STATE OF INDIANA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

BULLETIN NO. 36

GROUND-WATER RESOURCES OF MONTGOMERY COUNTY, INDIANA

Prepared by the

GEOLOGICAL SURVEY

UNITED STATES DEPARTMENT OF THE INTERIOR

in cooperation with the

DIVISION OF WATER

DEPARTMENT OF NATURAL RESOURCES

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Robert F. Jackson, Chief

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GROUND-WATER RESOURCES

OF

MONTGOMERY COUNTY, INDIANA

BY L. W. CABLE AND T. M. ROBISON

ABSTRACT

Both consolidated bedrock and unconsolidated deposits contain significant water-bearing zones which may serve as a water supply in Montgomery County, in west-central Indiana.

The uppermost part of the consolidated rocks consist of a wide variety of lithologic types, with shale predominating. Shales and siltstones of the Borden Group of Mississippian age are the best aquifers. All rock types yield ample domestic supplies and in some places yield supplies adequate for small to moderate municipal or industrial needs. The maximum reported yield from the consolidated rock is 270 gpm (gallons per minute).

The chief aquifers in the unconsolidated rocks are the sand and gravel beds of the glacial outwash deposits. Valley-train aquifers in buried bedrock valleys offer the best potential for large municipal or industrial supplies. Lens-shaped aquifers occur as relatively isolated bodies within the till and (or) lake sediments and yield quantities of water generally adequate for small industrial and municipal requirements.

Water in both the unconsolidated rocks and in the shallow consolidated rocks is potable and of the calcium bicarbonate type.

INTRODUCTION

Purpose and Scope

The purpose of this investigation is to determine the availability of ground water in Montgomery County, Indiana, for domestic, agricultural, industrial, and municipal use and to provide information to aid water users in the location and development of the ground-water resources. The chief problems are related to ground-water availability and potential of the sources now being used. Further consideration is given these two aspects with respect to future water-supply development. This report includes an identification of the principal sources of ground water, a determination of the hydrologic characteristics and potential of these sources, and a determination of the chemical quality of the water.

Previous Investigations

Detailed studies of the ground-water resources of Montgomery County have not been made previously. However, reconnaissance studies of these resources were published by Leverett (1897 and 1905) and by Harrell (1935). A preliminary report on the ground-water resources of the Crawfordsville area was published by Kingsbury and Cosner (1953). A preliminary ground-water report covering the entire county was published by Watkins and Jordan (1965).

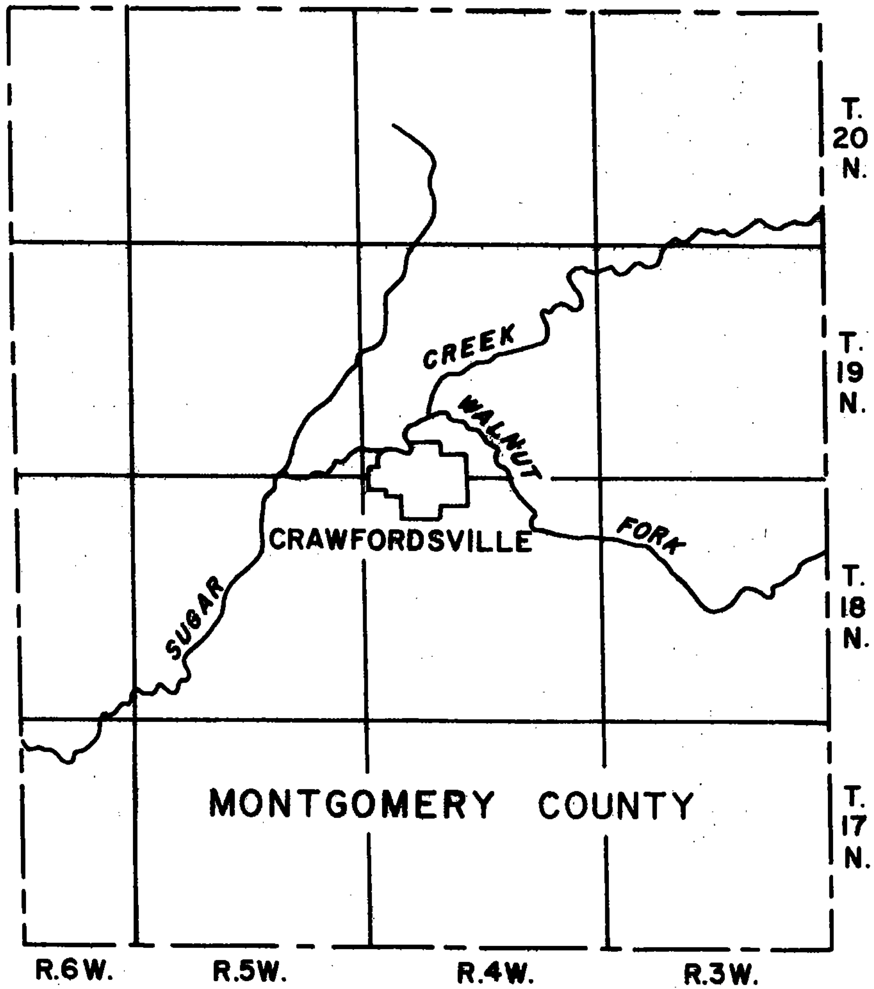
Cooperation and Acknowledgments

The investigation of the ground-water resources of Montgomery County was conducted by the U.S. Department of the Interior, Geological Survey, in cooperation with the Indiana Department of Natural Resources, Division of Water, as part of the statewide investigation of the ground-water resources of Indiana. The authors wish to express their sincere thanks to all persons who assisted in the preparation of this report. We are especially grateful to the following agencies for the information which they so generously provided: the Indiana Geological Survey, the Division of Oil and Gas, and the Division of Water, all of the Indiana Department of Natural Resources.

Physiography and Climate

Montgomery County is in west-central Indiana (fig. 1) and lies within the Tipton Till Plain physiographic province of Malott (1922, p. 59-256). The Tipton Till Plain is a constructional plain that was built up by glacial deposition during the Pleistocene Epoch. In Montgomery County, as elsewhere in this physiographic province, the topography is for the most part characterized by a level and featureless plain broken by occasional low rounded knolls and hills. In the immediate vicinity of the major streams, however, the topography may be steep and broken, and numerous bedrock outcrops are present. The county is drained by Sugar Creek and its tributaries, which are a part of the Wabash River system.

Continuous records of the air temperature and precipitation at Crawfordsville, Indiana have been kept since 1899 by the U. S. Weather Bureau. Based on normals for the 1931-1960 period the average annual air temperature was 54.9° F. and the average annual precipitation was 39.49 inches. The average monthly precipitation is shown in table 1.



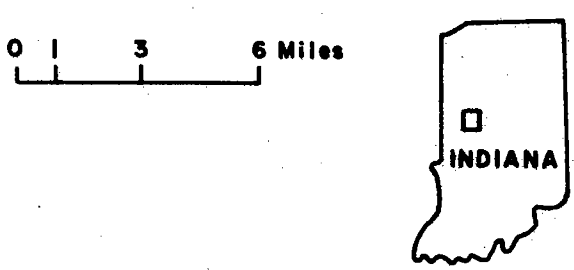


FIGURE 1.-- Map showing the location of Montgomery County, Indiana

Table 1. -- Average monthly precipitation at Crawfordsville, Indiana, 1931-1960.

Month	Precipitation (inches)
January	2.60
February	2.16
March	3.02
April	3.73
May	4.70
June	4.74
July	3.43
August	3.45
September	3.50
October	2.78
November	3.00
December	2.38

Ground-Water Occurrence and Movement

The principal source of ground water is precipitation that seeps into the soil and rock through open spaces (interstices) between individual particles. The size and degree of interconnection of the interstices (porosity) are factors important to the infiltration of water into the ground. Water in the soil or rock moves downward under the force of gravity until it reaches a level below which the interstices are saturated. This level marks the top of the zone of saturation and is termed the water table. Water in this zone is called ground water and rocks that will yield sufficient ground water to be a source of supply are referred to as aquifers.

Not all the water that seeps below land surface reaches the zone of saturation. Above the zone of saturation is the zone of aeration (suspended water) where some water is withdrawn by evaporation and transpiration and where some water is locked in the interstices by molecular attraction. Rocks in the zone of aeration are not completely saturated.

Two principal types of ground-water occurrence are present in the zone of saturation, unconfined and confined. Water in an aquifer occurs under unconfined (water-table) conditions if the aquifer is directly overlain by unsaturated material whose permeability (ability to transmit water) is similar to that of the aquifer. The water level in wells tapping such an aquifer will coincide approximately with the water level in the aquifer. Conversely, water in an aquifer is said to occur under confined (artesian) conditions if the water is under pressure, because the aquifer is directly overlain by a layer of material whose permeability is less than that of the aquifer. Such a layer retards ground-water movement and is termed "confining layer." The retardation of ground-water movement will result in an increase in hydrostatic pressure in the aquifer and this will cause the water level in wells tapping the aquifer to rise above the base of the confining layer.

The surface that coincides with the static water level in wells is termed "piezometric surface." The piezometric surface is imaginary in an artesian aquifer, because it represents not a real surface but indicates the distribution of hydrostatic pressure in the aquifer. However, under water-table conditions the piezometric surface is real because it represents the top of the zone of saturation.

Figure 2 shows diagrammatically the basic fundamentals of the source, occurrence, and movement of ground water. For a more complete explanation of the fundamentals of ground-water hydrology see Baldwin and McGuinness (1963).

GROUND-WATER RESOURCES

The rocks that underlie Montgomery County belong in two categories: consolidated and unconsolidated. Water-bearing zones in both types are sources of ground water. A summary of the stratigraphy and hydrologic properties of the principal aquifers in these rocks is shown in table 2. For this report a small municipal or industrial requirement is regarded as less than 100 gpm (gallons per minute); a moderate requirement is 100 to 300 gpm, and a large requirement is greater than 300 gpm.

The geologic names and age designations used in this report are those used by the Indiana Geological Survey and are not necessarily recognized by the U. S. Geological Survey.

Consolidated Rocks as Sources of Water

The upper part of the consolidated rocks in Montgomery County consists of a wide variety of lithologic types, with shale predominating. (See Patton, 1956). The rocks dip to the west-southwest at an average

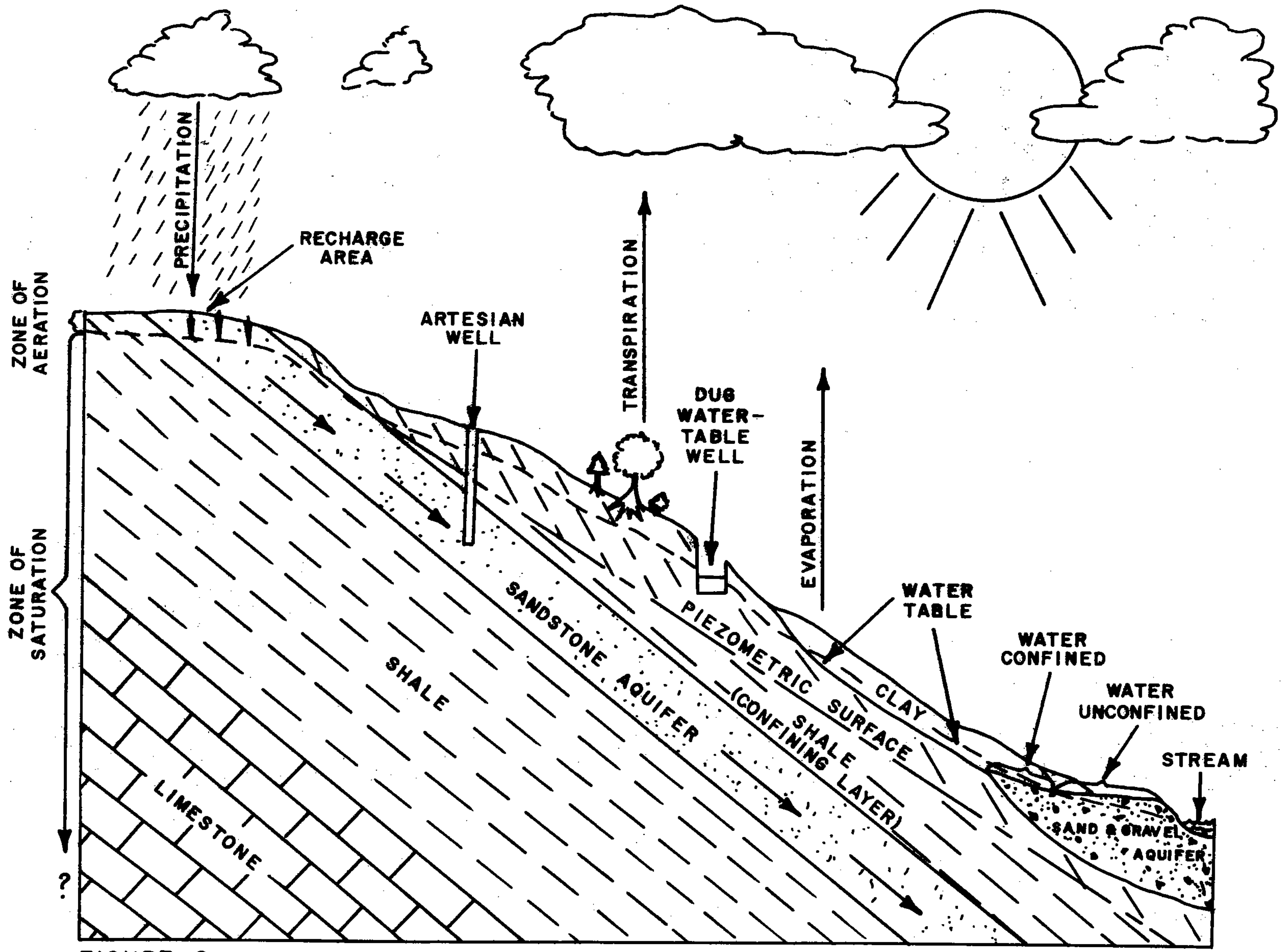


FIGURE 2. -- Fundamental principles of the source, occurrence, and movement of ground water.

Table 2.--Hydrologic properties of principal aquifers in Montgomery County, Indiana

(The rock units given are grouped chiefly by lithology and are not necessarily in stratigraphic order)

Geologic System	Aquifer description	Range and median of estimated field coefficients of permeability (gpd per sq. ft.)	Range and median of specific capacities (gpm per foot of drawdown)	Maximum reported yield (gpm)	Potential production considered adequate for:	Quality of Water	Estimated use in millions of gallons per day
Quaternary	Sand and gravel lenses within sheetlike unconsolidated deposits	150 - 7,200 median = 1,500 (20 wells)	0.2 - 30 median = 1.7 (20 wells)	120	Small to moderate municipal and industrial requirements	Calcium bicarbonate water predominates. Usually very hard and deficient in fluoride. Excessive total dissolved solids and iton common.	2.0
	Sand and gravel lenses within valley-train deposits	100 - 10,000 median = 1,000 (29 wells)	.2 - 10 median = 2.0 (30 wells)	200			
	Continuous bodies of sand and gravel within valley-train deposits	540 - 10,360 median = 1,550 (15 wells)	.7 - 175 median = 12 (14 wells)	1,000	Large municipal and industrial requirements		
Pennsylvanian	Sandstone and shale (Mansfield Formation)	*	*	60	Small municipal and industrial requirements (?)	*	
Mississippian	Limestone (limestones of Meramecian age; limestones of the Borden Group; Rockford Limestone)	12 - 770 median = 90 (17 wells)	.07 - 5 median = .7 (23 wells)	60	Small municipal and industrial requirements	Calcium bicarbonate water predominates. Usually very hard and deficient in fluoride. Excessive total dissolved solids and iron common. Moderate softening with depth.	.8
	Shale and siltstone (Borden Group)	2 - 1,000 median = 100 (56 wells)	.03 - 30 median = 1.2 (61 wells)	270	Small to moderate municipal and industrial requirements		
Mississippian and Devonian	New Albany Shale	*	*	*	*	*	.0
Devonian	Limestone	*	*	*	*	*	.0

*Insufficient data

rate of about 25 feet to the mile. Therefore, a rock unit outcropping on the bedrock surface in the northeasterly part of the county is at considerable depth below the bedrock surface in the southwestern part of the county.

It is possible that limestones of Devonian age contain fresh water in the north-central and northeastern portions of the county, where these rocks are encountered at their shallowest depth. There is no information available on the quality or quantity of water that can be obtained from these limestones.

The Devonian limestones are overlain by a black shale, the New Albany Shale of Devonian and Mississippian age. The hydrologic properties of this formation are not known. It is found at its shallowest depth in the north-central and northeastern portions of the county and is believed to crop out on the bedrock surface in the north-trending bedrock valleys in the north-central part of the county (See Patton, 1956).

The New Albany Shale in this area is overlain by a thin Mississippian limestone of unknown hydrologic characteristics, the Rockford Limestone, which is in turn overlain by the Borden Group, also of Mississippian age. The Borden Group, consisting largely of shales and siltstones (pl. 1), forms most of the bedrock surface. The group includes many irregular limestone bodies which may, in part, represent "reef" structures. (See Stockdale, 1931, p. 251-260). With the possible exception of a few widely spaced and discontinuous sandstones, the shales and siltstones are the better aquifers in this group. However, most wells in all the rock types yield more than adequate quantities of water for domestic use. A few wells yield supplies adequate for small to moderate municipal or industrial use. The highest reported yield of a well in this group, 270 gpm, is from a town well in shale at Ladoga. The towns of New Market, Wingate, Darlington, and New Richmond also obtain all or part of their public supplies from the rocks of this group.

The Borden Group is overlain by bedded limestones of Meramecian (Late Mississippian) age. The Meramecian limestones are present in the southwestern portion of the county, but probably have been eroded away north of Sugar Creek. One of the town wells at Waveland obtains most of its water from one of the Meramecian limestones. The Meramecian limestones are comparable to the Borden limestones as aquifers; several wells in both having been reported as yielding 25 gpm or more. The Meramecian limestones together with the Borden and Rockford Limestones are shown as a single unit on plate 1.

Sandstones and shales of Pennsylvanian age overlie the erosional remnants of the limestones of Meramecian age, and overlie the Borden Group where the Meramecian limestones have been eroded away. The Pennsylvanian rocks occur along the southwestern edge of the county (pl. 1). Very little is known about the Pennsylvanian rocks in the county, except that sandstone predominates and that a sandstone well at Shades Park had a reported yield of 60 gpm. Reported yields of wells in similar Pennsylvanian rocks in neighboring counties have a range of from 1 to 20 gpm and a median of 9 gpm.

The Bedrock Surface

The topography of the bedrock surface (pl. 2) controls the location and extent of major ground-water reservoirs in the unconsolidated deposits in Montgomery County. Bedrock valleys are, in many places, filled with relatively thick and continuous bodies of water-bearing sand and gravel which may serve as aquifers. The buried surface of the bedrock also forms an interface between the consolidated and unconsolidated rocks thus separating the two major ground-water environments.

The general configuration of the bedrock surface in Montgomery County is largely the result of a long interval of weathering and erosion which lasted from late Paleozoic time to the beginning of the Pleistocene Epoch, approximately 300 million years. As a result of several continental glaciations, which covered the area during Pleistocene time, the bedrock was buried beneath glacial sediments. River systems were diverted from their ancestral basins and their valleys were filled with glacial deposits so that the present land-surface topography gives very little, if any, evidence of the existence of these buried valleys.

At the beginning of the Pleistocene Epoch two major river systems, the Teays-Mahomet and the Wabash, drained the Montgomery County area and incised relatively deep and narrow V-shaped valleys into an otherwise gently rolling bedrock plain. These two bedrock valley systems are separated by a drainage divide that consists of series of bedrock highs extending diagonally across the county from approximately the southeast corner of T. 19 N., R. 3 W. to the northwest corner of T. 17 N., R. 6 W.

The Teays-Mahomet River drainage basin lies north of this bedrock divide. A prominent tributary of this drainage system, the Danville Valley (Horberg, 1950, p. 71), heads in T. 19 N., R. 3 W., near the city of Darlington, Indiana, and extends west and southwest about 20 miles to sections 18 and 19, T. 18 N., R. 6 W. The Danville Valley is the deepest and longest bedrock valley in the county. Other bedrock valley tributaries of the Teays-Mahomet system head in the northern and northwestern part of the county; however, these are of minor importance.

The pre-Pleistocene drainage basin of the Wabash River lies south of the bedrock divide. The Montclair Valley (Wayne, 1956, p. 43-44), which is actually the pre-Pleistocene course of the upper Wabash River, extends across the southeast corner of the county. Another bedrock valley of the ancestral Wabash system heads in sec. 17, T. 18 N., R. 3 W., extends generally in a southwestward direction through the southwest corner of the county.

Unconsolidated Rocks as Sources of Water

The chief source of ground water in the unconsolidated rocks of Montgomery County is the glacial outwash which contains relatively well-sorted coarse sand and gravel. Other unconsolidated rocks present in the county as till, lake sediments, loess, and Recent alluvium, are of minor importance as sources of water. No attempt has been made in this report to separate the unconsolidated rocks stratigraphically.

The glacial outwash sand and gravel aquifers are of two types: valley trains and lens-shaped deposits. (See pl. 1). The valley-train aquifers are sand and gravel bodies of significant extent and thickness that fill the principal bedrock valleys. These aquifers are mostly buried beneath relatively impervious layers of clay and (or) till so that the water is confined and under artesian pressures. Where these aquifers crop out in stream valleys, however, water-table conditions prevail.

The lens-shaped aquifers are relatively thin and discontinuous sand and gravel beds that are partially or completely enclosed within less permeable tills and lake sediments. The sand and gravel beds may occur alone, or they may be extensions of much larger bodies. Although these aquifers may be found throughout the county, they are more numerous in the north-central and northwestern parts of the county. (See pl. 1). They also occur at many places in the layers of clay and till which overlie the valley-train sand and gravel bodies.

A series of generalized geologic cross sections in the vicinity of the city of Crawfordsville, Indiana, is shown on plate 3. These cross sections illustrate the relationship of the valley-train aquifers to the bedrock valleys as well as to the overlying clay and till. As is shown by the cross section, the valley-train sand and gravel deposits are situated at the base of the Quaternary section and usually are in direct contact with the bedrock surface. Also shown in this illustration are a number of the lens-shaped aquifers which occur in the clay and till. These cross sections are considered to be representative of the unconsolidated rocks throughout the entire county. Wells included in the cross sections are numbered consecutively from 1 to 67, and their location to the nearest quarter, quarter section is given in the Appendix.

The average permeabilities of the lens-shaped aquifers and that of the valley-train aquifers are similar. (See table 2). However, the permeability within the valley-train aquifers is not uniform and tends to increase with depth. This is due to an increase in grain size from the top to the base of the aquifer. An increase in grain size with depth has been noted also in similar deposits in adjacent areas (Rosenshein, 1958, p. 12-13).

Yields of wells in the glacial outwash aquifers range from less than 10 gpm to as much as 1,000 gpm. Because of their thickness and areal extent, yields from wells in the valley-train aquifers generally are substantially higher than those from wells in the lens-shaped aquifers. The maximum yields reported from both aquifer types are shown in table 2.

The best potential sources of large supplies of potable ground water in the county are the valley-train aquifers but only a small part of the water available in these aquifers is currently being used. For example, in the vicinity of Crawfordsville, where valley-train aquifers are the principal source of ground water, current withdrawals are well below the amount that could be withdrawn without depleting aquifer storage. Yields from properly constructed wells in these aquifers should be adequate for large industrial or large municipal requirements.

When large quantities of water are being sought in the buried valleys it is advisable to do exploratory drilling in order to determine if sand and gravel bodies are present, and to locate the thickest parts of these bodies. A line of test holes should be drilled straight across the bedrock valley; the number and the spacing of test holes will depend on the size of the valley. Once the aquifer is located information concerning its lateral extent may be obtained by drilling an additional line of test holes at right angles to the first or along the valley trend.

Figure 3 shows schematically an example of the correct method of exploratory drilling in buried valleys. Illustration A in the figure shows contours on the bedrock surface revealing a buried valley, and two lines of test holes (A-A' and B-B'). The cross sections along the two lines are shown in B and C. Line A-A' goes straight across the valley and the cross section shows that test holes 4, 5, 6, 7, and 8 penetrated a body of sand and gravel, and that the thickest part of this body was encountered in test hole 6. Line B-B' goes along the valley trend and the cross section shows that the thickness of the sand and gravel body remains relatively constant laterally.

Recharge

Recharge to the consolidated and unconsolidated rock aquifers in Montgomery County is greatly in excess of current withdrawals. The total withdrawal is estimated to be 2.8 mgd (million gallons per day). Of this amount, 2.0 mgd cones from the unconsolidated rock aquifers, and 0.8 mgd comes from aquifers in the consolidated rock. It has been estimated that, of the total annual precipitation at Crawfordsville, 10 per cent is recharged into ground-water aquifers (Klaer, 1950). Over the entire county this would amount to approximately 30 mgd of recharge.

Water-Level Fluctuations

Water levels in wells fluctuate as the result of seasonal variations in the ratio of recharge to discharge in the aquifer. When the rate of recharge exceeds that of discharge, the supply of water in the aquifer is replenished and the water level in wells in the aquifer will rise; conversely, when the rate of discharge from the aquifer exceeds that of recharge, water is withdrawn from storage and the water level in wells in the aquifer will decline. Normally the water level in a nonpumped well

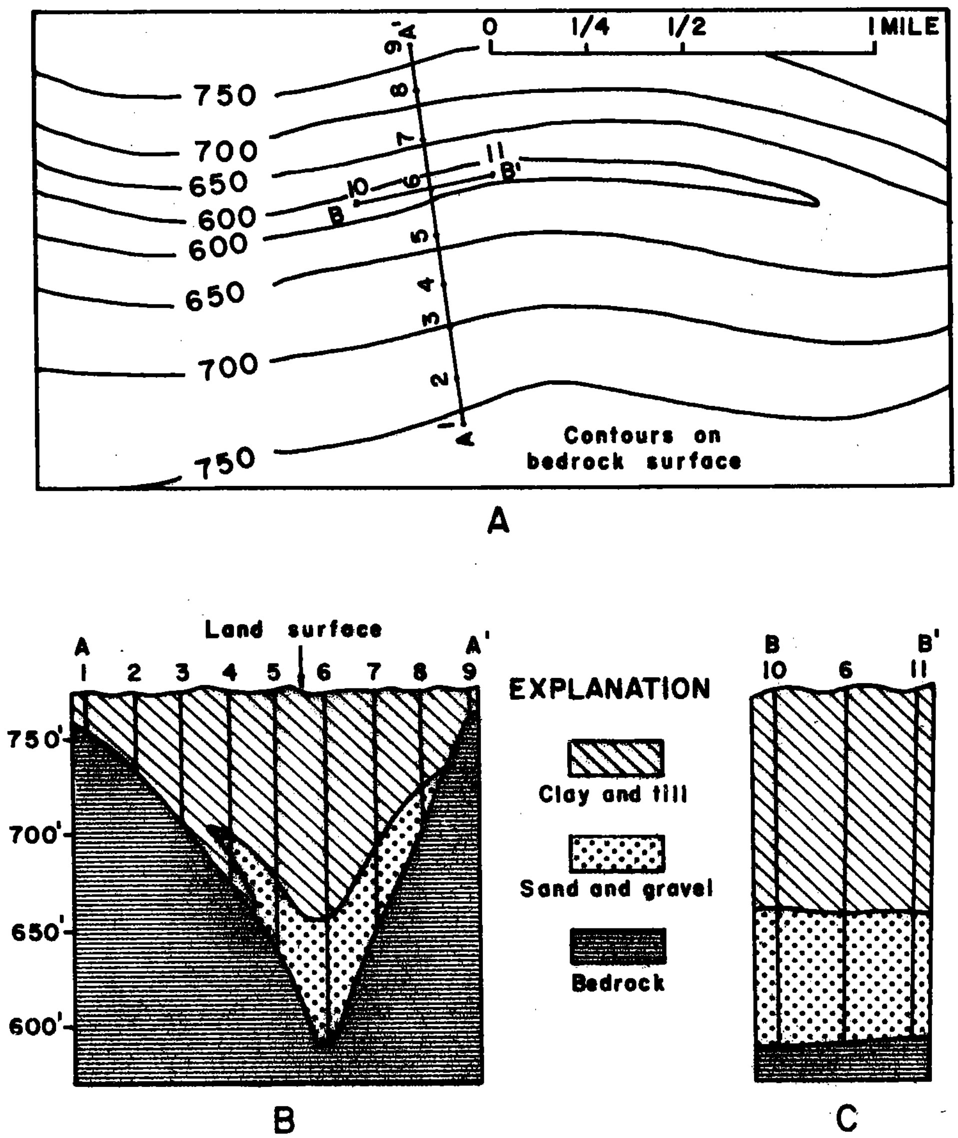


FIGURE 3.--Recommended method of exploratory drilling in buried bedrock valleys.

will be highest in midspring and will decline steadily throughout the remaining spring and summer months reaching its lowest point in mid-autumn. This is the result principally of an increase in the amount of water withdrawn from the soil by evaporation and transpiration during the late spring and summer months. The general increase in the amount of water used for agricultural, recreational, and domestic purposes during this period is also a contributing factor. After the low point is reached, the water level will begin a rising trend and will generally rise steadily throughout the late autumn and winter months.

The amount of seasonal fluctuation of water levels in the unconsolidated rocks and in the consolidated rocks is shown by the hydrographs for representative wells (fig. 4). A graph of the monthly precipitation at Crawfordsville, Indiana, is also shown on this figure. Figure 4A shows the hydrograph of observation well Montgomery 1 over a 5 year, 8 month period. This well is in an unconsolidated aquifer (sand and gravel) which is in the NE¼ NW¼ sec. 36, T. 17 N., R. 6 W. Figure 4B shows the hydrograph of observation well Montgomery 6 over a 4 year, 8 month period. This well is in consolidated rock and is located in the NW¼ SE¼ sec. 18, T. 17 N., R. 3 W. These hydrographs demonstrate the cyclic nature of annual water-level fluctuation to precipitation. The general shape of the hydrographs shown in figure 4 is considered to be representative of nonpumped wells in the two major rock types in Montgomery County.

Quality of Water

A tabulation of complete chemical analyses of water samples from both consolidated and unconsolidated rock aquifers is shown in table 3. A tabulation of 351 partial analyses can be found in Watkins and Jordan (1965). The significance of, and the recommended limits for, the various constituents are shown in table 4. The following conclusions are based on statistical interpretation of the complete and partial analyses.

The quality of water from the unconsolidated and shallow consolidated rocks is very similar. Most of the water in these rocks is very hard (see classification, table 4), having a hardness concentration exceeding 300 ppm (parts per million). In some instances, water from deep wells in the consolidated rock shows almost complete softening due to natural zeolitic action (analysis 7, table 3). However, most water from deep wells is very hard, having a hardness concentration exceeding 200 ppm.

Ground water in the area tends to be deficient in fluoride, but generally has high concentrations of iron, bicarbonate and total dissolved solids with relation to the recommended limits shown in table 4.

Reported or confirmed occurrences of mineralized water are too rare to permit determination of the depths to and types of mineralized waters in the county. Although there are minor increases in the mineral content of water in the consolidated rocks with depth, and to a lesser extent in the unconsolidated rocks, adequate supplies of water are normally obtained above the level at which mineralized water occurs.

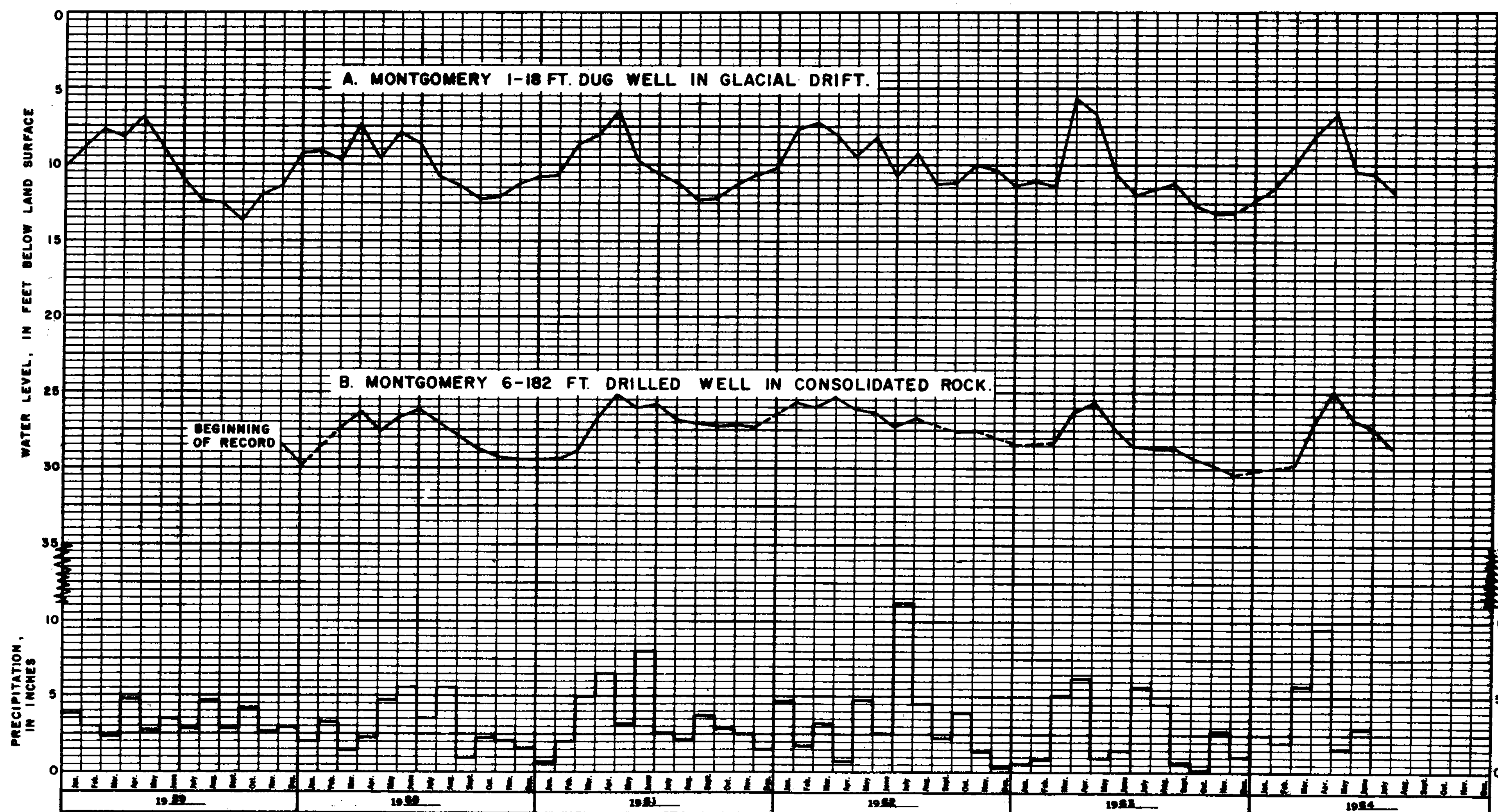


FIGURE 4.--HYDROGRAPHS OF OBSERVATION WELLS IN MONTGOMERY COUNTY AND PRECIPITATION AT CRAWFORDSVILLE, INDIANA SHOWING THE AVERAGE AMOUNT OF WATER-LEVEL FLUCTUATION TO BE EXPECTED AS A RESULT OF SEASONAL VARIATION IN RECHARGE.

Table 3.--Chemical analyses of Ground Water in Montgomery County, Indiana

(Results given in parts per million except as indicated)

No.	Well Location	Well Depth (feet)	Date of Collection	Temp. (°F.)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (Calculated)	Hardness as $CaCO_3$	Noncarbonate Hardness	Specific Conductance (Micromhos at 25° C.)	pH	Remarks
Rocks of Mississippian age																							
1.	Sec. 8, T. 19 N., R. 3 W.	------	11-54	----	----	0.03	0	96	36	29	5	340	--	89	17	0.0	0.6[a]	-----	385	-----	-----	7.4	Darlington PWS. ISBH.
2.	Sec. 36, T. 17 N., R. 6 W.	------	2-19-58	----	----	1.3	.05	84	34	20	2	351	--	19	8	.6	.1[a]	-----	348	-----	-----	7.6	Waveland PWS. ISBH. Chlorinated sample.
3.	Sec. 18, T. 17 N., R. 3 W.	------	6-11-59	----	----	1.1	.04±	92	28	7	1	285	--	58	10	.1	.2[a]	-----	285	-----	-----	7.7	Ladoga PWS. ISBH. Chlorinated sample.
4.	NE¼NW¼ sec. 26, T. 20 N., R. 3 W.	53	5-16-62	51	15	2.0	.13	123	35	11	1.1	398	0	105	30	.2	.1	519	451	125	835	7.8	USGS.
5.	NE¼NE¼ sec. 30, T. 19 N., R. 4 W.	55	5-25-64	53	10	.04	.03	96	38	7.7	.9	342	0	110	14	.2	4.5	450	396	116	734	6.9	USGS.
6.	SW¼NW¼ sec. 2, T. 17 N., R. 6 W.	100	5-25-64	52	16	1.5	.06	80	36	6.8	1.2	398	0	26	4.0	.3	1.0	369	348	22	622	7.0	USGS.
7.	SE¼SE¼ sec. 30, T. 18 N., R. 3 W.	132	5-25-64	51	14	.26	.03	.2	.0	231	.3	500	0	7.0	62	.8	.4	562	1	0	928	7.3	USGS.
Rocks of Quaternary age																							
8.	Sec. 14, T. 19 N., R. 6 W.	------	11-56	----	----	1.1	.05	88	29	16	2	318	--	42	3	.3	.1[a]	-----	339	-----	-----	7.5	Waynetown PWS. ISBH.
9.	Sec. 7 or 8, T. 20 N., R. 4 W.	------	2-27-58	----	----	1.6	0	67	36	24	3	358	--	0	5	.7	0[a]	-----	316	-----	-----	8.0	Linden PWS. ISBH. Chlorinated sample.
10.	Sec. 32, T. 19 N., R. 4 W.	------	10-11-60	----	----	1.5	.2	119	39	17	4	340	--	120	32	0	0[a]	-----	460	-----	-----	7.3	Crawfordsville PWS. ISBH.
11.	NW¼SW¼ sec. 13, T. 19 N., R. 3 W.	32	5-25-64	52	13	2.1	.06	87	29	5.1	.7	334	0	65	11	.2	.2	378	336	62	626	6.9	USGS.
12.	SW¼SW¼ sec. 8, T. 17 N., R. 3 W.	62	5-26-64	54	18	3.9	.03	119	41	8.8	.7	448	0	74	33	.3	.5	520	466	98	860	7.0	USGS.
13.	SW¼SW¼ sec. 32, T. 18 N., R. 4 W.	113?	8-3-53	58	11	.39	.13	108	39	12	3.1	406	0	89	19	.0	2.0	488	432	-----	803	7.4	USGS.
14.	SW¼SE¼ sec. 29, T. 18 N., R. 3 W.	136	5-26-64	52	14	1.7	.03	66	27	49	1.2	440	0	.2	14	.6	.2	391	276	0	686	6.8	USGS.

Abbreviations used: PWS = Public water supply; USGS = analysis by United States Geological Survey; ISBH = analysis by Indiana State Board of Health.

a/ Nitrate reported as N. To obtain an approximation as nitrate multiply by 4.43.

Table 4.--Significance of dissolved mineral constituents and properties of ground water

Constituent or property	Significance
Iron (Fe)	Excessive amounts cause: "red water"; yellowish- or reddish-brown laundry and fixture stains; slimy iron bacteria growths in wells, pipes and tanks; bitter taste. The U. S. Public Health Service recommends that iron should not exceed 0.3 ppm on the basis of taste and laundry use.*
Manganese (Mn)	Similar to iron. Causes dark stains. U. S. Public Health Service recommends that the manganese concentration should not exceed 0.05 ppm.*
Calcium (Ca) and Magnesium (Mg)	Principal cause of hardness. (See Hardness.)
Sodium (Na)	High concentrations may cause water to be unsuitable for agriculture.
Potassium (K)	Chemically similar to sodium.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Principal alkaline factors in water. (See Hardness.)
Sulfate (SO_4)	In combination with calcium forms hard scale in boilers. In high concentrations imparts bitter taste to water. U. S. Puble Health Service recommends that the sulfate concentration should not exceed 250 ppm, based largely on taste.*
Chloride (Cl)	In high concentrations chloride increases the corrosiveness of water and imparts a salty taste. The U. S. Public Health Service recommended maximum is 250 ppm, based upon taste.*
Fluoride (F)	In low concentrations fluoride reduces tooth decay. In higher concentrations tooth mottling or bone damage may occur. The U. S. Public Health Service recommendations are based on the annual average of maximum daily air temperatures. For Montgomery County area the recommended limits are: minimum= 0.7 ppm; optimum = 0.9 ppm; maximum = 1.2 ppm.*
Nitrate (NO_3)	A high nitrate concentration may cause methemoglobinemia (blue-baby disease) in infants. The U. S. Public Health Service recommends a limit of 45 ppm.*
Dissolved Solids	U. S. Public Health Service recommends a limit of 500 ppm.*
Hardness as $CaCO_3$	Consumes soap by formation of scum. Primarily due to calcium and magnesium. When these constituents are combined with bicarbonate they cause temporary or carbonate hardness. A widely used hardness scale is: 60 ppm, soft; 61 to 120 ppm, moderately hard; 121 to 200 ppm, hard; more than 200 ppm, very hard.
Hydrogen-ion concentration (pH)	Measure of alkalinity-acidity. 0 to 7 denotes decreasing acidity; 7 neutrality; 7 to 14 increasing alkalinity

*U. S. Public Health Service (1962)

SUMMARY

Consolidated rocks of Devonian, Mississippian and Pennsylvanian ages, and unconsolidated rocks of Quaternary age immediately underlie Montgomery County. Both the consolidated and unconsolidated rocks contain significant zones of potable ground water.

Aquifers in the unconsolidated rock consist chiefly of glacial outwash sand and gravel deposits. Sand and gravel aquifers are of two types: valley trains and lens-shaped. The valley-train aquifers are the thickest and most extensive unconsolidated rock aquifers of the area. They fill the major buried bedrock valleys and in places are more than 125 feet thick. The lens-shaped aquifers occur as relatively isolated bodies within the till and (or) lake sediments. These aquifers are either small disconnected pockets of sand and gravel or they may be stringers from larger bodies.

The best potential sources of large supplies of potable ground water in the county are the valley-train aquifers. Only a small part of the water available in these aquifers is currently being used. Yields from properly constructed wells in these aquifers should be adequate for large industrial or large municipal requirements. However, test drilling is necessary in order to determine the most suitable location for large-capacity wells.

The upper part of the consolidated rock consists of a variety of lithologic types, with shale predominating. Although shale, siltstone, and sandstone are the best aquifers, all rock types usually yield good supplies for domestic use and occasionally yield adequate supplies for small to moderate municipal or industrial needs.

Recharge to the consolidated and unconsolidated rocks is considered to be greatly in excess of current withdrawals. The total withdrawal from both rock types is estimated to be 2.8 mgd, while the total recharge is estimated to be approximately 30 mgd.

Water in both the unconsolidated and consolidated rocks is usually potable and is generally of the calcium bicarbonate type. However, the water in the bedrock tends to become increasingly mineralized with depth.

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______1958, Glacial geology of Indiana: Indiana Dept. Conserv., Geol. Survey Atlas of Mineral Resources of Indiana Map 10.

APPENDIX

LOCATION OF WELLS SHOWN IN CROSS SECTIONS ON PLATE 4.

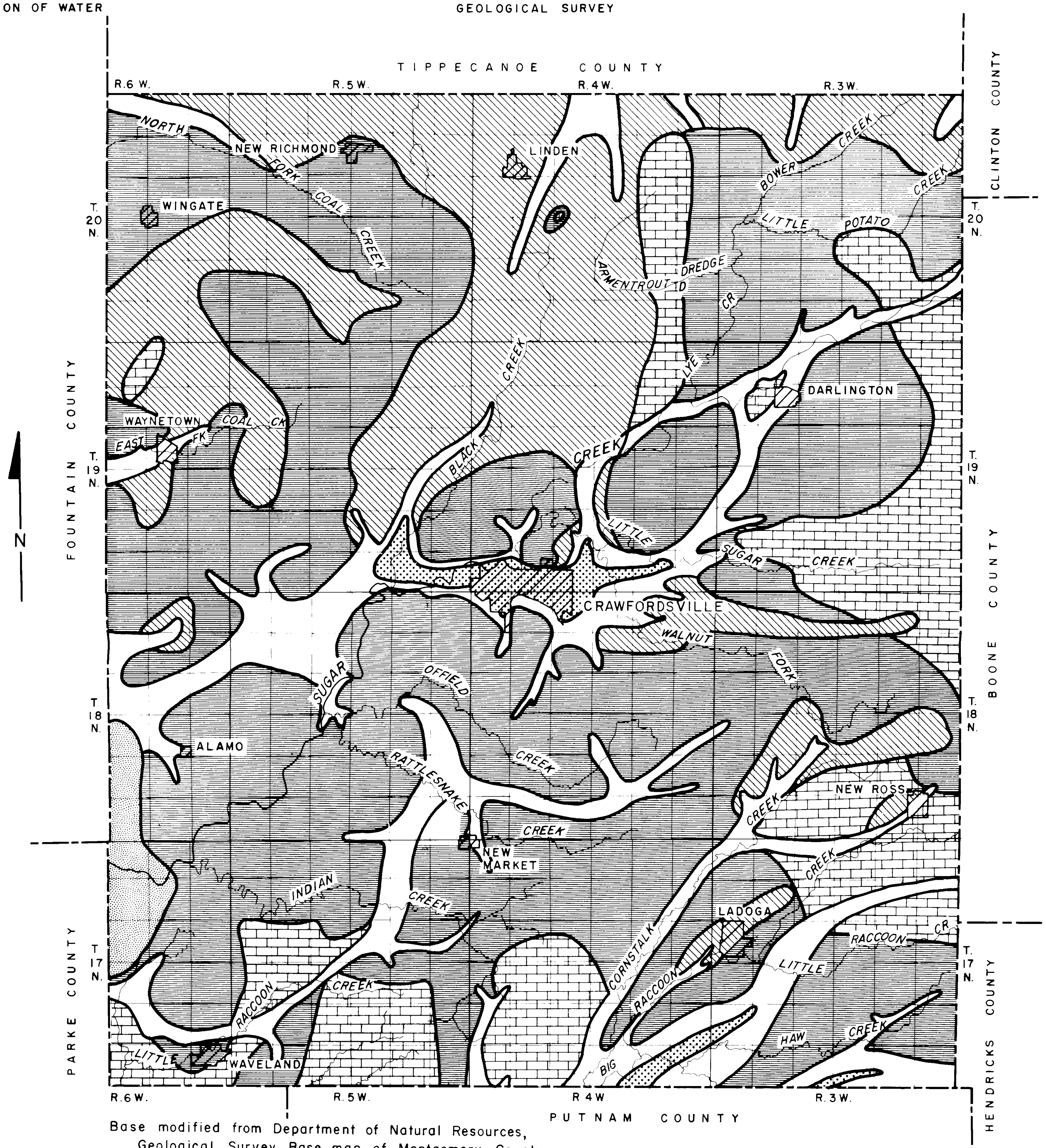
Well No.	Location
1	SE¼NW¼ sec. 2, T. 18 N., R. 5 W.
2	SE¼SW¼ sec. 35, T. 19 N., R. 5 W.
3	SW¼NE¼ sec. 2, T. 18 N., R. 5 W.
4	NW¼NE¼ sec. 2, T. 18 N., R. 5 W.
5	NE¼NE¼ sec. 2, T. 18 N., R. 5 W.
6	NE¼NE¼ sec. 2, T. 18 N., R. 5 W.
7	NE¼SE¼ sec. 3, T. 19 N., R. 5 W.
8	NW¼NE¼ sec. 35, T. 19 N., R. 5 W.
9	SE¼SE¼ sec. 26, T. 19 N., R. 5 W.
10	SE¼SE¼ sec. 26, T. 19 N., R. 5 W.
11	NW¼SE¼ sec. 26, T. 19 N., R. 5 W.
12	NW¼SE¼ sec. 26, T. 19 N., R. 5 W.
13	NE¼SE¼ sec. 26, T. 19 N., R. 5 W.
14	NE¼SE¼ sec. 26, T. 19 N., R. 5 W.
15	NE¼NE¼ sec. 2, T. 18 N., R. 5 W.
16	NE¼NW¼ sec. 1, T. 18 N., R. 5 W.
17	NE¼NW¼ sec. 1, T. 18 N., R. 5 W.
18	NW¼NE¼ sec. 1, T. 18 N., R. 5 W.
19	NE¼NW¼ sec. 6, T. 18 N., R. 4 W.
20	NW¼SW¼ sec. 17, T. 18 N., R. 4 W.
21	NE¼SE¼ sec. 7, T. 18 N., R. 4 W.
22	NE¼NW¼ sec. 7, T. 18 N., R. 4 W.
23	NW¼SE¼ sec. 6, T. 18 N., R. 4 W.
24	NE¼NE¼ sec. 6, T. 18 N., R. 4 W.
25	SE¼NE¼ sec. 31, T. 19 N., R. 4 W.
26	NE¼SE¼ sec. 30, T. 19 N., R. 4 W.
27	NE¼SE¼ sec. 30, T. 19 N., R. 4 W.
28	SW¼NE¼ sec. 30, T. 19 N., R. 4 W.
29	SW¼SE¼ sec. 19, T. 19 N., R. 4 W.
30	SE¼SE¼ sec. 19, T. 19 N., R. 4 W.
31	SE¼NE¼ sec. 19, T. 19 N., R. 4 W.
32	SE¼NE¼ sec. 7, T. 18 N., R. 4 W.
33	NW¼NW¼ sec. 8, T. 18 N., R. 4 W.
34	SE¼SE¼ sec. 6, T. 18 N., R. 4 W.
35	SE¼NE¼ sec. 6, T. 18 N., R. 4 W.
36	NE¼NE¼ sec. 6, T. 18 N., R. 4 W.
37	SW¼SW¼ sec. 32, T. 19 N., R. 4 W.
38	NE¼SW¼ sec. 32, T. 19 N., R. 4 W.
39	NW¼SE¼ sec. 32, T. 19 N., R. 4 W.
40	SE¼SW¼ sec. 28, T. 19 N., R. 4 W.
41	SE¼NE¼ sec. 28, T. 19 N., R. 4 W.
42	SE¼NE¼ sec. 28, T. 19 N., R. 4 W.
43	NE¼NE¼ sec. 28, T. 19 N., R. 4 W.
44	SE¼NE¼ sec. 21, T. 19 N., R. 4 W.
45	NW¼SW¼ sec. 5, T. 19 N., R. 4 W.
46	NW¼NE¼ sec. 5, T. 18 N., R. 4 W.

Well No.	Location
47	NE¼NE¼ sec. 5, T. 18 N., R. 4 W.
48	NE¼NE¼ sec. 5, T. 18 N., R. 4 W.
49	SE¼SE¼ sec. 8, T. 18 N., R. 4 W.
50	NW¼SW¼ sec. 9, T. 18 N., R. 4 W.
51	NW¼SE¼ sec. 4, T. 18 N., R. 4 W.
52	NE¼NE¼ sec. 4, T. 18 N., R. 4 W.
53	SE¼SE¼ sec. 33, T. 19 N., R. 4 W.
54	SE¼SE¼ sec. 33, T. 19 N., R. 4 W.
55	SW¼NW¼ sec. 34, T. 19 N., R. 4 W.
56	SW¼NW¼ sec. 34, T. 19 N., R. 4 W.
57	NW¼NW¼ sec. 34, T. 19 N., R. 4 W.
58	NW¼NW¼ sec. 34, T. 19 N., R. 4 W.
59	SE¼NW¼ sec. 27, T. 19 N., R. 4 W.
60	NW¼SW¼ sec. 3, T. 18 N., R. 4 W.
61	NW¼SW¼ sec. 3, T. 18 N., R. 4 W.
62	NW¼SE¼ sec. 11, T. 18 N., R. 4 W.
63	NW¼SW¼ sec. 2, T. 18 N., R. 4 W.
64	SW¼NW¼ sec. 2, T. 18 N., R. 4 W.
65	SW¼SW¼ sec. 35, T. 19 N., R. 4 W.
66	SE¼NW¼ sec. 35, T. 19 N., R. 4 W.
67	SE¼NE¼ sec. 27, T. 19 N., R. 4 W.

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BULLETIN 36 PLATE I



Base modified from Department of Natural Resources,
Geological Survey, Base map of Montgomery County,
No. 54 September 25, 1953

0 1 2 3 4 5 6 MILES

DATUM IS MEAN SEA LEVEL

HYDROLOGY BY
C.W. CABLE
1964

EXPLANATION

Production from unconsolidated rocks

Most wells obtain water from the sheetlike younger till deposits containing lens-shaped bodies of sand and gravel at one or more levels. Reported well depths range from 14 to 128 feet. Yields usually more than adequate for domestic and stock supplies and often adequate for small municipal and industrial supplies. In some areas these deposits overlie valley-train deposits, in which case, water supplies can be obtained from either.

Most wells obtain water from valley-train deposits containing discontinuous bodies of sand and gravel. Reported well depths range from 20 to 193 feet. Yields usually more than adequate for domestic and stock use and often adequate for small municipal and industrial supplies.

Most wells obtain water from valley-train deposits containing continuous bodies of sand and gravel. Reported well depths range from 43 to 164 feet. Yields usually adequate for small to large municipal and industrial supplies.

Production from consolidated rocks

Most wells obtain water from Pennsylvanian sandstones. Reported well depths range from 80 to 122 feet. Yields usually more than adequate for domestic and stock supplies and perhaps adequate for municipal and industrial supplies.

Most wells obtain water from Mississippian limestones. Reported well depths range from 25 to 295 feet. Yields usually more than adequate for domestic and stock supplies and occasionally adequate for small municipal and industrial supplies.

Most wells obtain water from Mississippian shales and siltstones (Borden Group). Reported well depths range from 30 to 320 feet. Yields usually more than adequate for domestic and stock use and occasionally adequate for small to moderate municipal and industrial supplies.

Approximate boundary of geologic formations

Drafting by: D.N.R.
Supv. B.C. Daniels
Drafts. C.K. Williams

MAP OF MONTGOMERY COUNTY, INDIANA SHOWING AVAILABILITY OF GROUND WATER
1964

STATE OF INDIANA
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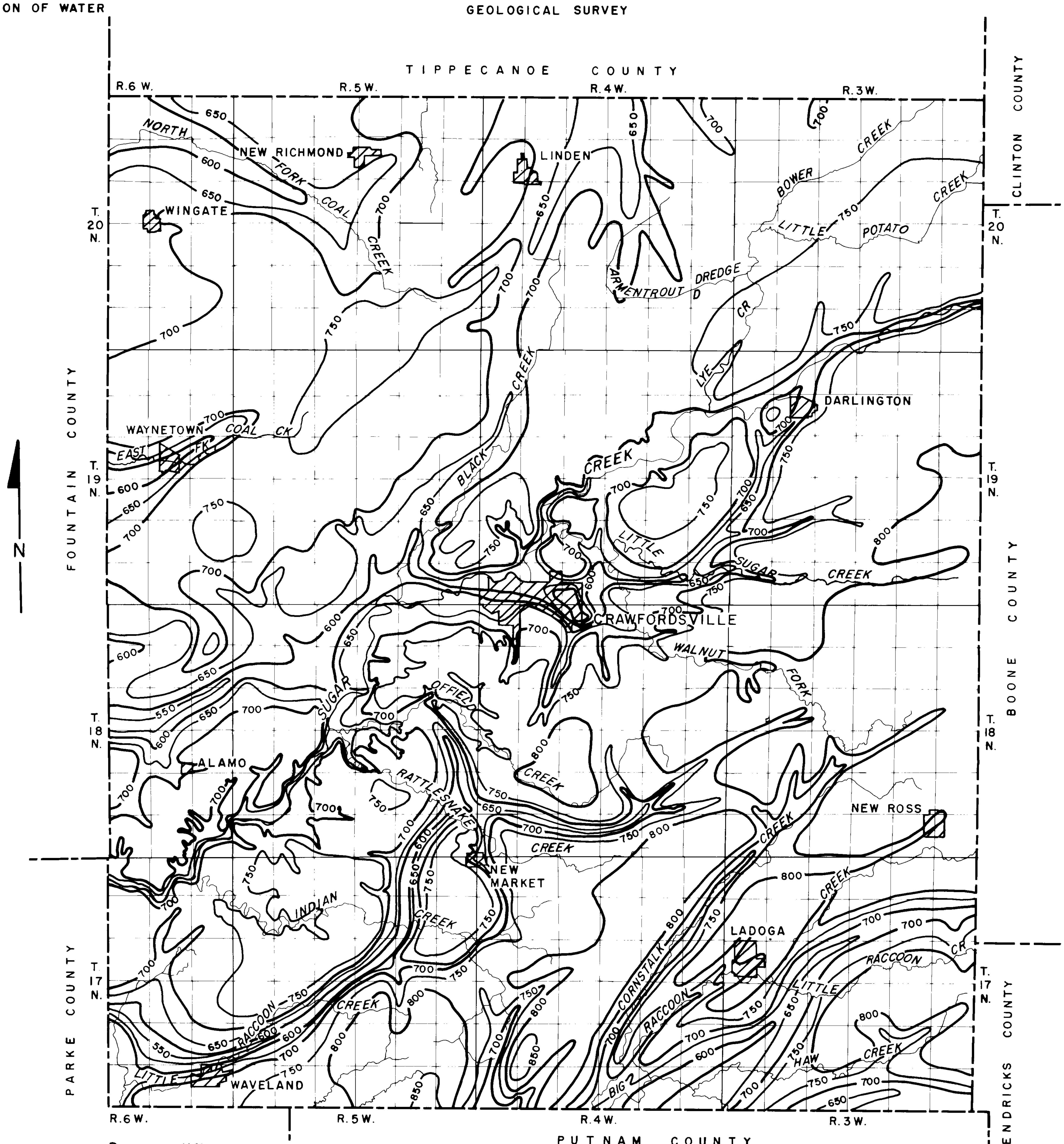
BULLETIN 36 PLATE 2



Base modified from Department of Natural Resources,
Geological Survey, Base map of Montgomery County,
No. 54 September 25, 1953.

Drafting by: D.N.R.
Supv. B.C. Daniels
Drafts. C.K. Williams

0 1 2 3 4 5 6 MILES

DATUM IS MEAN SEA LEVEL
CONTOUR INTERVAL IS 50 FEET

MAP OF MONTGOMERY COUNTY, INDIANA SHOWING TOPOGRAPHY OF BEDROCK SURFACE
1964

STATE OF INDIANA
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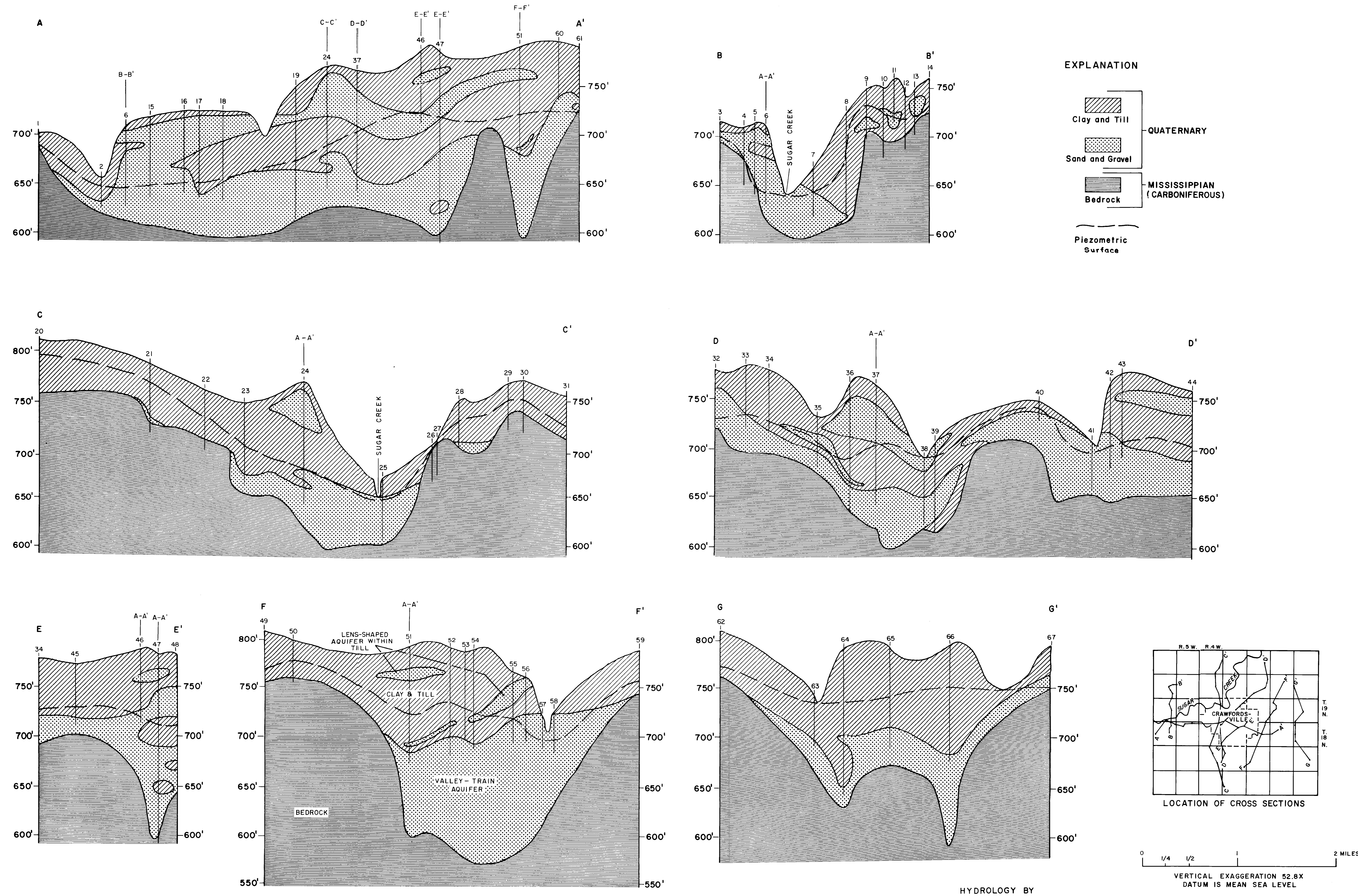

HYDROLOGY BY
C.W. CABLE
1964

Drafting by: D.N.R.
Supv. B.C. Daniels
Drafts. C.K. Williams

CROSS SECTIONS SHOWING GENERALIZED SUBSURFACE GEOLOGY IN THE VICINITY OF CRAWFORDSVILLE, INDIANA
1964