TECHNICAL ATLAS OF THE GROUND-WATER RESOURCES OF MARION COUNTY, INDIANA

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

1976

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Prepared by
WILLIAM C. HERRING

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MARION COUNTY, INDIANA

By William C. Herring

ABSTRACT

In Marion County it is estimated that approximately 55 million gallons per day (mgd) is withdrawn from sand and gravel aquifers in the glacial drift and from shallow aquifers in the bedrock. The principal sources of these supplies are the glacial outwash deposits of sand and gravel found in the valleys of White River, Fall Creek and Eagle Creek; the limestone and dolomite bedrock of Devonian and Silurian age in the central and eastern portions of the county and various intertill sand and gravel aquifers scattered throughout the county.

This report contains information on the expected yield to individual wells drilled into bedrock and glacial aquifers, the direction of ground-water movement as defined by piezometric maps, saturated thickness and transmissivity maps for the principal sand and gravel aquifers, and various maps depicting the bedrock and glacial geology as it relates to ground-water occurrence.

Underlying the county are several aquifer systems containing appreciable amounts of undeveloped ground water. The most prolific aquifers are found in the outwash sand and gravel deposits and limestone and dolomite bedrock, with wells in these formations ranging in yield from 100 to over 4000 gallons per minute each. Domestic and light commercial well supplies are obtained in nearly all parts of the county.

Ground water from either glacial or bedrock aquifers, is of the hard to very hard calcium bicarbonate type, containing iron and moderate amounts of dissolved solids. Water quality is generally satisfactory for most uses although softening and iron removal is sometimes required.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this report is to define the location, availability and general chemical quality of the ground water in Marion County, and to provide information that will assist in the development of these resources for domestic, industrial, agricultural, municipal and recreational uses. These purposes are achieved through the presentation of the most recently prepared technical and general information on the ground-water resources of the county.

During the last fifteen years there has been a steady but increasing volume of ground-water data generated for Marion County, with the outward spread of people and commercial concerns into formerly rural areas. As this expansion has occurred there has been an increasing demand for ground-water information of a type that could not be met by reports that supply only basic data. It is with this in mind that a more sophisticated in-depth analysis was undertaken, including a ground-water availability atlas, to provide information to the general public, private consultants, government agencies and others in need of ground-water information.

LOCATION AND SIZE OF AREA

Marion County is located in the geographic center of Indiana and covers an area of about 400 square miles (fig. 1). The county is nearly square in outline and contains the state capitol, Indianapolis, which has a population of 793,590 (1970 census).

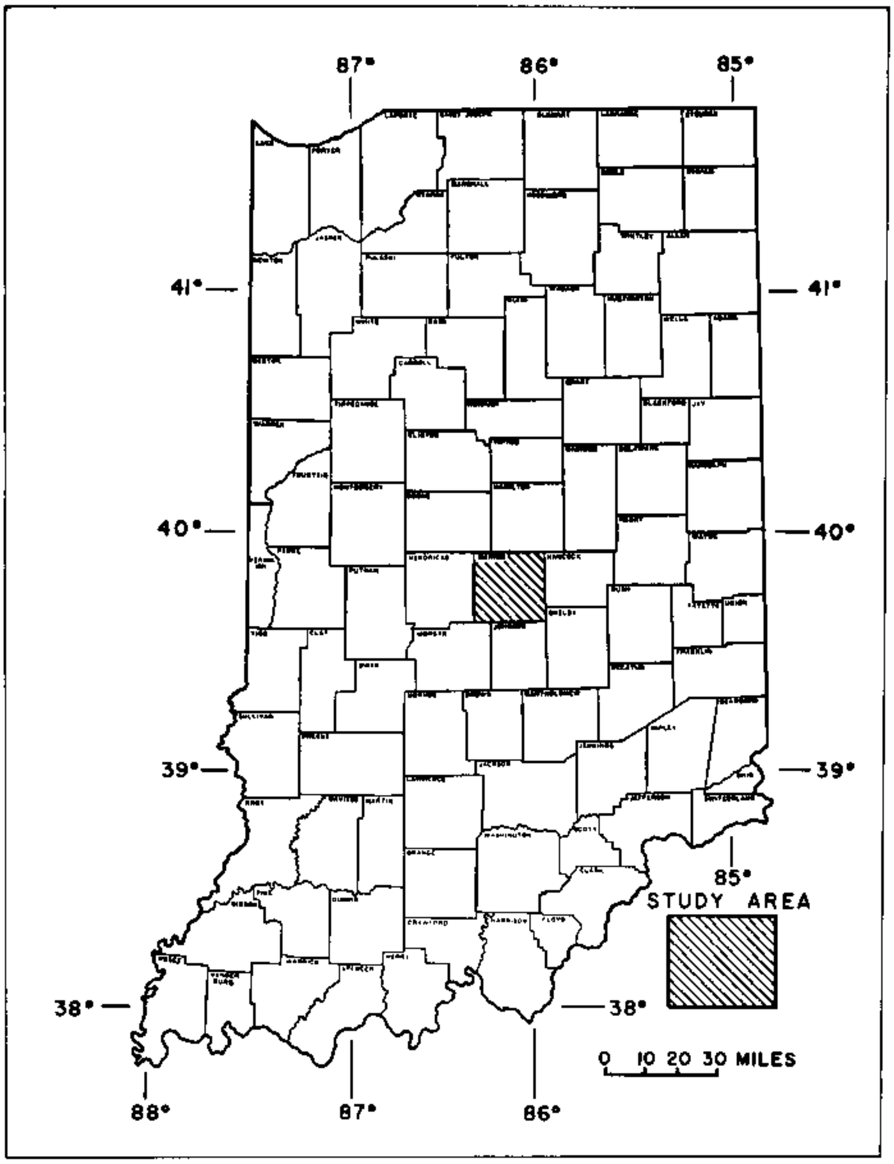


FIGURE 1. Map of Indiana showing location of study area

PREVIOUS INVESTIGATIONS

The nature of the ground-water resources of Marion County has been described to some extent in previous publications, most of which are quite old. A chronological listing and summarization of these publications are shown below:

1899. Leverett, Frank, Wells of southern Indiana: U.S. Geological Survey Water-Supply Paper 26, 64 p.

Contains brief summary of well data for Marion County.

1910. Capps, S.R., The underground waters of north-central Indiana, with a chapter on the chemical character of the waters, by R.B. Dole: U.S. Geological Survey Water-Supply Paper 254, 279 p.

Contains short summary of surface features, drainage, geology, ground water, and ground-water quality.

1935. Harrell, Marshall, Ground water in Indiana: Ind. Div. Geol. Pub. 133, 504 p.

Contains short summary of surface features, drainage, geology, ground water, and ground-water quality:

1943. McGuinness, C.L., Ground-water resources of the Indianapolis area, Marion County, Indiana: Ind. Dept. Conserv., 49 p.

The most complete report on the ground-water resources of Marion County. Includes nearly all facets of ground-water evaluation including movement, availability, quality, pumpage, water levels, artificial recharge, and future development. Contains bibliography listing all old reports relevant to geology and ground water in the county.

1955. Roberts, C.M., Widman, L.E., and Brown, P.N., Water resources of the Indianapolis area, Indiana: U.S. Geological Survey Circ. 366, 45 p.

Primary emphasis of report is on the quantity and quality of surface-water supplies, but includes considerable ground-water information. Estimates of the perennially available ground-water supply were made.

1972. Maclay, R.W., and Heisel, J.E., Electric analog model study of the upper White River basin, Indiana: U.S. Geological Survey Open-File Report, 27 p.

Includes some recent estimates of recharge, discharge, and aquifer coefficients in constructing an electric analog model of the White River basin, which includes most of Marion County. Model was used to investigate the effects of pumpage, principally in Marion County.

1975. Meyer, W., Reussow, J.P., and Gillies, D.C., Availability of Ground Water in Marion County, Indiana: U.S. Geological Survey Open-File Report, 87 p.

Report contains information on and analyses of ground-water pumpage in the metropolitan area. Primary emphasis on the determination of the development potential of ground-water resources in Marion County.

GEOGRAPHIC SETTING

Marion County lies within the Tipton Till Plain physiographic unit as defined by Malott (1922). The land surface is part of a generally level to rolling glacial till plain that has been locally dissected by White River with its major tributaries of Eagle Creek and Fall Creek, and numerous smaller streams. The greatest local changes in elevation and steepest slopes occur along Eagle Creek, Fall Creek, and White River in the north-central portions of the county where relief of 50 to 90 feet is noted. Elevations of the land surface range from the maximum of over 920 feet above mean sea level (msl) in the northwestern part of the county near the Boone County line to a minimum of about 645 feet where White River leaves the county at the southern edge.

White River is the principal stream in the county, entering the north boundary at a point slightly east of center and flowing generally southwest to an exit point west of center on the south county line. Eagle Creek and Fall Creek enter the county from the northwest and northeast, respectively, and join White River near the center of the county. White River and its tributaries drain about 88 percent of the county, while Buck Creek in the southeast part of the county drains the remaining 12 percent and flows into the East Fork of White River.

GEOLOGIC SETTING

The surficial geologic deposits underlying Marion County consist primarily of a compacted mixture of silt, sand, clay and pebbles called glacial till. These materials were deposited by the glaciers that covered this area some 15,000 to 20,000 years ago. These deposits and the alluvium of the present stream valleys are the source materials from which most of the fertile soils of Marion County have been formed. Within the deposits of glacial till and below the valleys of White River, Fall Creek and Eagle Creek are found layers of sand and gravel that vary in thickness from a few inches to over 120 feet. These deposits provide an abundant supply of material for the aggregate industry in addition to containing the major aquifers of the county.

Beneath the glacial deposits are found bedrock formations of Paleozoic age which range in age from 250 to 375 million years. These nearly flat-lying sedimentary formations consist primarily of limestone, dolomite, shale, siltstone and sandstone. These deposits range in thickness from 3800 to over 4800 feet in the county; but only the upper 300 to 400 feet can be considered as a potential source of potable water. In the northeastern, central and northwestern portions of the county irregularities exist on the bedrock surface which point to the presence of former drainage patterns developed during preglacial times. In some areas these buried valleys may offer potential for ground-water development.

UNCONSOLIDATED DEPOSITS

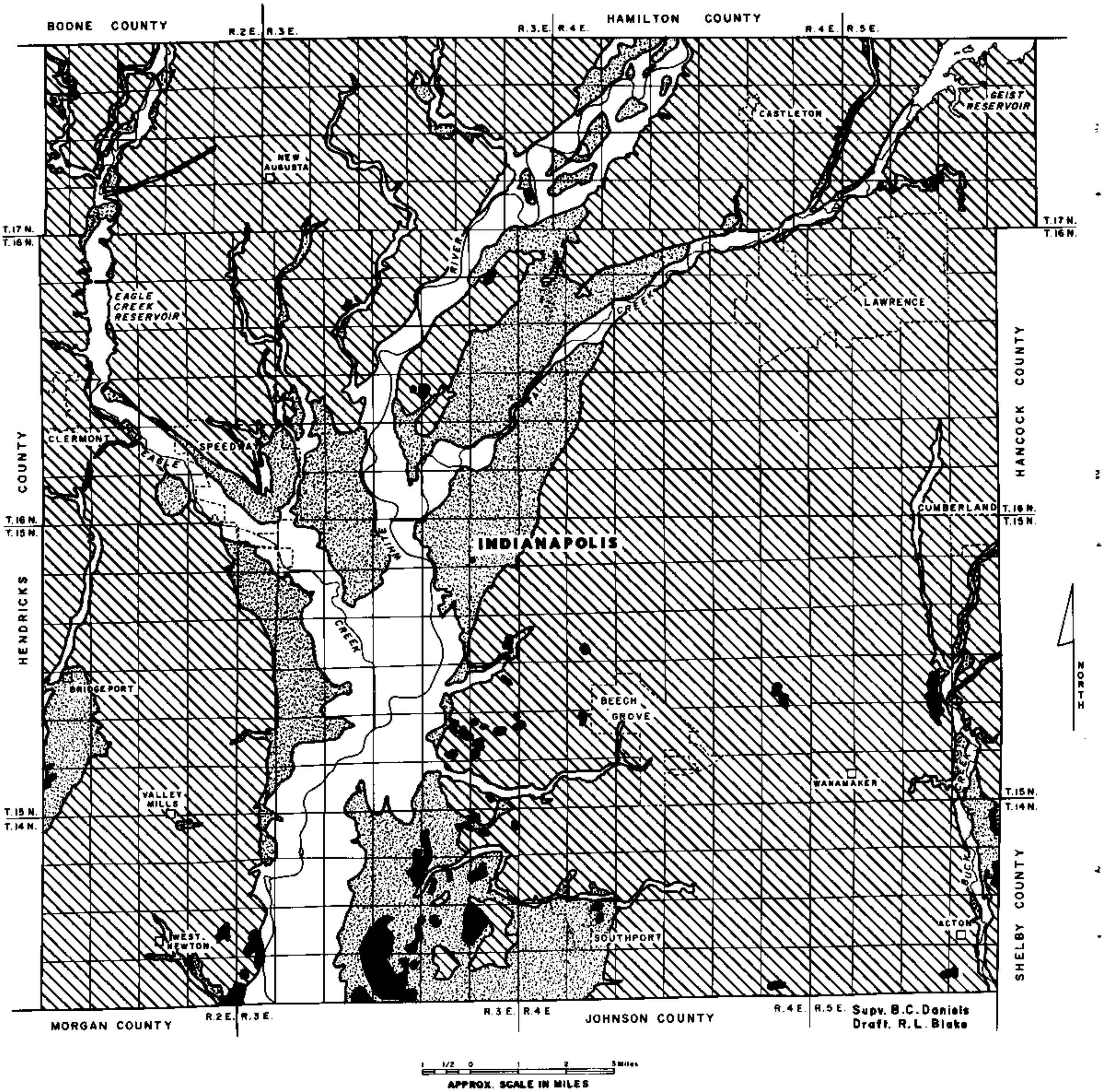
Figure 2 shows the surficial geology of Marion County and outlines the types of geologic materials found at the land surface. Although somewhat modified by recent stream action and the activities of man, these land features are primarily the result of the actions of the various continental glaciers that covered the county during the glacial period. As these ice sheets deposited their loads of clay, silt, sand and gravel, tremendous quantities of glacial meltwater cut broad deep valleys in the bedrock surface and unconsolidated deposits, reworking previous sediments and filling the eroded valleys with permeable deposits of sand and gravel. It is these deposits that form the most productive aquifers in the county.

The thickness of the glacial drift in the county varies from less than 15 feet in southwestern areas to over 300 feet in northeastern and northwestern parts of the county where major buried valleys exist (fig. 3). One method of showing this information is through an isopach map with contour lines depicting the thickness of the glacial materials. Figure 3 was drawn with the assumption that all unconsolidated deposits above the bedrock were glacial drift. No attempt was made to separate the drift sheets resulting from the three successive glacial stages which modified the county during the glacial advances.

With the exception of recent alluvium, man-made deposits, and possibly a thin basal "red clay" in the northeast portion of the county, all unconsolidated materials lying above the bedrock are the direct result of the three stages of glaciation -- Kansan, Illinoian and Wisconsinan. The red clay mentioned above is believed by some to be the remnant of residual and colluvial soils formed from limestone bedrock prior to glaciation. For a more complete and detailed discussion of the glacial history of the county the reader is referred to Harrison (1963).

CONSOLIDATED DEPOSITS
(BEDROCK)

The bedrock formations lying beneath the glacial drift in Marion County consist of a series of limestones and dolomites of Silurian and Devonian age in the central and eastern parts of the county and shales and sandstones of Devonian and Mississippian age in the western part of the county (fig. 4). These rocks dip gently to the southwest at a rate of 20 to 30 feet per mile with no major faults or deformations present, exclusive of the Fortville Fault in eastern Marion County. The youngest bedrock formations in the county are of the Borden Group (Mississippian age) and are found in the southwestern corner of the county. The oldest bedrock subcrops beneath the drift in the northeast part of the county and may be of Ordovician age; however, no drilling in the deep bedrock valley has yet substantiated this probability.



EXPLANATION

Alluvial sand, silt and clay

Recent stream deposits. Yellowish gray or gray, black when containing considerable organic material. Generally underlain by outwash sand and gravel.

Muck and peat

Swamp deposits, including some inwash. Gray or black, silty and clayey

Outwash sand and gravel

Glacial stream deposits. Yellowish gray or light gray. Principally sand and sandy gravel some silt and clay, and scattered cobbles and boulders

Kame sand and gravel

Ice-contact deposits. Light yellowish gray. Poorly sorted sand and gravel, beds of till within or on top

Till

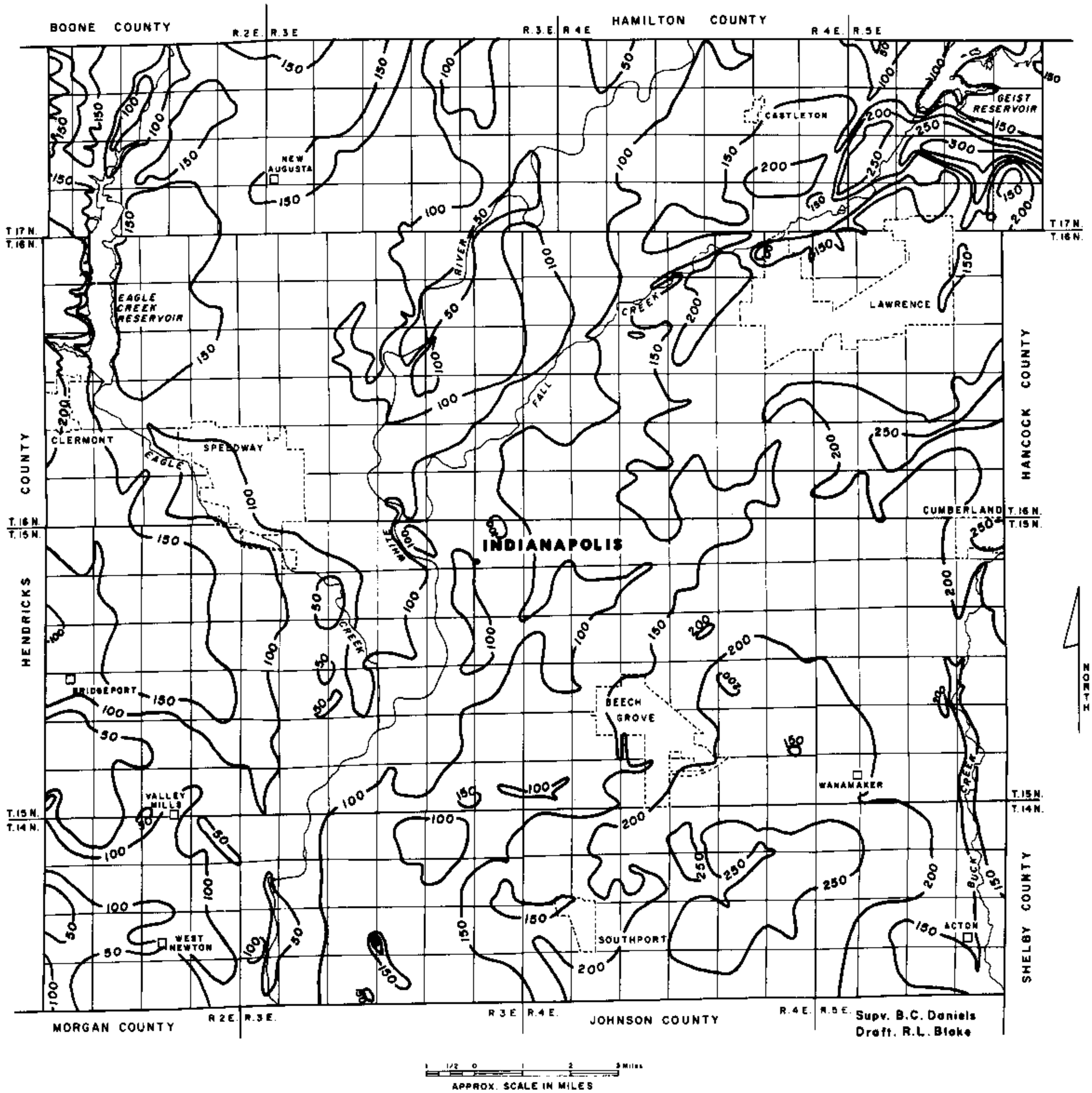
Glacial ice deposits. Yellowish gray, bluish gray or gray. Principally sand or silt, some clay and pebbles, and scattered cobbles and boulders

Geologic Boundary

Solid line where accurately located; longdash where approximately located; shortdash where indefinite or inferred

MAP MODIFIED FROM W. HARRISON, 1963, PLATE I.

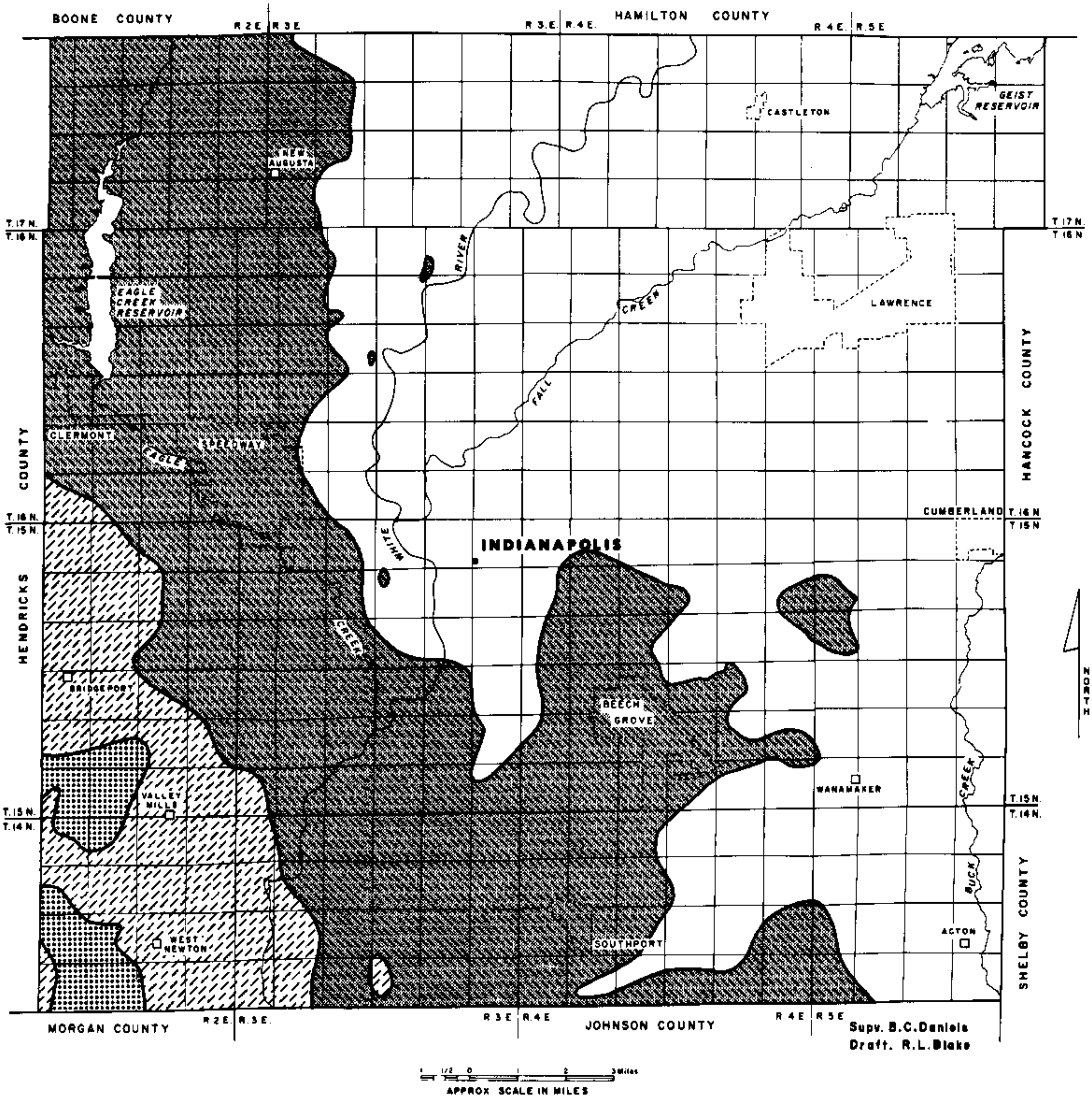
FIGURE 2. Map showing surficial geology



EXPLANATION

200 Isopach contour
Contour interval = 50 feet

FIGURE 3. Map showing thickness of glacial drift



EXPLANATION

- Silurian - Devonian limestones
- Borden shale (Mississippian age)
- New Albany Shale (Devonian - Mississippian age)
- Borden sandstone (Mississippian age)

FIGURE 4. Map showing generalized bedrock geology

In figure 4 the Silurian and Devonian bedrock formations are grouped together since they form a single but complex hydrologic system, and because separation of the individual formations, based on present data, would be at best difficult. A sandstone aquifer of the Borden Group is also shown because it is easily recognized in well logs and because it is the only significant bedrock aquifer in that area of the county.

Figure 5 defines the topography of the bedrock surface in Marion County. This map, when used in conjunction with a knowledge of the land surface topography, may be utilized to outline the thickness of the glacial drift and the presence of preglacial or early glacial valleys in the bedrock surface. The location and depth of buried bedrock valleys is of particular interest, since meltwaters from the various glacial stages may have been funneled through portions of these valleys, depositing sand and gravel which could serve as important sources of water. However, in many cases the materials contained in the buried valleys are of a fine-grained nature and are not capable of supplying large volumes of water.

GROUND-WATER HYDROLOGY

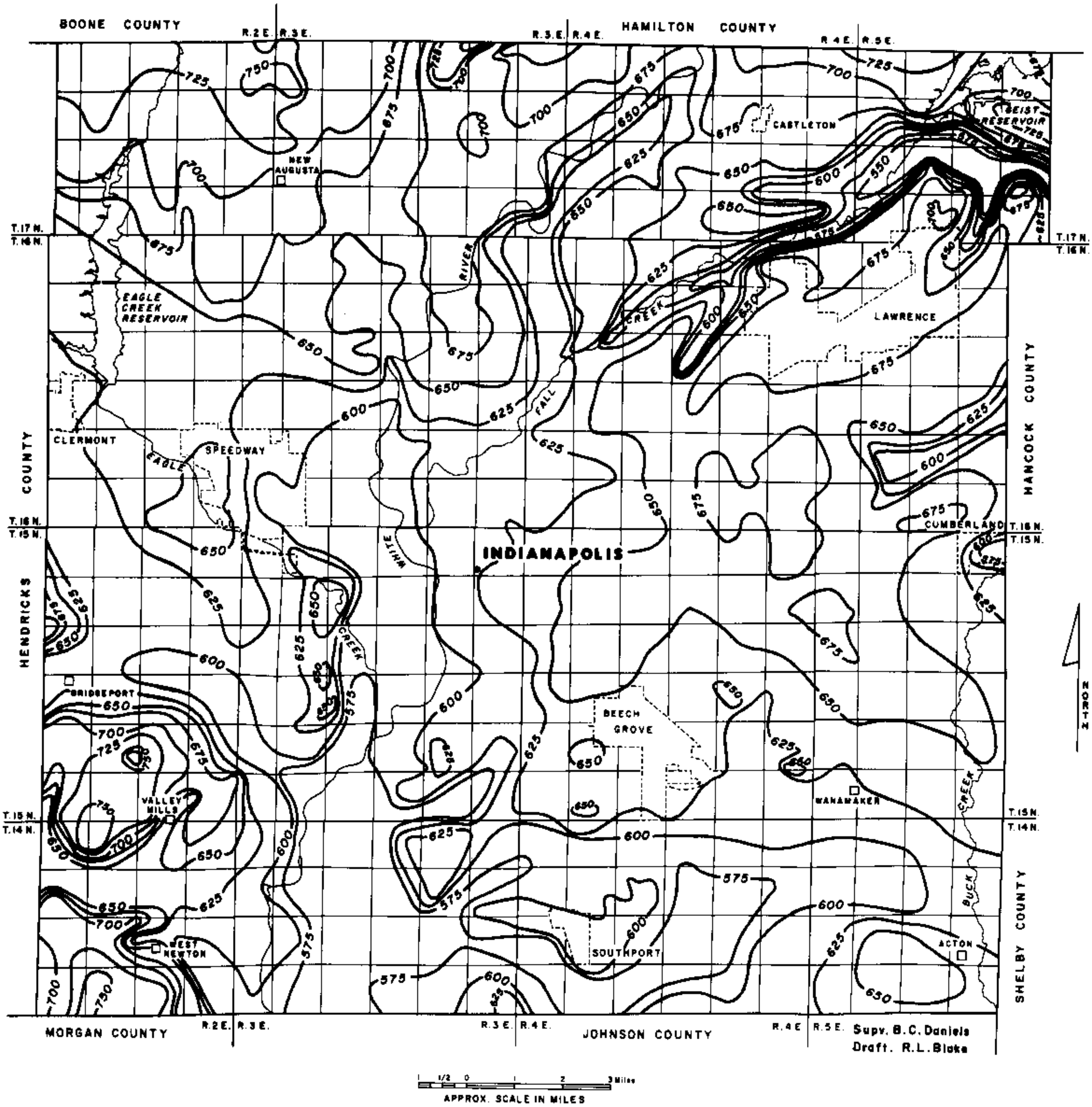
OCCURRENCE

Ground water is found in the open spaces between the individual particles composing bedrock and unconsolidated formations. This water, which is found below the water table, occurs in a variety of geologic formations and for this reason is highly variable in its availability to wells. The property that determines the amount of ground water stored in a formation is called porosity. Porosity, while an expression of the water stored in a material, is not an indication of the amount of water that may be pumped from a well in a particular formation. For example, while shale has a relatively high porosity, it holds the water very tightly within the small pore spaces and water is released from shale at a very slow rate. Therefore shale is generally regarded as a poor water-bearing formation. Sand and gravel, however, while having a much lower porosity than shale, releases its water more readily and is therefore considered a good water-bearing material.

The property that determines the ability of a formation to transmit water is called hydraulic conductivity, or permeability. The hydraulic conductivity of a formation is controlled principally by the size, shape, and degree of interconnection of the pore spaces. In coarse-grained and well sorted gravel formations the voids generally exhibit a high degree of interconnection, and thus hydraulic conductivity is good. Conversely, fine sand or poorly sorted formations do not have as good an interconnection and the hydraulic conductivity is less. Limestone, with its often unpredictable patterns of fractures and joint systems, often exhibits variable hydraulic conductivity within short distances, and consequently the yield of wells completed in limestone aquifers ranges widely.

GROUND-WATER AVAILABILITY

If one knows or has estimates of the hydraulic conductivities of the prevailing geologic formations, and can reasonably define their physical extent and thickness, it is possible to construct generalized ground-water availability maps that will approximate the maximum yields that can be expected in an area. Available water well records that include data on the geologic formations, water levels, pumping rates, and drawdown of water levels are utilized in defining the physical properties of the aquifers. The resultant ground-water availability maps outline the



EXPLANATION

650 — Elevation in feet above mean sea level (msl)

Contour interval = 25 feet

FIGURE 5. Map showing bedrock topography

expected yields that may be obtained by a properly constructed large-diameter production well penetrating the full thickness of the formation. These maps indicate, within a given range of values, the rate at which an aquifer will yield water to an individual well.

A generalized map depicting the availability of ground water in Marion County is shown in figure 6. The map is based upon work by Herring (1974), "Water Resources of Marion County." Figure 6 outlines the availability of ground water in all aquifer systems in the county, showing the highest average expected yield to a properly designed well. Thus, in one area the map may outline a sand and gravel aquifer as the dominant system while in another area a bedrock aquifer may be the predominant water-bearing unit. In some areas both aquifer types may be present and of nearly equal importance in determining the availability rating.

In the sections to follow, the availability of ground water in the various aquifer systems will be outlined.

Availability of Ground Water in the Glacial Drift

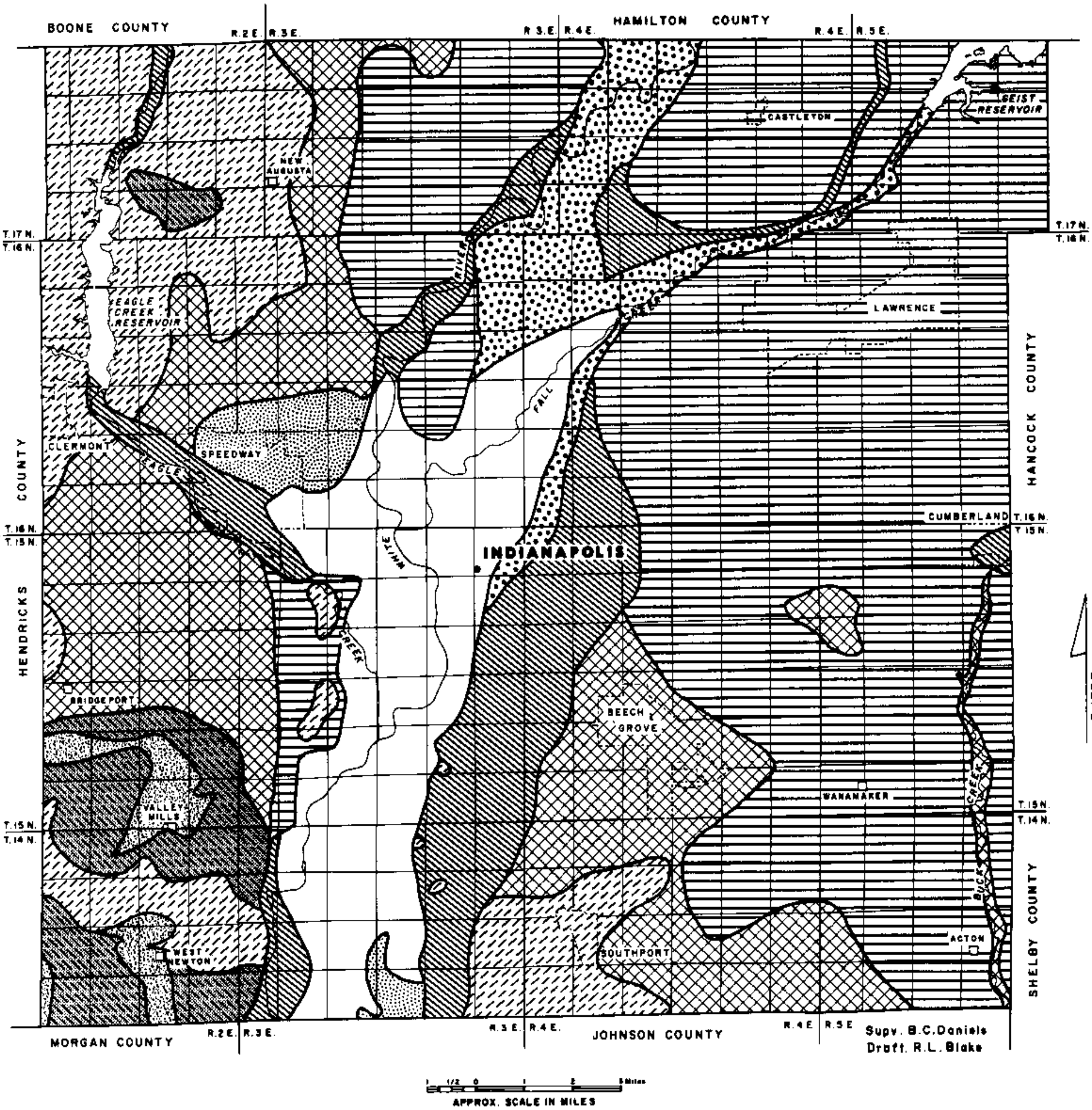
Figure 7 defines the availability of ground water in the glacial drift aquifers of the county. With the exception of three areas discussed below, the map shows the maximum yield that may be expected from a single well drilled in a given area. Assuming the well driller has constructed the well in a manner that will produce the highest practical yield, the well could be expected to produce near the maximum value for a particular area as shown in figure 7. Of course, some exceptions may occur as the local geology changes and as drilling or well completion techniques vary.

One of three areas excepted above is located in the central and south-central part of the county. The notation for the expected well yields in this area, "over 500 gpm", is a conventional term used in previous reports of the Division of Water, Indiana Department of Natural Resources. Its meaning, as far as availability is concerned, is that in this area properly constructed large-diameter wells can usually be expected to produce a minimum of 500 gpm and a maximum of two or three times that amount.

The other two areas excepted above are located in the southwest corner of the county where the glacial drift is very thin and contains little or no sand or gravel capable of supplying water to wells. The availability of ground water in the glacial drift in these areas is therefore practically zero.

Principal Pleistocene Aquifer

The sand and gravel deposits of the White River valley are part of an extensive aquifer system that is present not only in the topographic valley of White River but also to the east and west of the valley beneath the glacial till cover. This aquifer is primarily composed of a mixture of sand and gravel interspersed with thin clay lenses. In places, as in the vicinity of Speedway, the aquifer may be divided into two units by a relatively thick and extensive glacial till layer. Because of the thickness, extent, and development potential of this aquifer system, it is herein designated as the "principal Pleistocene aquifer." In the White River valley and in the lower reaches of Eagle Creek and Fall Creek saturated sand and gravel deposits range in thickness from 30 to over 80 feet, and constitute the most prolific source of ground water in the county. The saturated thickness, extent, and other hydraulic properties of this aquifer are defined later in this report.



EXPLANATION

Individual well production capability (Gallons per minute)

0 - 10
0 - 25
0 - 50
5 - 100
50 - 150
50 - 250
100 - 300
300 - 500
Over 500

FIGURE 6. Map showing generalized ground-water availability

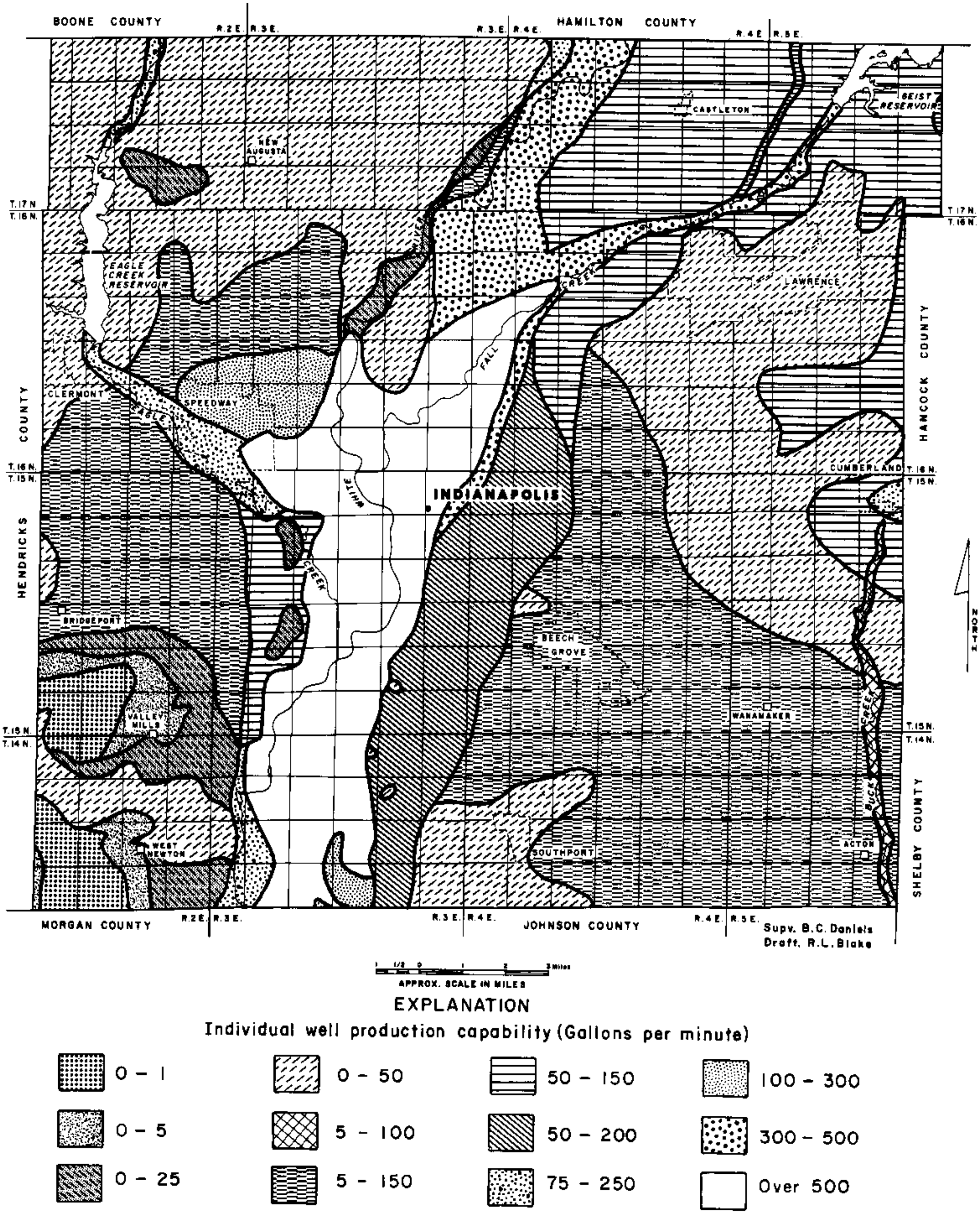


FIGURE 7. Map showing ground-water availability in the glacial drift aquifers

Availability of Ground Water in the Bedrock

Silurian-Devonian limestone and dolomite

The most prolific bedrock aquifer system in the county is composed of limestone and dolomite formations of Silurian and Devonian age (fig. 8). Wherever this aquifer system occurs at the bedrock surface, the most productive water-bearing zones are usually found within the first 100 feet of the bedrock, even though the geologic formation at the bedrock surface may vary within the area.

As shown in figure 8 the Silurian-Devonian aquifer exhibits considerable variability in its ability to transmit water to wells. For example, in the western and southern parts of the county, where the aquifer is overlain by the younger shales of Devonian and Mississippian age, the availability of ground water is much less than in the rest of the county where the aquifer is overlain only by glacial drift. The shale aquitards greatly reduce the downward percolation of water and thereby decrease the potential for solution channel development in the limestone and dolomite beneath, and/or other weathering processes that would be conducive to a more rapid movement of water into and through the aquifer. The additional weight of the shale overburden may also be a factor explaining the absence of significant fractures or joints in the aquifer.

In those areas where the Silurian-Devonian aquifer is overlain by valley-train or outwash plain deposits of sand and gravel the availability of ground water is quite good. In these areas the bedrock has been subjected to surficial weathering processes and more rapid solution channel development, and it is also exposed to a constant source of recharge from the overlying sand and gravel materials. Individual well yields of several hundred gallons per minute are common in these areas.

Where the Silurian-Devonian aquifer is overlain by glacial till, as in much of eastern Marion County, the yield of wells in this aquifer is generally about one-half as great as in those areas where the aquifer is overlain by sand and gravel. One prominent exception is in the area of the well field of the town of Lawrence. In this very small area there are some wells capable of producing 1000 gpm. Apparently a relatively high degree of jointing and/or solution channel development has occurred adjacent to a deeply incised buried valley in the bedrock surface (fig. 5).

New Albany Shale

Figure 9 shows the availability of water in the New Albany Shale of Devonian-Mississippian age. This formation ranges in thickness (where present) from a few inches to about 110 feet. Wells are seldom completed in this unit because of its relatively low yield and since more water can usually be found either above or below it. Where the New Albany Shale underlies the younger Borden shales it has very low permeability and yields almost no water. Where the New Albany subcrops beneath the glacial drift it has a somewhat higher degree of jointing, and consequently the yield of wells tends to be higher. However, most wells are limited suppliers and some contain noticeable amounts of hydrogen sulfide gas (H_2S), or "sulphur water" as it is commonly called.

Borden Group shale and sandstone

Figure 10 shows the availability of ground water in the Borden Group of Mississippian age. This system of shales and sandstones is a very limited supplier of water and "dry holes" are a common occurrence. With the exception of the two

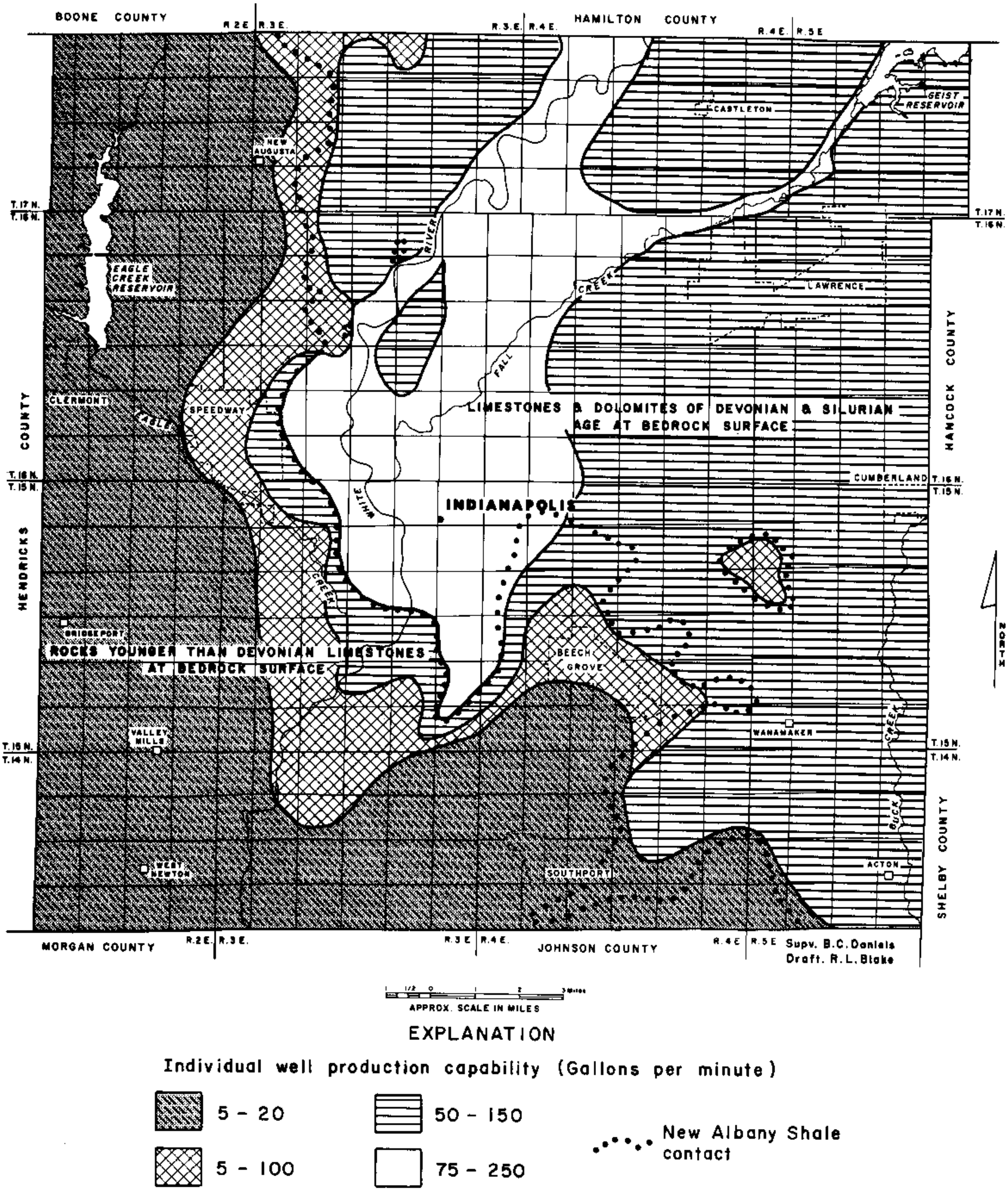
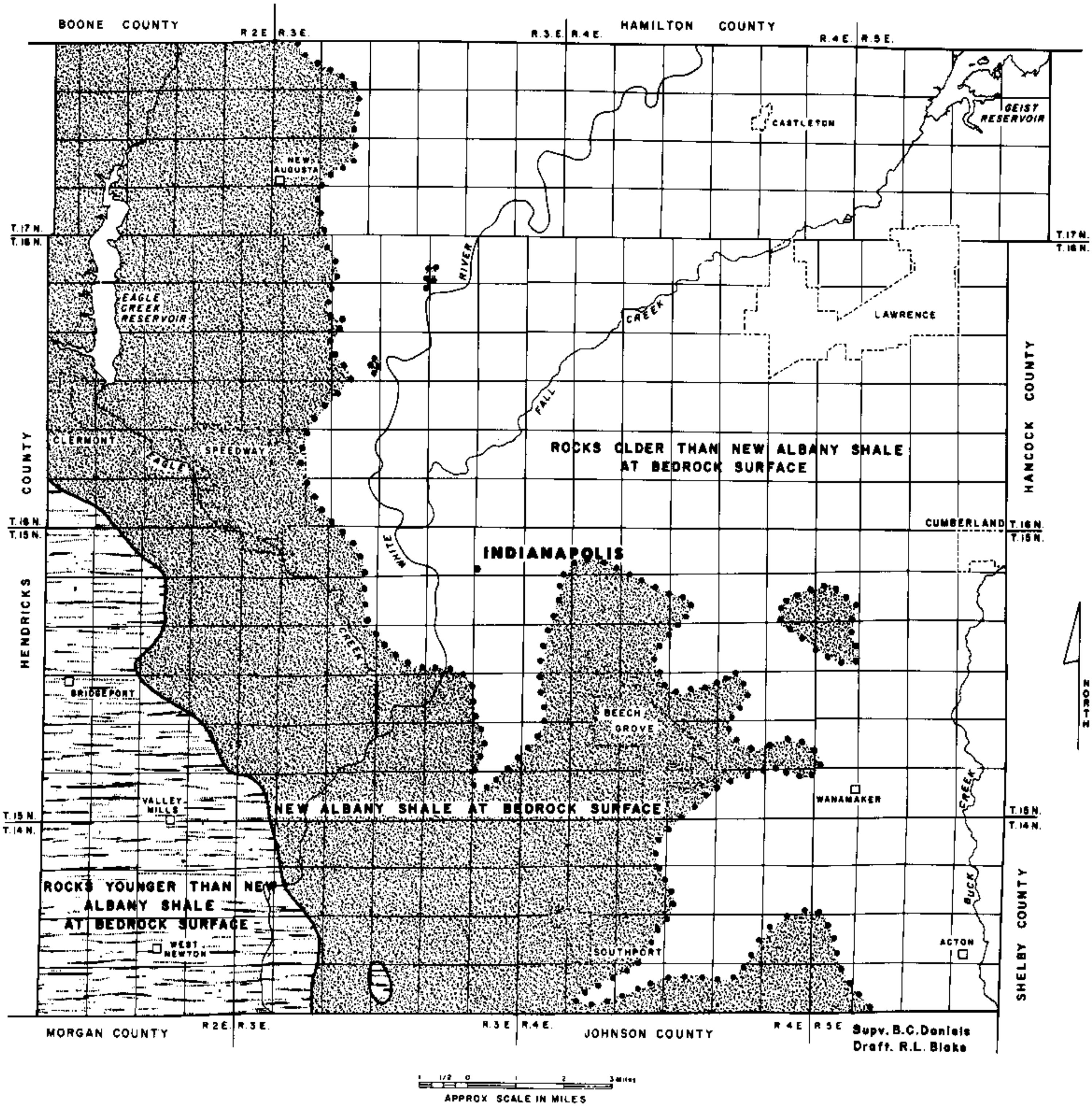


FIGURE 8. Map showing ground-water availability in the Silurian-Devonian aquifer



EXPLANATION

Individual well production capability (Gallons per minute)

"0" gpm

0–10 gpm

New Albany Shale contact

FIGURE 9. Map showing ground-water availability in the New Albany Shale

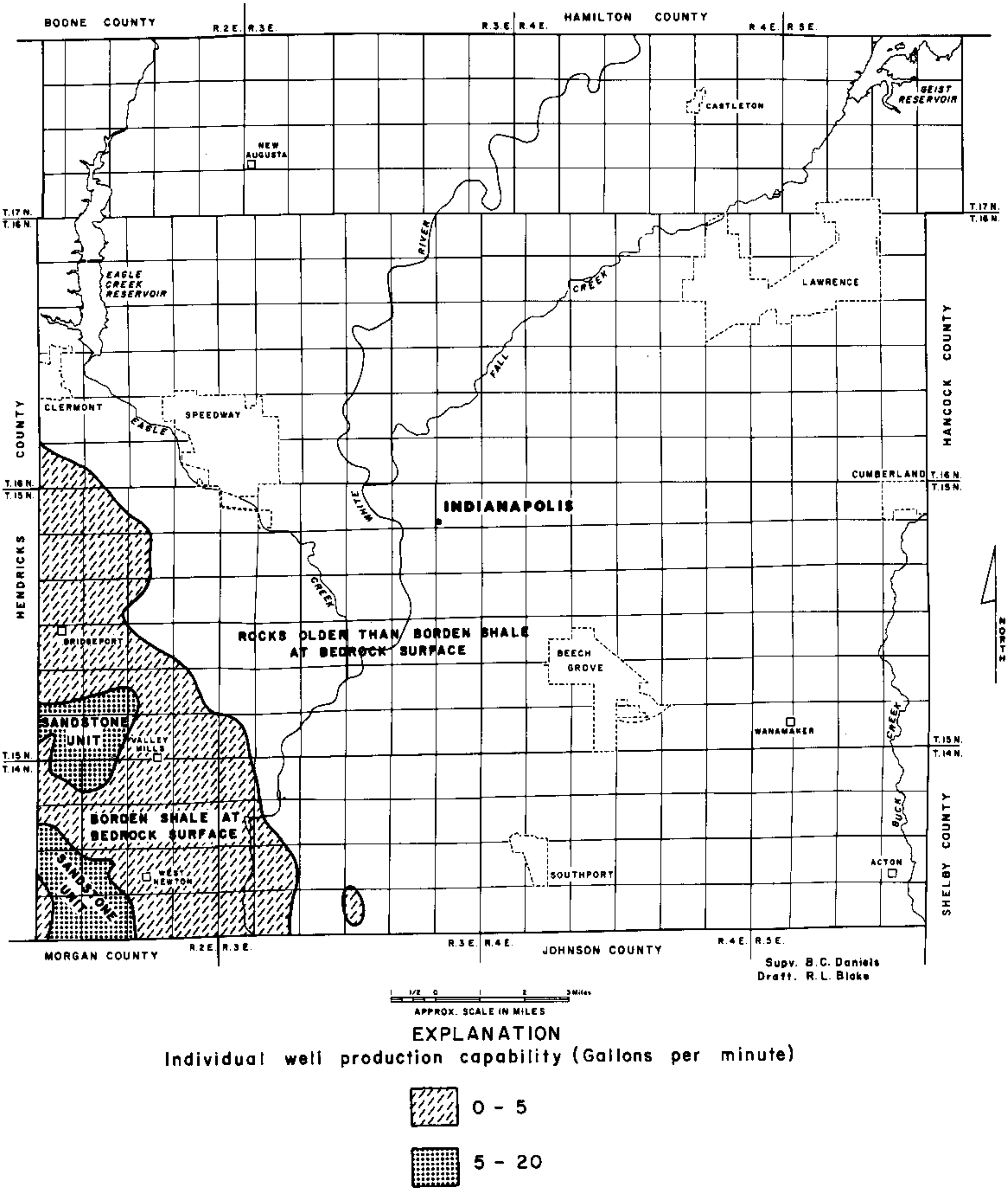


FIGURE 10. Map showing ground-water availability in the Borden Group

small areas shown in figure 10, where a higher yielding sandstone unit is present, few wells can be expected to yield more than 10 gallons per minute. The lower portion of the Borden Group is particularily lacking in usable water-bearing zones and this, when coupled with the lack of overlying glacial aquifers, severely limits the amount of available ground water in this portion of Marion County.

Hydrologic Sections

Figures 11 and 12 show cross sections of the geologic and piezometric profiles (water levels) of both the principal Pleistocene aquifer (sand and gravel) and the Silurian-Devonian aquifer. (See fig. 12 for locations of the cross sections.)

Section A-A'

Section A-A' shows a hydrologic section through Marion County along US 36 (west) and US 40 (east). In the White River valley the principal Pleistocene aquifer is composed primarily of outwash and valley-train sand and gravel deposits which average 80 to 100 feet in thickness. Except for occasional till lenses, the aquifer extends from the water table down to bedrock. Beneath the glacial till in the areas to the east and west of the river valley, the principal Pleistocene aquifer consists of a relatively continuous intertill sand and gravel deposit. The deposit in these areas is variable in thickness, ranging from about 5 to 40 feet, and it generally occurs between the elevations of 670 and 710 feet msl. It tends to be thinner and more sandy in the east-central portion of the county where the bedrock is found at a relatively high elevation.

The piezometric profile of the principal Pleistocene aquifer is also shown in Section A-A'. The profile shows that water moves from the areas of high hydraulic heads (water levels, or piezometric surface) near the east and west county lines to areas of lower heads in the White River valley. Under nonpumping conditions water in this aquifer discharges to the river. However, in those areas where high-volume pumping occurs, a large percentage of the water normally discharging to the river may be diverted into the pumping wells. In addition, some water from the river could be diverted into the wells if they are located sufficiently close to the river.

The piezometric profile of the Silurian-Devonian aquifer is similar to that of the principal Pleistocene aquifer, but it is generally 5 to 40 feet lower in much of the county. Areas that are exceptions to this rule occur (1) along the east county line, where the piezometric surfaces are at nearly the same elevation, and (2) west of High School Road where the piezometric surface of the Silurian-Devonian aquifer is from 65 to as much as 185 feet below that of the principal Pleistocene aquifer. Near the east county line the bedrock aquifer is quite removed from the effects of pumping and is overlain by glacial deposits of moderate permeability. It is recharged relatively easily, so that the water levels in it are approximately the same as those in the principal Pleistocene aquifer. Conditions on the west side of the county, however, are quite different. The Silurian-Devonian aquifer itself becomes less permeable and it is overlain by the Borden and New Albany shale aquitards, which greatly reduce any downward percolation of recharge. Where the overlying New Albany Shale is relatively thin and the aquifer is more permeable, there has been a resulting build up of head, particularly near the White River valley. However, further west the piezometric profile shows a lessening in head, and water levels nearly parallel the southwestward dip of the Silurian-Devonian aquifer.

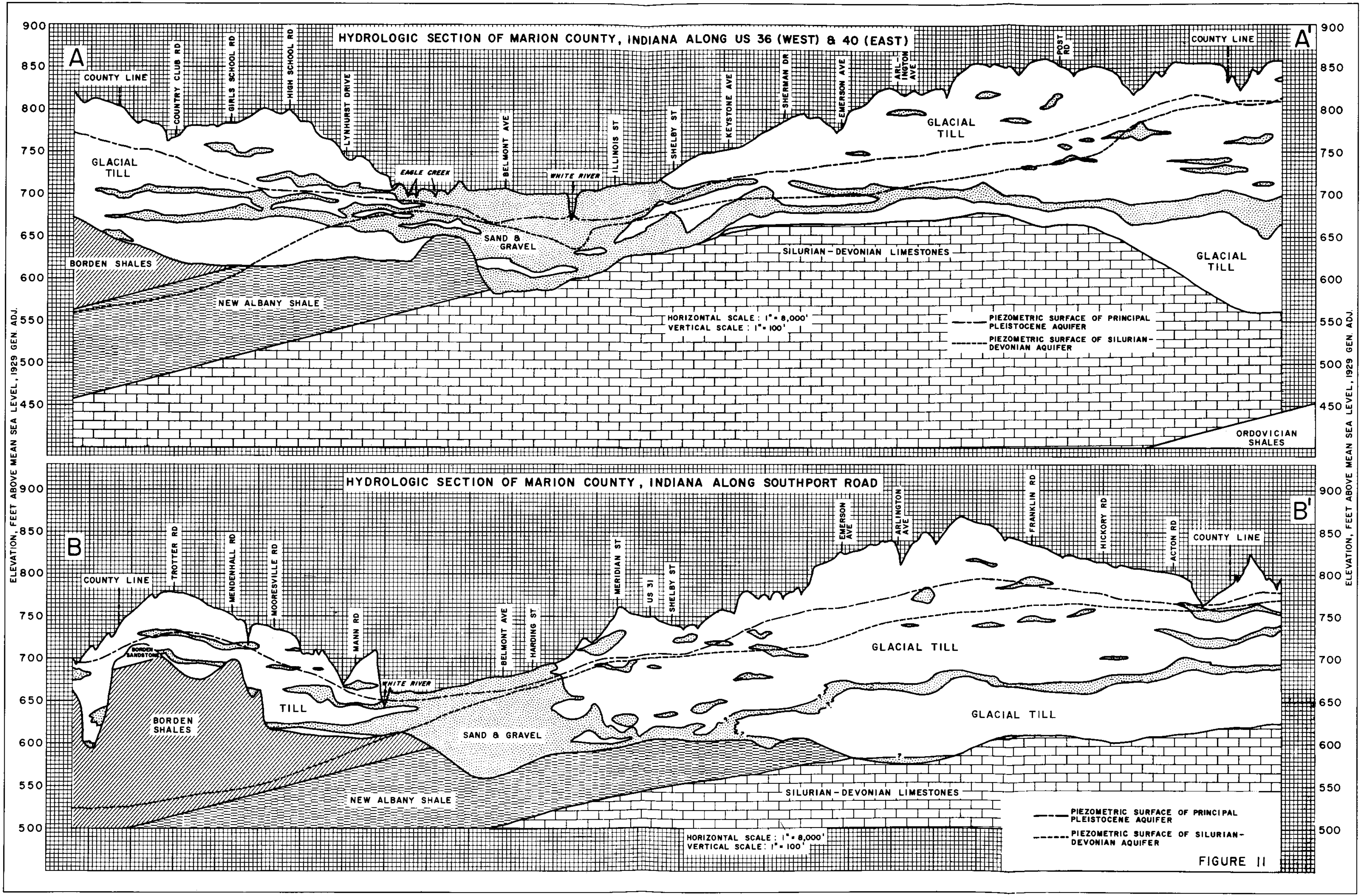

HYDROLOGIC SECTION OF MARION COUNTY, INDIANA ALONG US 36 (WEST) & 40 (EAST)
A
A'
COUNTY LINE
COUNTRY CLUB RD
GIRLS SCHOOL RD
HIGH SCHOOL RD
LYNHURST DRIVE
EAGLE CREEK
BELMONT AVE
WHITE RIVER
ILLINOIS ST
SHELBY ST
KEYSTONE AVE
SHERMAN DR
EMERSON AVE
ARL-INGTON AVE
POST RD
COUNTY LINE
GLACIAL TILL
SAND & GRAVEL
BORDEN SHALES
NEW ALBANY SHALE
SILURIAN-DEVONIAN LIMESTONES
GLACIAL TILL
GLACIAL TILL
ORDOVICIAN SHALES
HORIZONTAL SCALE: 1" = 8,000'
VERTICAL SCALE: 1" = 100'
PIEZOMETRIC SURFACE OF PRINCIPAL PLEISTOCENE AQUIFER
PIEZOMETRIC SURFACE OF SILURIAN-DEVONIAN AQUIFER
900
850
800
750
700
650
600
550
500
450
ELEVATION, FEET ABOVE MEAN SEA LEVEL, 1929 GEN. ADJ.
HYDROLOGIC SECTION OF MARION COUNTY, INDIANA ALONG SOUTHPORT ROAD
B
B'
COUNTY LINE
TROTTER RD
MENDENHALL RD
MOORESVILLE RD
MANN RD
WHITE RIVER
BELMONT AVE
HARDING ST
MERIDIAN ST
US 31
SHELBY ST
EMERSON AVE
ARLINGTON AVE
FRANKLIN RD
HICKORY RD
ACTON RD
COUNTY LINE
BORDEN SANDSTONE
BORDEN SHALES
TILL
SAND & GRAVEL
NEW ALBANY SHALE
GLACIAL TILL
GLACIAL TILL
SILURIAN-DEVONIAN LIMESTONES
PIEZOMETRIC SURFACE OF PRINCIPAL PLEISTOCENE AQUIFER
PIEZOMETRIC SURFACE OF SILURIAN-DEVONIAN AQUIFER
HORIZONTAL SCALE: 1" = 8,000'
VERTICAL SCALE: 1" = 100'

FIGURE 11

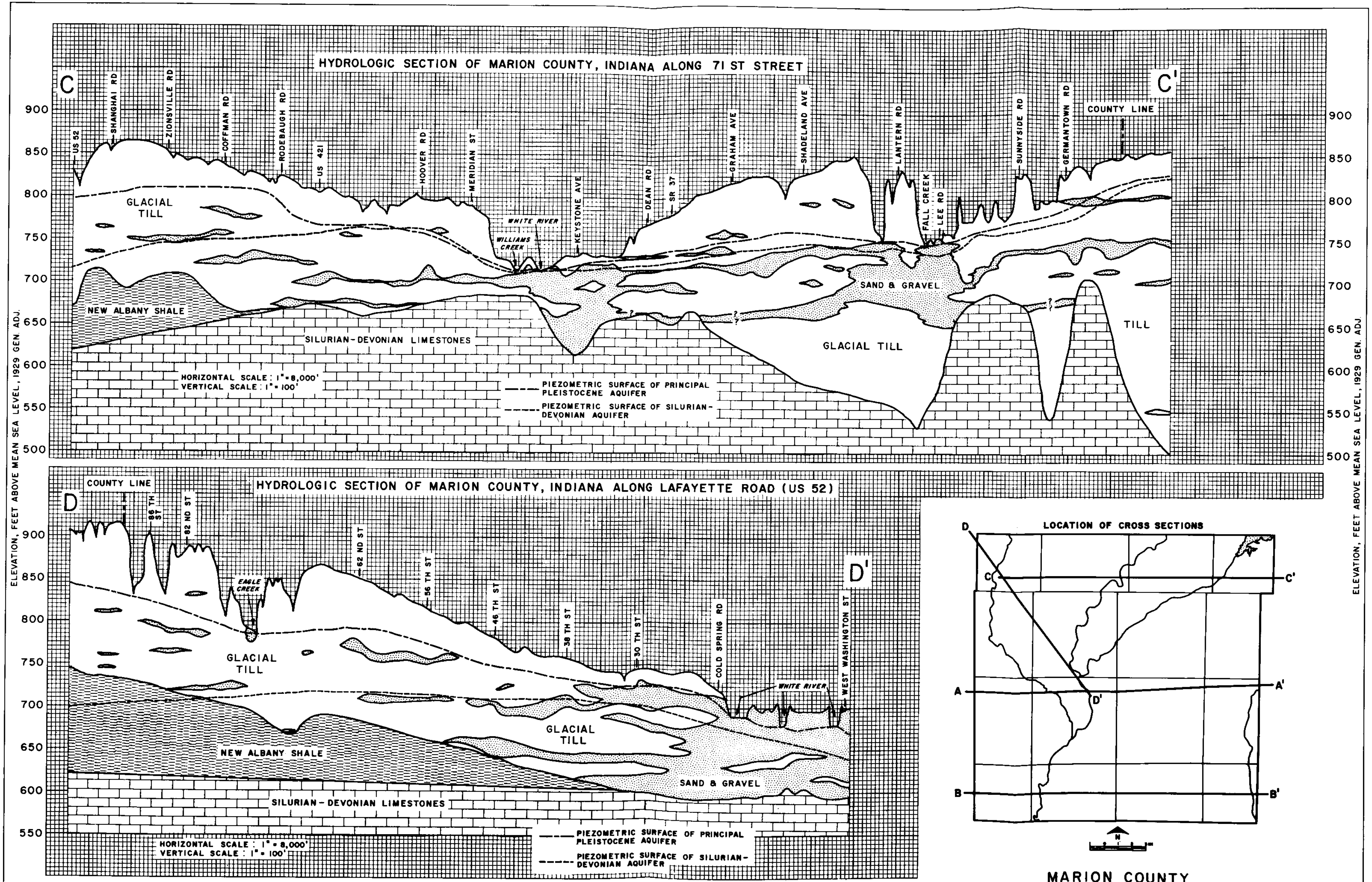

HYDROLOGIC SECTION OF MARION COUNTY, INDIANA ALONG 71 ST STREET
C
C'
US 52
SHANGHAI RD
ZIONSVILLE RD
COFFMAN RD
RODEBAUGH RD
US 421
HOOVER RD
MERIDIAN ST
WILLIAMS CREEK
WHITE RIVER
KEYSTONE AVE
DEAN RD
SR 37
GRAHAM AVE
SHADELAND AVE
LANTERN RD
FALL CREEK
LEE RD
SUNNYSIDE RD
GERMANTOWN RD
COUNTY LINE
GLACIAL TILL
NEW ALBANY SHALE
SILURIAN-DEVONIAN LIMESTONES
SAND & GRAVEL
GLACIAL TILL
TILL
HORIZONTAL SCALE: 1" = 8,000'
VERTICAL SCALE: 1" = 100'
PIEZOMETRIC SURFACE OF PRINCIPAL PLEISTOCENE AQUIFER
PIEZOMETRIC SURFACE OF SILURIAN-DEVONIAN AQUIFER
ELEVATION, FEET ABOVE MEAN SEA LEVEL, 1929 GEN. ADJ.
900
850
800
750
700
650
600
550
500
HYDROLOGIC SECTION OF MARION COUNTY, INDIANA ALONG LAFAYETTE ROAD (US 52)
D
D'
COUNTY LINE
86 TH ST
82 ND ST
EAGLE CREEK
62 ND ST
56 TH ST
46 TH ST
38 TH ST
30 TH ST
COLD SPRING RD
WHITE RIVER
WEST WASHINGTON ST
GLACIAL TILL
GLACIAL TILL
NEW ALBANY SHALE
SAND & GRAVEL
SILURIAN-DEVONIAN LIMESTONES
HORIZONTAL SCALE: 1" = 8,000'
VERTICAL SCALE: 1" = 100'
PIEZOMETRIC SURFACE OF PRINCIPAL PLEISTOCENE AQUIFER
PIEZOMETRIC SURFACE OF SILURIAN-DEVONIAN AQUIFER
LOCATION OF CROSS SECTIONS
D
C
C'
A
A'
D'
B
B'
N
MARION COUNTY

FIGURE 12

Section A-A' also shows a pronounced depression in the piezometric surface of the Silurian-Devonian aquifer beneath White River. This is due to local pumping of the aquifer. If this pumping were to cease, the piezometric surface again would closely approximate that of the overlying principal Pleistocene aquifer.

Section B-B'

The cross section along Southport Road (fig. 11) is, in many respects, similar to Section A-A'. However, east of the White River valley the principal Pleistocene aquifer is found at an elevation of about 600 to 700 feet msl. West of the river it is not as well defined and consists of at least two separate sand and gravel formations, one at an elevation of about 620 feet, and the other at about 700 feet msl. In the till upland away from the White River valley, the aquifer generally ranges from 5 to 15 feet in thickness, with that portion east of White River being the thicker. Within the White River valley the valley-train and outwash parts of the aquifer range from about 30 to 100 feet in thickness.

Because of the small amount of pumping (primarily domestic) along Southport Road the piezometric surfaces are not much different than they would be under natural conditions. Ground water in the principal Pleistocene aquifer discharges to Buck Creek near the east county line and to White River and its tributaries in the rest of the county. A minor amount leaves the county to discharge into East Fork White Lick Creek in Hendricks County. The ground-water divides are found positioned near the major topographic divides.

Section C-C'

Section C-C' (fig. 12) is a cross-section along 71st Street extending from US 52 (northwestern Marion County) to the east county line. A number of interesting features are shown in this profile, including a "buried valley" system cut into the Silurian-Devonian aquifer in the northeast part of the county, a substantial thickness of sand and gravel in Fall Creek valley near 71st Street, and a discontinuity of the principal Pleistocene aquifer west of US 421. (See figs. 5 and 12.)

Except for the Fort Benjamin Harrison well field in the Fall Creek valley and the Fairwood Hills Station (Mud Creek and Fall Creek valleys) of the Indianapolis Water Company, the bulk of water pumped near 71st Street is obtained from domestic wells. All these wells, including the public supplies noted, have had only a minor effect on the prevailing water levels. The piezometric profiles show that water is discharging to White River and Fall Creek-Mud Creek from both the Silurian-Devonian aquifer and the principal Pleistocene aquifer. West of Zionsville Road, the Pleistocene aquifers discharge to Eagle Creek.

Although available information is somewhat limited, there do not appear to be any major sand and gravel aquifers in the buried valley system in northeastern Marion County below an elevation of 650 feet msl. However, in the shallow buried valley over which the present White River flows, the major sand and gravel aquifer extends downward to as low as 560 feet msl in the southern part of the county. (See figs. 5 and 11.)

Section D-D'

Section D-D' (fig. 12) is a cross section along Lafayette Road (US 52) extending from the northwest corner of Marion County to Washington Street near the center of the county. The cross section closely parallels the prevailing strike of the bedrock formations. As in Section C-C', this cross section outlines the discontinuity of the principal Pleistocene aquifer west of White River. It also shows that the outwash aquifer in the Eagle Creek valley is relatively shallow and, in the vicinity of the cross section, is not well connected to any significant sand and gravel deposits within the glacial till. In contrast, the White River outwash is well connected to at least two definable sand and gravel formations that extend west and northwest for several miles. The outwash aquifer contains lenses of till, two of which are shown in the cross section. It may very well be that the gravels below these lenses are Illinoian in age, and that in places where the lenses are absent, gravels of Wisconsin age may occur at elevations below the adjacent clay lenses.

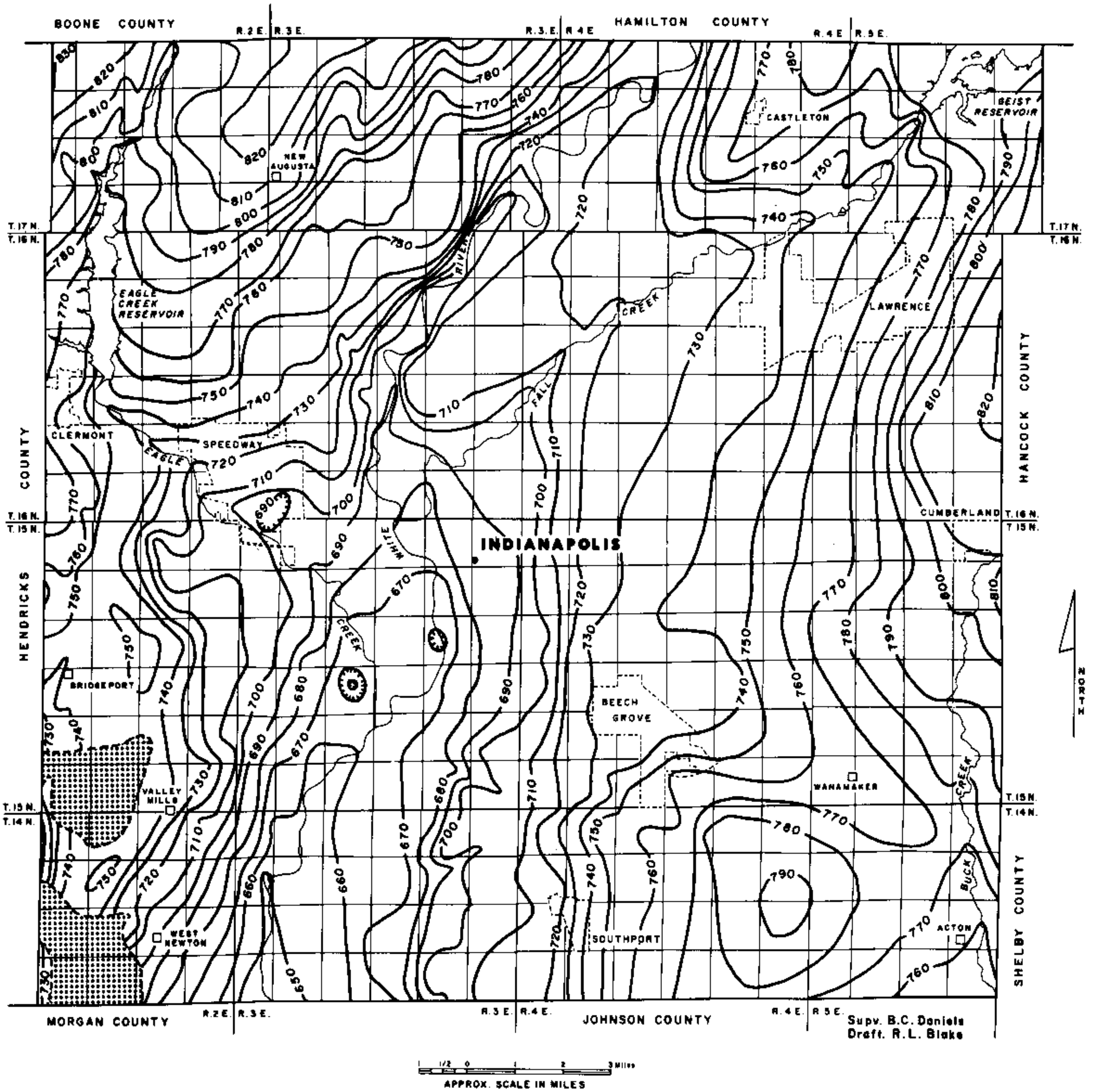
As shown by the profile of the piezometric surface, the principal Pleistocene aquifer northwest of the junction of US 52 and 62nd Street discharges to Eagle Creek. Southeast of 62nd Street the aquifer discharges to White River. In the downtown area near Washington Street, where there has been a considerable amount of pumping, the piezometric surface slopes away from the river, indicating at least some river recharge entering the aquifer.

The piezometric surface of the Silurian-Devonian aquifer also indicates pumping in the downtown area. As shown by the cross section, the piezometric surface of the Silurian-Devonian aquifer is several feet below that of the principal Pleistocene aquifer, indicating that water is moving downward through the principal Pleistocene aquifer into the bedrock aquifer. The leakage is more pronounced where the head in the bedrock aquifer has been lowered several feet below the head in the overlying sand and gravel aquifer by pumping. For a given head differential, leakage is greatest where there is no clay or shale separating the aquifers. In the western part of the county, where the Silurian-Devonian aquifer is separated from the principal Pleistocene aquifer by a considerable thickness of New Albany Shale, Borden shale, and till, the downward leakage is not great, even though a considerable head difference exists between the two aquifers. The leakage is greatly retarded by the relatively impermeable New Albany and Borden shales.

Piezometric Map of Principal Pleistocene Aquifer

A piezometric map defines the ground-water head surface and the direction of ground-water flow. The flow, as explained earlier, is from areas of high head (water level) to areas of lower head in directions perpendicular to the lines of equal head (contour lines). Thus, it can be seen in figure 13 that most of the ground water in the aquifer flows toward White River and its major tributaries, Eagle Creek and Fall Creek. Some, however, does flow toward Buck Creek and East Fork White Lick Creek in the southeastern and southwestern parts of the county, respectively.

Figure 13 is based on water level data obtained from records supplied by well drillers since 1959 and represents average water level conditions observed in recent years. Although there are seasonal variations in water levels on the order of 3 to 7 feet, there has been no discernible long-term change in water levels except in local heavily pumped areas. It is theoretically possible to construct separate maps showing both the high and low seasonal piezometric surfaces; however, the limited accuracy of the drillers' water level measurements and the use of topographic maps with a contour interval of 5 or 10 feet would make the accuracy of such maps highly questionable. To produce accurate seasonal piezometric maps a large number of surveyed measuring points (elevations) and accurate water level measurements would be needed.



EXPLANATION

Area where aquifer is absent

680 Elevation in feet above mean sea level (msl)
Contour interval = 10 feet

FIGURE 13. Map showing piezometric surface of principal Pleistocene aquifer

Figure 13 also shows three areas south and west of the center of the county where closed, hachured contour lines are present. These are areas of relatively heavy pumping, and water levels in the vicinity have been lowered several feet to form "cones of depression" in the piezometric surface. The piezometric surface has also been affected by pumping in some other parts of the county, but not to such a noticeable degree. Geist Reservoir, in the northeast corner of the county, has also affected the piezometric surface to some extent by causing water levels in the immediate vicinity to be somewhat higher than would be expected under natural conditions. Particularly noticeable is the flattening of the slope of the piezometric surface near the reservoir and the relatively steep slope just downstream from the dam, where there has been a "stacking" of the contour lines. The effect of Eagle Creek Reservoir should be very similar; however, the piezometric surface near the reservoir had not reached equilibrium during the period of time for which water level data were available.

Piezometric Map of Silurian-Devonian Aquifer

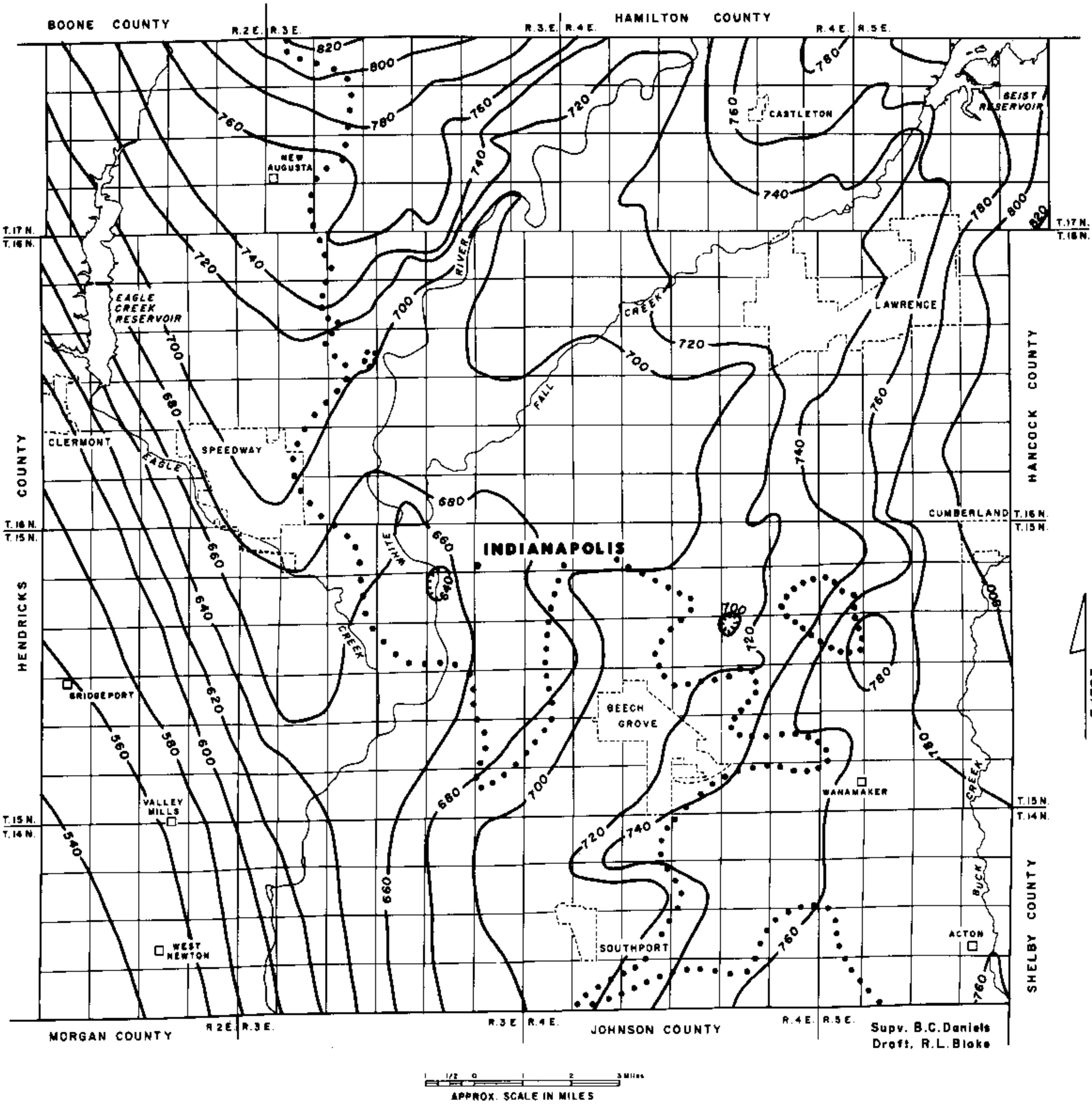
The piezometric surface of the Silurian-Devonian aquifer (fig. 14) is usually several feet lower than that of the principal Pleistocene aquifer, with the exception of two areas in the county. These areas are strips two or three miles wide near the east county line and the north county line east of US 421. (See figs. 11,12, 13.) Two cones of depression are also shown in figure 14 by the closed, hachured contour lines. However, the contour interval of 20 feet probably precludes the definition of other cones of depression that would otherwise be evident with a smaller contour interval.

In most of the downtown Indianapolis area the Silurian-Devonian aquifer is directly overlain by the principal Pleistocene aquifer. Pumpage of several million gallons per day (gpd) from the Silurian-Devonian aquifer has lowered the head several feet below that in the principal Pleistocene aquifer, thereby inducing recharge from the overlying outwash aquifer. This and other pumpage east of the downtown area to Shadeland Avenue caused a general lowering of the water level over several square miles. As indicated in figure 14 by the relatively steep slope of the piezometric surface, and in figure 11 by the piezometric profile, the effects of the combined pumpage from the Silurian-Devonian aquifer are not noticed any great distance east of Post Road.

AQUIFER COEFFICIENTS

Among those factors of major importance in the evaluation of the potential yield of an aquifer, and in the determination of the effects of any given aquifer development scheme, is the accurate determination of the aquifer coefficients which include the hydraulic conductivity, transmissivity, and storage coefficient. Additionally the physical extent, saturated thickness, and natural and potential recharge must be determined.

The hydraulic conductivity is a measure of the movement of water through a geologic formation. The hydraulic conductivity of an aquifer is defined as the rate of flow of water, in gallons per day (gpd), through a cross sectional area of one square foot under a hydraulic gradient of one foot per foot at the prevailing temperature of the water. Typical values of hydraulic conductivity for sand and gravel aquifers range from 1000 to 6000 gallons per day per square foot (gpd/ft^2). The transmissivity of an aquifer is related to the hydraulic conductivity. Transmissivity indicates the capacity of an aquifer to transmit water through its entire saturated thickness, and is equal to the hydraulic conductivity multiplied by the saturated



EXPLANATION

640 Elevation in feet above mean sea level (msl)
Contour interval = 20 feet

Geologic contact (In areas enclosed by and west of this line the New Albany Shale overlies the Silurian-Devonian aquifer)

FIGURE 14. Map showing piezometric surface of Silurian-Devonian aquifer

thickness of the aquifer in feet. Transmissivity is defined as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer one foot wide and extending the full saturated thickness under a hydraulic gradient of one foot per foot at the prevailing temperature of the water. The units of transmissivity are gallons per day per foot (gpd/ft).

The storage coefficient of an aquifer is defined as the volume of water the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The storage coefficient is thus a dimensionless term. For water table aquifers it ranges from about 0.02 to 0.30 and for artesian aquifers it may range from 0.001 to 0.00001. Water table aquifers are those in which the free water surface occurs within the aquifer, whereas artesian aquifers have a piezometric surface that occurs above the top of the aquifer.

Glacial Drift Aquifers

Saturated thickness of principal Pleistocene aquifer

Figure 15 shows the saturated thickness of the principal Pleistocene aquifer. This is defined by contour lines showing an equal thickness of that portion of the aquifer which is saturated. The saturated thickness of the aquifer varies from from less than one foot in parts of southwest Marion County to as much as 100 feet at one location in the White River valley near the south county line. It should also be noted that areas with the greatest saturated thickness usually correspond to areas having the greatest potential for ground-water development (fig. 7).

Transmissivity of principal Pleistocene aquifer

The transmissivity of the principal Pleistocene aquifer is shown in figure 16. This map is very similar to the map showing saturated thickness (fig. 15). The similarity is expected, since transmissivity is equal to the saturated thickness multiplied by the hydraulic conductivity of the aquifer.

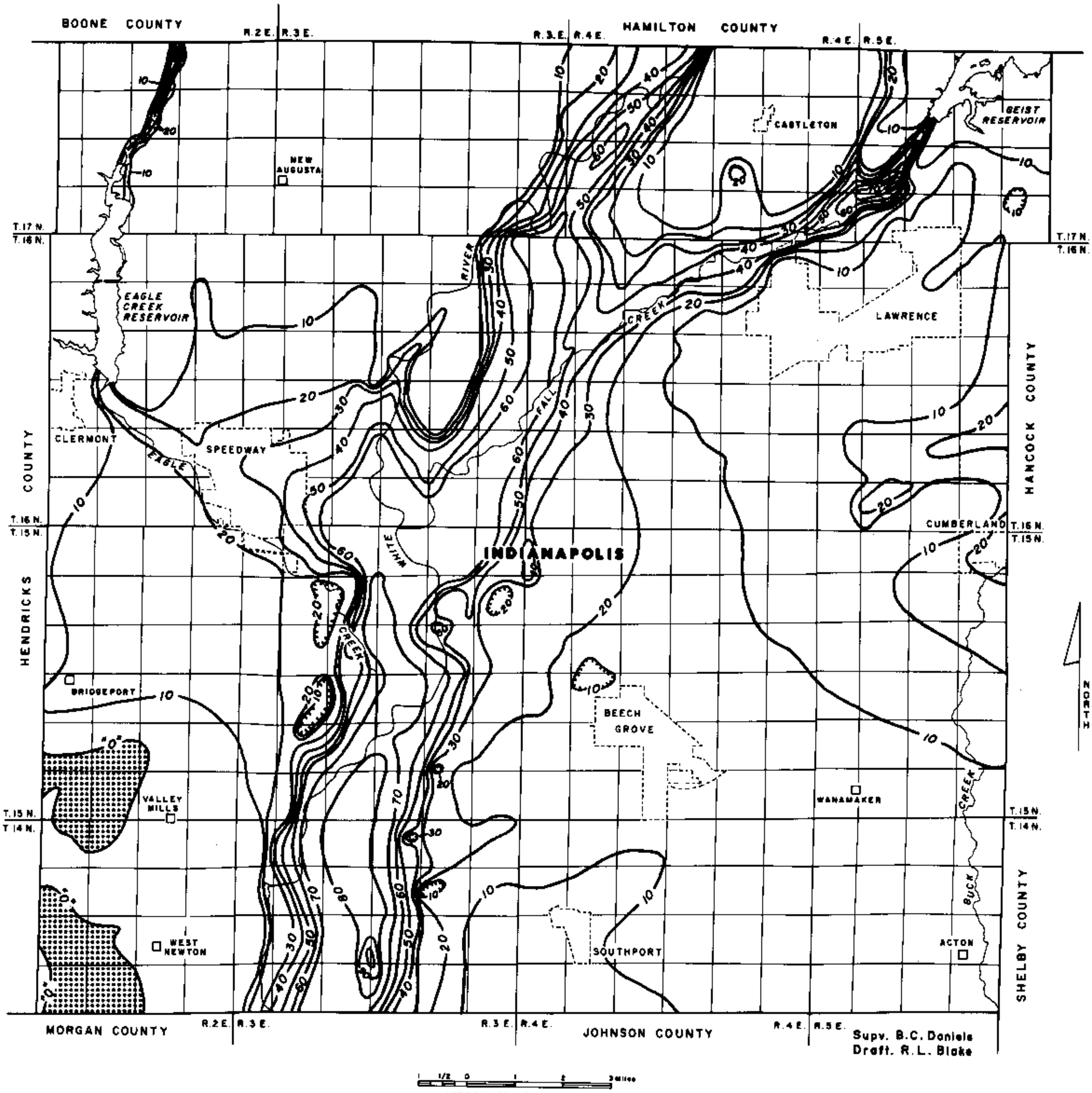
The equation for transmissivity may be written as:

$$T = Kb$$

where:

T = transmissivity, in gpd/ft
K = hydraulic conductivity, in gpd/ft^2
b = saturated thickness of aquifer, in ft

The transmissivity map was drawn using transmissivity values derived by two different methods. One method involves the use of the formula given above in which average values of hydraulic conductivity (either assumed or derived from pumping test data) are multiplied by the saturated thickness of the aquifer. The other method involves the use of transmissivity values obtained from available specific capacity data. (Specific capacity of a well is the pumping rate in gpm divided by the drawdown in feet.) Before specific capacity data can be used, however, observed drawdowns are corrected for the effects of dewatering, partial penetration, well diameter, and length of pumping period. Using these corrected drawdowns, corrected specific capacities can then be determined. These values were then used to derive the transmissivity values shown in figure 16 by means of appropriate graphs of transmissivity versus specific capacity. (See Walton, 1962, p. 6-13.)

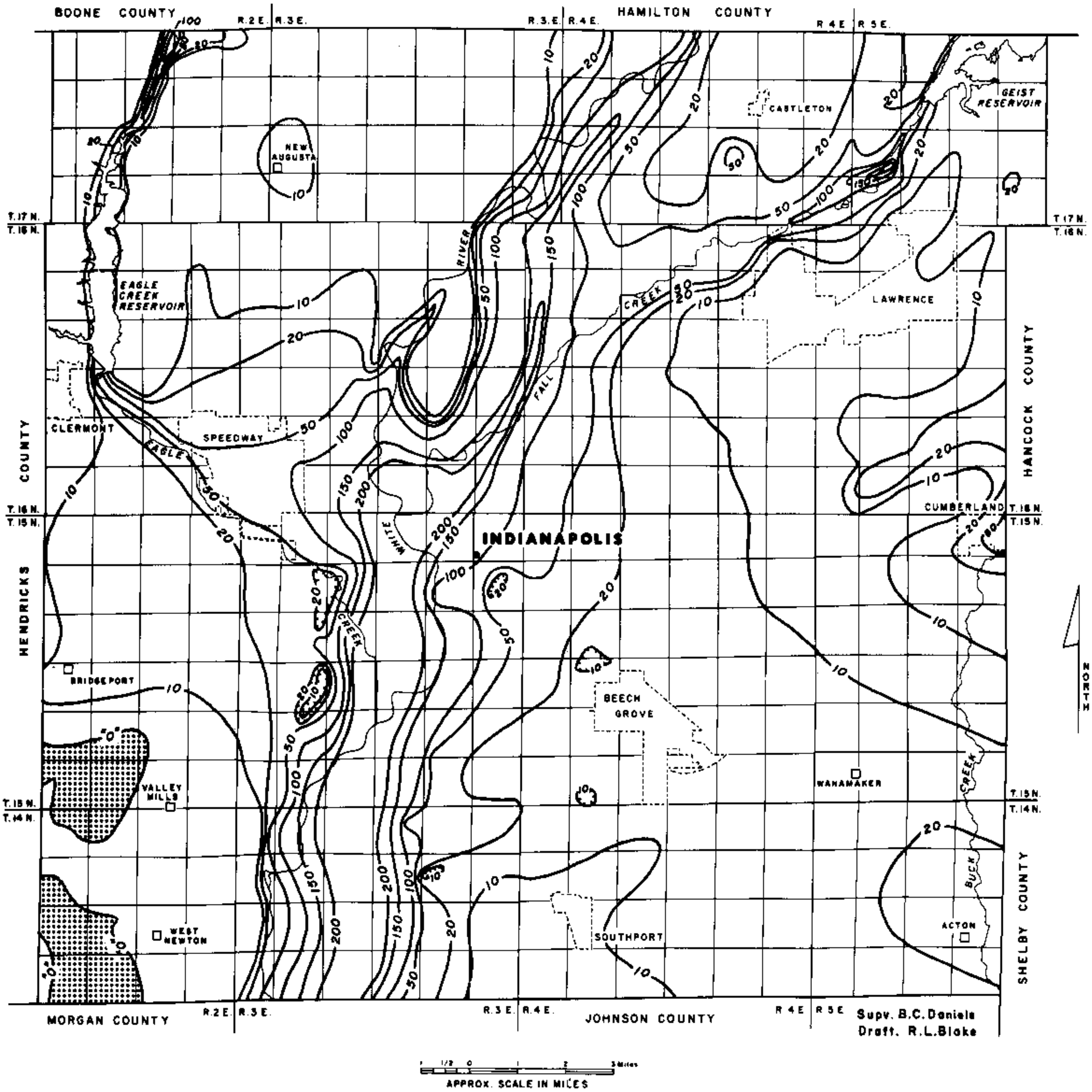


EXPLANATION

30 Isopach contour
Contour interval = 10 feet

Area where aquifer is absent

FIGURE 15. Map showing saturated thickness of principal Pleistocene aquifer



EXPLANATION

—20— Transmissivity in gallons per day per foot x1000

Area where aquifer is absent

FIGURE 16. Map showing estimated transmissivity of principal Pleistocene aquifer

Storage coefficient of principal Pleistocene aquifer

The most accurate way to determine variations in the storage coefficient of an aquifer over a wide area is by analysis of many high quality pumping tests distributed throughout the area of concern. However, such pumping tests are not available for the Pleistocene aquifers in Marion County. Estimates of storage coefficients usually can be made, however, from experience gained from examination of well records, other geologic data, and the knowledge from pumping test results for aquifers in geologically similar areas. The storage coefficients of outwash sand and gravel aquifers (such as the White River outwash aquifer) under water table conditions in Indiana usually range between 0.10 and 0.20. In the absence of quality pumping tests, a value of 0.15 can reasonably be applied as the storage coefficient of the water table part of the principal Pleistocene aquifer with good results.

The storage coefficients of artesian sand and gravel aquifers, such as those occurring within the till areas in the county, commonly show a great deal more variation than those of water table aquifers. Similar artesian aquifers in other parts of Indiana usually have storage coefficients of 0.001 to 0.00001. There appears to be a correlation between the depth of the aquifer and the storage coefficient. As a general rule, the deeper the aquifer the lower the storage coefficient. An average value of 0.0005 for the artesian portion of the principal Pleistocene aquifer could be applied until more quality pumping tests are available to provide more accurate values.

Bedrock Aquifers

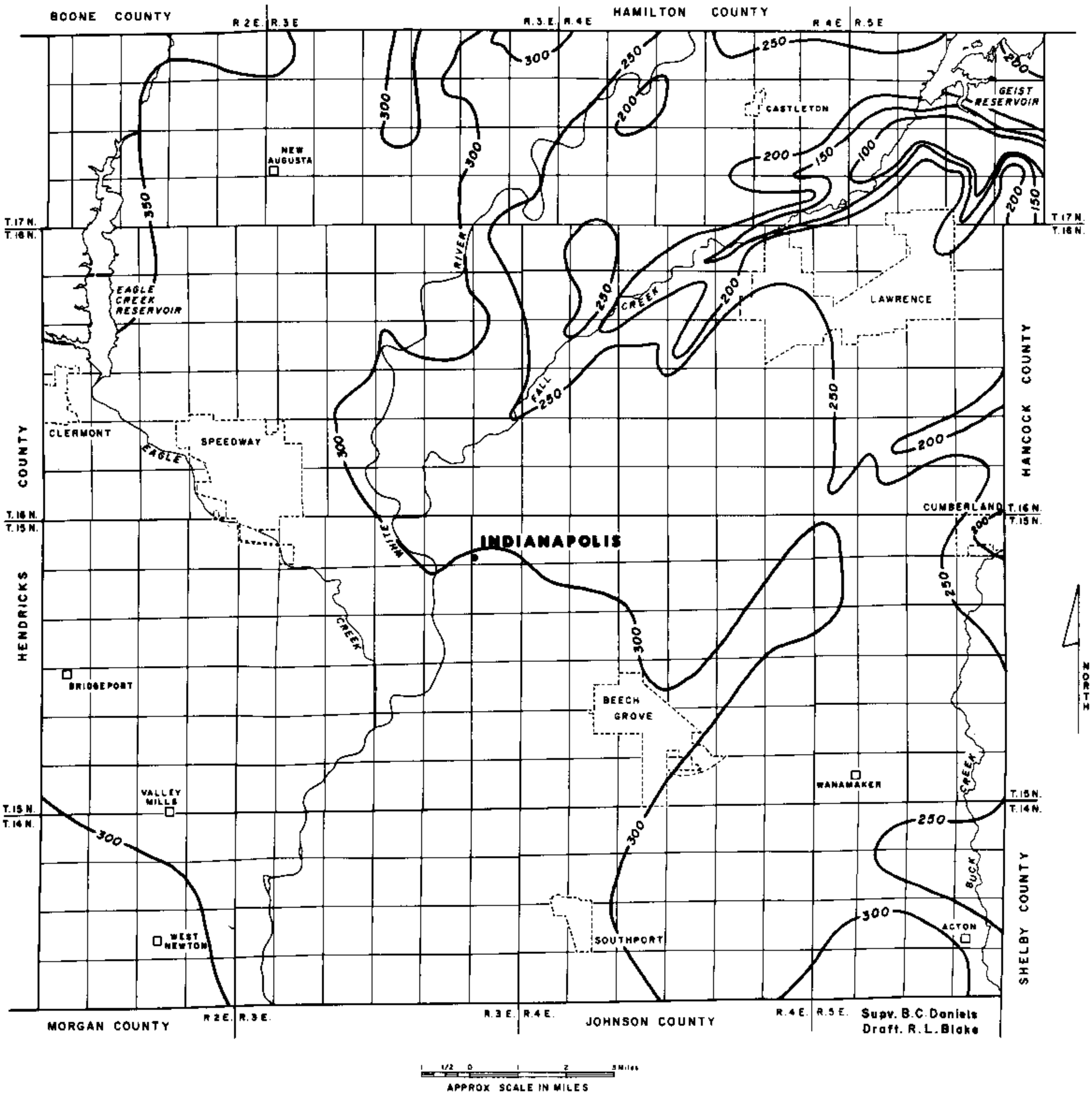
The aquifer coefficients of bedrock aquifers are not as easily defined as those of the unconsolidated aquifers, primarily because of the greater degree of variation in the hydraulic conductivity of the consolidated aquifers within short distances. Because of the lack of quality pumping tests of the bedrock aquifers in the county, estimates of transmissivity were made by using the method previously described involving graphs of transmissivity versus corrected specific capacity.

Saturated thickness of Silurian-Devonian aquifer

The saturated thickness of the Silurian-Devonian aquifer is shown in figure 17. The piezometric surface of the Silurian-Devonian aquifer is everywhere above the top of the aquifer; hence, the entire thickness of the Silurian-Devonian limestone and dolomite is also the saturated thickness. Figure 18 shows the elevation of the top of the Silurian-Devonian aquifer and areas of poor quality water in the western portions of the county.

In western Marion County the saturated thickness of the Silurian-Devonian aquifer is greatest where it is overlain by the younger New Albany and Borden shales, and not partially eroded as is the case in much of the eastern half of the county. In the northeastern corner of the county the aquifer is thinnest where erosion has removed it to within a few feet or tens of feet of the underlying Ordovician shales. (See also fig. 5.)

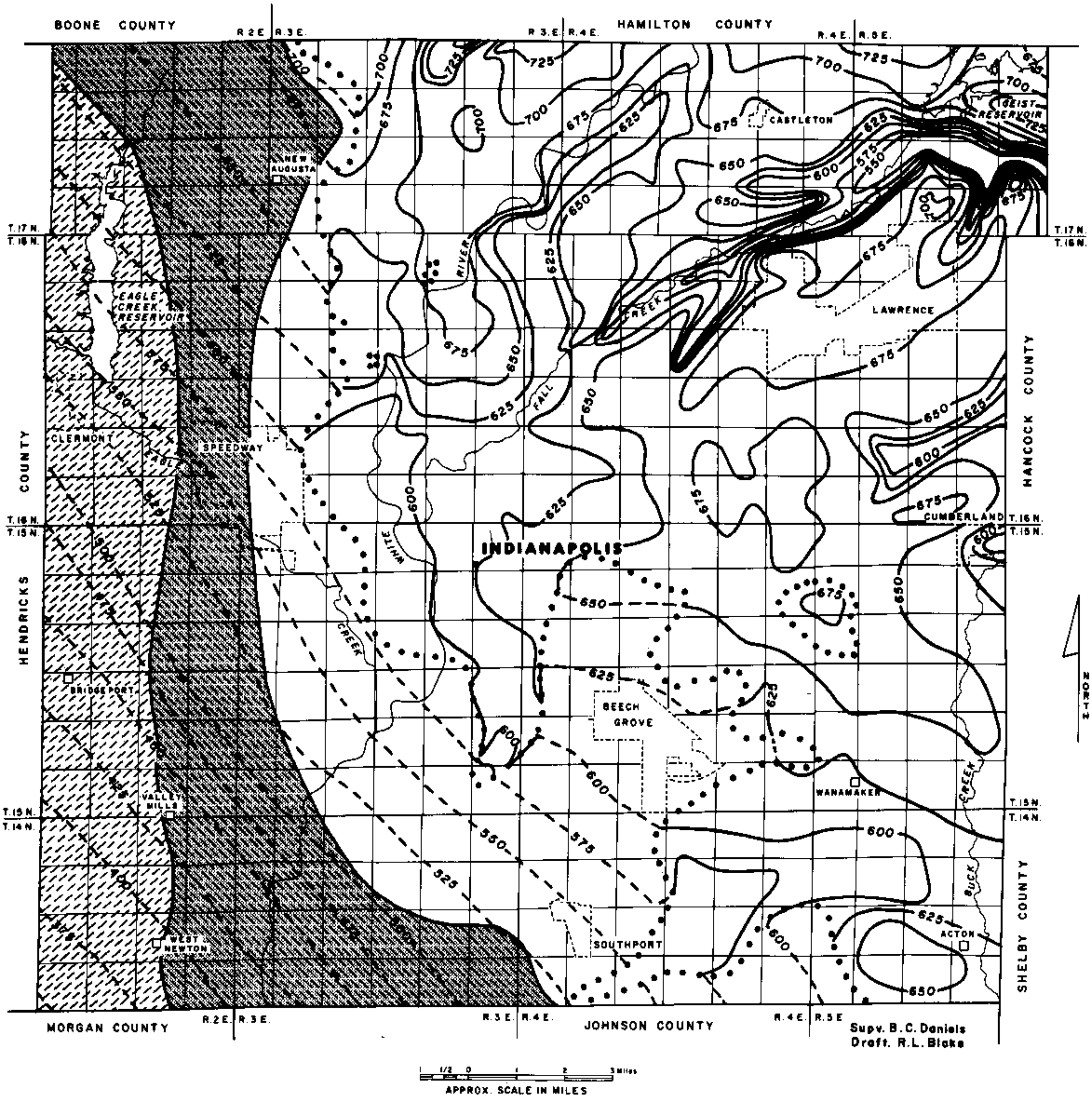
For the principal Pleistocene aquifer, there is a general rule that the greater the saturated thickness, the higher the expected well yields. (Compare figs. 15 and 7.) However, no such rule can be applied to the Silurian-Devonian aquifer, as can be seen if figures 17 and 8 are compared. Instead of a direct relation-



EXPLANATION

300 Isopach contour
Contour interval = 50 feet

FIGURE 17. Map showing saturated thickness of Silurian-Devonian aquifer



EXPLANATION

525 Elevation in feet above mean sea level (msl)
Contour interval = 25 feet

Contour lines dashed where the Silurian-Devonian aquifer is overlain by New Albany Shale

New Albany Shale contact

Area in which relatively poor quality water (including hydrogen sulfide gas) can be expected in the Silurian-Devonian aquifer

Area in which very poor quality water (including non-potable water) can be expected in the Silurian-Devonian aquifer

FIGURE 18. Map showing elevation of top of Silurian-Devonian aquifer

ship, the expected well yields are more dependent upon such factors as the number and size of fractures, joints, and solution channels, and the type and thickness of geologic formation overlying the Silurian-Devonian aquifer than that of total saturated thickness of the aquifer.

Transmissivity of Silurian-Devonian aquifer

As noted above, the hydraulic conductivity (and therefore transmissivity) of the Silurian-Devonian aquifer is highly variable within short distances. One method that can be used to present transmissivity values is to divide the county into several areas and assign average values to each area (fig. 19). The resulting transmissivity map is very similar to the map showing the availability of ground water in the Silurian-Devonian aquifer (fig. 8). The areas with the greatest potential yield generally correspond to areas having the greatest transmissivity and/or areas where sand and gravel overlies the aquifer.

Storage coefficient of Silurian-Devonian aquifer

No pumping test data are available to precisely define the variations in the storage coefficient of the Silurian-Devonian aquifer. However, the storage coefficient may vary from about 0.001 to 0.0001 in much of the study area where the aquifer is directly overlain by glacial deposits. A value of 0.001 could be applied to areas where sand and gravel overlies the aquifer, while a value of 0.0001 may be applied to areas where till overlies the aquifer. Where the aquifer is overlain by the New Albany and Borden shales, the storage coefficient may be as low as 0.00001.

RECHARGE

Recharge to aquifers in Marion County occurs principally from precipitation falling within the immediate county area. That part which does not run off, evaporate, or is not evapotranspired by plants, percolates downward through the overlying material to enter the aquifers. Some of the water found in these aquifers may have come from precipitation falling several miles away, but much of it is from the county proper. A certain amount of recharge to aquifers also comes artificially from such operations as crop irrigation, golf course watering, lawn sprinkling, return wells, and land or pit disposal of liquid wastes. Where pumping wells near streams have lowered water levels below stream levels, some recharge from the streams is induced into the aquifer.

The quantity of leakage (recharge) to artesian aquifers through overlying confining beds is controlled by the vertical permeability and thickness of confining beds and the differences between the heads in the aquifers and shallower deposits. The quantity of recharge to water table aquifers is primarily controlled by the vertical permeability and thickness of material above the water table and by the depth to the water table. Of course, the amount and time distribution of precipitation and other climatic and environmental factors also play a role in determining the recharge quantities to both artesian and water table aquifers. For example, the paving of streets and parking lots, the construction of buildings, and the installation of storm sewers have all served to reduce the quantity of recharge in urban areas. Ditches, tile drains, and crop changes have had some effect on recharge quantities in rural areas, although for the past several years these factors have not changed significantly when areas of several square miles are considered.

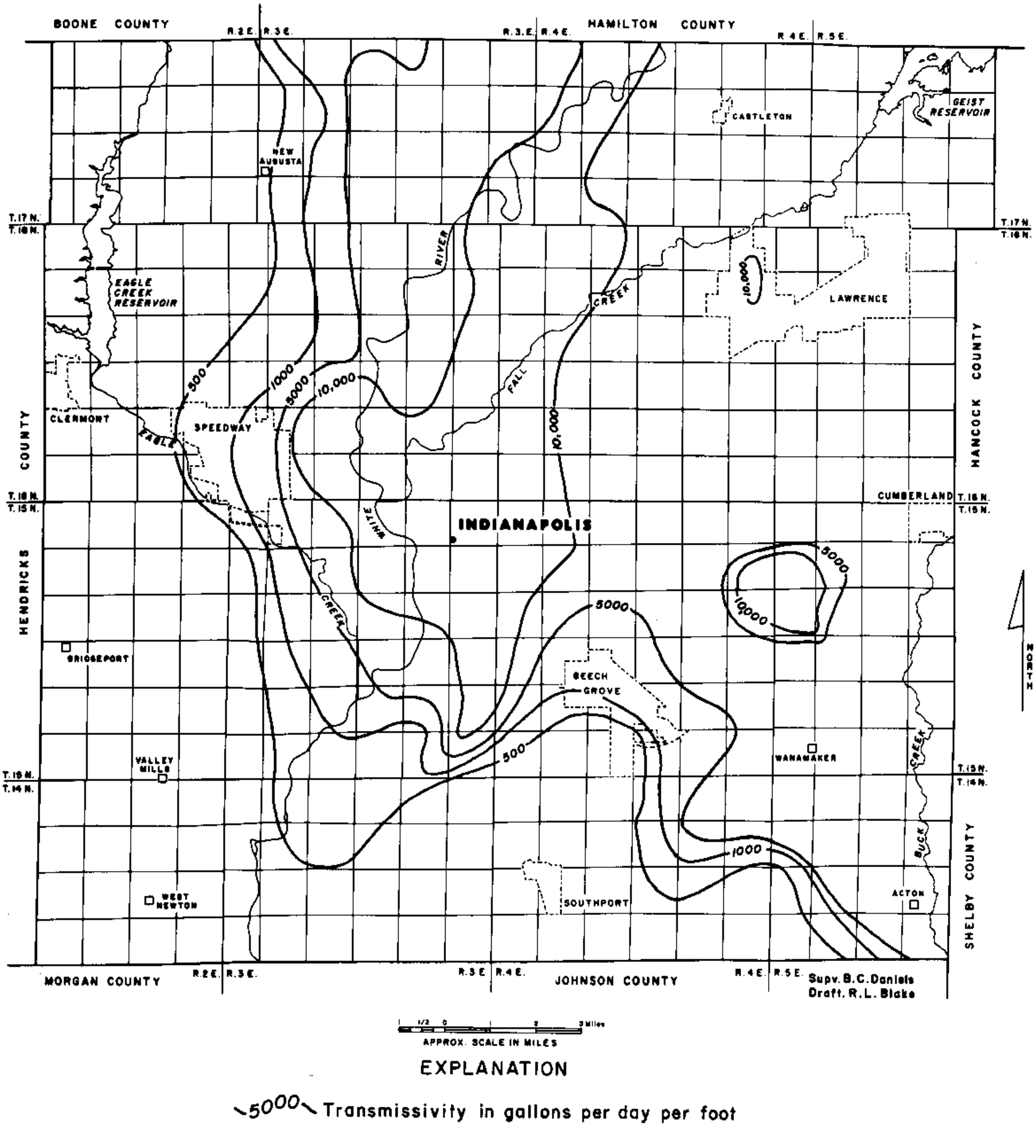


FIGURE 19. Map showing estimated transmissivity of Silurian-Devonian aquifer

Utilizing available information on the county (see appendix), an evaluation of the recharge potential to the principal Pleistocene aquifer was made by multiplying prevailing recharge rates by appropriate areas shown in figure 20, and the individual products then added. The result is the estimate of recharge to the principal Pleistocene aquifer in the county. This amount was determined to be nearly 100 million gallons per day (mgd) or 155 cfs.

GROUND-WATER DISCHARGE TO STREAMS

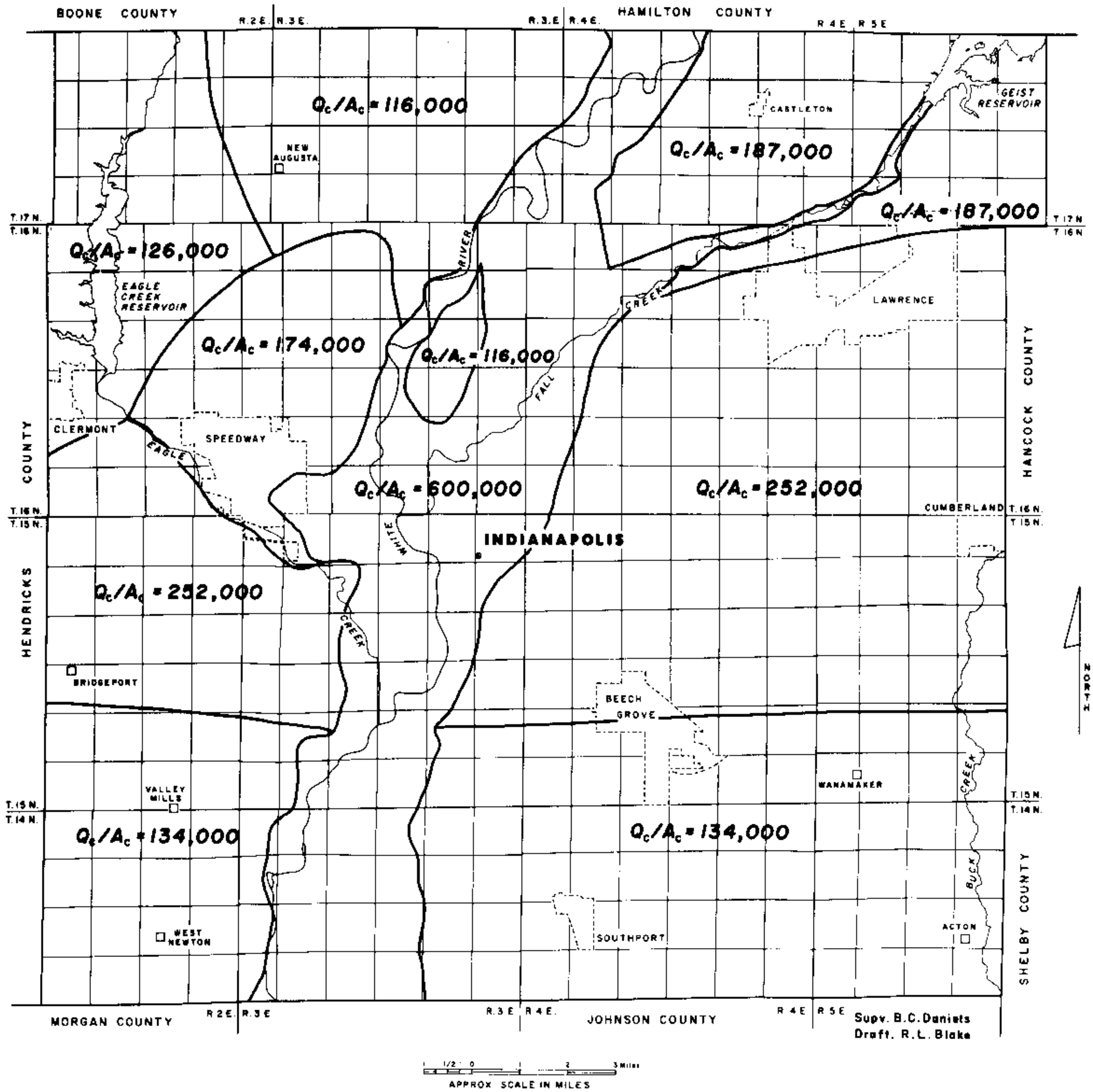
Ground-water discharge, or movement of water from the ground-water system, can occur by either natural or artificial means. Natural forms of discharge include springs, seeps, underflow into streams, evaporation, and transpiration by plants. Artificial discharge may occur by pumping of wells and dewatering of trenches, quarries, gravel pits, or other excavations.

One means of determining the amount of ground water discharged to streams is by the analysis of hydrographs obtained from stream gaging stations. That part of stream flow attributed to ground-water runoff is often called base flow or base runoff. Usually within three to five days after precipitation has ceased virtually all stream flow is derived from ground-water discharge. Several methods of estimating base runoff from hydrographs have been developed. Cable and others (1971), in a study of the water resources of the upper White River basin, used a method modified from that of Busby and Armentrout (1965). This study indicated that the ground-water discharge between gages numbered 3510 and 3540 (fig. 21) averages 551,000 gpd/sq mi, or 298 mgd total for the 541 square mile area. If this discharge is uniform throughout the area, about 154 mgd is discharged to the streams in the 280 square mile portion of the basin in Marion County. The study also indicated an average ground-water discharge rate of approximately 300,000 gpd/sq mi for the remaining 120 square miles in Marion County, or 36 mgd for the 120 square miles. The total ground-water discharge to stream flow for Marion County as derived above would therefore by 190 mgd.

Based on data obtained from an evaluation of the recharge rates to aquifers within the county and stream flow records as outlined herein, it has been estimated that about 110-150 mgd would be the potential yield for ground-water sources in Marion County, without artificial recharge. Approximately 55-95 mgd of this volume might be available for development beyond the present usage of about 55 mgd, if wells and well fields were established in accordance with accepted hydrogeologic determinations. However, because of the nature of the methods utilized in obtaining these figures, the impact of large scale ground-water withdrawals on stream flows and ground-water levels could not be adequately determined, and therefore these figures should be considered as tentative and subject to change. A detailed study conducted by the U.S. Geological Survey in cooperative arrangement with the State of Indiana provides an analysis of these effects.

QUALITY

Ground water in Marion County is classified as a hard to very hard calcium bicarbonate type containing iron and moderate amounts of dissolved solids. The waters from the unconsolidated sand and gravel aquifers and the Silurian-Devonian limestone aquifer are similar in composition, except for the western and southwestern parts of the county where the limestone aquifer is overlain by the New Albany Shale. In these areas, and in the immediate proximity, the limestone aquifer may contain noticeable amounts of hydrogen sulfide gas (H_2S). Where the limestone is more deeply buried by the New Albany and Borden shales (fig. 18),



EXPLANATION

Q_c/A_c = Recharge rate in gallons per day per square mile

Q_c = Vertical leakage through deposits, in gallons per day (gpd)

A_c = Recharge area, in square miles

FIGURE 20. Map showing average recharge rates for principal Pleistocene aquifer

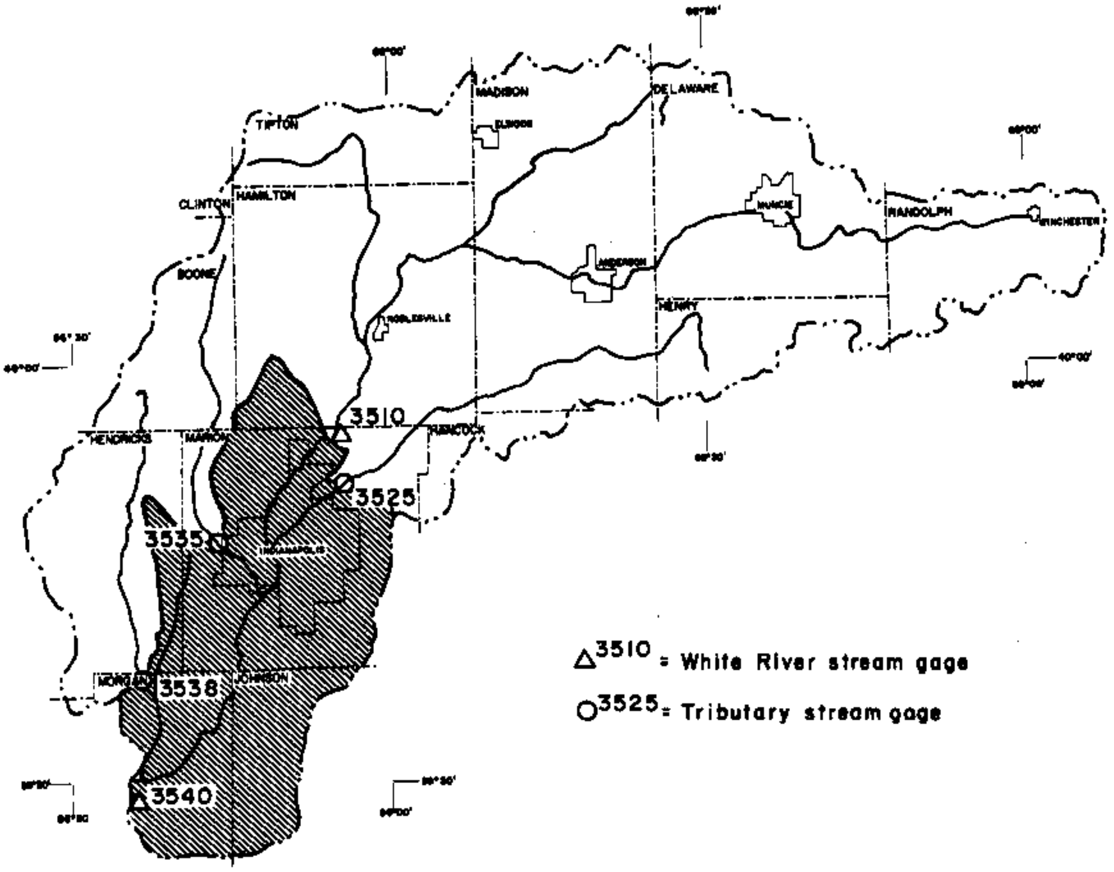


FIGURE 21. Map showing drainage area between White River stream gages 3510 and 3540 used for purposes of computation

chlorides, dissolved solids, and specific conductance may be considerably higher than in waters of the unconsolidated aquifers. An analysis of one well which was open to both the New Albany Shale and Devonian limestone in southwestern Marion County showed high levels of sodium, chlorides, dissolved solids, and specific conductance. The hardness was somewhat lower than in most of the county.

Table 1 gives the average and range of chemical parameters of ground water in the county. Some of the analyses are recent, but many are as much as 20 years old. Several of the older analyses are for wells in heavily pumped areas that correspond to normal discharge areas for ground water moving through the deeper parts of the Silurian-Devonian aquifer. Some of the wells are also in the vicinity of previous areas of recirculation of cooling water (thus showing higher than normal temperatures); a few may have been close to waste disposal sites. Some or all of these factors may have contributed to a slight bias in the data suggesting higher than actual mineral content of the ground water. Temperature data were not included in table 1. The usual ground-water temperature should be 53° to 55° F. for Marion County.

TABLE 1. Quality of ground water in Marion County, Indiana

Quality Parameter	Sand and Gravel Aquifers		Silurian-Devonian Limestone Aquifer	
	Range	Average	Range	Average
pH	6.9 - 8.1	7.5	7.2 - 8.3	7.6
Hardness	250 - 875	394	210 - 1017	382
Calcium	50 - 172	98	43 - 186	80
Magnesium	17 - 50	32	22 - 58	36
Sodium	3 - 60	24	13 - 180	42
Iron	0 - 4.8	1.7	0.1 - 4.5	1.7
Manganese	0 - 0.2	0.06	0 - 0.75	0.09
MO Alkalinity	256 - 450	315	284 - 350	321
Bicarbonate	289 - 432	375	304 - 476	385
Chloride	2 - 63	18	1 - 212	30
Sulfate	0 - 261	73	0 - 319	57
Fluoride	0 - 1.4	0.4	0.2 - 3.0	0.9
Nitrate	0 - 3.7	1.0	0 - 8.5	2.5
Specific Conductance	522 - 1180	736	520 - 1320	749
Total Dissolved Solids	296 - 767	476	273 - 946	464

All units are milligrams per liter except pH and specific conductance.
Specific conductance units are micromhos per centimeter.
Hardness and MO alkalinity are expressed as $CaCO_3$.

Because most of the stream flow during low flow conditions consists of ground water, the quality of the surface water (modified, of course, by the effects of sewage and other wastes) should in many respects be similar to that of ground water at those times. A comparison of table 1 and figure 22 (after Cable and others, 1971) shows that when the main stem of White River consists essentially of ground water (between 40 and 60 percent flow duration) the quality parameters of specific conductance, hardness, and alkalinity are not too different from those of ground water in the aquifers. During low flow periods (80 to 90 percent flow duration)the hardness and alkalinity are very close to that of ground water, but the specific conductance of the stream flow is considerably higher than ground water because of the possible influence of industrial and sewage wastes.

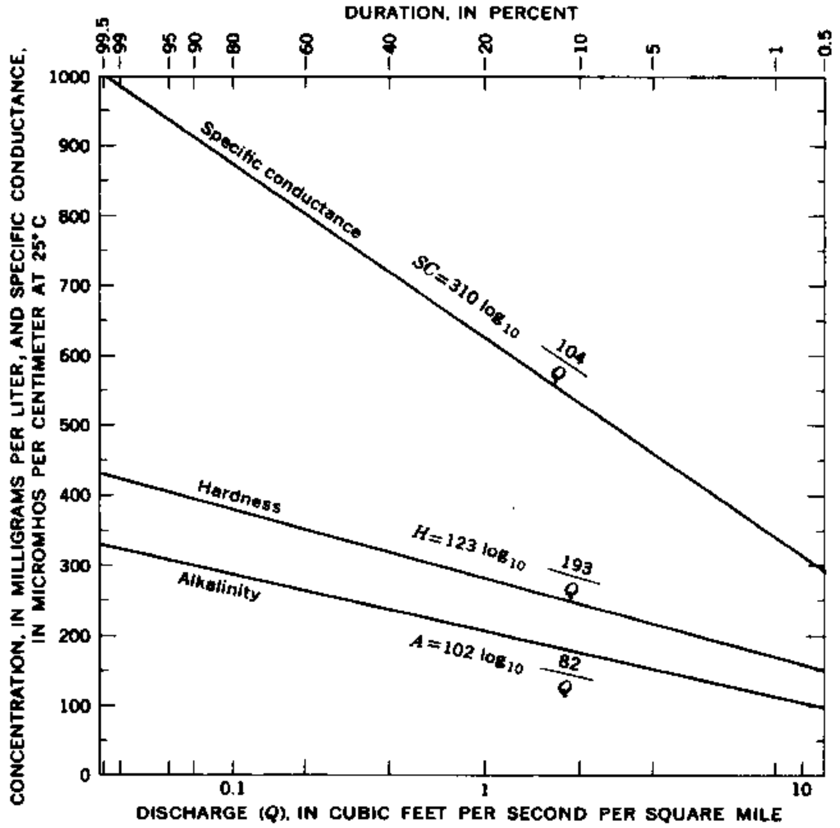


FIGURE 22. Graph showing main-stem White River quality parameters (after Cable and others, 1971)

GROUND-WATER DEVELOPMENT

PRESENT USAGE

Usage of ground water in the county has been variously estimated to be from about 48 to 55 mgd. This water is obtained from the various municipal and industrial wells scattered throughout the county and the thousands of domestic wells serving an estimated 100,000 people in the county. Industrial concerns are the largest users of ground water in the county, consuming approximately 60 per cent of the total volume. These industries are concentrated in the central portion of the county and obtain most of their water from the principal Pleistocene aquifer. Figure 23 shows the location of the major ground-water users and the approximate daily pumpage in 1970. A detailed breakout of the ground-water usage in 1970 is shown in table 2.

In addition to the above usage, an undetermined amount of ground water is discharged from dewatering operations connected with sewer construction projects, building construction sites, quarries and major sand and gravel operations scattered throughout the county. The exact amount of water being pumped cannot be accurately defined; however, it was estimated that during 1972 about 23 mgd was being pumped to waste (to White River) from major aggregate operations in the White River valley.

Table 2. Estimated 1970 ground-water usage in Marion County, Indiana

User Category	SW	GW	Sand and Gravel Sources: Outwash Valley Aquifers	Sand and Gravel Sources: Glacial Drift Aquifers	Bedrock Sources (Undifferentiated)
Clermont	-	.10	-	.10	-
Cumberland	-	.15	-	.15	-
IWCO	84.35	5.65	3.15	-	2.50
Lawrence	-	1.50	-	-	1.50
Speedway	2.2	.30	-	.30	-
SS Domestic	-	9.00	1.00	5.00	3.00
SS Indust.	-	29.00	23.00	1.50	4.50
SS Commer.	-	4.30	2.35	.45	1.50
SS Instit.	-	3.50	3.50	-	-
SS Irrig.	-	1.50	1.50	-	-
TOTALS (mgd)	86.55	55.00	34.50	7.50	13.00

SW = Surface Water
GW = Ground Water
S&G = Sand and Gravel
SS = Self-Supplied
IWCO = Indianapolis Water Co.
Indust. = Industrial
Commer. = Commercial
Instit. = Institutional
Irrig. = Irrigational
All figures are million gallons per day (mgd)

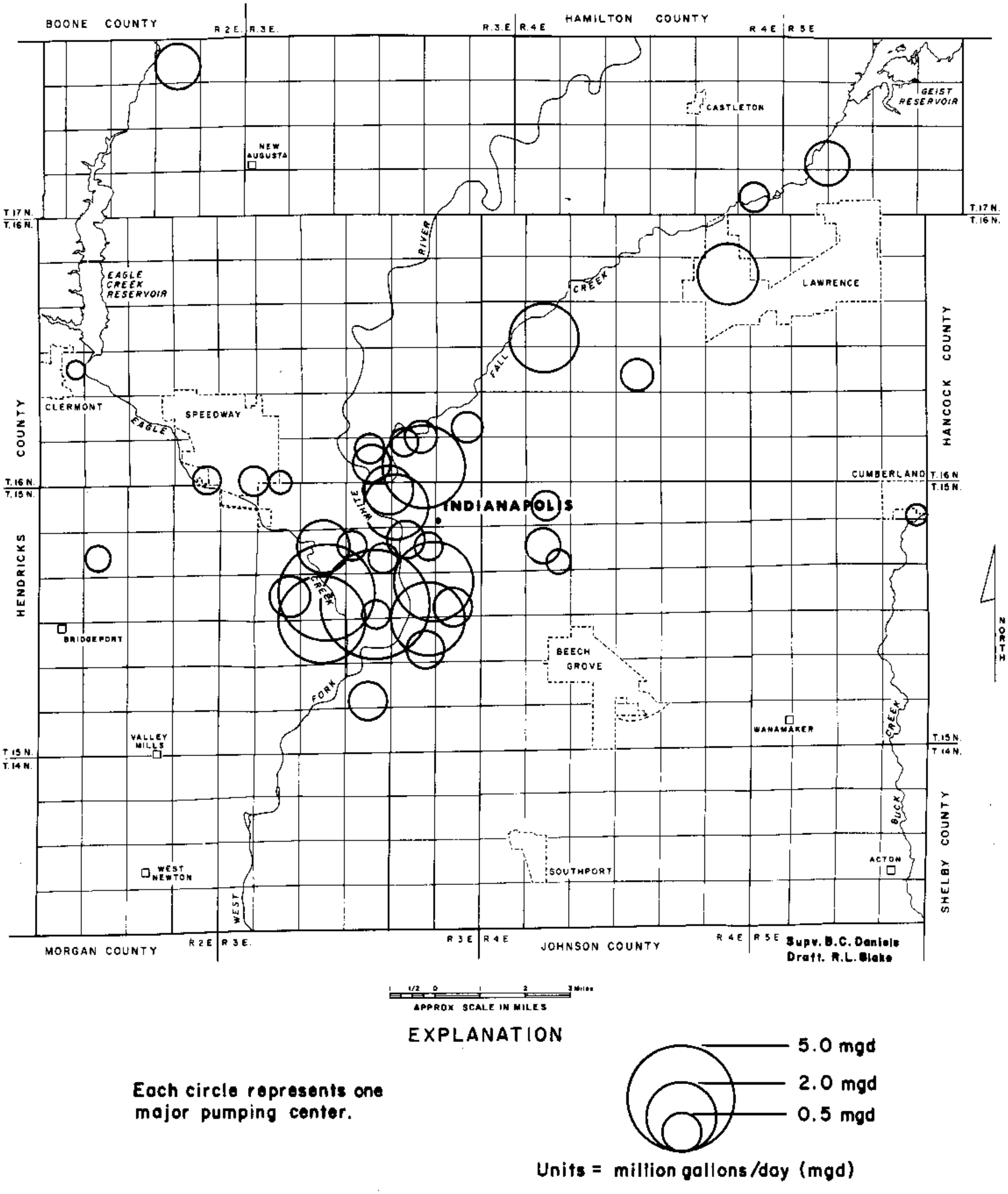


FIGURE 23. Map showing location of major pumping centers

DEVELOPMENT POTENTIAL

With the possible exception of the intensively developed areas in the central portion of the county noted in figure 23, the ground-water resources of Marion County remain largely undeveloped. As has been shown in the preceeding figures and cross sections, a series of diverse aquifer systems are present in the county which exhibit varying capabilities to supply water. The maximum amount of water that can be extracted from these units is dependent upon the potential yield or sustained yield of the aquifers. Schicht (1965, p. 59) has defined the sustained yield of an aquifer as "the maximum amount of water that can be continuously withdrawn from a selected system of wells or well fields without creating critical water levels or exceeding recharge". Water levels become critical when pumping levels reach the top of the well screens, or more than one-half of the aquifer is dewatered in the vicinity of the well field, or both. Estimates of potential yield include the aquifer coefficients (transmissivity, storage), aquifer thickness, water levels, and recharge (induced from stream flow, directly from precipitation, and from underflow).

Based on factors of aquifer thickness, extent, permeability, and soil and recharge conditions, that portion of the principal Pleistocene aquifer shown in figure 24 outlines the area of greatest potential for future ground-water development. Although much of the present ground-water pumpage from this system occurs in the north half of the area defined in figure 24, the south half remains undeveloped. Factors favoring high potential yields apply to this area of 43.5 square miles. Additionally, perennial streams including White River transect the area and are hydraulically connected to the aquifer, thus induced infiltration would occur from the streams under pumpage conditions. It should be noted, however, that the development of ground water in the area defined in figure 24 would necessarily change existing water level conditions and affect ground-water contribution to the streams, particularily during periods of low flow.

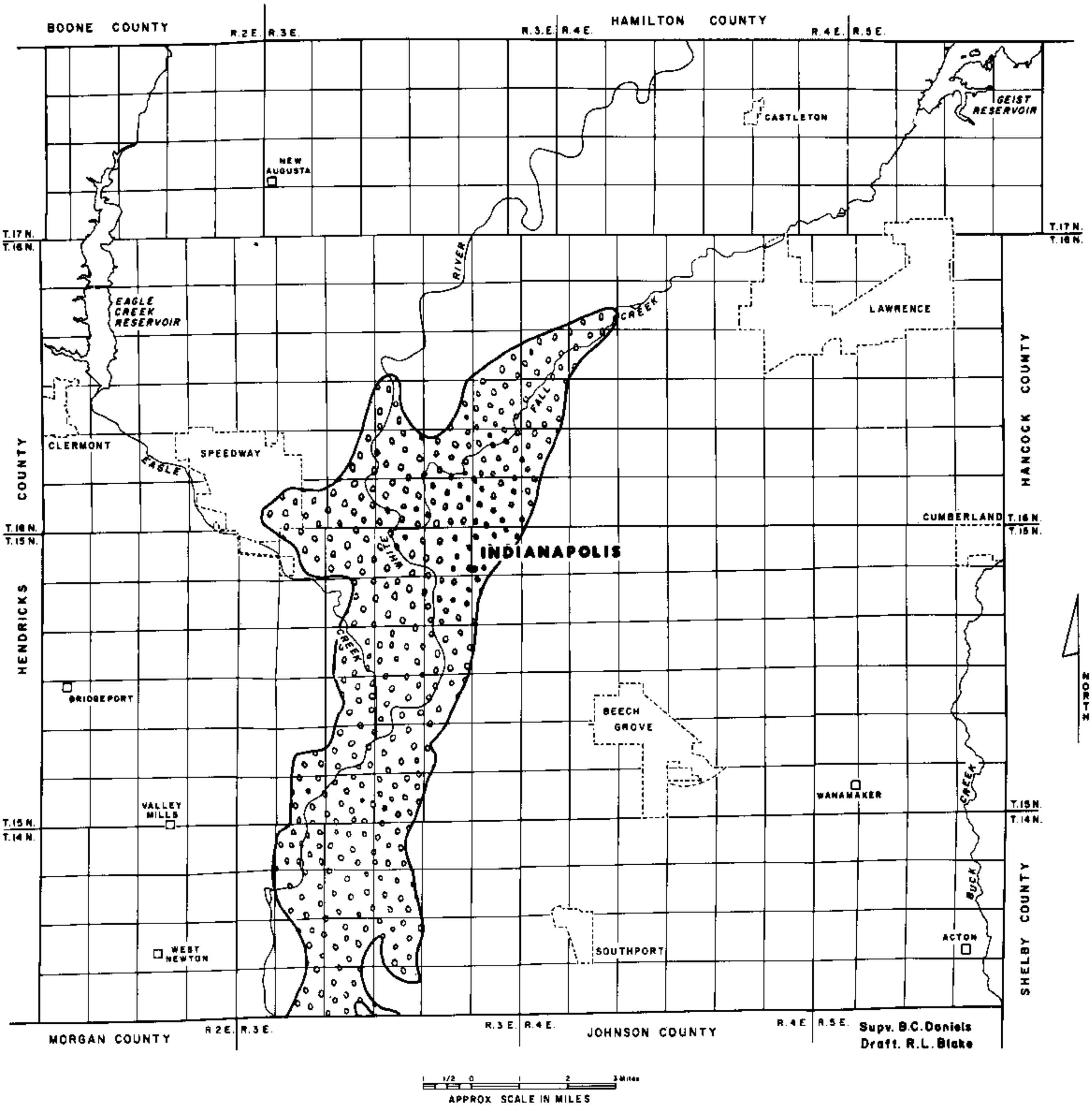
Elsewhere, significant sources of water are present in the Silurian-Devonian bedrock aquifer and in the outwash deposits of the valleys of Eagle and Fall Creeks. The full development potential of these aquifers has not yet been reached and additional yields beyond present levels could be attained.

In addition to the above sources, numerous small to moderate (10 - 150 gpm) capacity wells could be located in the relatively undeveloped glacial till areas to the east and west of the White River valley. The potential of these outlying areas has not been realized to this point, and domestic production could be increased several fold without anticipated problems or undue reduction in water levels.

Of a lesser capability is the southwestern portion of the county, where water supplies are limited because of inherent aquifer hydraulics. These aquifers are capable of additional production, and recharge to these sources exceed withdrawals, but well yields are restricted to essentially domestic use, because of the aforementioned conditions.

GROUND-WATER PROTECTION

In order to insure the continued availability of the ground-water resources in Marion County it is necessary to protect them from possible contamination. In many respects, the ground-water system, especially that part located in major outwash valleys, can be considered analogous to a surface water reservoir, and just as it would be unthinkable to place contaminants or solid wastes in a surface water reser-



EXPLANATION

Area of greatest potential for ground-water development

FIGURE 24. Map showing area of greatest potential for ground-water development

voir, it would be equally unwise to subject the ground-water system to similar degradation. In contrast to surface water, however, once ground water has been polluted it can take several years for the pollutants to be removed or diluted by natural means; because, under normal conditions, the rate of ground-water movement in an aquifer is generally less than one foot per day.

The potential for contamination is much less in upland areas, away from the major stream valleys, where aquifers are usually overlain by moderate thicknesses of glacial till. This till both retards the movement of and purifies, by ionic exchange, the pollutants introduced at the land surface. However, in the outwash valleys the till is generally absent and pollution of these important aquifers can easily occur.

Because the aquifer in the White River valley (fig. 23) constitutes the most prolific source of water in the county, it should be protected from sources of contamination, such as landfills, waste disposal pits, salt piles, etc. Additionally, from a hydrologic viewpoint, the White River floodplain and the rest of the area containing the outwash aquifers should be protected from developments that reduce the efficiency of the floodway to carry floodwater and, at the same time, result in the placing of materials above the aquifer which will reduce its capacity to be recharged by precipitation. Also, the practice of filling abandoned gravel pits and excavations with solid wastes results in the depreciation of the storage ability, recharge capacity, and potential yield, even if the water quality is not adversely affected. Ironically, in some areas, the outwash aquifers having the greatest potential do, in fact, already exhibit the effects of pollution. Care should be taken now to preserve this vast ground-water resource for potential future use.

SUMMARY

The availability of ground water in Marion County is primarily controlled by the prevailing geologic parameters. Well yields vary widely, ranging from 0 in limited areas where dry holes are encountered, to over 4,000 gpm in the central part of the county where the thicker glacial outwash deposits are present. Major sources of ground water are found in the Silurian-Devonian limestone aquifer system in the eastern, central and northeastern portions of the county, and wells yielding from 150 - 1000 gpm can be anticipated. Elsewhere, domestic wells and light utility supplies can be expected with maximum well yields ranging from 5 - 150 gpm.

Transmissivities and storage coefficients were determined for both the principal Pleistocene aquifer and the Silurian-Devonian bedrock aquifer. The principal Pleistocene aquifer has transmissivities that range from near 0 gpd/ft to more than 200,000 gpd/ft. The storage coefficients for the water table portion of this aquifer range between 0.07 and 0.25. The artesian portion has storage coefficients ranging between 0.001 to 0.00001 with an average value of about 0.0005. The Silurian-Devonian bedrock aquifer is under artesian conditions throughout the county. Transmissivities of this aquifer range from less than 500 gpd/ft to over 10,000 gpd/ft. The storage coefficients of the bedrock aquifer varies from about 0.001 in areas where the aquifer is overlain by glacial sand and gravel deposits to about 0.00001 where the aquifer is overlain by the New Albany and Borden shales.

Recharge rates to the principal Pleistocene aquifer range from an estimated 116,000 gpd/sq mi to 600,000 gpd/sq mi. Utilizing these figures and values of ground-water discharge to streams, it is estiamted that 55 - 95 mgd may be available beyond present ground-water usage.

Ground water in Marion County, from both the glacial and bedrock aquifers, is of the hard to very hard calcium bicarbonate type containing iron and moderate amounts of dissolved solids. The water quality is generally satisfactory for most uses, however, softening and/or iron removal may be required. In the western and southern parts of the county some hydrogen sulfide (H_2S) may occur in the Silurian-Devonian aquifer where it is overlain by the New Albany Shale, and when present is at best difficult to remove.

Present ground-water usage in the county is estimated to be about 55 million gallons per day (mgd). Most of the approximately 42 mgd presently taken from sand and gravel aquifers comes from the principal Pleistocene aquifer in the White River valley, while about 13 mgd is taken from the Silurian-Devonian aquifer system. The bulk of the present ground-water usage is located in the central part of the county.

The principal Pleistocene aquifer, composed primarily of outwash deposits of sand and gravel in the White River, Eagle Creek and Fall Creek valleys, as well as the thicker intertill sand and gravel deposits hydraulically connected to the outwash, offers the greatest potential for present and future ground-water development. The southern portion of Marion County underlain by the thicker outwash deposits offers the greatest potential for future development.

APPENDIX

The material in the following pages should serve to give the reader some background information on how recharge rates and potential yields may be determined. As indicated in the text, and in the following appendix, there is more than one way in which the problem may be attacked. It is not the purpose of this report to show which methods are best, but to outline in some detail those methods that apply to defining recharge rates and the potential yields of aquifers.

RECHARGE RATES

The rate of recharge to artesian aquifers can be expressed mathematically by the following form of Darcy's Law (Walton, 1965):

$$Q_c/A_c = 2.8 \times 10^7 \times (P'/m') \times \Delta h \qquad (2)$$

where:

Q_c/A_c = recharge rate, in gpd/sq mi

Q_c = leakage (recharge) through confining deposits, in gpd

A_c = area of diversion, in sq mi

P' = vertical permeability of confining deposits, in gpd/sq ft

m' = saturated thickness of confining deposits, in ft

Δh = difference between head in aquifer and in source bed above deposits through which leakage occurs, in ft

Before equation 2 can be used to calculate recharge rates, however, the vertical permeability of the confining deposits should be calculated or estimated. First, the quantity of water flowing through a given cross section (at right angles to the flow) must be determined using the equation:

$$Q = T\ I\ L \qquad (3)$$

where:

Q = discharge, in gpd

T = transmissivity, in gpd/ft

I = hydraulic gradient, in ft/mi

L = width of cross section, in mi

A width of cross section, L, is drawn on the piezometric map (fig. 13) and the transmissivity at the cross section noted (fig. 16). From the ends of the cross section, lines are drawn up gradient at right angles to contour lines until the two flow lines intersect. The area thus enclosed is A_c used in equation 2. Two examples of this problem are shown in figure 25. Applying equation 3 to the area in western Marion County:

$$Q = T\ I\ L$$

$$Q = 20{,}000 \times (20) \times (1.7)$$

$$Q = 680{,}000 \text{ gpd}$$

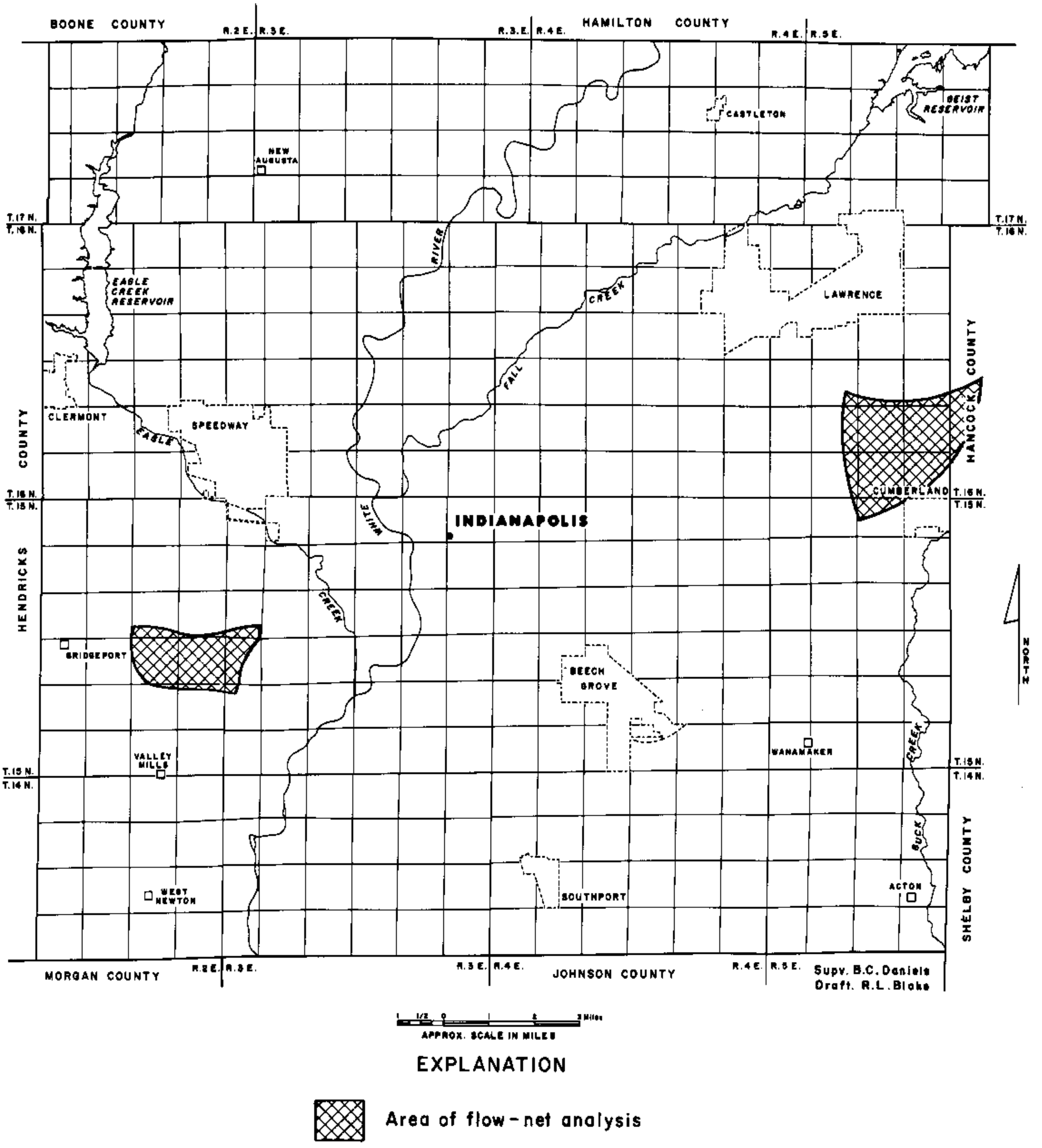


FIGURE 25. Map showing areas of flow-net analyses in Marion County

In this example $Q = Q_c$ and the area enclosed between the two flow lines and the cross section is 3.10 square miles. ($A_c = 3.10$ sq mi) Therefore:

$$Q_c/A_c = 680{,}000/3.10 = 220{,}000 \text{ gpd/sq mi}$$

Thus, the current recharge rate is 220,000 gpd/sq mi under the present conditions of head difference between the aquifer and source bed above the deposits through which leakage occurs. Since this recharge rate is valid for only the one value of vertical head loss, a more meaningful expression for recharge would be recharge rate per unit area per foot of head loss. Equation 2 then becomes:

$$P'/m' = \frac{Q_c}{Ac \times \Delta h \times (2.8 \times 10^7)} \qquad (4)$$

In the example above, Δh = 30 feet. Therefore:

$$P'/m' = 680{,}000/\ 3.10 \times (30) \times (2.8 \times 10^7)$$
$$P'/m' = 0.00026 \text{ gpd/sq ft/ft head loss, or gpd/cu ft}$$

Also, in the example above, m' = 80 feet. Therefore:

$$P' = 0.00026\ m' = 0.00026 \times (80)$$
$$P' = 0.021 \text{ gpd/sq ft}$$

The vertical permeability of the glacial till deposits overlying the principal Pleistocene aquifer in the example area has thus been determined. Before applying this value to the rest of the artesian areas in the county, however, another example (fig. 25) should be chosen on the eastern side of the county. Proceeding as before:

$$Q = T\ I\ L$$
$$Q = 10{,}000 \times (29.3) \times (2.84)$$
$$Q = 832{,}000 \text{ gpd}$$

$$Q_c/A_c = 832{,}000/5.73 = 145{,}000 \text{ gpd/sq mi}$$

$$P'/m' = \frac{Q_c}{A_c \times \Delta h \times (2.8 \times 10^7)}$$

$$P'/m' = 832{,}000/\ 5.73 \times (30) \times (2.8 \times 10^7)$$
$$P'/m' = 0.00017 \text{ gpd/cu ft}$$

$$P' = 0.00017\ m' = 0.00017 \times (120)$$
$$P' = 0.020 \text{ gpd/sq ft}$$

These two values of vertical permeability of the glacial till in Marion County are very close. A value of 0.02 gpd/sq ft can therefore be reasonably applied to the other till areas within the county. Using equation 2 and estimates of m' and Δh from the hydrologic sections (figs. 11,12) the current recharge rates of till areas can be calculated. The results are shown in figure 20.

Equation 2 can not be used to determine recharge rates to water table aquifers, however, because there is no confining layer of thickness m' and no source bed (aquifer) above the confining layer having a head difference Δh. A flow net analysis and comparison with other geologically similar areas suggests the water table portion of the principal Pleistocene aquifer has a recharge rate of about 600,000 gpd/sq mi.

Infiltration rates of stream beds in some of the major watercourse aquifers in Illinois, Indiana, and Ohio have been determined from aquifer test data. Schicht (1965, p. 51) reported infiltration rates of 37,500 gallons per day per acre per foot (gpd/ac/ft), 48,300 gpd/ac/ft, and 344,000 gpd/ac/ft for three sections of the Mississippi River in the East St. Louis area, Illinois. Walton (1963) reported 43,600 gpd/ac/ft along White River one mile west of Anderson, Indiana, one-half mile below the sewage treatment plant. He reported 216,000 or 275,000 gpd/ac/ft (depending on water temperature) along White River upstream from the confluence of White River and Killbuck Creek at Anderson, Indiana. Walton believes the infiltration rate at the site below the sewage plant is probably low largely because of the clogging effect of sewage.

A conservative estimate of the infiltration rate for the streambed of White River in the area shown in figure 24 in Marion County, Indiana would be around 100,000 gpd/ac/ft. The area of streambed (including that of Eagle Creek and Fall Creek, but not including gravel pits) was determined to be about 754 acres by planimetering 7½ minute topographic maps. The potential recharge by induced infiltration, in gpd, can be determined by the following formula (Schicht, 1965, p. 50):

$$R_i = I_t \, s_r \, A_r \qquad (5)$$

where:

R_i = potential recharge by induced infiltration, in gpd

I_t = average infiltration rate of river bed for a particular surface water temperature, in gpd/ac/ft

s_r = average head loss within river bed area of infiltration or average depth of water in river for a particular river stage, depending upon the position of the water table, in ft

A_r = river bed area of infiltration, in acres

Assuming an average head loss of one foot beneath the river bed area and an average infiltration rate of 100,000 gpd/ac/ft, the potential induced recharge is 75,400,000 gpd.

A possible head loss of only one foot, and therefore the potential induced recharge of 75,400,000 gpd, is believed to be conservative, especially when compared with results obtained by Norris and Fidler (1969) for a part of the Scioto River valley near Piketon, Ohio. The following table is a comparison of the two areas:

	Scioto River valley near Piketon, Ohio	White River valley at Indianapolis, Indiana
aquifer width	1 ½ miles	3 miles
saturated thickness	60-65 ft	60 - 80 ft
transmissivity	215,000 gpd/ft	about 200,000 gpd/ft
coefficient of storage	.20	.20 (est.)
stream width	260 ft[1]	
stream depth	3.6 ft[1]	
drawdown beneath river	0.40 ft[2]	
infiltration rate	235,000 gpd/ac/ft	100,000 gpd/ac/ft (est.)
95% flow duration	333 cfs (215 mgd)[3]	174 cfs (112 mgd)[4]
average discharge	4189 cfs (2,700 mgd)[3]	1410 cfs (911 mgd)[5]

1 measured at about 95% flow duration

[2] at the end of a 9-day pumping test at 1000 gpm

[3] at Higby station a few miles upstream from test site

[4] adjusted for diversion by the author by multiplying the 95% duration flow at gage 3-3540 (several miles downstream) by 0.60

[5] adjusted figure by U.S.G.S.

The pumping test conducted by Norris and Fidler (1969) to gather some information on the hydrogeology of the Scioto River valley near Piketon, Ohio began October 14, 1963 and ended 9 days later. The pumping rate was 1000 gpm and the distance of the pumped well from the near bank of the river was 450 feet. At the end of the test the piezometric surface of the aquifer under a 1020-foot length (twice the line-source of recharge distance) of the streambed was about 0.40 feet below the stream level. They determined that about 78 percent of the water pumped came from a reduction of ground-water flow to the stream and direct recharge through the streambed. This percentage was calculated using two different methods, flow-net analysis and the following equation of Theis (1941, p. 735):

$$P = 2/\pi \int_0^{\pi/2} e^{-k \sec^2 u} \, du \qquad (6)$$

where:

P = percentage of pumped water being diverted from streamflow
$k = 1.87\ a^2\ S/Tt$
a = distance from well to line-source of recharge, in ft
S = coefficient of storage, in percent
T = transmissivity, in gpd/ft
t = time since pumping began, in days
$u = \text{arc tan}\ x/a$
x = distance along line-source measured from perpendicular intersecting well, in ft

Theis gives solutions to his equation in the form of a graph of values of P versus k. Walton (1962, p. 19) has determined a modification of the Theis equation and graph. Norris and Fidler (1969, p. 41) state that it can be shown mathematically from the Theis equation that an amount equal to a little more than half the quantity derived from the stream originates opposite the pumped well between points on the line-source boundary whose distance apart is equal to twice the line-source distance. The average value determined by the two methods was 572,000 gpd, which represents the approximate quantity of water induced or diverted from the reach of the river opposite the pumped well equal in length to twice the line-source distance, or 1020 feet. This area of streambed is about 6 acres; therefore, the rate of infiltration was about 95,000 gpd/ac. Since there was about 0.40 ft. average drawdown beneath the streambed the unit infiltration rate can be expressed as 235,000 gpd/ac/ft.

Given the infiltration rate, width, and depth of the stream, and aquifer coefficients, it is possible to calculate the yields, drawdowns, and spacings of wells. Calculations of yield and drawdown for a 20 mgd well field in the Scioto River valley were done by Norris and Fidler (1969, p. 52). They were assuming a 10-well field. Their calculations were based on the following formula of Rorabaugh (1956, p. 156, eq. 30):

$$Q = \frac{\frac{m_1 + m_2}{m_1} \pi T s}{2.30 \log \left\{ \left[\frac{2x}{r_w}\right] \left[1+\left(\frac{2x}{d}\right)^2\right] \left[1+\left(\frac{2x}{2d}\right)^2\right] \cdot\cdot \left[1+\left(\frac{2x}{nd}\right)^2\right] \right\}} \quad (7)$$

where: Q = gallons per day per well

T = transmissivity; assumed, conservatively, to be 200,000 gpd/ft in the incised channel and 128,000 gpd/ft between the incised channel and the X-608 pumphouse (nearer the valley wall)

m_1 = saturated thickness of aquifer prior to pumping, in ft; assumed to be 60 ft in the incised channel and 40 ft between the incised channel and the X-608 pumphouse

m_2 = saturated thickness of aquifer at pumped well during pumping, in ft

s = drawdown in aquifer outside well, in ft

x = distance from the center of the well screen to the line-source, in ft; taken as 200-250 ft for wells in shallower parts of the aquifer

d = well spacing, in ft

r_w = radius of well, in ft; taken as 1.0 (?) for wells in the incised channel and 0.75 for wells in the shallower parts of the aquifer

n = number of intervals between wells

In the Scioto aquifer-test the average width of the Scioto River was 260 feet, and the average depth was 3.6 feet. Assuming all water to be pumped would be derived from infiltration from the stream, Norris and Fidler (1969, p. 52) used the following formula to determine the minimum well spacing for a line of wells parallel to the river:

$$L = \frac{Q}{W\ D\ I} \quad (8)$$

where: L = distance between wells, in ft
Q = pumping rate per well, in mgd
W = width of river, in ft
D = average depth of river, in ft
I = infiltration rate, in mgd/ac/ft

For wells yielding 2 mgd (1,400 gpm), the equation is:

$$L = \frac{2 \text{ mgd} \times 43{,}560 \text{ ft}^2 \text{ /ac}}{260 \text{ ft} \times 3.6 \text{ ft} \times .235 \text{ mgd/ac/ft}} = 400 \text{ ft}$$

This spacing gives 10 wells yielding 2 mgd each (total yield = 20 mgd) in about 3600 feet of river length. This is about 29 mgd per mile for the potential yield of the Scioto River outwash aquifer. (See Walker, Schmidt, Stein, Prée, and Bailey, 1965, p. 18.) Assuming the infiltration rate of the streambed of White River at Indianapolis is about one-half that of the Scioto River near Piketon, (and assuming other important hydrologic conditions are similar to those in the Scioto valley) a reasonable estimate of the potential yield of the White River outwash aquifer might be about 15 mgd per mile of river.

As can be seen from the various formulas herein presented, several approaches to ground-water analysis are available to the investigator in evaluating possible development capabilities. As was noted in the beginning, it is not the purpose of this report to define the best methods, but to outline those methods that apply to defining recharge rates and potential yields of aquifers.

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