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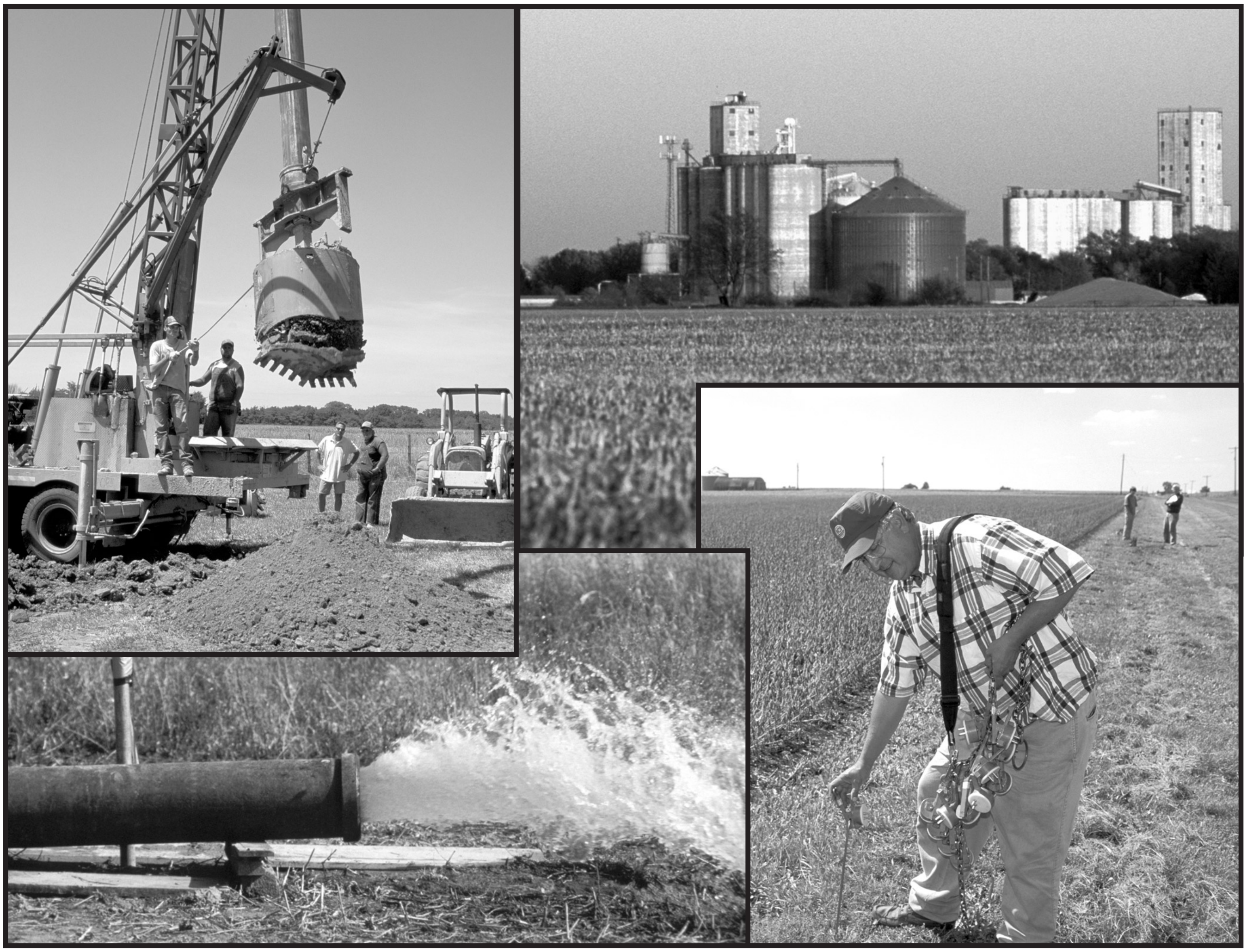
Groundwater Geology of DeWitt, Piatt, and Northern Macon Counties, Illinois

David R. Larson, Beverly L. Herzog, and Timothy H. Larson



Environmental Geology 155 2003
Rod R. Blagojevich, Governor

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Brent Manning, Director

ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

***Front Cover:** Drilling a large-diameter well (upper left). Skyline of Farmer City, a thriving community in DeWitt County, Illinois (upper right). Pipe discharging groundwater pumped from Mahomet aquifer (lower left). Ron Wolfe of Monticello helping with electrical resistivity survey (lower right).*

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Contents

Figures

Abstract

The Mahomet aquifer is one of the largest sources of groundwater in Illinois. This aquifer, which occupies the lower part of the buried Mahomet Bedrock Valley, arcs to the south across east-central Illinois from the Indiana state line westward to where it joins the Sankoty aquifer. Central Piatt and DeWitt Counties overlie a portion of the Mahomet aquifer. The characteristics of the Mahomet aquifer are understood sufficiently well to know that enough groundwater is available to meet foreseeable water needs arising within central Piatt and DeWitt Counties. In addition, shallower aquifers occur throughout both counties, scattered at various depths below the land surface. These aquifers are generally discontinuous, limited in areal extent, and relatively thin. Although their extent, distribution, and characteristics are less well understood than those of the Mahomet aquifer, the shallower aquifers are a significant resource in Piatt and DeWitt Counties. They are the source of water for numerous towns and most of the rural households, especially those located outside the boundaries of the Mahomet aquifer.

The Mahomet Valley Water Authority (MVWA) includes all of Piatt County and all but the southeast corner of DeWitt County. The MVWA determined that mapping the distribution and thickness of aquifers in its area of jurisdiction was an integral part of groundwater resource management. To accomplish this purpose, the MVWA began a cooperative project with the Illinois State Geological Survey (ISGS) in 1994 to map the aquifers located in Piatt and DeWitt Counties. Maps and cross sections were developed using data from 51 stratigraphic-control boreholes, sample sets from 15 boreholes, and approximately 100 of the best drillers' logs available. The maps in this report are based on the data obtained from nearly 3,500 drillers' logs of water wells and other boreholes. This study also incorporates data on depth to bedrock obtained from a shallow seismic refraction survey in the Farmer City–Mansfield area and data on aquifer depth and thickness from an extensive electrical earth resistivity (EER) survey in the southern half of Piatt County.

The maps included in this report show the thickness and extent of the Mahomet and four shallower aquifers in the area. The top of the Mahomet aquifer is more variable than previously thought. Maximum aquifer thickness reported in the drillers' logs is 174 feet. Based on the difference between elevations of the top of the Mahomet aquifer and the bedrock surface, aquifer thickness could locally be as much as 190 feet. Shallower aquifers above the Mahomet are widespread and are most common in areas not underlain by the Mahomet aquifer. Maps of these aquifers indicate that they are sufficiently thick in many parts of the study area to be reliable sources of supply for domestic wells.

Introduction

The Mahomet aquifer occurs in a broad arc that sweeps to the south across east-central Illinois, from the Illinois-Indiana state line to central Illinois where it merges with the Sankoty aquifer (fig. 1). The Mahomet aquifer consists of sand and gravel deposited during the pre-Illinois episode of glaciation that fills the lower one-third to one-half of the Mahomet Bedrock Valley. This valley is the westernmost reach of the Mahomet (Teays) Bedrock Valley, which was a major feature of the pre-glacial landscape of Illinois and the Midwest (fig. 2). The topography of the bedrock surface generally constrains the areal extent and thickness of the Mahomet aquifer (University of Illinois 1995). The thickness of the Mahomet aquifer across central Illinois averages about 100 feet but locally may be as much as 200 feet (University of Illinois 1995). Under confined conditions throughout most of its extent in Illinois, the Mahomet aquifer becomes unconfined near its western end, close to the Illinois River. Shallower sands and gravels deposited during later glacial episodes occur above the Mahomet aquifer. Although these shallower aquifers are not as continuous or productive as the Mahomet aquifer, they are important sources of water for many communities, farms, and rural households, especially where the Mahomet aquifer is absent.

Expanding municipal needs, new industrial uses (such as ethanol fuel production), large new livestock management facilities, and additional acres placed under irrigation as well as other factors have increased demand for water in east-central Illinois. The Mahomet aquifer is the resource typically used to meet the demand because this aquifer can support high-capacity wells. Several large communities located just beyond the edges of the Mahomet aquifer obtain their water from surface-water sources. Surface-water supplies are susceptible to problems with water quality, such as those caused by drought or elevated nitrate levels. Other communities use groundwater from aquifers of limited thickness and extent, but these

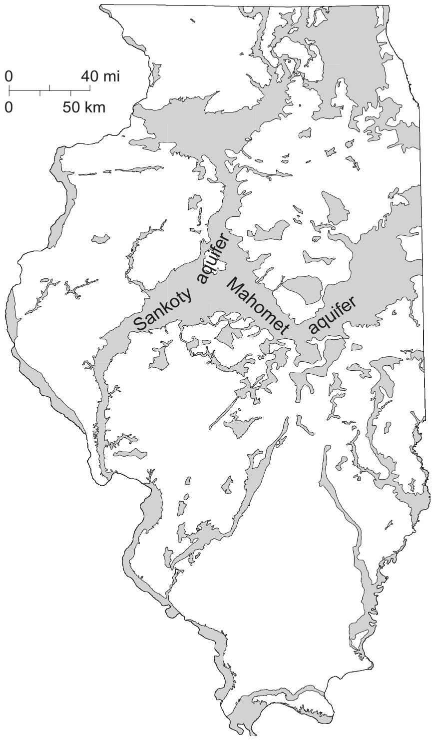


Figure 1 Major sand and gravel aquifers in Illinois showing the location of the Mahomet aquifer.

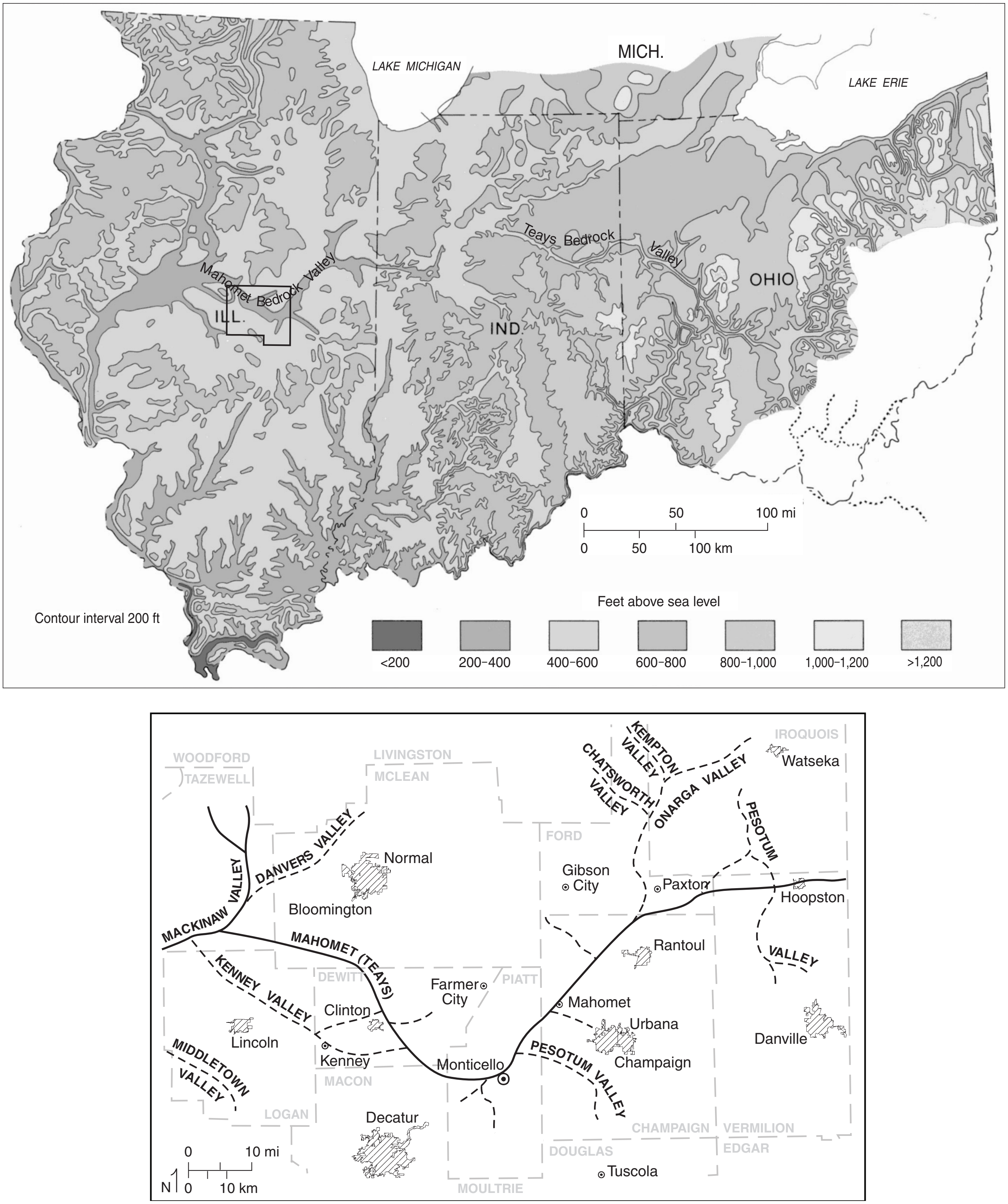


Figure 2 Top: Mahomet Bedrock Valley system from Illinois to Ohio (modified from Melhorn and Kempton 1991). Bottom: Mahomet Bedrock Valley in east-central Illinois in area outlined in top figure (adapted from Kempton et al. 1991).

aquifers have limited potential for further development. The Mahomet aquifer is a source of supplemental water for one of these communities. For others, it is a potential source of an assured water supply. The use of groundwater from the Mahomet aquifer to supplement surface-water supplies, as well as the potential for increased groundwater withdrawals for irrigation, municipal, and commercial uses, together have raised some concerns among local residents about future groundwater availability, particularly for domestic use.

Heightened concerns from individuals and small communities about the potential for adverse impacts to groundwater supplies caused regulatory bodies, such as water authorities, to be established under the Water Authorities Act in 1951 (Illinois Compiled Statutes 2001). Most of these water authorities were organized for a single purpose—to meet the challenge represented by a new demand placed on the water resource. The Mahomet Valley Water Authority (MVWA), for example, was formed after the City of Decatur began establishing its well field in the Mahomet aquifer. Water authorities control groundwater development through a permitting process for water wells, by reasonably regulating the use of water, and by setting limits or priorities on the use of water during actual or threatened shortages. According to the Water Authorities Act, water authority jurisdiction does not extend to groundwater used for agricultural or most domestic purposes.

To address concerns about potential adverse impacts to groundwater supplies, the MVWA initiated a program to gather information about the aquifers located within Piatt and DeWitt Counties. The MVWA helped support a reconnaissance study conducted by the Illinois State Water Survey in 1993 that provided information on water levels in wells completed in the Mahomet and overlying aquifers as well as groundwater flow in these aquifers (Anliker and Sanderson 1995). That study also provides a benchmark that can be used to quantify future changes in water levels.

The MVWA Board of Trustees recognized that detailed geologic mapping of aquifer and nonaquifer units is an integral part of successful groundwater resource management. In 1994, the board proposed expanding upon the 1:100,000-scale geologic mapping of the Champaign Quadrangle that was being done as a cooperative project between the ISGS and the U.S. Geological Survey (USGS). The area mapped for the Champaign Quadrangle included DeWitt County, the northern two tiers of townships of Macon County, and all but the southern tier of townships of Piatt County (Soller et al. 1999). Kempton and Herzog (1996) provided maps and cross sections showing the groundwater geology of an area that included all of Piatt and DeWitt Counties as well as northern Macon County. They used data from 51 stratigraphic-control boreholes, sample sets from 15 boreholes, and approximately 100 of the best drillers' logs for wells in the area. They also defined five geologic provinces in the area based on thickness of the glacial deposits and elevation of the bedrock surface.

This report presents the results of more detailed mapping of the hydrogeology of Piatt, DeWitt, and northern Macon Counties. The study area for this mapping, which is the same as that of Kempton and Herzog (1996), encompasses the 1,062 square miles of east-central Illinois that include all of Piatt and DeWitt Counties plus northern Macon County (fig. 3). We included northern Macon County in the study area to help us produce better maps of the aquifers from southern Piatt County to western DeWitt County. Including northern Macon County is particularly important because the Mahomet aquifer extends into the area. We also used a 3-mile wide buffer around the study area to help us interpret hydrogeologic data at the edges of the study area. The buffer area includes portions of Champaign, Douglas, Logan, McLean, and Moultrie Counties.

About 3,500 records of water wells and various other types of test borings were examined for this study. A spreadsheet containing information from these records was provided to the MVWA. As part of this study, reconnaissance-level geophysical surveys were conducted in the Farmer City–Mansfield area and the southern half of Piatt County. Seismic refraction was used in the Farmer City–Mansfield area to better define the shape of the bedrock valley that is tributary to the buried Mahomet Bedrock Valley. An electrical earth resistivity (EER) survey of this area was performed to investigate the extent of sand and gravel deposits from which Farmer City obtains its water supply (Larson 2000).

The southern half of Piatt County is generally south of the Mahomet aquifer, and so groundwater supplies are commonly obtained from relatively shallow sand and gravel deposits using drilled wells. Large-diameter bored wells are constructed if sand and gravel deposits

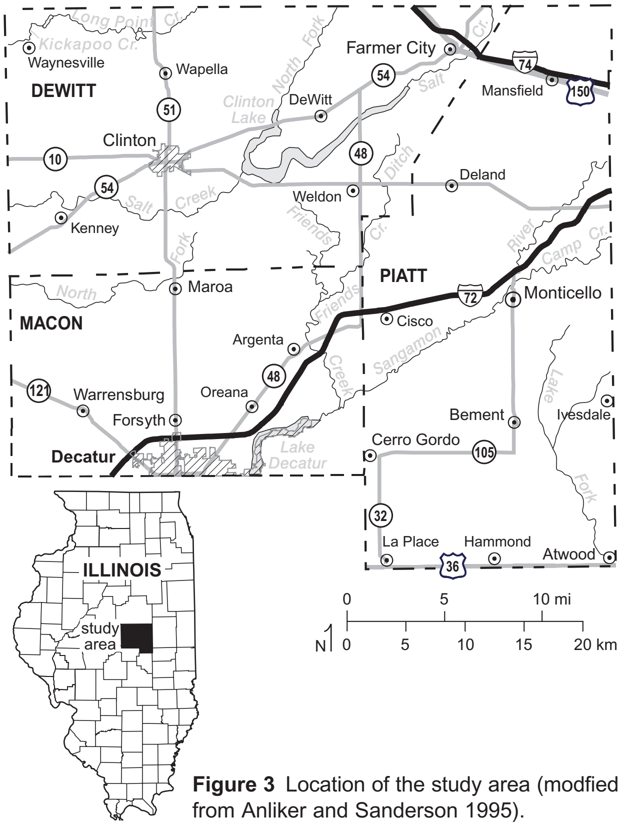


Figure 3 Location of the study area (modfied from Anliker and Sanderson 1995).

are thin or absent, but the use of this type of well may be partially due to the lack of information about the occurrence of the shallow sands and gravels. Properly constructed drilled wells typically have two advantages over large-diameter bored wells: (1) less susceptibility to contamination and (2) a more reliable supply. The annulus (the space between the well casing and the adjacent earth materials) of a drilled well can be sealed better than that of a large-diameter bored well. Also, a drilled well typically is deeper than a large-diameter bored well. For these reasons, the water supplied from a drilled well is generally less vulnerable to contamination from sources on the land surface than water supplied from a large-diameter bored well. Because a drilled well taps a greater thickness of aquifer material, its yield is usually more reliable and less susceptible to drought than that of a large-diameter bored well.

Mapping the thickness of shallow sands and gravels in greater detail should provide the MVWA, water-well drillers, and the general public with information encouraging the use of drilled wells in areas where the aquifers are thick enough to allow such wells to function properly. The EER survey of the southern half of Piatt County investigated the extent of shallow sand and gravel deposits. Results of this EER survey (Larson et al. 2000) helped corroborate the maps generated for this report.

Previous Studies

The geologic framework and history of the study area have been described in several recent studies (Hunt and Kempton 1977; Kempton et al. 1982, 1991; Kempton and Visocky 1992; Wilson et al. 1994). The investigations described by Herzog et al. (1995) and Wilson et al. (1998) increased understanding of the hydrogeologic framework of the glacial sediments, particularly the Mahomet aquifer, in southwestern McLean County and the northwestern corner of DeWitt County. Groundwater flow within the Mahomet aquifer was described by Panno et al. (1994) on the basis of changes in groundwater chemistry from Iroquois to Tazewell Counties. Anliker and Sanderson (1995) described the hydrology of the Mahomet aquifer and the sand and gravel aquifers in the Banner and Glasford Formations and discussed groundwater use.

Based on lithologic data from 51 stratigraphic-control boreholes used for the 1:100,000-scale geologic mapping project for the Champaign Quadrangle (Soller et al. 1999) and about 100 other drillers' logs, Kempton and Herzog (1996) mapped the elevation of the top of the Mahomet Sand Member as well as its thickness. They delineated the extent of sand and gravel in the upper Banner Formation that occurs in the Farmer City area of northern Piatt and northwestern DeWitt Counties. They also mapped the distribution of sand and gravel in the Glasford Formation. Figure 4 shows their bedrock topography map. Figure 5 presents their generalized cross sections of glacial deposits in the study area, which highlight the complex distribution of the sand and gravel aquifers. The geologic settings within the MVWA area are summarized by their geologic provinces map (fig. 6).

Geologic Framework

Geologic Features of the Landscape

Much of the study area is located in the Bloomington Ridged Plain–Till Plains Section–Central Lowland Province (Leighton et al. 1948) where deposits from the last continental glaciation form the land surface (fig. 7). Erosion and deposition by this glaciation defined the major features of the present-day landscape, which subsequent weathering and fluvial erosional processes have altered into their current shape. Broad, arcuate ridges of end moraines mark former ice-marginal positions of the Wisconsin Episode ice sheets (fig. 8). These include the north-south–trending Shelbyville Moraine in western DeWitt and Macon Counties, the Heyworth Moraine that arcs across central DeWitt County, the northeast-southwest–trending Cerro Gordo Moraine that crosses central Piatt County, and the Champaign Moraine that extends across northeastern Piatt County. The highest land-surface elevations in the

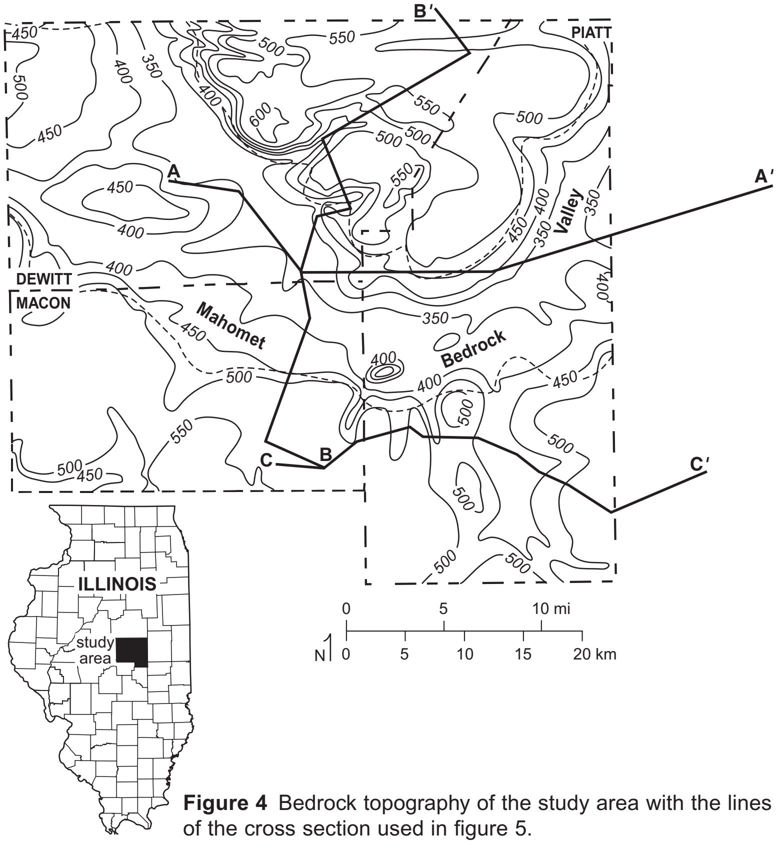


Figure 4 Bedrock topography of the study area with the lines of the cross section used in figure 5.

study area are found on the end moraines. Land-surface topography between the moraines is typically flat to gently rolling. The southwest corner of DeWitt County and western Macon County are beyond the Shelbyville Moraine, which marks the limit of Wisconsin Episode glaciation. This part of the study area is in the Springfield Plain–Till Plains Section–Central Lowland Province (fig. 7; Leighton et al. 1948), where deposits of the older Illinois Episode of glaciation form a distinctively flat landscape.

Surface water drains from most of the study area through southwesterly flowing streams (fig. 3). The principal streams are Kickapoo Creek in the northwest corner of the study area, Salt Creek in the north-central to central part of the study area, and the Sangamon River in the central to south-central part. The Sangamon River flows parallel to and just north of the Cerro Gordo Moraine across Piatt County and into eastern Macon County. The area south of the Cerro Gordo Moraine in southern Piatt County drains southward.

Bedrock Geology

Shallow bedrock in the study area is Pennsylvanian in age and is composed mostly of shale and relatively thin layers of sandstone, limestone, and coal of the Carbondale Formation (Willman et al. 1975). Rocks younger than the Carbondale are absent. Because the shale does not typically yield much water, no significant aquifers are found within the Carbondale Formation. The relatively fine-grained sandstone or fractures in the limestone and coal may yield limited quantities of water that are sufficient for a domestic supply, but the bedrock cannot produce enough water for a municipal supply. Because the mineral content of groundwater increases with depth, water found just 50 to 100 feet below the bedrock surface may be too highly mineralized for most uses.

Bedrock Topography

The topography of the bedrock surface controls the areal extent and thickness of the Mahomet aquifer

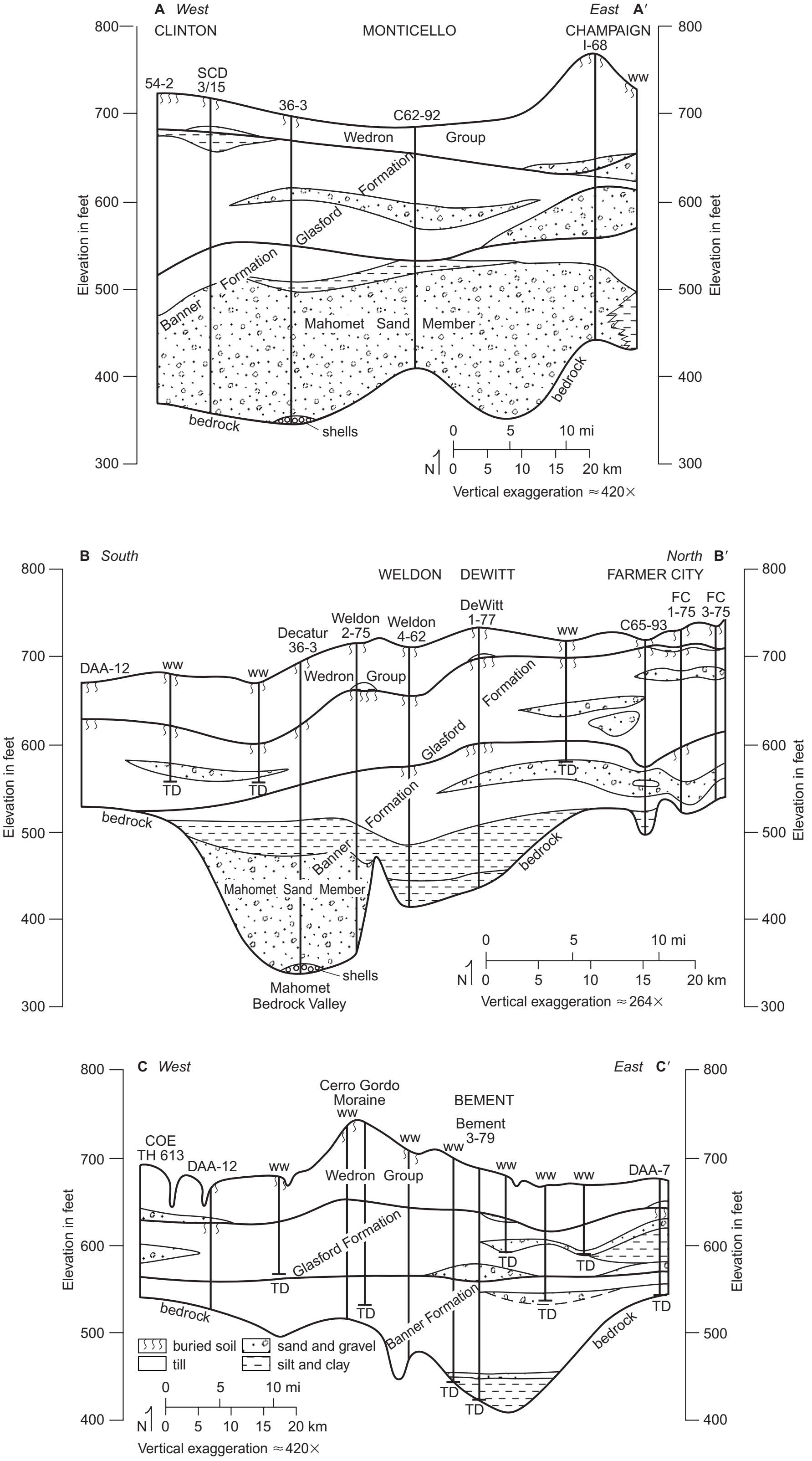


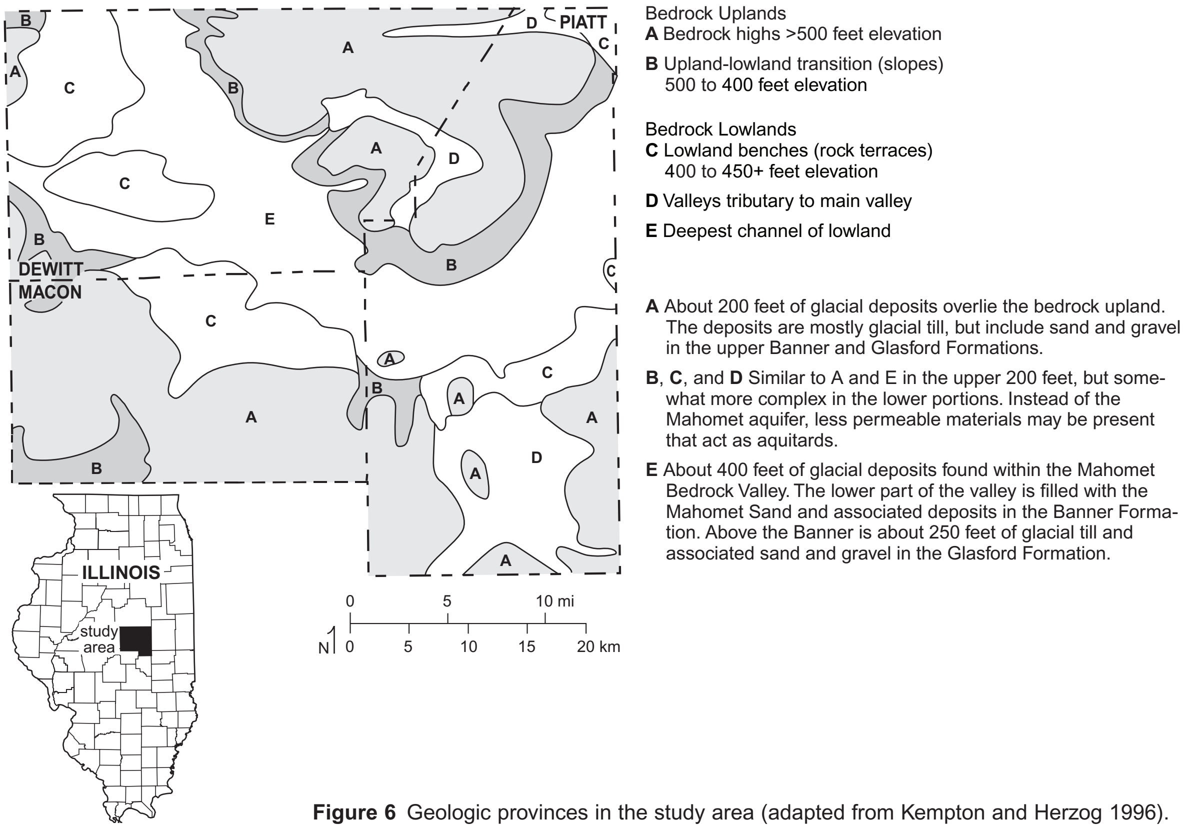
Figure 5 Three generalized cross sections of glacial deposits in the study area (Kempton and Herzog 1996). TD, total depth; ww, water well.

and, to a lesser extent, that of the shallower sand and gravel aquifers. The dominant feature of the bedrock surface within the study area is the Mahomet Bedrock Valley. The valley in the study area is part of the Mahomet (Teays) Bedrock Valley (fig. 2), which was a major drainageway for large volumes of glacial meltwater from eastern and northern Illinois and areas farther to the east (Kempton et al. 1991). In the study area, the Mahomet Bedrock Valley extends from Piatt County to northwestern DeWitt County in a broad arc (fig. 4). The deepest part of the Mahomet Bedrock Valley lies below an elevation of 350 feet, but most likely is not significantly lower than this. The Kenney Bedrock Valley (fig. 2), which is tributary to the Mahomet Bedrock Valley, trends west-northwest from its confluence with the Mahomet Bedrock Valley in DeWitt County. These two valleys rejoin in southeastern Tazewell County, northwest of the study area (fig. 2). The deepest part of the Kenney Bedrock Valley is also probably no lower than 350 feet in elevation. The bedrock valley in southern Piatt County and the one near Farmer City in eastern DeWitt and northern Piatt Counties are the most prominent of the tributary bedrock valleys (fig. 4). The bedrock surface within the Mahomet Bedrock Valley is locally variable, consisting of bedrock benches and remnant hills and channels (Kempton et al. 1991). Elevation of the bedrock surface within the valley locally exceeds 500 feet and on the adjacent uplands locally exceeds 600 feet (fig. 4). Kempton et al. (1991) more thoroughly discussed the features of the bedrock surface of the Mahomet Bedrock Valley.

Glacial Geology

Beginning about two million years ago, continental glaciers moved southward from Canada and advanced into Illinois as great sheets of ice several hundreds of feet thick. At least three major episodes of advance and retreat of the continental ice sheets left deposits of sediment. The older continental glaciers covered more of Illinois than the more recent ones did. Glaciation modified the topography of the pre-glacial bedrock surface of Illinois, initially by deepening the existing bedrock valleys through erosion and subsequently by filling them with proglacial and glacial sediment. Meltwater rivers flowing from the earliest, pre-Illinois episode glaciers filled most of the deeper parts of the bedrock valleys with sand and gravel outwash. During their repeated advances and retreats, continental glaciers modified the existing landscape by erosion and by deposition of sediment directly from glacial ice and meltwater streams and in proglacial lake basins. Shifting margins of ice fronts modified more than one drainage pattern and sediment deposition; lakes formed where ice or glacial sediments blocked the drainage. Glaciation ceased to affect Illinois directly about 12,000 years ago and left more than 400 feet of glacial and proglacial deposits in some parts of the study area (Kempton et al. 1991). The glacial sediments are thickest within the deepest reaches of the bedrock valleys and thinnest above the sides of the bedrock valleys and the bedrock uplands.

The glacial deposits found within the study area include till, outwash, and lacustrine sediments. Till is unsorted,



A About 200 feet of glacial deposits overlie the bedrock upland. The deposits are mostly glacial till, but include sand and gravel in the upper Banner and Glasford Formations.

B, **C**, and **D** Similar to A and E in the upper 200 feet, but somewhat more complex in the lower portions. Instead of the Mahomet aquifer, less permeable materials may be present that act as aquitards.

E About 400 feet of glacial deposits found within the Mahomet Bedrock Valley. The lower part of the valley is filled with the Mahomet Sand and associated deposits in the Banner Formation. Above the Banner is about 250 feet of glacial till and associated sand and gravel in the Glasford Formation.

Figure 6 Geologic provinces in the study area (adapted from Kempton and Herzog 1996).

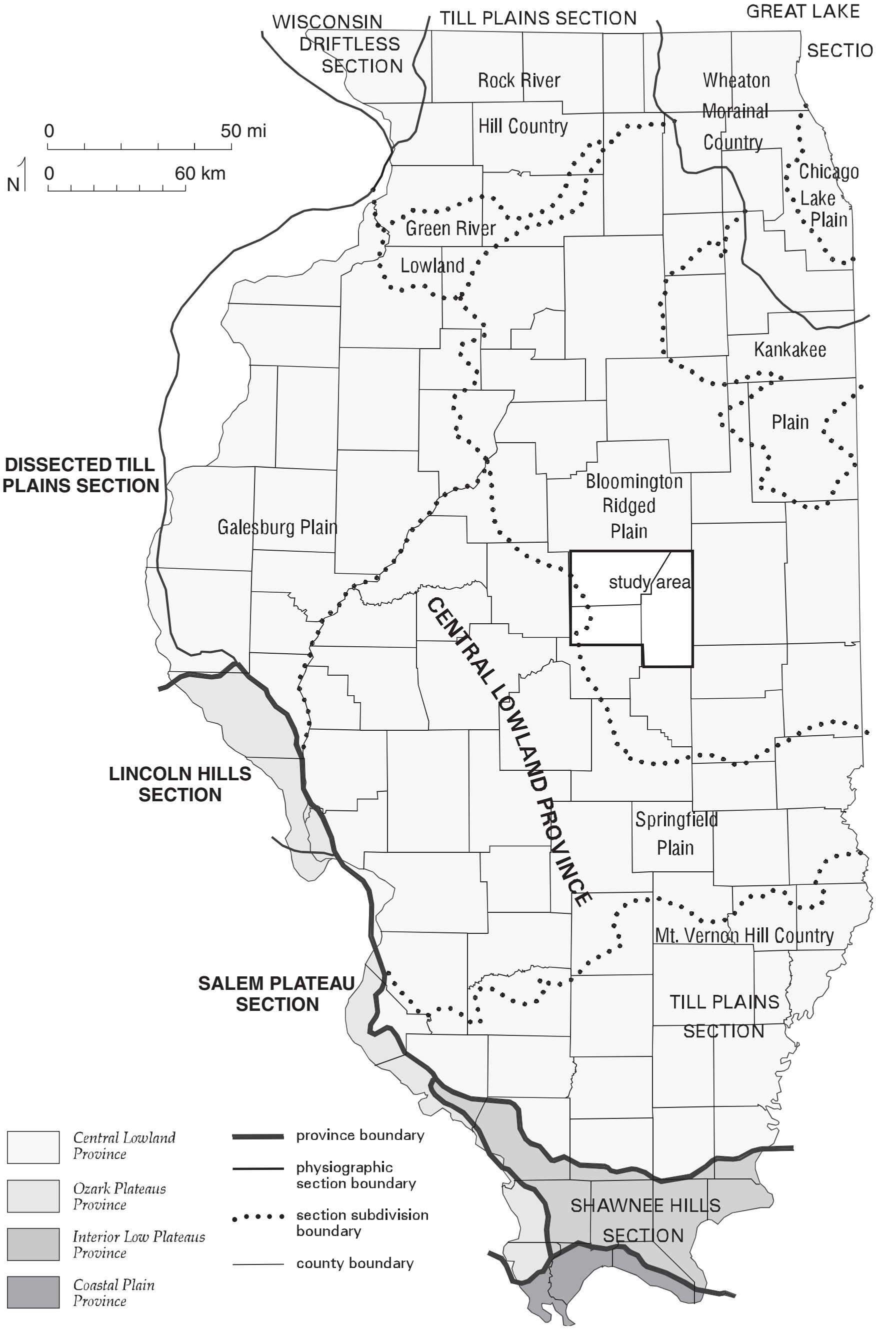


Figure 7 Physiographic divisions of Illinois (adapted from Leighton et al. 1948).

nonstratified sediment deposited adjacent to or directly from the ice. It consists mostly of clay and silt with widely variable amounts of sand, gravel, pebbles, cobbles, and boulders. Outwash consists mainly of layers of sorted sand and gravel deposited from the melt-water that flowed in huge volumes from the ice front as proglacial streams and rivers. Outwash may be found between valley walls in long, narrow deposits called valley trains, or it may spread out over a large area as a flat or gently sloping sheet of sediment called an outwash plain. The most significant outwash deposit in the study area is the thick layer of sand and gravel that directly overlies bedrock in most of the Mahomet Bedrock Valley and its tributaries. This deposit forms the Mahomet aquifer. Lacustrine silts and clays are fine-grained sediments deposited in pro-glacial lakes or in relatively quiet backwaters filled during floods along main drainageways.

The glacial and other related deposits are identified, distinguished, and classified based on their physical characteristics (such as color, lithology, or mineralogy), stratigraphic position, and age. Buried weathered zones (paleosols), some containing organic-rich horizons, serve as important marker beds. These zones indicate periods of warmth and weathering between glaciations, when these older glacial sediments formed the land surface. The zones mark significant discontinuities (unconformities) in the sedimentary record and are used to separate the glacial deposits into distinct stratigraphic units.

The glacial and related deposits that cover the study area are grouped, from oldest to youngest, into three major stratigraphic units (fig. 9): the Banner Formation, the Glasford Formation, and the Wedron and Mason Groups. Well-developed paleosols and organic horizons locally separate these units. The Yarmouth Soil and Lierle Clay commonly separate the Banner from the overlying Glasford Formation. The Sangamon Soil, Roxanna Silt, Berry Clay, and Robein Silt separate the Glasford Formation from the overlying Wedron and Mason Groups. Each of the major stratigraphic units contains sand and gravel deposits that form aquifers and the till and lake sediments that form aquitards.

Banner Formation The Banner Formation is the lowermost major stratigraphic unit of glacial deposits in the study area. It is thought to have been deposited during the pre-Illinois episode more than 500,000 years ago (Soller et al. 1999). The bottom of this formation rests on the bedrock surface, and the top is commonly marked by a discontinuous, buried weathered zone (Yarmouth Soil and Lierle Clay, fig. 9). Where the buried weathered zone is absent, the Banner directly underlies the younger Glasford Formation. The Banner not only fills the bedrock valleys, it also generally drapes over the surface of the adjacent bedrock uplands. Consequently, the Banner tends to be thickest along the axis of

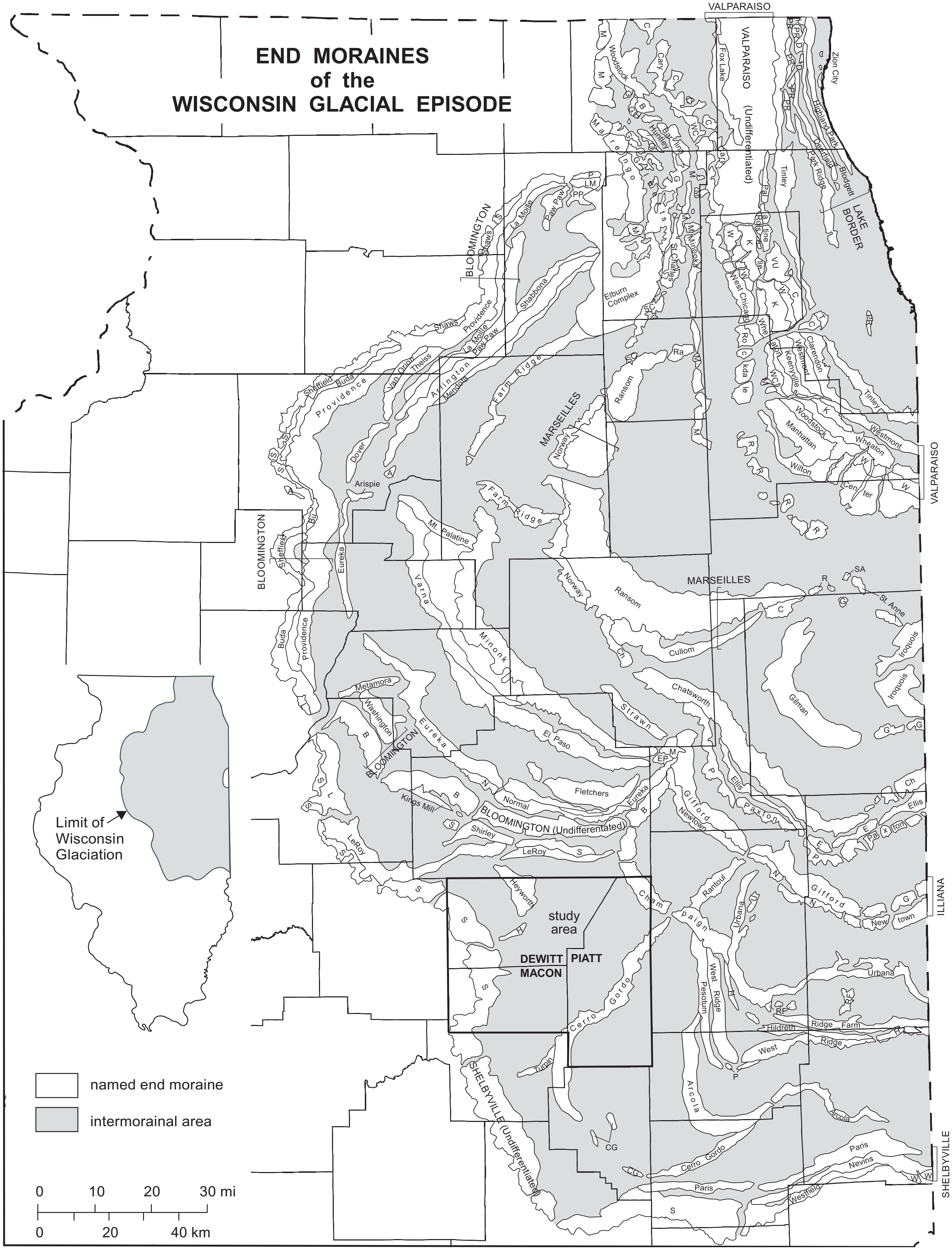


Figure 8 End moraines of the Wisconsin Episode ice sheets (Willman and Frye 1970).

the Mahomet Bedrock Valley, and the top of the Banner is typically deepest where the bedrock surface is lowest. The maximum thickness of the Banner Formation within the Mahomet Bedrock Valley is about 200 feet. The Banner Formation generally is not found on the higher parts of the bedrock uplands.

The Banner Formation contains three lithostratigraphic units (fig. 9). The deepest unit, the Mahomet Sand Member, fills the lowermost part of the Mahomet Bedrock Valley. This unit consists of a sand facies and a silt facies (Kempton et al. 1991). The sand facies is composed of sand to sand and gravel and tends to coarsen with depth. This facies is found in the deeper parts of the Mahomet Bedrock Valley where it locally may be more than 170 feet thick. The silt facies mostly consists of lacustrine sediments and glacial till. Although this facies is found mainly in the tributary valleys and along the edges of the Mahomet Bedrock Valley (Kempton et al. 1991), it may also occur along the main part of Mahomet Bedrock Valley. The fine-grained deposits limit the thickness of the sand and gravel within the Mahomet Sand Member, especially in the northwestern part of the study area. The thickness of the sand and gravel generally decreases toward the edges of the bedrock valley where the thickness of the fine-grained sediments increases (fig. 9). Because few water wells are drilled through the entire thickness of the Mahomet Sand Member, information about its thickness and physical characteristics is relatively sparse for the deepest parts of the Mahomet Bedrock Valley. Herzog et al. (1995) informally named the deepest sediments–the coarser sand and gravel generally below the silt facies–the sub-Mahomet (fig. 9). Because of the scarcity of information about the deeper deposits, the sub-Mahomet sand is grouped with the Mahomet Sand Member for this study.

Two till units, the Hillery and Tilton Members, overlie the Mahomet Sand Member. Locally significant deposits of sand and gravel may be found at the base of the Hillery and between the Hillery and Tilton (fig. 9). The till members and the sand and gravel deposits constitute the upper Banner Formation. Although the thickness and areal extent of the sand and gravel deposits are quite variable, they are a locally significant source of water that is tapped by domestic wells in the study area.

Glasford Formation The Glasford Formation overlies the Banner Formation and underlies the Wedron and Mason Groups. The Glasford was deposited during the Illinois Episode between about 180,000 and 125,000 years ago (Soller et al. 1999). At the top of the Glasford Formation are distinctive, organic-rich horizons (paleosols) that formed during the Sangamon Interglacial Episode following the Illinois Episode (Kempton et al. 1991). These paleosols include the Sangamon Soil, Roxanna Silt, Berry Clay, and Robein Silt (fig. 9). Although the Glasford Formation is composed primarily of two till units, the Vandalia and Radnor Members, it contains sand and gravel deposits that are generally thin and of limited areal extent (fig. 9). These deposits are typically found at the top of the Radnor, between the Radnor and the Vandalia, and at the base of the Vandalia. The deposits are more associated with the Vandalia than the Radnor (Kempton et al. 1991). Glasford sand and gravel deposits are important sources of water in the study area. Where these deposits are sufficiently thick, they are capable of yielding enough water for a domestic or small community supply.

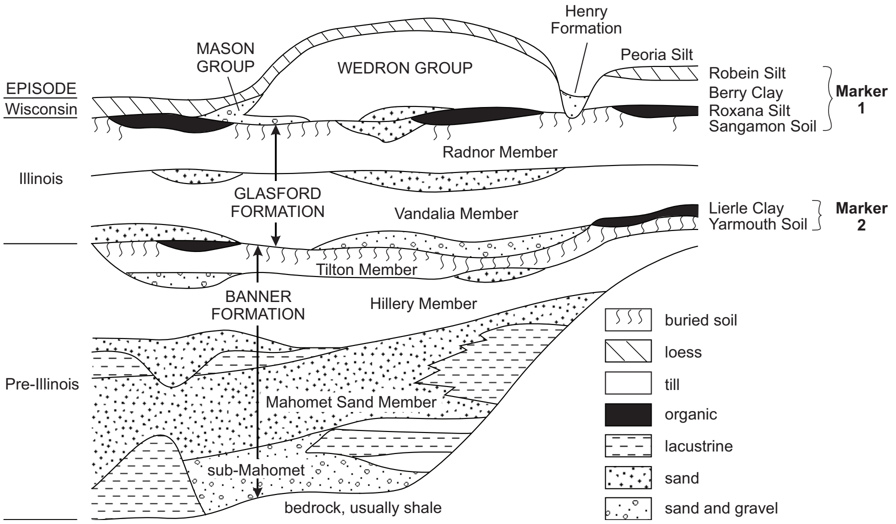


Figure 9 Schematic drawing showing stratigraphic position of Quaternary geologic materials in the study area (Herzog et al. 1995).

Wedron and Mason Groups Over much of the study area, the surficial sediments of the Wedron and Mason Groups directly overlie the Glasford Formation, Sangamon Soil, or Robein and Roxanna Silts (fig. 9). The sediments in the Wedron and Mason Groups were deposited during the Wisconsin Glacial Episode between 75,000 and 12,000 years ago (Soller et al. 1999). The Wedron Group is composed mostly of till (Hansel and Johnson 1996), but contains very thin deposits of sand and gravel that are typically discontinuous, very limited in areal extent, and found mostly near the bottom of this group. The thickness of the Wedron Group averages about 50 feet, but varies from less than 10 feet to about 100 feet (Kempton and Herzog 1996). It is thickest where the end moraines of the Wisconsin Glacial Episode are located. The Mason Group consists of sand and gravel deposits (Hansel and Johnson 1996), most of which belong to the Henry Formation that is locally present along the main drainageways, such as Salt Creek, the Sangamon River, and Kickapoo Creek. Although the sand and gravel deposits of the Mason Group are generally thin and of limited areal extent, thickness may locally exceed 60 feet. Data from drillers' logs are insufficient to map the Henry Formation because water wells are typically not located in stream valleys.

Quaternary Geologic Units as Aquifers or Aquitards

Most Quaternary deposits are classified as sand and/or gravel, clay, silt, or till. Groundwater occupies the pore spaces found between the particles of glacial sediments as well as fractures found in bedrock or in some tills. Groundwater moves through these openings. The porosity of fine-grained sediment, such as clay and silt, typically is greater than that of coarse-grained sediment, such as sand and gravel (Driscoll 1986). The volume of groundwater that can be stored depends on the porosity. Of more importance, however, is the ability of the sediment to transmit groundwater. This ability relates to the degree of connection between pore spaces. Because the pore spaces of coarse-grained sediment are larger and more interconnected than those of fine-grained sediment, water moves more readily through sand and gravel, for example, than it does through a silty clay. The capacity of a porous material to transmit groundwater is called hydraulic conductivity. The hydraulic conductivity of sand and gravel is typically greater than that of silt, clay, or till.

Earth materials are classified as aquifers or confining units (aquitards) on the basis of water transmission. An aquifer is a body of saturated earth materials that yields sufficient quantities of groundwater to a well for its intended purpose. The availability of groundwater from an aquifer depends upon several factors. Among these are (1) the rate at which groundwater moves through earth materials, (2) the extent and thickness of the aquifer, (3) the hydraulic conditions of the aquifer (whether confined or unconfined), and (4) the rate of groundwater movement into (recharge) and out of (discharge) the aquifer.

Aquifers overlie aquitards, which are made up of earth materials with low hydraulic conductivity. Deposits of till, clay, shale, or other fine-grained sediments form aquitards. Because water moves much more slowly through these materials, aquitards restrict the flow of groundwater into or out of adjacent aquifers. A confined aquifer also has an overlying aquitard. Groundwater in a confined aquifer is under enough pressure that the water in a well completed in the aquifer will rise to a level above the top of the aquifer. In an unconfined aquifer, the water table (the top of the saturated zone) marks the top of the aquifer. The water level in a well screened in an unconfined aquifer closely approximates the position of the water table of the adjacent aquifer.

Methods

The maps produced from this study are based primarily on about 3,500 records of water wells and borings on file at the ISGS. These were supplemented by extensive surface geophysical surveys in two areas. In the Farmer City–Mansfield area, seismic refraction was used to locate more precisely a buried bedrock valley that was thought to connect with the Mahomet Bedrock Valley. An EER survey was then used to determine the nature and thickness of deposits in the bedrock valley. In southern Piatt County, an extensive EER survey was used to better define the thickness and areal extent of sand and gravel deposits in a part of the study area that is not over the Mahomet Bedrock Valley and where large-diameter bored wells are common.

Data from Records of Water Wells and Test Borings

Of the available records of water wells, engineering boreholes, and test borings for coal, oil, and gas located in the study area and the 3-mile wide buffer strip, about 3,500 records were selected based on the usability of the geologic information presented in the drillers' logs. The information from the drillers' logs formed the basis for describing the hydrogeology of the study area and for producing the maps for this report. The locations of the wells corresponding to the selected records (plotted as data point locations) are unevenly spread throughout the study area (fig. 10). Areas with the fewest number of data points are found in southern Piatt County and north-central Macon County. In general, a greater density of data points in a particular area allows for a more detailed interpretation of the hydrogeology of the area.

For this study, the selected well records were copied so that the drillers' logs could be annotated. The location of each well and boring was plat-book verified using the locational information included in the record and plotted on 7.5-minute topographic maps. The locations and land-surface elevations of 545 of the wells had been field verified by Anliker and Sanderson (1995) for their study, and this information was used as reported by them. For the rest of the data points, land-surface elevations were estimated from 7.5-minute topographic maps. If an elevation was already noted in the well record, that elevation was used after it was checked against the appropriate 7.5-minute topographic map. Elevations are referenced to the 1929 National Geodetic Vertical Datum.

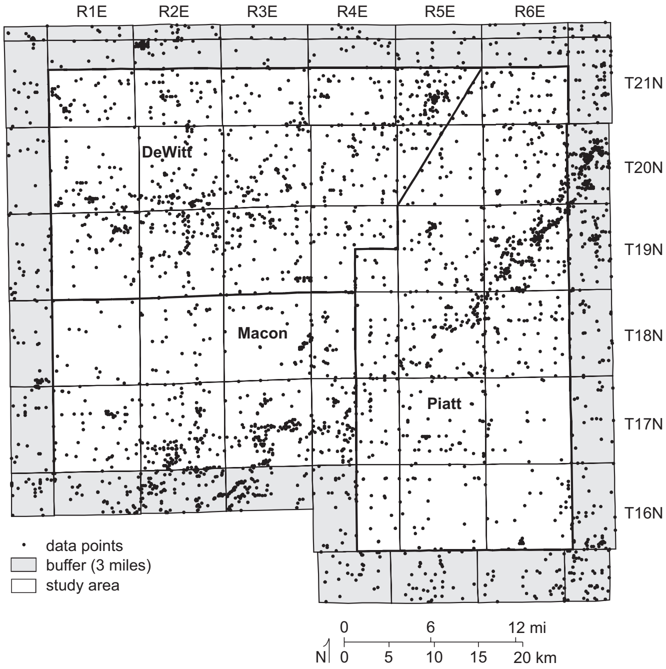


Figure 10 Distribution of data point locations.

On our copies of the drillers' logs, we identified and color coded intervals of wood, peat, "organic,"and green clay as "marker" beds. Some of these marker beds represent paleosols (Yarmouth and Sangamon soils) that have locally well-preserved organic horizons. Other marker beds denote the top of the till members within the Glasford Formation (fig. 9). Intervals of coarse-grained sediment (e.g., sand, sand and gravel, or gravel) and the top of the bedrock were color coded. This color coding aided the entry of depth and thickness values into a spreadsheet. Elevations for the tops of marker beds, for the tops and bottoms of sand and gravel intervals, and for the bedrock surface were calculated within the spreadsheet.

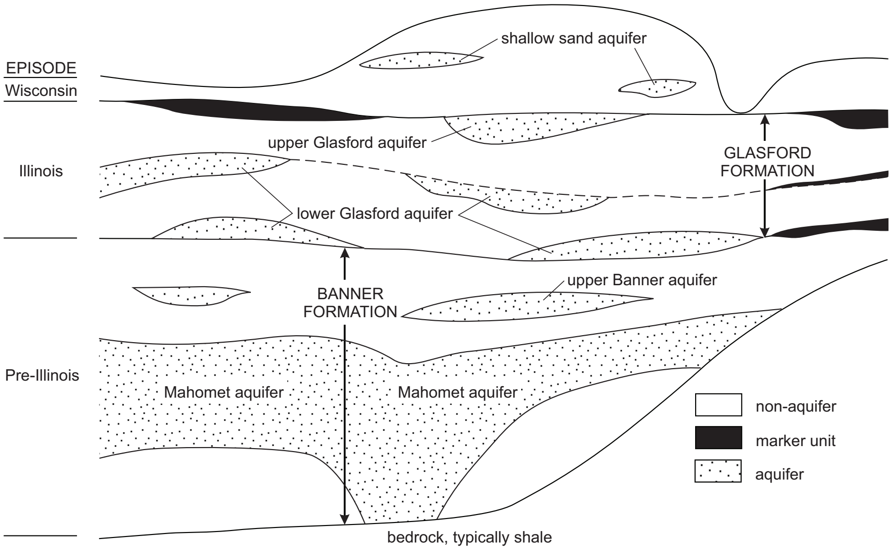


Figure 11 Classification of hydrogeologic units in the study area (modified from Herzog et al. 1995).

We assigned the sand and gravel intervals to one of five hydrogeologic units or layers, which for this study are informally designated as aquifers. Beginning with the deepest, these units are the Mahomet, upper Banner, lower and upper Glasford, and shallow sand aquifers (fig. 11). The Mahomet aquifer, for the most part, includes the sand and gravel of the Mahomet Sand Member (fig. 9). Also included in the Mahomet aquifer are sand and gravel deposits of the lower part of the Banner Formation that directly overlie the Mahomet Sand Member or are separated by just a few feet of fine-grained sediments. Unlike those of the Mahomet Sand Member, sand and gravel deposits in the Glasford and upper Banner Formations are typically discontinuous and limited in areal extent. Depth and thickness of these deposits are also very irregular. These characteristics made it difficult to organize the Glasford and upper Banner deposits into a hydrogeologic framework for an area as large as the study area. To reduce the complexity of these sands and gravels for mapping purposes, we combined units of sand and gravel as noted in the drillers' logs and assigned them to the upper Banner, lower and upper Glasford, or shallow sand aquifer based on the elevation of the top of the combined interval. The depth and elevation of the top of each of the five aquifers were contoured. The elevation of the bottom of each aquifer was determined by subtracting the thickness of that aquifer from the top of the aquifer. Although combining individual sand and gravel deposits into aquifers simplified the hydrogeologic framework of the study area, it is important to remember that each aquifer most likely includes several individual layers of sand and gravel.

Seismic Refraction

Two seismic refraction lines were recorded north of Farmer City during summer 1996 to provide more detailed data on the small bedrock valley in the area (Larson 2000). Seismic refraction surveys have been successful in locating buried bedrock valleys in northern and central Illinois (Larson and Poole 1989, Heigold 1990, Larson 1994). In a seismic refraction survey, energy radiating outward in all directions from a small, buried explosion travels through the subsurface. Some of this energy meets the bedrock surface, where it is refracted back up to the land surface (fig. 12). The returned energy is measured with a series of sensors (geophones) laid in a line near the explosion and recorded with a computer connected to the line of geophones. The recorded information is used to calculate the depth to the bedrock surface beneath the charge and sensors.

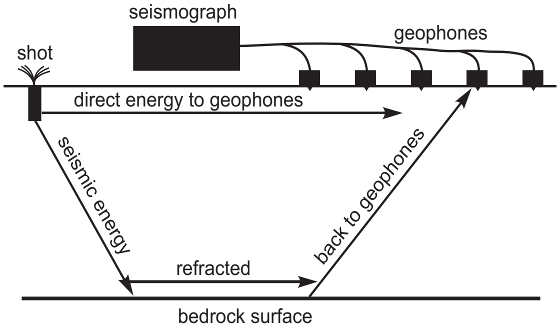


Figure 12 Schematic of the seismic refraction method.

For this study, the seismic refraction sensor configuration consisted of a line of 24 14-Hz geophones placed at 50-foot intervals for a total of 1,150 feet. Explosions at the center and at both ends of the geophone line were created by detonating one-third to one pound of Kinepak explosive buried in 5-foot deep boreholes. Longer profiles were created by aligning consecutive geophone lines end-to-end along the profile. Generally, successive lines were situated such that the last geophone of one line was placed at the same spot as the first geophone of the next line. Data were digitally recorded for later processing.

Two lines of seismic data were acquired (fig. 13). The Farmer City West Seismic Line was approximately one and a quarter miles long and was run along a north-south township road through the center of Sections 18 and 19, T21N, R5E. The Farmer City East Seismic Line was broken into two parts.

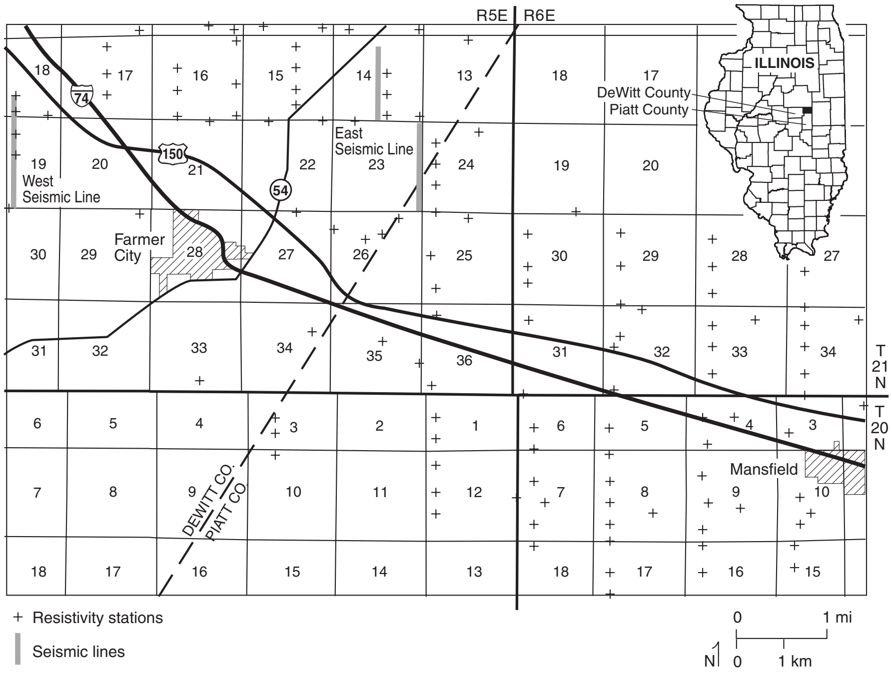


Figure 13 Location of seismic lines and resistivity stations in the Farmer City–Mansfield area (Larson 2000).

The northern part was approximately three-fourths of a mile long and was run along a township road through the center of Section 14, T21N, R5E. The southern part was about one mile long and was offset from the northern part by about a half mile. The southern part was run along a township road dividing Sections 23 and 24, T21N, R5E.

Refraction data were interpreted using the modified delay time and ray tracing method (Scott et al. 1972). A computer program (SIPT2, Rimrock Geophysics 1992) was used to calculate the elevation of the bedrock beneath each geophone. Geologic data from drillers' logs of water wells were available near the northern and southern parts of the East Line. These data were used to constrain the geophysical interpretation. Similar geologic data were not available for the West Seismic Line. Seismic velocities were manipulated in the calculations until the calculated bedrock-surface elevations closely matched the geologic data.

Two refracting surfaces (interfaces) were interpreted for this study, the water table and the top of the bedrock. Because seismic refraction measures bulk characteristics of earth materials, interfaces are usually interpreted at slightly deeper positions than those interpreted by other methods, such as drilling. For the top of the bedrock, as an example, the depth to bedrock derived by the seismic refraction method is to "fresh" or unfractured rock. Highly fractured or weathered rock is included as part of the unlithified overburden. Also, the seismic refraction method overestimates the depth to the bedrock if a layer of sand lies between the bedrock and a thick layer of clay. The seismic waves are not refracted by the sand, which has a lower seismic velocity than either clay or bedrock. Hence, the depth to bedrock is calculated based only on the higher velocity clay layer. Bedrock depths from the seismic refraction survey were entered into the spreadsheet without accounting for these possible errors.

Electrical Earth Resistivity

As a measure of the ease with which an electrical current passes through earth materials, EER is sensitive to the proportion of sand and clay in earth materials (Buhle and Brueckmann 1964). Sand generally has larger resistivity values than clay (or shale), but other factors also affect the earth resistivity, such as the fluid content of the sediment and the presence of other lithologies, especially limestone or sandstone. For example, the resistivity of unsaturated materials is generally much greater than that of water-saturated sediments. Although salinity or other chemical variations in the fluid can be important, in this study we assumed that the aquifers contained fresh water. Both limestone and sandstone have large resistivity values similar to, or greater than, sand. Also, cultural interferences from electrical utility wires and buried metal objects artificially reduce the apparent resistivity.

For each resistivity measurement (fig. 14), a known electrical current was passed into the ground through two outside electrodes (C1 and C2), and the resulting electrical potential was measured with two inside electrodes (P1 and P2). All four electrodes were kept in a line with equal spacings (a) between them. This system, known as a Wenner electrode array, can be used to obtain a one-dimensional profile of the apparent earth resistivity with depth by increasing the spacing between the electrodes (Reynolds 1997). Mathematical inversion of the apparent resistivity profile results in a set of resistivity layers at the site (Zohdy 1974, Zohdy and Bisdorf 1975) Each layer is characterized by a thickness and resistivity value (fig. 15). In general, the inversion process results in a non-unique solution of layer parameters. That is, the values of

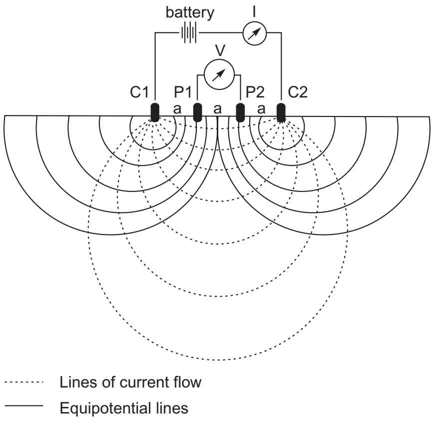


Figure 14 Schematic drawing of the Wenner electrode configuration used for EER surveys. The apparent resistivity is $2\pi a$ V/I, where a = distance between electrodes, V = voltage, and I = electrical current (Larson 1994).

the layer parameters (resistivity and thickness) are not uniquely determined, but are only one set of many equivalent solutions. A more unique property, the transverse resistance, is obtained by calculating the product of the thickness and resistivity for each layer (Maillet 1947).

Resistivity was measured at 133 stations spaced at about quarter-mile intervals along many rural roads in the Farmer City–Mansfield area (fig. 13). At each station, resistivity was measured using the Wenner electrode array (Reynolds 1997) with inter-electrode spacings varying from 5 to 320 feet. In the southern half of Piatt County, resistivity was measured at 566 locations spaced at approximately half-mile intervals along roadsides (fig. 16). Apparent resistivity soundings were measured at each station using the Wenner electrode array (Reynolds 1997), but with inter-electrode spacing varying from 5 to 200 feet. The apparent resistivity profiles were then inverted to resistivity layers (Zohdy 1974, Zohdy and Bisdorf 1975).

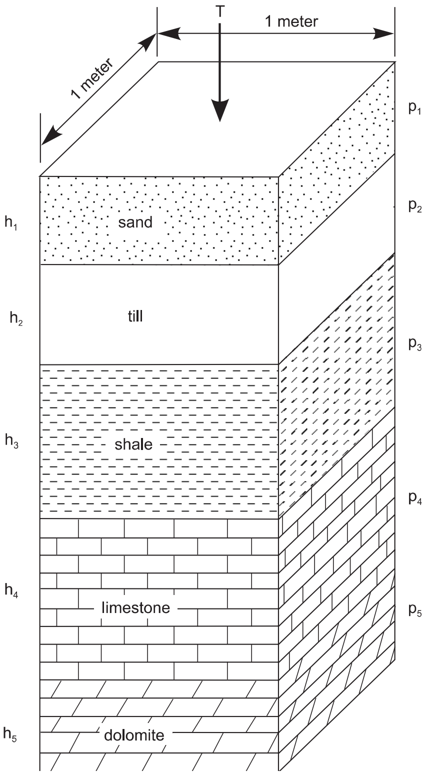


Figure 15 Schematic drawing of thickness (h) and true resistivity (p) of component layers with an indication of the total transverse resistance (T). T = h × p (after Reynolds 1997).

The transverse resistance was calculated for each layer. Results of the two geophysical surveys have been published previously (Larson 2000, Larson et al. 2000).

Map Development

Values for depth, elevation, and thickness were summarized by aquifer in the spreadsheet and subsequently were plotted as data point locations using Arc View, a geographic information system (GIS) program developed by Environmental Systems Research Institute in Redlands, California. A continuous, two-dimensional surface was interpolated from the point data using the inverse distance weighted method and a grid consisting of cells that represented quarter-mile squares. The assumption in this method is that the influence of each input data point decreases with distance. For this study, the value for each grid cell was calculated by averaging the values of the four neighboring points nearest the cell's center with the closest point having the greatest influence on the derived value. The interpolated two-dimensional surface was represented by contours. Contoured surfaces were generated for the depth to and elevation of the top of each aquifer as well as the thickness of the aquifer. Because of greater uncertainty in areas with thin sand and gravel, contours of depth and elevation were shown only in the areas where thickness of an aquifer was mapped as 5 feet or greater.

To determine whether the sand and gravel intervals had been assigned to the appropriate aquifer, the contoured surface of the elevation of the top of each aquifer was compared with the surface elevation of the top of the aquifer directly overlying it. For example, the elevation of the top of the upper Banner aquifer was compared with the elevation of the top of the overlying lower Glasford aquifer. Where the surface elevation of the lower aquifer was greater than that of the aquifer directly above it, the drillers' logs for the data points were reexamined where the two aquifers intersected, and intervals of sand and gravel were reassigned to the appropriate aquifer. The elevation of the top of each aquifer was re-contoured, and the two surfaces were subtracted to determine whether they still intersected. This process was repeated until the elevation of the top of the lower aquifer was everywhere equal to or below that of the upper aquifer.

The values used in contouring the thickness of each aquifer were calculated from the drillers' logs. This method tends to underestimate the thickness of the sand and gravel interval in which a well is constructed because well boreholes are generally drilled just deep enough to ensure that the required water yield is obtained. Incomplete aquifer penetration occurs in the sand and gravel deposits of the Glasford and upper Banner Formations and is very common for wells finished in the Mahomet aquifer.

The thickness map of each aquifer also incorporates points of zero thickness. These points identify the locations of wells that were sufficiently deep to have been drilled through a particular aquifer, but where the drillers' logs did not indicate the presence of sand and gravel within the interval for that aquifer. Because many logs include information only about the aquifer in which the well is finished, values of zero were included only if the log contained information on shallower aquifers or information on variations in the overlying materials (e.g., if a log noted only thick "drift" above the target aquifer, no zero values were included). Including points of zero thickness resulted in a conservative interpretation of the areal extent of the thickness for the aquifer because these points represent the limit of the aquifer. Data from the EER surveys were used to supplement well-log data and helped guide thickness contouring in areas of sparse data.

An isopach line was used to delineate areas where each aquifer above the Mahomet aquifer is 5 feet thick or greater. This thickness is generally adequate to supply sufficient groundwater to a drilled, domestic well. In areas where aquifer thickness is less than 5 feet, large-diameter bored wells are typically used for domestic supplies.

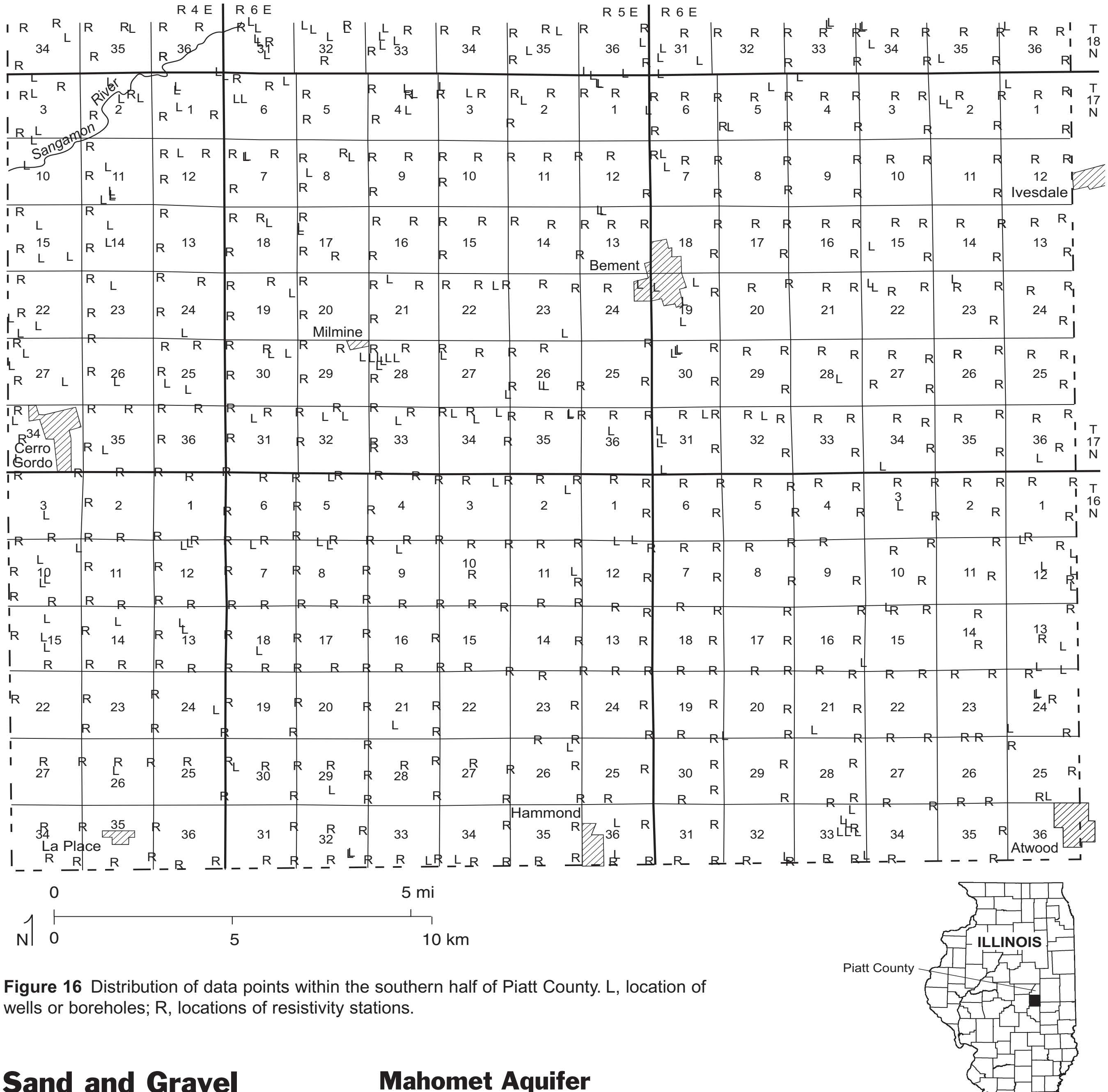


Figure 16 Distribution of data points within the southern half of Piatt County. L, location of wells or boreholes; R, locations of resistivity stations.

Sand and Gravel Aquifers

The data from drillers' logs were evaluated on the basis of five sand and gravel aquifers: the Mahomet, upper Banner, lower Glasford, upper Glasford, and shallow sand. The following sections describe the depth to each of these aquifers below land surface, the elevation of the top of each aquifer, and the thickness of each aquifer.

Mahomet Aquifer

The Mahomet aquifer is the principal sand and gravel aquifer in the study area, occupying the lower part of the Mahomet Bedrock Valley (fig. 4). All of the sand and gravel deposits between the top of the Mahomet Sand Member and the bedrock surface were included in this aquifer (fig. 11). As shown in figure 11, portions of the Mahomet aquifer directly overlie bedrock, so the bedrock surface is the aquifer boundary. Thus, the aquifer's thickness is influenced in part by the topography of the bedrock surface and also is locally influenced by till and lake-bottom silts and clays that occur within the Mahomet Sand Member (fig. 9). Where the fine-grained sediments are not present, the Mahomet Sand Member consists of a continuous interval of sand and gravel. Delineating the thickness and areal extent of the fine-grained deposits in the deeper parts of the Mahomet Bedrock

Valley requires collecting additional subsurface information. This information is not presently available because few wells are drilled into bedrock, thereby penetrating the entire thickness of the Mahomet aquifer.

Elevation of and depth to the top of the Mahomet aquifer were mapped using the information obtained from 946 drillers' logs (fig. 17). The elevation of the top of the Mahomet aquifer generally declines from east to west along the trend of the Mahomet Bedrock Valley (fig. 18). In the northeast corner of the study area, the elevation of 525 to 550 feet on the bedrock highs along the walls of the Mahomet Bedrock Valley decreases to about 500 feet over the bedrock valley. In the middle of the study area, the elevation is typically about 500 feet and decreases to less than 475 feet in the northwestern part. In the northwest corner, elevation locally declines to about 450 feet. Drillers and others seeking water supplies may find information about aquifer depth to be more useful than information about aquifer elevation. The depth to the top of the Mahomet aquifer in the study area ranges from less than 125 feet to more than 275 feet below land surface. Depths are typically greater in areas where the land surface is higher (fig. 19). These areas generally correspond to the positions of glacial end moraines (fig. 8). The greater depths are found in the north-central to northwestern and southeastern parts of the study area, as well as the northeast corner.

The thickness of the Mahomet aquifer was mapped using the information obtained from 1,189 drillers' logs (fig. 20). These logs were for wells that were drilled deep enough to have encountered the Mahomet aquifer if present. The presence of the Mahomet aquifer was not noted in 243 of the drillers' logs (fig. 21). These logs were used to identify locations in the study area where the aquifer is not present. Although the thickness reported in most of the drillers' logs ranged from 5 to 74 feet, the entire range of reported thickness was 1 to 172 feet (fig. 21). Only 186 of the data points used to map the thickness of the Mahomet aquifer represent wells or boreholes drilled completely through the Mahomet aquifer and into the underlying bedrock. Because most of the boreholes drilled for water wells were not drilled into bedrock, the Mahomet aquifer is likely to be somewhat thicker than the greatest reported thickness.

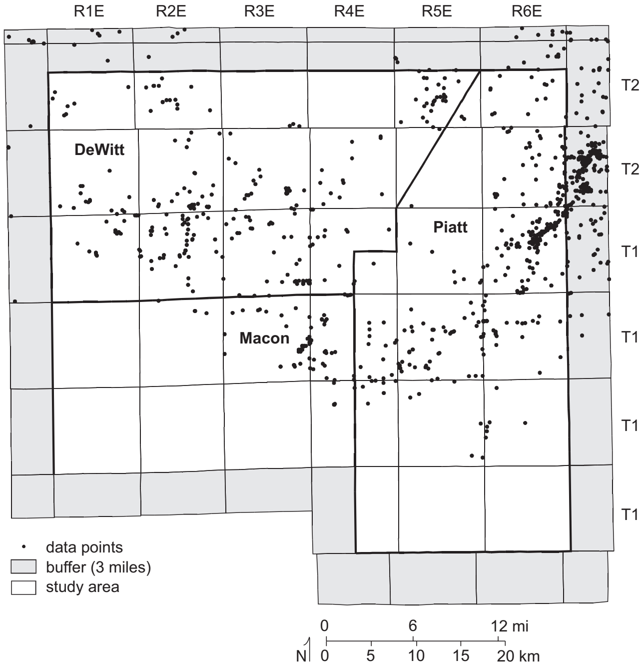


Figure 17 Distribution of data points used in determining the elevation of and depth to the top of the Mahomet aquifer.

The thickest part of the aquifer is generally found in the deepest part of the Mahomet Bedrock Valley (fig. 22). Subtracting the elevation of the bedrock surface from the elevation of the top of the Mahomet aquifer suggests a maximum potential thickness of about 190 feet for the Mahomet aquifer. This calculation assumes that the entire interval consists of aquifer material, such as sand and gravel. This potential thickness is almost 20 feet more than the maximum thickness of 172 feet reported in the drillers' logs. Fine-grained sediments are known to occur locally in the Mahomet Sand Member, however, and these sediments would decrease the total thickness of the aquifer. Delineating the areal extent of thickest part of this aquifer, as well as the areal extent and thickness of the fine-grained deposits within the aquifer interval, requires additional subsurface information.

Upper Banner Aquifer

Included in the upper Banner aquifer are the sand and gravel deposits that occur in the upper part of the Banner Formation below the Yarmouth Soil and above the top of the Mahomet aquifer (fig. 9). The sand and gravel deposits of this aquifer are typically thin, are of limited areal extent, and generally are found between the Tilton and Hillery Till Members that constitute the upper Banner Formation (fig. 9). Although this aquifer may be found over much of the study area, it is more widespread and thicker from the northern half to the east-central portions.

The elevation of and depth to the top of the upper Banner aquifer were defined using information from 537 drillers' logs (fig. 23). The thickness of this aquifer was mapped using the information obtained from 1,779 drillers' logs, which were for wells drilled deep enough to have encountered the upper Banner aquifer if present (fig. 24). Of the 1,779 logs, 537 noted sand and gravel units that corresponded to this aquifer. Information from the other 1,242 drillers' logs was used to identify areas of zero thickness for this aquifer (fig. 25).

Average thickness of this aquifer is 12 feet, based on information from the 537 drillers' logs. However, a thickness of less than 5 feet was noted in 204 of these logs (fig. 25). The distribution of these data points combined with the distribution of those where aquifer thickness is zero shows that the aquifer is less than 5 feet thick or absent over much of the study area. Relatively small areas where this aquifer is 10 feet thick or more are found predominantly in the north-central, northeastern, and east-central parts of the study area (fig. 26). Most of these areas are several

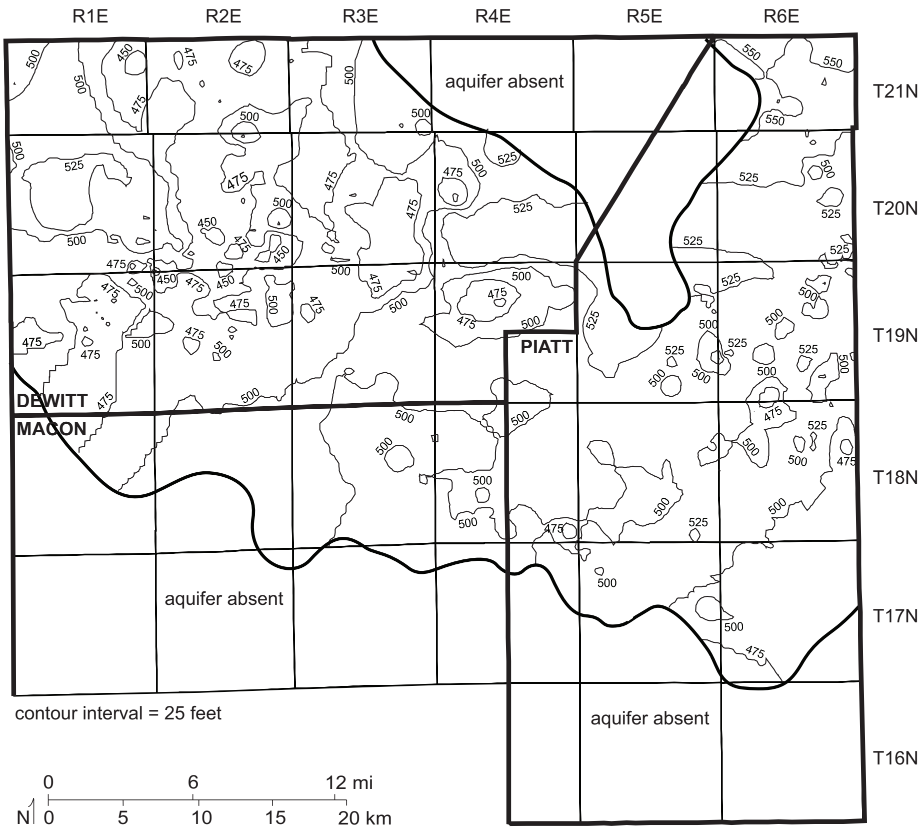


Figure 18 Elevation of the top of the Mahomet aquifer.

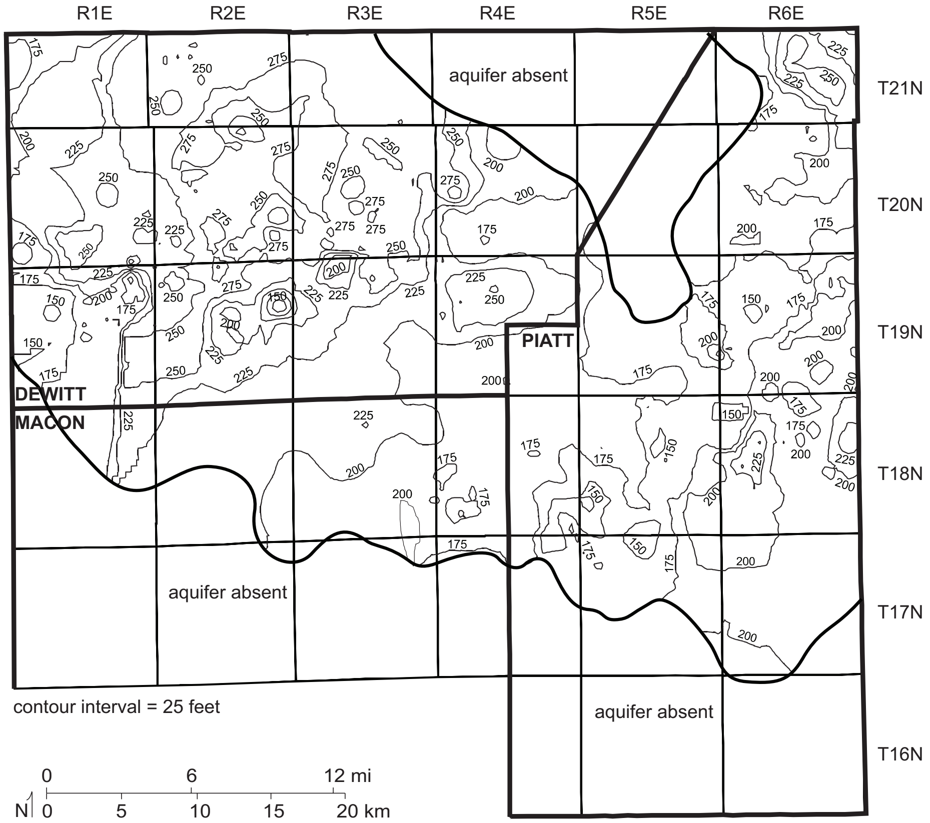


Figure 19 Depth to the top of the Mahomet aquifer.

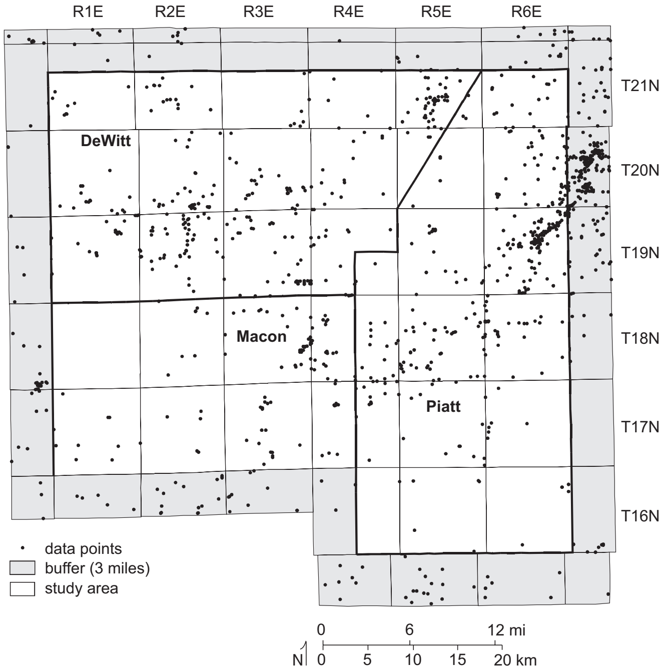


Figure 20 Distribution of data points used in determining the thickness of the Mahomet aquifer.

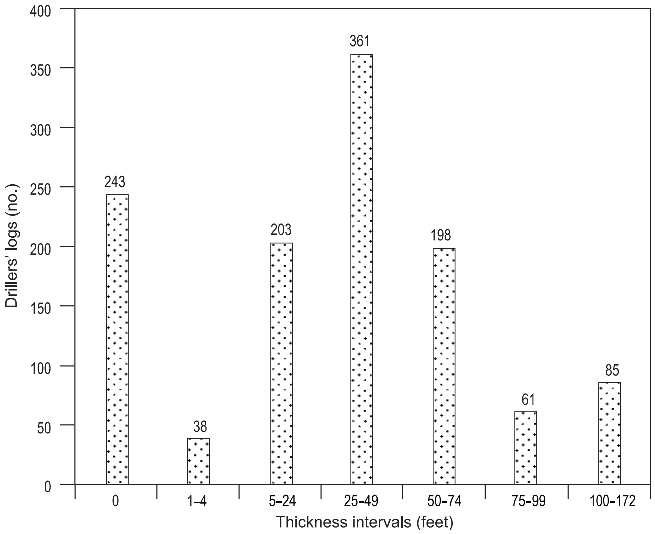


Figure 21 Frequency of thickness intervals for the Mahomet aquifer as interpreted from drillers' logs.

square miles in extent: the largest area encompasses about 40 square miles, and is located in T19–20N, R5–6E of Piatt County (fig. 26). Interpretation of data from the drillers' logs indicates some areas of limited extent where aquifer thickness may be 20 feet or greater. The largest areas of limited extent are scattered across the northern part of the study area and in T17–18N, R3–4E (fig. 26).

Elevation contours for the top of the upper Banner aquifer are shown only in the areas where the aquifer is at least 5 feet thick (fig. 27), the minimum thickness needed to provide a water supply from a drilled, domestic well. Elevation of the aquifer's upper surface generally decreases from northeast to southwest across the study area, roughly parallel to the top of the Mahomet aquifer. The highest elevations, locally exceeding 600 feet, occur in the northeast. Elevations of 525 to 550 feet are typically found in the northwest, and an elevation of 550 feet is common throughout the rest of the study area. The top of the upper Banner aquifer falls below an elevation of 525 feet in T18N, R2E and T21N, R1E (fig. 27).

Contours for the depth to the top of the upper Banner aquifer are also shown only in areas where aquifer thickness is at least 5 feet (fig. 28). Depth to this aquifer ranges from less than 75 feet to more than 200 feet below land surface. Greater depths are typically found in areas where glacial end moraines cause the land surface to be higher (fig. 8). The depths are greater in the northern half of the study area and locally in east-central Piatt County (fig. 28).

Lower and Upper Glasford Aquifers

The lower and upper Glasford aquifers consist of the sand and gravel deposits found within the Glasford Formation (fig. 9). Domestic wells in many parts of the study area tap this groundwater resource. These deposits were classified and mapped as two aquifers (fig. 11) to show the details of their extent and distribution. However, the thickness of the sand and gravel deposits as reported in the drillers' logs of wells in the same general area in many cases made it difficult to assign a particular deposit to one aquifer or the other. For example, the elevation of the bottom of a deposit reported in a driller's log would be lower than the elevation of the top of a deposit reported in the driller's log of a nearby well. Consequently, a map showing the combined thickness of the two Glasford aquifers is also included in this report.

Lower Glasford Aquifer The lower Glasford aquifer includes the sand and gravel deposits found chiefly between the Radnor and Vandalia Till Members and near the base of the Vandalia Till Member (fig. 9). These deposits are typically thin and of limited areal extent. Although this aquifer is scattered throughout much of the study area, it is most commonly found in Piatt County.

Information from 1,117 drillers' logs was used to define the elevation of and depth to the top of the lower Glasford aquifer. Distribution of these data points is shown in figure 29. Thickness of this aquifer was mapped using the information from 3,454 drillers' logs (fig. 30). About one-third of these (1,047 logs) noted sand and gravel units that corresponded to this aquifer. Information from the other 2,407 logs was used to identify areas where the aquifer is absent (fig. 31). Sand and gravel corresponding to this aquifer may have been encountered when some of the 2,407 wells were being drilled but not noted in the drillers' logs. For example, if a driller determined that the sand and gravel deposit was too thin to support a water well, a notation might have been omitted. Another reason might be that the Mahomet aquifer was the intended goal of the drilling; in that case, overlying minor aquifers might have been considered inconsequential and therefore might not have been noted.

Data from the drillers' logs show that the lower Glasford aquifer is not very thick. A total of 388 logs showed a thickness of less than 5 feet; 448 other logs showed thicknesses between 5 and 19 feet (fig. 31). Average thickness was calculated as 12 feet using information from all 1,047 logs that noted sand and gravel corresponding to this aquifer. The aquifer is 5 feet thick or greater in a number of relatively small areas scattered throughout much of the study area (fig. 32). These areas most commonly occur in T17–19N, R4–6E, generally along the course of the Sangamon River. Areas where this aquifer is 10 feet thick or greater are relatively limited in size and are widely spread across the study area (fig. 32). Two of the largest areas are found in T17–18N, R1–2E and T18–19N, R5–6E. Thickness of this aquifer locally exceeds 20 feet in a few areas that encompass several square miles (fig. 32). The largest of these areas is found in the southwest corner of the study area and in the east-central part in T18–19N, R6E (fig. 32).

Elevation contours for the top of the lower Glasford aquifer are shown only in the areas where the aquifer is at least 5 feet thick (fig. 33). Elevation of

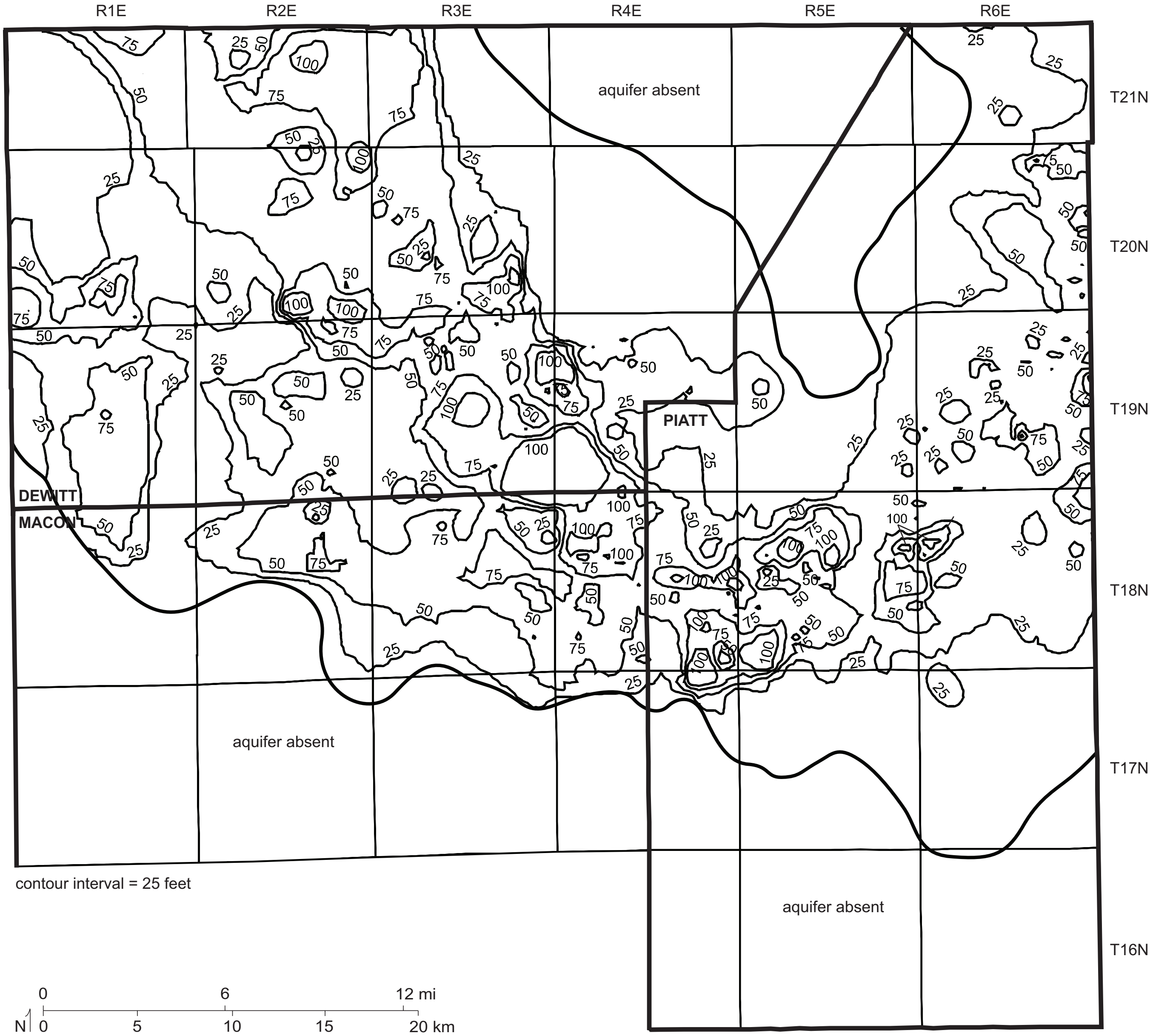


Figure 22 Thickness of the Mahomet aquifer.

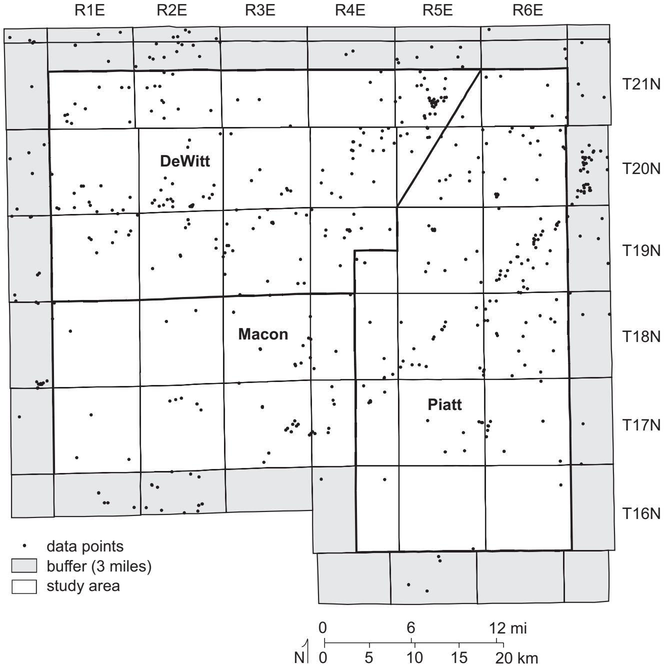


Figure 23 Distribution of data points used in determining the elevation of and depth to the top of the upper Banner aquifer.

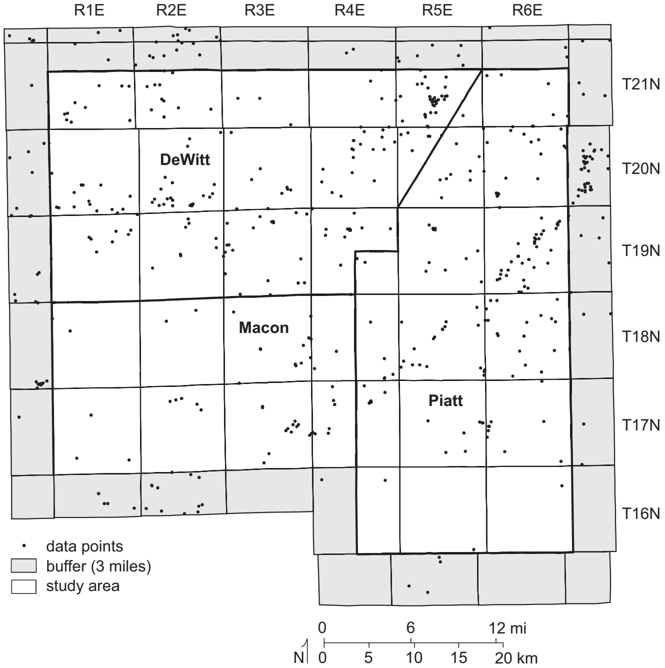


Figure 24 Distribution of data points used in determining the thickness of the upper Banner aquifer.

the aquifer is generally higher in the northern part of the study area than in the southern part (fig. 33). The highest elevation locally exceeds 660 feet in T21N, R3E in north-central DeWitt County and in T20N, R6E in northern Piatt County (fig. 33). Elevations of 580 to 600 feet are common in the central and southeastern parts of the study area. The lowest elevation (560 feet) is in the southwest corner of the study area in Macon County (fig. 33).

Contours of depth to the top of this aquifer are also shown only in areas where aquifer thickness is 5 feet or greater (fig. 34). Depth to the lower Glasford aquifer ranges from less than 50 feet to more than 150 feet below land surface, but averages about 100 feet (fig. 34). Like the deeper Mahomet and upper Banner aquifers, depths to this aquifer are generally greater where glacial end moraines cause the land surface to be higher. Depths locally exceed 150 feet in northwestern Macon County and in T21N, R3–4E in northwestern DeWitt County (fig. 34). Small areas where the depth is 50 feet or less are found along the west side of DeWitt County in T19–20N, R1E as well as in T17N, R1E in northern Macon County (fig. 34). These areas are mostly outside the boundary of Wisconsin Episode glaciation (fig. 8).

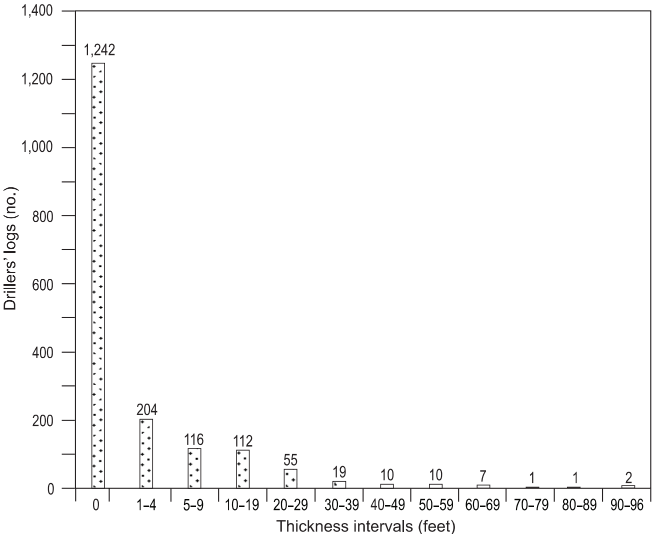


Figure 25 Frequency of thickness intervals for the upper Banner aquifer as interpreted from drillers' logs.

Upper Glasford Aquifer Sand and gravel deposits included in the upper Glasford aquifer are generally found near the top of the Radnor Till Member in the upper portion of the Glasford Formation (fig. 9). Like the sand and gravel constituting the lower Glasford aquifer, these deposits are typically thin and of limited areal extent. Although the pattern of occurrence of the upper Glasford aquifer is similar to that of the aquifer below it, the sand bodies of the upper Glasford aquifer tend to be larger than those of the lower Glasford aquifer.

A total of 1,669 drillers' logs provided the information used to define the elevation and depth of the top of this aquifer. Distribution of these data points is shown in figure 35. Aquifer thickness was mapped using information from 3,491 drillers' logs. Distribution of the data points is shown in figure 36. Sand and gravel units that corresponded to this aquifer were noted in 1,669 of these logs. Areas where this aquifer is absent were identified from the remaining 1,822 logs (fig. 37). As with the lower Glasford aquifer, thin sand and gravel deposits corresponding to the upper Glasford aquifer may have been encountered in some of the 1,669 wells but not noted in the drillers' logs.

A total of 643 logs showed an aquifer thickness of 1 to 4 feet; 719 other logs showed thicknesses of 5 to 19 feet (fig. 37). An average thickness of 11 feet was calculated from the 1,669 logs that noted sand and gravel. Although the upper Glasford aquifer is relatively thin, its thickness exceeds 5 feet in much of southern and east-central Piatt County (fig. 38). Other areas are scattered across the northwestern half of the study area (fig. 38). Areas where this aquifer is 10 feet thick or greater are commonly found in T16–19N, R4–6E in southern Piatt County and, to a lesser extent, along the west side of DeWitt County in T18–19N, R1–2E (fig. 38). The thickness of this aquifer locally exceeds 20 feet in small, scattered areas. Some of these areas may extend over a few square miles, as shown in T16–19N, R5–6E of central and southern Piatt County (fig. 38).

Elevation contours for the top of the upper Glasford aquifer are shown only in the areas where the thickness of this aquifer is 5 feet or greater (fig. 39). Elevation of the aquifer's upper surface follows a trend similar to that of the lower Glasford aquifer in that elevations generally are higher in the northern part of the study area than in the southern part (fig. 39).

Elevations of 680 to 700 feet are common in the north, where they locally exceed 720 feet in T20–21N, R3E in central DeWitt County (fig. 39).

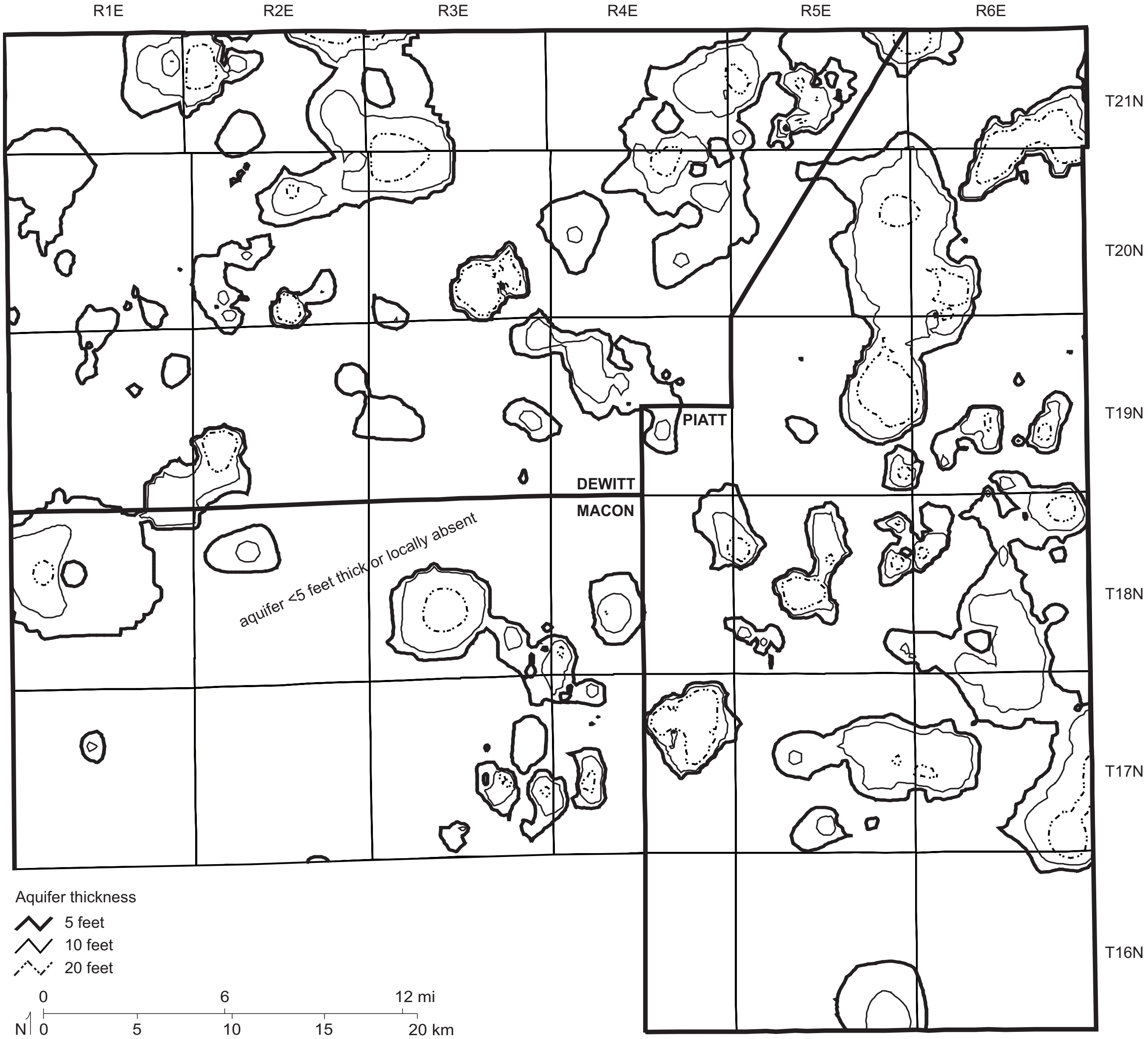


Figure 26 Thickness of the upper Banner aquifer.

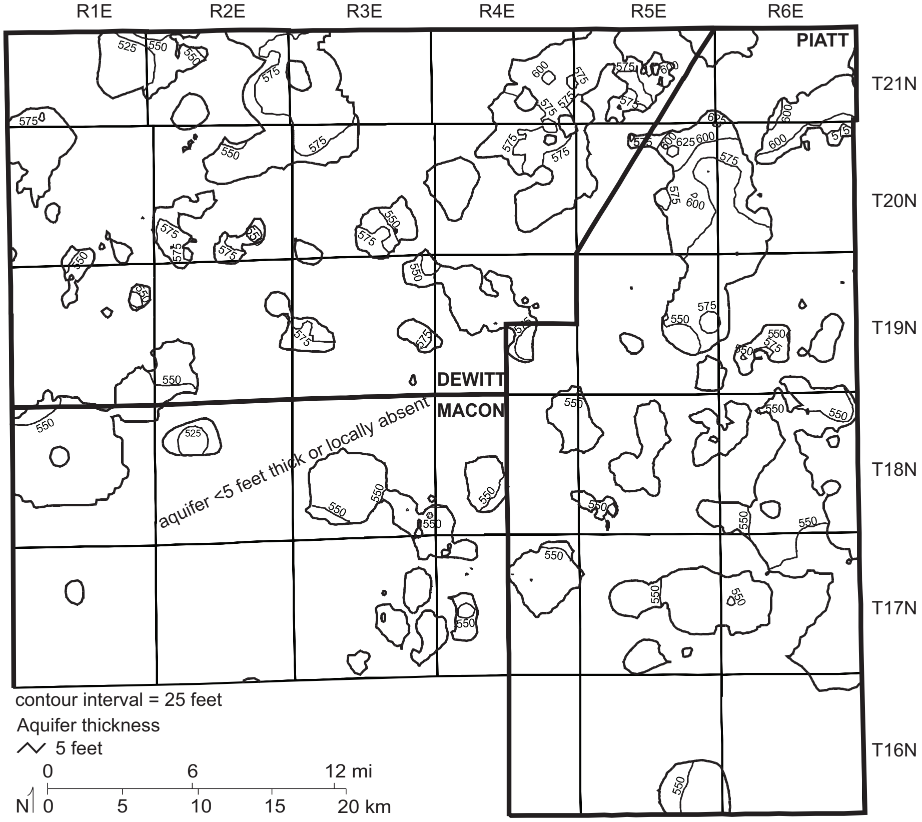


Figure 27 Elevation of the top of the upper Banner aquifer.

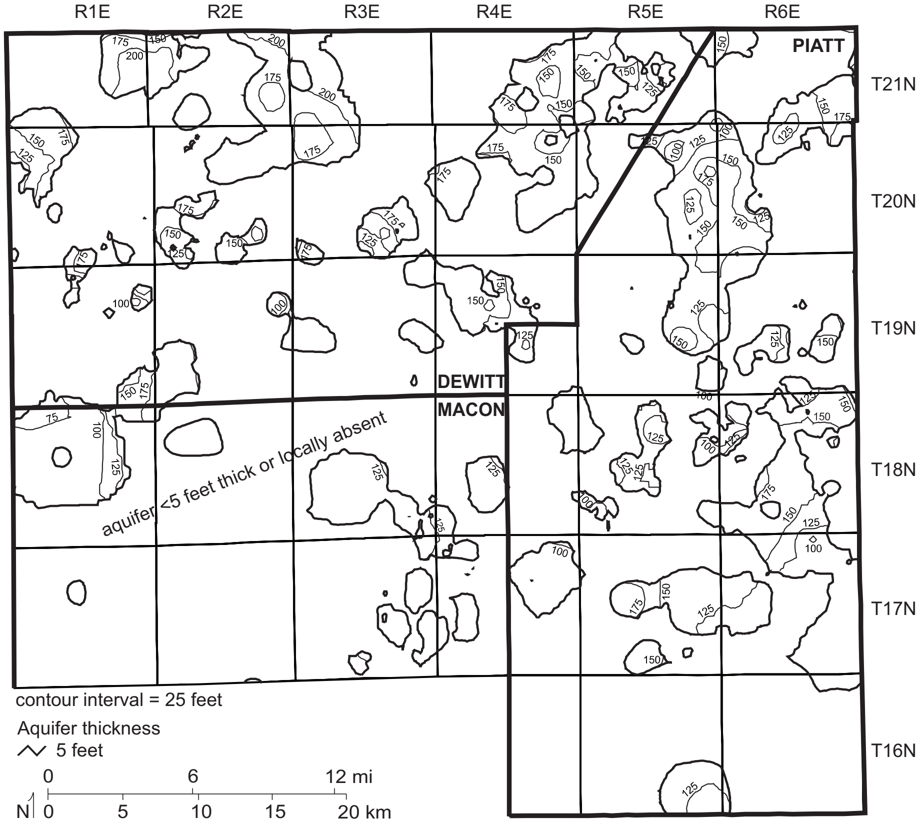


Figure 28 Depth to the top of the upper Banner aquifer.

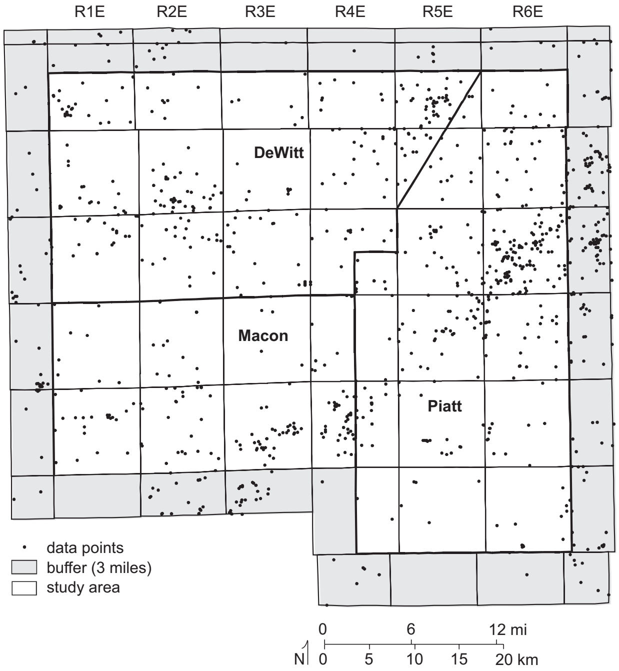


Figure 29 Distribution of data points used in determining the elevation of and depth to the top of the lower Glasford aquifer.

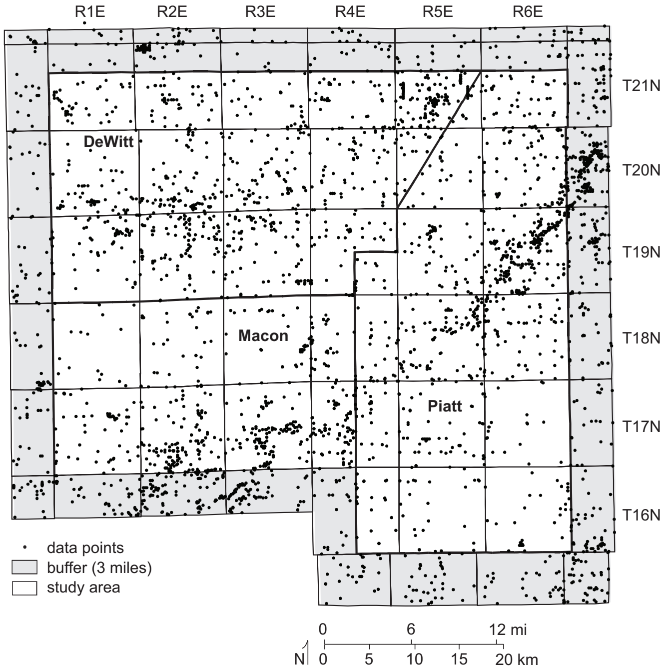


Figure 30 Distribution of data points used in determining the thickness of the lower Glasford aquifer.

Elevations of 600 to 640 feet are common throughout much of the rest of the area (fig. 39). The top of this aquifer rises slightly in T16N, R4E in southern Piatt County (fig. 39).

The depth to the top of the upper Glasford aquifer typically is greater where glacial end moraines cause the land surface to be higher (fig. 40). Depths locally exceed 100 to 125 feet in T20N, R1E in western DeWitt County and in T16–18N, R3–6E (fig. 40). Depths of less than 25 feet are found along the western edge of the study area in T17–19N, R1E, an area that is beyond the limit of the Wisconsin Episode glaciation (fig. 8).

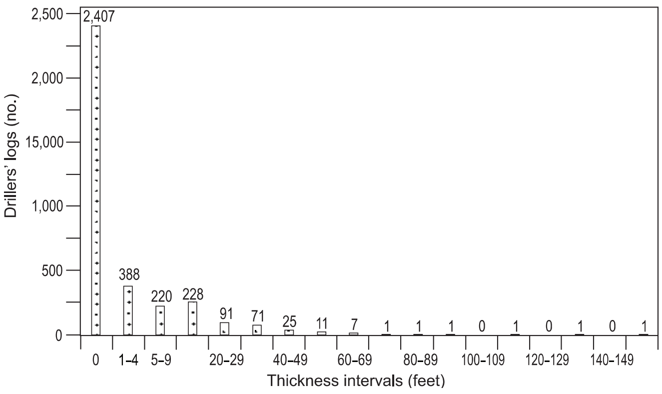


Figure 31 Frequency of thickness intervals for the lower Glasford aquifer as interpreted from drillers' logs.

Because of local variability in depth, thickness, and areal extent of the sand and gravel deposits mapped as the lower and upper Glasford aquifers, it is very probable that these aquifers are close together and, therefore, hydraulically connected in some parts of the study area. This proximity increases the overall thickness of sand and gravel as well as the potential of obtaining a domestic supply using a drilled well rather than a large-diameter bored well. The areas where the combined thickness of the Glasford aquifers is 5 feet or greater (fig. 41) form a pattern that is similar to that shown by the thickness maps of the individual aquifers (figs. 32 and 38). Areas where the combined thickness is 10 feet or more are common in the southern half of the study area, especially south of T17N, R4E to T19N, R6E in Piatt County and, to a lesser extent, in northwestern and southern DeWitt County (fig. 41). Areas where the combined thickness is less than 5 feet, or where the aquifers are locally absent, occur throughout the study area, but most commonly near the center (fig. 41). Fortuitously, the Mahomet aquifer is present beneath the largest area not underlain by Glasford aquifers (fig. 22).

Shallow Sand Aquifer

The shallow sand aquifer includes sand and gravel deposits found above the Glasford Formation that occur within glacial till of the Wedron Group or as relatively thick deposits of the Mason Group that occur along major streams (fig. 3). Thin deposits found at very shallow depths were not included in our maps of this aquifer. Although the sand and gravel deposits assigned to this aquifer are generally thin and very limited in areal extent, they may be saturated and sufficiently thick in some places to provide usable quantities of water for a domestic supply. Information used to define the elevation and depth of the top of this aquifer was obtained from 1,307 drillers' logs. Distribution of these data points is shown in figure 42. The thickness of this aquifer was mapped using the information from 3,492 drillers' logs; the distribution of these data points is shown in figure 43. Of this total, only 1,307 logs noted sand and gravel intervals that corresponded to this aquifer. The other 2,185 logs were used to identify areas where this aquifer is absent (fig. 44), which includes most of the study area (fig. 45). Deposits of sand and gravel corresponding to this aquifer might have been encountered during drilling of some of the 2,185 wells but were not reported because they are generally not thought to be a source of water supply.

Data from 664 of the 1,307 drillers' logs show that the shallow sand aquifer is less than 5 feet thick in most places where it was encountered (fig. 44). A total of 248 logs showed a thickness of 5 to 9 feet; 286 other logs showed a thickness of 10 to 19 feet (fig. 44). Areas where thickness of this aquifer is 10 feet or more are most prevalent in T16N, R5–6E in southern Piatt County, T17–18N, R6E in central Piatt County, and T20–21N, R2–3E in north central DeWitt County (fig. 45). Where this aquifer is sufficiently thick, it may provide domestic supplies if groundwater recharge is adequate to meet the demand for water.

Elevation contours for the top of the shallow sand aquifer are shown only in the areas where this unit is 5 feet thick or more (fig. 46). Elevation of the top of this unit is commonly 700 feet in the northern part of the study area, but locally exceeds 725 feet. Elevations of 650 to 675 feet are common in the other parts of the study area. The lowest elevation of 600 feet is found in T17N, R1E in the southwest corner of the study area (fig. 46). Although the depth to the top of this unit is commonly less than 25 feet, it may locally exceed 75 feet, such as in T18N, R4E (fig. 47).

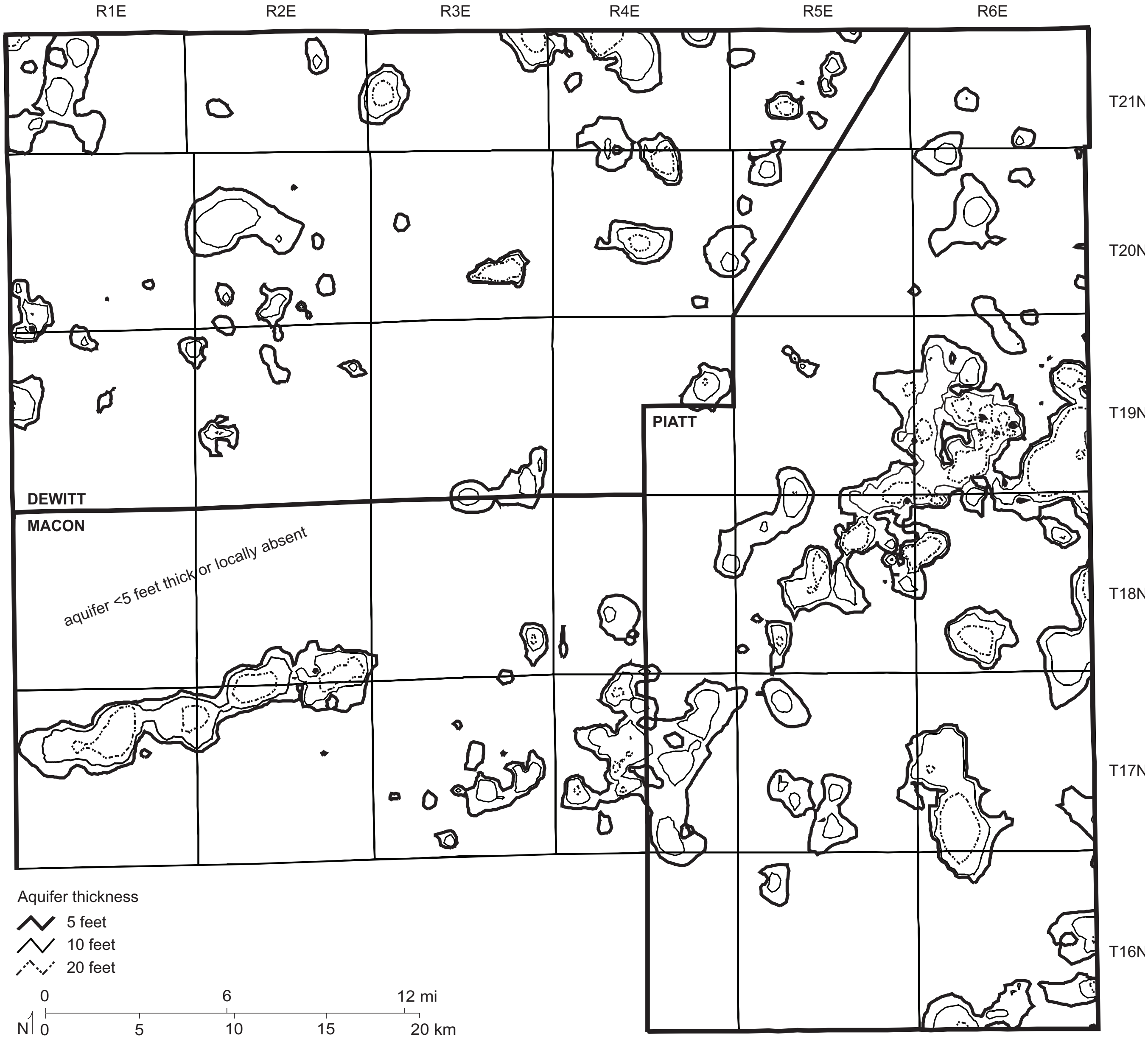


Figure 32 Thickness of the lower Glasford aquifer.

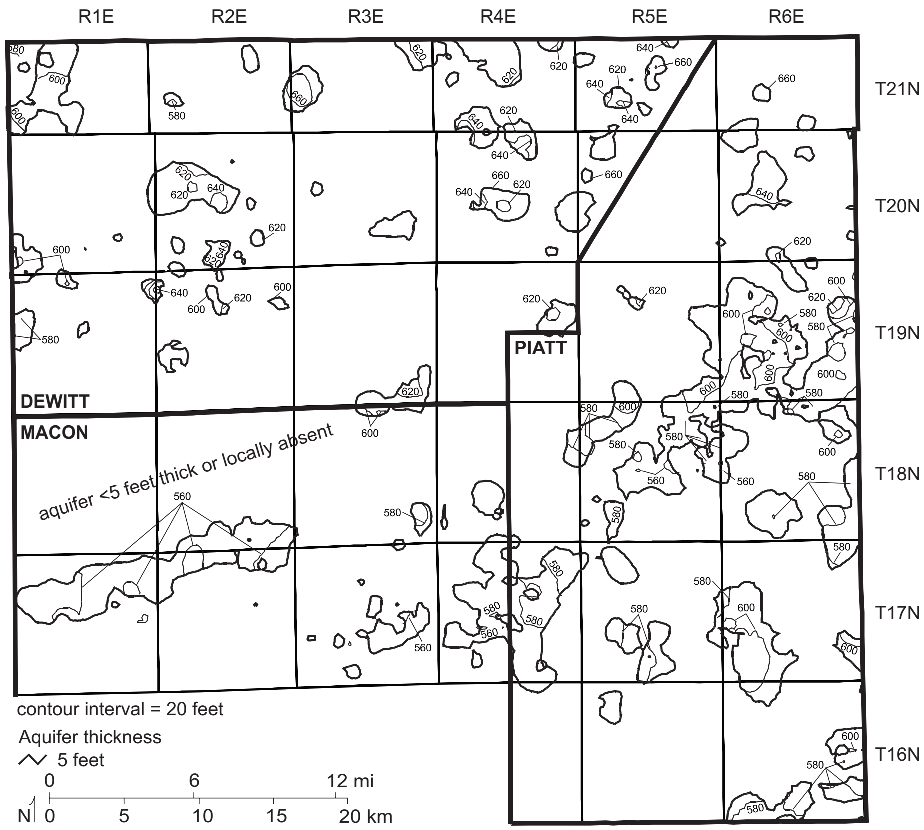


Figure 33 Elevation of the top of the lower Glasford aquifer.

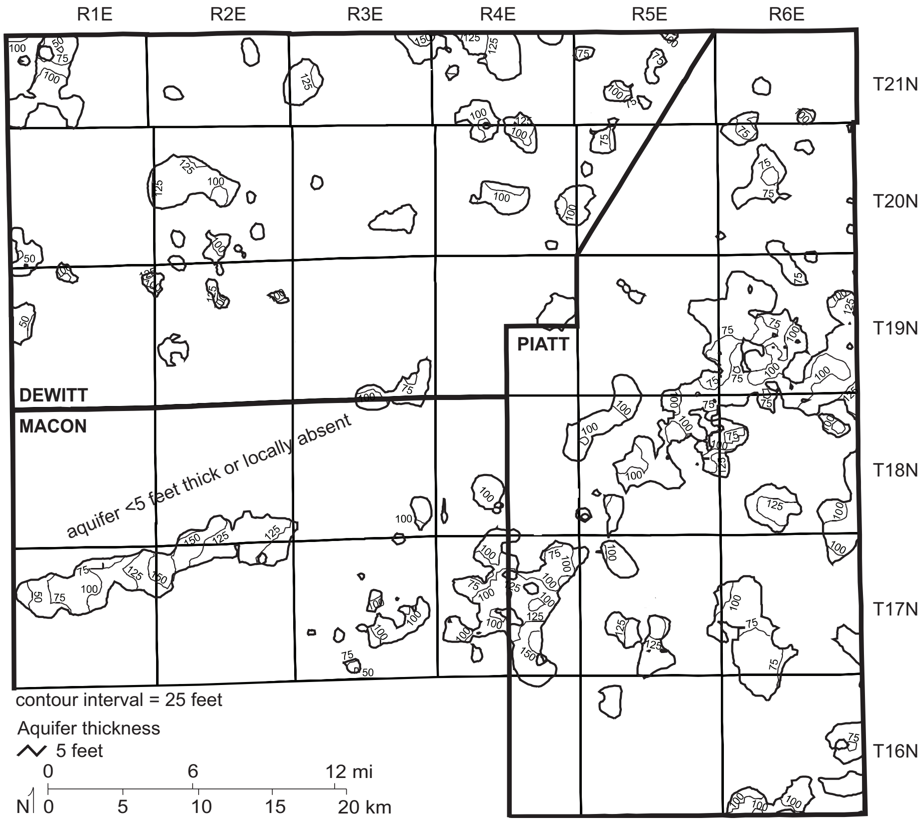


Figure 34 Depth to the top of the lower Glasford aquifer.

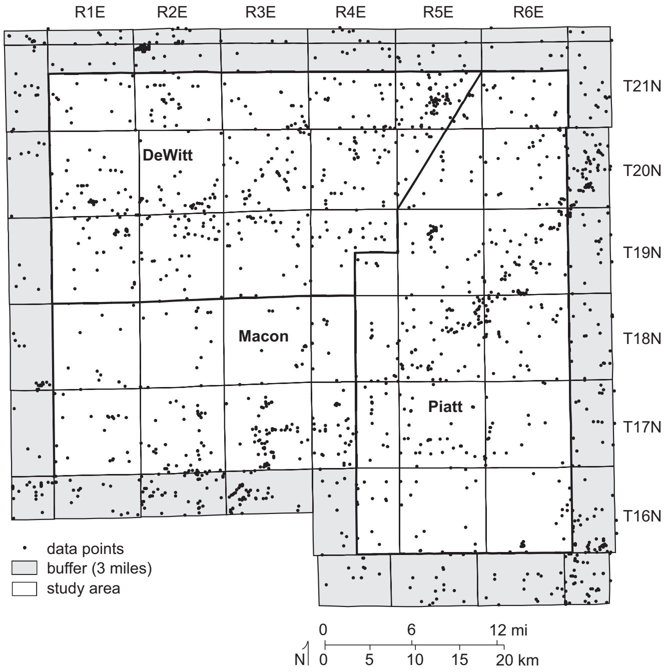


Figure 35 Distribution of data points used in determining the elevation of and depth to the top of the upper Glasford aquifer.

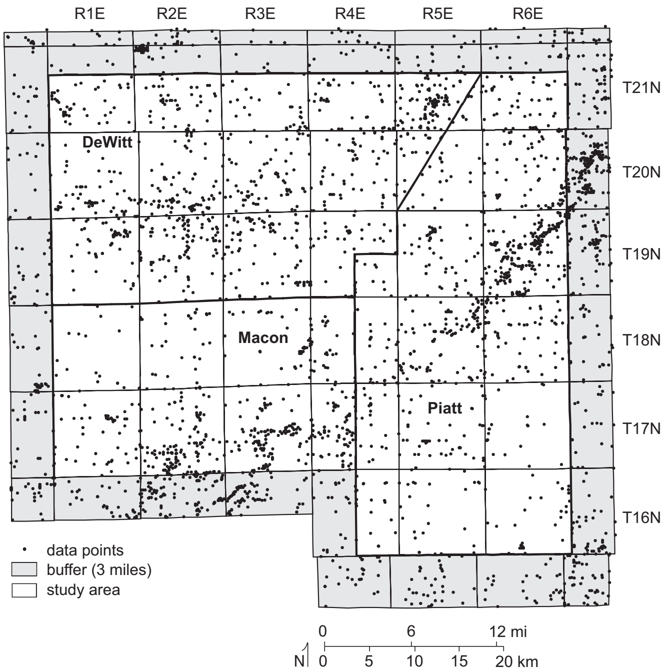


Figure 36 Distribution of data points used in determining the thickness of the upper Glasford aquifer.

Very shallow wells in this aquifer are likely to go dry during periods of below-normal precipitation because of the lack of recharge. The shallow depth of this aquifer makes the potential for groundwater contamination relatively high.

Results of Geophysical Surveys

Reconnaissance geophysical surveys were conducted in two areas to address specific issues. In the Farmer City–Mansfield area, we sought to determine whether the aquifer from which Farmer City gets its water is hydraulically connected to the Mahomet aquifer. We also tried to locate alternative aquifers, especially for smaller users, because of high iron, hardness, and natural gas concentrations in the Farmer City source. In the southern half of Piatt County, the MVWA wanted information to guide recommendations on well type (small-diameter drilled wells vs. large-diameter bored wells) in an area where the potential for obtaining a groundwater supply was poorly known. These two surveys required a major effort and consumed much of the project's budget. The results have been published (Larson 2000, Larson et al. 2000), but are summarized below to show how they were incorporated into the overall study.

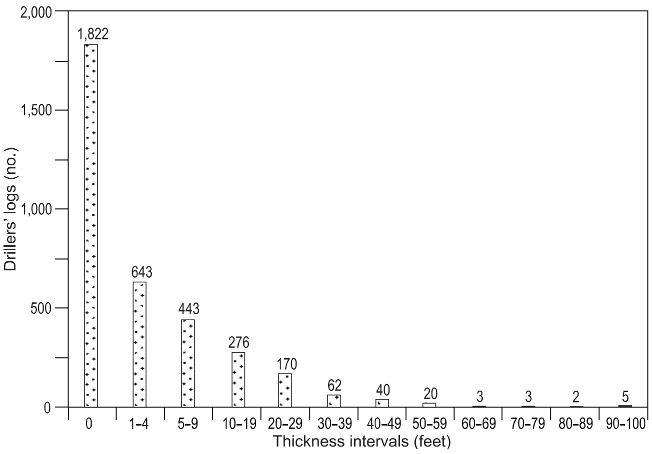


Figure 37 Frequency of thickness intervals for the upper Glasford aquifer as interpreted from drillers' logs.

Farmer City–Mansfield Area

Sand and gravel deposits in the upper Banner Formation are the source of water supply for Farmer City (Kempton and Herzog 1996). This aquifer seems to occur in a narrow, relatively shallow bedrock valley on the uplands along the Mahomet Bedrock Valley (Kempton and Herzog 1996). However, the shape of the bedrock valley and the areal extent of the aquifer are not well understood. It is not known whether a hydraulic connection exists between the aquifer in the Farmer City–Mansfield area and the Mahomet aquifer. To better delineate the shape of the bedrock valley, a seismic refraction survey was conducted (Larson 2000). The seismic survey did not detect a distinct, well-defined bedrock valley.

An EER survey was conducted to help define the areal extent of the aquifer and, if possible, determine whether a hydraulic connection with the Mahomet aquifer exists. The EER survey could not distinguish the sand and gravel deposits of the Glasford and upper Banner Formations as individual layers. Results of the survey indicated that the total thickness of sand and gravel might be 10 to 15 feet beneath most of the Farmer City–Mansfield area (Larson 2000).

Using drillers' logs, the sand and gravel deposits in the Glasford and upper Banner Formations were mapped separately for this study. This mapping shows that the upper Banner aquifer in the Farmer City–Mansfield area is relatively thin or entirely absent throughout about half of T20–21N, R4–6E (fig. 26). The areas where this aquifer is more than 10 feet thick are relatively small (a few square miles each) and discontinuous. The upper and lower Glasford aquifers are also found in T20–21N, R4–6E (fig. 41). Although these aquifers tend to be relatively thin or absent, their combined thickness exceeds 10 feet in some small areas. In general, these areas for the upper and lower Glasford aquifers tend to be smaller than the areas where the upper Banner aquifer is 10 feet thick or greater.

The combined thickness of sand and gravel in the Glasford and upper Banner Formations in the Farmer City–Mansfield area (T20–21N, R5–6E) ranges from less than 5 feet to more than 30 feet (fig. 48). The distribution and thickness of sand and gravel shown in figure 48 generally match the results of the EER survey conducted in the same area (Larson 2000). The occurrence of sand and gravel deposits in this part of Piatt and DeWitt Counties appears to be very complex, as suggested by the thickness maps of the upper Banner (fig. 26), lower Glasford (fig. 32), and upper Glasford aquifers (fig. 38). The Mahomet aquifer is not present in this area. More detailed investigation of the distribu-

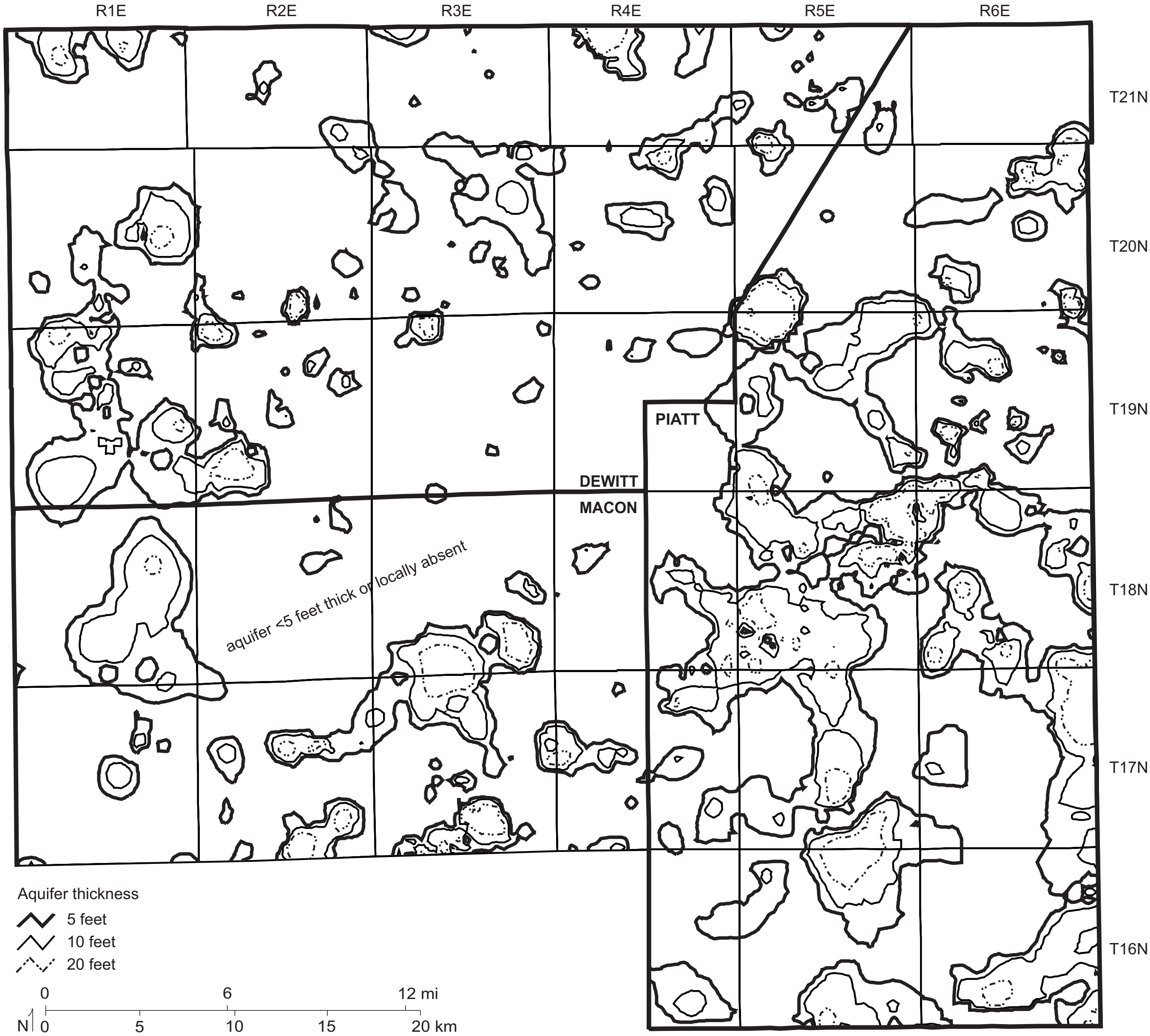


Figure 38 Thickness of the upper Glasford aquifer.

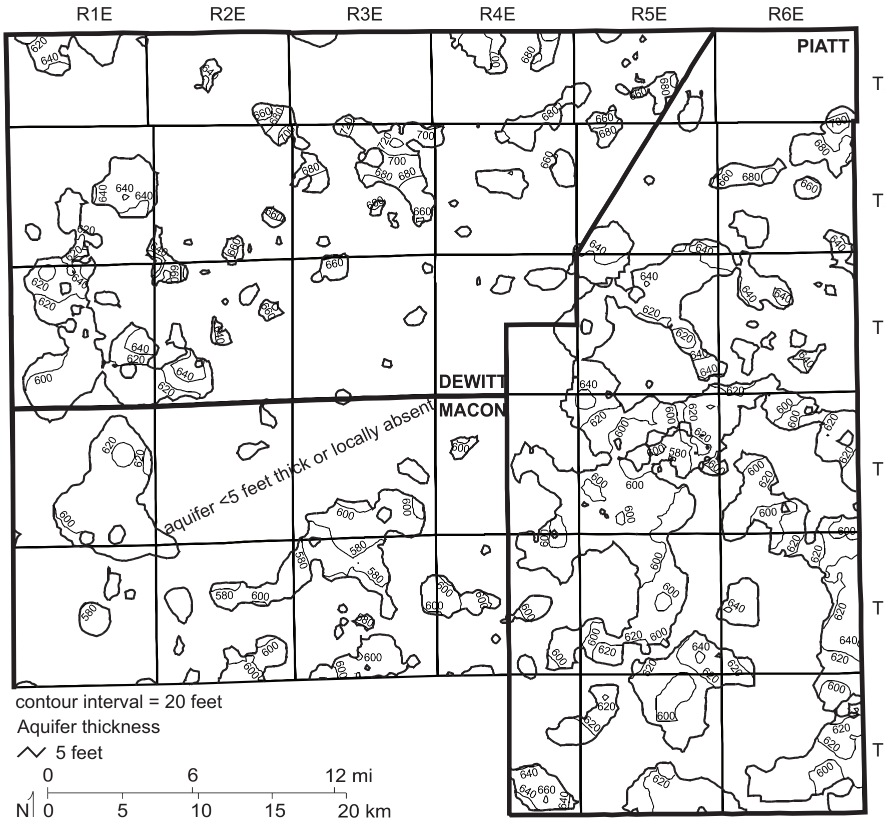


Figure 39 Elevation of the top of the upper Glasford aquifer.

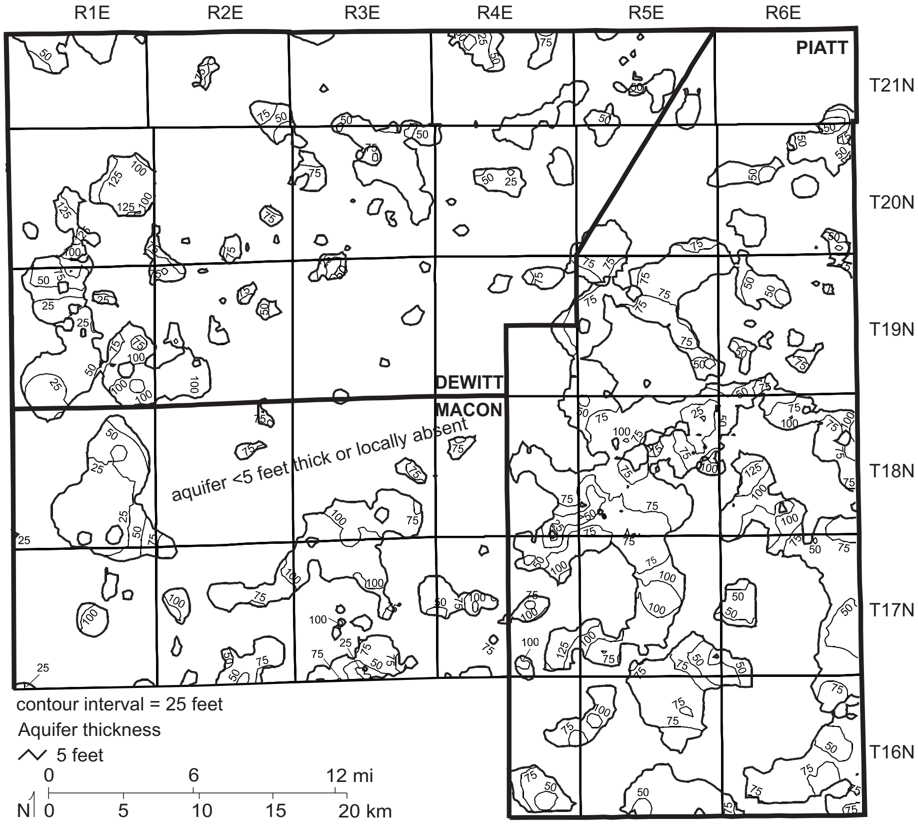


Figure 40 Depth to the top of the upper Glasford aquifer.

tion and thickness of these sand and gravel deposits is needed in this area to better understand the availability of groundwater in the Farmer City–Mansfield area.

Southern Half of Piatt County

The hydrogeology of sand and gravel deposits in the Glasford and upper Banner Formations in the southern half of Piatt County is complex because the deposits are typically thin and discontinuous. The overall lack of information for the southern half of Piatt County increases the difficulty of interpreting the physical characteristics, distribution, and areal extent of these deposits. The sparseness of information is evident from the distribution of data points used to map the aquifers, especially in T16–17N, R5–6E and T18N, R6E (figs. 23, 24, 29, 30, 35, 36). Because the Mahomet aquifer is relatively thin or absent in the southern half of Piatt County (fig. 22), obtaining a water supply in this area is less certain than in areas underlain by the Mahomet aquifer. A map of the combined thickness of the upper and lower Glasford and upper Banner aquifers is useful for indicating the potential of the groundwater resource as a source of supply (fig. 48). Areas with thicker deposits of sand and gravel generally have a greater groundwater resource potential than areas where sand and gravel deposits are thin. These areas are where a drilled well should be evaluated as an alternative to a large-diameter bored well.

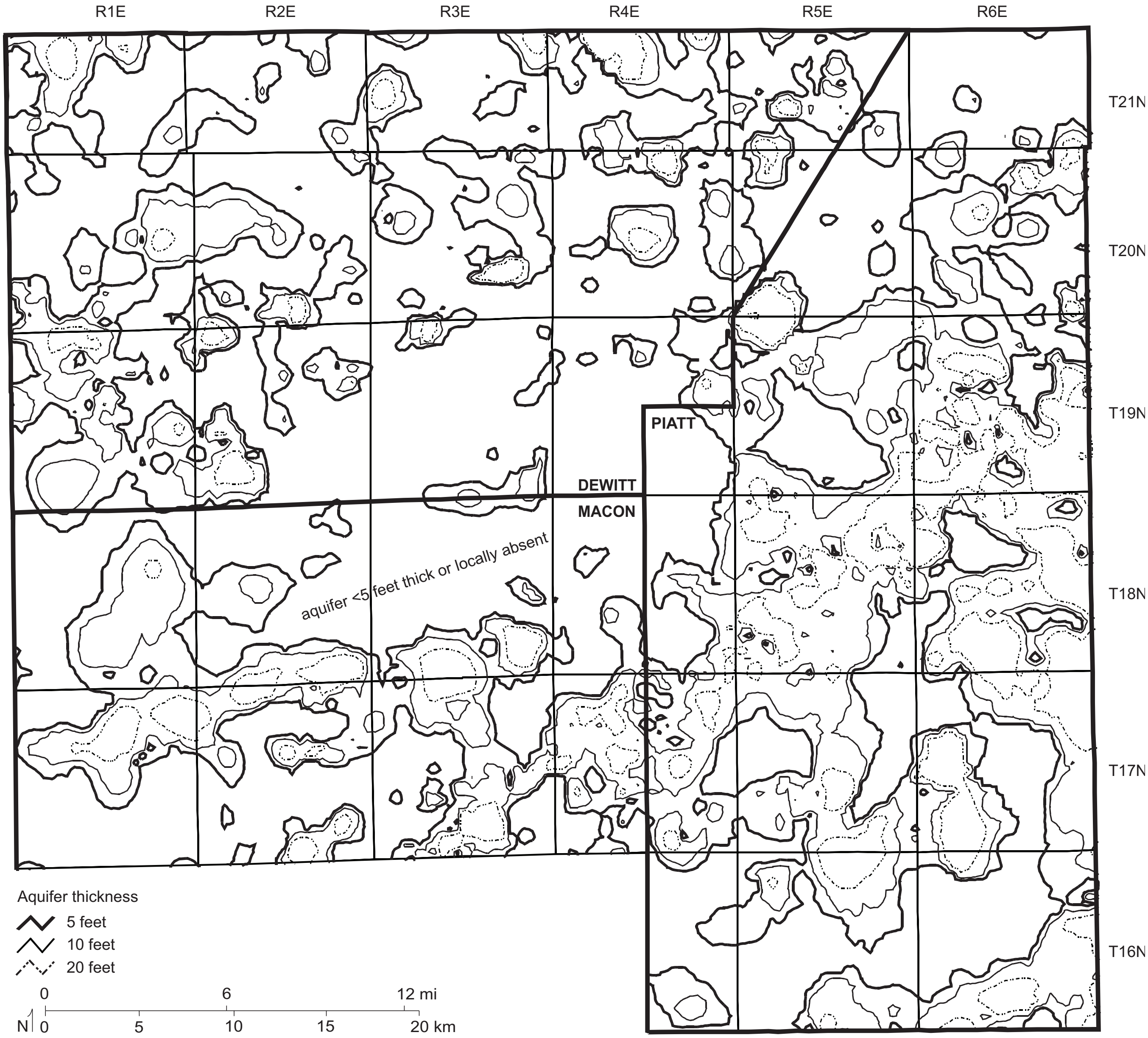


Figure 41 Combined thickness of the upper and lower Glasford aquifers.

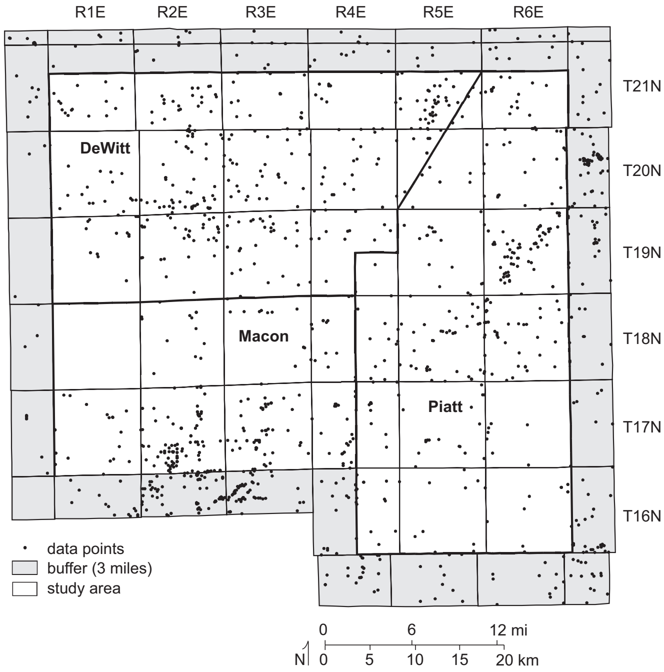


Figure 42 Distribution of data points used in determining the elevation of and depth to the top of the shallow sand aquifer.

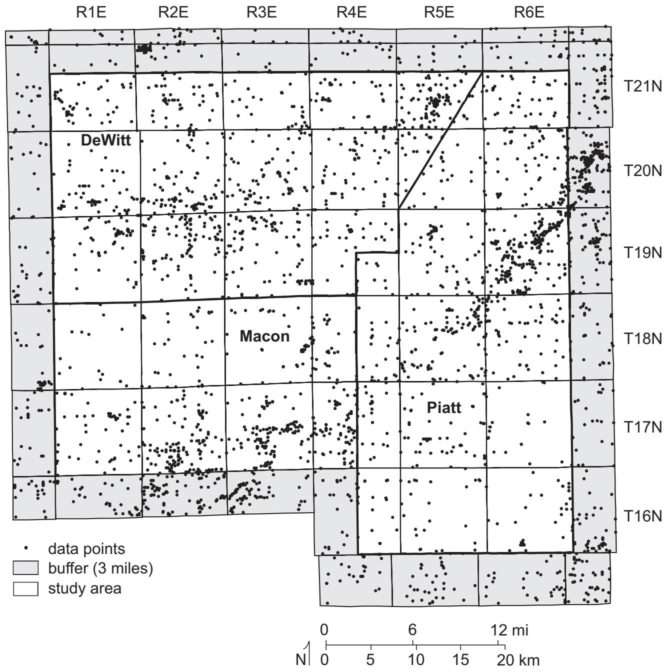


Figure 43 Distribution of data points used in determining the thickness of the shallow sand aquifer.

In the southern half of Piatt County (T16–17N, R4–6E), the upper and lower Glasford and upper Banner aquifers are relatively thin or entirely absent in a swath across T16N, R4–6E and in some smaller areas in T17N, R4–6E (fig. 48). The combined thickness of these three aquifers is 10 feet or more near the southern and western edges of the county and over much of T17N, R4–6E. Areas where the combined thickness is 20 to 30 feet or more are few and of very limited extent. The distribution of sand and gravel thickness shown in figure 48 in general matches the results of the EER survey conducted across the southern half of Piatt County (Larson et al. 2000), except for T17N, R4E, where the Mahomet aquifer was included in the EER survey.

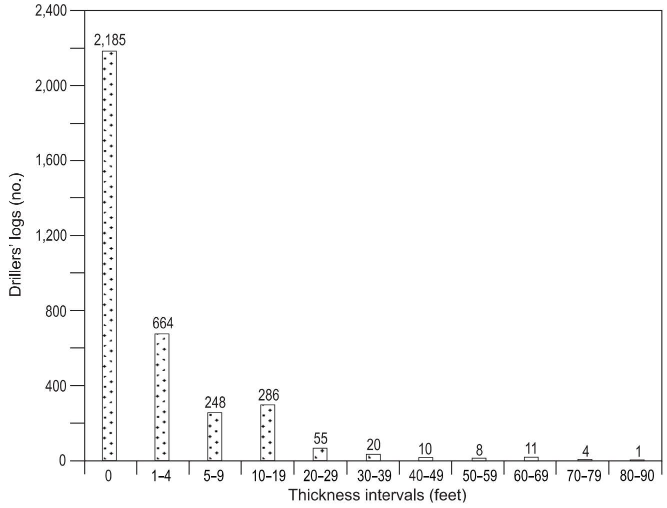


Figure 44 Frequency of thickness intervals for the shallow sand aquifer as interpreted from drillers' logs.

Summary

The Mahomet aquifer is the principal groundwater resource in the area under the jurisdiction of the MVWA. This aquifer, which is found within the Mahomet Bedrock Valley, sweeps across the area of the MVWA in a broad arc. Although the map showing the elevation of the top of the Mahomet aquifer exhibits somewhat more variability than the map by Kempton and Herzog (1996), the overall features of the two maps are very similar. The maximum thickness reported in the drillers' logs used to characterize the Mahomet aquifer is 172 feet, but the aquifer may be as much as 190 feet thick based on subtracting the bedrock elevation from the elevation of the top of the Mahomet aquifer. This calculation, however, is based on the assumption that the entire interval consists of sand and gravel.

Sand and gravel deposits are also found in the upper Banner Formation, in the Glasford Formation, in the Mason Group, and locally within the Wedron Group. The thickness and areal extent of these deposits are quite variable, but they comprise locally significant sources of water for domestic wells where they are sufficiently thick. These sand and gravel deposits were mapped as four separate aquifers: upper Banner, lower Glasford, upper Glasford, and shallow sand aquifer. The shallow sand aquifer is very limited in its occurrence and, where present, may be unreliable as a source of supply and may be susceptible to contamination. Maps of the other three aquifers show relatively large areas within the borders of the MVWA where they are sufficiently thick to be reliable sources of supply for domestic wells. Thicknesses of sand and gravel deposits within the Glasford and upper Banner Formations were mapped by assigning a zero thickness to the locations for the many drillers' logs in which such deposits were not reported. These deposits may not have been reported in the log because they were not encountered, because they were too thin to be of significance for a water supply, or because the deeper Mahomet aquifer was the intended goal of the drilling. The result of including the zero thickness points in the mapping is that it reduces the extent of the areas where the thickness of the sand and gravel is greater than 10 feet (Kempton and Herzog 1996) or 20 feet (Anliker and Sanderson 1995). The likelihood of drilling a dry hole targeted at these aquifers is also reduced. Thus, these maps should help in the evaluation of alternatives for domestic wells. Where the sand and gravel deposits are sufficiently thick (fig. 48), properly constructed drilled wells are preferable to large-diameter bored wells.

Recommendations for Further Action

The maps developed for this study used (1) information gathered from available drillers' logs on file at the ISGS that contained usable geologic information as well as (2) information obtained from two reconnaissance geophysical surveys. The data points used to map the elevation, depth, and thickness of the aquifers are scattered in clusters across the study area. The maps showing the data

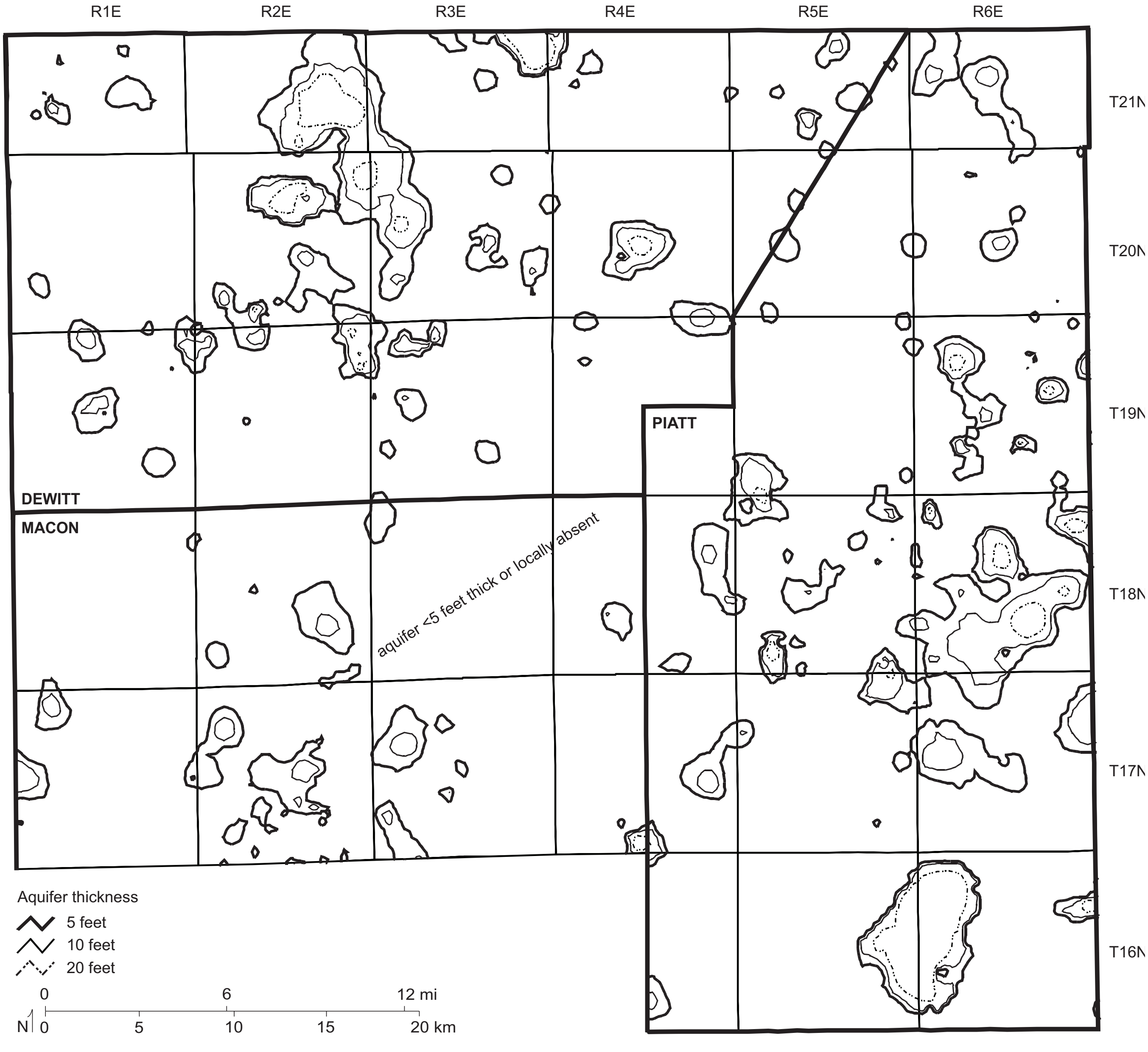


Figure 45 Thickness of the shallow sand aquifer.

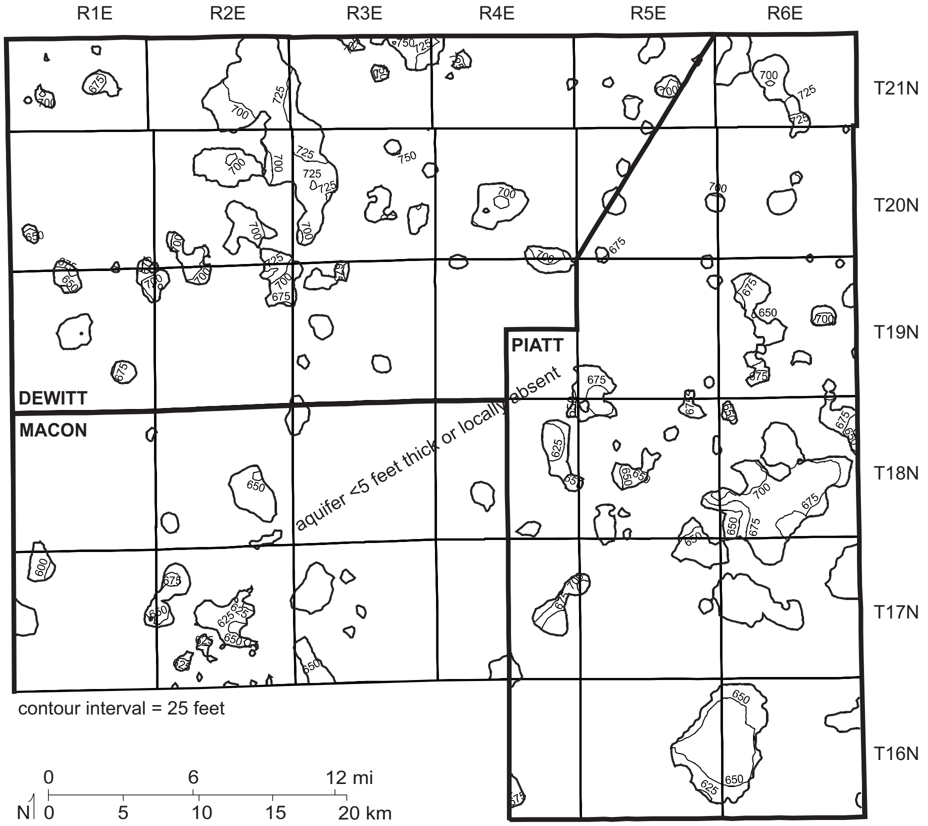


Figure 46 Elevation of the top of the shallow sand aquifer.

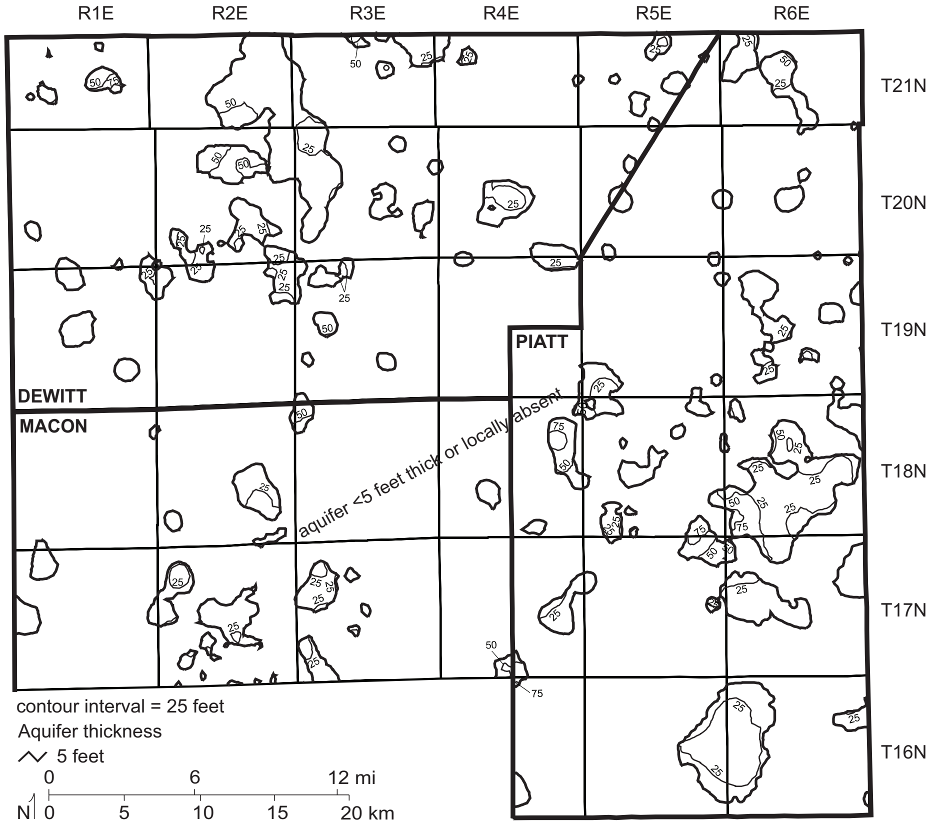


Figure 47 Depth to the top of the shallow sand aquifer.

distribution identify the parts of the study area (areas with relatively few data points) where additional information is needed to improve interpretation of the hydrogeologic setting of the area. Further study of the Mahomet aquifer and of the aquifers in the Glasford and upper Banner Formations would result in better management of the groundwater resources within the MVWA.

Of the 1,189 drillers' logs used to map the thickness of the Mahomet aquifer, only 186 were for water wells or other boreholes drilled entirely through the aquifer and into the underlying bedrock. Because the existing information is inadequate, the total thickness of the Mahomet aquifer in much of the MVWA can only be estimated by subtracting the elevation of the bedrock surface from that of the top of the aquifer. One disadvantage of this method is that it does not consider the thickness of fine-grained sediments found within the Mahomet Sand Member, such as the glacial till and lake-bottom silts and clays that occur near the bottom of the Mahomet Bedrock Valley from Ford County on the east to its confluence with the Mackinaw Valley on the west (Herzog et al. 1995, Kempton and Herzog 1996). Quantifying the amount of groundwater stored in the Mahomet aquifer as well as the capability of the Mahomet to transmit water (transmissivity) and assessing the effects of groundwater resource development (such as determining the impacts on

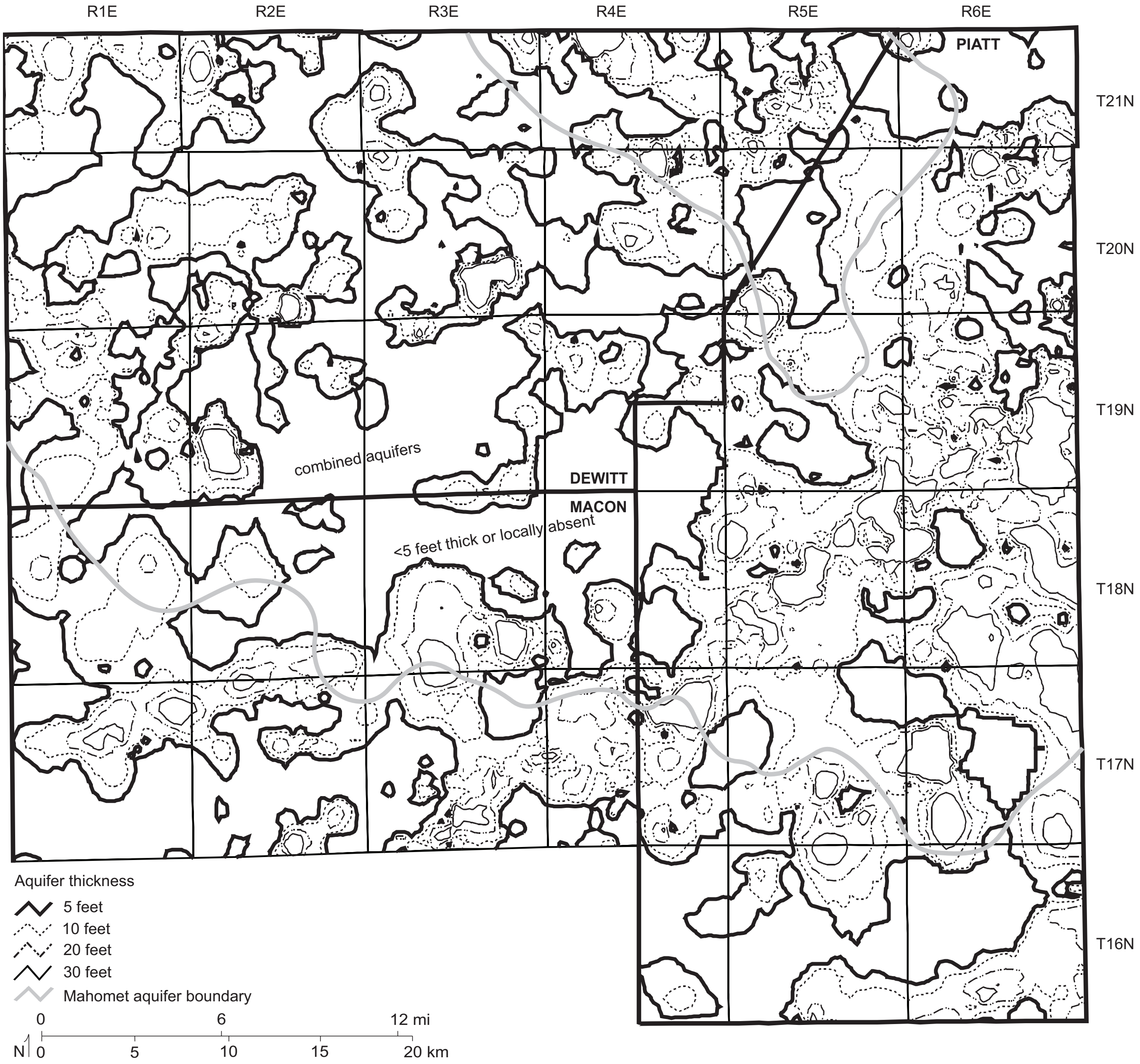


Figure 48 Combined thickness of the upper and lower Glasford and upper Banner aquifers with outline of the Mahomet aquifer.

nearby wells from a new high-capacity well) require accurate information about the thickness and extent of the aquifer and the variability of the materials making up the aquifer. Acquiring more information about the Mahomet aquifer both within and beyond the boundaries of the MVWA is essential.

The most effective means for gathering this information is through test drilling and high-resolution seismic reflection profiling. The first priority for test drilling should be in the townships along the Mahomet aquifer that have sparse data points, such as T19N, R5E (figs. 17 and 20). Test holes should be drilled into bedrock, and dedicated observation wells should be installed in them. These wells would be used to monitor changes in the potentiometric surface of the Mahomet aquifer. Water samples should be collected from these wells so that the groundwater chemistry of the aquifer can be characterized and monitored. Information provided by monitoring wells in the Mahomet aquifer is important for identifying the effects of continued development of the aquifer. High-resolution seismic reflection profiling can provide information not only on the depth to bedrock but also on the variability within the glacial deposits overlying the bedrock. High-resolution seismic reflection profiles across the western, middle, and eastern parts of the Mahomet aquifer would provide information essential for managing the groundwater resource of this aquifer.

Additional information would improve the accuracy of the maps for the other aquifers. Controlled test drilling at selected sites throughout the MVWA area, particularly in townships with relatively few wells, would help to determine the extent of aquifers in the Glasford and upper Banner Formations. High-resolution seismic reflection profiling in these areas would be beneficial, especially in the Farmer City–Mansfield area and in the southern half of Piatt County. Installation of dedicated observation wells to monitor changes in the potentiometric surfaces of aquifers in the Glasford and upper Banner Formations would provide information essential for managing the groundwater resources of the MVWA.

Although groundwater quality was not part of this project, further study should be conducted concerning arsenic in the groundwater and groundwater inflow from bedrock. Small amounts of arsenic can be harmful to human health (Hem 1985). Concerns about human-health consequences of long-term exposure to arsenic in drinking water recently caused the U.S. Environmental Protection Agency to lower the federal drinking water standard for the maximum allowable concentration from 50 µg/L to 10 µg/L (U.S. Environmental Protection Agency 1976, 2001). Trace amounts of naturally occurring arsenic are found in groundwater samples collected from a few wells completed in the Mahomet aquifer and from some wells completed in shallower sand and gravel aquifers (Panno et al. 1994, Holm 1995). The source and possible movement of the arsenic within the groundwater flow system need further investigation. Panno et al. (1994) thought the presence of arsenic might be related to groundwater flowing into the Mahomet aquifer from underlying bedrock or the presence of pyrite in the bedrock and glacial deposits. Noting changes in the chemistry of groundwater in the Mahomet aquifer in Piatt County, those workers concluded that there was a slight inflow of mineralized groundwater from bedrock underlying the Mahomet aquifer. It is important to investigate what the effects might be on groundwater quality of the Mahomet aquifer if additional groundwater withdrawals from the Mahomet were to increase the rate of flow of mineralized groundwater from the bedrock.

Because of the increasing demand for groundwater from the Mahomet aquifer, organizations and individuals interested in the long-term use of this groundwater resource recently organized the Mahomet Aquifer Consortium to foster communication about a wide range of concerns. These concerns include managing the groundwater resource so that future water demands can be met with a long-term assurance of a water supply, identifying and resolving water-quality issues, optimizing water-supply costs, and planning for economic development. The MVWA is a member of the Consortium. Other members represent the private sector; county, state, and federal agencies; agriculture; water authorities; municipalities; and professional organizations. The Consortium is working to obtain funding for additional studies of the Mahomet aquifer. Such funding should help address the recommendations in this report.

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