure 125). Data on nonpumping levels in table 35 were used to prepare the map. Data in the Cook County part of the LaGrange area were collected during the winter months of 1962 and 1963. Data in the DuPage County part of the LaGrange area (Zeizel et al., 1962) were collected during the late summer months of 1960; from water-

Table 35. Water-Level Data for Wells in Silurian Dolomite Aquifer in LaGrange Area

Well number	Owner	Depth (ft)	Depth to water (ft below measuring point)	Land surface elevation (ft above MSL)	Water level elevation (ft above MSL)	Date measured
DUP—38N11E–						
1.3a1	Hinsdale (V)	273	67	686	619	6/9/60
1.3a2	Hinsdale (V)	210	77	687	610	6/9/60
1.4a	Hinsdale (V)	209	53	676	623	6/9/60
4.3f2	Liberty Park Home Own. Assn.	278	99	745	646	6/13/60
7.6d	Downers Grove (V)	250	80	696	616	6/4/60
8.4b	Downers Grove (V)	291	98.5	742	643	5/31/60
8.7e	Downers Grove (V)	262	70	720	650	6/16/60
9.1h	Westmont (V)	313	101	752	651	6/14/60
10.1e	Clarendon Hills (V)	250	112	723	611	6/10/60
10.6e	Ill. Munic. Water Co.	295	116	740	624	7/11/60
10.7a	Westmont (V)	302	132	760	628	7/11/60
10.8e	Westmont (V)	313	128	755	627	6/14/60
11.5b	Clarendon Hills (V)	354	104	737	633	6/10/60
11.5d	Clarendon Hills (V)	370	89	710	621	6/10/60
COK—38N12E–						
1.3e	Cook Co. Forest Pres.	65	37	607	570	1/7/63
2.4e	Material Serv. Quarry	209	209	615	406	1/7/63
2.5f	Cook Co. Forest Pres.	200	173	612	439	1/7/63
3.2g	Culligan Soft Water Serv.	340	108	618	510	12/6/62
3.3a	Willow Farms Prod.	365	189	625	436	12/6/62
4.4h	Hi-Way Restaurant	250	45	645	600	12/6/62
4.8d	LaGrange (V)	459	80	649	569	9/5/62
4.8c	LaGrange (V)	475	102	646	544	9/28/62
5.4d	LaGrange (V)	356	82	658	576	9/28/62
5.3e	LaGrange (V)	352	124	652	528	10/2/62
5.8c	Western Springs (V)	385	90	670	580	9/16/62
5.8d	Western Springs (V)	313	95	674	579	9/21/62
8.1a	Country Club Heights	370	110	670	560	10/15/62
8.1d	LaGrange CCb.	356	122	655	533	10/15/62
10.7g	Material Serv. Quarry	—	—	—	462	1/14/63
11.1h	Rt. 66 Car Wash	300	13	611	598	12/7/62
15.1f	Consumers Quarry	—	—	—	394	1/14/63
15.5b	Dolese & Shepard Quarry	—	—	—	497	1/14/63
16.1h	UAW-CIO Hdq. Local #719	361	96	650	554	12/7/62
16.4e2	Kerry's Restaurant	363	82	655	573	12/7/62
17.1a	Dise Sbd.	375	92	690	598	10/19/62
17.2c	Edgewood Park Util.	420	110	688	578	10/19/62
17.8b	Par 3 Golf Course	388	95	712	617	11/27/62
18.2g	Forest-Ridgewood Water Co.	349	41	647	606	11/29/62
18.4b	Timber Trail CCb.	255	16	640	624	10/15/62
18.8f2	Cook Co. T.B. Sanit.	342	52	680	628	10/26/62
DUP—39N11E–						
8.8h3	Lombard (V)	210	18	696	678	12/4/62
10.4g5	Wander Co.	197	19	675	656	8/15/60
10.8e1	Villa Park (V)	285	55	702	647	5/2/60
10.8e2	Villa Park (V)	251	55	702	647	5/2/60
13.3g	Elmhurst (C)	290	88	710	622	8/13/60
13.6c	J. Livingston	110	25	677	652	7/11/60
13.7b	Swain & Skinner	110	13	667	654	7/11/60
14.8a	H. E. Voss	117	3	667	664	7/11/60
14.8e	J. Weskrna	155	20	672	652	7/11/60
16.4d	G. Wyns	—	29	700	671	8/23/60
17.2c	Pullman	—	27	708	681	8/18/60
18.5d	I. Frey	110	40	720	680	8/18/60
21.5e	D. Helms	—	51	725	674	7/13/60
22.4c	G. Kurtz	120	26	685	659	7/13/60
23.1h	V. Costelli	100	14	665	651	7/11/60
24.2g	J. H. Jones	350	39	690	651	6/24/60
24.3a2	American Can Co., No. 2	245	33	682	649	7/11/60
25.4d	E. Mulac	165	21	670	649	7/11/60
25.6e	Butler Co.	160	34	675	641	7/13/60
26.3b	Butler Co.	—	25	665	640	7/11/60
28.7d	C. Ballinger	117	45	720	675	7/13/60
33.1e	Midwest CCb.	170	59	720	661	11/27/62
33.2d	D. Kitzing	—	64	733	669	11/27/62
34.7h	G. Mueller	105	51	715	664	7/13/60

Table 35 (Continued)

Well number	Owner	Depth (ft)	Depth to water (ft below measuring point)	Land surface elevation (ft above MSL)	Water level elevation (ft above MSL)	Date measured
DUP—39N11E–(Cont'd)						
35.1d	J. Telander	90	28	672	644	7/11/60
36.4f	M. Carlson	45	12	650	638	7/11/60
COK—39N12E–						
18.2c	Mt. Carmel Cmty.	283	17	675	658	11/8/63
19.2a	Joe Jensek	290	12	655	643	12/10/62
23.3h	Cook Co. Forest Pres.	70	29	622	593	12/20/62
23.4b	Cook Co. Forest Pres.	127	24	621	597	12/20/62
26.8a	Cook Co. Forest Pres.	180	19	621	602	12/20/62
27.7e	Cook Co. Forest Pres.	130	15	620	605	12/20/62
28.7f	Cook Co. Forest Pres.	109	11	630	619	12/10/62
28.8a	Cook Co. Forest Pres.	100	23	640	617	12/10/62
31.1f	Cook Co. Forest Pres.	105	29	650	621	12/10/62
31.4e	Cook Co. Forest Pres.	65	24	643	619	12/10/62
32.4b	Our Lady of Bethlehem Acad.	465	35	635	600	12/10/62
33.2g	LaGrange Park	370	27	625	598	11/20/62
35.3f	Cook Co. Forest Pres.	100	22	613	591	12/20/62

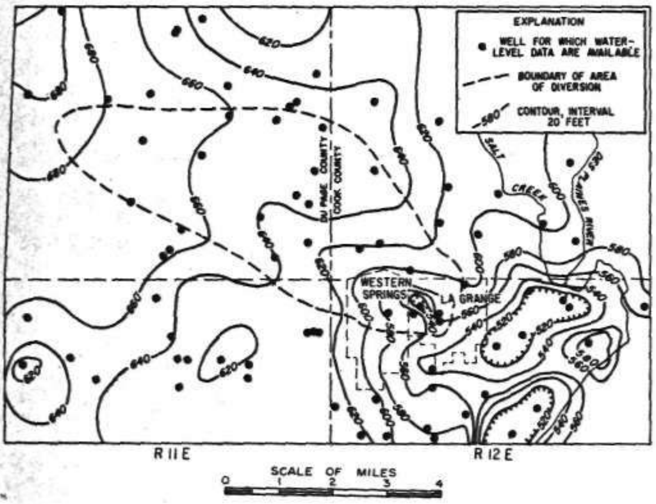

Figure 125. Piezometrie surface of Silurian dolomite aquifer in LaGrange area, 1962

level data for several wells during 1960 to 1963, it is probable that the general features of the piezometric surface in this part have changed little since 1960.

Pronounced cones of depression are centered around LaGrange and the three quarries in the southeast part of the LaGrange area. Other cones of depression are present at Downers Grove, Hinsdale, and Clarendon Hills. Ground-water movement is in all directions toward well fields, topographic lowlands, streams, and stone quarries.

Data were not sufficient to determine the hydraulic connection between the Silurian dolomite aquifer and the DesPlaines River in the southeast part of the LaGrange area. Therefore, the piezometrie surface contours in the immediate vicinity of the DesPlaines River must be considered as conjectural.

Flow fines were drawn at right angles to the piezometrie contours to define the area of diversion of the production wells at LaGrange and Western Springs. As measured from figure 125 the area of diversion is about 18 square miles.

Water-Yielding Properties of Silurian Dolomite Aquifer

More man 100 well-production tests were conducted by water well contractors and the State Water Survey in and near the LaGrange area from 1900 to 1962. A summary of information obtained from these tests is presented in table 36. The length of tests ranged from 15 minutes to 24 hours; pumping rates ranged from 15 gpm to 1000 gpm;

Table 36. Specific-Capacity Data for Dolomite Wells in LaGrange Area

											Unadjusted		Adjusted		
Well number	Owner	Depth (ft)	Diam. (in)	Penetration (ft)	Year drilled	Year of test	Length of test (hr)	Non-pumping level (ft)	Pumping rate (gpm)	• Drawdown (ft)	Specific capacity (gpm/ft)	Specific capacity per foot of penetration (gpm/ft²)	Specific capacity (gpm/ft)	Specific capacity per foot of penetration (gpm/ft²)	Estimated coefficient of transmissibility (gpd/ft)
COK—38N12E–															
2.6d	Werner Mfg. Co.	385	8	274	1957	1957	4.5	111	125	74	1.69	0.006	2.20	0.008	3,400
5.3e(6)	LaGrange (V)	352	24	277	1949	1949	6.8	75	1000	50	20.00	0.072	26.0	0.094	46,000
5.4d(5)	LaGrange (V)	358	20	299	1947	1947	12	48	900	143	6.30	0.021	8.20	0.027	13,400
5.4d(5)	LaGrange (V)	358	20	280	1947	1950	0.5	78	118	7	16.85	0.060	21.90	0.078	21,000
5.8c(1)	Western Springs (V)	385	15	285	1924	1937	12	60	500	22	22.70	0.080	45.0	0.158	85,000
5.8c(1)	Western Springs (V)	385	15	285	1924	1942	3	60	650	20	32.50	0.085	42.30	0.118	80,000
5.8c(1)	Western Springs (V)	385	15	285	1924	1954	3.8	98	500	20	25.00	0.088	32.5	0.115	58,000
5.8c(1)	Western Springs (V)	385	15	285	1924	1924	—	40	500	11	45.50	0.160	78.0	0.273	153,000
5.8d1(2)	Western Springs (V)	313	17	248	1930	1937	12	62	500	22	22.70	0.092	29.50	0.120	53,000
5.8d1(2)	Western Springs (V)	313	17	248	1930	1946	3.3	67	500	24	20.80	0.084	27.10	0.109	48,000
5.8d1(2)	Western Springs (V)	313	17	248	1930	1951	2.5	65	500	25	20.00	0.081	26.00	0.105	46,000
5.8d1(2)	Western Springs (V)	313	17	248	1930	1954	3.8	98	500	22	22.70	0.092	29.50	0.120	53,000
5.8d1(2)	Western Springs (V)	313	17	248	1930	1931	—	61	500	22	22.70	0.090	29.50	0.117	55,000

Table 36 (Continued)

Well number	Owner	Depth (ft)	Diam. (in)	Penetration (ft)	Year drilled	Year of test	Length of test (hr)	Nonpumping level (ft)	Pumping rate (gpm)	Drawdown (ft)	Unadjusted		Adjusted		Estimated coefficient of transmissibility (gpd/ft)
											Specific capacity (gpm/ft)	Specific capacity per foot of penetration (gpm/ft²)	Specific capacity (gpm/ft)	Specific capacity per foot of penetration (gpm/ft²)	
COK— 38N12E-(Cont'd)															
8.1a	Country Club Heights	370	6	260	1955	1955	—	110	70	10	7.00	0.027	12.7	0.049	22,000
8.3h	LaGrange Field Club	330	6	140	1955	1955	2	95	210	15	14.00	0.100	18.20	0.130	32,000
9.5a	Mark Magisano	327	8	260	1950	1950	24	67	40	18	2.22	0.009	3.50	0.013	6,400
9.8d	Mark Magisano	327	8	260	1950	1950	2	67	33	4	8.25	0.032	10.3	0.040	17,000
16.4c	School Dist. 105	377	6	193	1951	1951	1.3	54	55	33	1.67	0.009	3.67	0.019	5,600
16.8e	Finn Constr. Co.	325	6	82	1954	1954	10	75	100	51	1.96	0.024	2.55	0.031	3,900
17.1a	Midwest Water Co.	375	8	313	1952	1952	2	74	110	82	1.34	0.004	1.74	0.005	3,000
17.2c	Coronet Const. Co.	420	10	341	1953	1953	1.3	81	290	48	6.05	0.018	7.87	0.023	12,800
18.1h	E. G. Boone	190	6	120	1959	1959	3	43	50	40	1.25	0.010	2.78	0.013	4,200
18.2g	Ridgewood Sbd.	349	10	299	1957	1957	7	25	450	45	10.00	0.033	13.00	0.043	22,500
18.8f1(1)	Cook Co. T.B. Sanit.	357	12	232	1952	1952	1	35	158	91	1.74	0.007	2.26	0.009	3,400
18.8f1(1)	Cook Co. T.B. Sanit.	357	12	232	1952	1952	4	39	288	111	2.60	0.011	3.28	0.014	5,000
18.8f2(2)	Cook Co. T.B. Sanit.	342	15	289	1952	1952	1	39	299	16	18.70	0.065	27.2	0.078	39,000
19	Hinsdale San. Dist.	220	8	177	1957	1957	22	22	150	26	5.77	0.032	7.15	0.041	13,300
19.2f	Indian Head Park	295	8	253	1947	1947	—	35	130	86	1.51	0.006	1.96	0.008	3,000
19.2f	Indian Head Park	295	8	253	1947	1958	—	48	135	75	1.80	0.007	2.34	0.009	3,500
19.2f	Indian Head Park	295	8	253	1947	1960	0.3	48	130	72	1.81	0.007	2.35	0.009	2,800
20	Cook Co. Forest Pres.	93	6	30	—	—	—	38	25	18	1.39	0.046	1.50	0.050	2,200
20.8e	Acacia CCb.	409	8	354	1948	1948	4	55	330	9	36.70	0.104	38.0	0.107	72,000
28.8c	Buick Gen. Mot. Co.	180	6	91	1951	1951	6	68	260	32	8.14	0.090	10.58	0.117	18,000
30.8b	Maple Crest Golf Club	401	10	361	1957	1957	3	35	600	6	100.00	0.277	104	0.289	210,000
32.7h	Edgewood Acres Sbd.	150	10	102	1953	1953	3	15	210	34	6.19	0.061	12.4	0.122	21,500
32.7h	Edgewood Acres Sbd.	150	10	102	1953	1958	—	25	207	9	23.70	0.228	24.0	0.235	40,000
35	Midwest Justice Water Co.	145	10	58	1954	1954	8	15	235	19	12.35	0.213	12.5	0.215	22,000
36.5a	Ajax Box Co.	322	10	249	1959	1959	8	45	100	90	1.12	0.005	1.82	0.007	2,700
39N12E-															
2	Raytheon Mfg. Co.	306	12	243	1955	1955	8	57	305	18	16.95	0.070	22.00	0.091	70,000
4	Sacred Heart Sem.	250	6	77	—	1940	1.8	173	55	7	7.85	0.105	11.90	0.155	23,000
4.2b	Richardson Co.	315	—	250	1936	1952	1.3	170	165	3	55.00	—	119	0.475	240,000
4.2b	Richardson Co.	315	—	—	1936	1952	—	173	170	2	85.00	—	97	0.390	195,000
4.2h	Hiway Restaurant	250	10	190	1935	1935	4	25	135	80	1.69	—	6.18	0.033	10,400
4.8e	Stone Park (V)	291	12	119	1942	1942	5.5	172	57	8	7.12	0.060	8.45	0.071	14,500
11	Cook Co. Forest Pres.	202	6	128	—	—	—	75	15	30	0.50	0.004	0.63	0.005	1,000
17	Hillside Shopping Ctr.	242	12	206	1955	1955	2	36	200	110	1.81	0.009	2.35	0.011	4,100
17	Hillside (V)	178	6	113	1937	1937	8	35	40	25	1.60	0.014	1.75	0.016	2,600
17.1c	Vulcan Tin Can Co.	305	10	252	1948	1958	—	20	16	132	0.12	0.001	0.13	0.001	600
18	Unknown	130	5	49	1957	1957	1	60	30	50	0.60	0.012	1.00	0.020	1,700
18.7h	Berkeley (V)	151	10	47	1930	1930	1	44	150	8	18.75	0.400	24.40	0.520	50,000
19	Catholic Cemeteries	252	10	200	1959	1959	2	37	185	163	1.13	0.006	1.47	0.008	2,500
21.2h	Hub Planting Works	178	6	93	1952	1953	—	18	50	4	12.50	0.135	13.20	0.142	2,300
22.7b	Amphenal Corp.	345	19	292	1958	1958	6	9	400	111	3.60	0.012	4.68	0.016	7,500
31.2c	Salt Creek Camp	118	6	49	1936	1936	10	27	25	2	12.50	0.256	16.30	0.333	29,000
32	Cook Co. Forest Pres.	112	6	77	—	—	—	9	60	2	30.00	0.390	39.00	0.507	74,000
33.2g	LaGrange Park (V)	370	15	298	1954	1954	6	21	900	79	11.40	0.038	14.80	0.049	29,000
DUP— 38N11E-															
1.3a1(2)	Hinsdale (V)	271	20	226	1924	1947	3.5	58	970	76	12.8	0.06	33.3	0.15	61
1.3a2(3)	Hinsdale (V)	210	20	165	1928	1947	5	61	700	80	8.7	0.05	16.1	0.10	25
1.4a(1)	Hinsdale (V)	209	12	179	—	1924	—	17	520	3	173.2	0.97	347.0	1.94	750
3.1b	Hinsdale Golf Club	165	12	20	1944	1944	4.5	90	525	23	22.8	1.14	36.0	1.80	64
6.4c(9)	Downers Grove (V)	300	30	210	1956	1958	5	109	850	76	11.2	0.05	22.3	0.11	40
7.6d	Downers Grove (V)	250	30	183	1928	1947	1	46	860	12	71.5	0.39	218.0	1.19	500
8.4b	Downers Grove (V)	295	30	195	1930	1945	10	96	980	15	65.4	0.34	340.0	1.74	740
8.7e(8)	Downers Grove (V)	262	30	197	1950	1953	—	64	412	5	82.4	0.42	129.0	0.66	267
9.1h(2)	Westmont (V)	313	16	190	1926	1938	11	101	600	1.2	500.0	2.63	2000	10.52	5,000
10.2c(2)	Clarendon Hills (V)	250	12	210	1932	1932	—	95	150	11.5	13.0	0.06	14.6	0.07	26
10.2c(2)	Clarendon Hills (V)	—	12	—	1932	1947	2	113	300	4	75.0	—	93.8	—	193
10.6e(1)	Blackhawk Sbd.	295	12	205	1953	1953	8	102	210	24	8.7	0.04	10.4	0.05	17
10.7a(3)	Westmont (V)	302	17	167	1935	1947	24	123	250	20	12.5	0.08	15.8	0.09	28
10.8e(4)	Westmont (V)	313	12	208	1958	1958	12	128	259	27	9.6	0.06	12.1	0.06	21
11.5a(3)	Clarendon Hills (V)	354	12	239	1945	1945	—	91	385	12	32.1	0.13	45.9	0.19	87
11.5d(4)	Clarendon Hills (V)	370	12	255	1956	1956	3	90	838	8	105.0	0.41	440	1.72	1,000
12.8a(5)	Hinsdale (V)	319	15	230	1954	1954	—	69	708	10	70.8	0.31	173.0	0.75	366
(T)	Hinsdale (V)	212	—	119	1954	1954	—	73	360	12	30.0	0.25	41.0	0.34	78
12.8c(T)	Hinsdale (V)	291	—	198	1954	1954	—	73	388	7	55.5	0.28	80.8	0.41	160
(T)	Hinsdale Sanit. Dist.	200	8	182	1957	1957	—	22	150	126	1.2	0.01	1.3	0.01	2
(1)	Ill. Toll Hwy. Comm.	238	8	138	1957	1957	—	25	157	55	2.9	0.02	3.1	0.02	5
24.3b(1)	Inter. Harvester Co.	294	16	239	1956	1956	4	78	400	20	20.0	0.08	25.2	0.11	38
24.4b1(2)	Inter. Harvester Co.	398	16	296	1957	1957	—	70	500	10	50.0	0.17	84.8	0.29	170
24.4b2(3)	Inter. Harvester Co.	294	16	199	1957	1957	8	73	580	10	58.0	0.29	108.0	0.54	222
28.1c(2)	Brookhaven Manor	317	16	218	1960	1960	3	115	100	90	1.1	0.05	1.1	0.06	2
30.5d	Maple Crest Lake CCb.	395	10	250	1958	1958	8	134	320	22	14.5	0.06	19.5	0.07	34
33.2b(1)	Cass Schl. Dist.	250	6	155	1958	1958	8	90	147	10	14.7	0.10	17.3	0.11	32
39N11E-															
1	—	301	—	—	—	—	—	27	152	2	76.0	—	89.4	—	180
1	J. F. Kyle	237	6	183	1955	1955	5.5	61	190	27	7.0	0.04	8.5	0.05	15
3.2e	Black Top Road Co.	195	10	159	1956	1956	6	37	240	8	30.0	0.19	37.5	0.24	69
3.3a(1)	Robert Hall Clothes	114	5	26	1958	1958	2	38	200	2	100.0	3.86	131.0	5.04	260
4.1e(5)	Villa Park (V)	235	12	170	1930	1944	—	33	220	3	73.4	0.43	91.8	0.54	185
5.3g(1)	Lombard Heights	209	15	124	1954	1954	10	43	335	17	19.7	0.16	25.7	0.21	47
7.1h1(3)	Lombard (V)	175	20	115	1948	1948	—	9	365	27	13.5	0.12	21.3	0.19	39
7.1h2(T)	Lombard (V)	175	6	103	1948	1948	—	9	80	1.0	80.0	0.78	114.0	1.10	232
8.7h(1)	Lombard (V)	84	8	14	—	1939	—	10	465	21	22.1	1.58	33.7	2.41	63
10(3)	Wander Co.	220	—	—	—	1922	—	19	350	40	8.8	—	11.3	—	20
10(4)	Wander Co.	187	—	—	—	1924	—	26	500	55	9.1	—	13.5	—	24
10.8e(3)	Villa Park (V)	285	8	227	1919	1955	—	37	500	70	7.1	0.03	10.5	0.05	18
10.8d(4)	Villa Park (V)	251	12	193	1923	1955	—	57	500	4	125.0	0.65	238.0	1.23	558
10.8d(4)	Villa Park (V)	187	—	129	1923	1924	4.5	26	500	55	9.1	0.07	13.2	0.10	22
13.3g(7)	Elmhurst (C)	290	8	210	1959	1959	8	74	335	86	3.9	0.01	5.1	0.02	8
16(1)	Wheaton (C)	175	10	—	1960	1960	—	38	830	31	27.0	—	71.6	—	122
20.1g	West York Center Sbd.	235	—	140	1947	1947	—	66	195	55	3.5	0.03	6.9	0.05	11
20.6g(1)	Highland Hills Sbd.	241	10	135	1954	1954	—	29	483	114	4.2	0.03	5.9	0.04	10
23.1a(EP-3)	Ill. Toll Hwy. Comm.	290	6	227	1958	1958	—	26	60	1	60.0	0.26	66.6	0.29	132
24.2g	J. Harris Jones	350	10	290	1959	1959	—	45	350	65	5.4	0.02	6.9	0.02	12
34	Liberty Park Home Own. Assn.	279	8	179	1956	1956	—	103	136	53	2.6	0.01	2.8	0.02	4
34.2g	St. Francis Retreat	298	8	161	1950	1950	8	55	180	134	1.3	0.01	1.6	0.01	3
34.5e(2)	St. Joseph College	250	8	135	1958	1958	—	84	60	15	4.0	0.03	8.6	0.06	15
36	Camp Fullersburg	120	—	30	—	1933	—	14.5	30	0.5	60.0	2.00	60.0	2.00	118

casing diameters ranged from 5 to 30 inches and averaged about 12 inches.

Specific-capacity data obtained from the tests were corrected for well losses based on the results of studies made by Csallany and Walton (1963). Specific capacities adjusted for well losses were then further adjusted to a common radius and pumping period based on estimated coefficients of transmissibility. The average radius (6 inches) and pumping period (6 hours) based on data in table 36 were used as the bases. Coefficients of transmissibility were estimated by substituting values of specific capacity and the data in table 36 into the nonequilibrium equation.

Effects of Dewatering

Water-level declines are greatest near pumping centers. Close spacing of well fields and heavy pumpage from quarries in the southeastern part of the LaGrange area have caused water levels to decline to stages below the top of the Silurian dolomite aquifer. An extensive volume of dolomite centered around the well fields at LaGrange and Western Springs and the quarries east of LaGrange has been dewatered. Nonpumping level elevations in wells were compared with bedrock surface elevations to obtain the thickness of dewatered dolomite at many locations, as listed in table 37.

Table 37. Thickness of Dewatered Silurian Dolomite Aquifer in Vicinity of LaGrange

Well number	1962 Nonpumping water level elevation (*ft above MSL*)	Elevation of bedrock surface *ft above MSL)*	Thickness of dewatered dolomite at well site (*ft*)
DUP—38N11E-			
1.3al	620	648	28
COK—38N12E-			
1.1e	570	560	none
2.4e	406	611	205
2.5f	439	594	155
3.2g	510	597	87
3.3a	436	596	160
4.8c	544	626	82
4.8d	569	624	55
5.3e	528	628	100
5.8c	580	610	30
5.8d	579	639	60
8.1d	533	630	97
8.1a	560	620	60
10.7g	462	622	160
15.1f	394	619	225
16.1h	554	622	68
16.4e2	573	621	48
17.1a	598	630	32
17.2c	578	636	58
17.8b	617	635	18
18.2g	606	638	32
18.4b	624	614	none
18.8f	628	629	1
39N12E-			
31.1f	621	580	none
31.4e	619	589	none
32.4b	600	596	none
35.3f	591	563	none

The map in figure 126 was constructed with water-level data for individual wells, the piezometric surface map, and the bedrock topography map. The dewatered portion of the dolomite encompasses an area of 18.5 square miles. The average thickness of dewatered dolomite is about 60 feet.

It has been shown by Walton and Neill (1963) and Zeizel et al. (1962) that the specific capacity per foot of penetration decreases when the depth of the well increases,

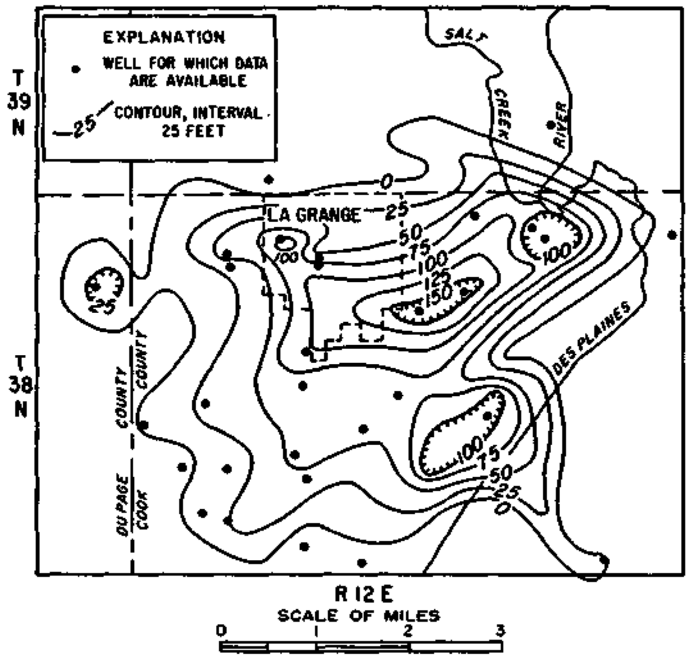

Figure 126. Thickness of dewatered Silurian dolomite aquifer in vicinity of LaGranga

indicating that the upper part of the Silurian dolomite aquifer is more productive than the lower part. When the upper portions of the dolomite are dewatered and cannot contribute to the capacity of a well, the specific capacities can be expected to decrease. In order to quantitatively study the effect of dewatering on specific capacities, the graph in figure 127 was constructed. Data for this graph were obtained by dividing the adjusted specific capacities in table 36 by the total depth of penetration of the wells.

Wells were divided into two categories depending upon whether wells are located within the dewatered area or outside of it. Adjusted specific capacities per foot of pene?? tration for wells in the two categories were tabulated in order of magnitude, and frequencies were computed. Values of adjusted specific capacity per foot of penetration were then plotted against percent of wells on logarithmic probability paper, as shown in figure 127. The frequency graphs indicate that the specific capacities of wells within the area of dewatering are much less than the specific capacities of wells outside the area of dewatering. Based on specific capacities with a frequency of 50 percent, it is estimated mat the specific capacities of wells widiin the area of

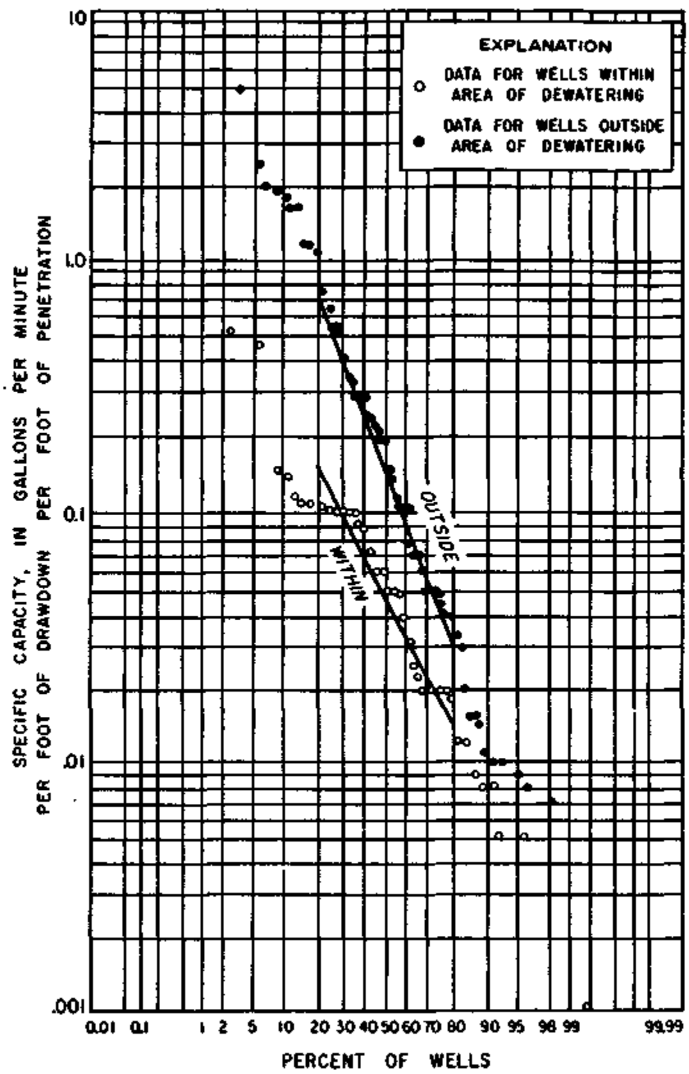

Figure 127. Specific-capacity frequency graphs for dolomite wells in LaGrange area

dewatering have decreased on the average about 70 percent as a result of dewatering. Specific-capacity data in table 36 indicate that the coefficient of transmissibility of the Silurian dolomite averages about 100,000 gpd/ft in areas where dewatering has not occurred. In areas where upper portions of the dolomite have been dewatered, the coefficient of transmissibility is reduced to about 30,000 gpd/ft.

Probable Yields of Wells

Probable range of yields of wells can be estimated from the frequency graphs in figure 127 and data on the thickness of the Silurian dolomite aquifer. Probable specific capacities of wells were estimated as the product of the specific capacity per foot of penetration measured in 50 percent of the existing wells and aquifer thicknesses. Specific capacities equal to or less than 45 gpm/ft can be expected in all parts of the LaGrange area except where extensive dewatering has taken place. Specific capacities equal to or less than 17 gpm/ft can be expected in the areas where extensive dewatering of the uppermost productive portion of the Silurian dolomite aquifer has taken place.

Probable specific capacities were in turn multiplied by available drawdowns based on water-level data in figure 125 to estimate the probable yields of wells. Pumping levels were limited to depths below the top of the Silurian dolomite aquifer equal to 100 feet.

It is possible to drill what is essentially a dry hole at any location; however, based on data for 50 percent of existing wells, the chances of obtaining a well yielding 500 gpm and sufficient to support heavy industrial or municipal well development are good in all of the Silurian dolomite aquifer of the LaGrange area, except near the limestone quarries in the southeast part of the area.

Recharge to Aquifer

Recharge from precipitation to the Silurian dolomite " aquifer in the LaGrange area occurs as vertical leakage of water through overlying glacial deposits. The rate of recharge to the aquifer was estimated using the piezometric surface map and past records of pumpage and water levels. The area of diversion of pumping was delineated as explained earlier and is shown in figure 125; pumpage data are given in figure 118. Because recharge balances discharge, the average rate of recharge to the aquifer during 1962 is the quotient of the average pumping rate and the area of diversion. Computations show that the average rate of recharge in 1962 to the Silurian dolomite aquifer in the LaGrange area was about 160,000 gpd/sq mi.

Darcy's equation indicates that the recharge rate varies with the vertical head loss (Δh) associated with leakage of water through materials. The average vertical head loss in 1962 was computed to be about 30 feet by comparing the piezometric surface map for the Silurian dolomite aquifer with water-level data for shallow dug wells. The average rate of recharge taking into account head loss is about 5300 gpd/sq mi/ft.

Vertical Permeability of Confining *Bed*

Based on Darcy's equation, the vertical permeability of the confining bed between the Silurian dolomite aquifer and surface deposits may be computed by multiplying the recharge rate per unit area per foot of head loss $(Q_c/A_c\Delta h)$ by the saturated thickness of the confining bed. Based on available logs, the average saturated thickness of the glacial drift confining bed within the area of diversion is about 40 feet. It is possible that shaly or argillaceous beds in the upper part of the Silurian dolomite aquifer also retard vertical movement of water towards permeable zones widiin the dolomite aquifer. An average coefficient of vertical permeability of 0.008 gpd/sq ft was computed by substituting appropriate data in Darcy's equation.

Practical Sustained Yield of Existing Well Fields at LaGrange and Western Springs

According to figure 125 and data on available drawdowns, the present area of diversion and vertical hydraulic gradients can be increased by additional pumpage from existing pumping centers, indicating that the practical sustained yield of the existing well fields is greater than present withdrawals. The inconsistency of productivity of wells in the Silurian dolomite aquifer has little effect on the regional response of the aquifer to pumping and should not deter full development of available ground-water resources.

The nonpumping levels of water in production wells at LaGrange and Western Springs were below the top of the Silurian dolomite aquifer in 1962. The yields of production wells will decrease as more of the aquifer is dewatered. Declines in yield will probably become critical after half of the Silurian dolomite aquifer is dewatered. Therefore available drawdown at LaGrange and Western Springs is limited.

The amounts of water, in addition to withdrawals in 1962, that can be withdrawn from the LaGrange and Western Springs pumping centers without creating critical water levels or exceeding recharge were estimated, taking into consideration the recharge rate, the hydraulic properties of the aquifer, and available drawdown. Computations indicate that the practical sustained yield of the existing wells at LaGrange and Western Springs is about 5 mgd or about twice the average annual pumpage from existing wells in 1962..

The pumping rate schedule required to fully develop the practical sustained yield is as follows: for wells 4.8c and 4.8d, an average daily pumpage rate of 0.6 mgd; for wells 5.3e and 5.4d, a rate of 1.0 mgd; for wells 5.8c and 5.8dl, a rate of 1.1 mgd. It should be emphasized that these pumpage figures are daily averages.

In order to increase the amount of recharge to the Silurian dolomite aquifer from the 1962 rate to the practical sustained yield, the product ΔhA_c must increase in direct proportion to the increase in pumpage. Thus, full development of the practical sustained yield will be accompanied by large increases in the area of diversion and by additional water-level declines.

OTHER SELECTED AREAS

There are other sand and gravel and shallow dolomite aquifers in northeastern Illinois, outside the areas described in this report, on which data for heavy pumping are available. Information is limited, however, and it is impossible to estimate recharge rates or make detailed studies concerning the practical sustained or potential yields of aquifers. Available data on specific capacities of individual wells and of pumping centers are presented in this section to demonstrate mat large quantities of water are being successfully obtained from shallow aquifers throughout most of northeastern Illinois. Areas of diversion of pumping centers in 1962 are discussed in relation to the total potential yield of sand and gravel and shallow dolomite aquifers.

Available specific-capacity data for wells in sand and gravel aquifers in areas aside from the five discussed earlier are summarized in table 38. Specific capacities range from 1.0 to 300 gpm/ft and average about 25 gpm/ft. Data suggest that the yields of sand and gravel aquifers are probably high enough to support heavy industrial or municipal well development in many areas in northeastern Illinois.

Figure 128 shows the areas of diversion of wells in sand : and gravel aquifers in 1962. The map is based on pump-, age data, collected from the files of the State Water Survey, and estimated recharge rates presented earlier in this report. There are large areas where heavy well development is possible that are outside these areas of diversion. This suggests that the potential yield of sand and gravel aquifers is much greater than present withdrawals. Total withdrawals from sand and gravel wells in northeastern Illinois were about 21 mgd in 1960.

Fairly extensive surficial sand and gravel deposits are found in parts of Lake, McHenry, Kane, DuPage, Kendall, and Will Counties. Deeply buried sand and gravel deposits are widely scattered in McHenry and Kane Counties, western Lake County, northwestern Cook and DuPage Counties, northwestern Kendall County, and central Will County *(see figure 12 in* Suter et al., 1959). The chances of penetrating continuous water-yielding beds of considerable thickness are better within bedrock valleys *(see figure 13 in* Suter et al„ 1959) than in bedrock uplands. However, bedrock valleys in Lake, Cook, and DuPage Counties that slope eastward toward Lake Michigan are generally filled with fine sediment.

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

Available specific-capacity data for wells in the shallow dolomite aquifers in northeastern Illinois were given by Csallany and Walton (1963). Specific capacities range from 0.03 gpm/ft to over 3000 gpm/ft.

The shallow dolomite aquifers consist of Silurian rocks in most of northeastern Illinois *(see figure 16 in* Suter et al., 1959) and dolomites of the Maquoketa and Galena-Platteville Formations in the western part of the area.

Csallany and Walton (1963) concluded that the Niagaran Series, Alexandrian Series, and Galena-Platteville Dolomite

Table 38. Specific-Capacity Data for Wells in Sand and Gravel Aquifers in Northeastern Illinois

Location and owner of well	Depth of well (ft)	Diam. of casing (in)	Screen length (ft)	Screen diam. (in)	Thickness of aquifer (ft)	Year of test	Non-pumping level (ft)	Pumping rate (gpm)	Drawdown (ft)	Specific capacity (gpm/ft)
Cook County										
Chicago										
Chicago Art Inst.	65			18		1935	6	46	6	7.8
Northbrook										
Sunset Ridge Club	123					1934	60	250	33	7.6
Palatine										
Anderson	184			4		1960	73.8	65	18.9	3.4
T. A. Gelderman	170			4		1960	83.1	80	4.3	18.6
Schaumburg										
Elmhurst-Chicago Stone Co.	85		10	8		1959	10	250	50	5.0
Streamwood Sbd.	120		10			1957	60	1300	10	130.0
Streamwood Sbd.	108		10	6		1956	61	60	3	20.0
DuPage County										
Bloomingdale										
Medinah CCb.	68	8	15	16		1956	14.0	1100	27.0	40.7
Elmhurst										
Standard Oil Co.	218	8				1958	25.0	60	62.0	1.0
Lemont										
State Geological Survey	75	10	14	7		1943	19.5	273	24.8	11.0
Lombard										
York Center Comm. Co-op	81	6	10	6		1960	37.0	150	5.5	2.7
Grundy County										
Morris										
DuPont Seneca Works	135			17		1951	96	320	9	35.6
Wilmington										
Village	221					1947	21	300	1	300.0
Kendall County										
Plano										
City	40		10	26-38		1946	6.0	325	14.8	22.0
City	39.5		10	26		1960	5.0	354	8.2	43.2
Yorkville										
Village	42		15	12		1958	2.6	203	17.9	11.4
Lake County										
Antioch										
Village	226	10	20		70	1946	39	200	22	9.1
Lake Villa										
Village	167	12–10	26	10	233	1938	55	154	4.5	34.2
Libertyville										
Fould's Milling	202	8	14	8	190	1945	7	275	84.5	3.3
Milburn										
Traer Well	190	12	17		90	1948	42	127	13	9.8
McHenry County										
Crystal Lake										
City	45				250	1948	15	307	28.7	10.7
City	48	12	10	10	25	1948	17.8	250	17.8	14
Harvard										
City	71	14	15			1947	17	600	50.0	12
City	69	26	20		120	1946	17	375	29.0	12.9
Huntley										
Village	74	6			55	1947	23	100	3.0	33.3
Village	69	10			52	1953	22	317	11.0	28.8
Marengo										
City	21	240			19+	1947	7.3	150	4.3	34.9
McHenry										
City	104	24	20		95+	1947	9	400	22.0	18.2
Richmond										
Village	170	10	10	14	140	1947	23	150	42.0	3.6
Kane County										
Burlington										
City	111	6	15			1941	33.0	40	5.0	8
Elburn										
Village	153	8–10	11		68	1947	85	75	20	3.7
Elgin										
St. Charles	105	16			92	1945	13.0	950	60.0	15.8
N. State	43	25	18		27	1946	28.5	215	5.5	39
Crighton	53	25	12		34+	1946	8.3	200	23.7	8.5
Ill. Tool Works	249					1944	23.5	237	21.5	11
Sugar Grove										
Village	104				135	1948	49.6	106	5.8	18.3

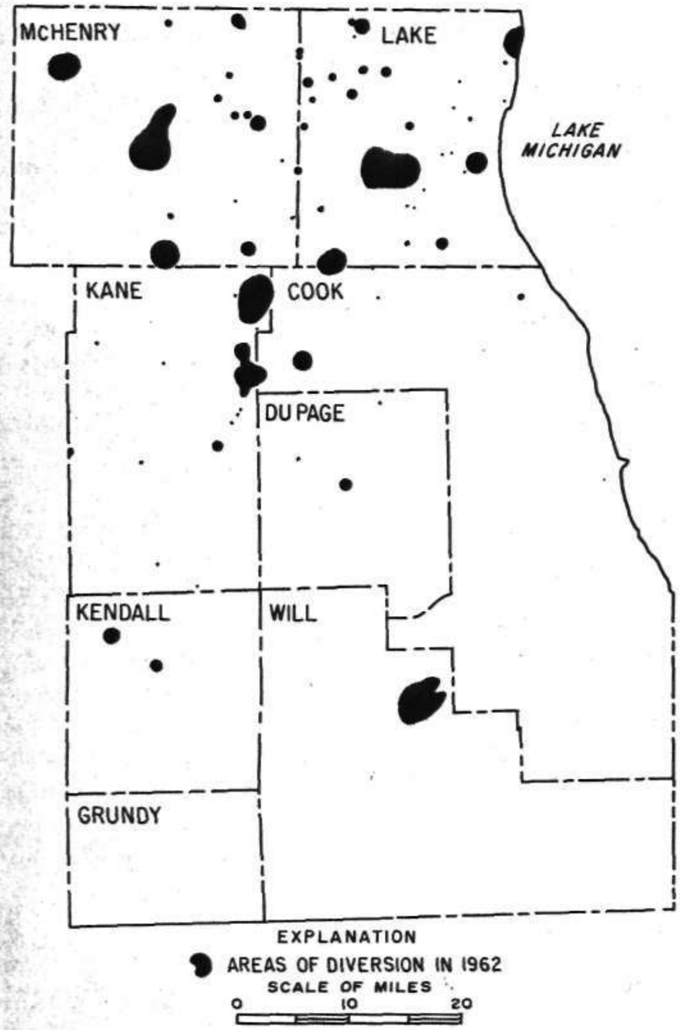

Figure 128. Areas **of diversion of sand and gravel wells in** northeastern **Illinois**

all have similar moderate to high yields and inconsistency of yields in areas throughout northern Illinois where these rocks directly underlie glacial drift. These Silurian and Ordovician rocks have similar low yields and inconsistency of yields in areas where these rocks are overlain by bedrock. Most water-yielding openings occur in the upper third of the shallow dolomite aquifers. There is a good connection between the glacial drift and the upper part of the shallow dolomite aquifers. Highest yielding wells are found in bedrock upland areas, in areas where the glacial drift immediately overlying the shallow dolomite aquifers is composed of sand and gravel, and in areas where reefs and associated strata are present

The thickness of the Silurian rocks increases from less than 50 feet in the western part to more than 450 feet in the southeast part of northeastern Illinois *(see figure 27 in* Suter et al., 1959). Where valleys occur in the bedrock, the Silurian rocks are thin.

Figure 129 shows the areas of diversion of wells in Silurian rocks in 1962. The map is based on pumpage data, collected from the files of the State Water Survey, and estimated recharge rates given earlier in this report. There are large areas where heavy well devlopment is possible that are not influenced by present pumpage, suggesting that the potential yield of the Silurian rocks is much greater than present withdrawals. Total pumpage from shallow dolomite wells in northeastern Illinois was about 55 mgd in 1960.

Csallany and Walton (1963, *see figure 29)* estimated the probable range of yields of shallow dolomite wells in northeastern Illinois. It is possible to drill what is essentially a dry hole at any location; however, based on data for 50 percent of existing wells, the chances of obtaining a well with a production of 250 gpm or more are good in all areas except areas where the Silurian rocks and Galena-Platteville Dolomite are thin, or where the Maquoketa Formation is the uppermost bedrock. The chances of obtaining a well with a production of 500 gpm or more are good in large portions of northeastem Illinois.

Areas of diversion in figure 129 include sites where the shallow dolomite aquifers yield very little water to individual wells. However, the piezometric surface maps for the Libertyville, LaGrange, and Chicago Heights areas are

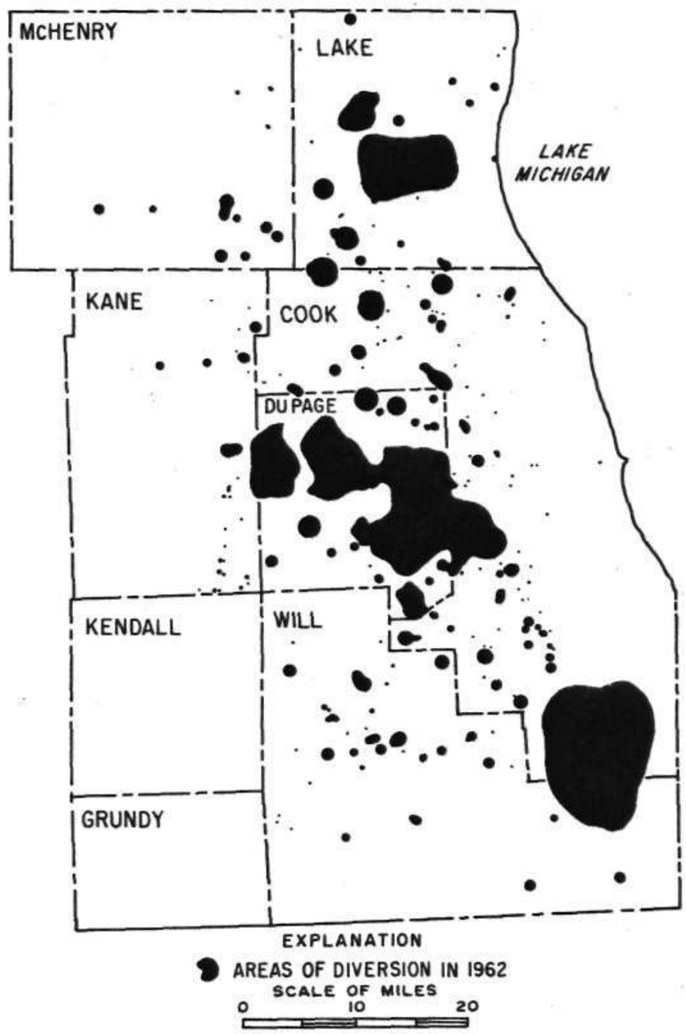

Figure 129. Areas of diversion of shallow dolomite 1wells in northeastern Illinois

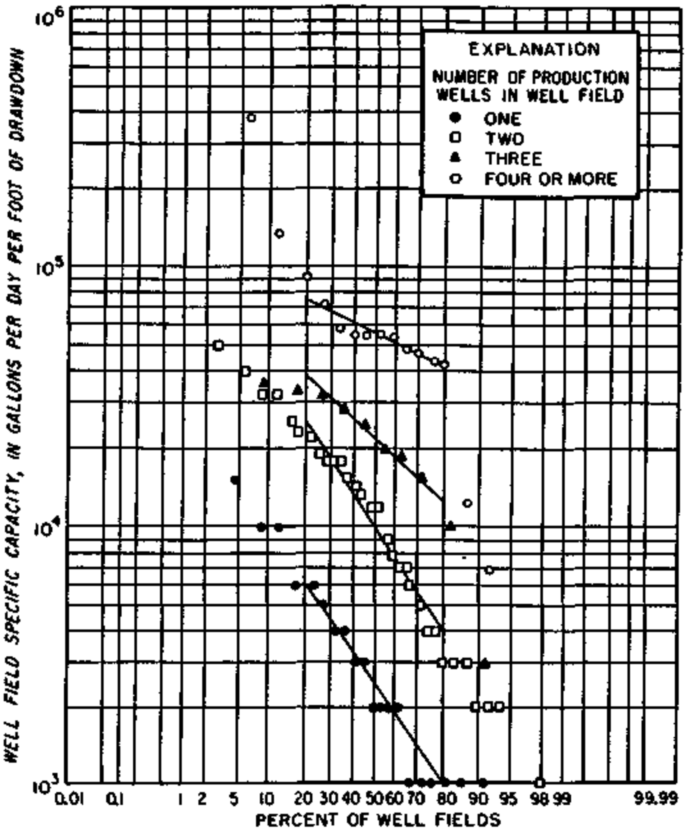

Figure 130. Specific-capacity frequency graphs for well fields in northeastern Illinois

regular in appearance and could be favorably compared to piezometric surface maps for uniform sand and gravel aquifers. These facts indicate that the inconsistency of yield of the shallow dolomite aquifers has little effect on the regional response of the aquifers to pumping, and should not seriously deter the field development of available ground-water resources. Because the shallow dolomite aquifers are thick, fairly deeply buried, and on a regional basis have high to moderate permeabilities and great areal extent, areas of diversion of production wells extend for considerable distances, and available ground-water resources can be developed with a reasonably small number of wells and well fields.

That large quantities of water can be successfully obtained from sand and gravel and shallow dolomite aquifers is further indicated by the data in tables 39 and 40. Specific capacity of well fields is defined here as the total pumpage from wells within a given well field per foot of average drawdown within the given well field. Specific capacities of well fields vary greatly from place to place, depending primarily upon the number of production wells in the field, the average spacing of the wells, and the water-yielding properties of the aquifer penetrated by the wells.

Specific capacities of well fields where wells are in sand and gravel aquifers range from 900 to 388,000 gpd/ft and average about 42,000 gpd/ft. As a comparison, specific capacities of well fields with wells in Silurian rocks range from 200 to 120,000 gpd/ft and. average about 22,000 gpd/ft.

Well fields were segregated into four categories: those which had one, two, three, and four or more wells. Specific capacities in each of the four categories were tabulated in order of magnitude, and frequencies were computed. Values of specific capacity of well fields in each category were then plotted against percent of well fields on logarithmic probability paper as shown in figure 130. Specific capacities increase as the number of wells in a well field increases. Thus, the yield of an aquifer is dependent in part upon the number and spacing of wells in a well field. The greater the number of wells and distances between wells, the greater the amount of water that can be developed within an area with a given allowable drawdown.

Well fields containing two production wells were further segregated into two categories: those in which the two wells had specific capacities 1) greater than 25 gpm/ft, and 2) less man 25 gpm/ft. Specific capacities in the two categories were tabulated in order of magnitude, and frequencies were computed. Figure 131 shows the frequency graphs for the two categories. The higher the specific capacity of the individual well, the higher the specific capacity of the well field. As with individual wells, specific capacities of well fields depend upon the hydraulic properties of an aquifer, and increase as the coefficient of transmissibility of the aquifer increases.

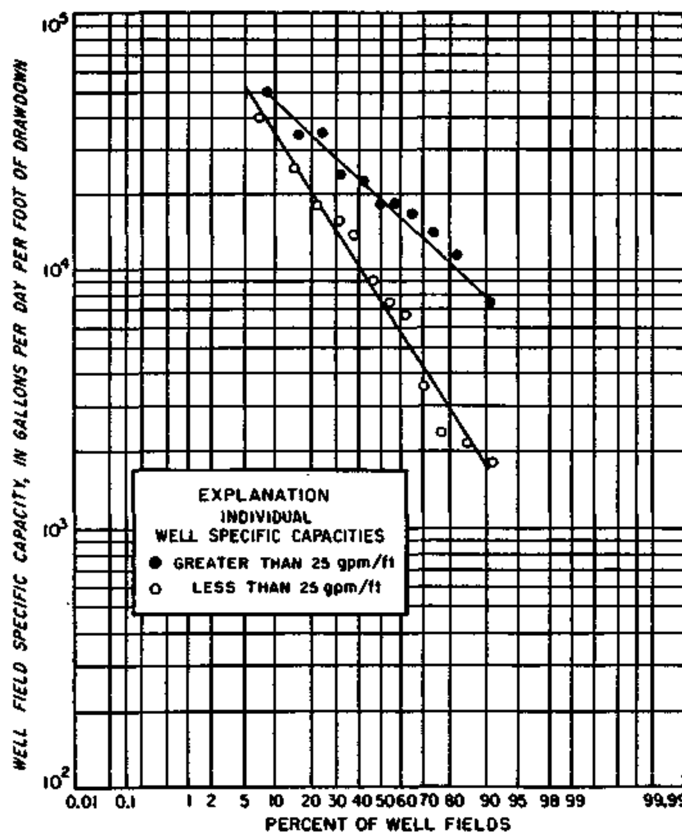

Figure 131. Specific-capacity frequency graphs for selected two-well systems In northeastern Illinois

Geohydrologic settings in many areas have heretofore been considered too complex to permit their quantitative description with existing ground-water formulas. The case histories of ground-water development described in this report suggest that it is often possible to appraise ground-water resources with analytical expressions by devising methods of analysis based on idealized models of aquifer situations. Statistical analysis is required when dolomite aquifers are involved. By checking computed performance of wells and aquifers with records of past pumpage and water levels, the investigator is assured of reasonably accurate solutions.

Geohydrologic conditions often can be highly idealized with little sacrifice in accuracy of analysis, if this is done with sound professional judgment. In addition, the adequacy and accuracy of basic data are seldom sufficient to warrant a rigorous theoretical and precise quantitative evaluation of ground-water conditions. In many cases, the complexity of geologic conditions dictates that quantitative appraisals derived from any method of analysis can at best be considered only approximations.

It is recognized that methods of analysis described in this report and based on idealized assumptions provide only approximate answers on a bulk basis.

The case histories of ground-water development presented in this report point out the need to place more emphasis on tying together scattered and apparently disconnected studies of wells and aquifers into areal studies. It is apparent that quantitative answers depend primarily upon the accurate description of geologic conditions. In the future, more emphasis should be placed on relating the geology to hydrologic parameters.

Table 39. Data on Response of Sand and Gravel Aquifers in Northeastern Illinois to Heavy Pumping

Location and owner of well field	Number of wells in well field	Nonpumping water level elevation (ft above MSL) and date measured: early	recent	Decline in water level elevation (ft)	Recent pumping rate (gpd)	Well field specific capacity (gpd/ft)
Cook County						
Streamwood (V)	2	770(8/57)	769(1/58)	1	50,000	50,000
Sunset Ridge CCb.	1	595(5/34)	561(10/60)	34	30,000	900
Kendall County						
Yorkville (V)	2	670(5/54)	656(10/60)	14	80,000	5,700
Kane County						
Sugar Grove (V)	2	777(4/48)	775(7/61)	2	18,000	9,000
Elburn (V)	1	765(3/37)	742(11/60)	23	29,000	1,300
Maple Park (V)	1	846(10/46)	836(1/59)	10	35,000	3,500
Skyline Estates Sbd.	1	691(11/58)	685(7/60)	6	15,000	2,500
McGraw Electric Co.	–	717(4/57)	712(1/60)	5	317,000	63,000
South Elgin (V)	1	696(5/57)	682(11/60)	14	25,000	1,800
Meadowdale Sbd.	2	782(10/55)	746(3/60)	36	1,121,000	33,000
East Dundee (V)	1	728(12/58)	708(2/60)	20	115,000	5,800
Lake County						
Jewel Tea Co.	–	772(1936)	751(6/61)	21	500,000	24,000
Island Lake Wtr. Co.	–	761(1940)	754(3/60)	7	36,000	5,100
Mundelein (V)	3	681(5/54)	663(7/60)	20	400,000	20,000
Wildwood Sbd.	2	702(1952)	665(11/61)	37	69,000	1,900
Antioch (V)	2	740(11/32)	680(4/59)	60	200,000	3,300
McHenry County						
Union Special Co.	–	866(1945)	859(1/59)	7	200,000	29,000
Dean Milk Co.	–	879(1/46)	868(8/58)	11	250,000	23,000
Huntley (V)	2	867(11/53)	864(1/59)	3	100,000	33,000
Cary (V)	1	728(11/56)	702(6/61)	26	145,000	5,600
Woodstock (C)	4	866(2/21)	833(2/60)	33	1,765,000	54,000
McHenry (V)	1	755(1923)	746(7/47)	9	90,000	10,000
Pistakee Highlands Sbd.	2	744(1954)	736(2/61)	8	60,000	7,500
Harvard (C)	3	908(1929)	890(1/61)	18	638,000	35,000
Hebron (V)	2	869(1905)	855(1951)	14	110,000	7,900
Richmond (V)	2	819(4/27)	791(5/58)	28	60,000	2,100
Will County						
Joliet (C)	5	640(6/50)	624(12/60)	10.5	4,067,000	388,000

Table 40. Data on Response of Silurian Rocks in Northeastern Illinois to Heavy Pumping

Location and owner of well field	Number of wells in well field	Nonpumping water level elevation (ft above MSL) and date measured: early	recent	Decline in water level elevation (ft)	Recent pumping rate (gpd)	Well field specific capacity (gpd/ft)
Cook County						
Flossmoor (V)	5	634(8/26)	621(12/57)	13	608,000	47,000
Olympia Fields (V)	2	666(7/59)	664(2/62)	2	30,000	15,000
Park Forest (V)	5	671(2/47)	644(12/60)	27	1,927,000	71,000
Matteson (V)	2	691(1914)	674(2/61)	17	300,000	17,600
Richton Park (V)	1	715(1926)	694(4/61)	21	50,000	2,400
Flintkote Co.	—	559(10/46)	552(3/61)	7	204,000	29,000
Chicago Heights (C)	15	597(1917)	507(4/61)	90	5,230,000	58,000
Orland Park (V)	3	677(5/56)	672(4/60)	5	169,000	34,000
Tinley Park St. Hosp.	—	687(10/52)	646(7/58)	41	50,000	1,200
Oak Forest (V)	2	635(2/52)	640(1/58)	5	80,000	16,000
Homewood (V)	8	621(3/46)	610(9/61)	24	1,320,000	55,000
Lemont (V)	2	628(12/54)	614(12/60)	14	247,000	18,000
LaGrange (V)	6	588(4/50)	558(11/59)	30	1,625,000	54,000
Dise Sbd.	—	616(9/52)	615(3/58)	1	23,500	23,500
Edgewood Acres Sbd.	1	612(11/53)	607(3/58)	5	12,180	2,400
Justice (V)	1	603(5/54)	595(1/58)	8	21,000	2,700
Berkeley (V)	2	635(12/35)	625(2/44)	10	178,000	17,800
Bartlett (V)	2	769(2/48)	745(2/59)	24	75,000	3,100
Weathersfield Sbd.	—	763(12/58)	759(10/62)	4	175,000	44,000
Hatlen Heights Sbd.	1	656(12/55)	641(6/58)	15	33,000	2,200
Barrington (V)	2	758(1/29)	731(1/59)	27	612,000	23,000
Palatine (V)	3	738(10/45)	722(6/61)	16	259,000	16,000
Wheeling (V)	2	632(1926)	604(10/58)	36	374,000	14,000
Citizens Bluett Co.	—	634(1953)	630(7/58)	4	36,000	9,000
DuPage County						
Argonne Nat. Lab.	—	648(1948)	612(6/60)	36	951,000	26,000
Bellmont-Highwood Wtr. Dist.	2	656(1954)	648(7/60)	8	35,000	4,400
Hinsdale (V)	6	594(1947)	610(6/60)	16	1,914,000	120,000
Downers Grove (V)	4	655(1934)	616(7/60)	39	1,901,000	49,000
West Chicago (C)	3	710(1915)	660(7/60)	50	512,000	10,000
Glen Ellyn(V)	3	712(1934)	668(6/60)	44	1,268,000	29,000
Wheaton (C)	5	717(1917)	695(6/60)	22	2,000,000	91,000
Lombard (V)	—	686(1918)	680(7/60)	6	317,000	53,000
Villa Park (V)	2	662(1925)	647(7/60)	15	265,000	18,000
Roselle (V)	2	709(1953)	716(3/60)	7	279,000	40,000
Itasca (V)	3	684(1939)	676(1960)	8	189,000	24,000
Addison (V)	4	672(1924)	662(6/60)	10	477,000	48,000
Kane County						
North Lake Manor	—	674(6/41)	642(6/57)	32	60,000	1,900
Montgomery (V)	1	618(5/28)	588(8/47)	30	30,000	1,000
Campana Co.	—	659(6/36)	559(6/57)	100	20,000	200
Valley View Sbd.	2	688(7/57)	685(10/58)	3	12,000	4,000
Illinois Tool Works	—	725(6/41)	708(3/46)	17	210,000	12,300
Hampshire (V)	1	870(7/43)	844(12/58)	26	90,000	3,500
Lake County						
Lake Zurich (V)	2	760(1921)	742(5/59)	18	200,000	11,000
Wauconda (V)	3	754(5/39)	746(3/59)	8	250,000	31,000
Mundelein (V)	4	668(1954)	652(8/62)	31	220,000	7,100
N. Libertyville (V)	1	610(8/54)	624(4/62)	14	30,000	2,200
Libertyville (V)	6	660(1/48)	602(1/60)	78	869,000	11,000
Grays Lake (V)	3	714(9/58)	702(10/60)	12	230,000	19,000
Round Lake Pk. (V)	2	754(1939)	720(1958)	34	250,000	7,300
Round Lake (V)	2	755(1922)	715(8/58)	40	92,000	2,300
McHenry County						
Union (V)	1	793(10/55)	790(7/58)	3	30,000	10,000
Fox River Grove (V)	2	732(1928)	728(1961)	4	103,000	26,000
Sunnyside (V)	1	849(1942)	771(6/55)	78	20,000	260
Will County						
Peotone (V)	2	693(1922)	685(1961)	8	100,000	12,000
Manhattan (V)	2	660(10/23)	592(9/55)	68	50,000	730
Monee (V)	3	735(1915)	720(1960)	15	45,000	3,000
Steger (V)	2	680(1926)	660(1961)	20	437,000	22,000
Crete (V)	2	689(6/15)	658(8/49)	31	110,000	3,500
Ridgewood Sbd.	1	529(1940)	512(3/59)	17	17,000	1,000
Mokena (V)	1	664(1/45)	659(6/52)	5	70,000	14,000
Plainfield (V)	1	600(1929)	554(1953)	46	100,000	2,200

REFERENCES

Atlas of Illinois resources, sec. 1; Water resources and climate. 1958. State of Illinois, Dept. of Registration and Education, Div. of Industrial Planning and Development.

Copper, H. H., Jr., and C. E. Jacob. 1946. A generalized graphical method for evaluating formation constants and summarizing well-field history. Trans. Am. Geophys. Union v. 27(4).

Csallany, Sandor, and W. C. Walton. 1963. Yields of shallow dolomite wells in northern Illinois. Illinois State Water Survey Rept. of Invest. 46.

Ferris, J. G. 1959. Ground water, chap. 7. In C. O. Wisler and E. F. Brater, ed., Hydrology, John Wiley & Sons, Inc., New York.

Hantush, M. S., and G. E. Jacob. 1955. Non-steady radial flow in an infinite leaky aquifer. Trans. Am. Geophys. Union v. 36(1).

Horberg, Leland. 1950. Bedrock topography of Illinois. Illinois State Geol. Survey Bull. 73.

Horberg, Leland, and K. O. Emery. 1943. Buried bedrock valleys east of Joliet and their relation to water supply. Illinois State Geol. Survey Circ. 95.

Horberg, Leland, and Paul E. Potter. 1955. Stratigraphic and sedimentologic aspects of the Lemont drift of northeastern Illinois. Illinois State Geol. Survey Rept of Invest. 185.

Jacob, C. E. 1946a. Drawdown test to determine effective radius of an artesian well. Proc. Am. Soc. Civil Engrs. v. 72(5).

Jacob, C. E 1946b. Radial flow in a leaky artesian aquifer. Trans Am. Soc. Civil Engrs. v. 27(2).

Kimball, B. F. 1946. Assignment of frequencies to a completely ordered set of sample data. Trans. Am. Geophys. Union v.)27.

Linsley, R. K., Jr., Max A. Kohler, and J. L. Paulhus. 1958. Hydrology for engineers. McGraw-Hill Book Co., New York.

Mitchell) W. D. 1957. Flow duration of Illinois streams. Illinois Division of Waterways, Springfield.

Muskat, M 1946. The flow of homogeneous fluids through porous media. McGraw-Hill Book Co., New York.

Public ground-water supplies in Illinois. 1950. Illinois State Water Survey Bull. 40.

Rasmussen, W. C, and G. E. Andreasen. 1959. Hydrologic budget of the Beaverdam Creek basin, Maryland. U. S. Geol. Survey Water Supply Paper 1472.

Sasman, R. T., W. H. Baker, Jr., and W. P. Patzer. 1962. Water-level decline and pumpage during 1961 in deep wells in the Chicago region, Illinois. Illinois State Water Survey Circ. 85.

Schicht, R. J., and W. C. Walton. 1961. Hydrologic budgets for three small watersheds in Illinois. Illinois State Water Survey Rept. of Invest. 40.

Suter, Max, R. E. Bergstrom, H. F. Smith, G. H. Emrich, W. C. Walton, and T. E. Larson. 1959. Preliminary report on ground-water resources of the Chicago region, Illinois. Illinois State Water Survey and Geol. Survey Cooperative Ground-Water Rept. 1.

Theis, C. V. 1935. The relation between the lowering of piezometric surface and the rate and duration of discharge of a well using ground-water storage. Trans. Am. Geophys. Union 16th Ann. Meeting, pt. 2.

U.S. Dept. of Commerce, Weather Bureau. 1961. Local climatological data with comparative data, Chicago, Illinois.

Walton, W. C. 1960. Leaky artesian aquifer conditions in Illinois. Illinois State Water Survey Rept. of Invest. 39.

Walton, W. C. 1962. Selected analytical methods for well and aquifer evaluation. Illinois State Water Survey Bull. 49.

Walton, W. C, and J. C. Neill. 1963. Statistical analysis of specific capacity data for a dolomite aquifer. Jour. Geophys. Research v. 68(8).

Walton, W. C, and W. H. Walker. 1961. Evaluating wells and aquifers by analytical methods. Jour. Geophys. Research v. 66(10).

Zeizel, A. J., W. C. Walton, R. T. Sasman, and T. A. Prickett. 1962. Ground-water resources of DuPage County, Illinois. Illinois State Water Survey and Geol. Survey, Cooperative Ground-Water Rept. 2.

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