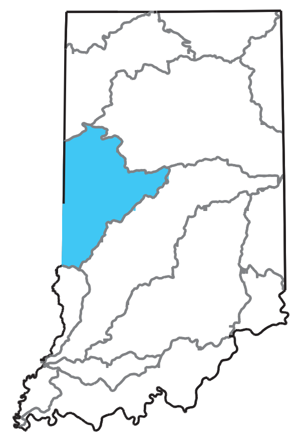


MIDDLE WABASH RIVER BASIN

By Paul K. Doss

General Description

The Middle Wabash River basin, as defined in this report, encompasses 3,453 mi^2 of west-central Indiana (Hoggatt, 1975). The basin is bounded on the west by Illinois, extends eastward to approximately 12 mi east of Lebanon, and extends north-south from approximately 10 mi south of Terre Haute to approximately 18 mi north of Lafayette (fig. 42). The Middle Wabash River basin includes all of Fountain, Montgomery, Vermillion, and Warren Counties, significant parts of Benton, Boone, Parke, Tippecanoe, and Vigo Counties, and small parts of six other counties. The largest population centers in the Middle Wabash River basin, listed in order of relative size, are Terre Haute, Lafayette, West Lafayette, Crawfordsville, and Lebanon.

Previous Studies

Several facets of the water resources of a large part of the Middle Wabash River basin were examined by Wangsness and others (1983), who summarized regional ground-water quantity and quality, surface-water quantity and quality, and precipitation characteristics. Another large-scale study was done by the Wabash River Coordinating Committee (1971) on the entire Wabash River basin. The Middle Wabash River basin, as defined in that report, included the Middle Wabash River basin as defined here, along with drainage areas in Illinois. Nyman and Pettijohn (1971) concentrated on the ground-water resources component of that study and reported on aquifer definition, base flow to streams, chemical quality, and management considerations. A report by Marie and Davis (1974) refers to a Middle Wabash River basin that is geographically different from the Middle Wabash River basin defined in this report. The downstream limit of the basin studied by Marie and Davis is virtually the upstream limit of this report; however, the water budget, ground-water availability, surface-water data, and other aspects of the report by Marie and Davis are pertinent because aquifers common to both areas may be hydraulically connected and of common origin. In addition, climatic and surface-water characteristics are similar for both basins.

The cities of Lafayette and West Lafayette, combined, form the largest population center within the Middle Wabash River basin. Several studies have examined the hydrogeology of glacial deposits underlying the Lafayette area. Maarouf and Melhorn (1975) discussed shallow-bedrock and unconsolidated aquifers and produced lithofacies maps of the unconsolidated materials to a depth of 400 ft. The ground-water resources of buried bedrock-valley deposits west of the Lafayette area in Illinois, were described by Visocky and Schicht (1969). The potentiometric surface in, and hydraulic conductivity of, outwash deposits near Lafayette were determined by Pohlmann (1986), who also suggested values for recharge rates through overlying tills. Some management considerations for the potential exploitation of ground-water resources in the Lafayette area were suggested by Loganathan and others (1980).

Several reports have been prepared on a county scale that describe the ground-water resources of counties in the Middle Wabash River basin. Reports by Watkins and Jordan list well-records and give preliminary information on geology and ground-water resources in Montgomery, Fountain and Vermillion Counties (1965a, 1965b, 1965c), and Putnam and Parke Counties (1964a, 1964b). Other county reports not only describe these aspects of ground-water resources but also include discussions of geology and water quality for Boone County (Brown, 1949), Tippecanoe County (Rosenshein and Cosner, 1956; Rosenshein, 1958), and Montgomery County (Cable and Robison, 1974). Several reports discuss the ground-water resources in Vigo County (Steen and Uhl, 1959; Watkins and Jordan, 1963). Cable and others (1971) delineate and discuss the principal bedrock and unconsolidated aquifers in Vigo and Clay Counties. The flow system and ground-water quality in the Pennsylvanian Mansfield Formation in Clay County are described by Thomas (1980).

Physiography

Topographic relief within the Middle Wabash River basin is approximately 530 ft. Altitudes range from a low of nearly 440 ft above sea level to a high of 970 ft above sea level. The lowest point is in the valley of the Wabash River at its exit from the basin in Vigo County and the highest point is in the uplands of Boone County in the eastern part of the basin.

The valley of the Wabash River is a dominant physiographic feature within the basin. In places the valley is 2 to 3 mi wide. Large expanses of flood-plain lowlands are present at the confluences of major tributaries such as the Vermillion River and Big Raccoon Creek. Prominent terrace surfaces can also be seen in many areas along the course of the river valley.

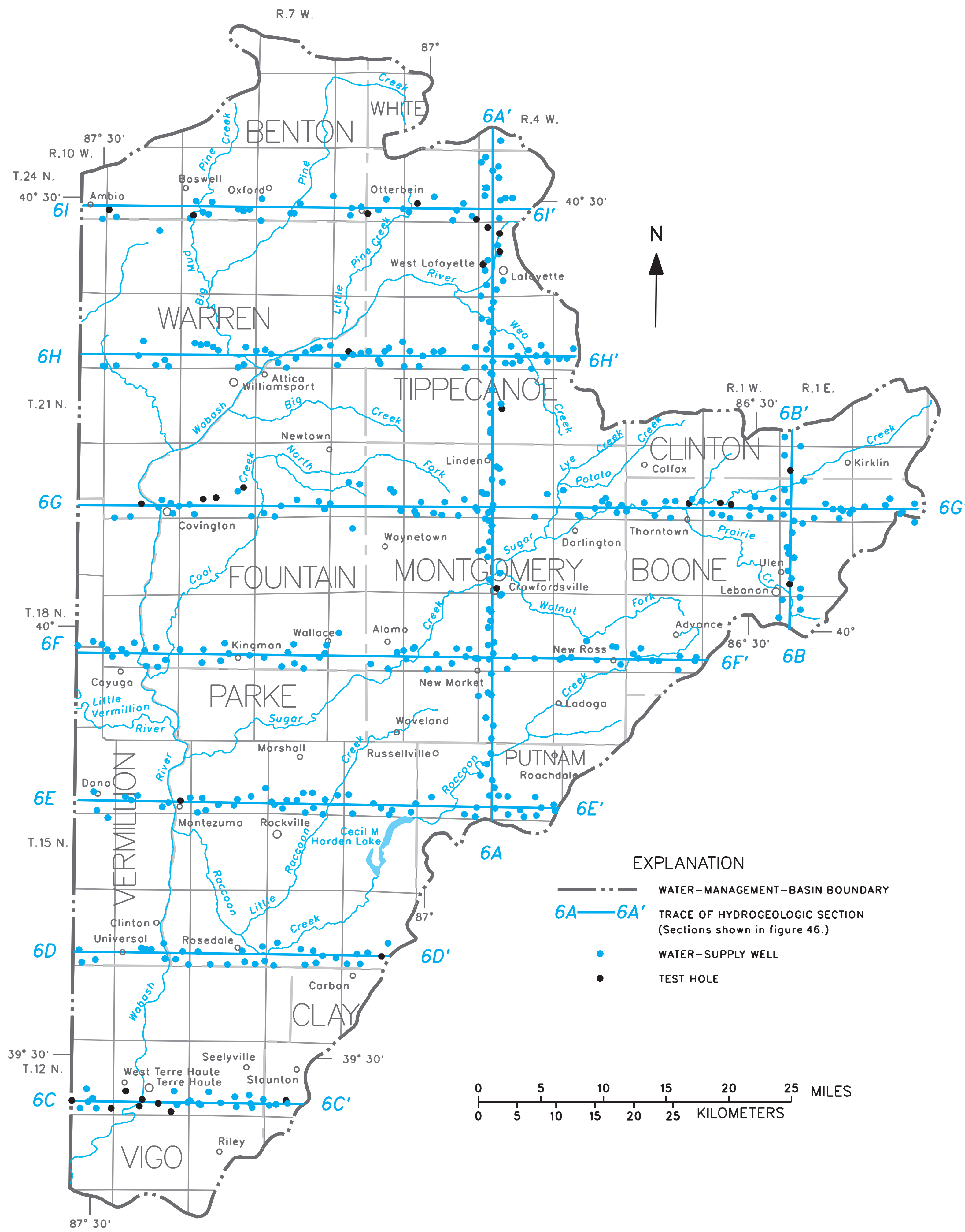
The surface physiography of the Middle Wabash River basin is dominated by the Tipton Till Plain (fig. 43). The southern extent of the Tipton Till Plain is marked by the Shelbyville Moraine and coincides with the southern extent of Wisconsinan glaciation in the basin. The Tipton Till Plain is a generally featureless, flat to gently-rolling plain, which is interrupted in places by very low-relief end moraines, including the Chatsworth, Crawfordsville, and Shelbyville Moraines (Malott, 1922, pl. III, p. 107; Schneider, 1966, p. 50). Some ice-disintegration features, including disintegration ridges and prairie mounds, also can be seen within the Tipton Till Plain in the Middle Wabash River basin (Bleuer, 1974).

South of the Wisconsinan glacial boundary, physiography is controlled by bedrock, although pre-Wisconsinan glacial deposits and Wisconsinan loess are present at land surface. The Wabash Lowland makes up most of the area south of the Wisconsinan glacial boundary within the Middle Wabash River basin (fig. 43). The Wabash Lowland is characterized by broad, terraced valley bottoms and undulating uplands (Schneider, 1966, p. 48). The overall subdued topography is controlled dominantly by the underlying fine-grained, clastic Pennsylvanian bedrock. Immediately east of the Wabash Lowland is the Crawford Upland (fig. 43), a dissected, westward-sloping upland (Schneider, 1966, p. 47). The diverse topography of the Crawford Upland reflects the underlying bedrock, an alternating sequence of resistant and nonresistant strata of Upper Mississippian Chester rocks and the basal-Pennsylvanian Mansfield Formation.

There are several large areas of human-disturbed land in the basin, particularly in the southern part in Vermillion, Vigo, Clay, and Parke Counties. Most of the disturbed land in those counties results from surface mining of coal and tailings disposal.

Surface-Water Hydrology

The Wabash River is the main surface drainage channel within the Middle Wabash River basin. Mean discharges at gaging stations which monitor the Wabash River range from 6,484 ft^3/s at Lafayette to 10,870 ft^3/s at Terre Haute (Arvin, 1989). Daily mean discharges for the 1988 calendar year at Lafayette range from a minimum of 702 ft^3/s to a maximum of 32,600 ft^3/s (Thompson and Nell, 1990, p. 99). The Wabash River flows from east to west in the northern part of the basin and from north to south in the central and southern parts; the major change in



Base from U.S. Geological Survey
State Base Map, 1:500,000, 1974

Figure 42. Location of section lines and wells plotted in the Middle Wabash River basin.

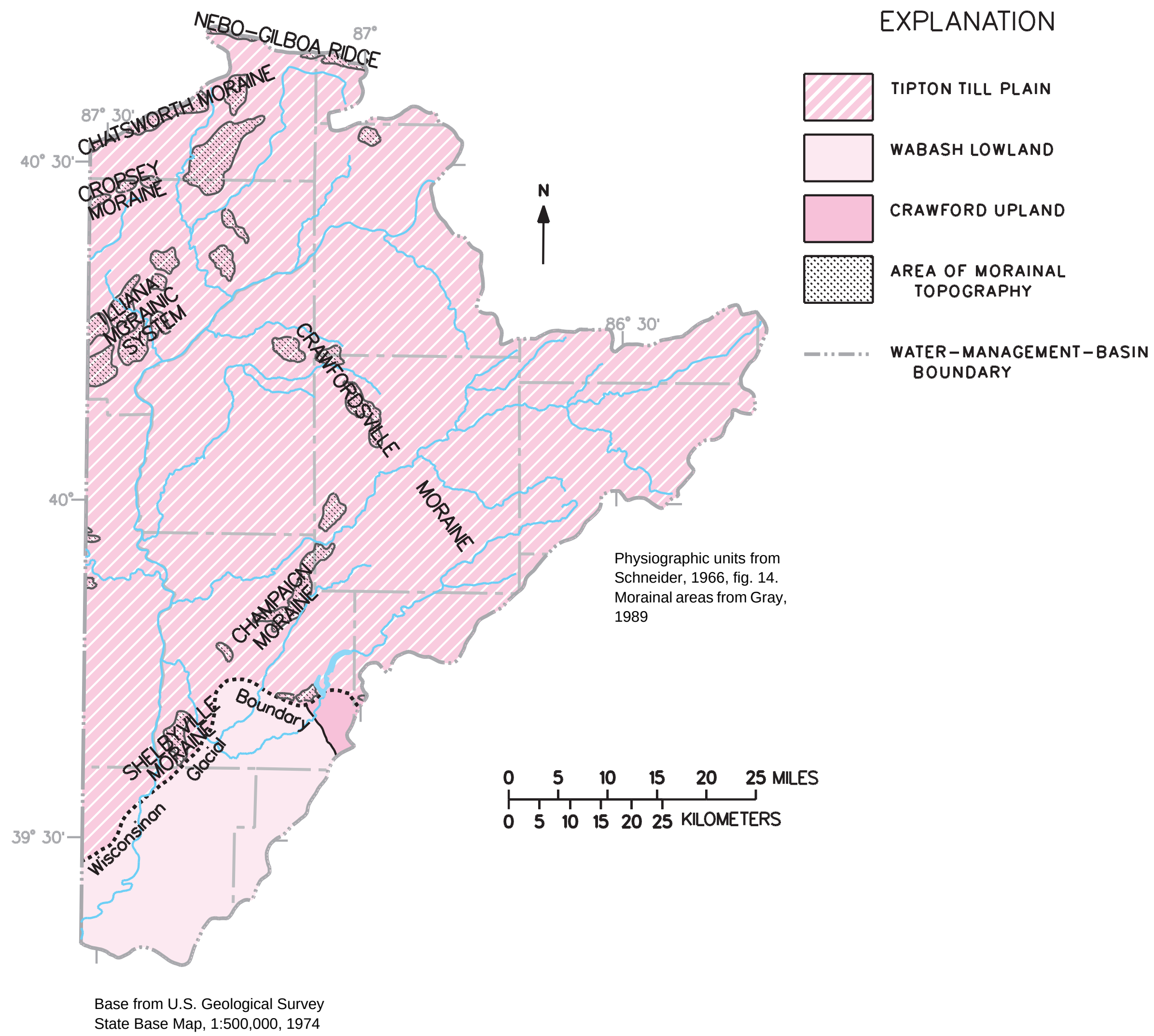


Figure 43. Physiographic units, moraines, and extent of glaciation in the Middle Wabash River basin.

direction of flow is near Covington, Ind. (fig. 42). The Wabash River enters the basin near Lafayette in Tippecanoe County, flows through Tippecanoe and Warren Counties, continues along the county line between Vermillion County and Fountain and Parke Counties, and then exits the basin through Vigo County at the Illinois-Indiana State line.

Little Pine, Big Pine, and Mud Pine Creeks drain the northern part of the Middle Wabash River basin (fig. 42). The confluence of Big Pine Creek with the Wabash River is at Attica, Indiana. The Coal Creek system drains the north-central and central part of the basin. The confluence of Coal Creek with the Wabash River is just east of Cayuga. Sugar Creek, a major tributary in the basin, flows southwest out of Crawfordsville and drains the entire eastern and south-central part of the basin. The confluence of Sugar Creek with the Wabash River is north of Montezuma. Raccoon Creek drains the southeastern and southern part of the basin. A reach of Raccoon Creek has been dammed to create Cecil M. Hardin Lake (Mansfield Reservoir), east of Rockville in Eastern Parke County. The confluence of Raccoon Creek with the Wabash River is south of Montezuma. The Vermillion River drains the western part of the basin and joins the Wabash River southeast of Cayuga. Much of the Vermillion River basin is in Illinois and hence, is not covered in this report. Most of the major tributaries to the Wabash River in western Indiana have, in places, cut through the cover of unconsolidated deposits and occupy valleys with exposed bedrock valley walls.

Geology

Bedrock Deposits

The Middle Wabash River basin lies on the eastern and northeastern margin of the structural Illinois Basin and on the southwestern limb of the Kankakee Arch (fig. 4). Bedrock units strike generally northwest, dipping gently into the interior of the Illinois Basin. Subcrops of rock units at the bedrock surface are progressively younger westward (fig. 44). The oldest rocks exposed at the bedrock surface are carbonate rocks of the Wabash Formation of Silurian age in Boone, Clinton, and Tipton Counties (fig. 44; Gray and others, 1987). The youngest bedrock subcrop includes clastic rocks of the Pennsylvanian McLeansboro Group in Vigo and Vermillion Counties along the Illinois-Indiana State line.

At least three major unconformities are present in the stratigraphic sequence, including the Silurian-Devonian disconformity, the Mississippian-Pennsylvanian angular unconformity, and the pre-Pleistocene angular unconformity (the Silurian-Devonian disconformity is not shown on hydrogeologic sections of the Middle Wabash River basin; Silurian and Devonian rocks are represented as a continuous sequence of parallel carbonate rocks). The erosional surface at the Mississippian-Pennsylvanian boundary, in some places, is characterized by topography with significant relief, including valleys as much as 115 ft deep (Gray, 1979, p. 12). A comprehensive interpretation of the configuration of the pre-Pennsylvanian surface by Keller (1990) was used as an aid in verification of the position of the Mississippian-Pennsylvanian boundary in the subsurface of the Middle Wabash River basin. An example of the Mississippian-Pennsylvanian angular unconformity can be seen in hydrogeologic section 6G–6G′ (fig. 46).

The bedrock surface underlying unconsolidated materials has preserved a topography that was at least partially acquired before Pleistocene glacial deposition. A regional, east-west paleodrainage system with many tributary valleys converge into a trunk valley in the vicinity of Lafayette, Ind. This bedrock valley system has historically been referred to as the Teays-Mahomet bedrock valley (Wayne, 1956, p. 36) and, more recently, as the Lafayette Bedrock Valley System (Bleuer, 1989; 1991; Bleuer and others, 1991). Excellent examples of this buried drainage system can be seen in hydrogeologic sections 6A–6A′ and 6I–6I′ (fig. 46). Detailed information on the altitude of the bedrock surface in the vicinity of Lafayette, Ind. near the complex coalescence of bedrock valleys was verified with information from Bruns and others (1985). Other bedrock elevations not specifically in the area of bedrock-valley convergence were verified with information from Gray (1982).

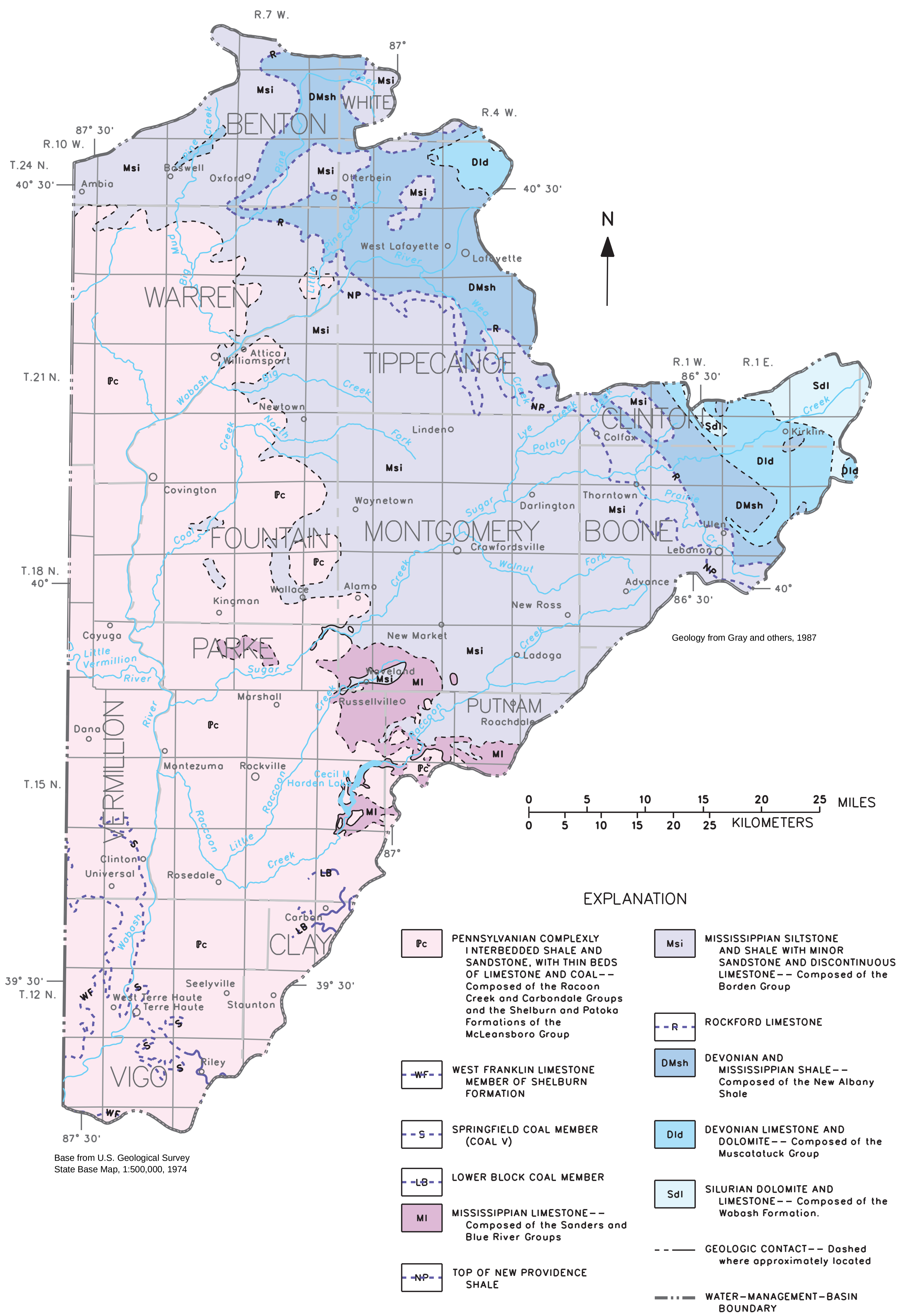


Figure 44. Bedrock geology of the Middle Wabash River basin.

The oldest rocks shown in the subsurface in this report are shales of the Ordovician Maquoketa Group. The Maquoketa Group is principally a shale unit that is slightly greater than 200 ft thick in northwestern Indiana (Shaver and others, 1986, p. 88). Only the upper 150 ft of the Maquoketa is shown in the subsurface of section 6G–6G′ (fig. 46).

Overlying Ordovician rocks is a sequence of Silurian and Devonian carbonate rocks. The entire thickness of these carbonate rocks is shown in the subsurface only in section 6G–6G′ (fig. 46) in which the thickness is 375 ft. The dominant unit in the Silurian and Devonian sequence is the Wabash Formation, which, in the vicinity of the Middle Wabash River basin, is greater than 250 ft thick (Shaver and others, 1986, p. 164). Other carbonate rocks that make up the Silurian and Devonian sequence include the Sexton Creek Limestone, the Salamonie Dolomite, and dolomites and limestones of the Muscatatuck Group (Shaver and others, 1986). Although not shown on the hydrogeologic sections, two test wells and one industrial water-supply well along sections 6B–6B′ and 6I–6I′ (fig. 46) penetrated the entire thickness of Silurian and Devonian carbonate rocks. Overlying the carbonate rock sequence is the New Albany Shale (Devonian and Mississippian). The New Albany Shale is a dark, carbon-rich shale that ranges in thickness from 100 to 120 ft in the Middle Wabash River basin (fig. 46).

Mississippian rocks in the Middle Wabash River basin are dominated by the Borden Group. Most of the Borden Group consists of siltstones, shales, fine sandstones, and discontinuous limestones (Shaver and others, 1986, p. 18). Where the entire thickness of the Borden Group has been interpreted in the subsurface of the Middle Wabash River basin, it is approximately 660 ft thick (section 6A–6A′, fig. 46).

In the northern part of the basin, the Borden Group is overlain unconformably by clastic rocks of the Pennsylvanian Mansfield Formation (fig. 44) (Gray and others, 1987). In the southeastern part of the basin, however, the Borden Group is overlain by truncated Mississippian carbonate rocks of the Sanders and Blue River Groups. The Sanders Group is made up of a variety of carbonate rocks, including fine-grained dolomites and fossiliferous limestones (Shaver and others, 1986, p. 137). The Blue River Group is composed largely of carbonate rocks (Shaver and others, 1986, p. 16). The maximum combined thickness of the Sanders and Blue River Groups in the Middle Wabash River basin is approximately 250 ft (section 6D–6D′, fig. 46).

Clastic rocks of the basal Pennsylvanian Raccoon Creek Group overlie Mississippian carbonate rocks in the south-central part of the basin and overlie Borden Group rocks in the northern part of the basin (fig. 44) (Gray and others, 1987). The Raccoon Creek Group is dominated by shales and sandstones, but it includes coals and minor limestones (Shaver and others, 1986, pp. 120-121). Much variability in the thickness of basal Pennsylvanian rocks is due to thick rock sequences in pre-Pennsylvanian valleys and thin rock sequences on top of pre-Pennsylvanian highlands (Gray, 1979, p. 13-14). The basal Mansfield Formation, ranging from 50 to 300 ft thick, is dominated by sandstones and contains coarse sands and conglomerates at its base (Shaver and others, 1986, p. 86). Thick Mansfield sandstones are interpreted along section 6D–6D′ (fig. 46) in R. 6 and 7 W. Similar thicknesses of the Mansfield Formation were documented for the same area by Hutchison (1976, pl. 4). The Mansfield Formation is overlain by the Brazil and Staunton Formations of the Raccoon Creek Group.

Clastic rocks of the Carbondale and McLeansboro Groups overlie the Raccoon Creek Group (fig. 44). The Carbondale Group, which is dominated by shales and sandstones and which contains four economically significant coals, consists of the Linton, Petersburg, and Dugger Formations (Shaver and others, 1986, p. 27). The only formation of the McLeansboro Group in the subsurface in the Middle Wabash River basin is the Shelburn Formation, which consists mainly of shale, siltstone, and sandstone and is less than 175 ft thick.

The maximum thickness of Pennsylvanian rocks interpreted in the Middle Wabash River basin is approximately 750 ft (sections 6C–6C′ and 6D–6D′, fig. 46).

Unconsolidated Deposits

The entire Middle Wabash River basin was glaciated during the Pleistocene, and unconsolidated materials at the surface are dominated by deposits of the Wisconsinan glaciation. The southern extent of Wisconsinan glaciation in the basin is in Vigo and Parke Counties (fig. 43). Total thickness of unconsolidated deposits ranges from zero at bedrock exposures along tributary valleys to greater than 350 ft in buried valleys near Lafayette (fig. 45). Bleuer (1989, 1991) examined the stratigraphy of bedrock-valley fill and geomorphic characteristics of the buried valleys to define the developmental history of the valley system.

North of the Wisconsinan glacial boundary, surficial deposits are dominated by loamy tills of the Trafalgar and Wedron Formations (Gray, 1989). At least three main Wisconsinan till deposits have been documented in a single exposure north of Williamsport, Ind. (fig. 42) (Bleuer, 1975). Sands and gravels deposited during Wisconsinan glaciation as outwash and stratified drift also are common. Sands and gravels, both at the surface and in the subsurface, are most extensive in the northern part of the basin and in bedrock valleys. Many large bodies of sand and gravel in the subsurface that are confined by tills and other nonaquifer material are correlative for lengths as much as 18 mi. Some basal sands and gravels at the bedrock surface and separated from overlying sands, as well as some basal sands in bedrock valleys are certainly of a pre-Wisconsinan origin. Surficial sand and gravel in recent river valleys may extend throughout the length of the basin.

South of the Wisconsinan glacial boundary, pre-Wisconsinan loamy tills of the Jessup and Glasford Formations are present at the land surface (Gray, 1989). Some pre-Wisconsinan lake silts and clays are at the surface southwest of Rosedale (fig. 42).

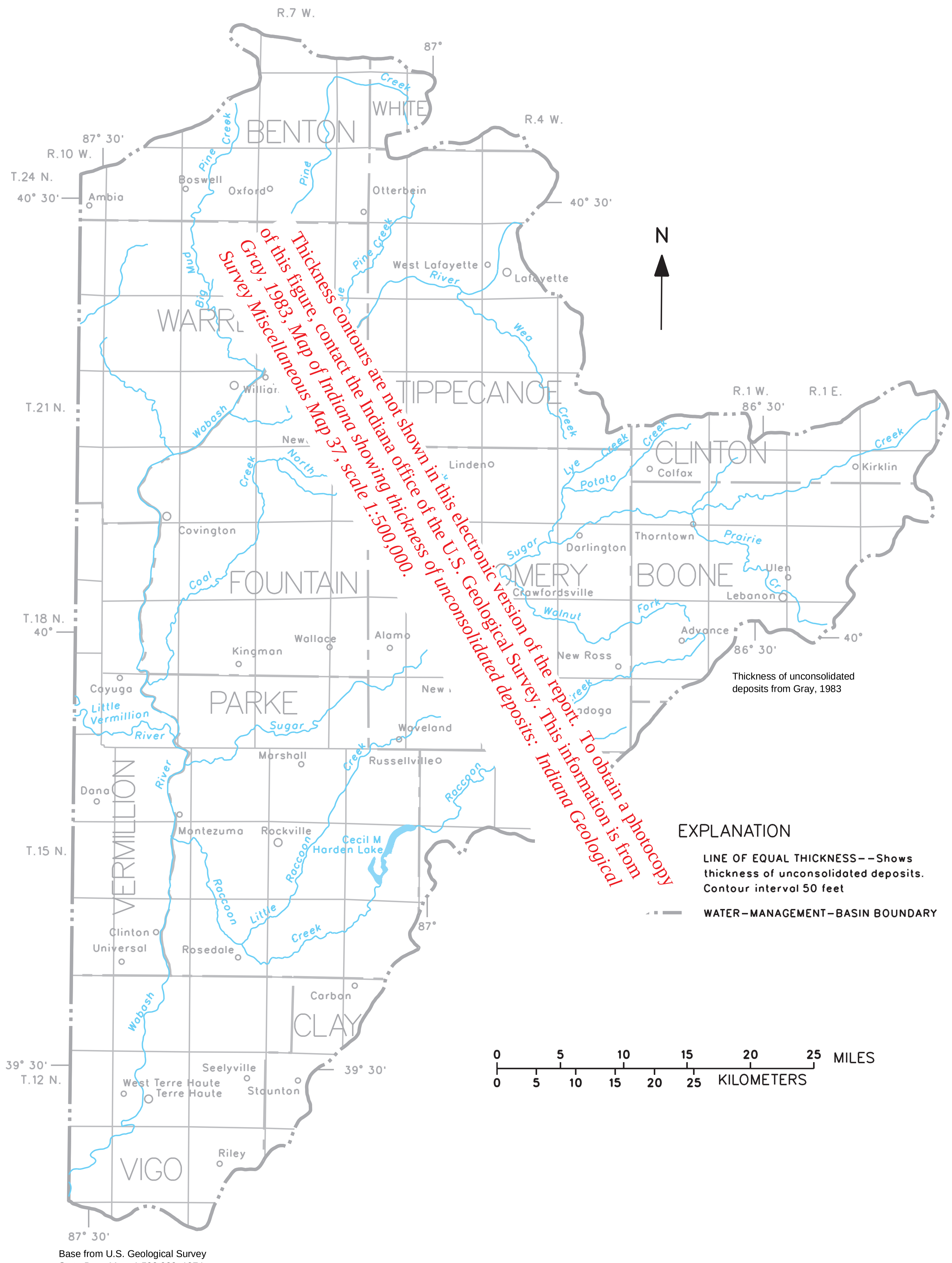
Holocene alluvium and colluvium are found in valleys of the Wabash River and its tributaries throughout the basin. Scattered loess (wind-blown silt) and dune-sand deposits are present in the central and southern parts of the basin. Most of these materials were derived from outwash in the Wabash Valley and are concentrated along the eastern margin and to the east of the valley.

Some Pleistocene sands and gravels have been cemented by calcium carbonate to form lithified sandstones and conglomerates interbedded with unconsolidated deposits (Rosenshein, 1955). These deposits are associated with the Wabash River and Wildcat Creek drainage basins and can be seen in outcrop overlying gray clays.

Aquifer Types

Nine hydrogeologic sections with a total length of 347 mi were constructed to describe aquifer types in the Middle Wabash River basin. Individual sections range in length from 16 to 67 mi. In total, 470 well records were used and the average density of plotted wells is 1.4 wells per mile. Sections 6A–6A′ and 6B–6B′ (fig. 46) are oriented south-north with a spacing of approximately 24 mi, and sections 6C–6C′ to 6I–6I′ (fig. 46) trend west-east with a spacing of 12 mi (fig. 42). The location and orientation of all the section lines provide coverage approximately perpendicular to each of the two major drainage directions of the Wabash and tributary rivers.

At least seven aquifer types are present in the Middle Wabash River basin: surficial sand and gravel; buried sand and gravel; discontinuous buried sand and gravel; complexly interbedded sandstone, shale, limestone, and coal; sandstone; Mississippian and Silurian-Devonian carbonate rocks; and an upper weathered-bedrock zone. Physical characteristics and some common or stratigraphic names for each aquifer type are listed in table 8. The areal distribution of these aquifers is shown in figure 47.



Thickness contours are not shown in this electronic version of the report. To obtain a photocopy of this figure, contact the Indiana office of the U.S. Geological Survey. This information is from Gray, 1983, Map of Indiana showing thickness of unconsolidated deposits: Indiana Geological Survey Miscellaneous Map 37, scale 1:500,000.

Figure 45. Thickness of unconsolidated deposits in the Middle Wabash River basin.

Unconsolidated Aquifers

The most significant aquifer systems in the Middle Wabash River basin consist of unconsolidated surficial and buried sand and gravel that originated as outwash and alluvial valley fill and typically are found in both recent and relict river valleys. Some large areas of buried sand and gravel are not associated with bedrock valleys and most likely originated as ice-marginal stratified drift. Discontinuous buried sand and gravel is present in large areas throughout the basin. The surficial and buried sands and gravels are extensive in their distributions. Surficial sand and gravel is found within 10 ft of land surface, whereas buried sand and gravel is covered by more than 10 ft of nonaquifer material.

Surficial sand and gravel aquifers can be seen in sections 6A–6A′ and 6C–6C′ to 6I–6I′ (fig. 46). In all cases, the surficial aquifer is within and along the valley of the Wabash River and its tributaries. Surficial sand and gravel aquifers range from 10 to 150 ft in thickness, but, are commonly 80 to 120 ft thick. In places where an entire valley is filled from bedrock to land surface with sand and gravel (sections 6C–6C′ to 6F–6F′, fig. 46), that system is called a surficial aquifer. That entire thickness of permeable materials may not represent a single depositional unit, but because of the absence of interlayered, nonaquifer material, it functions as a single hydrogeologic unit.

Buried sand and gravel is found in various places throughout the basin, but it is most common in bedrock valleys (fig. 46). The most extensive buried sand and gravel is in the buried Lafayette Bedrock Valley System. The valley is mapped in figure 47 as “buried bedrock valley aquifer”. Section 6I–6I′ (fig. 46) roughly coincides with the main axis of the bedrock valley where it exits the basin and enters Illinois. The bedrock knobs shown in the bedrock valley are a function of the 2-mile width of the hydrogeologic section and are actually bedrock highs on the interfluves between adjacent tributary bedrock valleys. More than 200 ft of buried sand and gravel are found in this part of the Lafayette Bedrock Valley System.

Some buried sand and gravel that does not appear to be basal fill in bedrock valleys can be seen along section 6B–6B′ (fig. 46), in R. 4 W. of section 6F–6F′ (fig. 46), and in several areas along section 6G–6G′ (fig. 46). In some places, multiple zones of buried sand and gravel are separated by nonaquifer material and are therefore stratigraphically and hydraulically distinct (sections 6A–6A′, 6H–6H′, and 6I–6I′, fig. 46). Buried sands and gravels that are not necessarily valley-fill deposits are large-scale intertill sands and gravels, outwash-fan deposits and ice-contact stratified drift within Wisconsinan and pre-Wisconsinan sediment sequences (Gray, 1989).

Potential well yields from the surficial sand and gravel range from 300 to 2,700 gal/min (Bechert and Heckard, 1966; Cable and others, 1971), whereas pumping rates noted on well logs that were used to construct sections range from 10 to 781 gal/min (table 8). Buried sand and gravel has a slightly lower expected range of yields, from 25 to 1,500 gal/min (Cable and others, 1971; Nyman and Pettijohn, 1971); yet, some high pumping rates from buried sand and gravels that are noted on well logs exceed pumping rates from the surficial sands. It is likely that the full production potential of the surficial and buried sand and gravel aquifers have not been realized in many cases and that each aquifer type is capable of significant yields.

The natural discharge points for the surficial sands and gravels are adjoining streams, such as the Wabash River (Pohlmann, 1986). Much ground-water flow in the thick sand and gravel sequences is lateral flow (Maarouf and Melhorn, 1975, p. 74; Pohlmann, 1986, p. 138) that follows regional flow paths. In some cases, natural discharge to buried sand and gravel and well pumpage may locally induce flow in the surficial sand and gravel away from the Wabash River and tributaries.

Recharge to surficial sands and gravels may range from 6.4 in/yr (Maarouf and Melhorn, 1975, p. 73) to 10.0 in/yr (Pohlmann, 1986, p. 138), whereas recharge to sands and gravels buried under low-permeability nonaquifer material may be less than 2 in/yr (Pohlmann, 1986, p. 138).

Discontinuous buried sand and gravel is another ground-water resource within the unconsolidated deposits. Examples of this aquifer type can be seen in virtually every hydrogeologic section; however, it is a significant source of water only in areas shown on sections 6A–6A′, 6B–6B′, 6F–6F′, 6G–6G′, and 6H–6H′ (fig. 46). The occurrence of discontinuous buried sand and gravel is similar to that of buried sand and gravel that is not related to bedrock valleys; however, it tends to be thinner and of smaller areal extent. Discontinuous stringers of sand and gravel are ubiquitous, in as much as almost 80 percent of the examined well logs note some discontinuous sand and gravel in the unconsolidated sediments. The sand and gravel deposits are 5 to 55 ft thick and are an important source of water for domestic needs. Expected yields from discontinuous buried sand and gravel range from 5 to 300 gal/min (Bechert and Heckard, 1966; Nyman and Pettijohn, 1971), whereas reported pumping rates noted on well logs range from 2 to 320 gal/min (table 8). The actual productivity of an individual well screened in a discontinuous buried sand and gravel aquifer is a function of the thickness of that unit, the storage characteristics (storativity), the hydraulic conductivity of the confining nonaquifer material, and the interconnection of the aquifer with other water-bearing sand and gravel bodies.

Most buried sand and gravel aquifers, both continuous and discontinuous, are artesian; that is, water levels in wells that are screened in buried sand and gravel are typically higher than the top of the permeable unit. One large buried sand and gravel unit that underlies the eastern part of R. 2 W. in section 6G–6G′(fig. 46) is penetrated by four wells, three of which are flowing wells. Buried sand and gravel deposits that are under artesian pressures will, in some cases, serve as sources of recharge for nearby unconsolidated aquifers, confining units, and bedrock units.

In general, discontinuous and continuous buried sands and gravels that are confined above and below by tills and other nonaquifer material have higher hydraulic heads than basal sands and shallow bedrock. These observations suggest that over most of the basin, some vertical ground-water flow is downward through the glacial cover, into shallow bedrock. In some areas however, most commonly near the Wabash River and major tributaries such as Sugar Creek, water levels in bedrock wells are higher than those in the overlying drift, and suggest vertically upward ground-water flow.

Other generalizations can be made regarding the overall distribution of sand and gravel aquifer material in unconsolidated sediments in the Middle Wabash River basin. Sands and gravels, whether they are surficial or buried, are most extensive in thick drift sequences (fig. 45). Thick drift is most common along buried bedrock valleys, the present valley of the Wabash River, and north of the Wisconsinan glacial boundary in the Tipton Till Plain (fig. 43). The overall lack of sand and gravel aquifers in the southern part of the basin and away from bedrock and river valleys can best be seen along sections 6A–6A′ and 6E–6E′ (fig. 46).

Bedrock Aquifers

At least four distinct aquifer types have been defined in different bedrock units within the Middle Wabash River basin. These bedrock aquifers include complexly interbedded sandstones, shales, limestones, and coals; sandstone; Mississippian and Silurian-Devonian carbonate rocks; and an upper weathered zone in low permeability rocks (table 8). Because the bedrock surface and the Mississippian-Pennsylvanian unconformity truncate bedrock units of different ages (fig. 44), not all bedrock aquifers are laterally continuous. Moreover, aquifers in the upper weathered bedrock and, in some cases, in the complexly interbedded Pennsylvanian bedrock, are not present throughout the stratigraphic unit but simply represent water-bearing horizons within these units (table 8). Where an aquifer does not include the entire stratigraphic unit, the interpretations of the basal or lateral boundaries of the aquifer are based on well-completion depths and locations of lithologic change.

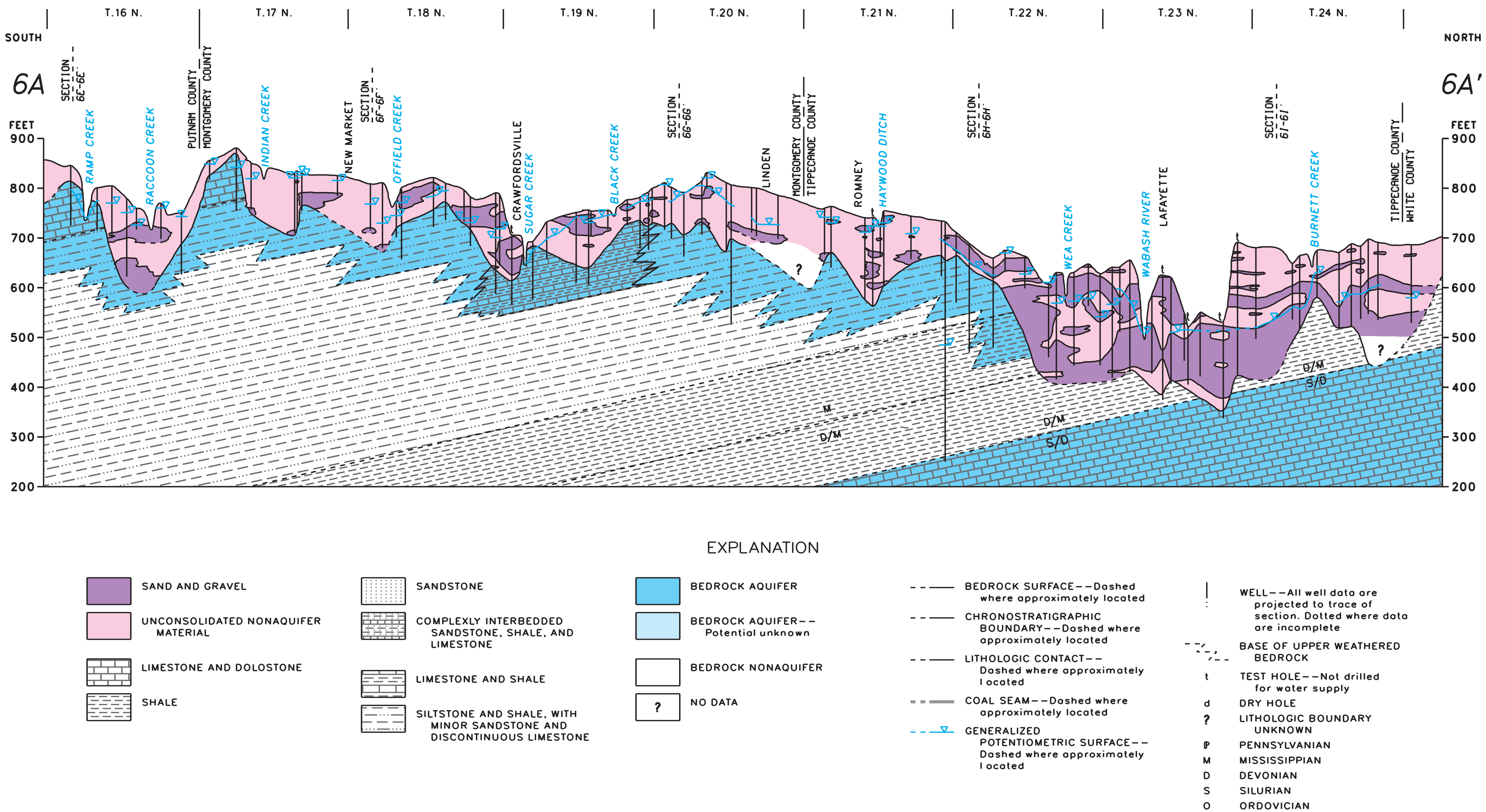
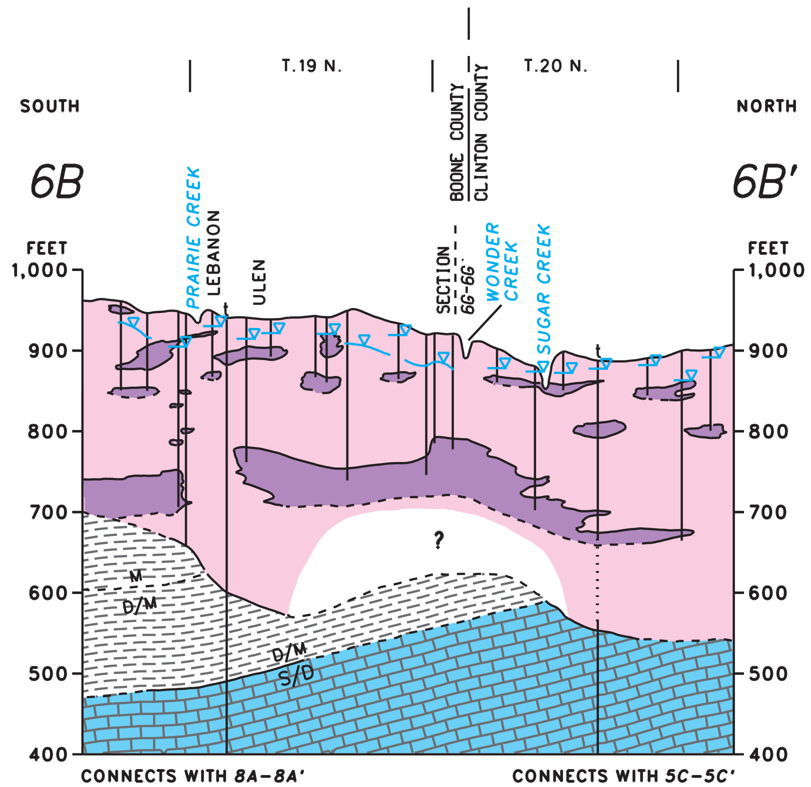
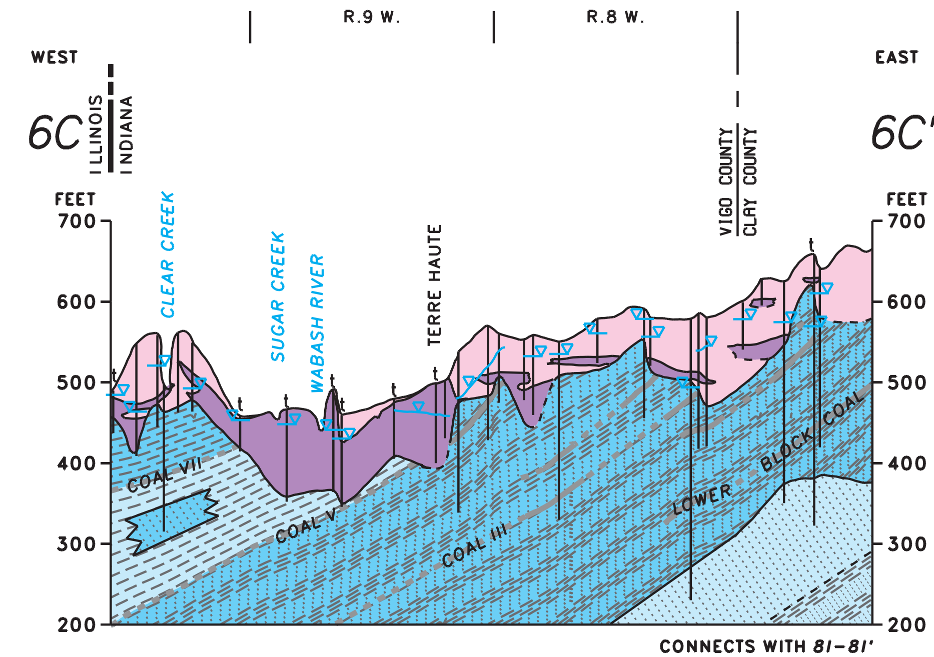
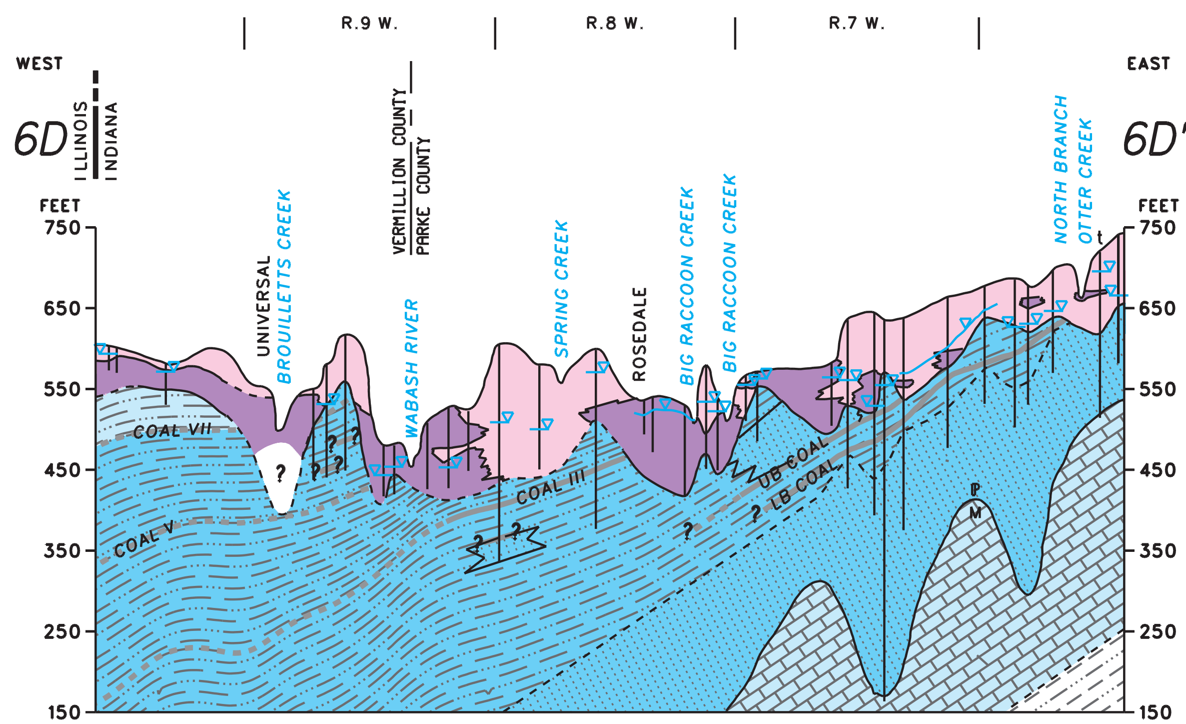


Figure 46. Hydrogeologic sections *6A–6A′* to *6I–6I′* of the Middle Wabash River basin.







DATUM IS SEA LEVEL

VERTICAL SCALE GREATLY EXAGGERATED

0 5 10 MILES

0 5 10 KILOMETERS

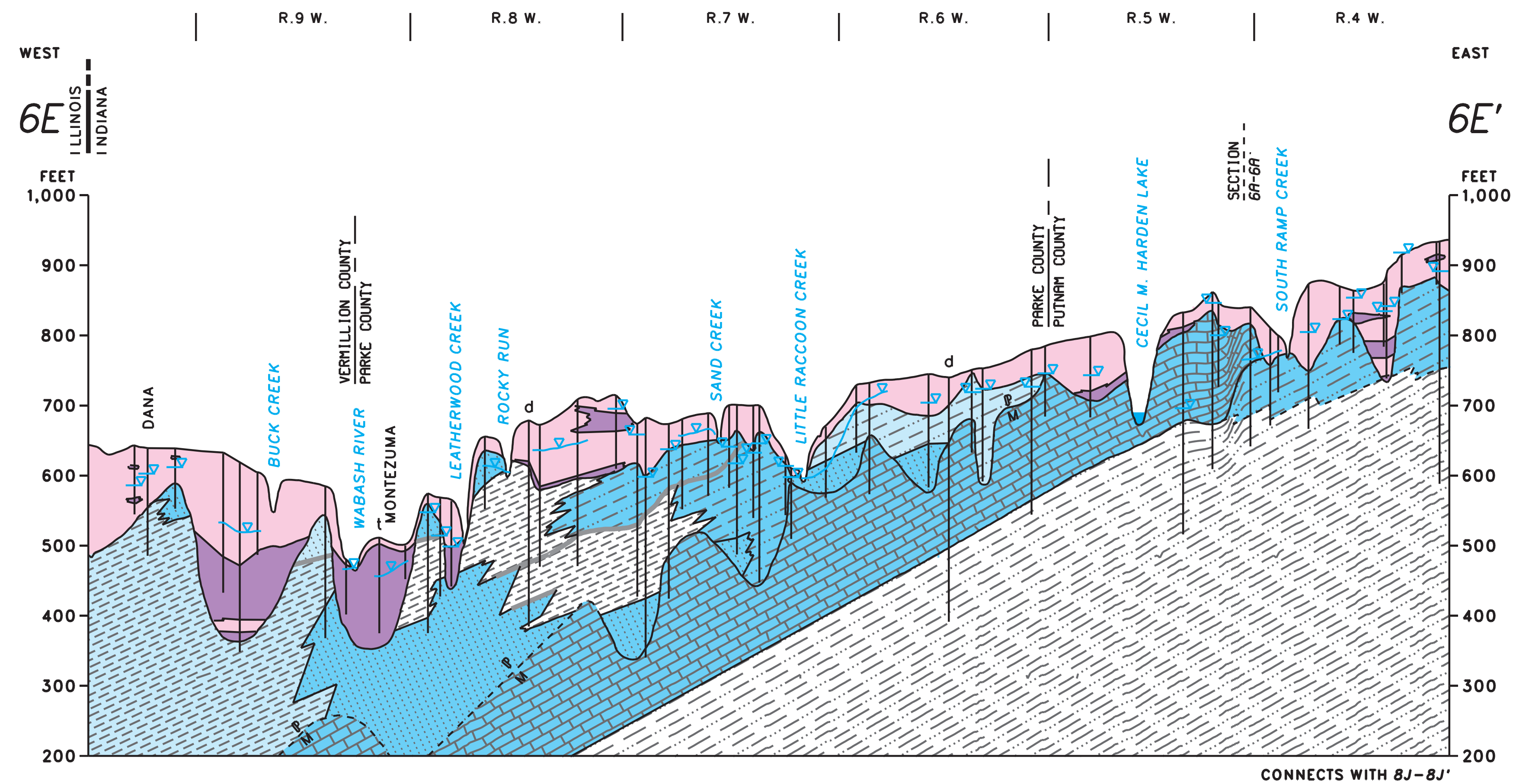
Figure 46. Hydrogeologic sections *6A–6A′* to *6I–6I′* of the Middle Wabash River basin—Continued.

DATUM IS SEA LEVEL

VERTICAL SCALE GREATLY EXAGGERATED

0 5 10 MILES

0 5 10 KILOMETERS



Complexly interbedded Pennsylvanian rocks, consisting dominantly of sandstones, siltstones, shales, and coals, are used as an aquifer only in the southern and western part of the basin (fig. 47). This aquifer system, shown in sections 6C–6C′ to 6H–6H′ (fig. 46), is characterized by thick sequences of irregularly alternating clastic lithologies and coal. Limestones are reported within the Pennsylvanian rocks, but they are minor. In several locations (sections 6C–6C′ and 6D–6D′, fig. 46), major coals were identifiable in the subsurface with the aid of published coal maps (Powell, 1968; Hutchison, 1961; Wier, 1952). The coals are important as stratigraphic markers; in addition, they may influence water chemistry (Smith and Krothe, 1983, p. 24), and they can be the dominant source of water for some uncased wells that are open to the entire complexly interbedded sequence (Banaszak, 1980).

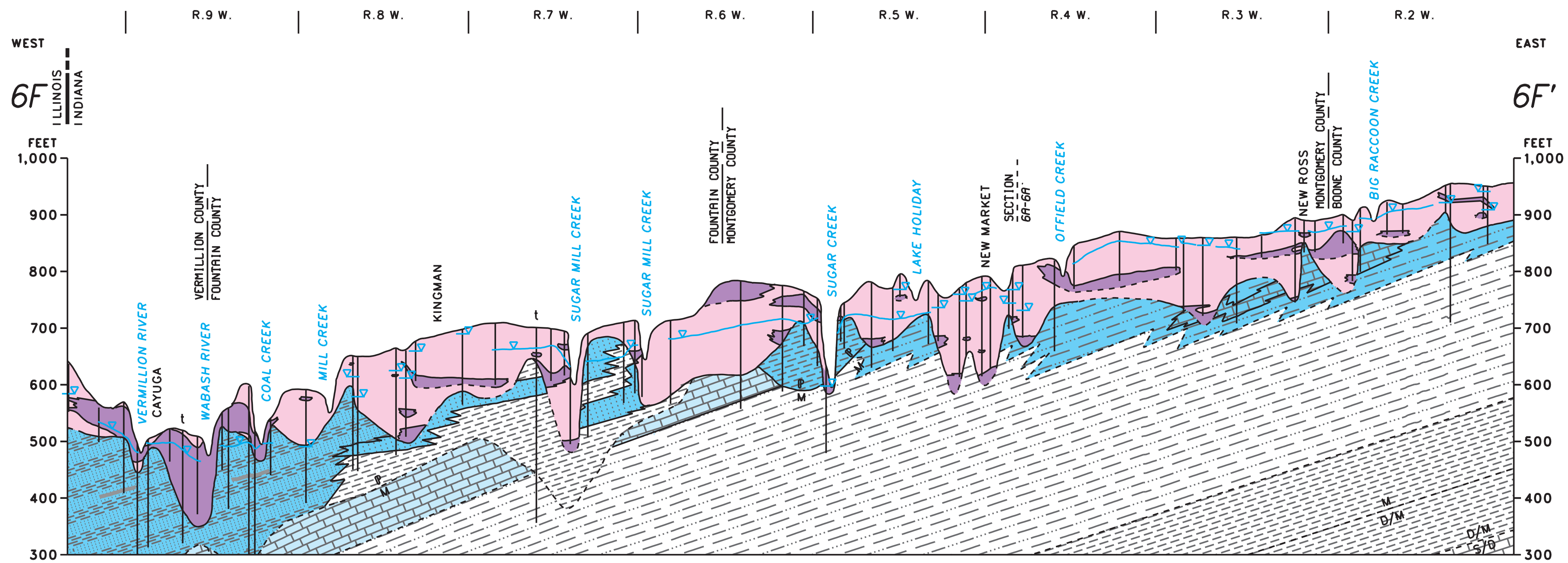
In almost all cases where wells tap the complexly interbedded aquifer, it is impossible to determine the exact source of water. Wells are commonly drilled several hundred feet into the bedrock and left uncased for the entire thickness of rocks penetrated. The interpreted thickness of the complexly interbedded aquifer ranges from 30 to 375 ft; however, those estimates are based on well penetrations and could be modified with additional data (table 8).

Expected yields from these Pennsylvanian interbedded bedrock units range from 3 to 70 gal/min (Cable and others, 1971; Nyman and Pettijohn, 1971); however reported pumping rates range from 0.1 to 35 gal/min (table 8). Smith and Krothe (1983) suggest that coal units in Vigo and Clay Counties have higher transmissivities and specific capacities than other water-bearing units in the same lithostratigraphic sequence. Drawdown during pumping at most wells open through the complexly interbedded bedrock is large (as much as a few hundred feet).

In several locations, individual lithologies were interpreted within the Pennsylvanian rocks. Shale and sandstone units are defined within the interbedded sequence, and are best represented in R. 7 W. and R. 8 W. along sections 6E–6E′ and 6F–6F′ (fig. 46). One well that penetrated a thick shale unit was noted as a dry hole. Some sandstone units can provide a supply of water and are discussed as a separate aquifer.

Many surface and underground coal mines have been developed in the coal-bearing, complexly interbedded strata of southwestern Indiana. Mining-related activities have affected the hydrogeology of the complexly interbedded aquifer and adjacent aquifers. Banaszak (1980, p. 240) suggests that cast overburden piles have significant water-storage capability and can increase the amount of infiltration and recharge to underlying coal aquifers. However, overburden piles that provide recharge to underlying aquifers can be detrimental to water quality. There also are abandoned coal-mine shafts and rooms in the subsurface of the coal-mining region. Many water wells drilled along sections 6C–6C′, 6D–6D′, and 6E–6E′ intercepted open mine rooms at various depths. In at least one location, water from saturated rocks above an open mine was discharged into the open room as soon as it was encountered.

The sandstones defined as a distinct aquifer in the Middle Wabash River basin are generally basal Pennsylvanian rocks of the Mansfield Formation. Most of these sandstones immediately overlie the Mississippian-Pennsylvanian unconformity and are depicted in sections 6D–6D′, 6E–6E′, and 6G–6G′ (fig. 46). Smaller sandstone units are noted above the unconformity in sections 6C–6C′, 6D–6D′, 6E–6E′, and 6F–6F′ (fig. 46). Basal sandstones, many of which contain conglomerates near their bases, typically fill “valleys” in the Mississippian-Pennsylvanian unconformity and originated as channel-fill and fluvial sands (section 6E–6E′, fig. 46).



The thickness of the sandstone aquifer was interpreted from the depth of well penetrations and ranges from 30 to 250 ft (table 8). The sandstones are laterally discontinuous and bounded on all sides by rocks of different lithology and(or) the underlying unconformity.

Expected well yields for Pennsylvanian sandstones range from 8 to 75 gal/min (Cable and others, 1971; Arihood and Mackenzie, 1983) and reported pumping rates range from 1 to 40 gal/min (table 8).

Recharge to the sandstone and the complexly interbedded aquifers is from precipitation on outcrop areas and downward percolation through overlying unconsolidated material (Cable and others, 1971, p. 5; Arihood and Mackenzie, 1983, p. 54). Recharge to the Mansfield Formation in the vicinity of Terre Haute was estimated on the basis of several assumptions and a simple water balance equation to be 1.64 in/yr (Thomas, 1980, p. 29).

Most of the sandstones rest on an erosional surface formed prior to and during the deposition of Mansfield sands; therefore, it is likely that the basal sandstones and conglomerates have a good hydraulic connection with the underlying Mississippian limestones. The erosional surface represents a period of weathering that most likely developed a zone of enhanced permeability at the surface of underlying carbonate rocks that is now in contact with the overlying clastic rocks. Sufficient data are not available to determine the degree or nature of the hydraulic connection between the sandstones and the limestones, and whether water is discharged from the limestones into the sandstones or vice versa.

The Mississippian carbonate bedrock aquifer is composed of rocks of the Mississippian Blue River and Sanders Groups. These carbonate rocks are truncated by the Mississippian-Pennsylvanian unconformity and are found only in the southeastern and south-central part of the basin (fig. 47). Rocks of the Blue River and Sanders Groups are seen on sections 6A–6A′ and 6D–6D′ to 6F–6F′ (fig. 46). The only known usage of these carbonate rocks as an aquifer, however, is in areas shown on sections 6A–6A′ and 6E–6E′. The carbonate rocks in these areas are 25 to 225 ft thick.

Expected yields for the Mississippian carbonate bedrock aquifer range from 5 to 60 gal/min (Bechert and Heckard, 1966; Cable and Robison, 1974); reported pumping rates range from 1 to 30 gal/min (table 8). The water-producing characteristics of these carbonate rocks are highly variable, with some dry holes occurring in the Mississippian carbonate rocks (see section 6E–6E′, fig. 46).

In general, well yields and permeability in carbonate bedrock aquifers can be highly variable (Siddiqui and Parizek, 1971; Lattman and Parizek, 1964). Variable yields result from an uneven distribution of permeability that develops from preferential dissolution of carbonate along fractures, joints, and bedding planes (Legrand and Stringfield, 1971; White, 1969). Statistical analyses have indicated a direct relation between well locations on fractures and fracture traces and a higher productivity of the well (Siddiqui and Parizek, 1971). Clearly, wells need to be in connection with water-bearing zones to maximize potential yields. In contrast, wells sited in nonfracture locations may not provide sufficient ground water for their intended use.

Another carbonate bedrock aquifer, the Silurian-Devonian aquifer, is present in the Middle Wabash River basin and shown in sections 6A–6A′, 6B–6B′, and 6F–6F′ to 6I–6I′ (fig. 46). The Silurian-Devonian carbonate bedrock aquifer is an important aquifer in the State; however, only three wells used to construct the sections in the Middle Wabash River basin were identified as producing water from the

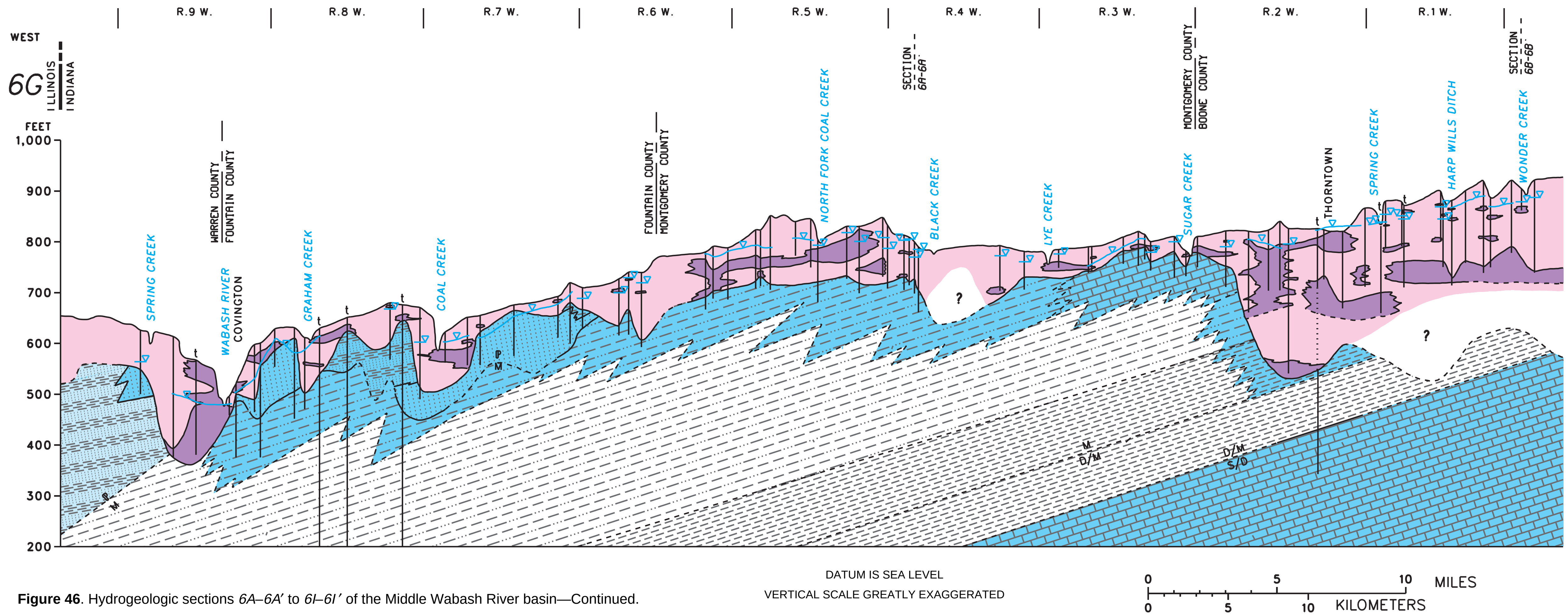


Figure 46. Hydrogeologic sections *6A–6A′* to *6I–6I′* of the Middle Wabash River basin—Continued.

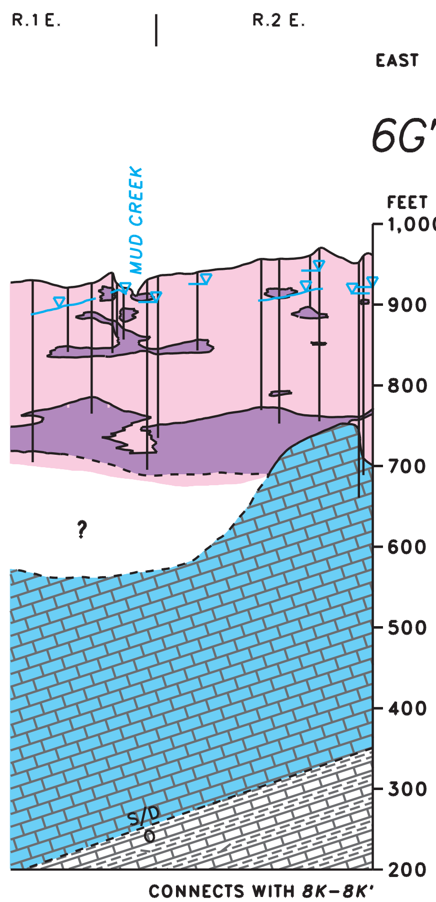
aquifer (two domestic wells in section 6G–6G′ and one industrial well in section 6I–6I′). The aquifer is not significant in the basin because of its considerable depth, the presence of highly mineralized water at depth, and the availability of water from shallower bedrock aquifers and overlying sand and gravel. Characteristics of the aquifer are listed in table 8. Detailed information on the Silurian-Devonian carbonate bedrock aquifer is provided in the sections on the Lake Michigan and Kankakee River basins in this report.

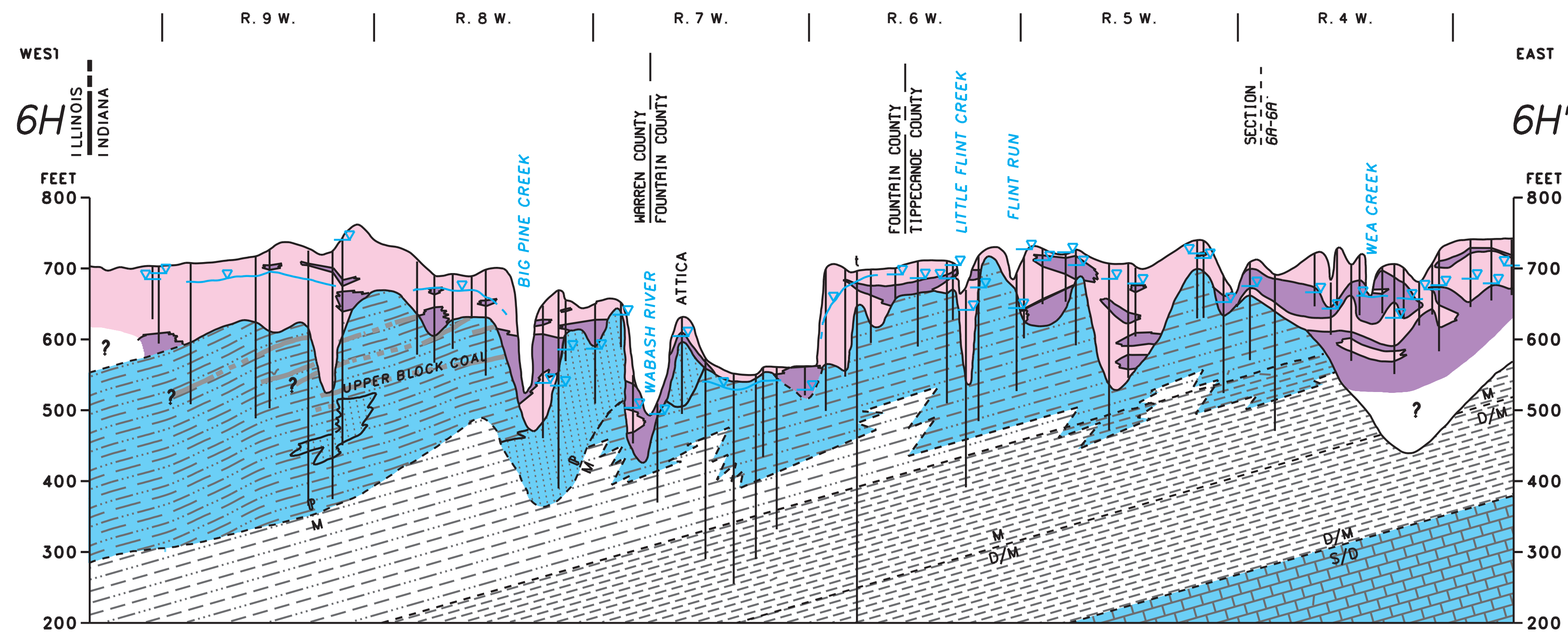
An upper weathered zone in low-permeability bedrock is another significant bedrock aquifer in the Middle Wabash River basin. The aquifer is primarily at and immediately below the bedrock surface in Mississippian Borden Group rocks. The aquifer is significant only in areas underlain by typically nonaquifer bedrock (Borden Group), however, it is likely that some of the characteristics of the upper weathered-bedrock aquifer are present in all units at the bedrock surface. The upper weathered zone formed in the bedrock during various weathering processes before and during deposition of the overlying drift. The aquifer characteristics result from the enhanced permeability in the weathered zone.

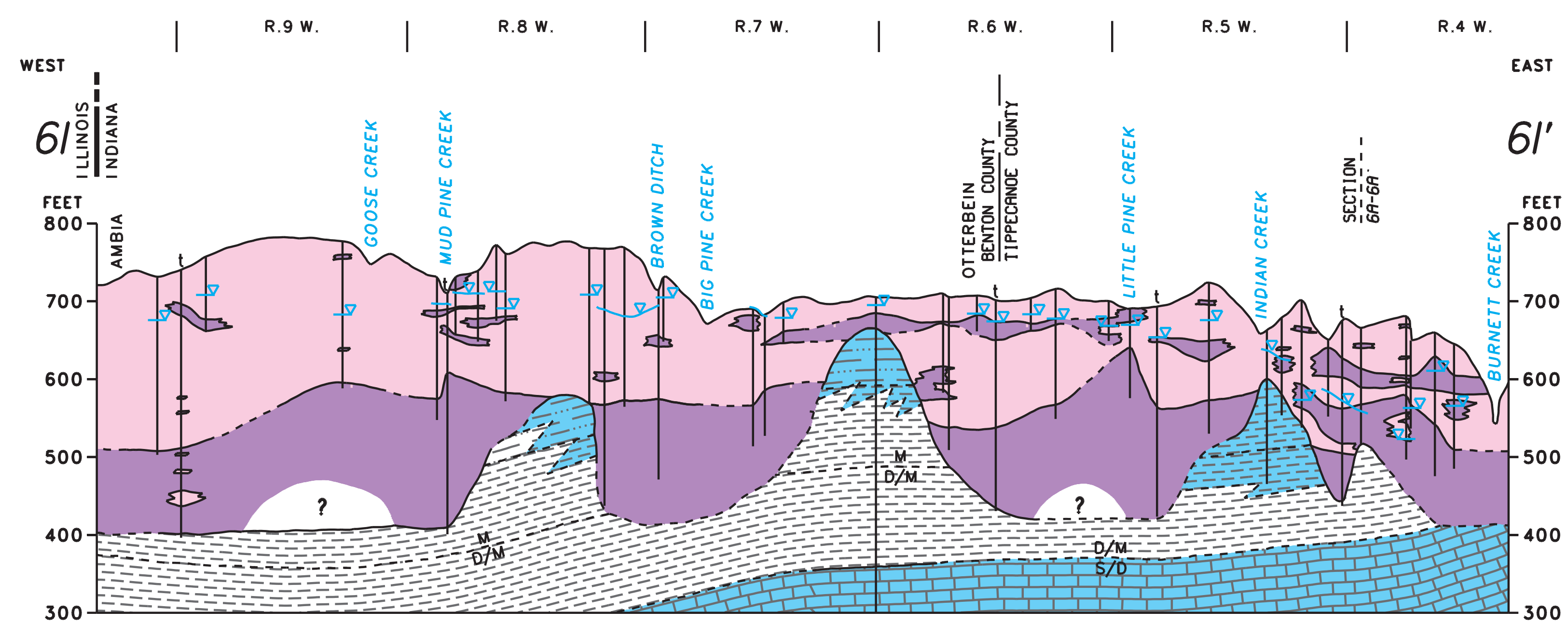
The upper weathered-bedrock aquifer is areally extensive (fig. 47), and is most significant in the thick Borden Group rocks shown in sections 6A–6A′ and sections 6F–6F′ to 6H–6H′ (fig. 46). Small areas have also been inferred in section 6I–6I′ (fig. 46). This aquifer, by its nature, is not restricted by lithologic boundaries. Rather its existence is entirely a function of weathering at and below the bedrock surface. Lithologic variations are shown within the upper weathered-bedrock aquifer along sections 6A–6A′, 6F–6F′ and 6G–6G′ (fig. 46) and produce spatial variability in hydraulic properties of the aquifer.

The true thickness of the upper weathered bedrock is unknown, but it has been inferred from the total penetration of wells that use it as an aquifer. Suggested thicknesses of the upper weathered-bedrock aquifer range from 25 to 175 ft (table 8), but the true enhanced-permeability zone is most likely limited to approximately the upper 50 ft.

Expected yields for Borden Group rocks in the upper weathered zone range from 1 to 270 gal/min (Cable and Robison, 1974; Wangsness and others, 1983) and up to 590 gal/min from siltstones and shales (Nyman and Pettijohn, 1971, p. 61); however, these yields are far greater than those noted on logs used to construct the sections. Reported pumping rates for the upper weathered-bedrock aquifer range from 2 to 150 gal/min (table 8). Some of the variability in yields from this aquifer are attributable to the observed lithologic variations in the Borden Group, the variability in







degree of weathering and fracturing, and the hydrogeologic character of the overlying drift.

Recharge to the upper weathered-bedrock aquifer is through the overlying drift. There is most likely a good hydraulic connection between rocks of the Borden Group and basal sands and gravels in buried bedrock valleys and buried sand and gravels on some areas of bedrock uplands (sections 6A–6A′ and 6G–6G′ to 6I–6I′, fig. 46). Most of the Borden Group rocks underlying the Lafayette Bedrock Valley along section 6I–6I′ are not interpreted as being an aquifer because no wells are completed in it and because sufficient ground-water resources are available in sand and gravel aquifers that overlie the bedrock.

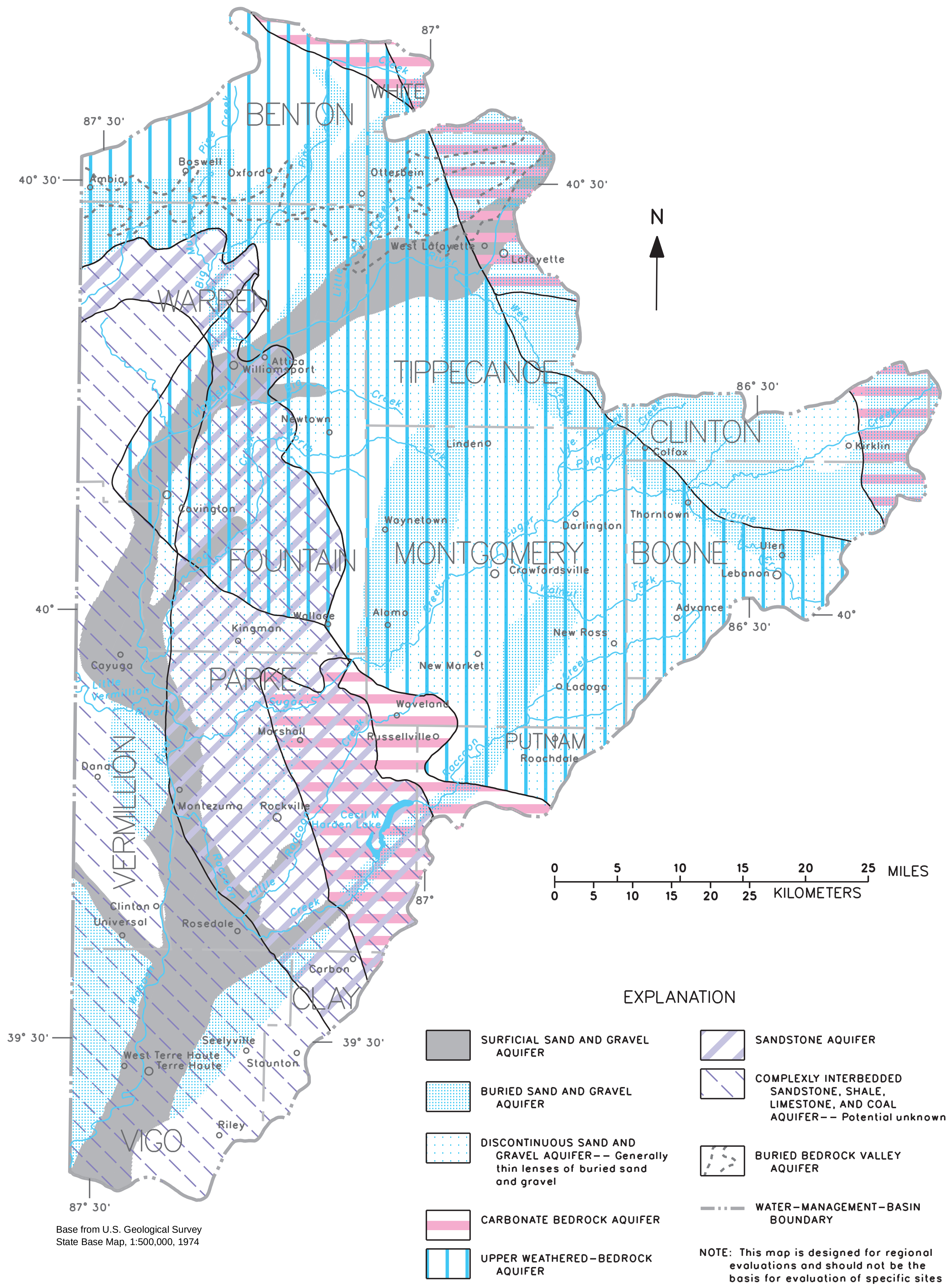


Figure 47. Extent of aquifer types in the Middle Wabash River basin.

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Table 8. Characteristics of aquifer types in the Middle Wabash River basin
[<, less than; locations of aquifer types shown in fig. 47]

Aquifer type	Thickness (feet)	Range of yield (gallons per minute)	Reported[1] pump rates (gallons per minute)	Common name(s)
Surficial sand and gravel	10-150	[2,3]300-2,700	10- 781	Outwash, valley train
Buried sand and gravel	10-225	[3,4]25-1,500	5-1,012	Valley fill
Discontinuous sand and gravel	5- 55	[2,4]5- 300	2- 320	Intertill sands
Complexly interbedded sandstone, shale, limestone, and coal	[5]30-375	[3,4]3- 70	0.1- 35	Raccoon Creek Group, Carbondale Group
Sandstone	[5]30-250	[3,6]8- 75	1- 40	Mansfield Formation
Carbonate bedrock				
Mississippian	25-225	[2,7]5- 60	10- 30	Sanders Group Blue River Group
Silurian-Devonian	[5]20- 90	[2]<500	50- 800	Wabash Formation
Upper weathered bedrock	[5]25-175	[6,7]1- 270	2- 150	Borden Group

[1]Reported pump rates refer to noted pump rates at the time of well installation and may not represent a "true" well-yield.
[2]Bechert and Heckard, 1966.
[3]Cable and others, 1971.
[4]Nyman and Pettijohn, 1971.
[5]Reported thicknesses refer to observed and inferred permeable zones and may not correlate with specific formation thicknesses.
[6]Arihood and Mackenzie, 1983.
[7]Cable and Robison, 1974.

Summary

Ground water is available throughout the Middle Wabash River basin from unconsolidated and bedrock deposits; however, yields that tap these deposits differ greatly among aquifer types. The most productive aquifers and among the most extensive are the thick sands and gravels within buried bedrock valleys and along present river courses. These deposits currently yield 1,000 gal/min or more to individual wells and are capable of yielding greater than 2,500 gal/min. Discontinuous sands and gravels are also important and yield greater than 300 gal/min. Perhaps the next most important aquifer, simply because of its areal extent, is the upper weathered-bedrock aquifer. This aquifer supplies a large part of the domestic water requirement for the northern and eastern two-thirds of the basin. Pumping rates for wells in the upper weathered bedrock are as high as 150 gal/min. Sandstones and complexly interbedded sandstones, shales, limestones, and coals, of Pennsylvanian age, provide for the domestic water needs in the southwestern one-third of the basin and yield as much as 75 gal/min. The Mississippian carbonate bedrock aquifer is unpredictable because of permeability differences common to carbonate rocks. Dry holes are noted in these rocks, whereas some wells yield as much as 30 gal/min. Although the Silurian-Devonian carbonate bedrock aquifer is an important aquifer in the State, it is rarely used in the Middle Wabash River basin, generally because of its depth.

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