IOWA GEOLOGICAL SURVEY
Iowa City, Iowa
SAMUEL J. TUTHILL, Director and State Geologist

WATER-SUPPLY BULLETIN No. 10

GEOLOGY AND GROUND-WATER RESOURCES OF LINN COUNTY, IOWA

by

ROBERT E. HANSEN
Hydrologist, U. S. Geological Survey

Prepared Cooperatively
by the United States Geological Survey
and Iowa Geological Survey

Published by the
STATE OF IOWA
Des Moines
1970

State of Iowa
1970

GEOLOGY AND GROUND-WATER RESOURCES OF LINN COUNTY, IOWA

by

ROBERT E. HANSEN

Prepared cooperatively by the
United States Geological Survey
and the Iowa Geological Survey

Published by the
STATE OF IOWA
Des Moines
1970

CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY AND GROUND-WATER RESOURCES Of LINN COUNTY, IOWA

by ROBERT E. HANSEN

ABSTRACT

Linn County, in east-central Iowa, covers about 713 square miles and lies in the Western Young Drift section of the Central Lowlands physiographic province. The normal annual rainfall in the county is about 33 inches and the annual mean temperature is about 48°F. The population in 1960 was 136,899, of which 75 percent was urban.

Ground water is a vital natural resource in Linn County—all municipal, farm-domestic, livestock, and most industrial supplies are obtained from this source. An estimated 24 mgd (million gallons per day) of ground water was used in the county in 1964.

The principal aquifers are alluvium, buried channel deposits, Silurian-Devonian limestones and dolomites, and the Jordan Sandstone. All yield fair-to-good quality water, although the water is hard and locally contains high concentrations of iron. All are capable of yielding as much as 500 gallons or more per minute to wells.

Alluvium has been developed for water supplies only at Cedar Rapids, where withdrawals in 1964 averaged 12 mgd for municipal supplies and 2.7 mgd for industrial supplies. The alluvial aquifer yields up to 2,000 gpm (gallons per minute) to wells in the Cedar Rapids well field. Similar yields from alluvium may be available along several reaches of the Cedar and Wapsipinicon Rivers. Smaller quantities are available from the alluvium of Prairie Creek. Alluvial aquifers are readily recharged by precipitation and induced infiltration.

Buried channel deposits occur in preglacial or interglacial valleys that were carved into the bedrock. These old valleys, whose trends roughly parallel the present Cedar River and Prairie Creek, contain water-bearing alluvial deposits that are covered by glacial drift. Data from a few wells tapping these deposits indicate that yields of up to 500 gpm of good-quality water are available from this source. The most favorable areas for development of water supplies are those areas where the

channel deposits underlie and receive recharge from the alluvium of the Cedar River and Prairie Creek.

The Silurian-Devonian aquifer's county-wide occurrence, near-surface position, and ability to yield as much as several hundred gallons per minute of good-quality water makes it the most widely used aquifer in Linn County. During 1960-64, withdrawals averaged about 1.5 mgd for domestic-livestock use, about 0.6 mgd for small community use, and about 4 mgd for industrial-commercial use. Withdrawals are concentrated in the Cedar Rapids area, where 65 percent of the withdrawals from the aquifer occur. This concentrated pumpage has caused a progressive lowering of the aquifer's piezometric surface in downtown Cedar Rapids. During the past 70 years, water levels in wells in this locality have declined about 105 feet in the center of the cone of depression and about 26 feet about one mile from the cone's center. Water level in the center of the cone presently is declining at an average rate of 1 foot per year. Because the rate of decline in the same area was determined to have been 2 to 3 feet per year during the 1940's and 50's, the cone is believed to be stabilizing or pumpage is being reduced. The aquifer probably could withstand an additional 150 to 200 feet of piezometric lowering in the Cedar Rapids area, but individual wells would be adversely affected.

The Jordan aquifer, which underlies the entire county, is considered to be the most isotropic and homogeneous aquifer in Linn County. Yields of 1,000 gpm or more of fair-to-good quality water from this source are believed to be available anywhere in the county. The aquifer is not yet developed extensively; an average of about 2.4 mgd was pumped during 1964 for industrial and municipal use in the Cedar Rapids-Marion area.

The shallow bedrock and glacial drift aquifers yield only small quantities of good quality water. Their widespread extent and shallow depth, however, make them suitable for the development of small supplies for domestic and livestock use.

INTRODUCTION

Purpose and Scope

Although two large rivers traverse the county, the residents of Linn County depend primarily on ground water for their water supplies. All farms get their entire domestic and stock, and some of their irrigation, supplies from underground sources. All municipalities in the county develop ground water for water supplies. In the Cedar Rapids area, the second largest population and manufacturing center in Iowa, large quantities of ground water are pumped for municipal and industrial purposes. Present supplies seem to be adequate throughout the county; however, in the Cedar Rapids area, the concentrated withdrawals of ground water have caused a lowering of water levels in the Silurian-Devonian aquifer. Increasing water demands of new and expanding industry could aggravate the problem.

The objective of this report is to evaluate the various ground-water sources in Linn County. This involves the identification and delineation of the water-bearing rock units and an evaluation of the availability, yield, and chemical quality of water contained in these rocks This information will supply the data necessary to determine alternate sources of ground water in problem areas and to define the most favorable ground-water sources for future needs. Although information on surface water is not considered in this report, publications cited will provide considerable data on this resource.

Cooperation and Acknowledgments

This report is one of a series on the ground-water supplies in Iowa made by the Water Resources Division, U. S. Geological Survey in cooperation with the Iowa Geological Survey. Personnel of the Iowa Geological Survey are actively engaged in these cooperative projects by making subsurface studies that permit correlation of rock units. For this project, they also aided in gathering water-level data and drafting illustrations for this report.

The residents of the county cooperated in supplying information on their wells and permitting measurements of water levels in some wells. Drilling contractors operating in the area were especially cooperative by collecting well cuttings and making available the data in their files. Information on municipal supplies was generously provided by the water superintendents. In particular, George S. Lee, Superintendent, Cedar Rapids Water Department, devoted considerable time in supplying in-

formation on the Cedar Rapids' well field and water supply. The County Engineer's office supplied information on bench marks.

Geography

Linn County, comprising an area of 713 square miles, is in east-central Iowa (fig. 1) and is drained by two large streams.

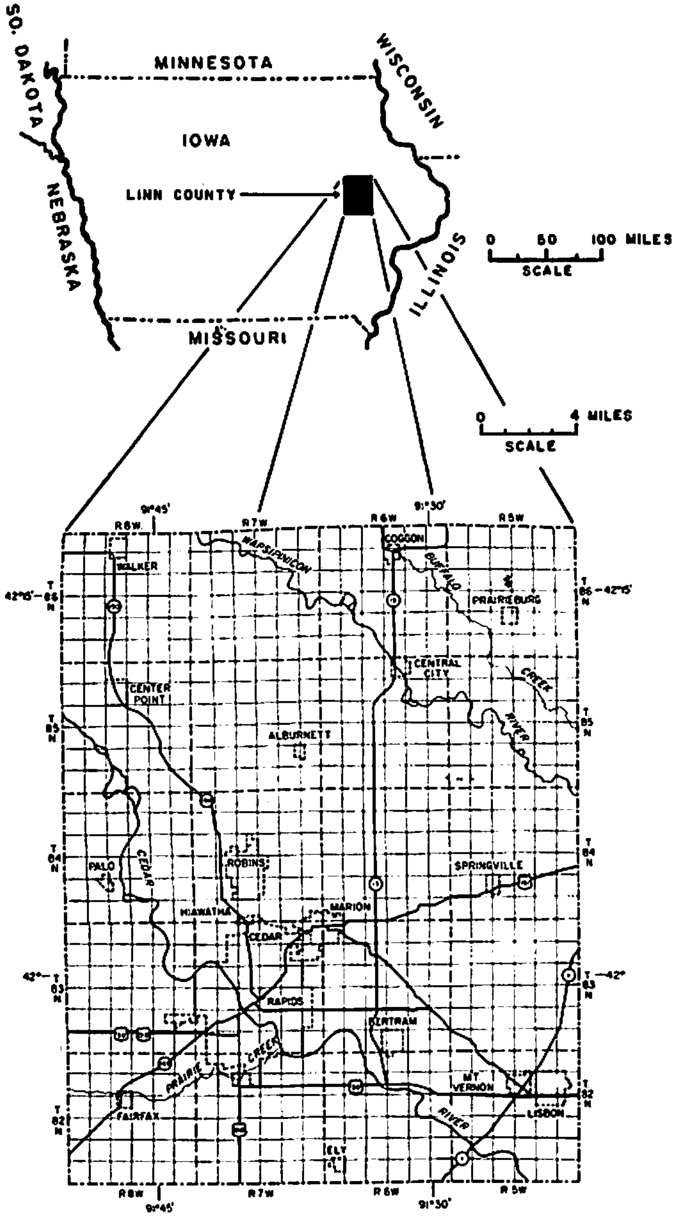
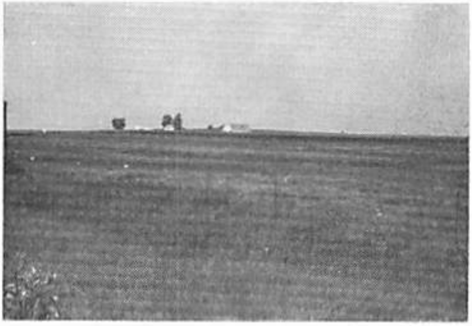


Figure 1.—Location of report area.

The Cedar River, the principal stream, and its tributaries drain the southwestern three-fourths of the county. The northeastern quarter of the county is drained by the Wapsipinicon River and its tributaries. Both of these rivers cut diagonally across the county from northwest to southeast (fig. 1).

The topography of the county is characterized by a generally subdued land surface with greatest relief occurring in the areas adjacent to the Cedar and Wapsipinicon Rivers. Typical upland features of the topography are the generally flat horizon, low relief, and a gently undulating surface (fig. 2A). Topography

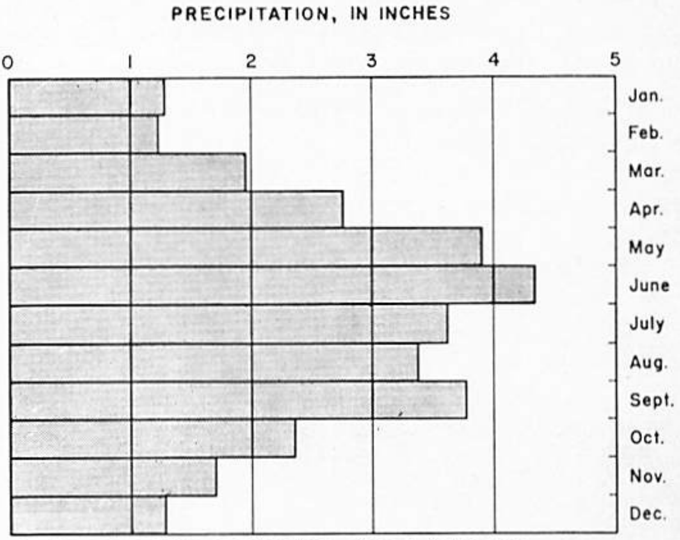


A. The uplands—central Linn County.

B. Rock walls—Cedar River at Palisades-Kepler State Park.

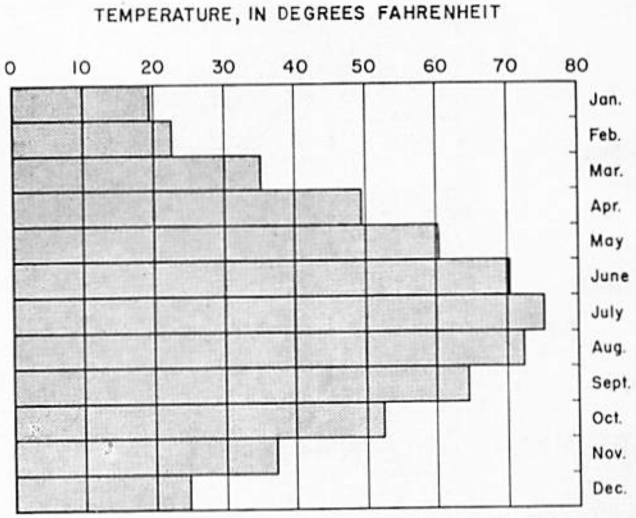
C. Wide flood plain—Cedar River south of Mount Vernon.

Figure 2.—Views of topography in Linn County.



A. Average monthly precipitation. Over 3 inches per month occurs from May through September.

(Data from US Weather Bureau, Cedar Rapids No. 1)



B. Average monthly temperature. From January to July the change is about 55 F.

Figure 3.—Average monthly precipitation and temperature.

along the rivers is generally rough and hilly; in several localities the valley walls are sheer cliffs (fig. 2B). In some areas, however, the rivers have well developed flood plains that are several miles wide (fig. 2C). The highest altitude, about 1,010 feet, is in the northeastern corner of the county; the lowest altitude, about 690 feet, is in the southeastern corner where the Cedar River leaves the county.

Linn County has a subhumid climate. Summers are sunny and warm with relatively high humidity. In recent years the winters have been generally mild, broken only by an occasional severe cold wave. The growing season averages about 170 days; the last killing frost is usually in April or early May, the first is usually in October. U. S. Weather Bureau records (Cedar Rapids No. 1) indicates that most of the precipitation occurs during the summer months (fig. 3A) and that there is a large annual range in average temperature (fig. 3B). The average annual precipitation is nearly 33 inches and has ranged from a low of about 18 inches in 1909 to a high of about 50 inches in 1965. Monthly pan evaporation reaches a maximum of about 8 inches during July.

Agriculture is an important part of the economy of Linn County. There are more than 3,000 farms on land area comprising about 92 percent of the county. Livestock and grain are the principal farm products.

Cedar Rapids is a large industrial center having many local manufacturing plants and branch offices of larger industrial concerns. Some of the products and equipment produced are power machinery, structural steel, radio equipment, plastics, corn products, cereals and flour, farm and livestock accessories, chemical supplies, and meat. Many of these industries use large quantities of ground water for processing and cooling purposes.

The steadily growing population of Linn County is related directly to the growth of Marion and of Cedar Rapids, the second largest city in Iowa (fig. 4). Census data show that the small-town populations have increased only slightly during the last 40 years (table 1). These statistics illustrate why water problems are concentrated in the Cedar Rapids area.

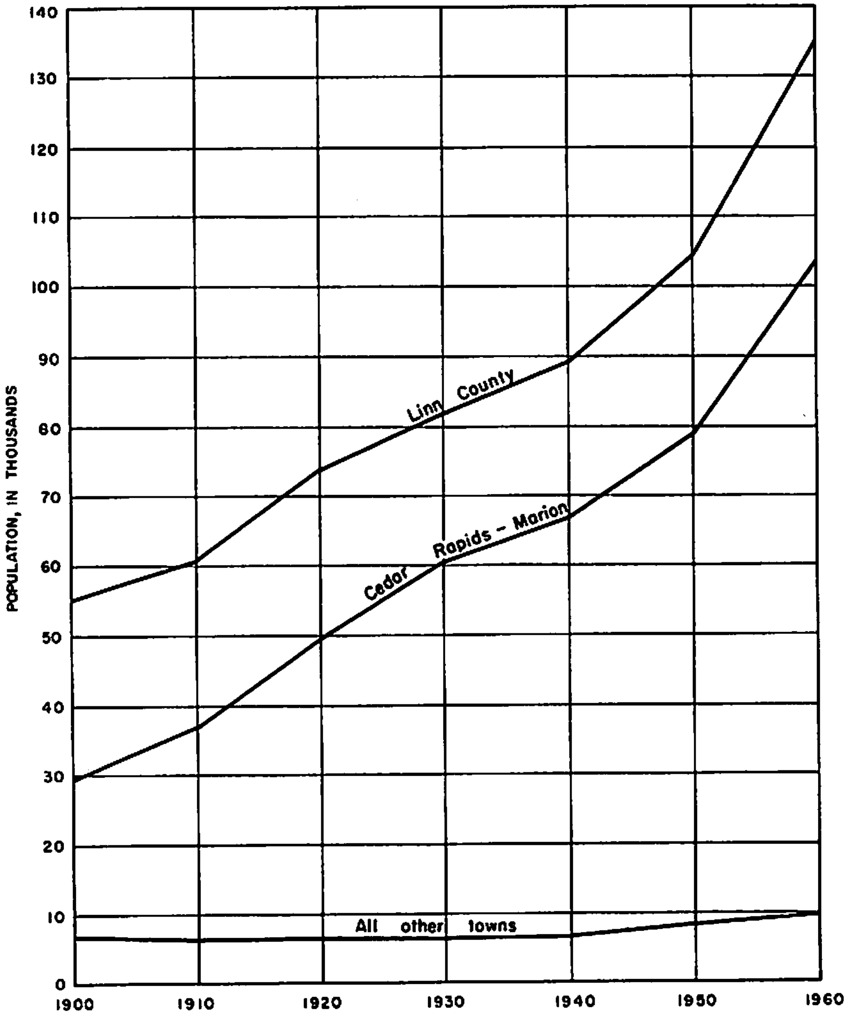


Figure 4.—Population graph, 1900-1960.

TABLE 1.—POPULATION OF CITIES AND TOWNS IN LINN COUNTY.

Cities and Towns	1920	1960	1965[1]
Alburnett	201	341	....
Bertram	92	170	....
Cedar Rapids	45,566	92,035	103,545
Center Point	773	1,236	....
Central City	688	1,087	....
Coggon	553	672	....
Ely	175	226	268
Fairfax	250	528	642
Lisbon	803	1,221	....
Marion	4,138	10,800	15,267
Mt. Vernon	1,466	2,575	3,030
Palo	224	387	....
Prairieburg	176	226	....
Robins	....	426	....
Springville	597	785	918
Walker	464	584	....
Linn County	74,004	136,899	....

[1] Data from the 1969 Iowa Highway map, Iowa State Highway Commission.

Previous Investigations

The geology of Linn County was described in a report by Norton in 1895[1]. Norton and others (1912) summarized the county's ground-water resources as a part of a survey of underground water in the state. Similar reports are available for the bordering counties.

In 1927 Howard E. Simpson prepared an unpublished report for the city of Cedar Rapids concerning the potential sources of water supply in that area. He discussed the surface and subsurface reservoirs in terms of water quality, quantity, and availability. Reference was made to Simpson's report by Norton (1928) when reporting on several deep wells in the Cedar Rapids area. Additional ground-water information for Linn County is found in reports by Norton (1897 and 1935) and Lees (1935).

Surface-water data for streams in Linn County are found in reports by Crawford (1942 and 1944), Mummey (1953), Iowa Geological Survey (1955), Bennion (1956), Myers (1963), Schwob (1958 and 1963), and U. S. Department of the Interior (1961-68).

Well-Numbering System

The public-land survey divisions form the basis for the well-numbering system used in this report. Each well number consists of three parts, separated by hyphens, representing first

---

[1] Citations of literature are made by giving the author's name and date of references at the end of this report.

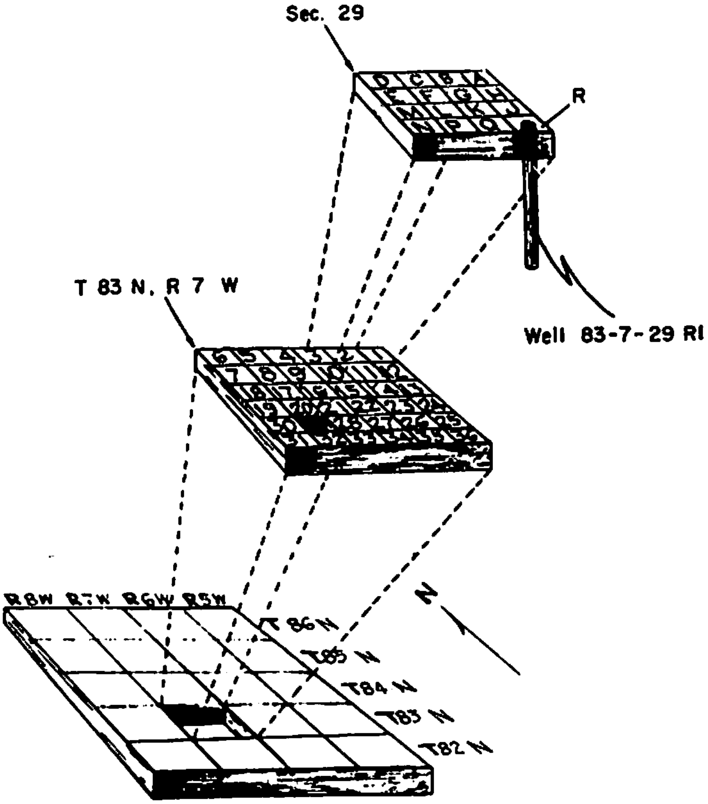


Figure 5.—The well-numbering system used in this report.

the township, second the range, and third the section. A letter following the section number indicates the 40-acre tract in which the well is located (fig. 5). A number is added after the letter, which indicates the order in which the wells were inventoried. As an example, in figure 5, well number 83-7-29R1 is the first well inventoried in the SE¼SE¼ sec. 29, T. 83 N., R. 7 W. This numbering system is used throughout the report.

Springs are numbered the same as wells but, in addition, have the letter S after the location numbers.

The location of the wells and springs inventoried for this report are shown on plates 1 and 2. The township and range designations are along the edge of the maps. The symbol for each well is located in its respective section and is identified by the last part of the well number.

GEOLOGY

Rocks underlying Linn County are subdivided into three major divisions based on the lithology, mode of deposition, and stratigraphic position. The three major divisions, in ascending order, are the basement complex; consolidated sedimentary rocks, also commonly called bedrock; and unconsolidated sedimentary rocks, commonly called surficial materials.

The basement complex in Iowa consists of Precambrian crystalline rocks, which are considered to form the bottom of the ground-water reservoir in the State.

The basement complex is overlain by a succession of consolidated sedimentary rocks that belong, in ascending order, to the Cambrian, Ordovician, Silurian, and Devonian Systems (table 2). These strata, composed of sandstone, limestone, dolomite, and shale, are stacked one on the other in layer-cake fashion. The layer-cake sequence, however, is not level—in general it slopes about 20 feet per mile to the southwest (pls. 4 and 5).

The bedrock surface has been modified considerably by preglacial and, possibly, inter-glacial erosion. The relief of the bedrock surface is about 450 feet (pl. 6), which is considerably greater than the present-day land-surface relief. Older rock formations were exposed along many of the deep valleys that were carved into the bedrock (pl. 4). These buried bedrock valleys have no surface expression and can be located only by test drilling or geophysical methods.

The bedrock is overlain by variable thicknesses of unconsolidated sedimentary rocks, which consist of glacial drift, loess, and alluvium. Glacial drift is rock debris, principally sandy, pebbly clay, containing occasional lenses of sand and gravel, deposited by glaciers that overrode the county. This material, which has a maximum thickness of about 300 feet in the county, mantles the bedrock except locally where it has been removed by erosion (pl. 4). Loess is a wind-blown silt that mantles the glacial drift in upland areas of the county. Alluvium comprises the sand, gravel, silt, and clay that were deposited by streams. This material underlies valley bottoms of major water courses and also is in some of the buried bedrock valleys. The latter alluvial material is often called buried channel deposits.

The geologic framework (stratigraphy) of the ground-water reservoir in Linn County with a description of the rock units and their general water-bearing features is summarized in table

TABLE 2.—GEOLOGIC AND HYDROLOGIC UNITS AND THEIR WATER-BEARING FEATURES IN LINN COUNTY.

System	Rock Units[1]	Hydrogeologic Units		Maximum Known Thickness (feet)	Physical Character	Water-bearing Features
Quaternary	Alluvium	Surficial aquifers	Alluvial aquifers	95	Sand, gravel, silt, and clay.	Moderate-to-large yields available in valleys of major water courses.
	Glacial drift (undifferentiated)		Drift aquifer	305	Predominantly till containing scattered, irregular bodies of sand and gravel.	Yields small quantities of water to dug wells.
	Buried channel deposits		Buried channel aquifers		Sand, gravel, silt, and clay.	Moderate-to-large yields of water available locally.
Devonian	Cedar Valley Limestone	Silurian-Devonian aquifer		97	Limestone.	Yields small-to-moderate quantities of water. Adequate for farm supplies.
	Wapsipinicon Formation			128	Limestone, dolomite, and shale.	
	LaPorte City Chert			50	Dolomite and chert.	Not known to yield water to wells.
Silurian	Gower Dolomite			286	Dolomite; contains 'reef' type beds.	Yields moderate-to-large quantities of water to wells. Many farm, municipal, and industrial wells developed in this aquifer.
	Hopkinton Dolomite				Dolomite with occasional shale layers.	
	Kankakee Formation			100	Dolomite containing chert; some shale at base.	
	Edgewood Dolomite					
Ordovician	Maquoketa Formation	Aquiclude		278	Shale and dolomite.	Does not yield water to wells.
	Galena Formation			242	Limestone and dolomite.	May yield small quantities of water to wells.
	Decorah Formation	Aquiclude		33	Dolomitic limestone and interbedded shale.	Does not yield water to wells.
	Platteville Formation			86	Limestone and dolomite with shale at base.	
	St. Peter Sandstone			55	Poorly cemented sandstone.	Yields small-to-moderate quantities of water to wells.
	Prairie du Chien Formation			395	Dolomite and dolomitic sandstone.	Yields small-to-moderate quantities of water to wells.
Cambrian	Jordan Sandstone	Jordan aquifer		108	Poorly cemented sandstone.	Yields large quantities of water to wells.
	St. Lawrence Formation			177	Silty dolomite.	Yields moderate quantities of water to wells.
	Franconia Sandstone			178	Interbedded glauconitic siltstone, dolomite, and shale. Lower part is glauconitic sandstone.	Not known to yield water to wells.

Cambrian (cont.)	Dresbach Group	Galesville Sandstone Eau Claire Sandstone Mt. Simon Sandstone		668+	Sandstone with minor amount of dolomite and silty shale.	Water is highly mineralized and is not a source of water supply.
Precambrian	Sedimentary rocks				Not penetrated in Linn County. (Shale and sandstone in NE Iowa)	Not known to yield water to wells.
	Igneous and metamorphic rocks				Not penetrated in Linn County. (Crystalline rocks in NE Iowa)	Not known to yield water to wells.

[1] The stratigraphic nomenclature in this report is that used by the Iowa Geological Survey and does not conform in every detail with the nomenclature used by the U. S. Geological Survey.

2. The principal water-bearing rocks, designated aquifers in table 2, are the main concern of this report and are described and evaluated in a subsequent section. Stratigraphic relationships between the upper bedrock units and the glacial drift are illustrated in plate 4. A bedrock geologic map (pl. 3) and a bedrock topographic map (pl. 6) describe the bedrock surface.

Precambrian Rocks

Precambrian rocks are known to underlie Linn County although no wells, as yet (1969), have been drilled deep enough to penetrate these rocks. However, it is reasonable to assume that their physical characteristics are very similar to those in many other parts of the State. That is, the older Precambrian rocks are crystalline rocks of igneous and metamorphic origin; these in turn are overlain by younger Precambrian rocks that are stratified and of sedimentary origin. These younger rocks commonly consist of red flaky shale and medium- to fine-grained sandstone.

Because no wells have penetrated the Precambrian rocks in Linn County, the exact depth to these rocks is not known. Rocks of Precambrian age were not encountered in well 83-7-21P5, which was drilled to a depth of 2,525 feet. On this basis and on the basis of stratigraphic data from wells that have penetrated Precambrian rocks in adjoining areas, it is estimated that the top of the Precambrian rocks throughout much of Linn County lies at a depth of between 2,800 to 3,000 feet.

Cambrian System

Rock units of the Cambrian System do not crop out in Linn County; the nearest exposures are located in Minnesota, Wisconsin, and the extreme northeastern corner of Iowa. In Linn County the top of this system of rocks occurs at a depth of between 1,400 and 1,500 feet and the units are identified from rock samples obtained by drilling.

Dresbach Group

The oldest Cambrian beds in Linn County are the Dresbach Group which, in ascending order, comprise the Mt. Simon, Eau Claire, and Galesville Sandstones. Well 83-7-21P5 at the Quaker Oats Company plant penetrates only 380 feet of the Mt. Simon Sandstone. Here, the Mt. Simon consists of sandstone which is composed of light-gray and amber, coarse to fine, subangular to rounded, frosted quartz grains, and some pink and gray silty shale lenses. The Eau Claire, which is 270 feet thick, is composed of glauconitic sandstone and siltstone with minor amounts of dolomite and shale. The Galesville is represented by 18 feet of fine-grained well-sorted sandstone. Because the base of the Dresbach was not penetrated in well 83-7-21P5, its total thickness in the county is not known.

Franconia Sandstone

The Franconia Sandstone includes four members which, in ascending order, are the Ironton, Goodenough, Hudson, and Bad Axe (Raasch, 1935). Because differentiation of the members is based on fossils, subdivision of the formation from well cuttings is difficult and was not attempted for this report. Samples from well 83-7-21P5 show that the upper part of the Franconia consists of interbedded glauconitic dolomites, siltstones, and shales. The lower 73 feet consists of coarse- to fine-grained, glauconitic sandstone which is characteristic of the Ironton Member. The total thickness of the Franconia in well 83-7-21P5 is 178 feet.

St. Lawrence Formation

All strata between the Franconia Sandstone and the overlying Jordan Sandstone are assigned to the St. Lawrence Formation. In Linn County the formation consists mainly of cream and tan, fine-textured, silty dolomite which is glauconitic at the base. In the Quaker Oats well (83-7-21P5) the formation is 177 feet thick.

Jordan Sandstone

The Jordan Sandstone in Linn County includes all beds of sandstone between the overlying Prairie du Chien Formation and the St. Lawrence Formation. The Jordan Sandstone underlies the entire county and consists of gray-white, fine to coarse, poorly cemented sand grains that have a frosted surface. Data from wells in surrounding counties and in the Cedar Rapids area indicate the maximum thickness of the Jordan in Linn County is 108 feet.

Ordovician System

Rock units of the Ordovician System do not crop out in Linn County; they are exposed in a narrow band along the northeastern edge of Iowa. In Linn County the top of this system of rocks occurs at a depth of between 350 and 500 feet and the units are identified from rock samples obtained by drilling.

Prairie du Chien Formation

The oldest Ordovician beds in Linn County belong to the Prairie du Chien Formation. Its thickness is 395 feet at Walker, 367 feet at Marion, and between 353 and 385 feet at Cedar Rapids. The three members of the formation, in ascending order, are the Oneota Dolomite, the Root Valley Sandstone, and the Willow River Dolomite. The Oneota is a tan, finely crystalline, cherty dolomite that ranges in thickness from 200 to 230 feet; the Root Valley is mostly a white, fine- to medium-grained, dolomitic sandstone; and the Willow River is a tan, cherty, sandy dolomite.

St. Peter Sandstone

The St. Peter Sandstone occupies the interval between the Prairie du Chien Formation and the overlying Platteville Formation. In Linn County the St. Peter is white, fine- to medium-grained, friable, frosted quartz sandstone that ranges in thickness from 40 to 55 feet. The St. Peter generally is cased off in deep wells to prevent the friable sands from caving into the well bore.

Platteville Formation

The Platteville Formation includes three members which, in ascending order, are the Glenwood Shale, Pecatonica Dolomite, and McGregor Member. The formation generally is characterized by gray and tan, fine-textured limestone and dolomite; however, the basal member is a soft, green shale. The maximum recorded thickness in Linn County is 86 feet.

Decorah Formation

The Decorah Formation consists of three members which, in ascending order, are the Spechts Ferry Member, the Guttenburg Limestone, and the Ion Member. The formation is characterized by cream and tan dolomitic limestones with some interbedded shales. The maximum recorded thickness in Linn County is 33 feet.

Galena Formation

The members of the Galena Formation, in ascending order, are the Prosser Limestone, the Stewartville Dolomite, and the Dubuque Dolomite. The recorded thickness of the Galena ranges from 205 to 242 feet. In Linn County the Galena is composed mostly of cream-to-tan limestone and dolomite with some interbedded chert layers in the Prosser Member. In the subsurface the Dubuque and Stewartville Members cannot be readily differentiated. The top of the Galena commonly is marked by minute orange specks called "cinnamon specks."

Maquoketa Formation

The Maquoketa Formation is subdivided into four members which, in ascending order, are the Elgin Limestone, the Clermont Shale, the Fort Atkinson Dolomite, and the Brainard Shale. The thickness of the Maquoketa ranges from 200 to 278 feet. In Linn County the Elgin Limestone is a brown, sandy dolomite containing chert. The Fort Atkinson Dolomite is a gray medium-to-coarse textured dolomite containing chert and shale partings. Green dolomitic shale is the predominant rock in the Clermont and Brainard members.

Silurian System

Silurian rock units occur in outcrop and immediately below the glacial drift (subcrop) in eastern Iowa, including most of the eastern one-third of Linn County (pls. 3 and 5). Only the basal rock unit has not been identified in exposures within the county. Narrow, steep-walled channels have been cut into the Silurian rocks in the subcrop area (pls. 4 and 6).

Edgewood Dolomite and Kankakee Formation

The Edgewood Dolomite is the oldest Silurian formation in Linn County. Overlying it is the Kankakee Formation. Both formations are present throughout the county; but because of their lithologic similarity, differentiation of the two in the subsurface is difficult and generally is not attempted. The total maximum thickness of both units is 100 feet. The only exposure in which the Kankakee was identified is a quarry in sec. 36, T. 85 N., R. 5 W. Both formations are composed of gray and buff, medium- and fine-textured dolomite which contains tripolitic chert. Chert, in concentrations greater than 20 percent, is typical of the Kankakee and often is used to differentiate this formation from overlying units.

Hopkinton Dolomite and Gower Dolomite

Overlying the Kankakee Limestone is the Hopkinton Dolomite which in turn is overlain by the Gower Dolomite. The Hopkinton and Gower Dolomites form the bedrock surface over approximately one-third of Linn County (pl. 3). The Hopkinton crops out in the eastern part of Linn County. The Gower is exposed in the southeastern corner of the county in Palisades-Kepler State Park (sec. 14, T. 82 N., R. 6 W.) where the Cedar River has cut into the formation leaving prominent bluffs on both sides of the river (fig. 2B). Where exposed at the surface lithological varieties of the Gower, named the LeClaire and Anamosa Members, can be identified. The combined thickness of the Hopkinton and Gower ranges from 258 to 286 feet. Subsurface differentiation of the Hopkinton and Gower Dolomites was not made for this report because the two formations are lithologically similar. These formations are usually buff to tan, cavernous, vuggy dolomites which are locally silty and which contain some shale, possibly as cavern fill. These rocks generally are medium-textured except for about the upper 30 feet which is mostly fine-textured. White, tripolitic chert containing some dolomite rhombs occurs locally near the base.

Devonian System

Devonian rocks form a large part of the bedrock surface in the western two-thirds of Linn County (pl. 3). In this subcrop area, several bedrock channels breach the Devonian rocks and reveal the underlying Silurian strata (pls. 4 and 5).

LaPorte City Chert

The LaPorte City Chert is a formation of Early Devonian age which is present in the northwestern corner of Linn County (Parker, 1967). However, there are no known exposures of this formation within the county. The principal lithology is chert which ranges in color from white to dark gray. Secondary lithologies are finely crystalline limestone and some fine-to-medium crystalline dolomite. In Linn County the formation has a maximum thickness of about 50 feet.

Wapsipinicon Formation

The Wapsipinicon Formation, which has a maximum thickness of 128 feet, consists of gray and brown, lithographic to coarse-textured limestone and dolomite which are argillaceous in places and brecciated near the top. The formation is divided, in ascending order, into the Coggon, Otis, Kenwood, Spring Grove, and Davenport Members. All members are exposed within the county, but locally because of erosion or non-deposition, the Coggon and the Otis may be missing. Church (1967) included the Bertram Dolomite as the basal member of the Wapsipinicon Formation. The Bertram is restricted in occurrence to a belt several miles wide between Paralta and the Beverly Railroad crossing in sec. 6, T. 82 N., R. 7 W.

Cedar Valley Limestone

The Cedar Valley Limestone crops out along the western edge and in the west-central part of Linn County (pl. 3). The formation is as much as 97 feet thick and consists of gray to buff, hard, fossiliferous limestone that is locally argillaceous at the base.

The three members of the Cedar Valley, in ascending order, are the Solon, the Rapid, and the Coralville. In Linn County, however, the Coralville has not been identified in outcrop or from well cuttings.

Quaternary System

Unconsolidated glacial deposits and alluvium cover the bedrock in Linn County. The glacial deposits that cover the bedrock were deposited by two glaciers—the Nebraskan and the Kansan. In this report, however, no attempt was made to differentiate the two drifts.

Glacial Deposits

At least twice during the Pleistocene Epoch, continental ice sheets or glaciers overrode Linn County. The record of these ice invasions is contained in the unconsolidated rock material, which locally is more than 300 feet thick, that was deposited by the melting ice and by meltwater streams. The rock material deposited directly by melting stagnant glacial ice is composed predominantly of clay with subordinate amounts of sand, pebbles, and boulders. This heterogeneous, unsorted rock debris is called till. The rock materials derived from glacial meltwaters and interglacial streams are sorted, lenticular and sheet-like deposits of sand, gravel, silt, and clay. These outwash materials occur locally within and at the base of the till—particularly within the bedrock channels. The till and associated outwash materials are called glacial drift. The glacial drift at many places in the county is mantled by wind-blown silt (loess) and fine sand.

Alluvium

Alluvial deposits of late Wisconsin and Holocene age occur under the flood plains and terraces of water courses in the county. These materials occur as lenses and layers of sand, gravel, silt, and clay (fig. 12). The thicknesses of alluvial materials are variable. Along major streams they are up to 95 feet thick; along smaller streams they are less than 5 feet thick.

SOURCE AND USE OF WATER

Two major sources of water—surface and ground water—are available to the people of Linn County. Streams are a potential source for large supplies of water[2]. They are not, however, a major source for water in Linn County at present, primarily because of their limited geographical distribution and because water from this source needs extensive purification. Prior to 1962, large quantities of water were pumped from the Cedar River for the municipal supply at Cedar Rapids. However, an odor problem that became increasingly difficult to treat forced the city in 1964 to abandon the river as a source of supply. Nevertheless, large supplies of water are available for purposes in which odor is not a serious problem.

---

[2] Records of streamflow can be obtained from the publications cited.

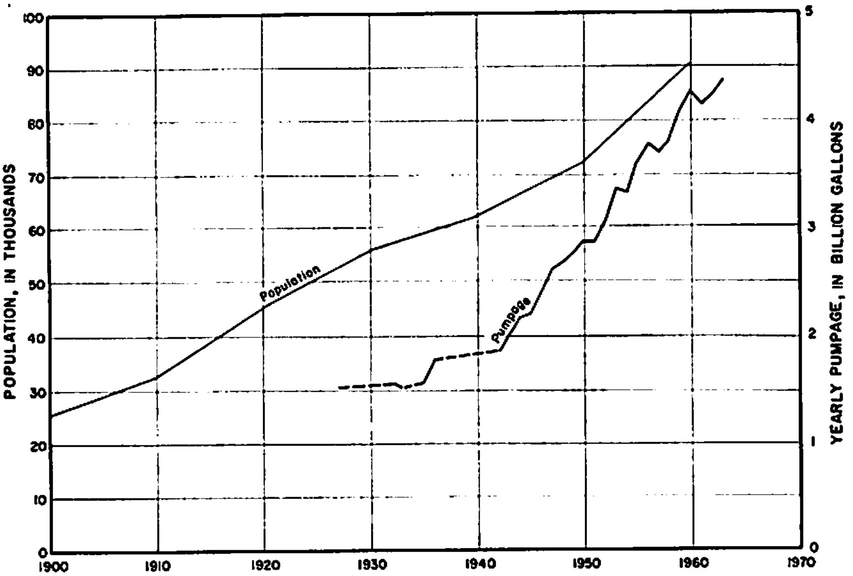


Figure 6.—Population and municipal pumpage in the Cedar Rapids area.

Ground water is the present source of water for all city, community, domestic and stock supplies, and most industrial supplies in Linn County. At least 24 mgd of water were pumped from underground reservoirs in the county during 1964.

Pumpage for municipal supplies (table 3), all of which were from ground-water sources, averaged about 13.3 mgd in 1964. The city of Cedar Rapids, the largest user of water in the county, pumped an average of about 12 mgd during 1964. Water use in the city has steadily increased (fig. 6) because of increased population and per capita consumption. In 1900 the

TABLE 3.—MUNICIPAL WATER SUPPLIES.

Well No.	Date Drilled	Producing Aquifer	Average Pumpage (gpd)[1]	Remarks
			CEDAR RAPIDS	
GP 1	1962	Alluvium	...	Data not available on another well field west of this one. Total pumpage from both fields was an average of 12 mgd during 1964.
GP 2	1962	do	...	
GP 3	1962	do	...	
GP 4	1962	do	...	
GP 5	1962	do	...	
GP 6	1963	do	...	
GP 7	1963	do	...	
GP 8	1963	do	...	
			CENTER POINT	
1	1934	Silurian	...	Standby well
2	1942	Alluvium	...	Principal source
3	1956	do	...	
			CENTRAL CITY	
	1912	Silurian	70,000	
	1912	do		
			COGGON	
1	1894	Silurian	50,000	
2	1910	do	13,000	
			FAIRFAX	
1	1959	Silurian	14,500-17,500	
			LISBON	
1	...	Silurian	60,000	Water supply prior to 1932 was from a spring in the northwest part of town (Norton, 1912).
			MARION	
1	1941	Silurian	107,000	
2	1953	do		
3	1957	Jordan ss	578,000	
			MT. VERNON	
1	...	Silurian	217,000	Well No. 3 is pumped every other day along with one of the other wells. Yearly pumpage is over 79 million gallons.
2	...	do		
3	1958	do		
			PRAIRIEBURG	
1	...	Silurian	14,000	
			SPRINGVILLE	
1	...	Silurian	55,000	
			WALKER	
1	...	Devonian, Silurian	38,000	

[1] Inventory period for all municipalities except Cedar Rapids was 1959. Because average daily pumpage during 1964 for these communities is estimated to have increased only five to ten percent, the total average daily pumpage during 1964 was about 13.3 mgd.

population of Cedar Rapids was about 25,000; now (1969) it is more than 100,000. Thus, on the basis of population growth alone, water use today is four times what is was in 1900 (an increase of 300 percent). However, because the daily average per capita consumption increased also (80 gallons in 1927 [Norton, 1928] to more than 125 gallons in 1964), water use in this city actually has increased about 500 percent since 1900.

Pumpage for industrial and commercial use in Linn County was about 8.8 mgd in 1964—nearly all water withdrawals for these uses were in the Cedar Rapids area.

Withdrawals for domestic and stock supplies in the county are estimated to be 1.9 mgd. Most of these supplies are obtained from drilled wells; some shallow dug wells are used, but primarily to supply water for stock.

AQUIFERS IN LINN COUNTY

The water-bearing rock units underlying Linn County range in geologic age from the Holocene (Recent) to the Cambrian (table 2). In the county, as elsewhere in Iowa, the effective base of the saturated zone is considered to be the Precambrian crystalline basement complex. Four units, the alluvium, buried channel deposits, Silurian-age dolomites, and Jordan Sandstone are principal aquifers, capable of yielding up to 500 gpm or more to individual wells. Two units, the glacial drift and Devonian-age limestones (shallow bedrock), generally yield only small quantities of water to wells. Because of their near-surface occurrence and widespread distribution, however, the glacial drift and shallow bedrock are important sources of water for domestic and stock supplies. The remaining units, the Galena Dolomite, St. Peter Sandstone, and Dresbach Sandstone, are not used as sources of supply in the county although the Galena and St. Peter may contribute some water to uncased wells producing from the Jordan Sandstone. The Dresbach Group, particularly the Mt. Simon Sandstone, yields highly mineralized water (table 5) and is not considered a usable source at the present time.

Ground water occurs under both water-table and artesian conditions in Linn County. Water-table conditions occur in the shallow glacial drift aquifers, in the alluvium, and locally, in some shallow bedrock aquifers where the drift cover is thin. Artesian conditions occur in the buried channel aquifers, in most of the glacial drift aquifers, and in the bedrock aquifers.

Water-table aquifers in Linn County are recharged principally by local precipitation. Most of the recharge occurs in the spring and fall before or after the growing season when the ground is not frozen. Figure 7 shows the fluctuation of water level in a shallow well in Linn County and illustrates the relation between precipitation, the growing season, and recharge to the water-table aquifer. Figure 8 also shows the relationship between precipitation and recharge and illustrates differences in infiltration rates and the time lag of recharge to a deeper aquifer.

Normally, in Iowa, precipitation provides enough recharge to alluvial aquifers to maintain the water table above the local stream stage. During floods, however, the stream stage may be higher than the water table and water infiltrates from the stream to the aquifer. Most of the water is discharged back into the stream as the flood recedes. In areas where wells are

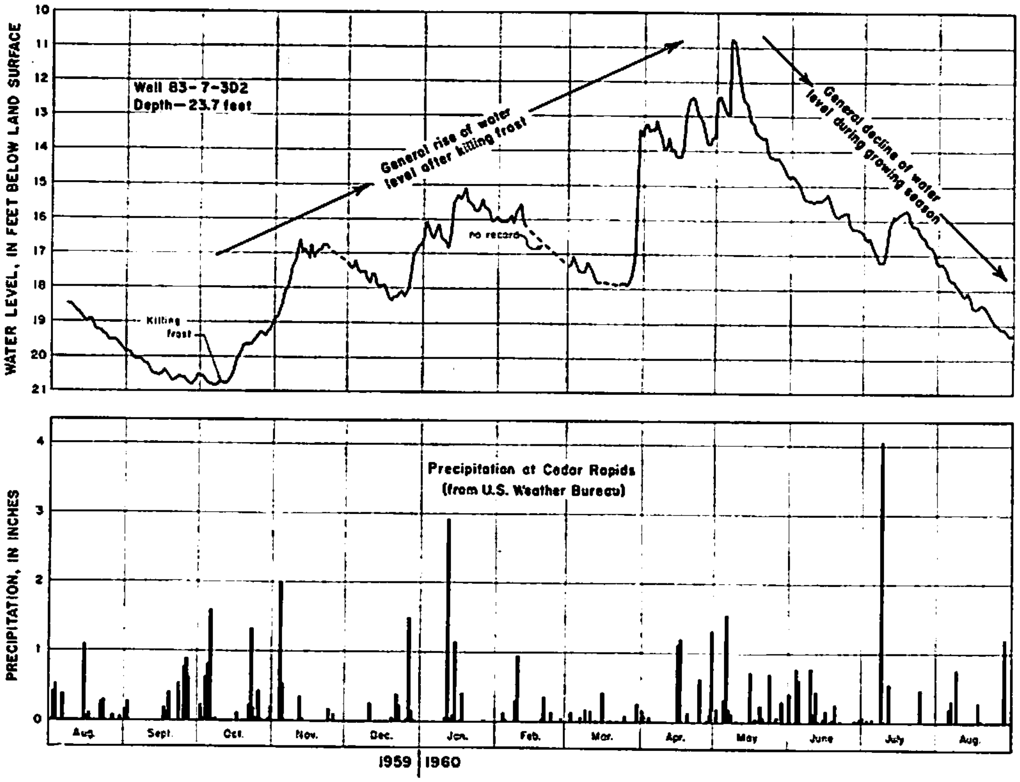


Figure 7.—Relation of water level to precipitation and to the growing season.

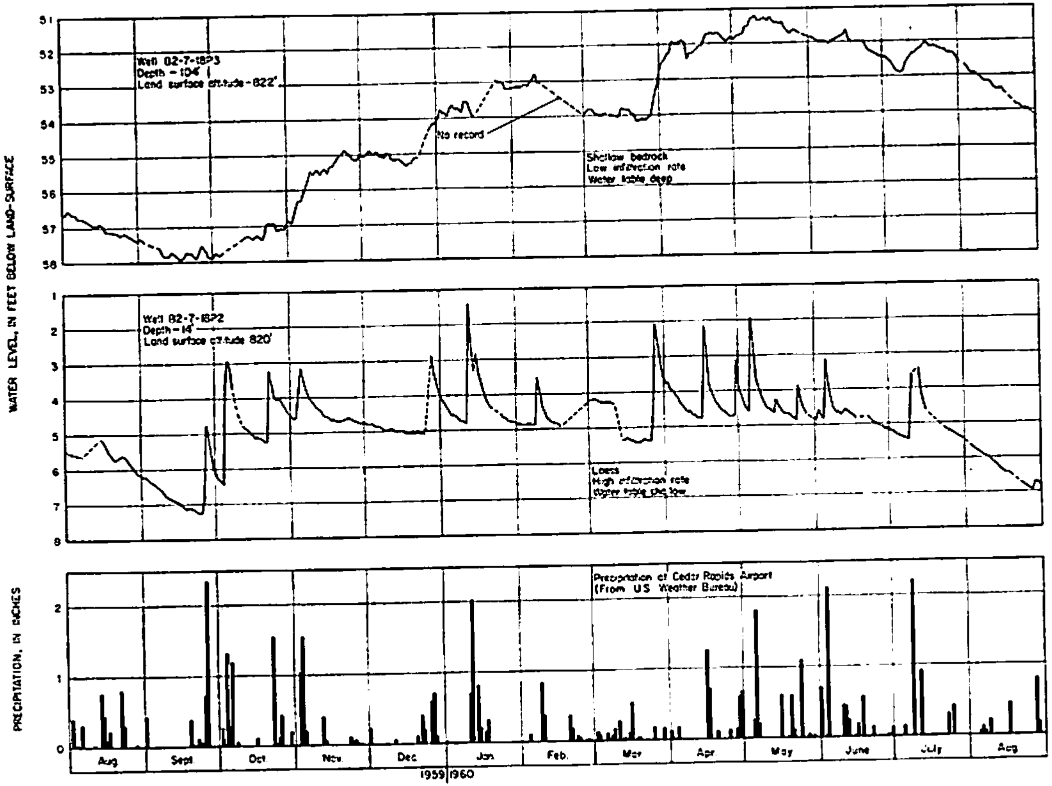


Figure 8.—Difference in recharge to shallow and deep aquifers.

pumping from the alluvial aquifer, the water table will be lowered around the well and the water table may be below stream stage. In those areas significant quantities of water may infiltrate to the aquifer even at low-stream stage. Such recharge is called induced infiltration. The city of Cedar Rapids' well field, in the Cedar River alluvium, is dependent principally on this form of recharge.

The principal forms of recharge to artesian aquifers in Linn County are subsurface inflow and cross-bed leakage. Recharge by subsurface inflow originates from precipitation at the outcrop of the aquifer. Cross-bed leakage is recharge entering the aquifer by leakage from adjacent aquifers. For the Silurian dolomites the outcrop and area of recharge by precipitation is within, east, and northeast of Linn County (pl. 3). For the Jordan Sandstone and other deeper formations, the outcrop area is in Minnesota, 200 miles or more from Linn County.

Recharge by cross-bed leakage occurs throughout Linn County, the most notable example being recharge to the drift aquifers or shallow bedrock aquifers from overlying alluvium or loess. Cross-bed leakage is evident in the Cedar Rapids area where pumpage from the Cedar River alluvium has had an effect on water levels in the underlying Silurian-age rocks. Cross-bed leakage is also probable between the buried-channel deposits and the Silurian-Devonian aquifer because the chemical quality of the water and the water levels are similar in adjacent parts of the two aquifers. Cross-bed leakage between bedrock aquifers having different water levels probably occurs at a very low rate, but because of the large areas involved the total quantities may be quite large.

Ground-water discharge, which generally results in declining water levels, is the removal of water from the zone of saturation. The principal mode of natural discharge from water-table aquifers in Linn County is by springs and seeps. Discharge of that type occurs whenever the water table intersects the land surface, such as along the banks of streams. Because much of the recharge to water-table aquifers occurs in the uplands and discharge occurs along streams, the water table generally slopes from the uplands to the main streams (fig. 9) and in many cases follows the local topography. Natural discharge from artesian aquifers in Linn County is by subsurface outflow and cross-bed leakage.

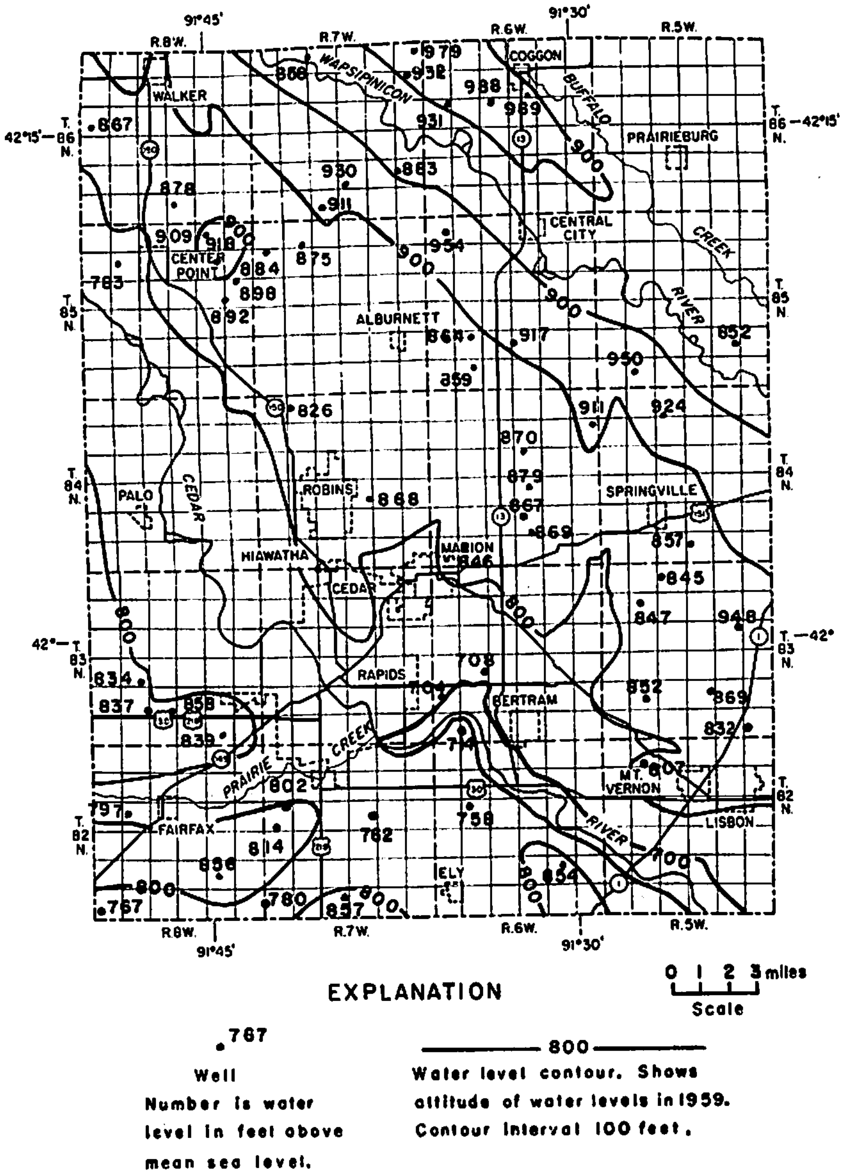


Figure 9.—Map of Linn County showing altitude and configuration of the water table.

Discharge from aquifers by pumping of wells is classified as artificial discharge. Fluctuations in water level because of pumping is illustrated by the hydrograph of observation well 83-7-8H1

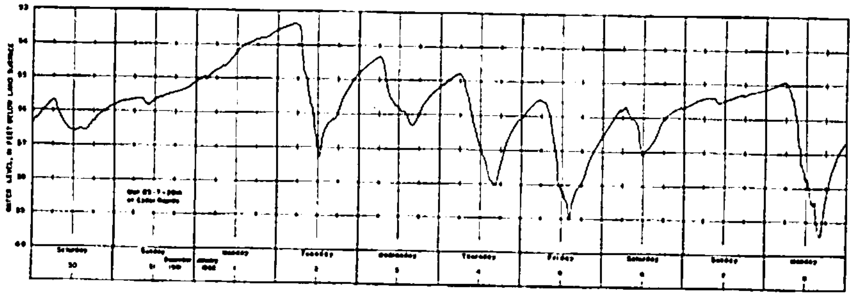


Figure 10.—Daily fluctuations in water level caused by pumping.

(fig. 10). On weekends and during the night when many wells in the area are shut down, the water level rises and when pumping is resumed it begins to decline again. Because the amount of water-level recovery is a function of time the effect of a 3-day weekend, December 30-January 1, is greater than that of a 2-day weekend, January 6-7.

As water moves through the aquifers from recharge to discharge areas, it acquires chemical constituents by dissolving minerals from the rocks through which it flows. Water in the shallower aquifers usually acquires less mineral matter than water from the deeper aquifers because the contact time is shorter. The chemical constituents and physical properties most commonly determined are listed in table 4.

The chemical quality of water is an important aspect of any ground-water supply. Certain constituents in large amounts and some in small amounts can make the water objectionable or harmful for many purposes. Standards for drinking water set by the U. S. Public Health Service (1962) define the maximum recommended concentrations of some constituents (table 4).

About 90 analyses of water from various aquifers in Linn County that show the concentration of the common constituents are on open file at the Iowa or U. S. Geological Surveys, Geological

Survey Building, Iowa City, Iowa 52240. Some of the analyses that are representative of the water from the different rock units are given in table 5. The chemical quality of water from the principal aquifers is discussed in more detail in the following sections of the report describing the aquifers.

TABLE 4.—SIGNIFICANCE OF MINERAL CONSTITUENTS AND PHYSICAL PROPERTIES OF WATER[1].

Constituent or Property	Maximum Recommended Concentration	Significance
Iron (Fe)	0.3 mg/l	Objectional as it causes red and brown staining of clothing and porcelain. High concentrations affect the color and taste of beverages.
Manganese (Mn)	0.05 mg/l	Objectionable for the same reasons as iron. When both iron and manganese are present, it is recommended that the total concentration not exceed 0.3 mg/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 central Iowa, concentrations of 0.8 to 1.3 mg/l are considered to play a part in the reduction of tooth decay. However, concentrations over 2.0 mg/l will cause the mottling of the enamel of children's teeth.
Nitrate (NO_3)	45 mg/l	Waters with high nitrate content should not be used for infant feeding as it may 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 of the material in water that is in solution. It affects the chemical and physical properties of water for many uses. Amounts over 2,000 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 $CaCO_3$)		This affects the lathering ability of soap. It is generally produced by calcium and magnesium. Hardness is expressed in milligrams per liter equivalent to $CaCO_3$ as if all the hardness were caused by this compound. Water becomes objectionable for domestic use when the hardness is above 100 mg/l; however, it can be treated readily by softening.
Temperature		Affects the desirability and economy of water use, especially for industrial cooling and air conditioning. Most users want a water with a low and constant temperature.

[1] For additional discussion of chemical and physical properties of water, see Hem (1959) and U. S. Public Health Service (1962).

TABLE 5.—CHEMICAL CHARACTER OF

[Analyses by State Hygienic Laboratory of Iowa;

Location: For explanation see section on well-numbering system.

Location	Owner or Tenant	Date of Collection	Principal Source	Depth (feet)	Temperature (°C)	Silica (SiO_2)	Iron (Fe)
82-5-10M2	Mt. Vernon, City Well 3	4-10-61	Silurian	405	11	19	0.84
82-5-12L1	Lisbon City	10-21-59	Silurian	350	....	13	.08
82-7-21C1	Col. Twp. School 2	6- -63	Galena	890	....	6.6	5.6
82-7-30C1	Cedar Rapids Municipal Airport.	4-12-45	Silurian	530	11	....	.40
82-8-12A1	Chicago and Northwestern R.R. Co.	9-21-44	Pleistocene	109	11	....	1.6
83-6-6G1	Marion, City Well 3	1-25-60	Jordan	1663	16	8.8	1.1
83-7-4Q1S	Coopers Spring	7-20-43	Wapsipinicon	....	....	....	.15
83-7-11N1	Kilborn Photo Paper Co.	8-27-46	Silurian	205	11	....	.0
83-7-17F1	Cedar Rapids, Well 1 West	3- 6-64	Alluvium	67	12	....	.40
83-7-21P5	Quaker Oats Company	12- 7-64	Dresbach	2525	23	....	4.0
83-7-21Q2	Gazette Company	4-25-40	Galena-St. Peter[1]	1031	14	....	.20
87-7-21Q2	Gazette Company	6- 5-40	Galena-Prairie du Chien[1]	1208	....	....	.30
83-7-21Q2	Gazette Company	6- 5-40	Jordan[1]	1495	17	....	.30
83-7-27M1	Wilson and Company, Well 6	10-21-43	Silurian and Jordan	1493	15	....	.30
83-7-32J1	Cherry-Burrell Corp	6-24-46	Silurian	521	12	....	1.4
83-8-15B1	Lester Hall	6- 9-47	Wapsipinicon	70	12	....	1.1
84-6-28D1	Springville Water Co	9-16-58	Silurian	159	....	12	.46
84-8-20P1	L. L. Burgess	4- 9-36	Alluvium	36	11	....	.0
85-6-3A1	Central City, Well 1	7-13-59	Silurian	104	12	15	.04
85-8-9K1	Center Point, Well 1	3-28-49	Silurian	397	....	....	.10
85-8-9K3	Center Point, Well 3	6-13-58	Pleistocene	42	....	14	.06
86-6-10F1	Coggon, City Well 1	6-17-58	Silurian	285	12	12	.02
86-8-4G1	Walker, City Well 2	9- 2-58	Silurian	350	....	14	.05

---

[1] Sampled during drilling.

Alluvial Aquifers

Large yields of water often are obtainable from alluvial deposits that underlie the flood plains and terraces of the major streams in the county. The materials of these deposits characteristically occur in lenses (fig. 12) which vary in thickness and extent throughout the valley bottoms. Coarse sand and gravel are the most permeable of the materials and, where thick, provide the greatest potential for large yields of water. Test drilling and test pumping of selected wells are necessary to determine the best well sites and to determine the amount of water available.

GROUND WATER IN LINN COUNTY.
constituents reported in milligrams per liter]

Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (calculated as $CaCO_3$) Total	Hardness Carbonate	Hardness Non-carbonate	Specific conductance (micromhos at 25°C)	pH
0.06	77	32	6.3	1.0	......	349	32	8.0	0.2	0.1	358	324	286	38	594	7.3
.05	56	38	5.9	.5	......	305	33	6.0	.2	2.1	319	296	250	46	526	7.4
.05	59	20	4.6	.7	......	270	30	.5	.2	.1	259	229	222	7	439	7.5
.....	65	24	18		......	354	6	2.8	.4	.0	292	263	263	0	......	7.4
.06	76	22	21		......	359	21	1.8	.4	.7	340	282	282	0	......	7.3
.05	45	61	62	14	......	342	152	10	1.4	.1	523	523	280	243	823	7.7
.0	65	24	8.1		......	244	40	5.0	......	6.0	295	262	200	62	......	7.2
.0	83	21	1.3		......	283	49	12	.2	1.2	328	294	232	62	572	7.8
.15	116	32	32	2.1	0	442	35	12	.1	.1	448	422	362	60	780	7.7
.0	288	67	1480	44	......	264	1100	1970	3.4	.0	6270	994	252	742	7920	8.0
.0	23	20	35		......	156	91	28	1.2	.4	356	178	128	50	......	8.0
Tr.	22	57	38		20	222	72	48	1.4	.3	422	299	230	69	......	8.4
.0	86	34	71		......	347	201	15	1.2	.0	581	354	284	70	......	7.4
.0	69	25	72		......	337	137	12	1.0	.1	452	276	276	0	......	7.4
.0	66	22	6.0		......	290	14	3.0	.3	.0	328	255	238	17	450	7.7
.15	170	42	50		......	432	115	140	.0	13	912	620	354	266	......	7.4
.05	54	24	3.3	2.3	......	266	17	4.0	.2	.0	248	233	218	15	430	7.7
.0	69	14	4.8		......	200	30	12	.0	8.0	276	230	164	66	......	7.1
.05	84	21	7.2	3.0	......	325	26	11	.1	4.0	358	296	266	30	500	7.5
.0	78	20	13		......	278	48	8.0	.3	1.3	351	277	228	49	480	7.4
.05	103	11	13	1.9	......	261	80	19	.1	6.5	415	303	214	89	620	7.9
.05	75	25	8.5	1.0	......	307	43	5.0	.2	.5	319	290	252	38	560	7.6
.05	71	21	13	2.8	......	232	63	30	.3	.4	348	264	190	74	550	7.6

The principal alluvial aquifer in the county is the alluvium along Cedar River. Other alluvial aquifers of consequence are believed to occur along the Wapsipinicon River in those reaches where the flood plain widens and along the lower reach of Prairie Creek.

Cedar River Alluvium

The areal extent of the Cedar River alluvium is readily determined from topographic maps. The width of the alluvium ranges from 2.3 miles to just a few feet in those areas where the river flows on bedrock. At the Cedar Rapids well fields (fig. 11) the thickness ranges from 5 to 95 feet (fig. 12). The maximum

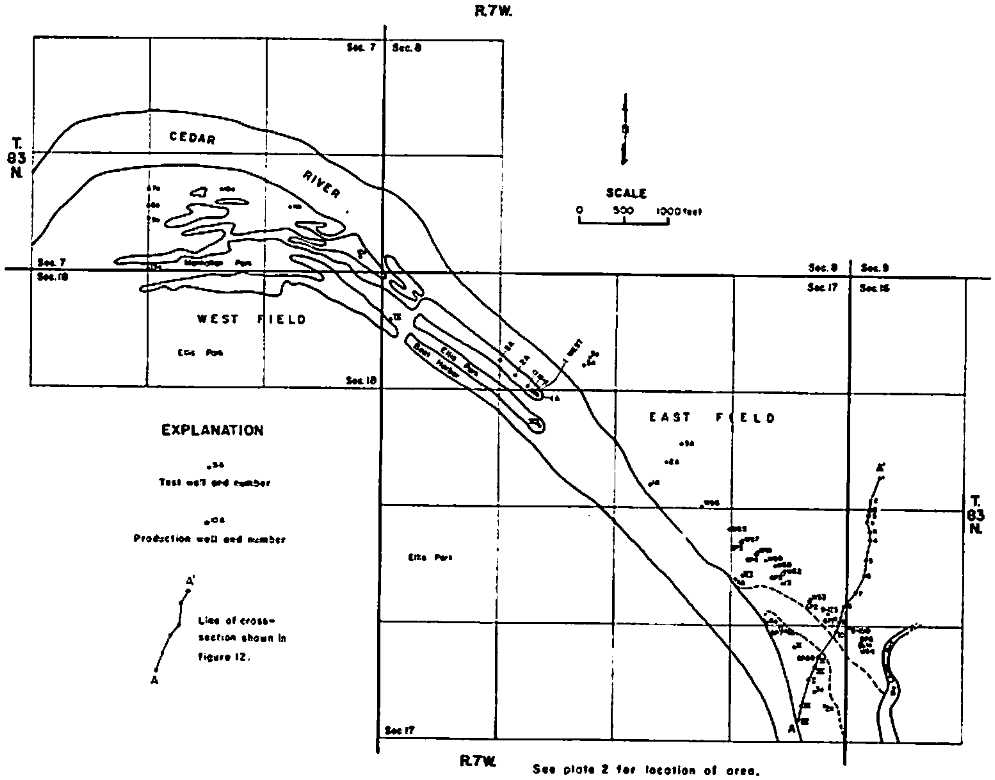


Figure 11.—Cedar Rapids east and west well fields.

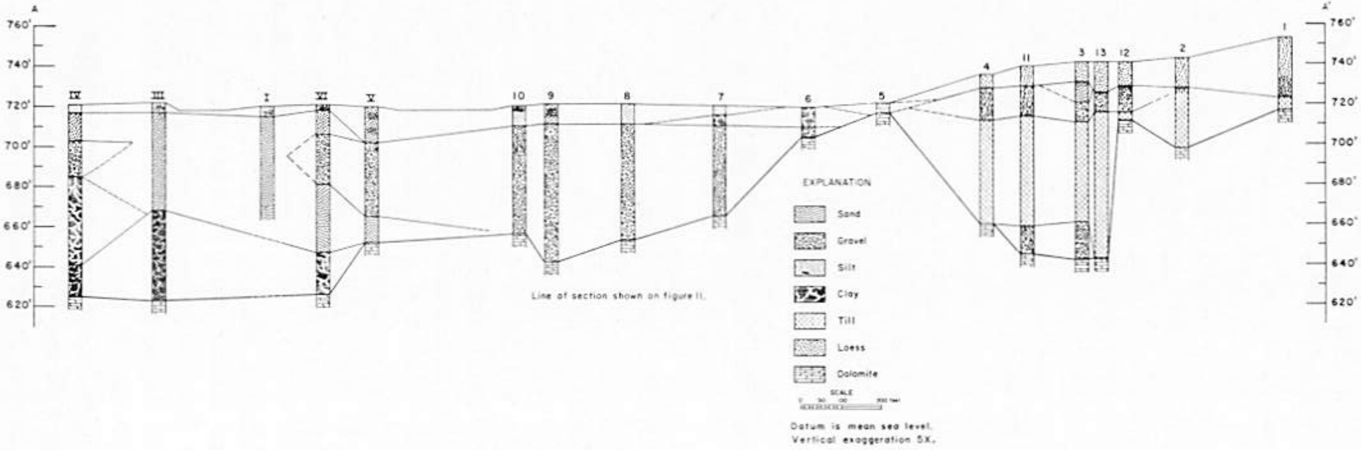


Figure 12.—Section across the Cedar Rapids east well field.

known thickness of the sand and gravel part of the alluvium is about 80 feet at the Cedar Rapids well fields and 70 feet at the Wilson Packing Company (well 83-7-27M1).

Based on methods described by Bedinger and Emmett (1963), the permeability of the coarser fraction of alluvium in the Cedar Rapids area is estimated from visual inspection of the material to range from 2,000 to 4,000 gpd per ft^2 (gallons per day per square foot). Analysis of specific capacity data (Brown and others, 1963, p. 131-138) indicates a maximum transmissibility of about 150,000 gpd per ft, which is consistent with the permeability estimates. Storage coefficient is estimated to be at least 0.1. More detailed studies are needed before definite aquifer characteristics can be determined.

Natural recharge to the aquifer is principally by precipitation and infiltration of river water during flood flows. The amount of each is not known and would require intensive quantitative studies to determine. A study at nearby Muscatine Island, where the annual amount and monthly distribution of precipitation is similar, indicates that recharge by precipitation probably is somewhat less than 6 inches per year. This amount is equivalent to approximately 100 mgy (million gallons per year) per square mile and is not enough to sustain large-scale withdrawals from the alluvial aquifers in Linn County.

A form of recharge, which is the most significant to the development of alluvial aquifers for water supplies, is induced infiltration of river water. The amount of induced infiltration available to such an aquifer is dependent on the permeability of the aquifer, the hydraulic gradient that can be established from the river (which will depend on the thickness of the aquifer, the well field's distance from the river, and the pumping levels in the wells), and the infiltration capacity of the river bed materials (Rorabaugh, 1956). These data were not available during this investigation to determine the amount of induced infiltration to the Cedar Rapids' well fields. However, the amount may be somewhat less than the pumpage (12 mgd in 1964) from the well fields, because water levels in some wells periodically are drawn down into the well screens indicating that withdrawals occasionally exceed replenishment. Additional development of the alluvial aquifer should be preceded by an investigation to determine the sustained yield available by induced infiltration.

Natural discharge from the aquifer is by seepage into the Cedar River, evaporation from the water table, and transpiration by phreatophytes. The average amount of discharge by these processes is equivalent to the average recharge, which is estimated to be about 100 mgy per square mile of aquifer. However, data are not available to determine the amount of discharge by each process. Evaporation losses may be significant, because the water table is within 5 feet of the surface in some areas. Transpiration losses by phreatophytes are believed to be high, because numerous cottonwood trees grow along the flood plain. As the aquifer is developed more extensively, it will become necessary to determine the discharge relations more accurately.

The aquifer is not widely developed for water supplies at present. Only in the Cedar Rapids area has extensive development taken place. Here the entire municipal water supply (12 mgd in 1964) and about 35 percent of the total industrial water supply (2.7 mgd in 1964) is obtained from wells finished in the alluvium. These wells yield water at rates ranging between 500 and 2,000 gpm. The wells used for municipal supply yield from 1,100 to 2,000 gpm and have specific capacities ranging from 24 to 78 gpm per ft of drawdown, as is shown below.

Well	Static water level[1] in feet below LSD	Discharge in gpm	Drawdown in feet	Specific capacity gpm per ft drawdown[1]
GP 1	4.15	1120	47+	24
GP 2	4.50	1540	30.58	50
GP 3	8.12	2040	29.75	69
GP 4	6.58	1540	22.17	68
GP 5	5.57	1875	24.07	78
GP 6	13.00*	1500	35.00	43
GP 7	15.50*	1400	32.00	45
GP 8	15.00*	1400	32.00	45
1 West	6.50	1600	21.33	75

*Low static water level reflects interference effects from nearby well.

[1] The static or non-pumping water levels, and hence, the specific capacities, of the wells will decline as the well field is fully developed.

Additional development of water supplies from this aquifer in the county appears very promising along several reaches of the Cedar River (fig. 13). The reach that trends through T. 84

and 85 N., R. 8 W.—particularly the part in T. 85 N.—appears most promising. Here the flood plain and terraces are widest and the alluvial aquifer overlies or crosses the buried channel deposits. Other promising reaches are near the town of Bertram

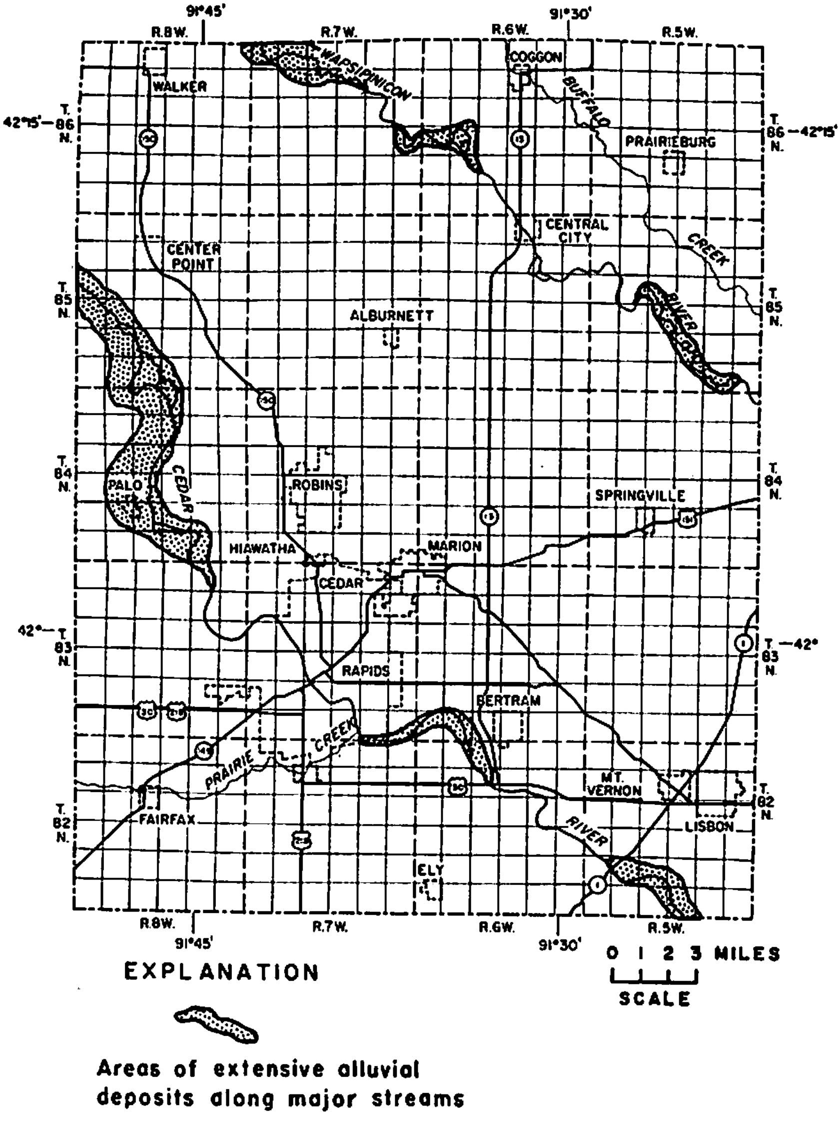


Figure 13.—Areas favorable for development of water supplies from alluvial aquifers.

and in the southeast corner of the county. Yields from the aquifer at these locations may be as much as at Cedar Rapids.

The quality of water from the aquifer, based on two analyses in the Cedar Rapids area, is good though somewhat hard. The dissolved-solids content is consistent with water from other alluvial aquifers in eastern Iowa. However, the concentration of iron is high and extremely variable. Data supplied by the superintendent of the Cedar Rapids Municipal Water Works shows that iron concentrations range from 0.08 to 13 mg/l (milligrams per liter). Temperature of the water at the Cedar Rapids well fields is also extremely variable, ranging from 2 to 14°C in the winter and from 10 to 18°C in the summer. Other significant constituents are summarized below:

Constituent	Number of samples	Concentration mg/l Maximum	Minimum
Fluoride	2	0.1	0
Nitrate	2	8.0	.1
Dissolved solids	2	448	276
Total hardness	2	422	230

The chemical quality of water from other alluvial aquifers in the county should be similar.

Prairie Creek Alluvium

The alluvium in this valley is not as extensive nor as wide as the Cedar River alluvium. The thickness of alluvial materials is reported by Simpson (1927) to be about 25 feet. The alluvial aquifer overlies a buried channel aquifer (pl. 6); but the two are separated by glacial drift. Simpson (1927) reports only small yields from the alluvial aquifer. Maximum yields to wells are estimated to be no more than 20 to 30 gpm. The chemical quality of the water should be similar to water from the Cedar River alluvium.

Wapsipinicon River Alluvium

No information concerning this aquifer is available. Inspection of topographic maps, however, indicates several promising areas for potential development of water supplies. These are along the reaches in the northwestern part of T. 86 N., R. 7 W.; western part of T. 86 N., R. 6 W.; and southern part of T. 85 N., R. 5 W. (fig. 13).

Buried Channel Aquifers

Buried channel aquifers are confined to preglacial channels scoured in bedrock; channels which may or may not coincide with present stream valleys. These channels are deeper than those carved by more recent streams and where the buried channels are filled with sand and gravel they are good aquifers. The areal extent of the buried channels is limited and consists of at least two distinct stream systems (pl. 6). Based on geologic logs (Iowa Geological Survey files) prepared from samples from wells 83-8-12A1, 83-7-31L1, -32J1, -33Q1, and 83-8-32M1, the channel system in the southwestern part of the county contains from 50 to 100 feet of water-bearing sand and gravel. Based on limited information, the channel in the northeastern part of the county contains randomly occurring water-bearing sand and gravel from 5 to 25 feet thick.

The buried channels underlie alluvial aquifers in many areas of the county (pl. 6). Water occurring in the channel deposits is under artesian conditions, except possibly in those areas where the alluvial deposits are contiguous with the channel deposits. Generally, however, the two deposits are separated by glacial till. Because the buried channel deposits occur in valleys carved into porous, fissured Silurian dolomites, water movement in the channel deposits may be, at least in part, related to movement in the bedrock aquifer. This would imply an accordant piezometric surface. Static water levels in adjacent wells, 86-5-2D2 and D1, finished in the Silurian and in buried channel deposits respectively, have water levels of 144 and 142 feet and provide evidence of this accordance.

The potential of the channel aquifers to provide a dependable, sustained yield is unknown. Simpson (1927) reported yields of 350 gpm from flowing artesian wells tapping the buried channel deposit along Prairie Creek. No significant yield data are available for the channel deposits in the northeastern part of the county. Because of this limited hydrologic information it is obvious that anyone considering these deposits for major water supply developments should follow a careful program of test drilling and test pumping. Further, based on the comparative thickness of the sands and gravels in the two principal buried channel systems, the greatest potential for large yields would be in the channel in the western-southwestern part of the county.

Silurian-Devonian Aquifer

The Silurian-Devonian aquifer is the most widely used aquifer in Linn County. The aquifer is developed for domestic and livestock supplies at farms throughout the county, for municipal and light industrial supplies at most rural communities, and for industrial-commercial supplies at many industries and businesses in the Cedar Rapids area. The total pumpage from the aquifer was estimated to be 6.1 mgd during the period 1960-64. Domestic-livestock use was about 1.5 mgd, municipal supply was about 0.6 mgd, and industrial-commercial use was about 4 mgd. Pumpage from the aquifer is concentrated in the Cedar Rapids area, where 65 percent of the total withdrawal from the Silurian-Devonian aquifer occurs.

The Silurian-Devonian aquifer in Linn County, comprising the Gower, Hopkinton, Kankakee, and Edgewood Formations of Silurian age and the Cedar Valley and Wapsipinicon Formations of Devonian age, is composed chiefly of relatively dense dolomite and limestone. Rocks of Silurian age underlie the entire county, occurring immediately beneath the glacial drift (subcrop) in the eastern part of the county and under rocks of Devonian age in the west (pl. 3). Rocks of Silurian age range in thickness from 150 to 350 feet over the county (fig. 14) and are thickest in the Cedar Rapids area. Devonian rocks overlie the Silurian in the western part of the county and have a maximum thickness of about 200 feet. Because the Silurian and Devonian are not separated by an aquiclude, they act as a single hydrologic unit in most parts of the county as evidenced by the continuity of the water-level surface as depicted on figure 17. However, well yields and related information indicate that the Silurian is the principal water-bearing unit and will be the main concern of the following discussion.

The aquifer is highly anisotropic with respect to ground-water flow because the rock openings in the normally dense dolomites and limestones consist of irregular fissures (solution channels) and fractures. These openings have a random distribution and are variable in size and extent, as evidenced by the variable yields and specific capacities of wells tapping the aquifer. Yields range from about 5 gpm to as much as 900 gpm and specific

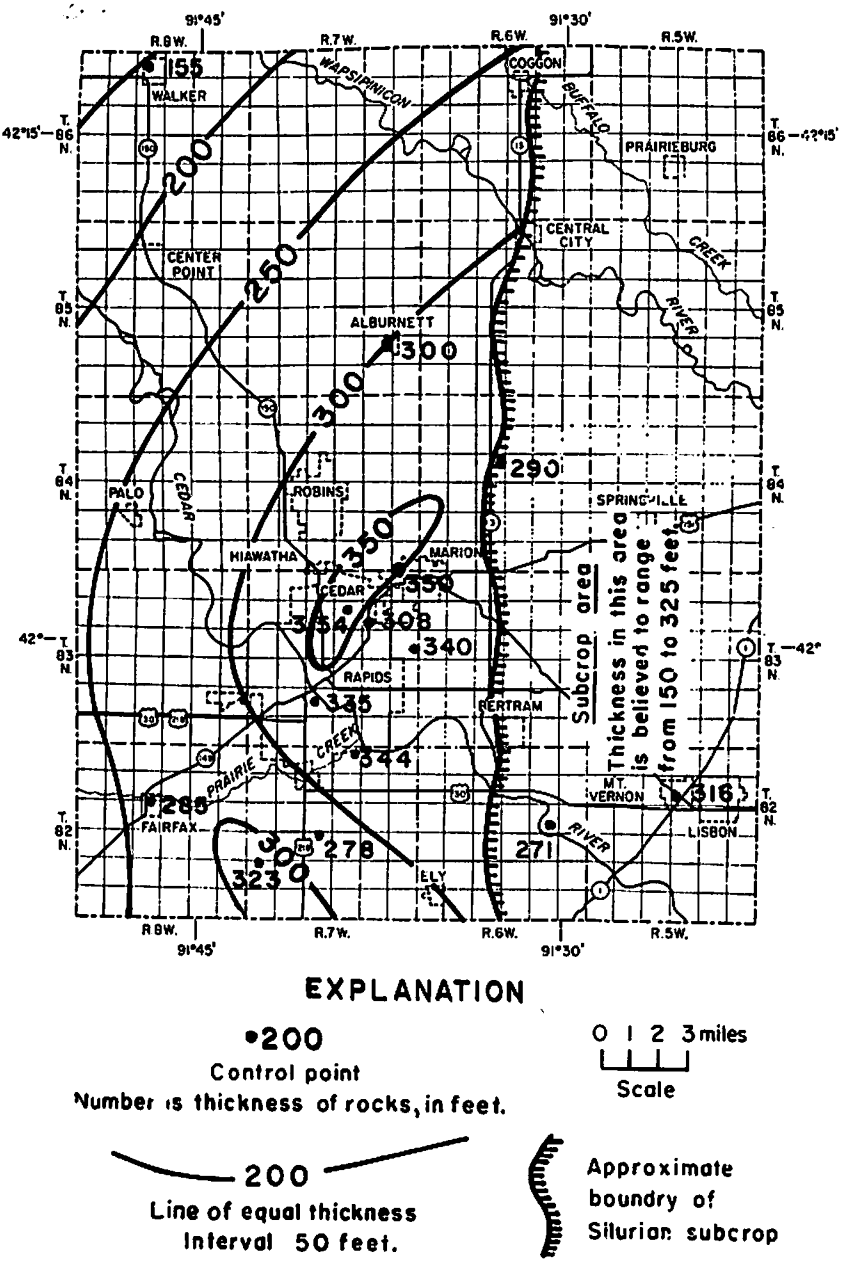


Figure 14.—Thickness of Silurian age rocks.

capacities range from 0.9 to 23 gpm per ft drawdown. Specific capacity data show the county-wide variability and the extreme local variability of the aquifer (fig. 15). The higher specific capacities occur in the Cedar Rapids area, indicating that the transmissibility is higher in this area than elsewhere in the county. Other areas of high transmissibility may occur beneath and immediately adjacent to deep bedrock channels (pl. 6) and the Cedar River valley, where solution activity probably was intense during channel cutting.

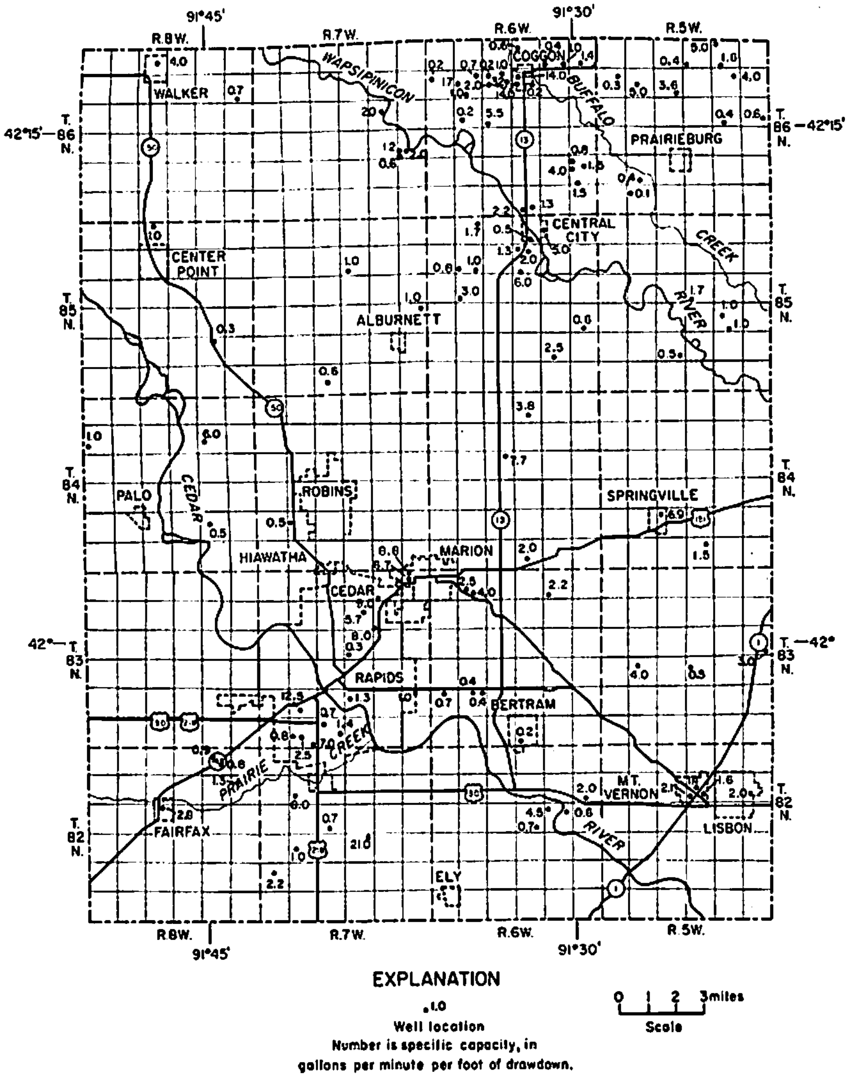


Figure 15.—Specific capacities of wells tapping the Silurian-Devonian aquifer.

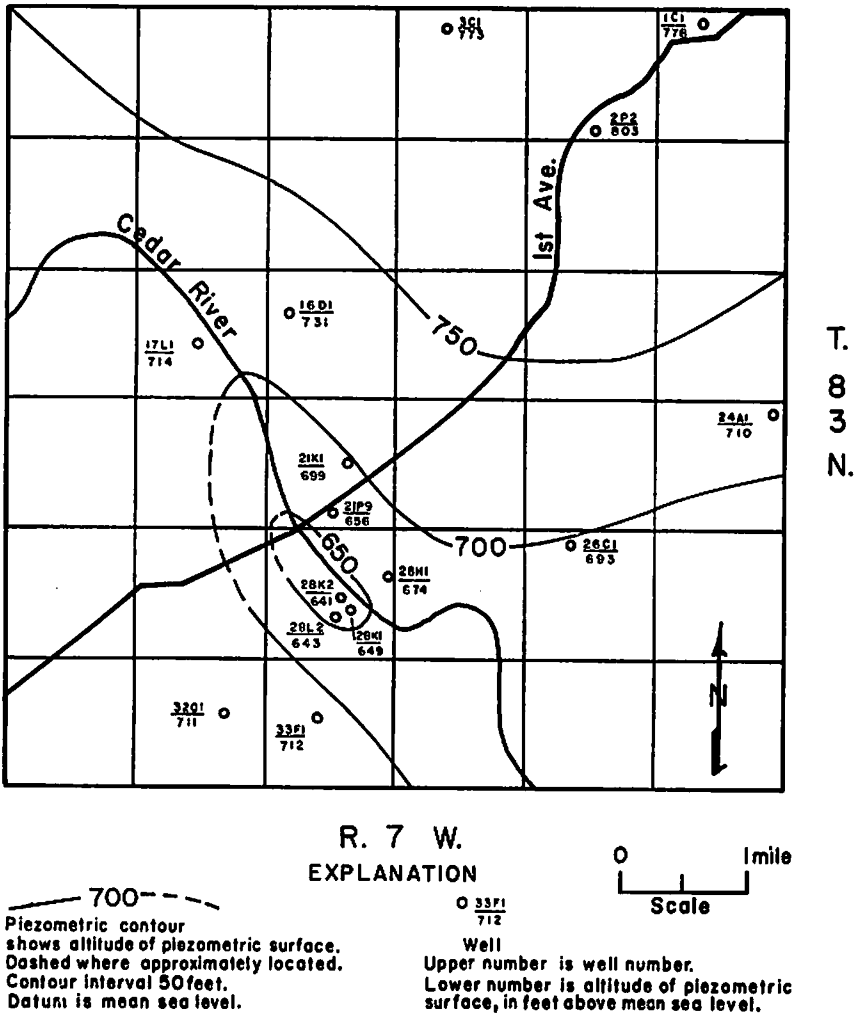


Figure 16.—Piezometric surface of the Silurian-Devonian aquifer in the Cedar Rapids area, 1959.

Water is available from the aquifer anywhere in the county. However, the anisotropic nature of the rocks makes it impossible to predict yields with any assurance. Areas with the best potential, outside the Cedar Rapids area, appear to be near bedrock channels. In most areas the yields are sufficient to meet the needs of farms, light industry, and small communities. Only occasionally can more than 500 gpm be developed from a well in the aquifer. Because of the aquifer's anisotropic nature, all wells drilled for high yields should completely penetrate the Silurian rocks to be certain that all water-bearing fissures are encountered.

The Silurian-Devonian aquifer is under artesian conditions in the county, and recharge to the aquifer is by subsurface inflow from areas southwest and northeast of the county and by seepage from the overlying glacial drift. Where concentrated pumpage has caused an extensive cone of depression, as at Cedar Rapids (fig. 16), additional recharge is by induced infiltration of water from the Cedar River.

Recharge to the Silurian-Devonian aquifer by seepage from the overlying glacial drift occurs throughout the county. The quantity of water seeping to the aquifer can be estimated by Darcey's law ($Q = PIA$) from the vertical gradient calculated from figure 8 and the permeability of upland glacial till as determined by Kunkle (1968, p. 12), where: Q is the quantity of water, in cubic feet per day, P is the permeability, in feet per day, I is the gradient, in feet per foot, and A is the area, in square feet. Thus, $Q = 0.0005 \times 50 \div 90 \times (5280)^2$ and Q is 7,700 cubic feet per day per square mile or 57,500 gallons per day per square mile. As a check of the values used, the quantity of water moving across the 850 contour in the central part of Linn County (fig. 17) can be calculated by the equation $Q = TIL$. The transmissibility of the aquifer, based on short aquifer tests and analysis of the cone of depression at Cedar Rapids is considered to be about 10,000 gallons per day per foot. The average gradient (I) is about 100 feet in 6 miles, and the length (L) is 33 miles. Thus, $Q = 10{,}000 \times 100 \div 6 \times 33$ and Q is about 5.5 million gallons per day. The area between the contour line and the groundwater divide is about 100 square miles; this, Q is about 55,000 gallons per day per square mile and agrees closely with the seepage calculated.

Natural discharge from the aquifer occurs as flow to surface-water bodies, principally the Cedar and Wapsipinicon Rivers

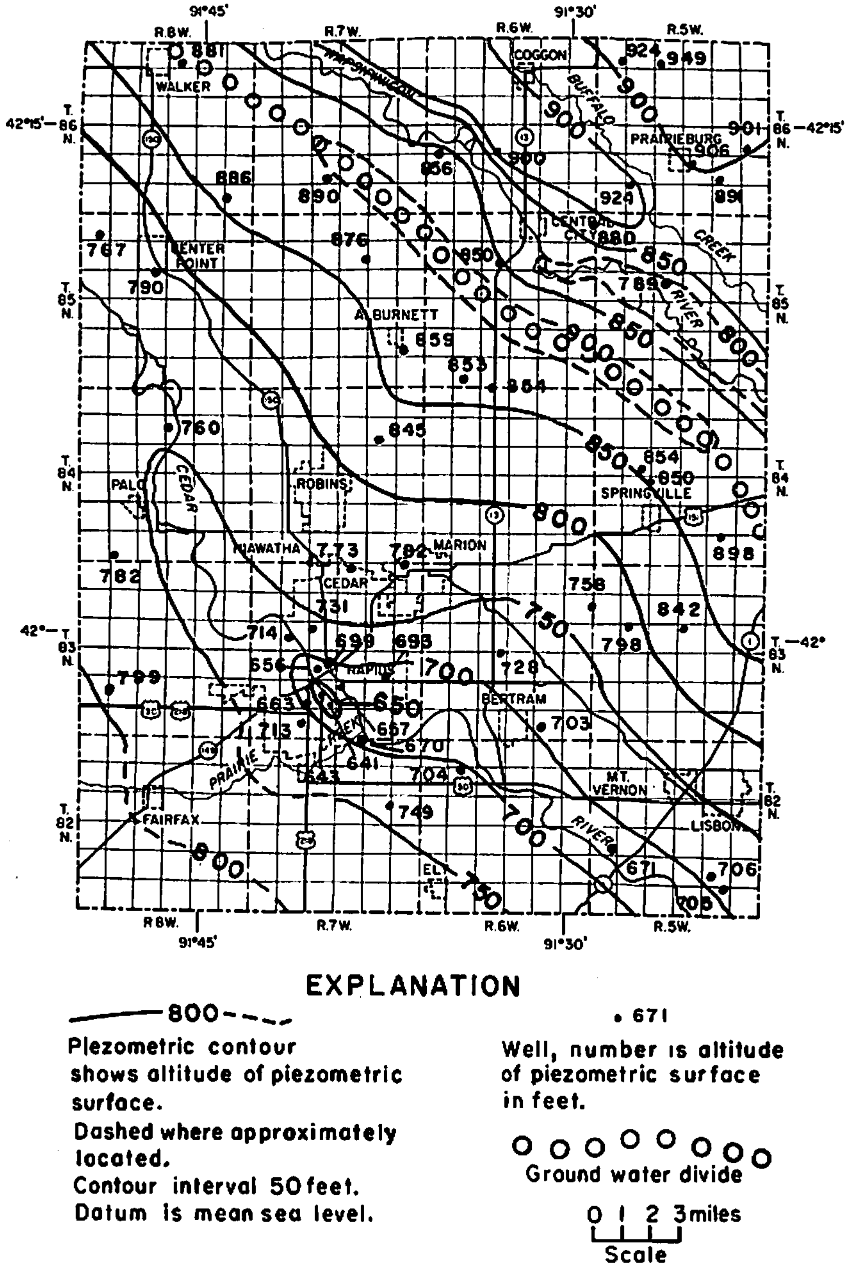


Figure 17.—Piezometric surface of the Silurian-Devonian aquifer in 1959.

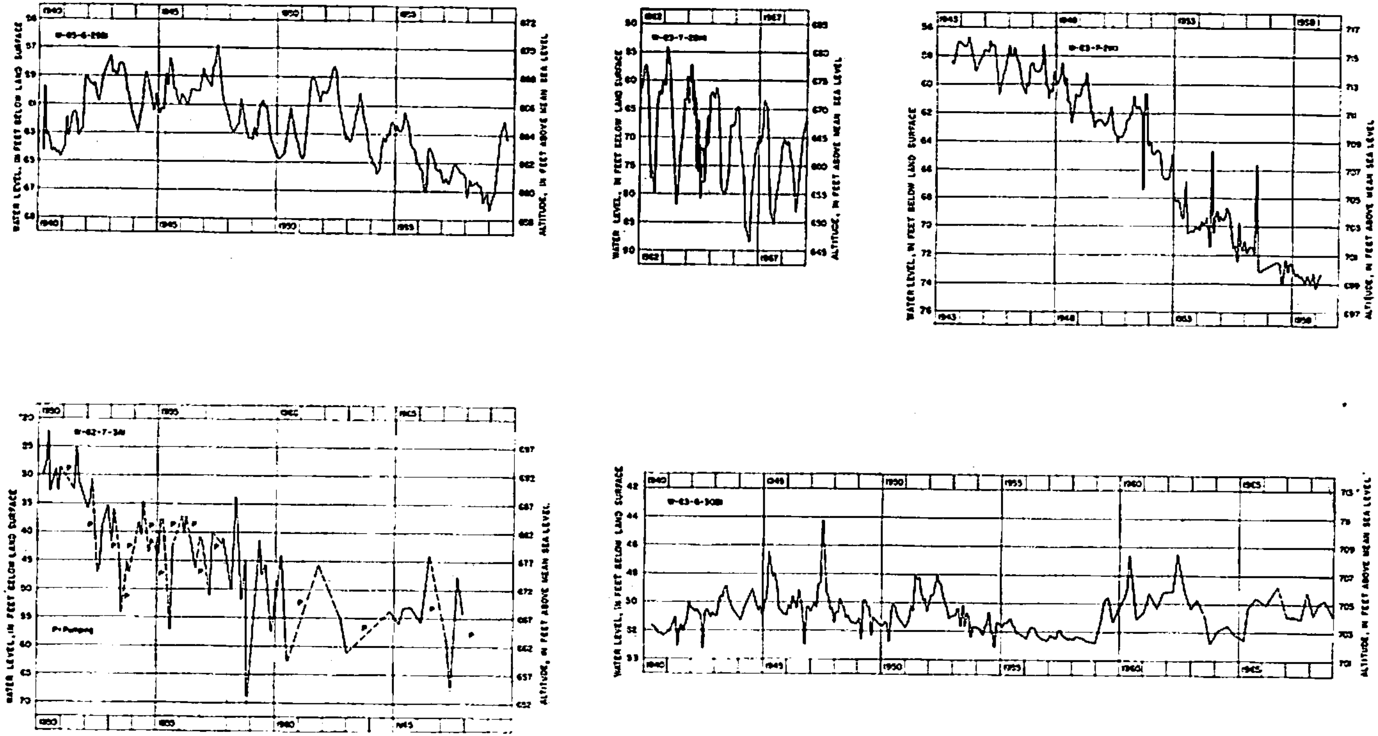


Figure 18.—Hydrographs of wells 82-7-3A1, 83-6-30B1, 83-7-21K1, 83-7-28H1, and 85-6-29B1.

(fig. 17), and by outflow as seeps and springs. Ground water that occurs near the surface may be discharged directly to the atmosphere by evaporation and transpiration. Such subsurface outflow as may exist probably occurs in the deep buried bedrock channels. Permeable sands in the channels divert water from the limestone aquifer into a different flow system that discharges outside the county.

Discharge by pumping has caused a progressive lowering of the piezometric surface of the Silurian-Devonian aquifer in the Cedar Rapids area. Earliest information (Norton, 1897, p. 246) indicates that the undisturbed piezometric surface in the central part of the city was slightly above land surface, about 725 feet. The initial heavy development occurred in the decade of the 1930's and was greatly intensified in the following two decades. By the 1930's the piezometric head was lowered at least 25 feet in the center of town (wells 83-7-28K1 and K2, table 6). Continued heavy pumping has caused further deepening and widening of the cone so that by 1959 the altitude of the piezometric surface in the center of the cone was about 640 feet (fig. 16) and about 620 feet in 1966. Thus, the piezometric head in this area has declined about 105 feet in approximately 70 years.

Hydrographs of most observation wells in and near the area of the cone of depression reflect the declining piezometric head (figs. 18 and 19). Most centrally located is well 83-7-28H1 which shows the seasonal highs and lows along with a general downward trend; daily water-level variations at this observation well site are shown in figure 10. Water levels about a mile north of the center of the cone in well 83-7-21K1 (now destroyed) illustrates the sharp decline in head which occurred during the 1940 and 1950 decades. Nearly 16 feet of an estimated 26-foot head loss in the area of this well occurred from 1943 to 1959. On the south edge of the cone is well 83-7-32G1 whose hydrograph shows a long, steady decline and together with 83-7-28H1 shows that the cone is still growing and deepening. Approximately 4 miles east of the cone, well 83-6-30B1 shows no appreciable effects from the heavy pumpage at Cedar Rapids. Well 83-7-3A1 is a producing industrial well (in a field of five wells) about 2 miles southeast of the center of the main cone; the hydrograph shows a general decline of about 1.4 feet per year for the period 1952-1967, due in part to expansion of the main cone and in part to local pumping.

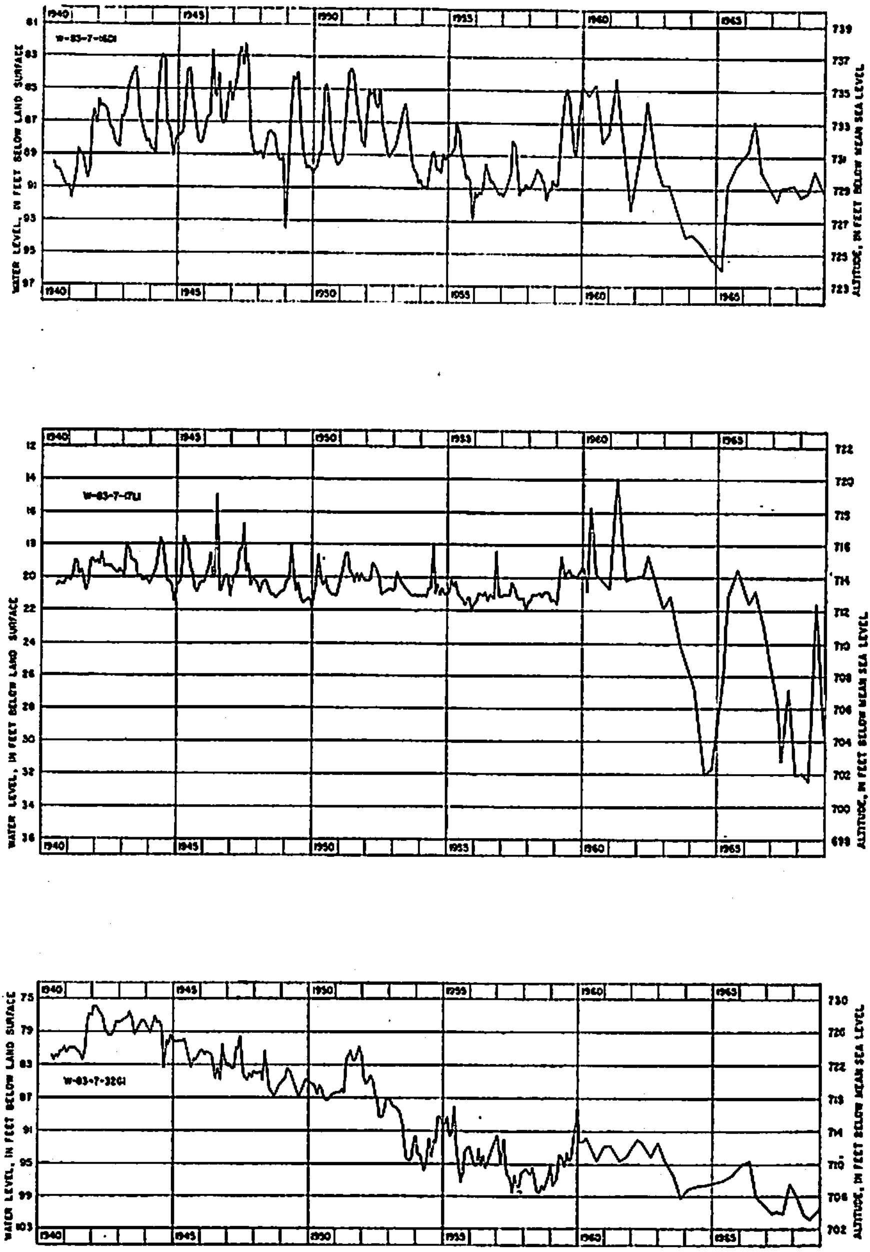


Figure 19.—Hydrographs of wells 83-7-16D1, 17L1, and 32G1.

Table 6.—Summary of water-level data from wells in the Silurian-Devonian aquifer (measurements in feet above sea level; the year of measurement shown in parentheses).

Well No.	1920-29	1930-39	1940-49	1950-60	Well No.	1920-29	1930-39	1940-49	1950-61
83-7-1C1	....	....	777(41)	782(60)	83-7-21Q4	706(20)	....	694(41)	....
1C2	....	....	....	778(60)	21Q5	....	706(38)	701(41)	....
1F1	....	783(36)	....	....	25B1	....	....	....	712(50)
2P2	....	....	770(41)	....	26C1	....	....	....	693(54)
3C1	....	....	....	773(56)	27E1	....	....	665(45)	....
10K1	....	....	757(41)	....	28A1	....	....	688(40)	....
11N2	....	....	727(43)[1]	....	28A2	....	688(38)	....	....
15N1	....	....	742(42)	....	28B1	....	....	693(40)	....
21A1	....	....	723(47)	....	28B4	....	694(39)	....	....
21K1	....	717(38)	715(43)	699(59)	28B6	717(28)	....	....	....
21K2	....	....	....	695(60)	28G1	....	....	675(45)	....
21M1	....	....	678(47)	....	28H1	....	....	....	657(61)
21N1	....	....	671(41)	....	28H4	....	....	665(40)	....
21P2	....	696(35)	....	....	28K1	700(28)	....	667(40)	649(58)
21P3	....	....	....	672(53)	28K2	700(28)	....	659(40)	641(58)
21P4	....	700(39)[1]	....	....	28L2	....	....	690(40)	643(58)
21P6	....	....	699(40)	....	28N1	....	....	693(46)	663(57)
21P7	....	....	669(48)	....	29Q1	....	....	691(46)	....
21P9	....	695(38)	671(48)	656(57)	31L1	....	....	739(44)	....
21P10	....	701(39)	....	....	32D1	....	....	719(49)	....
21Q1	....	700(34)	691(40)	....	32H1	....	....	725(40)	713(59)
21Q3	....	705(36)	....	....	32J1	....	....	721(46)	....

[1] Water level measured prior to deepening of well to Jordan sandstone.

The most significant water-level changes to occur recently are in wells 83-7-16D1 and 83-7-17L1; these are limestone wells, one on each side of the Cedar River and adjacent to the municipal well fields which obtain water from the alluvium. During most of the period of record, the hydrographs show no particular trends indicating that recharge from the alluvial aquifer was stabilizing the cone of depression in this area. Between 1962 and 1964 the city of Cedar Rapids developed and completed a number of wells in alluvium and converted the entire city supply from surface to ground water. Examination of the above hydrographs shows a definite change in the water-level pattern in the Silurian-Devonian aquifer during and after this time period. The heavy pumpage from the alluvial aquifer has lowered the water table in the well field more than 40 feet (see p. 35) and has diverted water that formerly recharged the Silurian-Devonian aquifer. Moreover, the former discharge-recharge relations between the two aquifers in the area have been reversed; water from the rock aquifer now is moving into the alluvial aquifer because of the new head relationship. Thus, the cone of depression in the Silurian-Devonian aquifer has expanded in response to upward movement of water to the alluvium and lateral movement to the center of pumping from the rock aquifer in downtown Cedar Rapids. Apparently, a new dynamic equilibrium has been established between the Cedar River and the two aquifers in the municipal well field area, as indicated by hydrographs of wells 83-7-16D1 and 83-7-17L1 (fig. 19). The 1965 and 1968 peaks shown on the hydrographs correspond to flood stages of the Cedar River (U. S. Dept. Interior, 1965, 1968) and indicate that water levels since 1962 fluctuate with the river stage.

To summarize, between 1900 and 1966 the piezometric surface in the center of the cone declined at an average rate of about 1.6 feet per year and 1 mile north of the cone's center 0.4 foot per year. During the 1940's and 50's the average head decline at the center of the cone was about 2 to 3 feet per year, and the decline 1 mile from the center of the cone was about 1 foot per year. The hydrograph of observation well 83-7-28H1, which was installed shortly after well 83-7-21K1 was destroyed, shows that this decline in head in the center of the cone has decelerated to about 1 foot per year since 1961. This reduced rate of decline is attributed to a decrease in pumpage from the area because several commercial establishments have changed from water cooling to electrical air conditioning.

If pumpage from the aquifer is not increased, the growth of the cone will decelerate and stabilize when enough water is diverted from areas of recharge and/or natural discharge to balance the pumpage. But should the pumpage again be increased, the cone's depth and area will continue to grow. The aquifer probably could withstand an additional 150 to 200 feet of piezometric lowering in the Cedar Rapids area; however, individual wells may be adversely affected and pumping costs would increase. It would be prudent, therefore, to locate new wells away from the center of the cone. The collection of water-level and pumpage data in the Cedar Rapids area will be continued, which will allow periodic re-evaluation of the cone's extent, depth, and growth.

The quality of water from the Silurian aquifer generally is good, as shown in the summary below. The total dissolved solids are slightly higher than usual in a few of the wells in downtown Cedar Rapids, probably owing to intermixing of water from other rock units that are open to several deep multi-aquifer wells in the area. The concentration of iron and the hardness are troublesome in some places, but both are readily treated. The temperature of the water, based on 49 samples, ranges from 7 to 15°C and averages about 12°C.

Constituent	Number of samples	Concentration (mg/l) maximum	minimum	average
Fluoride	71	1.5	0	0.28
Nitrate	70	10.15	0	1.25
Dissolved solids	70	749	231	380
Hardness	71	544	226	319
Iron	73	8.0	0	.3

Jordan Aquifer

The Jordan aquifer in Linn County, as elsewhere in Iowa, is a hydrogeologic unit that consists principally of the Jordan Sandstone, but also includes the lower part of the Prairie du Chien Formation and the upper part of the St. Lawrence Formation (table 2). The Jordan Sandstone, however, is the principal water-bearing rock unit in this part of the state. Thus, the following discussion is concerned only with the characteristics of the Jordan Sandstone.

The Jordan Sandstone is a deep artesian aquifer underlying all of Linn County. The formation is composed of well sorted, loosely cemented, fine-to-coarse grained sand and is between 75 and 108 feet thick (table 2). Dipping to the southwest across the county, the top of the aquifer is 400 feet below sea level in the northeast and 700 feet below sea level in the southwest (fig. 20). To estimate drilling depth add the estimated altitude of the top (from fig. 20) to the land-surface altitude (from a topographic map) at the location selected. At Cedar Rapids the depth is about 1,450 feet below land surface.

The Jordan Sandstone is considered to be the most isotropic and homogeneous aquifer in Iowa. Water moves through pore spaces between fairly well sorted, fine-to-coarse, sand grains. The permeability of this type of sand generally ranges between 300 to 500 gpd per ft^2. The permeability, however, can be reduced locally by cementation. The transmissibility at one locality in the county was determined from a pumping test to be 38,000 gpd per ft (fig. 21). Based on other determinations in the surrounding counties, this figure is believed to be fairly representative of the aquifer's transmissibility throughout the county. The storage coefficient is estimated to be 3×10^{-4}, which also is consistent with determinations made elsewhere in the region.

Data on figure 21 can also be used to predict future drawdown in the well. For example, if the Marion well were to be pumped continuously at the same rate of discharge and no boundary conditions were encounted, the extended time-drawdown graph

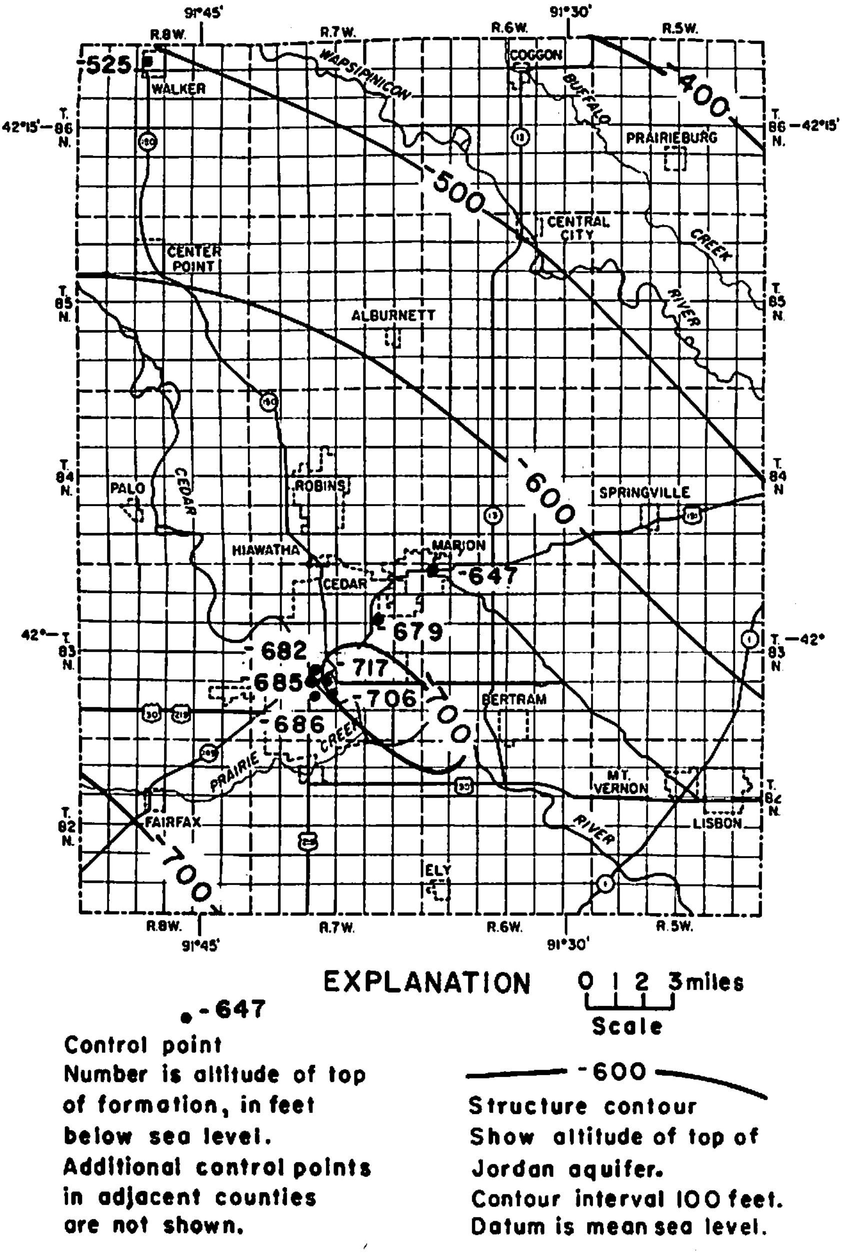


Figure 20.—Configuration and altitude of the top of the Jordan aquifer.

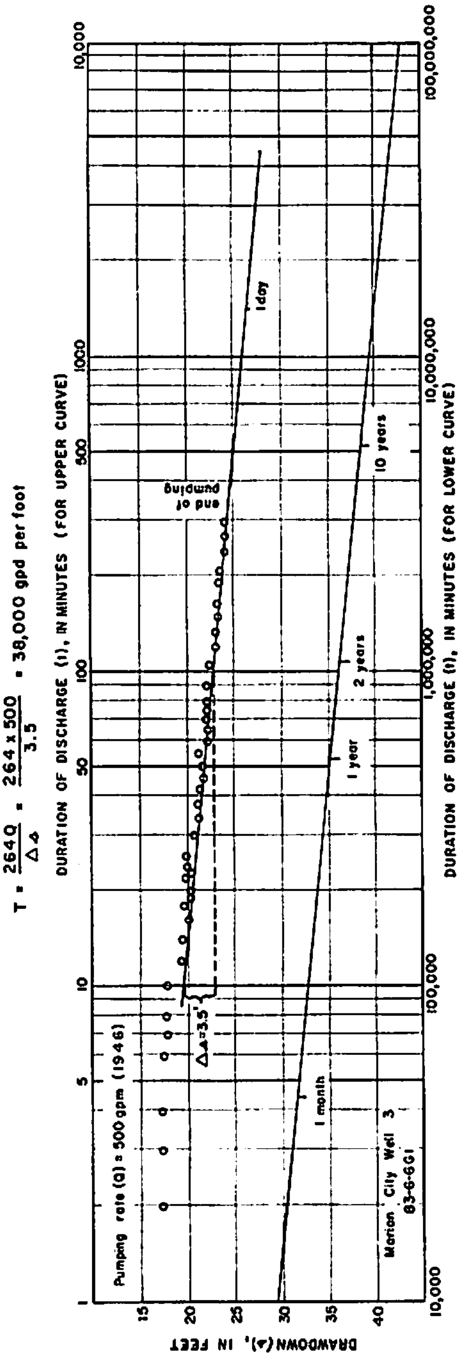


Figure 21.—Drawdown and projected drawdown of water level in well 83-6-6G1 being pumped at rate of 500 gallons per minute.

indicates that the drawdown would be about 31 feet at the end of one month and about 36 feet at the end of two years. If the pumping rate were different, the drawdown at any time on the graph would be multiplied by the ratio of the different rate to the test rate. For example, if the Marion well were to be pumped at 500 gpm for 10 hours a day, which is an average daily rate of 208 gpm, the drawdown at the end of 100 days would be 23 × 208 ÷ 500 = 9.6 ft.

The time-drawdown graph (fig. 21) can be used to approximate the drawdowns in most wells pumping water from the Jordan aquifer in the county, because the aquifer parameters throughout the county are believed to be fairly constant (except locally, where cementation may have reduced the permeability). However, if drawdown (head-loss) information at various distances from the pumped well is required, a distance-drawdown graph can be constructed from transmissibility and storage coefficient data. For complete flexibility, a family of distance-drawdown curves at different values of time can be constructed (fig. 22). The time values in figure 22 were selected at log-cycle intervals to aid in interpolation. Drawdowns caused by pumping

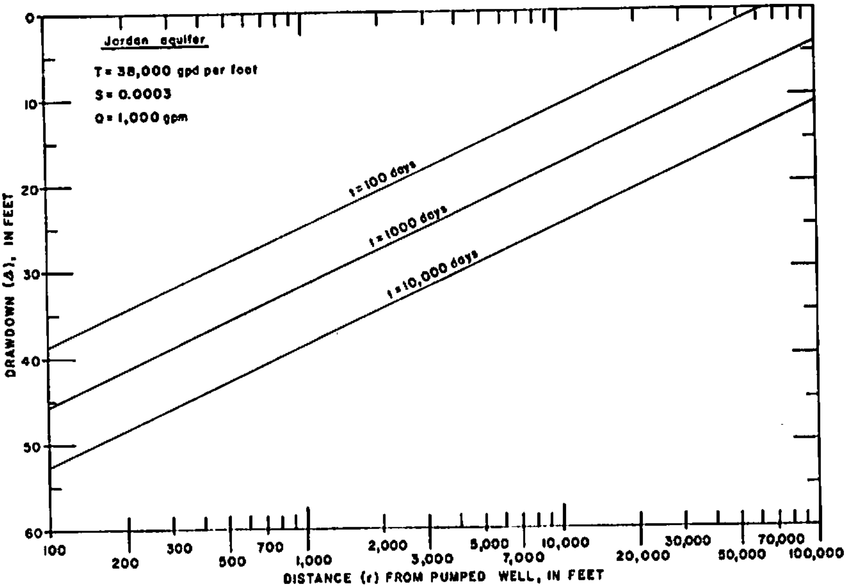
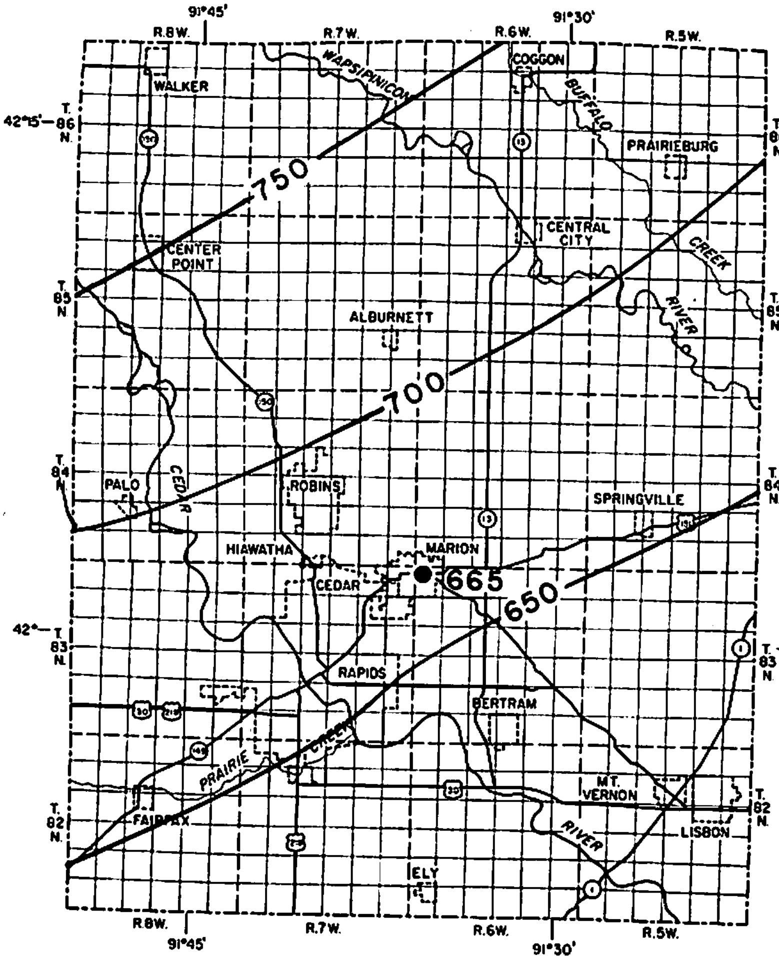


Figure 22.—Distance-drawdown graph to determine drawdown at any distance from a well pumping 1,000 gallons per minute from the Jordan aquifer.

rates other than the one used in constructing the graph are adjusted as explained above.

A generalized piezometric map of the aquifer (fig. 23), which



EXPLANATION

•665

Control Well; number is altitude of water level in well, in feet above mean sea level. Additional control points adjacent to Linn County are not shown.

0 1 2 3 miles

Scale

—— 650 ——

Piesometric contour shows altitude of piesometric surface. Contour interval 50 feet.

Figure 28.—Generalized piezometric surface of the Jordan aquifer.

is based principally on regional data, indicates the natural piezometric head and gradient in this areally-extensive aquifer. Water enters the county by subsurface inflow from the north and northwest and leaves the county by subsurface outflow to the south and southeast. If the aquifer is not disturbed by pumpage and/or if boundary conditions are not encountered, the outflow will equal the inflow.

Water is pumped from wells tapping the Jordan aquifer for both public supply and industrial use at the rate of about 2.4 mgd. Most of the pumpage from the aquifer is in the Cedar Rapids-Marion area, although one well is at the town of Walker. In the Cedar Rapids-Marion area, nine wells penetrate the Jordan, but only four obtain all of their water from this aquifer. The others are multiple-aquifer wells, which means the well bores also are open partially or fully to the Silurian and/or Ordovician Formations. Pumpage from four wells tapping only the Jordan ranges from 315 to 725 gpm per well with specific capacities ranging from 9.8 to 20 gpm per ft. Pumpage from the other five wells ranges from 293 to 1,050 gpm per well with specific capacities from 4.1 to 24 gpm per ft. Water levels in the latter wells vary considerably because most are also open to the Silurian-Devonian aquifer (table 7).

Multiple-aquifer wells will allow inter-aquifer movement of water through the well bore if a head difference exists between the aquifers involved. In the downtown Cedar Rapids area, the head of the Jordan aquifer is higher than the depressed head of the Silurian-Devonian aquifer; thus, water from the Jordan will flow up the well bore in deep multi-aquifer wells and discharge into the Silurian-Devonian aquifer. Other than disturbing the head relations in the area, this condition is not a major problem yet because the quality of water in the two aquifers is similar. However, should the Galesville-Mt. Simon Sandstones ever be developed, under no circumstances should wells drilled to the Galesville-Mt. Simon Sandstones be left uncased opposite the overlying aquifers. Water from these sandstones is highly mineralized (table 5) and the head is higher than in the overlying aquifers. Hence, highly mineralized water would enter and contaminate the overlying aquifers.

Large quantities of water are available from the Jordan aquifer. Many wells developed in this aquifer in counties surrounding Linn County yield 1,000 gpm or more. Not all wells tapping the Jordan in Linn County are pumped at the rate of

TABLE 7.—SUMMARY OF WATER-LEVEL DATA FOR WELLS IN THE JORDAN AQUIFER.

Well Number	Owner	Depth of Well (feet)	Land Surface Altitude (feet above sea level)	Water Level above (+) or below (—) Land Surface (feet)	Altitude of Water Level	Year Water Level Measured	Remarks
83-7-21P8.......	Cedar Rapids, City well 1..............	1450	733	+ 28.00 — 2.00 — 14.00	761.00 731.00 717.00	1888 1911 1928	Two other similar Jordan wells drilled at same time very close to 21P8. All three wells abandoned before 1928.
83-7-21P1.......	YMCA..............................	1462	733	+ 2.50	735.50	1894	Located at site of old building, abandoned.
	Cedar Rapids, City well 4.............	1591	736	— 15.00	721.00	1914	Location not known. Abandoned.
83-7-21Q2.......	Gazette Company......................	1495	733	— 21.00	712.00	1940	Well open below Maquoketa Shale.
83-7-27L1.......	Wilson and Co., Inc. 2.................	1484	719	— 55.00	664.00	1941	Well open to Silurian and open below Maquoketa Shale.
83-7-28L1.......	Penick and Ford Ltd., Inc..............	1507	729	— 45.25	683.75	1942	Well open below Maquoketa Shale.
83-7-27M1......	Wilson and Co., Inc. 6.................	1493	716	— 60.00	656.00	1943	Well open to Silurian and open below Maquoketa Shale; well reported to have caved in at 300 feet from bottom and now abandoned.
83-7-11N2......	Allis-Chalmers Mfg. Co...............	1560	793	— 66.40 —120.00 —165.00	726.60 673.00 628.00	1944 1958 1960	Well open to Silurian and open below Maquoketa Shale.
83-7-28D1......	Iowa Electric Light and Power Co.......	1490	725	— 65.00	660.00	1949	Well open to Silurian and open below Maquoketa Shale.
83-7-21P4.......	Quaker Oats Co. 2.....................	1511	725	— 65.00	660.00	1954	Well open to Prairie du Chien and Jordan.
83-7-21M2......	Hubbard Ice and Fuel Co..............	1515	726	— 90.00	636.00	1956	Well open to Prairie du Chien and Jordan.
83-6-6G1.......	Marion City well 3....................	1663	861	—195.29	665.71	1958	Well open to Prairie du Chien, Jordan, and St. Lawrence.

1,000 gpm, but that yield probably is available if needed. If yields greater than 1,000 gpm are required, more than one well may be needed, and it would be necessary to determine the mutual interference effects between the wells.

An analysis of mutual interference effects is of great aid in planning optimum well spacing, in determining pump settings, and in estimating costs of pumping. Mutual interference between wells tapping the Jordan aquifer can be determined from the distance-drawdown graph (fig. 22) as shown in the following example.

An industry requires a continuous supply of water for 100 days at a rate of 3,000 gpm. Three wells, which are located as shown in figure 24, will pump 1,000 gpm each. What will be the total drawdown in each well at the end of 100 days of continuous pumping?

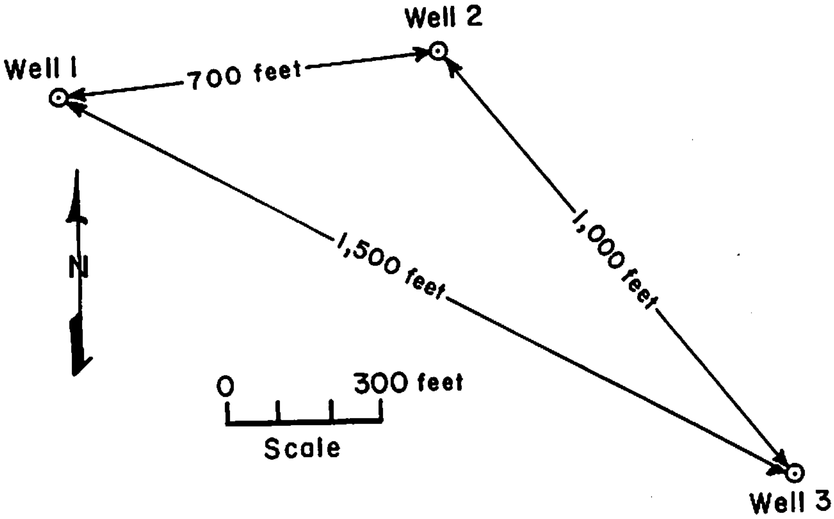


Figure 24.—Hypothetical well field producing from the Jordan aquifer.

Drawdowns at the various distances involved are determined from figure 22 and are tabulated and added as follows:

Effect of	Drawdown in wells (ft) 1	2	3
Well 1 on 2		27	
Well 1 on 3			22.5
Well 2 on 1	27		
Well 2 on 3			25
Well 3 on 1	22.5		
Well 3 on 2		25	
Well 1 on 1, 2 on 2, 3 on 3	52.5	52.5	52.5
Total drawdown	102.0	104.5	100.0

Drawdown determinations for other pumping rates and other pumping periods (t) can be adjusted as described above.

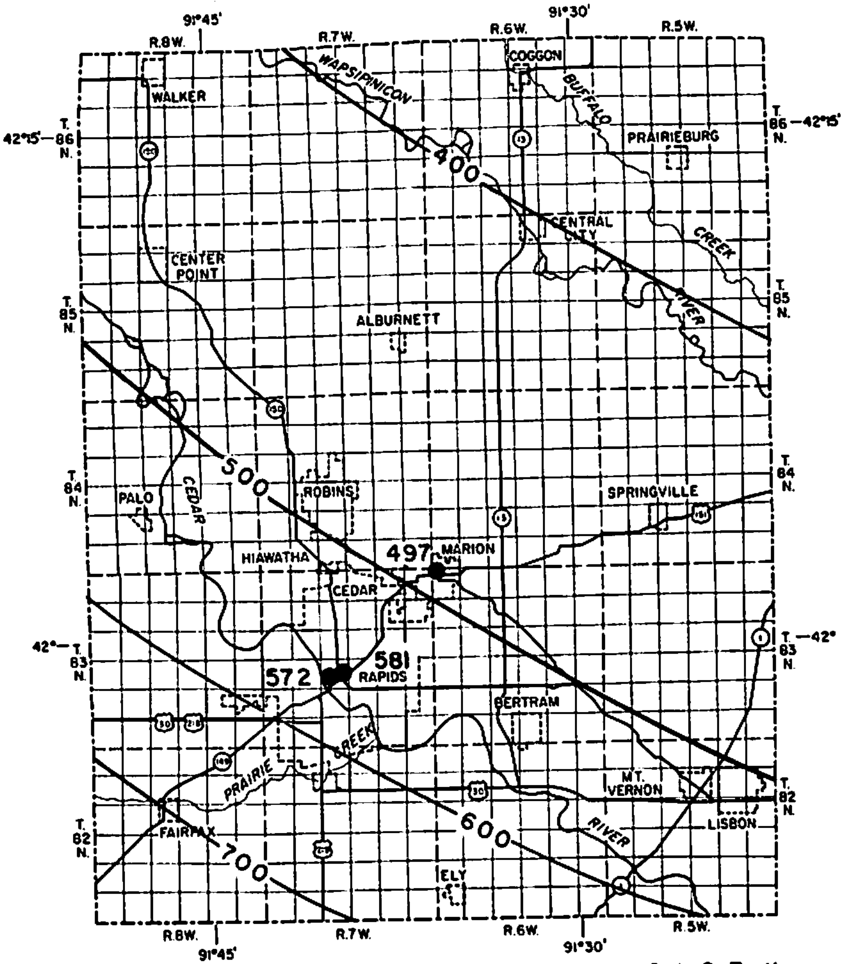
The quality of water from the Jordan aquifer is consistently good in this area, although generally hard. Locally, high concentrations of iron may occur but this is readily treated. The total dissolved solids increases in the down-dip direction across the county (fig. 25). Based on three samples, the temperature of the water is about 16°C. Below is a summary of several properties and constituents of samples taken in Linn County.

Constituent	Number of samples	Concentration mg/l maximum	minimum
Fluoride	3	1.4	1.1
Nitrate	3	.1	.0
Dissolved solids	5	731	497
Total hardness	5	523	286

Glacial Drift and Devonian Limestone Aquifers

The Pleistocene glacial deposits that cover the county serve as a minor source of ground water in the county. Little information about the water-bearing characteristics of these deposits is available other than a reported specific capacity of 5 gpm/ft in one well. Several farm wells yield from 5 to 15 gpm for domestic and stock use from near-surface sand and gravel deposits in the glacial drift. Although the quality of the water generally is good, the susceptibility of these shallow waters to surface contamination has led to their general disuse.

Wells that obtain water from the glacial drift usually are between 10 and 30 feet deep although several are 50 to 60 feet deep. The water in these wells is under water-table conditions and the depth to water ranges from 4 to 23 feet. In some wells, water levels less than 4 feet below land surface have been re-



0 1 2 3 miles
Scale

EXPLANATION

● 497

Well producing from the Jordan aquifer; number is total dissolved solids content. Additional control points adjacent to Linn County not shown.

——400——

Line of equal total dissolved solids. Interval 100 milligrams per liter.

Figure 25.—Total dissolved solids of water from the Jordan aquifer.

corded during periods of excess precipitation; whereas, other wells reportedly have gone dry during extended periods of deficient precipitation. A few springs flow from the glacial drift, but their rate of flow is only a few gallons a minute. A generalized water-table map of the glacial deposits is shown on figure 9.

The Devonian limestone, which forms the bedrock surface over much of the western part of Linn County, is a minor source of water for rural domestic and stock wells. Although the Devonian limestones are in hydrologic connection with the underlying Silurian aquifer, the yield of shallow wells penetrating only the Devonian generally is less than those penetrating the Silurian. Yields from wells finished in the Devonian limestone usually range from 5 to 40 gpm with specific capacities ranging from 1 to 5 gpm per ft. Well 83-7-15M1 is the only well finished in this aquifer that is known to yield over 40 gpm; it produced 150 gpm with a specific capacity of 10 gpm per ft. Several large springs in the Cedar Rapids-Marion area discharge from Devonian limestone (table 8).

TABLE 8.—SELECTED SPRINGS IN LINN COUNTY.

Location	Name	Geologic Source	Flow (gpm)[1]	Temperature (°C)	Dates Inventoried	Use of Water	Remarks
83-7-4Q1S	Coopers Spring	Cedar Valley Limestone and Wapsipinicon Formation	400e 495m 300f	.... 10 12	1927 Oct. 1943 June 1961	Not used	Flow varies with precipitation; spring reported to have dried up in 1934 and twice in the early 1950's; Ca.[2]
83-7-9B1S	McCloud Spring	Wapsipinicon Formation	400e 418r 525r	.... 10 11	1927 Oct. 1943 June 1961	Bottling	Flow generally constant; occasional yields of about 1,000 gpm reported during periods of extreme wet weather.
83-7-9K1S	Glass Spring	do	150e 31f	....	July 1943 June 1961	Not used	Flow is from a group of several springs.
84-6-31E1S	Sulphur Spring	do	25e 25e	....	July 1943 June 1961	do	Flows into Indian Creek; formerly used for domestic purposes.
84-7-35J1S	Bowman Spring	do	100v	10	June 1961	do	Formerly supplied part of Marion public supply; flows reported to have decreased after city began pumping from wells. Many other small springs and seeps nearby. Flow from these springs estimated at 3 million gallons per day in 1927.
84-7-35J2S	Middle Spring	do	10f	10	June 1961	do	
84-7-35J3S	Lower Spring	do	15f	10	June 1961	do	

---

[1] Flow determined (e), estimation, (f), modified Parshall flume, (m), measure cross section of channel and velocity, (r), rectangular wier, and (v), 90° "V" notch wier.
[2] Ca: Chemical analysis given in table 5.

CONCLUSIONS

The principal purpose of this report is to provide information on the availability and quality of water from the ground-water reservoir in Linn County. From the data set forth in previous sections of this report, it has been shown that four rock units are major sources of water and two others are of minor importance. The potential and limitations of these rock units are summarized below.

POTENTIAL AND LIMITATIONS OF THE AQUIFERS

Alluvium

POTENTIAL—Excellent for development of industrial and municipal supplies. Yields of 1,000 gpm and more are believed to be available from several areas in the valley of Cedar River; smaller yields may be available from several areas in the valleys of Wapsipinicon River and Prairie Creek. Transmissibilities and storage coefficients are high. Aquifers are recharged by induced infiltration and precipitation. Chemical quality of water generally is good although, locally, concentrations of iron are high.

LIMITATIONS—Occurs only along water courses and is not geographically widespread. Hence, county-wide availability is limited. The near-surface position of aquifer makes it susceptible to contamination.

Buried Channel Deposits

POTENTIAL—Good for light industry, small community, and domestic-stock supplies. Yields of 500 gpm and more are estimated to be available from the bedrock channels that underlie Prairie Creek and several reaches of Cedar River. Chemical quality of water probably is similar to quality of water from Silurian rocks, which is good.

LIMITATIONS—Aquifers are geographically restricted, thus county-wide availability is limited. Recharge opportunities may be limited, except in areas where alluvium is contiguous with buried channel deposits; hence sustained yields may be low.

Silurian Rocks

POTENTIAL—Good for development of industrial and municipal supplies. Underlies entire county and is everywhere available as a source of water. Yields of 200 gpm and more available in many areas; in some places yields of more than 500 gpm available. The available drawdowns in wells are at least 200 feet, which will sustain present pumpage for many years. Chemical quality of the water generally is good.

LIMITATIONS—Yields are extremely variable because of anisotropic nature of aquifer and random distribution of rock openings. Recharge to the aquifer is not sufficient to balance heavy localized pumpage, thus water levels continue to decline and pumping costs increase.

Jordan Sandstone

POTENTIAL—Excellent to good for development of large industrial and municipal supplies. Underlies entire county and is thus everywhere available as source of water. Yields of 1,000 gpm or more are available in most areas. The moderate transmissibility and high piezometric head will sustain heavy pumpage for many years. The chemical quality of water generally is good.

LIMITATIONS—Heavy, concentrated pumpage will cause significant lowering of water levels; thus pumping costs will increase. Aquifer is not economically available to everyone because of depth of drilling.

Devonian Limestones

POTENTIAL—Fair to good for development of domestic-livestock supplies. Yields of 5-20 gpm generally available; in some places larger yields are available. Yields often supplemented with water from underlying Silurian rocks. The chemical quality is good.

LIMITATIONS—Aquifer underlies only western half of county. Yields are variable because of random distribution of rock openings.

Glacial Drift

POTENTIAL—Fair to poor for development of domestic farm supplies. Yields generally are less than 5 gpm; occasional yields of 10 gpm available. Chemical quality of water generally is good.

LIMITATIONS—Yields are variable because water availability depends on occurrence of randomly distributed sand and gravel deposits in the glacial drift. The aquifer is susceptible to contamination because of its near-surface position.

SELECTED REFERENCES

Bedinger, M. S., and Emmett, L. F., 1963, Mapping transmissibility of alluvium in the lower Arkansas River Valley, Arkansas: U. S. Geol. Survey Prof. Paper 475-C, p. c188-c190.

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

Brown, R. H., Ferris, J. C., Jacob, C. E., Knowles, D. B., Meyer, R. R., Skibitzke, H. E., and Theis, C. V., 1963, Methods of determining permeability, transmissibility, and drawdown: U. S. Geol. Survey Water-Supply Paper 1536-I, 341 p.

Church, N. K., 1967, Lithostratigraphy and carbonate-evaporite petrology of the Middle Devonian-Wapsipinicon Formation in Iowa: Unpublished master's thesis, University of Iowa, Iowa City, Iowa.

Cooper, H. H., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Trans. Am. Geophys. Union, v. 27, p. 526-534.

Crawford, L. C., 1942, Summaries of yearly and flood flow relating to Iowa streams 1873-1940: Iowa Geol. Survey Water-Supply Bull. no. 1, 129 p.

———, 1944, Surface-water resources of Iowa, October 1, 1940 to September 30, 1942: Iowa Geol. Survey Water-Supply Bull., no. 2, 222 p.

Fenneman, N. N., 1938, Physiography of Eastern United States: New York McGraw-Hill Book Co., 714 p.

Ferris, J. G., and others, 1962, Theory of aquifer tests: U. S. Geol. Survey Water-Supply Paper 1536-E, p. 69-174.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U. S. Geol. Survey Water-Supply Paper 1473.

Iowa Geological Survey, 1955, Quality of surface waters of Iowa, 1886-1954: Iowa Geol. Survey Water-Supply Bull., no. 5, 351 p.

Jeffords, R. M., 1952, Pumping tests on wells in Iowa: Iowa Acad. Sci. Proc., v. 59, 266-287.

Kunkle, G. R., 1968, A hydrogeologic study of the ground-water reservoirs contributing base runoff to Four Mile Creek, east-central Iowa: U. S. Geol. Survey Water-Supply Paper 1839-O, 41 p.

Lees, J. H., 1935, Additional deep wells: Iowa Geol. Survey Ann. Rept., v. 36, p. 365-420.

Mummy, Samuel, Jr., 1953, Surface-water resources of Iowa, October 1, 1942 to September 30, 1950: Iowa Geol. Survey Water-Supply Bull., no. 3, 583 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.

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

———, 1897, Artesian wells of Iowa: Iowa Geol. Survey Ann. Rept., v. 6, p. 113-428.

———, 1928, Deep wells of Iowa (a supplementary report): Iowa Geol. Survey Ann. Rept., v. 33, p. 8-374.

———, 1935, Deep wells drilled in Iowa, 1928-32: Iowa Geol. Survey Ann. Rept., v. 36, p. 312-364.

Norton, W. H., and others, 1912, Underground-water resources of Iowa: Iowa Geol. Survey Ann. Rept., v. 21, p. 29-1186. Also, U. S. Geol. Survey Water-Supply Paper 293, 994 p.

Parker, M. C., 1967, LaPorte City Chert—A Devonian subsurface formation in central Iowa: Iowa Geol. Survey Rept. Inv. 4, 12 p.

Raasch, G. O., 1935, Stratigraphy of the Cambrian System of the upper Mississippi Valley (upper Cambrian St. Croxian Series): Kansas Geol. Soc. Guidebook 9th Ann. Field Conf., p. 302-315.

Rorabaugh, M. I., 1956, Ground water in northeastern Louisville, Ky., with references to induced infiltration: U. S. Geol. Survey Water-Supply Paper 1360-B, p. 101-169, 28 figs., 8 tables.

Ruhe, R. V., and others, 1968, Iowa drift problem, northeastern Iowa: Iowa Geol. Survey Rept. Inv. 7, 40 p.

Schwob, Harlan H., 1958, Low-flow characteristics of Iowa streams: Iowa Natural Resources Council Bull. 9, 111 p.

———, 1963, Cedar River basin floods: Iowa Highway Research Board Bull. No. 27, 59 p., 32 pls., 9 figs.

Simpson, H. E., 1927, A report on the ground-water resources of Cedar Rapids, Iowa: Unpublished open-file report, Iowa City, Iowa.

Stevenson, W. H., and others, 1920, Soil survey of Iowa, Linn County: Iowa State Coll. Agr. Exper. Sta., Soil Survey Rept. 17, 60 p., 9 figs., soils map.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the date and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., v. 16, pt. 2, p. 519-524.

———, and others, 1963, Estimating the transmissibility of aquifers from the specific capacity of wells: U. S. Geol. Survey Water-Supply Paper 1536-I, p. 331-341.

U. S. Department of Interior, published annually 1961-68, Surface-water records of Iowa: U. S. Dept. Interior, Geol. Survey ann. repts.

U. S. Public Health Service, 1962, Drinking-water standards 1962: U. S. Public Health Service Pub. 956, 61 p.