Iowa Geological Survey Water Atlas No. 6

WATER RESOURCES OF EAST - CENTRAL IOWA

Iowa Geological Survey Water Atlas Number 6

Water Resources of East-Central Iowa

by

K. D. Wahl, G. A. Ludvigson
G. L. Ryan, and W. C. Steinkampf

This atlas presents information on the
occurrence, availability, quality, and
utilization of water in east-central Iowa.

Prepared by the U.S. Geological Survey
in cooperation with the Iowa Geological Survey.

Published by the
STATE OF IOWA
1978

FOREWORD

An adequate and safe water supply has always been one of man's fundamental needs. For man to meet this need and yet live in rational balance with the environment he must understand the hydrology of the supply area. Limits imposed by the quality and quantity of water available and the effects of development of alternative sources should be assessed before developments are made.

This report presents a summary of the hydrology of east-central Iowa for both the long-range planner and developer and the individual water user. The areas chosen by the planner to establish solid and liquid waste-disposal sites, the spacing of major water-using developments, and the manner in which agriculture is managed should all be considered if wise use of our resources is to prevail. Individual users are of course most interested in the one fundamental need; location of an adequate, safe water supply. This report should be of significant use to both the planner and user.

Information presently available through the U.S. Geological Survey and the Iowa Geological Survey is presented in the report. These two agencies, however, have a continuing data-gathering program and new data accumulates daily. Persons requiring water-resources data and geologic information can use this report for a thorough, concise summary of information as of the date of publication. If more or later information is needed, inquiry directed to the Surveys is welcome.

Stanley C. Grant
Director & State Geologist
Iowa Geological Survey

Iowa City, Iowa
January, 1978

CONTENTS

CONTENTS
Illustrations

CONTENTS

Illustrations

Tables

GLOSSARY

Abbreviations

cfs - cubic feet per second; 1 cfs equals 449 gallons per minute or about 0.65 million gallons per day.

cfsm - cubic feet per second per square mile.

gpm - gallons per minute.

mgd - million gallons per day.

mg/L - milligram per liter; approximately equal to 1 part per million.

ug/L - microgram per liter; approximately equal to 1 part per billion.

Alluvium - Clay, sand, gravel, boulders, and other matter laid down by streams upon land not submerged beneath the waters of lakes or seas.

Anticline - A fold in rock strata in which the strata dip (slope) in opposite directions from a common ridge or axis. Opposite of syncline.

Aquifer - Rocks that contain and transmit water and thus are a source for water supplies.

Artesian water - Ground water that is under sufficient pressure to rise above the level at which it is encountered by a well—does not necessarily rise to or above the land surface.

Average discharge - The arithmetic average of the streamflow or discharge of all the complete water years of record, whether consecutive or not. It represents the long-term total amount of water that a stream produces.

Basement complex - A complex of Precambrian igneous and metamorphic rocks that lie beneath the dominantly sedimentary rocks in Iowa.

Carbonate - A sedimentary rock containing the radical CO_3. In this report carbonate refers to the limestone and dolomite formations in eastern Iowa.

Climatic year - In U. S. Geological Survey reports dealing with surface-water supply, the 12-month period beginning April 1 and ending the following March 31. The climatic year is designated by the calendar year in which it begins. It is used especially for low-water studies.

Confining bed - A rock unit that retards the flow of water so as to restrict the amount of water which can reach an underlying aquifer or restrict circulation between aquifers.

Contour - A line used to connect points of equal altitude, whether they be points on the land surface, on the bedrock surface, on the surface of a particular rock layer, on the water table, or on a potentiometric surface.

Contour interval - The difference in altitude between two adjacent contour lines.

Conversion factors - For those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	**By**	**To obtain metric unit**
inches	$2.54 \times 10^{+1}$	millimeters
feet	3.048×10^{-1}	meters
mile	1.609	kilometers
square feet	9.29×10^{-2}	square meters
acre	4.047×10^{-3}	square kilometers
square mile	2.590	square kilometers
cubic feet	2.832×10^{-2}	cubic meters
gallon	3.785	liters
gallon	3.785×10^{-3}	cubic meters
gallons per minute	6.309×10^{-2}	liters per second
gallons per day	3.785×10^{-3}	cubic meters per day
million gallons per day	$3.785 \times 10^{+3}$	cubic meters per day
million gallons per year	$3.785 \times 10^{+3}$	cubic meters per year
billion gallons per year	$3.785 \times 10^{+6}$	cubic meters per year

Dissolved solids - The total concentration of dissolved material, ordinarily determined from the weight of the dry residue remaining after evaporation of the volatile portion of an aliquot of the water sample.

Drawdown - The lowering of the water table or potentiometric surface due to the pumping of a well.

Drift - A mixture of rocks, such as boulders, gravel, sand, or clay, transported by glaciers and deposited by or from the ice or deposited by or in water derived from the melting of the ice.

Evapotranspiration - A term embracing water returned as vapor to the air through direct evaporation from water surfaces and moist soil and by transpiration of vegetation, no attempt being made to distinguish between the two.

Fault - A rock fracture or fracture zone along which there has been displacement of the two sides relative to one another. This displacement may range from a few inches to many miles.

Fold axis - The line following the apex of an anticline or the lowest part of a syncline.

Glacial till - Nonsorted, nonstratified sediment composed of material of all size fractions—from clay to boulders carried or deposited by a glacier.

Head potential - The energy to move a fluid resulting from the difference in altitude of the fluid between two points. Usually expressed in feet.

Hydrostatic head - The height of a vertical column of water, the weight of which, if of unit cross section, is equal to the hydrostatic pressure at a point.

Hydrostatic pressure - The pressure exerted by the water at any given point in a body of water at rest. That of ground water is generally due to the weight of water at higher levels in the same zone of saturation.

Igneous rocks - Rocks formed by solidification of hot mobile rock matter or magma.

Infiltration - The movement of water through the soil surface into the ground.

Joint - A fracture or parting which interrupts abruptly the physical continuity of a rock mass.

Karst - The enlargement of openings in carbonate rocks by the action of solution. The process by which caverns are formed and an important source of secondary permeability in the carbonate aquifers.

Mean discharge - The arithmetic average of a stream's discharge for a definite period of time, such as a day, month, or year.

Metamorphic rocks - Rocks that have formed in the solid state by recrystallization and reactions between rock matter in response to pronounced changes of temperature, pressure, and chemical environment.

Natural storage - Water naturally detained in a drainage basin in the stream channel, lakes, reservoirs, natural depressions, and ground-water reservoir.

Normal annual air temperature - The arithmetic average of air temperature values for a 30-year period ending with an even 10-year. In this report, the period is 1941-70.

Normal annual precipitation - The arithmetic average of annual quantities of precipitation for a 30-year period ending with an even 10-year. In this report, the period is 1941-70.

Normal pool altitude - The level of a flat-water pool of a controlled stream is maintained at this altitude or at higher altitudes during the navigation season (March 16 to December 9 on the Mississippi River adjacent to east-central Iowa).

Percolation - Movement, under hydrostatic pressure, of water through the interstices of rock or soil.

Permeable rocks - Rocks having a texture that permits water to move through them perceptibly under the head difference ordinarily found in ground water systems.

Potentiometric surface - The surface that everywhere coincides with the level to which water from a given aquifer will rise in wells.

Recharge - The processes by which water is added to the zone of saturation.

Runoff - Water discharged through surface streams.

Sedimentary rocks - Rocks formed in a stratified fashion, layer upon layer, by the accumulation of sediment in water or on land.

Structural deformation - Warping and/or faulting of the Earth's crust by forces within the earth.

Suspended sediment - Fragmental material such as clay or mud particles, silt, sand, and small rocks that is transported by being held in suspension by moving water.

Syncline - A fold in rock strata in which the strata dip (slope) inward from both sides toward the axis. Opposite of anticline.

Terrace - Flat, horizontal or slightly inclined surfaces usually found along the edge of a stream valley or in isolated patches within the valley which are at perceptibly higher altitudes than the flood-plain surface.

Terrace deposits - Deposits beneath and forming a terrace.

Water stage - Height of a water surface above any chosen datum plane, often above an established low-water plane.

Water table - The upper surface of the zone of saturation except where that surface is formed by an impermeable body.

Water year - In U.S. Geological Survey reports dealing with surface-water supply, the 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends.

Zone of saturation - The zone in which all pores in the rocks are saturated with water.

ACKNOWLEDGMENTS

Appreciation is expressed to the water superintendents of all the communities in east-central Iowa and to the plant engineers of many industries who willingly provided water-use data. Many individual farmers and homeowners provided information about their water supplies and permitted the sampling of water from their wells. The Iowa Natural Resources Council and the Iowa Department of Environmental Quality supplied information on municipal and industrial water use in the report area.

Much of the credit for this report must be given to the past and present personnel of the Iowa Geological Survey who, through the years, have analyzed many thousands of samples of drill cuttings and have accumulated and stored a wealth of geologic and ground-water data. Their work was the basis upon which the aquifers in this study were defined.

The cooperation of the well drillers who work in east-central Iowa is acknowledged. Their efforts in carefully collecting drill cuttings and recording water data have resulted in a good understanding of the water resources of this area.

All the chemical analyses used in this study were made by personnel of the State Hygienic Laboratory.

The base maps for this report were drafted by Diana Gilmore. The final data maps and illustrations were drafted by Yvonne Hacker.

INTRODUCTION

A safe and dependable supply of water is vital in the lives of the people and to the economy of any area. To utilize this natural resource in the most efficient and beneficial manner, a basic knowledge and understanding of water sources and the occurrence and potential of each source must be gained. To provide this knowledge, the Water Resources Division of the U.S. Geological Survey and the Iowa Geological Survey have compiled this atlas describing the water resources available for development in a 12-county area in east-central Iowa. The report contains information on the availability, quality, and utilization of water from all known sources and a projection of the future demands upon the water resources in east-central Iowa. The information is presented to aid water users and other persons searching for and evaluating sources of water in a particular place, and planners and water managers who must consider water resources on a regional basis.

Lake Macbride

Mill Creek at Bellevue

Maquoketa River at Pictured Rock State Park

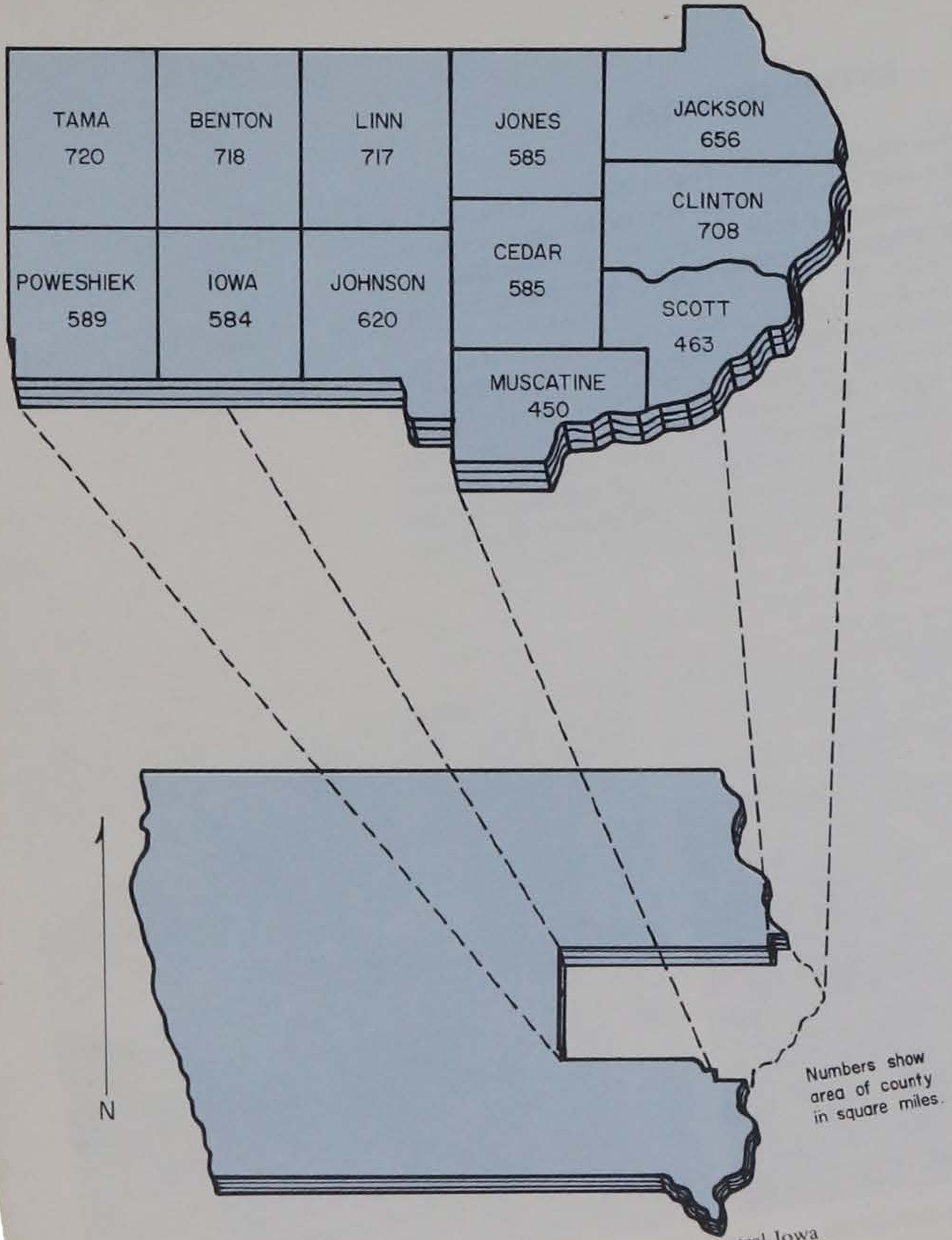


Figure 1.—The 12 counties in east-central Iowa

EAST-CENTRAL IOWA

The report area consists of 12 counties in the eastern part of the state. These 12 counties cover 7,395 square miles, about 13 percent of the land area of Iowa.

The area includes parts of five large drainage basins — the Skunk, Iov Cedar, Wapsipinicon, and Maquoketa — and several smaller ones. All th basins drain into the Mississippi River, which forms the eastern boundar the area.

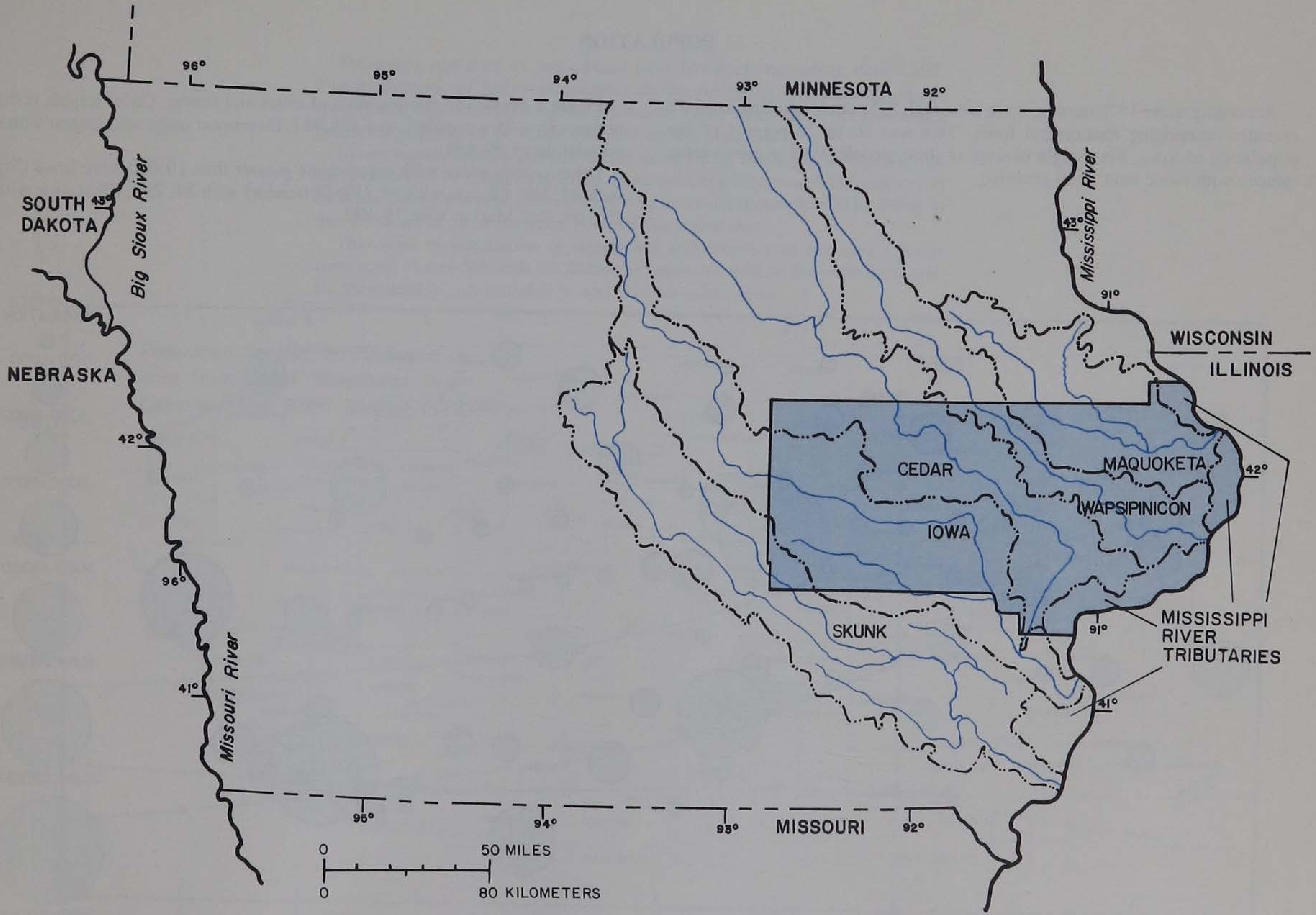


Figure 2.—Drainage basins in east-central Iowa

POPULATION

According to the 1970 census, there were 607,573 people residing in the 12 counties comprising east-central Iowa. This was about 22 percent of the population of Iowa. Sixty-eight percent of these people lived in urban areas (places with more than 2500 persons).

Figure 3 shows the relative sizes of cities and towns. Cedar Rapids is the largest city with a population of 108,987; Davenport is the next largest with a population of 99,836.

Other communities with populations greater than 10,000 were Iowa City with 47,744, Clinton with 34,719, Bettendorf with 24, 290, Muscatine with 23,166, and Marion with 18,190.

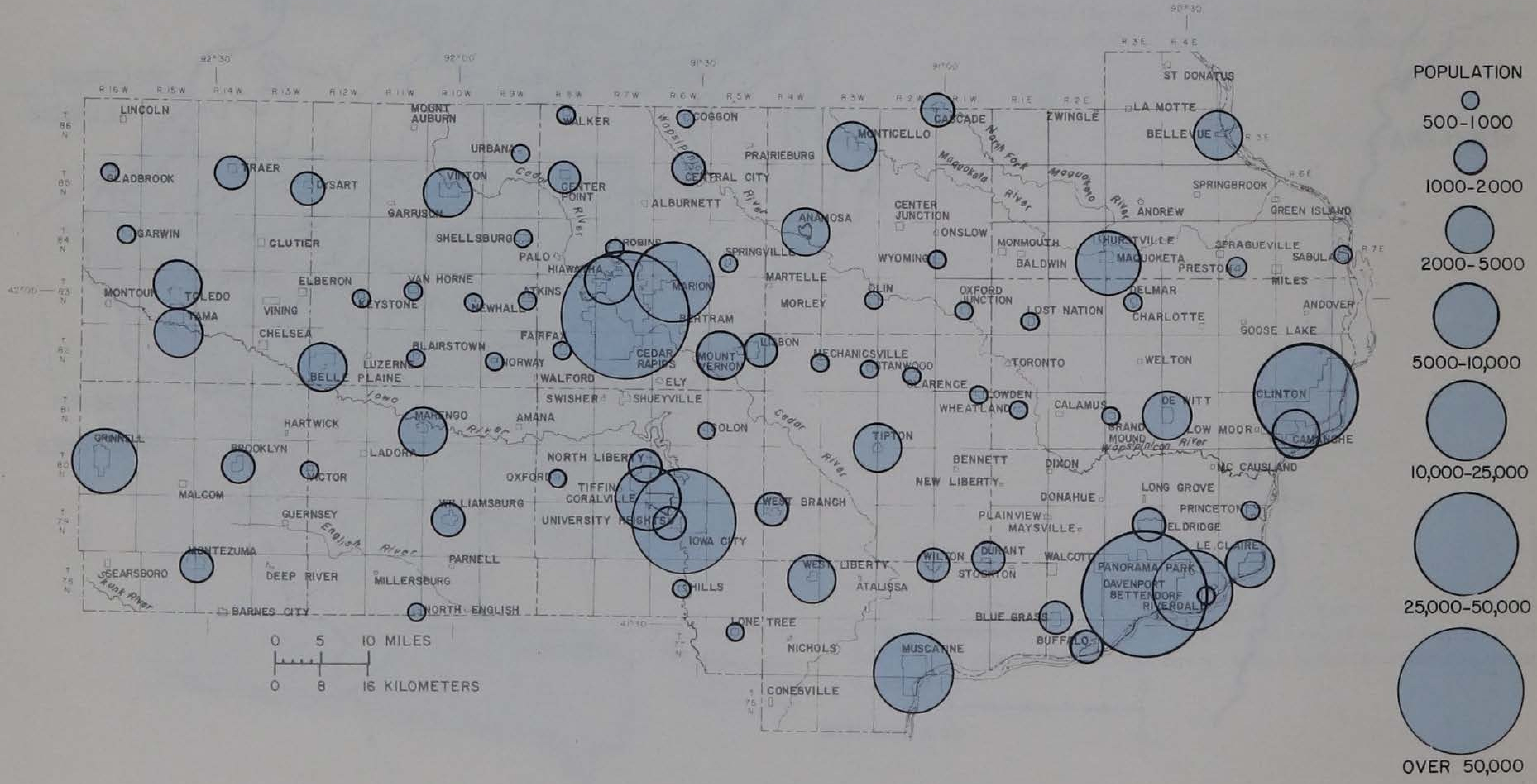


Figure 3.—Population of cities and towns in 1970

The total population in east-central Iowa has been increasing since 1900. The predictions of future population shown on figure 4 are based on the assumption of a continued annual growth of about 2 percent. This indicates a projected population of about 850,000 by the year 2000.

Urban population has grown steadily since 1900, when it was 36 percent of the total; by 1970 it had climbed to approximately 62 percent. Present trends indicate that by the year 2000, over 6.5 times as many people will be living in the urban areas as in the rural parts of the report area.

This shift in population is significant with respect to the area's water resources. Water demands for domestic needs, as well as for industries, will be increasingly concentrated in and around urban areas.

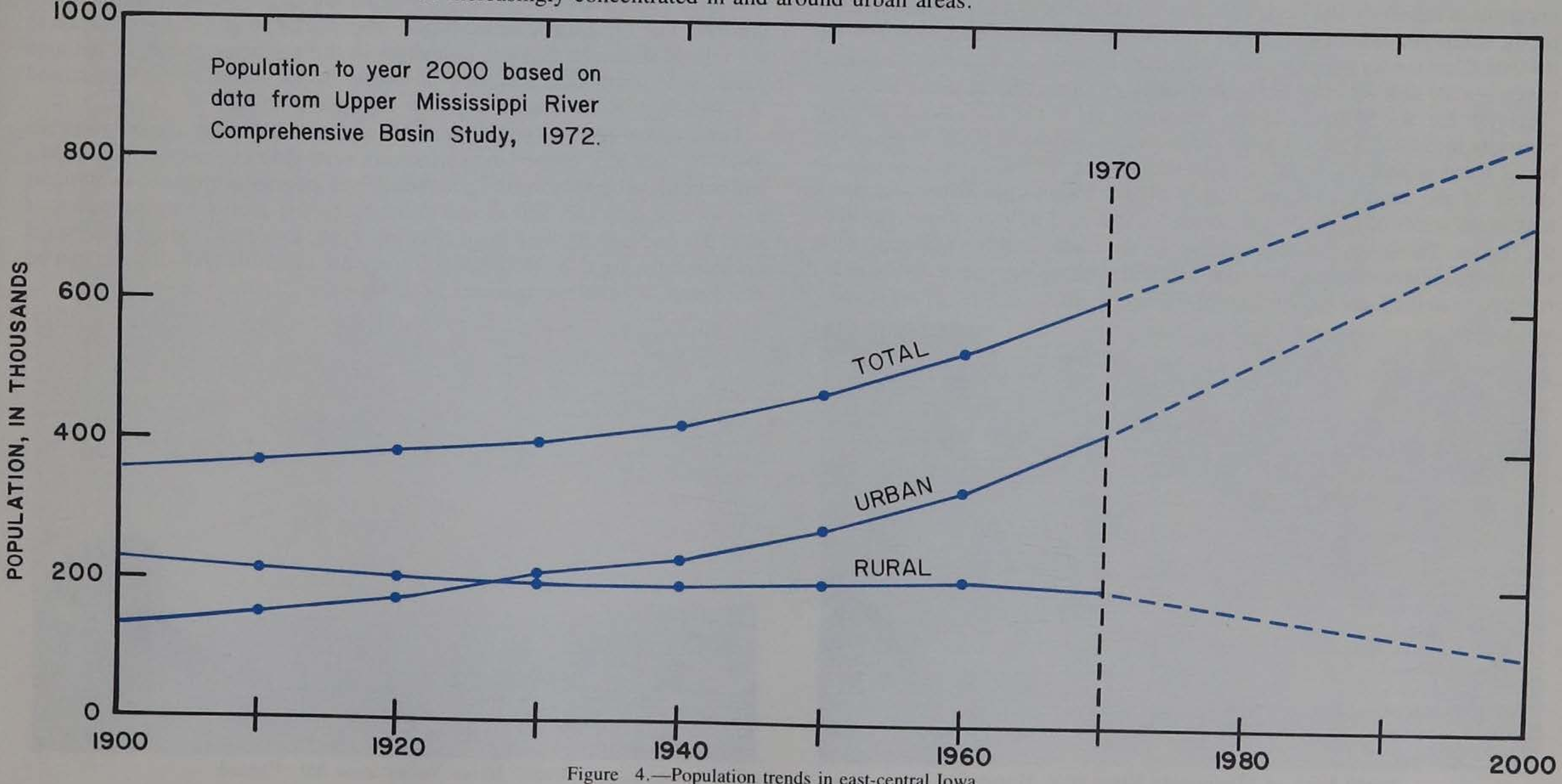


Figure 4.—Population trends in east-central Iowa

THE LAND SURFACE

A wide variety of landforms are exhibited in east-central Iowa. These landforms are closely related to geologic processes that were operating in the relatively recent geologic history of Iowa. The southwest and south-central parts are dissected glacial-till plains that consist of rolling hills with steep-walled valleys and a few flat upland divides. In the northwest and north-central parts, the land surface is a gently undulating surface of low relief that has been named the Iowan surface. It is believed to be an erosional feature of an intraglacial period. Except for a small hilly area along the Mississippi River in Scott and Muscatine Counties, the southeast part consists of broad expanses of relatively flat land. This area is underlain by glacial materials that partly fill large buried channels of ancient streams. The topography of the northeast part is very rugged, with steep rocky hillsides. In this area the glacial cover is very thin and has been completely eroded away in many places.

Except for the Skunk, each of the major river valleys exhibit striking contrasts in width. Valley widths range from constricted bedrock gorges to broad flood plains. In the Muscatine Island area, in the extreme southeast corner of the report area, the valley of the Mississippi River reaches a maximum width of 8.5 miles, although a width of 2 miles is more typical of the region. The lower drainage courses of the Cedar and Iowa Rivers in the vicinity of their confluence flow through wide valleys that are in combination referred to as the Lake Calvin Basin. While the valleys in most of the streams seldom reach as much as 2 miles in width, the lower drainage of the Wapsipinicon River widens into a broad open valley about 6 miles in width.

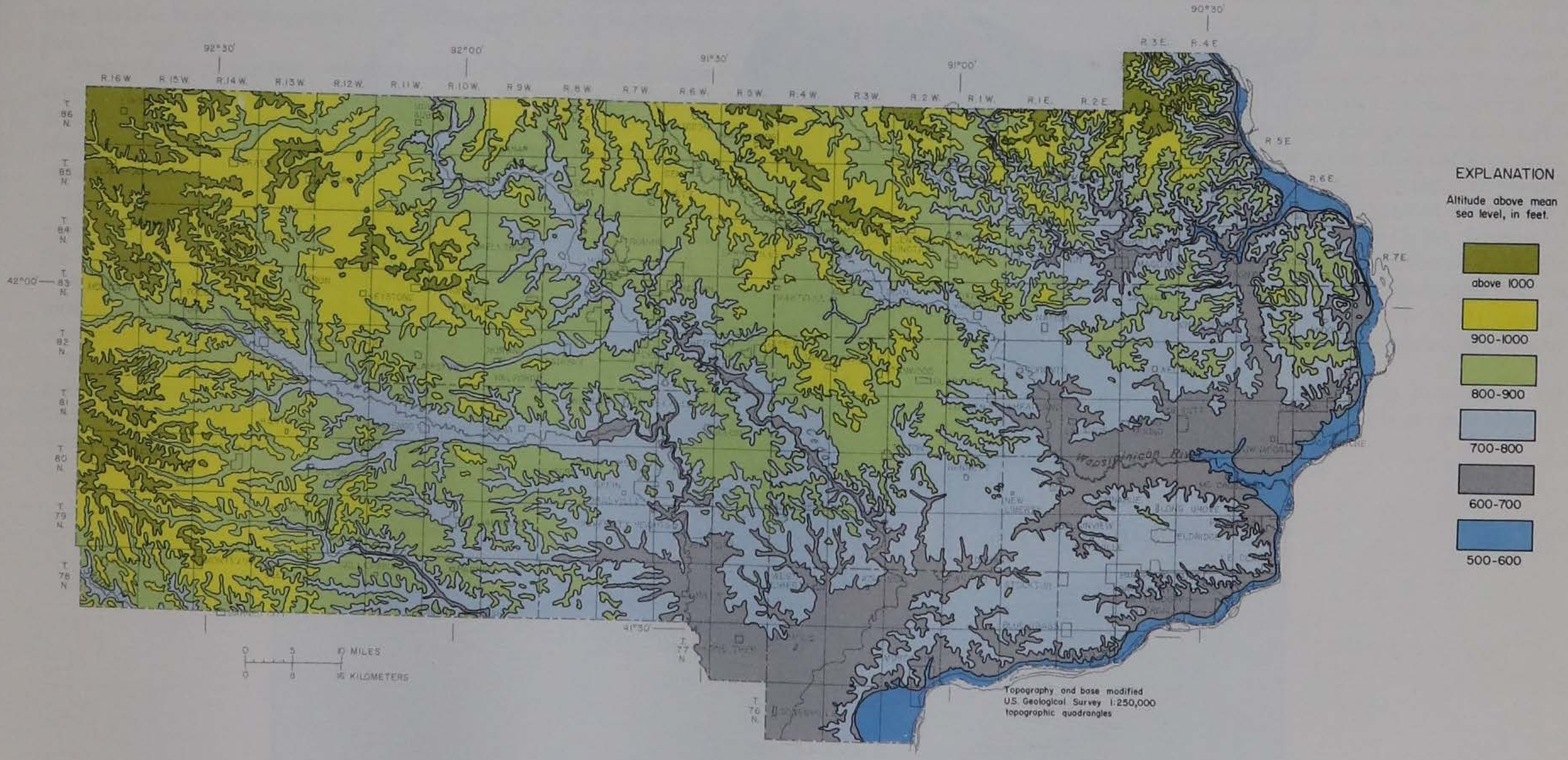
Rivers and streams on flood plains gradually shift their courses and meander. Meander development is extensive in the Mississippi, Iowa, Cedar, and Wapsipinicon River valleys, where numerous oxbow lakes and sloughs appear as related phenomena.

The maximum topographic relief is about 500 feet. As shown on the topographic map (fig. 5), the lowest altitude, less than 600 feet above mean sea level, is along the banks of the Mississippi River. The highest altitudes, over 1000 feet above mean sea level, are along the western and northern borders. The local topographic relief, from major stream-valley bottoms to the upland drainage divides, is highest in the northeast corner of the area where it is about 500 feet, and is lowest in the lower Iowa, Cedar, and Wapsipinicon River basins, where it is about 100 feet.

Because aquifers and water levels are conveniently referenced to mean sea level, the altitudes of the land surface are needed to estimate drilling depths and water-level depths in well planning. The topographic map shows altitudes in 100-foot intervals and is useful for preparing preliminary estimates of altitudes and depths. For more detailed work, however, topographic maps published by the U.S. Geological Survey are available (fig. 20) and can be purchased through the agencies listed on page 27.

North Fork of Maquoketa River near Hurstville

Cedar River Valley near Mt. Vernon



Topography and base modified U.S. Geological Survey 1:250,000 topographic quadrangles

Figure 5.—Topography of east-central Iowa

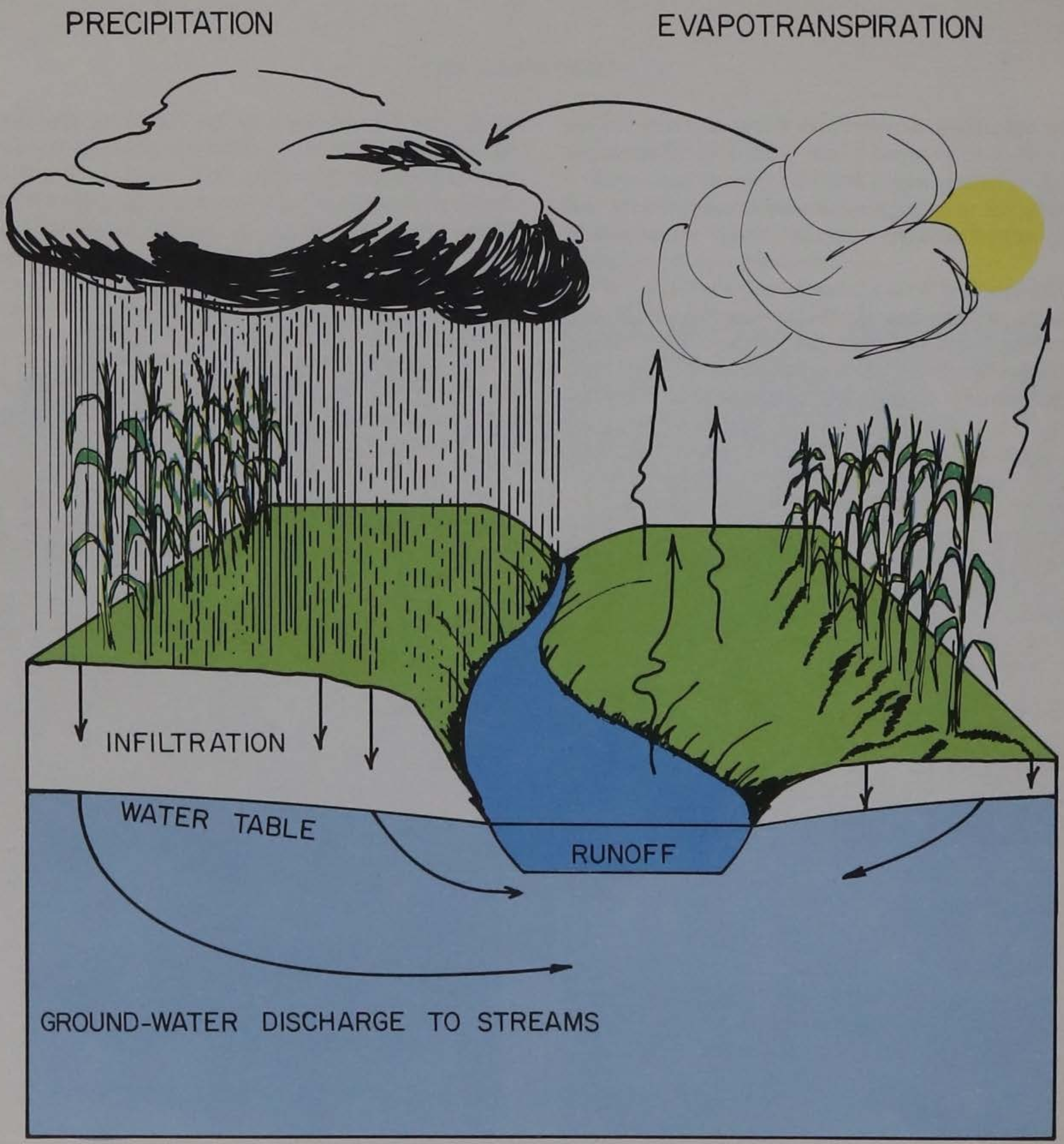


Figure 6.—The hydrologic cycle

THE HYDROLOGIC CYCLE

The source of all our usable water is precipitation. Once water reaches the land surface it either evaporates, transpires, runs off, or infiltrates into the soil. See figure 6.

Much of this precipitated water returns to the atmosphere through evapotranspiration. Some of the water moves over the land as surface runoff. A lesser amount infiltrates through the soil; part of this water moves slowly through earth materials and layers of rocks toward the streams, where it emerges to become part of streamflow.

Normal precipitation in east-central Iowa averages about 33.5 inches per year. This amounts to an average of 11.8 billion gallons of water per day over the entire area.

A little less than three-fourths of the precipitation, an equivalent of about 25 inches, is returned to the atmosphere by evapotranspiration. Once the water is converted to vapor it is no longer available for use or manipulation by man.

Streamflow amounts to about 8.5 inches or just over one-fourth of the annual precipitation. A large part of this runoff occurs during times of flood or high streamflow shortly after a rain. The rest of the time, streamflow is sustained mainly by ground-water discharge.

Probably less than 10 percent of the total precipitation, or about 3 inches, infiltrates into the soil. Some of this is returned to the atmosphere by evapotranspiration. The remainder reaches the ground-water reservoir where it moves through open spaces in granular materials and through cracks and small openings in the rocks. The water generally moves slowly, from less than a foot to several hundred feet per year, and at any one time constitutes a considerable amount of water in storage. Most of the ground water eventually reappears at the surface to contribute to the streamflow. Discharge from the ground-water reservoir is a continuous although variable process, and depletion of storage in the reservoir may result from a decrease in the recharge rate.

The area is not entirely dependent for its water supply on the precipitation that falls within the area. The volume of water carried into east-central Iowa from other parts of Iowa and from Minnesota by the Iowa, Cedar, Wapsipinicon, and Maquoketa Rivers is about equal to the runoff contributed within the area. The volume of water carried into the region by the Mississippi River is about 10 times the runoff generated within east-central Iowa. Also, some of the ground water beneath the report area is derived from outside of the area by underflow.

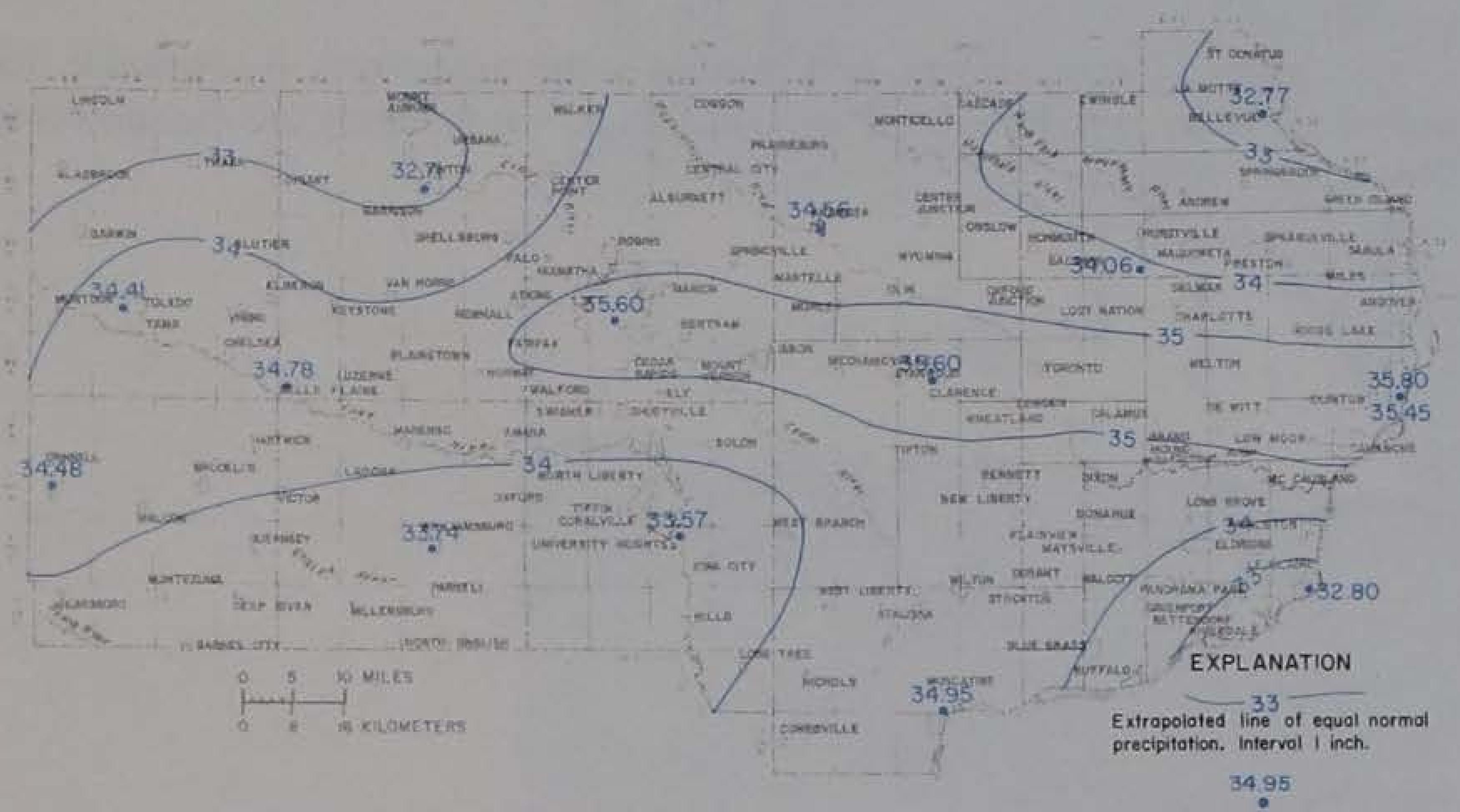
The water in the streams and ground-water reservoirs is available for management and use by man. These sources of water supply are the subject of this report.

CLIMATE

The normal annual precipitation[1] for the report area is about 32 to 36 inches (fig. 7); at various stations within the area it ranges from 32.71 to 35.80 inches.

---

[1] See glossary.



Precipitation data from National Oceanic and Atmospheric Administration, 1975

Figure 7.—Normal annual precipitation in east-central Iowa

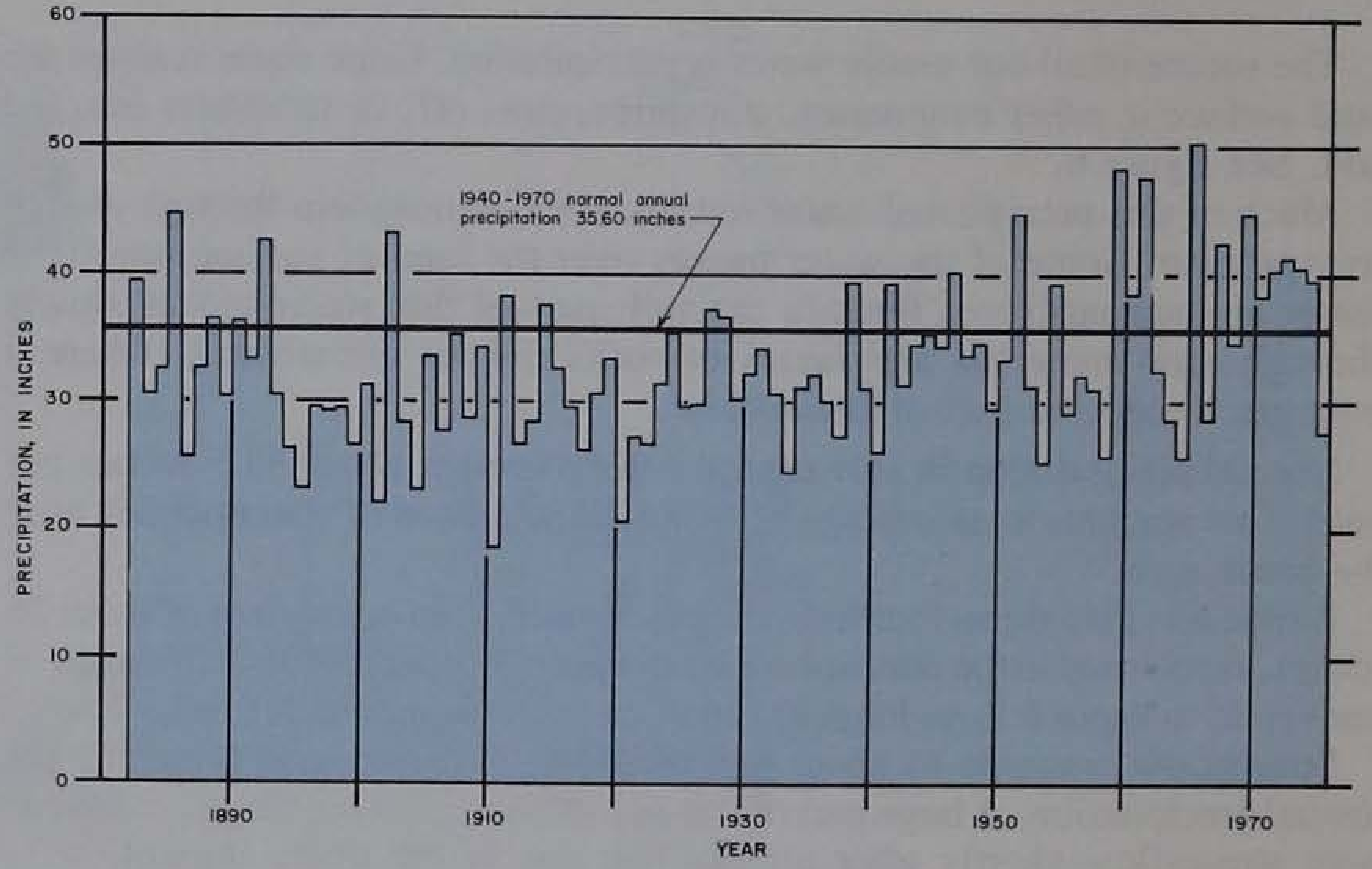


Figure 8.—Annual precipitation at Cedar Rapids, Iowa

Although the amount of precipitation varies from year to year, the annual departure from normal usually is less than 10 inches. For example, analysis of a 94-year record from a station at Cedar Rapids (fig. 8) shows a departure of more than 5 inches from the normal 35.60 inches occurred during 50 percent of the years, and a departure of more than 10 inches in only about 16 percent of the years. Records at other stations in the area exhibit similar departures.

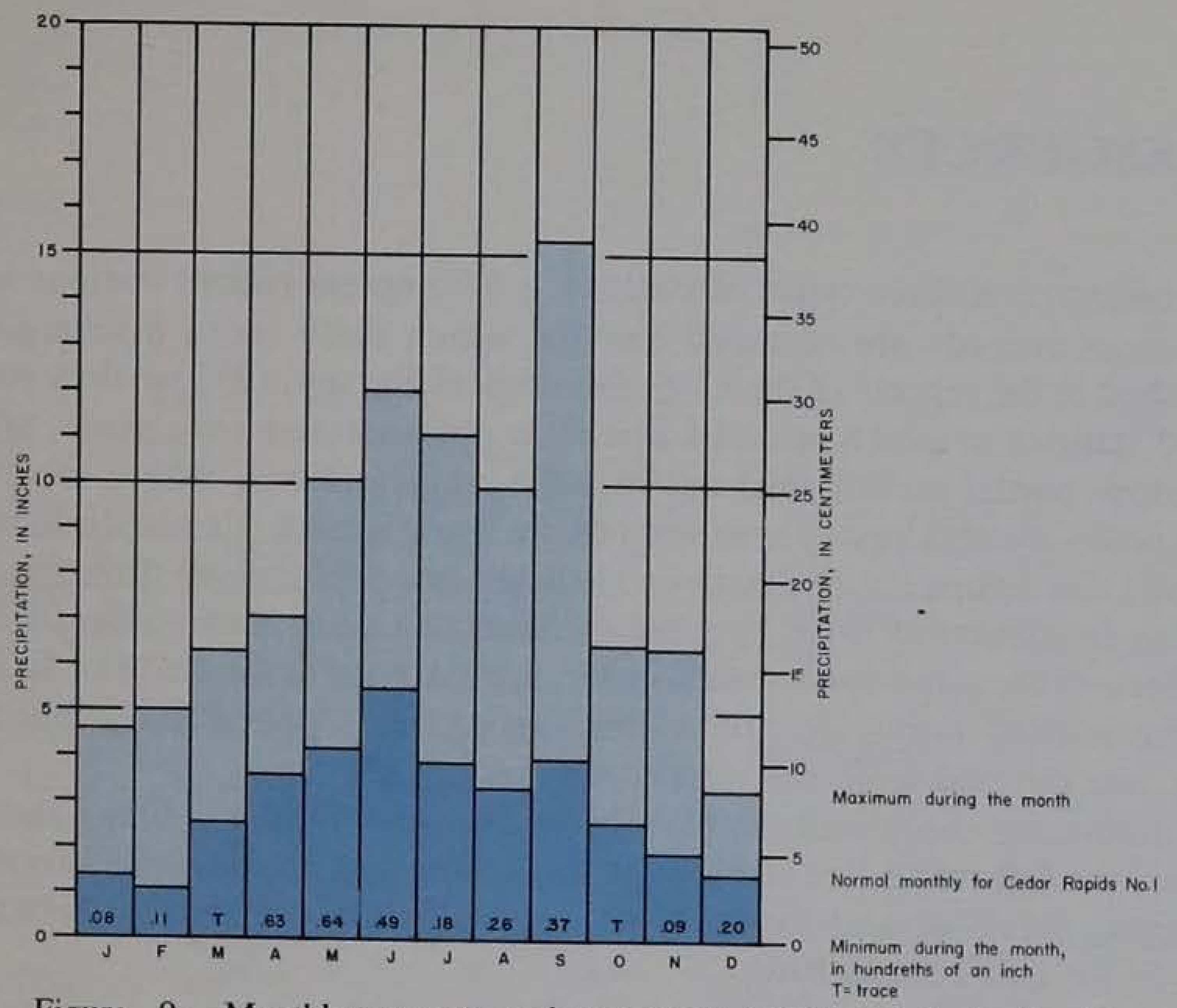


Figure 9.—Monthly extremes and normal precipitation at Cedar Rapids

Normal monthly precipitation is greatest during the spring and summer months and least in fall and winter months. The most rainfall occurs from April through June. Monthly precipitation is highly variable from year to year (fig. 9).

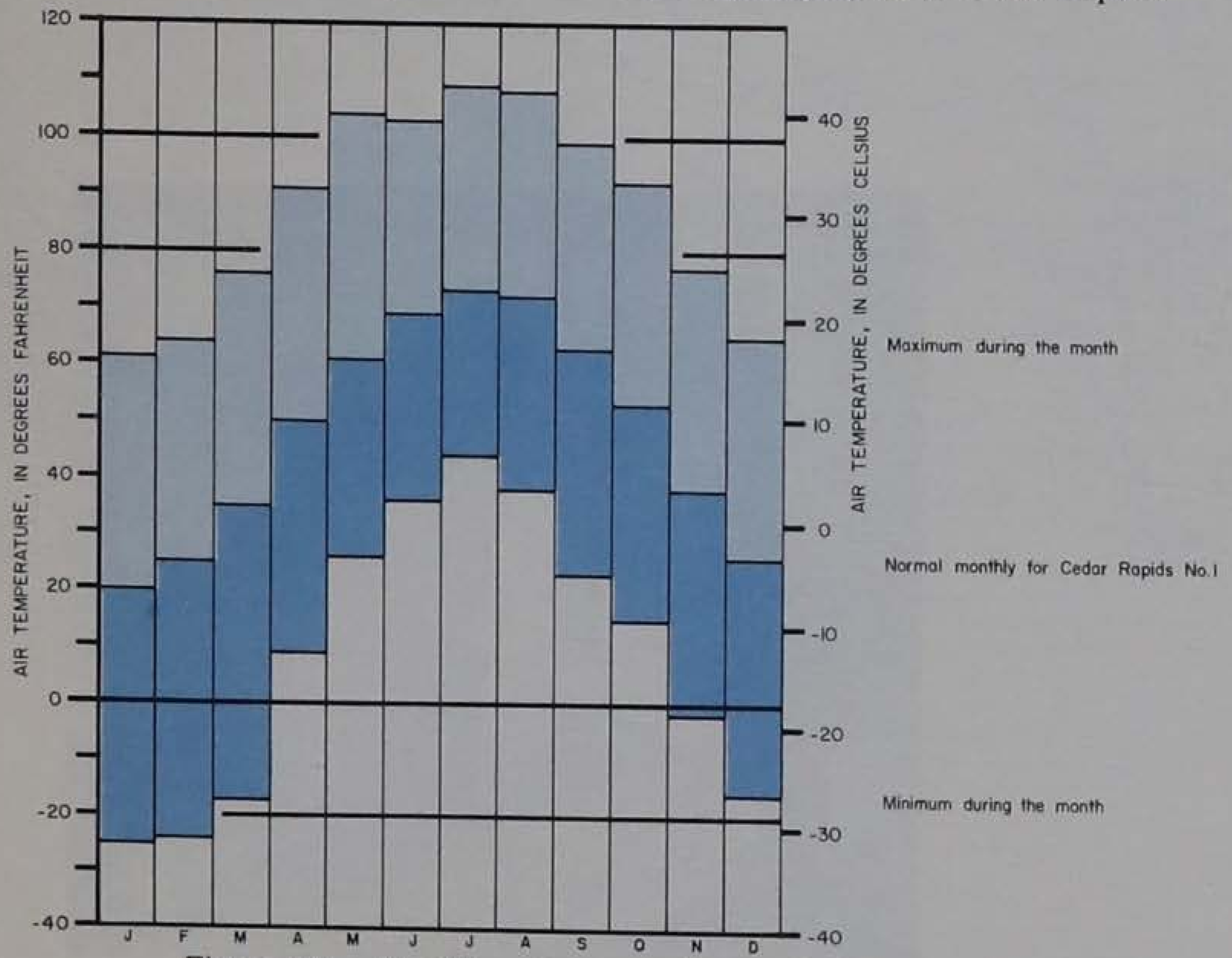


Figure 10.—Monthly extremes and normal air temperature

The mean annual air temperature in the report area is 49.6°F (9.7°C). Monthly mean temperatures throughout the area range from about 20°F (−7.0°C) to about 76°F (24.0°C). Figure 10 shows that extreme temperatures of more than 100°F (38°C) have occurred in Cedar Rapids during the four months from May through August, and temperatures have dropped below freezing at least once during every month except June, July, and August.

SURFACE-WATER RESOURCES

Streams, lakes, reservoirs, and ponds are the sources of surface water in east-central Iowa. The availability of surface water can be described by the answers to the questions Where?, How much?, and What is its distribution in time?

The first question can be answered by simply referring to a map and noting that five major streams and one large reservoir are in the study area (fig. 11). The Mississippi River forms the eastern boundary, and the other four major rivers, — the Maquoketa, Wapsipinicon, Cedar, and Iowa, — flow generally in a northwest-to-southeast direction across the area. Coralville Lake, a flood-control reservoir operated by the U.S. Army Corps of Engineers, is on the Iowa River in the south-central part of the area. Some smaller impoundments and numerous farm ponds are scattered over the area. There are no natural lakes of significant size.

The other two questions can be answered by examining and analyzing the streamflow records that have been obtained in the area. These records have been collected at three types of stations; (1) complete-record stations where continuous records are obtained and for which daily mean discharges are published in the reports of the U. S. Geological Survey, (2) low-flow partial-record stations at which periodic low-flow measurements are made, and (3) high-flow partial-record stations, or crest-stage stations, where records of flood peaks are obtained. These stations are listed in table 1 and their locations are shown in figure 11. The stations are listed in a downstream direction, with stations on tributaries listed between stations on a main stream. Identification numbers, in the same downstream order, are assigned to the stations. In figure 11, the leading numerals "05", designating the Upper Mississippi River basin, are omitted from the station numbers.

In answering the questions, How is the flow distributed in time? and How much?, the following five sections of this report will consider the variability, averages, duration, and extremes of streamflow as defined by streamflow records for east-central Iowa.


Coralville Dam and Reservoir


Gage house; Iowa River

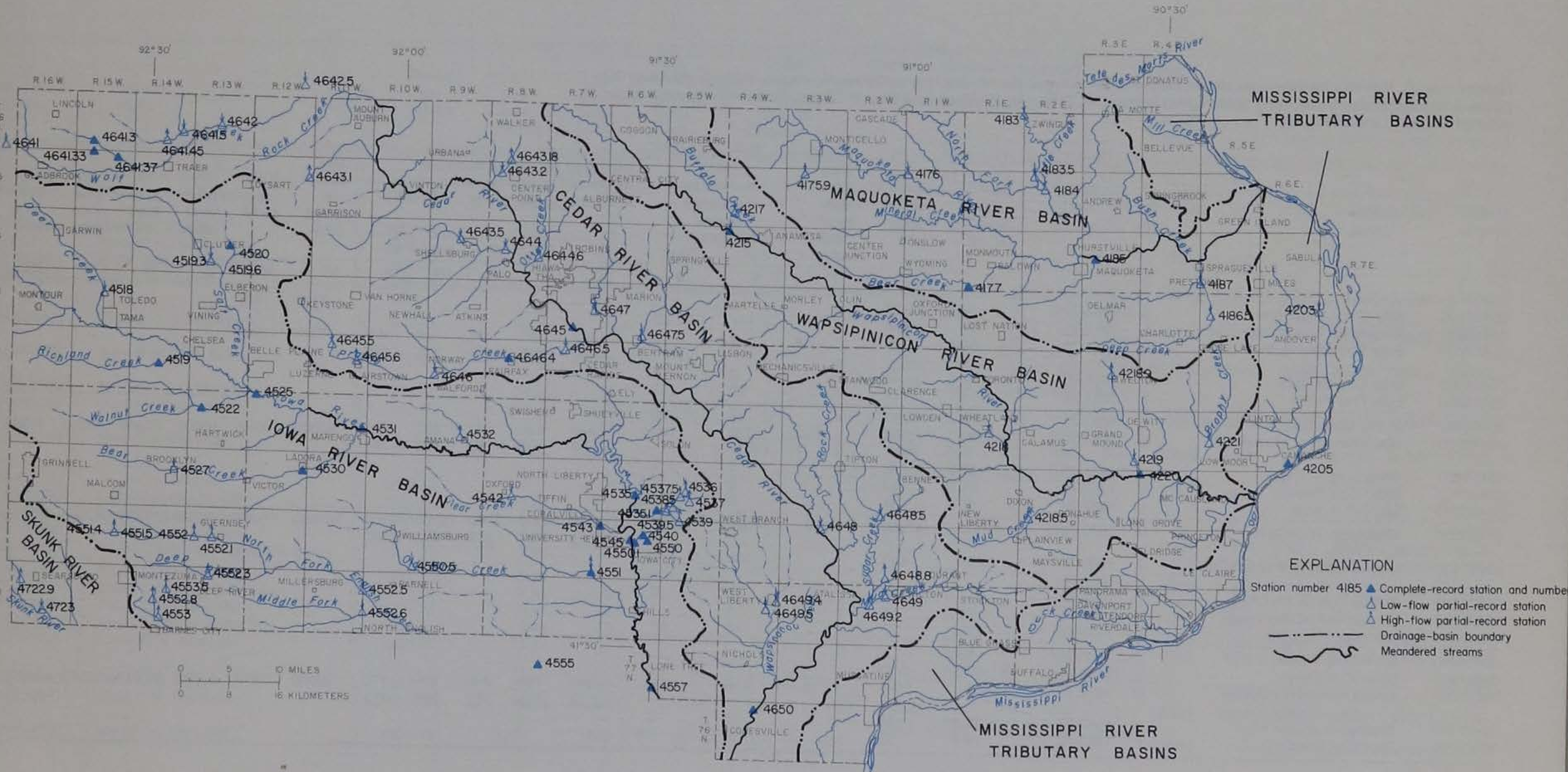


Figure 11.—Location of surface-water data sites in east-central Iowa

Table 1. — Streamflow statistics for gaging stations in east-central Iowa.

[Station type: C, high-flow partial-record station; G, complete-record station; L, low-flow partial-record station. Average discharge for partial-record stations computed using relation given in figure 14. Except for the Mississippi River at Clinton, flood discharges in last four columns are from Lara (1973)]

Station number	Station name	Sta type	Period of record	Drain-age area (sq. mi)	Avg. dis-charge (cfs)	Min-imum daily mean disch (cfs)	7-day low flow for recurrence interval indicated cfs		Discharge equaled or exceeded for percent of time indicated, in cfs and cfs per sq. mi.					Max. disch. re-corded (cfs)	Year oc-cured	2-year flood (cfs)	10-year flood (cfs)	50-year flood (cfs)	100-year flood (cfs)
							2-yr	10-yr	5	50	70	90	95						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
05417590	Kitty C nr Langworthy	C	1966-75	14.4	10									3700	1969				
05417600	Maquoketa R nr Scotch Grove	L	1957-75	704	434		111	57											
05417700	Bear C nr Monmouth	G	1957-75	61.3	46.5	1.8	6.3	2.9	147 2.40	20 .326	12 .196	5.6 .091	4.0 .065	7340	1965				
05418300	Lytle C nr Bernard	L	1957-75	62.7	42		9	4											
05418350	Lytle C nr Fulton	L	1957-75	114	74		22	12											
05418400	N. Fk. Maquoketa R nr Fulton	L	1957-75	499	311		97	60											
05418500	Maquoketa R nr Maquoketa	G	1913-75	1553	1023	105	286	157	2940 1.89	620 .400	440 .283	280 .180	230 .148	48000	1944	10800	23900	36200	41300
05418650	Deep C nr Charlotte	L	1957-75	67.7	45		5	2											
05418700	Deep C nr Preston	L	1957-75	91.9	60		8	3.5											
05420300	Elk R nr Almont	L	1957-75	55.9	37		8	3.5											
05420500	Mississippi R at Clinton	G	1873-1975	85600	47360	6500	15090	9880	113000 1.32	36000 .421	25700 .300	18700 .218	16300 .190	307000	1965	135000	207000	262000	282000
05421500	Wapsipinicon R at Stone City	G L	1903-14 1957-75	1324	616		100	50						11500	1912				
05421700	Buffalo C nr Stone City	L	1957-75	217	138		15	5											
05421800	Yankee Run at Wheatland	L	1957-75	52.2	35		4	1.5											
05421850	Mud C nr Plainview	L	1957-75	109	71		3	<1											
05421890	Silver C at Welton	C	1966-75	9.03	6														
05421900	Silver C nr DeWitt	L	1957-75	60.8	40		7	4											
05422000	Wapsipinicon R nr DeWitt	G	1934-75	2330	1477	70	216	103	4940 2.12	790 .339	440 .189	220 .094	170 .073	29900	1974	11600	25900	39300	44900
05422100	Brophys C nr Low Moor	L	1957-75	72.8	48		10	5											
05451800	Deer C at Toledo	L	1957-75	76.4	50		2.5	<.5											

Station number	Station name	Sta type	Period of record	Drain-age area (sq. mi)	Avg. dis-charge (cfs)	Min--imum daily mean disch (cfs)	7-day low flow for recurrence interval indicated cfs		Discharge equaled or exceeded for percent of time indicated, in cfs and cfs per sq. mi.					Max. disch. re-corded (cfs)	Year oc-cured	2-year flood (cfs)	10-year flood (cfs)	50-year flood (cfs)	100-year flood (cfs)
							2-yr	10-yr	5	50	70	90	95						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
05451900	Richland C nr Haven	G	1949-75	56.1	33.6	0.1	1.4	0.2	110 1.96	11 .196	4.4 .078	0.8 .014	0.4 .007	7000	1974	1560	4280	7620	9270
05451930	Salt C nr Clutier	L	1957-75	85.2	56		4	1											
05451955	Stein C nr Clutier	C	1972-75	23.4	16									2200	1974				
05451960	E. Br. Salt C nr Elberon	L	1957-75	71.3	47		2.5	1											
05452000	Salt C nr Elberon	G	1945-75	201	126	2.4	9.0	3.1	400 1.99	47 .234	23 .114	8.7 .043	6.0 .030	35000	1947	3560	8890	14700	17300
05452200	Walnut C nr Hartwick	G	1949-75	70.9	42.2	0	1.7	0	140 1.97	13 .183	4.8 .068	0.8 .011	0.2 .003	5650	1974	1840	4950	8670	10500
05452500	Iowa R nr Belle Plaine	G	1939-59	2455	1156	19	108	41	4120 1.68	520 .212	250 .102	93 .038	72 .0293	b34000	1947	11500	25700	39200	44800
05452700	Big Bear C at Brooklyn	L	1957-75	77.9	51		1.5	<.4											
05453000	Big Bear C at Ladora	G	1945-75	189	118	0	5.1	0.7	410 2.17	39 .206	16 .085	4.4 .023	2.2 .012	10500	1960	3200	8110	13600	16100
05453100	Iowa R at Marengo	G	1956-75	2794	1753	54	195	91	6480 2.32	840 .301	420 .150	210 .075	160 .057	30800	1960	12200	27100	41300	47100
05453200	Price C at Amana	C	1966-75	29.1	20									3700	1974				
05453500	Lake Macbride nr Solon	G	1936-71	27.0															
05453510	Coralville Lake nr Coralville	G	1958-75	3115															
05453600	Rapid C below Morse	C	1951-75	8.12	6									2800	1972	539	1660	3210	4050
05453700	Rapid C trib. No. 4 nr Oasis	C	1951-75	1.95	1									956	1953	239	796	1640	2110
05453750	Rapid C SW of Morse	C	1951-75	15.21	11									4300	1972	779	2300	4320	5370
05453850	Rapid C trib. No. 3 nr Oasis	C	1951-75	1.62	1									3050	1962				
05453900	Rapid C trib. nr Oasis	C	1951-75	0.97	0.7									809	1956				
05453950	Rapid C trib. nr Iowa City	C	1951-75	3.43	2									2300	1972	391	1240	2430	3070
05454000	Rapid C nr Iowa City	G	1937-75	25.3	15.7	0	0	0	57 2.25	4.0 .158	1.1 .043	0.1 .004	<.01 <.001	6100	1965	979	2830	5230	6460
05454200	Clear C nr Oxford	L	1957-75	55.0	37		.6	<.1											
05454300	Clear C nr Coralville	G	1952-75	98.1	64.7	0.1	2.2	0.3	230 2.34	22 .224	7.6 .077	1.8 .018	1.0 .010	6630	1974	2020	5400	9460	11400
05454500	Iowa R at Iowa City	G	1903-75	3271	1648	29	d152	d56						42500	1918	d13300	d29300	d44300	d50400

Station number	Station name	Sta type	Period of record	Drainage area (sq. mi)	Avg. discharge (cfs)	Minimum daily mean disch (cfs)	7-day low flow for recurrence interval indicated cfs		Discharge equaled or exceeded for percent of time indicated, in cfs and cfs per sq. mi.					Max. disch. recorded (cfs)	Year occured	2-year flood (cfs)	10-year flood (cfs)	50-year flood (cfs)	100-year flood (cfs)
							2-yr	10-yr	5	50	70	90	95						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
05455000	Ralston C at Iowa City	G	1924-75	3.01	1.7	0	0	0	6.3 2.09	0.4 .133	0.1 .033	<.01 <.003	<.01 <.003	1940	1965	363	1150	2280	2900
05455010	S. Br. Ralston C at Iowa City	G	1963-75	2.94	2.7	0	0	0	11 3.74	0.8 .272	0.4 .136	.01 .003	<.01 <.003	1070	1972				
05455050	Old Mans C nr Parnell	L	1957-75	81.2	53		.6	<.1											
05455100	Old Mans C nr Iowa City	C,L	1965-75	201	97.7	0.1	3	<.8	410 2.04	19 .095	4.6 .023	0.7 .003	0.4 .002	1200	1962	2510	6630	11600	13900
		G	1950-64																
05455140	N. English R nr Montezuma	C	1973-75	31.0	21									4000	1974				
05455150	N. English R nr Montezuma	C	1953-73	34.0	23									4240	1953	864	2570	4920	6150
05455200	N. English R nr Guernsey	C	1953-75	68.7	45		1	<.3						7000	1953				
		L	1957-75																
05455210	N. English R at Guernsey	C	1960,66-75	81.5	54									6600	1970				
05455230	Deep R at Deep River	C	1960,66-75	30.5	21									6200	1970				
05455250	N. English R nr North English	L	1957-75	221	141		4	< 1											
05455260	M. English R nr North English	L	1957-75	66.7	44		<.1												
05455280	S. English R trib. nr Barnes City	C	1953-75	2.51	2									900	1970	258	862	1780	2310
05455300	S. English R nr Barnes City	C	1953-75	11.5	8									1850	1970	552	1710	3350	4230
05455350	S. English R tr 2 nr Montezuma	C	1953-75	0.52	0.4									344	1961				
05455500	English R at Kalona	G	1939-75	573	370	1.1	10.8	2.6	1570 2.74	100 .175	39 .068	8.8 .015	4.8 .008	20000	1965	5410	13000	21100	24700
05455700	Iowa R nr Lone Tree	G	1956-75	4293	2846	75	regulated		9620	1460	740	300	220	35700	1974	regulated			
05464100	Wolf C nr Beaman	L	1957-75	63.2	42		1.3	<.2											
05464130	Fourmile C nr Lincoln	G	1962-67	13.78	9.5	0.11	0.4	0.1	30 2.18	3.7 .268	1.5 .109	0.6 .044	0.4 .029	1450	1974				
05464133	Half Mile C nr Gladbrook	G	1962-67	1.33	0.8	0	0	0						307	1965				
05464137	Fourmile C nr Traer	G	1962-74	19.51	15.9	0.2	0.8	0.3	41 2.10	5.1 .261	2.2 .113	0.9 .046	0.6 .031	1040	1974				
05464145	Twelvemile C nr Traer	C	1966-75	43.8	29														
05464150	Twelvemile C nr Buckingham	L	1957-75	76.8	51		1	<.1											
05464200	Wolf C nr Buckingham	L	1957-75	287	182		11	3											
05464250	Wolf C at LaPorte City	L	1957-75	327	206		13	4											

Station number	Station name	Sta type	Period of record	Drainage area (sq. mi)	Avg. discharge (cfs)	Min-imum daily mean disch (cfs)	7-day low flow for recurrence interval indicated cfs		Discharge equaled or exceeded for percent of time indicated, in cfs and cfs per sq. mi.					Max. disch. recorded (cfs)	Year occured	2-year flood (cfs)	10-year flood (cfs)	50-year flood (cfs)	100-year flood (cfs)
							2-yr	10-yr	5	50	70	90	95						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
05464310	Pratt C nr Garrison	C	1966-75	23.4	16														
05464318	East Blue C at Center Point	C	1966-75	17.6	12									4000	1969				
05464320	East Blue C nr Center Point	L	1957-75	27.1	18		1.5	<.5											
05464350	Bear C at Shellsburg	L	1957-75	55.8	37		1	<.3											
05464400	Bear C nr Palo	L	1957-75	95.9	63		2	< 1											
05464460	Otter C nr Cedar Rapids	L	1957-75	65.1	43		3	1											
05464500	Cedar R at Cedar Rapids	G	1902-75	6510	3276	212	625	345	10200 1.57	1870 .287	1150 .177	640 .098	510 .078	73000	1961	23600	52100	76800	86600
04564550	Prairie C nr Blairstown	L	1957-75	64.2	42		1												
05464560	Prairie C at Blairstown	C	1966-75	87.0	57									4600	1970				
05464600	Prairie C at Norway	L	1957-75	126	82		3												
05464640	Prairie C at Fairfax	G	1966-75	178	142	3.7	6	2	460 2.58	61 .343	35 .197	14 .079	10 .056	6160	1974				
05464650	Prairie C at Cedar Rapids	L	1957-75	208	133		7												
05464700	Indian C at Cedar Rapids	L	1957-75	72.0	48		2	<1											
05464750	Big C at Bertram	L	1957-75	81.2	53		4	1											
05464800	Rock C at Rochester	L	1957-75	63.4	42		3	<1											
05464850	Sugar C nr Bennett	L	1957-75	80.7	53		1												
05464880	Otter C at Wilton	C	1966-75	10.7	7									2200	1967				
05464900	Mud C nr Wilton	L	1957-75	102	67														
05464920	Sugar C nr Moscow	L	1957-75	218	139		10												
05464940	Wapsinonoc C at West Liberty	L	1957-75	51.7	34		2	<1											
05464950	WB Wapsinonoc C at West Liberty	L	1957-75	52.5	35														
05465000	Cedar R nr Conesville	G	1939-75	7785	4458	250	919	482	14200 1.82	2710 .348	1670 .215	870 .112	680 .087	70800	1961	25800	55000	81000	92000
05472290	Sugar C nr Searsboro	C	1966-75	52.7	35									4100	1966				
05472300	N. Skunk R nr Searsboro	L	1957-75	358	225		7	1											

b. Flood of June 5, 1918, reached flow of 43,000 cfs, from information by Corps of Engineers.

c. Floods of July 17, 1881, and June 1851 reached flows of 51,000 and 70,000 cfs, respectively; from information by local residents.

d. For natural conditions prior to operation of Coralville Lake.

STREAMFLOW VARIABLILITY

Streamflow is a dynamic resource that responds to occurrences of precipitation and snowmelt and to seasonal changes in land use, land cover, and temperature. Figure 12 depicts the streamflow hydrographs for the Wapsipinicon River near DeWitt for the lowest, 1956, and the highest water year, 1973, of runoff in the period of record since 1934. The runoff in 1956 was 2.48 inches and in 1973 it was 20.48 inches, indicating that large differences can occur in annual runoff. Both hydrographs show a pronounced increase in streamflow during the normal "flood season" months of March, April, May, and June. In the dry year, 1956, there was practically no runoff-producing activity from October 1955 to near the end of February 1956 and only minor activity in the summer months July through September 1956. In 1973, on the other hand, there were frequent runoff events throughout the year except for a 6- or 7-week period in August and September 1973.

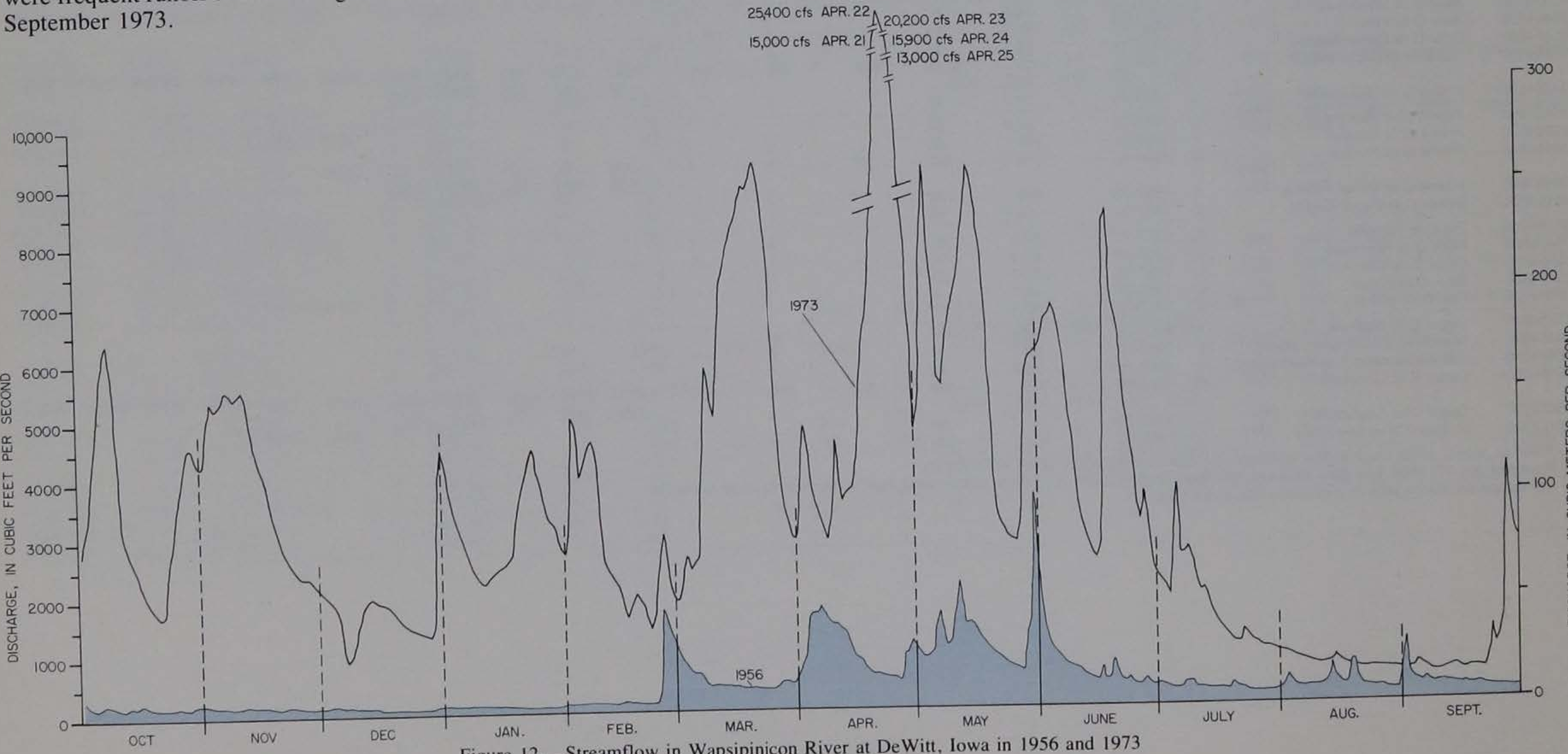


Figure 12.—Streamflow in Wapsipinicon River at DeWitt, Iowa in 1956 and 1973

Although precipitation is the source of all streamflow, the relationship between them is not direct throughout the year. The relationship is tempered seasonally by the condition of the basin cover, evaporation from land and water surfaces, and the water demands of vegetation. This is illustrated in figure 13 where monthly precipitation at Cedar Rapids is plotted with monthly runoff for the Cedar River at Cedar Rapids for the period 1941-70. Despite the abundance of precipitation in the summer months, the greatest runoff occurs in March and April when much of the basin surface is bare, vegetation is dormant, and evapotranspiration demands are at a low level. In the growing season, evapotranspiration extracts a large part of the precipitation that falls on the basin.

As streamflow is always changing, continuing records must be obtained to monitor the resource. High flows and floods occur most often between March and July. Small streams, which are more responsive to the summer thunderstorms, may therefore show a somewhat different runoff pattern than that shown in figure 13. The lowest flows occur most often in the winter although some have been recorded in late summer or early fall.

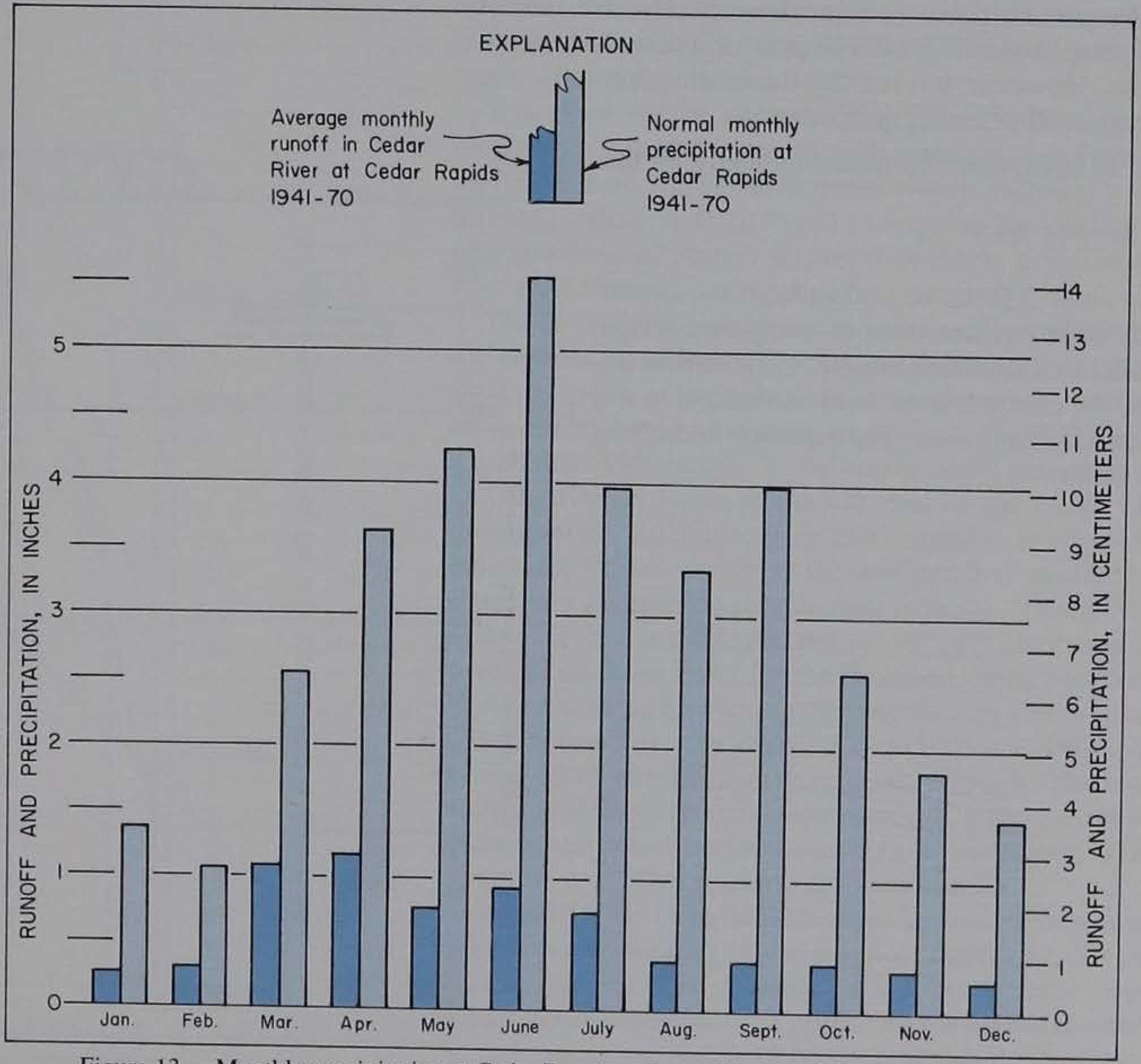


Figure 13.—Monthly precipitation at Cedar Rapids and monthly runoff for the Cedar River at Cedar Rapids, Iowa, 1941-70

AVERAGE DISCHARGE

Over a long period of time the total volume of flow that has passed a given point on a stream can be expressed as an average flow rate. Theoretically this is the upper limit of water available for use at that point. For the complete-record stations in east-central Iowa, the recorded average discharge for the given period of record is contained in column 6, table 1. These average discharges have been plotted versus corresponding drainage area sizes in figure 14. The plotted points define a relatively close relationship despite the fact that they represent different lengths and periods of record. It is generally known that sequences of wet and dry periods occur so that, theoretically, a relationship such as that shown in figure 14 should be developed for a period of record that is common to all stations. However, it is felt that the relationship shown in figure 14 is adequate for general planning purposes.

The relationship shown in figure 14 is represented mathematically by the equation,

$$Q_a = 0.75\ A^{0.97}$$

where Q_a is the average discharge in cubic feet per second and A is the size of drainage area in square miles. This equation was used to compute average discharges for the partial-record stations tabulated in table 1. Considering the limited accuracy of the relationship, the computations were carried out to the nearest unit except for one very small drainage area. The equation and curve are only applicable to east-central Iowa.

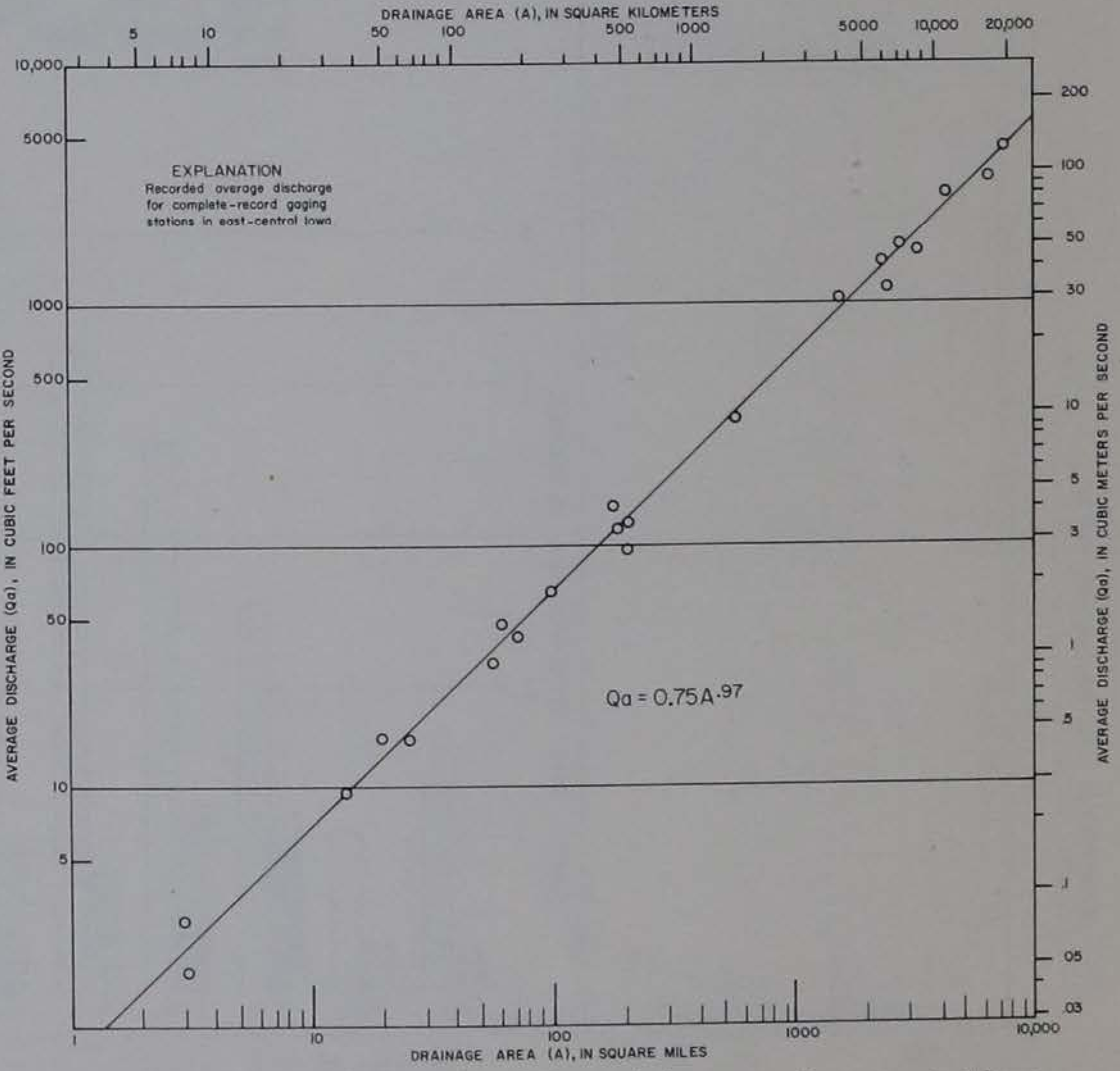


Figure 14.—Average discharge in relation to drainage area in east-central Iowa

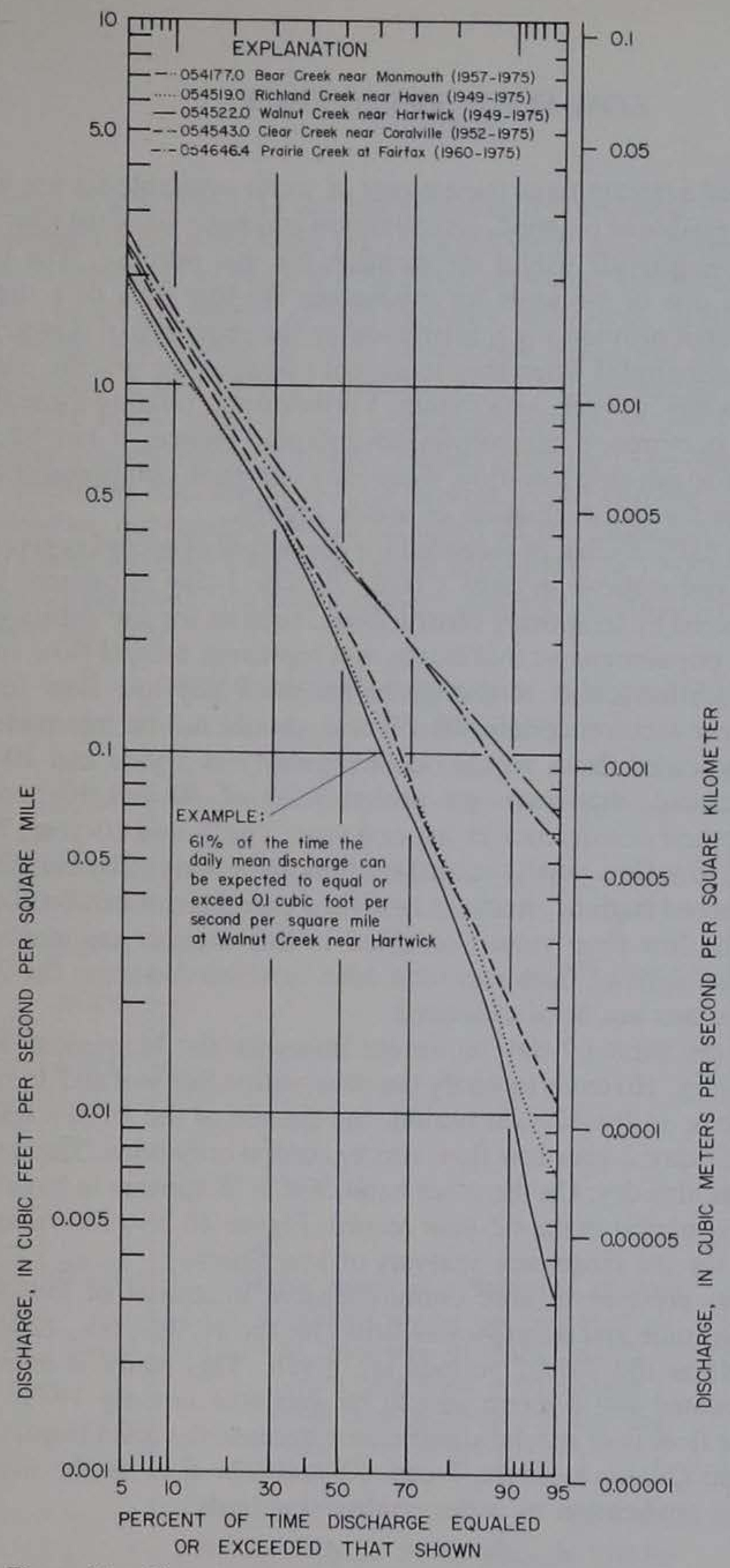


Figure 15.—Flow-duration curves for five east-central Iowa streams

FLOW DURATION

Flow-duration curves show the percentage of time that specific discharges of a stream were equaled or exceeded during a given period of time. If the period of time is long enough to be representative of a stream's flow regime, the flow-duration curve provides information on the flow distribution that can be expected in the future. The flow-duration curve shows by one graph, or curve, the entire range of discharges at a site on a stream, how they were distributed, and gives an insight on the influence of basin characteristics of the stream. It provides useful information for water planning, construction design, regulatory needs, and convenient comparison of the flow- and basin characteristics of different streams. Flow-duration data have been compiled for all complete-record stations in east-central Iowa and selected values from these data are tabulated in table 1 (cols. 10-14).

The slope of the flow-duration curve reflects basin characteristics. A steep slope indicates a "flashy" stream with little basin storage where flow is made up largely of surface runoff. Curves with flatter slopes, especially at the lower end, indicate that water is being released from basin storage to the stream at slow steady rates. These are characteristic of stream basins with thick, permeable aquifers or extensive natural or man-made surface storage.

The flow-duration curves for gages on five relatively small streams (fig. 15) illustrate differences in the low-flow characteristics between the northeastern and the southern and western parts of east-central Iowa (fig. 11). Differences in drainage-area size are removed by having the ordinate scale in discharge per square mile. The curve for Bear Creek near Monmouth, in the northeastern part of the area, shows the highest low flow and the flattest slope at the low end of the curve. This stream drains an area where ground-water discharge from thick aquifers is appreciable. The curves for Clear, Richland, and Walnut Creeks in the southern and western parts of the area have steep slopes, especially at their lower ends, and indicate "flashy" flow conditions. At the 95 percent point, the flow in cubic feet per second per square mile, for the Bear Creek station is more than 10 times the flows for the Richland Creek and Walnut Creek stations. The curve for Prairie Creek at Fairfax, in the central part of the area, is similar to the curve for Bear Creek. However, the Prairie Creek record is short, from 1966 to 1975, and covers a period when streamflows were generally high. The lower part of the Prairie Creek curve would probably drop to a lower position if the record were longer so as to cover a period more representative of long-term flow conditions. The medium- and high-flow characteristics of all five streams are very similar.

In table 1, flows in cubic feet per second, and in cubic feet per second per square mile (shown underscored), correspond to the 5, 50, 70, 90, and 95 percent points on the flow-duration curve. If other values are required, they can be estimated by plotting a rough curve using the data given and taking the desired values from the curve. In figure 15, actual flow values can be determined for the five streams by multiplying the curve value by the drainage area given in table 1 (col. 5).

The Iowa Natural Resources Council uses the flow-duration curve in regulating withdrawal of water from streams for consumptive uses. The Council has set the 84 percent point on the flow-duration curve as the "protected" flow of a stream and withdrawal of water is prohibited when the streamflow is less than that value.

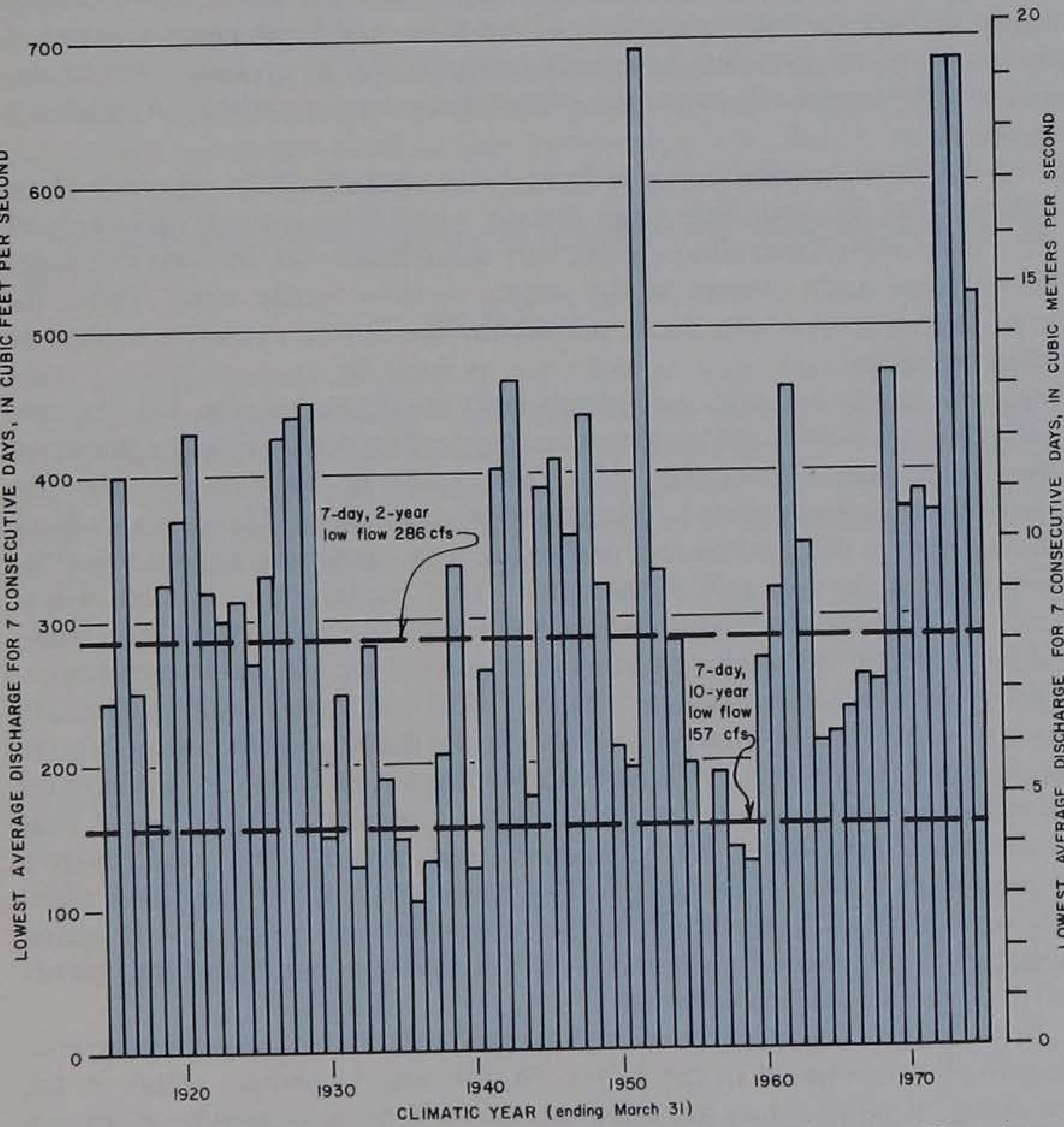


Figure 16.—Annual 7-day minimum flows for the Maquoketa River near Maquoketa

LOW-FLOW FREQUENCY

The low flow of a stream fixes the amount of water available for use when storage is not accessible or planned. Examination and analysis of the low-flow records of streams provide useful information for this purpose. The flow-duration curve is one of the tools for evaluating the low flow of a stream. However, it does not provide any information on the sequence of flows. Low flows are more meaningful when they represent averages for specific periods of time, such as a day, a week, or a month. Furthermore, relating these flows to frequency of occurrence has certain advantages. Hence, it has become common practice to develop low-flow frequency curves to complement other data and analyses for the evaluation of water supply.

The minimum daily discharge recorded for the period of record is given for the complete-record stations in table 1 (col. 7). The 1-day minimum, however, can be affected by temporary obstructions, such as ice and debris jams, or other unusual phenomena so that it may not represent natural flow conditions. Therefore, information is also given for the 7-day low flow for the 2-year and 10-year recurrence intervals. These should not be interpreted to mean that the indicated flows would occur regularly at 2-year and 10-year intervals but, instead, that there are probabilities of 50 and 10 percent, respectively, for their occurrrence in any one year. The 2- and 10-year, 7-day low flows for the low-flow partial-record stations were derived by correlation with complete-record stations. Because low-flow correlations exhibit considerable scatter, the low-flow values obtained in this manner are much less reliable than those derived from recorded data; in some instances the 7-day 10-year low flow has not been estimated.

The graph of the annual 7-day minimum flows for the Maquoketa River near Maquoketa (fig. 16) tends to verify the observation that wet and dry years occur in sequences. In the 62-year period, the decade of the 1930's was the driest, when the 7-day 2-year low flow was exceeded only once. The decade of the 1950's was also dry. On the other hand, 1969-75 appears to have been the wettest 6-year period in the 62-year record. Figure 16 also illustrates the basic data used for the frequency analysis of low flows.

Heinitz (1970) presents a more comprehensive treatment of low flows wherein the magnitude and frequency of flows for the 1-, 30-, 60-, 120-, and 183-day, as well as the 7-day, periods are given. This study is currently (1977) being updated and a report should be available in early 1979.

The 7-day low flow is of special significance because the Iowa Department of Environmental Quality uses the 7-day 10-year low flow as the limiting discharge for the application of water-quality standards.

FLOODS

Interest in low flows is concerned primarily with the sufficiency of water. High flows, on the other hand, present a different set of problems that concern the destructiveness of an overabundance of water. Information on floods is needed (1) for the proper design of dams, spillways, bridges, levees, and other facilities in stream channels or on flood plains; (2) for management of water-control works such as reservoirs; (3) for regulation of the usage of flood-prone lands; and (4) for forecasting services to avert or alleviate the disastrous consequences of floods. Floods continue to be one of the principal water problems that are of special interest to the citizens of Iowa. In east-central Iowa, outstanding floods occurred on the Mississippi River in 1965, on the Cedar River in 1961, and on the Iowa River in 1918 and 1947. Severe thunderstorms cause significant floods randomly on small streams in the area almost every year.

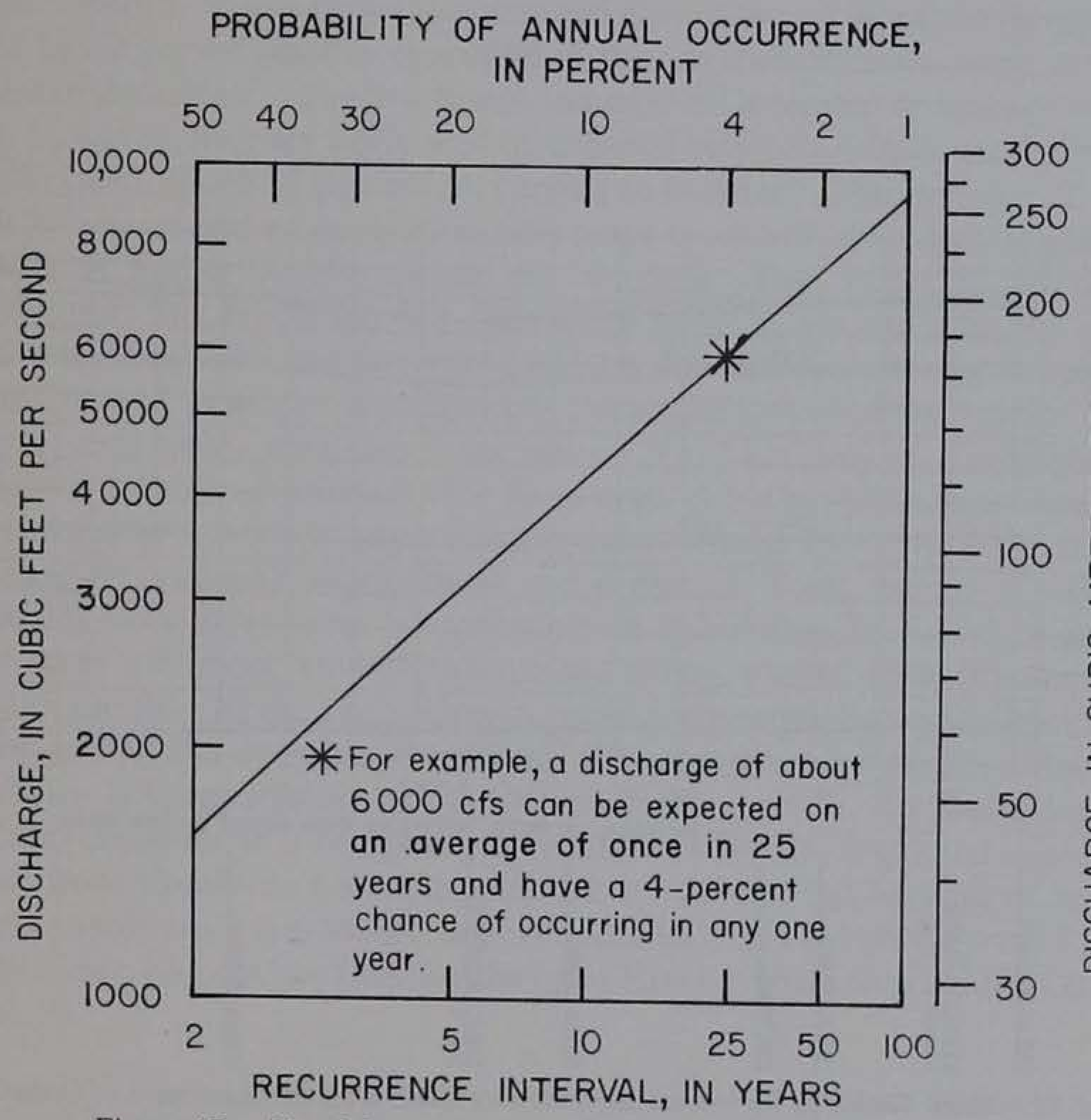


Figure 17.—Flood frequency curve for Richland Creek near Haven

Lara (1973) has analyzed all the flood records in Iowa and developed procedures for determination of the flood magnitude-frequency relationship for gaged, as well as ungaged sites, on Iowa streams. Except for the Mississippi River at Clinton, all the flood data given in columns 17-20 of table 1 are taken from the Lara report. The guidelines of the U.S. Water Resources Council (1976) were used in developing the flood data for the Mississippi River at Clinton. The flood-frequency curve for Richland Creek near Haven (fig. 17) is an example of the flood magnitude-frequency relationship. As with low-flow frequency, the designation "recurrence interval" is not intended to mean a regular periodicity between floods of a specific magnitude. It is perhaps better to think of the frequency as the probability of occurrence in percent in any year, and that is equal to the reciprocal of the recurrence interval multiplied by 100.

The magnitudes of floods for selected frequencies for any point on any stream in east-central Iowa, except on the main stems of the Cedar River and the Iowa River downstream from Coralville Lake, can be determined from the curves in figure 18 if the drainage area size is known. These curves were developed from the relations determined by Lara (1973, p. 51). Similar flood information for the main stem of the Cedar River can be obtained from figure 19. Flood magnitude-frequency relations for the main stem of the Iowa River where the flows are controlled by the operation of Coralville Lake have not been determined.

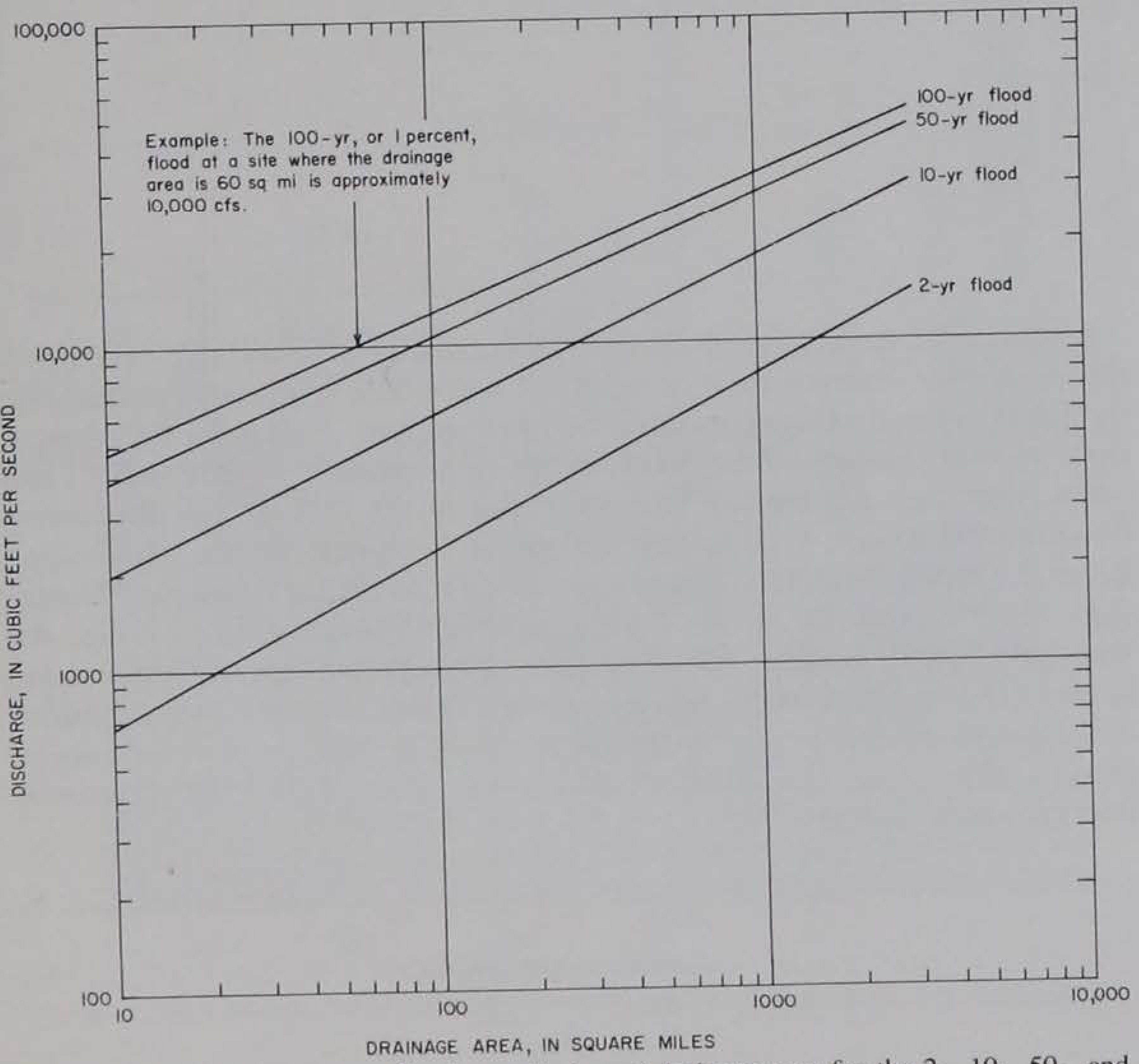


Figure 18.—Relation between flood magnitude and drainage area for the 2-, 10-, 50-, and 100-year floods, east-central Iowa.

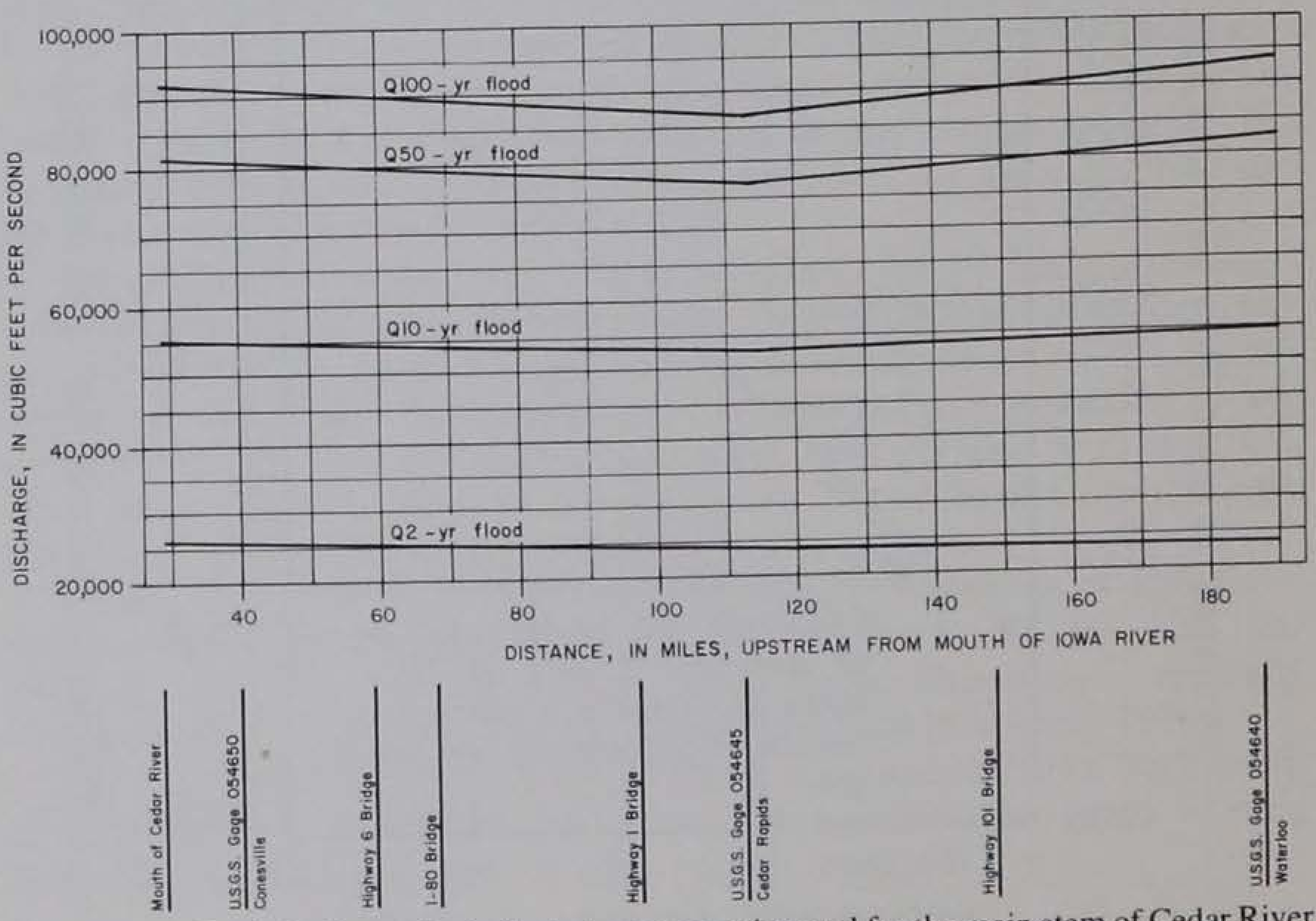


Figure 19.—Peak discharge for indicated recurrence interval for the main stem of Cedar River (from Lara, 1973)

REGULATED STREAMFLOW

The Corps of Engineers operates a series of locks and dams on the Mississippi River to maintain a 9-foot navigation channel. Five of the locks and dams — Nos. 12-16, at Bellevue, Clinton, Le Claire, Davenport, and Muscatine, Iowa — are along the eastern boundary of this report area. For the most part, they are operated on a run-of-the-river basis and have no significant effect upon medium and high flows in the Mississippi River. Low flows, however, appear to be affected to some extent. Analysis of the records through 1968 for the Mississippi River at Clinton indicated that the 7-day 10-year low flow was 8,500 cfs for the 65-year period, 1874 to 1939, prior to operation of the navigation dams, and 13,200 cfs for the 29-year period, 1939-68, after operation of the dams began. For the complete period of record, 1874 to 1975, the 7-day 10-year low flow is 9,880 cfs (table 1, col. 9). The distribution of low flows has changed also as the result of the navigation dams. In the period prior to operation of the navigation dams, more than 80 percent of the annual 7-day low flows occurred in December or January. Since 1938, however, they are fairly well distributed between August and February with the most, about 25 percent, occurring in February. Maintenance of river levels to accommodate navigation also helps to sustain the adjacent alluvial aquifers at higher levels during dry weather. This effect is discussed elsewhere in this report (p. 52). The large pools upstream from the dams create excellent fish- and waterfowl habitat and recreational opportunities.

The Corps of Engineers also operates Coralville Lake and Dam on the Iowa River several miles upstream from Iowa City. This project, completed in 1958, was authorized primarily for flood control but supplementary benefits are realized in low-flow augmentation downstream from the dam and in increased recreational development and potential. Total storage volume at maximum flood-pool level is equivalent to 3.3 inches of runoff from the upstream basin, about one-half the average annual runoff. Downstream from the dam, the flow of the Iowa River is completely regulated by the operation of this facility. For example, the natural 100-year flood for the Iowa River at Iowa City is computed to be 50,400 cfs (table 1, col. 20) while for the regulated condition it is computed to be 25,000 cfs. The regulated minimum release from Coralville Lake has been set at 150 cfs, but because of severe drought conditions it was temporarily reduced to 75 cfs in February 1977. The natural 7-day 10-year low flow for the Iowa River at Iowa City is 56 cfs (table 1, col. 9).

The Iowa Natural Resources Council is responsible for the licensing of dams that are constructed, maintained, or operated in any navigable or meandered stream or in any other stream for manufacturing or power purposes. Meandered streams in east-central Iowa are shown in figure 11. Licensed dams in east-central Iowa are:

Stream	**Nearest town**	**County**	**Permitted use**
Maquoketa River	Maquoketa	Jackson	Hydroelectric
Do	Monticello	Jones	Recreation
Wapsipinicon River	Oxford Mills	Do	Hydroelectric*
Do	Anamosa	Do	Do
Cedar River	Cedar Rapids	Linn	Recreation and municipal supply
Do	Do	Do	Cooling water
Do	Palo	Do	Water intake
Wapsipinicon River	Central City	Do	Recreation
Iowa River	Coralville	Johnson	Do
Do	West Amana	Iowa	Hydroelectric

* No longer used for purpose for which permit was granted.

The small impoundments at dams that are no longer used for the purpose for which the permit was granted generally serve recreation use. None of the above dams affect natural streamflow significantly.

Recreational lakes and impoundments in east-central Iowa, listed by county, are as follows (Iowa Conservation Commission, 1968, App. C):

Jackson County	Delton Lake
Clinton County	Goose Lake
Muscatine County	Keokuk Lake
Johnson County	Lake Macbride
	Kent Lake
	Swan Lake
Linn County	Palisades Park, Cedar River
Benton County	Dudgeon Lake
Poweshiek County	Diamond Lake
Tama County	Union Grove

Numerous farm ponds are scattered throughout the area. Their effect upon streamflows has not been evaluated.

Topographic maps available for east-central Iowa

1. Dubuque South 1955-(72PR)
2. Menominee 1955-(72PR)
3. Galena 1968
4. Lincoln 1971
5. Reinbeck 1971
6. Buckingham 1963-(72PR)
7. Eagle Center 1963-(72PR)
8. La Porte City 1971
9. Brandon 1971
10. Cheney
11. Walker
12. Ryan
13. Hopkinton West
14. Hopkinton East 1966
15. Cascade 1966
16. Fillmore 1966
17. Bernard 1966-(72PR)
18. Zwingle 1962-(72PR)
19. La Motte 1962-(72PR)
20. Bellevue 1968
21. Conrad East 1960
22. Gladbrook 1971
23. Gladbrook NE 1971
24. Traer 1971
25. Dysart 1971
26. Garrison 1971
27. Vinton 1971
28. Center Point NW 1968
29. Center Point 1968
30. Lafayette 1968
31. Central City 1968
32. Prairieburg
33. Anamosa NE
34. Green Island 1953
35. Blackhawk 1953
36. Le Grand 1960
37. Garwin 1971
38. Gladbrook SE 1971
39. Clutier 1971
40. Elberon 1971
41. Keystone North 1971
42. Van Horne 1971
43. Center Point SW 1968
44. Shellsburg 1968
45. Cedar Rapids North 1967
46. Marion 1968
47. Springville
48. Anamosa
49. Savanna 1967
50. Ferguson NE
51. Tama NW
52. Tama NE
53. Chelsea 1968
54. Belle Plaine 1968
55. Keystone South 1965
56. Blairstown 1965
57. Newhall 1968
58. Fairfax 1968
59. Cedar Rapids South 1967
60. Bertram 1968
61. Mt. Vernon 1965
62. Mechanicsville 1965
63. Stanwood 1965
64. Andover 1967
65. Clinton NW 1967
66. Ferguson SE
67. Tama SW
68. Tama SE
69. Belle Plaine SW 1968
70. Hartwick 1968
71. Ladora 1965
72. Marengo 1965
73. Middle Amana 1968
74. Amana 1968
75. Swisher 1968
76. Ely 1968
77. Solon 1965
78. Cedar Bluff 1965
79. Tipton West 1965
80. Tipton East 1965
81. Lowden 1953
82. Wheatland 1953
83. Grand Mound 1953
84. De Witt 1953
85. Malone 1953
86. Camanche 1953
87. Clinton 1953
88. Sully NE
89. Montezuma NW
90. Montezuma NE
91. Brooklyn 1968
92. Victor 1968
93. Williamsburg NW 1968
94. Williamsburg 1968
95. Conroy
96. Oxford
97. Tiffin 1965
98. Iowa City West 1965
99. Iowa City East 1965
100. West Branch 1965
101. Rochester 1965
102. Lime City 1953-(70PR)
103. Bennett 1953-(70PR)
104. Dixon 1953-(70PR)
105. Donahue 1953-(70PR)
106. Eldridge 1953-(70PR)
107. McCausland 1953-(70PR)
108. Cordova 1953-(70PR)
109. Sully SE
110. Montezuma SW
111. Montezuma SE
112. Barnes City 1968
113. Deep River 1968
114. Millersburg 1968
115. North English 1968
116. Holbrook
117. Amish
118. Williamstown 1965
119. Hills 1965
120. West Liberty SW 1965
121. West Liberty 1965
122. Atalissa 1965
123. Wilton Junction 1953-(70PR)
124. Durant 1953-(70PR)
125. Walcott 1953-(70PR)
126. Davenport West 1953-(70PR)
127. Davenport East 1948-53-(70PR)
128. Silvis 1948-53-(70PR)
129. Port Byron 1949-53-(70PR)
130. Riverside 1969
131. Lone Tree 1969
132. Nichols 1970
133. Muscatine NW 1965
134. Muscatine 1953-(70PR)
135. Illinois City 1953-(70PR)
136. Montpelier 1953-(70PR)
137. Andalusia 1953-(70PR)
138. Milan 1948-53-(70PR)
139. Columbus Junction 1970
140. Letts 1965
141. Blanchard Island 1953

Areas of coverage are shown by index numbers on figure 20. Date or dates of publication follow quadrangle name. PR indicates photorevision date.

FLOOD INUNDATION

For many streams in Iowa, the U.S. Geological Survey has delineated the inundation limits of the 100-year, or of a historic, flood on the 7½ minute topographic maps of the U.S. Geological Survey. These flood-prone area maps are useful for general planning purposes and may be obtained from the U.S. Geological Survey, P.O. Box 1230, Iowa City, Iowa 52240. Figure 20 is an index of the maps available for east-central Iowa. The topographic maps without flood-prone area delineations may be purchased from the Iowa Geological Survey, 123 North Capitol St., Iowa City, Iowa 52242 or from the U.S. Geological Survey, Federal Center, Denver, Colo. 80225.

Detailed information on flood profiles and inundation limits is available in the flood-plain information reports of the U.S. Army Corps of Engineers and in the reports on flood insurance rate studies prepared for the U.S. Department of Housing and Urban Development (HUD).

The following Corps' flood-plain information reports for east-central Iowa are available:

Mississippi River, Scott and Muscatine Counties, June 1969
Mississippi River, Jackson and Clinton Counties, June 1973
Indian and Dry Creeks, Linn County, December 1964
Prairie Creek, Linn County, February 1966
Cedar River, Linn County, October 1967
Wapsinonoc Creek, Muscatine County, June 1971
Duck Creek, Scott County, July 1965
Crow Creek, Scott County, May 1971

HUD flood-insurance studies have been completed, or are in progress, for the cities of Cedar Rapids, Clinton, Coralville, Iowa City, Marengo, Monticello, Muscatine, Vinton, and for Scott County. Inquires concerning these studies should be made directly to the appropoiate communities.

Flood-profile reports for Big, Hoosier, Morgan, Otter, and Squaw Creeks, all in Linn County, are available from the U.S. Geological Survey, Iowa City.

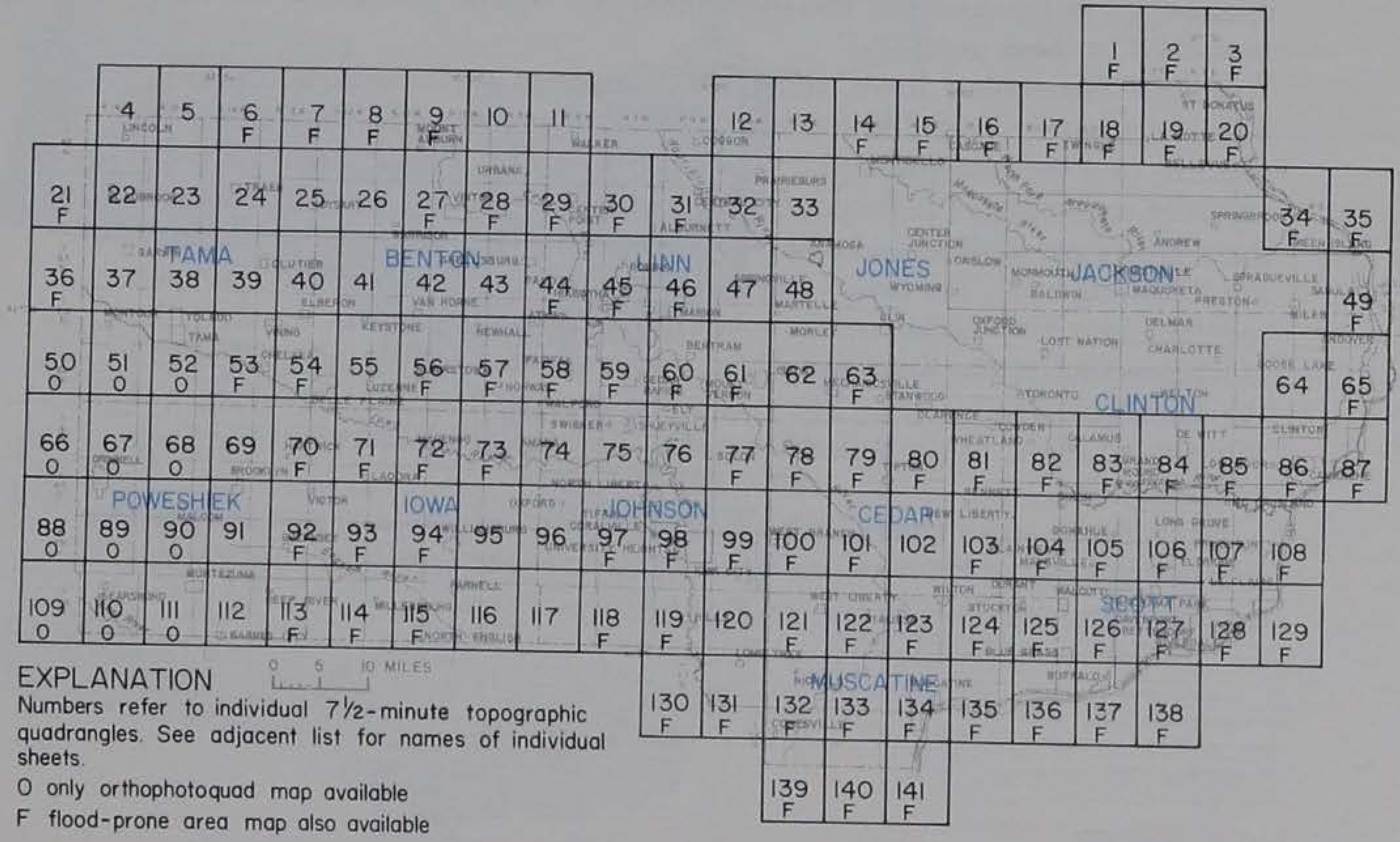


Figure 20.—Index of topographic and related maps available in east-central Iowa

GROUND-WATER RESOURCES

THE AQUIFERS

Wells supply water for many communities, farms, and industries in east-central Iowa. The water from these wells comes from deposits of unconsolidated materials and layered rocks whose characteristics are consistent enough to allow fairly reliable predictions as to their location and water-yielding potential. These predictions are based on the analysis of records from about 5,000 wells in the report area and adjacent counties.

Rocks that store and transmit water are called aquifers. In this report, only those aquifers that yield appreciable amounts of water to wells will be considered. The first part of this discussion concentrates on the spatial relationsips of the aquifers, and the second part will be devoted to the water contained in these aquifers.

Within east-central Iowa, there are 3 separate surficial aquifers and 5 bedrock aquifers available for use as water supplies. The unconsolidated deposits near the land surface comprise the surficial aquifers. Underlying are layers of consolidated sedimentary rock collectively called bedrock. Some of these layers are aquifers and others will yield little or no water to wells; these are confining beds. The layers that do yield water to wells have been grouped together into five major bedrock aquifers; the Mississippian aquifer, the Devonian aquifer, the Silurian aquifer, the Cambrian-Ordovician aquifer, and the Dresbach aquifer (fig. 21). With the exception of the Devonian and Silurian aquifers, these bedrock aquifers are separated by relatively thick confining beds.

Beneath the sedimentary bedrock sequence lie igneous and metamorphic crystalline rocks of Precambrian age referred to as the ''basement complex.'' These rocks have little or no water-yielding potential.

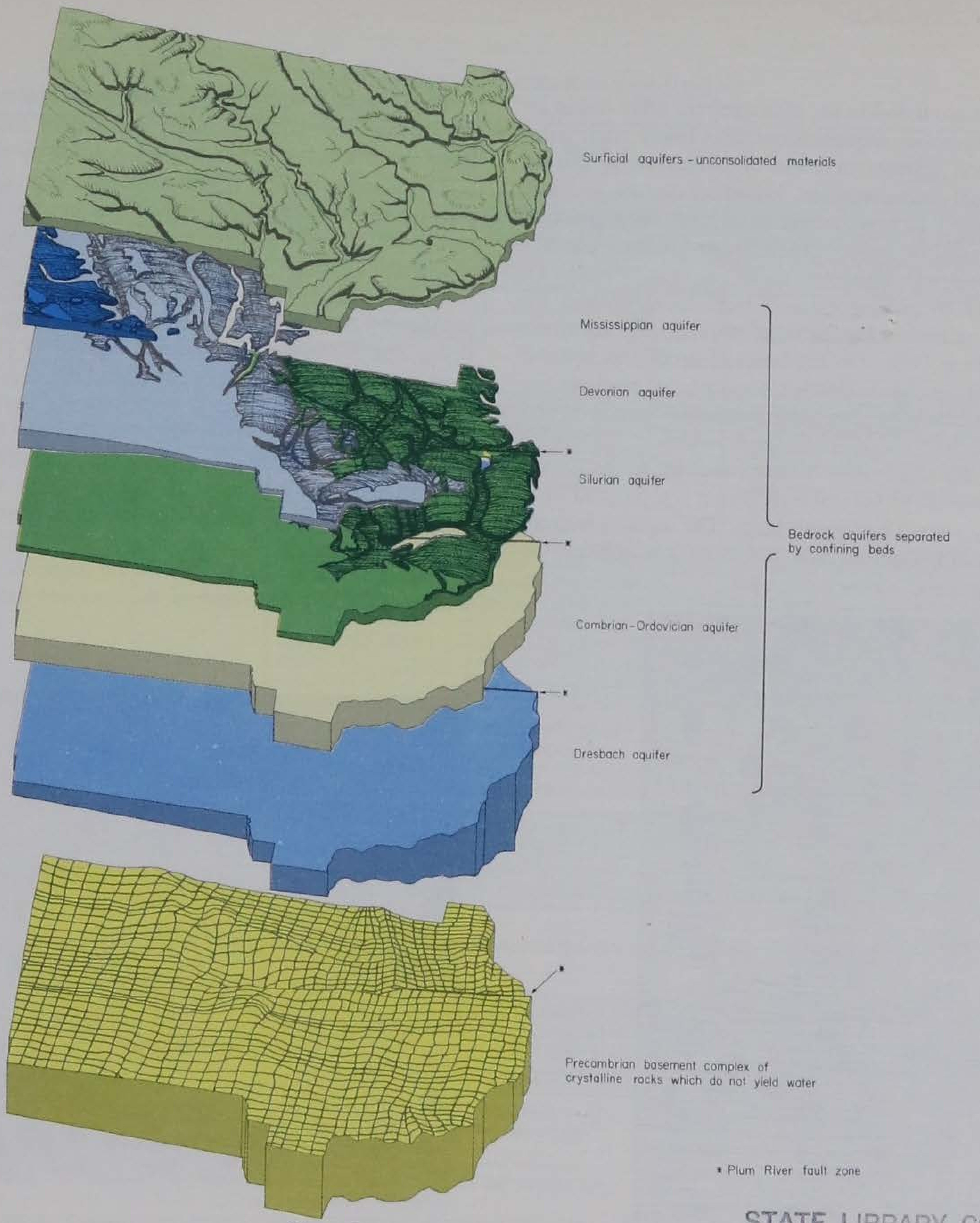
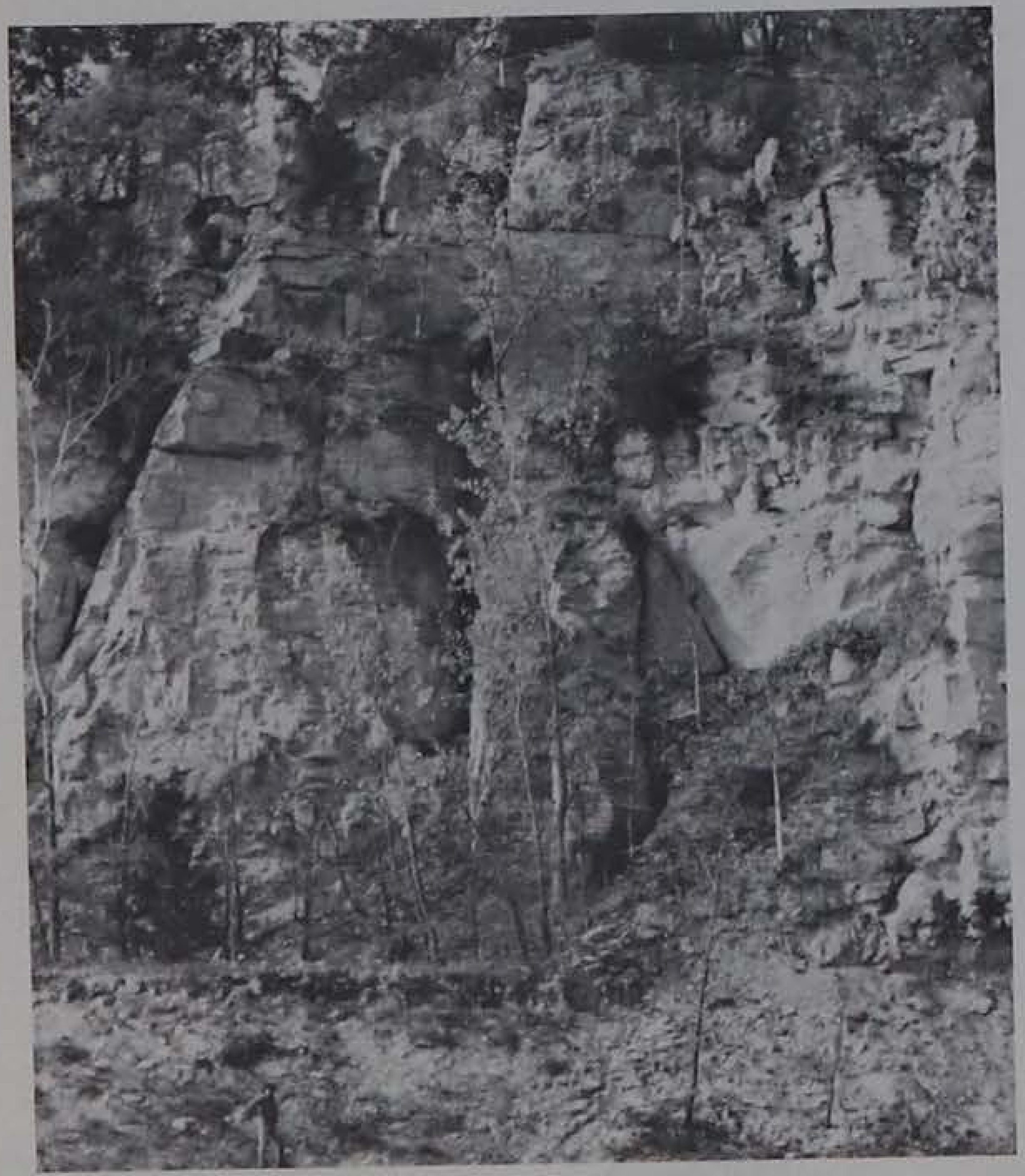


Figure 21.—The aquifers in east-central Iowa

The rocks of east-central Iowa are listed in the stratigraphic table (table 2) on the opposite page. The stratigraphic sequence contains many rock units that are distinguishable from one another because of numerous physical, mineralogical, and paleontological characteristics. However, for the purpose of describing the general availability of water, these units have been grouped into aquifers and confining beds on the basis of their water-yielding characteristics.

The surficial aquifers consist of unconsolidated material deposited by glaciers and streams. Sand and gravel in the surficial deposits are aquifers; clays and glacial tills are confining beds. On the basis of areal and vertical distribution as well as water-bearing characteristics, the surficial aquifers are subdivided into three types: the alluvial aquifers, buried channel aquifers, and drift aquifers.

The Mississippian aquifer is the shallowest bedrock aquifer in the southwest part of the report area. However, in several localities it is separated from the surficial deposits by Pennsylvanian confining beds. The aquifer is composed mainly of carbonate rocks (limestone and dolomite), which are the major water-yielding material.



Basal Silurian rocks at Bellevue State Park

The Devonian aquifer is the shallowest bedrock aquifer in the central part of the region. This aquifer chiefly consists of carbonate rocks and is separated from the overlying Mississippian aquifer by the Devonian confining beds.

The Silurian aquifer is the shallowest bedrock aquifer in the eastern half of the report area. This aquifer consists mostly of dolomite, with some limestone, and is separated from the overlying Devonian aquifer by a relatively thin irregular shale occurring near the base of the Devonian aquifer.

The Cambrian-Ordovician aquifer is separated from the overlying Silurian aquifer by the thick shale and dense dolomite of the Ordovician confining beds. The Cambrian-Ordovician aquifer is predominantly dolomite; however, two sandstone beds occur within the aquifer. The lower one, the Jordan Sandstone, is the principal water-bearing unit in the Cambrian-Ordovician aquifer; it accounts for the high yields from these rocks.

Underlying the Cambrian-Ordovician aquifer, and separated from it by the Cambrian confining beds, is the Dresbach aquifer. This aquifer consists chiefly of sandstone, and is an excellent aquifer in the eastern part of the report area.

The information on the following pages is concerned with areal distribution, depth, and thickness of the aquifers listed in table 2.

Silurian rocks at Maquoketa Caves State Park

Table 2. — Hydrologic units in east-central Iowa

Hydrologic unit	General thickness in feet	Age of rocks	Name of rock units	Type of rock
Surficial aquifers alluvial buried-channel drift	0 to 400	Quaternary (0 to 1 million years old)	Quaternary deposits, undifferentiated	Sand, gravel, silt, and clay Sand, gravel, silt, and clay Till (sandy, pebbly clay) sand, and silt
Pennsylvanian rocks principally confining beds; locally contains waterbearing sandstone	0 to 70	Pennsylvanian (280 to 310 million years old)	Pennsylvanian rocks, undifferentiated	Shale, sandstone, limestone, and coal
Mississippian aquifer	0 to 220	Mississippian (310 to 345 million years old)	Meramecian Series Osagean Series Kinderhookian Series	Limestone and sandstone Dolomite, limestone, and shale Limestone, dolomite, and siltstone
Devonian confining beds	0 to 350	Devonian (345 to 400 million years old)	Yellow Spring Group Lime Creek Shale	Shale, dolomite and siltstone Dolomite and shale
Devonian aquifer	0 to 400		Cedar Valley Limestone Wapsipinicon Limestone	Limestone and dolomite Dolomite, limestone, and shale
Silurian aquifer	0 to 450	Silurian (400 to 425 million years old)	Gower Dolomite * Hopkinton Dolomite Kankakee Limestone Edgewood Dolomite	Dolomite, with some chert and limestone
Ordovician confining beds	300 - 600	Ordovician (425 to 500 million years old)	Maquoketa Shale Galena Dolomite Decorah Formation Platteville Formation	Dolomite and shale Dolomite and chert Limestone and shale Limestone and shale
Cambrian-Ordovician aquifer	400 to 650		St. Peter Sandstone Prairie du Chien Formation Jordan Sandstone St. Lawrence Dolomite	Sandstone Dolomite, sandstone, and shale Sandstone Dolomite
Cambrian confining beds	90 - 290	Cambrian (500 to 600 million years old)	Franconia Sandstone	Shale, siltstone, and sandstone
Dresbach aquifer	157 to 1644		Dresbach Group Galesville Sandstone Eau Claire Sandstone Mt. Simon Sandstone	Sandstone Sandstone, shale, and dolomite Sandstone
Precambrian rocks		Precambrian (600 to more than 2 billion years old)	Crystalline rocks, undifferentiated	Sandstone, igneous and metamorphic rocks.

*Upper part includes the LaPorte City Chert in the northwest part of the report area.

The nomenclature and classification of rock units in this report are those of the Iowa Geological Survey and do not necessarily coincide with those accepted by the U.S. Geological Survey.

Surficial Aquifers

The surficial aquifers are located within the unconsolidated materials above the bedrock surface. They are subdivided into alluvial, buried-channel, and drift aquifers.

The alluvial aquifers are deposits located along present-day watercourses. They consist of sands and gravels interbedded with less-permeable silts and clays and lie beneath the flood plains of larger rivers and creeks. In the eastern half of the report area, the Iowa, Cedar, Wapsipinicon, and Maquoketa Rivers as well as Buffalo Creek alternately flow through narrow bedrock gorges and wide flood plains (fig. 22). Thus the alluvial aquifers occur irregularly in the valleys of these rivers.

The buried-channel aquifers (fig. 23) are the unconsolidated material deposited by ancient streams that carved valleys prior to or between glacial advances. Many of these ancient valleys were scoured deeply into the bedrock and are much wider than the valleys of present streams (fig. 24). Buried channels may be easily recognized on the bedrock topography map (fig. 25), but are only poorly expressed in the modern landscape. While they are not generally expressed as primary features of present topography, they exert noticeable influences on modern drainage. Prairie Creek near Cedar Rapids, Deep Creek near Preston, and the lower stretches of the Cedar, Wapsipinicon, and Maquoketa Rivers follow the courses of buried channels. See figures 22 and 23. In addition, most of the irregularly occurring alluvial aquifers in the eastern half of the report area are located where modern stream valleys intersect buried bedrock channels.

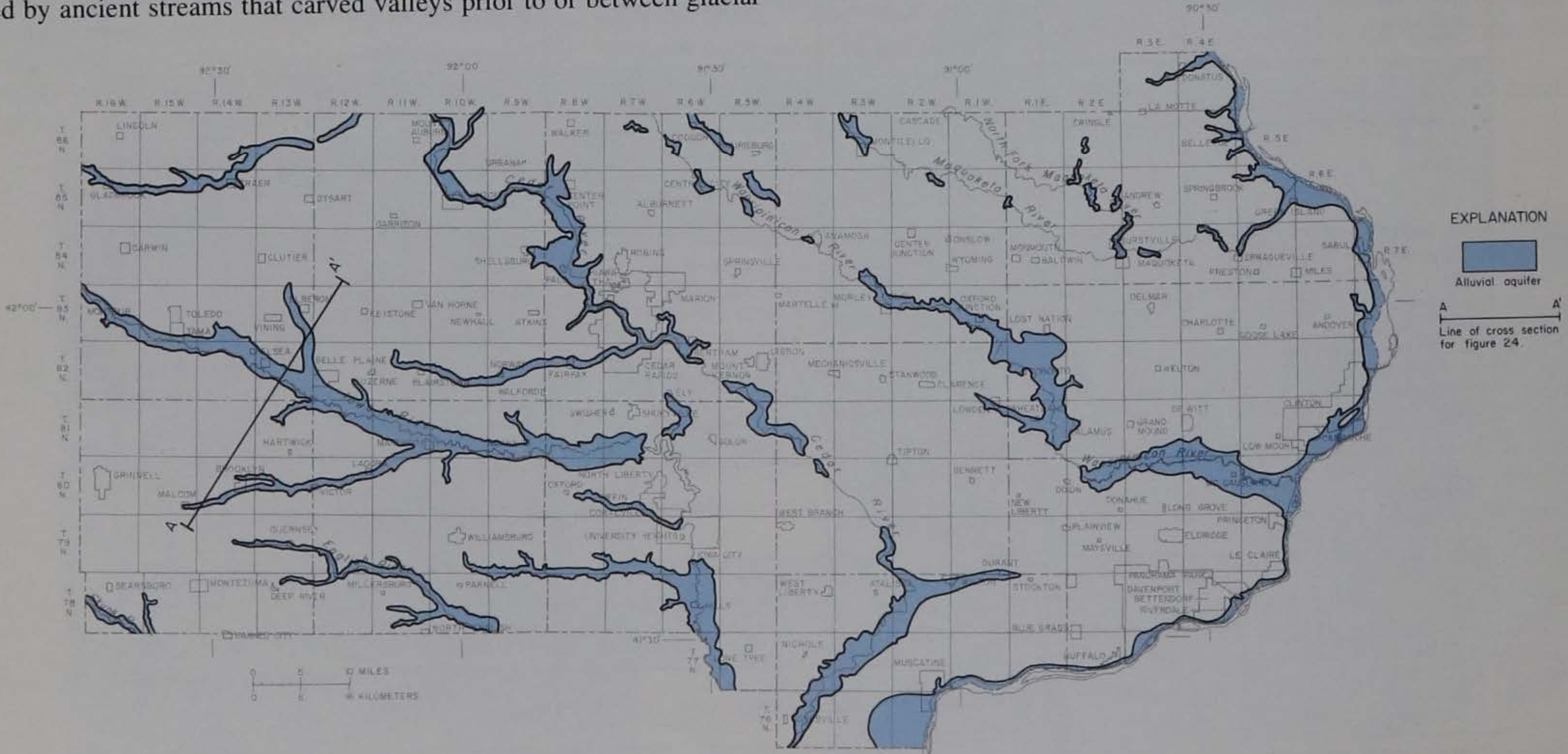


Figure 22.—Areal distribution of alluvial aquifers in east-central Iowa

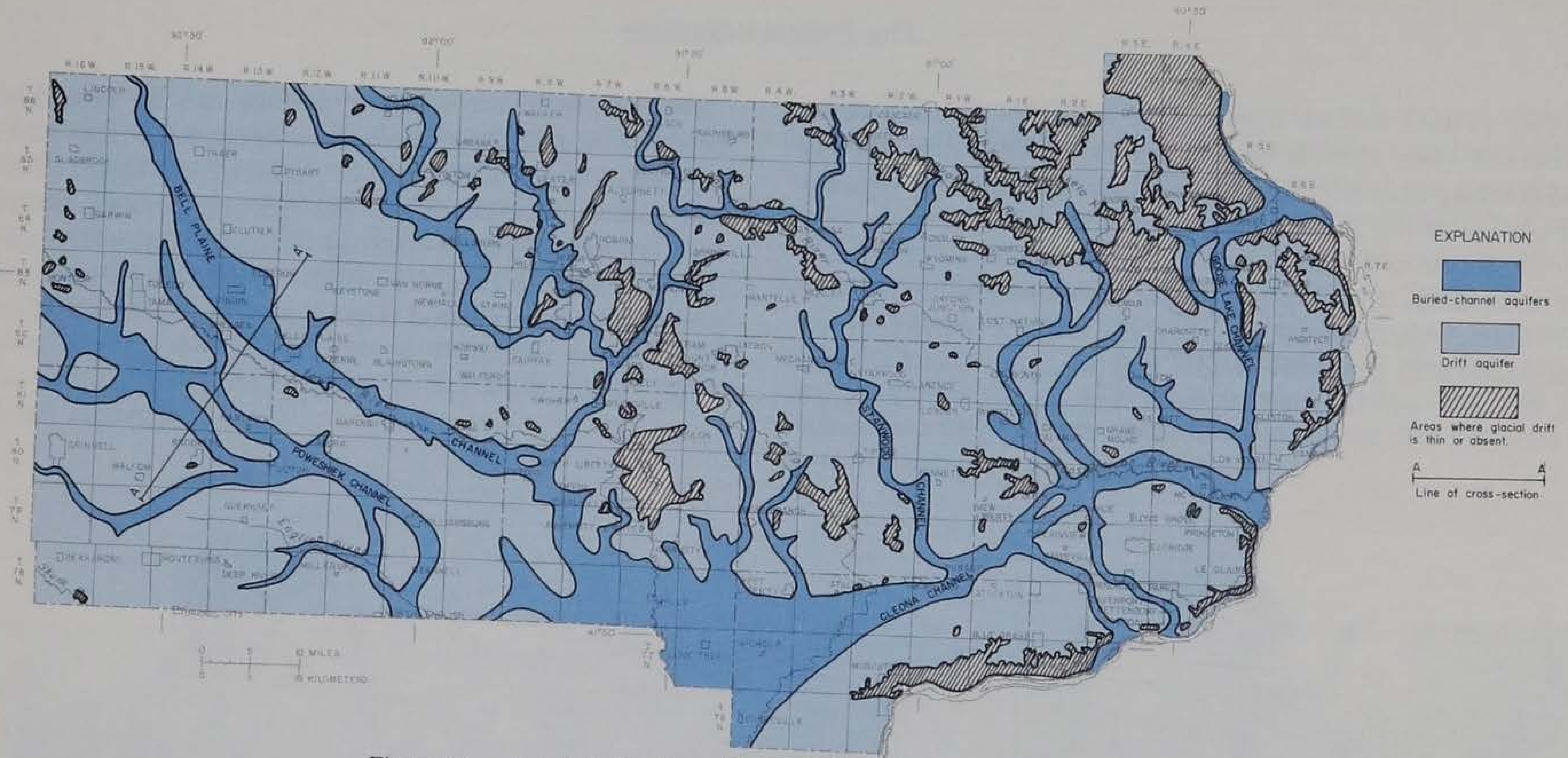


Figure 23.—Areal distribution of buried-channel and drift aquifers

The drift aquifers are irregularly occurring beds of sand and/or gravel that are within the drift. These sands and gravels were deposited by glacial meltwater and their areal extent, thickness, and stratigraphic position cannot be predicted. For this reason, the suitability of the drift aquifer as a water source in any given location is uncertain. The greatest thicknesses of glacial drift generally occur on the upland stream divides, although in places, bedrock is shallow enough on these divides to effectively preclude use of the drift as an aquifer (fig. 23). In most places, including areas with little or no till, the uplands are capped with loess (windblown silt) derived from the receding glaciers. In the past, shallow dug and bored wells in loess served as farmstead wells, but modern water demands have relegated the loess aquifers to a postition of little or no practical significance.

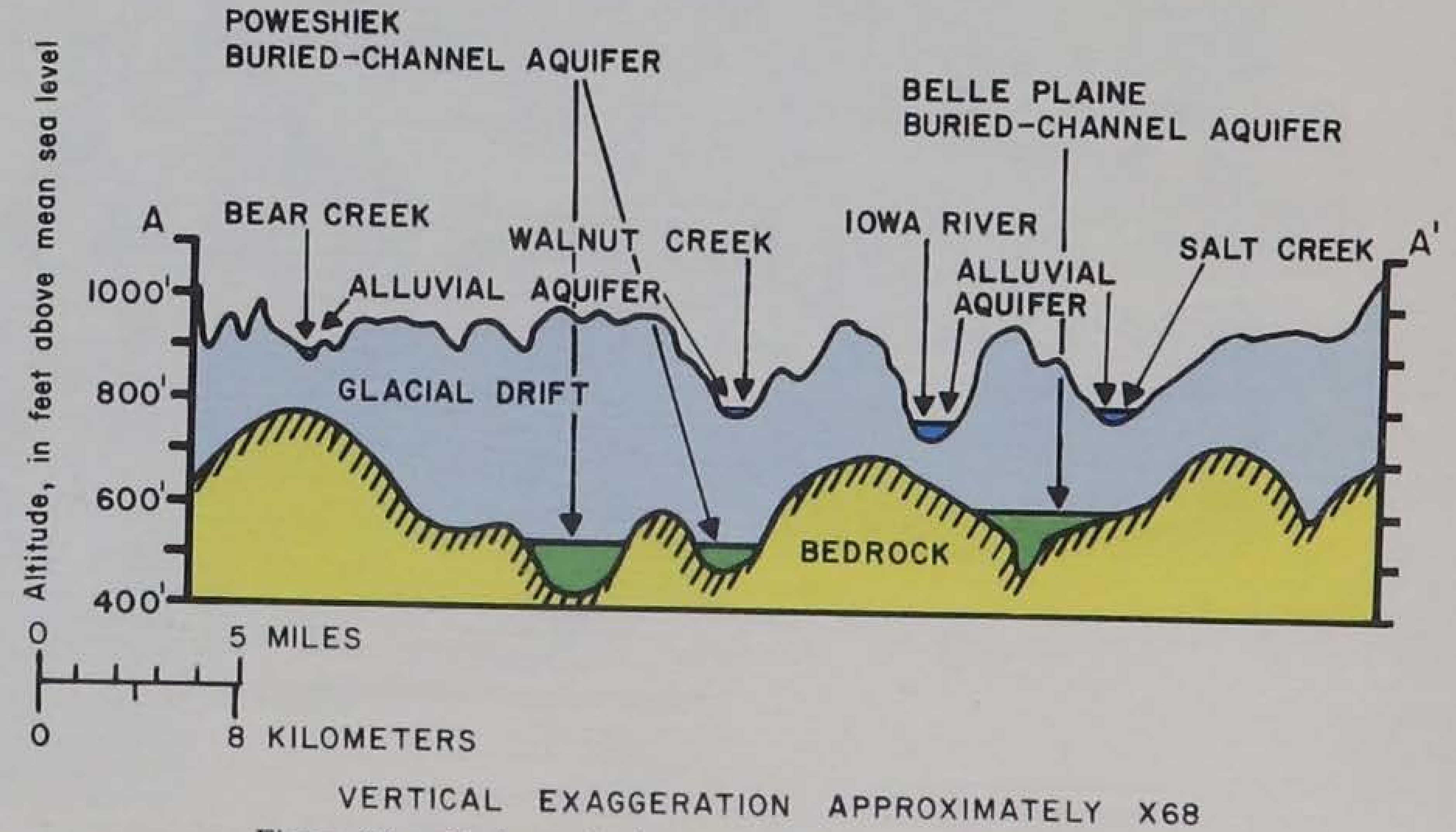


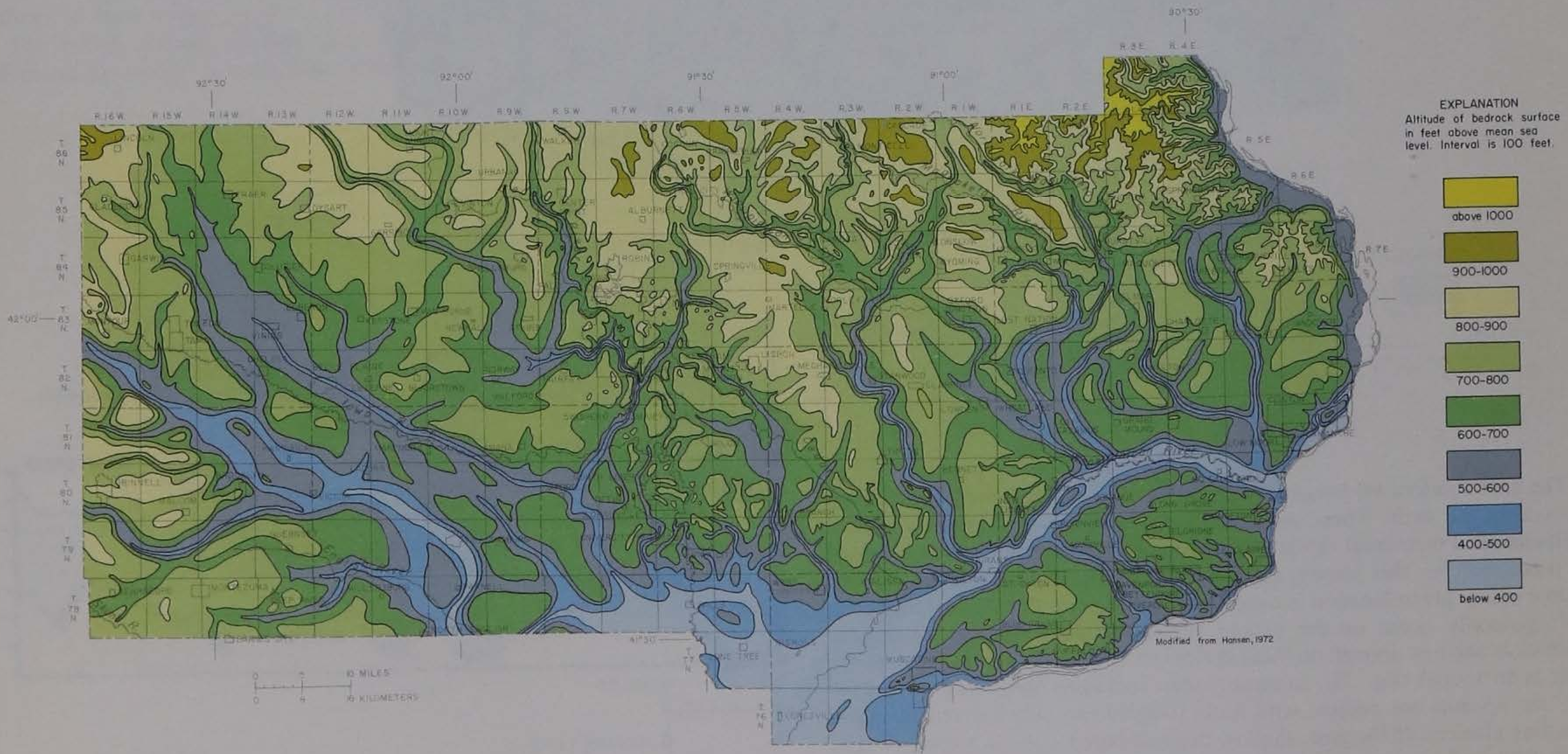
Figure 24.—Hydrogeologic cross section of surficial aquifers

The Bedrock Surface

The bedrock surface is the interface between the unconsolidated surficial deposits and the bedrock. The altitude and configuration of this surface is shown on the accompanying map (fig. 25). This is a topographic map of what would be the land surface if the surficial deposits were removed.

The map shows the location and depth of the buried channels that were carved into the bedrock; hence this map and figure 23 can be used to find the locations of buried-channels aquifers. Also, where the altitude of the bedrock surface is high, the glacial drift generally is thin, and the chances of finding a source of water in the drift will be slight.

The depth to the bedrock surface can be determined by the difference between the surface altitude from figure 5 (or from USGS topographic maps) and the altitude of the bedrock surface from figure 25. Although the bedrock map indicates the position of the bedrock surface, it will not show what type of rock comprises that surface. In some places the bedrock will be an aquifer; in others it will be confining beds. In order to predict this, a bedrock hydrogeologic map is needed (fig. 26).



Modified from Hansen, 1972

Figure 25.—Altitude and configuration of the bedrock surface

Bedrock Aquifers

The bedrock hydrogeologic map (fig. 26) shows the aquifers and confining beds that make up the bedrock surface in east-central Iowa. Pennsylvanian confining beds are the bedrock in the extreme southwest corner of the area, in southeast Muscatine County and southwest Scott County, and in other small outlying localities. The Mississippian aquifer is found beneath the surficial deposits in most of the southwest part of the region. The Devonian confining beds comprise the bedrock surface in an area about 25 miles wide extending from the northwest corner to the south-central part of the report area. They have been partly or completely removed in parts of the Belle Plaine and Poweshiek buried bedrock channels.

The Devonian aquifer is the bedrock in a broad belt that parallels the northeast side of the Devonian confining beds. This belt is from 12 to 25 miles wide and extends from northern Benton and Linn Counties to the southern border of Muscatine County. The Devonian and Silurian aquifers are separated by an irregular zone of relatively thin shale occurring near the base of the Devonian and represented by a single line on figure 26.

The Silurian aquifer comprises the bedrock surface over most of the eastern half of the area. In the extreme northeastern border area the Ordovician confining beds are found at the bedrock surface. They also appear in several buried bedrock channels where the Silurian aquifer has been removed locally by erosion.

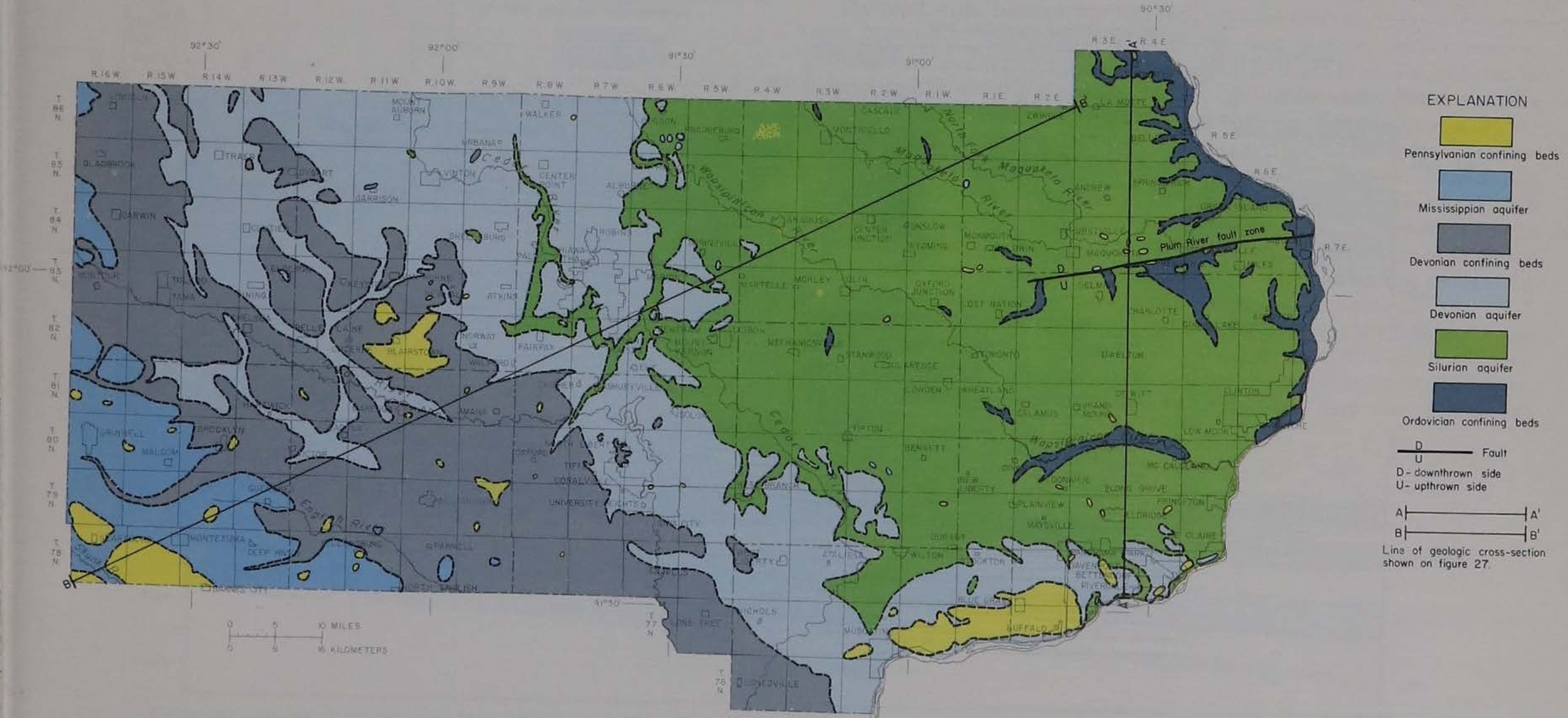


Figure 26.—Bedrock hydrogeologic map

The Cambrian-Ordovician aquifer and the underlying Dresbach aquifer are not at the bedrock surface in east-central Iowa. These aquifers are shallowest in the northeastern part of the area; they slope southwest and become progressively deeper in the subsurface. Figure 27 shows that all the rock units are approximately parallel to each other and dip (slope) toward the southwest.

A major structural feature, the Plum River fault zone, extends approximately 30 miles through southern Jackson County and northwest Clinton County. This structure continues eastward approximately 40 miles into northwest Illinois, where it was originally recognized and mapped (Kolata and Buschbach, 1976). As much as 400 feet of vertical displacement has been inferred by the Illinois State Geological Survey in the vicinity of Savannah, Illinois, and similar displacements may occur in Iowa between Preston and Maquoketa. In the vicinity of Preston, an uplifted area south of the fault zone is indicated by the anomalous presence of the Ordovician confining beds at the land surface. Preliminary results from an ongoing research drilling program in the Devonian and Silurian aquifers have indicated a possible extension of the structure as far west as southern Linn County, Iowa. The Plum River fault zone is probably quiescent, as no evidence of geologically recent movement along the fault has been found.

The fault zone has cut the various bedrock aquifers and confining beds, and faulting has placed them adjacent to rock units of dissimilar hydrologic characteristics (fig. 27). Depending on the local displacement or associated fracturing, the fault may serve either as a barrier to or a conduit for ground water movement. Where an aquifer is placed against a confining bed the fault may serve as an impediment to ground-water movement. Where two different aquifers are placed against one another by the fault there may be continuity between the two aquifers.

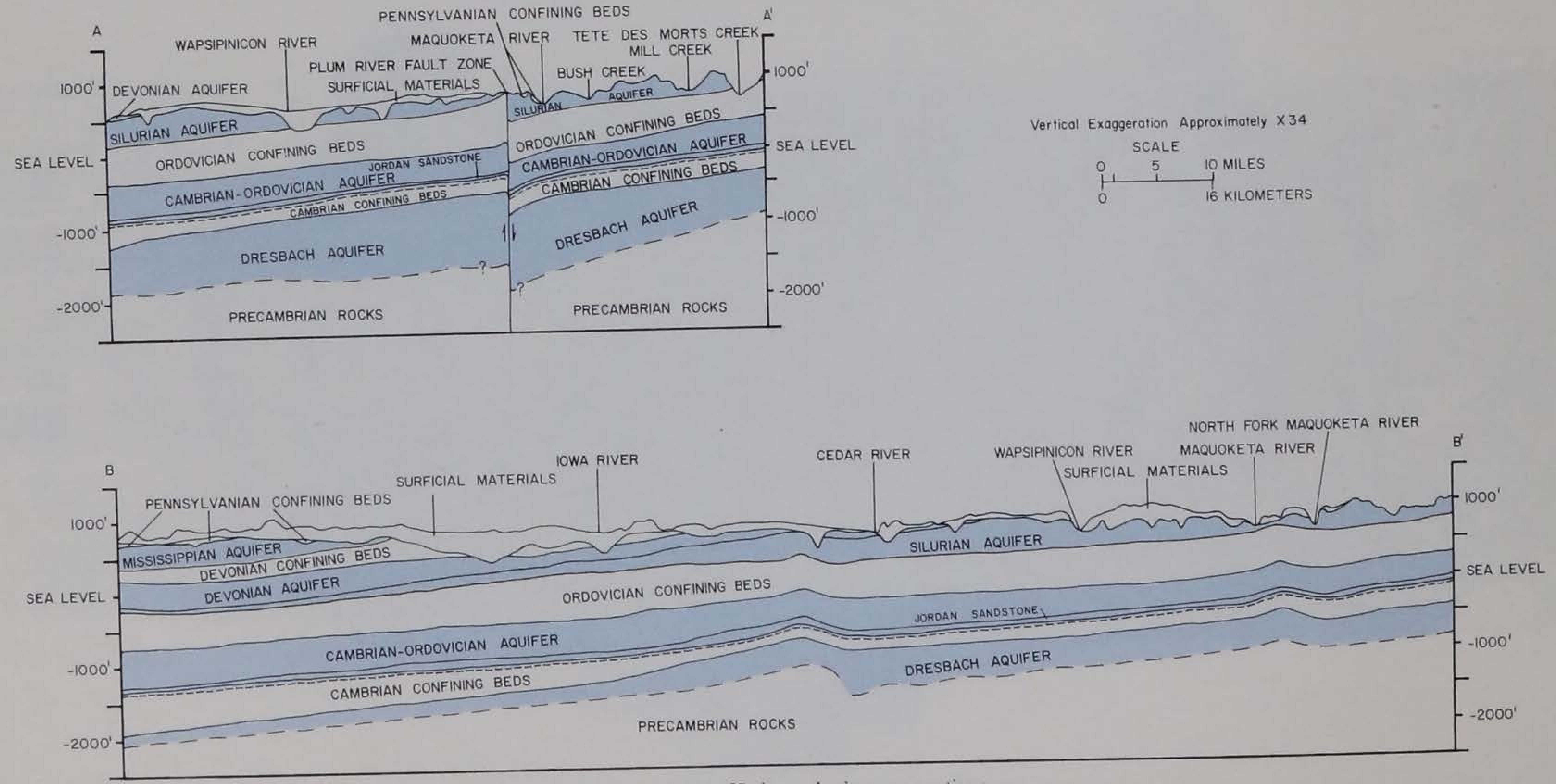


Figure 27.—Hydrogeologic cross sections

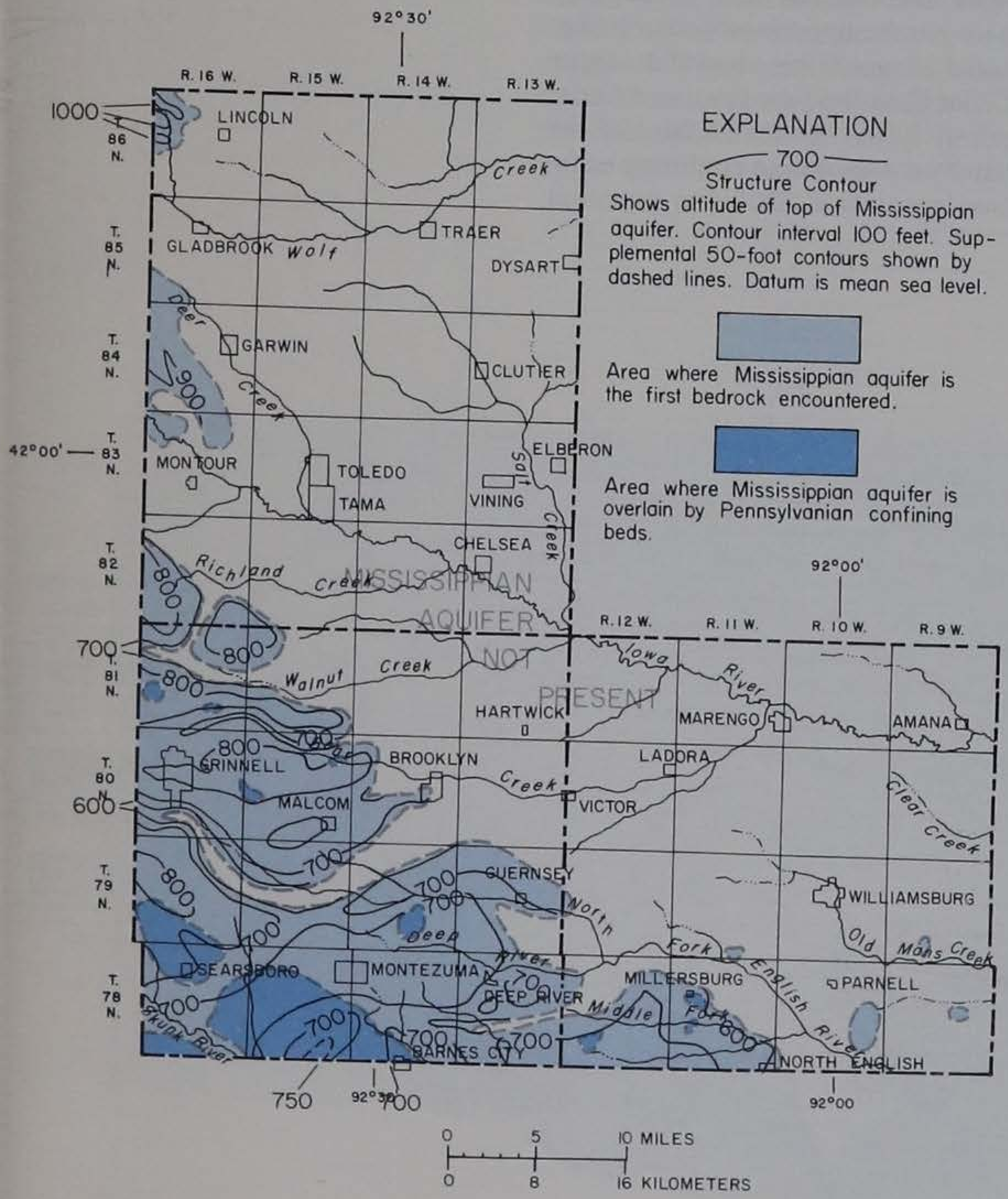


Figure 28.—Altitude of the top of the Mississippian aquifer

Depths to Bedrock Aquifers

The depth to the bedrock aquifers varies considerably throughout the report area because of topographic relief of the land surface, ancient erosion, deformation, and slope of the bedrock units. The depth to each aquifer can be determined by the difference between the land-surface altitude (topographic map fig. 5) and the altitude of the various aquifers shown in figures 28-33.

The altitude and configuration of the upper surfaces of the bedrock aquifers have been modified by erosion and structural deformation. Erosion has occurred during several periods of geologic time resulting in the development of extensive drainage systems (figs. 23 and 25) and the removal of large volumes of rock material. All the rock layers in the area have been subjected to structural deformation, which has caused a regional tilt of the rocks to the southwest as well as local folding and faulting of the strata.

The upper surface of the Mississippian aquifer is very irregular and is the result of erosion which occurred during three separate time intervals; post-Mississippian and prior to deposition of Pennsylvanian rocks, post-Pennsylvanian and prior to Pleistocene glaciation, and after Pleistocene glaciation.

Erosion and structural deformation have played equally important roles in shaping the upper surface of the Devonian aquifer. The Devonian aquifer is missing in the eastern half of the report area, where it has been removed by erosion. In the southeast-trending belt where it is the uppermost bedrock (fig. 29), erosion previous to and between glacial advances has shaped its upper surface. In Benton, Linn, Johnson and Cedar Counties, the Iowa and Cedar Rivers presently are cutting into the aquifer. In the southwest third of the report area the Devonian aquifer is overlain by the Devonian confining beds. There the configuration of its upper surface is mainly attributed to structural deformation.

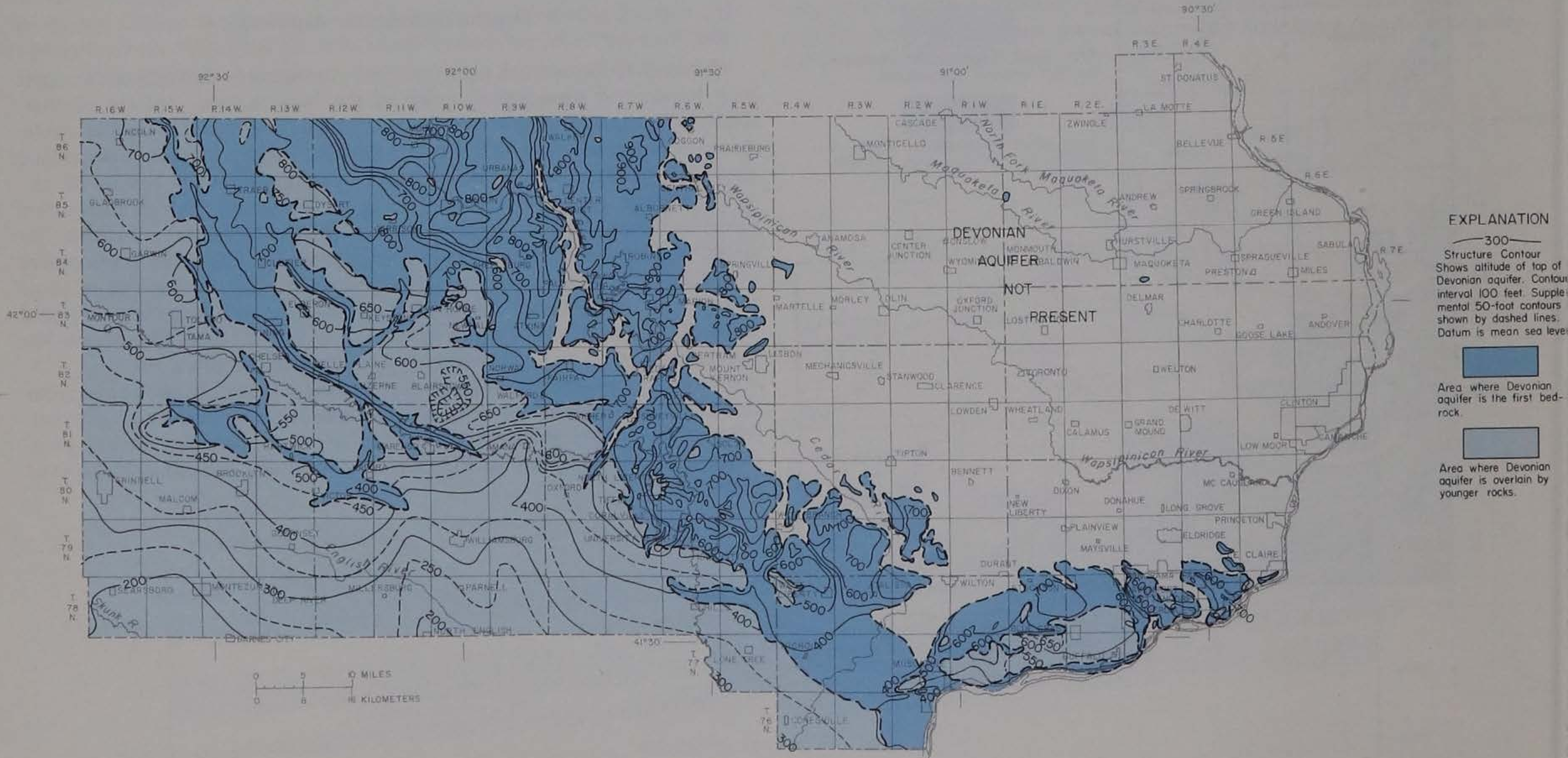


Figure 29.—Altitude of the top of the Devonian aquifer

In the eastern half of the region, erosion before and after continental glaciation has cut away much of the Silurian aquifer. In the extreme northeast corner of the area, erosion has completely removed the aquifer, exposing the underlying Ordovician confining beds. To the south of the Plum River fault zone in Jackson and Clinton Counties, the Silurian aquifer has been locally uplifted and removed by erosion. In the western half of the area, where the Silurian aquifer is overlain by the Devonian aquifer, the configuration of its upper surface is mainly due to structural deformation.

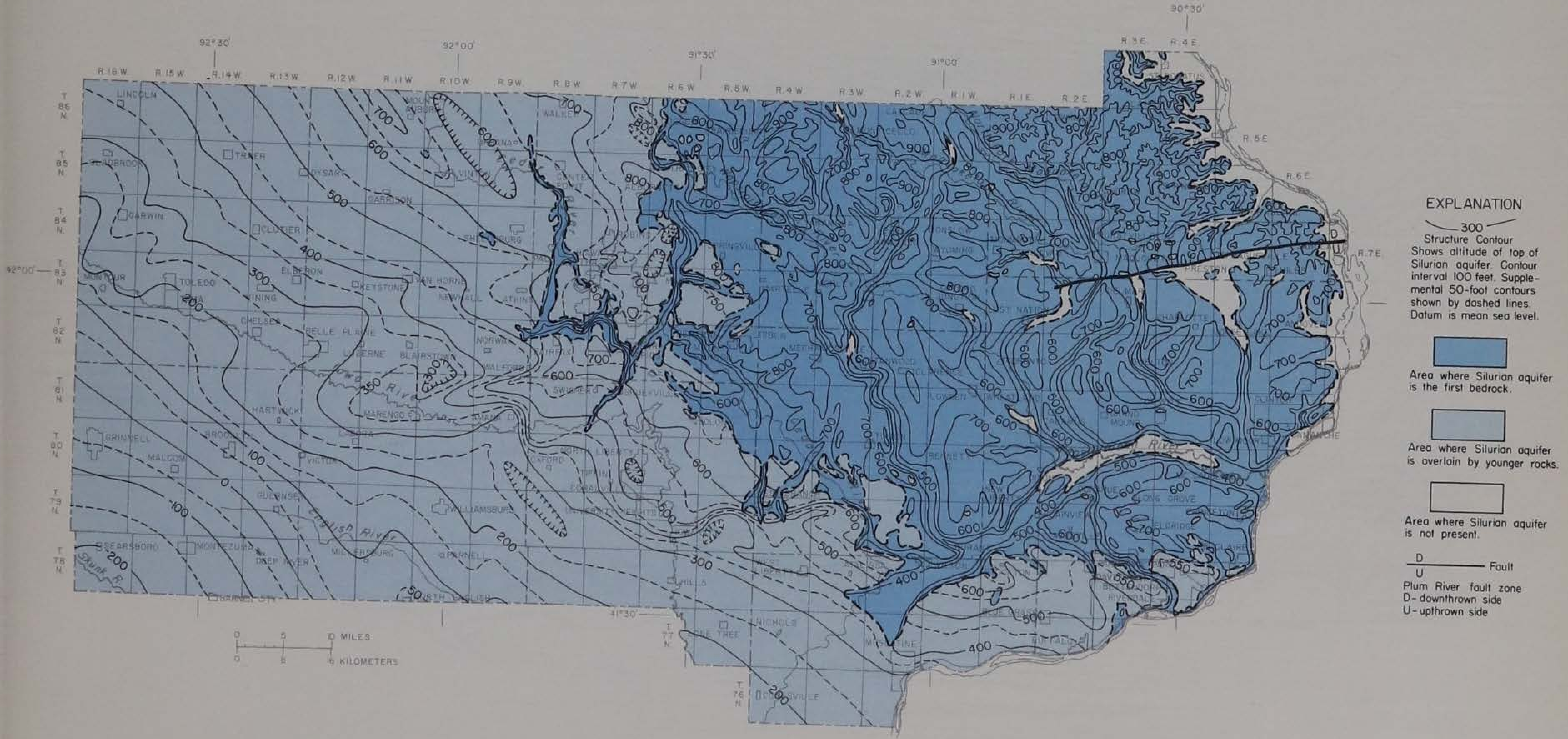


Figure 30.—Altitude of the top of the Silurian aquifer

Structural deformation has been the principal process in shaping the upper surface of the Cambrian-Ordovician and Dresbach aquifers. Regional deformation of the earth's crust has tilted all the rocks in the report area to the southwest. Superimposed on this regional dip are numerous anticlines and synclines (upfolds and downfolds, respectively). The axes of many of these folds trend in a southeast direction, perpendicular to the southwesterly regional dip. Adjacent to and along the extrapolated trend of the Plum River fault zone, the most conspicuous structural feature of the report area, are several anticlines and synclines whose axes trend eastward. They are apparently related to the deforming forces which disrupted the strata along the fault zone.

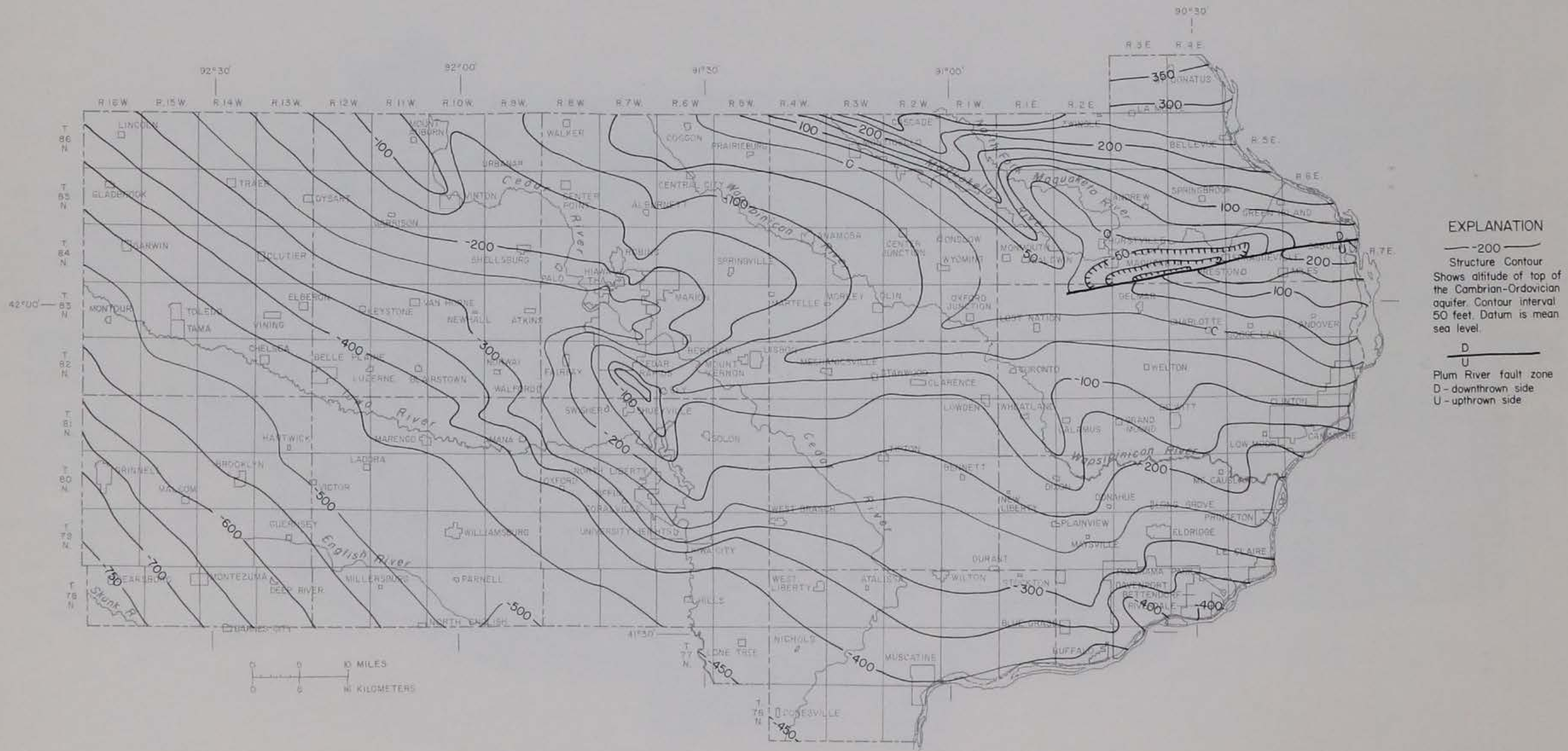


Figure 31.—Altitude of the top of the Cambrian-Ordovician aquifer

The upper surface of the Jordan Sandstone, the principal water-bearing unit in the Cambrian-Ordovician aquifer, is essentially parallel to the top of the aquifer, but lies approximately 400 feet below it.

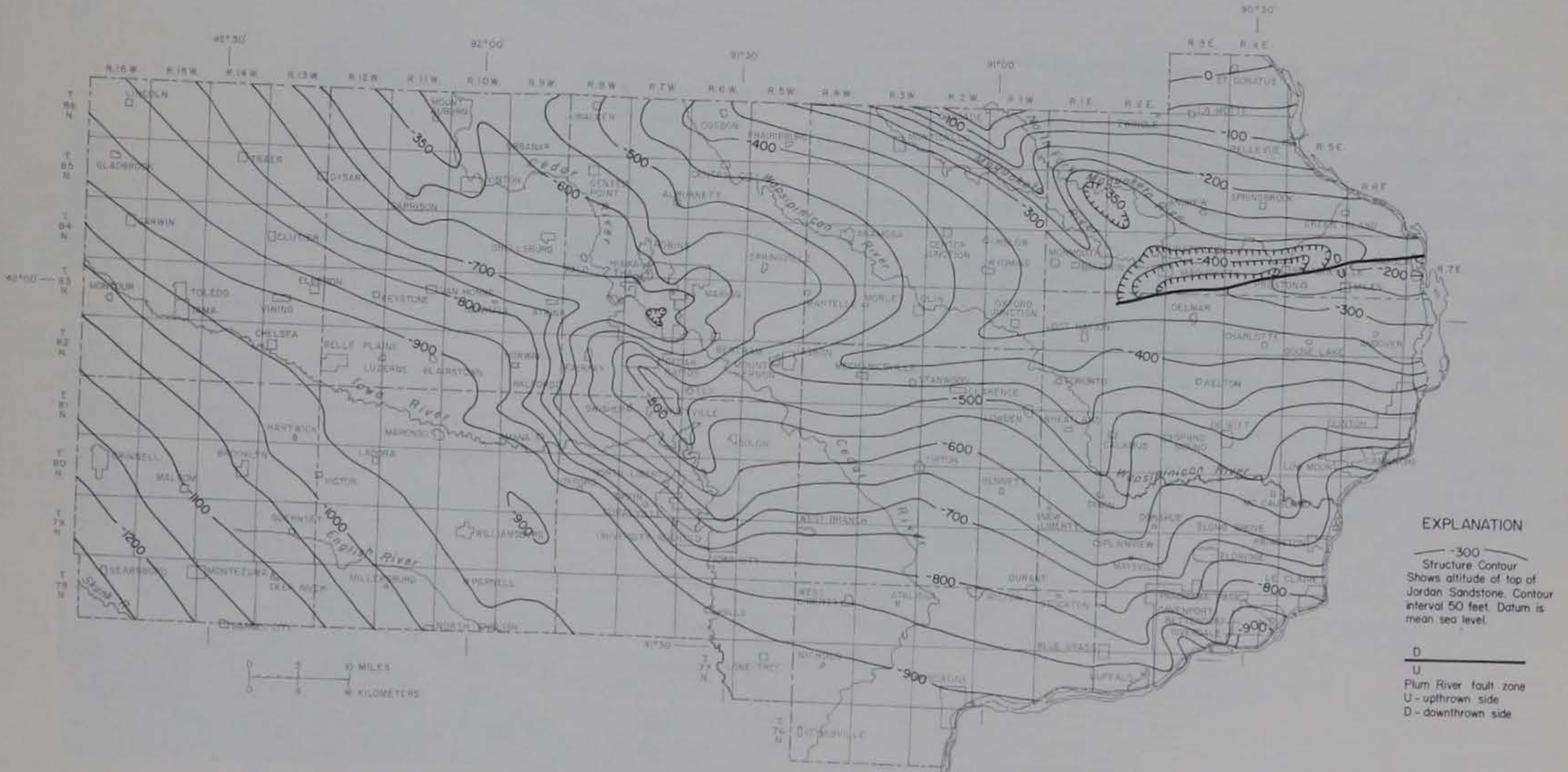


Figure 32.—Altitude of the top of the Jordan Sandstone

The top of the Dresbach aquifer has a configuration similar to that of the Cambrian-Ordovician aquifer and lies 400 to 600 feet below the top of the Jordan.

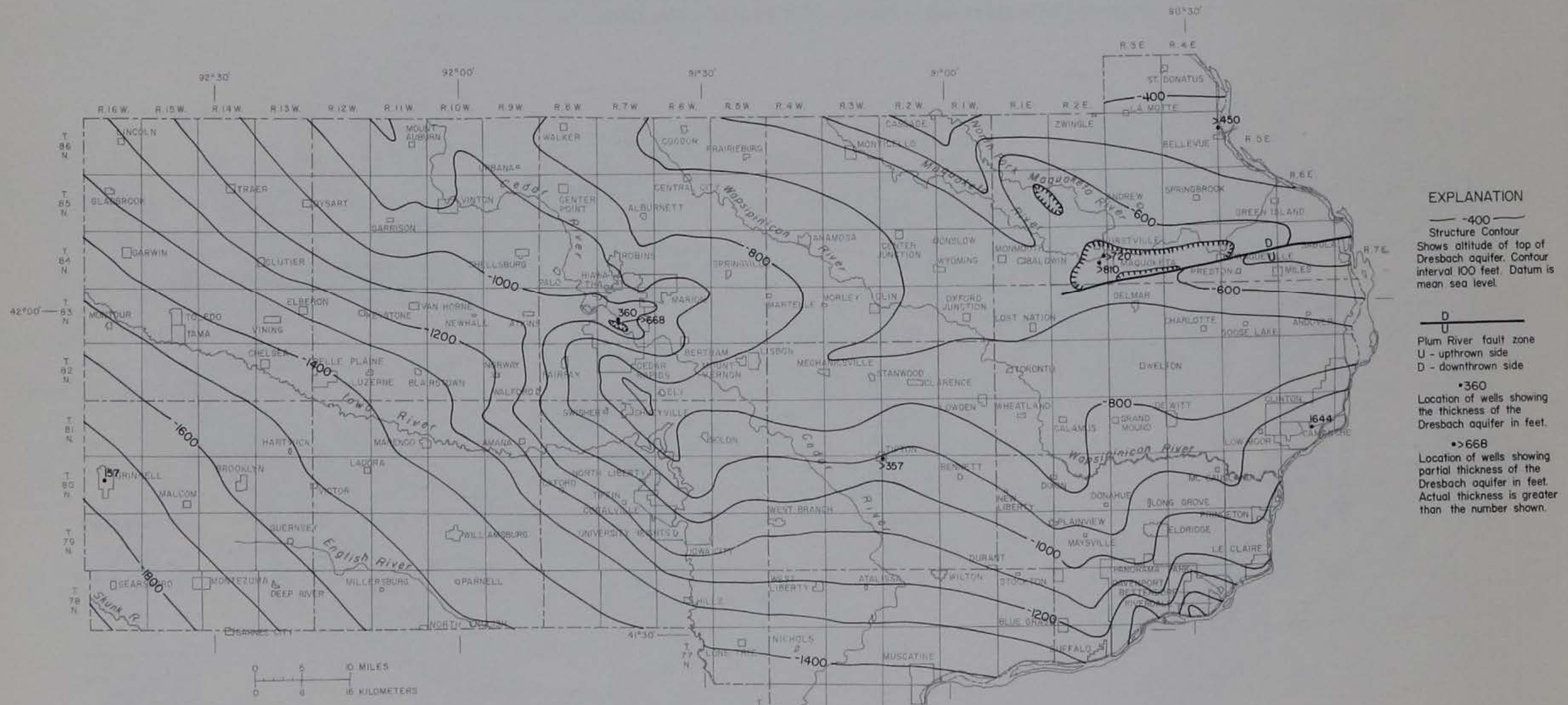


Figure 33.—Altitude of the top and thickness of the Dresbach aquifer

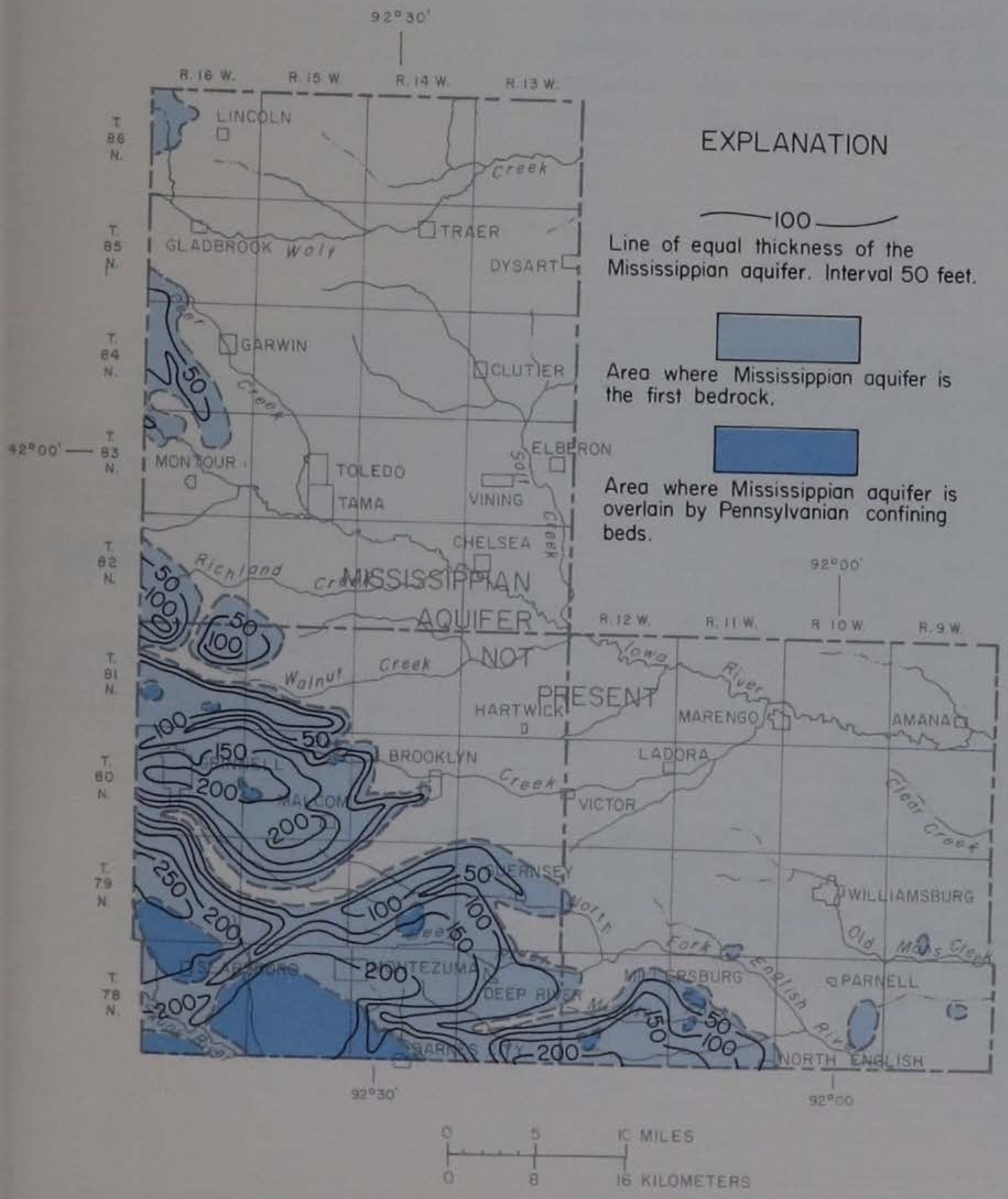


Figure 34.—Thickness of the Mississippian aquifer

Thickness of the Bedrock Aquifers

An aquifer will normally yield the largest quantity of water to a well where the aquifer is thickest and the well fully penetrates the aquifer. Maps depicting the thickness of the aquifers can be used in conjunction with altitude maps to determine the depth to which wells must be drilled to fully penetrate these water-bearing rocks.

The thickness of each bedrock aquifer varies locally throughout east-central Iowa, because (1) the surface upon which these rocks were deposited was not smooth, and more material accumulated in low areas than higher areas; (2) more material was carried to or precipitated over some areas than others; and (3) erosion following deposition removed large volumes of material from some places.

The thickness of the Mississippian aquifer ranges from 0 to over 250 feet in east-central Iowa (fig. 34). It is thickest near the southwestern corner and becomes progressively thinner toward the northeast. Erosion has removed the aquifer from all but the southwestern part of the report area and is the cause of most local variations in thickness.

The thickness of the Devonian aquifer ranges from 0 to more than 400 feet, the greatest thickness occurring in the extreme northwestern part of the area (fig. 35). In the eastern half the aquifer has been removed by erosion. In the northwest-trending belt where the Devonian aquifer is the uppermost bedrock, erosion has caused local variations in thickness.

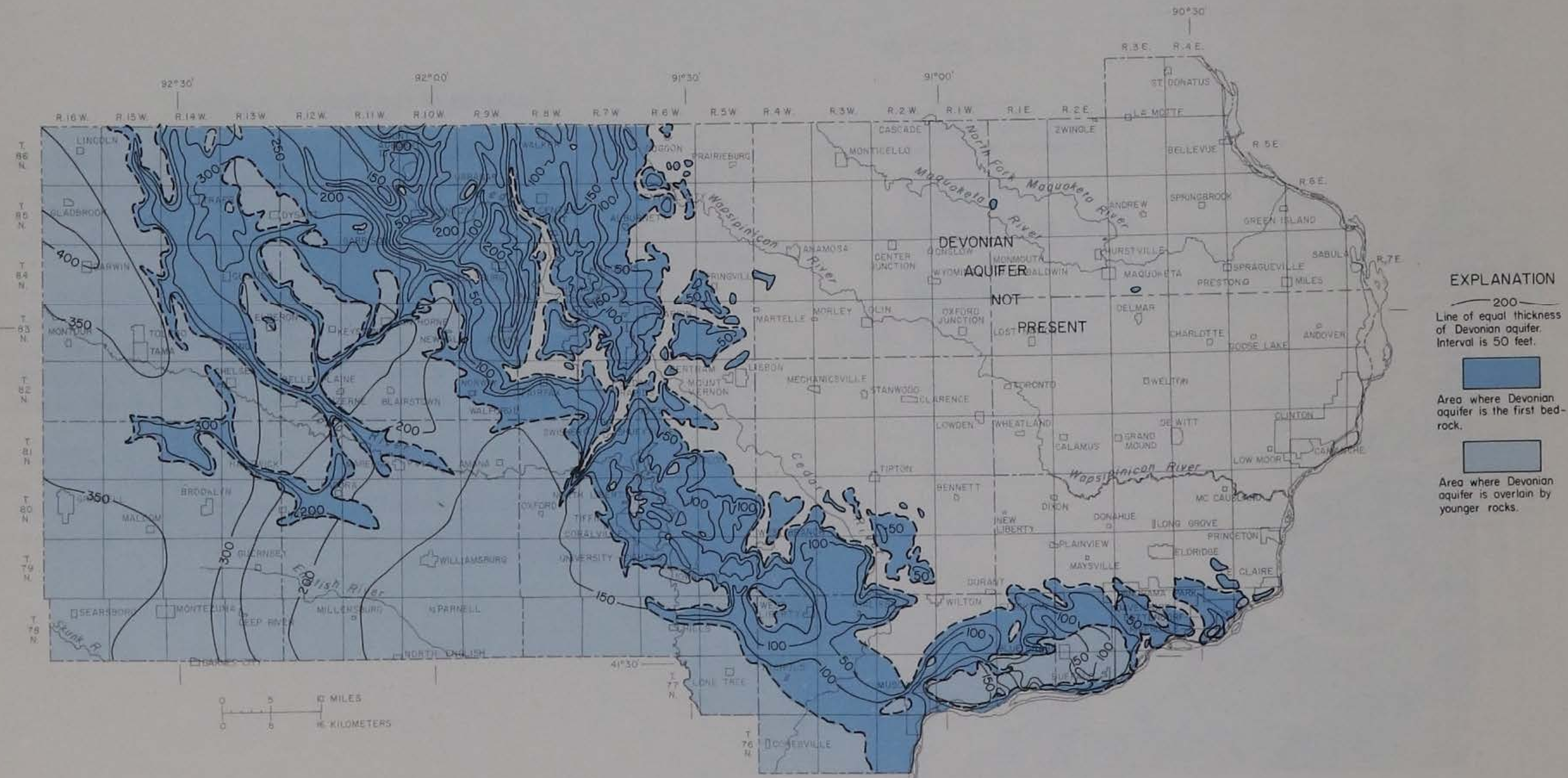


Figure 35.—Thickness of the Devonian aquifer

The Silurian aquifer exhibits considerable variation in thickness (fig. 36) as the result of structural deformation and erosion during several periods of geologic time. In the eastern half of the area, the Silurian aquifer is the uppermost bedrock and due to erosion the thickness ranges from 0 to more than 400 feet. On the upthrown (south) side of the Plum River fault zone, erosion has completely removed the aquifer at a few places.

From the western half of the area, where the Silurian aquifer is overlain by younger rocks, to the eastern half, where it is at the bedrock surface, the thickness ranges from less than 50 feet to a maximum of nearly 400 feet along a line from Davenport to Cedar Rapids.

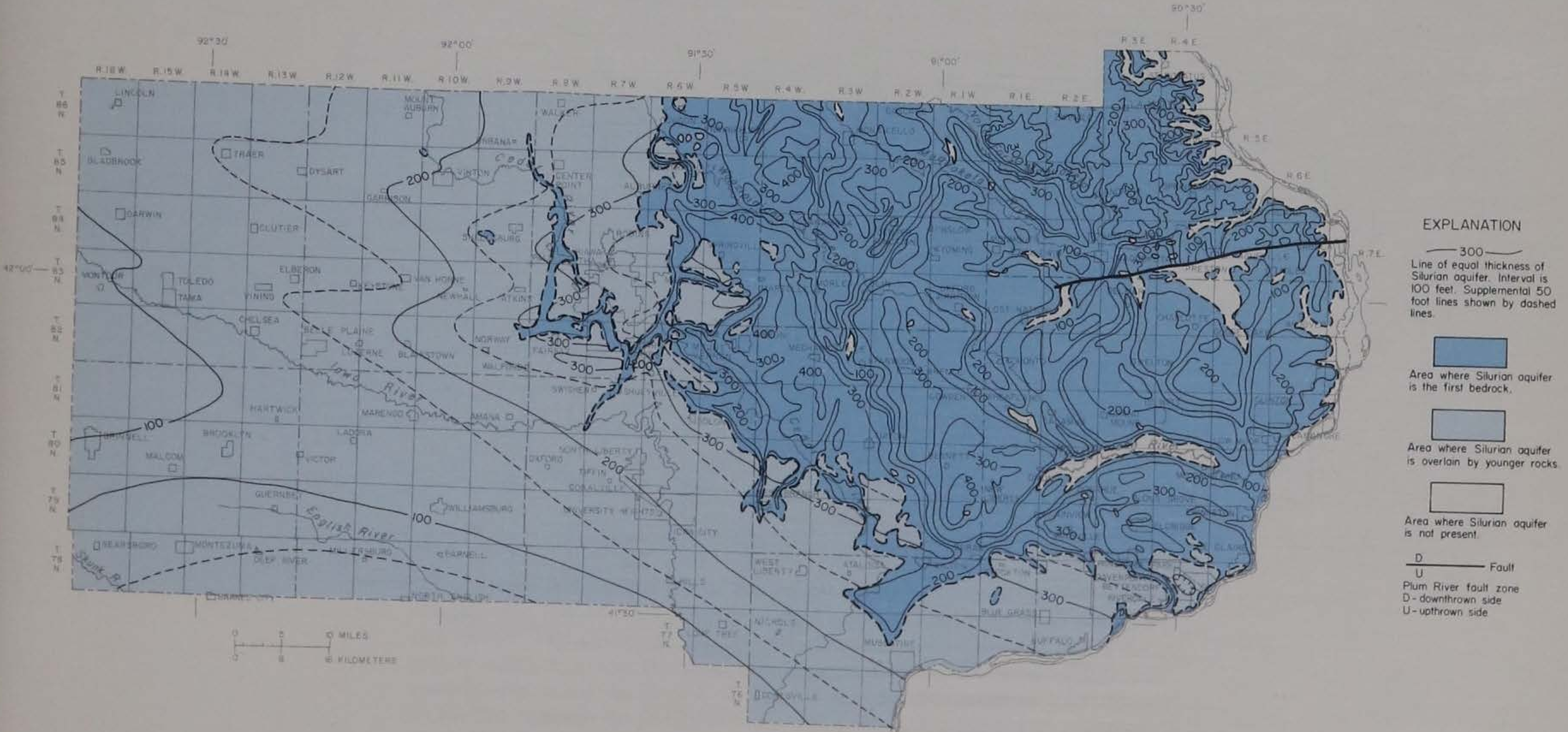


Figure 36.—Thickness of the Silurian aquifer

The Cambrian-Ordovician aquifer regionally varies from about 400 feet to over 650 feet in thickness. The aquifer is thickest along a northwest-trending axis that passes through the Iowa City area. Much of this increased thickness is due to a thickening of the Jordan Sandstone, figures 37 and 38. Figure 37 does not include the thickness of the St. Lawrence Dolomite, the lower unit of the Cambrian-Ordovician aquifer because few wells fully penetrate that formation and thickness data is unavailable. From what little information is available, the St. Lawrence Dolomite appears to range in thickness from about 100 to 250 feet.

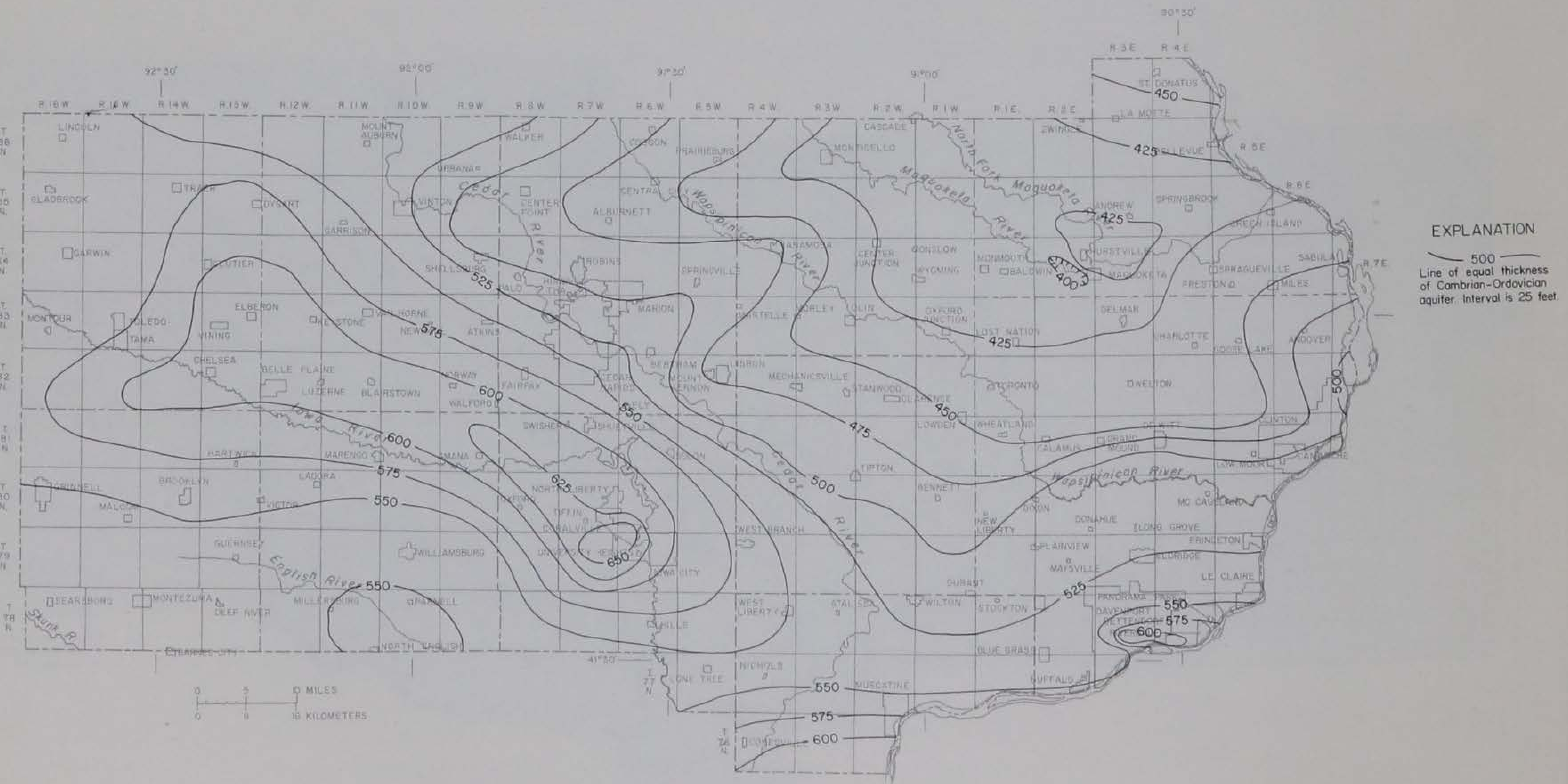


Figure 37.—Thickness of the Cambrian-Ordovician aquifer

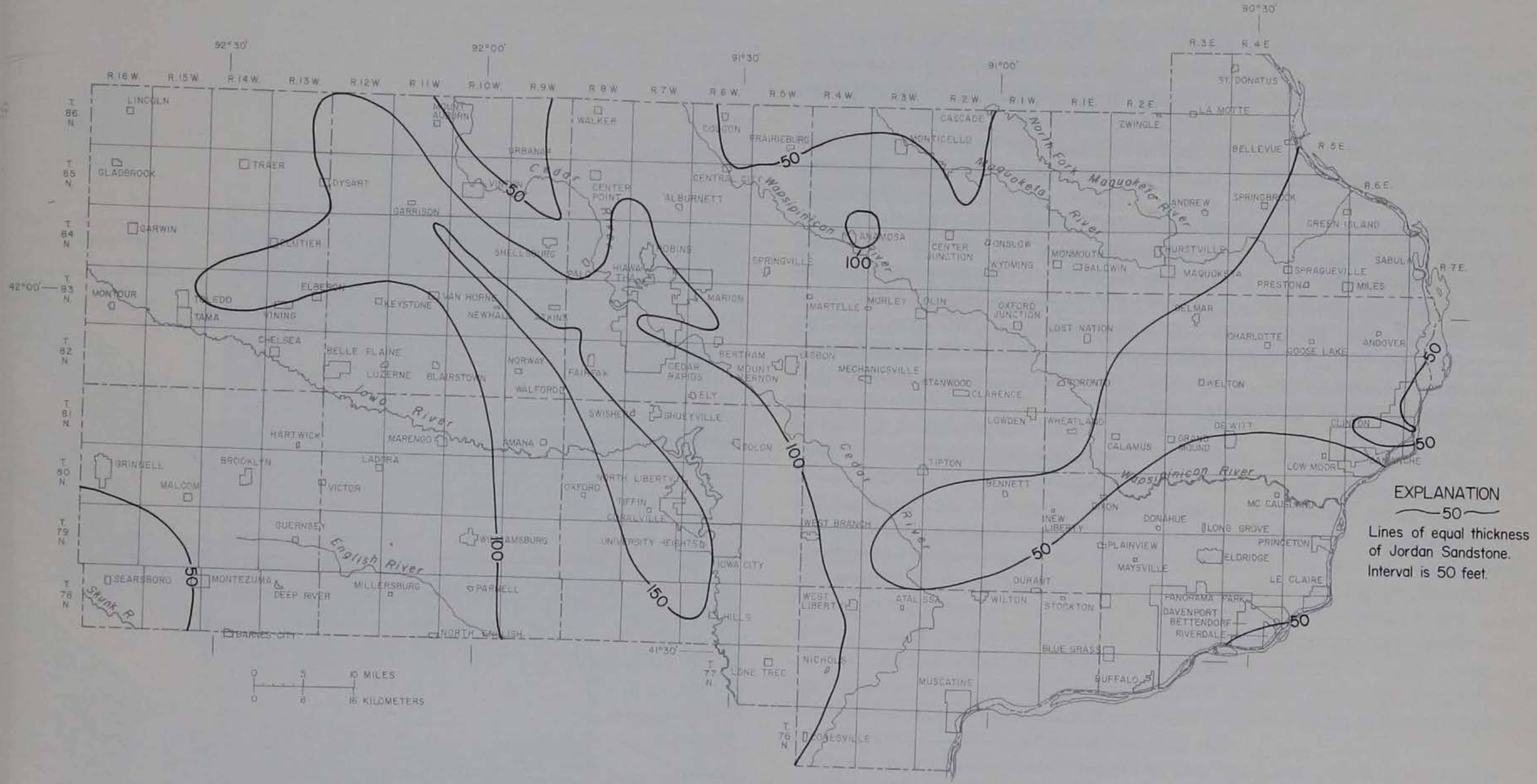


Figure 38.—Thickness of the Jordan Sandstone

Only three wells in the region fully penetrate the Dresbach aquifer. They indicate that large local changes in thickness (157 to 1644 feet) may be anticipated. The Dresbach aquifer, which is the lowermost aquifer of the ground-water reservoir in Iowa, was deposited on an erosional surface of considerable relief developed on the much older Precambrian crystalline rocks. The information available is not sufficient to develop a thickness map for the Dresbach aquifer; however, points indicating the thickness penetrated by individual wells are shown on figure 33.

Use of Maps to Predict Depths of Drilling

The preceding maps can be used to predict the depths to the aquifers and their thicknesses as an aid in estimating the accessibility of ground water. Well depths and required length of casing can be estimated from the maps as a guide in designing and estimating costs of new wells.

All of the significant horizons, the land surface, the bedrock surface, and the tops of the major aquifers, have been referenced to a common datum; mean sea level. When planning a well, the land-surface altitude is the datum to which all horizons are referenced to determine depth. The depth to a given aquifer is the difference between the land-surface altitude (fig. 5) and the altitude of the aquifer (figs. 28-33). The depth of a well fully penetrating the aquifer is the sum of the previously derived difference and the thickness of the given aquifer (figs. 34-38). This information is provided for all the bedrock aquifers in east-central Iowa. The example on figure 39 shows a comparison aquifers in east-central Iowa. The example on figure 39 shows a comparison of altitudes referenced to mean sea level, and depths referenced to the land surface for the Grinnell Municipal Well #7.

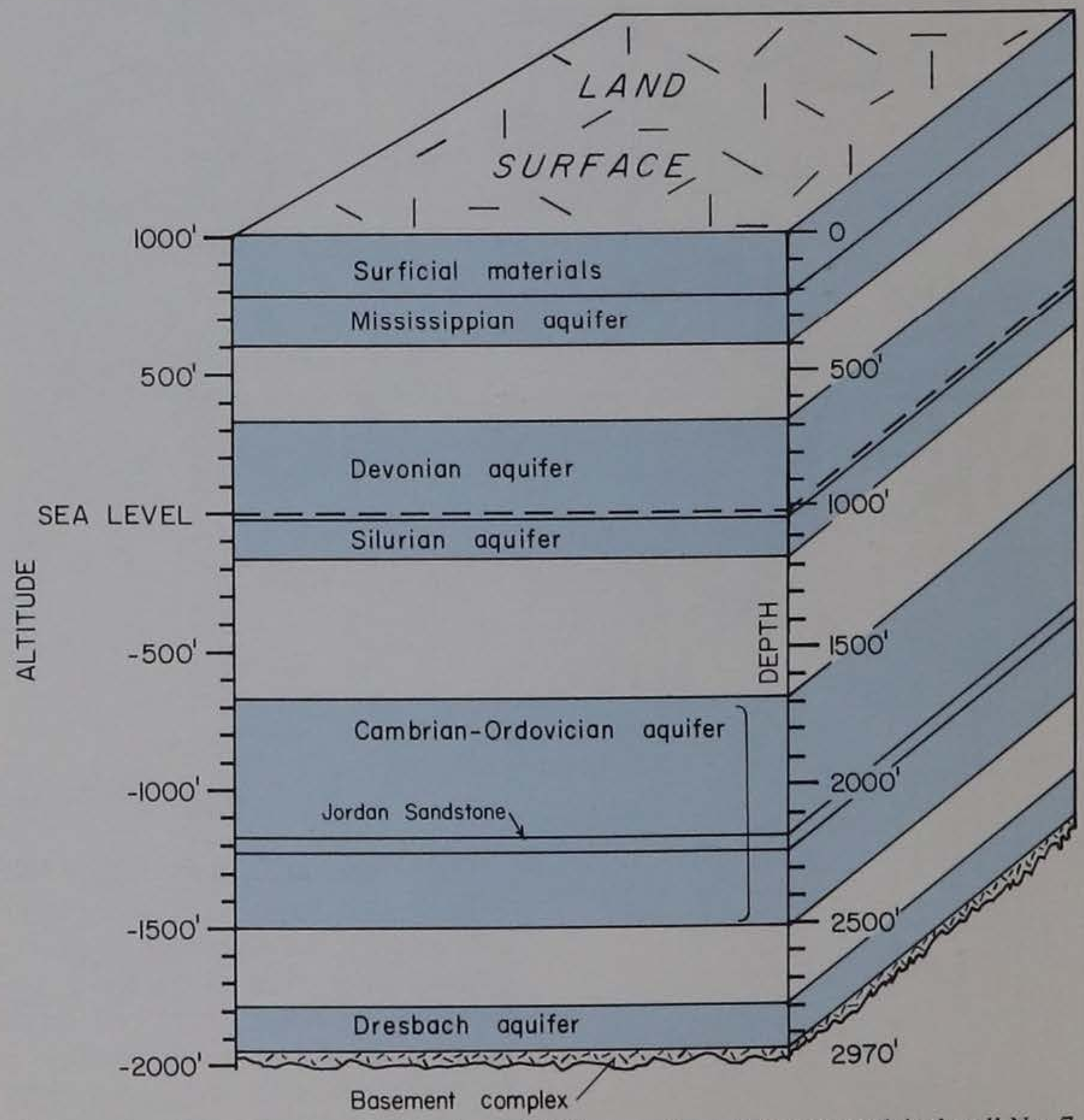


Figure 39.—Example of aquifer depths and thicknesses from Grinnell municipal well No. 7

WATER IN THE AQUIFERS

Water occurs in most rocks, filling open spaces between rock grains of sandstone, and sand and gravel, and filling joints, fractures, and solution channels in limestone and dolomite (fig. 40). Aquifers consist of rocks with numerous or relatively large interconnected openings which yield large amounts of water to wells.

Confining beds, such as shale and clay, can store a large amount of water in spaces between the very small rock particles; but the molecular attraction between the water and the rock particles and the poor connection between voids tends to retain the water rather than allow it to move into a well. Other confining beds consist of limestones and dolomites containing few openings through which water can flow; these rocks may in fact be nearly dry.

Although aquifers are of primary concern in the discussion of the water resources, confining beds have considerable hydrological significance. They prevent or retard the movement of water between the land surface and an aquifer, and between separate aquifers. Aquifers overlain by confining beds do not readily receive recharge from local precipitation; and will usually contain water that is more mineralized than in unconfined areas.

In the bedrock aquifers and in some of the surficial aquifers, where they are overlain by confining beds, the water is confined under pressure. Water in a well which taps these confined aquifers will rise above the top of the aquifer. The water may rise several feet or it may rise from great depths to the land surface. Under these conditions, the aquifer is called an artesian aquifer and contains artesian water. The level to which water will rise in a well which is tapping a given artesian aquifer represents a point on an imaginary surface referred to as a potentiometric surface. Each artesian aquifer in the report area has a separate potentiometric surface (fig. 40).

Where the aquifers are not overlain by confining beds, such as some of the surficial aquifers and parts of the Mississippian, Devonian, and Silurian aquifers, the top of the zone of saturation is free to move up or down. Water in a well tapping these unconfined aquifers will not rise above the level where it was first encountered. Under this condition the aquifer is referred to as a water-table aquifer and the upper surface of the zone that is saturated with ground water is called the water table (fig. 40).

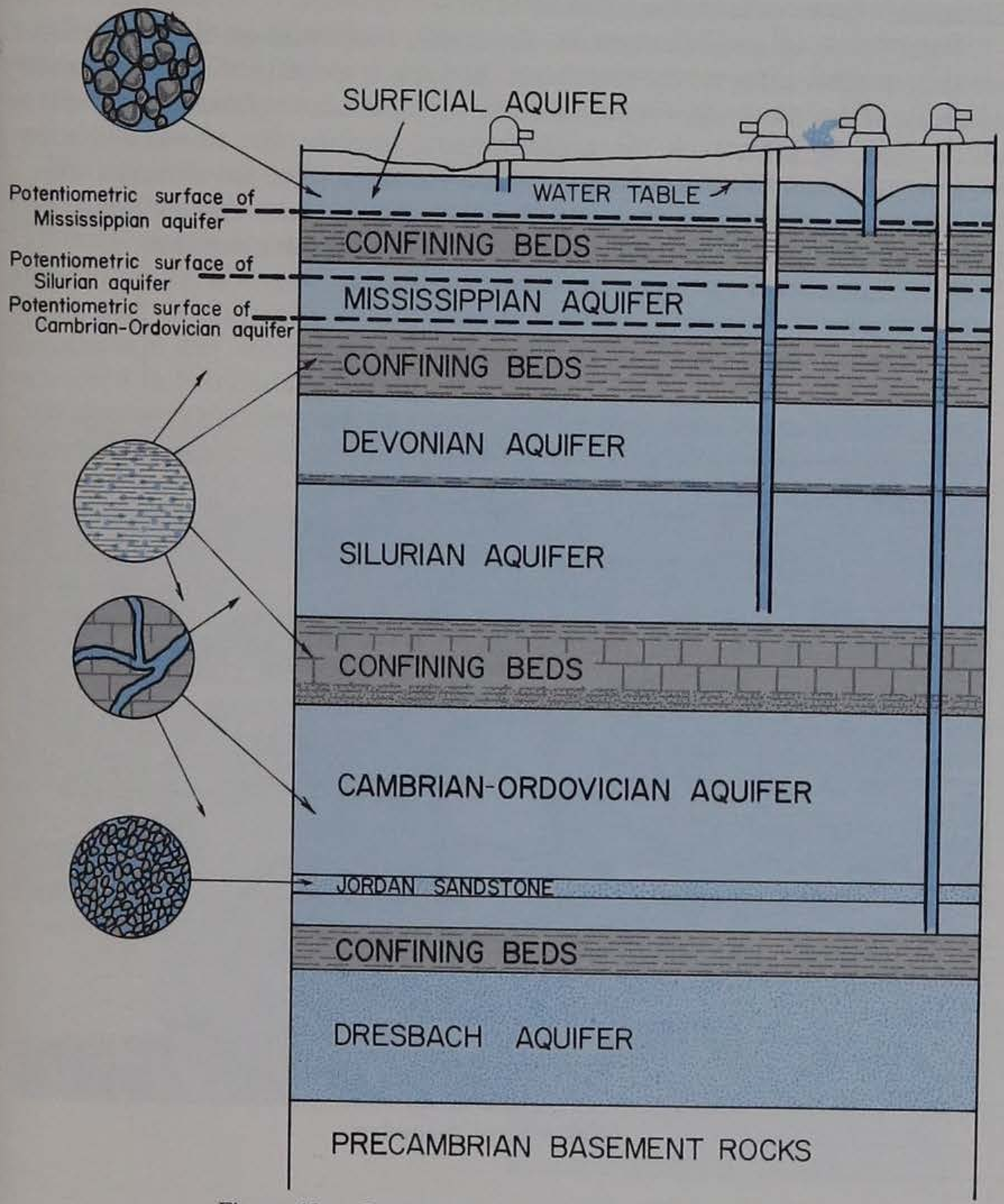


Figure 40.—Occurrence of water in the aquifers

Water Levels

The water level in a well represents the position of the water table or potentiometric surface at the well site. A number of water-level measurements in many wells finished in an aquifer, when compiled on maps, will define the water table or the potentiometric surface of that aquifer. This water surface can be represented by altitude contours in much the same way that the land surface and the tops of the aquifers are mapped. Such maps can be used to predict nonpumping water levels for proposed wells in that aquifer.

The configurations of the water table or potentiometric surfaces define ground-water movement in two dimensions. Water in each aquifer moves from areas of high head (high contour values) to areas of low head (low contour values), and the general direction of flow is perpendicular to the contour lines. Water-level maps for some of the deep confined aquifers indicate that water is moving directly across the region, and local topography and streams have little or no effect on the direction of water movement. These aquifers receive the major part of their recharge from outside the area, and the water has moved a long distance through the aquifer before reaching the study area. Water-level maps for other shallow aquifers indicate that the water movement is influenced by local topography. The higher contour values in the upland areas, and the lower ones near the streams, indicate that recharge and discharge occurs within the study area. Recharge to these aquifers is from local precipitation; discharge is to nearby streams.

Most recharge reaches the water table and near-surface artesian aquifers during two periods each year. Between the spring thaw and the beginning of the growing season water is available because plant transpiration is low; this water infiltrates into the unfrozen soil and moves down to the water table. Recharge also occurs in the interval between the first killing frost in the fall and before the ground is frozen in the late fall or winter. During most of the winter when the soil is frozen, very little water infiltrates the soil. During the growing season, vegetation intercepts most infiltrating moisture; only large rainstorms or periods of prolonged precipitation will provide enough water to satisfy the demands of plants and still offer an excess which might infiltrate to the saturated zone. Hence, water levels in water-table and near-surface artesian aquifers generally are highest in late spring and fall, and are lowest in late summer and winter.

During times of drought, recharge is minimal and the water table will fall because discharge is a continuous process. Many shallow wells in water table aquifers "go dry" in the summer and some winter periods. The wells go dry because the water table drops below the bottom of the well. These wells will usually contain water again when recharge is sufficient to raise the water table. Because water levels in water-table wells show considerable fluctuations, maps of water-table aquifers are usually based on water-level measurements made over a short period of time.

Water levels in artesian aquifers, especially those that are deeply buried, are only slightly affected by short-term changes in recharge. The major areas of recharge for these aquifers are usually miles or tens to hundreds of miles away, and the effects on the potentiometric surface due to variations in weather will be minimized because of the distance from the recharge area. Therefore, the potentiometric surface of deep artesian aquifers that are undisturbed by pumping fluctuates much less than water-table aquifers.

Water level recorder

In addition to fluctuations produced by weather, water levels also decline when artificial discharge through pumping wells is imposed on the hydrologic system. When water is removed by a well pumping from an unconfined aquifer, the water table at and near the well is lowered quickly. This causes a conical depression, a drawdown cone, in the water table around the pumped well (fig. 41). In aquifers that are under artesian conditions, the withdrawal of water has a similar effect in that it produces a depression in the potentiometric surface representing a decrease in the hydrostatic pressure in the aquifer around the well.

The size and shape of a drawdown cone around a pumping well depends on the characteristics of the aquifer and the rate and duration of pumping. Generally speaking, with the same pumping rate, the drawdown cone in an artesian aquifer is larger than one in a water-table aquifer. The diameter of the upper part of the cone in an artesian aquifer generally is measured in thousands of feet, whereas the diameter of the cone in an unconfined aquifer is measured in hundreds of feet.

When two or more pumping wells are located close to each other, their drawdown cones are likely to overlap (fig. 41). This interference may result in a decreased yield from each well and water levels may drop to the point where pumping costs become prohibitive. For this reason, wells pumping large volumes of water from the same aquifer should be spaced some distance apart. If data are available, analysis of aquifer characteristics can be used to determine the distances needed between wells to avoid interference or keep it within acceptable limits.

Continuous pumping of an artesian or water-table well at a constant rate will cause a continual lowering of the potentiometric surface or water table in the vicinity of the well and enlarging of the drawdown cone. The cone will spread until it covers an area large enough to intercept a sufficient amount of water to supply the demands of pumping. At this time, the water level will approach stability. Any increase in pumping rate will again lower water levels. At a reduced pumping rate, the drawdown cone will adjust by becoming shallower and smaller. If pumping is stopped entirely, water levels will return essentially to where they were before pumping began.

Owing to the inherent characteristics of water-table and artesian aquifers, each has its advantages and disadvantages. A water-table aquifer can usually sustain a moderate to large supply of water, because recharge is local and rapid. Several wells can be placed in a relatively small area because their drawdown cones are relatively small. Drawdown cones in an artesian aquifer tend to be large. Thus, most artesian wells must be widely spaced to minimize interference. The water levels in water-table wells are not excessively deep; therefore the cost of lifting the water is low. The water levels in artesian wells tend to be deep and because they may continue to decline with sustained pumping, the cost of lifting the water may become relatively high. A water-table aquifer is responsive to local short-term changes in weather; artesian aquifers, especially the deeper ones, are not greatly affected by short-term trends in the weather.

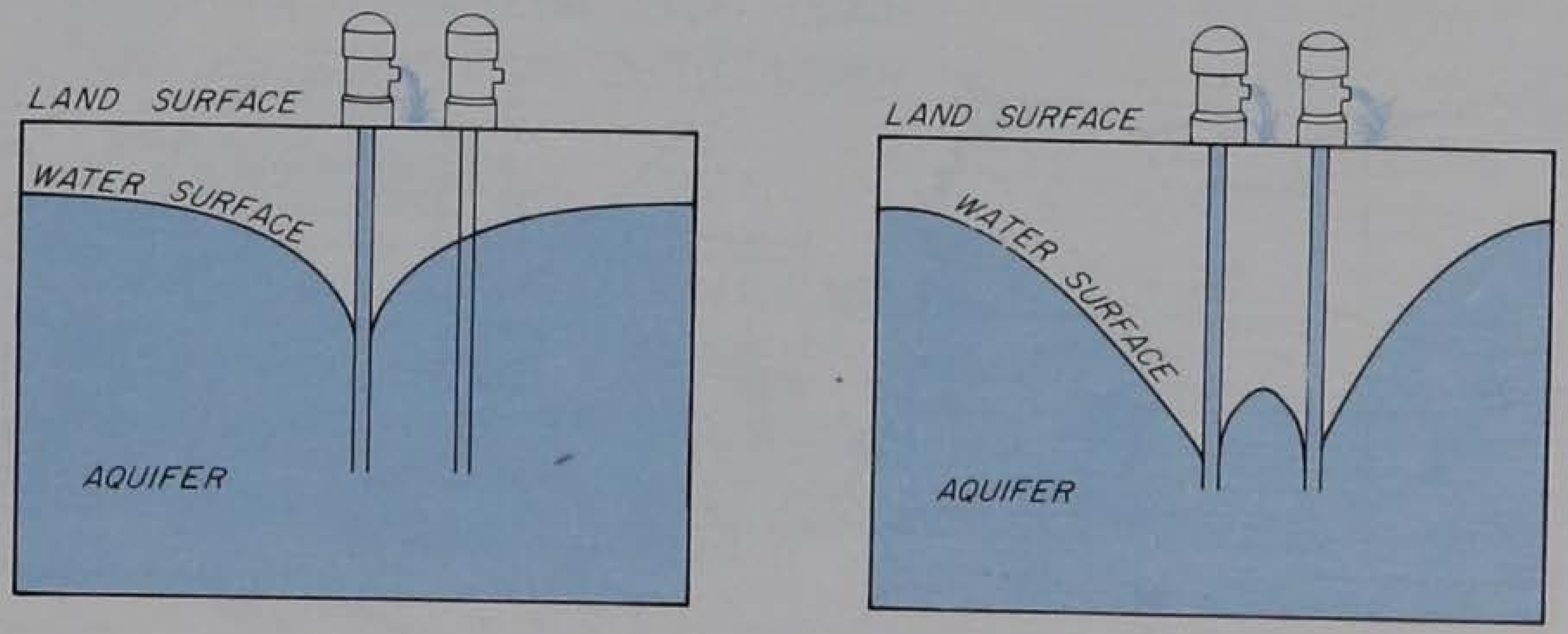


Figure 41.—Drawdown cones around pumping wells

Water Levels in Surficial Aquifers

A discussion of the complex hydrostatic head relationships within the surficial aquifers are beyond the scope of this report, and only a general discussion will be presented. Water levels in the surficial aquifers change noticeably throughout the year. Levels in drift, alluvial and buried-channel aquifers respond rapidly to recharge from precipitation. However, water levels in alluvial aquifers show a direct response to the stage (level) of associated streams. The depth to water in alluvial wells generally is from 4 to 20 feet below the flood-plain surface, and the depth to water will be accordingly deeper in wells located on adjoining terrace surfaces. Along the Mississippi River and for short distances upstream from the mouths of tributaries, water levels in the alluvial aquifers are sustained at or above the normal pool altitudes behind the navigation dams (fig. 42). Lower water levels will be found only in areas where the aquifer is subjected to heavy pumping or where drainage projects have been constructed.

Water levels in the drift aquifers commonly are from 10 to 50 feet below the land surface. The water table in the drift aquifer generally slopes from high topographic areas toward the streams. Those in the buried-channel aquifers occur at similar and greater depths; some have been reported to be as low as 200 feet below the land surface.

In a few locations, the potentiometric surfaces in some confined buried-channel aquifers are known to be above the land surface. This is true of the Belle Plaine Channel in the vicinity of Belle Plaine.

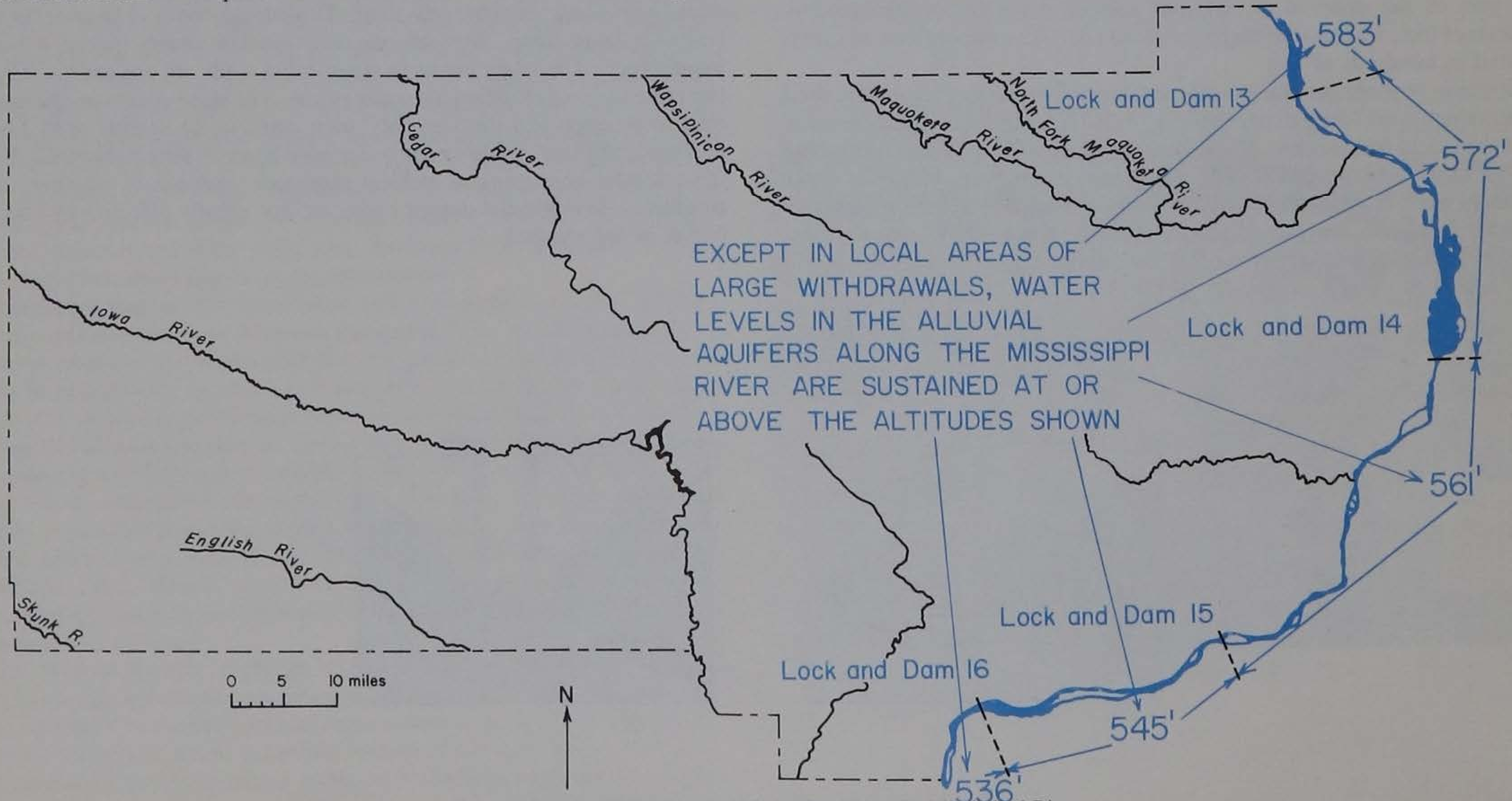


Figure 42.—Water levels in alluvial aquifers along the Mississippi River

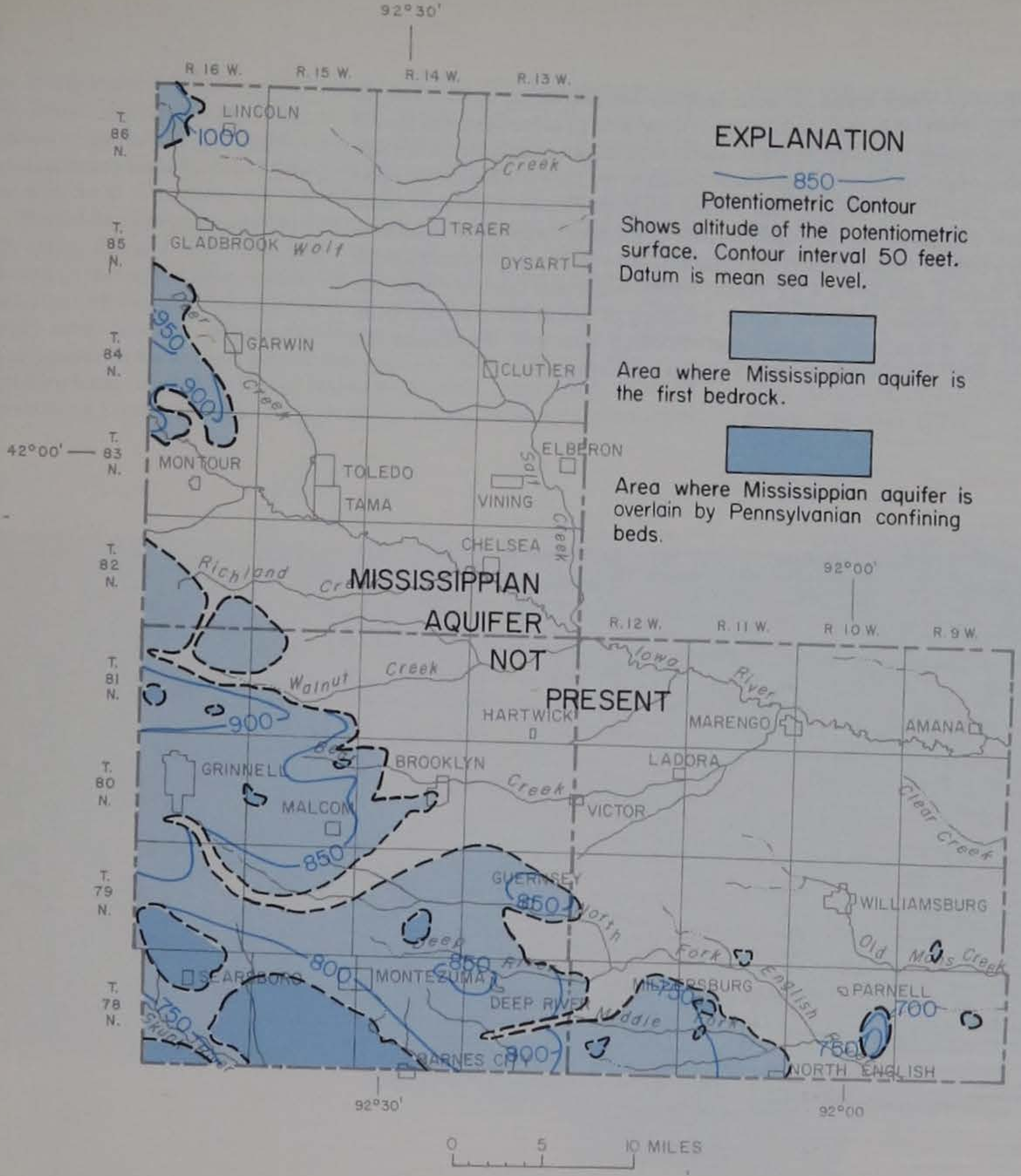


Figure 43.—Potentiometric surface of the Mississippian aquifer

Water Levels in Bedrock Aquifers

Water levels in the Mississippian aquifer range in altitude from less than 750 feet to more than 1,000 feet (fig. 43). The higher altitudes occur in major stream-divide areas and in the northern part of the area. Lower altitudes near streams and along some buried bedrock channels indicate aquifer discharge to the streams and bedrock channels.

The altitude of water levels in wells tapping the Devonian aquifer ranges from less than 550 feet in the southern part of the area to more than 900 feet in the northwest corner (fig. 44). In areas where the Devonian aquifer comprises the bedrock surface, relatively high water levels in the interstream divides and lower water levels near streams and buried bedrock channels indicate local recharge and discharge. In the southern part of the area, where the aquifer is covered by younger rocks, flow is regional and in a southeasterly direction. In the Cedar Rapids and Iowa City areas, many wells are open to both the Devonian and Silurian aquifers. Large volumes of water are pumped from these wells on a continuous basis, and resulting cones of depression are indicated in both the Devonian and Silurian aquifers.

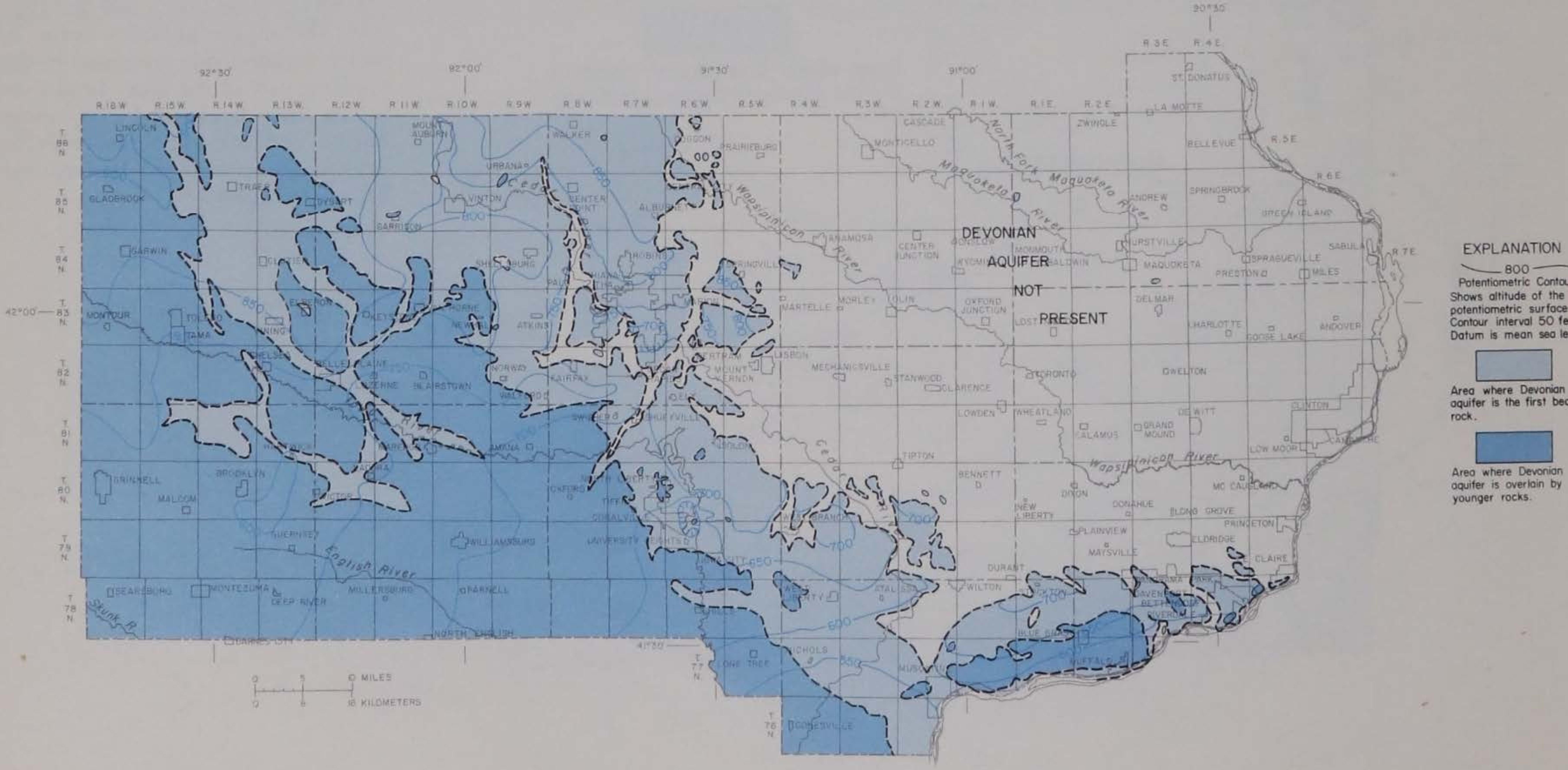


Figure 44.—Potentiometric surface of the Devonian aquifer

Water levels in the Silurian aquifer range from less than 600 to more than 900 feet above sea level (fig. 45). In the eastern half of the area, the potentiometric surface of the aquifer shows that it is locally recharged on upland interstream divides and discharges into nearby streams. In Jackson, Clinton, and Scott Counties, the potentiometric surface of the aquifer is greatly affected by discharge into the Goose Lake and Cleona buried bedrock channels (figs. 25 and 45). The high topographic relief in the extreme northeastern corner of the area, where the Silurian rocks form a near-vertical erosional escarpment, has caused the potentiometric surface to have a correspondingly steep gradient. Where the Silurian rocks are overlapped by the Devonian aquifer in the central part of the area, the flow regime is relatively unaffected by local relief. The buried bedrock channels, particularly those in which overlying Devonian rocks have been cut away, behave as subsurface drains which lower the potentiometric surface of the Silurian aquifer. This is clearly shown in Linn County (fig. 45). In most places where both aquifers are present, the potentiometric surface of the Devonian aquifer is higher than that of the Silurian aquifer because the Devonian is receiving local recharge and is partly separated from the underlying Silurian aquifer by discontinuous thin shale beds. However, in some areas where the Devonian potentiometric surface has been influenced by discharge into surface streams, the potentiometric surface of the Silurian aquifer is higher than that of the Devonian aquifer. In the west, where the Silurian aquifer is overlain by the Devonian aquifer and is deeply buried, most wells are open to both aquifers and independent water-level data on the Silurian aquifer therefore are not available. Although the Silurian aquifer is present in this area, it is not regarded as a major source of water.

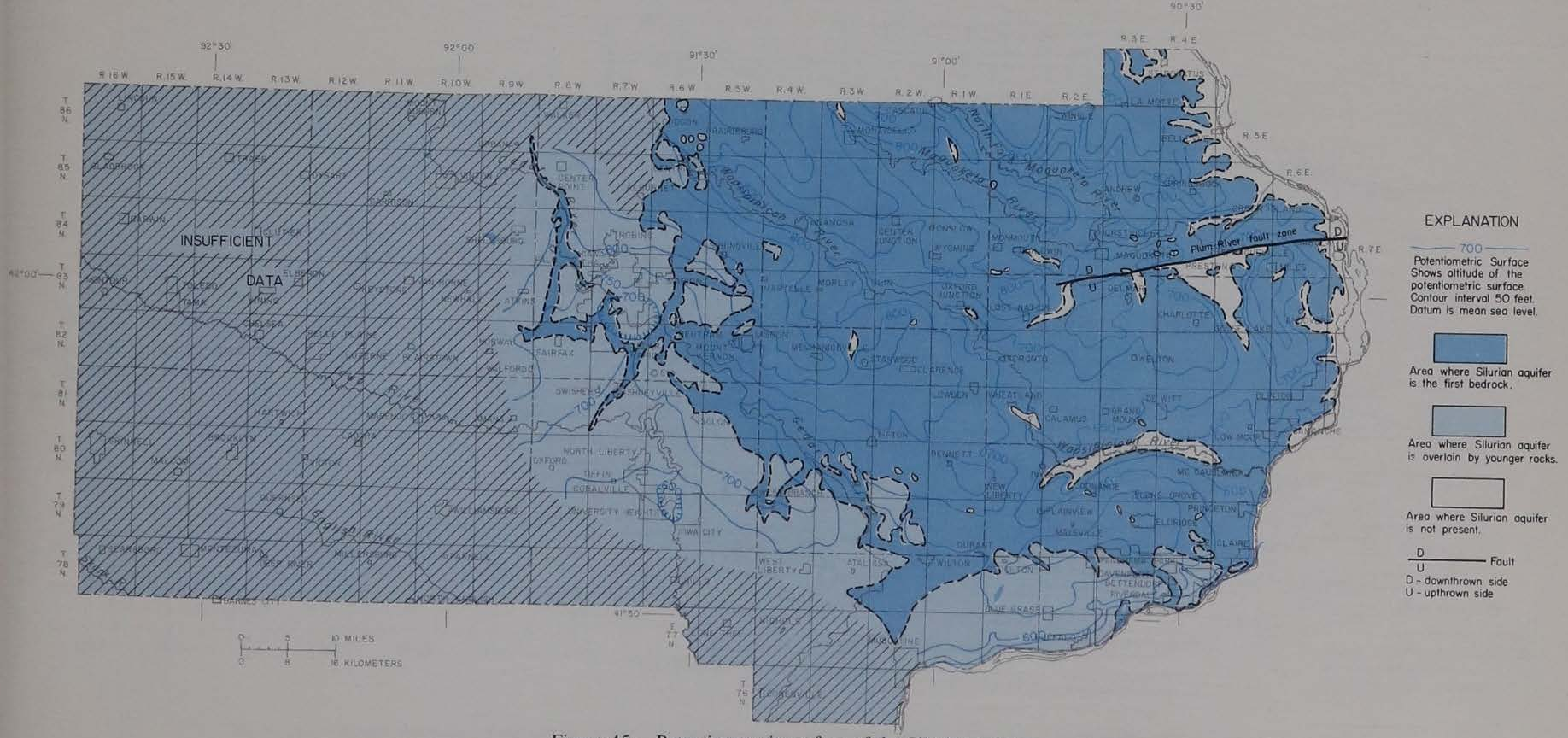


Figure 45.—Potentionmetric surface of the Silurian aquifer

A generalized reconstruction of the potentiometric surface of the Cambrian-Ordovician aquifer before it was extensively developed is shown in figure 46. This map is based on data from only a few early wells in and around the report area. The data indicate that early in the development history of the aquifer its potentiometric surface ranged in altitude from over 850 feet above sea level in the northwest corner to less than 600 feet in the southeast corner of the area.

Steadily increasing water withdrawals from the Cambrian-Ordovician aquifer have resulted in a continual lowering of the potentiometric surface. Major pumping centers withdrawing water from the aquifer have been established in Cedar Rapids, Grinnell, the Tama-Toledo area and the Iowa City-Coralville area. In Cedar Rapids, where pumping began in 1888, the potentiometric surface has been lowered about 200 feet in 88 years. In Grinnell the water level has been lowered about 114 feet in 49 years. At more recently developed pumping centers, a static head loss of approximately 100 feet in the last 14 years is indicated in the Tama-Toledo area, and in Anamosa a static head loss of 60 feet has occurred over a 7 year period.

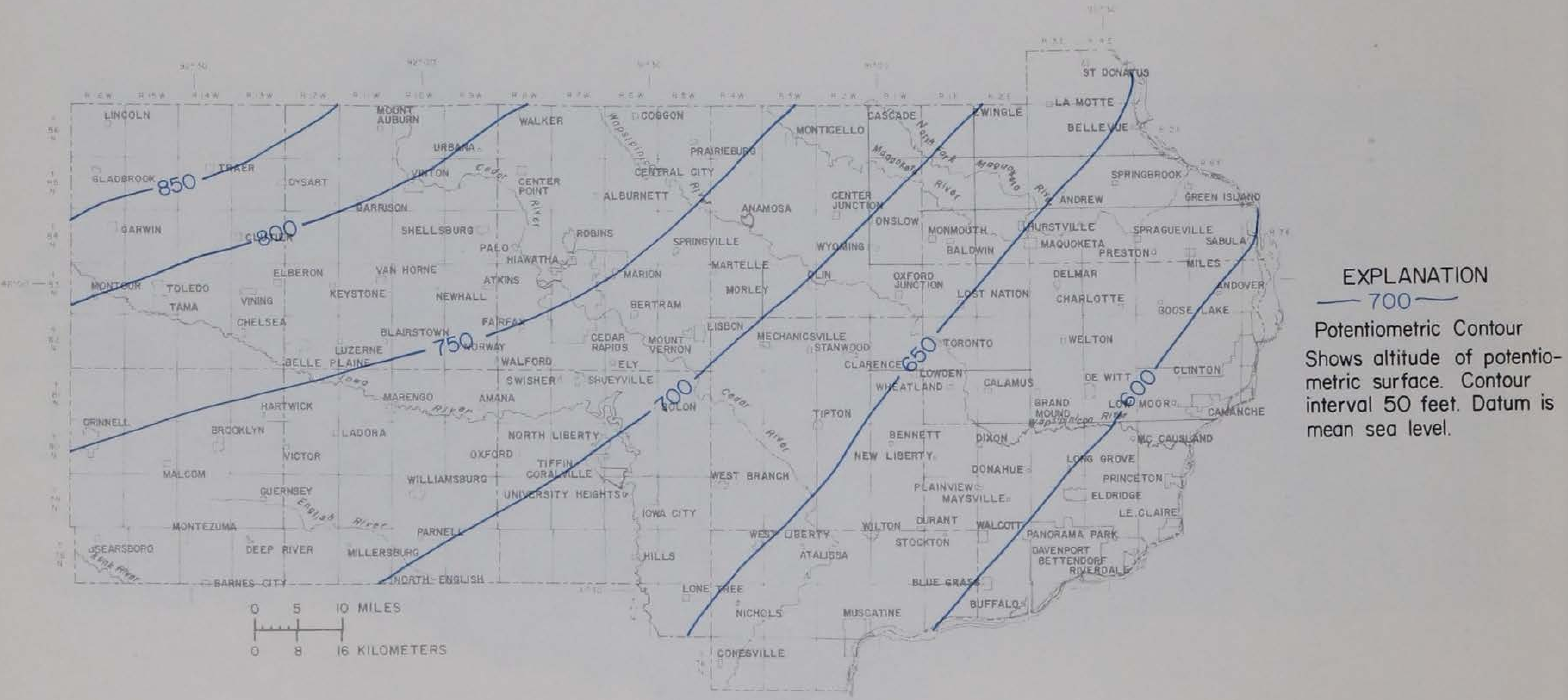


Figure 46.—Potentiometric surface of the Cambrian-Ordovician aquifer before extensive withdrawals began

The present (1975-76) potentiometric surface of the Cambrian-Ordovician aquifer and water-level trends at several pumping centers are shown in figure 47. Water withdrawals at the major pumping centers are still increasing. For this reason water levels at these centers are not stabilized, and the potentiometric surface is continuing to decline.

In the report area, the present (1976) potentiometric surface of the aquifer ranges from an altitude of more than 750 feet above sea level in the northwest corner, to less than 400 feet in the far eastern part of the area. The present regional flow of water in the aquifer is unchanged from the pre-development regional flow, from northwest to southeast. However, locally it is diverted toward the major pumping centers. Regionally the potentiometric surface has been lowered from 90 to 200 feet below predevelopment levels (figs. 46 and 47).

The potentiometric surface of the Dresbach aquifer cannot be accurately depicted because the few wells that tap the unit are usually open to several aquifers. In Jackson and Clinton Counties, subsurface data indicate that the Jordan Sandstone of the Cambrian-Ordovician aquifer, and the Galesville Sandstone of the Dresbach aquifer have been faulted into juxtaposition by the Plum River fault zone in the vicinity of Maquoketa (fig. 27). Potentiometric head relationships between the two aquifers are not known, but the lowered head in the vicinity of the Plum River fault zone (fig. 47) may indicate that the Cambrian-Ordovician aquifer is recharging the Dresbach aquifer along the fault zone. The only large pumping center using the Dresbach aquifer in east-central Iowa is at Clinton. Water withdrawals from the aquifer there began in the late 1800's and water levels had declined about 200 feet in the Clinton area by 1969.

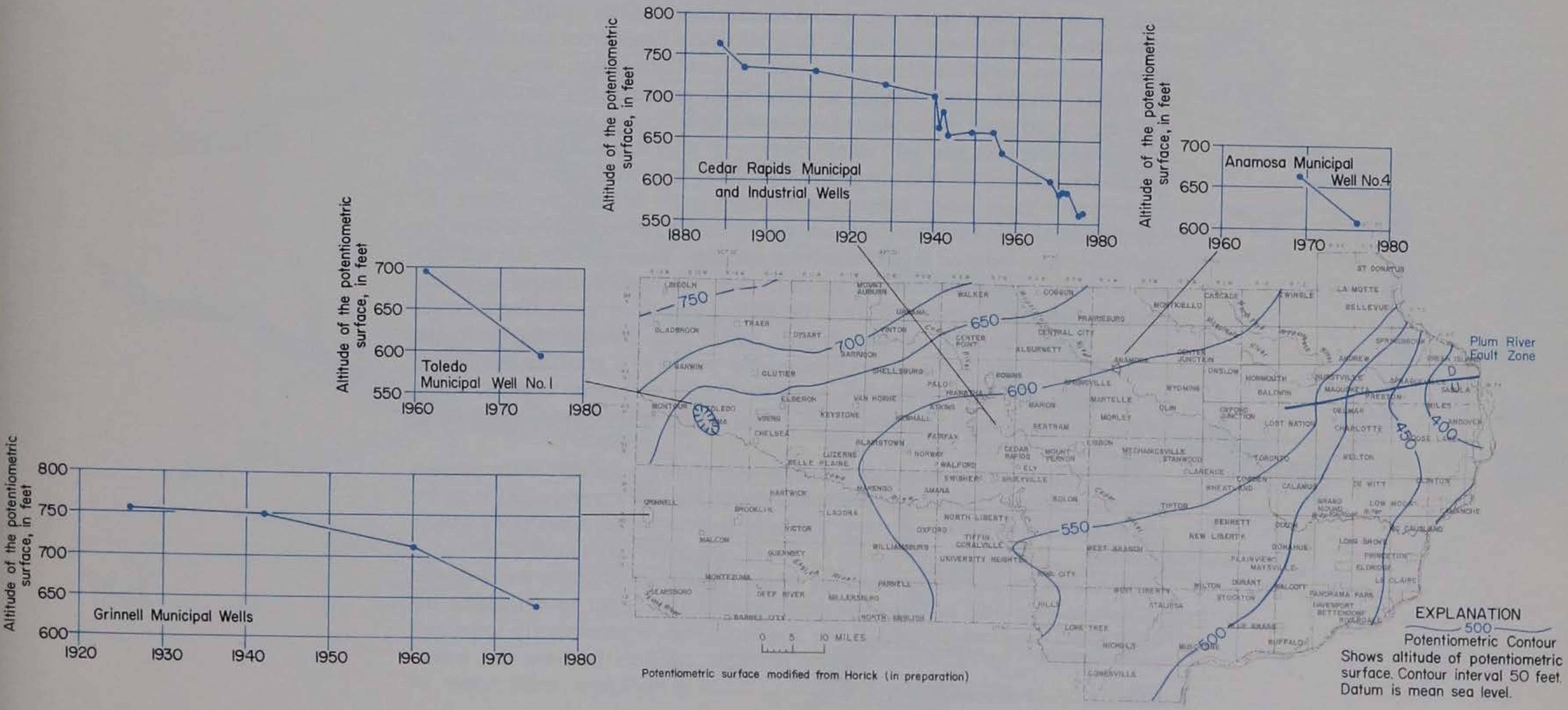


Figure 47.—Potentiometric surface of the Cambrian-Ordovician aquifer in 1975-76, and hydrographs for selected pumping centers

Well Yields

The rate at which water can be withdrawn from wells in the area is not only different for the various aquifers, but varies areally within each aquifer. On the next few pages, maps for each aquifer delineate probable yields that can be obtained from properly constructed wells. The data used in constructing these maps include production records of existing wells, drawdown of water levels at a given pumping rate, and regional geologic information.

Production records include the pumping rate and the drawdown, (the distance that the water level in the well declined while the well was pumped at that rate). From these data estimates are made of the probable maximum sustainable yield for a well. This value is independent of the capacity of the pump which may be installed in the well.

Geologic data indicate the type of rock that comprises each aquifer, the thickness of the rock units, the spatial relationships of the aquifers, and the characteristics of the rock openings. In areas where limestones and dolomites lie near the land surface and are not covered by confining beds, one can expect any joints, cracks, and fissures to have been enlarged by solution. This facilitates more rapid movement of water into and through the aquifer than in areas where the rock has only small openings. Other factors being equal, the thicker the aquifer the more water it will yield to a well. Sand and gravel deposits will yield more water to individual wells in localities where the deposits are exposed at the surface and can be recharged readily by infiltrating precipitation or induced infiltration from streams. Thus, the alluvial aquifers will normally yield more water to wells than the buried-channel aquifers, which are often deeply buried. In some areas where alluvial aquifers directly overlie buried-channel aquifers, higher yields may be expected from the combined aquifers. If the spaces between the grains of a granular aquifer are partly filled with other materials, such as clay or carbonate cement, water cannot move through the aquifer as readily, and a reduction in yields to individual wells will result.

The following yield maps are based on information available at the present time and represent known and predicted yields from the several aquifers in the report area. As new data are made available more accurate predictions will be possible.

An important part of the planning phase for high-production wells should include test-drilling and test-pumping programs in order to determine the water-producing capabilities of the aquifers. This is particularly important when planning development of the surficial aquifers because the water-yielding sands and gravels are seldom uniform in thickness, areal extent, or hydrologic character.

Yields from Surficial Aquifers

The three surficial aquifers — the alluvial, buried-channel, and drift aquifers — have a wide range of potential yield.

Actual yields from the alluvial aquifers range from less than 50 to more than 1600 gpm. For most of the larger deposits, yields in excess of 100 gpm may be expected and larger yields are common (fig. 48). Alluvium in the Mississippi River Valley consistently has the highest yields, with many wells producing over 1000 gpm. Yields from the alluvium of the major tributary rivers are generally lower and more variable; exceptions are places where alluvium is superposed over buried-channel sand deposits, such as at Cedar Rapids. The wells in a municipal well field there yield over 100 gpm. Generally, the larger alluvial aquifers have the highest yields, and the yields tend to increase downstream.

Figure 48.—Possible yields to individual wells; alluvial aquifers

Actual yields from buried-channel aquifers range from 20 to 640 gpm. Yields between 50 and 100 gpm can generally be anticipated from these aquifers. The yields generally tend to increase toward the south, the direction toward which most of the channels originally drained. The highest potential yields may be expected in parts of the Cleona, Poweshiek, and Belle Plaine Channels which are the largest buried channels in the region. See figures 23 and 49. In the western half of the region, Hartwick, Williamsburg, and several other small communities have obtained adequate water supplies from these aquifers.

Actual yields from the drift aquifers are generally less than 20 gpm, although yields as high as 150 gpm have occasionally been obtained. Of the surficial aquifers, yields from the drift aquifers are the least predictable. Because of the low yields, drift aquifers generally are only used to supply water for rural domestic and livestock supplies.

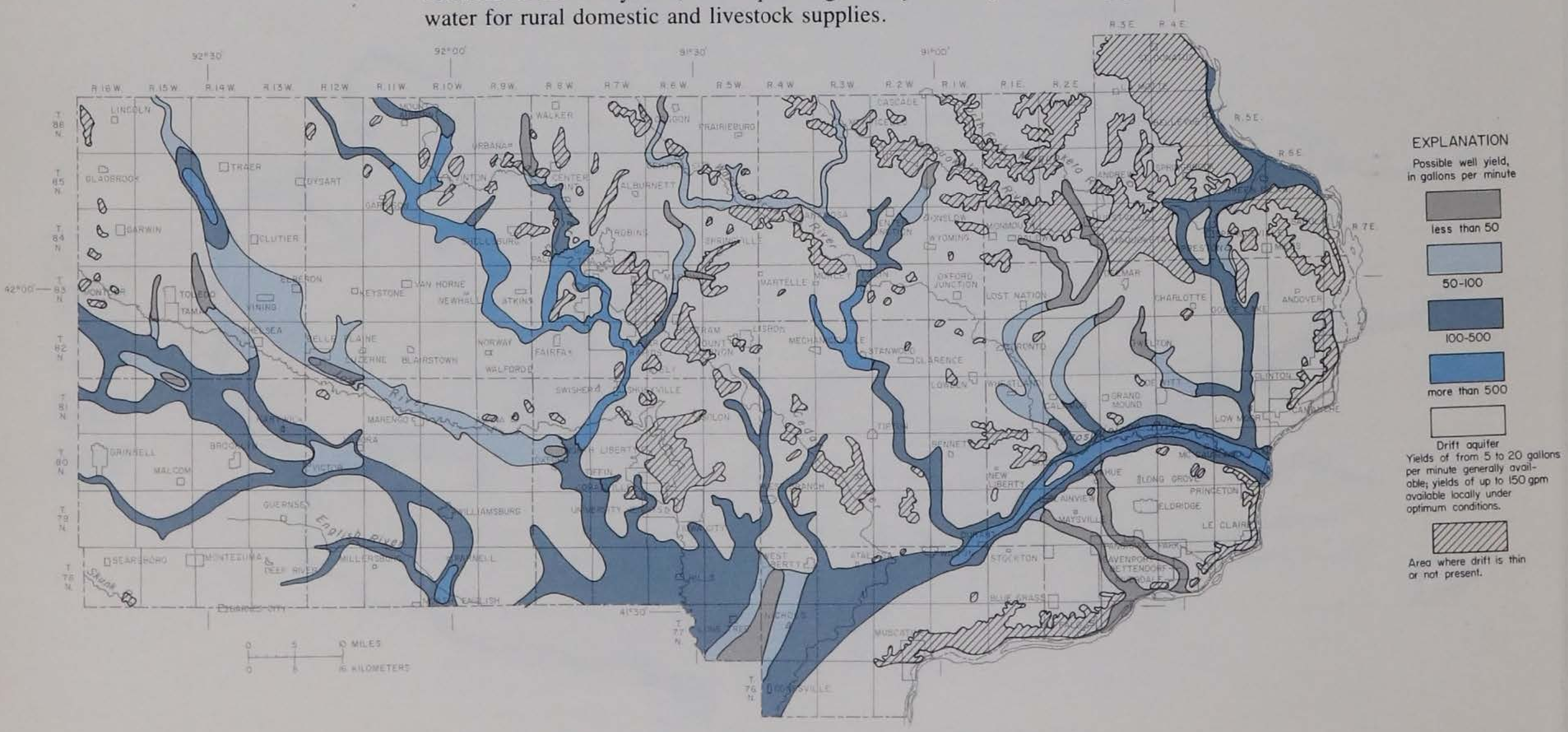


Figure 49.—Possible yields to individual wells; buried-channel and drift aquifers

Yields from Bedrock Aquifers

Potential yields from the Mississippian aquifer range from less than 10 to 150 gpm (fig. 50). The lowest yields are usually adjacent to the boundaries of the aquifer, and probably reflect thinning of the aquifer. High-yield areas are local, and do not fit a regional pattern. These areas have probably been locally influenced by solution enlargement of secondary openings. Typical yields for the Mississippian aquifer range between 20 and 30 gpm. The use of the aquifer in the area is almost exclusively restricted to private-domestic and livestock supplies.

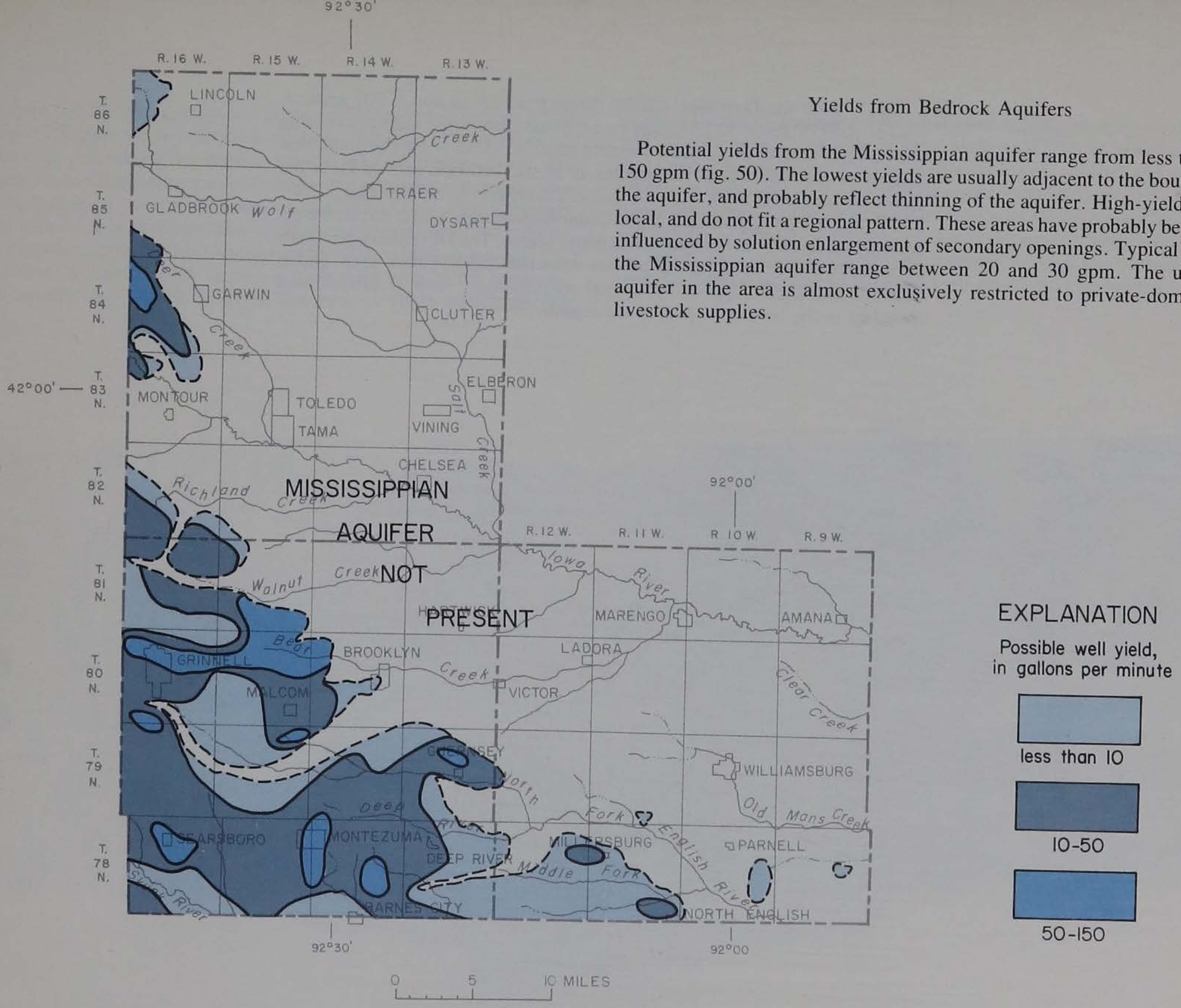


Figure 50.—Possible yields to individual wells; Mississippian aquifer

Yields from the Devonian aquifer range from 50 to about 300 gpm. A typical yield of about 50 gpm may be expected from wells fully penetrating this aquifer. One of the highest yielding areas is found along the southwest margin of the belt where the aquifer is at the bedrock surface. Here the Devonian aquifer is thick and able to receive relatively rapid recharge (fig. 51). Another high yield-area is in the Cedar Rapids area, where the Devonian aquifer is at or near the land surface in many places. The Devonian aquifer is a dependable source of water for private domestic and livestock uses, and is used for municipal supplies by several communities, such as Lincoln and Dinsdale in the northwest part of the region.

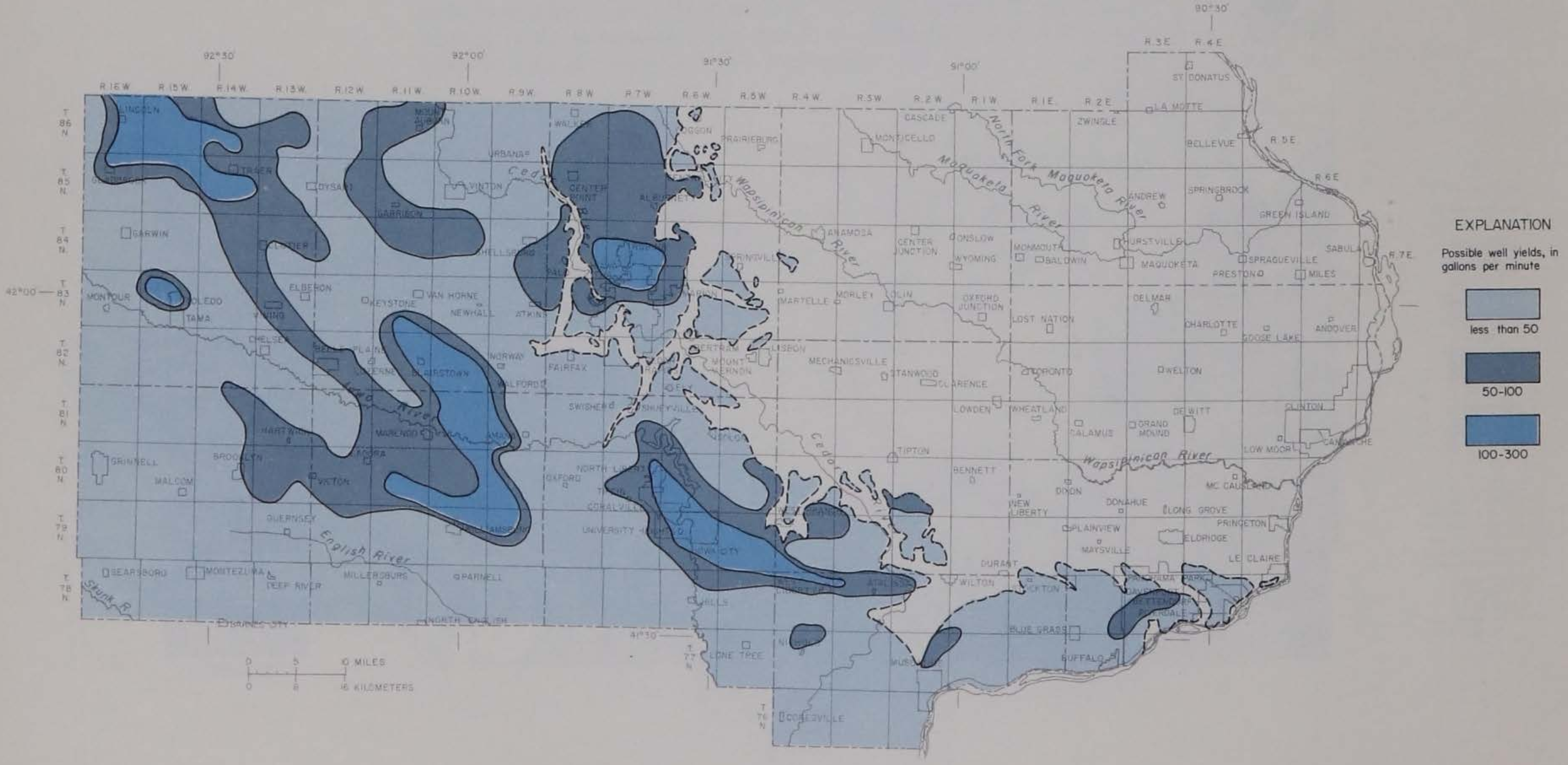


Figure 51.—Possible yields to individual wells; Devonian aquifer

Yields from the Silurian aquifer are highly variable, ranging from a few tens to about 700 gpm. A typical yield of about 100 gpm may be expected from wells fully penetrating the aquifer. As with the Devonian aquifer, the highest yields in the Silurian aquifer are found in the area where younger rocks are just beginning to overlap the aquifer (fig. 52). This area is largely coincident with the area of the greatest thickness of the aquifer. Also because the aquifer is at or near the bedrock surface, infiltration is relatively rapid. The high-yield area in Linn County is also a high-yield area in the overlying Devonian aquifer (fig. 51). It is likely that both of these carbonate-rock aquifers are highly fractured with subsequent modification by solution in this area. The localization of some isolated high-yield areas in the eastern half of the region is suggestive of karst formation within the aquifer, and may also be related to fracturing of the aquifer along the extrapolated trend of the Plum River fault zone. The Silurian aquifer is extensively developed for municipal and industrial supplies in the eastern part of the region. In the western half of the report area, many wells have been drilled through the Devonian aquifer into the Silurian aquifer to augment their production capacities.

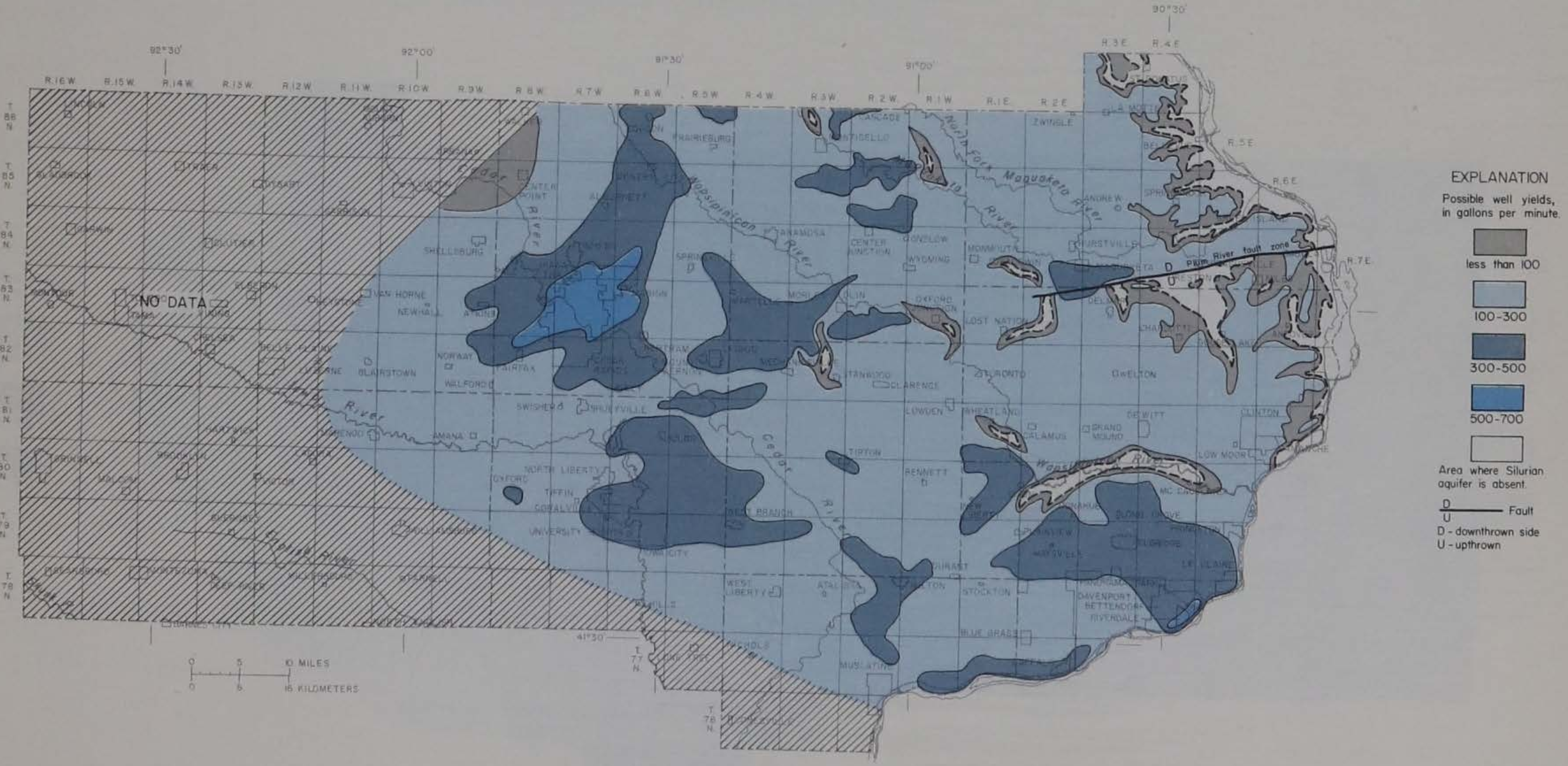


Figure 52.—Possible yields to individual wells; Silurian aquifer

Yields from the Cambrian-Ordovician aquifer are the most consistent and dependable of any aquifer in the report area. The aquifer has been extensively developed for municipal and industrial supplies throughout the area; actual yields range from 100 to 2300 gpm. Potential yields of at least 500 gpm may be anticipated from properly-developed wells in most places (fig. 53). Yields of 1000 gpm can be obtained in all but the easternmost part of the area, if drawdown of water levels are not a major concern. High-yield areas of the aquifer are, in part, controlled by the thickness and degree of cementation of the Jordan Sandstone, a principal water-bearing zone. The upper part of the Cambrian-Ordovician aquifer, the St. Peter Sandstone and the Prairie du Chien Formation (table 2) will also yield dependable supplies of water. Wells drilled into the upper part of the aquifer generally produce at least 50 gpm, and yields up to 300 gpm are not unusual. Several communities in the eastern half of the report area obtain adequate municipal supplies from the upper part of the Cambrian-Ordovician aquifer.

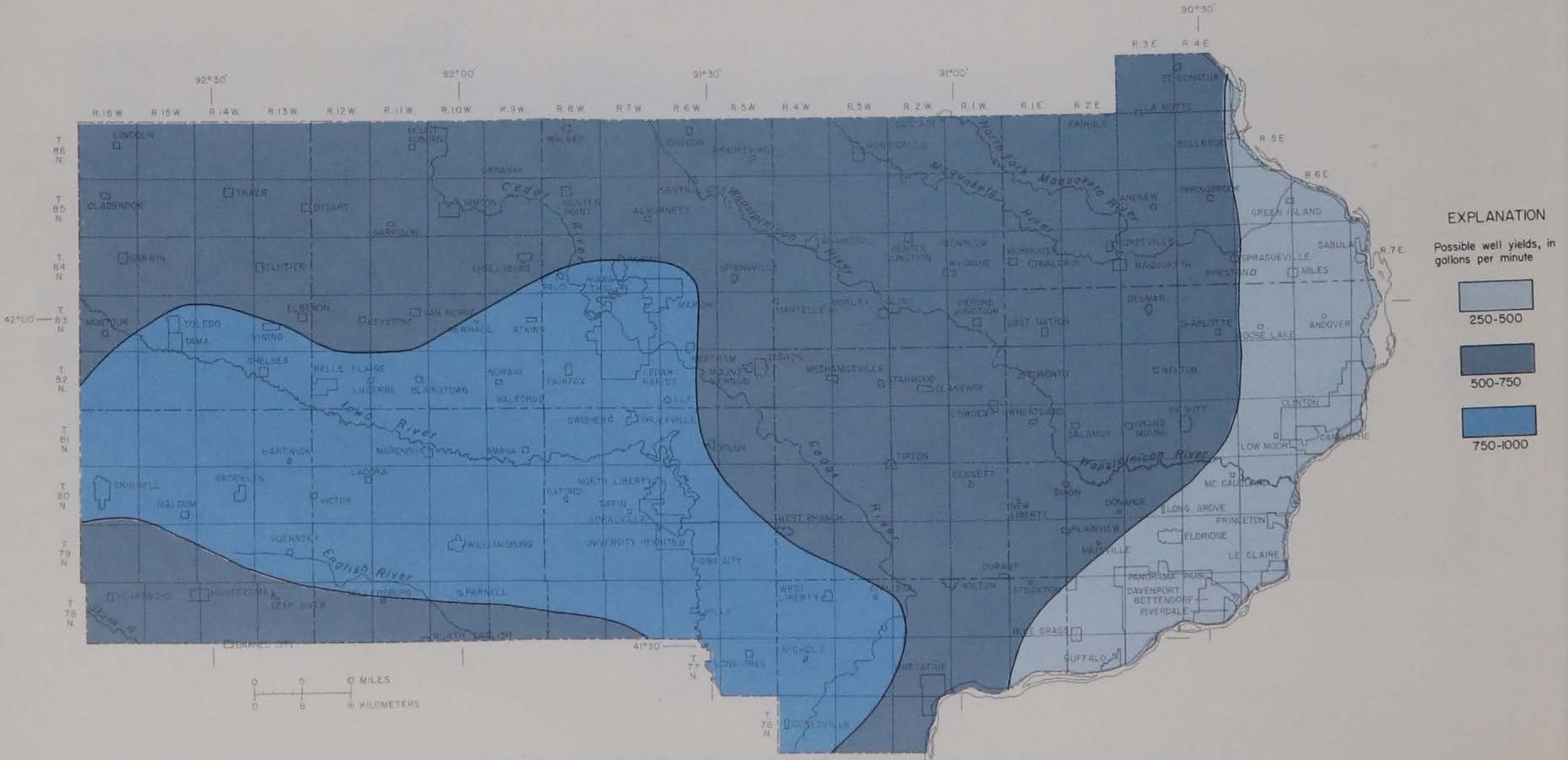


Figure 53.—Possible yields to individual wells; Cambrian-Ordovician aquifer

In the eastern part of the report area, the Dresbach aquifer is a very consistent and dependable water producer. Actual yields in this area range from 280 to 2560 gpm, and yields of at least 500 gpm are common in most wells penetrating the aquifer. The highest yields in the report area are in the Clinton area (fig. 54). Yields from the aquifer appear to attenuate rapidly to the west, where the aquifer is not used because of poor water quality. A notable exception is found in the Maquoketa area, where high production capacities are found in two municipal wells. In this area, geologic data indicate that the Jordan Sandstone of the Cambrian-Ordovician aquifer and the Galesville Sandstone of the Dresbach aquifer have been faulted into juxtaposition in the Plum River fault zone. The high yields found in this area may in part be due to continuity between the two aquifers.

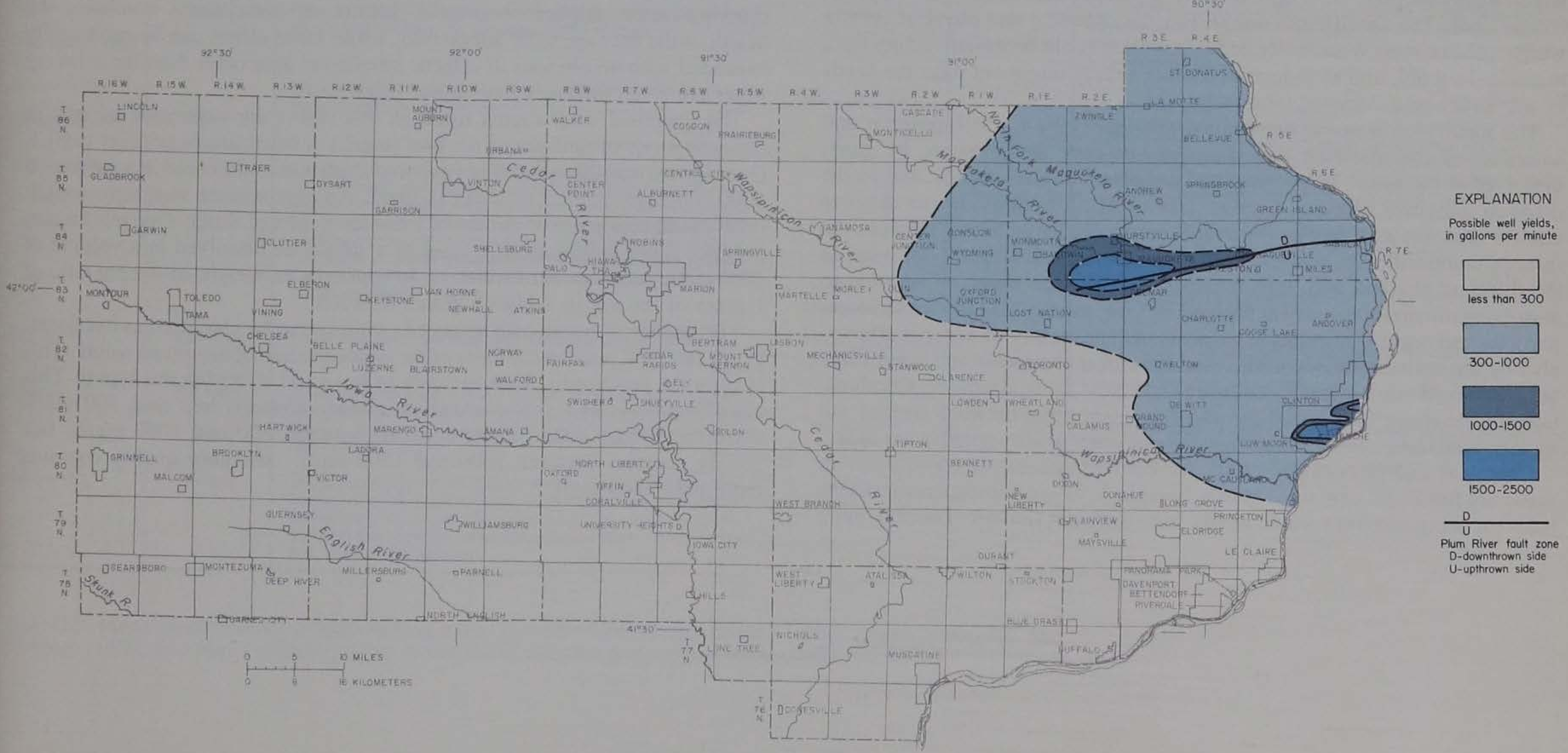


Figure 54.—Possible yields to individual wells; Dresbach aquifer

WATER QUALITY

Water quality is a major factor in the development and operation of any water-supply facility, be it agricultural, domestic, industrial, municipal, or recreational. The specific use establishes the chemical and physical criteria which must be met. Water suitable for irrigation could be unsatisfactory for a municipal supply, and an industrial cooling supply might not meet the needs of a brewery or a commercial laundry.

The quality of water is determined principally by the composition and solubility of the materials that water moves over and through, by gases dissolved in the water, by pressure and temperature relationships, and by the disposal activities of man. Ground water has an opportunity to dissolve aquifer minerals as it moves from recharge to discharge areas. Because the mineral composition of aquifers are diverse, the chemical quality of water in the different aquifers will vary considerably. Surface water, in addition to dissolving minerals on and near the land surface, usually also carries sediment particles and organic mateials in suspension. The quality of water is affected also by the agricultural, domestic, and industrial chemicals and wastes that are discharged into waterways and onto and below the land surface. Combinations of the above factors and the intimate relationship between surface and most ground waters result in a wide variety of water quality noted in any area.

Chemical and physical properties of common chemical constituents of water are listed and explained briefly in table 3. These constituents form the basis for comparisons of water quality from different sources. The maximum recommended concentrations shown are limits established by the U.S. Public Health Service as standards for interstate carriers and are suggested for drinking-water supplies in general. Limits on constituents involving the health of the user are to be adhered to, while some others can be moderately exceeded with no obvious ill effects. Limits for uses other than for drinking water are often different from those listed.

The chemical constituents listed in this report are expressed as ions in concentrations of milligrams per liter (mg/L) or micrograms per liter (ug/L). One mg/L is one-thousandth of 1 gram of a substance dissolved in a volume of 1000 cubic centimeters of water (1 liter). An approximate weight-to-weight ratio would be 1 gram of the ion in 1 million grams of water. One microgram per liter is one-millionth of 1 gram of a substance dissolved in a volume of 1000 cubic centimeters of water, or an approximate weight-to-weight ratio of 1 gram of the ion in 1 billion grams of water.

The quality of water with respect to salinity can be classified as excellent, good, fair, and poor on the basis of the concentration of dissolved solids. This is common practice by State agencies in Iowa and is used in this report. This classification is as follows: excellent quality contains less than 500 mg/L dissolved solids; good quality contains between 500 and 1000 mg/L, fair quality contains between 1000 and 1500 mg/L, and poor quality contains more than 1500 mg/L.

Table 3. — Significance of chemical constituents and physical properties of water

Constituent or Property	Maximum Recommended Concentration	Significance
Iron (Fe)	300 ug/L	Objectionable as it causes red and brown staining of clothing and porcelain. High concentrations affect the color and taste of beverages.
Manganese (Mn)	50 ug/L	Objectionable for the same reasons as iron. When both iron and manganese are present, it is recommended that the total concentration not exceed 300 ug/L.
Calcium (Ca) and Magnesium (Mg)		Principal causes for hardness and scale-forming properties of water. They reduce the lathering ability of soap.
Sodium (Na) and Potassium (K)		Impart a salty or brackish taste when combined with chloride. Sodium salts cause foaming in boilers.
Sulfate (SO_4)	250 mg/L	Commonly has a laxative effect when the concentration is 600 to 1,000 mg/L, particularly when combined with magnesium or sodium. The effect is much less when combined with calcium. This laxative effect is commonly noted by newcomers, but they become acclimated to the water in a short time. The effect is noticeable in almost all persons when concentrations exceed 750 mg/L. Sulfate combined with calcium forms a hard scale in boilers and water heaters.
Chloride (Cl)	250 mg/L	Large amounts combined with sodium impart a salty taste.
Fluoride (F)	2.0 mg/L	In east-central Iowa, 0.8 to 1.3 mg/L of fluoride is the recommended concentration range for water supplies containing fluoride. Excessive quantities can cause discoloration of children's teeth.
Nitrate (N)	10 mg/L	Waters with high nitrate content should not be used for infant feeding or for very young livestock as it can cause methemoglobinemia or cyanosis. High concentrations suggest organic pollution from sewage, decayed organic matter, nitrate in the soil, or chemical fertilizer.
Dissolved Solids	500 mg/L	This refers to all the material in water that is in solution. Amounts over 2000 mg/L will have a laxative effect on most persons. Amounts up to 1,000 mg/L are generally considered acceptable for drinking purposes if no other water is available.
Hardness (as $CaCO_3$)		Hardness, together with other chemical parameters, affects the lathering ability of soap. Hardness is primarily due to dissolved calcium and magnesium; and is reported in terms of an equivalent amount of calcium carbonate. Water becomes objectionable for domestic use when the hardness is greater than 100 mg/L; however, this can be easily remedied by using a water softener.
Phosphate (PO_4)		An aquatic plant nutrient which can cause noxious algal growths (blooms) in flowing and standing water. This often results in odor and taste problems. Usually will not cause problems if less than 0.30 mg/L in flowing streams, or 0.15 mg/L in water entering ponds or reservoirs. Amounts over 0.30 mg/L can cause difficulties with coagulation processes in water treatment. Common sources are industrial and domestic sewage effluents, plant and animal wastes, and fertilizer and sediment from erosion of agricultural areas.
Organic Nitrogen		Nitrogen from plant and animal sources in its unoxidized state.
Chemical Oxygen Demand (COD)		The amount of oxygen needed to oxidize the biological and organic chemical materials, such as industrial wastes, in the water.
Temperature		Affects the desirability and economy of water use, especially for industrial cooling and air conditioning. Most users want water with a low and constant temperature.

See: U.S. Public Health Service (1962); Federal Water Pollution Control Administration (1968); Brown, Skougstad, and Fishman (1970); and Hem (1970) for further discussion of chemical and physical water quality parameters.

SURFACE-WATER QUALITY

Sediment in Streams

Sediment is one of the principal pollutants in Iowa streams. It is derived from sheet and gully erosion on the land surface, and from erosion of the bed and banks of stream channels. In addition to the loss of valuable topsoil, many detrimental effects are associated with sediment in streams. These include deposition of infertile sand upon flood plains; obstruction of drainageways; increased inundation due to decreased channel capacity; loss of storage space in reservoirs; damage to pumps and other facilities at water filtration plants; depostion on roadbeds, and blockage of bridge and culvert openings through highway and railroad embankments; hazards to river navigation and increased maintenance costs; destruction of feeding and nesting areas for fish and other aquatic life; and impairment of recreational values.

A wealth of information on fluvial sediment in the Upper Mississippi River basin is contained in a report to the Upper Mississippi River Comprehensive Basin Study Coordinating Committee (1970, Appendix G). The data in table 4 and figure 55 are taken from that report. These show that the highest sediment yields are in the southern and western two-thirds of east-central Iowa. The lowest yields are in the Wapsipinicon basin in the north-central part of the area. From the diagram in figure 55, it is obvious that the natural sediment yields in east-central Iowa generally do not violate the State's soil-loss limitation of 5 tons per acre per year, or 3200 tons per square mile per year.

Sediment concentrations vary widely. Minimum concentrations are near zero. Maximum concentrations, which are associated with flood periods, depend upon rainfall intensity, season, and condition of the surface contributing runoff. A concentration of 76,400 mg/L was observed in Ralston Creek in July 1958. Fluvial sediment in east-central Iowa is composed predominantly of silt and clay. For the Cedar River at Cedar Rapids and Ralston Creek at Iowa City, sediment compositions were approximately 50 percent silt, 40 percent clay, and 10 percent sand; for the Wapsipinicon River near DeWitt and the Iowa River at Marengo, they were approximately 75 percent silt, 20 percent clay, and 5 percent sand. Detailed information on sediment concentrations, loads, and particle sizes is published annually in the water-resources-data reports of the U.S. Geological Survey.

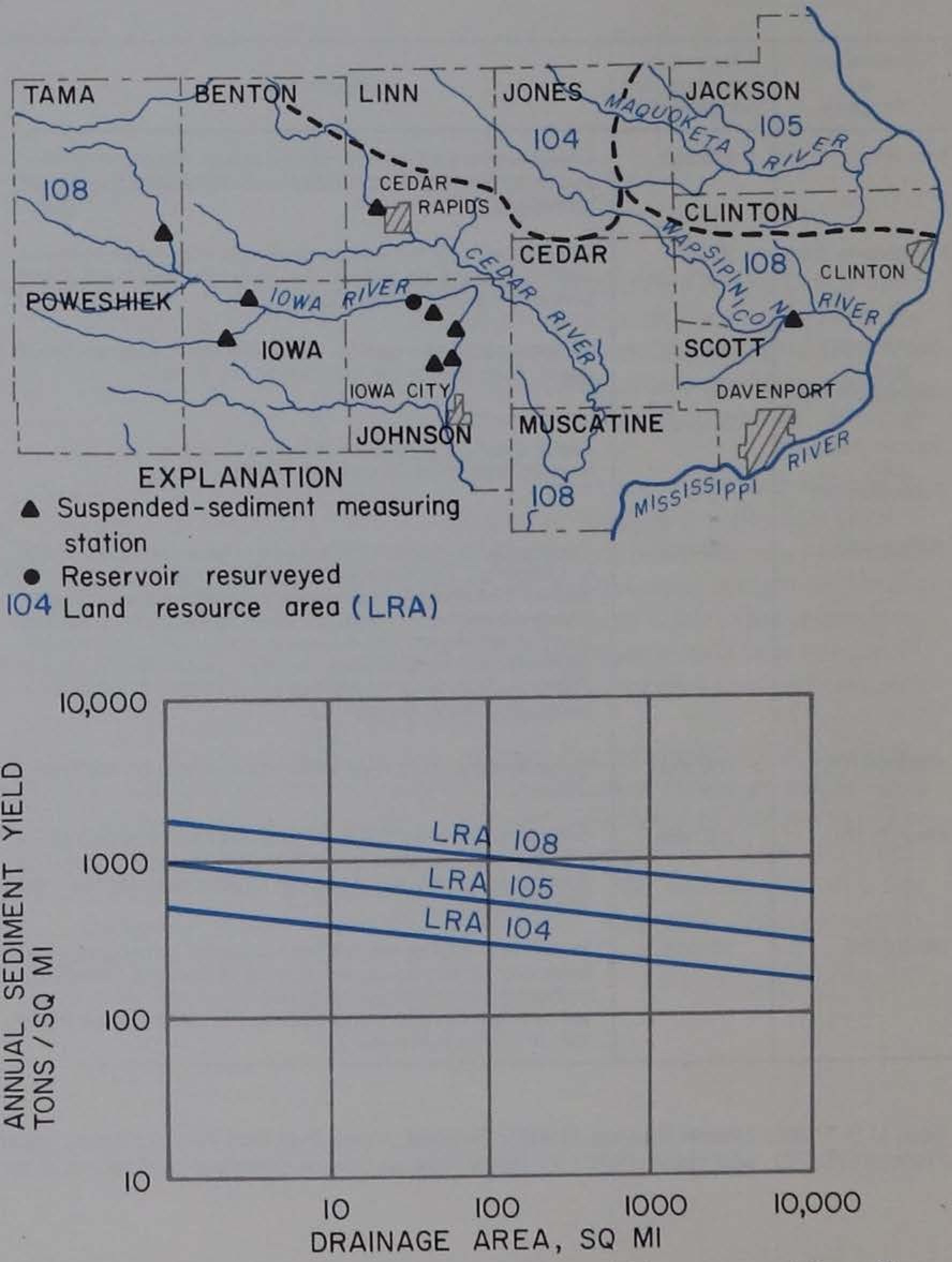


Figure 55.—Land-resource areas and annual sediment yields, east-central Iowa (from UMRCBS Coordinating Committee, 1970, App.G)

Table 4. Annual sediment yields for sediment stations in east-central Iowa.
[CE, U.S. Army Corps of Engineers; GS, U.S. Geological Survey]

Station No.	Stream	Drainage area (sq mi)	Annual sediment yield* (tons/sq mi)	Agency supplying data
054220	Wapsipinicon River near DeWitt	2330	221	CE
054520	Salt Creek near Elberon	201	1083	CE
054530	Big Bear Creek at Ladora	189	962	CE
054531	Iowa River at Marengo	2794	365	CE
054534	Iowa River above Coralville	3035	445	GS
054535.1	Coralville Lake, Iowa River	3076	436±	CE
054540	Rapid Creek near Iowa City	24.6	600	GS
054545	Iowa River at Iowa City	3271	260	GS
054550	Ralston Creek at Iowa City	3.01	1800	GS
054645	Cedar River at Cedar Rapids	6510	120	GS

* Adjusted to represent 20-year period 1945-64.
± From reservoir sedimentation survey

Chemical Quality

The chemical quality of surface water flowing past a certain point may change continuously. Runoff from a basin comes from two primary sources: (1) that which flows either over the land or through the soil at shallow depths; and (2) ground water seepage that is the source of the base flow to streams. The dissolved mineral content of stream water usually is lowest when it is principally runoff from snowmelt or recent precipitation. Higher concentrations occur when the major part of the stream water is ground-water seepage. Although these generalizations are true for total concentrations, the concentration of some constituents may vary independently of flow. Man's activities, such as the discharge of municipal or industrial wastes, also may alter the chemical quality of some streams.

Chemical analysis of water samples collected at 12 sites in east-central Iowa delineate some of the variations in surface-water quality (table 5). These samples include a broad range of drainage-basin sizes and flow conditions. The following generalizations are based on these chemical analyses.

Table 5. — Chemical analyses of stream water at selected sampling sites 1975 water year.

Except as noted, values are for dissolved constituents and are in milligrams per liter. Chemical analysis by State Hygienic Laboratory of Iowa.

Date Collected	Time Collected	Discharge (cfs)	Silica (SiO_2)	Iron (Fe) (ug/L)	Manganese (Mn) (ug/L)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity (as $CACO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (N)	Nitrite (N)	Ammonia Nitrogen (N)	Organic Nitrogen (N) total	Phosphate (PO_4) total	Phosphate (PO_4) total soluble	Dissolved Solids - total	Hardness as $CaCO_3$	Non-Carbonate Hardness	Specific Conductance (Micromhos at 25°C)	pH - Units	Temperature (°C)	Arsenic (As) (ug/L)	Barium (Ba) (ug/L)	Cadmium (Cd) (ug/L)	Chromium (Cr) (ug/L)	Copper (Cu) (ug/L)	Lead (Pb) (ug/L)	Nickel (Ni) (ug/L)	Silver (Ag) (ug/L)	Zinc (Zn) (ug/L)	Suspended Sediment
05418500 — MAQUOKETA RIVER NEAR MAQUOKETA, IOWA																																					
NOV. 25...	1000	652	9.6	70	20	73	33	8.8	2.0	341	7	292	31	10	.2	2.3	.02	.05	.32	.28	.15	391	312	20	580	8.1	3.0	—	—	—	—	—	—	—	—	—	—
MAR. 18...	0915	858	9.6	80	20	61	29	7.2	3.1	268	0	220	43	11	.2	2.2	.04	.51	1.2	1.1	.37	310	272	52	510	8.0	3.0	—	—	—	—	—	—	—	—	—	440
JUNE 23...	1000	1290	9.8	10	<10	63	24	7.4	2.7	243	0	199	45	12	.2	3.9	.04	.11	.87	.43	.43	326	256	57	480	8.1	25.6	<10	100	<10	<10	<10	<10	<10	<10	10	158
05453100 — IOWA RIVER NEAR MARENGO, IOWA																																					
NOV. 26...	1415	1030	14	10	10	89	31	8.6	1.5	317	5	268	71	15	.2	4.9	.02	.08	.52	.43	.31	382	340	72	550	8.5	2.0	—	—	—	—	—	—	—	—	—	—
MAR. 19...	1150	6800	6.6	190	200	22	3.9	4.5	8.3	67	0	55	21	8.0	.1	1.2	.07	1.6	4.6	3.7	1.5	121	72	17	265	7.9	.5	—	—	—	—	—	—	—	—	—	1260
JUNE 24...	1345	8750	9.7	410	10	33	10	3.3	3.1	121	0	99	21	7.0	1.2	3.0	.07	.09	11	5.2	.31	210	120	25	265	7.4	22.6	<10	1200	<10	100	90	90	<10	<10	340	4630
05422000 — WAPSIPINICON RIVER NEAR DE WITT, IOWA																																					
NOV. 25...	1100	562	7.3	40	10	67	22	9.0	1.8	244	10	217	43	14	.2	1.9	.02	.01	.76	.37	.06	286	252	35	460	8.7	4.0	—	—	—	—	—	—	—	—	—	—
MAR. 18...	1020	1750	6.6	190	110	35	11	5.2	6.2	244	0	200	24	9.0	.2	1.1	.07	1.6	3.8	3.4	.83	213	132	0	290	8.0	.5	—	—	—	—	—	—	—	—	—	873
JUNE 23...	1100	1900	8.6	40	<10	59	15	7.0	2.4	178	0	146	33	16	.2	4.4	.04	.05	1.5	1.3	.37	284	210	63	420	8.1	26.7	<10	200	<10	<10	<10	<10	<10	<10	100	510
05454300 — CLEAR CREEK NR CORALVILLE, IOWA																																					
NOV. 26...	0700	19	13	60	410	65	25	16	1.6	250	0	205	52	21	.2	1.6	.03	.16	.37	.31	.18	307	256	51	520	8.2	.0	—	—	—	—	—	—	—	—	—	—
MAR. 19...	0655	1100	6.8	550	320	16	4.9	3.8	9.6	61	0	50	15	8.0	<.1	.40	.06	1.8	3.6	2.9	1.1	117	60	10	165	8.1	.0	—	—	—	—	—	—	—	—	—	1550
JUNE 24...	0730	16	6.3	20	10	61	25	14	2.4	236	0	194	48	21	.2	3.3	.08	.10	.97	1.1	.67	357	260	62	510	7.6	22.5	<10	200	<10	<10	<10	<10	<10	<10	20	231
05455100 — OLD MANS CREEK NEAR IOWA CITY, IOWA																																					
NOV. 25...	1630	36	9.9	80	380	56	23	11	1.5	238	0	195	40	12	.2	2.0	.03	.08	.35	.21	.09	265	236	41	450	8.6	2.0	—	—	—	—	—	—	—	—	—	—
MAR. 18...	1630	2420	6.0	300	270	12	4.7	4.4	9.4	61	0	50	18	7.0	.1	.50	.07	1.8	4.5	4.3	1.0	113	52	2	145	8.6	.5	—	—	—	—	—	—	—	—	—	3100
JUNE 23...	1750	69	12	10	10	52	21	9.9	2.0	199	0	163	29	12	.2	4.7	.08	.15	.91	.80	.40	308	220	53	435	7.7	28.7	<10	200	<10	<10	<10	<10	<10	<10	20	243
05455500 — ENGLISH RIVER AT KALONA, IOWA																																					
NOV. 25...	1500	83	8.8	30	200	56	20	12	2.0	213	0	175	51	12	.2	1.7	.02	.05	.35	.18	.09	268	222	47	475	8.3	2.0	—	—	—	—	—	—	—	—	—	—
MAR. 18...	1535	3860	5.4	240	350	14	6.8	3.0	7.0	55	0	45	18	5.0	.1	.60	.07	1.3	4.6	4.0	.49	107	60	15	142	8.2	1.0	—	—	—	—	—	—	—	—	—	2090
JUNE 23...	1620	216	12	100	<10	44	16	9.2	3.0	166	0	136	31	8.0	.2	3.5	.06	.15	.21	1.6	.43	293	180	40	370	7.7	27.2	<10	400	<10	10	10	10	<10	<10	170	877

(1) The predominant water type in all streams is calcium-magnesium::bicarbonate-sulfate.

(2) In streams draining less than 1000 square miles, dissolved-solids concentrations are higher during periods of low discharge and lowest during high discharges. After the first spring runoff, the dissolved-solids concentration at sampling points draining more than 1000 square miles tended to increase with increasing discharge.

(3) Chloride concentrations are all well below the recommended maximum concentration of 250 mg/L (U.S. Public Health Serv., 1962).

(4) Nitrate concentrations are highest during periods of high discharge, when runoff from the land surface predominates. During spring runoff organic-nitrogen compounds, including ammonia, are the dominant nitrogen species.

Date Collected	Time Collected	Discharge (cfs)	Silica (SiO_2)	Iron (Fe) (ug/L)	Manganese (Mn) (ug/L)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity (as $CACO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (N)	Nitrite (N)	Ammonia Nitrogen (N)	Organic Nitrogen (N) total	Phosphate (PO_4) total	Phosphate (PO_4) total soluble	Dissolved Solids - total	Hardness as $CaCO_3$	Non-Carbonate Hardness	Specific Conductance (Micromhos at 25°C)	pH - Units	Temperature (°C)	Arsenic (As) (ug/L)	Barium (Ba) (ug/L)	Cadmium (Cd) (ug/L)	Chromium (Cr) (ug/L)	Copper (Cu) (ug/L)	Lead (Pb) (ug/L)	Nickel (Ni) (ug/L)	Silver (Ag) (ug/L)	Zinc (Zn) (ug/L)	Suspended Sediment
05455700 — IOWA RIVER NEAR LONE TREE, IOWA																																					
NOV. 25...	1430	1360	13	<10	20	78	28	10	2.2	293	7	252	47	16	.2	4.1	.03	.11	.57	.49	.34	361	310	58	600	7.8	3.0	—	—	—	—	—	—	—	—	—	—
MAR. 18...	1450	8790	6.6	170	260	27	8.7	6.4	7.4	98	0	80	26	10	.2	1.2	.07	1.5	3.8	1.5	.61	172	104	24	250	7.8	1.0	—	—	—	—	—	—	—	—	—	1080
JUNE 23...	1530	4380	11	20	<10	57	20	7.1	2.7	172	0	141	35	13	.2	5.0	.06	.13	.84	.64	.43	303	230	84	435	7.7	25.5	<10	100	<10	<10	<10	<10	<10	<10	10	207
05464250 — WOLF CR AT LAPORTE CITY, IOWA																																					
NOV. 26...	1300	159	12	20	<10	81	27	7.2	8	274	0	225	57	13	.2	6.8	.02	.09	.37	.37	.18	348	316	91	560	8.5	0	—	—	—	—	—	—	—	—	—	—
MAR. 19...	1300	1200	7.4	210	30	30	10	5.6	7.0	104	0	85	26	10	.1	2.6	.07	1.4	4.0	1.8	1.1	176	120	35	330	8.1	.5	—	—	—	—	—	—	—	—	—	562
JUNE 24...	1200	986	8.0	20	<10	54	18	5.7	2.4	183	0	150	29	10	.2	5.0	.04	.09	7.3	3.1	.49	310	210	60	430	7.6	21.0	<10	1100	<10	40	40	60	<10	<10	230	2680
05464460 — OTTER C NR CEDAR RAPIDS, IOWA																																					
NOV. 26...	1100	13	9.6	<10	90	83	16	6.8	1.2	244	0	200	58	12	.2	3.4	.02	.03	.29	.15	.03	300	276	76	450	8.4	0	—	—	—	—	—	—	—	—	—	—
MAR. 19...	1100	215	6.0	270	30	23	4.7	3.6	9.2	73	0	60	29	8.0	.1	.80	.05	1.5	3.4	4.3	.61	136	92	32	150	8.5	0	—	—	—	—	—	—	—	—	—	370
JUNE 24...	0940	119	9.1	110	<10	42	7.7	5.3	3.1	111	0	91	29	9.0	.2	3.9	.09	.15	3.2	1.6	.40	238	140	46	300	7.7	20.3	<10	300	<10	<10	10	10	<10	<10	30	755
05464640 — PRAIRIE CREEK AT FAIRFAX, IOWA																																					
NOV. 26...	0855	39	11	20	40	83	25	9.6	1.0	262	0	215	58	16	.2	5.0	.04	.17	.25	.34	.18	347	304	89	550	8.2	0	—	—	—	—	—	—	—	—	—	—
MAR. 19...	0735	1500	7.2	300	110	21	7.7	4.1	10	67	0	55	26	9.0	.1	<.10	.07	2.1	4.4	3.4	.64	143	84	29	210	8.2	0	—	—	—	—	—	—	—	—	—	752
JUNE 24...	0820	347	8.5	20	<10	38	10	5.0	2.0	124	0	102	23	7.0	.2	3.7	.05	.20	18	7.7	.49	250	140	36	285	7.7	21.7	<10	2200	<10	130	120	150	<10	<10	470	6980
05454920 — SUGAR C NR MOSCOW, IOWA																																					
NOV. 25...	1200	33	11	60	240	71	30	14	2.0	311	0	255	42	16	.2	1.7	.05	.33	.55	.80	.49	352	306	51	620	8.2	3.0	—	—	—	—	—	—	—	—	—	—
MAR. 18...	1200	1590	6.0	450	340	15	5.7	3.9	11	49	0	40	20	8.0	.1	.30	.17	2.8	5.5	3.4	2.2	132	68	28	170	8.5	.5	—	—	—	—	—	—	—	—	—	4470
JUNE 23...	1230	55	9.8	20	70	70	30	11	2.4	284	0	233	46	14	.2	4.5	.14	.11	1.2	.80	.61	356	300	66	520	8.2	27.9	<10	200	<10	<10	<10	<10	<10	<10	10	162
05465000 — CEDAR RIVER NEAR CONESVILLE, IOWA																																					
NOV. 25...	1400	2500	8.7	20	<10	78	25	16	2.2	280	10	246	59	26	.2	3.5	.04	.37	.97	.86	.55	355	290	44	630	8.4	3.0	—	—	—	—	—	—	—	—	—	—
MAR. 18...	1410	6190	6.0	240	210	26	9.0	8.2	8.8	98	0	80	30	15	.2	1.0	.09	2.0	4.5	4.9	1.3	173	104	24	290	7.7	2.0	—	—	—	—	—	—	—	—	—	1030
JUNE 23...	1445	10400	11	20	<10	67	21	8.9	2.5	217	0	178	43	20	.2	5.5	.06	.06	2.1	1.4	.52	353	250	76	505	7.7	27.0	<10	200	<10	<10	10	10	<10	<10	40	512

GROUND-WATER QUALITY

Surficial Aquifers

The surficial aquifers, with some exceptions in the western part of the region, generally contain the least mineralized ground waters in east-central Iowa. The aquifers are recharged primarily by rainfall, which rapidly percolates to the water table. Because of the short recharge time, only a small amount of the relatively insoluble inorganic soil material can be dissolved. Exceptions to the overall excellent-to-good quality of water from the surficial aquifers are often the result of either man-made contamination, such as highly soluble fertilizer and wastes being introduced into the aquifer, or hydraulic connection with an adjacent or underlying aquifer containing poorer quality water.

The dissolved-solids concentrations in water from the surficial aquifers ranges from about 200 to 650 mg/L in the eastern two-thirds of the region and from about 300 to 2500 mg/L in the western one-third (fig. 56). In the eastern part, the dissolved-solids concentrations in about 80 percent of the wells sampled are less than 500 mg/L. The principal ions in solution are calcium, magnesium, bicarbonate, and sulfate. The waters are hard, but less so than waters from bedrock aquifers. Most water analyses on record note iron concentrations as being higher than 0.30 mg/L; the highest value is 12.00 mg/L. Over half of the manganese concentrations are over 0.05 mg/L; the highest is 6.00 mg/L. The range of fluoride concentrations is from 0.05 to 3.00 mg/L, and the majority of the values range between 0.25 and 1.50 mg/L. Water temperatures in the surficial aquifers range from 45°F to 63°F, and most values are between 50°F and 56°F.

The alluvial aquifers, particularly the Mississippi River alluvium, yield water with the lowest overall dissolved-solids concentrations of the surficial aquifers. However, nitrate concentrations at a few localities exceed the maximum recommended limit of 10 mg/L, and the nitrate concentrations range between 4.5 and 10 mg/L in about 10 percent of the wells sampled.

The shallow drift aquifers contain water that consistently is less mineralized than water from the deep drift and buried-channel aquifers, although nitrate concentrations ranging between 4.5 and 10 mg/L are not uncommon. The above-average nitrate concentrations probably result from poor well construction and proximity to cattle yards and feed lots.

Water from the buried-channel aquifers often is more mineralized than water from either the alluvial or drift because of hydraulic connection with bedrock aquifers. The buried channels are incised in bedrock, often into water-bearing zones. In such cases, the water in the buried-channel aquifer chemically resembles that in the adjacent bedrock aquifer, which almost invariably has a higher dissolved-solids concentration. This condition is especially noticeable in the western part of the region where the bedrock aquifers contain highly mineralized water.

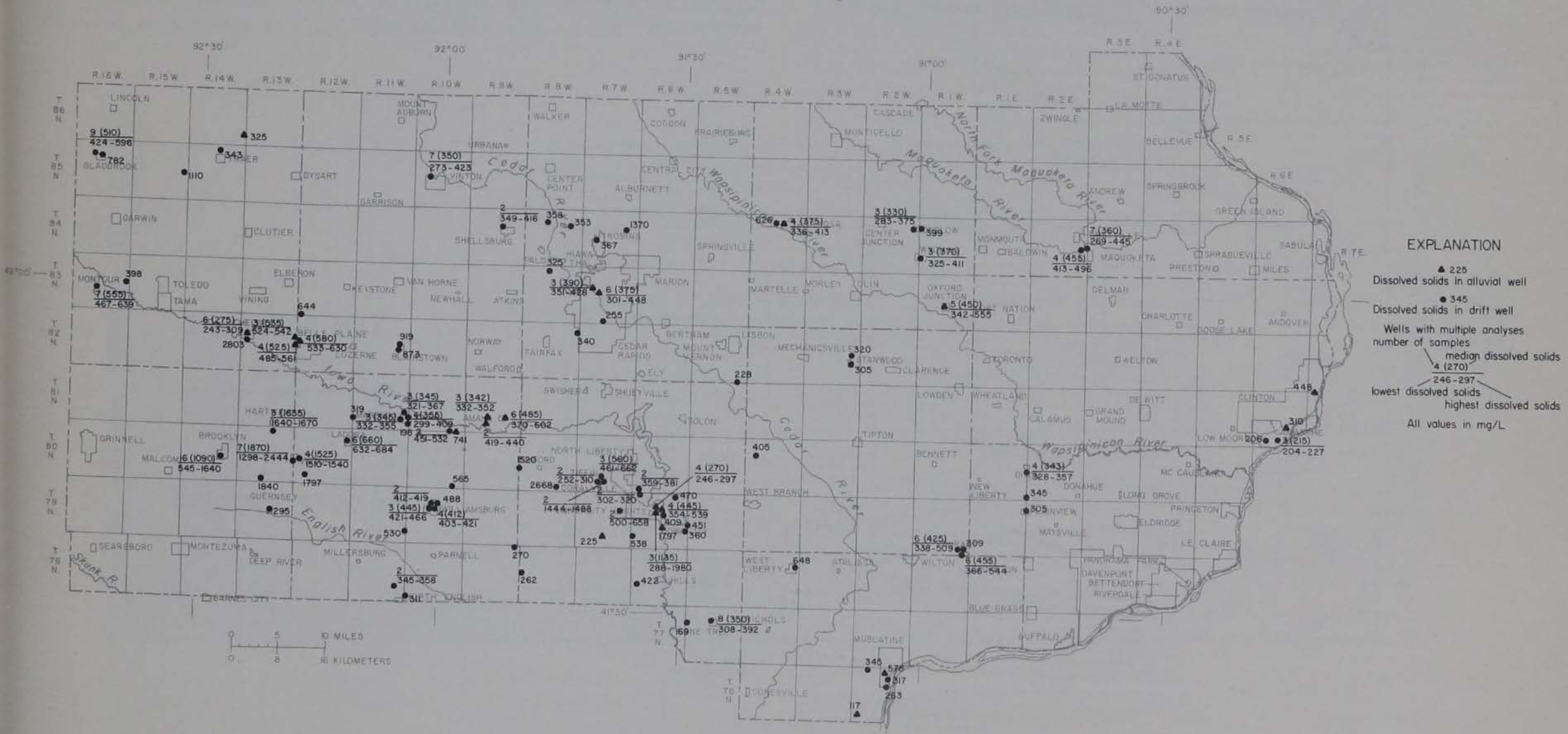


Figure 56.—Dissolved-solids concentrations in the surficial aquifer

Mississippian Aquifer

Good-quality water usually cannot be obtained from the Mississippian aquifer. Because of the poor quality, and its limited occurrence, few wells are completed in the aquifer. Existing wells (fig. 57) commonly yield water with more than 1400 mg/L of dissolved solids, more than 750 mg/L of sulfate, and hardness values greater than 850.

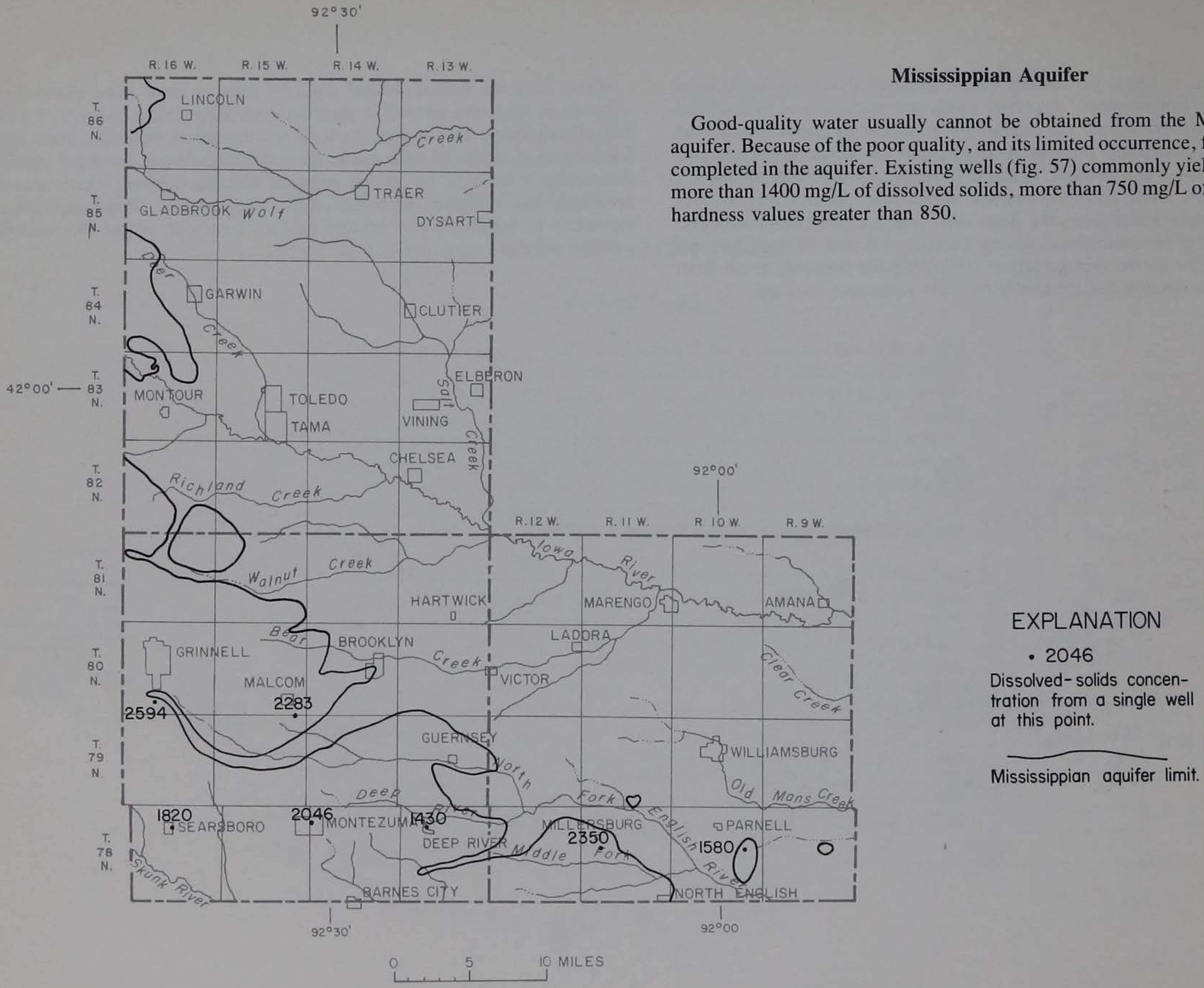


Figure 57.—Dissolved-solids concentrations in the Mississippian aquifer

Devonian Aquifer

Good-quality water is available in the Devonian aquifer in the eastern half of its area of occurrence (fig. 58). An approximate dividing line, the 1000 mg/L dissolved-solids contour, runs from the northwest corner of Tama County about to the city of Muscatine. East of the 1000 mg/L line the dissolved-solids values are as low as 250 mg/L although the most common values are 300 to 500 mg/L. As can be seen in figure 58, the dissolved-solids concentration generally increases to the south and west. As in the surficial aquifers, anomalous dissolved-solids concentrations may result from hydraulic connection with an underlying or overlying aquifer.

Calcium, magnesium, sodium, bicarbonate, and sulfate are the major dissolved constituents in water from the Devonian aquifer. The relative abundances depend on the type of rock from which the water is withdrawn, and on any leakage from adjacent aquifers and/or streams. The water is very hard, having an average hardness value of 700 mg/L. The occurrence of hardness is similar to that of dissolved solids, in that the concentration tends to increase to the south and west. Iron concentrations from 0.01 to 31 mg/L are recorded, the average is 2.85 mg/L. Manganese, also a common dissolved constituent, has concentrations of 0.01 to 0.56 mg/L and an average value of 0.13 mg/L. The average fluoride concentration is 0.74 mg/L, and values range from 0.10 to 3.20 mg/L. Depending upon well depth and location, water temperature can be expected to be between 48°F and 57°F.

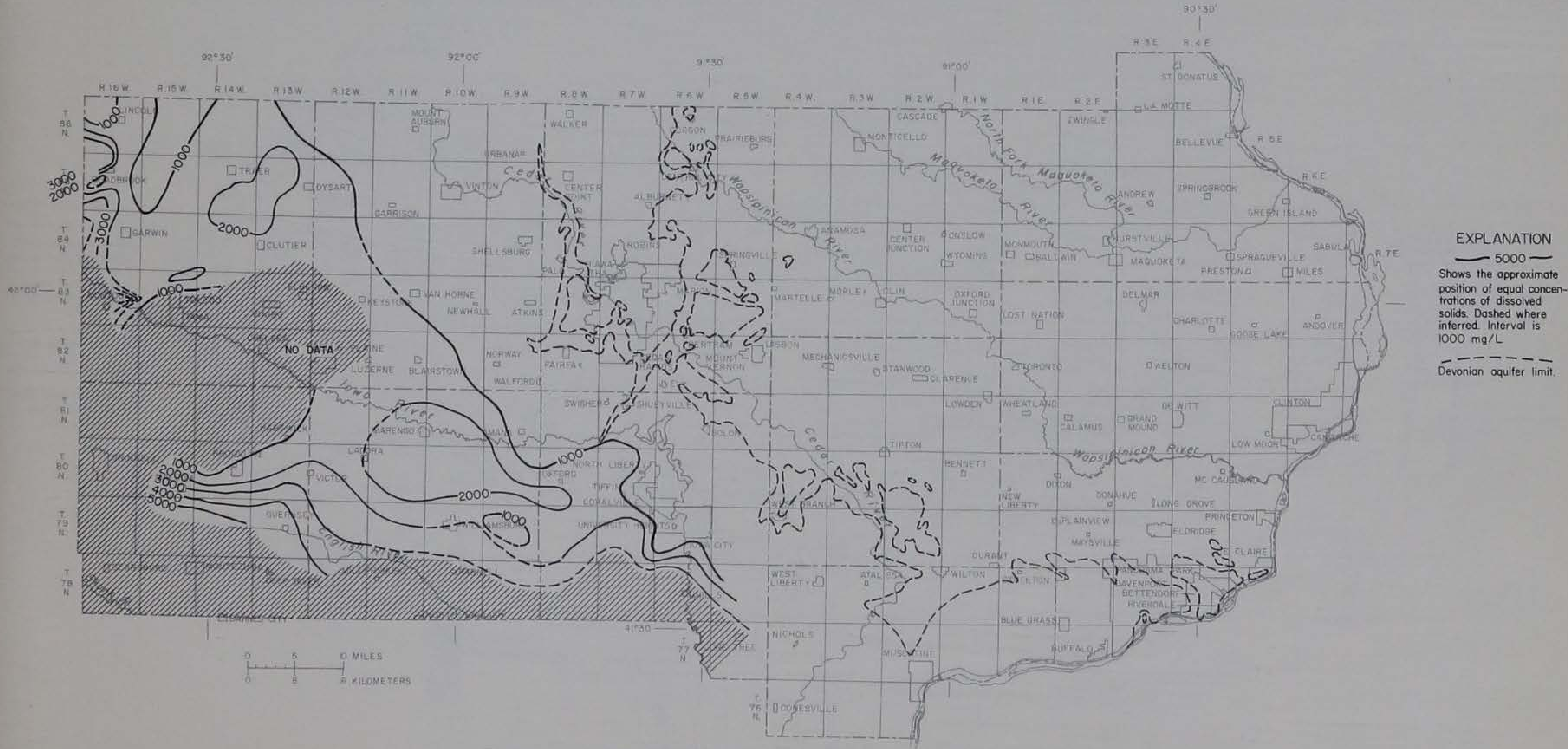


Figure 58.—Dissolved-solids concentrations in the Devonian aquifer

Silurian Aquifer

The Silurian aquifer contains relatively good water in most of east-central Iowa (fig. 59). The 1000-mg/L dissolved-solids concentration line has about the same orientation as that of the Devonian aquifer (fig. 58). East of the 1000-mg/L line the dissolved solids are as low as 200 mg/L and about 80 percent of the values are less than 500 mg/L. Southwest of the 1000-mg/L line, quality appears to deteriorate rapidly, as concentrations of over 3500 mg/L are found in southwestern Tama and southern Poweshiek counties.

Wells in the Silurian aquifer generally yield ‘‘calcium-magnesium: :bicarbonate’’ water typical of carbonate aquifers. The next most abundant ion is sulfate. The waters are characteristically hard, the range of values being from 200 to 2000 mg/L, with most values between 250 and 400 mg/L. Hardness also increases to the southwest.

Iron ranges from 0.01 to 12 mg/L; most waters have less than 1.00 mg/L. Manganese ranges from 0.01 to 0.83 mg/L. About 60 percent of the 134 water analyses examined list manganese as present in concentrations equal to or in excess of the recommended limit. Nine wells were found to contain fluoride over the concentration recommended for east-central Iowa (table 3). However, more than 90 percent of the analyses on record list fluoride as less than 0.80 mg/L. Water temperature is commonly between 50°F and 57°F.

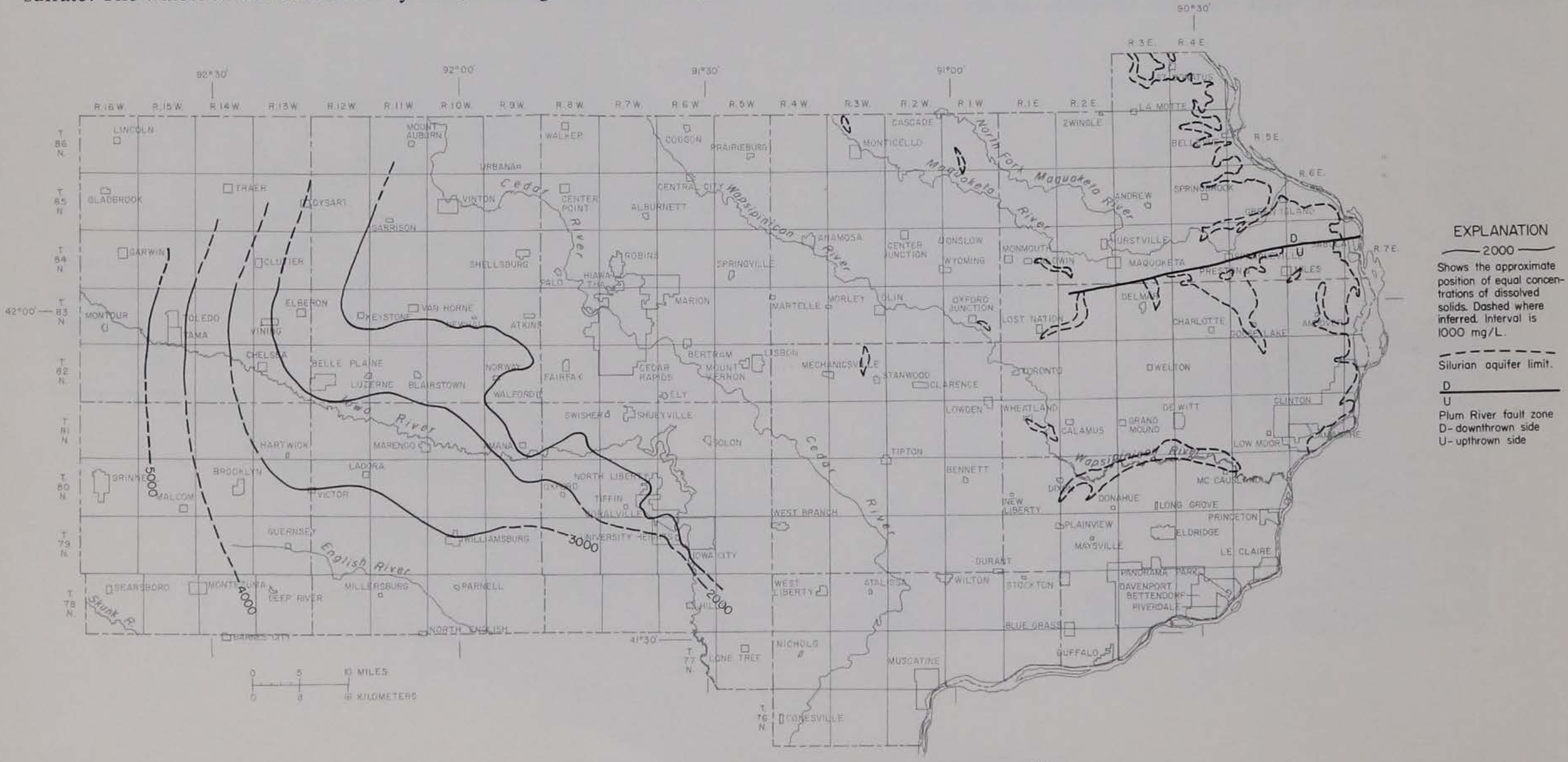


Figure 59.—Dissolved-solids concentrations in the Silurian aquifer

Cambrian-Ordovician Aquifer

This aquifer contains good to fair quality water throughout the region, except for a very small area along the Mississippi River in Scott County. The dissolved solids are less than 500 mg/L in about one-third of the region and less than 1000 mg/L in about two-thirds of the region (fig. 60). The water is rather hard, commonly between 250 and 500 mg/L, with extreme values of 216 and 800 mg/L noted. The average iron concentration is 1.06 mg/L with a range from 0.05 to 3.20 mg/L. Manganese varies from 0.01 to 0.15 mg/L, with an average of 0.04 mg/L. Minimum and maximum recorded fluoride concentrations are 0.10 and 2.00 mg/L, respectively; most analyses list fluoride between 1.00 and 1.50 mg/L. Water temperature is usually between 59°F and 72°F, the actual value depending somewhat on well depth.

Wells that are tightly cased into the upper part of the aquifer (Prairie du Chien Formation) yield water that ranges from about 350 to about 1200 mg/L dissolved solids. However, wells tapping the aquifer that also are open to overlying formations often yield water with lower dissolved solids in the eastern part of the region and higher dissolved solids in the western part (fig. 60). The anomalous high dissolved solids in the western part of the area are attributed to leakage of highly mineralized water from the overlying aquifers through uncased boreholes and through corroded or leaking casings. Because the potential for this type of contamination exists in the western part of the region, where this aquifer contains much better quality water than the overlying aquifers, wells must be properly cased and cemented. Moreover, old, abandoned wells should be plugged and sealed.

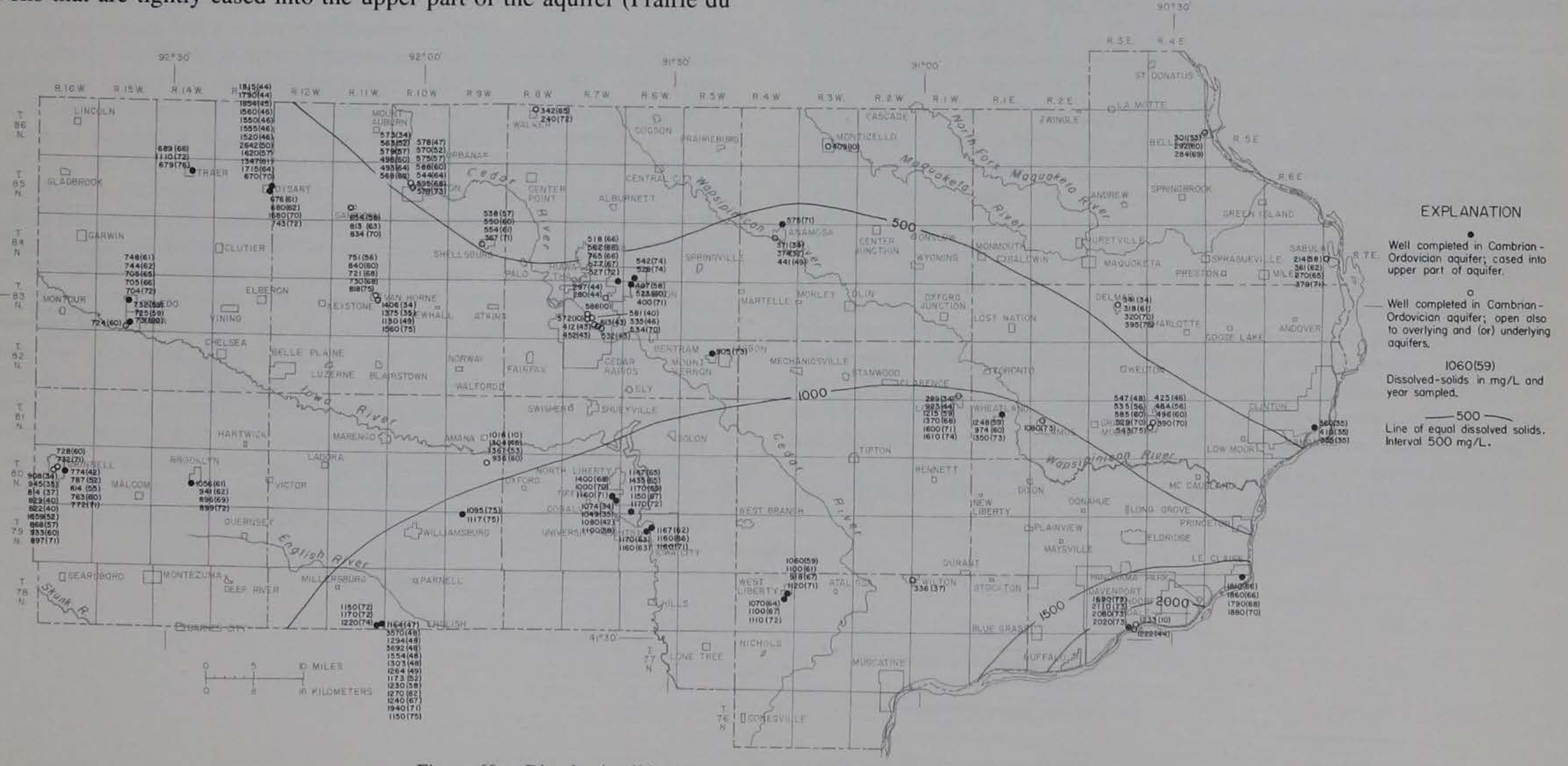


Figure 60.—Dissolved-solids concentrations in the Cambrian-Ordovician aquifer

Dresbach Aquifer

Most of the wells completed in the Dresbach aquifer are located in Clinton County. These wells, together with wells in Jackson and Scott Counties, yield the best quality water from the aquifer. The sparse data, presented in figure 61, indicate that water quality in the Dresbach aquifer follows the general trend delineated in most other bedrock aquifers, that of degradation to the west.

Concentrations of dissolved solids increase rapidly to the west. The concentration ranges of some constituents are smaller than for other bedrock aquifers. Hardness values are nearly all between 250 and 300 mg/L, only three values were over 300 mg/L. Iron ranges from 0.05 to 2.00 mg/L, with an average value of 0.41 mg/L. Manganese concentrations are quite uniform, with a range of 0.01 to 0.44 mg/L, and most analyses listing a value of 0.05 mg/L. Fluoride varies between 0.20 and 0.90 mg/L, with an average of 0.46 mg/L. Water temperatures in the Dresbach aquifer vary from 57°F to 68°F. Most observations are between 61°F and 66°F.

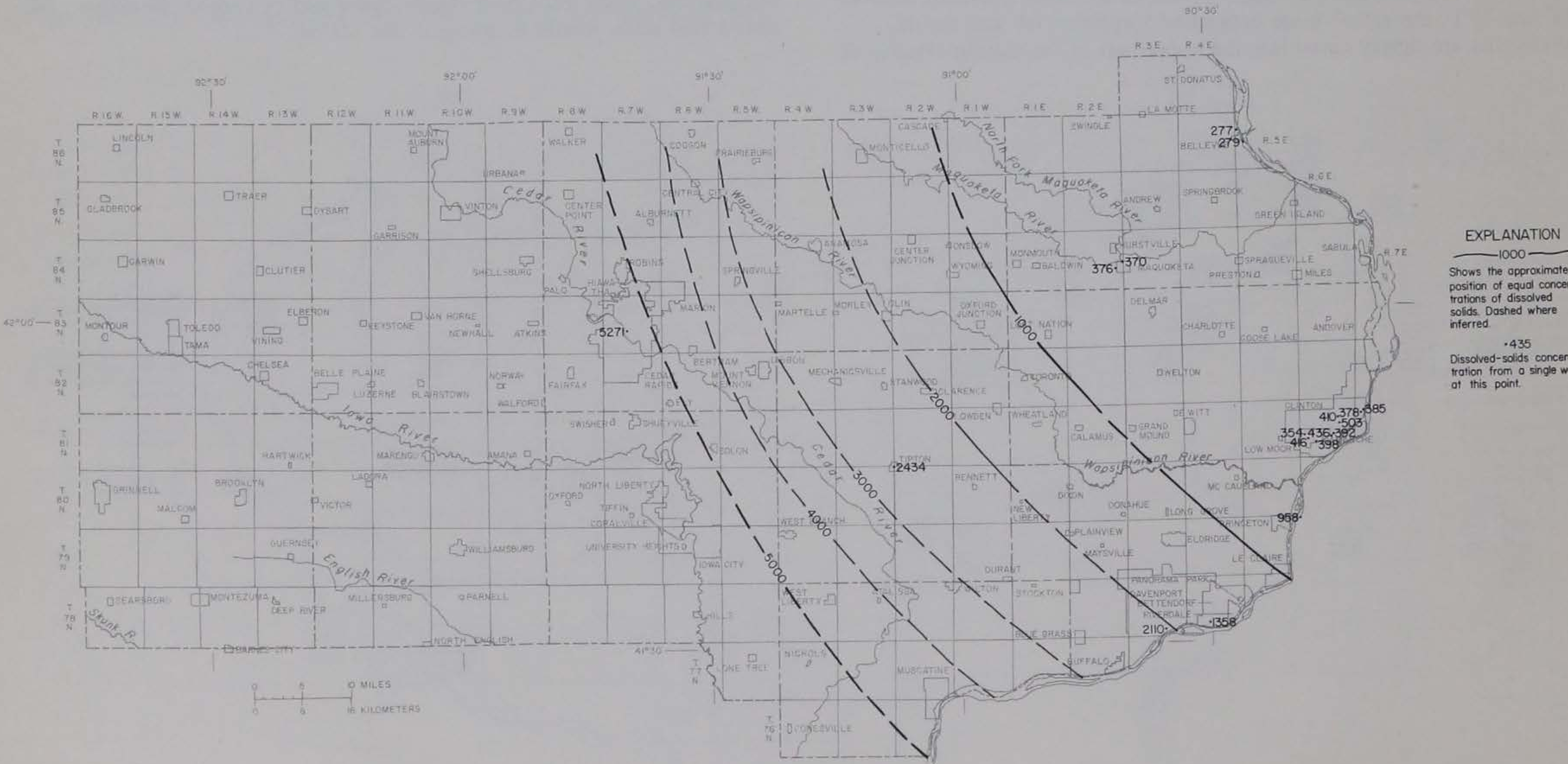


Figure 61.—Dissolved-solids concentrations in the Dresbach aquifer

WATER USE

The major categories of water use in east-central Iowa are: (1) thermoelectric power generation. (2) public supply, (3) self-supplied industrial and commercial, (4) rural, and (5) irrigation. Lesser amounts of water are used in quarrying and sand and gravel operations.

Water withdrawn for the generation of fuel-electric power is used mainly for cooling steam condensors; the amount used to produce steam is small in comparison. This category includes only public utilities. Water used for power generation by private firms for their own use is combined with industrial use.

Public supply, in this report, includes all water withdrawn by municipalities for urban-domestic use and for sale to industrial and commercial concerns. In addition, the water attributed to public supply encompasses transmission losses from water-distribution systems, water-main flushing, and water used for fire fighting and street cleaning. Where information on the quantities of withdrawn or purchased water was not available, both urban-domestic and purchased industrial-commercial water use were estimated on the basis of per-capita-use information from similar communities.

Self supplied industrial and commercial use includes the water withdrawn from company-owned wells and river intake systems. Industrial and commercial uses are varied. The water is used for making steam, condensing steam, cooling various products, refrigeration and air-conditioning, washing products and facilities, and processing food products.

Rural uses are subdivided into domestic drinking and sanitation, and water for livestock. Accurate metering of water on each farm is infeasible. Domestic use was estimated on the basis of a per-capita use of 70 gallons a day. Livestock use was also determined by applying an average per-capita consumption for each animal. Animal-population figures were taken from the 1974 agricultural census (U.S. Bureau of Census, 1976).

The term "water use" can have several meanings. Water can be used in the sense that it is utilized in the navigation of the Mississippi River. The water is passed through locks and is used to either raise or lower tow boats and barges. This water has been used, but none was lost or consumed; the water temperature was not changed, and nothing was added to or removed from the water. Its desirability for other uses has not been altered.

In many water uses, however, water is consumed by evapotranspiration or its chemical quality is altered. For example, the water used for heat transfer in air conditioning or industrial cooling is considerably warmer when discharged. Because the water is warmer, some will be lost (consumed) through evaporation and the remainder will be less desirable for many other uses because it is warmer. The chemical quality of water is altered considerably by domestic water uses. Dissolved solids are concentrated by high evaporative losses, and the chemical quality is altered by softening, disinfection, disposal of commercial reagents, and organic wastes. Livestock and many industrial uses affect water similarly.

Finally, highly consumptive water uses deplete manageable water sources. When the water is lost to the atmosphere, it is no longer locally available for manageable use until it has passed through the hydrologic cycle. Water is evaporated in many ways, some of which were described before. Two uses in which most water is lost to the atmosphere are the production of steam which is eventually released, and irrigation, where the water is either transpired by plants or evaporated from the soil or land surface.

Water use is described and tabulated in three ways on the following pages. First are water withdrawals. This refers to water taken from where it occurs as a natural resource, even though some users may recirculate or reuse the water. Tabulations of water withdrawals have been made for each drainage basin and each county according to the type of water use and the source of the water supply. The second tabulation is termed resource depletion. This refers to the amount of water returned to the atmosphere by evaporation and transpiration and is tabulated for each type of use in each drainage basin. The third is called source depletion. This is a calculation of the net amount of water either lost or gained by each of the sources of water; surface waters and individual aquifers.

WATER WITHDRAWALS

During the period from 1974 to 1975, about 2.7 billion gallons of water per day were withdrawn for various uses in east-central Iowa. These withdrawals are categorized by use in tables 6 and 7, and in figure 62. About 88 percent of the total was withdrawn for use in producing fuel-electric power. Of the remaining 12 percent, self-supplied industrial and commercial use accounted for 43 percent, public supplies 25 percent, irrigation 21 percent, rural domestic 3 percent, livestock 6 percent, cooling 0.5 percent, and quarry dewatering 1.5 percent.

Most of the water withdrawals occur in the Cedar River Valley, where water use for thermoelectric power generation exceeds all the remaining water use in the region. If water used for fuel-electric power generation were to be excluded, withdrawals for industrial and domestic use in the Mississippi and Cedar River Valleys far surpass those of other basins.

On the average, about 2,695 million gallons of water were withdrawn each day from the various water resources of east-central Iowa during 1974-75.

This water is utilized for:

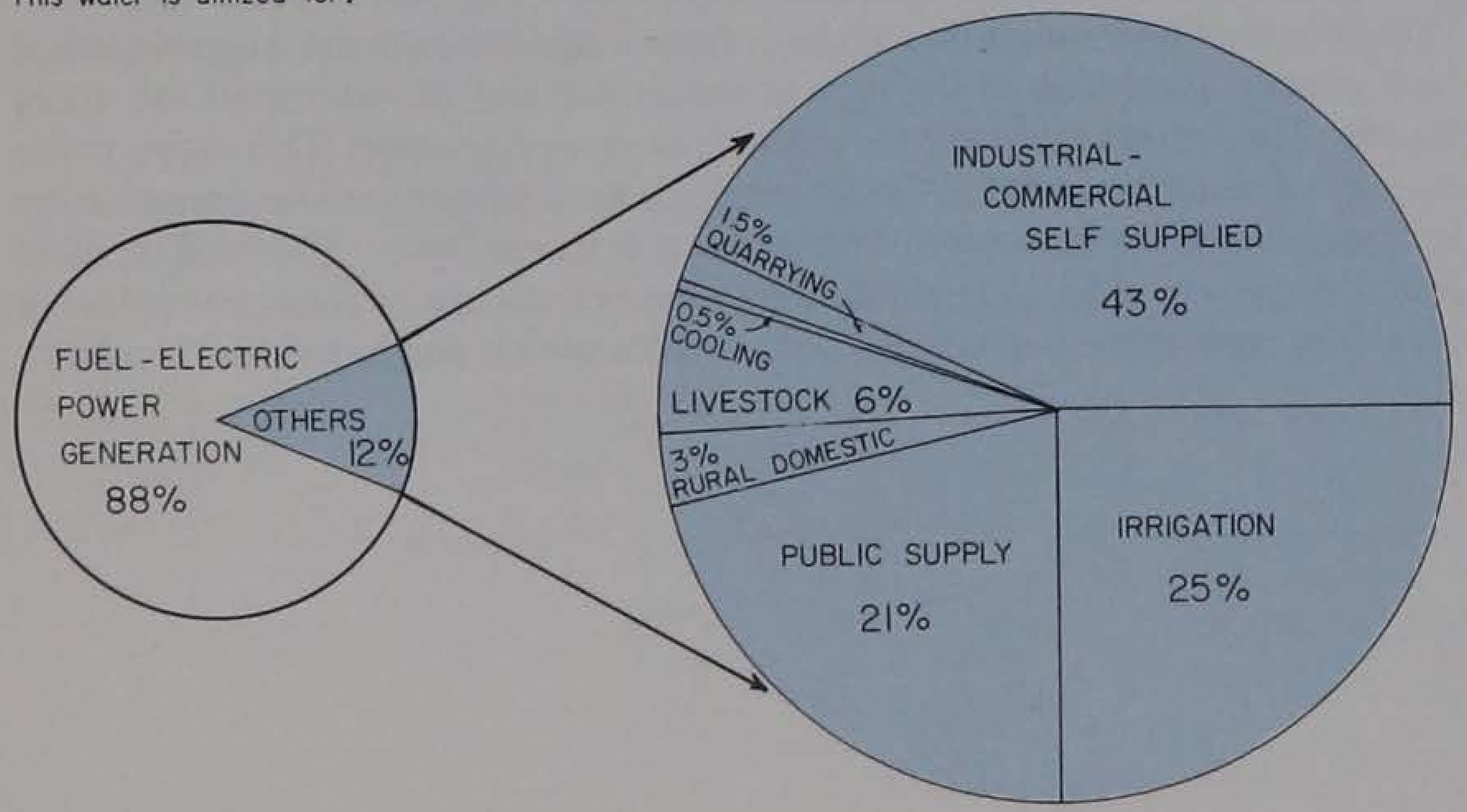


Figure 62.—Average daily water withdrawals, in percentages, by type of use during 1974-75

Table 6. — Water withdrawals by type of use in basins, 1974-75

Basins	Population	Water withdrawn, in mgd, for type of use indicated								Total
		Public supply	Industrial-commercial self-supplied	Irrigation	Cooling *	Power generation	Quarrying and mining	Rural		
								Domestic	Livestock	
Skunk River	11,421	1.32	0.0	0.0	0.0	0.0	0.0	0.11	0.26	1.69
Iowa River	108,870	11.33	.46	.04	.83	10.28	.44	2.29	5.26	30.93
Cedar River	205,883	23.29	23.49	.01	.04	1860.00	4.59	3.11	4.67	1919.20
Wapsipinicon River	44,133	2.14	.0	.0	.01	.25	.18	1.65	3.33	7.56
Maquoketa River	26,962	1.04	.0	.0	.35	0	.0	1.30	2.64	5.33
Mississippi River valley and minor tributary basins.	210,304	40.44	110.96	67.77	.40	508.00	.09	1.16	1.54	730.36
Total	607,573	79.56	134.91	67.82	1.63	2378.53	5.30	9.62	17.70	2695.07

* Includes airconditioning and refrigeration in those smaller communities for which data were available.

Table 7. — Water withdrawals by type of use in counties, 1974-75

County	Population	Water withdrawn, in mgd, for type of use indicated								Total
		Public supply	Industrial-commercial self-supplied	Irrigation	Cooling	Power generation	Quarrying and mining	Rural		
								Domestic	Livestock	
Benton	22,885	1.27	0.0	0.0	0.0	0.0	0.0	0.70	1.68	3.65
Cedar	17,655	.99	.0	.01	.0	.0	.0	.59	1.63	3.22
Clinton	56,749	8.11	67.70	.0	.0	171.00	.17	.76	2.00	249.74
Iowa	15,419	1.19	.0	.0	.54	0	.0	.69	1.62	4.04
Jackson	20,839	1.27	.0	.0	.75	.0	.0	.67	1.83	4.52
Johnson	72,127	8.66	.01	.03	.23	10.28	.44	1.07	1.35	22.07
Jones	19,868	.97	.0	.0	.01	.25	.0	.65	1.77	3.65
Linn	163,213	21.04	23.40	.0	.03	1860.00	2.41	1.76	1.13	1909.77
Muscatine	37,181	16.13	13.79	67.56	.0	75.00	2.18	.71	.84	176.21
Poweshiek	18,803	1.48	.0	.0	.0	.0	.0	.47	1.30	3.25
Scott	142,687	17.28	29.56	.21	.0	262.00	.10	.92	1.09	311.16
Tama	20,147	1.17	.45	.01	.07	.0	.0	.63	1.46	3.79
Total	607,573	79.56	134.91	67.82	1.63	2378.53	5.30	9.62	17.70	2695.07

Water Withdrawals in Urban Areas

Urban withdrawals in this report are defined as withdrawals in communities with populations greater than 1000 in the 1970 census (this excludes two major non-urban thermoelectric power plants that withdraw very large quantities of water and are shown in figure 63). Total withdrawals for the seven largest cities for all categories of use — Cedar Rapids, Davenport, Bettendorf, Iowa City, Clinton, Muscatine, and Coralville — was 864 mgd, or 91 percent of the total daily urban withdrawal. In Cedar Rapids, Davenport-Bettendorf, and Clinton most of the water is used for fuel-electric power generation. Industrial and commercial use constitute a lesser but still important portion. Twenty-six percent of the total urban use in the report area is concentrated in Clinton. Cedar Rapids accounts for 27 percent of the total, and the Davenport-Bettendorf area 33 percent.

The amount of water used in urban areas varies considerably throughout the year. Data from several cities indicate the average daily use during the hot summer months is about 20 percent higher than during the cooler months (fig. 64). The data presented here apply only to public supplies. Accurate data for other uses are not available, but the pattern is probably very similar to that for municipal systems. Most of the industrial and commercial withdrawals are for cooling and air-conditioning, and the volumes of water required vary with the weather.

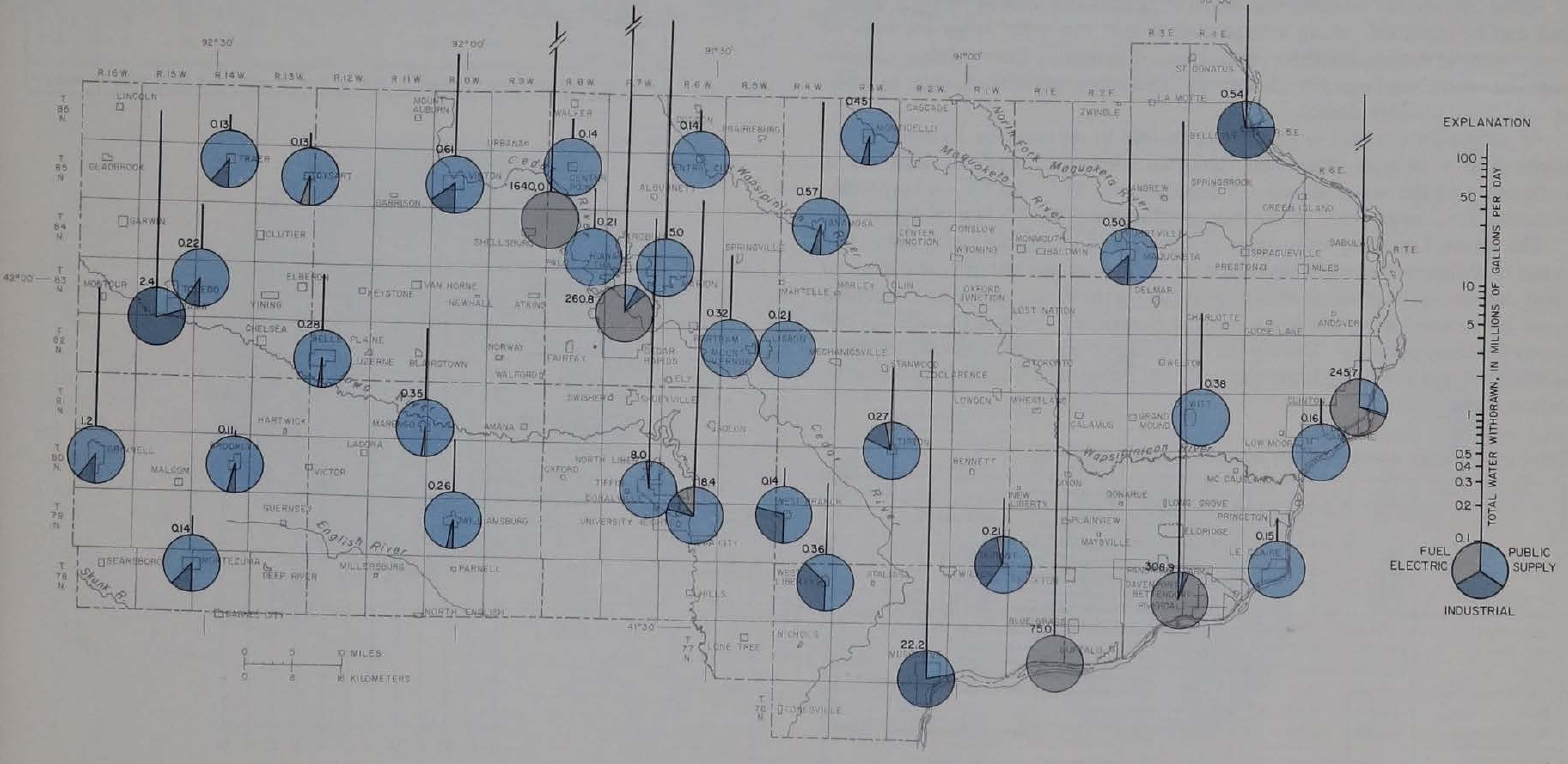


Figure 63.—Average daily water withdrawals from major pumping centers and type of use, 1974-75

Water Use By Irrigators and the Mineral Industry

Sprinkler irrigation, which is practiced in east-central Iowa, is a highly consumptive use of water; nearly all the water applied is evaporated or transpired by plants. The average amount used for irrigation in the report area through 1974-75 was 67.82 mgd. The amount of water used for irrigation varies considerably from year to year, because most irrigation currently is practiced only when rainfall is deficient. The amount of water used is dependent upon the type of crop, the interval within the growing season when deficient rainfall might occur, the water-holding capacity of the soil in a particular area, and the market conditions pertaining to a particular irrigated crop. Irrigation is currently practiced only in areas where a sufficient amount of water can readily be obtained. Most irrigators are located along a stream that can be dammed, along a large stream that can yield large amounts of water without storage facilities, or in areas of extensive flood-plain or terrace deposits where sand and gravel aquifers yield large amounts of water to wells at relatively shallow depths.

An irrigation use that is nearly impossible to measure or estimate is the water used to irrigate urban and suburban lawns and gardens. This use is included with the water shown for domestic use in figure 63, and probably accounts for a large share of the increased summer use shown on figure 64.

The mineral industry uses water in quarry and gravel pit operations. The water is withdrawn to wash aggregate, to drain quarries and pits, and in some sand and gravel operations to transport the material out of the pit. A permit must be secured from the Iowa Natural Resources Council in order to use water for these purposes. During the 1974-75 period, 1930 million gallons of water per year (or 5.3 mgd) were recorded as being used for this purpose in the report area.

Table 8. — Water withdrawals by source in basins, 1974-75

Drainage Basin	Population of basin 1970	Water withdrawn, in mgd, from sources indicated								Total
		Surface water		Ground Water						
		Streams	Reservoirs	Surficial aquifers	Mississ-ippian aquifer	Devonian aquifer	Silurian aquifer	Cambrian-Ordovician aquifer	Dresbach aquifer	
Skunk River	11,421	0.13	0.15	0.0	0.01	0.24	0.0	1.16	0.0	1.69
Iowa River	108,870	20.60	.02	2.69	.01	5.19	.75	1.67	.0	30.93
Cedar River	205,883	1868.02	4.25	19.04	.0	3.81	15.31	8.77	.0	1919.20
Wapsipinicon River	44,133	1.67	.19	.33	.0	.0	4.55	.82	.0	7.56
Maquoketa River	26,962	1.32	.0	.17	.0	.0	3.22	.27	.35	5.33
Mississippi River valley and minor tributary basins.	210,304	601.89	.86	104.73	.0	.0	6.99	.36	15.53	730.36
Total	607,573	2493.63	5.47	126.96	0.02	9.24	30.82	13.05	15.88	2695.07

Table 9. — Water withdrawals by source in counties, 1974-75

County	Population	Water withdrawn, in mgd, from various sources								Total
		Streams	Reservoirs	Surficial aquifers	Mississ-ippian aquifer	Devonian aquifer	Silurian aquifer	Cambrian-Ordovician aquifer	Dresbach aquifer	
Benton	22,885	0.84	0.0	0.57	0.0	1.53	0.22	0.49	0.0	3.65
Cedar	17,655	.82	.0	.21	.0	.82	1.33	.04	.0	3.22
Clinton	56,749	224.04	.17	7.69	.0	.0	1.98	.47	15.39	249.74
Iowa	15,419	.81	.0	1.51	.0	1.52	.08	.12	.0	4.04
Jackson	20,839	.92	.0	.56	.0	.0	2.35	.20	.49	4.52
Johnson	72,127	18.22	.45	.21	.0	.89	1.50	.80	.0	22.07
Jones	19,868	.89	.01	.33	.0	.0	2.12	.30	.0	3.65
Linn	163,213	1866.34	2.41	18.20	.0	1.33	13.48	8.01	.0	1909.77
Muscatine	37,181	75.08	2.18	97.00	.0	.56	1.16	.23	.0	176.21
Poweshiek	18,803	.66	.14	.03	.02	1.12	.0	1.28	.0	3.25
Scott	142,687	304.28	.10	.03	.0	.0	6.58	.17	.0	311.16
Tama	20,147	.73	.01	.62	.0	1.47	.02	.94	.0	3.79
Total	607,573	2493.63	5.47	126.96	0.02	9.24	30.82	13.05	15.88	2695.07

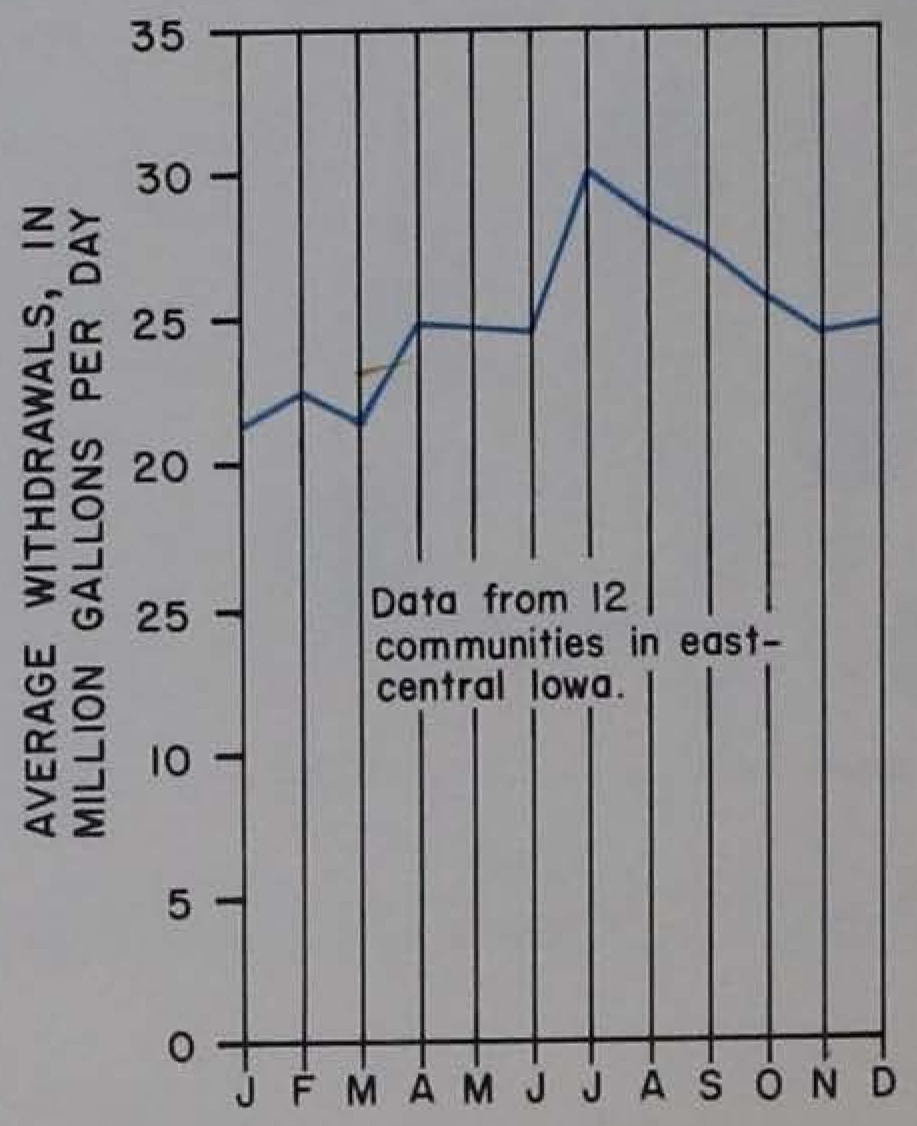


Figure 64.—Monthly variations in water withdrawals, 1974-75

Sources of Withdrawals

The amount of water withdrawn from each source in the report area has been tabulated for 1974-75 in tables 8 and 9 and figure 65. Surface-water sources supply 93 percent of the 2695 mgd average withdrawals, with the remaining withdrawals coming from the various ground-water aquifers. In the Cedar and Mississippi River Valleys, surface water is the major source, accounting for 93 percent of the withdrawals. In all the other drainage basins in the report area, ground water supplies 70 percent of the withdrawals.

Approximately 65 percent of the ground water withdrawn during 1974-75 came from the surficial aquifers—alluvium, buried-channel, and drift. Most of this water came from alluvial aquifers, which supplies several municipal public systems, including Muscatine and Cedar Rapids. Of the total water withdrawn from the bedrock aquifers, the Mississippian aquifer supplied less than one-tenth of 1 percent. Five percent of the ground-water withdrawals were taken from the Devonian aquifer, and 15 percent from the Silurian aquifer. The Silurian aquifer supplies water for municipal and industrial uses in the central and eastern parts of the report area. The Cambrian-Ordovician aquifer supplies 7 percent of the ground-water withdrawals. Many communities and industries in the area use this aquifer as a primary or secondary source of water. The Dresbach aquifer supplied 8 percent of the total ground water withdrawn during 1974-75. Approximately 98 percent of this was used in the Clinton area, where the aquifer is extensively developed for municipal and industrial use.

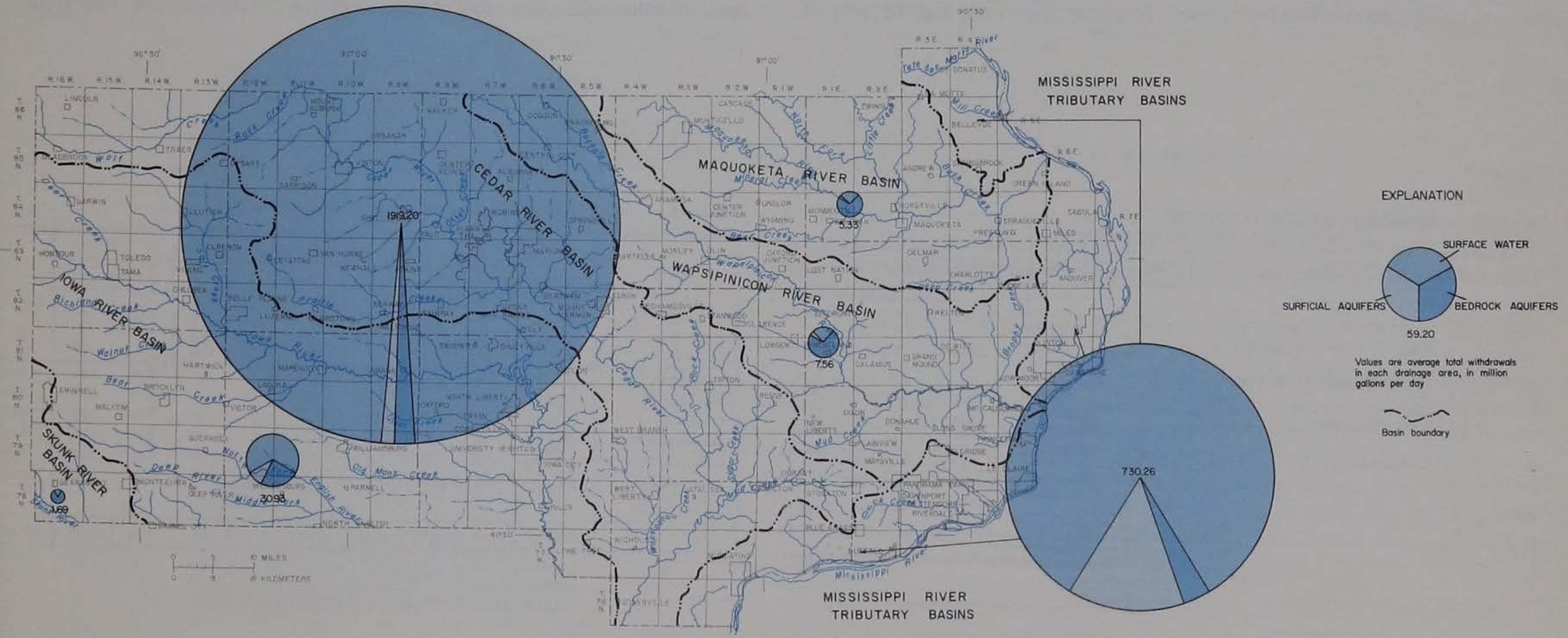


Figure 65.—Sources of water withdrawn, 1974-75

Resource Depletion

After water has been used it is either returned to the environment in a liquid state or returned to the atmosphere as water vapor. Most municipal systems and self-supplied industrial operations return their discarded water to streams. Most private domestic systems, especially rural domestic, discharge water by way of septic tanks or on the land surface. Livestock water generally is discharged on the land surface. Irrigation water which is not lost to the atmosphere will usually reach the water table and the saturated zone.

The water which is not returned to surface- or ground-water sources is consumed. Most of this water is lost to the atmosphere as vapor through evapotranspiration, and is no longer available for use or management. This constitutes a depletion of the resource.

The amount of water consumed varies with the type of water use. Estimates of consumptive use, taken from data throughout the United States, are given in table 10. Rural-domestic and livestock uses result in the highest rate of loss, mainly because water is discharged on or near the land surface where evaporation and transpiration effect high losses. Irrigation losses are high because of plant transpiration and evaporation from the soil. Consumption of 17 percent for public supplies is the result of high evaporation losses from car washing, laundering, street cleaning, fire fighting, and leaks from water mains as well as with evapotranspiration from lawn and garden irrigation. Losses from industrial and fuel-electric power generation activities are low, the bulk of the evaporation being boiler steam losses and some from heated cooling water.

The largest part of the total depletion in the report area occurs through irrigation (table 11), which accounts for 40 percent of the total consumptive losses, even though it comprises only 2.5 percent of the total water withdrawn. Although it is not a consumptive use, power generation is responsible for 23 percent of the resource depletion, due to the immense volume of water used. Public supplies and rural livestock each account for 13 percent of the total consumptive loss, with rural domestic use constituting 7 percent, industrial use 3 percent, and cooling under 1 percent.

Consumptive losses are highest in the Mississippi River Valley, because most irrigators and a large part of the population (35 percent) are in the basin.

Table 10. — Water consumed
Data from MacKichan, K.A., and Kammerer, J.C., 1961.

Type of Withdrawal	Percent of Water Consumed
Public supply	17
Industrial self-supplied	2
Rural domestic and stock	77
Electric power	1
Irrigation	60

Table 11. — Water consumed within each basin, 1974-75

Drainage basin	Population of basin, 1970	Water Consumed, in mgd, by use indicated								Total
		Public supply	Industrial-commercial self-supplied	Irrigation	Cooling	Power generation	Quarrying and mining	Rural		
								Domestic	Livestock	
Skunk River	11,421	0.22	.0	0.0	0.0	0.0	0.0	0.08	0.20	0.50
Iowa River	108,870	1.93	.01	.02	.01	.10	.0	1.76	4.05	7.88
Cedar River	205,883	3.96	.47	.0	.0	18.6	.0	2.39	3.60	29.02
Wapsipinicon River	44,133	.36	.0	.0	.0	.0	.0	1.27	2.56	4.19
Maquoketa River	26,962	.18	.0	.0	.0	.0	.0	1.00	2.03	3.21
Mississippi River valley and minor tributary basins	210,304	6.87	2.22	40.66	.0	5.08	.0	.89	1.18	56.9
Total	607,573	13.52	2.70	40.68	0.01	23.78	0.0	7.39	13.62	101.70

Source Depletion

Waste water, returned to its original source, depletes that source only to the extent of consumptive loss of the particular use. However, waste water taken from one source and discharged to another, depletes the original source and provides a net gain to the source receiving the waste water. For example, ground water pumped for municipal or industrial supply may be discharged to and increase the flow of a stream, but the ground water reservoir has been depleted.

The average net water-resource depletion in east-central Iowa was 101.7 mgd during 1974-75 (table 12). The depletion of ground-water sources was 164.47 mgd while surface water sources gained 62.77 mgd (table 12). The surficial aquifers experienced the largest depletion because of extensive withdrawals, even though 28.67 mgd was returned to it (compare tables 8 and 12). Of the bedrock aquifers, the Silurian aquifer, which experienced the most extensive withdrawals, had the highest net loss, even though some water is returned to it where it is a water-table aquifer. All major streams had a net gain of water.

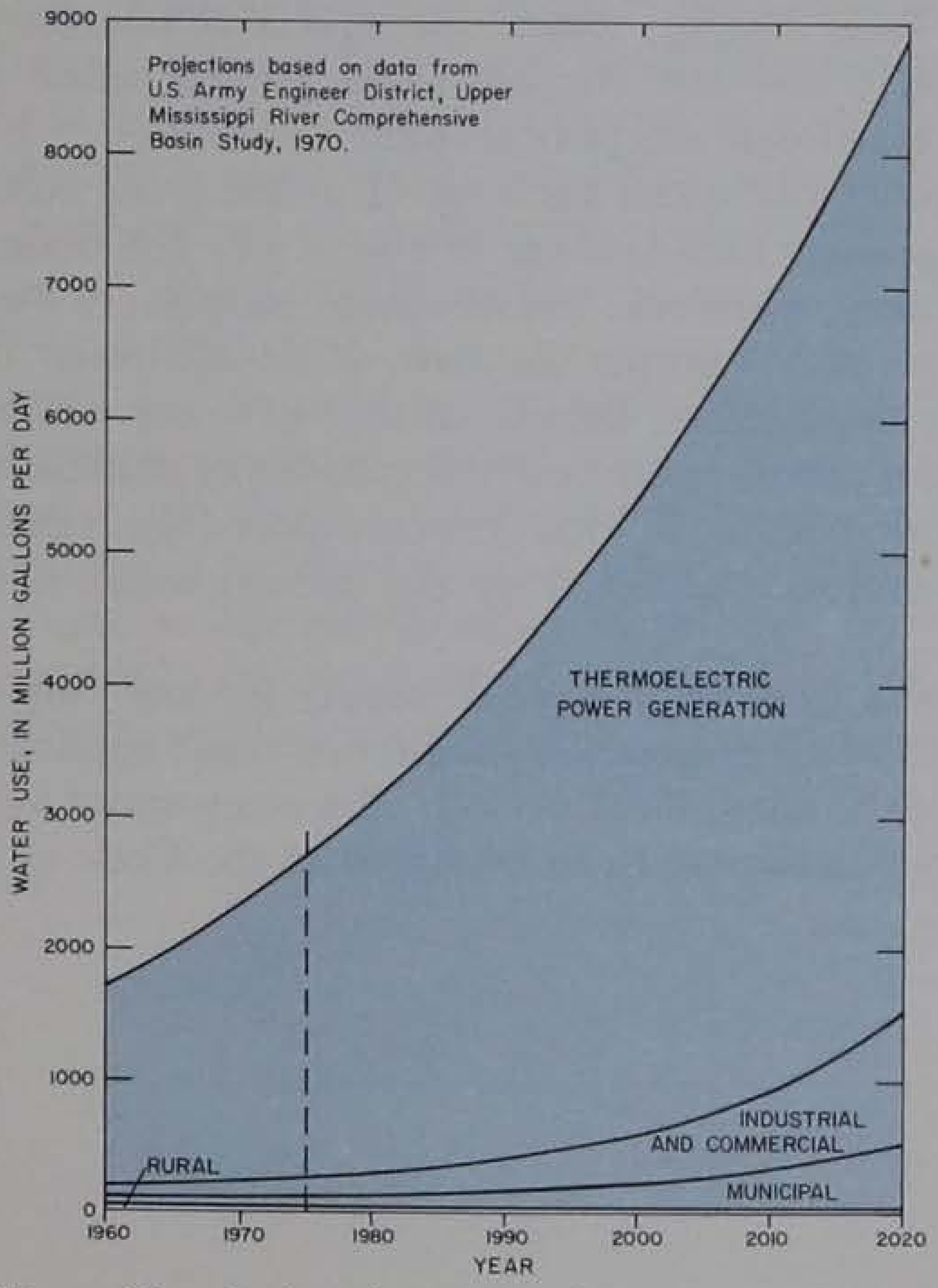


Figure 66.—Projected water use in east-central Iowa

Table 12. — Water gained or lost from each source, 1974-75

Drainage Basin	Estimated net loss (–) or gain (+) in mgd for sources indicated							Total
	Surface Water	Ground Water						
	Streams and Reservoirs	Surficial aquifers	Mississippian aquifer	Devonian aquifer	Silurian aquifer	Cambrian-Ordovician aquifer	Dresbach aquifer	
Skunk River	+ 0.85	+ 0.04	+0.01	–0.24	0.0	–1.16	0.0	– 0.50
Iowa River	+ .49	– 2.59	– .01	–3.35	– .75	–1.67	.0	– 7.88
Cedar River	+17.54	–18.44	.0	–3.47	–15.11	–8.77	.0	– 28.25
Wapsipinicon River	+ .90	+ .09	.0	.0	– 4.36	– .82	.0	– 4.19
Maquoketa River	+ .53	– .01	.0	.0	– 3.11	– .27	– .35	– 3.21
Mississippi River valley and minor tributary basins	+42.46	–77.38	.0	+ .04	– 6.9	– .36	–15.53	– 57.67
Total	+62.77	–98.29	0.0	–7.02	–30.23	–13.05	–15.88	–101.70
		–164.47						

FUTURE DEMANDS

The quantity of water withdrawn and used in east-central Iowa has increased in the past, and it is expected that water withdrawals will continue to grow in the future. Figure 66 shows a projection of water use in the report area to the year 2020.

The projected mean annual increase in water use from 1960 to 2020 was calculated from data presented on water use in drainage basins in and adjacent to the report area in the Upper Mississippi River Comprehensive Basin Study (1972). The growth curve generated from this projection was then calibrated by current water-use data (dashed line, fig. 66) presented in this report. Water withdrawals on the scale shown near the end of the projection would have a definite impact on the availability, cost, and quality of water used in the report area. Social, political, and economic factors influencing the rate of growth cannot be accurately predicted; however, it is likely that they will have a limiting effect on increasing water withdrawals.

The following assumptions were made in estimating the future water use:

1. The mean annual growth rate of total water use for 1960-76 will continue indefinitely into the future.
2. The amount withdrawn for rural domestic and for livestock use will remain nearly the same. It is assumed that the livestock population will not change significantly. The number of persons living in rural areas is expected to decrease, but the per-capita water use will increase.
3. The amount of water distributed through municipal systems will increase in proportion to the growth in urban population (fig. 5). This estimate may be conservative, as it does not anticipate an increase in per-capita use.
4. The remaining increase in total water use will be accounted for by fuel-electric power generation, self-supplied industrial and commercial use and irrigation; presently these are the largest and fastest growing uses. These types of uses may be most affected and limited by cost and availability factors. In the case of thermoelectric power generation, it is assumed that the water use per kilowatt hours generated will not change.

WATER RESOURCES LAWS AND REGULATIONS

Three State agencies, the Iowa Natural Resources Council, the Iowa Department of Environmental Quality, and the Iowa Conservation Commission, regulate and administer laws relating to water use, flood-plain management, waste disposal and dams in the State. In addition, the U.S. Army Corps of Engineers has regulatory responsibilities for waters of the United States under Section 404 of the Federal Water Pollution Act Amendments of 1972 and prior Federal legislation.

The Iowa Natural Resources Council has the authority to establish and enforce a comprehensive state-wide plan for the control of water and the protection of the water resources of the State. Under this authority, the use of water for many purposes is regulated through a permit system administered by the Water Commissioner.

Regulated uses include (1) any municipal corporation or person supplying a municipal corporation which increases its water use more than 100,000 gallons, or more than 3 percent, over its highest per-day beneficial use prior to May 16, 1957; (2) except for nonregulated use, any person using in excess of 5000 gallons per day, diverted, stored, or withdrawn from any source of supply except a municipal water system or another source specifically exempted (this category includes irrigation); (3) diverting water or any other material from the surface directly into any underground water course or basin (a permit is not needed for this purpose if diversion existed prior to May 16, 1957, and does not create waste or water pollution); and (4) industrial water users who have their own water supply, within the territorial boundary of municipal corporations, and whose use exceeds three percent more water than the highest per-day beneficial use prior to May 16, 1957.

Many uses do not fall under the control of the Iowa Natural Resources Council. Nonregulated uses include use of water for ordinary household purposes, for poultry, livestock, and domestic animals, or the use of surface waters from rivers which border the state or ground water from islands or former islands in these rivers. Beneficial uses of water within the territorial boundaries of cities that do not exceed 3 percent more than the highest per-day beneficial use prior to May 16, 1957, are considered nonregulated uses as are any other beneficial uses of water by any person which is less than 5000 gallons per day.

Persons planning to develop a water supply for any purpose which falls under the category of a regulated use should first make application to the Iowa Natural Resources Council for a permit. The rules under which the water-permit system is administered can be found in the Code of Iowa, Chapter 455A.

Flood-plain regulation is practiced in Iowa in an attempt to reduce flood hazards and damage. The Iowa Natural Resources Council has the authority to establish floodways along rivers and streams. A floodway is the channel of a river or stream and those portions of the flood plain adjoining the channel, which are reasonably required to carry and discharge the flood water or flood flow of any river or stream. It is unlawful to erect any structure, dam, obstruction, deposit, or excavation on any floodway which will adversely affect the efficiency or unduly restrict the capacity of the floodway. Written application must be made to the Iowa Natural Resources Council for a permit to erect any of the aforementioned structures on a flood plain. The Iowa Natural Resources Council has the power to remove or eliminate any structure which affects the efficiency or restricts the capacity of a floodway. The procedures for obtaining permission to erect any of these structures are also set forth in the Code of Iowa, Chapter 455A. Proposals for, and changes in, encroachment limits, flood-plain regulations, or flood-plain zoning ordinances must be submitted by local units of government to the Iowa Natural Resources Council for review and approval.

The Iowa Natural Resources Council also administers Chapter 469 of the Iowa Code which, in Section 469.1, states, "No dam shall be constructed, maintained, or operated in this State in any navigable or meandered stream for any purpose, or in any other stream for manufacturing or power purposes, unless a permit has been granted by the Iowa Natural Resources Council to the person, firm, corporation, or municipality constructing, maintaining, or operating the same". The Council conducts an annual inspection of all dams licensed under these provisions.

The Department of Environmental Quality is the agency of the State authorized to prevent, abate, or control water pollution. These duties are carried out through the Water Quality Commission. The Commission is responsible for establishing, modifying, or repealing quality standards for the waters of the State, or for establishing, modifying, or repealing effluent standards for disposal systems. Instructions outlining the operation of the Water Quality Commission are set forth in the Code of Iowa, Chapter 455B.

Written permits are required from the executive director of the Department of Environmental Quality to carry on any of the following activities: (1) The construction, installation, or modification of any disposal system for disposing of sewage, industrial waste, and other wastes and includes sewer systems, treatment works, and dispersal systems. (2) The construction or use of any new outlet for the discharge of any sewage or wastes directly into the waters of the State. (3) The operation of any waste-disposal system other than sewage or industrial waste.

Approval of the Iowa Conservation Commission is required for projects that involve construction on the bed or banks of a meandered stream or if they constitute obstructions in navigable waters. Projects in, or on the banks of, navigable streams also require approval by the Corps of Engineers.

Section 404 of the Federal Water Pollution Act Amendments of 1972 assigns responsibility for the regulation of the discharge of dredged or fill material in the waters of the United States to the U.S. Army Corps of Engineers. The following additional types of activities will also be regulated under this program: site developmental fills for recreational, industrial, commercial, residential, and other uses; causeways or road fills; dams and dikes; artificial islands; property protection and/or reclamation devices such as riprap, groins, seawalls, breakwaters and bulkheads, and fills; beach nourishment; levees; sanitary landfills, and backfill required for the placement of structures such as sewage treatment facilities. For projects in east-central Iowa, approval should be requested from the U.S. Army Corps of Engineers, Rock Island District, Clock Tower Building, Rock Island, Ill. 61201.

CONCLUSIONS

Large amounts of water are available for present and future use in east-central Iowa, although the cost, availability, and quality of water will continue to create problems in some parts of the area. All sites on or near major streams have an accessible source of water that could be developed and would be adequate to supply much more water than is now needed. One or more of 3 surficial aquifers and 5 bedrock aquifers have the capabilities of supplying moderate to large amounts of good-quality water in most of the region.

AVAILABILITY AND QUALITY OF WATER FROM STREAMS

In east-central Iowa the surface water available for use is provided principally by the five major rivers — the Maquoketa, Wapsipinicon, Cedar, Iowa, and Mississippi Rivers. The four major interior rivers can supply approximately 5600 cfs 50 percent of the time and 1700 cfs 90 percent of the time. These quantities are equivalent to 5950 and 1800 gallons per day per capita, respectively, for the residents in the area in 1970. The Mississippi River, the largest surface-water source, can supply approximately 36,000 and 19,000 cfs 50 and 90 percent of the time, respectively. The small streams, which are all tributaries of one or another of the major rivers, are not dependable sources of supply. Their low flows are so small that, without storage, they can support only minor, or intermittent, usage. The one large reservoir, Coralville Lake, is operated so that the normal dependable low flow in the Iowa River at Iowa City is about three times the natural 7-day 10-year low flow.

Floods present recurring problems in connection with the development and use of flood-plain lands. Sediment in streams and water quality must also be considered in any plans to utilize the surface-water resource. Sediment concentrations as high as 76,000 mg/L have been observed, and annual sediment yields of 3000 tons per square mile, and probably more, are possible in small streams.

Surface waters are of the calcium-bicarbonate type. At low flows they are very hard and contain up to 400 mg/L of dissolved solids. At high flows they are moderately hard to soft and contain less dissolved solids, usually less than 200 mg/L. The waters are basic, with pH ranging from 7.5 to 9.

AVAILABILITY AND QUALITY OF WATER FROM SURFICIAL AQUIFERS

The alluvial aquifers offer some of the highest yields of any aquifers in the report area. Yields of more than 1000 gpm are not uncommon for the Mississippi River alluvium, and yields of 200 to about 1000 gpm are available from wells in the alluvium in places along the Iowa, Cedar, Wapsipinicon, and Maquoketa Rivers. Recharge to the alluvium, through precipitation or by induced infiltration from the rivers, is rapid and can support large withdrawals in many places. The water induced into the alluvial aquifers, however, can deplete streamflow, particularly during periods of low flow. The chemical quality of the alluvial water generally is good. Although the highly productive parts of the alluvial aquifers are restricted in occurrence to parts of large stream valleys, they have the greatest potential for future developments of large quantities of ground water in east-central Iowa. The concentrations of dissolved solids generally are less than 500 mg/L in the eastern two-thirds of the region and somewhat higher in the rest of the area. Nitrate concentrations slightly exceed 10 mg/L at a few places.

Moderate to high yields are sometimes available from the buried-channel aquifers. Yields ranging from 500 to 1200 gpm are available from these deposits where they are contiguous with alluvium of present-day watercourses. In areas where these aquifers are overlain by drift, the yields are drastically reduced. Where the buried-channel aquifers are contiguous with alluvial aquifers, such as at Cedar Rapids, the quality of water is similar to the quality in the alluvium. In other areas, the quality of the water from these aquifers approaches the quality of the underlying bedrock—good in the eastern part of the region and poor in the western part.

The thin and discontinuous sands and gravels of the drift aquifer generally yield about 5 to 20 gpm and occasionally will sustain withdrawals of 50 to 150 gpm. Recharge to the drift aquifers is fairly rapid. In places where the sand and gravel lenses within the drift are thin and discontinuous the water table may drop below the pump intake during drought periods. The water from the shallow drift aquifer is usually below 500 mg/L in dissolved-solids concentration; however, nitrate concentrations between 4.4 and 10 mg/L occur locally. Nitrate contamination of the drift aquifer is attributed to infiltration of agricultural chemicals, or contamination by septic tank effluent.

AVAILABILITY AND QUALITY OF WATER FROM THE BEDROCK AQUIFERS

At least one of the carbonate bedrock aquifers of Mississippian, Devonian, and Silurian age can be reached at depths of about 50 to 400 feet in almost all of the report area. These three bedrock aquifers generally yield water from irregularly distributed openings along bedding planes and joints and for that reason the yields are variable.

Limited yields, usually less than 50 gpm, are available from the Mississippian aquifer, which is used for rural supplies and for municipal supplies in a few small communities. The water quality of the Mississippian aquifers is generally poor, with the dissolved-solids content of the water exceeding 1000 mg/L in most places.

The Devonian aquifer supplies higher yields of better quality water over a larger area than the Mississippian aquifer. In most places yields of at least 50 gpm may be expected from wells fully penetrating the aquifer, and in a few areas, yields of as much as 300 gpm can be obtained. This aquifer is used for rural domestic and livestock supplies, and municipal supplies for some communities in the central and northwest parts of the report area. In the eastern part of its area of occurrence, the quality of water from the aquifer is good with the dissolved-solids content ranging from 250 to 1000 mg/L. Southwest of a line from northwest Tama County to Muscatine, however, the dissolved-solids content is greater than 1000 mg/L, and concentrations exceed 5000 mg/L in the southwest part of the report area.

Fully penetrating wells in the Silurian aquifer generally produce at least 100 gpm with maximum yields of about 700 gpm. The aquifer has been developed extensively for municipal and industrial use in the eastern half of the report area. In this area, the dissolved-solids content generally is less than 500 mg/L. As in the Devonian aquifer, the dissolved-solids content is greater than 1000 mg/L southwest of a line from northwest Tama County to Muscatine. In the southwest part of the report area concentrations as high as 3500 mg/L are encountered, and concentrations as high as 5000 mg/L are inferred.

The Cambrian-Ordovician aquifer yields at least 500 gpm to properly constructed wells in the region, except for a small easternmost segment near the Mississippi River. Yields of 500 to 750 gpm are available in the southwest and northwest parts, and 750 to 1000 in the west-central parts. The high yields in these latter areas are particularly significant, because the yields from overlying aquifers are much less. The Jordan Sandstone, the principal water-bearing unit in this aquifer, is at depths ranging from 600 feet in the northeast corner to 2300 feet below the land surface in the southwest part of the region. The great depth and numerous confining beds between this aquifer and the land surface precludes any significant amount of recharge to the aquifer from precipitation falling in the report area. Water moving laterally through the aquifer into this area is probably not sufficient to replenish the present withdrawals of about 13 mgd. As a result, the potentiometric surface has been lowered from 90 to 200 feet over the entire area. The water levels will be lowered further as withdrawals continue. However, vast amounts of water are still available from the aquifer but at higher costs. Good quality water, with dissolved-solids concentrations of less than 1000 mg/L, is available from the aquifer in most of the region. In the northern part of east-central Iowa, dissolved-solids concentrations in the aquifer are less than 500 mg/L. The water becomes progressively more mineralized to the south and east and maximum concentrations in excess of 2000 mg/L occur in southeast Scott County. In the western part of the region the water from this aquifer is much better in quality than from the overlying aquifers, hence wells tapping the aquifer should be tightly cased and cemented into the upper part of the aquifer.

The Dresbach aquifer is an excellent source of water in the extreme eastern part of the report area. Yields of at least 500 gpm may be anticipated from properly constructed wells in Jackson and Clinton Counties. In the Clinton area, yields as high as 2500 gpm can be obtained. The Dresbach aquifer is at depths ranging from 1000 to1600 feet below the land surface in these counties, and almost all the recharge to the aquifer in the report area is by underflow. Recharge is not sufficient to replenish the approximately 16 mgd withdrawn from the aquifer, and a continual lowering of the aquifer's potentiometric surface has been noted. The greater drilling depths, lower yields, and poor water quality to the south and west of Jackson and Clinton Counties limit the use of the Dresbach aquifer in the rest of the area. In Jackson and Clinton Counties, the dissolved-solids concentration of the water in the aquifer is less than 500 mg/L. Outside Jackson and Clinton Counties it exceeds 1000 mg/L and is greater than 5000 mg/L in the central part of the report area. Water analyses from the western part of the report area are not available; however it is likely that water from the Dresbach aquifer in this area is highly mineralized.

SELECTED REFERENCES

Brown, Eugene, Skougstad, M. W., and Fishman, M. J., 1970, Methods for collection and analysis of water samples for dissolved minerals and gasses: U.S. Geol. Survey Techniques for Water-Resource Inv., bk. 5, chap. A1, 160 p.

Calvin, Samuel, 1883, On the fauna found at Lime Creek, Iowa, and its relation to other geological faunas: Am. Jour. Sci., ser. 3, v. 25, p. 432-436.

____ 1896, Geology of Jones County: Iowa Geol. Survey Ann. Rept., v. 5. 1895, p. 33-112.

____ 1897, Geology of Johnson County: Iowa Geol. Survey Ann. Rept., v. 7, 1896, p. 33-116.

Chang, H. C., and others, 1972, Population trends of incorporated places in Iowa 1900-1970: Pm 539, Coop. Ext. Service, Iowa State Univ., Ames, Ia., 36 p.

Collinson, Charles, 1967, Devonian of the north-central region, United States, *in* International Symposium on the Devonian System: Alberta Soc. of Petroleum Geologist, v. 1, p. 933-971.

Dorheim, F. H., 1953, Devonian outlier in Jackson County, Iowa: Iowa Acad. Sci., v. 60, p. 362-365.

Dow, V. E., and Mettler, S. D., 1962, The structure and stratigraphy of the Skvor-Hartl Area, southeast Linn County, Iowa: Iowa Acad. Sci., v. 69, p. 326-332.

Economics Advisory Committee, 1970, Upper Mississippi River comprehensive basin study, economic base study and projections: v. VIII, app. P, Upper Mississippi River Comprehensive Basin Study Coordinating Committee, 194 p.

Hall, James, and Whitfield, R. P., 1873, Descriptions of new species of fossils from Devonian rocks of Iowa: N.Y. State Cabinet Ann. Rept. 23, p. 223-239.

Hansen, R. E., 1970, Geology and ground-water resources of Linn County, Iowa: Iowa Geol. Survey Water-Supply Bull. no. 10, 66 p.

____ 1972, Bedrock topography of east-central Iowa: U.S. Geol. Survey Misc. Geol. Inv. Map I-717.

Hansen, R. E., and Steinhilber, W. L., 1977, Geohydrology of Muscatine Island, Muscatine County, Iowa: Iowa Geol. Survey Water-Supply Bull. no. 11, 60 p.

Heinitz, A. J., 1970, Low-Flow characteristics of Iowa streams through 1966: Iowa Nat. Res. Council Bull. no. 10, 178 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: (2d ed.), U.S. Geol. Survey Water-Supply Paper 1473, 363 p.

Horick, P. J., and Steinhilber, W. L., 1973, Mississippian aquifer of Iowa: Iowa Geol. Survey Misc. Map Ser. 3.

Horick, P. J., (in preparation), Jordan aquifer of Iowa: Iowa Geol. Survey Misc. Map Ser. 6.

Iowa Geological Survey, 1969, Preliminary interpretaion report, airborne magnetometer survey of east central Iowa: 19 p.

Kolata, D. R., and Buschbach, T. C., 1976, Plum River fault zone of northwestern Illinois: Illinois State Geol. Survey Circ. 491, 20 p.

Lara, O. G., 1973, Floods in Iowa: technical manual for estimating their magnitude and frequency: Iowa Nat. Res. Council Bull. no. 11, 56 p.

MacKichan, K. A., and Kammerer, J. C., 1961, Estimated use of water in the United States, 1960: U.S. Geol. Survey Circ. 456, 44 p.

Mosnat, H. R., 1898, Artesian wells of the Belle Plaine area: Iowa Geol. Survey Ann. Rept. v.9, p. 521-562.

Mummey, Samuel, Jr., 1953, Surface water resources of Iowa October 1. 1942, to September 30, 1950: Iowa Geol. Survey Water-Supply Bull. no. 3, 538 p.

Myers, R. E., 1963, Surface water resources of Iowa October 1, 1955, to September 30, 1960: Iowa Geol. Survey Water-Supply Bull. no. 8, 526 p.

National Oceanic and Atmospheric Administration, 1975, Climatological data-annual summary, 1974, Iowa: U.S. Dept. of Commerce, v. 85, no. 13, 15 p.

Norton, W. H., 1895, Geology of Linn County: Iowa Geol. Survey Ann. Rept., v. 4, 1894, p. 121-195.

—— 1898, Geology of Scott County: Iowa Geol. Survey Ann. Rept.. v. 9, p. 389-519.

—— 1901, Geology of Cedar County: Iowa Geol. Survey Ann. Rept., v. 11. 1900, p. 279-396.

—— 1920, Wapsipinicon breccias of Iowa: Iowa Geol. Survey Ann. Rept., v. 17, 1916, p. 359-547.

—— 1928, Deep wells of Iowa: Iowa Geol. Survey Ann. Rept., v. 33, 1927, p. 10-374, pl. 1.

Parker, M. C., 1971, The Maquoketa Formation (Upper Ordovician) in Iowa: Iowa Geol. Survey Misc. Map Ser. No. 1.

Ruhe, R. V., Dietz, W. P., Fenton, T. E., and Hall, G. F., 1968, Iowan drift problem, northeastern Iowa: Iowa Geol. Survey Repts. of Inv. 7, 40 p.

Savage, T. E., 1903, Geology of Tama County: Iowa Geol. Survey Ann. Rept., v. 13, 1902, p. 185-253.

—— 1905, Geology of Benton County: Iowa Geol. Survey Ann. Rept., v. 15, 1904, p. 125-225.

—— 1906, Geology of Jackson County: Iowa Geol. Survey Ann. Rept., v.16, 1905, p. 563-648.

Stainbrook, M. A., 1941, Biotic analysis of Owen's Cedar Valley Limestone: Pan -Am. Geologist, v. 75, p. 321-327.

—— 1944, The Devonian system in Iowa: Illinois Geol. Survey Bull. 68, p. 182-188.

State Conservation Commission, 1968, Outdoor recreation in Iowa: State of Iowa, Des Moines, Ia., 343 p.

Stookey, S. W., 1910, Geology of Poweshiek County: Iowa Geol. Survey Ann. Rept., v. 20, 1909, p. 237-269.

—— 1910, Geology of Iowa County: Iowa Geol. Survey Ann. Rept.. v. 20, 1909,p. 151-198.

Udden, J. A., 1898, Geology of Muscatine County: Iowa Geol. Survey Ann. Rept., v. 9, p. 247-388.

—— 1905, Geology of Clinton County: Iowa Geol. Survey Ann. Rept., v. 15, 1904, p. 369-431.

U.S. Army Engineer District, Rock Island, and others, 1970, Upper Mississippi River comprehensive basin study, fluvial sediment: v. III, app. G, Upper Mississippi River Comprehensive Basin Study Coordinating Committee, p. G-1-G-100.

U.S. Bureau of the Census, (in preparation), 1974 Census of Agriculture area reports, Iowa: U.S. Department of Commerce.

U.S. Federal Water Pollution Control Administration, 1968, Water quality criteria: report of the National Technical Advisory Committee to the Secretary of the Interior: U.S. Dept. of the Interior, 234 p.

U.S. Geological Survey, (published annually to 1961), Surface-water supply of the United States, Part 5, Hudson Bay and Upper Mississippi River Basin: U.S. Geol. Survey Water-Supply Papers.

—— 1956, Surface water resources of Iowa October 1, 1950, to September 30, 1955: Iowa Geol. Survey Water-Supply Bull. no. 6, 405 p.

—— 1961-75, Water resources data for Iowa: Water Res. Div., U.S. Geol. Survey Water Data Rept., Iowa City, (published annually 1961-75).

—— 1976, Water resources data for Iowa, 1975: Water Res. Div., U.S. Geol. Survey Water Data Rept. IA-75-1, Iowa City, 305 p.

U.S. Public Health Service, 1962, Public Health Service drinking water standards—1962: Public Health Service Pub. no. 956, U.S. Dept. of Health, Education, and Welfare, 61 p.

Waite, P. J., 1970, Iowa precipitation *in* Water Resources of Iowa, Horick, P. J., (ed.), Univ. Printing Service, Iowa City, p. 3-16.

Webster, C. L., 1889, A general preliminary description of the Devonian rocks of Iowa: Am. Naturalist, v. 23, p. 229-243.

Yoho, W. H., 1967, Preliminary report on basement complex rocks of Iowa: Iowa Geol. Survey Repts. of Inv. 3, 19 p.