STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

BULLETIN NO. 4

GROUND-WATER RESOURCES
OF
BOONE COUNTY, INDIANA

PREPARED IN COOPERATION WITH
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

INDIANAPOLIS, INDIANA
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INDIANA DEPARTMENT OF CONSERVATION

Kenneth M. Kunkel, Director

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DIVISION OF WATER RESOURCES

Charles H. Bechert, Director

By

EDWIN A. BROWN

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GROUND-WATER RESOURCES OF BOONE COUNTY, INDIANA

By Edwin A. Brown

ABSTRACT

Boone County is in central Indiana on the drainage divide between the West Fork of White River and the Wabash River. The county is rectangular in shape, comprising 427 square miles. Lebanon, the county seat, is in the center of the county, about 27 miles northwest of Indianapolis.

The topography is mainly that of a rather level, gently undulating till plain, traversed by relatively small streams and the remnants of a moraine. A chain of low morainal knolls trends northwest diagonally across the center of the county. Kames and kame-like structures are common. The greatest local relief (about 75 feet) occurs in the southeastern part of the county where the morainal hills are cut by the tributaries of Eagle Creek, which flows southward, draining the eastern part of the county. Sugar Creek, a somewhat larger stream, flows westward and drains the northern half of the county. The headwaters of Eel River, flowing southwestward, drain the south-central and southwestern parts of the county.

According to U. S. Weather Bureau data, the normal annual precipitation at Whitestown is 38.74 inches and the humidity averages about 70 percent. The mean annual air temperature is 51.3° F. The county is principally an agricultural center with a few industries in the larger communities. Three

of the municipalities have a population greater than 1,000. Numerous small agricultural communities are common throughout the county.

A mantle of glacial drift, at least 354 feet thick according to one record, covers the entire county with the exception of a bedrock outcrop along the bed of Sugar Creek on the county line in the northwestern part of the county. The rocks cropping out beneath the drift are Paleozoic in age, ranging from the Middle Devonian limestones in the east to lower Mississippian sediments in the west. The rocks apparently dip west-southwest at a rate of about 25 feet per mile. A few wells indicate that the formations below the Devonian yield mineralized water. The best bedrock wells--which, however, do not have large yields--obtain water from the Devonian limestones and Mississippian limestones, sandstones, and other clastic sediments.

The topography of the buried bedrock surface is relatively rugged. The main bedrock drainage system follows rather closely the present course of Sugar Creek. In the areas of the Devonian rocks, the slopes of the bedrock surface are gentle. However, the contact of the Mississippian and Devonian formations is marked by a steep escarpment trending northwest through the approximate center of the county. The buried upland in the western part of the county is dissected by ravine-like valleys.

The major part of the county outside the valleys of Sugar Creek, Eagle Creek, and the headwaters of Eel River is underlain by gravelly till or "blue clay" containing interbedded deposits of sand and gravel outwash. The surficial materials in the northeastern part of the county are considered to be deposits of the Bloomington morainic system and those in the southwestern part of the Champaign morainic system.

Outwash terrace remnants are moderately extensive along the valleys of Eagle and Sugar Creeks. Many kames and kame-like deposits of sand and gravel are scattered throughout the county.

The buried sand and gravel deposits within the drift are fairly numerous, especially in the upper part, but usually are thin and not extensive over broad areas. They are believed to be connected hydraulically, however, and furnish the major part of the ground water used in the county. Thick units of fine sand, many of which contain well-preserved vegetal material and combustible gas, are fairly common. Buried swamp-type muck deposits containing vegetal remains were reported in several wells. Yellow clay is present within the drift at various levels. Such evidence suggests that some of the drift is of Illinoian age or older. The thicker deposits of sand and gravel are more common in the bedrock valleys than in the adjacent bedrock upland areas. The glacial deposits of Boone County are extremely complex.

The glacial deposits of Boone County form a large underground reservoir in which large quantities of water are stored. The reservoir is replenished by recharge from precipitation and is depleted by losses from evaporation and plant use, by natural drainage of ground water into streams, and by pumping from wells.

Throughout most of the county, ground water occurs under artesian conditions--that is, it is confined under artesian pressure. Flowing wells occur in several areas mainly along the valleys of the present streams. The piezometric surface, in general, is similar to the surface topography, and ground water discharges naturally into Sugar and Eagle Creeks.

Records of water levels in observation wells show that water levels in Boone County have a seasonal fluctuation of about 8 to 10 feet, generally being highest in April or May and lowest in November or December. In the vicinities of the larger communities where ground water is used for municipal and industrial purposes, the water levels in many wells are affected to a large extent by pumping from the municipal and industrial wells.

Water levels doubtless have declined throughout the county to a certain

extent, but the decline during the past 10 years, except where affected by pumping, has been negligible. The general trends in ground-water levels are similar to trends in precipitation throughout most of the county.

Ground water is used principally for domestic, stock-watering, public supply, industrial, railroad, air-conditioning, and other purposes. The water is obtained chiefly from drilled and from dug wells. The communities of Lebanon, Zionsville, Thorntown, and Jamestown have municipally owned and operated waterworks, and Advance is constructing one at present.

In general, the ground water is generally satisfactory from a sanitary standpoint, but it is high in mineral content. The high iron content and hardness are the chief objections for present usage. According to the chemical analyses of waters from public supplies, the average iron content is about 1.2 parts per million, the average alkalinity about 360 to 370 parts as calcium carbonate, the average total hardness about 300 to 450 parts, and the average hydrogen-ion concentration, or pH value, about 7.5. The mean temperature of the ground water measured in water from 21 wells and 3 springs during 1947 was about 52.5° F.

The present pumpage of ground water in Boone County is estimated to be about 500 million gallons a year, of which about 200 million gallons a year is used in the Lebanon area. It is also estimated that nearly 200 million gallons of water a year is wasted by the uncontrolled discharge of flowing wells throughout the county.

The municipal water supply of Lebanon is taken from wells tapping three zones of glacial sand and gravel aquifers at depths of about 50, 100, and 220 feet. The shallow zone is apparently relatively poor as a source of water, as shown by the operational difficulties in maintaining adequate yields from wells in this zone. The intermediate zone is the main source of supply at the present time. Coefficients of transmissibility and storage in this zone

were determined by pumping tests to be 10,000 gallons per day per foot and 5.7×10^{-4}, respectively. Differences in specific capacities and well loss in the four wells tapping the intermediate zone suggest that there may be a highly permeable lens of sand and gravel in the southwest part of the well filled that is not present in the northeastern part. It appears likely that additional water might be obtained from the deeper zone from widely spaced wells.

The future potentialities of ground-water supplies in Boone County appear to be fairly promising, particularly for small supplies. The complexity of the glacial deposits make the correlation of individual aquifers difficult and often impossible, and considerable test drilling may be required to locate sand and gravel deposits of sufficient thickness and areal extent to provide adequate water supplies. Care should be taken in developing new supplies, in rehabilitating and maintaining existing wells and well fields, and in conserving ground water for beneficial use. Wells should be spaced as far apart as possible to avoid excessive interference between wells.

The sand and gravel terrace deposits along the valleys of Sugar and Eagle Creeks appear to be potentially the most productive sources of ground water in the county. Next in importance are the buried lenses of sand and gravel, many of which are described in the report. In the development of new sources of supply, the importance of test drilling and test pumping cannot be overemphasized. Information on nearby existing wells should be utilized where possible.

The waste of water from flowing wells should be reduced to prevent the lowering of ground-water levels and the depletion of ground-water supplies.

Tables of well records and chemical analyses of water from the several public water-supply systems, and maps showing the surface topography, locations of wells, topography of the bedrock surface, data on the aquifers and the piezometric surface, are included in the report.

GROUND-WATER RESOURCES OF BOONE COUNTY, INDIANA

INTRODUCTION

STATE-WIDE COOPERATIVE PROGRAM

A cooperative investigation of the ground-water resources of Indiana by the Indiana Department of Conservation and the Geological Survey, United States Department of the Interior, has been in progress since 1935. The Department of Conservation was represented prior to 1943 by the Division of Geology, from 1943 to 1945 by the Division of Engineering, and since that time by the Division of Water Resources. Detailed investigations of the ground-water resources of individual areas, generally counties, are being made as a part of the larger State-wide project. The present report is the second areal report to be prepared since the detailed county investigations were started in 1943, the first being a report on the South Bend area, St. Joseph County. 1/ The areas of Indiana on which reports have been released, the area described in this report, and the areas under investigation are shown in figure 1.

The present investigation was made under the general supervision of C. H. Bechert, Director, Division of Water Resources, Indiana Department of Conservation, and O. E. Meinzer and A. N. Sayre, successive chiefs of the Division of Ground Water, U. S. Geological Survey.

PURPOSE AND SCOPE

The importance of ground water as a natural resource has increased considerably in recent years in both rural and urban areas. The increased

1/ Klaer, F. H., Jr., and Stallman, R. W., Ground-water resources of St. Joseph County, Indiana; Part 1, South Bend area: Indiana Dept. Cons., Div. Water Resources Bull. 3, 1948.

availability of electricity and the demand for better sanitary facilities on farms and the increasing demand for water by municipalities and industries in towns and cities have resulted in a greater demand for dependable ground-water supplies. The City of Lebanon, the county seat of Boone County, has had difficulty for several years in maintaining an adequate supply of water from wells during periods of peak demand. In response to a request from the officials of the Lebanon Utilities, Inc., a municipally owned and operated corporation, a preliminary investigation of the ground-water resources of the Lebanon area was made in May 1945 by F. H. Klaer, Jr., of the U. S. Geological Survey, as a part of the State-wide investigation. The results of this work, released in typewritten form, included a summary of the available information on ground-water supply in the Lebanon area and pointed out the need for a detailed study of the ground-water resources of the entire county in order to obtain the basic information needed for the proper and economic maintenance of the existing ground-water supply. The county investigation, the results of which are presented in this report, was started in December 1945 in cooperation with the City of Lebanon.

The investigation as proposed included the detailed study of the surface and subsurface geology of the entire county to determine the thickness, areal extent, and outcrop areas of water-bearing and non-water-bearing formations, and their relations to potential sources of recharge; the relation of changes in ground-water levels to precipitation, pumping, and other factors; the seasonal and long-term trends in ground-water levels; the running of pumping tests to determine the hydraulic characteristics of the water-bearing formations; and a study of chemical analyses of ground water to determine the quality of water in each water-bearing zone and the changes in quality over a period of time.

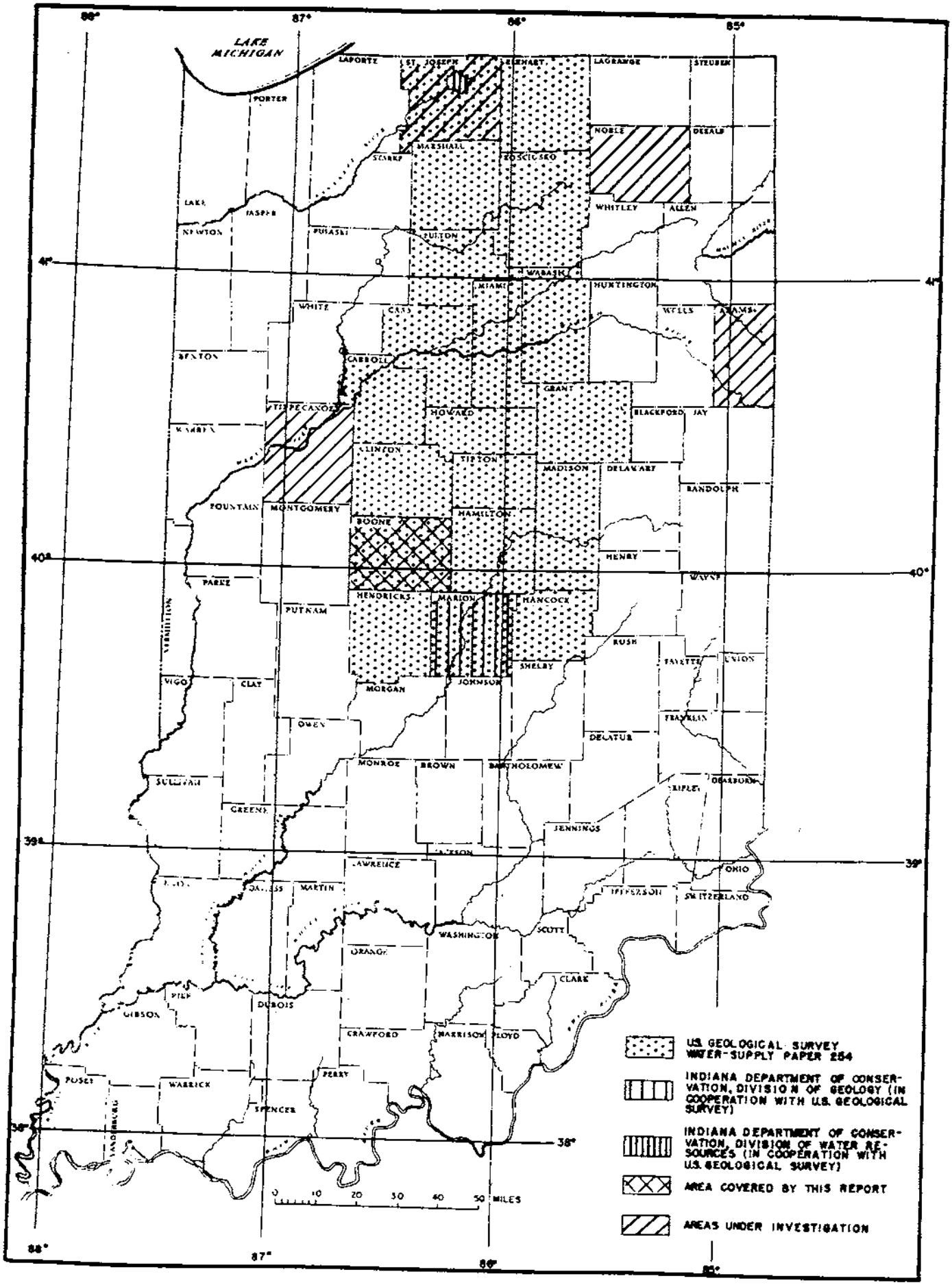

FIGURE 1. MAP OF INDIANA SHOWING LOCATION OF AREAS ON WHICH REPORTS HAVE BEEN PUBLISHED, AREA DESCRIBED IN THIS REPORT, AND AREAS UNDER INVESTIGATION

SUMMARY OF FIELD WORK

A preliminary investigation of the available information on the geology and ground water resources of the Lebanon area was made by F. H. Klaer, Jr., in May 1945. During 1945 several observation wells were established and regular measurements of water levels in these wells were started on October 26, 1945, and have been continued to date, by Fred Price of the Lebanon Utilities, Inc. Two observation wells had been established near Lebanon in the fall of 1935 as a part of the State-wide observation well program, but measurements of water levels had been discontinued in October 1941. Measurements of water levels in these wells were resumed in 1945.

Information on other wells was obtained by B. W. Swartz and the writer during January 1946. The well inventory was resumed in January 1947 by the writer and was continued through July 1947. The surficial deposits and glacial geology of the county were studied and mapped by W. D. Thornbury, of Indiana University, and the writer in August 1946. Pumping tests were made in the municipal well field at Lebanon in February 1947 by R. W. Stallman, assisted by B. W. Swartz, H. L. Ballard, and D. T. King. Surface elevations at wells on which information had been obtained were determined by the writer in July and August 1947, using a Paulin altimeter and bench marks established by the U. S. Coast and Geodetic Survey.

ACKNOWLEDGMENTS

The author wishes to acknowledge the helpful assistance given by the officials and other members of cities, towns, and industries, in providing information on existing wells and water supplies. Special thanks are due the many well drillers, particularly those listed on pages 10 and 11 of this report, who provided much of the information included in the tables of well records in appendix A.

The employees of the Lebanon Utilities, Inc., T. J. Burrin, Manager,

Fred Price, and others, have helped greatly in providing information, making water-level measurements, and assisting on pumping tests in the Lebanon area.

The aerial photographs provided by the State Highway Commission of Indiana have been used to great advantage in studying the topography and drainage of Boone County. Chemical analyses in appendix C were made by the Indiana State Board of Health. Data on pumpage from the public water-supply systems of the several cities and towns of Boone County were provided by the Public Service Commission of Indiana.

Thanks are due F. H. Klaer, Jr., under whose supervision the investigation was made, for his guidance and criticism throughout the project, and R. W. Stallman for his suggestions and criticism of the report.

PREVIOUS WORK

Information on the geology, geography, and ground-water resources of Boone County is given in several published reports. One of the earliest publications is that by Gorby and Lee (7),[2/] which includes a general discussion of the geography and geology and contains detailed logs of many wells. Leverett (10) presents a brief description of the geography of the county and detailed discussions and logs of many wells, including some of those published by Gorby and Lee. Capp's report (4) gives a more detailed account of the ground-water geology and resources of the county, containing records of wells, water levels, and chemical analyses of ground waters. Leverett and Taylor (11) discuss in considerable detail the glacial geology of the county in relation to the surrounding region and include many logs of wells, mostly those from former reports. Harrell's publication (8) is a general summary of the ground-water geology and resources of the county based mainly on information in previous reports. Tharp and Quinn (17) give a brief discussion of the topography, drainage, and agriculture of the county and a

[2/] See references in bibliography, appendix D.

detailed discussion of the soils. Much of the information in this report on the geology and glacial history has been taken from these publications.

WELL RECORDS

Much information on the geology and ground-water resources of a given area can be obtained by a study of existing wells and the records obtained during the drilling of wells and tese holes. In Boone County, information on wells and well drilling was obtained from well owners, residents, and well drillers. The records thus obtained are summarized and tabulated in appendix A. The locations of the individual wells are shown on plate 2.

The records of wells in appendix A have been provided in large part by the following well drillers, who gave freely of their time and information to help in the present study:

John Bomaine	Clayton
Flem Boyd	Lebanon
Willard English	Clayton
R. A. Holt and Sons	Darlington
A. R. Kelly	Frankfort
Claude Kersey	Lebanon
Clyde Kersey	Lebanon
James Kersey	Lebanon
Noble Niger	Colfax
Charles Krauss & Sons	Indianapolis
Harold Lister	Clarks Hill
Ray Lister	Thorntown
Kamp Lomax	Sheridan
Earl Merritt	New Augusta
Thomas Walton	Zionsville

It should be realized that many of the well data included in appendix A were obtained mainly from conversation and not from written records. Information obtained from different persons regarding the same well was sometimes different, and it was not possible to check much of the information obtained. Many of the wells in Boone County are sealed at the top or otherwise constructed in such a way as to prevent the measurement of the total depth or of the water level. The author has attempted to present the best data available where questions exist, and where serious disagreement has been found the uncertainty is indicated by a question mark.

In order to facilitate the identification of a particular well, each well is assigned a number. In the numbering system adopted for use in Indiana, the well number has a geographic significance that enables its location to be determined within a 1-square-mile section.

Boone County contains all or parts of 16 townships of land as it is divided in the township and range system of the General Land Office. Each of these townships is designated by a capital letter, starting with A and lettering alphabetically from the westernmost boundary in the northern tier and proceeding eastward, then dropping one tier south, following the same plan of lettering alphabetically eastward. (See plan in lower right corner of pl. 2.)

The well number includes the prefix "Bo" to designate Boone County. To this is added the capital letter indicating the township in which the well is located, and to this group of letters is added the number of the section of the township within which the well is located. This tripartite symbol of the well number indicates the geographic location of the well.

To this symbol is added a number which identifies the individual well of well owner. It is separated from the former symbol by a dash. If one owner has several wells within the same section, additional identifying

numbers are given to each of these wells. These numbers are added to the geographic symbols and owner's number following a dash. Test wells are designated by the letter T before the last number in the well-numbered symbol. Gas or oil wells are designated by the letter G and a dash which appears in front of the county prefix. Observation wells are noted by the letter O and a dash which appear before the county prefix. Those parts of the geographic tripartite symbol for which the information is not known are replaced by question marks. Examples of well numbers are BoAlh-1, BoF36-1-10, and G-Bo ??-1.

Some of those wells for which only a general location is known are listed first in appendix A. They are given an identification in numerical order as the information was recorded. A few records of wells in surrounding counties are included in this report. The county prefix for these wells is shown on plate 2, and at the end of the tables in appendix A.

GENERAL DESCRIPTION OF THE AREA

LOCATION AND SIZE

Boone County is in central Indiana. Lebanon, the county seat and the largest city, is at the geographic center of the county (see pl. 1), about 27 miles northwest of Indianapolis. The intersection of longitude 86°30' and latitude 40°00' is about 2½ miles south and 1½ miles west of the county courthouse in Lebanon, through the center of which the second principal meridian of Indiana runs. The county is rectangular in shape, being about 24 miles in an east-west direction and about 17½ miles in a north-south direction, and comprises about 427 square miles. Its population according to the U. S. Census was 22,081 in 1940, and 22,290 in 1930.

TOPOGRAPHY AND DRAINAGE

The area under discussion lies within the Tipton Till Plain physiographic division of central Indiana. The land surface ranges in elevation from about 774 feet above mean sea level, along Sugar Creek at the Montgomery County line, to about 976 feet on knolls 2½ miles east-southeast of Lebanon in sec. 3, T. 18 N., R. 1 E., and about 5 miles south-southwest of Lebanon in sec. 34, T. 18 N., R. 1 W., as determined by altimeter traverses. The contours of the land surface shown on plate 1 were based on the bench marks established by the U. S. Coast and Geodetic Survey, 110 of which are located along the major highways in the county.

The land is an almost flat to gently rolling plain on the broad divide between the drainage basins of the Wabash River and the West Fork of White River. The slopes throughout most of the county are very gentle and the local relief is generally less than 30 feet within an area of several square miles. A belt of morainal knolls runs diagonally across the county from the

northwest to the southeast corner, having somewhat greater local relief along its margins.

The natural drainage on the uplands throughout most of the county is generally very poor. According to Gorby and Lee (7, p. 162) there were originally many depressions in which water accumulated to form swamps and bogs of considerable depth. The greater number of these areas are now drained by open ditches and tile. During periods of heavy rainfall, however, many fields are flooded for several weeks because of slow drainage through the tile drains.

Near the streams the slopes are more pronounced, especially along Eagle Creek, which flows south in the eastern part of the county. In the area of its headwaters between Whitestown and Zionsville, where morainal hills are common, the topography is the most rugged in the county. Eagle Creek and its tributaries are youthful streams with V-shaped valleys. The gradient of Eagle Creek is estimated to be about 9 feet per mile, and the local relief between the stream and the uplands may be as much as 75 feet.

Sugar Creek, flowing west across the northern part of the county, and its tributaries drain the major part of the county. It is somewhat more mature than Eagle Creek, its gradient being estimated as about 5 feet per mile. It has a relatively broad valley with rather gentle slopes, the local relief between the flood plain and the valley walls being about 50 feet.

Little Sugar Creek and Walnut Fork are minor drainage lines in the western part of the county. They flow west, joining Sugar Creek in Montgomery County. Big Racoon Creek, draining the southwestern part of the county, flows southwest to join the Wabash River near Montezuma.

A major part of southwestern and south-central Boone County is drained by the headwaters of Eel River. The three main tributaries, North Fork of Walnut Creek, Edlin Ditch, and Grassey Branch, have low gradients estimated

as 2.4, 2.9, and 2.7 feet per mile, respectively. They are small, shallow streams, following the original drainage lines in a broad, shallow basin or depression with an outlet near Jamestown.

Within this area are some mounds or knolls that have elevations similar to those on the drainage divide between Sugar and Eagle Creeks. They are in alinement with this divide, the axis of which would form a gently curved arc across the entire county from northeast to southwest, bending toward the southeast.

CLIMATE

The U. S. Weather Bureau has maintained a station in southeastern Boone County since March 1896. It was first located in Northfield but was transferred 4 miles southwest to Whitestown in November 1908. The climatological data given in this report are taken from the records (18) of this station.

The climate of Boone County is typical of that of the interior Midwestern States; i.e., rather cold winters, hot summers, a relatively high humidity, and considerable precipitation. The mean annual air temperature is 51.3° F. The temperature has ranged from a maximum of 105° F. to a minimum of -14° F. in the last 10 years. The growing season between killing frosts has averaged 162 days in this period. The prevailing winds are from the southwest. The humidity in this general region averaged about 70 percent for the period 1944-46, according to records of the U. S. Weather Bureau station at the Indianapolis municipal airport.

Table 1. Annual precipitation, in inches, at Northfield, 1896-1907, and Whitestown, (1908-47), Indiana. (U. S. Weather Bureau data.)

YEAR	PRECIPITATION	YEAR	PRECIPITATION	YEAR	PRECIPITATION
1896[1/]	35.09[2/]	1914	30.31	1932	40.73
1897	38.30	1915	45.90	1933	33.13

Table 1. (Con't.).

YEAR	PRECIPITATION	YEAR	PRECIPITATION	YEAR	PRECIPITATION
1898	47.54	1916	37.45	1934	27.34
1899	32.90	1917	40.90	1935	36.69
1900	36.08	1918	42.34	1936	32.34
1901	30.34	1919	37.88	1937	43.52
1902	33.25	1920	35.47	1938	44.07
1903	37.12	1921	42.93	1939	36.12
1904	37.60	1922	44.13	1940	27.37
1905	40.15	1923	46.44	1941	29.32
1906	38.94	1924	39.81	1942	38.75
1907	37.49	1925	36.76	1943	34.13
1908[c/]	28.99	1926	50.25	1944	31.47
1909	50.31	1927	47.89	1945	48.61
1910	26.55+[b/]	1928	41.49	1946	39.88
1911	38.13	1929	49.93	1947	36.98
1912	37.75	1930	33.42		
1913	44.52	1931	36.12		

a/ Northfield.

b/ Incomplete record.

c/ Whitestown.

According to the U. S. Weather Bureau, the normal annual precipitation at Whitestown is 38.74 inches. The total annual precipitation at Northfield (1896-1907), and Whitestown (1908-47), is given in table 1 and is shown in figure 2.

The four years of greatest rainfall were 1909, 1926, 1929, and 1945; and the four years of least rainfall were 1934, 1940, 1908, and 1941, in

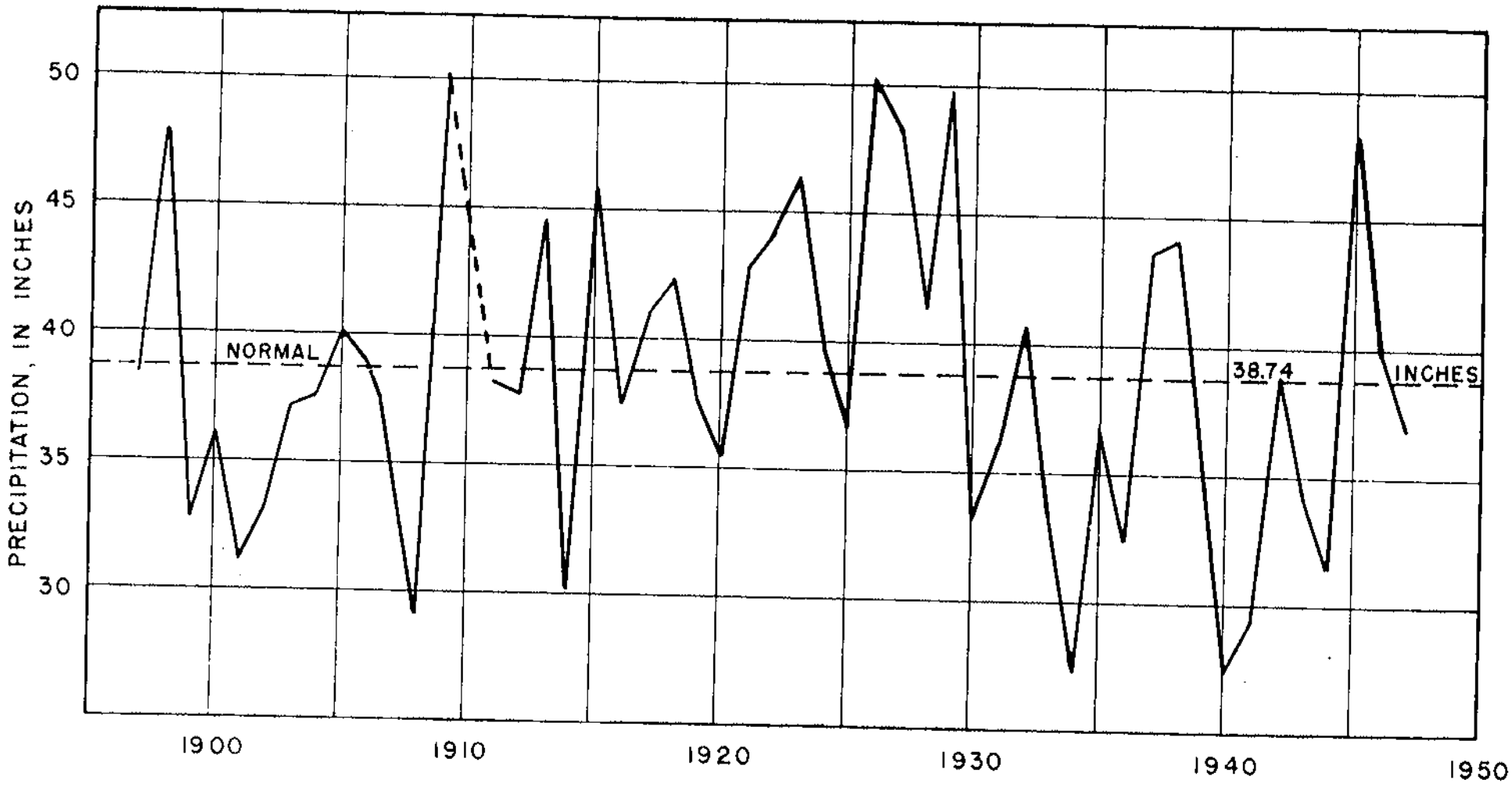

FIGURE 2. ANNUAL PRECIPITATION AT NORTHFIELD (1897-1907) AND AT WHITESTOWN (1908-47), BOONE COUNTY, INDIANA. (U. S. Weather Bureau data)

order from highest to lowest. Since 1930 there have been five years during which precipitation was 6 inches or more below normal and only one year during which precipitation was 6 inches or more above normal.

The normal monthly and seasonal precipitation at Whitestown is shown in table 2.

Table 2. Normal precipitation, in inches, at Whitestown, Ind., by months and seasons. (U. S. Weather Bureau.)

Winter		Spring		Summer		Autumn	
Dec.	2.65	Mar.	4.09	June	3.63	Sept.	3.46
Jan.	2.98	Apr.	3.57	July	3.55	Oct.	2.79
Feb.	1.99	May	4.05	Aug.	3.28	Nov.	2.70
	7.62		11.71		10.46		8.95

March or May usually is the wettest month and February usually is the driest. The heaviest precipitation of the year generally occurs during the spring, when conditions for ground-water recharge are favorable because evapo-transpiration losses are low and temperatures are usually sufficiently high to permit thawing of frozen ground.

GENERAL GEOGRAPHY

The city of Lebanon is situated on an upland flat, near the center of the main drainage divide of the county, on the upper reaches of Prairie Creek. It had a population of 6,529 in 1940, and 6,445 in 1930, according to U. S. Census data. The figure is doubtless somewhat larger now, owing to the migration of population to the towns and cities during the war years. Lebanon is an expanding industrial and agricultural center. Industries include stoker and other heating-equipment production, bus-body fabrication, assorted iron and steel products, canning, a milk plant, and other smaller varied industries. It is on main lines of the New York Central and Pennsyl-

vania Railroads and is a terminus of the Central Indiana Railroad. Three major highways pass through the town. (See pl. 1 and fig. 3.)

Zionsville, which had a population of 1,314 in 1940, and 1,131 in 1930, is mainly a residential and agricultural community. It is in the southeastern corner of the county on the upland of the west bank of Eagle Creek. Several large oil and gas tank farms, pumping stations, and an oil refinery are located in Marion County about 2 miles south of the town, and a large bio-chemical plant is just south of the town.

Thorntown, which had a population of 1,226 in 1940, and 1,325 in 1930, is an agricultural town with minor industries. It is on the south bank and uplands of Sugar Creek at its junction with Prairie Creek, in the northwestern part of the county.

Jamestown is a small agricultural and industrial community on the county line in the southwestern section of the county, on the northwest bank of Eel River. It had a population of 583 in 1930. A pumping station of an oil and gas company is located just southeast of the town in Hendricks County.

Advance, population 365 in 1940, is a small agricultural community 5 miles north of Jamestown.

Numerous smaller communities are rather evenly distributed over the county.

ROCKS AND THEIR RELATION TO THE OCCURRENCE OF GROUND WATER

The occurrence of ground water is controlled largely by the geologic and hydrologic characteristics and relationships of the various rocks and soils of the earth's crust. The rocks of Boone County may be divided into two general groups: the consolidated Paleozoic sediments, or bedrock formations, and the unconsolidated Pleistocene glacial deposits. Ground-water conditions in the two groups are quite different.

The bedrock is buried under a mantle of glacial drift over practically the entire county. The only outcrop of bedrock known to the writer is in the bed of Sugar Creek in the northwestern part of the county. The outcrop serves as the foundation for the bridge on the Montgomery-Boone County line road, a quarter of a mile north of State Highway 47. The greatest thickness of glacial drift on record is 354 feet, in well BoK17-1 (pl. 2). In this well limestone was struck at that depth. Other wells that penetrated great thicknesses of glacial drift are: BoK5-4-2, 350 feet; G-Bo??-2, 342 feet; BoB35-1, 320 feet; BoC5-1, 314 feet; and G-Bo??-3, 285 feet.

The majority of wells in Boone County derive their water supply from sand and gravel in the glacial drift; detailed records of wells penetrating bedrock are relatively scarce. Most of the information on the bedrock was obtained from wells in the western part of the county, where the elevation of the bedrock is greater and the glacial deposits are thinner.

BEDROCK GEOLOGY

Rock Units and Their Water-Bearing Properties

The general succession of rock formations underlying Boone County and their water-bearing properties are shown in table 3. As the majority of wells in Boone County obtain their water supplies from the glacial drift or

Table 3. Generalized section of the geologic formations of Boone County a/

System	Series	Stratigraphic Unit	Character of Material	Ground-Water Conditions
Quaternary	Recent	Alluvium	Clay, silt, sand, and gravel in bottom of larger streams	Moderate supplies available from sands and gravels. Deposits are fine-grained and less permeable than the glacial outwash deposits. Limited in Boone County to valleys of main streams.
	Pleistocene	Wisconsin glacial drift	Till (boulder clay), sand and gravel	Moderate to abundant supplies from outwash deposits of sand and gravel; moderate supplies from lenses of sand and gravel interbedded with till. Small supplies from dug wells in till.
		Illinoian glacial drift	Till (boulder clay), sand and gravel	Moderate to abundant supplies from outwash deposits of sand and gravel; moderate supplies from lenses of sand and gravel interbedded with till.
		Older glacial drift?b/	Red clay above bedrock, in southeastern part of county	Unimportant as a source of ground water. Generally necessary to drill into underlying bedrock formations to get adequate supplies.
Mississippian c/	Lower Mississippian c/	Borden group Edwardsville formation Floyds Knob formation Carwood formation Locust Point formation New Providence shale	Shale, siltstone, and sandstone Limestone Sandstone and siltstone Shaly siltstone, and shale Shale and sandstone	Small supplies from limestone or sandstone layers.
		Rockford limestone	Limestone	Unimportant as a source of water.
Devonian	Upper Devonian	New Albany shale	Black and brown shale	Meager supplies only. May supply a few domestic wells in Boone County. Water likely to be rather highly mineralized.
	Middle Devonian	Jeffersonville (?) ("Corniferous") d/ limestone	White to gray limestone much creviced and channeled in some places	Moderate to abundant supplies from crevices. Supplies meager where limestone is dense, with few crevices.
Silurian		Niagara limestone	Blue to buff limestone, massive to crystalline, creviced in places	Moderate to abundant supplies from crevices. Supplies meager where limestones are dense, with few crevices.
Ordovician	Upper Ordovician	Cincinnatian series	Shales, with a few thin interbedded limestones	Unimportant as a source of ground water.
	Middle Ordovician	Trenton limestone d/	Massive limestones, in places dolomitic	Yields salt water; also gas and oil in relatively small quantities in some places.
	Lower Ordovician	St. Peter sandstone	Porous sandstone	Small supplies of highly mineralized water.

Table 3. Generalized section of the geologic formations of Boone County a/ (continued)

a/ Based on section by C. L. McGuinness in "Ground-water resources of the Indianapolis area, Marion County, Indiana": Ind. Dept. Conservation, Div. of Geology, pp.16-19, (mimeographed) Jan. 1, 1943, modified by the writer.

b. May be residual soil or deposit of pre-Pleistocene age.

c. The Mississippian is regarded by the U. S. Geological Survey as a series of the Carboniferous system and by the Indiana Division of Geology as a separate system.

d. Geologic names in common use by drillers.

from the upper bedrock formations, detailed information on the deeper bedrock formations is incomplete.

The regional dip of the bedrock formations is west-southwest and the younger formations are present only in the western part of the county. These are the shales and siltstones (perhaps the Carwood formation) of the Borden group of Mississippian age, which are underlain by the Rockford limestone, also of Mississippian age, and the New Albany shale of Devonian age. Underlying the New Albany shale in the central and western parts of the county and immediately underlying the glacial drift in the eastern part of the county are the limestones of Devonian age. The locations of wells that penetrated bedrock and the type of bedrock penetrated are shown in plate 3. The logs of wells penetrating bedrock are included in appendix B.

Silurian and Ordovician Rocks

Several wells in Boone County that penetrate the Silurian and Ordovician formations are G-Bo??-1 at Lebanon, G-Bo??-4 at Thorntown, G-Bo??-7 at Zionsville, BoF36-1-11 at Lebanon, and G-BoH34-2 near Rosston. The well near Rosston is the deepest known in the county (1,825 feet), penetrating the St. Peter sandstone of Ordovician age. The well was reported to yield mineralized water from the St. Peter sandstone at a depth of 1,600 feet and salt water (10 gallons per hour) from the Trenton "lime" between depths of 1,048 and 1,142 feet. A 47-foot stratum of limestone (probably of Niagaran age) at a depth of 515 feet was also reported to be water bearing (app. B). In well BoF36-1-11 at Lebanon, the limestone (probably of Niagaran age) 407 feet thick did not yield sufficient water for municipal supply, although in other parts of the state the limestones of Niagaran age generally yield moderate supplies of water to wells. Conditions do not appear favorable for obtaining moderate to large supplies of potable water from the Silurian and Ordovician formations in Boone County.

Devonian Rocks

Limestones

The limestones of Devonian age are the uppermost bedrock formations in the eastern part of the county, east of a line running northwest from the southeast corner of the county through Zionsville, between Whitestown and Gadsden, and near Pike. The wells in which the Devonian limestones were found at the bedrock surface are included in table 4, with the elevations of the top of the limestones and the thicknesses penetrated.

Table 4

Wells in Boone County penetrating Devonian limestones

Well	Type of rock	Thickness (feet)	Elevation of top, in feet above mean sea level	Position
BoB35-1	Probably limestone	?	590	At bedrock surface
BoG5-1	Limestone	?	623	do.
BoL14-2	Blue Limestone	17	720	do.
BoL27-1-1	Limestone	10	676	do.
HaE31-1	do.	19	707	do.
G-Bo??-4	"Corniferous" limestone (4, p. 74; 6, p. 263; 12, p.45)	37	460	Below New Albany shale
G-Bo??-7	"Devonian limestone with sandstone at base" (12, p. 44)	75	625	do.
BoH31-2-1	Hard white limestone	93	656	Below shale
G-BoH34-2	Limestone; water	67	713	do.
BoL7-1	Limestone	65+	693	do.

The mention of sandstone at the "base of the Devonian limestone" in the log of well G-Bo??-7 is the only known record in Boone County of what may be the Pendleton sandstone or its correlative. The limestone is known to be water bearing in the wells given above, except in wells G-Bo??-4 and G-Bo??-7, for which no information is available. The yields of the wells

are generally ample for domestic and farm use. The water from well BoL14-2 was reported to be slightly mineralized and that from well HaE31-1 was reported to be somewhat "oily."

New Albany shale

Many wells in the eastern and southeastern parts of the county have penetrated a black shale, the New Albany shale of Upper Devonian age, which overlies the middle Devonian limestones. Its complete thickness in the eastern half of the county is not known, the greatest thickness penetrated being 90 feet in well BoH31-2-2 where it is the uppermost bedrock formation at an elevation of 751 feet above sea level.

Wells in which the complete thickness of the New Albany shale was drilled are G-Bo??-4, at Thorntown, in which 87 feet of "Hamilton shale" (New Albany) was reported, and BoF36-1-11, in Lebanon, in which 75 feet of black shale was logged. It is probable that much of the 204 feet of blue and black shales in well G-Bo??-1 and possibly all the shale in well G-Bo??-2, both in Lebanon, is the New Albany. Shale was reported as the uppermost bedrock in well BoK5-4-2 at an elevation of 570 feet above sea level. This is probably the New Albany shale, as the top of the New Albany was reported at an elevation of 607 feet above sea level in well BoK4-1-2, about a mile northeast. If so, this is the westernmost point known where the New Albany shale forms the bedrock surface. The New Albany shale generally does not yield water to wells in sufficient quantities to be considered as a source of water supply.

Mississippian Rocks

Rockford limestone

The Rockford limestone, which marks the base of the Mississippian, is a relatively thin (generally less than 20 feet thick) but rather persistent

limestone. It was found in Lebanon in well BoF36-1-11, at an elevation of 601 feet above sea level, where 7 feet of limestone is overlain by 100 feet of blue shale and is underlain by 75 feet of black shale. About 3 miles south of Lebanon, in well BoK17-1, 7 feet of non-water-bearing limestone, which is probably the Rockford, was found at an elevation of about 600 feet above sea level.

In the eastern part of the county, a limestone aquifer was found at an elevation of about 760 feet above sea level in wells BoH14-1, BoH16-1, and BoH20-1. The elevation of the limestone in relation to that of the New Albany shale in nearby wells indicates that the limestone lies above the black shale and, therefore, is probably the Rockford. The limestone was 18 feet thick in well BoH14-1 and 12 feet thick in well BoH20-1. The Rockford limestone generally does not yield large quantities of water to wells.

Borden group

The majority of the wells in the southwestern half of the county that penetrate bedrock end in rocks of the Borden group of Mississippian age. Rocks of this group have been described by drillers as "soapstone," "blue shale," "green shale," "limestone," "sandstone," "porous rock," and "hard white rock." The Borden group in its outcrop area in southern Indiana has been described in detail by Stockdale (15). It is pointed out that there is considerable variation in lithology both vertically and laterally, and major changes in the type and character of the formations are common. Stockdale (pl. 2, column 3), has separated the Borden group in southern Indiana into the following formations:

Formation	Lithologic character	Average thickness (in feet)
Edwardsville formation	Mainly sandstone, shale, and siltstone, with local limestone reef deposits	50-55

Formation	Lithologic character	Average thickness (in feet)
Floyds Knob formation	Limestone and shale	2-6
Carwood formation	Sandstones, siltstone, and shale, with local limestone reef deposits	115-120
Locust Point formation	Siltstone, sandstone, shale	120-130
New Providence shale	Kenwood beds - sandstone and shale. ("soapstone) Argillaceous shale (soapstone with local limestone reef deposits)	200

He also reports (15, p. 62), that the Borden group becomes thicker from south to north and from east to west. The maximum thickness of the Borden group in Boone County is not known. A well at Thorntown (G-Bo??-4) showed 238 feet of "Subcarboniferous limestone and shale" (6, p. 23; 4, p. 74; 12, p. 45).

A study of well logs and of the elevations at which the Mississippian-Devonian contact was encountered indicate that the base of the Borden group dips southwestward at a rate of from about 15 to 40 feet per mile, the average dip being about 25 feet, or less, per mile.

New Providence shale. - According to Stockdale (15), although the New Providence shale, like the other formations of the Borden group, may vary widely in character, it is usually an argillaceous shale, commonly known by many well drillers as "soapstone." The blue shale or "soapstone" generally is not water bearing. The logs of several wells in the central and western parts of the county showed the presence of sandstones and "yellow limestones" about 230 feet above the base of the Mississippian strata. The "yellow limestone" may be an iron-stained calcareous sandstone. These strata are believed to be in the upper part of the New Providence shale or perhaps at the base of the Locust Point formation.

The eastern limit of the formations of the Borden group, including the basal New Providence shale, runs roughly parallel to and 1 to 2 miles east of U. S. Highway 52, as indicated by the logs in about 25 wells. This coincides fairly well with the line of the buried "Knobstone" escarpment as shown in plate 3.

In general the New Providence shales yield little or no water to wells, although the sandstone and "yellow limestones" in the upper part may yield sufficient water for domestic and stock use.

Locust Point formation. - In southern Indiana the Locust Point formation is composed mainly of alternating sandstones, siltstones, and shales with interbedded calcareous lenses. In Boone County many of the bedrock strata between 230 and 370 feet above the base of the Borden group are reported to be limestone. It is possible that the "limestones" in reality may be calcareous sandstone, or the Locust Point formation may be largely calcareous in Boone County. Most of the so-called "limestone" aquifers that produce sufficient water for domestic and stock use are in this interval, as shown by wells BoJ8-1 (12 feet of white limestone), BoJ15-2-1 (15 feet of limestone), and BoL36-1 (18 feet of limestone).

Carwood, Floyds Knob, and Edwardsville formations. - The remainder of the bedrock formations of the Borden group in Boone County fall in the interval between 370 and 470 feet above the base of the group. The upper 100-foot interval may represent the Carwood formation and may perhaps include part of the Floyds Knob and Edwardsville formations.

In southern Indiana the Carwood is mainly a sandstone with minor shale and siltstone lenses. The only sandstone reported in this interval is that found in well HaA16-1-1, in Hamilton County in which its thickness is not

recorded. The elevation of the sandstone is about 390 feet above the base of the Borden group. In Boone County several "limestone" aquifers that supply sufficient water for domestic and stock use occur in this interval, such as those found in wells BoI18-1-3 (5 feet of yellow porous rock), BoI29-1 (70 feet of hard white limestone), and BoM15-1-3 (17 feet of white porous limestone).

As described above, much of the bedrock is listed as blue shale. This type of rock does not seem to be diagnostic as the term is used to describe the bedrock at many elevations and in many different areas. It does suggest, however, that the rock is in the Borden group. Most of the drillers report that water is obtained from crevices in this type of rock and from nonporous limestones and sandstones. The crevices are reported to decrease in abundance with depth, so that if water is not obtained in the upper part of the rock the chances of success decrease accordingly. The logs of certain wells, such as BoM10-6-5 (412 feet of soft blue shale), G-Bo??-4 (238 feet of "Subcarboniferous" limestone and shale), and BoM9-2-1 (123 feet of soft blue shale), probably are not sufficiently accurate or detailed for correlative purposes.

The only outcrop of bedrock in Boone County known to the writer, the location of which is described on page 19, is a light- to medium-drab to greenish-gray fine-grained siltstone containing a minor percentage of mica flakes and sand grains. It appears to be slightly porous and contains a small percentage of small pyrite inclusions. Small impressions about 10 millimeters in length and 2 millimeters in width, with parallel lines along the long axis, are believed to be plant remains. Irregular, hairlike impressions suggest worm trails.

Fragments of the relatively "fresh" unoxidized rock do not react to cold or warm hydrochloric acid. The surface of the rocks of the outcrop is

buff to dark brown to black, oxidized, leached, somewhat porous, and iron-stained. The rocks have a blocky appearance and a hackly fracture. Certain parts of the outcrop are reported by a local well driller to contain "Indian beads," the description of which suggests crinoid columnals.

This outcrop occurs probably about 345 feet above the base of the Borden group. Its stratigraphic location is in the upper part of the Locust Point formation, but it is possible that the rocks are basal beds of the Carwood formation. The reported abundance of crinoid columnals and the topographic location seem to favor the latter hypothesis. The Carwood formation is the resistant rock that caps the Knobstone escarpment in many places in southern Indiana. However, the Locust Point formation is also found at the crests of some hills in the outcrop area in southern Indiana.

TOPOGRAPHY OF THE BEDROCK SURFACE

The topography of the bedrock erosion surface in Boone County as shown in plate 3 is considerably rougher than the topography of the present surface. Because of the unequal distribution of wells drilled to bedrock, the detail of mapping throughout the county is variable. The accuracy of the map is dependent on that of the available well records, and as additional information is obtained revision of the map will doubtless be necessary.

The wells in which bedrock has the highest elevations are BoJ26-4 (limestone at an elevation of 914 feet) and BoJ26-5 (limestone at 907 feet), in Milledgeville, and BoI22-1 (shale at 899 feet), in Advance; and the wells with lowest bedrock elevations are BoB35-1 (bedrock at 590 feet), near Pike, and BoK5-4-2 (shale at 590 feet) and BoK17-1 (limestone at approximately 600 feet), just southeast of Lebanon. The relief based on the measured elevation of bedrock in individual wells is, therefore, about 324 feet, but according to the contour map the relief within the county may be as much as 400 feet.

The contours of elevation show an escarpment paralleling the trace of the Mississippian-Devonian contact described above. A similar escarpment occurs in the outcrop area of the Borden group in southern Indiana, because of differential erosion of the more resistant rocks of the Borden group and the less resistant New Albany shale.

It is noted that east of this buried escarpment the bedrock slopes are rather gentle and uniform, averaging about 70 to 80 feet per mile, but that west of it the topography appears as a rather well defined plateau with relatively flat uplands and almost precipitous ravines. The highest elevation east of the escarpment is on a bedrock mound in secs. 9, 10, 15, and 16, T. 19 N., R. 2 E. Well HaE30-1, east of this area in Hamilton County, entered limestone at an elevation of 800 feet. West of the escarpment the plateau averages about 800 to 890 feet in elevation, with the exceptions in Milledgeville and Advance previously mentioned. The elevation of the bedrock upland declines to about 800 feet near Thorntown. Two mounds that reach elevations of 820 to 830 feet occur 2 miles north of Lebanon and midway between Royalton and Zionsville, respectively. These are probably outliers of Mississippian rocks.

The former drainage pattern of the bedrock erosion surface agrees generally with the regional subsurface drainage of central Indiana. The main tributary to the main trunk stream headed south through the center of T. 19 N., R. 1 E. It drained practically the entire eastern half and the extreme southern part of the county. The dashed line extending northeast from Lebanon on plate 3 indicates the possibility that the bedrock drainage entering Lebanon from the south might have drained along this line instead of turning northwest, as shown.

GLACIAL GEOLOGY

Glacial History

Following withdrawal of the shallow continental seas in which the sediments were deposited during the Paleozoic era, the land surface was subjected to weathering and erosion. The rock strata became consolidated and were gently folded, and erosion and weathering removed a large quantity of rock material. The surface topography, as shown by plate 3, was quite similar to parts of southern Indiana today.

During the Pleistocene epoch of geologic time, climatic changes caused the accumulation of large masses of snow and ice in the northern part of North America. As the accumulation continued, the ice masses expanded horizontally, with the greatest expansion to the south. The large masses of ice and snow, called continental glaciers, advanced at a faster rate in troughs or depressions than on the upland. The ice fronts became irregular as the rate and direction of movement of the ice front varied because of changes in climatic conditions. The glacial history and the conditions under which the glacial materials of Boone County were deposited were rather complex.

The major glacial stages, during which the ice sheets covered much of the North Central States, were separated by interglacial stages during which the materials were subject to modification by weathering and erosion. Climatic conditions during the interglacial stages may have been somewhat similar to those of the present time, as shown by the presence of swamp deposits, buried trees, and other plants within the mass of glacial deposits.

According to published reports on the glacial geology of the Midwestern States, Indiana was covered by at least two large continental ice sheets. Minor advances and retreats of the ice front were common during the major stages.

Although the deposits of the Illinoian stage are the oldest glacial deposits in Indiana for which identification has been definitely established, an earlier glacial stage may be represented. In many localities in Indiana a bed of red clay and gravel that lies immediately above the bedrock may represent the Kansan or Nebraskan stage. The deposits of the earlier glacial stage have been recognized in several states west of Indiana.

The Illinoian ice sheet covered nearly three-quarters of the State, being absent only in a triangle-shaped area in south-central Indiana. Where the Illinoian deposits are exposed at the surface their thickness is generally less than 50 feet. They may be considerably thicker, however, in central and northern Indiana.

The last ice sheet to cover central Indiana was that of the Wisconsin stage. From west to east the southern boundary of Wisconsin glaciation extends through Vigo, Parke, Putnam, Morgan, Bartholomew, Decatur, Fayette, and Franklin Counties. As the Wisconsin drift and underlying Illinoian drift are quite similar in appearance and general character, it is difficult and sometimes impossible to determine the contact between the deposits of the two glacial stages. The maximum known thickness of combined Illinoian and Wisconsin drift in Indiana is more than 500 feet and the average thickness is at least 300 feet in several counties in northern Indiana.

Subsurface Glacial Deposits

The information on the subsurface glacial materials of Boone County must be obtained from records of wells, most of which are based on the memory of the well driller or owner. Actual drilling samples were seen in only a few places and it was not possible to obtain a complete set of samples for any well. It should be remembered that these deposits were laid down under

a complex set of natural conditions and the materials may change radically within short distances both horizontally and vertically. Several gravel-pit operators claim that they have removed sand and gravel up to a nearly vertical wall of blue clay. Wells within several feet of each other are reported to have penetrated entirely different materials at similar depths. Specific examples of such differences were found in wells BoG31-4-1 and BoG31-4-2; and in BoK18-3-1 and BoK18-3-2, where one well struck a sand and gravel aquifer and the other, blue clay at the same depth.

The major part of the glacial material underlying the surface of Boone County is described by drillers as "tough blue clay" with assorted stones and boulders. This is typical boulder clay of glacial till. Interbedded with the till deposits are beds and lenses of sand and gravel that serve as underground reservoirs in which ground water is stored and from which water supplies can be obtained through wells. The sand and gravel deposits where water bearing are called aquifers. Normally sand and gravel aquifers occur at many different levels within the till deposits, but, because of their irregular areal extent, in several locations in the county wells have been drilled to bedrock without encountering an aquifer. Such failures were reported not only in the western part of the county where the drift is relatively thin but also in the eastern part when the drift cover is considerably thicker. In many cases, however, productive wells were obtained within short distances of the unsuccessful wells.

Most of the wells do not penetrate the full thickness of the aquifer tapped. The general practice for farm and domestic wells is to drill into the water-bearing formation only so far as is necessary to obtain the desired yield.

The elevation of the tops of glacial aquifers penetrated by wells in Boone County are shown on plate 4 and figures 3 and 4. These elevations are

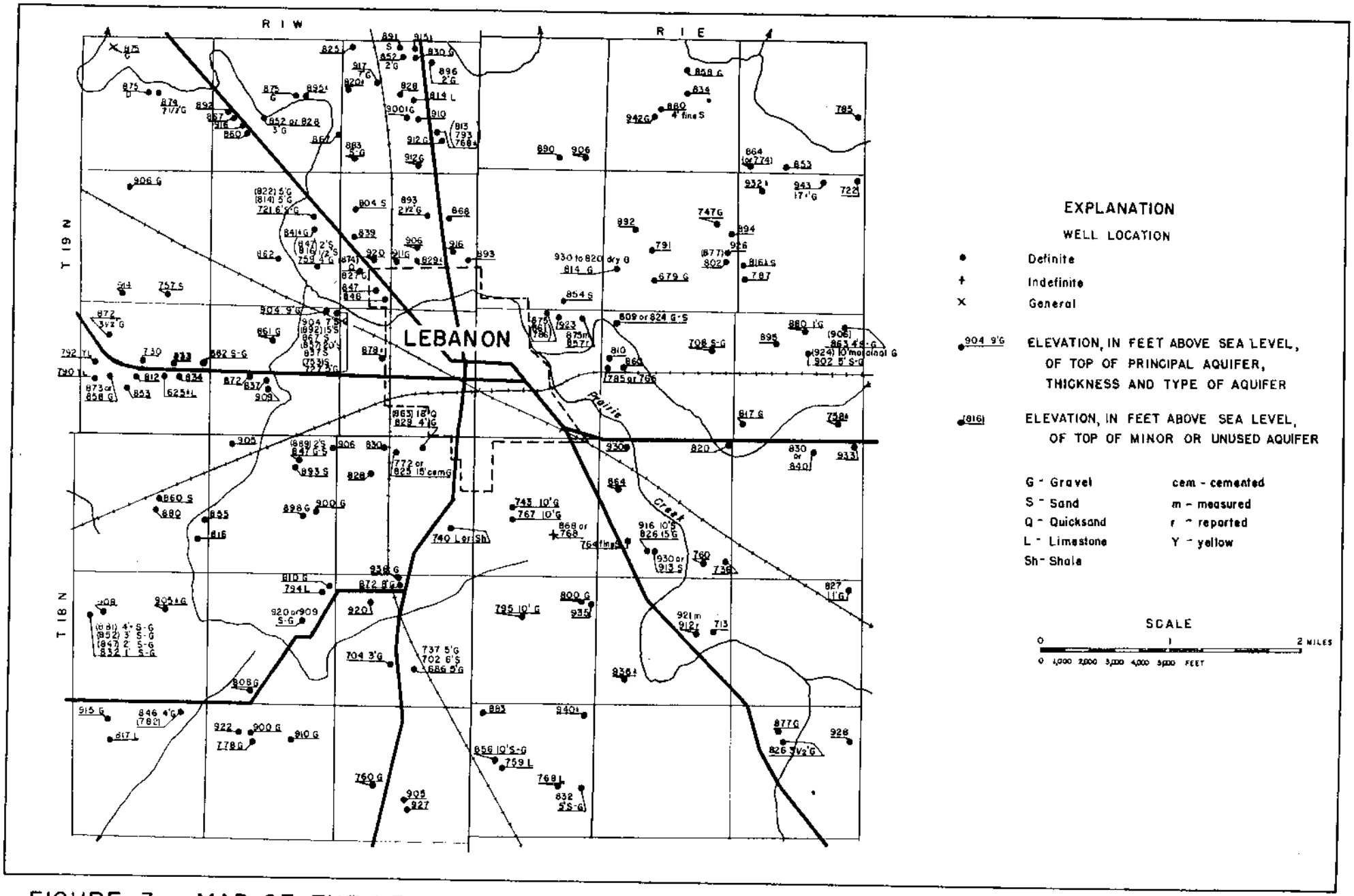

FIGURE 3. MAP OF THE LEBANON AREA, BOONE COUNTY, INDIANA, SHOWING DATA ON AQUIFERS.

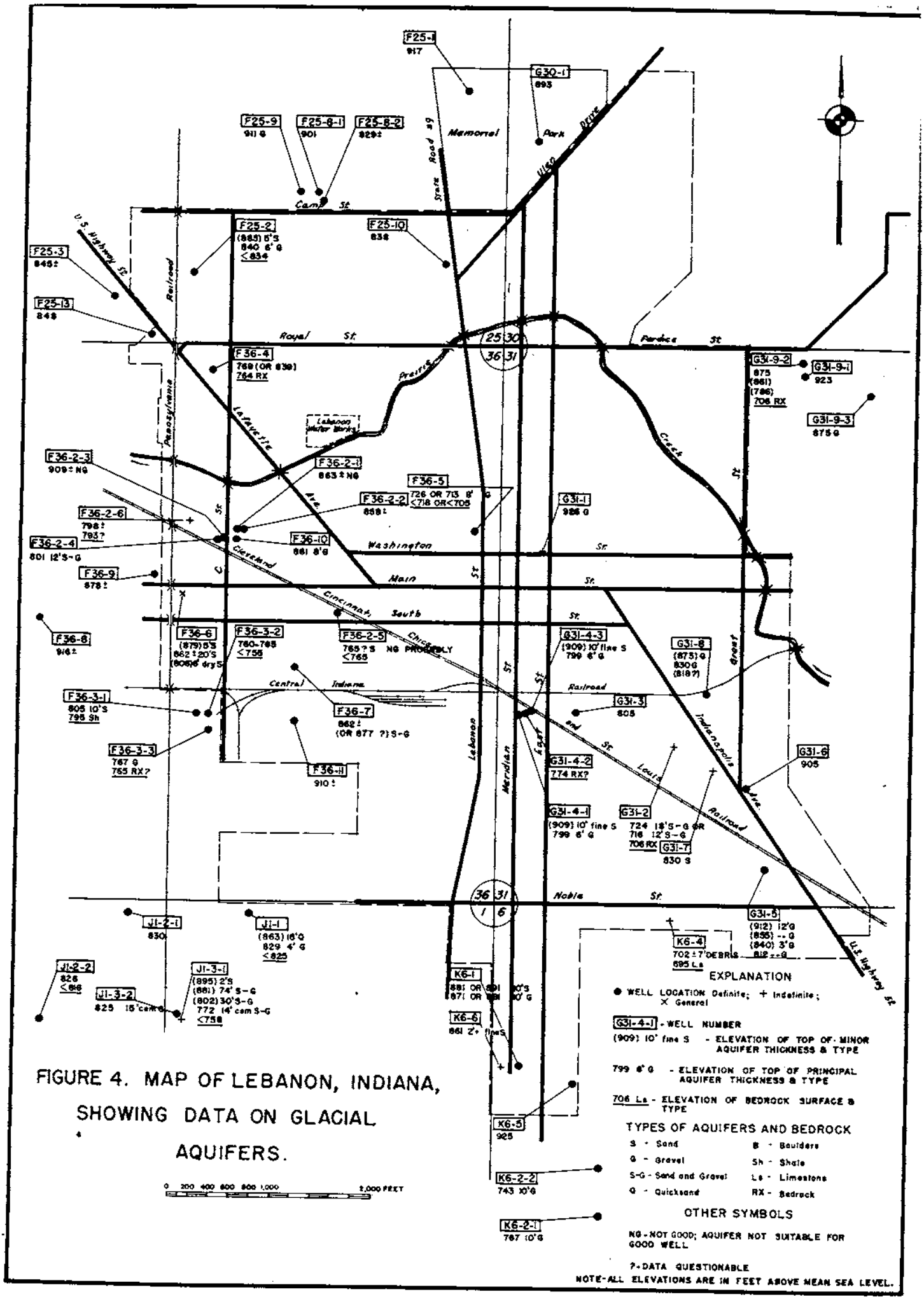

FIGURE 4. MAP OF LEBANON, INDIANA, SHOWING DATA ON GLACIAL AQUIFERS.

in feet above sea level, and in many cases are estimated on the basis of the depths of wells. The thickness in feet and/or type of aquifer are noted after the elevation for those wells in which this information is known. More detailed data are included in the well records. A study of the maps and well records reveals that the elevations of the tops of aquifers in many wells in the county are identical or nearly so, and that in certain areas some aquifers are evidently more common than others. This evidence, plus the fact that there appear to be relatively impermeable beds of considerable thickness between the aquifers, suggests that many of the aquifers were probably deposited over many parts of the county on a relatively level surface. The aquifers in certain wells may have been formed by the irregular deposition of outwash or may be the remnants of sand and gravel deposits partially removed by later erosion.

According to the well records, certain aquifers are rather extensive throughout the county outside the present stream valleys. The tops of these aquifers are found at elevations of 930, 903 to 908, 874, (860), 830 to 840, 808±, (765-775), and 740 to 750 feet above sea level. Those shown in parentheses are of relatively local importance.

The elevations above sea level of the tops of important aquifers in different parts of specific areas are given below:

Lebanon area	Sugar Creek drainage area	Eagle Creek drainage area	Southwest part of county	Extreme northeast part of county
905 to 920	874	928	925 to 930	930
(892)	860	903 to 908	910	874
875	830 to 834	868	906	750 ±
860	820	840	896 to 900	
820 to 838	808	820	884 to 890	

Lebanon area	Sugar Creek drainage area	Eagle Creek drainage area	Southwest part of county	Extreme northeast part of county
805	796	798 to 808	878 to 880	
765	785	775	870	
	773	760	832 to 838	
	734 to 740	750	810 to 814	
	724	740	784 to 788	
	701 to 706	730	740	
	662 to 666		704	

A spring in the NE¼SE¼ sec. 22, T. 19 N., R. 1 W., occurs at an elevation of about 920 feet; springs and seeps in sec. 19 and 20, T. 20 N., R. 1 E., near the center of the NE¼ sec. 26, in the N½ sec. 25, and in the SE¼SE¼ sec. 23, T. 18 N., R. 2 E., are at elevations of about 860 to 870 feet; and a spring numbered as well BoL25-2 is at an elevation of 837 feet. A number of springs in the vicinity of Big Springs occur at elevations of 915 to 935 feet.

Wells in the Lebanon area reported to have penetrated aquifers 8 feet or more are listed below:

Well No.	Owner	Elevation of top of aquifer	Thickness in feet, and type of aquifer
BoF36-1-11	Lebanon Utilities, Inc.	709	8±, Sand and gravel
BoF36-1-10A	do.	714±	12, Gravel and quicksand
BoG31-2	Industrial Land Co. of Indianapolis	724 (or 716)	18 (or 12), Sand and gravel
BoK6-2-2	Joseph Tyre	743	10, Gravel
BoK6-2-1	do.	767	10, Gravel
BoJ1-3	Pennsylvania R.R.	772	14, Cemented gravel
BoK7-2	O. E. Heflin	795	10, Gravel

Well No.	Owner	Elevation of top of aquifer	Thickness in feet, and type of aquifer
BoJ1-3	Pennsylvania R.R.	(802)	30, Sand, gravel, and boulders
BoF36-1-3	Lebanon Utilities, Inc.	833	10 or 40, Sand and gravel
BoF36-1-7	do.	842	19±, Sand and gravel
BoF36-1-8	do.	858 (or 843)	35±, Sand and gravel
BoK18-3-1	Seth Agan	856	10, Gravel and sand
BoF36-6	Pennsylvania R.R.	862±	20, Sand
BoJ1-1	Joseph LaBolle	(863)	18, Quicksand
BoK6-1	Ed Piercol	871 (or 881)	10, Gravel overlain by 10 feet of sand
BoF36-1-2	Lebanon Utilities, Inc.	886	12, Sand and gravel
BoF35-1-7	Dan Presser	904	9, Gray gravel
BoG31-5	Indiana Condensed Milk Company	(912)	12, Gravel

It is notable that the majority of wells in the Lebanon area that are reported to penetrate thick aquifers are in the southern part of Lebanon and south of it (fig. 3).

Cemented gravel was report in wells BoJ1-3 and BoF?-37 and was observed in outcrops in sec. 23, T. 18 N., R. 2 E.

Lenses of "fine sand" which may be water bearing in part are reported in many localities in the glacial drift. The greatest concentration of these sands, ranging in thickness from a few inches to as much as 70 feet (in wells BoJ22-1 and BoK30-2), is along the former drainage lines of the bedrock surface. Beds of quicksand are reported in many wells near Sugar Creek.

Other glacial materials of interest occur within the till in Boone County. Although many of these materials have little direct significance to the ground-water supplies of the area, they do assist in the interpretation of the glacial geology and, therefore, are discussed in this report.

Gas, and vegetal material ranging in size from leaves and twigs to branches and tree trunks greater than a foot in diameter (in well BoB19-2), have been found in the glacial till of Boone County. The gas is reported to be combustible in most cases, suggesting its source to be the buried vegetal material undergoing decay. Most of the wells in which gas has been reported either yield small quantities over a rather long period, or else yield strong flows for several minutes or hours and then practically cease giving off the gas. However, well BoF26-2-2, northwest of Lebanon, supplied enough gas for cooking purposes for one family for about a year before the pressure became too low. The gas may have come from a 6-foot interval of sand and gravel at a depth of 216 feet, although it did not gush forth until 8 feet of the underlying blue shale bedrock was penetrated. Fine sand forming a cone about 150 feet in diameter and 3 feet high at the apex was blown out of the well by the gas pressure in a period of about 24 hours. Gas in well BoL7-1 is believed by the owner to come from the limestone aquifer tapped at a depth of about 245 feet, under approximately 45 feet of shale.

The elevations of the top of the deposits in which vegetal matter was discovered are 676, 689, 704, 730 to 737, 750 to 753, 760 to 764, 778, 814 to 822, and 891 to 903 feet above sea level. The elevations at which gas was found are 700, 720 to 740, 760, 820±, 850, 890, and 903 feet. The source of the vegetal materials doubtless is vegetation that grew locally during interglacial stages or substages and was later buried by glacial deposition.

Leverett believed that some of the formations drilled belonged to the Illinoian or older drifts. (See notes regarding wells G-Bo??-2, at Lebanon, and G-Bo??-8, at Zionsville, in app. B.)

The term "hardpan" is used by drillers to describe several types of deposits. It is evident that some use this term to designate the usual bluish-gray boulder clay, some to designate a firm, uniform bluish-gray clay through

which it is hard to drill, and some to designate a yellow to reddish-brown compact clay. There seems to be no consistent usage of this term.

A study of the locations of wells in which unusual thicknesses of sand and buried vegetal matter are found shows that these deposits are confined largely to areas that are underlain by the deeper V-shaped bedrock valleys. It is notable that deposits ranging from 3 to 12 feet in thickness, containing dark swamp-type muck in which leaves, twigs, and branches of trees are embedded, occur at depths of 46 to 61 feet below the surface in areas that aline closely with the position and direction of a glacial sluiceway mentioned by Leverett (11, p. 96). These deposits are penetrated by wells BoH?-12, BoI?-16, and Bo?-22 at an elevation of about 895 feet above sea level. Although well BoH?-12 lies northeast of the sluiceway in the morainal area, and the muck is buried beneath the morainal deposits, the well is in line with the sluiceway. These beds probably were deposited during a minor retreat of the ice front during the Wisconsin stage.

A large elongated area along the headwaters of Eel River, heading into the morainal hills trending northwest across the county from the vicinity of Zionsville, has been mapped by Leverett (11, pl. 5), as a glacial sluiceway for the meltwaters from the ice front that formed the moraine (pl. 1). He noted that the present streams are now filling the channel, an indication that the streams were probably larger than at present. The channel appears to be quite shallow, as records of wells fail to show any thick or extensive deposits of outwash materials in this area. The greatest thickness of outwash noted is 70 feet of sand, the top of which is at an elevation of 931 feet, in well BoJ33-2. Many wells throughout Boone County were reported to penetrate a layer of sand and gravel, 2 to 10 feet thick, at elevations of about 900 to 930 feet above sea level. A comparison of plates 1 and 3 shows that the headwaters of Eel River largely overlie deep ravines in the bedrock

surface, except near Jamestown where the present stream crosses the buried uplands of the bedrock.

Yellow clay is common in the drift. It is commonly present at the top of the blue clay, but it also occurs at scattered horizons in the blue clay. Sections at an outcrop in the south side of Eagle Creek in the center of the W½W½ sec. 1, T. 17 N., R. 2 E., and in gravel pits in the SE¼SW¼ sec. 10, T. 18 N., R. 1 W., and in the W½W½NE¼ sec. 12, T. 17 N., R. 2 W., show a leached and oxidized subsoil zone below a bluish-gray calcareous clay. A 2- to 2½-foot zone of gumbotil is present above the subsoil zone in the section mentioned second above. These occurrences may be the remnants of a soil zone of the Illinoian or an older drift.

If the drainage area of the headwaters of Eel River is the site of a glacial sluiceway, as proposed by Leverett, it would have been of only local importance because of its topographic position along the divide between the White River and Wabash River drainage areas. Subsurface evidence agrees with this, as described above. A possible explanation of this basinlike area is that the moraine that was deposited diagonally across the county blocked the drainage of the area of the headwaters of Eel River and the drainage of the southeastern portion of the county from Zionsville and Northfield through the area just north of Whitestown, as shown on the bedrock map (pl. 3), causing reversal of flow and resulting in the present drainage pattern, in which the headwaters of Eel River flow southwest and Eagle Creek flows south. The morainal deposits are assumed to have filled in and built up the area of the main valley tributary to ancestral Sugar Creek, and the mouths of most of its tributaries, so that it became topographically high. (Compare pls. 1 and 3.) The position of the Sugar Creek-Eagle Creek drainage divide and the highs at Milledgeville and north of Jamestown on the present surface, occurring as a gently curved arc, might be explained by this hypothesis, or by

the theory that this area is underlain by morainal deposits of an earlier age, possibly Illinoian or earlier, or by a combination of both of these.

Surficial Glacial Deposits

The most extensive glacial deposit in Boone County is boulder clay or glacial till, commonly referred to by well drillers and natives as "blue clay." This material is primarily a blue or gray clay containing varying percentages of angular rock fragments, sand, gravel, and silt. It is derived from materials picked up by the advancing ice sheets, ground in part into a rock "flour," and dropped in place without sorting or stratification when the ice sheet became overloaded or when it melted. The till is compact and relatively impermeable and generally yields only small quantities of water to wells.

The surficial deposits of Boone County are mainly glacial till, which forms a generally level to gently rolling plain known as a till plain or ground moraine. The low mounds of the same general type of material, which occur as a discontinuous belt running northwest from the southeastern part of the county, were formed when the ice front remained at approximately the same position for a considerable time. They indicate the location of a moraine.

The stratified coarse materials found along the major drainage lines in Boone County are alluvial deposits laid down by meltwaters which issued from the glacier front when it remained stationary or retreated. They constitute outwash or a "valley train." In areas where sands and gravels were deposited by meltwaters on an almost flat surface, the deposit is called on outwash plain. The fine materials were carried away by the water.

The numerous small deposits of stratified sand and gravel scattered over Boone County were probably deposited by streams within or at the base