Iowa Geological Survey Water Atlas Number 2

AVAILABILITY OF GROUND WATER IN DECATUR COUNTY, IOWA

by

J. W. CAGLE and W. L. STEINHILBER

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

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FOREWORD

Decatur County is one of several counties in south-central Iowa beset with water-supply problems. All classes of water users experience difficulties in obtaining sufficient quantities of good-quality water. In an effort to aid the present and potential water users, the Iowa Geological Survey in cooperation with the U. S. Geological Survey started a comprehensive investigation of the water resources in the region. The objectives of the investigation are to locate and define the sources of water and to determine the quality and availability of water from each source.

Because of the pressing needs for this information, it was decided to release the ground-water data as it became available rather than await the the completion of the overall investigation. This atlas is a preliminary report that presents information on the availability and quality of water from underground sources in Decatur County. Preliminary reports on the ground water conditions in the other counties will be forthcoming. These will be followed by a comprehensive report on the total water resources of the region.

H. GARLAND HERSHEY
State Geologist

Iowa City, Iowa
August 1967

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ACKNOWLEDGMENTS

Appreciation is expressed to the many residents of Decatur County who furnished information about their water supplies and who permitted the sampling and measuring of their wells; to city officials for their cooperation in the collection of data on municipal supplies; and to county officials for their cooperation and assistance in the test-drilling program. Thanks are also due to well drillers in the area who furnished drill cuttings and logs of wells.

Special acknowledgment is made to Dr. H. Garland Hershey, Director of the Iowa Geological Survey, and his staff who through the past years have collected and analyzed many rock samples. This information was essential in appraising the geology of the county.

INTRODUCTION

The water problem in the region

Decatur County and several other counties in south-central Iowa comprise an area that has been chronically short of good-quality water. Municipalities, industries and rural water users alike have been affected by the water shortage. Municipalities have experienced serious problems in obtaining potable supplies adequate to keep pace with their growth and development; industrial expansion has been hindered and continues to be hindered by the shortage of good-quality water; and rural supplies for domestic and livestock use are difficult to obtain at many places. The increased use of water for all purposes and periodic drought conditions have greatly magnified an already serious problem of water shortage.

Sources of water in the region

Probably most water used for all purposes in the south-central area is ground water that is obtained from wells and springs, but water from surface sources is used to a substantial degree. The two sources of ground water in the area are the bedrock and the unconsolidated deposits of glacial drift and alluvium that lie above the bedrock. Sources of surface water include reservoirs, streams, ponds and cisterns. Reservoirs are the source of supply for some municipalities and industries in the area and ponds and cisterns supplement rural supplies obtained from wells. Unregulated streams are not a source of supply at present.

Why the problem

Some of the sources of water in the area yield insufficient amounts of water, some have erratic and unpredictable yields, some yield highly mineralized water, and some are not developed or are not completely understood. Collectively, these factors contribute to the shortage problem in the area.

Water facts are required to solve problem

Obviously the shortage of water could be alleviated by developing additional supplies of good-quality water from one or more of the sources in the area. Additional development, however, depends on a better understanding of the entire hydrologic system. In particular, more detailed information is needed on the occurrence, availability and chemical quality of water from the unconsolidated deposits, on the quality of water from the bedrock, and on the streamflow regimen in the area. The need for these facts on water — facts that could be made readily available to municipalities, industries, and individuals alike — prompted an investigation of the water resources of south-central Iowa. The investigation, which will encompass both ground-water and surface-water studies, will culminate in a comprehensive report that will appraise the total water resources of the region.

Regional study to obtain ground-water facts

The ground-water study, which will provide the basic geologic and ground-water data necessary for the comprehensive regional report, was started in 1962 by the U. S. Geological Survey in cooperation with the Iowa Geological Survey. This project, which involves an extensive amount of test drilling, is being conducted on a county-by-county basis. In order to aid the water users in the respective counties, the results of the ground-water investigation will be released as a series of county reports pending completion of the comprehensive regional report. This report on Decatur County is the first in the series; others will be forthcoming.

Purpose and scope of this report

The objective of this report is to present timely ground-water information that will help solve the supply problems of some water users in Decatur County. The information presented encompasses the location, definition, and estimated potential yields of the water-bearing materials in the unconsolidated deposits and the uppermost bedrock; an evaluation of the general occurrence and availability of water from bedrock sources; and a determination of the chemical quality of water from all ground-water sources.

Methods of study

Test drilling has comprised the major part of the ground-water investigation in Decatur County. A total of 121 test holes were drilled through the unconsolidated deposits and into the uppermost part of the underlying bedrock.[1] Drill samples were taken at intervals of 5 feet or less in the unconsolidated deposits to more closely define boundaries between geologic units and, most importantly, to define as accurately as possible the positions of the beds of sand and gravel which are the sources of water in the unconsolidated deposits. Cores up to a maximum of 20 feet and drill samples to a maximum of 80 feet were taken in the bedrock to (1) make a definite determination that bedrock had been penetrated and (2) determine the character and composition of the bedrock so that a general evaluation of the water-bearing potential and economic value of these rocks could be made. Most of the test holes were logged with an electric logger to confirm the position and thickness of the sands and gravels, to determine the top of bedrock, and to identify bedrock units. In addition to the test drilling, supplemental data were collected by an inventory of rural water supplies.

Progress of ground-water investigation in south-central Iowa.

[1]Logs of test holes are not published in this report, but copies are available from the U. S. Geological Survey or the Iowa Geological Survey, Geological Survey Building, Iowa City, Iowa 52240.

GEOGRAPHY AND TOPOGRAPHY

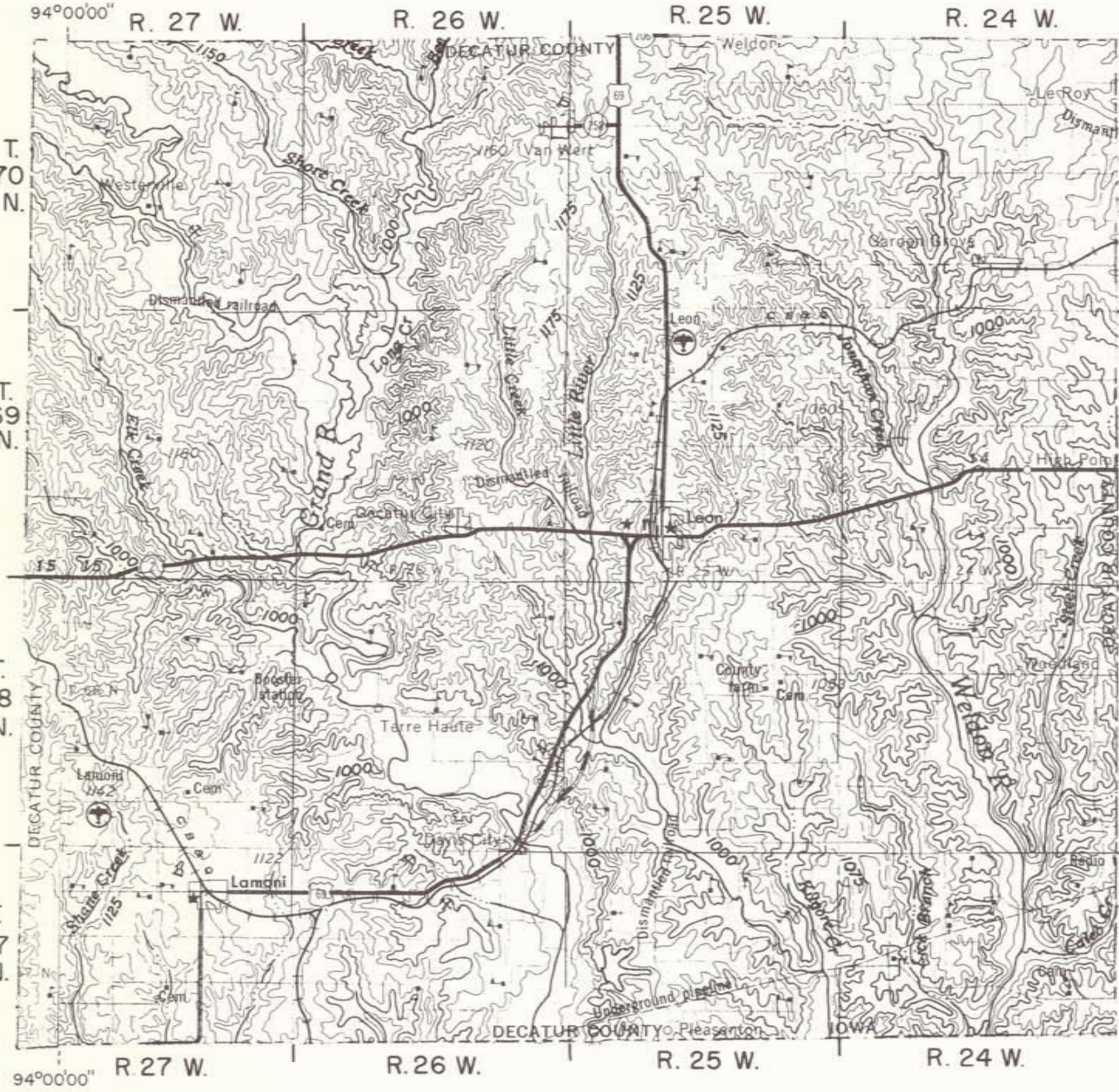
Decatur County has an area of 530 square miles and, according to the 1960 census, has a population of 10,539. The population distribution reflects the water-use pattern in the county and is largely rural. About 55 percent of the population live on farms or in small communities and towns where the water supply is obtained from private wells, ponds and cisterns. The remainder of the residents live in towns that have municipal water systems.

The topography of the county is largely the result of the dissection of the "drift plain" which formed the land surface in the county during the Pleistocene (ice age) epoch. For the purposes of this report, the county may be divided topographically into two areas — the flood plains and terraces, and the uplands. The flood plains and terraces occupy the valleys of the Thompson (Grand), Weldon, and Little Rivers and the larger tributary streams and are underlain by alluvial deposits. The dissected uplands, which are surfaces that rise above the major stream valleys, occupy areas underlain by the glacial drift. The uplands are for the most part relatively rugged, highly dissected areas composed of hills, knobs, and ridges; but at places the uplands are gently rolling and only slightly dissected. Land-surface elevations in the county range from about 1,190 feet above mean sea level on upland surfaces to about 890 feet along the flood plains of the Thompson and Weldon Rivers near the Iowa-Missouri State line, giving a maximum relief of approximately 300 feet between the highest and lowest surfaces.

Topography and geology control the movement and distribution of water both above and beneath the land surface. Decatur County receives an average of about 33 inches of precipitation a year but topographic and geologic conditions are unfavorable for retaining a significant amount of this water in the area. This is because most of the area is highly dissected and is underlain by relatively impermeable glacial deposits. These two factors promote rapid runoff which is the cause of flashy streamflow and relatively little ground-water recharge.

Topographic maps show or indicate by contours the elevation of the land surface and topographic features such as those described above. The principal use of topographic maps in this report is to determine land-surface elevations, which need to be known to compute the depth that a subsurface horizon lies beneath the land surface. (See p. 8 for use of land-surface elevations in this regard.) The approximate land-surface elevation at a given site can be determined from a topographic map in the following manner: locate the site on the map with reference to roads and road junctions, railroad and road intersections and other reference points; then approximate the elevation of the site from its position relative to the contours and from the contour values. For example, if the site is on a contour line the elevation would be the contour value; if the site lies between two contour lines, the elevation would, for all practical purposes, be a value halfway between the two contour values.

The small-scale topographic map shown below has highly generalized contours and is suitable only for determining approximate land-surface elevations — usually within an accuracy of ±25 feet. However, land-surface elevations with an accuracy of ±5 feet can be obtained in the eastern part of the county, because this area is covered by modern large-scale topographic maps. (See p. 21.)



EXPLANATION

—1000—

Contour line connecting points of equal elevation on the land surface; supplementary contours are indicated by dashed lines.

Contour interval 50 feet with supplementary contours at intervals of 25 feet. Datum is mean sea level.

Map is a composite of Map Series NK 15-10 and NK 15-11, See page 21 for additional information.

Scale 1:250,000

5 0 5 Miles

THE BEDROCK AS A SOURCE OF WATER SUPPLIES

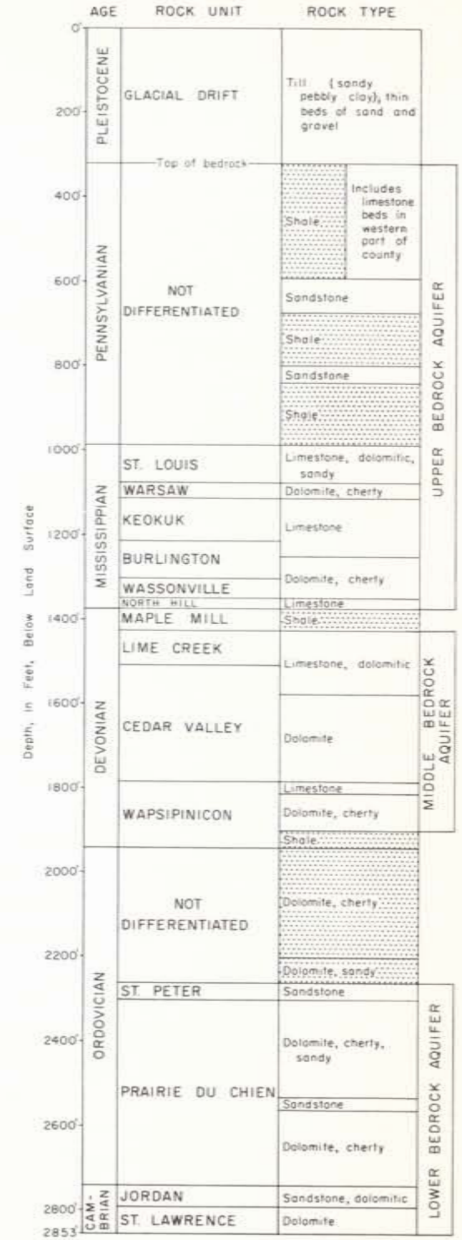
The bedrock is a sequence of consolidated sedimentary rocks that nearly everywhere in the county are covered by younger unconsolidated deposits. These rocks are predominantly shale, limestone, sandstone, and dolomite and contain thin coal beds in the upper few hundred feet. The geologic section shown here is believed to be representative of bedrock of Pennsylvanian to Cambrian age throughout the subsurface in Decatur County. An additional several hundred feet of sedimentary rocks that lie on the crystalline "basement" occur beneath the section shown. The depth to each rock unit anywhere in the county probably will be within 100 feet of the depths shown on the accompanying illustration.

Ground water occurs and moves in fractures, joints and solution openings in limestone and dolomite, and in the voids between the grains in sandstone. Shale is generally impervious to the movement of water and is not a source of water supplies. The water-bearing consolidated rocks underlying the county are grouped into the upper, middle, and lower bedrock aquifers.[1] The characteristics of each aquifer are discussed below.

The upper bedrock aquifer is the source of most public water supplies for municipal use in Decatur County. The main producing zones in the aquifer are the sandstones in the Pennsylvanian, which occur at a depth of between 500 and 800 feet beneath the land surface, and the limestones and dolomites in the Mississippian. Municipal wells that tap the combined Pennsylvanian and Mississippian rocks have average yields of as much as 80 gpm (gallons per minute), but wells that develop water from these two units separately usually have average yields of less than 50 gpm. The aquifer is also a source of small supplies, usually less than 5 gpm, for a few domestic-farm wells. (See p. 23.) These supplies are obtained from limestone units of restricted areal extent in the uppermost part of the Pennsylvanian. The areal extent of these limestones, which is the area most promising for development of additional small supplies from the bedrock, is indicated on page 7.

The middle bedrock aquifer is tapped for supplies by only one well in the county — the municipal well at Lamoni. This well, which is cased into the top of the Devonian and which is open to most of the aquifer, has an average yield of about 80 gpm. The purpose of drilling to the Devonian was an attempt, which proved to be unsuccessful, to obtain water of better chemical quality than was known to be available from the upper bedrock aquifer. The potential of the middle bedrock aquifer outside the Lamoni area is not known, but yields comparable to those obtained at Lamoni probably are available from the aquifer in most other parts of the county.

[1]Aquifer — rocks that contain and transmit water and thus are a source for water supplies.



Rock units that underlie the county. Data is based on log of Leon well No. 4

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

Water from the upper and middle bedrock aquifers is highly mineralized. (See p. 16.) Water from these aquifers contains a high concentration of sulfate and dissolved solids. Moreover, water from the middle bedrock aquifer has a very high chloride content based on a chemical analysis of water from the Lamoni well.

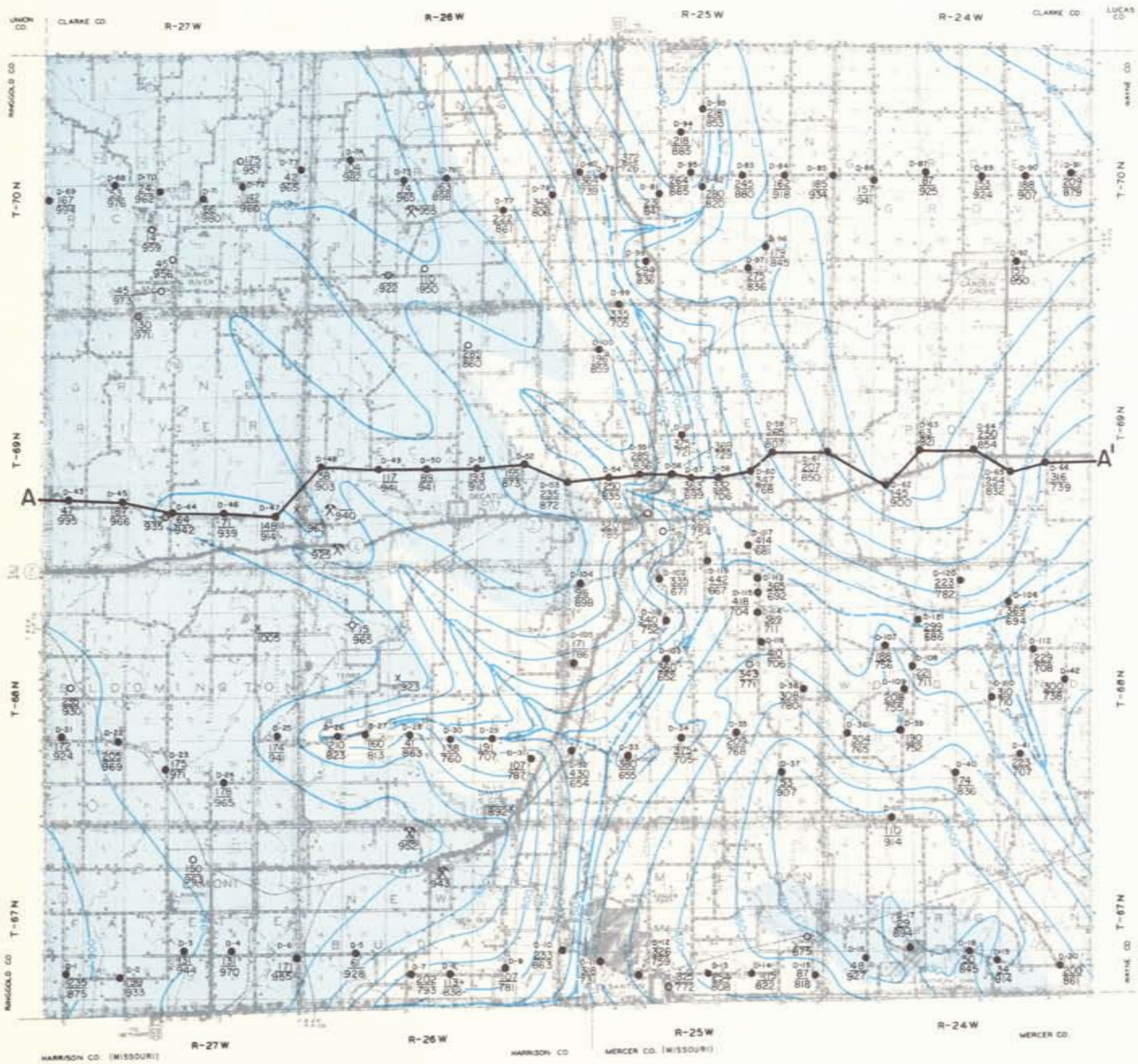
The lower bedrock aquifer was an untapped source of supply and its potential in Decatur County was unknown until recently. In 1964, municipal well No. 4 was drilled at Leon in an effort to obtain additional supplies from two rock units in the aquifer — the Jordan Sandstone and the Prairie du Chien Formation. Separate production tests were made for each source. The Jordan was unsatisfactory as a source of supply principally because of a low yield and a low specific capacity (gallons per minute per foot of drawdown). Similar production results were obtained from initial tests on the Prairie du Chien; however, acidization of the formation resulted in an increase in both the yield and specific capacity. The production from the Prairie du Chien in well No. 4, as shown in the accompanying table, is substantially larger than the production from individual wells completed in either the upper or middle bedrock aquifers. Similar production from the lower bedrock aquifer can be expected in other parts of the county. Water from the Prairie du Chien is of poor chemical quality but is less mineralized in some respects than water from the upper and middle bedrock aquifers. The water contains lower concentrations of sulfate and dissolved solids than water from the upper bedrock aquifer, but its chloride content is considerably higher. Moreover, it contains lower concentrations of sulfate, dissolved solids and chloride than water from the middle bedrock aquifer. (See p. 16.)

In Decatur County adequate quantities of water for most purposes can be obtained from the upper, middle and lower bedrock aquifers by one or more wells; but the high mineralization limits the use of the water and is a deterrent to a more extensive development of the bedrock aquifers. Therefore, the future development and large-scale use of water from the bedrock aquifers would depend upon the development of an economical method of demineralization.

Data on deep bedrock wells

Owner or Name	Source of water	Depth of well when drilled (feet)	Year drilled	Remarks
Town of Davis City	Pennsylvanian	950	1914	Municipal supply. Reported yield was 25 gpm in 1963. Located in SE¼, sec.35, T68N, R26W.
Town of Garden Grove	Mississippian	1114	1958	Municipal supply. Test pumped at 43 gpm in 1960 with specific capacity of 1.5. Located in NE¼, sec. 33, T70N, R24W.
Town of Lamoni	Devonian-Upper Ordovician	2193	1927	Reserve municipal supply. Surface reservoir is principal source of municipal supply. Well was test pumped at 100 gpm with specific capacity of less than 1.0; average yield about 80 gpm. Located in SE¼, sec. 3, T67N, R27W.
Town of Leon Well No. 1	Pennsylvanian	765	1909	Formerly furnished municipal supply; now plugged and abandoned. Reported yield was 70 gpm when in use.
Town of Leon Well No. 2	Pennsylvanian-Mississippian	1103	1923	Formerly furnished municipal supply; now plugged and abandoned. Reported yield was 77 gpm when in use.
Town of Leon Well No. 3	Pennsylvanian-Mississippian	1396	1949	Reserve municipal supply. Test pumped at 180 gpm with specific capacity of less than 1.0; average yield about 80 gpm. Located in NW¼, sec. 33, T69N, R25W.
Town of Leon Well No. 4	Cambrian (Jordan)	2853	1964	Test pumped at about 80 gpm with specific capacity of less than 1.0. After test, well was plugged back to 2715 feet.
	Lower Ordovician (Prairie du Chien)	2853[1/] 1/ Plug set at 2715 feet	1964	After well was plugged and acidized, it was test pumped at 307 gpm with a specific capacity of 3.4. Well put into production for municipal supply in 1964; average yield about 275 gpm. Located in SE¼, sec. 29, T69N, R25W.
Decatur County Farm Home	Pennsylvanian	942	1924	Institutional supply. Reported yield is 25 gpm. Located in NW¼, sec. 14, T68N, R25W.
W. P. Ireland	Pennsylvanian	770	1955	Domestic supply. Located in SE¼, sec. 33, T70N, R27W.
L. B. Jackson No. 1 Oil Test	---------	2335	1952	Well ended in Ordovician; dry and abandoned. Located in NW¼, sec. 8, T68N, R26W.

THE BEDROCK SURFACE — ITS ELEVATION, CONFIGURATION, AND SIGNIFICANT FEATURES



Bedrock topography and geology.

EXPLANATION

U. S. G. S. test hole

Oil test

Water well

Outcrop

Bridge boring

Quarry

369
694

Upper number is depth to bedrock, in feet below land surface; lower number is bedrock elevation in feet above mean sea level. (Upper numbers not shown for bridge borings, outcrops, and quarries.)

Contour line connecting points of equal elevation on the bedrock surface. Contour interval is 50 feet; datum is mean sea level.

Line along the center of major buried valleys.

A——————A'

Line of geologic cross-section shown on page 11.

Approximate area where the upper bedrock of Pennsylvanian age is composed of alternating limestone and shale units. In this area, one or more water-bearing limestone units generally can be encountered within 30 to 50 feet of the bedrock surface. Some of these units are capable of yielding up to 5 gallons per minute of water, although the water generally is highly mineralized.

Approximate area where the bedrock of Pennsylvanian age is composed of a thick sequence of shale containing some interbedded sandstone, shaly limestone, and coal units. In this area, water generally is not available from the upper 200 to 300 feet of the bedrock.

Base map taken from General Highway and Transportation map of Decatur County, 1962, prepared by the Iowa State Highway Commission.

SCALE
1 0 1 2 3 MILES

The bedrock surface in Decatur County is composed of consolidated sedimentary rocks of Pennsylvanian age and is covered by unconsolidated deposits of glacial drift and alluvium. The accompanying map shows the topography and composition of the bedrock surface as it would appear if the unconsolidated deposits were removed. The contour lines depict the elevation and configuration of the bedrock surface and indicate the position of topographic features such as buried valleys and uplands. The color pattern depicts compositional features, such as areas underlain by different rock types. (A profile view of these features along line A-A′ is shown on page 11.)

The physical features of the bedrock surface have a special significance in most glaciated regions. In Decatur County, the results of the test drilling indicate a relationship between the bedrock topography and ground-water occurrence in the overlying glacial deposits. Areas underlain by buried valleys generally are more favorable for the development of ground-water supplies than are areas underlain by buried uplands. (Compare the accompanying illustration with the one on page 13.) Furthermore, the compositional features of the uppermost bedrock in the county have a significance in the occurrence of water in the bedrock. The accompanying map depicts the areas where small supplies of water generally can be developed from the uppermost bedrock.

The depth that the bedrock surface lies below the land surface at a given point in the county is important in planning the construction and development of water wells. Contours on the bedrock surface are used as a means of determining this depth. The approximate depth to bedrock at a given site is obtained by subtracting the elevation of the bedrock surface (determined from the contours shown on the bedrock map) from the elevation of the land surface (determined from topographic maps or other sources).[1]

The following examples show how the elevation of the bedrock surface is obtained and how the depth to bedrock (which is equivalent to the thickness of the unconsolidated deposits) is then computed at two assumed sites.

1. Site is located at a "T" road junction in the center of section 25, T. 70 N., R. 26 W., where the land-surface elevation is about 1,135 feet. The site is about one-half the distance between contours on the bedrock map whose elevations are 800 and 850 feet; therefore, the elevation of the bedrock surface at the site is estimated to be 825 feet. The approximate depth to bedrock is 1,135 − 825 = 310 feet.

2. Site is located at a "T" road junction on the north line of section 19, T. 69 N., R. 24 W., where the land-surface elevation is about 1,060 feet. The site is on or very near the 900-foot contour and the elevation of the bedrock surface from the bedrock map is estimated to be 900 feet. The approximate depth to bedrock is 1,060 − 900 = 160 feet.

[1]See page 21 for availability of topographic maps in Decatur County.

EXISTING WATER SUPPLIES FROM THE GLACIAL DRIFT AND ALLUVIUM

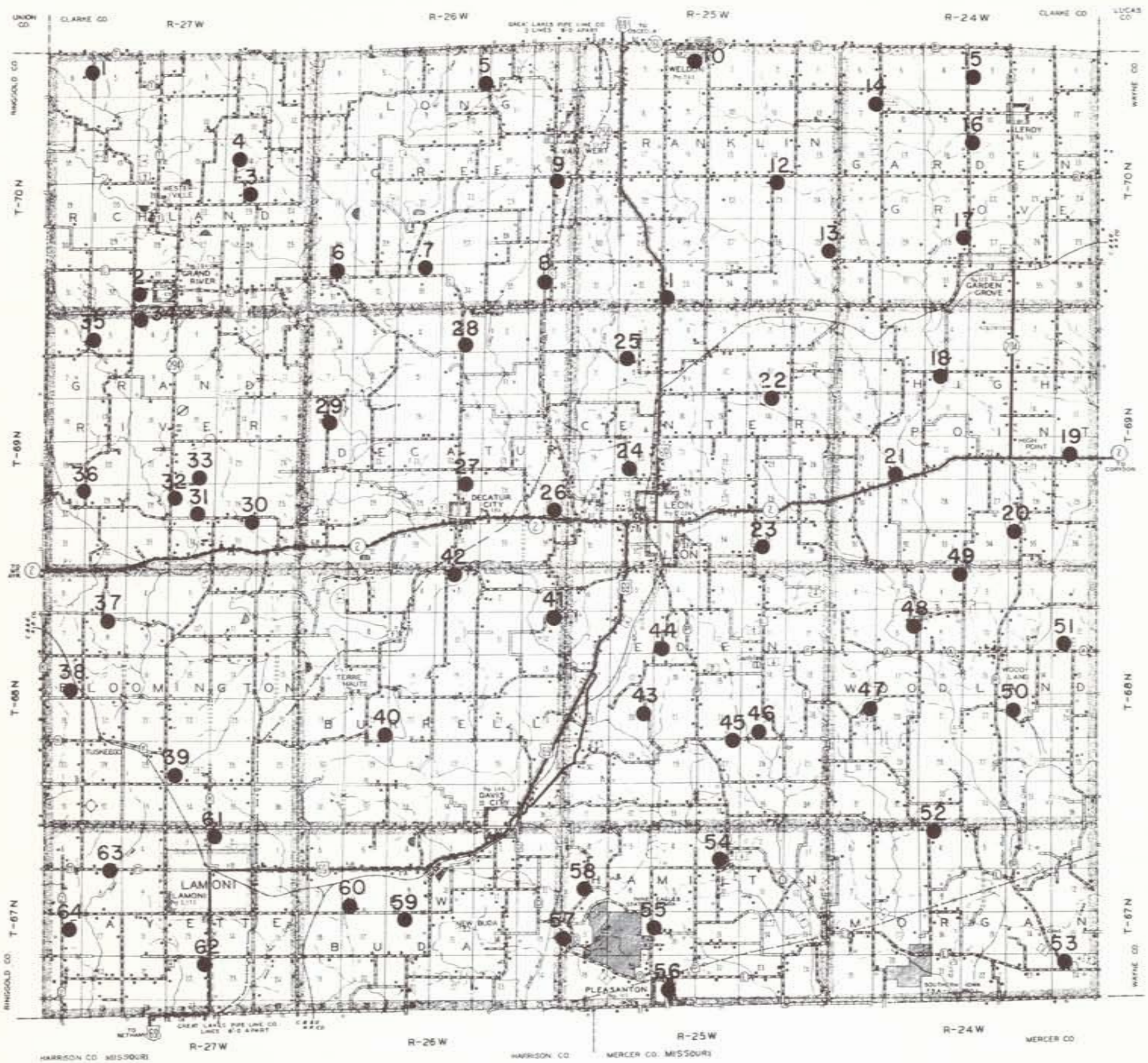
An intensive inventory of existing rural water supplies in the county was conducted before the test-drilling operations were started. Information from this inventory was used to plan the test drilling and to obtain data on sources of water and well yields that could be related to the test-drilling results. Data on some representative wells are presented on page 23.

Most rural water supplies are obtained from the glacial drift and alluvium, but a few wells tap the bedrock and substantial amounts of water are obtained from ponds and cisterns. (See p. 23.) Yields from wells tapping the glacial drift and alluvium generally range from 1 gpm or less to 3 gpm except locally where yields may be larger. The largest known yield from the glacial drift was from the Weldon School well, which reportedly was pumped at a rate of 36 gpm.

Wells tapping the glacial drift and alluvium are predominantly bored or dug and are constructed with brick or cement-tile casing that in most wells ranges from 12 to 48 inches in diameter. Most wells are equipped with cylinder-type (lift or force) pumps that are operated by hand, windmill or electric or gasoline pump jacks, but some have shallow-well electric pumps. A few wells that tap the glacial drift are drilled and have small-diameter steel casing that is either slotted or has an attached screen set opposite the sand and gravel; water lift is by electric pumps.

Most bored wells that tap the glacial drift are ended at relatively shallow depths (usually 50 feet or less) in the first water-bearing sand and gravel encountered. Because the shallow sands and gravels receive most of their ground-water recharge from local precipitation, water levels in these deposits fluctuate in response to variations in precipitation. Therefore, wells developed at shallow depths in the glacial drift often have decreasing yields during periods of drought when water levels decline and water that is withdrawn from storage by pumping is not replenished. On the other hand, sands and gravels at relatively greater depths have a greater storage capacity than the shallow deposits; therefore, deeper wells in the glacial drift generally are affected less by variations in local precipitation. Consequently, the capacities of shallow wells in the glacial drift often may be increased by deepening the wells to locate and develop additional water-bearing sands.

Most bored or dug wells that tap the alluvium generally extend only into the upper part of the water-bearing sands. These wells may go dry during drought periods, because water levels in the alluvium, which also respond to variations in local precipitation, may fall below the well floor. Yields of these wells can be restored by deepening the well so that it taps the full saturated thickness of the alluvial sands.



N

EXPLANATION

● Inventoried well for which data is given on page 23.

Base map taken from General Highway and Transportation map of Decatur County, 1962, prepared by the Iowa State Highway Commission.

SCALE

1 0 1 2 3 Miles

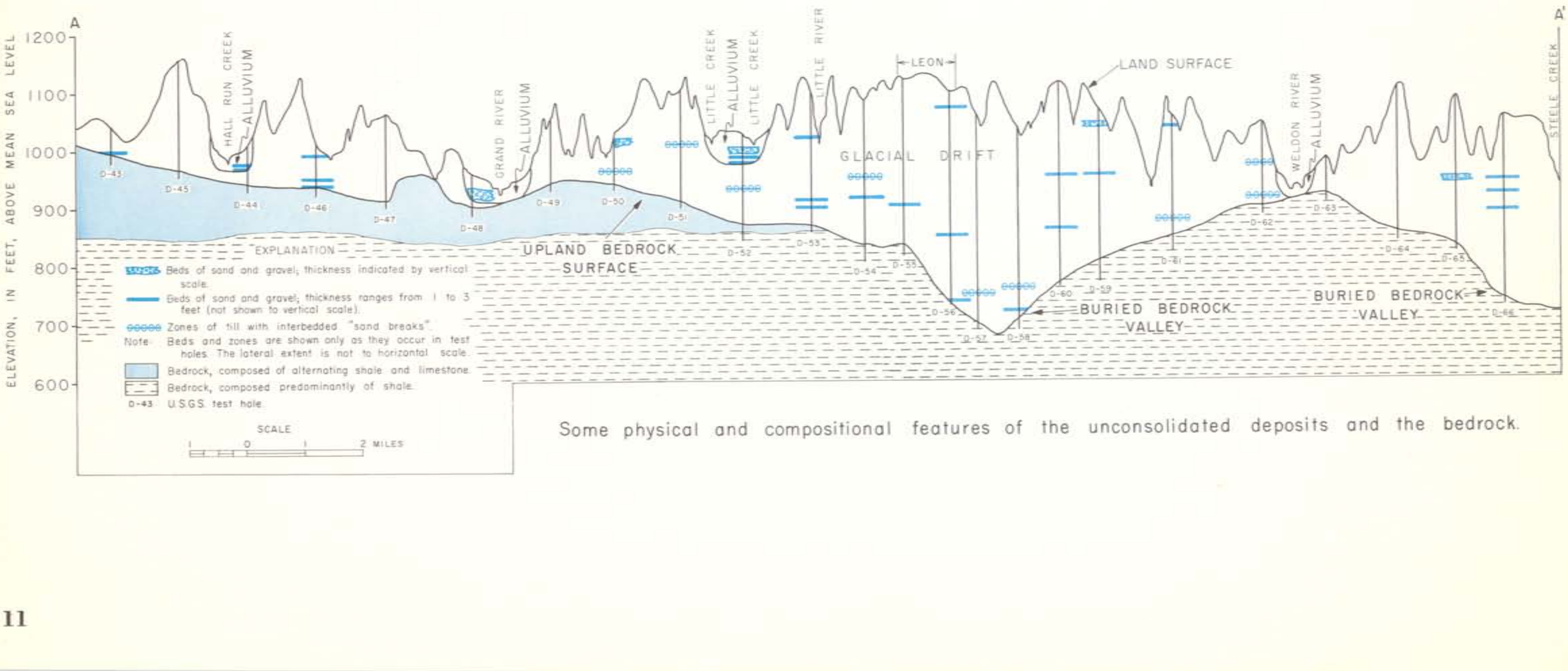
Location of selected wells from the rural inventory.

GLACIAL DRIFT AND ALLUVIUM

Unconsolidated deposits comprised of two geologic units, the glacial drift and alluvium, overlie the bedrock and form the land surface in Decatur County. (See cross-section below.) The glacial drift, which is the oldest of the two units and which rests on the bedrock at most places, was laid down by glaciers during the Pleistocene epoch. Streams later cut deep valleys in the glacial drift and deposited the younger alluvium. The glacial drift underlies upland areas in Decatur County, whereas the alluvium is confined to stream valleys.

Physical Properties

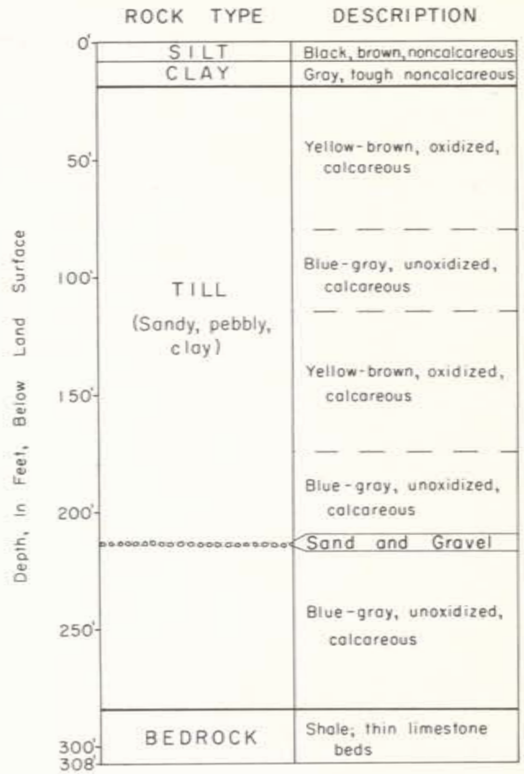
***Glacial drift* — The glacial drift is composed predominantly of sandy, pebbly clay (till) that generally contains sand-and-gravel deposits of varying thickness and extent. The log of test hole D-51 is generally representative of the glacial drift in the county; however, parts of the sequence may be missing at places owing to erosion or non-deposition. The glacial drift is absent or only a few feet thick beneath some stream valleys and is thickest where the land surface is highest over the deepest parts of buried valleys. The maximum thickness of the glacial drift in the county is believed to be about 440 feet.**



Some physical and compositional features of the unconsolidated deposits and the bedrock.

Sand and gravel was penetrated in about 70 percent of the test holes; the remainder of the test holes did not encounter significant amounts of sand or gravel. Beds of sand and gravel penetrated in test holes usually were from 1 to 3 feet in thickness and seldom exceeded 5 feet. These beds occur at different horizons in the glacial drift and only locally could a given horizon be traced between test holes. Sands occur also as very thin stringers — usually ranging from ½ inch to 6 inches in thickness — that are interbedded with till. These interbedded "sand breaks" occur in definable zones, which range from a few feet to as much as 30 feet in thickness.

Alluvium — Alluvium composed of clay, silt, sand and gravel is at the surface and underlies the flood plains (first bottom) and terraces (second and third bottoms) in the valleys of the Thompson, Weldon, and Little Rivers and their larger tributaries. The alluvium has a maximum thickness of about 55 feet in the valleys of the Thompson, Weldon, and Little Rivers and it ranges from 35 to 55 feet in thickness in the valleys of their larger tributaries. Test holes penetrated individual beds of sand and gravel as much as 25, 15, and 20 feet thick in the alluvium in the valleys of the Thompson, Weldon, and Little Rivers, respectively. The beds of sand and gravel generally are thickest near the centers of stream valleys and thin toward the valley margins.



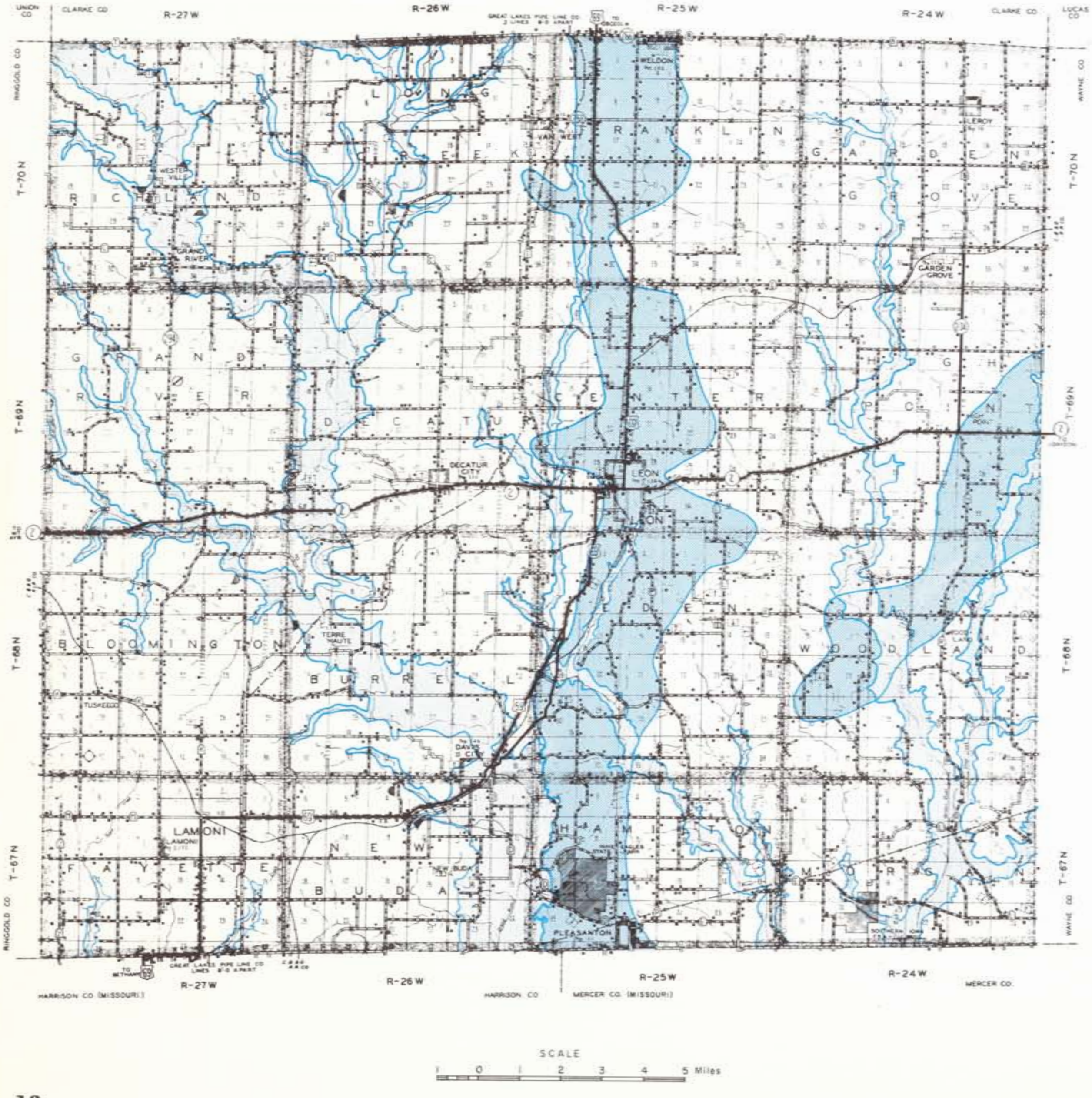
Log of test hole D-51, which is generally representative of the composition of the glacial drift in the county.

Water-bearing Properties

Ground water, which is derived from precipitation, saturates all the rock materials comprising the glacial drift and alluvium beneath the water table. However, only the coarse-grained materials, such as sand and gravel, will yield water readily to wells; the fine-grained rocks, such as clays and silts, yield little or no water to wells. Hence, the occurrence and availability of ground water from the glacial drift and alluvium depend on the occurrence and distribution of the sands and gravels within these deposits. Saturated sand and gravel deposits of widespread distribution are capable of yielding large quantities of water; deposits of limited thickness and distribution generally yield only small-to-moderate quantities of water.

This investigation shows that widespread deposits of sand and gravel do not occur in the glacial drift in Decatur County; therefore large yields of water from the glacial drift are not to be expected. However, sands and gravels of limited distribution do occur in the glacial drift and alluvium; therefore small-to-moderate quantities of water are available from the unconsolidated deposits of the county.

GENERAL AVAILABILITY OF WATER FROM THE GLACIAL DRIFT AND ALLUVIUM



EXPLANATION

Areas Most Favorable for Development of Ground-Water Supplies

A

Alluvium

Alluvium is confined to and underlies the floodplains and terraces of the major river valleys to a maximum depth of 55 feet. Glacial drift is beneath the alluvium, except at places where the alluvium lies directly on bedrock. Yields of 10 to 50 gpm (gallons per minute) are estimated to be available from the alluvium, with the largest yields to be expected where the sand and gravel is as much as 20-25 feet thick.

(Surface distribution of alluvium adopted in part from Soil Survey of Decatur County, Iowa: U.S. Dept. of Agriculture, Series 1935, No. 7.)

B

Glacial drift

Glacial drift [1/] is at surface and underlies area to bedrock. Beds of sand and gravel in the glacial drift appear to be relatively thicker and more extensive and continuous between test holes in Area B than between test holes penetrating the glacial drift in other parts of the county. Yields of 3 to 10 gpm are estimated to be available from the glacial drift at most places, but larger yields can be obtained locally.

Area Least Favorable for Development of Ground-Water Supplies

C

Glacial drift

Glacial drift[1/] is at surface and underlies area to bedrock. Sands and gravels in Area C occur mostly as discontinuous beds and stringers and usually could not be traced between test holes. Yields of only 1 gpm or less (about 1,000 gallons per day) are estimated to be available from the glacial drift at most places. Locally, yields may be larger, but will seldom exceed 3 gpm. Also, locally, the glacial drift will not yield any water.

1/ Glacial drift in this usage includes the relatively thin mantle of loess and slope wash on the uplands and hillsides.

The appraisal of the general availability of ground water from the glacial drift and alluvium is based (1) on the occurrence and characteristics of sand and gravel encountered in test holes and (2) on the few quantitative data from the well inventory. The estimated yields in Areas A, B, and C are yields that can be expected from properly constructed and developed wells. Information is not available to predict pumping water levels or to determine whether the estimated yields can be sustained over an extended period of time. Quantitative information of this type will be obtained for the subsequent comprehensive regional report.

The most favorable areas for the development of ground-water supplies from the glacial drift and alluvium are Areas A and B. Yields from existing wells tapping the glacial drift and alluvium in these areas range generally from 1 to 3 gpm; however, test-drilling and well-inventory data indicate that the aquifers in both areas have the potential to furnish additional supplies. The general availability of ground water in Areas A and B is summarized as follows:

Area A — The alluvium is potentially the largest source of ground water from the unconsolidated deposits and, at most places, will yield larger quantities of water than the underlying glacial drift. The yields estimated to be available from the alluvium in Area A would be adequate for modern-day domestic-stock needs, small-scale irrigation, supplies for small communities and towns and the needs of light industry. Any development of water from the alluvium should be preceded by drilling several test holes to locate the thickest and most permeable deposits of sand and gravel. The test holes should be drilled to the underlying glacial drift, which generally will be no deeper than 55 feet.

Area B — The yields estimated to be available from the glacial drift in this area would suffice for modern-day domestic-stock needs where pressure systems are used. Locally, larger yields may be obtained as indicated by a reported yield of 36 gpm from the Weldon School well. Most parts of Area B coincide with the subsurface positions of buried valleys.

The least favorable area for the development of ground-water supplies from the unconsolidated deposits is Area C. Yields from existing wells tapping the glacial drift at most places in this area are only 1 gpm or less. The test-drilling data indicate that only locally can enough water be obtained to satisfy modern-day domestic-stock needs. Area C generally overlies a relatively high (upland) bedrock surface.

Many wells in the county probably do not obtain the maximum yields of which they are capable. Some ways of increasing yields are (1) deeper drilling and drilling to bedrock if necessary to locate all potential water-bearing sands and gravels, (2) improved methods of well construction and development, and (3) multiple development of water-bearing beds in the glacial drift.

CHEMICAL QUALITY OF WATER

Water dissolves minerals from the soils and rocks through which it passes. Some of these dissolved mineral constituents are objectionable in water when they occur in large concentrations; others are objectionable when they occur in only small concentrations. Mineralization of water may restrict its use for human consumption and for agricultural and industrial purposes.

Exact limits of dissolved minerals that can be tolerated for specific uses are difficult to define; however, recommended standards (shown in adjoining table) for some mineral constituents have been established by the U. S. Public Health Service for drinking water, and water-quality limits have been set or recommended by other agencies for agricultural and industrial supplies. Most mineral constituents in municipal ground-water supplies and some constituents in the few domestic-stock supplies sampled in Decatur County exceed the drinking-water standards. However, where domestic and public supplies do not meet the standards, U. S. Public Health Service Publication No. 956 (revised 1962) states that "Although waters of such quality are not generally desirable, it is recognized that a considerable number of supplies with dissolved solids in excess of the recommended limits are used without obvious ill effects."

The mineral constituents most commonly determined in chemical analyses of water are those given in the adjacent table. These analyses show only the chemical quality of water and do not show its sanitary condition. The chemical quality of ground water in Decatur County, based on analyses presented in the table on the opposite page, is summarized below.

1. Water from all bedrock sources is highly mineralized, has a laxative effect, and is objectionable to many people because of its bitter taste. Water from the lower bedrock aquifer, although highly mineralized, is generally of better chemical quality than water from the upper and middle bedrock aquifers. Based on general water-quality requirements, water from the bedrock is not suitable, principally with respect to its hardness and dissolved-solids content, for most municipal and industrial uses without extensive treatment. However, some industries can utilize mineralized water for certain purposes, i. e., washing, cooling, or fire fighting.

Significance of mineral constituents and physical properties of water.

Constituent or Property	Maximum Recommended Concentration	Significance
Iron (Fe)	0.3 ppm	Objectionable as it causes red and brown staining of clothing and porcelain. Higu concentrations affect the color and taste of beverages.
Manganese (Mn)	0.05 ppm	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 ppm.
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 ppm	Commonly has a laxative effect when the concentration is 600 to 1,000 ppm, 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 ppm. Sulfate combined with calcium forms a hard scale in boilers and water heaters.
Chloride (Cl)	250 ppm	Large amounts combined with sodium impart a salty taste.
Fluoride (F)	2.0 ppm	In south-central Iowa, concentrations of 0.8 to 1.3 ppm are considered to play a part in the reduction of tooth decay. However, concentrations over 2.0 ppm will cause the mottling of the enamel of children's teeth.
Nitrate (NO_3)	45 ppm	Waters with high nitrate content should not be used for infant feeding as it may cause methemoglobinenia or cyanosis. High concentrations suggest organic pollution from sewage, decayed organic matter, nitrate in the soil, or chemical fertilizer.
Dissolved Solids	500 ppm	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 2000 ppm will have a laxative effect on most persons. Amounts up to 1000 ppm 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 parts per million 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 ppm; 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.

See U. S. Public Health Service Publication No. 956 (revised 1962) and U. S. Geological Survey Water Supply Paper No. 1473 (both available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20242) for further discussion of chemical and physical properties of water.

2. The few analyses of water from the glacial drift indicate that water from this source is generally less mineralized than water from the bedrock. Water at relatively shallow depths (about 50 feet or less) in the glacial drift usually has a low mineral content, but may contain undesirable concentrations of nitrate and iron. Generally there is an increase in mineralization at progressively greater depths in the glacial drift; at many places, water in the basal part of these deposits has chemical-quality characteristics similar to water in the bedrock.

3. No analyses were made of water from the alluvium. However, data from adjoining counties indicate that water from this source has a low mineral content, but undesirable concentrations of nitrate and iron may be present.

The few data available on the high nitrate concentration of water from shallow depths suggest localized pollution of this source by runoff or infiltration from barnyards and privies. For this reason, all shallow supplies in the county should be tested for nitrate content and the presence of bacteria. Information concerning this type of analysis can be obtained from the State Hygienic Laboratory, University of Iowa, Iowa City, Iowa 52240.

CHEMICAL ANALYSES OF GROUND WATER FROM SELECTED WELLS IN DECATUR COUNTY.

Dissolved constituents and hardness given in parts per million (ppm); these may be converted to grains per gallon by dividing the values by 17.12. Analysis by the State Hygienic Laboratory of Iowa.

Owner	Location	Date of collection	Depth of well (feet)	Source of water	Temperature (°F)	Silica	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids	Total Hardness as $CaCO_3$	pH	Specific Conductance (micromhos at 25°C)	Remarks
Town of Davis City	Davis City	1-7-63	950±	Bedrock Pennsylvanian	--	8.8	1.1	0.05	34	12	13	932	505	1310	245	2.4	0.1	2857	132	7.9	4120	
Town of Garden Grove	Garden Grove	9-14-60	1144	Bedrock Mississippian	66	10.4	1.5	.05	277	80	29	952	361	2560	180	2.6	.1	4596	1020	7.5	5230	
Town of Lamoni	Lamoni	4-24-35	2193	Bedrock Devonian-Ordovician	--	--	1.2	0.0	321	88	1743		321	3042	1063	1.5	0.0	6632	1164	7.1	--	
Town of Leon, Well No. 3	Leon	12-5-60	1396	Bedrock Pennsylvanian-Mississippian	65	11.2	4.7	.05	50	18	8.7	795	490	1250	180	2.5	.3	2738	200	7.9	3910	
Town of Leon, Well No. 4	Leon	11-1-63	2853	Bedrock Cambrian (Jordan)	80	13.2	5.0	.05	183	62	35	508	212	831	580	2.2	.1	2489	708	7.5	3720	Sample collected during production test prior to completion of well.
		3-26-64	2715	Bedrock Lower Ordovician (Prairie du Chien)	--	15.2	0.66	.05	171	63	36	492	229	797	545	2.8	.1	2398	688	8.0	3570	Sample collected after acidizing and prior to completion of well.
		3-22-66	2715		81	14.4	0.56	.05	172	58	28	500	239	821	550	2.9	3.2	2390	670	7.5	3510	
Decatur County Farm Home	NW¼, sec 14, T68N, R25W	10-25-40	942	Bedrock Pennsylvanian	--	--	1.7	.0	43	15	--	--	403	1327	125	2.0	8.9	2625	169	7.4	--	
U. S. G. S. test hole D-5	NE¼, sec 20, T67N, R26W	3-29-62	71	Glacial drift(?) and bedrock Pennsylvanian	48	14.8	.08	.8	432	146	9.0	228	266	1940	21	0.35	.1	3312	1680	7.8	3490	Well flowed when drilled. Location shown on page 7.
Earl Elmore	NE¼, sec 27, T68N, R25W	11-24-63	51	Glacial drift	54	31.6	.2	.05	102	29	1.8	53	539	12	9.5	.55	43	579	373	7.3	940	Well No. 45 on page 26.
W. Flockhart	SW¼, sec 33, T70N, R25W	11-24-63	77	Glacial drift	--	28	.16	.4	378	87	3.3	47	322	1050	3	.7	5.7	1914	1300	7.1	2150	Sample collected 150 feet from pump after passing through pressure tank and pipe. Well No. 11 on page 24.
Pearl Foland	NE¼, sec 23, T70N, R27W	11-24-63	30	Glacial drift	54	28.4	1.5	.05	114	36	1.6	34	290	15	28	.8	240	656	431	7.4	1030	Well No. 3 on page 23.
O. C. Tompkins	NW¼, sec 36, T70N, R26W	11-24-63	185	Glacial drift	--	16.4	9.9	.05	133	40	4.6	204	439	541	19	.6	16	1252	498	7.1	2110	Sample collected 200 feet from pump after passing through pressure tank and pipe. Well No. 8 on page 23.
U. S. Public Health Service drinking-water standards							0.3	.05						250	250	2.0	45	1000				Recommended maximum concentration

HOW TO USE THIS REPORT TO LOCATE AND DEVELOP A WATER SUPPLY

The water user should ask several questions that will guide him in applying the information in this report to locating and developing a ground-water supply. What are the sources of water in the area of my interest and which is the best source for developing a supply for my needs? What thickness of rock must be penetrated (so that the maximum depth of drilling can be approximated and preliminary plans made for the construction of a well)? What yield of water can be obtained? What is the chemical quality of the water and how does it affect the usage of water? The following hypothetical examples will illustrate the use of the report in solving a supply problem.

Problem: A domestic supply of about 5 gpm is required at a farm site located in the NE¼, sec. 9, T.69N., R.25W.

Solution: The potential sources of ground water at this site are the glacial drift and the bedrock. Because the glacial drift in this area has a high probability of yielding the required 5 gpm (p. 13) and because water-bearing beds in the upper bedrock aquifer are fairly deep (p. 7) and yield highly mineralized water (p. 16), the glacial drift should be considered the most likely source. The maximum depth of a well tapping the glacial drift at this site would be about 420 feet, which is determined from the procedures outlined on page 8. The actual depth of the well will depend on the depth of the water-bearing sands that will yield the required amount of water. Because the chemical quality of water from the glacial drift deteriorates with depth (p. 16), all efforts should be made to complete the well in the upper part of the glacial drift. Therefore, the first significant sand layer (at least 3 to 5 feet in thickness) encountered during drilling should be tested for the required yield, and the well completed at that horizon if the yield is sufficient. If the yield is not sufficient, or if only thin sand layers are encountered, the well should be drilled to the top of bedrock and all sandy zones should be developed (p. 14). The potential yield of a well finished in the glacial drift in this area is estimated to be 3 to 10 gpm, but the actual yield will have to be determined by test pumping or bailing. The water probably will contain about 500 to 700 ppm of total dissolved solids if the well is completed in the middle or upper part of the drift, and at least 1,000 ppm of total dissolved solids and a high sulfate content if the well completely penetrates the drift (p. 16). If the water is obtained from a shallow depth, it should be tested for bacteria and nitrate content (p. 16).

Problem: A farm supply of about 5 gpm is needed at a farm site located in the NE¼, sec. 9, T.67N., R.27W.

Solution: Observe from the availability map (p. 13) that the farm site is in an area where there is no alluvium and where there is a low probability of obtaining a domestic supply from the glacial drift. However, the uppermost bedrock at this site is indicated by the bedrock map (p. 7) to be a potential source of small supplies. The indicated procedure here is to drill a well that fully penetrates the glacial drift and attempt to develop a supply from any water-bearing sands and gravels that are encountered; then, if an adequate supply is not obtained, the well should be extended at least 50 feet into the bedrock. The maximum depth of a well at this site would be 235 ± 25 feet, which is determined by adding 50 feet to the calculated depth to bedrock (the bedrock depth is calculated by procedures outlined on page 8). Because yields of water-bearing materials are estimated yields, test pumping would be necessary to determine whether an adequate yield for a domestic supply is available from either the glacial drift or the uppermost bedrock. The section on chemical quality (p. 15) is of special importance to the water user who is planning the development of a supply from the uppermost bedrock. Although the water from this source is highly mineralized and contains some undesirable qualities, it probably is satisfactory for a livestock supply and for most domestic purposes. However, some users may want to obtain supplies for drinking and cooking purposes elsewhere (see next example).

Problem: A domestic supply of 5 gpm is required at a site located in the center sec. 24, T.68N., R.25W.

Solution: Observe from the availability map (p. 13) that at this site the alluvium is not accessible and the glacial drift has a low probability of yielding even small quantities of water. Moreover, the probability is low for obtaining the required supply from within the upper 200 to 300 feet of the bedrock (p. 7). The required supply probably could be obtained from a deep well, but the water would be highly mineralized (p. 16). The minimum depth of the well would be about 490 to 590 feet, which is determined by adding 200 to 300 feet to the calculated depth to bedrock (the bedrock depth is calculated by procedures outlined on page 8).

An alternate possibility for a water supply would be to use surface water (pond) for household purposes other than cooking and drinking, and haul water or attempt to develop a small supply of ground water for drinking and cooking purposes. Small supplies (usually about 1 gpm) often can be developed in the upper 60 to 80 feet of the glacial drift. The procedure to follow is to drill one or more test holes to depths of about 60 to 80 feet. Any thin sand layer encountered might be developed as the source of drinking water. Before the water is used, however, it should be tested for nitrate and bacterial content.

Problem: A supply of about 100 gpm of good-quality water is required by an industrial plant.

Solution: The only potential ground-water source of good-quality water to meet the required needs is the alluvium — particularly in the Thompson (Grand) River valley. The estimated yield from this source is 10 to 50 gpm per well (p. 13). Hence, two or three properly-spaced wells probably can obtain the required amount of water. Test drilling to locate the thickest and most permeable deposits should precede the well construction (p. 14).

An alternate possibility is a bedrock well. The upper bedrock aquifer can yield the required amount of water (p. 5). But because the water is highly mineralized (p. 15), it will have to be treated by some process that will decrease the mineral content to acceptable levels.

Problem: An industry or municipality requires about 1 million gallons of water per day (about 700 gpm).

Solution: The only potential ground-water source in the county to meet this need is the lower bedrock aquifer (p. 6). At least two wells will be needed to produce the required amount of water from this source. The maximum depths of the wells will be about 2,700 feet (p. 5). The water from this source is highly mineralized and contains high concentrations of sulfate and chloride. If the quality of water is a consideration (as it will be for a municipal supply), the mineral content will have to be brought to an acceptable level by some demineralizing process.

SUMMARY AND CONCLUSIONS

The purpose of the ground-water investigation in south-central Iowa is to obtain some of the water facts (ground-water facts) that are needed to help solve the water-shortage problem in the region. This report provides these facts for one county in the region by evaluating data on the occurrence, general availability, and chemical quality of ground water in Decatur County. An evaluation of these data is summarized in the following statements.

Availability of water from unconsolidated deposits and uppermost bedrock

Small-to-moderate supplies of water are available for development from the unconsolidated deposits in the county; large supplies are not available for development. The alluvium of the major river valleys is the best potential source for the development of moderate quantities of water from the unconsolidated deposits; yields[1] of 10 to 50 gpm per well are estimated to be available from this source. The glacial drift in a few areas of the county is capable of yielding an estimated 3 to 10 gpm per well; elsewhere yields will seldom exceed 1 gpm. Wherever water cannot be obtained from the unconsolidated deposits in the western part of the county, small supplies (up to 5 gpm) generally are available from the upper 50 feet of the bedrock.

Availability of water from bedrock

Moderate-to-large supplies of water are available from bedrock strata at various depths. Yields of several hundred gpm per well can be obtained from the deeper bedrock strata at about 2,600 to 2,700 feet in depth. Bedrock strata of shallower and more intermediate depths are capable of yielding 80 to 100 gpm per well.

Chemical quality of ground water

Water in the alluvium and at shallow and intermediate depths in the glacial drift generally is hard and often contains undesirable concentrations of iron and nitrate, but otherwise is of relatively good chemical quality. Water in the deeper parts of the glacial drift generally is highly mineralized and has chemical characteristics similar to water in the underlying bedrock. Water from all bedrock sources is highly mineralized and of poor chemical quality. The shallower bedrock strata contain water with an objectionable concentration of sulfate; deeper strata contain water with an objectionable concentration of chloride.

[1]The yields available from the various ground-water sources discussed in this report were estimated by comparing data from the well inventory with test-drilling data. More quantitative data on actual yields, in addition to water-level data, are needed to evaluate fully the availability of water. These data will be collected for the comprehensive regional report.

The principal conclusion to be drawn from the information presented in this report is that only locally and in restricted areas, or only after extensive quality treatment, are adequate supplies of ground water available to satisfy the water needs in the county.

Modern rural (including small rural community) needs for readily-accessible, good-quality water can be satisfied only in restricted areas, where sufficient good-quality water is available from the alluvium and at places from the glacial drift. Elsewhere, particularly in the western part of the country, the rural user generally can develop sufficient water for his needs from the bedrock; but the water is highly mineralized. The mineralized water probably is satisfactory for a livestock supply and for some domestic purposes.

See the first three examples on pages 17 and 18

Industrial needs for large quantities of water can be satisfied anywhere in the county by developing water from the bedrock at depth, if water quality is not an important consideration or if water treatment is contemplated. Light industrial and small-scale irrigation needs for moderate amounts of good-quality water can be satisfied by obtaining water, which requires little or no treatment, from the alluvium.

See examples 4 and 5 on page 18

Municipal needs for large amounts of good-quality water can be satisfied only by extensive quality treatment of water from the deep bedrock. An alternate possibility may be development of a surface-water supply — but this supply also will require treatment.

See example 5 on page 18

Another conclusion necessarily follows — surface-water sources will have to be developed to meet the various needs that ground-water sources cannot satisfy. However, before surface-water sources can be developed for reliable water supplies, data on the flow regimen of streams will have to be collected and evaluated. This study will comprise the next phase of work in the area, and the results will be incorporated in the comprehensive regional report.

AVAILABLE TOPOGRAPHIC MAPS

Published topographic maps on a scale of 1:24,000 (1 inch on the map = 2,000 feet on the ground) are available for areas in Decatur County shown on the accompanying map. These maps, which are prepared by the U. S. Geological Survey, can be used to determine the elevation of the land surface within an accuracy of ± 5 feet or less. The maps cover 7½ minutes of latitude and longitude and have a contour interval of 10 feet.

Listed below are 1:250,000 scale NK Series maps that are also available.

Name of Map	*Area in Decatur County Covered by Map*	*Map Series*	*Contour Interval (feet)*	*Remarks*
Centerville, Iowa; Missouri	That part of county east of Longitude 94° 00′ 00″	NK 15-11	50 with supplementary 25-foot contours	Scale 1:250,000 (1 in. on map = approximately 4 miles on ground)
Nebraska City, Neb.; Iowa; Missouri; Kansas	That part of county west of Longitude 94° 00′ 00″	NK 15-10	50 with supplementary 25-foot contours	

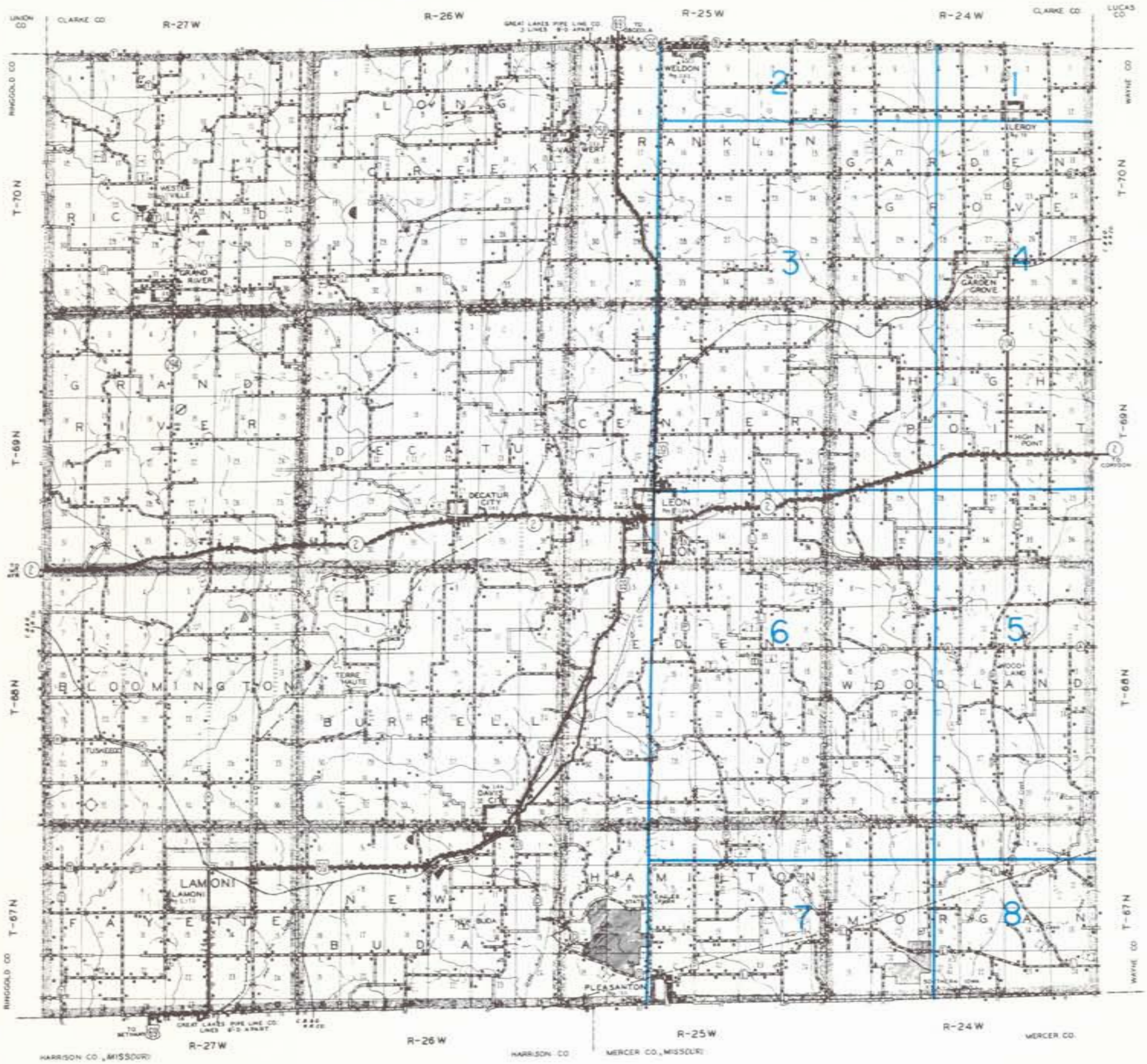
Published topographic maps are for sale and may be ordered from governmental agencies at a nominal charge. The map order should include the map name and the map series designation: for example, Woodland, Iowa, 7½-minute series; or Centerville, Iowa-Missouri, NK 15-11 series. Maps may be ordered from the following governmental agencies:

Iowa Geological Survey, Geological Survey Building, Iowa City, Iowa 52240

Denver Distribution Section, Geological Survey, Federal Center, Denver, Colorado 80225

An index map of the state showing areas where topographic maps have been published is available upon request from the Iowa Geological Survey.

Additional information concerning the progress of mapping in Iowa may be obtained from the Topographic Division, U. S. Geological Survey, Box 133, Rolla, Missouri 65401; or the Map Information Office, U. S. Geological Survey, Washington, D. C. 20242.



EXPLANATION

Area Number	Map Name
1	Leroy, Iowa
2	Weldon, Iowa
3	Garden Grove, SW, Iowa
4	Garden Grove, Iowa
5	Woodland, Iowa
6	Leon, Iowa
7	Pleasanton, Missouri-Iowa
8	Lineville, Missouri-Iowa

SCALE
1 0 1 2 3 Miles

Availability of modern $7\frac{1}{2}$-minute quadrangle topographic maps.

RECORDS OF SELECTED WELLS IN DECATUR COUNTY, IOWA

Well number: Numbers correspond to those shown on page 10.
Type of well: B, bored; Du, dug; Dr, drilled.
Depth of well and water level: Depths and water levels shown in feet are reported; those shown in feet and tenths are measured.

Elevation: Elevations determined by engineer's level and aneroid barometer.
Method of lift: M, manual; E, electric motor or pump; W, windmill.
Use: D, domestic; S, stock; I, Institutional; U, unused.

Well number	Owner Well location	Type of well	Depth of well (feet)	Diameter of well (inches)	Source of water	Water level: Below land surface (feet)	Water level: Date of measurement	Method of lift	Use of water	Remarks (yield given in gallons per minute)
	T. 70 N., R. 27 W. - Richland Township									
1	------------ NE$\frac{1}{4}$ sec. 6	B	47	--	Alluvium	----	--------	--	D, S	Well reportedly drilled to top of bedrock at 47 feet.
2	------------ SW$\frac{1}{4}$ sec. 33	Du	27.8	--	Glacial drift	4.2	11-29-61	M	D, S	
3	Pearl Foland NE$\frac{1}{4}$ sec. 23	Du	30.0	--	Glacial drift	14.3	10-24-63	M	D	Mineral analysis given on page 16.
4	L. Arnold NW$\frac{1}{4}$ sec. 14	Dr	175	--	Glacial drift	----	--------	--	D, S	Well reportedly drilled to top of bedrock at 175 feet.
	T. 70 N., R. 26 W. - Long Creek Township									
5	Walter F. King SE$\frac{1}{4}$ sec. 3	B	35	12	Glacial drift	28	--------	E	D, S	
6	Paul German NE$\frac{1}{4}$ sec. 31	Dr	164	--	Glacial drift	54	1959	--	D, S	Reported yield 8; water hard; also uses 3 ponds for stock.
7	Leonard Redman NE$\frac{1}{4}$ sec. 33	Dr	134	8	Bedrock	----	--------	--	D, S	Reported yield 5; limestone reported at 110 feet.
8	O. C. Tompkins NW$\frac{1}{4}$ sec. 36	Dr	185	--	Glacial drift	65	8- -56	E	D, S	Mineral analysis given on page 16. Also uses ponds.

9	Harry Blair NE¼ sec. 24	B	84	12	Glacial drift	----	--------	E	S	
	T. 70 N., R. 25 W. - Franklin Township									
10	Clarke Community NE¼ sec. 4	Dr	148	6, 5	Glacial drift	55.1	11-30-61	E	I	Casing: 6-inch and 5-inch from 0 to 148 feet; screened interval from 136 to 148 feet. Reported yield 36 on test in 1938. Sample log in files of Iowa Geological Survey.
11	W. Flockhart SW¼ sec. 33	B	77.0	24-12	Glacial drift	39.3	8-25-61	E	D, S	Mineral analysis given on page 16. Also uses pond.
12	Victor Hull NE¼ sec. 23	B	75.0	15	Glacial drift	6.2	8-25-61	E	S	Also uses pond.
13	Lew Irwin SE¼ sec. 25	Du	40	36	Glacial drift	2	1961	W	S	
	T. 70 N., R. 24 W. - Garden Grove Township									
14	Lynn Patton NE¼ sec. 7	B	62.6	18	Glacial drift	20.8	1961	E	D	
15	Harold Cline SW¼ sec. 3	B	47.2	12	Glacial drift	15.9	12-1-61	E	D, S	Also uses pond and cistern.
16	Dan Thurlow NW¼ sec. 15	B	60.0	12	Glacial drift	15.1	11-30-61	E	D, S	Also uses pond and cistern.
17	---------- SE¼ sec. 28	B	65.0	12	Glacial drift	29.8	11-30-61	M	D	
	T. 69 N., R. 24 W. - High Point Township									
18	Dale Sharbaum SW¼ sec. 9	B	18.0	12	Alluvium	16.0	11-30-61	E	D, S	Also uses 2 ponds and cistern.
19	Ollie Persons NW¼ sec. 24	--	150	24	Glacial drift	----	--------	M	D, S	Well reported to furnish adequate supply.
20	Fred Skinner NW¼ sec. 35	Du	33.7	48	Glacial drift	16.3	11-29-61	E	D, S	Also uses 2 ponds.
21	H. R. Creveling SW¼ sec. 20	B	62.4	12	Glacial drift	8.7	12-1-61	E	D	Also uses pond.

	T. 69 N., R. 25 W. - Center Township									
22	Car Gettinger NE¼ sec. 14	B	37	20	Glacial drift	17	1959	M	D, S	
23	J. E. Albaugh SW¼ sec. 35	B	59.0	12	Glacial drift	11.5	8-24-61	M	U	
24	Vern Webb SW¼ sec. 20	B	48.7	12	Glacial drift	0.6	11-28-61	E	D, S	
25	O. Kirkpatrick NW¼ sec. 8	B	69.0	20	Glacial drift	28.9	11-28-61	E	D, S	Also uses 2 ponds.
	T. 69 N., R. 26 W. - Decatur Township									
26	Roy S. Smith SE¼ sec. 25	B, Dr	86.5	12	Glacial drift	26.2	8-24-61	M	D	Well reportedly pumped 24 hours without going dry; also uses pond.
27	Floyd Wilson NE¼ sec. 27	Dr	225	8-6	Bedrock(?)	10	--------	--	D, S	Water has mineral taste; also uses cistern and 2 ponds.
28	Robert Greenhalgh SE¼ sec. 3	Dr	285	--	Bedrock(?)	----	--------	--	D, S	Limestone reported at 285 feet. Also uses 2 ponds for stock.
29	Luther Woodward SE¼ sec. 18	--	30	36	Alluvium	----	--------	E	D, S	
	T. 69 N., R. 27 W. - Grand River Township									
30	---------- SE¼ sec. 26	B	115.0	12	Glacial drift	----	-------	--	U	
31	---------- SE¼ sec. 27	B	79.9	12	Glacial drift	10.0	11-28-61	--	U	
32	Carl Hilterbrand NW¼ sec. 27	Dr	140	6	Bedrock	55	--------	E	S	Well reported easily pumped dry.
33	---------- SE¼ sec. 22	B	67.3	12	Glacial drift	22.0	12-1-61	--	U	
34	Emery Burchett NW¼ sec. 4	Dr	130.0	5	Glacial drift	106.7	12-1-61	E	D, S	Casing: 0 to 130 feet; casing slotted 113-130 feet. Draw-down 5 feet after bailing 10 gallons per minute for 1 hour.

35	Lee Hewlett SW¼ sec. 5	--	25	--	Alluvium	----	--------	E	D	Well reported to furnish adequate supply for 2 houses.
36	Dale Trawer NE¼ sec. 30	B	50.7	--	Glacial drift	21.6	11-28-61	M	D	Water reported hard and adequate only for household use.
	T. 68 N., R. 27 W. - Bloomington Township									
37	George Phillips NE¼ sec. 8	B	60	16	Glacial drift	20	--------	--	D, S	Well reported to yield adequate supply; also uses 3 stock ponds.
38	Smith Heirs SE¼ sec. 18	Dr	427	4	Bedrock	----	--------	--	N	Well reported abandoned because of low water level.
39	---------- SW¼ sec. 27	B	65	--	Glacial drift	6	1960	E	D	Well reported to furnish supply adequate for domestic use. Ponds for stock.
	T. 68 N., R. 26 W. - Burrell Township									
40	F. McClure SE¼ sec. 20	Dr	86.0	6	Bedrock	63.3	8-24-61	--	D, S	Water reported hard; also uses pond.
41	Ray Wyant NE¼ sec. 12	B	37.0	15	Glacial drift	19.0	8-22-61	M	D	Also uses ponds.
42	Harry Smith NW¼ sec. 3	B	40	12	Glacial drift	7.5	8-22-61	--	D, S	Also uses cistern and pond.
	T. 68 N., R. 25 W. - Eden Township									
43	C. L. Griffin SE¼ sec. 20	Dr	161	6	Glacial drift	80	1956	E	D, S	Also uses ponds for stock.
44	F. E. Ward SW¼ sec. 9	B	36.0	36	Glacial drift	19.2	8-23-61	M	D, S	Well furnishes adequate supply; also uses 3 ponds.
45	Earl Elmore NE¼ sec. 27	B	39.0	12	Glacial drift	21.0	8-22-61	M	D	Mineral analysis given on page 16. Also uses 2 ponds.
46	Jess Fleming SW¼ sec. 23	B	69.0	12	Glacial drift	33.6	8-22-61	M	S	Well furnishes plenty of water.
	T. 68 N., R. 24 W. - Woodland Township									
47	V. W. Starry NE¼ sec. 19	Dr	120	30-20	Glacial drift	105	6-28-60	E	D, S	Sample log in files of Iowa Geological Survey.

48 Dean Vaughn SE¼ sec. 8	B	32	32	Alluvium	0.0	8-22-61	D	D, S	Reported drawdown in well was 7 feet after pumping 10 hours.
49 M. Cannon NE¼ sec. 4	B	40	24	Glacial drift	2	--------	E	D, S	Well furnishes adequate supply.
50 Louis Jelsma NW¼ sec. 23	B	130.5	24	Glacial drift	120.0	8-23-61	E	D, S	Well reported never to have gone dry.
51 Carmon Gatliss SW¼ sec. 12	B	65	24	Glacial drift	18.7	8-23-61	M	D, S	Well reported almost dry in dry years.
T. 67 N., R. 24 W. - Morgan Township									
52 M. Phelps NW¼ sec. 4	--	44	--	Glacial drift	----	--------	--	D, S	
53 Sebastian Kufer NW¼ sec. 24	--	60.0	--	Glacial drift	----	--------	--	D, S	
T. 67 N., R. 25 W. - Hamilton Township									
54 Dale Cowles SE¼ sec. 3	B	22.1	18	Alluvium	4.0	8-24-61	M	D, S	Also uses cistern and pond.
55 Walter Morey NW¼ sec. 16	B	65	12	Glacial drift	1.0	8-23-61	W	U	
56 Pleasanton School SW¼ sec. 21	Dr	341	5	Glacial drift Bedrock	156	9-12-59	--	U	Casing: 5-inch from 0 to 341 feet; casing slotted 312 to 341 feet. Reported yield 300-400 gallons per day. Sample log in files of Iowa Geological Survey.
57 Alfred Boswell SW¼ sec. 18	B	36.5	36	Alluvium	12.1	8-22-61	E	D, S	Water reported very hard, some iron. Well reported never pumped dry.
58 Garland Craig NW¼ sec. 7	B	50	16	Alluvium	33.8	8-21-61	E	D, S	

T. 67 N., R. 26 W. - New Buda Township									
59 Lloyd Gordon NW$\frac{1}{4}$ sec. 16	B	34	18	Glacial drift	6	--------	E	D	Also has pond for stock.
60 Ray Waddell SW$\frac{1}{4}$ sec. 8	B	35	12	Glacial drift	----	--------	E	D, S	
T. 67 N., R. 27 W. - Fayette Township									
61 Glenn Turpin NW$\frac{1}{4}$ sec. 2	B	62	16	Glacial drift	6	--------	--	D	Well reported never pumped dry; also uses 3 ponds.
62 J. E. Carr NE$\frac{1}{4}$ sec. 22	--	35	12	Glacial drift	22	--------	M	D	Water reported high in iron; well pumps dry but recovers.
63 Nelson Bowen NE$\frac{1}{4}$ sec. 8	B	30	16	Glacial drift	3	--------	E	D	Water reported high in iron; well pumps dry but recovers; 3 ponds for stock.
64 Wayne Pease NE$\frac{1}{4}$ sec. 18	B	50	12	Glacial drift	40	--------	E	S	Also uses 2 ponds for stock.