CHANGES IN CHLORIDE CONCENTRATION IN WATER FROM MUNICIPAL WELLS THAT TAP AQUIFERS IN ROCKS OF CAMBRIAN AND ORDOVICIAN AGE IN NORTHEASTERN ILLINOIS, 1915-84

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 90-4116

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By G. O. Balding

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may want to use metric (International System) units, the inch-pound values in this report may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
square mile (mi^2)	259.0	hectare (ha)
	2.590	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per day per foot [(gal/d)/ft]	0.0124	meter squared per day (m^2/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
parts per million (ppm)	1.0	milligrams per liter (mg/L)

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

During the past few decades, several municipalities in northeastern Illinois have noted increases in the salinity of water from wells that tap aquifers in rocks of Cambrian and Ordovician age. The municipalities have discontinued the use of, or sealed-off sections of, those wells. The aquifers involved include the Ancell, the Ironton-Galesville, and the Elmhurst-Mt. Simon.

To define the location, magnitude, and possible causes for the salinity increases in the six northeastern counties of Illinois, 17 municipal wells and 1 deep test well were selected on the basis of their proximity to major pumping centers, the availability of water-quality data, and their documented maintenance history. Well depths ranged from about 960 to 3,475 feet. One well was finished in the middle confining unit, 2 wells were finished in the Ironton-Galesville aquifer, 4 wells were finished in the Eau Claire confining unit, and 10 wells were finished in the Elmhurst-Mt. Simon aquifer. The deep test well was finished below the Elmhurst-Mt. Simon aquifer in Precambrian-age rock.

Chloride concentrations in the municipal wells ranged from less than 5 to greater than 600 milligrams per liter; in the deep test well, they ranged from 13 to 37,000 milligrams per liter. Some changes in the chloride concentration in water from the studied municipal wells can be related to physical changes to the wells, including the partial filling in of a well, bridging within a well, the cleaning out of a well, or the deepening of a well. Some changes in chloride concentration are not related to physical changes but may be caused by increased pumpage; changes in pumping rate, frequency, or duration; cessation of pumping; improper abandonment of wells; and the upconing of highly mineralized water. The data base was inadequate for a quantitative study of the changes in chloride concentration in water from individual aquifers in rocks of Cambrian and Ordovician age.

INTRODUCTION

In the late 1970's, the U.S. Geological Survey (USGS) initiated the Regional Aquifer-System Analysis (RASA) to study regional aquifer systems throughout the United States. The general goals of a RASA investigation are to evaluate each aquifer's water-supply potential and water quality, and, using computer models of the ground-water flow system, to provide a means for evaluating aquifer response to stresses placed on the flow system.

The Northern Midwest RASA, which began in October 1978, studied the aquifers in the Cambrian and Ordovician Systems that lie beneath almost all of Iowa and parts of Minnesota, Wisconsin, Indiana, Illinois, and Missouri (fig. 1). A part of the Northern Midwest RASA study, as summarized by Steinhilber and Young (1979), pertains to the regional assessment of water quality and includes a study of the saline water to define its characteristics, occurrence, potential movement to fresh-water zones, and historical changes in the water quality as a result of aquifer development.

In northern Illinois, the aquifers in rocks of Cambrian and Ordovician age (hereafter termed "Cambrian and Ordovician Systems") are a major source of water for municipal, industrial, and agricultural use. Demands are heaviest in the Chicago area where development of the aquifers began in 1864. Continued development of the aquifers has caused the potentiometric surface to decline several hundred feet and has enlarged the cone of depression to such a degree that it extends into southeastern Wisconsin. Demands on the aquifers are projected to increase, resulting in further declines in the potentiometric surface.

During the past few decades, several municipalities in northeastern Illinois have noted increases in the chloride concentration in water from wells that tap the aquifers in the Cambrian and Ordovician Systems [concentrations at some wells exceeded 250 mg/L (milligrams per liter), the State limit for chloride in public drinking-water supplies (Illinois Pollution Control Board, 1984a, 1984b)]. As a result, some municipalities have discontinued the use of, or sealed-off sections of, those wells.

In 1985, the USGS began a study--using only readily available data--to examine the occurrence and possible causes of changes in chloride concentration in water from wells that tap the aquifers in the Cambrian and Ordovician Systems in northeastern Illinois. Available data include information on well location, well construction and maintenance, water levels, and water quality. Data were available from State and Federal reports and data bases, including those of the Illinois State Water Survey (ISWS), the Illinois State Geological Survey (ISGS), and the USGS.

Purpose and Scope

This report describes the location, magnitude, and causes of the changes in chloride concentration in the aquifers in the Cambrian and Ordovician Systems in a six-county area of northeastern Illinois (fig. 1). The report includes stratigraphic columns, maps, and graphs that show the geology and hydrogeology of the study area and the changes in chloride concentration in

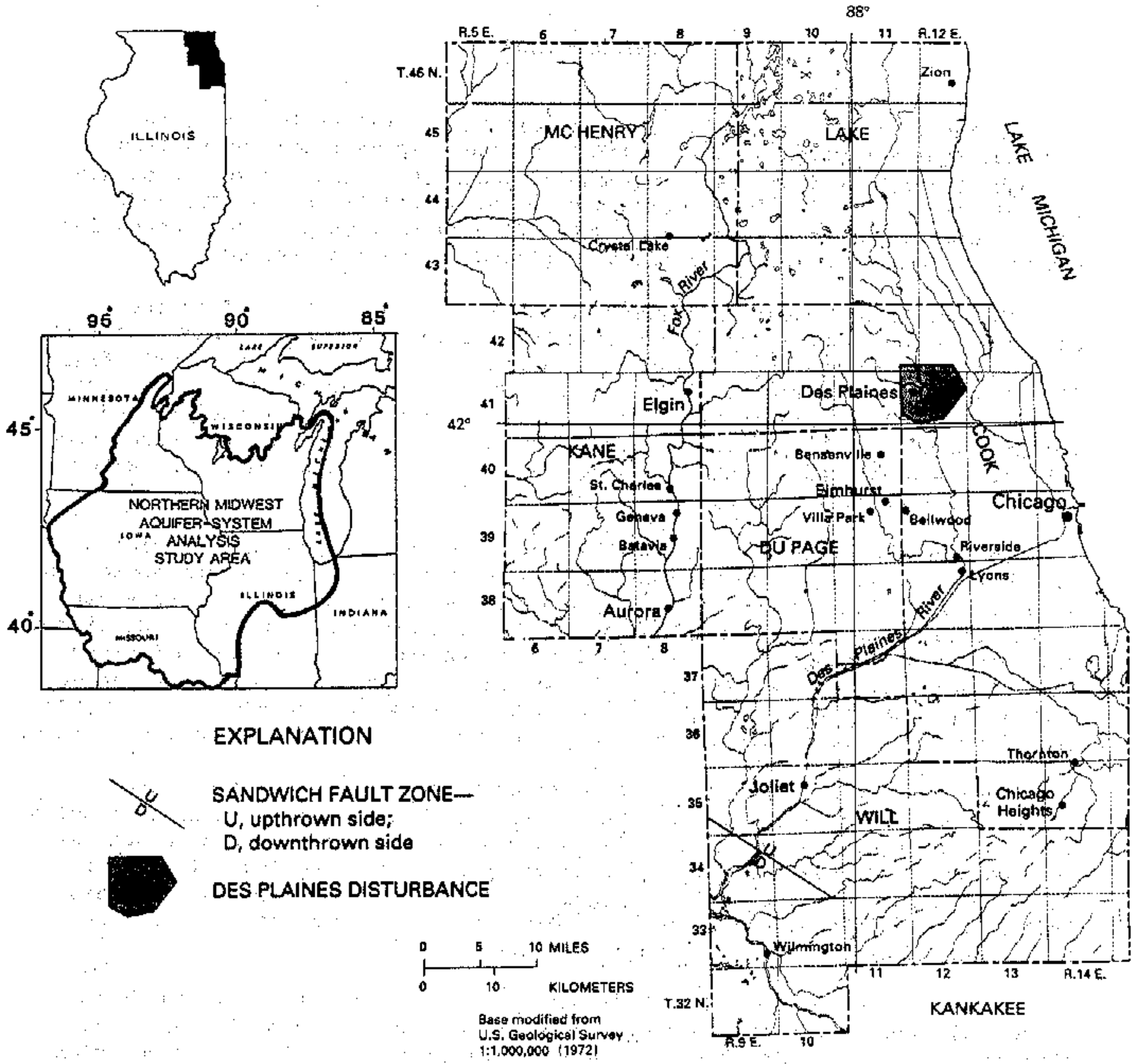


Figure 1.--Location of the study area in Illinois within the Northern Midwest Regional Aquifer-System Analysis study area.

water from wells that tap the aquifers in the Cambrian and Ordovician Systems. The geologic and hydrogeologic nomenclature used in this report is that used by Visocky and others (1985) and does not necessarily follow the usage of the USGS.

Description of study area

Geology

The geology of the area, as described by Visocky and others (1985), consists of consolidated and unconsolidated stratigraphic units ranging in age from Precambrian to Quaternary (fig. 2). The Cambrian System, in northeastern Illinois, contains, in ascending order, the Mt. Simon Formation, the Eau Claire Formation, the Galesville Sandstone, the Ironton Sandstone, and part of the Knox Megagroup including the Franconia Formation, the Potosi Dolomite, the Eminence Formation, and the Jordan Sandstone; the rest of the Knox Megagroup (the Prairie du Chien Group) is in the Ordovician System. The Ordovician System above the Knox Megagroup contains the Ancell Group, the Ottawa Limestone Megagroup (Platteville Group and Galena Group), and the Maquoketa Shale Group. The Silurian through Quaternary rocks overlie the Maquoketa Shale Group.

The structural geology of the area is relatively simple. The rocks dip eastward at a gradient of 10 to 15 feet per mile and exhibit minor east-west trending structural features (Hughes and others, 1966, p. 5). Two major structural features are present in the area--the Sandwich Fault Zone in southwestern Will County and the Des Plaines Disturbance in northern Cook County (fig. 1). The Sandwich Fault Zone is described in detail by Suter and others (1959, p. 36). Faulting is complex and a maximum upward displacement of more than 125 ft (feet) has been identified.

The Des Plaines Disturbance, also an area of complex faulting, has been described in detail by Emrich and Bergstrom (1962). Many high-angle normal faults, a graben, and a central uplifted core comprise the complex structure. Relative movement within the structure is mainly upward and amounts to a maximum displacement of at least 900 ft.

Hydrogeology

The sandstone aquifers in the Cambrian and Ordovician Systems directly underlie the dolomite bedrock aquifers of the Silurian System (fig. 2). The Maquoketa Shale Group forms the Maquoketa confining unit, the upper hydrogeologic boundary of the aquifers in the Ordovician System in most of the area. The Maquoketa, together with the Galena and Platteville Groups that comprise the Galena-Platteville unit, acts as a leaky barrier between the overlying Silurian dolomite aquifer and the underlying Ancell aquifer. The Ancell aquifer consists of the Glenwood Formation and the St. Peter Sandstone of the Ancell Group and lies above the middle confining unit. Walton (1960, p. 25) calculated that 8.4 Mgal/d (million gallons per day), or 11 percent of the water pumped from the Cambrian and Ordovician Systems in 1958, leaked from the overlying Silurian dolomite aquifer through the Maquoketa confining unit to the Ancell aquifer.

The middle confining unit spans both the Lower Ordovician System and the Upper Cambrian System, consists of the Knox Megagroup, and overlies the Ironton-Galesville aquifer, one of two sandstone aquifers in the Cambrian System. The Ironton-Galesville aquifer consists of the Ironton and Galesville Sandstones. The second sandstone aquifer in the Cambrian System is the Elmhurst-Mt. Simon aquifer. It is separated from the Ironton-Galesville aquifer by the confining, yet leaky, Eau Claire Formation. All but the Elmhurst Sandstone Member of the Eau Claire Formation make up the Eau Claire confining unit. The Elmhurst Sandstone Member is part of the Elmhurst-Mt. Simon aquifer.

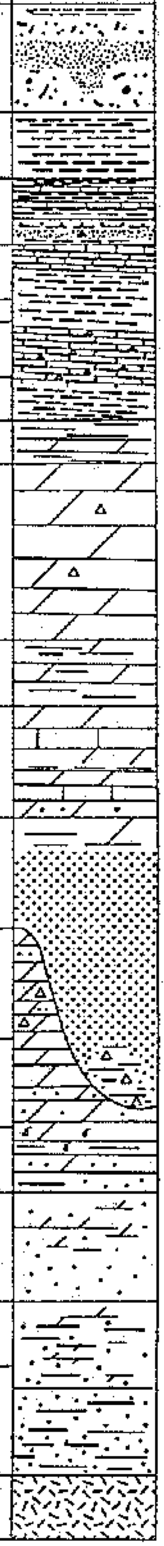
Transmissivities differ throughout the study area. Wells that tap the Ironton-Galesville aquifer are usually open to the Ancell aquifer and the middle confining unit. Calculated hydraulic properties as a result of aquifer tests, therefore, represent the combined hydraulic properties of all three units. Visocky and others (1985, p. 63) state that transmissivities range from 10,000 to 20,000 (gal/d)/ft (gallons per day per foot), or about 1,340 to 2,670 ft^2/d (feet squared per day); locally, where the Ancell aquifer thickens and the middle confining unit thins, transmissivities exceed 20,000 (gal/d)/ft (2,670 ft^2/d). Visocky and others (1985, p. 53) also state that, of the total combined transmissivities of the three major hydrogeologic units (Ancell aquifer, middle confining unit, and Ironton-Galesville aquifer) above the Elmhurst-Mt. Simon aquifer, transmissivities in the Ancell aquifer represent 15 percent; in the middle confining unit, 35 percent; and in the Ironton-Galesville aquifer, 50 percent.

Aquifer tests at the Zion Test Well (Nicholas and others, 1987, p. 17) indicate transmissivities ranged from 250 ft^2/d (1,870 (gal/d)/ft) in the Ancell aquifer to 1,100 ft^2/d (8,230 (gal/d)/ft) in the Ironton-Galesville aquifer. Water levels at the Zion Test Well also indicate that the potentiometric head in the Ironton-Galesville aquifer is lower than in the other aquifers in the Cambrian and Ordovician Systems; as a result, ground water can move downward from the overlying Ancell aquifer and upward from the underlying Elmhurst-Mt. Simon aquifer (Nicholas and others, 1987, p. 18).

The transmissivity of the Elmhurst-Mt. Simon aquifer at the Zion Test Well was 840 ft^2/d (6,280 (gal/d)/ft). Calculated transmissivities from three long-term aquifer tests at gas-storage facilities southwest of the study area, however, ranged from 980 to 10,600 (gal/d)/ft (130 to 1,420 ft^2/d) (Illinois State Water Survey and Hittman Associates, 1973, p. 23). Well-driller reports indicate that water levels in 1960, in the Elmhurst-Mt. Simon aquifer along the Fox River, were more than 50 ft higher than in the other overlying aquifers in the Cambrian and Ordovician Systems (Walton and Csallany, 1962, p. 8).

Three geohydrologic boundaries exist in the study area (Suter and others 1959, p. 51-52). A recharge boundary is located about 47 mi (miles) west of Chicago, and two barrier boundaries are located about 37 mi east and 60 mi south of Chicago. The Sandwich Fault Zone, located about 10 mi southwest of Joliet, acts as a barrier boundary locally but does not seem to have any effect on a regional scale; the same is true for the Des Plaines Disturbance in northern Cook County.

SYSTEM		SERIES AND MEGAGROUP		GROUP AND FORMATION[1]		HYDROSTRATIGRAPHIC UNITS		LITHOLOGY
Quaternary		Pleistocene		Undifferentiated		Pleistocene		
Tertiary & Cretaceous				Undifferentiated				
Carboniferous	Pennsylvanian			Undifferentiated		Pennsylvanian		
Carboniferous	Mississippian	Valmeyeran		St. Louis Ls Salem Ls		St. Louis-Salem aquifer		
Carboniferous	Mississippian	Valmeyeran		Warsaw Ls				
Carboniferous	Mississippian	Valmeyeran		Keokuk Ls Burlington Ls		Keokuk-Burlington aquifer		
Carboniferous	Mississippian	Kinderhookian		Undifferentiated				
Devonian				Undifferentiated		Devonian		
Silurian		Niagaran		Port Byron Fm Racine Fm Waukesha Ls Joliet Ls		Silurian dolomite aquifer		
Silurian		Alexandrian		Kankakee Ls Edgewood Ls		Silurian dolomite aquifer		
Ordovician		Cincinnatian		Maquoketa Shale Group		Maquoketa confining unit		
Ordovician		Mohawkian	Ottawa Ls Megagroup	Galena Group Decaorah Subgroup Platteville Group		Galena-Platteville unit		
Ordovician		Mohawkian		Ancell Group	Glenwood Fm	Ancell aquifer		
Ordovician		Chazyan		Ancell Group	St. Peter Ss	Ancell aquifer		
Ordovician		Canadian	Knox Megagroup	Prairie du Chien Group	Shakopee Dol New Richmond Ss Oneota Dol Gunter Ss	Middle confining unit	Prairie du Chien	
Cambrian		St. Croixian	Knox Megagroup	Jordan Ss Eminence Fm- Potosi Dol		Middle confining unit	Eminence-Potosi	
Cambrian		St. Croixian	Knox Megagroup	Franconia Fm		Middle confining unit	Franconia	
Cambrian		St. Croixian		Ironton Ss		Ironton-Galesville aquifer		
Cambrian		St. Croixian		Galesville Ss		Ironton-Galesville aquifer		
Cambrian		St. Croixian		Eau Claire Fm		Eau Claire confining unit		
Cambrian		St. Croixian		Mt. Simon Fm		Elmhurst-Mt. Simon aquifer		
Precambrian								



[1]Ls, Limestone; Fm, Formation; Ss, Sandstone; Dol, Dolomite.
[2]gal/min, gallons per minute.

Figure 2.--Stratigraphy, hydrogeology, and water-yielding properties

THICKNESS (feet)	DESCRIPTION	WATER-YIELDING PROPERTIES[2]
0-600	Unconsolidated glacial deposits--pebbly clay (till), silt, and gravel. Loess (windblown silt) and alluvial silts, sands, and gravels.	Wells yield as much as 3,000 gal/min.
0-100	Sand and silt.	
0-500	Mainly shale with thin sandstone, limestone, and coal beds.	Wells generally yield less than 10 gal/min.
0-600	Limestone, cherty limestone; green, brown and black shale; silty dolomite.	Wells generally yield less than 25 gal/min in the southern two-thirds of Illinois.
0-400	Shale, calcareous; limestone beds, thin.	
0-465	Dolomite, silty at base, locally cherty.	Well yields can be greater than 1,000 gal/min.
0-250	Shale, gray or brown; locally dolomite and(or) limestone, argillaceous.	Generally not water yielding.
0-450	Dolomite and(or) limestone, cherty. Dolomite, shale partings, speckled. Dolomite and(or) limestone, cherty, sandy at base.	Well yields are small to moderate.
100-650	Sandstone, fine- and course-grained; little dolomite; shale at top. Sandstone, fine- to medium-grained; locally cherty red shale at base.	Well yields are small to moderate.
100-1,300	Dolomite, sandy, cherty (oolitic), sandstone. Sandstone, interbedded with dolomite. Dolomite, white to pink, course-grained, cherty (oolitic), sandy at base.	Well yields are small to moderate.
	Dolomite, white, fine-grained, geodic quartz, sandy at base.	
	Dolomite, sandstone, and shale, glauconitic, green to red, micaceous.	
0-270	Sandstone, fine- to medium-grained, well sorted, upper part dolomitic.	Well yields of over 500 gal/min are common.
0-450	Shale and siltstone; dolomite, glauconitic; sandstone, dolomitic, galuconitic.	Generally not water yielding.
0-2,600	Sandstone, coarse-grained, white, red in lower half; lenses of shale and siltstone, red, micaceous.	Well yields are moderate.
		No significant aquifers in Illinois.

representative of the six northeastern counties in Illinois.

Ground-water flow in 1864, prior to extensive ground-water development in the area, generally was from northwest to southeast (fig. 3). Ground-water pumpage in the Chicago region gradually increased from 200,000 gal/d (gallons per day) in 1864 to more than 78 Mgal/d in 1958 (Walton and others, 1960, p. 8). As more and more deep wells were developed, a pattern began to emerge in 1958 that eventually defined the major pumping centers in Will County near Joliet, in Cook County southwest of Chicago and at Des Plaines, and in Du Page County near Elmhurst (fig. 4).

As the development of the ground-water resources increased in northeastern Illinois, water levels continued to decline. By 1973, the cone of depression had enlarged and occupied about 440 square miles in southeastern Wisconsin (Fetter, 1981, p. 207). In 1985, public and industrial pumpage totaled almost 147 Mgal/d, and the potentiometric surface in the Chicago area was more than 850 ft below its original level (fig. 5) (Sasman and others, 1986, p. 13 and 19). Figure 6 illustrates the annual and accumulated pumpage from the Ancell and Ironton-Galesville aquifers for public and industrial water usage in each of the six counties for the period 1957-86.

Data Availability and Limitations

Published reports on ground water in the area, in addition to the reports already cited, are numerous. The ISWS has reported on the chemical and biological characteristics of the waters (Habermeyer, 1925; Illinois State Water Survey, 1938, 1940; Hanson, 1950, 1958, 1961) and on ground-water resources of individual counties (Zeizel and others, 1962; Woller and Gibb, 1976; Woller and Sanderson, 1976, 1978, 1983; Woller and others, 1986) and areas (Gerber and others, 1941; Hanson and others, 1943; Hanson and Larson, 1945). The ISGS also has studied ground water in the State (Bartow and others, 1909; Anderson, 1919; Bergstrom and others, 1955).

Published reports on aquifer yields and aquifer characteristics are available for the area (Walton and Csallany, 1962; Csallany and Walton, 1963; Walton, 1965; Hughes and others, 1966; Bond, 1972). Published reports on ground-water-level trends and pumpage also are available (Sasman, 1965; Sasman and others, 1961, 1962, 1967, 1973, 1974, 1977, 1982, and 1986).

Ground-water quality has been addressed, to a degree, in most of the reports. The main sources of water-quality data used in the study reported here include Hanson (1950, 1958, 1961), Woller and Gibb (1976), Woller and Sanderson (1976, 1978, 1983), Woller and others (1986), and water-quality analyses obtained from the ISWS.

For this study, water-quality data for about 190 commercial, industrial, and municipal wells that tap the aquifers in the Cambrian and Ordovician Systems were tabulated from existing reports to get an idea of the areal and temporal coverage in the study area. As a result, it was evident that water-quality data for the commercial and industrial wells were sparse and could not be used to develop any trends. The study effort was, therefore, centered on about 90 municipal wells in the area that tapped the aquifers in the Cambrian and Ordovician Systems, the public-water-supply source. Long-term water-quality data that could be used to indicate possible trends in chloride concentration were available for only 17 of the 90 municipal wells (fig. 7).

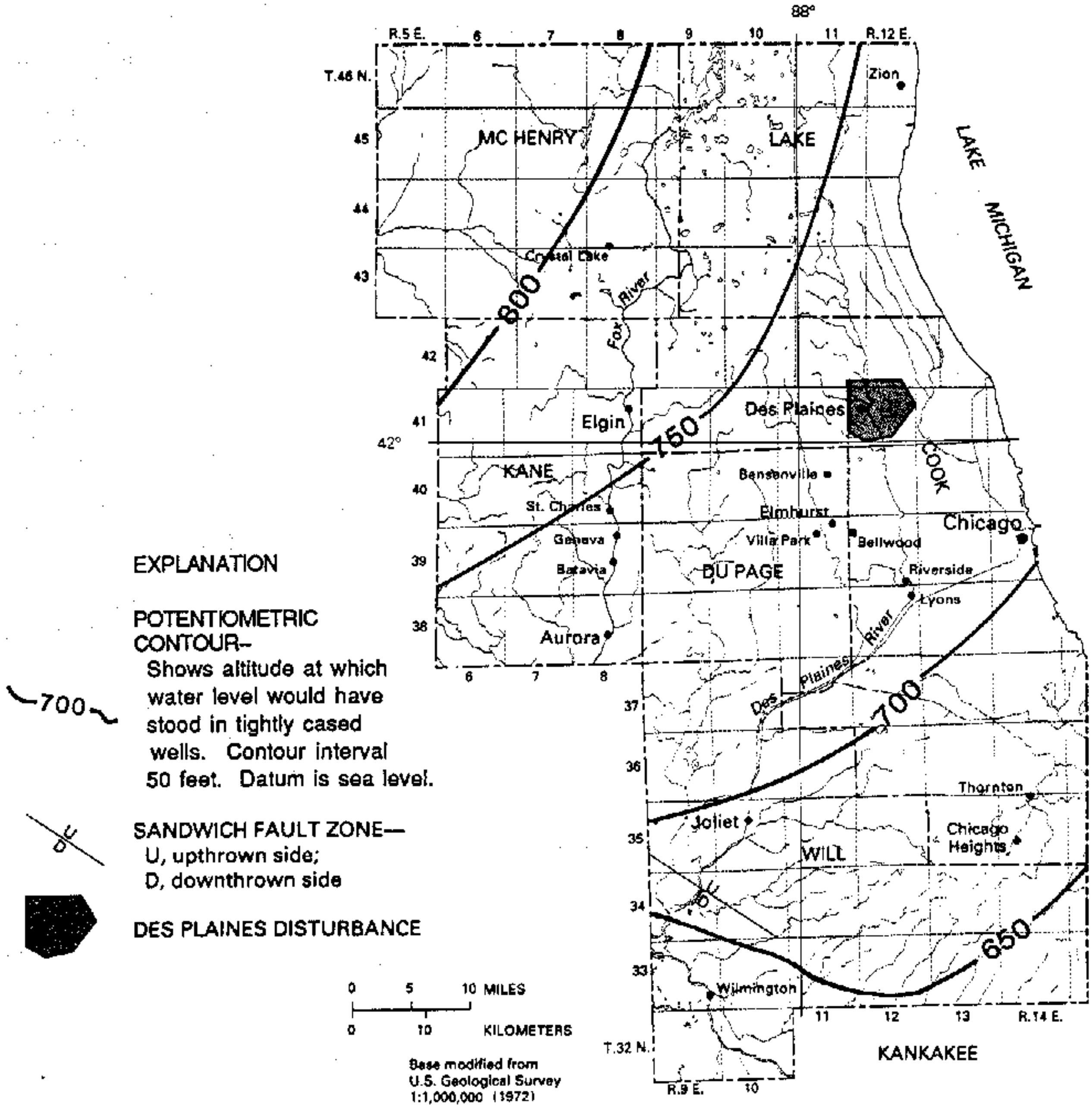


Figure 3.--Altitude of the potentiometric surface of the Ancell and Ironton-Galesville aquifers in about 1864. (Modified from Visocky and others, 1985, fig. 26.)

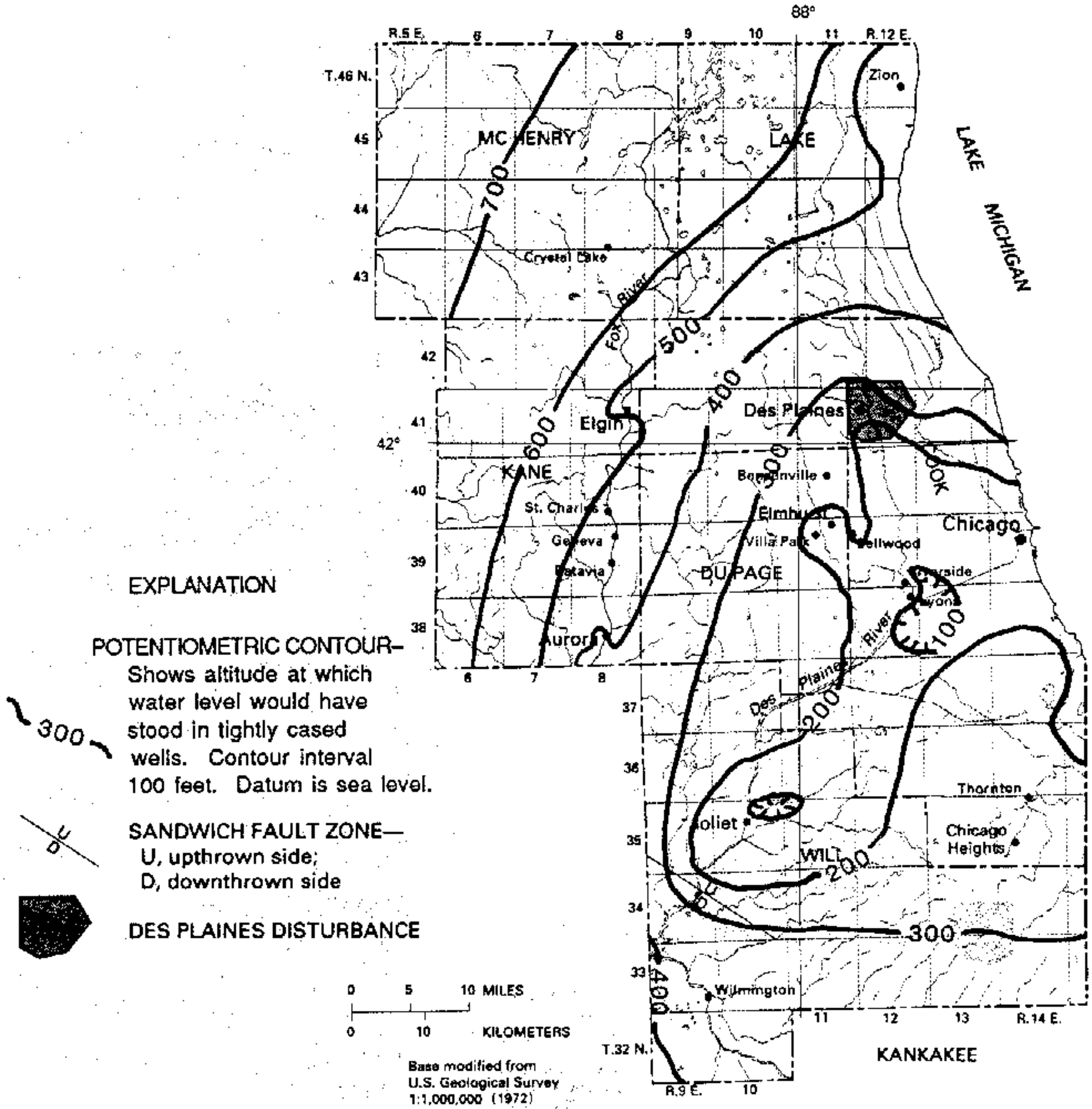


Figure 4.--Altitude of the potentiometric surface of the Ancell and Ironton-Galesville aquifers in 1958. (Modified from Suter and others, 1959, fig. 34.)

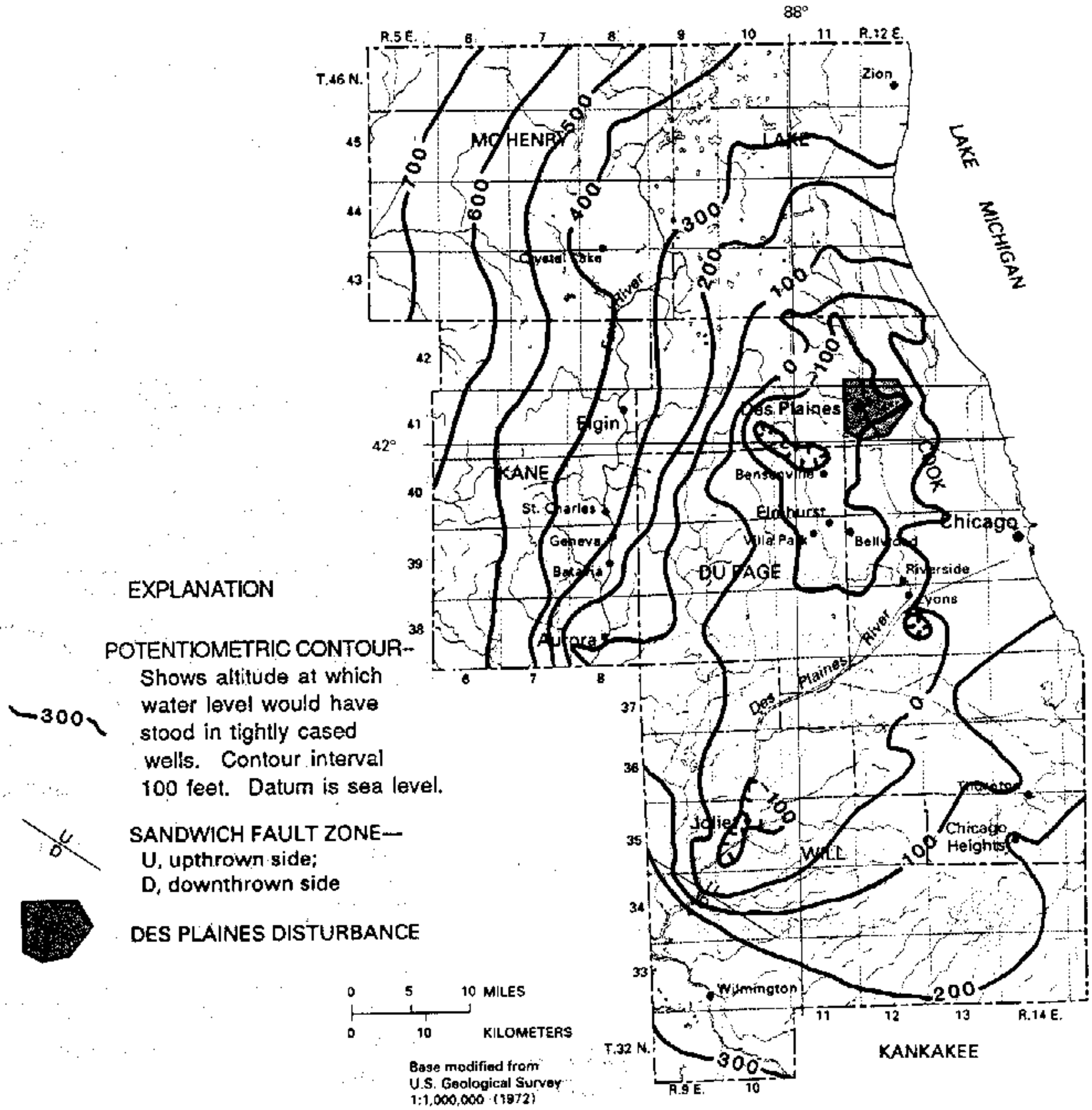


Figure 5.--Altitude of the potentiometric surface of the Ancell and Ironton-Galesville aquifers in October 1985. (Modified from Sasman and others, 1986, fig. 11.)

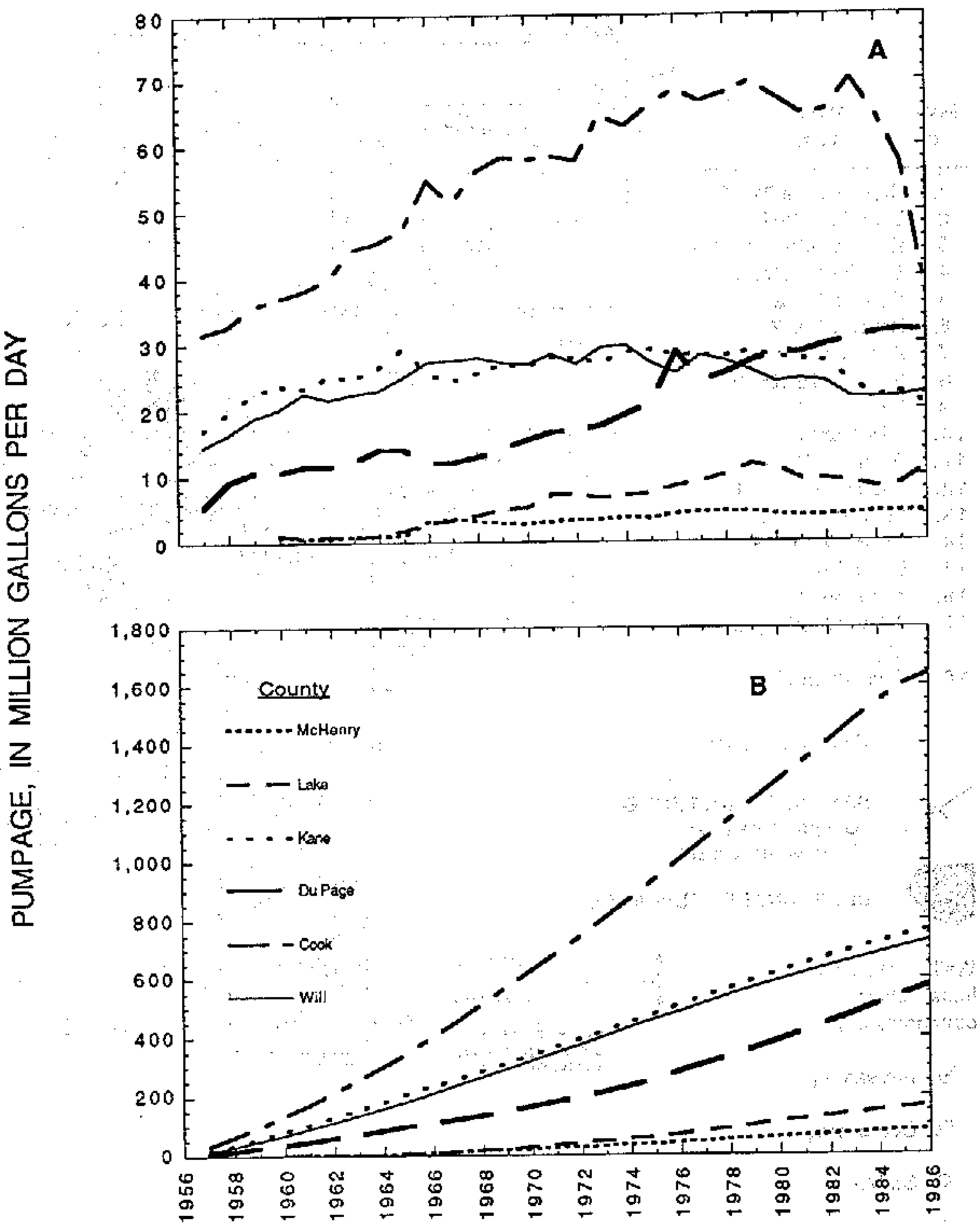


Figure 6.--Annual pumpage (A) and accumulated pumpage (B) from the Ancell and Ironton-Galesville aquifers for public and industrial uses in each of the six northeastern counties in Illinois, 1957-86. (Data from Suter and others, 1959; Walton and others, 1960; Sasman and others, 1961, 62, 67, 73, 77, 82, and 86; and Kirk, 1987.)

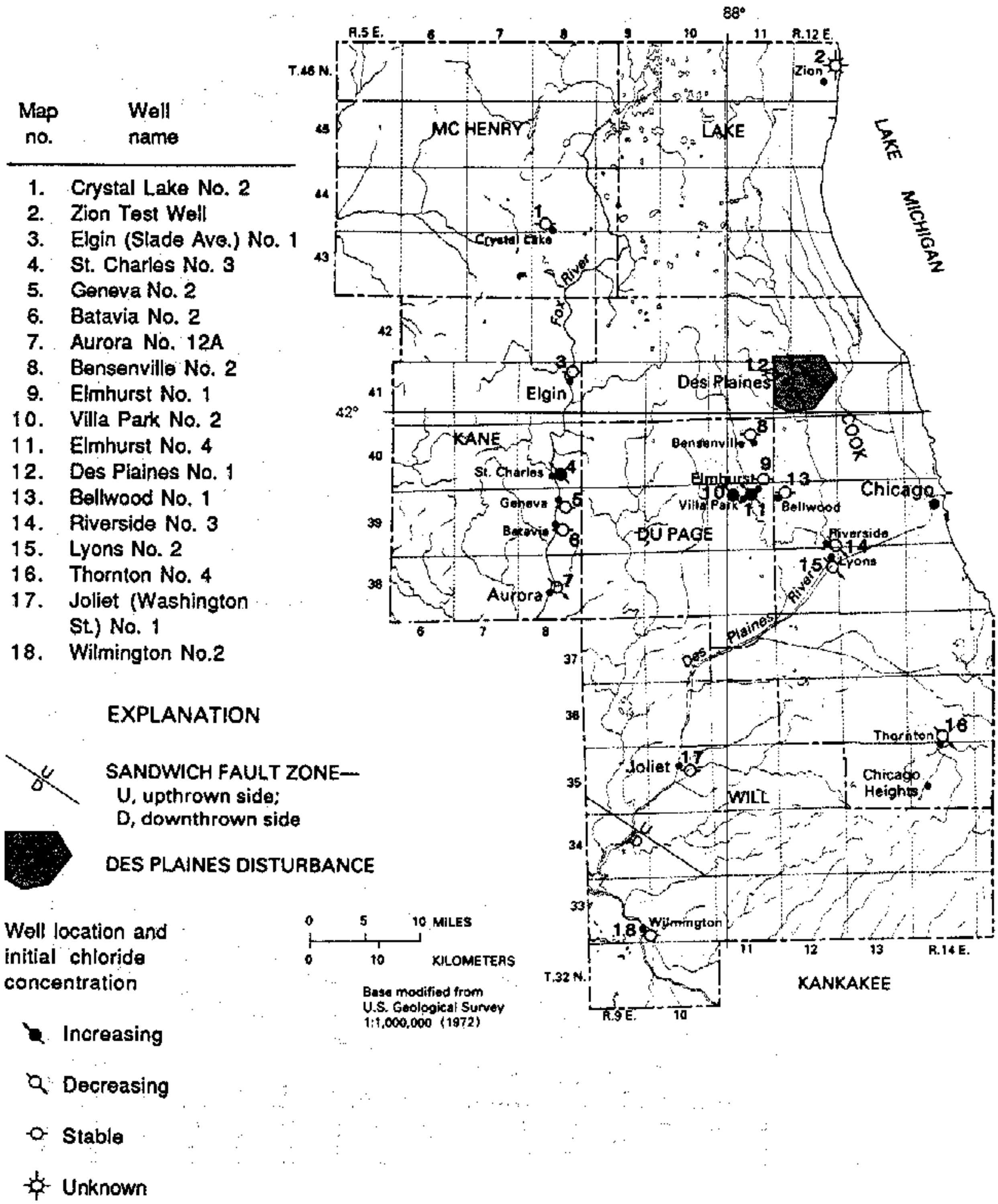


Figure 7.--Location of the municipal wells and the Zion Test Well.

The wells shown in figure 7 were selected on the basis of their proximity to the historic major pumping centers, the availability of water-quality data, and their documented maintenance history. Three of the wells--Crystal Lake No. 2, Zion Test Well, and Wilmington No. 2--are representative of a part of the study area rather than of a major pumping center. Of the 17 municipal wells shown in figure 7, 1 penetrates 73 ft of the middle confining unit, 2 penetrate 166 ft of the Ironton-Galesville aquifer, 4 penetrate from 17 to 61 ft of the Eau Claire confining unit, and 10 penetrate from more than 60 to more than 560 ft into the Elmhurst-Mt. Simon aquifer. The Zion Test Well penetrates the entire Elmhurst-Mt. Simon aquifer and 40 ft of the Precambrian crystalline rocks.

The data compiled during the study were of limited value. For example, water-quality samples had not been collected at the municipal wells on a regular basis; as a result, the changes in chloride concentration were not well documented as to when those changes occurred. Physical changes to a well that could change the chloride concentration in water from the well were not consistently documented in the literature. Physical changes could include such things as the infilling or bridging of the well bore with material that had caved from above; or intentionally plugging, cleaning, or deepening the well bore. For some wells, a record of casing installation (or noninstallation) was not available. Chloride concentrations in water from the municipal wells, along with some characteristics of the wells, pumping rate and duration prior to sampling for water quality, and laboratory-analysis number, are listed in table 1 at the back of this report.

CHANGES IN CHLORIDE CONCENTRATION

Chloride concentrations in water from wells in the study area differ depending on the location of the well, the depth of the well, and the aquifers open to the well. The chloride concentrations in the water from the municipal wells ranged from less than 5 mg/L in McHenry and Lake Counties to greater than 600 mg/L in Du Page and Kane Counties. Water from the Ancell aquifer had a higher chloride concentration than water from the deeper Ironton-Galesville aquifer; water from the Ironton-Galesville aquifer was relatively uniform in chloride concentration in the western part of the study area but increased to the east and southeast as the Ironton-Galesville aquifer increased in depth (Suter and others, 1959, p. 76) (fig. 8). Visocky and others (1985, p. 97) indicate that, along with the gradual increase in the concentration from northwest to southeast, the water changes from a calcium bicarbonate type to a sodium sulfate type.

The Elmhurst-Mt. Simon aquifer characteristically yields water that increases in chloride concentration with increasing depth within the aquifer. The wells that yield water with chloride concentrations exceeding 600 mg/L are Aurora No. 12A and Elmhurst No. 4, both of which penetrated more than 520 ft of the Elmhurst-Mt. Simon aquiifer. Figure 9 shows the relative change in chloride concentrations with depth at the Zion Test Well in Lake County (Nicholas and others, 1987, p. 21) and the chloride-to-depth relation developed by Suter and others (1959, p. 77). A marked difference in the chloride concentration-to-depth relation between the two figures is attributable to the geographic

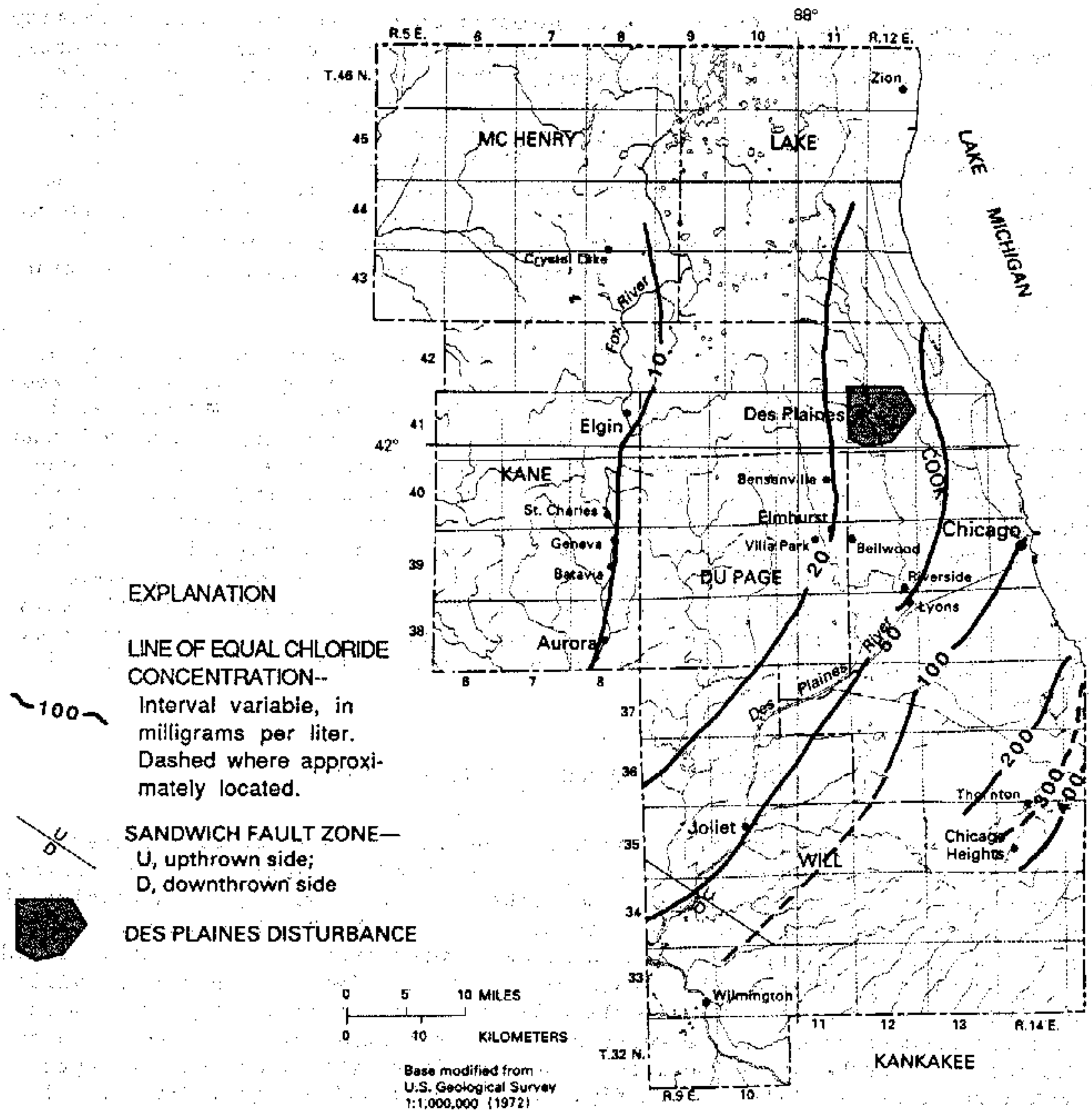


Figure 8.--Chloride concentrations in water from the Ancell and Ironton-Galesville aquifers prior to 1959. (Modified from Suter and others, 1959, fig. 49.)

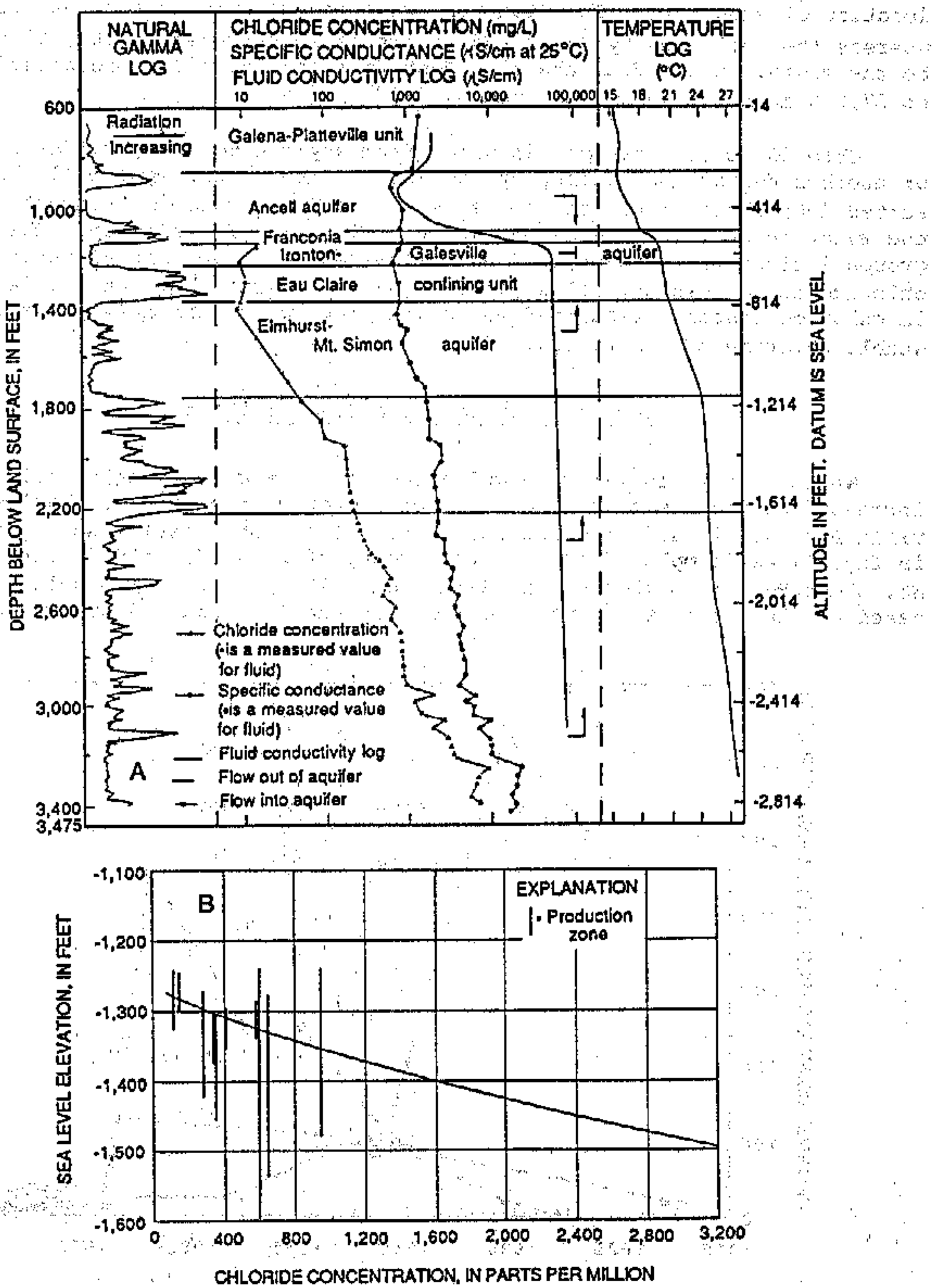


Figure 9.--Change in chloride concentration at the Zion Test Well near Zion, Illinois (A) (modified from Nicholas and others, 1987, fig. 7.1-1) and chloride as a function of depth relation in the Elmhurst-Mt. Simon aquifer (B) (modified from Suter and others, 1959, fig. 50).

location of each well. The Zion Test Well is in northeastern Lake County, whereas the well used by Suter and others is in Kankakee County, 85 mi or more to the south. Water from the Zion Test Well had chloride concentrations of 13 to 37,000 mg/L (Nicholas and others, 1987, p. 29).

Chloride concentrations in water from any one well may differ at one time or another during the history of the well. The 17 municipal wells have been sorted into three groups on the basis of trends in chloride concentrations in the water pumped during each well's initial years of operation. The three groups include wells that yield water indicative of an initial increase in chloride concentration, wells yielding water indicative of an initial decrease in chloride concentration, and wells yielding water indicative of an initially stable chloride concentration.

Increases in Chloride Concentrations

Wells that yield water in which the chloride concentration initially increased during the first few years of operation include St. Charles No. 3, Villa Park No. 2, and Elmhurst No. 4 (fig. 10). St. Charles No. 3 (map No. 4 in fig. 7) was completed in 1919 to a depth of 2,198 ft--560 ft into the Mt. Simon Formation (Woller and Sanderson, 1978, p. 82). The well was partly cased and left open to all the aquifers in the Cambrian and Ordovician Systems.

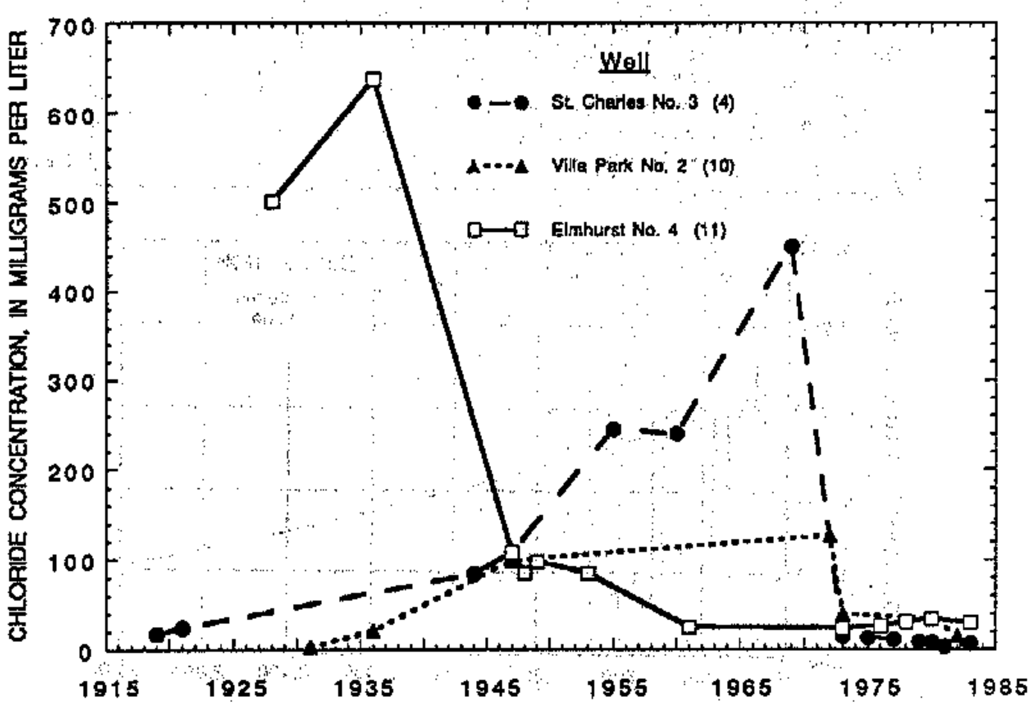


Figure 10.--Change in chloride concentration at wells where chloride concentration initially increased after the start of pumping. (Numbers in parentheses refer to map number in figure 7.)

Villa Park No. 2 (map No. 10) was completed in 1931 to a depth of 2,125 ft--about 310 ft into the Mt. Simon Formation (Woller and others, 1986, p. 213). The well was partly cased and left open to all the aquifers in the Cambrian and Ordovician Systems.

Elmhurst No. 4 (map No. 11) was completed in 1927 to a depth of 2,219 ft--520 ft into the Mt. Simon Formation (Woller and others, 1986, p. 106). The well was partly cased and left open to all the aquifers in the Cambrian and Ordovician Systems.

Decreases in Chloride Concentrations

Wells that yield water in which chloride concentration initially decreased during the first few years of operation include Aurora No. 12A, Riverside No. 3, and Lyons No. 2 (fig. 11).

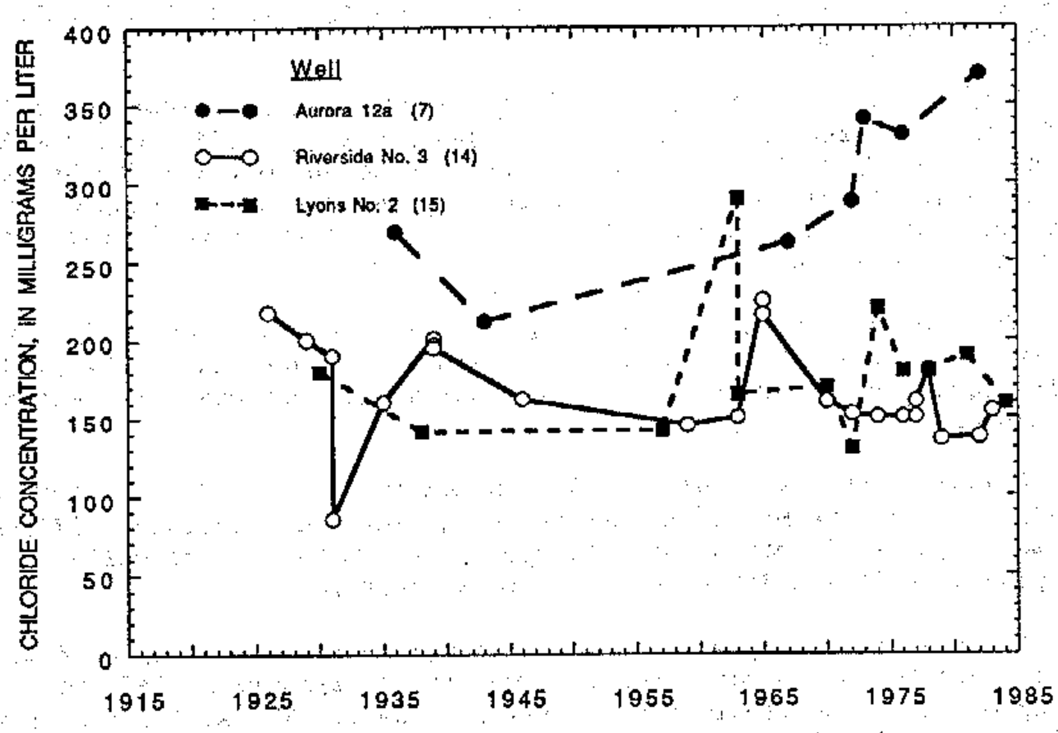


Figure 11.--Change in chloride concentration at wells where chloride concentration initially decreased after the start of pumping. (Numbers in parentheses refer to map number in figure 7.)

Aurora No. 12A (map No. 7) was completed in 1936 to a depth of 2,251 ft--521 ft into the Mt. Simon Formation (Woller and Sanderson, 1976, p. 14). The well was partly cased and left open to all aquifers in the Cambrian and Ordovician Systems.

Riverside No. 3 (map No. 14) was completed in 1923 to a depth of 2,047 ft--67 ft into the Mt. Simon Formation (Hanson, 1950). The well was partly cased and left open to the Silurian dolomite aquifer and all the aquifers in the Cambrian and Ordovician Systems.

Lyons No. 2 (map No. 15) was completed in 1929 to a depth of 2,020 ft--60 ft into the Mt. Simon Formation (Hanson, 1958). The well was partly cased and left open to the Silurian dolomite aquifer and all the aquifers in the Cambrian and Ordovician Systems.

Stable Chloride Concentrations

Wells that yield water in which chloride concentration initially remained relatively stable during the first few years of operation include Joliet No. 1, Geneva No. 2, Elgin No. 1, Crystal Lake No. 2, Batavia No. 2, Elmhurst No. 1, Bensenville No. 2, Des Plaines No. 1, Bellwood No. 1, Wilmington No. 2, and Thornton No. 4 (fig. 12).

Joliet (Washington St.) No. 1 (map No. 17) was completed in 1937 to a depth of 1,608 ft--61 ft into the Eau Claire Formation (Woller and Sanderson, 1983, p. 57). The well was partly cased and left open to the Ancell and Ironton-Galesville aquifers.

Geneva No. 2 (map No. 5) was initially drilled to a depth of 1,156 ft--96 ft into the Ironton and Galesville Sandstones--in 1924 (Woller and Sanderson, 1978, p. 51). In 1928, it was deepened to 2,217 ft--587 ft into the Mt. Simon Formation--and cased from land surface to 4 ft below the Maquoketa confining unit and left open to all the aquifers in the Cambrian and Ordovician Systems.

Elgin No. 1 (map No. 3) was completed in 1901 to a depth of 2,000 ft--370 ft into the Mt. Simon Formation (Woller and Sanderson, 1978, p. 34). The casing record for the well is unknown; which aquifers the well is open to also is unknown.

Crystal Lake No. 2 (map No. 1) was completed in 1930 to a depth of 2,000 ft--225 ft into the Mt. Simon Formation (Woller and Sanderson, 1976, p. 12). The well was partly cased and left open to the Galena-Platteville unit and the Ironton-Galesville and Elmhurst-Mt. Simon aquifers.

Batavia No. 2 (map No. 6) was completed in 1915 to a depth of 2,000 ft--340 ft into the Mt. Simon Formation (Woller and Sanderson, 1978, p. 24). No casing record is available for the original well. The well was deepened in 1945 to 2,200 ft--540 ft into the Mt. Simon Formation--partly cased, and left open to all the aquifers in the Cambrian and Ordovician Systems.

Elmhurst No. 1 (map No. 9) was initially drilled in 1915 to a depth of 958 ft--73 ft into the Prairie du Chien Group (Woller and others, 1986, p. 102). It was partly cased and left open to the Silurian dolomite and Ancell aquifers. It was deepened in 1940 to 1,480 ft--35 ft into the Eau Claire Formation--partly cased, and left open to the Ancell and Ironton-Galesville aquifers.

Bensenville No. 2 (map No. 8) was completed in 1929 to a depth of 1,442 ft--17 ft into the Eau Claire Formation (Woller and others, 1986, p. 42). The well was left open to the Ancell and Ironton-Galesville aquifers.

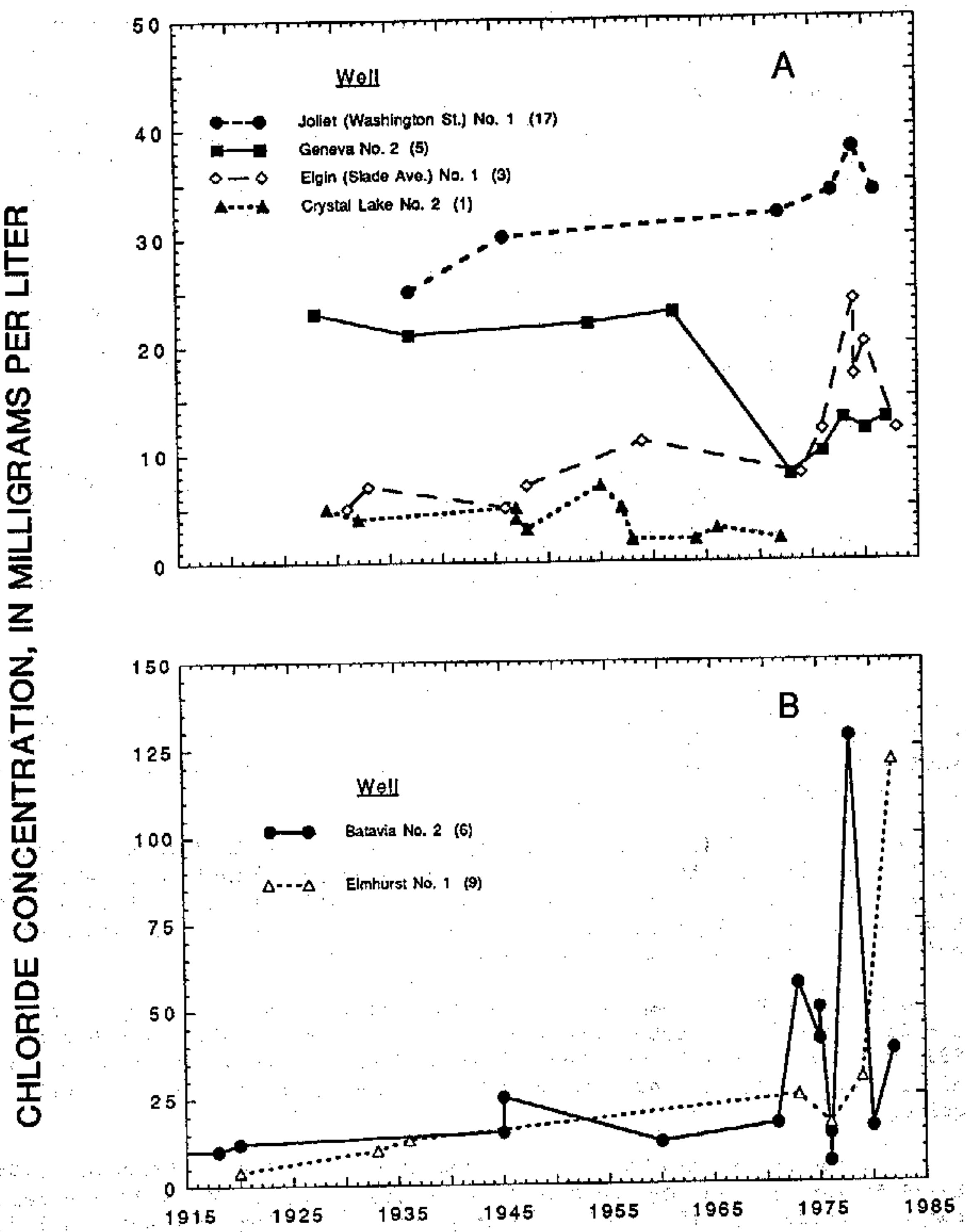


Figure 12.--Change in chloride concentration at wells where chloride concentration remained relatively stable after the start of pumping. (Numbers in parentheses refer to map number in figure 7.)

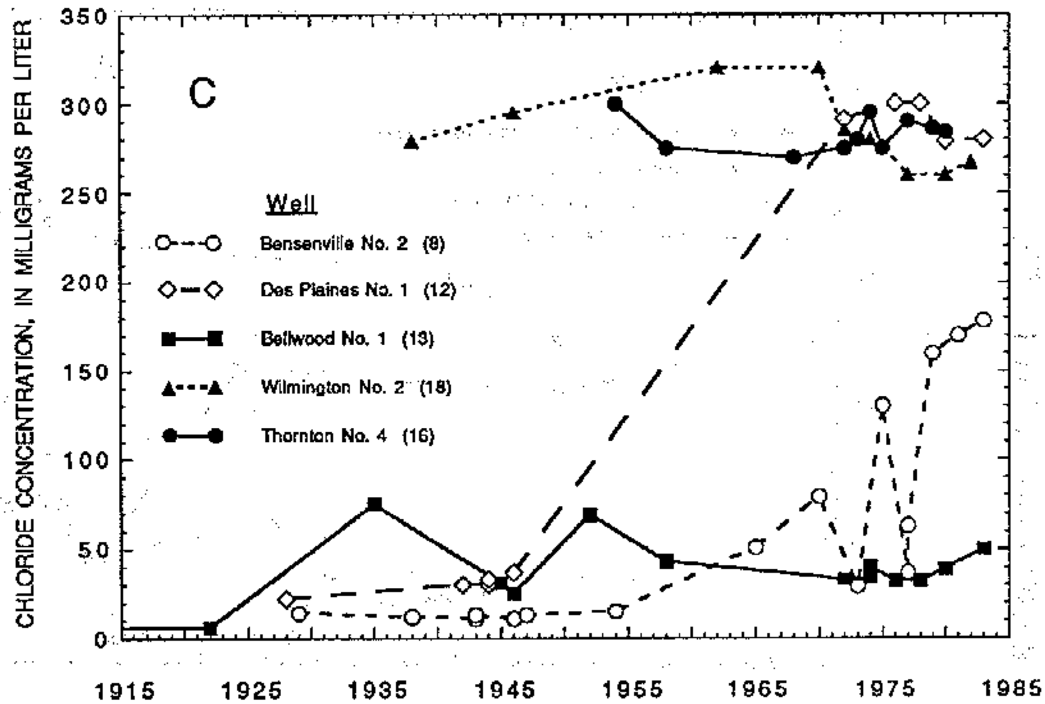


Figure 12.--Continued.

Des Plaines No. 1 (map No. 12) was completed in 1927 to a depth of 1,735 ft--205 ft into the Mt. Simon Formation (Hanson, 1950). The well was partly cased and left open to the Ancell, upper Ironton-Galesville, and Elmhurst-Mt. Simon aquifers.

Bellwood No. 1 (map No. 13) was initially drilled in 1913 to a depth of 1,538 ft--43 ft into the Eau Claire Formation--partly cased, and left open to the Silurian dolomite, Ancell, and Ironton-Galesville aquifers (Hanson, 1950). It was deepened in 1935 to 1,956 ft--156 ft into the Mt. Simon Formation; no casing record was noted after the well was deepened.

Wilmington No. 2 (map No. 18) was completed in 1936 to a depth of 1,566 ft--166 ft into the Ironton and Galesville Sandstones (Woller and Sanderson, 1983, p. 126). The well was cased from land surface to 70 ft into the Galena and Platteville Groups and left open to the Ancell and Ironton-Galesville aquifers.

Thornton No. 4 (map No. 16) was completed in 1954 to a depth of 1,785 ft--25 ft into the Eau Claire Formation (Hanson, 1961). The well was cased from land surface to 45 ft below the Maquoketa confining unit and was left open to the Ancell and Ironton-Galesville aquifers.

KNOWN CAUSES FOR CHANGES IN CHLORIDE CONCENTRATION

Changes in chloride concentration in water from the municipal wells studied can be attributed to several known causes, including the partial filling in of a well, bridging within a well, the cleaning out of a well, intentional plugging of a well, and the deepening of a well. The determination of these causes is based on the known changes in chloride concentration in the water yielded by the wells as related to known changes in the physical characteristics of the wells themselves or activities associated with them. The relations are graphically presented in appendix A.

Changes in chloride concentration caused by the partial filling in of a well has occurred in Lyons No. 2 and Villa Park No. 2. The fill material, which caved in from the stratigraphic units penetrated by the wells, acts as a plug that decreases the amount of water entering the open wells--in this case, from the Elmhurst-Mt. Simon aquifer where the water contains elevated concentrations of chloride.

The chloride concentration in water from Lyons No. 2 was less after the well was reported as being partly filled in up to and within the Eau Claire confining unit than it was before it was partly filled in. The chloride concentration decreased from about 180 to about 140 mg/L in 1938 and was about 140 mg/L in 1957. In 1963, however, the chloride concentration increased to 290 mg/L, decreased to 165 mg/L 1 month later, decreased to 130 mg/L in 1972, increased to 220 mg/L in 1974, and fluctuated between 160 and 190 mg/L thereafter. No changes in physical activities at the well were recorded that would explain these fluctuations.

The chloride concentration in water from Villa Park No. 2 was increasing until 1973 when the well was reported to be only open about 180 ft in the Eau Claire Formation (originally open 310 ft in the Mt. Simon Formation). The filling in of the well plugged off water entering from the Elmhurst-Mt. Simon aquifer and decreased the chloride concentration from about 130 to about 15 mg/L for the period 1973-82.

Changes in chloride concentrations also have occurred as a result of bridging in wells in the area. Bridging can occur when large pieces of consolidated materials become lodged in a well, or a part of the casing collapses, creating an obstruction that traps material caving in from above. The accumulation of material above the bridge can eventually form a plug and isolate the water column below the plug from the water column above the plug. If the two isolated columns of water contain different chemical and physical characteristics, the quality of water yielded by the well would depend on the location of the pump in relation to the bridge.

Bridging has resulted in a decrease in chloride concentrations in water from Bellwood No. 1, which taps the Elmhurst-Mt. Simon aquifer. A bridge formed at a depth of 1,649 ft--154 ft into the Eau Claire confining unit--sometime between 1935 and 1944. Chloride concentration in the water yielded by the well before the bridge formed was 75 mg/L; after bridging it was 25 to 30 mg/L. Bridging may have occurred again between 1952 and 1958, as indicated by a decrease in the chloride concentration in 1958. Bridging in other wells (Elgin No. 1, Geneva No. 2, and Joliet No. 1) appeared to have little, if any, effect on the chloride concentrations in water from those wells, even though Elgin No. 1 and Geneva No. 2 penetrate from about 300 to about 590 ft into the Elmhurst-Mt. Simon aquifer. Their proximity to the margin of the Maquoketa confining unit to the west (the recharge area for the aquifers in the Cambrian and Ordovician Systems); the relative shallowness of the Elmhurst-Mt. Simon aquifer; and the lack of development of a major pumping center in the area that possibly could induce water of reduced quality into the wells, probably accounts for the stability of the chloride concentrations in these two wells.

The chloride concentration in water from Riverside No. 3 had decreased from 220 mg/L in 1926 to 85 mg/L in 1931. Repairs of an unknown nature were performed in 1932; after that, the chloride concentration increased to near the original concentration of about 220 mg/L. On the basis of known causes and effects in the other wells studied, Riverside No. 3 probably had become partly filled in or bridged--either condition could have decreased the inflow of water from the Elmhurst-Mt. Simon aquifer into the open well. The repairs probably entailed a cleaning out of the well that allowed water from the Elmhurst-Mt. Simon aquifer to enter the well and increase the chloride concentration in the water yielded by the well. Chloride concentrations fluctuated between about 135 and 225 mg/L during the period 1935-83, possibly as a result of periodic cleaning of the well; however, record of any such activity could not be found.

Changes in chloride concentration also can result from the intentional plugging of a well with cement to seal off sources of excessive chloride concentration. This was done to Elmhurst No. 4 and St. Charles No. 3. Elmhurst No. 4 was originally drilled more than 520 ft into the Elmhurst-Mt. Simon aquifer. The well was plugged twice in the Elmhurst-Mt. Simon aquifer and once in the Eau Claire confining unit. The plugs in the Elmhurst-Mt. Simon aquifer had little, if any, affect on the water quality. The plug in the Eau Claire confining unit resulted in a decrease in chloride concentration from about 640 mg/L to about 110 mg/L. A fourth plug, located at the base of the Ironton-Galesville aquifer, resulted in an eventual decrease in chloride concentration to about 20 to 30 mg/L.

St. Charles No. 3 was originally drilled more than 560 ft into the Elmhurst-Mt. Simon aquifer in 1919. The chloride concentration increased from about 20 mg/L in 1919 to about 450 mg/L in 1969. The well was plugged up to the lower Ironton-Galesville aquifer in 1971, thus restricting the flow of water to the Ancell and Ironton-Galesville aquifers; the chloride concentration decreased to about 10 mg/L.

Changes in chloride concentration also can result from the deepening of a well. The deepening of Bellwood No. 1 resulted in an increase in the chloride concentration in the water yielded by the well. The well was originally drilled 43 ft into the Eau Claire confining unit but was deepened to more than 150 ft into the Elmhurst-Mt. Simon aquifer. This resulted in an increase in the chloride concentration from less than 10 to about 75 mg/L. In contrast, however, the deepening of Geneva No. 2 to more than 587 ft into the Elmhurst-Mt. Simon aquifer, Batavia No. 2 to more than 540 ft into the Elmhurst-Mt. Simon aquifer, and Elmhurst No. 1 to 35 ft into the Eau Claire confining unit did not have any immediate affect on the low (less than 30 mg/L) chloride concentrations in the water yielded by those wells.

The increased chloride concentration in water from Aurora No. 12A can be attributed to the deepening of the well. Water samples collected at different depths while the well was being drilled provide insight as to the chloride concentrations that were encountered. It is not known if these samples represent water quality in a single aquifer or composite water quality in multiple aquifers, but they do give an indication of the relative chloride concentrations at the sampling depths. The first two samples were collected at depths equivalent to a depth at the mid- to lower-Galena-Platteville unit and had chloride concentrations of 12 mg/L. The third sample was collected at a depth equivalent to a depth at or below the bottom of the Ancell aquifer and contained a chloride concentration of 59 mg/L. The fourth sample was collected at a depth equivalent to the depth of the upper Eau Claire confining unit and had a chloride concentration of 612 mg/L. The fifth and last sample was collected at a depth equivalent to a depth of about 530 ft in the Elmhurst-Mt. Simon aquifer, had a chloride concentration of 287 mg/L, and may or may not have represented a composite sample of water from all the aquifers in the Cambrian and Ordovician Systems.

The chloride concentration-to-depth relation between two neighboring wells can be significantly different as well. Villa Park No. 2 and Elmhurst No. 4 are about 1 mile apart and within about 100 ft of having the same depth. Elmhurst No. 4, however, penetrates about 220 ft farther into the Elmhurst-Mt. Simon aquifer and, in 1936, water from the well had 30 times the chloride concentration of Villa Park No. 2.

The initial stablility of chloride concentration in water from some wells, after the start of pumping, can be attributed to the location of the well or the aquifer(s) to which the wells are open. Wells that tap the Elmhurst-Mt. Simon aquifer and yield water having chloride concentrations consistently lower than would be expected (all less than 30 mg/L; most 10 mg/L or less) include Elgin No. 1, Geneva No. 2, Batavia No. 2, and Crystal Lake No. 2. All these wells are located near the western edge of the study area and are the closest, of the wells studied, to the margin of the Maquoketa confining unit--the recharge area for the aquifers in the Cambrian and Ordovician Systems. The relation of well location and the shallowness of the Elmhurst-Mt. Simon aquifer penetrated by these wells contribute to the consistently low chloride concentrations in the water yielded by them. This is in sharp contrast to the wells farther to the east and southeast that are about 200 ft deeper and penetrate a comparable distance into the Elmhurst-Mt. Simon aquifer; they yield water having a chloride concentration as much as 200 times greater (Elmhurst No. 4) than those wells closer to the recharge area.

Other wells that yield water with relatively consistent chloride concentrations include Joliet No. 1, Elmhurst No. 1, Thornton No. 4, and Wilmington No. 2. Both Joliet No. 1 and Elmhurst No. 1 penetrate the Eau Claire confining unit and both have had problems with caving and filling up to, and within, the Ironton-Galesville aquifer. The consistently low (less than 40 mg/L) chloride concentrations in the water from these two wells can be attributed to the shallow penetration of the wells in the Eau Claire confining unit and the periodic filling in of the wells. Thornton No. 4 also penetrates the Eau Claire confining unit, but the depth of penetration is less than that of the other two wells, yet the chloride concentration in the water from this well is about 10 to 30 times that of the other two wells. Even though penetration of the Eau Claire confining unit by Thornton No. 4 is about 35 ft less than that of Joliet No. 1 and about 5 ft less than that of Elmhurst No. 1, the depth of Thornton No. 4 is 200 and 300 ft deeper, respectively, than the other two wells because it is down dip from them.

Wilmington No. 2 is somewhat unique in that it is open to the Ancell and Ironton-Galesville aquifers, yet yields water with chloride concentrations of 260 to 320 mg/L--concentrations far greater than would be expected from those aquifers on the basis of chloride concentrations at the previously discussed wells. The chloride concentration increased from about 280 to 320 mg/L by 1962 and apparently remained at about that concentration until 1970 or 1971, after which the concentration eventually decreased to 260 mg/L. The only recorded change to the well (filled in about 30 ft) was reported in 1954. Factors that could account for the initially high chloride concentration in water from Wilmington No. 2 include the relative depth of the aquifers at this well and(or) the fact the well is in close proximity (1.5 to 2.0 mi) to the margin of the overlying shales and sandstones of Pennsylvanian age (Hughes and others, 1966, p. 6 and pl. 1B). Visocky and others (1985, p. 97) indicate that where the Ancell aquifer is confined by Pennsylvanian-aged shales rather than by the Maquoketa shales of Ordovician age, the water is a sodium sulfate type rather than a calcium magnesium bicarbonate type, and the dissolved solids concentration is greater than 1,000 mg/L rather than less than 400 mg/L. Chemical analyses of water from Wilmington No. 2 indicate that the water is of a sodium sulfate chloride type, with a dissolved solids concentration greater than 1,000 mg/L. In comparison, Joliet No. 1, about 14 mi north of Wilmington No. 2, has a comparable depth and is open to the same aquifers, but yields water that is a calcium sodium bicarbonate type with a dissolved solids concentration of about 500 to 550 mg/L.

PROBABLE CAUSES OF CHANGES IN CHLORIDE CONCENTRATION

Changes in chloride concentrations occurring in about half of the wells studied cannot be associated with any physical changes in the well, such as filling in, plugging, or deepening. Some wells, for instance, have yielded water in which large increases or erratic fluctuations in chloride concentrations occurred. The increases in chloride concentrations in water from wells Villa Park No. 2, St. Charles No. 3, Aurora No. 12A, and Des Plaines No. 1 are probably attributable to the fact that they penetrate about 200 to 500 ft of the Elmhurst-Mt. Simon aquifer and, except for St. Charles No. 3, are located in a major pumping center. The increased pumpage demands in the area between Elmhurst and Des Plaines (fig. 5) probably increased induced inflow from the Elmhurst-Mt. Simon aquifer, coupled with a commensurate decline in the static water level, that contributed an increased percentage of the water to the wells from the Elmhurst-Mt. Simon aquifer and, thus, increased the chloride concentrations.

Significant fluctuations in chloride concentrations occurred in water from wells Lyons No. 2, Riverside No. 3, Batavia No. 2, and Bensenville No. 2. The cause of these fluctuations is uncertain, but one possibility is a change in the operation of the well--namely the pumping frequency and duration. Some of these wells could have been put on standby or idled periodically while another well was being pumped, or a nearby well was put on standby or idled while the well in question was being pumped. Either way, such a situation could affect the chloride concentration in the water yielded and on the static water level in the well. The erratic fluctuations in these four wells suggest that either could be the case. Chloride-concentration data for the first three wells appears most erratic, whereas data for Bensenville No. 2 appears to have a generally upward trend in chloride concentration. This trend is even more obvious if the three lowest concentrations after 1970 are ignored, in which case the data reflect the chloride concentration in water from the well if the well were continually pumped.

Other probable causes for changes in chloride concentration include improper abandonment of water-supply wells or injection wells that could contribute to the degradation of the water quality in the freshwater aquifers. Such wells can provide a conduit for water of poor quality from an aquifer to mix with and(or) replace water of better quality in another aquifer. Improperly abandoned wells in the study area could contribute to the general degradation of the aquifers in the Cambrian and Ordovician Systems.

Gibb and O'Hearn (1980, p. 55) note an interesting trend in the chloride concentrations in water from the Bensenville municipal wells. Beginning about 1965, the chloride concentrations began to increase and fluctuate over a wide range of values, and the water-quality analyses suggested several possible sources for the chlorides and an explanation for the fluctuation in the concentrations. Bensenville No. 1 is about 75 ft from Bensenville No. 2 and has been abandoned and reportedly sealed at the surface. Several nearby wells owned by a railroad company have been abandoned and probably were not sealed. A poor or deteriorating seal in Bensenville No. 1, and the probable lack of seals in the railroad wells, could allow surface-derived chlorides and chlorides at depth to enter the wells and the aquifers and eventually be detected at Bensenville No. 2. Gibb and O'Hearn also state that, because of overpumping of the Ancell and Ironton-Galesville aquifers, the water levels have declined; this decline probably resulted in the upward migration of water from the Elmhurst-Mt. Simon aquifer, which contains water with a higher chloride concentration than that in the Ancell and Ironton-Galesville aquifers. This possibility is supported by the fluctuations in chloride concentrations in Bensenville No. 2. When the well was pumped infrequently, the chloride concentrations were less than concentrations when the well was pumped.

Increased pumping demands on the aquifers in the Cambrian and Ordovician Systems in the study area, excluding the Elmhurst-Mt. Simon aquifer, has lowered the static water level and probably contributed to the degradation of water quality in the aquifers by inducing the inflow (upconing) of poor quality water from the Elmhurst-Mt. Simon aquifer into wells. Model simulations by the Illinois State Water Survey and Hittman Associates (1973, p. 40) indicate that total dissolved solids concentration in water pumped from the Elmhurst-Mt. Simon aquifer would increase as a function of time. Barnes (1987) concluded that both local and regional upconing are apparent in the Elmhurst-Mt. Simon aquifer.

SUMMARY AND CONCLUSIONS

Ground-water development of the aquifers in the Cambrian and Ordovician Systems in the Chicago area began about 1864. Ground-water pumpage increased from about 200,000 gal/d in 1864 to about 147 Mgal/d by 1985. As a result, the potentiometric surface in the Chicago area was greater than 850 ft below the level in 1985.

Several municipalities in northeastern Illinois have experienced, over time, increases in chloride in water from wells that tap the aquifers in the Cambrian and Ordovician Systems. To define the causes for the chloride increases in the aquifers, historic data on municipal wells, including their location; history of construction, development, and maintenance; and the quality of water pumped from them were compiled.

Water-quality data were available for about 90 municipal wells that tap the aquifers in the Cambrian and Ordovician Systems in the study area; data were available for only 17 of those wells in sufficient quantity to indicate trends in chloride concentration. Of the 17 municipal wells selected, 1 was finished in the middle confining unit, 2 were finished in the Ironton-Galesville aquifer, 4 were finished in the Eau Claire confining unit, and 10 were finished in the Elmhurst-Mt. Simon aquifer. An additional deep test well was finished below the Elmhurst-Mt. Simon aquifer in the Precambrian System.

Chloride concentrations in the municipal wells ranged from less than 5 to greater than 600 mg/L; in the deep test well, they ranged from 13 to 37,000 mg/L. Known causes for changes in chloride concentration in the water yielded by the municipal wells studied include the partial filling in of a well, bridging within a well, cleaning out of a well, intentional plugging of a well, and(or) deepening of a well. Probable causes include increased pumpage demands; change in pumping rate, frequency, or duration; cessation of pumping; improper abandonment of wells; and upconing of highly mineralized water.

The data base was inadequate to quantify the changes in chloride concentration in water from the aquifers in the Cambrian and Ordovician Systems. Compounding the problem is the fact that most, if not all, municipal wells that penetrate the aquifers in the Cambrian and Ordovician Systems in the study area derive water from more than one aquifer; attempts to evaluate chloride concentrations in water from a single aquifer were impossible. The apparent randomness with which water-quality samples were collected for analysis and the lack of well inspection and(or) maintenance data provide insufficient information on the causes, and especially the quantification of certain changes in chloride concentration in wells in the study area.

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TABLE 1

Table 1.--Well characteristics, water-sampling conditions, and chloride concentrations

[gal/min, gallons per minute; h, hours; mg/L, milligrams per liter; dashes indicate no data]

Map number	Well name	Township/ range-section, quarter section	Elevation of land surface (feet)	Well depth (feet)	Casing (diameter in inches/interval in feet)	Date	Pumping		Chloride concentration (mg/L)	Laboratory analysis number
							Rate (gal/min)	Duration (h)		
					MCHENRY COUNTY					
1	CRYSTAL LAKE No. 2	43/08-05,NE	917	2,000	20/0-234	08/25/30	--	--	5.0	67285
					16/205-242					
					10/235-569					
					8/748-964					
						02/01/32	--	--	4.0	70266
						07/03/47	400	7	5.0	110907
						09/29/47	235	--	4	--
	Well sounded.			1,978		01/09/48	400	2.2	3	--
						00/00/52	--	--	--	--
	Reported depth.			1,218		12/27/55	--	--	7	139368
						--/--/56	--	--	--	--
						10/01/57	400	4	5	144648
						11/07/58	420	7	2	148178
						09/21/64	--	--	2	164392
						03/03/66	--	--	3	168450
						08/24/66	340	2.3	3	169720
						05/09/72	200	.8	2	188639
					LAKE COUNTY					
2	ZION TEST WELL	46/12-14,NW	586	3,435						
	Sampling depth, 909 to 1,046 feet.					09/01/81	--	--	13	--
	Sampling depth, 1,775 to 1,932 feet.					12/10/80	--	--	370	--
	Sampling depth, 3,120 feet.					01/14/81	--	--	37,000	--
					KANE COUNTY					
3	ELGIN No. 1 (Slade Ave.)	41/08-11,NE	725	2,000		--/--/01	--	--	--	--
				1,159		--/--/17	--	--	--	--
				1,850		--/--/31	--	--	--	--
						03/17/31	--	--	5.0	68791
	Found part of casing; shot and cleaned.					01/18/33	--	--	7.0	72336
					10/800- ?	--/--/43	--	--	--	--
				1,960		03/22/46	600	20	5.0	105959

	Cleaned out (bridged at 1,145 and 1,560 feet).			1,945		04/--/46	--	--	--	--
						06/29/48	1,076	18	7.0	115155
	Cleaned out (bridged at 1,145 feet).			1,935		--/--/56	--	--	--	--
						05/06/59	656	3	11.0	149549
	Rehabilitated.			1,945	20/0-125 16/0-160	--/--/60	--	--	--	--
						06/14/74	984	16	8	C008783
						11/15/76	1,039	2	12	B19905
						02/07/79	700	298	24	C003172
						09/21/79	--	10	17	B13604
						12/04/80	--	72	20	B27924
						05/11/83	--	--	12	B37088
4	ST. CHARLES No. 3	40/08-27,SW	690	2,198	0/0-10 12/0-243 10/243-489 8/830-930	--/--/19	--	--	--	--
	Sampled during drilling at 2,045 feet.					03/20/19	--	--	17	40787
	Sampled during drilling at 2,198 feet.					06/22/21	--	--	24	43318
						11/08/44	--	--	84	101813
						08/15/47	850	1.8	108	111561
	Reamed and cased.			2,197	16/0-670 12/820-935	--/--/55	--	--	--	--
						05/04/55	1,065	24	245	137602
						12/13/60	--	.8	240	20025
						10/09/69	--	--	450	179790
	Plugged back and acidized.			1,191		05/--/71	--	--	--	--
						03/31/73	950	--	18	191550
						11/27/73	950	1.5	15	A107023
						03/31/75	920	1.5	13	C007458
						04/25/77	850	1	11	B43427
						03/11/79	1,000	2	8.8	B37354
						05/07/80	--	--	8	213428
						03/09/81	1,000	2	3.5	B043421
						09/14/83	820	1.5	6.5	B011467
5	GENEVA No. 2	39/08-03,SE	678	1,156		--/--/24	--	--	--	--
	Deepened.			2,217	12/0-224	--/--/28	--	--	--	--
						03/12/28	--	--	23	61315
						11/10/37	--	--	21	82316
	Recased.				12/removed 20/0-6 16/0-352					
						06/16/54	750	1	22	135128
						03/09/62	--	days	23	156969
	Cleaned out (bridged at 1,562 feet).			2,172		--/--/62	--	--	--	--
						11/26/73	750	3	8	C003862

Table 1.--Well characteristics, water-sampling conditions, and chloride concentrations--Continued

Map number	Well name	Township/ range-section, quarter section	Elevation of land surface (feet)	Well depth (feet)	Casing (diameter in inches/interval in feet)	Date	Pumping: Rate (gal/min)	Pumping: Duration (h)	Chloride concentration (mg/L)	Laboratory analysis number
				KANE COUNTY--Continued						
5	GENEVA No. 2--Continued					02/12/76	700	2	10	B31938
						01/25/78	610	1	13	B31591
						03/18/80	600	6	12	B40844
						04/15/82	610	1	13	B041945
6	BATAVIA No. 2	39/08-22,NE	667	2,000		--/--/15	--	--	--	--
						10/--/15	--	--	10	31679
						01/30/18	--	--	10.0	38931
						07/01/20	--	--	12	43359
	Found filled to 1,547 feet; deepened and rehabilitated.			2,200	26/0-50	--/--/45	--	--	--	--
					20/0-233					
					16/790-940					
					12/1,260-1,670					
						10/02/45	--	--	15.0	104424
						10/03/45	--	--	15.0	104425
						10/03/45	475	23	15.0	104426
						11/30/45	--	.1	14.0	104924
						11/30/45	850	2.3	25.0	104925
						12/01/45	1,420	24	24.0	104927
						12/12/60	--	--	12	153767
						10/18/71	--	--	17	02234
						11/13/73	1,000	3.5	57	C03452
						07/17/75	1,050	.8	41	199252
						08/18/75	1,000	.5	50	C001538
						02/09/76	1,100	.5	14	B31396
						02/09/76	1,100	.5	6	B31398
						01/--/78	--	--	128	B31462
						03/19/80	1,000	3	16	B41045
						04/15/82	--	--	38	B041948
7	AURORA No. 12A	38/08-15,NE	670	2,251		03/--/36	--	--	--	--
	Sampled during drilling at 457 feet.					07/24/35	--	--	12.0	76390
	Sampled during drilling between 455 and 595 feet.					09/10/35	--	--	12.0	76589
	Sampled during drilling at 840 feet.					10/--/35	--	--	59.0	76728
	Sampled during drilling at 1,450 feet.					11/--/35	--	--	612	77062

				2,250	22/7-32	03/--/36	--	--	287	77564
					18/7-455					
					16/771-839					
					16/1,333-1,633					
	Sampled at start of test.					09/24/36	1,100	--	161	78756
	Sampled at end of test.					09/25/36	1,300	--	269	78757
						02/02/43	1,300	12	212	95188
						11/15/67	940	12	262	173476
						01/19/72	450	48	288	03720
						08/08/73	1,375	24	340	B101326
						06/10/76	1,422	24	330	B49193
						04/08/82	1,367	57	369	B041164
				DU PAGE COUNTY						
8	BENSENVILLE No. 2	40/11-13,NW	676	1,442		--/--/29	--	--	--	--
	Sampled during drilling at 1,310 feet					10/25/29	--	--	14.0	65325
	Sampled during drilling at 1,360 feet.					11/04/29	--	--	14.0	65324
	Cased.				20/0-106					
					17/98-322					
					12/301-622					
					10/1,083-1,165					
					10/1,244-1,300					
						01/17/38	--	--	12.0	82769
						02/22/43	250	.5	11.0	95365
						08/10/43	350	1	13	--
						--/--/43	--	--	14	97034
						09/10/46	--	--	11.0	107676
						05/15/47	300	3	13.0	110309
	Discovered leak; replaced liner.				12/0-126	--/--/50	--	--	--	--
						11/12/54	600	5	15	136270
						05/27/65	510	40 days	51	166066
						02/10/70	350	14	79	180723
						10/01/73	500	2	29	B103323
						02/26/75	500	1	130	C006409
						02/23/77	500	.8	37	B34442
						11/25/77	375	1	63	C002115
						04/11/79	575	1	160	B40849
						03/19/81	515	2	170	B045326
						04/06/83	550	4	178	B32698
9	ELMHURST No. 1	39/11-01,NW	685	958	18/10-65	09/--/15	--	--	--	--
					10/529-622					
						06/23/20	--	--	4.0	43322
						03/02/33	--	--	10.0	72549
	Rehabilitated--removed liner; water level went from 85 to 265 feet.				10/removed	--/--/36	--	--	--	--

Table 1.--Well characteristics, water-sampling conditions, and chloride concentrations--Continued

Map number	Well name	Township/ range-section, quarter section	Elevation of land surface (feet)	Well depth (feet)	Casing (diameter in inches/interval in feet)	Date	Pumping Rate (gal/min)	Pumping Duration (h)	Chloride concentration (mg/L)	Laboratory analysis number
	DU PAGE COUNTY--Continued									
9	ELMHURST No. 1--Continued					08/03/36	--	--	13.0	78498
	Deepened and recased.			1,480	18/0-65	--/--/40	--	--	--	--
					13/0-466					
					10/883-1,244					
	Sounded.			1,480		--/--/47	--	--	--	--
	Cleaned and repaired holes in pipe and casing.			1,483	13/0-465	07/--/51	--	--	--	--
	Rehabilitated, shot, and measured.			1,423		--/--/55	--	--	--	--
						10/23/73	600	5.5	25	C002971
						10/12/76	1,000	5	17	B15572
						06/06/79	1,025	3	30	C004833
						09/30/82	826	3	121	B10736
10	VILLA PARK No. 2	39/11-09,NE	699	2,125		08/--/31	--	--	--	--
	Sampled during drilling at 2,025 feet.					07/24/31	--	--	3.0	69498
	Sampled during drilling at 2,075 feet.					07/30/31	--	--	4.0	69527
	Sampled during drilling at 2,100 feet.				20/0-97	07/31/31	--	--	3.0	69528
					16/0-108					
					16/188-434					
					12/1,050-1,116					
					10/1,170-1,262					
				2,125		04/17/36	--	--	21.0	77752
						05/22/47	625	2.5	99.0	110369
	Cleaned out.			2,104		--/--/52	--	--	--	--
	Reported depth.			2,100		--/--/54	--	--	--	--
						03/27/72	550	2	127	B0011323
	Reported depth.			1,605		--/--/73	--	--	--	--
						12/05/73	560	2	40	C04162
						03/13/80	1,050	1.5	35	B40071
						03/23/82	--	--	16	B039297
11	ELMHURST No. 4	39/11-10,NE	669	2,219	22/0-65	--/--/27	--	--	--	--
					18/0-230					
					14/960-1,130					
						12/12/28	--	--	500	63159
						08/03/36	--	--	637	78501
	Beginning of rehabilitation.				14/removed	--/--/37				

	Shot; well filled to 2,130 feet; concrete plug to to 2,100 feet. Shot again; well bridged at 900 feet with water level at 85 feet; broke bridge and found another at 1,200 feet; water level at 325 feet, broke bridge and water level rose to 255 feet; placed concrete plug between 2,025 and 1,985 feet with no improvement in water quality; placed third plug between 1,560 and 1,500 feet, but salt content increased again.					--/--/38				
	Cleaned out.			1,545		02/--/47	--	--	--	--
	Pumped well for almost 10 days (12/12/47 to 12/22/47) at about 650 gal/min; chlorides went from 74 to 176 mg/L in that time.									
						12/31/47	--	19 days	108	113027
	Well plugged.			1,400		--/--/48	--	--	--	--
						06/09/48	620	2.2	85	114990
						06/09/49	1,000	1.8	98	118442
						--/--/53	--	--	85	131130
						03/06/53	1,000	2	86	131377
						04/10/61	--	--	25	31656
	Reported depth.			1,370	22/0-65 16/0-416 14/1,020-1,137	--/--/62	--	--	--	--
						10/23/73	1,050	29.5	24	C02970
						10/12/76	1,320	5.2	26	B15082
						09/20/78	500	24	31	C001123
						10/30/80	--	--	34	B21942
						02/02/83	1,100	12	30	B23145
				COOK COUNTY						
12	DES PLAINES No. 1	41/12-18,SW	652	1,735	19/0-170 16/0-300 12/699-800 10/1,010-1,600	06/--/27	--	--	--	--
						08/28/28	--	--	22	62466
						07/03/42	800	15	30	93307
						01/13/44	700	4.5	30	98770
	Measured depth.			1,604		10/18/44	--	--	--	--
						12/07/44	1,000	4.2	33	102038
						05/03/46	815	28	37	106378
						04/25/72	500	.2	291	15677
						08/04/76	500	2	300	B05319
						07/10/78	350	200	300	B01895
						09/04/80	300	24	279	B16206
						01/11/83	300	24	280	B020477

Table 1.--Well characteristics, water-sampling conditions, and chloride concentrations--Continued

Map number	Well name	Township/range-section, quarter section	Elevation of land surface (feet)	Well depth (feet)	Casing (diameter in inches/interval in feet)	Date	Pumping: Rate (gal/min)	Pumping: Duration (h)	Chloride concentration (mg/L)	Laboratory analysis number
					COOK COUNTY--Continued					
13	BELLWOOD No. 1	39/12-09,NE	632	1,538	12/0-88 10/315-520 8/913-974	--/--/13	--	--	--	--
						07/07/14	--	--	6	28011
						06/21/22	--	--	6	7765
	Well deepened.			1,956		--/--/35	--	--	--	--
	Sampled after deepening.					07/16/35	--	--	75	75890
	Production dropped.					07/--/43	--	--	--	--
	Pumping air at 450 feet.					12/--/43	--	--	--	--
	Pump pulled; found hole in pipe.					06/28/44	--	--	--	--
	Well found bridged at 1,649 feet.					06/30/44	--	--	--	--
	Shot Galesville Sandstone; replaced liner.				8/replaced	09/--/44	--	--	--	--
						01/09/45	850	3.5	31	102248
						04/29/46	850	.8	25	106337
						03/11/52	640	24	69	128107
						11/06/58	1,200	2	43	148176
						03/30/72	1,050	1	33	188169
						01/29/74	1,010	25.5	34	B107698
						07/30/74	900	.8	40	C00821
						08/--/76	--	56	32	B07384
						07/--/78	525	--	32	C000044
						09/30/80	1,050	--	39	B16917
						07/06/83	--	--	50	B000624
14	RIVERSIDE No. 3	39/12-36,SW	617	2,047	20/0-52 16/348-510 12/855-937	--/--/23	--	--	--	--
						02/06/26	--	--	218	56074
						11/05/29	--	--	200	65340
						03/10/31	--	--	190	68755
						07/05/31	--	--	85	69407
	Repairs made of an unknown nature.					--/--/32	--	--	--	--
						09/13/35	--	--	160	76613
						12/02/39	--	1	201	86827
						12/02/39	--	3	197	86828
						12/02/39	--	6	195	86829
	Pump lowered.					--/--/44	--	--	--	--
						05/07/46	840	1	162	106407
						--/--/59	--	--	145	149419

						02/20/63	539	1.5	150	159631
						11/16/65	--	--	225	illegible
						12/08/65	1,100	1	216	167830
						05/05/70	1,000	.5	160	181623
						05/17/72	1,150	1	152	B0019545
						08/23/74	1,225	.8	150	C001617
						03/22/76	1,225	1.2	150	B37395
						02/17/77	1,250	1.2	150	B33978
						06/13/77	1,250	--	160	C006187
						07/11/78	1,200	4	180	208723
						12/03/79	1,250	.5	136	B25192
						03/--/82	1,250	--	137	B038104
						04/28/83	1,250	1	154	B35893
15	LYONS No. 2	38/12-01,NW	621	2,020	24/0-9 18/341-524	06/01/29	--	--	--	--
						08/05/30	--	--	180	67110
	Measured depth.			1,907		--/--/36	--	--	--	--
						11/14/38	--	--	141	84547
	Measured depth.			1,892		--/--/44	--	--	--	--
						09/04/57	1,310	--	142	144203
						01/09/63	1,350	7	290	159405
						02/01/63	1,350	8	165	159462
						04/06/70	900	1.5	170	181206
						04/26/72	890	1	130	B0016010
						07/15/74	800	48	220	C00336
						03/29/76	700	--	180	B38305
						04/18/78	1,000	24	180	C003491
						04/15/81	--	--	190	215576
						12/04/84	1,025	1	159	B021990
16	THORNTON No. 4	36/14-34,SE	617	1,785	16/0-48 10/0-675	06/--/54	--	--	--	--
						07/01/54	572	8	300	135216
						05/14/58	300	2	275	146633
	Reported that well is being maintained for reserve use.					05/26/59				
						09/10/68	--	6	270	176170
						05/23/72	620	2	275	B0020732
						09/11/73	620	4	280	B102616
						04/08/74	550	12	295	C006970
						09/02/75	580	1	275	C002019
						06/28/77	560	6	290	C006535
						11/04/79	--	--	286	B20773
						01/--/80	480	2	284	B27546

Table 1.--Well characteristics, water-sampling conditions, and chloride concentrations--Continued

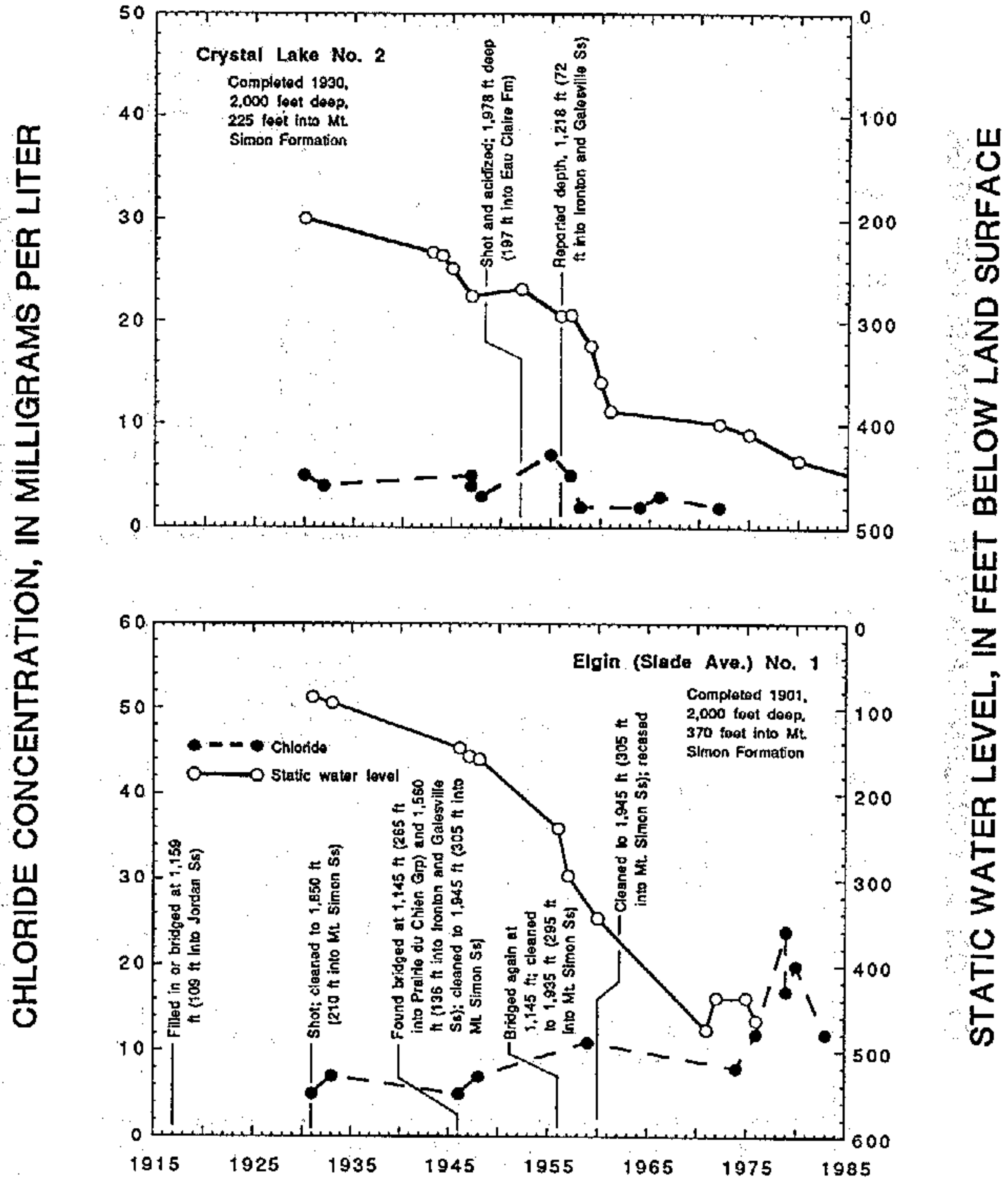
Map number	Well name	Township/ range-section, quarter section	Elevation of land surface (feet)	Well depth (feet)	Casing (diameter in inches/interval in feet)	Date	Pumping Rate (gal/min)	Pumping Duration (h)	Chloride concentration (mg/L)	Laboratory analysis number
					WILL COUNTY					
17	JOLIET No. 1 (Washington St.)	35/10-14,NW	564	1,608	24/0-39 18/0-68 18/239-350 12/918-980 10/1,076-1,134	--/--/37	--	--	--	--
						07/13/37	--	--	25.0	81613
	Found bridged at 1,192 feet; filled to 1,484 feet; cleaned out.					10/30/44	--	--	--	--
	Measured depth.			1,677		04/10/46	--	--	--	--
						10/30/46	1,120	--	30.0	108173
	Rehabilitated.				18/removed 16/0-358	12/--/56				
	Reamed, cleaned, shot, cleaned.			1,609		01/--/57	--	--	--	--
	Removed liners, reamed; new liners.				12/removed 10/removed 12/915-1,134	--/--/71	--	--	--	--
						03/01/72	1,000	24	32.0	B008466
						04/22/77	900	24	34.0	B42691
						04/02/79	850	24	38	C003735
						04/29/81	796	24	34	B052856
18	WILMINGTON No. 2	33/09-25,SW	546	1,566	12/0-23 10/0-218	--/--/36	--	--	--	--
						05/03/38	--	--	279	83455
						10/09/46	620	1.2	295	107910
	Measured depth.			1,536		10/--/54	--	--	--	--
						06/26/62	--	--	320	43433
						03/30/70	--	--	320	39214
						03/08/72	760	.5	285	04428
						03/04/74	760	1.5	280	L108797
						10/29/75	760	1	276	B18485
						11/14/77	760	.5	260	C001978
						01/21/80	760	2	260	B32218
						02/02/82	750	4	267	B034421

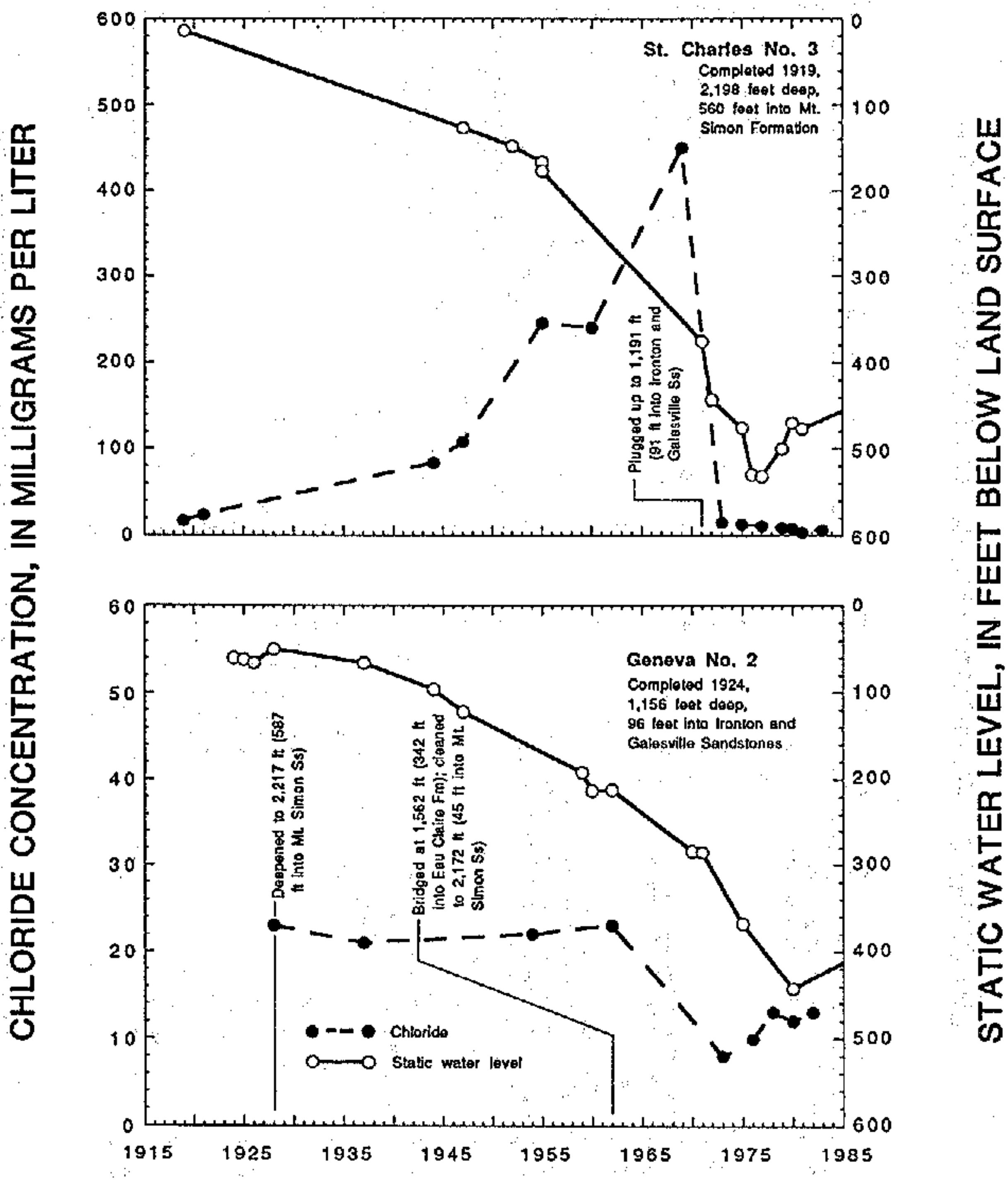
Appendix A

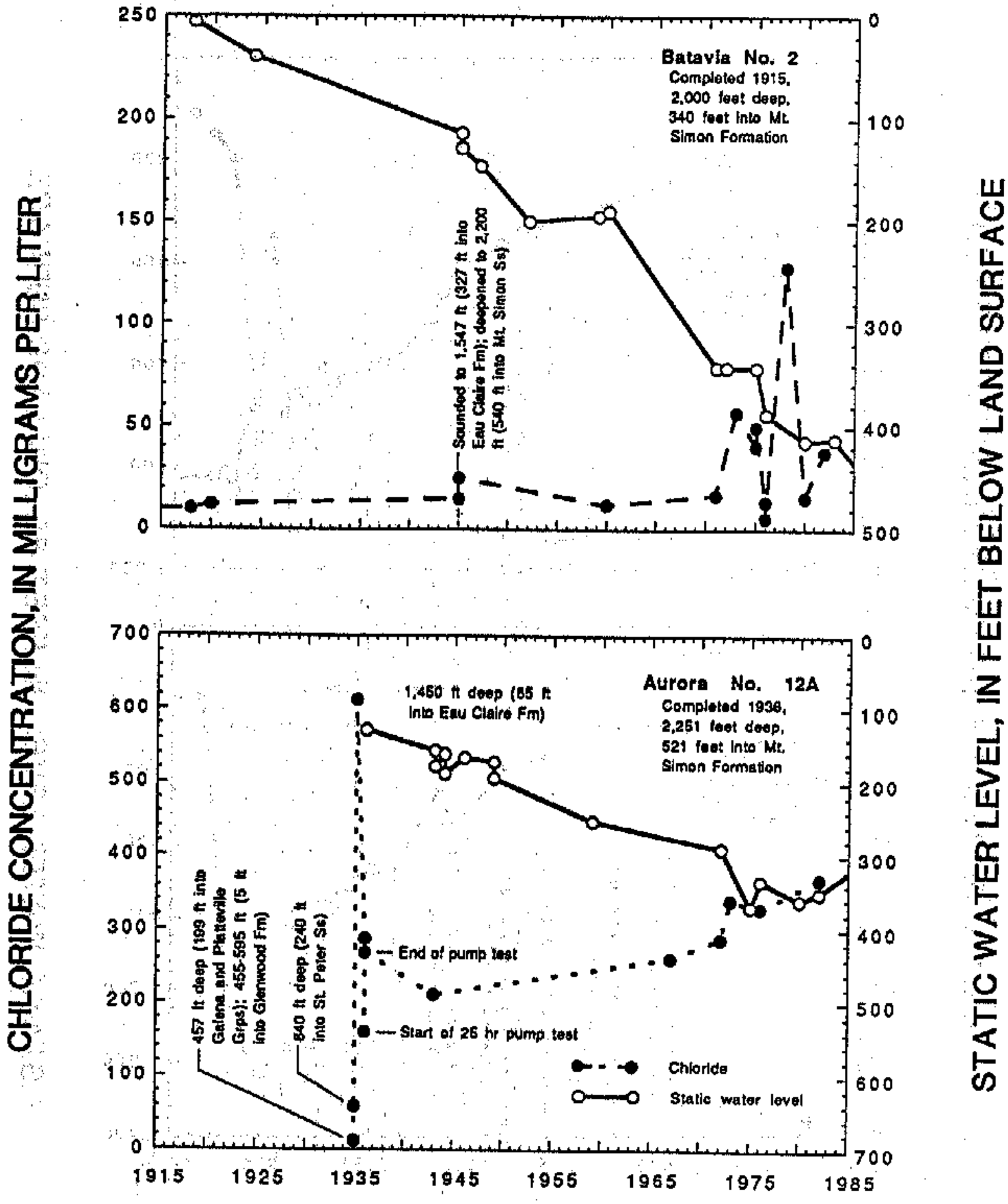
Chloride concentration and static ground-water levels as a function of time, and well-completion and well-history data for selected wells in northeastern Illinois.

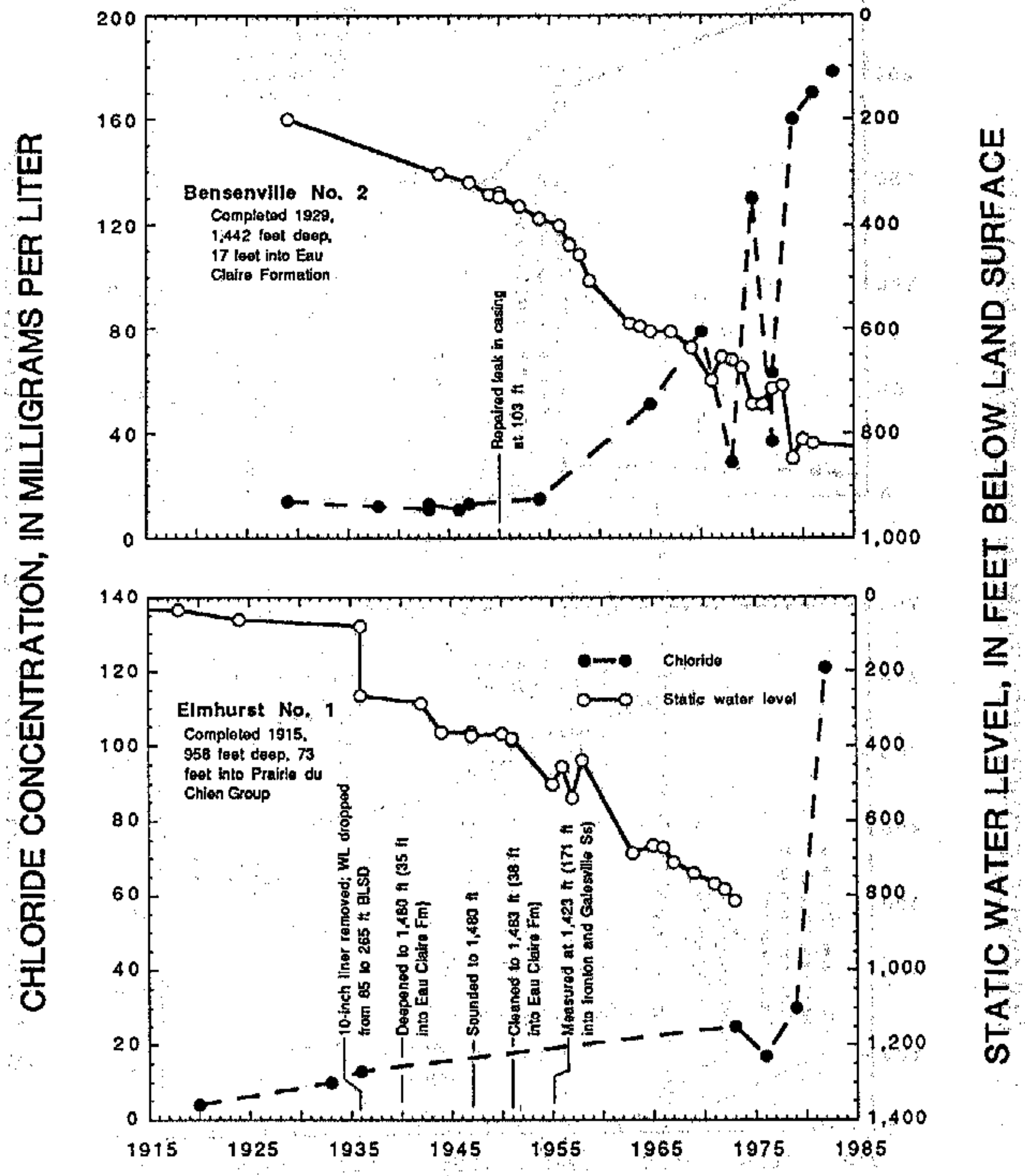
ABBREVIATIONS

ft	feet
Fm	Formation
Ss	Sandstone
Grp	Group
Ave	Avenue
St	Street
Sys	System
BLSD	below land surface datum
Ls	Limestone
hr	hour
WL	water level

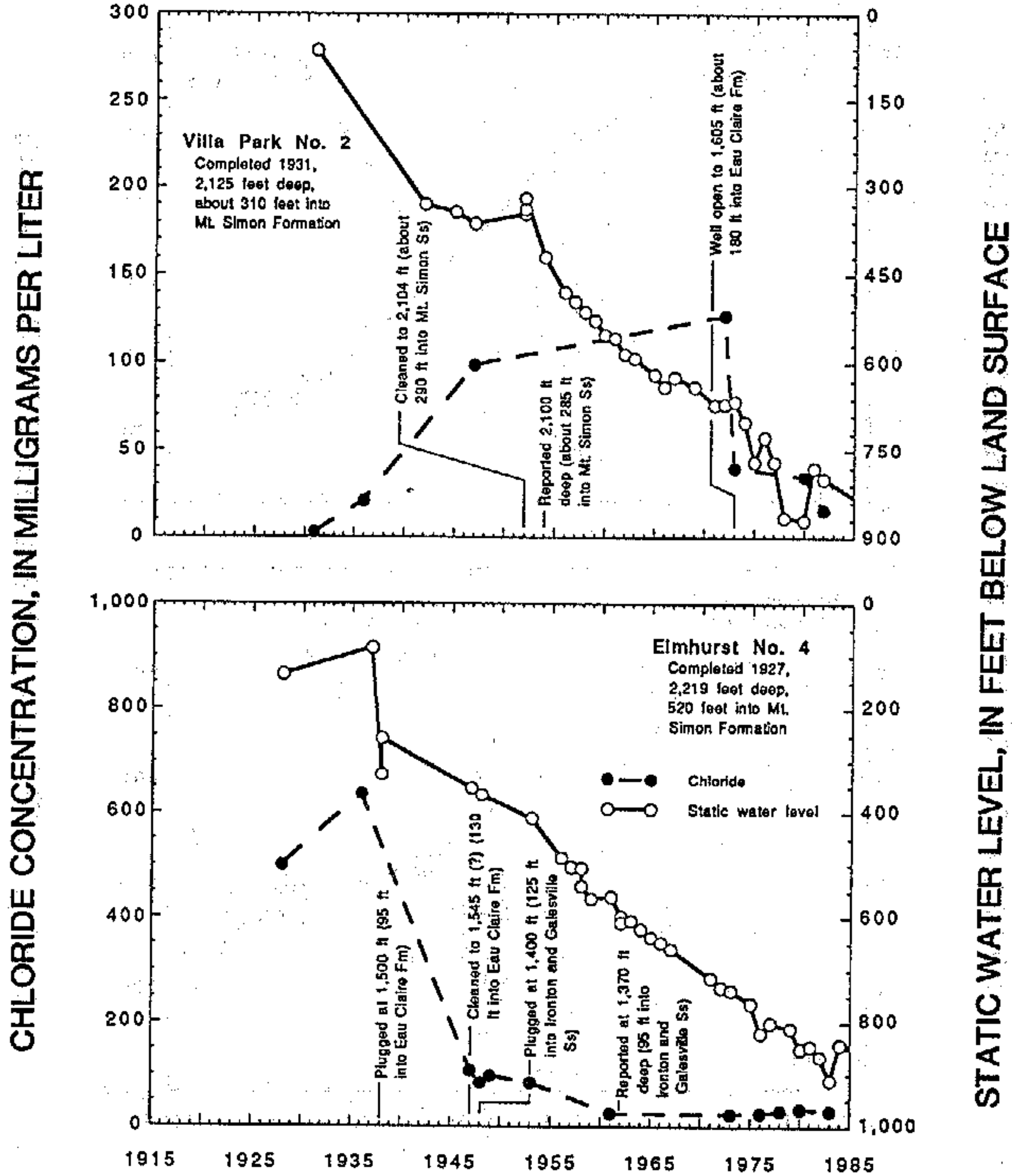

Crystal Lake No. 2
Completed 1930, 2,000 feet deep, 225 feet into Mt. Simon Formation
Shot and acidized; 1,978 ft deep (197 ft into Eau Claire Fm)
Reported depth, 1,218 ft (72 ft into Ironton and Galesville Ss)
Elgin (Slade Ave.) No. 1
Completed 1901, 2,000 feet deep, 370 feet into Mt. Simon Formation
Chloride
Static water level
Filled in or bridged at 1,159 ft (109 ft into Jordan Ss)
Shot; cleaned to 1,850 ft (210 ft into Mt. Simon Ss)
Found bridged at 1,145 ft (265 ft into Prairie du Chien Grp) and 1,560 ft (136 ft into Ironton and Galesville Ss); cleaned to 1,945 ft (305 ft into Mt. Simon Ss)
Bridged again at 1,145 ft; cleaned to 1,935 ft (295 ft into Mt. Simon Ss)
Cleaned to 1,945 ft (305 ft into Mt. Simon Ss); recased
CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
1915
1925
1935
1945
1955
1965
1975
1985


CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
St. Charles No. 3
Completed 1919, 2,198 feet deep, 560 feet into Mt. Simon Formation
Plugged up to 1,191 ft (91 ft into Ironton and Galesville Ss)
Geneva No. 2
Completed 1924, 1,156 feet deep, 96 feet into Ironton and Galesville Sandstones
Deepened to 2,217 ft (587 ft into Mt. Simon Ss)
Bridged at 1,562 ft (342 ft into Eau Claire Fm); cleaned to 2,172 ft (45 ft into Mt. Simon Ss)
Chloride
Static water level
600
500
400
300
200
100
0
60
50
40
30
20
10
0
100
200
300
400
500
600
1915
1925
1935
1945
1955
1965
1975
1985

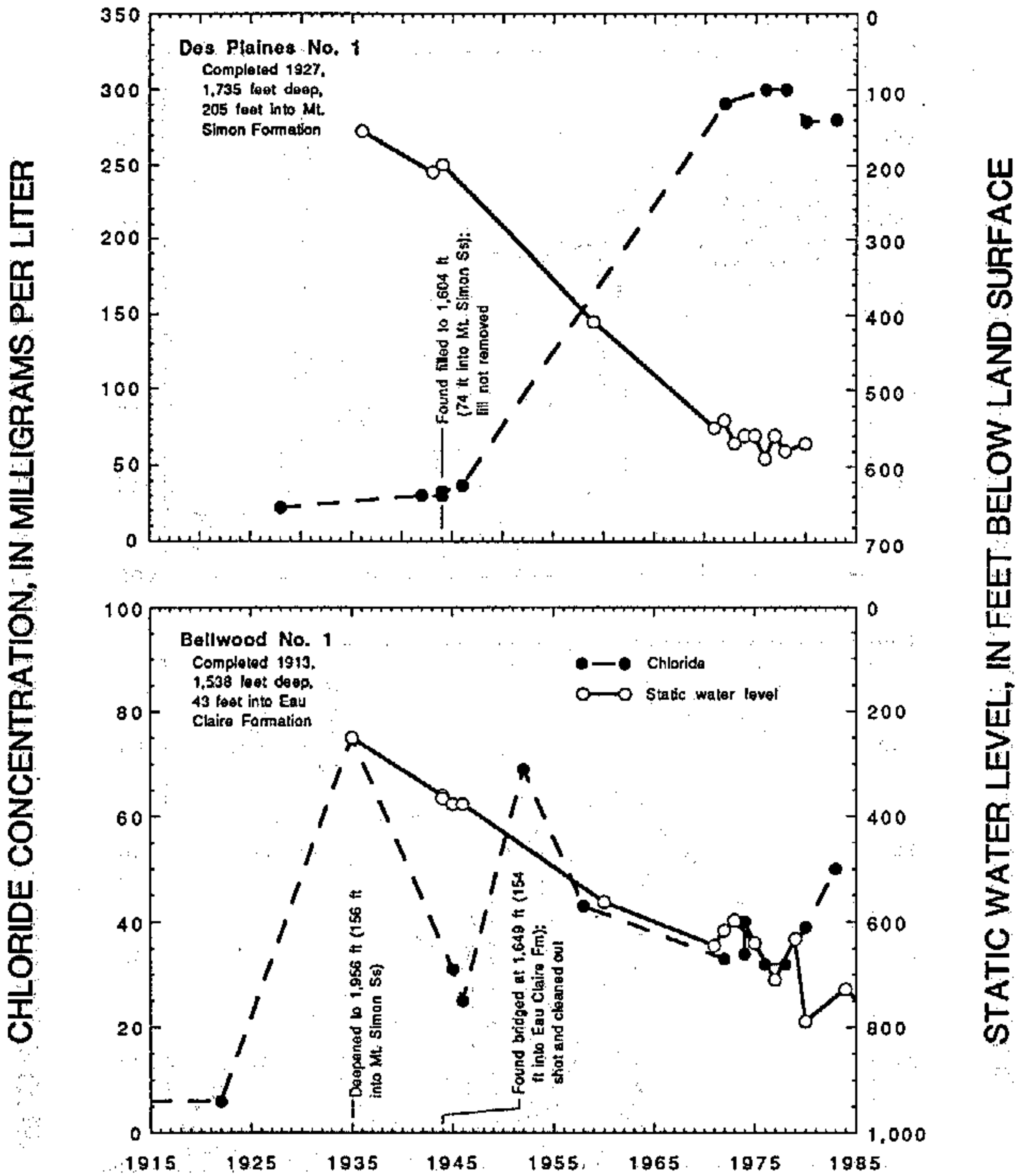

CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
Batavia No. 2
Completed 1915,
2,000 feet deep,
340 feet into Mt.
Simon Formation
Sounded to 1,547 ft (327 ft into Eau Claire Fm); deepened to 2,200 ft (540 ft into Mt. Simon Ss)
Aurora No. 12A
Completed 1936,
2,251 feet deep,
521 feet into Mt.
Simon Formation
1,450 ft deep (85 ft into Eau Claire Fm)
457 ft deep (199 ft into Galena and Platteville Grps); 455-595 ft (5 ft into Glenwood Fm)
640 ft deep (240 ft into St. Peter Ss)
End of pump test
Start of 26 hr pump test
Chloride
Static water level
250
200
150
100
50
0
700
600
500
400
300
200
100
0
100
200
300
400
500
600
700
1915
1925
1935
1945
1955
1965
1975
1985



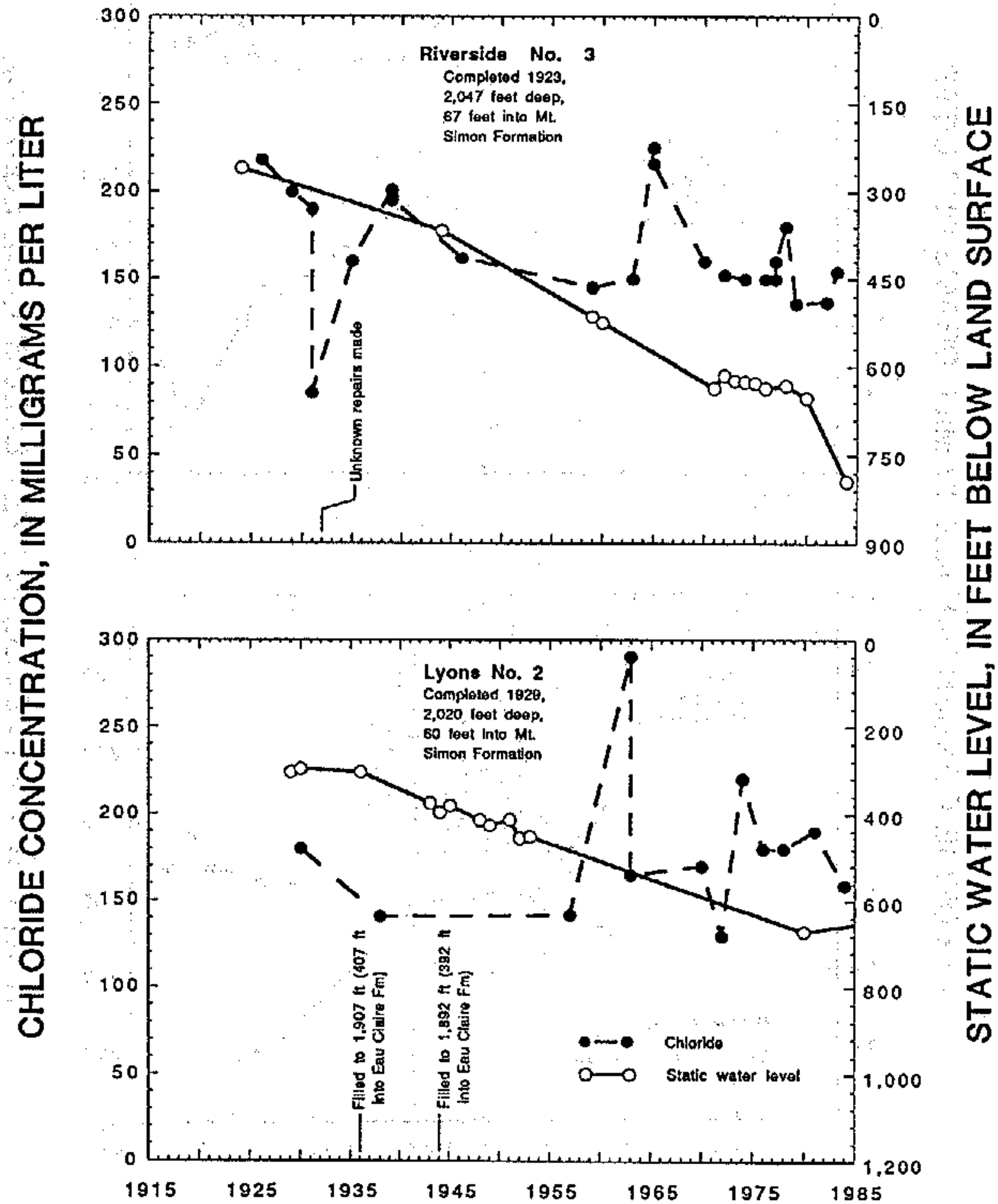
CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
Bensenville No. 2
Completed 1929, 1,442 feet deep, 17 feet into Eau Claire Formation
Repaired leak in casing at 103 ft
Elmhurst No. 1
Completed 1915, 958 feet deep, 73 feet into Prairie du Chien Group
Chloride
Static water level
10-inch liner removed; WL dropped from 85 to 265 ft BLSD
Deepened to 1,480 ft (35 ft into Eau Claire Fm)
Sounded to 1,480 ft
Cleaned to 1,483 ft (38 ft into Eau Claire Fm)
Measured at 1,423 ft (171 ft into Ironton and Galesville Ss)
200
160
120
80
40
0
140
120
100
80
60
40
20
0
0
200
400
600
800
1,000
0
200
400
600
800
1,000
1,200
1,400
1915
1925
1935
1945
1955
1965
1975
1985

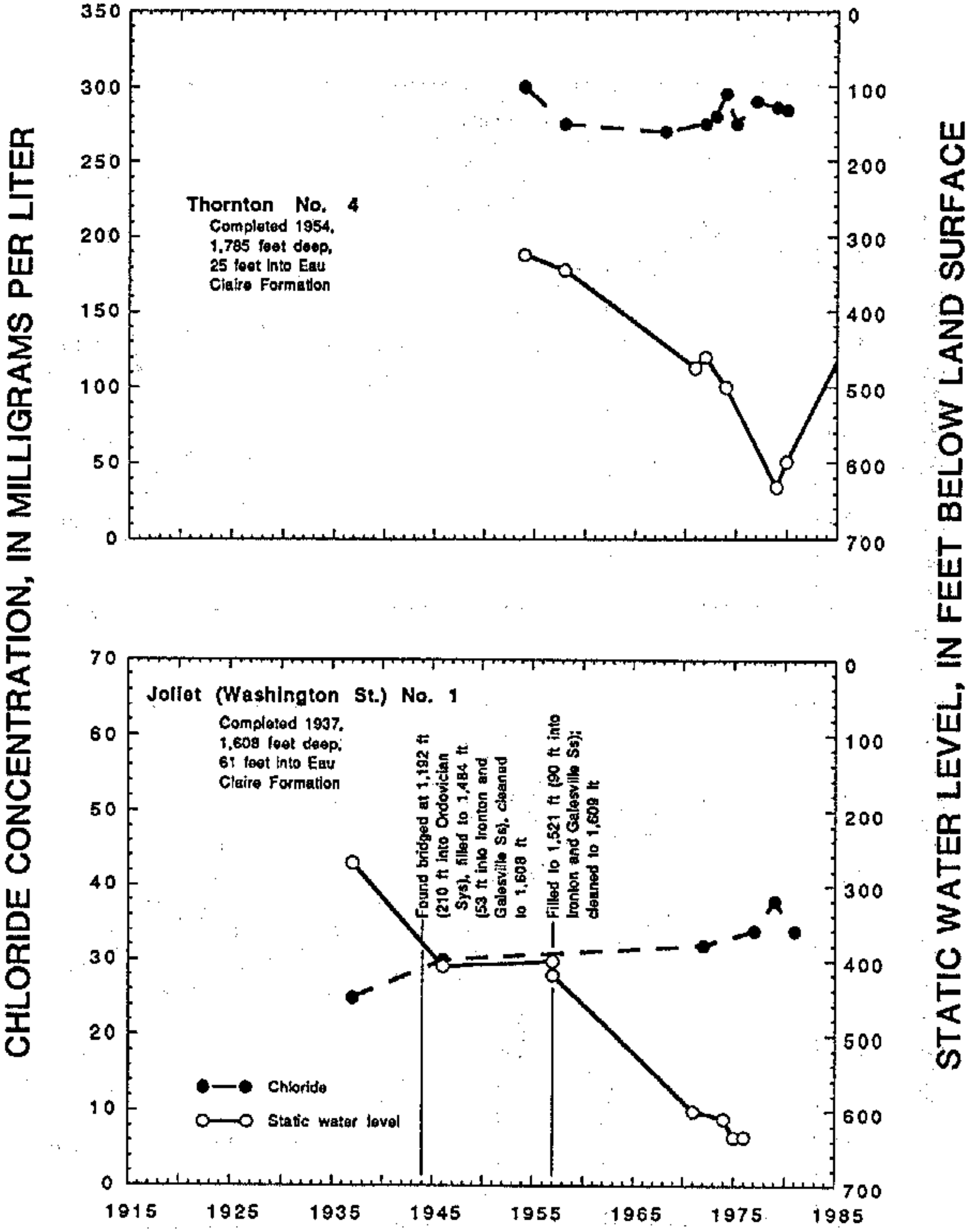


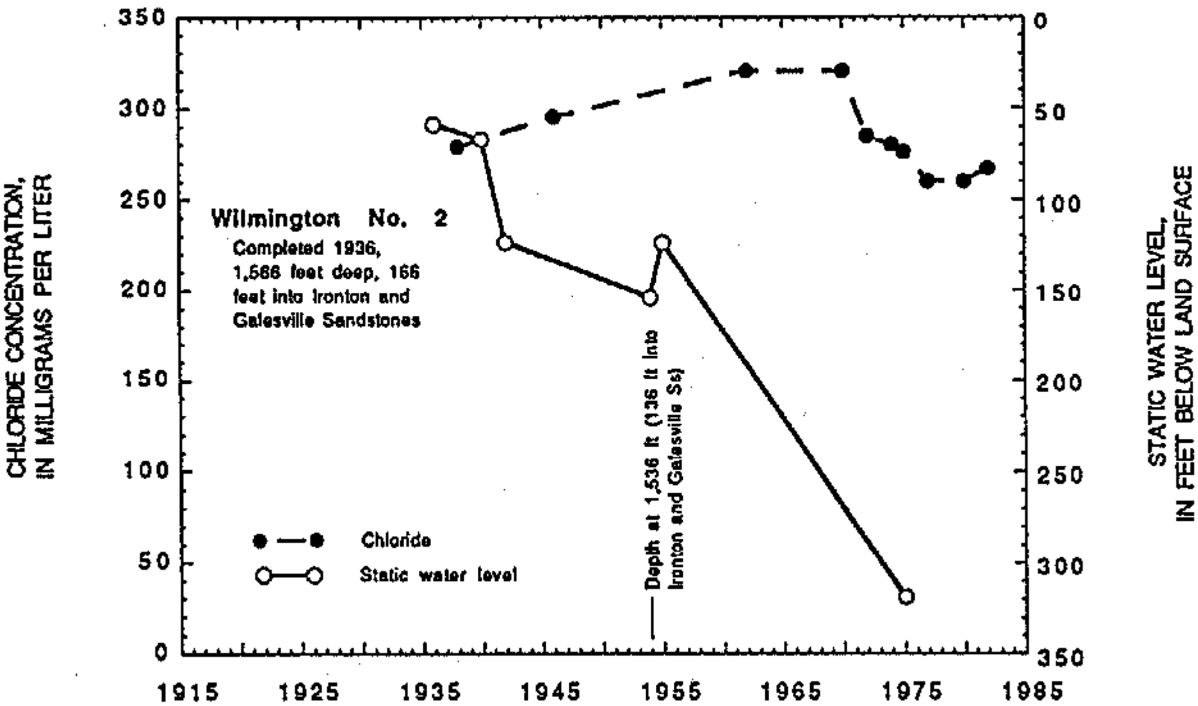
CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
Villa Park No. 2
Completed 1931, 2,125 feet deep, about 310 feet into Mt. Simon Formation
Cleaned to 2,104 ft (about 290 ft into Mt. Simon Ss)
Reported 2,100 ft deep (about 285 ft into Mt. Simon Ss)
Well open to 1,605 ft (about 180 ft into Eau Claire Fm)
Elmhurst No. 4
Completed 1927, 2,219 feet deep, 520 feet into Mt. Simon Formation
Chloride
Static water level
Plugged at 1,500 ft (95 ft into Eau Claire Fm)
Cleaned to 1,545 ft (?) (130 ft into Eau Claire Fm)
Plugged at 1,400 ft (125 ft into Ironton and Galesville Ss)
Reported at 1,370 ft deep (95 ft into Ironton and Galesville Ss)
300
250
200
150
100
50
0
1,000
800
600
400
200
0
150
300
450
600
750
900
1,000
1915
1925
1935
1945
1955
1965
1975
1985



CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
Des Plaines No. 1
Completed 1927, 1,735 feet deep, 205 feet into Mt. Simon Formation
Found filled to 1,604 ft (74 ft into Mt. Simon Ss); fill not removed
Bellwood No. 1
Completed 1913, 1,538 feet deep, 43 feet into Eau Claire Formation
Chloride
Static water level
Deepened to 1,956 ft (156 ft into Mt. Simon Ss)
Found bridged at 1,649 ft (154 ft into Eau Claire Fm); shot and cleaned out
1915
1925
1935
1945
1955
1965
1975
1985


CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
Riverside No. 3
Completed 1923, 2,047 feet deep, 67 feet into Mt. Simon Formation
Unknown repairs made
Lyons No. 2
Completed 1929, 2,020 feet deep, 60 feet into Mt. Simon Formation
Filled to 1,907 ft (407 ft into Eau Claire Fm)
Filled to 1,892 ft (392 ft into Eau Claire Fm)
Chloride
Static water level
0
50
100
150
200
250
300
150
300
450
600
750
900
200
400
600
800
1,000
1,200
1915
1925
1935
1945
1955
1965
1975
1985


CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
STATIC WATER LEVEL, IN FEET BELOW LAND SURFACE
Thornton No. 4
Completed 1954,
1,785 feet deep,
25 feet into Eau
Claire Formation
Joliet (Washington St.) No. 1
Completed 1937,
1,608 feet deep,
61 feet into Eau
Claire Formation
Found bridged at 1,192 ft (210 ft into Ordovician Sys), filled to 1,484 ft (53 ft into Ironton and Galesville Ss), cleaned to 1,608 ft
Filled to 1,521 ft (90 ft into Ironton and Galesville Ss); cleaned to 1,609 ft
Chloride
Static water level
350
300
250
200
150
100
50
0
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
1915
1925
1935
1945
1955
1965
1975
1985



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