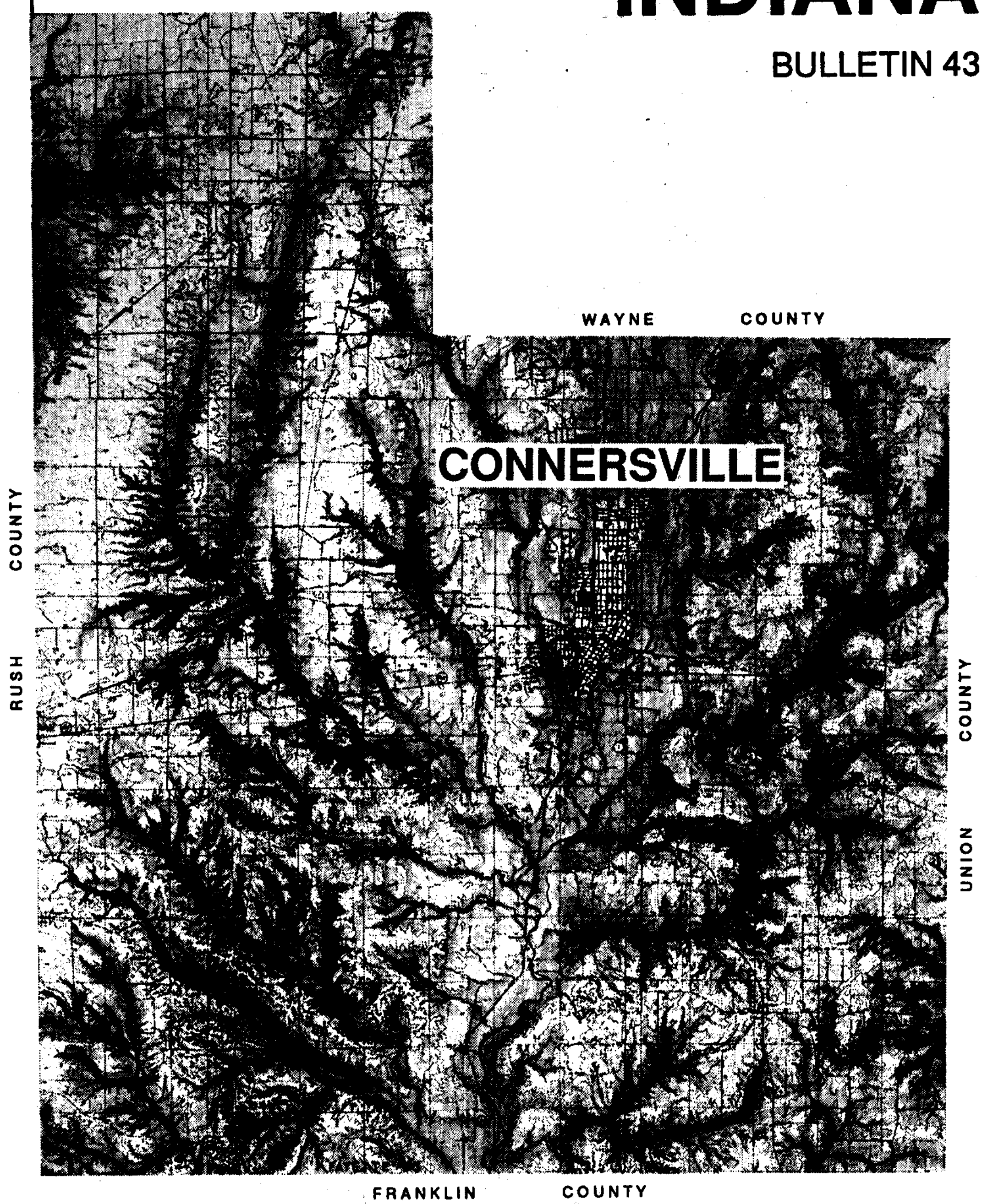
HYDROGEOLOGY OF FAYETTE COUNTY, INDIANA

BULLETIN 43



STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

1993

HYDROGEOLOGY OF FAYETTE COUNTY, INDIANA

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STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
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INTRODUCTION

Fayette County is located in east-central Indiana and covers an area of approximately 215 square miles (Figure 1). The largest population center, Connersville is located in the north-central area of the county.

The availability of ground water in Fayette County is controlled to a high degree by the location and type of aquifer materials present in a given area. Well yields range from less than 1 gallon per minute (gpm) to over 1000 gpm. Wells completed in sand and gravel deposits in the Whitewater River Valley can produce 1000 gpm or more. Wells completed in upland areas usually yield less than 10 gpm.

PURPOSE AND SCOPE

The purpose of this report is to present a compilation of existing information on the geology, ground-water availability and general ground-water quality in Fayette County.

Data on which this report is based were collected from water well logs, maps and geologic reports and ground-water quality samples collected by or in a cooperative effort with the Indiana Department of Natural Resources, Division of Water, Basin Studies Section.

PHYSIOGRAPHY

Fayette County is located within Malott's (1922, p. 66) Dearborn Upland physiographic region. This region is dominated by steep slopes and dissected uplands. Flat areas of limited extent are present in valley bottoms. The topography of the upland is related to a predominance of shaly bedrock and to drainage modifications caused by glaciation.

Approximately 95 percent of Fayette County is located within the Whitewater River Basin. The remaining 5 percent, a narrow strip along the northwestern edge, drains to the East Fork White River Basin. Surface drainage is uniformly established throughout the county. A dendritic drainage system conveys surface water roughly northeast to southwest (Plate 1). Approximately 85 percent of the county is drained by the West Fork Whitewater River. Another 10 percent is drained by the East Fork Whitewater River. The remaining 5 percent is drained by the East Fork White River. Larger tributaries to the West Fork Whitewater River include Williams Creek and North and South Garrison Creeks in western Fayette, and Village and Wilson Creeks in the eastern part of the county. Simpson Creek and a few smaller creeks drain into the East Fork Whitewater River.

BEDROCK TOPOGRAPHY

Bedrock topography of Fayette County is shown on Plate 2. The bedrock surface throughout the county is covered by a variable thickness of glacial deposits of Wisconsinan and pre-Wisconsinan age. Present day surface topography roughly parallels the bedrock topography

The highest bedrock elevation is approximately 1000 feet mean sea level (msl). This area is located in the northwestern part of the county and is associated with relatively undissected uplands. The lowest elevation of approximately 720 feet msl is in the area where the West Fork Whitewater River exits Fayette County.

Evidence suggests the existence of a buried bedrock valley located in northwestern Fayette County. Information from water well logs and seismic records, which was used in the construction of the bedrock topographic surface map, shows a buried bedrock valley located

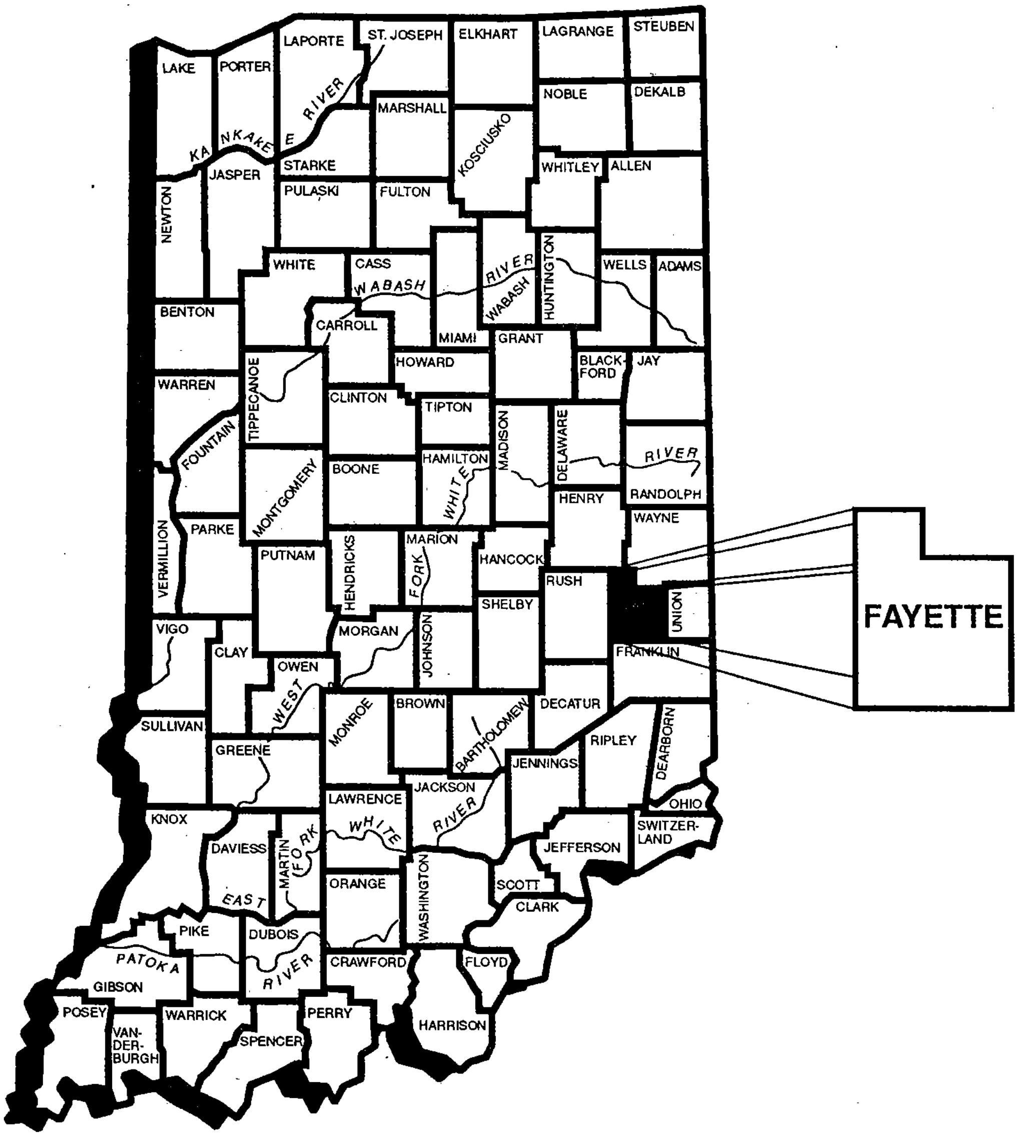

Figure 1. Location of Fayette County

slightly west of Connersville and trending north-northwest. Previous work by Wayne (1956, p. 45) and Gray (1983, 1987) also reported the possible existence of a deep, narrow buried bedrock valley in northwestern Fayette County. However, water well data does not support the extensive buried bedrock valley that Wayne depicted in his Report of Progress (1956, p. 26).

BEDROCK GEOLOGY
Stratigraphy

The bedrock underlying Fayette County is comprised of Late Ordovician Dillsboro and Whitewater Formations and Silurian Brassfield Limestone and Salamonie Dolomite (Figure 2). These rocks are among the oldest found in Indiana. Older sedimentary bedrock of Ordovician and Cambrian age exists above a basement complex of igneous rocks. Figure 3 shows the areal distribution of bedrock units within the county.

Ordovician System
Dillsboro Formation

The Dillsboro Formation, as described by Brown and Lineback (1966, p. 1020-1021), occupies a large percentage of the Fayette County bedrock surface. This formation consists of thin-bedded calcareous shales and fossiliferous argillaceous limestones and is located between the underlying Kope Formation and overlying Whitewater Formation.

The designated type area is in the vicinity of Dillsboro, Dearborn County, Indiana. At this location, the formation contains an equal percentage of argillaceous limestone and calcareous shale. The shale content increases north of the type area and decreases southward. Limestone comprises 30 percent of this formation. Brown and Lineback (1966, p. 1020-1021) and Shaver and others (1986, p. 37-38) discuss the stratigraphy of the Dillsboro Formation.

Whitewater Formation

The Whitewater Formation conformably overlies the Dillsboro Formation (Shaver and others, 1986, p. 169). This unit varies from a thin-bedded, fossiliferous and argillaceous limestone to a medium-bedded, burrowed to rubbly limestone. Overall limestone content of the Whitewater is greater than the underlying Dillsboro Formation. The Whitewater occurs in an irregular pattern in eastern Fayette County and as narrow bands in the west (Figure 3).

A dolomitic mudstone and dolomite at the base of the Whitewater is Gray's (1972b, p. 21-22) Saluda Member. The contact between the Saluda and the rest of the Whitewater is placed at the highest dolomite bed within the Saluda. The lower part of this unit contains a distinctive coralline zone (Brown and Lineback, 1966, p. 1021). The dolomitic nature of the Saluda readily distinguishes it from the underlying shaly Dillsboro Formation.

The Saluda has a maximum thickness of 60 feet in Decatur County and thins northward to less than 10 feet in Wayne County. Changes in thickness of the Saluda are accompanied by similar changes in the Whitewater. A thorough discussion of the Whitewater and Saluda is found in Shaver and others (1986, p. 135-136, 168-169) and Brown and Lineback (1986, p. 1021-1022).

Figure 2. Bedrock stratigraphy of Fayette County.

System	Formation	Member	Thickness	Description
Silurian	Salamonie Dolomite	Laurel	27' to 55'	Laurel Member is light-gray to tan dolomitic limestone. Osgood Member varies from shaly unit in upper and lower, carbonate middle, and on occasions a dolomitic base.
		Osgood	10' to 30'	
	Brassfield Limestone		0' to 20'	Yellowish-orange, orange-gray, salmon or gray, medium to coarse-grained, fossiliferous limestone.
Ordovician	Whitewater Formation		60' to 100'	Thin to medium-bedded, rubbly limestone.
		Saluda	9' to 60'	Saluda Member is a dolomite mudstone and dolomite. Thin coralline zone in lower part.
	Dillsboro Formation		300'	Thin-bedded fossiliferous, argillaceous limestone and calcareous shales.
	Kope Formation		250' to 550'	Bluish to brownish-gray shale.

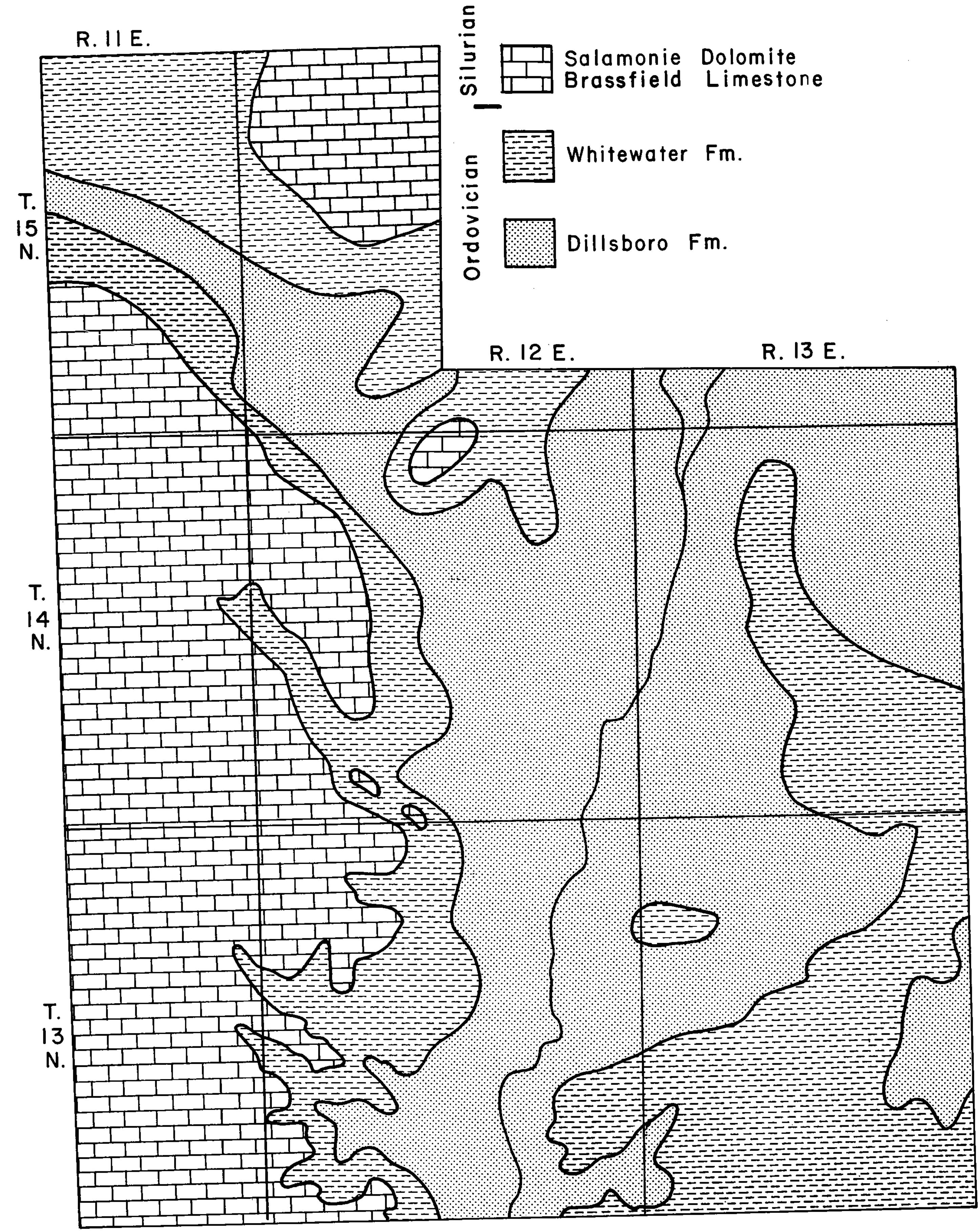

Figure 3. Map of Fayette County Showing Areal Distribution of Bedrock Units. Modified from Gray and Others, 1987.

Silurian System

Silurian rocks occupy much of the bedrock surface of western Fayette County (Figure 3). The oldest Silurian rock in the county, the Brassfield Limestone, is separated from the Ordovician Whitewater Formation by a regional erosional unconformity.

In Late Ordovician time, shallow seas retreated. Whitewater deposition ended and widespread erosion of the Whitewater Formation began. With the onset of Silurian time, the sea once again invaded the area. Deposition of Brassfield Limestone (Figure 2) signified the beginning of the Silurian Period. Laferriere and others (1986, p. 9-10) and Pinsak and Shaver (1964, p. 58-59) provide detailed discussions of Late Ordivician - Early Silurian geologic history.

Brassfield Limestone

Brassfield Limestone crops out in Fayette County approximately three miles southwest of Connersville along Williams Creek. Utgard and Perry (1964, p.21) described this limestone as light yellow-orange and orange-gray, hard, and coarsely crystalline with abundant fossils. Shaver and others (1986, p. 20) indicated that a color of yellowish-brown to salmon-pink and medium to coarse-grained fossiliferous limestone is common. In general, the Brassfield is less than 4 feet thick along the outcrop and reaches a maximum thickness of 20 feet in the subsurface. In parts of Decatur, Ripley, Jennings and Jefferson Counties, the Brassfield is absent (Shaver and others, 1986, p.20).

Salamonie Dolomite

In southeastern Indiana, the Salamonie Dolomite consists of two members, the lower Osgood and upper Laurel. The contact between the underlying Brassfield Limestone and Salamonie Dolomite is unconformable in Fayette County (Shaver and others, 1986, p. 131).

The Osgood Member consists of an upper and lower shaly unit, a middle carbonate zone, and an occasional occurrence of dolomitic limestone as a basal unit. Thickness ranges from 10 to 30 feet and averages approximately 15 feet. North and west of Fayette County, the carbonate content increases and the overlying Laurel cannot be differentiated from the Osgood (Shaver and others, 1986, p. 106-107).

The Laurel Member is a light-gray to tan dolomitic limestone. Lenticular and nodular chert is common in the upper part of this member. Thickness ranges from approximately 27 to 55 feet. This unit thickens to the north. The contact between the underlying Osgood and Laurel is conformable (Shaver and others, 1986, p. 73).

Structure

Fayette County is located within a broad structural feature known as the Cincinnati Arch. This arch bifurcates north of Fayette County into the Kankakee and Findlay Arches and separates the Illinois, Michigan and Appalachian Basins (Figure 4). The crest of the Cincinnati Arch is as much as 75 miles wide (Becker and others, 1978, p. 13). Rocks along the flank of the arch dip about 35 feet per mile (Pinsak and Shaver, 1964, p. 13). Erosion of this structural feature has resulted in a pattern of older rocks in the center and younger rocks along the margins (Figure 3).

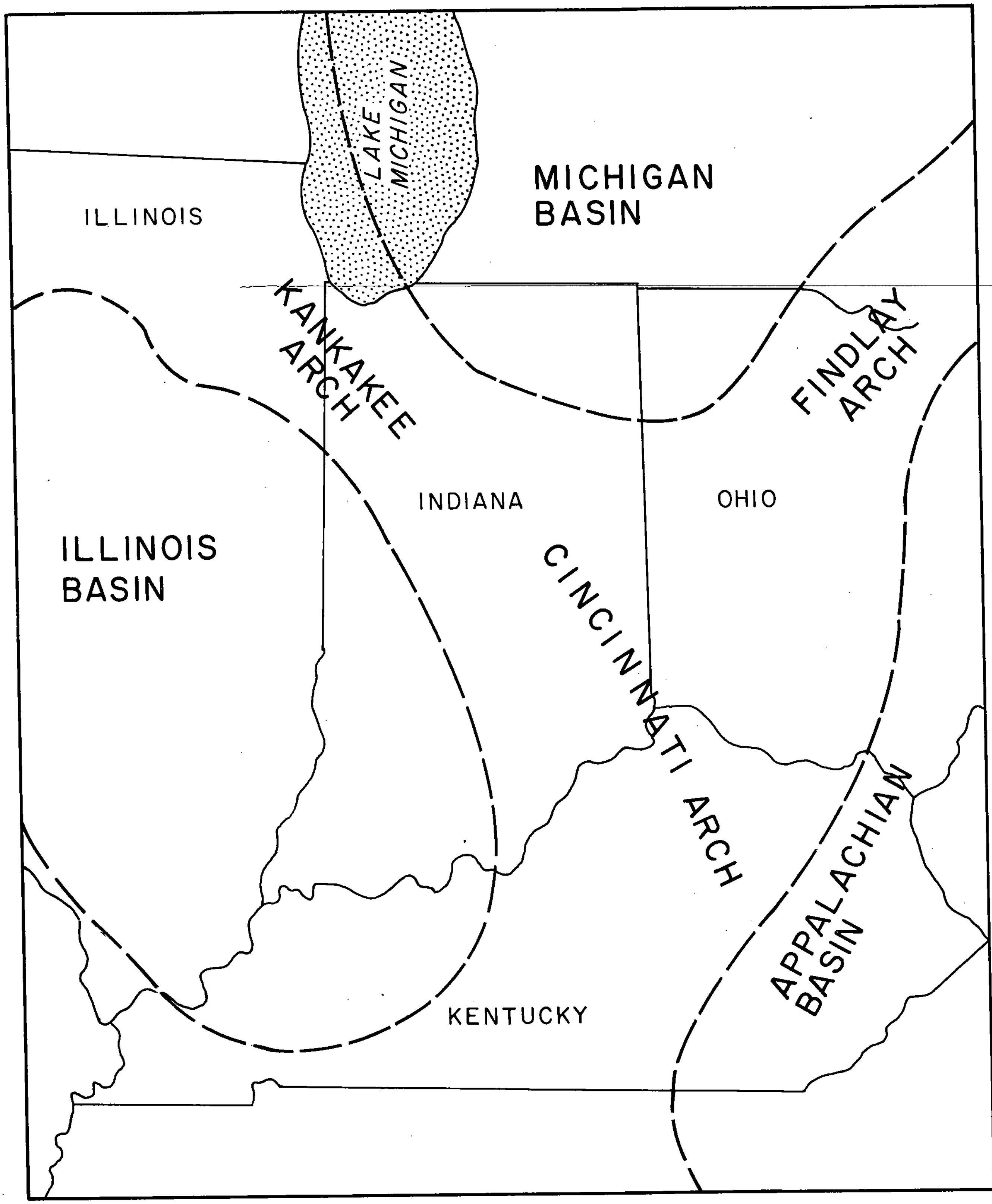

Figure 4. Map Showing Regional Geologic Structures

GLACIAL GEOLOGY

Southeastern Indiana, which includes Fayette County, has endured numerous periods of glaciation. A variety of unconsolidated glacial deposits are present in the county, they include moraines, outwash, and valley train materials. Much of the county is covered by morainal deposits which is an accumulation of glacially transported material that was deposited directly by the glaciers. The main component of a moraine is till, an unsorted and unstratified compacted mixture of clay, silt, sand and rock material. Because till is composed of a large percentage of fine-grained sediment it generally transmits only small quantities of water to a well. These glacial deposits are illustrated in cross section through Fayette county (Figure 5 & 6).

There are two main types of moraine, ground moraine and end moraine. Ground moraine is moraine having little topographic variation. It is usually thought of as being deposited beneath the glacier as lodgement till, although ablation till from the glacier surface may be included (Flint, 1971, pgs. 198-205). Most of the county is covered with ground moraine (Figure 7).

End moraines are formed at the edges of active glaciers and are composed primarily of till, although they may have some stratified drift. End moraines may have a distinct ridge-like topographic form and may mark the farthest extent of an ice advance. End moraine deposits are found in various parts of the county (Figure 7).

Outwash is a deposit of sorted, stratified material washed from the glacial margin by meltwaters. Fine materials, silts and clays, are usually washed away leaving the coarser grained sands and gravels. Outwash deposits confined to a valley are referred to as valley train deposits and may substantially fill the valley. The coarse-grained sediments of outwash deposits often make excellent aquifers.

Valley train deposits may be partially eroded by glacial meltwaters leaving outwash terraces along a valley wall. Terraces are former floodplain levels perched above present river levels. In Fayette County deposits of outwash, valley trains, outwash terraces, and recent alluvium are confined to the West Fork Whitewater River and its major tributaries (Figure 7).

GROUND WATER

The two most significant sources of ground water in Fayette County are the valley train outwash deposits, localized ice contact deposits and alluvium. Till and intertill sand and gravel lenses of limited extent and thickness provide another source in selected areas. An additional source of ground water is Ordovician and Silurian bedrock. Each of these aquifer systems is depicted in (Figure 8).

The general availability of ground water (Plate 3) is a composite of both unconsolidated and bedrock well yields. Therefore, significant variations in yield can be expected within each of the various zones.

Well yield results (Plate 3) do not necessarily indicate that an unlimited number of wells of the stated yield can be developed within any given zone. Detailed studies including test pumping are needed to adequately evaluate ground-water yields within any given zone.

Ground-Water Availability

The most productive and dependable aquifer system is that defined as the combined valley train outwash, ice contact and alluvium deposits in the Whitewater River Valley and selected tributary valleys (Figure 8). These deposits in the range of 50 to 100 feet thick (Plate 4) occur in the Whitewater River Valley. Tributaries to the Whitewater River can have similar thicknesses of sand and gravel deposits.

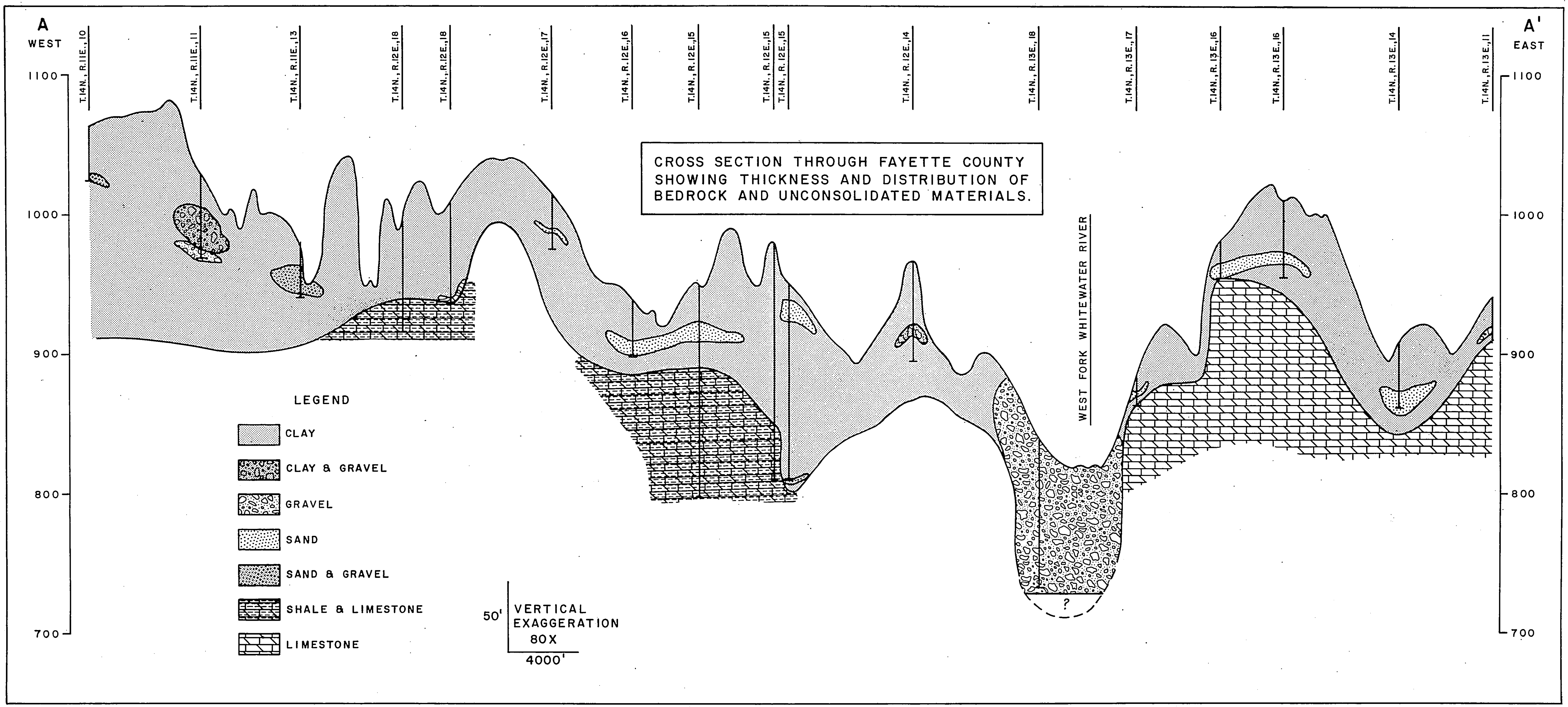

Figure 5. Cross Section A–A'

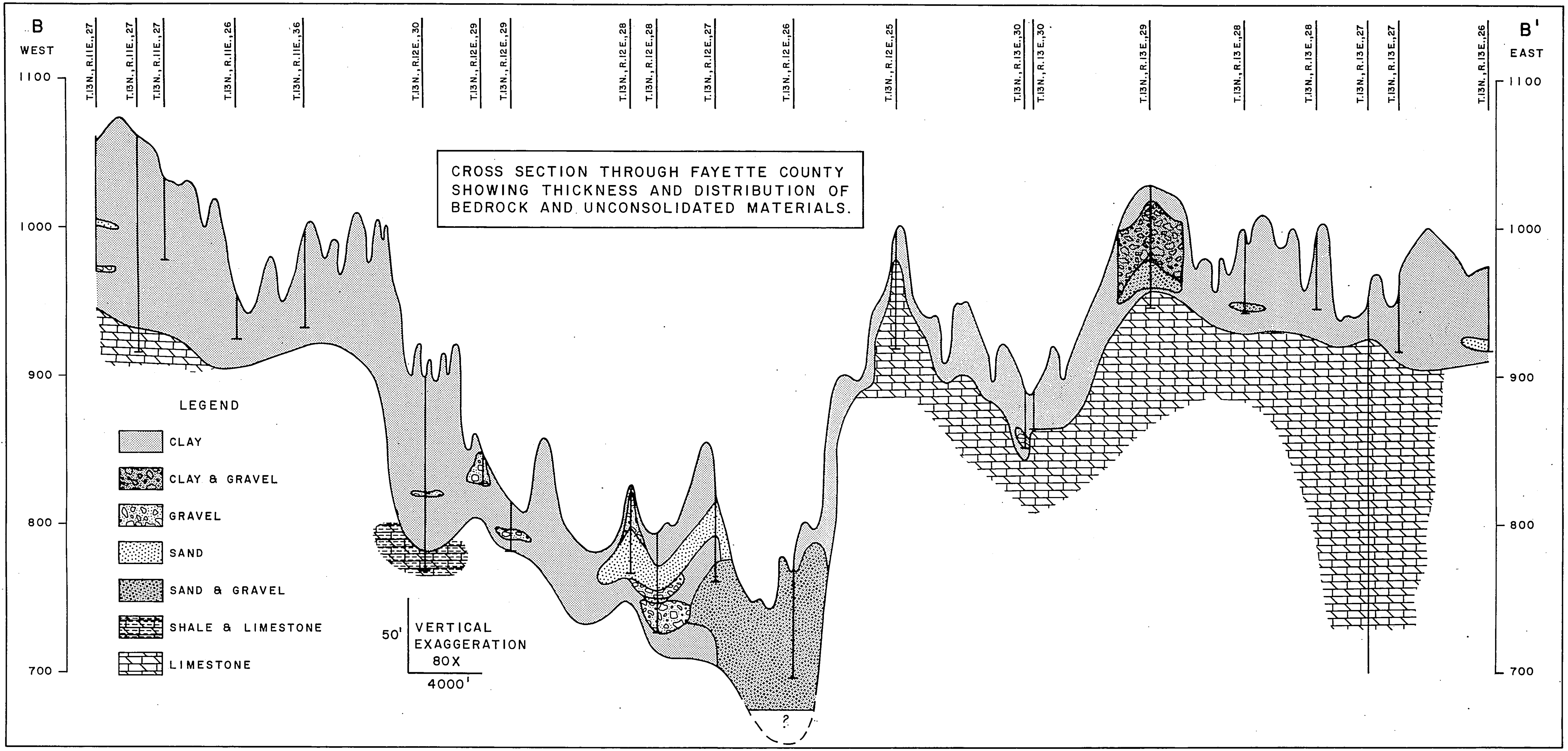

Figure 6. Cross Section B-B'

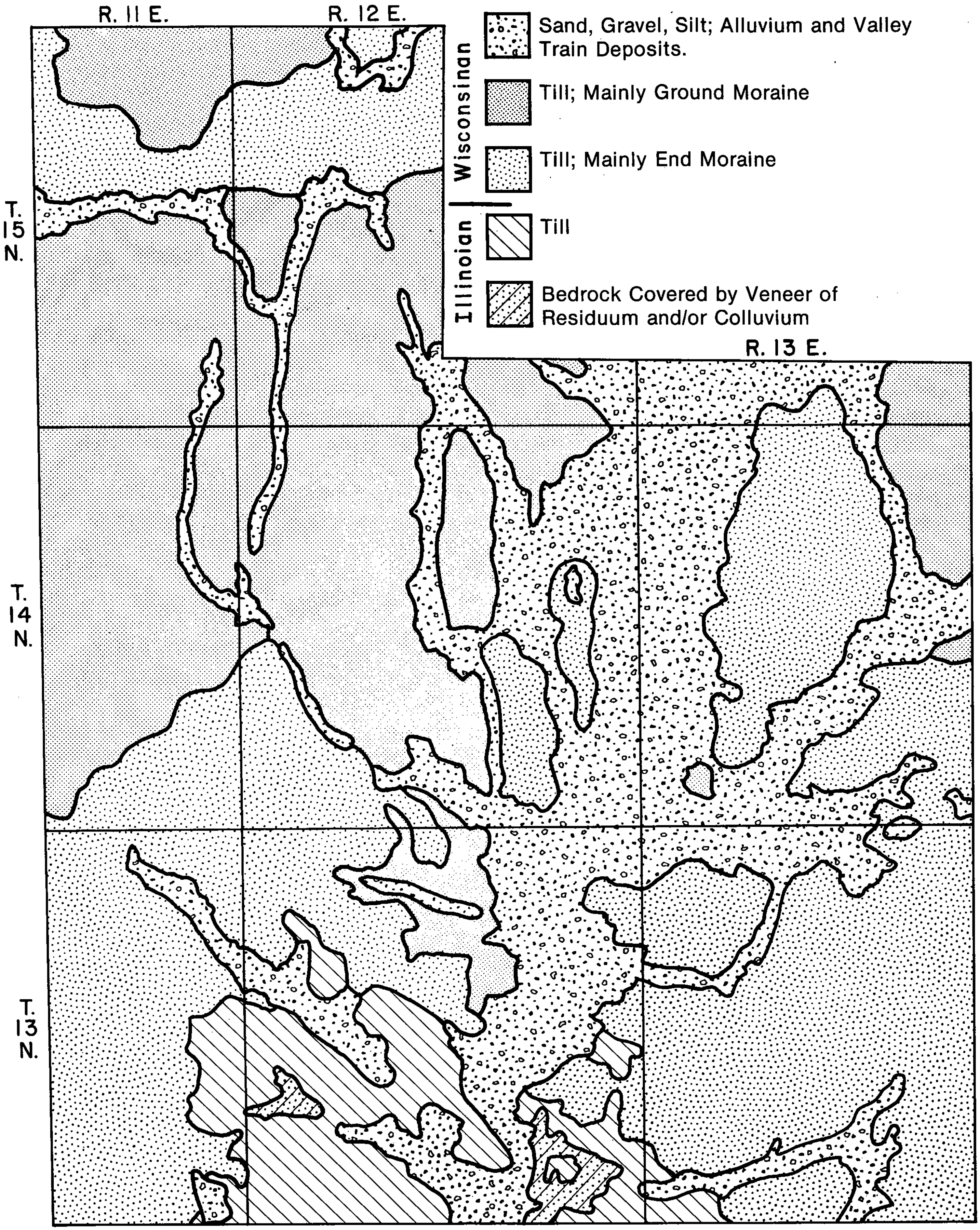

Figure 7. Map of Fayette County Showing Unconsolidated Deposits. Modified From Gray and Others, 1972.

The valley train outwash, ice contact and alluvium aquifer system can provide wells that yield in excess of 1000 gallons per minute (gpm). Well yields in the 10 to 20 gpm range are common. Wells completed in sand and gravel deposits of major tributaries to the Whitewater River yield 10 to 15 gpm.

Five of the seven high capacity users registered for Fayette County are developed in Whitewater River Valley sand and gravel deposits. Records of wells for Connersville Utilities show that properly constructed large diameter wells can produce yields of 1200 gpm. High capacity wells in the 200 to 300 gpm range have been developed in Williams Creek and Little Williams Creek, which are located west of Connersville, Indiana.

Although Whitewater Valley sand and gravel deposits underlie the lowest percentage of the county's total area, these deposits offer significant potential for further development because of the aquifer's large storage and recharge capabilities.

A second source of ground water is glacial deposits (Figure 8), usually 50 to 100 feet thick, which are predominately clay-rich till. Occasional intertill sand and gravel lenses of limited extent and thickness occur within the till. Permeability in the till is low because of the clay content. Therefore, wells completed in the till normally do not produce large volumes of water.

Well yields from wells completed in this area are in the 3 to 5 gpm range (Plate 2). Dry holes are common. Ten to 15 gpm wells are occasionally completed; however, yields in this range are not common. Wells completed in the northwest part of the county may produce 20 to 25 gpm. This significant increase in production is related to abundant intertill sand and gravel deposits.

Bucket-rig wells are common in the unconsolidated glacial till deposits. These are 30 to 36 inch diameter shallow wells, which collect and store the small volume of water available from the till. This type of well is suited for materials with low permeability; however, its use is restricted to unconsolidated materials. Wells completed in the till, because of their low yields of 3 to 5 gpm, are marginal for domestic use. Adequate storage capacity is necessary to accommodate drought conditions. Efficient use of water in combination with prudent conservation practices are necessary for most wells completed within this material.

The least productive aquifer system in the county is the Ordovician and Silurian bedrock (Figure 8). Ground-water availability in this system is generally marginal to small. Yields of 1 to 3 gpm are common, although an occasional yield of 15 to 20 gpm is encountered.

The Ordovician rocks are thin-bedded and shaly, a characteristic which limits the number of high yield wells. In addition, thick clay-rich till materials overlying these rocks inhibit ground-water recharge and movement. The productivity of wells developed in Ordovician age bedrock does not appear to be affected by the amount of bedrock penetration. Well yields of 1 to 3 gpm with extreme drawdown are prevalent and dry holes are common.

The Silurian limestone and dolomite aquifer provide common yields of 3 to 5 gpm with a high yield of 18 gpm reported. Yields along the contact between the Silurian and Ordovician rocks are transitional and can be erratic. Drawdown values are high in the area of the contact and wells may pump dry.

Potentiometric Surface

In a confined aquifer, water is under pressure. When a well penetrates a confined aquifer, water rises to some elevation above the top of the aquifer which is referred to as the potentiometric level. The potentiometric level reflects the hydrostatic head or confining pressure at the top of the aquifer. The potentiometric surface represents the contoured water level elevations for wells in a given area. This surface elevation is the static level of water in a well which penetrates a confined aquifer, and not the level at which the aquifer or water will be encountered.

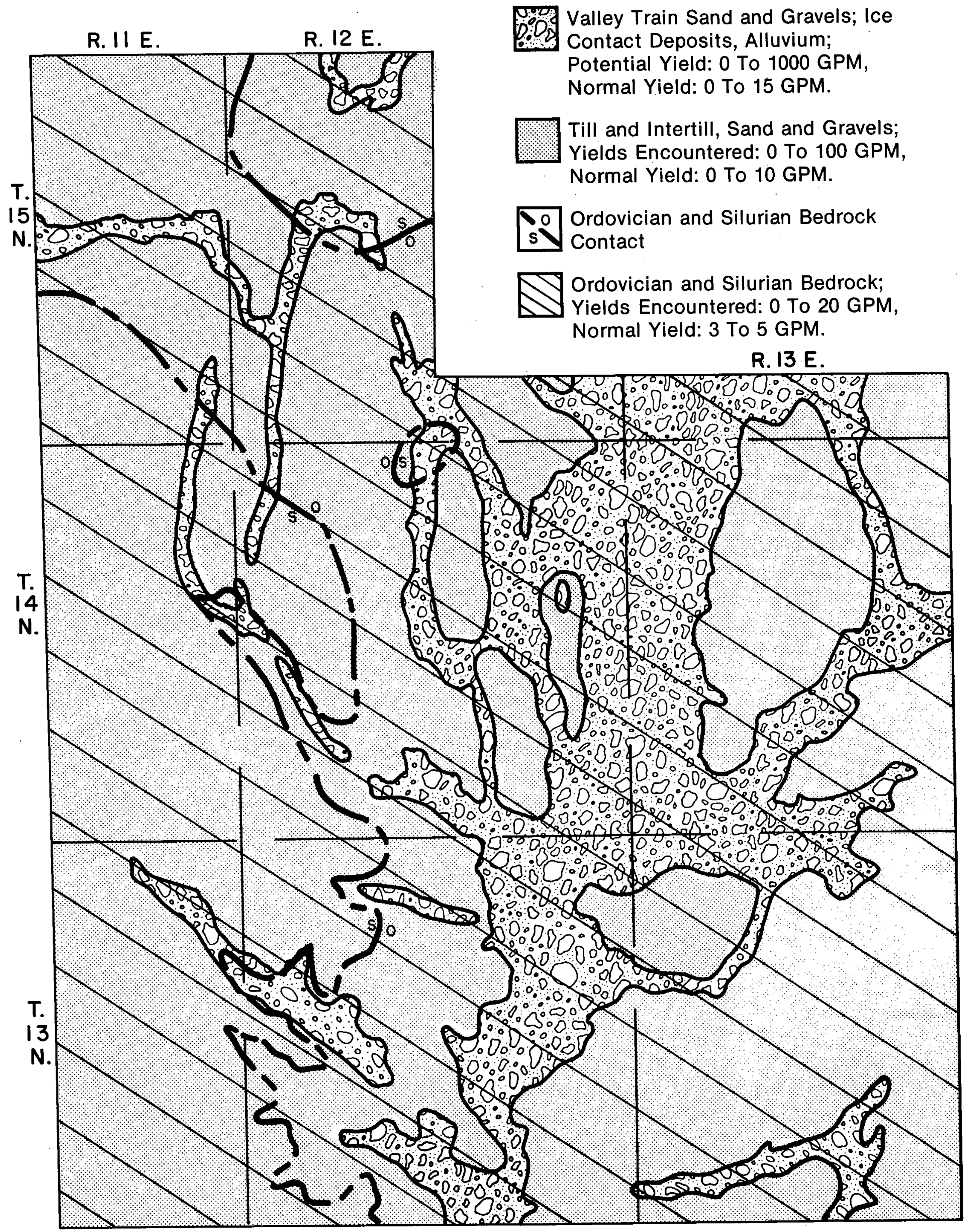

Figure 8. Map of Fayette County Showing General Aquifer Systems.

The potentiometric surface shows the general direction of ground-water flow and areas of recharge and discharge. Flow direction is perpendicular to the contours and down gradient at a rate proportional to the gradient. Recharge normally occurs in upland areas with discharge in lower areas along surface streams.

Plate 5 is a composite potentiometric surface map of Fayette County. The potentiometric surface roughly parallels the surface topography. Data were obtained from several different aquifers for this map. Therefore, the map is an approximation of the potentiometric surface and represents the general direction of ground-water flow.

The potentiometric surface (Plate 5) suggests that recharge areas occur along the east and west margins of the county. In addition, this map shows several ground-water divides. The northwestern part of the county has a major potentiometric surface high of 1050 feet msl. Flow is both west into Rush County and east toward the West Fork Whitewater River. In the northeast, the potentiometric surface is 975 feet msl with flow east into Union County and west toward the West Fork Whitewater River. The potentiometric surface in the southeastern part of the county is at 1050 feet msl with flow directions both east and west.

High Capacity Wells

The Water Resource Management Act of Indiana requires any facility which has the capability to withdraw 100,000 gallons per day (gpd), or approximately 70 gpm, to register this facility with the Indiana Department of Natural Resources, Division of Water. The sources for this water can be surface, ground water, or a combination of surface water and ground water. One or more wells or surface inlets can comprise a facility. Few, if any, facilities operate at the rated withdrawal capability.

Seven facilities in the county are registered as high capacity ground-water users. Included in the registered category are four public water supply facilities and one each in the industrial, irrigation and rural groups. The public water supply group is comprised of 23 registered wells capable of producing 11,144,160 gpd. The remaining industrial, irrigation, and rural water system users are capable of producing 878,400 gpd.

Five of the seven facilities produce from valley train outwash, ice contact and alluvium deposits of the Whitewater River Valley. The other registered high capacity wells are in bedrock and in outwash deposits in the Williams Creek Valley.

Ground-Water Quality

Analyses of water samples from 37 wells in Fayette County were used to ascertain ground-water quality. Quality analyses for unconsolidated (Table 1) and bedrock (Table 2) aquifers are shown separately because each type of aquifer is expected to have significant differences in chemical constituents.

In 1988, ground-water samples from 12 wells were collected by the Division of Water and analyzed by the Indiana State Board of Health. An additional 21 analyses are from wells sampled in 1985 in a cooperative effort by the Division of Water and Indiana Geological Survey. The remaining four analyses are from public water supply wells that were sampled prior to 1986.

The source for samples collected in 1988 was water taps located as close as possible to each individual well. Water collected for analysis was unsoftened. No information is available on sampling techniques used for wells sampled prior to 1988. However, despite the potential sources of variability inherent with the sample sets, results of the analyses can provide insight on ground-water quality for Fayette County aquifers.

Minor concentrations of various chemical constituents can produce undesirable taste, color, staining, odor, or can even adversely affect health. Because of the undesirable characteristics of certain constituents in water, the U. S. Environmental Protection Agency (E.P.A.) has established regulations that limit the concentrations of common chemical constituents permitted in public drinking water systems (Table 3). Although these limits were established for public water supplies, they are useful for assessing ground-water quality and in interpreting the analyses tabulated in Tables 1 and 2.

The E.P.A. has established two separate sets of limits that regulate water quality. The primary standards list shows maximum contaminant levels (MCL) for inorganic constituents considered toxic and enforceable. Consumption of these constituents at levels greater than the stated MCL can be a health hazard. The secondary standards list shows contaminant levels for inorganic constituents that are recommended, but not enforceable. Constituents in the secondary list, which are recommended maximum secondary levels (RMCL) are not known to be detrimental to health. Selected inorganic chemical constituents common in ground water and the health and aesthetic significance of these constituents are shown in (Table 4).

The environment in which ground water resides is dynamic with numerous factors affecting the chemical composition. A few of the factors in this environment are the chemical composition of the rock in the aquifer or the composition of the rock along the flow path in reaching the aquifer, solubility of the rock material, residence time of water, water temperature, oxidation-reduction reactions, acid-base reactions and the activities of man. Detailed discussions about these factors and how they affect ground-water chemistry can be found in Freeze and Cherry (1979) and Drever (1988).

Hard and soft water are subjective terms that have no exact meaning to most people. Water referred to as hard in one region might be considered soft in another region. Therefore, to facilitate the discussion on hardness, the following scale can be used: soft water, 0-60 ppm (parts per million); moderately hard water, 61-120 ppm; hard water, 121-180 ppm; and very hard water, more than 180 ppm (Durfor and Becker, 1964, p. 27). Ground water hardness values for Fayette County are significantly greater than 180. ppm.

The recommended secondary maximum level (RMCL) for iron is 0.3 ppm. This level, which is commonly exceeded in both unconsolidated and bedrock well water samples in Fayette County, is based on aesthetic and taste considerations. Specifically, iron stains occur at concentrations in excess of 0.3 ppm, and a metallic taste can be detected at levels as low as 0.1 ppm.

The EPA recommended secondary maximum contaminant level (RMCL) for chloride is 250 ppm. Water samples from two bedrock wells exceed the RMCL, one well has a chloride level of 656 ppm and the other well 420 ppm. These elevated levels of chloride are naturally occurring and thought to originate from seawater trapped in shale at the time of deposition (Drever, 1988, p. 205). None of the unconsolidated wells have chloride levels which exceed the secondary level.

Sulfate is a major dissolved constituent in rain. The sources for this constituent are related to both natural and human pollution of the environment. A common natural source of sulfate is organic-rich shales, and a major source from human activities is the burning of high sulfur fuels. Sulfate concentrations tend to be less for shallow wells and increase with depth. Water analyses from all wells sampled in this study are below the recommended secondary maximum level (RMCL) of 250 ppm for sulfate.

Natural sources of fluoride in ground water include the mineral apatite and various clay minerals. In the wells sampled, fluoride levels are below the secondary maximum level (RMCL) of 2.0 ppm.

Nitrate in ground water can originate from several possible sources including decaying

Table 1. Ground-water chemistry Fayette County
Unconsolidated Wells.

Well #	FA-1	FA-2	FA-3	FA-4	FA-5	FA-6	FA-7	FA-8	WW-30	WW-31	WW-32	WW-44	WW-52	WW-53	WW-60	WW-61	WW-66
Township	15N	14N	14N	14N	13N	13N	13N	13N	15N	15N	14N	15N	14N	13N	15N	14N	14N
Range	11E	11E	11E	13E	12E	12E	11E	12E	12E	12E	12E	13E	11E	11E	13E	13E	12E
Section	13	34	10	28	17	14	12	21	16	19	6	36	13	15	32	9	15
Well Depth	94.0	87.0	91.0	60.0	60.0	85.0	75.0	27.0	132.0	46.0	35.0	84.0	45.0	90.0	28.0	115.0	161.0
Ph	7.3	7.0	7.5	6.9	7.8	7.2	6.8	~ ~	7.7	7.3	7.1	7.2	7.1	7.7	7.2	7.7	7.5
Hardness	386.0	368.0	326.0	384.0	252.0	346.0	434.0	312.0	340.0	315.0	414.0	358.0	426.0	312.0	349.0	375.0	274.0
Calcium	92.0	89.0	86.0	98.0	68.0	92.0	117.0	82.0	84.6	83.7	105.3	91.9	112.9	75.8	96.5	95.3	66.4
Magnesium	38.0	35.0	27.0	34.0	22.0	28.0	35.0	26.0	31.5	25.9	36.8	31.3	35.0	29.9	26.3	33.4	26.2
Sodium	9.0	12.0	24.0	3.7	6.3	3.5	4.8	3.9	17.6	3.8	4.5	5.0	5.9	13.5	4.5	8.8	58.8
Potassium	1.2	0.9	0.9	1.1	0.5	0.9	0.7	1.5	0.6	0.4	0.5	0.4	0.6	0.4	0.9	0.4	0.8
Iron	1.6	2.7	1.1	0.02	1.5	<0.02	0.27	<0.02	1.0	1.4	<0.1	1.3	2.5	3.1	<0.1	1.6	1.0
Manganese	0.06	0.02	0.01	<0.01	0.08	<0.01	0.06	<0.01	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
Alkalinity	386.0	390.0	366.0	310.0	232.0	262.0	394.0	254.0	357.5	256.8	317.2	351.2	344.4	346.8	284.8	401.6	369.7
Chloride	<5.0	<5.0	<5.0	12.0	5.0	15.0	6.0	12.0	12.8	9.6	14.4	2.6	21.1	18.7	20.5	0.9	21.6
Sulfate	18.0	<5.0	<5.0	48.0	15.0	31.0	32.0	36.0	5.6	62.8	77.5	20.4	66.8	0.9	42.4	6.1	<0.1
Fluoride	0.9	1.0	0.4	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.1	0.3	0.9	0.3	0.1	0.2	0.4
Nitrates	<0.1	<0.1	<0.1	~ ~	<0.1	~ ~	0.6	2.4	<0.02	<0.02	2.8	<0.02	<0.02	<0.02	9.4	<0.02	<0.02
Phosphates	<0.09	0.2	0.3	<0.09	<0.09	<0.09	<0.09	<0.09	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~
Temp. (c)	17.0	19.0	14.0	14.0	14.0	14.0	14.0	~ ~	13.0	15.3	13.7	12.7	12.0	12.8	13.9	14.7	12.0

fayette co. unconsolidated wells

Well #	WW-67	WW-68	WW-75	WW-76	WW-88	WW-89	WW-99	WW-100	WW-131	WW-132	WW-133a	WW-133b	Sample Size	Average	Standard Dev.
Township	13N	13N	14N	13N	14N	13N	13N	13N	14N	13N	14N	14N			
Range	12E	13E	13E	12E	13E	13E	13E	13E	12E	12E	13E	13E			
Section	34	14	3	2	14	5	9	4	36	1	18	18			
Well Depth	35.0	38.0	50.0	85.0	31.0	183.0	82.0	50.0	49.0	78.0	97.0	81.0			
Ph	7.1	7.0	7.0	6.6	6.8	6.9	7.1	7.3	7.1	7.3	7.5	7.8	28	7.2	0.3
Hardness	319.0	331.0	382.0	315.0	351.0	265.0	392.0	351.0	380.0	300.0	346.0	300.0	29	344.9	45.6
Calcium	83.2	86.8	99.5	83.9	93.0	68.5	97.4	89.5	100.0	75.0	89.0	75.0	29	88.9	12.3
Magnesium	27.1	27.9	32.5	25.6	28.9	22.7	36.3	31.1	37.4	27.0	30.0	27.0	29	30.2	4.5
Sodium	3.6	3.6	3.9	12.0	3.8	110.4	8.9	11.4	~ ~	4.0	5.0	5.0	28	12.9	22.0
Potassium	0.9	0.6	0.4	0.5	0.4	2.3	0.5	0.5	~ ~	2.0	2.0	2.0	28	0.9	0.6
Iron	<0.1	<0.1	<0.1	<0.1	2.0	2.7	0.8	3.2	0.4	0.4	1.7	<0.1	20	1.5	0.9
Manganese	<0.1	<0.1	0.1	0.5	0.1	<0.1	0.2	<0.1	~ ~	0.09	0.08	<0.02	12	0.1	0.1
Alkalinity	273.9	269.0	308.2	318.0	322.1	312.5	434.3	325.3	~ ~	254.0	272.0	238.0	28	319.7	55.1
Chloride	10.1	6.7	19.6	16.8	8.5	161.0	3.3	9.8	16.0	7.0	10.0	10.0	26	17.3	29.9
Sulfate	27.0	57.4	65.3	14.0	47.7	<0.1	5.4	39.6	95.0	51.0	61.0	42.0	25	38.7	24.9
Fluoride	0.1	0.1	0.1	0.1	0.3	0.1	0.5	0.4	~ ~	0.2	0.2	0.2	28	0.3	0.3
Nitrates	6.4	3.1	<0.02	1.0	<0.02	<0.02	<0.02	<0.02	~ ~	~ ~	<0.1	2.4	8	3.5	3.0
Phosphates	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	~ ~	2	0.3	0.1
Temp. (c)	13.2	14.8	14.0	13.0	13.5	14.0	13.0	13.4	~ ~	~ ~	~ ~	~ ~	24	12.7	3.6

Table 2. Ground-water chemistry Fayette County
Bedrock Wells.

Well #	FA-9	FA-10	FA-11	FA-12	WW-51	WW-65	WW-98	WW-112	Sample Size	Average	Standard Dev.
Township	14N	14N	14N	13N	14N	14N	13N	13N			
Range	12E	12E	13E	12E	12E	12E	12E	13E			
Section	27	21	21	36	30	11	8	9			
Well Depth	100.0	150.0	55.0	110.0	83.0	65.0	55.0	290.0			
Ph	6.9	6.9	6.7	6.4	7.4	6.8	6.8	7.0	8	6.9	0.3
Hardness	376.0	190.0	550.0	288.0	350.0	433.0	356.0	450.0	8	374.2	108.5
Calcium	92.0	42.0	140.0	76.0	86.7	115.5	85.6	116.5	8	94.3	29.9
Magnesium	35.0	20.0	49.0	24.0	32.5	35.1	34.6	38.6	8	33.6	8.8
Sodium	36.0	290.0	11.0	92.0	10.0	20.4	5.2	324.0	8	98.6	131.9
Potassium	3.5	5.1	1.1	5.0	0.5	1.5	0.6	5.8	8	2.9	2.2
Iron	0.77	0.77	<0.02	0.2	2.2	<0.1	3.4	1.7	6	1.51	1.17
Manganese	0.0	0.1	<0.01	0.1	<0.1	<0.1	<0.1	0.1	4	0.07	0.05
Alkalinity	330.0	210.0	434.0	320.0	356.8	353.4	345.2	401.1	8	343.8	65.8
Chloride	52.0	420.0	10.0	110.0	20.6	40.8	5.1	656.0	8	164.3	241.4
Sulfate	45.0	32.0	120.0	18.0	9.4	61.6	23.5	0.7	8	38.8	38.1
Fluoride	0.7	1.8	0.2	0.5	0.2	0.4	0.4	0.3	8	0.6	0.5
Nitrates	<0.1	<0.1	0.8	0.2	<0.02	5.4	<0.02	<0.02	3	2.13	2.84
Phosphates	<0.09	<0.09	<0.09	<0.09	~~~	~~~	~~~	~~~	0	~~~	~~~
Temp. (c)	17.0	14.0	15.0	15.0	14.0	13.2	11.0	14.0	8	14.2	1.7

Wells numbered FA from open files, Indiana Dept. of Natural Resources, 1988
Wells numbered WW from Clendenon, p. 121-125

Note: Criterion reported as (<0.2) is below detectable levels for that constituent at the time the sample was analyzed.

Table 3. Contaminant levels for selected inorganic chemical constituents in drinking water.

(Source: U.S. Environmental Protection Agency, 1979, 1986a, 1986b)

Constituent	Value	Reference
Arsenic	0.05	EPA, 1986a
Barium	* 1.0	EPA, 1986a
Cadmium	* 0.01	EPA, 1986a
Chloride	250.0	EPA, 1979
Chromium	* 0.05	EPA, 1986a
Copper	1.0	EPA, 1979
Fluoride	* 4.0	EPA, 1986b
	2.0	EPA, 1986b
Iron	0.3	EPA, 1979
Lead	* 0.05	EPA, 1986a
Manganese	0.05	EPA, 1979
Mercury	* 0.002	EPA, 1986a
Nitrate (as Nitrogen)	* 10.0	EPA, 1986a
Selenium	* 0.1	EPA, 1986a
Silver	* 0.05	EPA, 1986a
Sulfate	250.0	EPA, 1979
Zinc	5.0	EPA, 1979
Ph	6.5-8.5	EPA, 1979

All values except pH in parts per million (ppm).

* Maximum contaminant levels (MCL) that are enforceable limits for public drinking water. All other values are
secondary or recommended maximum contaminant levels (RMCL).

Table 4.
Significance of selected chemical constituents in ground water. From Clark, 1980 and Driscoll, 1986.

Constituent	Significance
Hardness	Hardness in water is caused primarily by calcium and magnesium compounds such as bicarbonates, chlorides and sulfates. Water is classified as hard in the 120 to 180 ppm range and very hard above 180 ppm. The normal range of values in Indiana is 200 to 400 ppm. Residential users commonly soften water when hardness values exceed 200 ppm. Hard water is a nuisance property. Hard water reduces the effectiveness of soaps and detergents and causes soap scum. Hardness reduces the life of hot water heaters and causes scale deposits in steam heating systems.
Iron	Indiana groundwater commonly contains iron in amounts above 0.5 ppm. Concentrations above 0.3 ppm, the EPA recommended level, cause staining of laundry and plumbing fixtures. Well screens and pipes can become encrusted due to iron, and iron bacteria growth can be a problem.
Manganese	Manganese is objectionable in water in the same general way as iron. However, it is less abundant than iron. EPA recommended level is 0.05 ppm for drinking water. Indiana ground-water values range from 0.01 to 1.0 ppm. Manganese, like iron, causes staining. However, these stains are more difficult to remove. Well screen openings can become constricted or plugged in ground water containing elevated manganese levels.
Chloride	Indiana ground water has chloride concentrations that range from 10 to 50 ppm. This range is well below the EPA recommended limit of 250 ppm. Chloride levels as low as 50 ppm can affect the taste of various beverages. Sand and gravel aquifers usually have low concentrations of chloride, and bedrock aquifers generally have higher levels. Chloride levels in bedrock aquifers almost always increase with depth.
Sulfate	The normal range of sulfates in Indiana ground water is 0 to 1000 ppm. The EPA recommended limit is 250 ppm. Sulfate in drinking water is more of a nuisance than a serious health hazard. Sulfate concentrations above 250 ppm may act as a laxative for people not accustomed to drinking high-sulfate water.

Table 4. Continued.

Constituent	Significance
Fluoride	Fluoride is a naturally occurring element in Indiana ground water. The normal range of values is 0.1 to 1.5 ppm. The EPA has established a primary limit of 4 ppm and a secondary limit of 2 ppm for public drinking water. Fluoride concentrations in the 0.7 to 1.4 ppm range are considered beneficial in the prevention of tooth decay. However, concentrations above 1.7 ppm may cause mottled teeth.
Nitrate	Background levels for nitrate concentrations in Indiana ground water range from 0.1 to 3.0 ppm. The EPA has established a primary nitrate level of 45 ppm or 10 ppm nitrate (as nitrogen). Concentrations as low as 5 ppm nitrate (as nitrogen) in the food of infants under one year old can cause a blood-oxygen deficiency known as methemoglobinemia. Elevated nitrate concentrations is indicative of some form of contamination. The primary sources for nitrate are human and animal waste, and agricultural chemicals.
pH	The pH of water is a measure of the the degree of acidity or alkalinity and is expressed in values ranging from 0 to 14. A pH of 7 is considered neutral; below 7 indicates acidity; above 7 is alkaline. Indiana ground water ranges in value from 6.5 to 8.0. The EPA recommended limit is 6.5 to 8.5.

organic matter such as animal excrement or sewage, leachates of nitrogenous fertilizers and some industrial wastes, plant debris, and the atmosphere. The decay of organic matter, and agriculture and industrial chemicals generates most of the nitrate.

The MCL for nitrate (as nitrogen) is 10.0 ppm. Concentrations of nitrate (as nitrogen) above this level can cause health problems in infants. The nitrate level in unconsolidated wells averages 3.5 ppm and ranges from 0.2 to 9.4 ppm. Seventeen ground-water samples from unconsolidated wells are below the detectable level. Ground-water samples from bedrock wells have an average nitrate level of 2.13 ppm and range from 0.2 to 5.4 ppm.

CONTAMINATION POTENTIAL

Protecting ground water from contaminates requires the development, implementation and enforcement of a comprehensive ground-water management and protection program that recognizes the factors that are associated with ground-water contamination. Factors that make an aquifer susceptible to contamination include, but are not limited to, the presence and proximity to potential sources of contamination, depth to the aquifer or water table and the type and hydraulic characteristics of the material overlying the aquifer.

The valley train sand and gravel, ice contact and alluvium deposits that comprise the area in Figure 7 is the area most susceptible to ground-water contamination. These various sand and gravel deposits allow surface contaminants to infiltrate and move quickly through the geologic profile and into the underlying aquifer. Because the water table is shallow, contaminants will reach the water without the benefit of any significant natural filtering process. These factors, in combination with shallow wells in the area, increase the risk of contamination for users of ground water.

The areas consisting predominately of till and intertill sand and gravels are defined in Figure 7. In general, these areas have an adequate thickness of clay-rich material which will inhibit contaminant infiltration and migration. Wells completed on bedrock highs tend to be shallow and more susceptible to contamination. Confined intertill sand and gravel aquifers are deeper and better protected from surface contamination.

SUMMARY

Three distinct aquifer systems occur in Fayette County, see (Figure 8). Valley train and alluvial sand and gravel deposits comprise the most productive and dependable aquifer. Till and intertill sand and gravel lenses make up a second aquifer system. Ordovician and Silurian age bedrock is the third aquifer system within the county.

Unconsolidated sand and gravel deposits of glacial and fluvial origin located in the West Fork Whitewater River Valley and selected tributary valleys comprise the most productive and dependable aquifer system in Fayette County. Wells properly developed in these deposits are shallow and commonly yield 10 to 20 gpm. Large diameter high capacity wells can yield up to 1200 gpm. This system serves as an aquifer for five of the seven high capacity wells in the county.

The second aquifer system in the county is comprised of till and intertill sand and gravel deposits. Wells completed in the till yield 3 to 5 gpm. Wells completed in the intertill sand and gravel zones yield from 10 to 15 gpm. Well yields of 20 to 25 gpm occur in the northwest part of the county because of abundant intertill deposits. Dry holes and bucket rig wells are common in this system.

The least productive and dependable aquifer system consists of Ordovician and Silurian age limestone and argillaceous limestone. An occasional yield of 15 to 20 gpm occurs, however, 1 to 5 gpm is typical. Dry holes are common and extreme drawdown is associated with wells completed in this system.

Chemical analyses for selected inorganic constituents indicate that ground-water quality in Fayette County is acceptable. Ground water has an average hardness of 360.0 ppm and is rated as very hard, and iron levels commonly exceed the RMCL of 0.3 ppm. Average iron for bedrock wells is 1.51 ppm and unconsolidated wells average 1.5 ppm. Manganese levels for all wells average 0.09 ppm, which exceeds the RMCL. Chloride and sulfate averages for bedrock and unconsolidated wells are below the RMCL. Nitrate levels for all wells are below the MCL of 10.0 ppm.

The potential for ground-water contamination is highest in the sand and gravel deposits in the Whitewater River Valley. Clay-rich till throughout the rest of the county provides reasonable protection from surficial sources of contamination.

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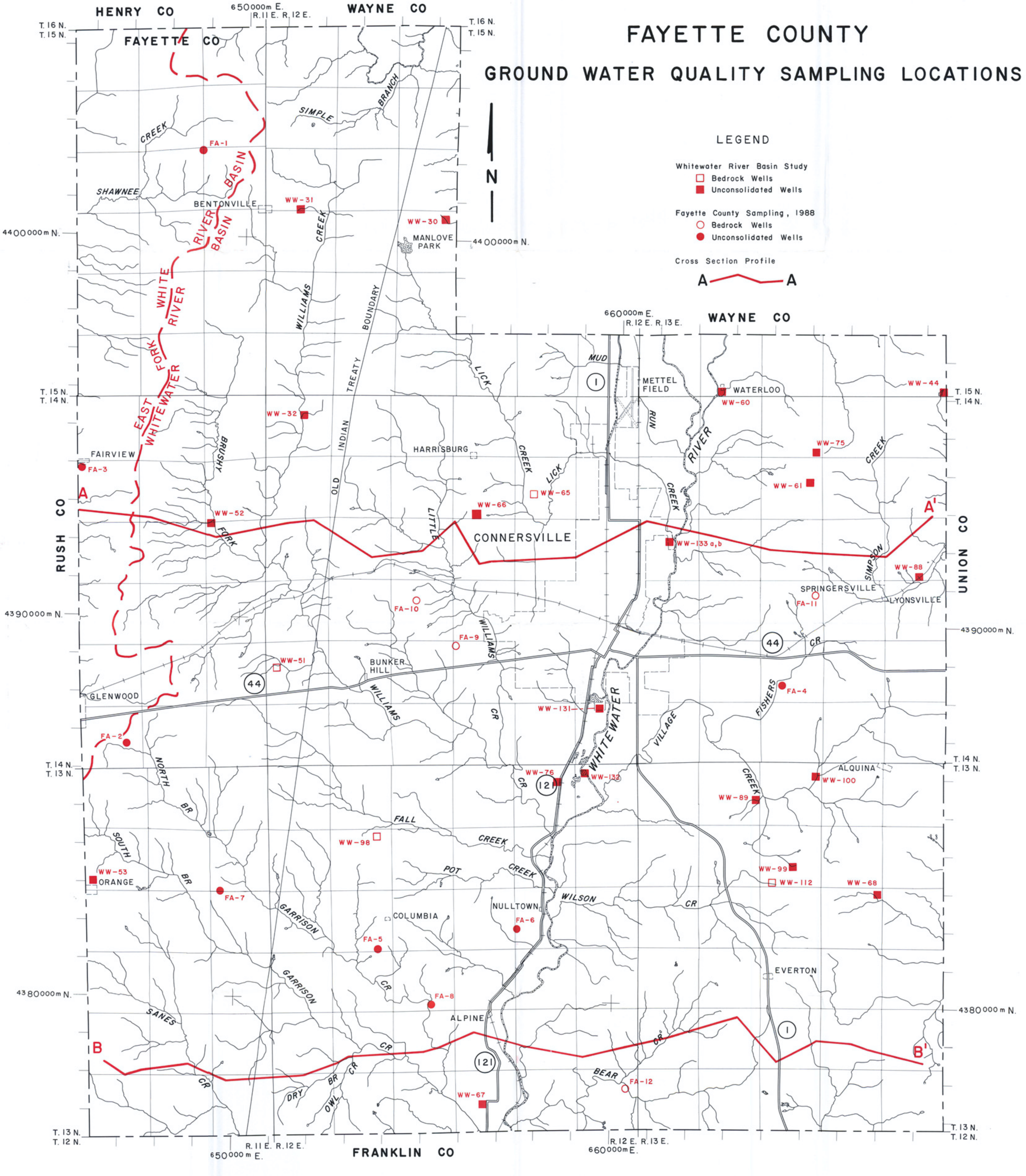
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

FAYETTE COUNTY
GROUND WATER QUALITY SAMPLING LOCATIONS



Compiled from USGS 1:24000 scale topographic maps.

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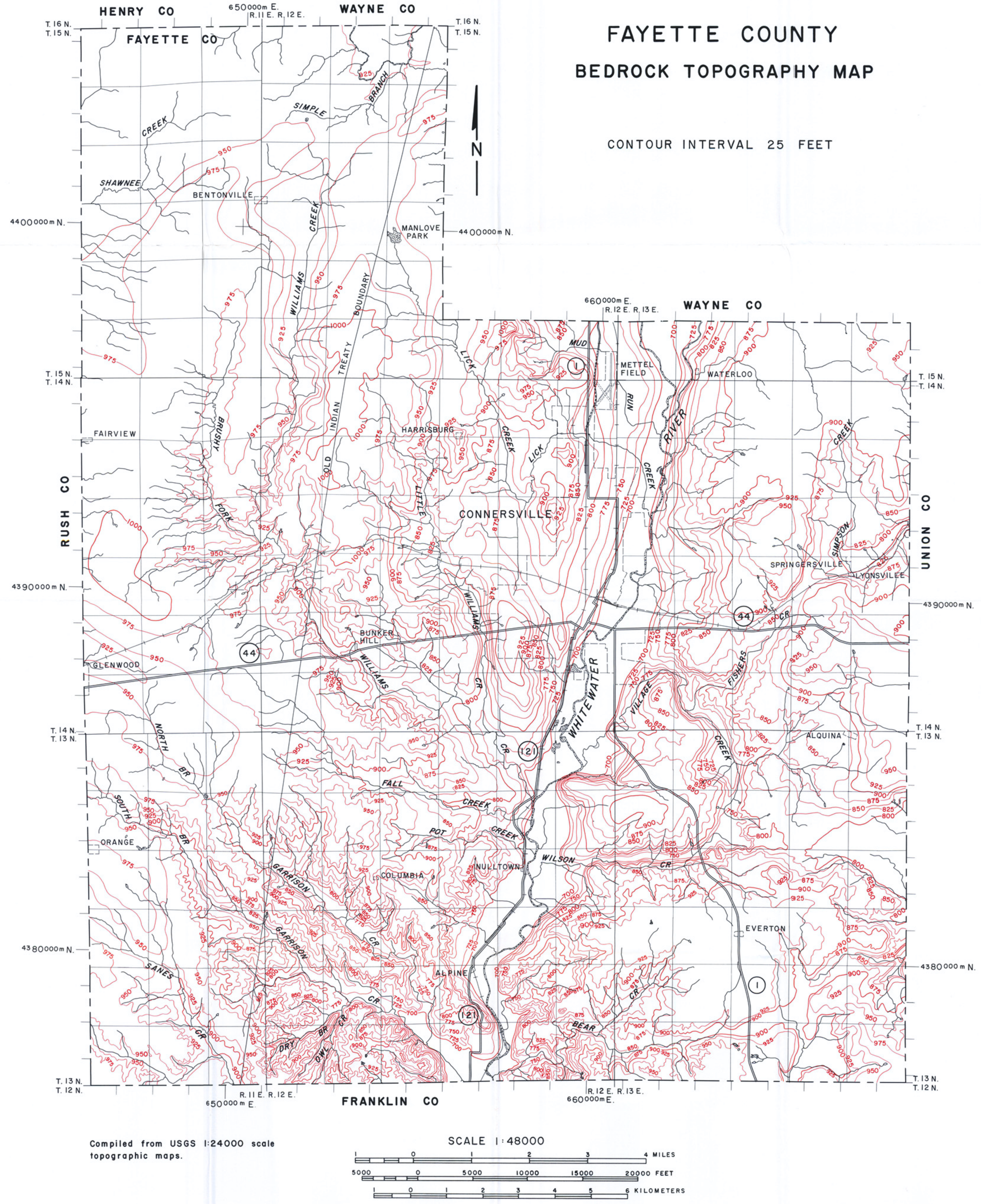
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

FAYETTE COUNTY
BEDROCK TOPOGRAPHY MAP

CONTOUR INTERVAL 25 FEET



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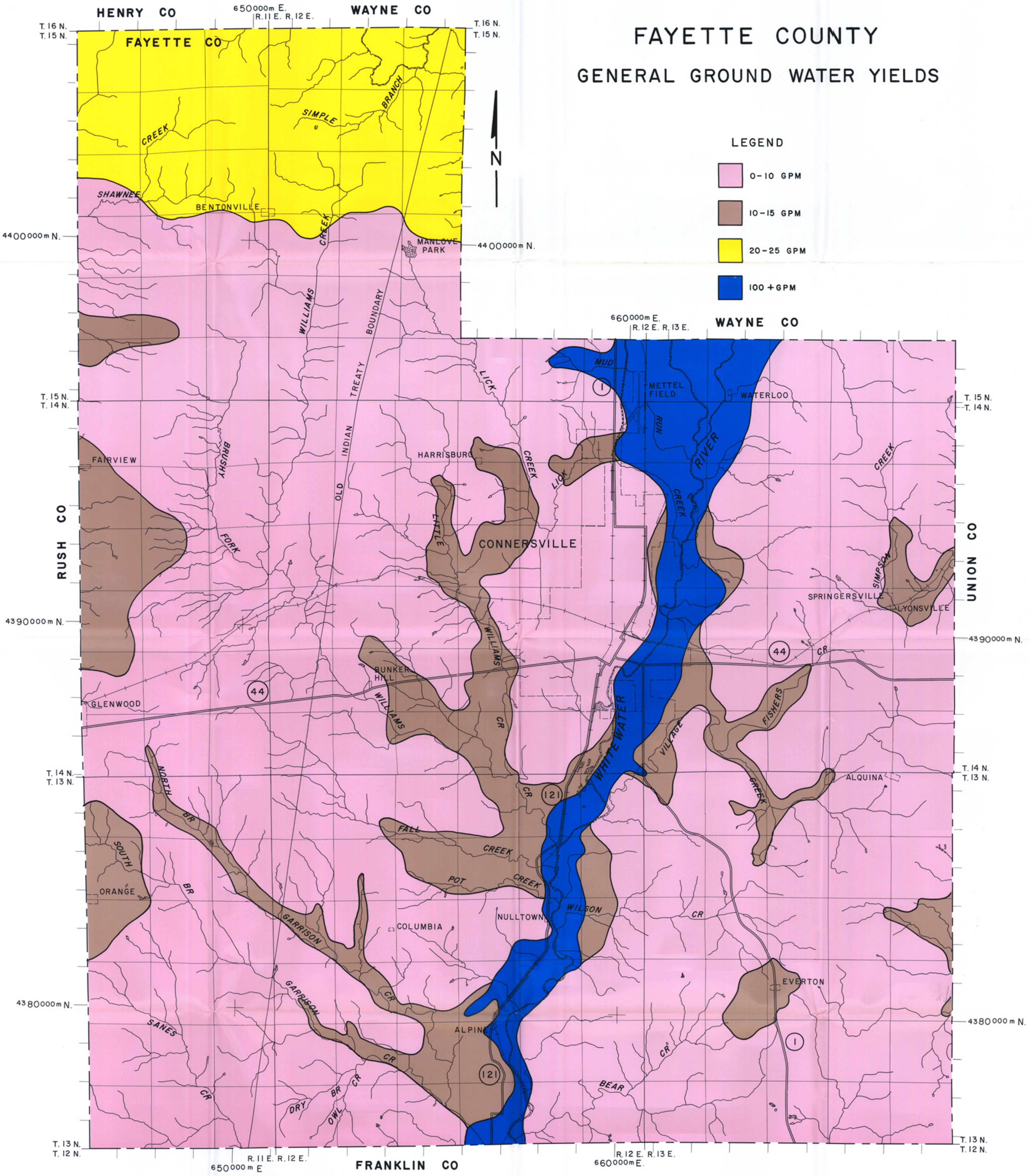
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

FAYETTE COUNTY

GENERAL GROUND WATER YIELDS



LEGEND

- 0-10 GPM
- 10-15 GPM
- 20-25 GPM
- 100 + GPM

Compiled from USGS 1:24000 scale topographic maps.

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5000 0 5000 10000 15000 20000 FEET

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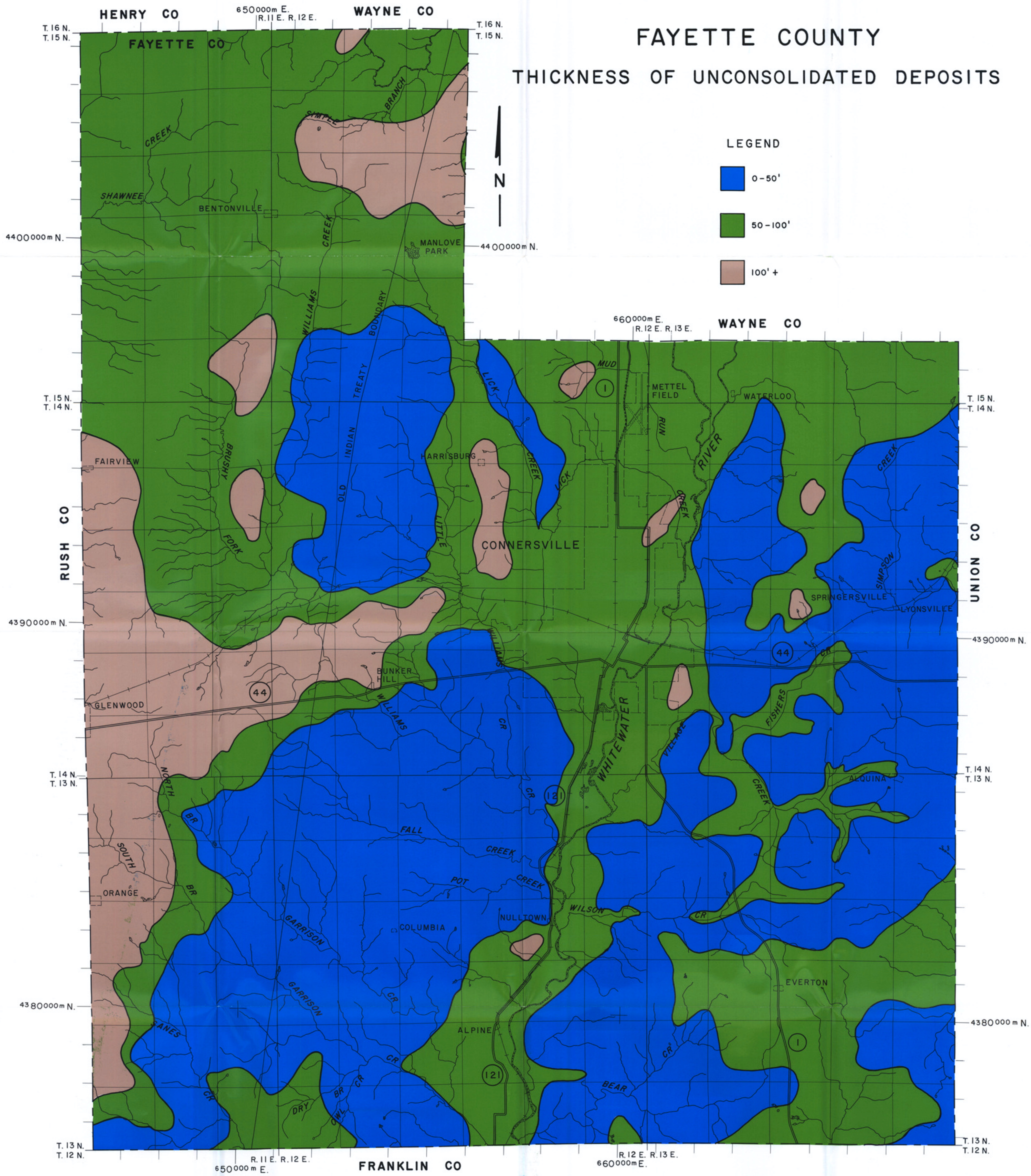
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

FAYETTE COUNTY

THICKNESS OF UNCONSOLIDATED DEPOSITS



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DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

FAYETTE COUNTY

POTENTIOMETRIC SURFACE MAP

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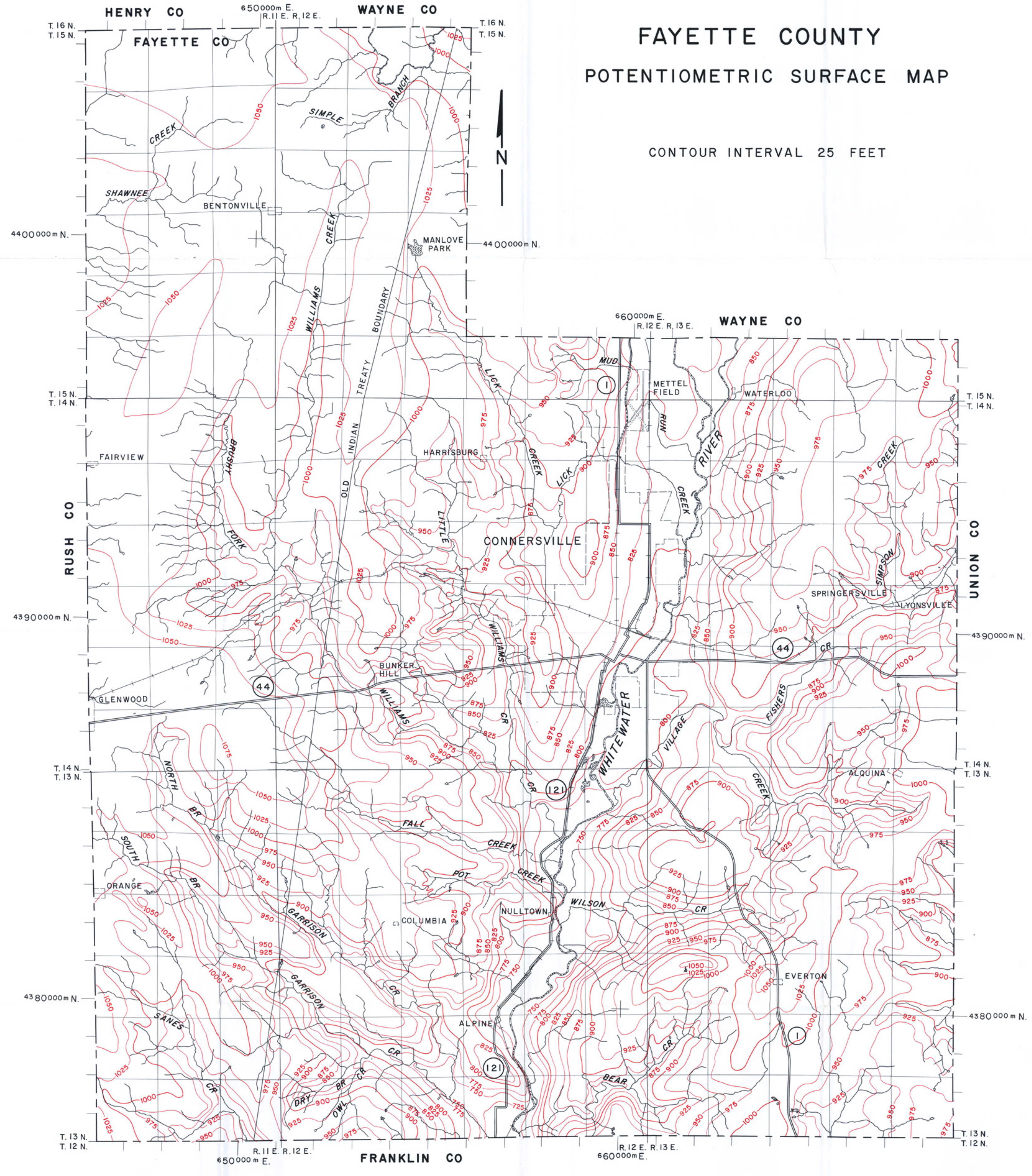

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