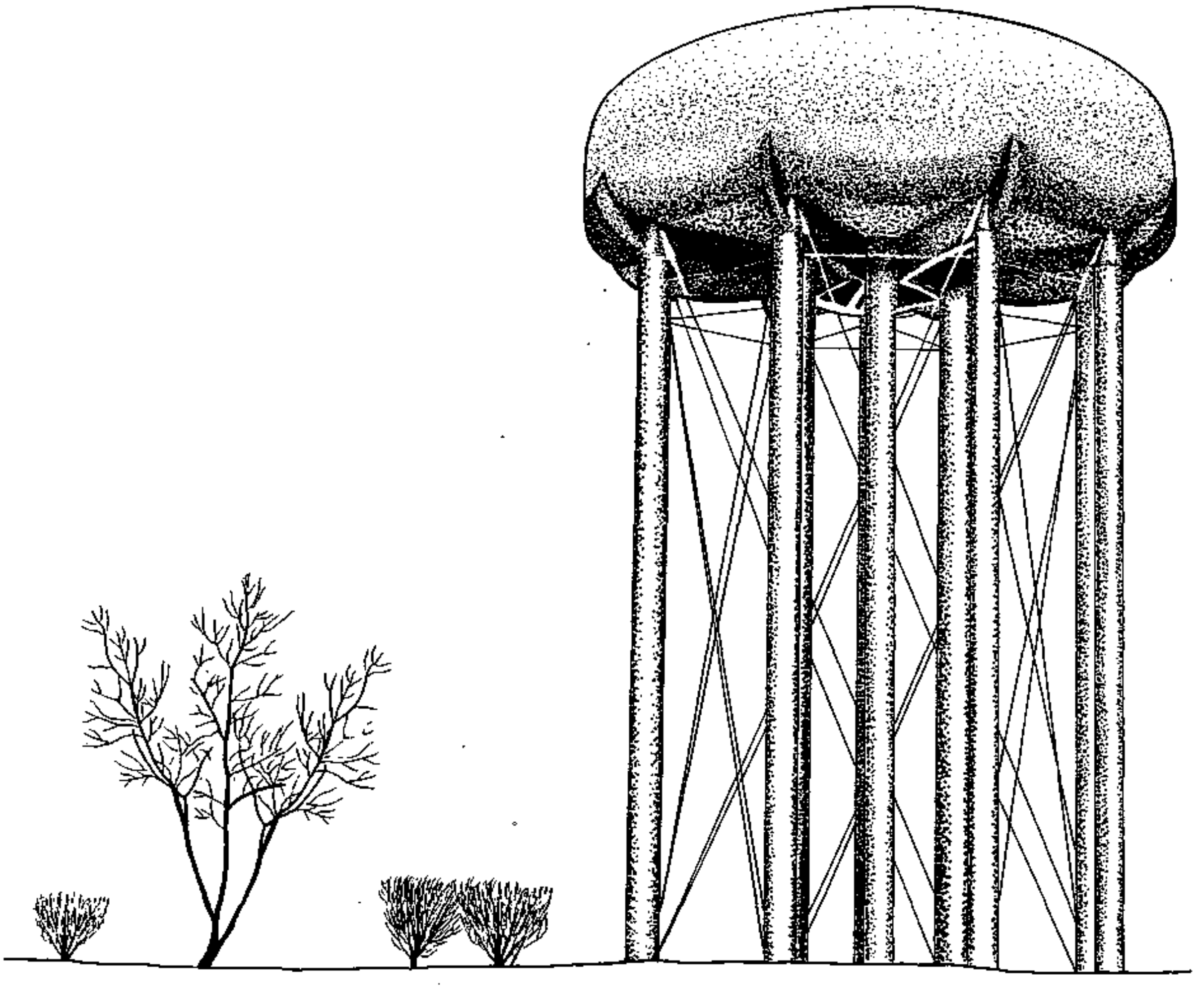
Coop 13

Regional Groundwater Resources in Western McLean and Eastern Tazewell Counties

with Emphasis on the Mahomet Bedrock Valley

John P. Kempton, Illinois State Geological Survey
Adrian P. Visocky, Illinois State Water Survey



1992 Cooperative Groundwater Report 13
Department of Energy and Natural Resources

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1 Location and summary of well and test hole data used, map scale 1:62,500
2 An interpretation of the bedrock topography of the confluence area of the Mahomet and Mackinaw Bedrock Valleys, map scale 1:62,500 (see fig. 10)
3 Distribution and elevation of the top of the Mahomet-Sankoty Sand, map scale 1:62,500 (see fig. 16)
4 Occurrence of Mahomet-Sankoty Sand and probable aquifer characteristics, map scale 1:62,500 (see fig. 18)

ABSTRACT

In this study, we examined groundwater resources and aquifers in the Mahomet Bedrock Valley, especially the Mahomet Sand and the Sankoty Sand and related aquifers in eastern Tazewell County. The study (1) identified potential aquifers capable of sustaining production of 20 to 50 million gallons of water per day (mgd), (2) estimated the rate and direction of groundwater flow and aquifer recharge potential, and (3) estimated the safe yield of the major aquifers.

Our purpose specifically was to compile all geologic and hydrologic information available in the confluence area of the Mahomet and the Mackinaw Bedrock Valleys to determine the areas where highly productive aquifers occur. In addition, areas with the greatest potential for the development of municipal groundwater supplies were identified. We also identified areas where inadequate data exist, but where further exploration may be warranted.

Our findings, based on the geologic maps and cross sections prepared during the study and analysis of the hydrologic data compiled, indicate that 70 to 75 million gallons per day of groundwater might be developed from some aquifers within the study area. These quantities of groundwater would most likely be developed from the deep, thick, and extensive sand and gravel aquifers contained within the buried Mahomet Bedrock Valley in southwestern McLean County and related aquifers within the buried Mackinaw Bedrock Valley of eastern Tazewell County.

Areas identified as having the greatest potential and overall suitability for municipal well-field development must be verified by test drilling and aquifer tests to ensure anticipated aquifer properties and provide data for proper development and management. More extensive exploration is necessary to locate the best sites for aquifer tests and, ultimately, production wells in areas with good potential. The database, although extensive (mainly drillers' logs of water wells), needs considerable enhancement both in quality and distribution to verify specific geologic and/or hydrologic conditions and conclusions.

ACKNOWLEDGMENTS

This project, a joint study of the Illinois State Geological Survey and Illinois State Water Survey, was supported in part by funds provided through the University of Illinois by a Joint Steering Committee including representatives from McLean County, the City of Bloomington, and the Town of Normal, with the City of Bloomington as contracting agent. George A. Farnsworth, Farnsworth and Wylie, P. C, Bloomington, IL provided technical coordination between the two Surveys and the Joint Steering Committee.

Jacquelyn L. Hannah, ISGS, and Scott C. Meyer, ISWS, provided technical assistance for the project. Ellis W. Sanderson, ISWS, and B. Brandon Curry and Keros Cartwright, ISGS, provided technical reviews of the manuscript and offered valuable suggestions.

INTRODUCTION

Background and Location of Study Area

Officials of the City of Bloomington, the Town of Normal, and McLean County are investigating the feasibility of developing a regional water system to serve western McLean County and eastern Tazewell and Woodford Counties. Among the various options being considered, is the development of a major groundwater supply to serve this region.

This cooperative feasibility study by the Illinois State Geological Survey (ISGS) and Illinois State Water Survey (ISWS) was funded by a Joint Steering Committee, which included representatives from McLean County, Bloomington, and Normal. The City of Bloomington was the contracting agent. In the study, we examined the western Mahomet Bedrock Valley aquifer and the aquifers of eastern Tazewell County. Three issues were addressed: (1) preliminary identification and mapping of potential sand and gravel aquifers capable of sustaining a production well field producing 20 to 50 million gallons per day, (2) estimation of the rate and direction of groundwater flow and the recharge potential of the regions aquifers, and (3) estimation of the safe renewable yield of the major aquifers.

All parties agreed that in this preliminary study the ISGS and ISWS would integrate and assess the adequacy of all available data and previous reports for the region. Furthermore, if the data and reports were considered inadequate by the ISGS and ISWS, the agencies would be prepared to submit a proposal for further work to the Joint Steering Committee.

This study was undertaken with a sense of urgency as a result of several factors. The most important of these are the (1) drought conditions experienced that threatened Bloomington's surface water supply in late 1987 through 1988, (2) increased need for water by the growing Bloomington-Normal metropolitan area, and (3) limited availability of groundwater within the immediate vicinity of Bloomington and Normal.

The study area (fig. 1) covered about 1,080 square miles, located almost precisely in the center of Illinois, and included portions of McLean, Tazewell, Logan, and De Witt Counties (fig. 2). With a combined population of nearly 100,000, Bloomington-Normal is the largest metropolitan area in McLean County. Although the study area is largely rural, Bloomington and Normal have attracted new manufacturing and service companies, as well as suburban developments. The cities of Clinton in De Witt County and Lincoln in Logan County (fig. 1) also have increasing water needs.

Our emphasis, however, was reviewing all data available in southwestern and western McLean County and eastern Tazewell County, an area considered to have the greatest potential for developing large groundwater supplies. We also looked at parts of northern De Witt and Logan Counties.

The surface topography of the area (fig. 1) reflects landforms left by the melting of the last continental glacier and subsequent weathering and erosion. The principal topographic features are (1) the glacial end moraines (ice-marginal positions), which form the relatively high ridges that trend generally northwest-southeast (see fig. 3), and (2) the stream valleys, which are the lowest features of the landscape and trend generally northeast-southwest.

Purpose and Scope

Our purpose was to review and compile all available data and previous reports on the region, and determine the extent of available data. If enough data were available, we were to map aquifer classifications and provide preliminary maps and estimates of groundwater availability. Because groundwater is a renewable resource, it is critical to provide enough information so

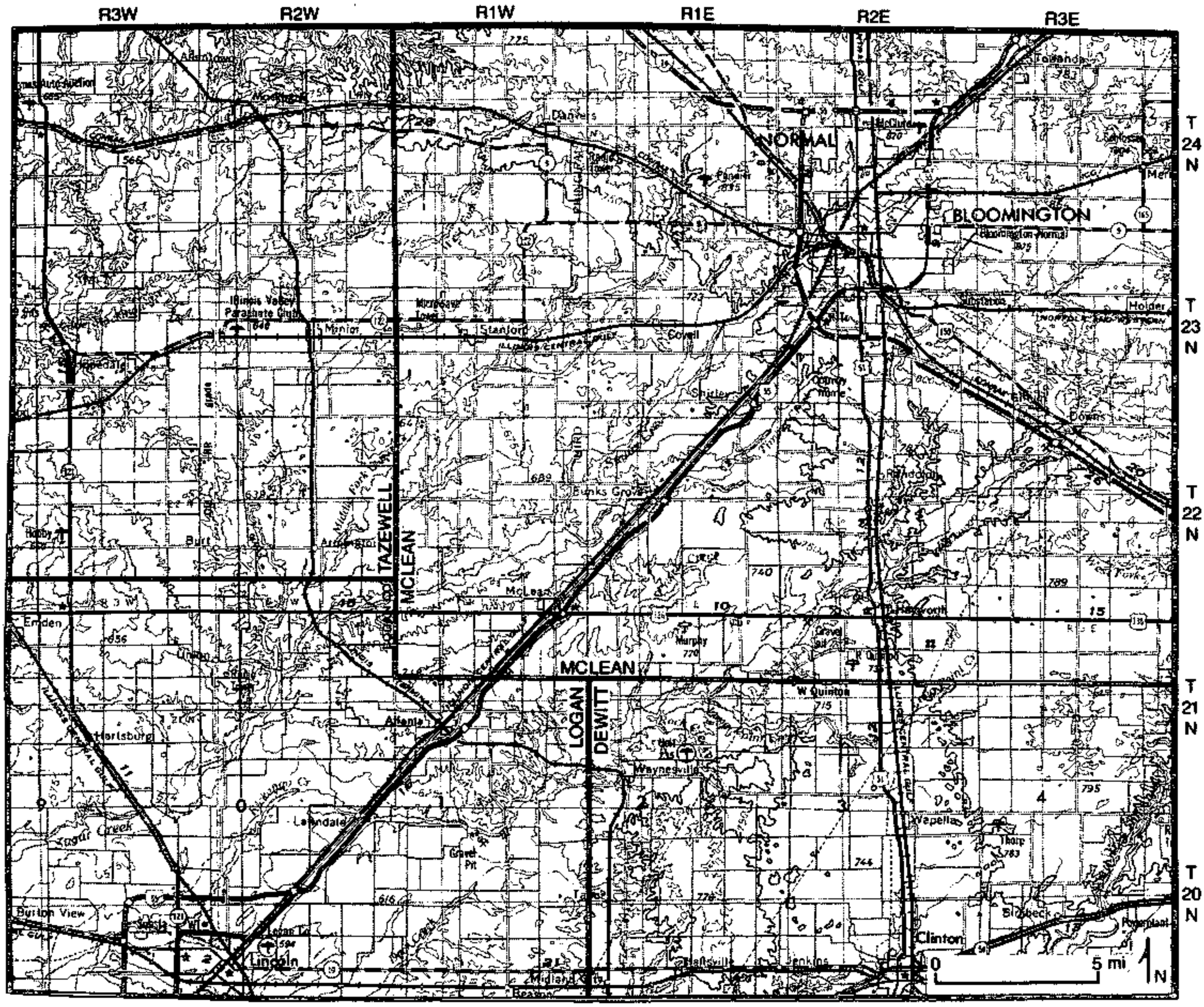


Figure 1   Portion of Peoria 1:250,000-scale topographic map showing study area.

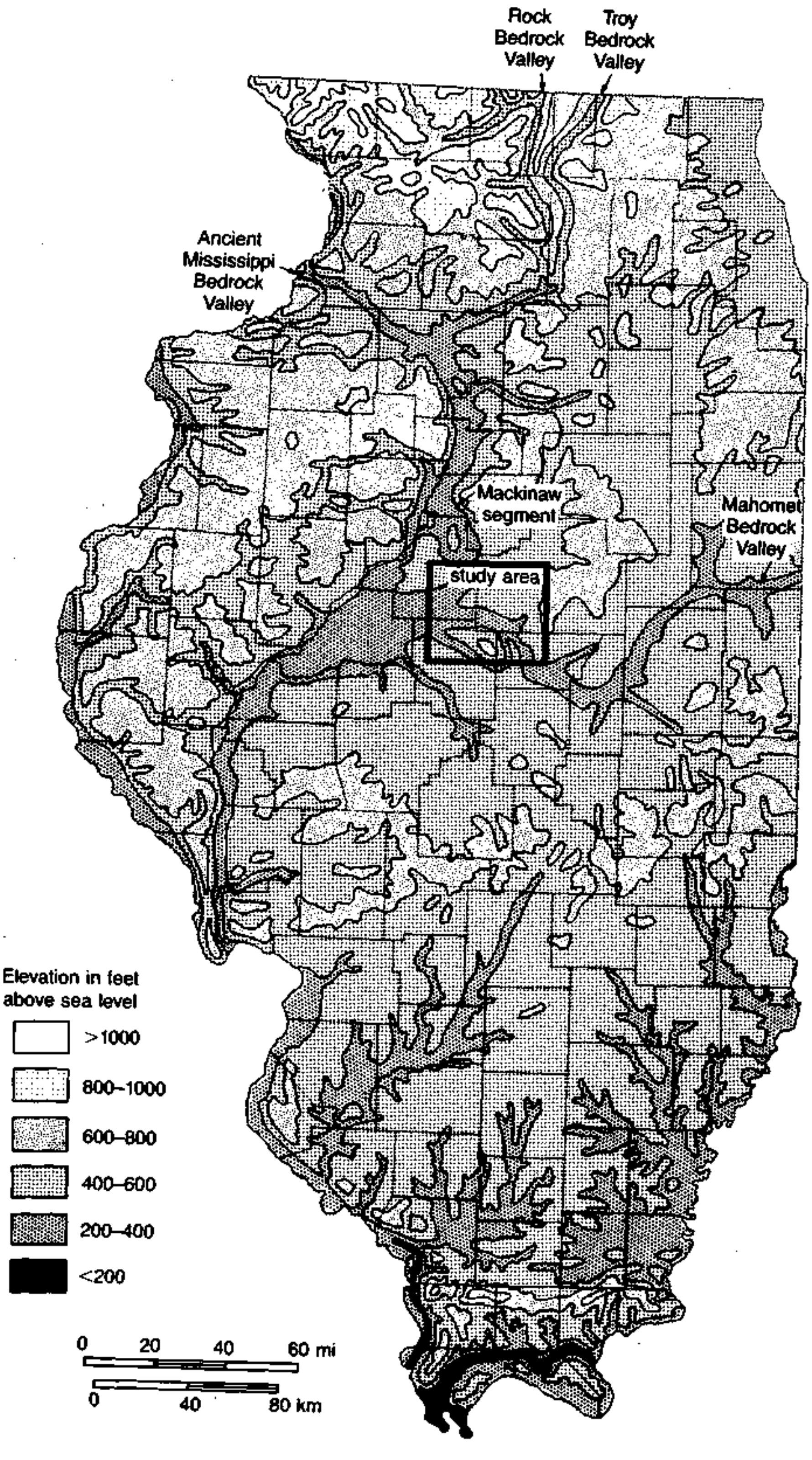


Figure 2 Generalized map of the bedrock topography of Illinois showing locations of Mahomet and Ancient Mississippi Bedrock Valleys and study area (modified from Willman and Frye 1970).

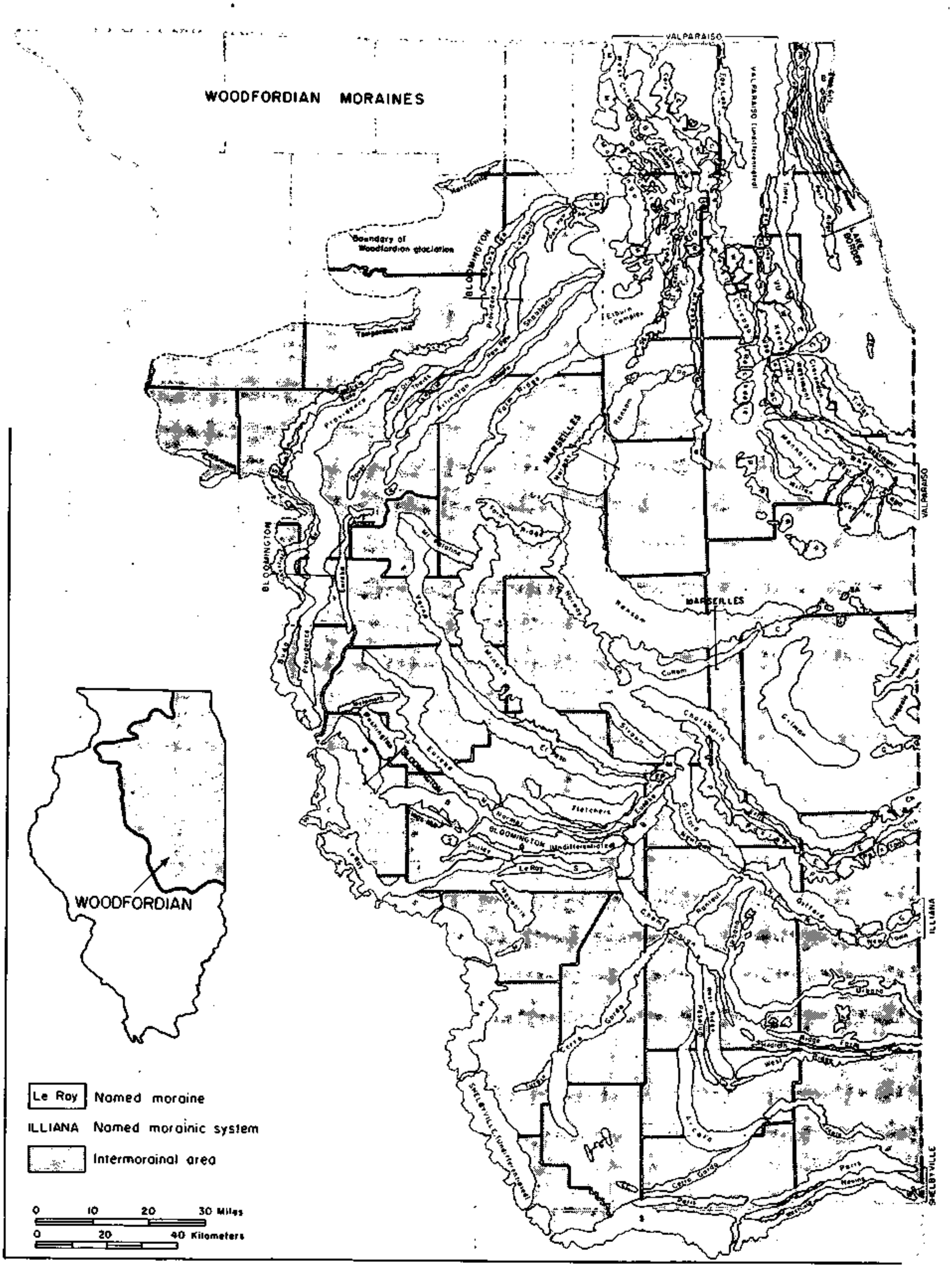


Figure 3 Woodfordian moraines of Illinois (from plate 1 in Willman and Frye 1970, which presents morphostratigraphic units in greater detail).

that the groundwater resource can be developed and managed in a manner that will ensure its availability in perpetuity for all users of the region.

We concentrated our study on the Mahomet Bedrock Valley in southwestern McLean County and the confluence area of the Mahomet with the Mackinaw segment of the Ancient Mississippi Bedrock Valley in westernmost McLean County and eastern Tazewell County (fig. 2). The thickest, most extensive sand and gravel aquifers are probably located within these bedrock valleys. We outline areas where, as indicated by our review, the potential is greatest for development of municipal groundwater supplies. We also describe areas where highly productive aquifers may occur, but available data are too limited for a confident appraisal.

Previous Studies

The bedrock of east-central Illinois has a very limited potential for development of municipal groundwater supplies. Therefore, recent geologic and hydrologic studies related to groundwater availability have focused on the glacial deposits (Foster 1953). Horberg (1945, 1950, 1953) and Piskin and Bergstrom (1975) provided some of the hydrogeologic background for later studies by establishing the regional character of bedrock topography and the thickness of overlying glacial deposits. One of Horberg's most significant contributions was the definition of major aquifers in east-central and central Illinois: the Mahomet Sand Member (Banner Formation) in the Mahomet Bedrock Valley and the Sankoty Sand Member (Banner Formation) in the Mackinaw Bedrock Valley.

A number of local and regional hydrogeologic studies of east-central Illinois have followed the work of Horberg. These include regional studies summarizing general groundwater conditions (Foster 1953, Selkregg and Kempton 1958, Kempton et al. 1982), a regional study focusing on the Mahomet Valley aquifers (Stephenson 1967), and local studies (Foster and Buhle 1951, Bergstrom et al. 1976, Hunt and Kempton 1977). Kempton et al. (1991) conducted the most recent regional study of the Mahomet Valley.

Hydrologic research includes the studies of groundwater availability in Piatt County by Sanderson (1971) and in Champaign County by Smith (1950) and Sanderson and Zewde (1976), as well as Visocky and Schicht's (1969) study of the Mahomet Valley aquifers. Specific data on public groundwater supplies have been provided by Hanson (1950) and Woller (1975). Visocky et al. (1978) and Wehrmann et al. (1980) made detailed assessments of selected groundwater supplies. Richards and Visocky (1982) evaluated the well field west of the Town of Normal in the Mackinaw Bedrock Valley.

GEOLOGIC SETTING AND CONTROLS OF GROUNDWATER AVAILABILITY

General Principles

An aquifer is a body of earth materials that will yield sufficient quantities of groundwater to a well for its intended use. Nearly all geologic materials will transmit water, but at different rates depending on the type of material (for example, very slowly through clay but relatively rapidly through gravel). The amount of water available from an aquifer during a given period of time depends on (1) the rates at which the materials transmit water, (2) the dimensions of the body of materials yielding water, and (3) the amount and rate of recharge to that body of materials. The thicker and more extensive the sand and gravel deposit, the greater its significance as a potential source of a municipal groundwater supply.

The availability of groundwater is, therefore, controlled by the nature and arrangement of the various earth materials beneath the surface. Because geologic conditions vary, groundwater is readily available in some areas and difficult to obtain in others. Consequently, gathering information on the distribution and character of aquifers assists in the proper development of groundwater resources.

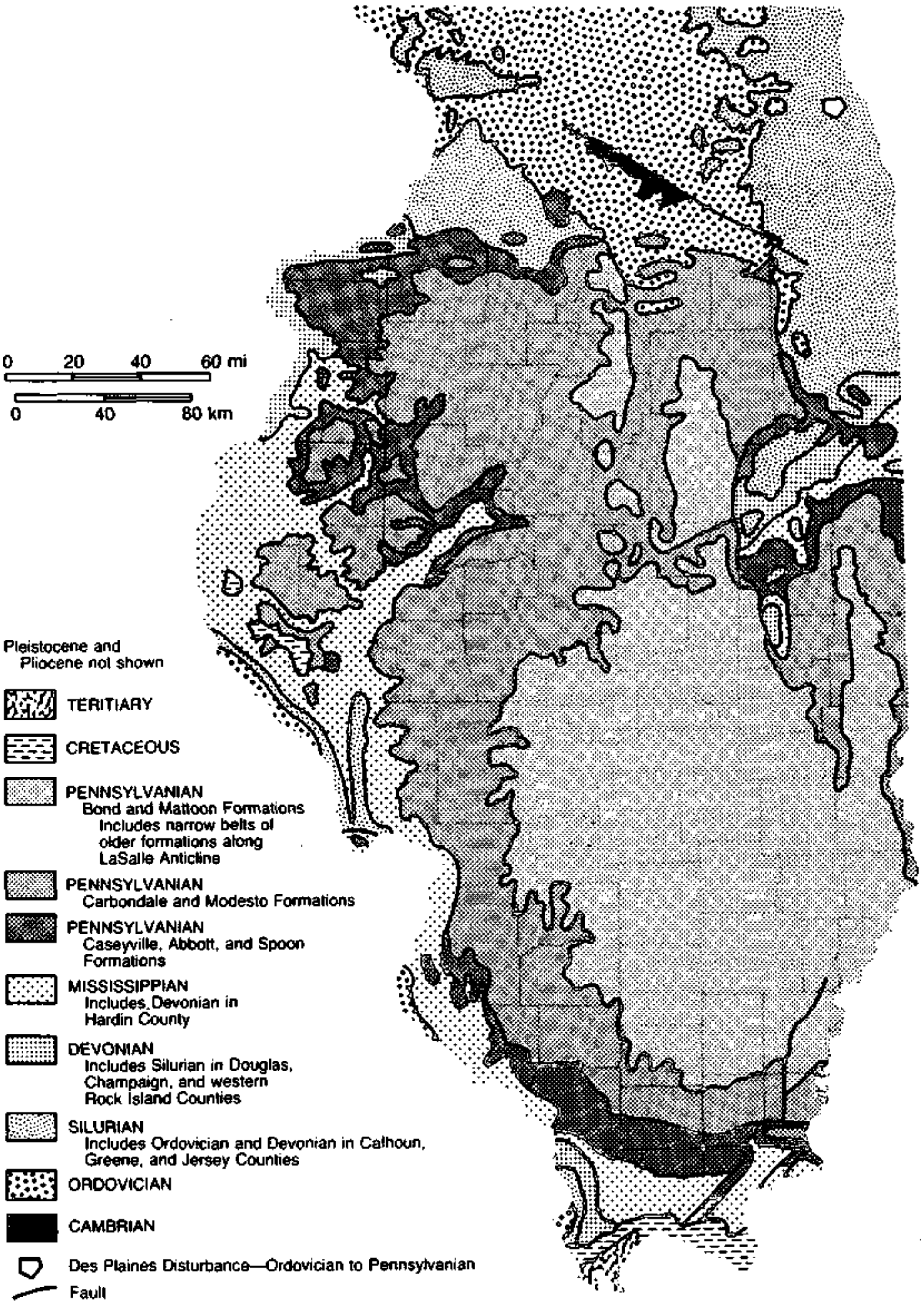


Figure 4 Bedrock geology of Illinois (from Willman and Frye 1970)

Geologic Setting

The bedrock formations in central Illinois (fig. 4) consist of a succession of sedimentary rocks several thousand feet thick, including sandstone, limestone, dolomite, shale, and coal. These sedimentary rocks were warped and tilted over many millions of years to form the Illinois Basin, which is centered in southeastern Illinois.

The older, generally deeper, rocks of central Illinois are mainly composed of limestone, dolomite, and sandstone, which frequently yield water. The younger rocks that are at or within a few hundred feet of the bedrock surface are composed largely of shale, which does not yield water, interbedded with a few, relatively thin layers of sandstone, limestone, and coal. In addition, below depths of 200 to 400 feet, water is generally nonpotable both in the younger and older rocks. Therefore, groundwater resources are extremely limited in the shallow bedrock and normally available only in small quantities where permeable sandstone or fractured limestone is encountered.

After the deposition of the sediments that now form the bedrock of the region, a long period of uplift resulted in the development of an erosional topography on the bedrock surface that included major river valleys and their drainage system of numerous large and small tributary valleys. The major bedrock valleys in Illinois are the Ancient Mississippi and Mahomet Bedrock Valleys (fig. 2). The Mahomet, along with the Rock and Troy Bedrock Valleys to the north were major tributaries to the Ancient Mississippi. The confluence of the Mahomet with the Ancient Mississippi lies in the southwestern portion of the study area.

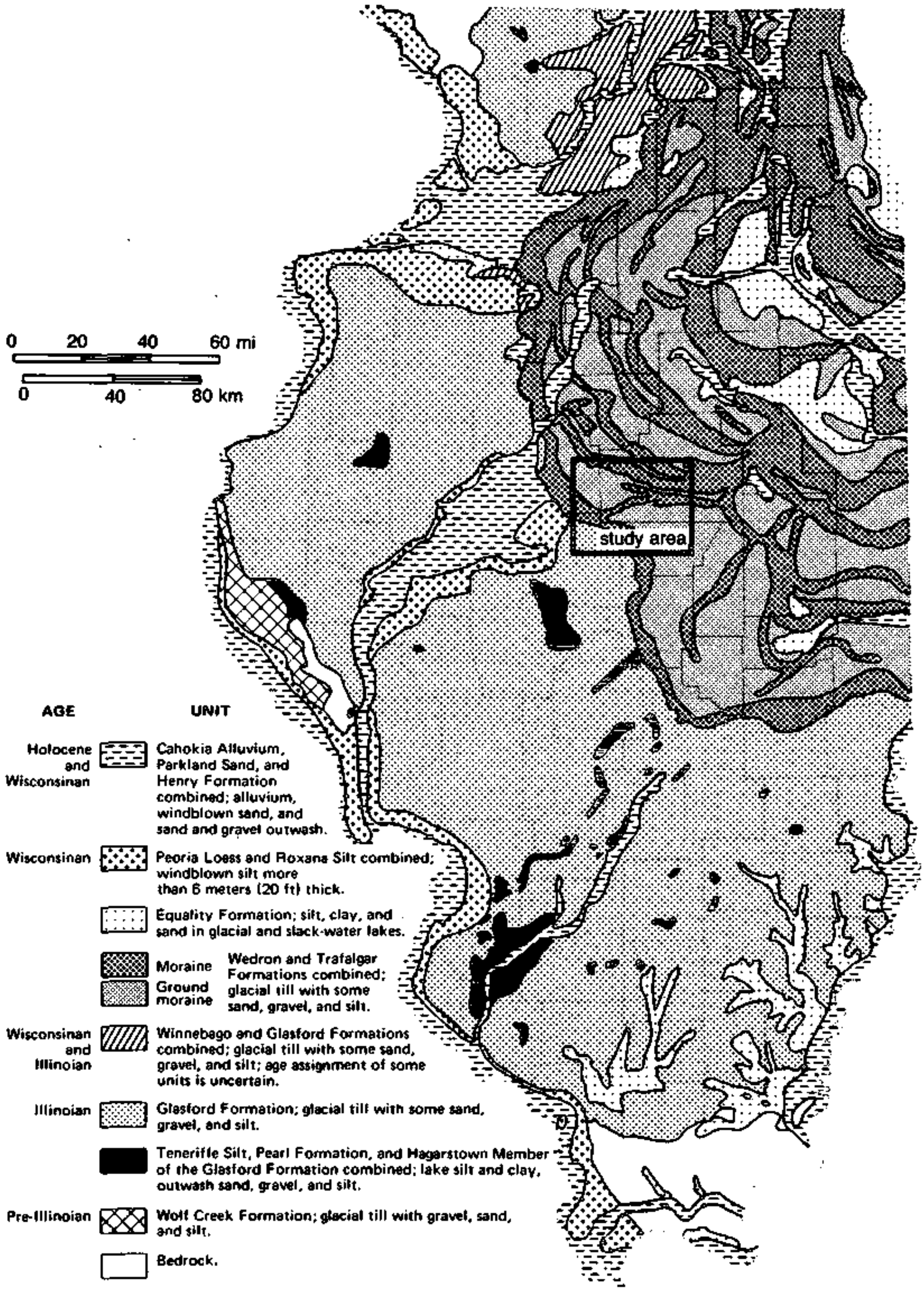
The onset of continental glaciation some 2 million years ago began the process of diversion, deepening, and ultimate burial of the bedrock valleys. Repeated pulses of debris-carrying ice covered much of Illinois (fig. 5); the older glaciers (pre-Illinoian and Illinoian) covered larger areas of the state than the youngest (Wisconsinan). As each glacier melted, it left a layer of debris, resulting in as much as 400 to 600 feet of material (commonly called glacial drift) covering the bedrock surface (fig. 6). These deposits can be classified and mapped from subsurface information (logs and samples from wells).

The onset of continental glaciation and the subsequent, repeated pulses of glaciers over central Illinois ending about 14,000 years ago profoundly changed the original bedrock landscape. The early glaciers (pre-Illinoian) significantly modified the preglacial bedrock surface by initially deepening the existing bedrock valleys through erosion from the surges of meltwater and later filling them with coarse sand and gravel, which acted to block and divert several major channels away from the glacial margins. Through such a complex series of events over 1.5 million years, the Mahomet Bedrock Valley and the Mackinaw segment of the Ancient Mississippi Valley were modified to the extent that the bedrock floor is now covered with as much as 150 feet of sand and gravel.

Figure 7 shows the possible thickness of sand and gravel (Mahomet Sand Member in the Mahomet Valley and Sankoty Sand Member in the Mackinaw Bedrock Valley) that fills the lower parts of each bedrock valley as interpreted from data available and studies completed through 1983. We suggest some modifications in this study.

DATA COMPILATION AND SOURCES OF DATA

The primary sources of data for the study of any subsurface material or resource come from logs and samples collected from drill holes or from geophysical methods, either surface or downhole. Samples or downhole geophysical measurements taken from drill holes are the most direct and definitive sources of geologic information on the depth to and nature of



Figur® 5 Generalized map of glacial deposits of Illinois (Lineback 1981).

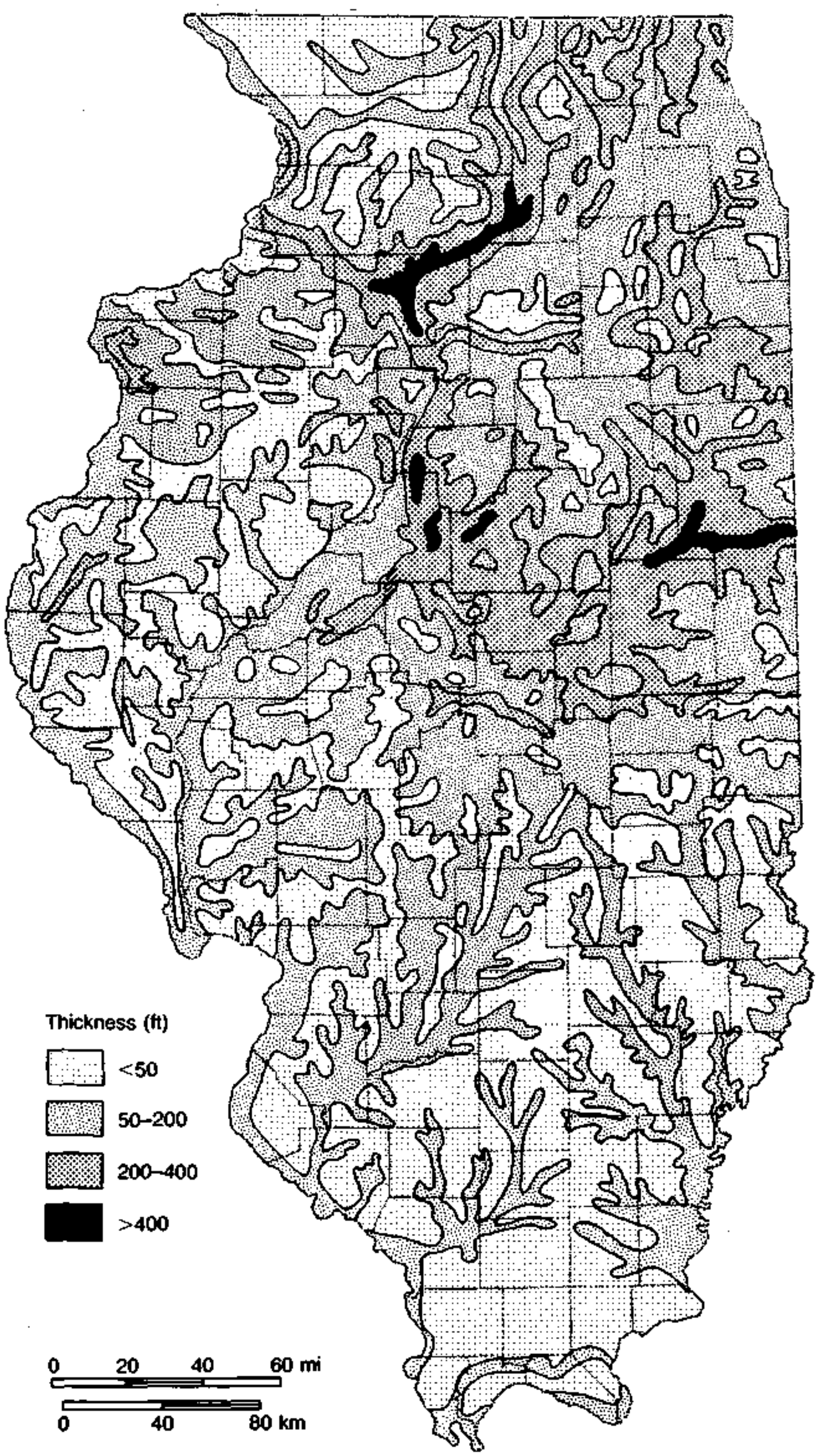


Figure 6 Thickness of Pleistocene deposits in Illinois (from Willman and Fyre 1970).

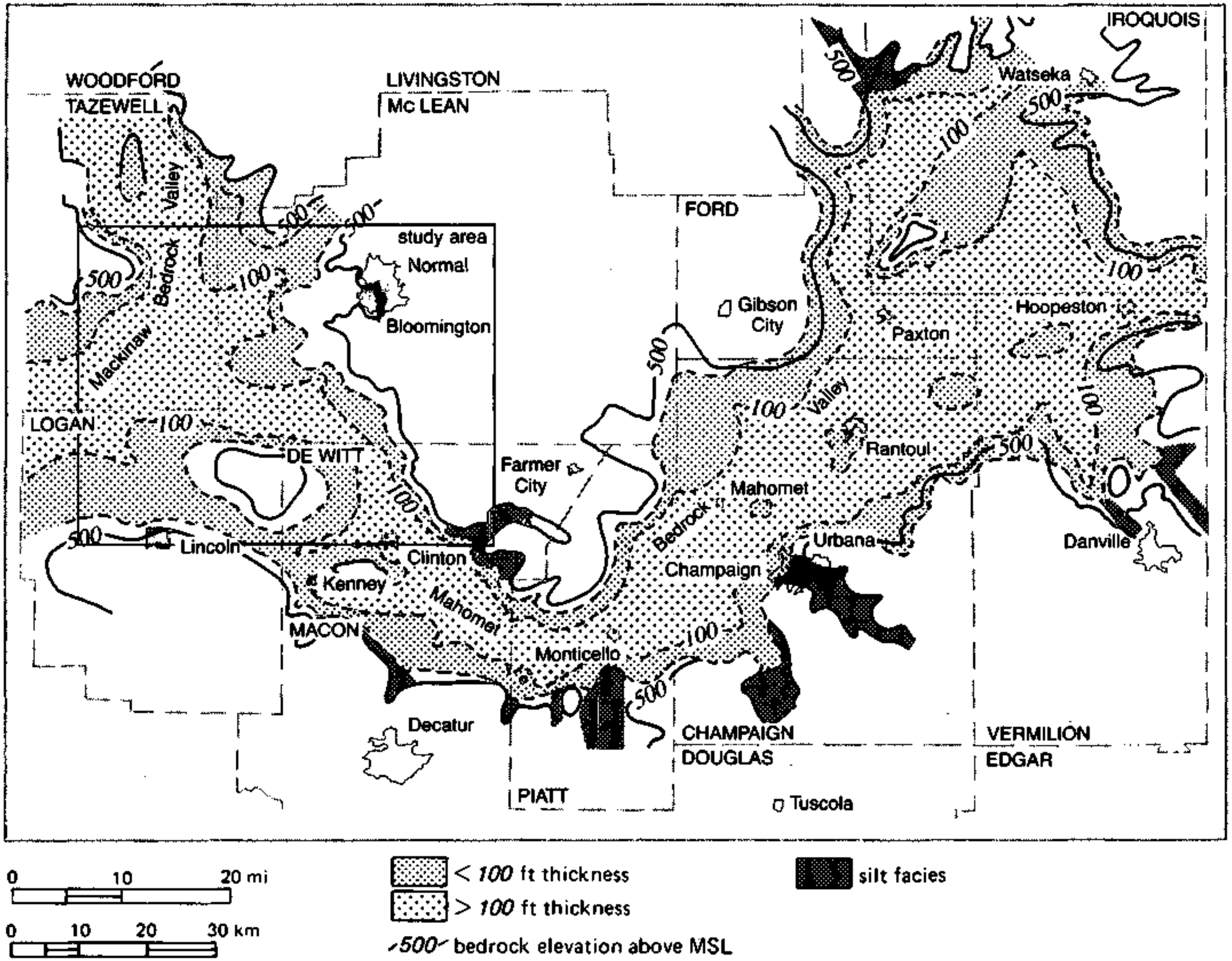


Figure 7 Thickness of the Mahomet and Sankoty Sand Members in east-central Illinois (from Kempton et al. 1991).

underlying materials. Hydrologic data such as permeability, potential yields of, and recharge to aquifers are determined by standard pumping test measurements of individual aquifers.

In western McLean and eastern Tazewell Counties, the primary sources of subsurface data are the logs of materials encountered and reported by private drilling contractors. These logs also contain information on well construction and static and pumping water levels. Well yields are generally given in gallons per minute. Other geologic data are available from downhole geophysical logs from a number of oil and gas and coal tests made in the region. The occurrence of sand and gravel aquifers and the top of bedrock can usually be determined from these logs. The locations of the well data used are shown on plate 1 (the plates are published separately as ISGS Open File Series 1991-14, Kempton and Visocky 1991).

In addition to the basic hydrologic data provided routinely by private drilling contractors, controlled pumping tests have been made for a number of wells in the region. The tests, often run over many hours or days, indicate the long-term yield of an aquifer, probable impact on nearby wells, and potential recharge to the aquifer.

Geologic Methods

For this study, we evaluated all available drillers' logs, sample descriptions, and downhole geophysical logs for the areas not previously studied in detail. When possible, we verified locations of wells, using plat books to match the well owner's name with the property location. For each location, the depth to and elevation of the bedrock surface, if encountered, was plotted along with the depth to and the thickness and elevation of the top of the principal sand and gravel aquifer encountered. Usually, the entire thickness of the aquifer in which the well was completed was not penetrated. We also plotted, when the data were available, the depth to and elevation of the static water level reported in the well when completed. Elevation of marker horizons such as buried "peat" were also recorded. These marker horizons provided stratigraphic data to aid in the correlation of the various geologic units.

Hydrologic Methods

Hydrologic information from the ISWS files included well-production test data from municipal, industrial, state-owned, institutional, and privately owned wells in the study area (table 1). Test data were analyzed for hydraulic properties of aquifers, including transmissivity and hydraulic conductivity. Where observation-well data were available, we also determined storage coefficients. In addition, the analysis of specific-capacity data provided estimates of transmissivity and hydraulic conductivity.

HYDROGEOLOGY

Glacial Geologic Framework

The glacial deposits covering the bedrock surface in central Illinois range in thickness from about 75 feet to more than 400 feet, and bedrock is not exposed in the study area. The thickest glacial drift is generally found over bedrock valleys and it averages more than 200 feet thick throughout the region. The drift, deposited during multiple fluctuations of the continental glaciers that entered the area that is now central Illinois, is composed principally of glacial till.

Glacial tills are mixtures of clay, silt, sand, gravel, and scattered boulders. They are widespread blanket deposits of individual glaciers. Although many tills have similar properties, each till sheet can usually be distinguished by a specific set of properties or by its relation to other identifiable underlying or overlying materials; therefore, its distribution can be mapped.

Glacial outwash is debris (e.g., sand and gravel) deposited by meltwater on the surface of the ice, in crevasses in the ice, in channels below the ice, or along or beyond the margin of the ice. If outwash is deposited as sheets along the margin of the ice, the deposits are called outwash

Table 1 Aquifer teats and specific-capacity data.

Well location	Well owner	Depth (ft)	Aquifer*	Land elevation (ft MSL)	Static level (ft)	Pumping rate (gpm)	Specific capacity (gpm/ft)	Analysis method†	Transmissibity (gpd/ft)	Hydraulic conductivity (gpd/sg ft)	Storage coefficient
De Witt											
20N2E-											
33.4h(l)	Westside Pk Est Tr Pk	108	W	722	27.44	8	0.2				
33.6h(2)	Westside Pk Est	66	W	720	31.15	9	0.3	T	634	317	
33.6h(2)	Westide Pk (deepened)	112	W	720	32.70	9	0.1	T			
33.6h(3)	Westside Pk Est	86	W	720	7.53	8	0.2	T			
34.1e(8)	Clinton (C)	338	B	710	104.65	620	60.2	T	85,500	900	
34.2d(6)	Clinton (C)	345	B	702	104.00	585	24.4	T	89,000	480	
34.2d(7)	Clinton (C)	345	B	702		265	19.6	S	100,000	940	
34.3d(3)	Clinton (C)	360	B	730	118.00	250	8.3	S	20,500	1,025	
34.3d(4)	Clinton (C)	344	B	702	106.24	200	8.7	S	165,000	1,040	
33.4d(5)	Clinton (C)	358	B	725	121.00	508	8.8	S	40,000	400	
35.7f(10)	Clinton (C)	360	B	725	123.58	1032	80.8	T	153,600	1,540	0.0004
35.8f(ll)	Clinton (C)	360	B	720	121.23	1180	80.7	T	170,000	1,910	0.0003
20N3E-											
22.3e(l)	Clinton Power	40	W		13.60	49	6.2				
32.2f(l)	Clinton Lake	80	W	745	25.00	10	1.3	T	1,200	150	
35.1c(2)	Clinton Marina	298	B	722	113.22	40	2.0	T	7,800	223	
21N1E-											
29.7b(8)	Waynesville (V)	207	G	725	94.35	54	3.7	T	4,700	204	0.0007
21N2E-											
34.3b(l)	Wapella (V)	78	W	750	16.70	233	8.1	S	16,500	750	
34.3b(l)	Wapella (V)	78	W	750	15.04	100	9.7	T	22,000	1,000	
34.3b(2)	Wapella (V)	79	W	750	18.00	230	38.4	S	88,000	4,000	
34.3c(3)	Wapella (V)	80	W	740	17.60	200	29.5	T	65,000	2,500	0.0004
LOGAN											
20N3W-											
24.1b(6)	Lincoln (C)	49	A	560	2.50	720	34.3	S	79,000	3,160	
24.8d(ll)	Ctrl I11 El Gas Co.	50	H	560	11.30	680	43.2	T	105,000	2,690	
21N1W-											
20.2c(TWl)	Atlanta (C)	134	G	690	99.29	33	8.1	T	20,250	1,446	
20.2c(l)	Atlanta (C)	191	G	720	133.71	64	2.0	T	12,000	860	0.0001
20.3e(2)	Atlanta (C)	147	G	720	110.35	65	3.9	T	15,000	1,000	0.0001
20.3e(3)	Atlanta (C)	158	G	690	104.20	46	3.0	T	4,000	444	
20.3f(5)	Atlanta (C)	142	G		111.82	49	4.9	T	15,000	1,154	0.0001
20.5e(4)	Atlanta (C)	150	G	690	110.80	110	7.2	T	17,000	945	
20.5e(TW4)	Atlanta (C)	150	G	690	111.40	21	5.1	T	16,300	906	
20.5e	Willow Farms Dairy	152	G	690	112.04	30	6.3	S	14,000	1,400	
21N3W-											
6.5b	Emden	124	B	598	41.00	205	14.6	S	62,000	2,580	
21.4a(l)	Hartsburg	96	B	600	49.20	18	6.0	S	10,500	660	
21.4a(2)	Hartsburg	105	B	600	52.60	40	2.3	S	7,300	290	
21.4a(3)	Hartsburg	103	B	603	46.86	52	6.2	T	30,000	1,200	
McLean											
21N2E-											
5.8h(l)	Heyworth (V)	62	H	685	20.00	155	103.3	S	120,000	2,110	
5.8h(2)	Heyworth (V)	61	H	680	23.20	325	101.6	S	120,000	2,110	

(Table 1 continued)

22N1E-											
16.6d(l)	IDOT MCL Co Rest Area	322	B		85.59	37	2.9	T	5,900	490	
16.7d(l)	I11 Div of Highways	322	B	680	82.83	36	1.4	T	2,400	200	
22N1W-											
6.1h(l)	Olympia High School	250	B	640	52.30	215	21.6	T	153,000	1,870	
35.1b	McLean (V)	353	B	709	108.00	43	1.0	T	8,500	470	
36.8b(4)	McLean (V)	332	B	700	108.28	205	11.6	T	155,000	2,385	
22N2E-											
4.4g(l)	Country Acres Subd	111	W	790	43.53	16	2.6	T	4,720	390	
32.7a(2)	Heyworth	59	H	682	10.00	317	105.7	S	125,000	2,120	
32.7a(TW8)	Heyworth	66	H	682	6.75	250	62.5	S	84,000	1,420	
34.8a(TWl)	Heyworth	96	H	750	21.00	47	0.9	S	1,600	145	
22N3E-											
4.2h<2)	Downs (V)	119	W	805	48.31	32	6.3	T	29,000	1,710	
4.4b(l)	Downs (V)	108	W	800	46.00	125	25.0	S	49,000	1,960	
4.4f(3)	Downs (V)	134	W	800	48.71	159	35.8	T	45,400	967	
23N1E-											
6.8h(100)	Normal (T)	345	B		162.82	1444	130.8	T	340,000	3,656	
6.8h[TW20)	Normal (T)	268	B	734	160.11	430	155.0	T	286,000	3,145	
6.8h(TW20)	Normal Ob Well	268	B		161.76			T	187,333	2,014	0.007
23N1W-											
10.1h(103)	Normal (T)	328	B	700	146.78	1050	57.9	T	141,400	1,300	0.0004
10.1h(TW21)	Normal (T)	324	B	693	121.36	576	31.0	T	119,000	1,380	
21.5c(l)	Stanford (V)	235	B	680	98.41			T	86,000	4,778	0.0002
21.5c(3)	Stanford (V)	247	B	680	96.00	81	22.1	T	89,100	2,410	
21.7d(4)	Stanford (V)	246	B	675	90.00	150	13.0	T	89,100	3,426	
23N2E-											
1.2a(l)	Colonial Meadow Subd	229	G	760	82.83	33	3.5	T	29,000	2,070	
5.7h(13)	Normal (T)	65	W	749	31.55	300	26.6	T	63,300	1,980	
5.8f(3)	Bible Truth Crus MHP	46	W	755	18.75	20	23.8	T			
5.8h(14)	Normal (T)	65	W	750	25.80	503	83.8	T	52,400	1,250	
6.2a(2)	Blm-Norm San Dist	55	W	735	18.80	125	81.7	S	101,000	2,810	
7.3h(l)	Blm-Norm San Di3t	25	W	735	17.91	18	15.2	S	14,000	930	
18.7g(l)	James Armstrong	87	W	770	56.51	34	15.6	T	99,800	8,300	
19.3e(l)	Paul L Beich Co	204	G	755	46.73	402	42.4	T	88,300	2,940	
27.2a(l)	Brookside Farms	90	W	755	24.22	50	7.2	T	18,900	1,890	0.00005
27.2b(2)	Brookside Farms	90	W	758	25.40	50	10.1	T	15,000	1,500	
27.2b(3)	Brookside Farms	127	W	765	29.70	100	11.0	T	12,970	763	
27.3a(l)	Brookside Farms	110	W	780	25.86	15	3.1	T	6,600	550	
27.3a(l)	Brookside Farms	110	W	790	69.20	29	1.9	T	4,800	680	
27.3b(lA)	Brookside Farms	116	W	772	30.25	34	0.9	T	5,300		
27.7a(2)	Crestwicke Cntry Club	95	W	770	17.02	15	9.1	T	12,100	807	
27. (2)	Brookside Farms Subd	90	W	770	36.01	68	10.9	T	18,000	1,878	0.0002
28.4h	Park City S MHP (E)	93	W	790	69.20	29	1.9	T	4,800	680	
28.4h	Park City S MHP (E)	93	W	780	25.86	15	3.1	T	6,600	550	
23N3E-											
5.8e(l)	MCL Co Highway Dept	49	W	850	13.16	11	0.8	T	730	183	
24N1E-											
9.4d	State Highway Dept	197	G	810	105.62	15	0.7	T	880	110	
9.7a(l)	Dave Grieder Sod Farm	280	G	811	181.03	55	7.2	T	2,800	875	

(Table 1 continued)

24N1W-											
23.1g(3)	Danvers (V)	416	B	825	284.50	100	9.1	S	38,500	1,170	
23.1h(4)	Danvers (V)	438	B	825	276.80	110	6.8	S	24,000	520	
35.2a(102)	Normal (T)	364	B	740	167.58	1409	106.7	T	470,000	2,626	
35.2a(TW)	Normal (T)	240	B		168.84			T	173,625		0.09
35.2a(TW)	Normal (T)	240	B		170.00	488	22.2				
36.5a(101)	Normal (T)	345	B	740	173.40	1409	143.3	T	546,000	3,413	0.06
36.5a(TW)	Normal (T)	243	B		173.00	480	25.3	T			
24N2E-											
14.6h(l)	Ironwood Golf Course	138	W	800	41.00	170	6.5	T	6,000	444	
20.1d(2)	ISO Golf Course	231	G	830	109.42	452	14.8	T	33,000	1,375	
20.3e(l)	ISU Golf Course	109	W	830	89.61	54	38.3	T	72,000	4,000	
20.3f(1)	ISU Golf Course	109	W	830	84.25	51	48.6	T	73,300	4,060	
22.5a(5)	Soldiers/Sailors Hme	108	W	800	55.00	200	40.0	S	80,000	3,960	
22.5c(3)	Soldiers/Sailors Hme	115	W	830		168	7.0	S	15,000	1,000	
22.5c(4)	Soldiers/Sailors Hme	106	W	830	46.00	180	13.8	S	26,000	1,730	
23.5f(l)	Firestone Rubber Co	217	W	800	61.00	152	11.5	T	100,000	3,030	
27.5g(6)	Normal (T)	85	G	780	13.70	240	53.3	S	203,000	5,640	
27.5g(7)	Normal (T)	94	W	780	37.50	259	92.5	S	190,000	7,050	
27.6d(8)	Normal (T)	38	W	780	18.00	205	82.0	S	120,000	6,860	
27.7c(5)	Normal (T)	35	W	775	7.28	450	43.9	S	71,500	4,080	
27.8f(4)	Normal (T)	217	G	785	190.00	200	117.6	S	255,000	7,100	
28.1d(3)	Normal (T)	210	G	785	176.00	690	115.0	S	240,000	12,600	
33.7g(10)	Normal (T)	57	W	757	26.33	490	66.2	T	45,000	2,500	
35.1h(l)	General Electric Corp	184	G	810	69.87	69	9.3	T	34,700	1,240	
Tazewell											
22N2W-											
22.5A	Armington (V)	213	B	630	37.50	23	6.5	S	14,000	820	
23N3W-											
26.6g(5)	Hopedale (V)	205	B	634	96.00	250	25.8	T	140,000	1,450	
24N2W-											
10.4h(TH75)	Ill Dept Conservation	295	B	660	124.71	1001	23.3	T	284,000	2,000	
10.	All wells averaged		B			1001		T	300,000	2,200	0.0006
17.6f	Mackinaw (V)	44	W	670	28.83	200	51.0	S	68,000	4,480	
18.4d(3)	Mackinaw (V)	41	G	600	28.00	185	46.3	S	62,000	4,760	
18.4d(4)	Mackinaw (V)	42	G	595	32.76	180	38.4	T	96,000	9,600	
18.4d(5)	Mackinaw (V)	151	G	600	67.40	190	40.0	T			
18.4d	Mackinaw (V)	37	G	600	26.57	29	31.2	S	58,000	2,000	
24N3W-											
19.3h(7)	Tremont (V)	202	B	660	125.55	398	17.7	S	55,000	1,180	
19.5h(6)	Tremont (V)	212	B	660	130.28	424	12.0	T	28,000	2,080	
19.6g(4)	Tremont (V)	154	B?	660	122.50	51	2.6	S	21,500	740	

*H - Alluvial (glacial outwash) deposits of Henry Formation or younger
W - Wedron Formation deposits
G - Glasford Formation deposits
B - Banner Formation deposits
(C) - City
(V) - Village
(T) - Town
(E) - Emergency

†S - Specific-capacity analysis
T - Time-drawdown or distance-drawdown analysis

plains. Valley trains result from outwash deposited downvalley from the ice, and ice contact deposits are associated directly with melting ice. Debris that collects on the surface of a melting glacier is also called ablation drift and may consist of both till and water-laid materials. Such deposits have been recognized from the study of present glaciers and by mapping the surficial deposits of glaciated regions such as east-central Illinois.

Glacial till commonly is present over much of the area covered by the glacier that deposited it; however, the occurrence of buried sand and gravel is usually less widespread and less predictable. Outwash plains are generally extensive. Other types of outwash deposits are more restricted in area, having formed as long-narrow channels or mounds and ridges of limited size and distribution.

High-energy meltwater streams that flow from a glacier transport relatively coarse- to medium-textured materials (e.g., sand and gravel) and some fine material (silt and clay), much of which is deposited as outwash. Glacial meltwater normally carries the fine silt and clay great distances. Occasionally, these sediments are trapped behind rapidly accumulating outwash, especially in tributary valleys, and are deposited as fine-textured (silt and clay) lake sediments.

All of the conditions described above occur in central Illinois throughout the succession of glacial deposits. Although the thicker and more extensive subsurface outwash materials have been identified and mapped (especially the Mahomet and Sankoty Sand Members), many thinner and less extensive sand and gravel deposits have been identified only in specific localities or from individual well records. The distribution of the surficial materials is now well known (fig. 5; Lineback 1979).

In figure 8, a generalized sequence is shown of the materials in the northern part of the study area that is very similar to the sequence in the southern part of the area as well. In the Mahomet Bedrock Valley, the Sankoty Sand Member in the Mackinaw Bedrock Valley would be replaced by the Mahomet Sand Member, but the deposits are otherwise similar. Collectively, these deposits are referred to as the Mahomet-Sankoty aquifer.

The pre-Illinoian deposits throughout this area (about 2,000,000-500,000 years old) are called the Banner Formation. (The pre-Illinoian deposits in western Illinois area are named the Wolf Creek Formation on fig. 5.) The pre-Illinoian are the oldest glacial deposits identified in the area and include the principal sand and gravel aquifer of the region, the Mahomet-Sankoty Sand aquifer. These sand and gravel deposits, where present, are found only within the bedrock valleys generally below an elevation of 500 feet (see fig. 7). Along the bedrock valley walls, these deposits may grade into fine-textured silts and sands or be interbedded with glacial tills directly deposited by the melting glaciers.

Identification of the tills of the Banner Formation is aided because they have somewhat different physical and mineralogical characteristics than the overlying tills; occasionally buried soil or organic deposits are found at the top, suggesting a significant period of time between deposition of the Banner Formation and overlying Glasford Formation. Banner Formation deposits are locally identified near the base of the glacial deposits on the bedrock uplands away from the major bedrock valleys. They are generally much thinner and contain only scattered, thin, and less extensive sand and gravel layers on the uplands.

The overlying Glasford Formation, deposited during the Illinoian episode of glaciation (500,000-150,000 years ago), is present throughout the study area and contains several sand and gravel layers, which are interbedded with tills and used as aquifers throughout the area. As indicated in figure 8 (and subsequent cross sections), one locally significant sand and gravel aquifer lies at or near the base of the Glasford Formation. This particular deposit is the deepest aquifer used within the Town of Normal. It also directly overlies the Mahomet-Sankoty Sand

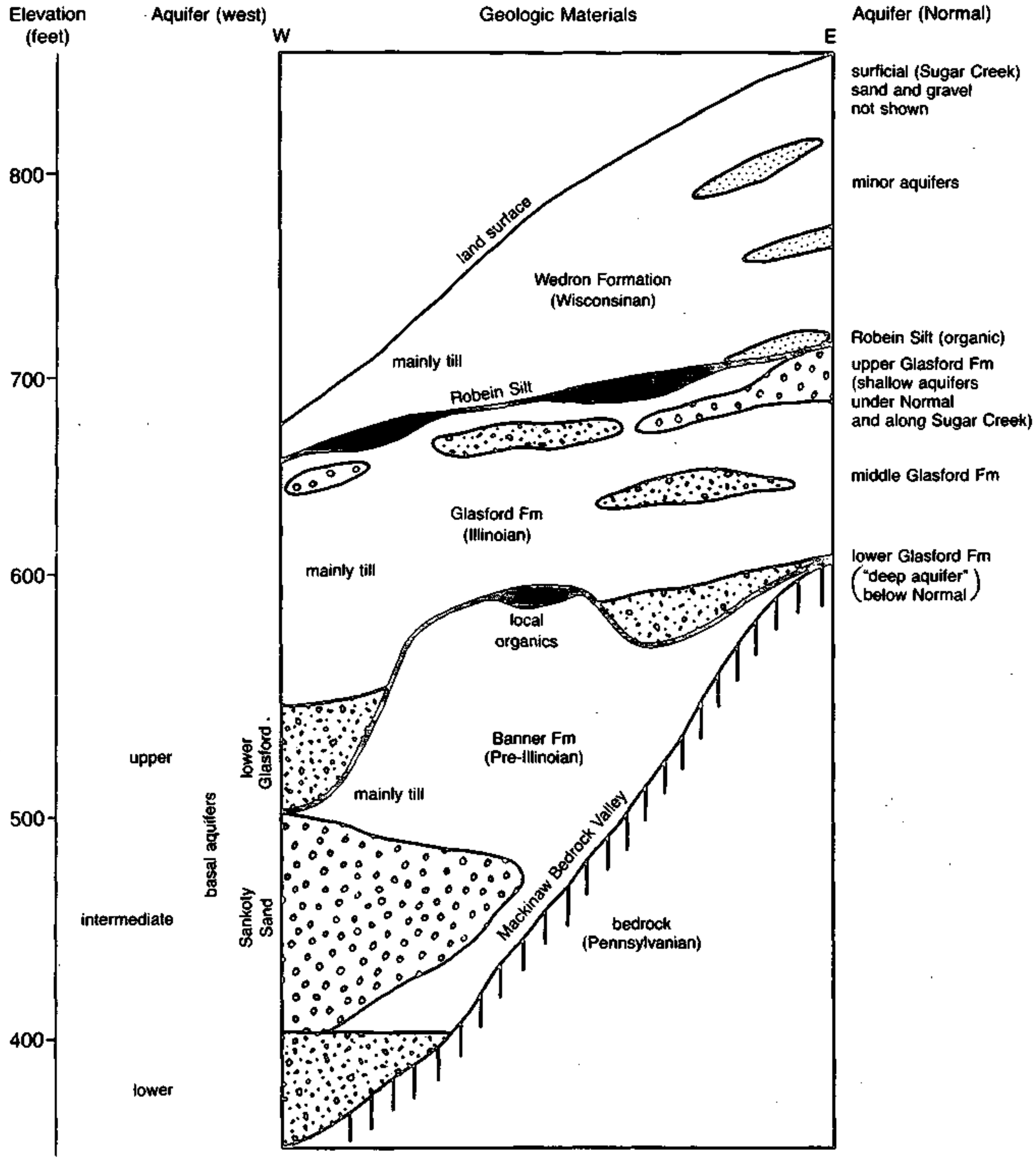


Figure 8 Diagrammatic sequences of geologic materials under the Town of Normal westward to Normal's West Well Field. The diagram shows the relative position of sand and gravel aquifers (from Vaiden and Kempton, in preparation).

aquifer locally within the area of Normal's West Well Field and elsewhere in the study area. Where directly overlying the Mahomet-Sankoty aquifers, the two aquifers are hydraulically connected.

The upper Glasford Formation sand and gravel may be regionally extensive, but it is often thin. It is used as an aquifer, however, for many individual farm and domestic groundwater supplies as well as for subdivisions and small commercial supplies. The top of the Glasford Formation is capped by a widespread buried soil, silt beds, and discontinuous organic deposits (Robein Silt) that provide a regional marker horizon.

The Wedron Formation, composed principally of till, was deposited during the Wisconsinan Age of glaciation (75,000-12,000 years ago) and is the uppermost of the glacial deposits in Illinois. Only scattered sand and gravel lenses are present within or at the base of the Wedron Formation. These are currently used only locally for small domestic and farm groundwater supplies.

The Henry Formation directly underlies the land surface along the principal streams of the area (Sugar Creek, Kickapoo Creek, Mackinaw River). These sands and gravel were deposited by outwash draining from the melting Wisconsinan glacier and may be as thick as 50 to 70 feet along these streams, although the average is 20 to 30 feet. Prior to Henry Formation deposition, each of these valleys was initially eroded into the Glasford Formation. Therefore, the sand and gravel of the Henry Formation may be directly connected in some places with the sand and gravel in the upper part of the Glasford Formation. In these situations, there is potential for development of moderate groundwater supplies (e.g., Kickapoo Creek near Heyworth, Sugar Creek in and just south of Bloomington-Normal; Vaiden and Kempton, in preparation).

Bedrock Topography

We prepared the map of the bedrock topography (fig. 9, pl. 2) specifically for this study, concentrating on the major bedrock valleys. More than 8 years of accumulated subsurface data have been added since the last regional map was completed. The map therefore includes some locally significant changes from previous maps, although use of previous regional maps is important to ensure integration with the regional patterns. We also used local maps prepared for recent studies for Normal (Kempton and Poole 1985, Vaiden and Kempton, in preparation), but modified them where new data and a more regional approach warranted. The new map, however, differs only in detail from that of Kempton et al. (1991) shown in figure 10.

The bedrock topography of the confluence area of the Mahomet and Mackinaw Bedrock Valleys is shown in figure 9 and plate 2. At Clinton in northwestern De Witt County, bedrock ridges separate the main channel from a narrower channel, the Kenney Valley, to the southwest. The main channel turns nearly west in southwestern McLean County, then opens into the wide lowland of the Mackinaw Valley segment of the Ancient Mississippi River Bedrock Valley at the southeastern corner of Tazewell County. The narrower channel, beginning near the Village of Kenney, trends in a northwest direction across northeastern Logan County, joining the Mackinaw Valley about 12 miles west of the confluence of the Mahomet.

The Mahomet Bedrock Valley appears to be graded to (at the same elevation as) the Mackinaw Bedrock Valley, with the deepest part of each valley at or just below an elevation of 350 feet. The confluence area of the Mahomet with the Mackinaw forms a wide bedrock lowland emphasized by the Danvers Bedrock Valley opening into the lowland from the northeast (fig. 9) just west of Bloomington and Normal.

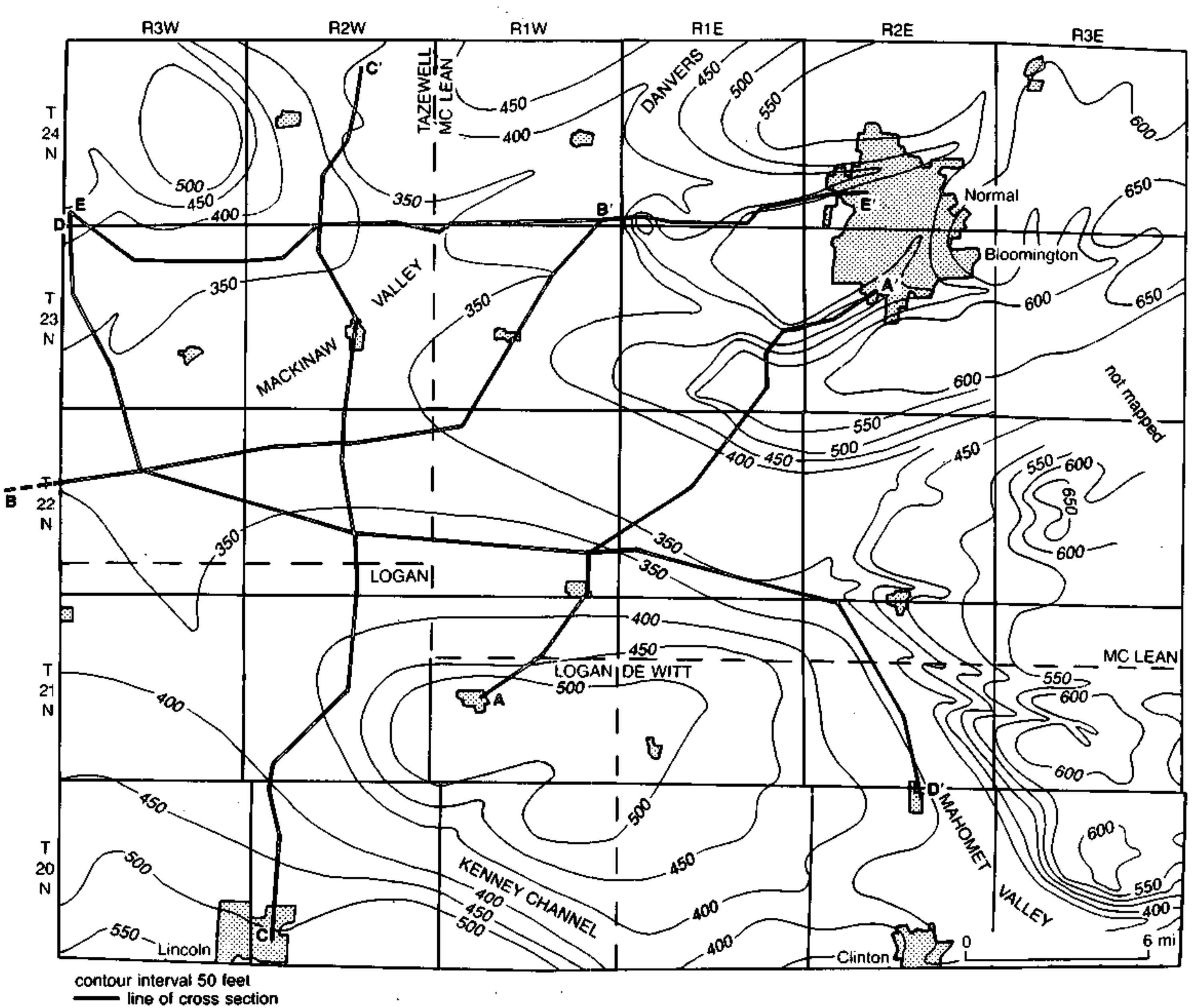


Figure 9 Bedrock topography of study area showing location of lines of cross sections presented in figures 11-15 (see plate 2; plates should be used as primary source of information—figures represent a summary).

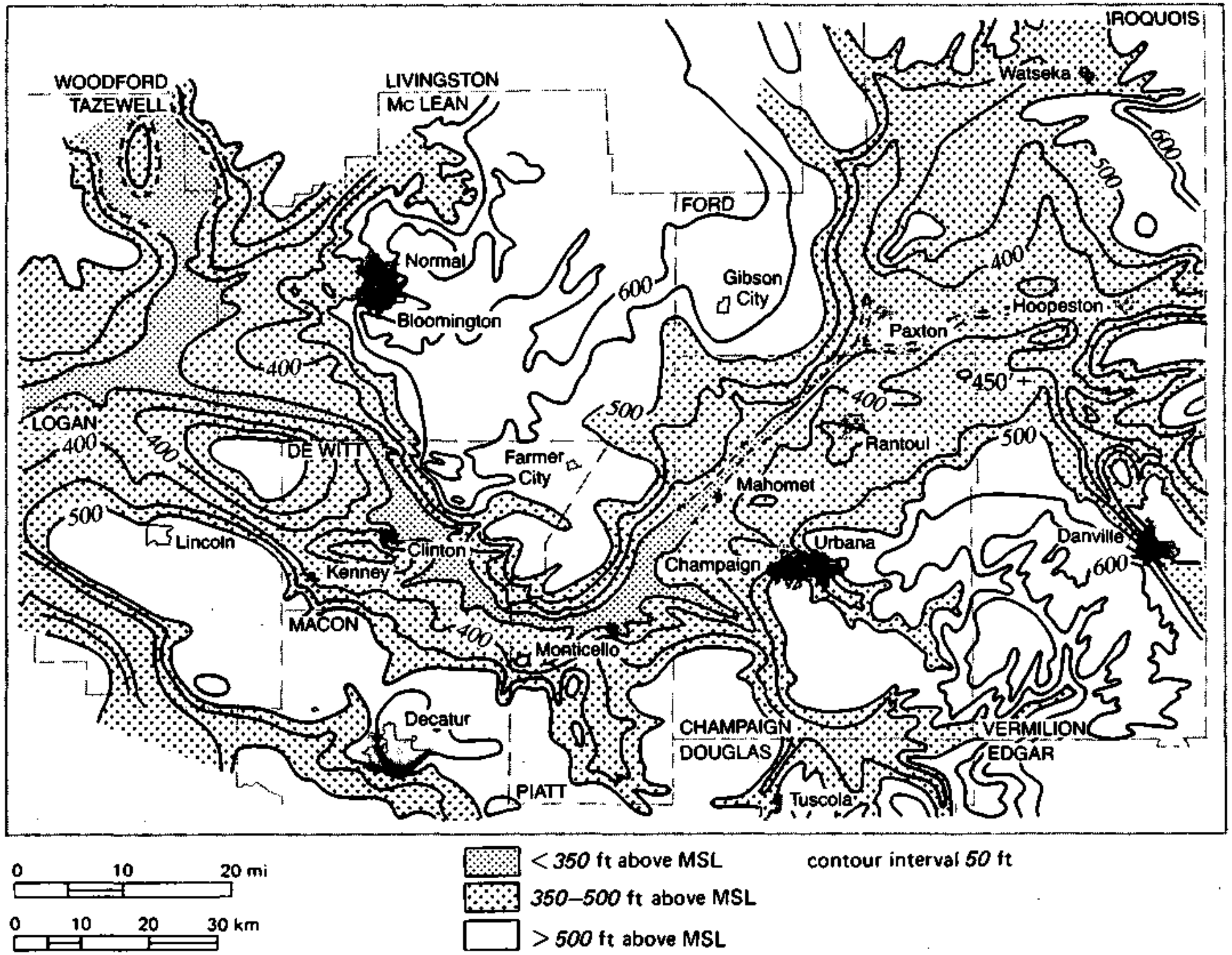


Figure 10 Bedrock topography of the buried Mahomet and Mackinaw Bedrock Valley systems in central Illinois (from Kempton et al. 1991; see pl. 2).

Description and Distribution of Principal Aquifers

The location of the lines of cross section (figs. 9, 11-15) were selected to show the relationship of the various materials, particularly the sand and gravel aquifers, to each other and to the bedrock surface throughout the study area, using the best subsurface data available. Where the continuity of a given layer was unclear, we made no attempt to show such continuity.

Cross section A-A' (fig. 11) shows the relationship of the Glasford Formation (Illinoian) sand and gravel aquifers to the Mahomet Sand Member aquifer. In particular, it shows the coarse-textured (sand and gravel) and fine-textured (sand and silt) materials of the Mahomet Sand Member in this portion of the Mahomet Bedrock Valley near the confluence with the Mackinaw Bedrock Valley. The coarsest deposits are in a relatively narrow channel near the center of the valley. The channel apparently was eroded into older, generally finer textured materials.

Cross section B-B' (fig. 12) shows the sequence of deposits across the Mackinaw Bedrock Valley. The relationship of interest is that of the Sankoty Sand Member to the land surface just west of the study area (near Delavan) where the overlying glacial tills are absent. Here, sand and gravel is continuous from the land surface to bedrock; the Sankoty Sand Member is directly overlain by younger sand and gravel deposits (Henry Formation) to the land surface. Also of importance is the relationship of the basal Glasford Formation sand and gravel directly overlying the Sankoty Sand Member in the Normal West Well Field because the two aquifers are hydraulically connected in this area.

Cross section C-C' (fig. 13) is an interpretation of the sequence of materials from the south wall of the Mackinaw Bedrock Valley near Lincoln northward across the broad floor of the Mackinaw Bedrock Valley as it turns northward just west of the confluence of the Mahomet Bedrock Valley. Of note in this cross section is the implication that most wells are finished in the Lower Glasford Formation sand and gravel, but only a few penetrate the Mahomet and Sankoty Sand to bedrock. There is a possibility that the top of the Sankoty Sand Member may actually rise to slightly above elevation 500 feet in northern Logan County. The margin of the Wedron Formation is marked by the Shelbyville Moraine about 10 miles north of Lincoln (fig. 3).

Cross section D-D' (fig. 14) traces the sequence of deposits from the northwest bedrock wall of the Mackinaw Bedrock Valley across the confluence of the Mahomet Bedrock Valley and then follows the channel of coarser deposits up the Mahomet Bedrock Valley to Wapella. The lower Glasford Formation sand and gravel appears to be well developed mainly in the Mackinaw Bedrock Valley area. There appears to be no change in the elevation or general character of the Sankoty and Mahomet Sand Members in the confluence area when considering only the coarse channel deposits in the Mahomet Valley.

Cross section E-E' (fig. 15) is an expansion and reinterpretation of previous W-E cross sections (Richards and Visocky 1982, Kempton and Poole 1985, Vaiden and Kempton, in preparation) across the Normal West Well Field. It shows the relationship of the west well field sequence to that under Normal and westward to the west bedrock valley wall of the Mackinaw Bedrock Valley. The complexity shown in the area of the West Well Field may in part be a function of the amount of data available. It now appears, however, that there is a more complex sequence of deposits along the northeast-east valley walls of the Mahomet and Mackinaw Bedrock Valleys. An older sequence of interbedded outwash, tills, and more finely textured materials has been partially protected from erosion by its position near the bedrock valley walls. The channeling effects of later streams and subsequent filling of the main valleys with sand and gravel are indicated by this cross section in both the Banner and Glasford Formations. This complexity of deposits along the east valley wall has had a significant impact in evaluating the groundwater resources of the West Well Field (Richards and Visocky 1982).

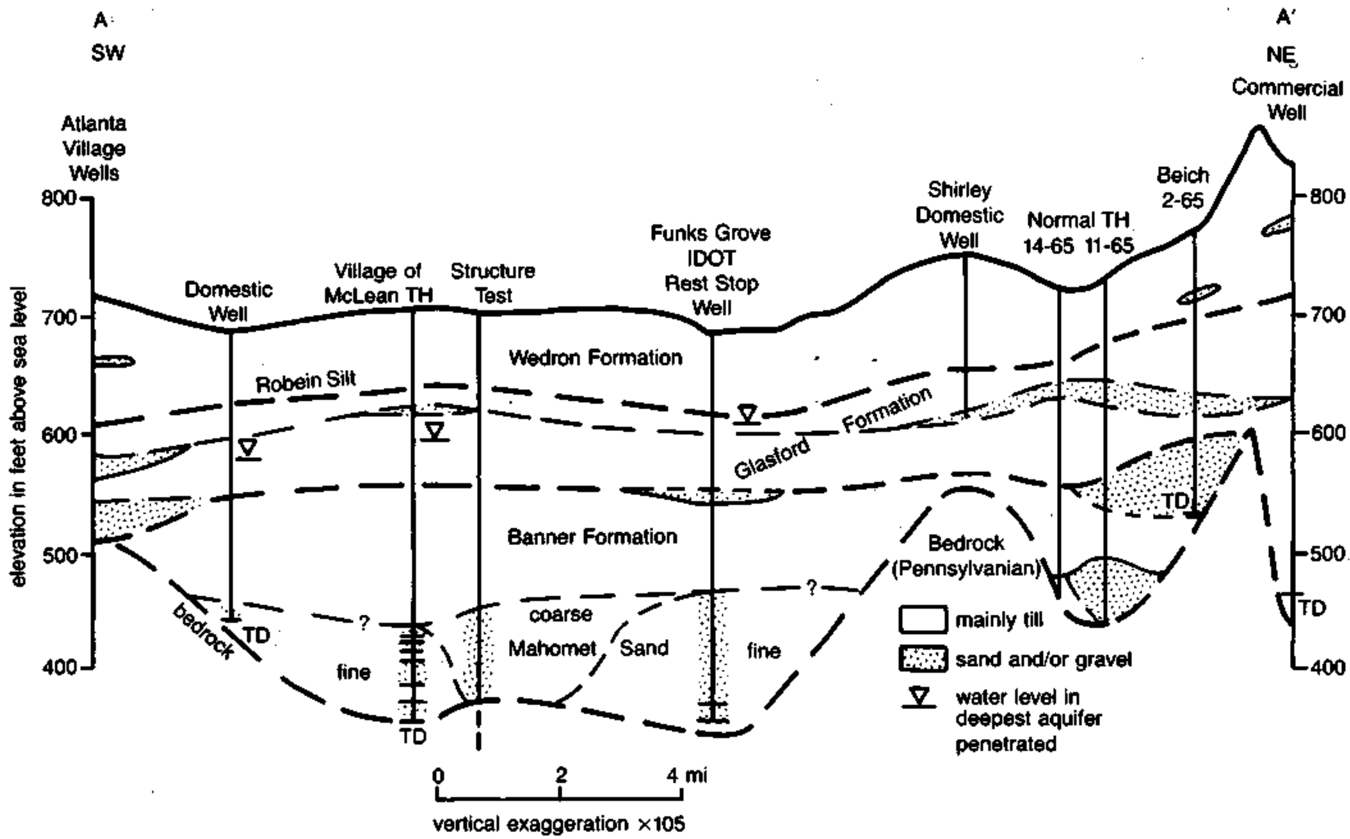


Figure 11 Cross section A-A', southwest to northeast cross section from Atlanta to Bloomington across the Mahomet Valley.

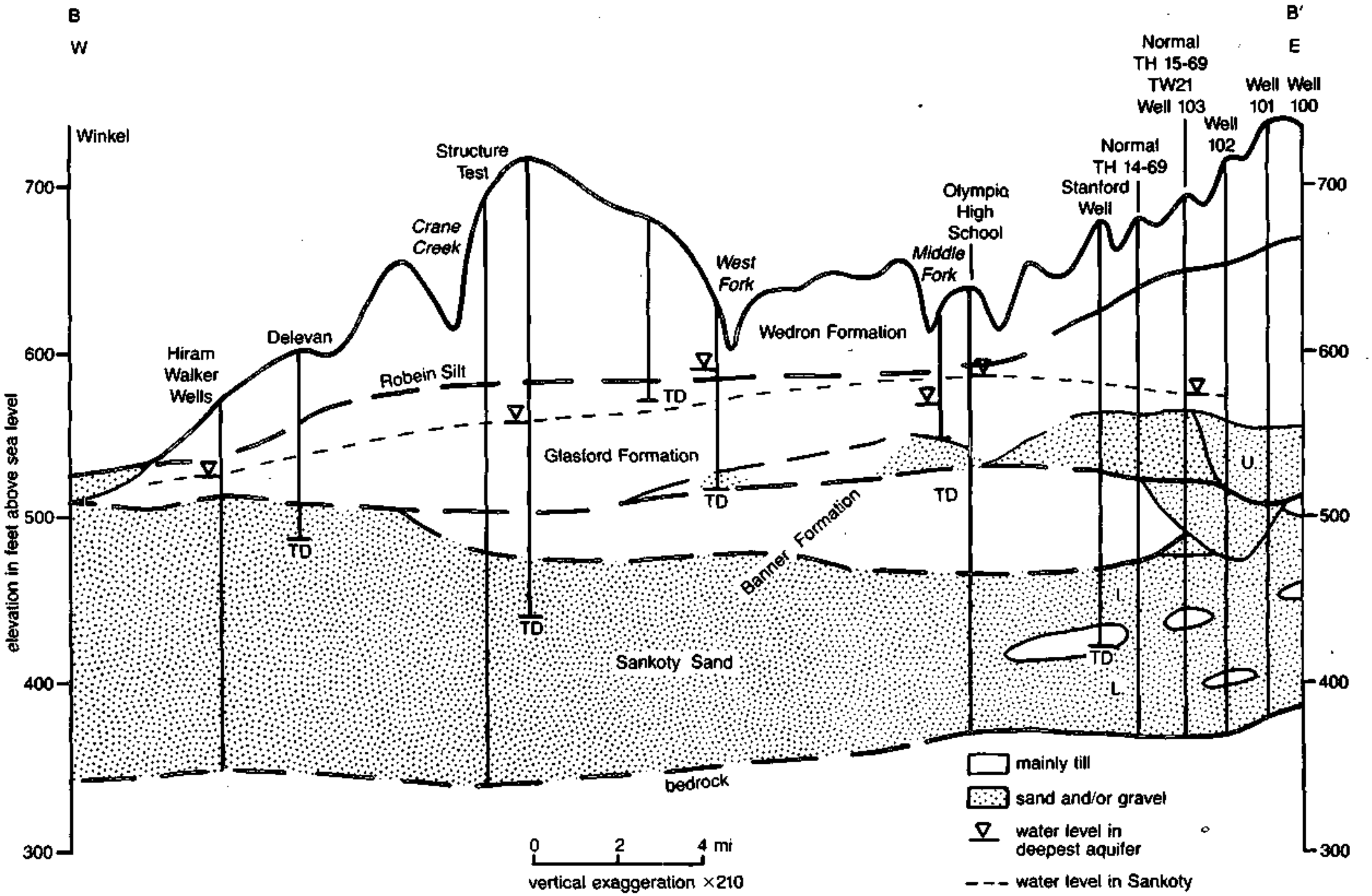


Figure 12 Cross section B-B', generally west to east cross section from just southwest of Delavan to Normal's West Well Field showing sequence within and across the Mackinaw Bedrock Valley (U: upper aquifer; I: intermediate; L: lower; see fig. 8).

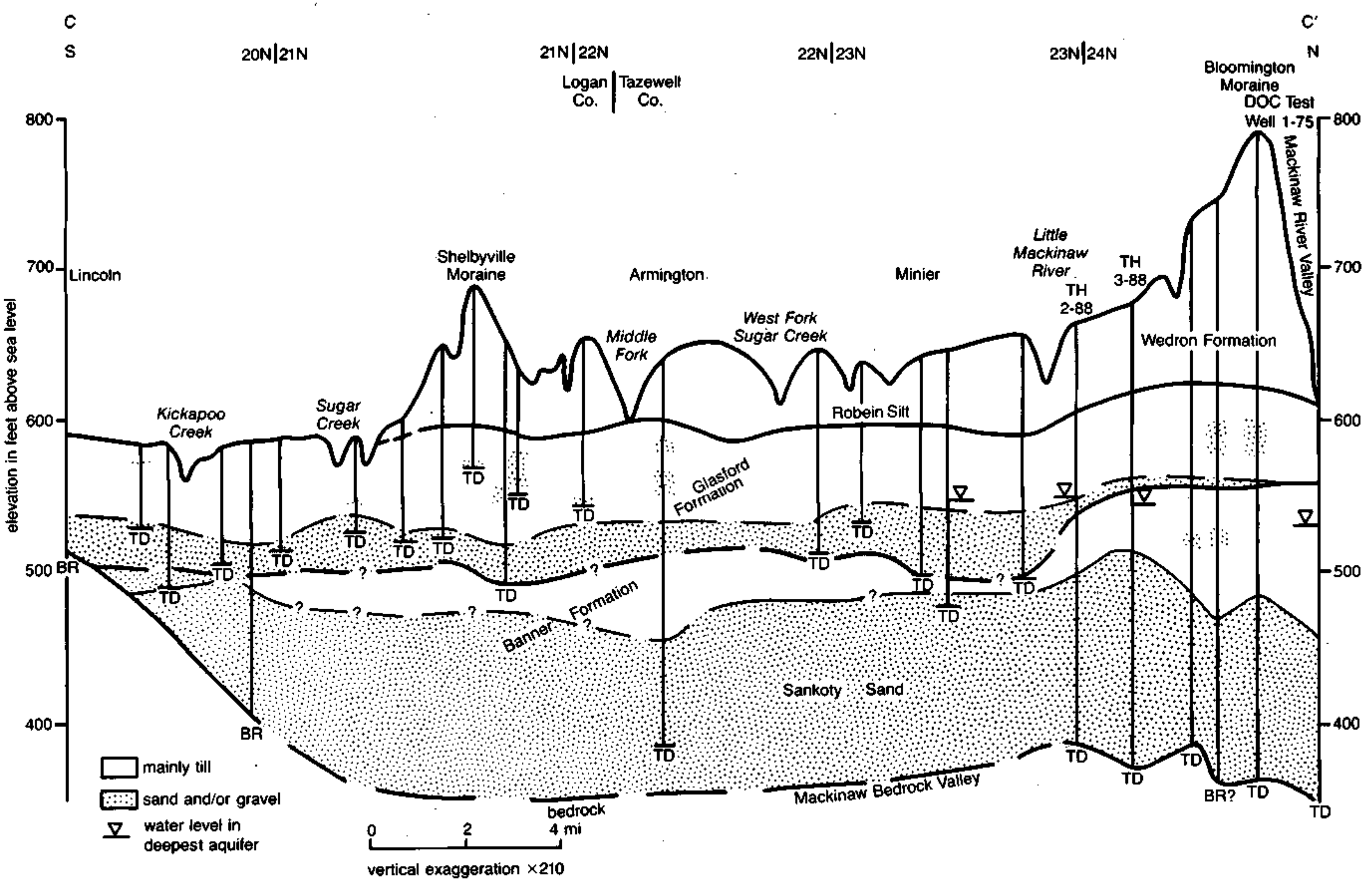


Figure 13 Cross section C-C', south to north cross section from Lincoln to just east of the Village of Mackinaw.

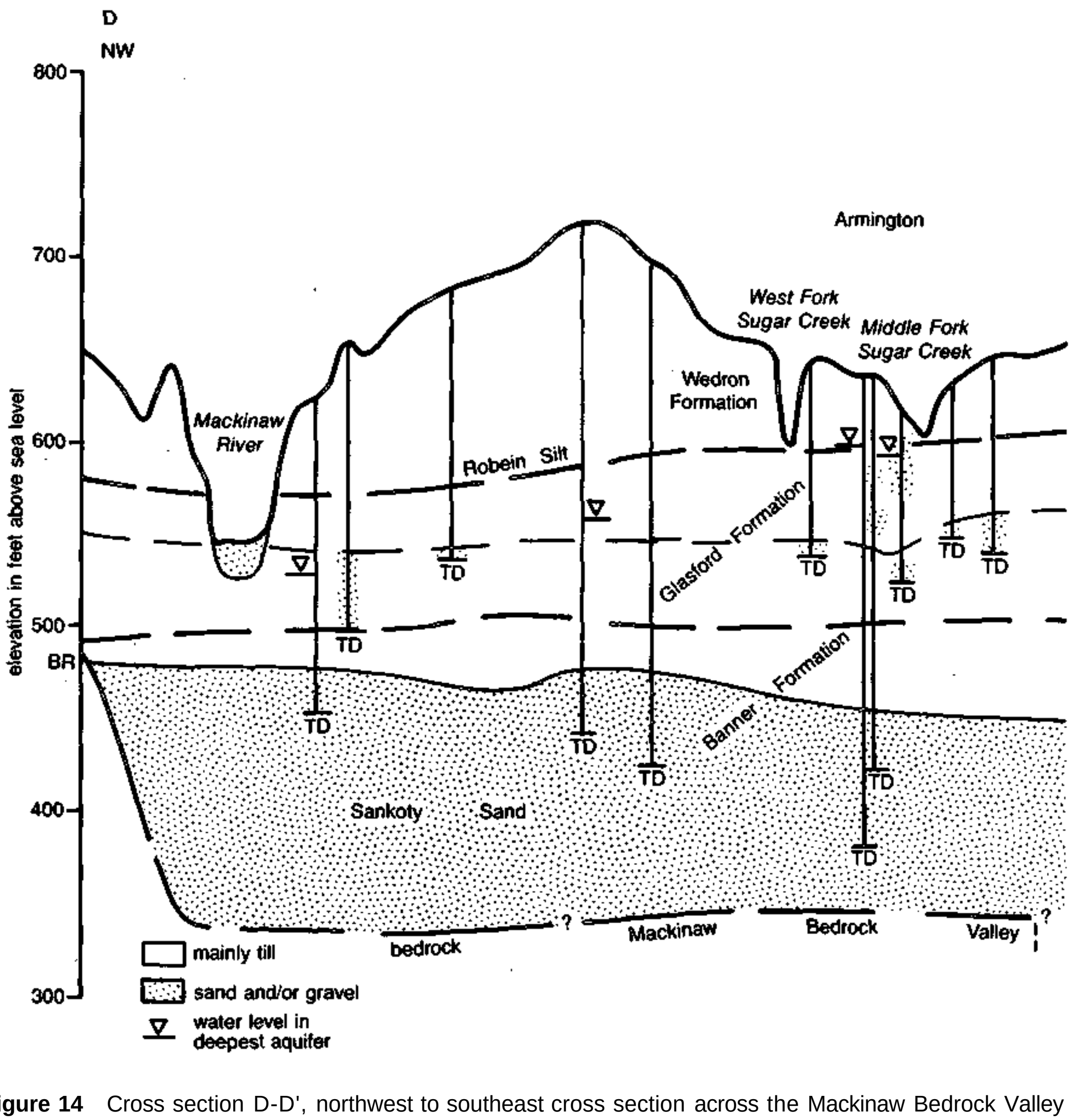
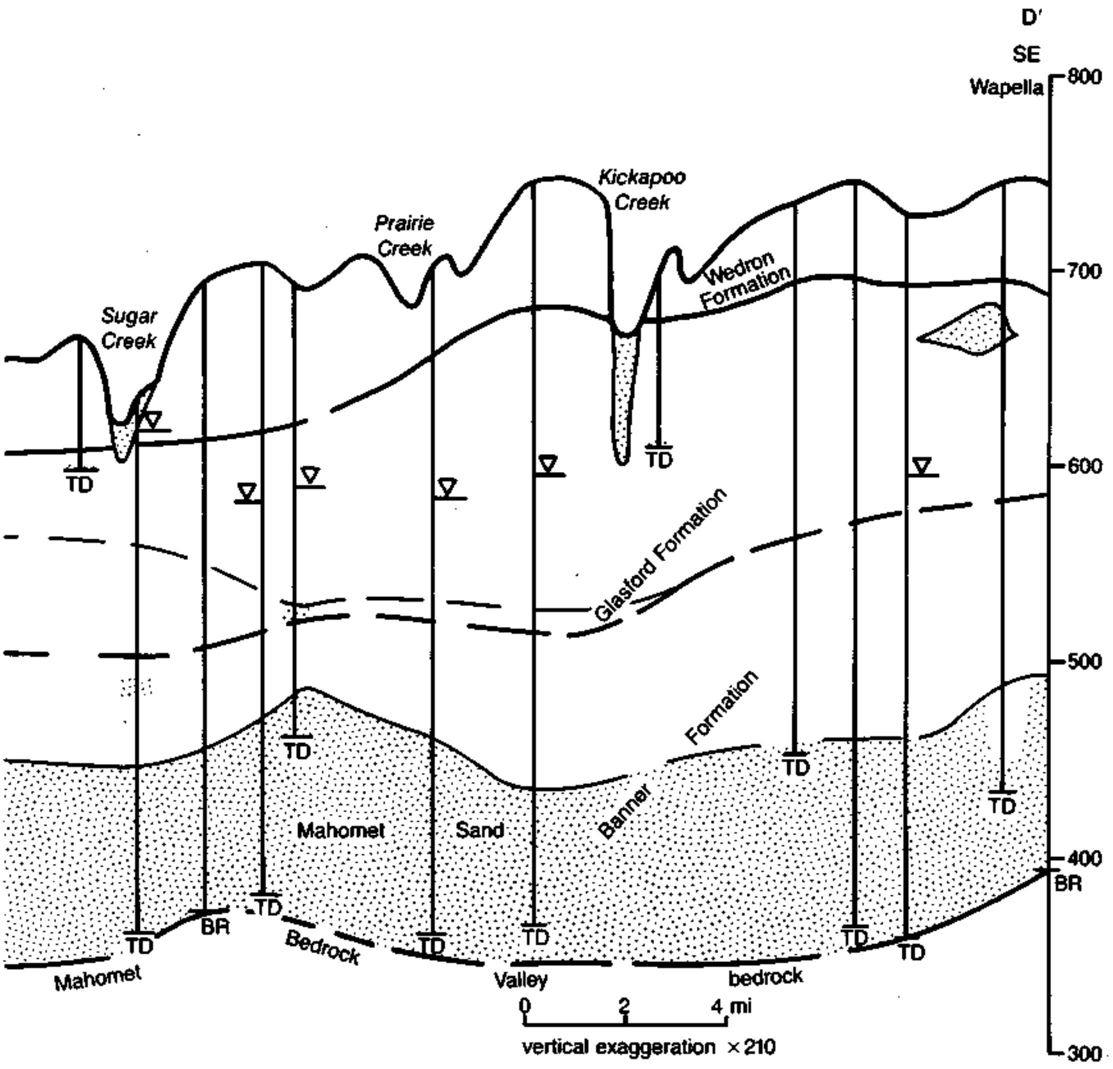


Figure 14 Cross section D-D', northwest to southeast cross section across the Mackinaw Bedrock Valley and up the center of the Mahomet Valley from just south of Tremont to Wapella.



D′
SE
Wapella
800
700
600
500
400
300
BR
Kickapoo Creek
Prairie Creek
Sugar Creek
Wedron Formation
Glasford Formation
Banner Formation
Mahomet Sand
Mahomet Bedrock Valley bedrock
TD
BR
0 2 4 mi
vertical exaggeration ×210

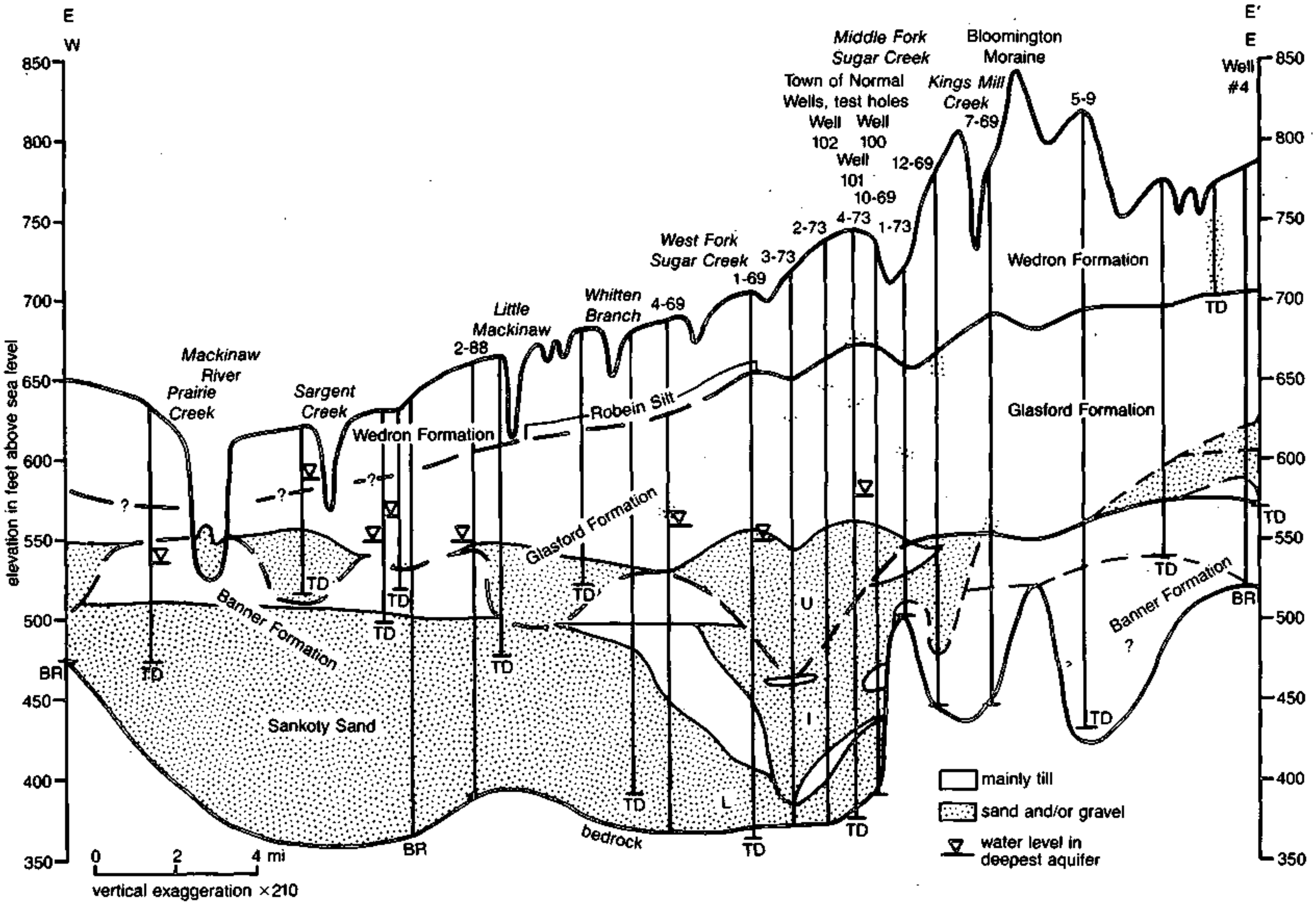


Figure 15 Cross section E-E', west to east cross section from south of Tremont to the Town of Normal generally extending **due west of** Normal (U: upper aquifer; I: intermediate; L: lower; see fig. 8).

Figure 16 and plate 3, based on the data available (pl. 1) and interpretations derived from the cross sections, show the extent and elevation of the top of the Mahomet-Sankoty Sand aquifer. The irregularities of the surface may be related to uneven primary deposition, subsequent erosion of that surface, or both. In some areas, the upper surface of the lower Glasford Formation sand and gravel may have been included with the Mahomet-Sankoty aquifer. The elevation of the top of the Mahomet-Sankoty aquifer ranges from about 500 feet to as low as 400 feet or less. The elevation of the top of the lower Glasford Formation sand and gravel generally is about 550 feet within the bedrock valleys, but it is higher where present above the bedrock uplands (fig. 8).

HYDROLOGY

Basic Flow Conditions

Although a great deal can be determined about an aquifer from a strictly geologic appraisal of its stratigraphic position, boundaries, and physical characteristics, a knowledge of the hydraulic properties of an aquifer system is necessary to provide more specific information on the amount of water available. Ultimately, a combination of geologic and hydrologic appraisals will provide the best estimate of an aquifer's performance.

Groundwater in the unlithified deposits that fill the Mahomet and Mackinaw Bedrock Valleys occurs under artesian, leaky artesian, and water-table conditions. Artesian or leaky artesian conditions exist where till or other fine-grained deposits overlie the aquifer and impede or retard the vertical movement of ground water and confine the water in the aquifer under artesian head. Leaky artesian conditions exist in the Banner and Glasford Formation aquifers in the eastern part of the Mahomet Valley and to an unknown extent elsewhere. Under leaky artesian conditions, a pressure (head) difference between water above and below the confining bed allows water to move vertically through the confining bed from one aquifer to another. Although leakage is possible in either direction, downward leakage is more common, especially when heavy groundwater pumping occurs from the deeper aquifers. Water-table conditions occur in the shallow sand and gravel zones of the Henry and Wedron Formations where water is unconfined. The water table is in direct connection with surface streams in most places.

Hydraulic Properties

The principal hydraulic properties influencing well fields, particularly the water-level response to pumpage, are the hydraulic conductivity, transmissivity, and storage coefficient. In some locations to the east, such as the Banner and Glasford Formation aquifers at Champaign-Urbana, the vertical hydraulic conductivity of the confining beds also plays an important role. A limited number of controlled aquifer tests have been conducted within the study area, and these have not shown evidence of significant vertical leakage. However, because vertical leakage is generally the major process through which recharge to buried aquifers occurs, this hydraulic property needs further evaluation.

The capacity of an aquifer to transmit groundwater is expressed by the *transmissivity,* T. Transmissivity is defined as the rate of flow of water through a vertical strip through the saturated aquifer of unit width and extending the full saturated thickness under a unit hydraulic gradient and at the prevailing temperature of the water. The transmissivity is the product of the *saturated thickness* of the aquifer, m, and the *hydraulic conductivity,* K, defined as the rate of flow of water through a unit cross-sectional area of the aquifer under a unit hydraulic gradient and at the prevailing temperature of the water.

The storage properties of an aquifer are expressed by the *storage coefficient,* S, which is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in head normal to that surface. For a confined or artesian aquifer, in which water levels rise above the top of the aquifer in wells penetrating the aquifer, water

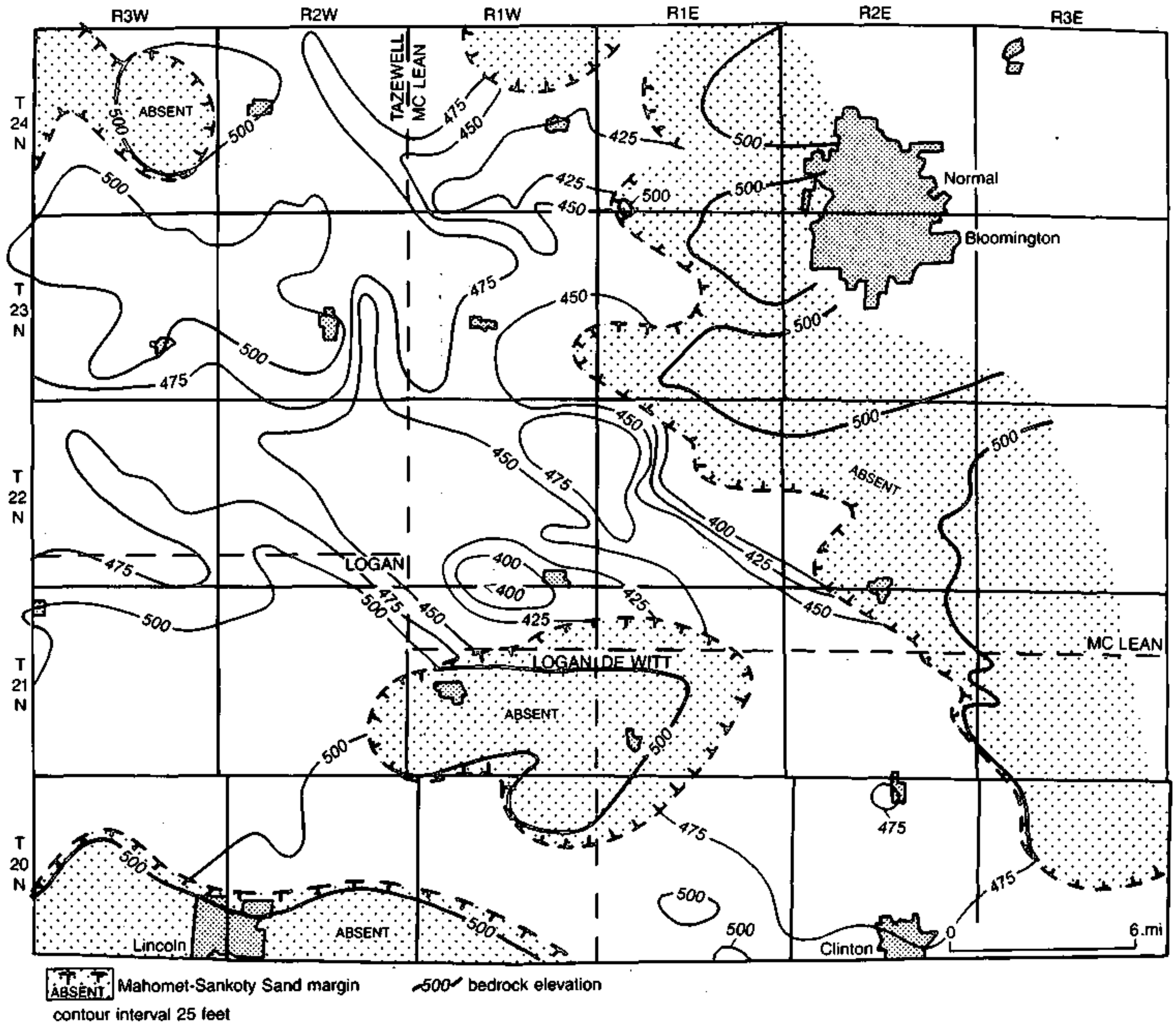


Figure 16 Map showing the extent and elevation of the top of the Mahomet-Sankoty Sand in the study area (see pl. 3).

Table 2 Summary of **aquifer-test and** specific-capacity data.

Aquifer	Transmissivities (gpd/ft) Range	Median	Hydraulic conductivities (gpd/sq ft) Range	Median	Storage coefficients Range	Specific capacities (gpm/ft) Range	Median
Henry or Wedron Formation	35-105,000	15,000	12-8,300	1,000	0.0002-0.0005	0.1-105.7	12.6
Glasford Formation	880-96,000	16,300	110-9,600	1,000	0.0001	0.7-117.6	8.0
Banner Formation	2,400-546,000	140,000	200-4,778	1,705	0.0002-0.09	1.0-155.0	16.2

released from or taken into storage is attributed solely to compressibility properties of the aquifer and water. Such coefficients are usually very small (generally in the range of 10^{-5} to 10^{-3}, see Banner, Glasford, and Wedron Formations, tables 1 and 2). For unconfined or water-table aquifers, in which water levels in wells represent the top of the saturated thickness of the aquifer, water released from or taken into storage is attributed almost entirely to gravity drainage or refilling of the zone through which the change of the water table takes place. A small portion of the change in water volume results from compressibility of the aquifer and water, but this volume is proportionately insignificant. The storage coefficient in water-table aquifers is often referred to as the specific yield, and typically ranges in value from about 0.05 to 0.3 (see Henry Formation, tables 1 and 2).

The rate of vertical leakage of groundwater through a confining bed in response to a given vertical hydraulic gradient is dependent upon the *vertical hydraulic conductivity* of the confining bed, K'. In cases where the confining bed is not well defined or is unknown, the ratio K7m' (where m' is the thickness of the confining bed) is used. This ratio, termed the *leakage coefficient* by Hantush (1956), is defined as the rate of flow of water that crosses a unit area of the interface between an aquifer and its confining bed per unit of head difference across the confining bed.

■ Aquifer tests

The hydraulic properties of aquifers and confining beds may be determined by aquifer tests wherein the effect of pumping a well at a known constant rate is measured in the pumped well and in observation wells penetrating the aquifer. Graphs of the lowering of the water level (drawdown) versus time or versus distance from the pumped well are used to solve formulas that express the relationship of the hydraulic properties of an aquifer and its confining bed, if present, to the drawdown in the vicinity of a pumping well. Graphic analysis may use the leaky artesian formula (Hantush and Jacob 1955), the nonequilibrium formula (Theis 1935), or the modified nonequilibrium formula (Cooper and Jacob 1946). Type-curve and straight-line methods for graphic analysis were described by Walton (1962). Test data collected under water-table conditions may be analyzed by a method devised by Boulton (1963) and described by Prickett (1965), or by the method of Neumann (1975). Where hydrogeologic boundaries are known to exist, their effect on drawdowns can be determined by means of image-well theory described by Ferris (1959).

Controlled aquifer tests in glacial drift aquifers have been made at 69 sites in the study area since 1934. Tests involving only the pumped well were made at 54 of the sites. The effects of leakage were negligible during these tests, and analysis was limited to the use of nonleaky or modified nonequilibrium formulas. The storage coefficient was not determined from pumped well data, because considerable error is involved in estimating the effective radius of the well. The results of the test analyses are listed in table 1.

Data in table 1 from De Witt and Logan Counties, as well as data from the eastern townships and T22N, R1W in McLean County, are from the Mahomet Valley portion of the study area. Data in table 1 for Tazewell County and the western townships north of T22N are from the Mackinaw Valley portion of the study area.

■ Specific-capacity analyses

Specific capacity, defined as the yield of the well in gallons per minute per foot of drawdown for a given pumping period and discharge rate, is one way to express the yield of a well. Walton (1962) showed that the Theis nonequilibrium formula can be expressed in terms of the theoretical specific capacity of a well discharging at a constant rate in a homogeneous, isotropic, areally infinite, nonleaky aquifer.

The theoretical specific capacity of a well varies with the radius of the well and the pumping period. For example, a well 30 inches in diameter has a specific capacity about 13 percent greater than that of a well 12 inches in diameter. The theoretical specific capacity decreases with the length of the pumping period because drawdown continuously increases with time.

Specific capacity data collected during production tests of 37 wells are also summarized in table 1, along with the aquifer test data. We obtained the transmissivity from the relationship between transmissivity and specific capacity determined by the modified nonequilibrium formula (Walton 1962). To solve this formula, the storage coefficient must be assumed, depending upon whether a water-table or artesian aquifer is being tested. Because of the imprecise nature of the above data, transmissivities and hydraulic conductivities derived from specific capacities are considered only approximations. Because the number of analyses from specific-capacity data was limited, table 1 also shows the ranges of specific capacities from all tests, including aquifer tests.

Summary of Aquifer Properties

In fable 2, ranges and median values are given for the transmissivity and hydraulic conductivity. Storage coefficients, as determined from aquifer tests in glacial drift aquifers within the study area, and specific-capacity data are also summarized. Data are summarized by geologic formation in which the aquifers occur, i.e., Banner Formation, Mahomet-Sankoty Sand (pre-Illinoian), Glasford Formation (Illinoian), and Wedron and Henry Formations (Wisconsinan) from earliest to most recent, respectively (fig. 8).

The hydraulic properties are noticeably more variable in the aquifers related to the shallower (younger) formations and are generally less variable in the aquifers of the deeper (older) formations. In addition, specific capacities, hydraulic conductivities, and transmissivities generally increase in the deeper aquifers. Storage coefficients usually are highly variable in shallow aquifers because these deposits can be under water-table or artesian conditions, whereas deeper aquifers are usually under artesian conditions only. The limited number of storage coefficients obtained from aquifer tests in the study area, however, are not sufficient to demonstrate this general trend.

Water Levels in Wells

Groundwater levels in wells, whether they reflect the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer, indicate the elevation of atmospheric pressure of the aquifer (Todd 1980). Any phenomenon that produces a change in pressure on groundwater will cause the groundwater level to vary. Fluctuations in the water level can result from a wide variety of hydrological phenomena, including those caused by human activities. More than one mechanism may be operating simultaneously in some cases. Freeze and Cherry (1979) list 13 mechanisms that lead to fluctuations in groundwater levels, including pumpage, groundwater recharge (both natural and artificial), evapotranspiration, atmospheric effects, aquifer loading, and earthquakes. The measurement of water-level fluctuations in wells is, therefore, an important facet in the study of groundwater as well as in good management of groundwater resources.

Systematic measurement of groundwater levels in areas remote from pumping centers began in 1959, when an automatic water-level recorder was installed on a shallow, large-diameter well just outside the study area in Logan County (LOG 19N4W-22.4c). This well and others used for special studies within the Mahomet Valley were added to the Illinois State Water Survey's network of observation wells, established in 1958, to obtain data on long-term trends of the water table. The water table has been observed to recede in late spring, summer, and early fall, when discharge from the groundwater reservoir by evapotranspiration and groundwater runoff exceeds recharge from precipitation. Water levels begin to recover in the winter, and the water table reaches its peak during the spring, when conditions for recharge are most favorable (Visocky and Schicht 1969).

The only systematic measurements of water levels near pumping centers within the study area are the monthly measurements at two observation wells near Normal's West Well Field. These measurements, begun in 1971 to monitor regional effects of the well field, have indicated that water levels near the three wells within the well field have more or less stabilized since pumping began in 1976. A fourth well was drilled in the summer of 1989.

Groundwater Recharge

Recharge to aquifers in the study area occurs locally as vertical leakage from precipitation through deposits and from downward percolation of stream runoff (induced infiltration). A large proportion of precipitation runs off to streams or is discharged by evapotranspiration. Some precipitation reaches the water table and becomes groundwater. Eventually, the groundwater either discharges into streams as groundwater runoff or into the atmosphere by evapotranspiration. Part of the water stored temporarily in the upper deposits may move downward into the lower formations. Vertical movement is possible if differentials in head exist between the water table in the upper formations and the potentiometric surfaces of the Glasford and Banner Formation aquifers. Visocky and Schicht (1969) found that water table elevations in shallow deposits of the Mahomet Valley area range from approximately 600 feet at the western end of the valley to about 750 feet in the central and eastern portions. They also indicated that Banner and Glasford Formation aquifers had potentiometric levels ranging from 540 to 700 feet from west to east in the Valley.

Over a given period of time, the precipitation reaching the water table (recharge) is balanced largely by groundwater runoff and evapotranspiration, plus or minus changes in groundwater storage. Recharge from precipitation occurs irregularly through the year. During spring months, when rainfall is heavy and evapotranspiration losses are low, recharge is greatest. Recharge is generally lower during the summer and early fall, when evapotranspiration and soil-moisture requirements prevent most rainfall from percolating to the water table. Recharge is usually negligible during winter months if the ground is frozen.

■ Groundwater runoff

Data on groundwater runoff can be useful in estimating potential recharge to aquifers. Under natural conditions, changes in groundwater storage over a period of years are negligible, and groundwater recharge is balanced by groundwater runoff and evapotranspiration. Zeizel et al. (1962) indicated that 60 percent of groundwater runoff in Du Page County can be diverted into cones of depression in deeply buried aquifers. Data on reduction in groundwater evapotranspiration in Illinois as a result of lower water levels caused by heavy pumping conditions are not available.

Walton (1965) used streamflow data to determine groundwater runoff from 109 drainage basins within Illinois (fig. 17). To estimate the total groundwater runoff within the study area, we superposed onto figure 17 the approximate area within the 500-foot bedrock contour in the study area from figure 16 and summed the two runoff categories present in the study area, 0.3 to 0.4 cfs/sq mi and 0.2 to 0.3 cfs/sq mi (194,000 to 259,000 gpd/sq mi and 129,000 to 194,000 gpd/sq mi). Using this procedure, we estimated that total groundwater runoff in the study area is about 147 million gallons per day.

As stated above, not all of the groundwater runoff can be diverted to cones of depression because, even under heavy pumping conditions, there is lateral as well as vertical movement of groundwater. Walton (1965), for example, calculated that groundwater recharge at Champaign-Urbana was about 51 percent of estimated groundwater runoff near Champaign. Assuming that future centers of pumpage could capture about 50 percent of groundwater runoff, approximately 70 to 75 mgd might be developed from major aquifers in the study area.

Groundwater Pumpage

Within the Mahomet Valley area, the only comprehensive summary of groundwater use has been that of Visocky and Schicht (1969). According to their report, Petersburg (Menard County) developed the first municipal groundwater supply in 1878, and the villages of Blue Mound (Macon County) and Danvers (McLean County) developed supplies in 1882. By 1900, 30 municipalities were pumping groundwater. In 1988, municipalities and industries in 75 communities pumped an average of about 48.5 million gallons per day.

Within the study area, 17 communities pumped an average 8.74 mgd in 1988. Of this amount, Clinton (1.24 mgd), Lincoln (3.11 mgd), and Normal (3.23 mgd) were the largest users of groundwater. Wells in Lincoln pumped from surficial alluvial deposits, while Normal pumped 1.83 mgd from its West Well Field in the Mackinaw Valley. Of the groundwater withdrawals in the study area, therefore, Clinton and the West Well Field at Normal are the only major developments within the deep, pre-Illinoian deposits. A large potential supply (estimated at 7,200 gpm) was located in 1975 for the Illinois Department of Conservation near Lilly in T24N, R2W, Tazewell County, but this supply has never been developed. It suggests, however, the magnitude of potential groundwater supplies in the study area.

Water Quality

The quality of water is now recognized as being as important as the quantity. Quality criteria vary widely, depending on the intended use. For example, standards of drinking water for human consumption are more strict than are standards for livestock or irrigation. Water-quality data can often provide insights into the flow regimes of aquifer systems. Changes in water quality from one aquifer to another can be an indicator of chemical transformations of water in moving between aquifers or can suggest flow systems that are mutually independent. A water-quality summary by Visocky and Schicht (1969) for groundwater in the Banner and Glasford Formation aquifers within the Mahomet Valley suggested that the quality of water in these aquifers does not differ substantially.

Within the study area, water quality of aquifers within the glacial drift is known from analyses of 55 water samples collected from wells. A summary of ranges and mean values of selected chemical constituents from the database is presented in table 3. The statistical sampling from aquifer to aquifer was not uniform and only eight analyses from Glasford Formation aquifers were found in the database, compared with 18 analyses from Wedron Formation aquifers or Henry Formation deposits and 29 analyses from Banner Formation deposits. These data show that mean values of total dissolved minerals and iron are very similar in concentration within all aquifers. Mean hardness appears to decrease with depth (age), and alkalinity increases with depth, although the sample size for the Glasford Formation aquifers was small. In general, the mean concentrations shown in table 3 are somewhat higher than the values for the entire Mahomet Valley reported by Visocky and Schicht (1969). Visocky and Schicht gave mean

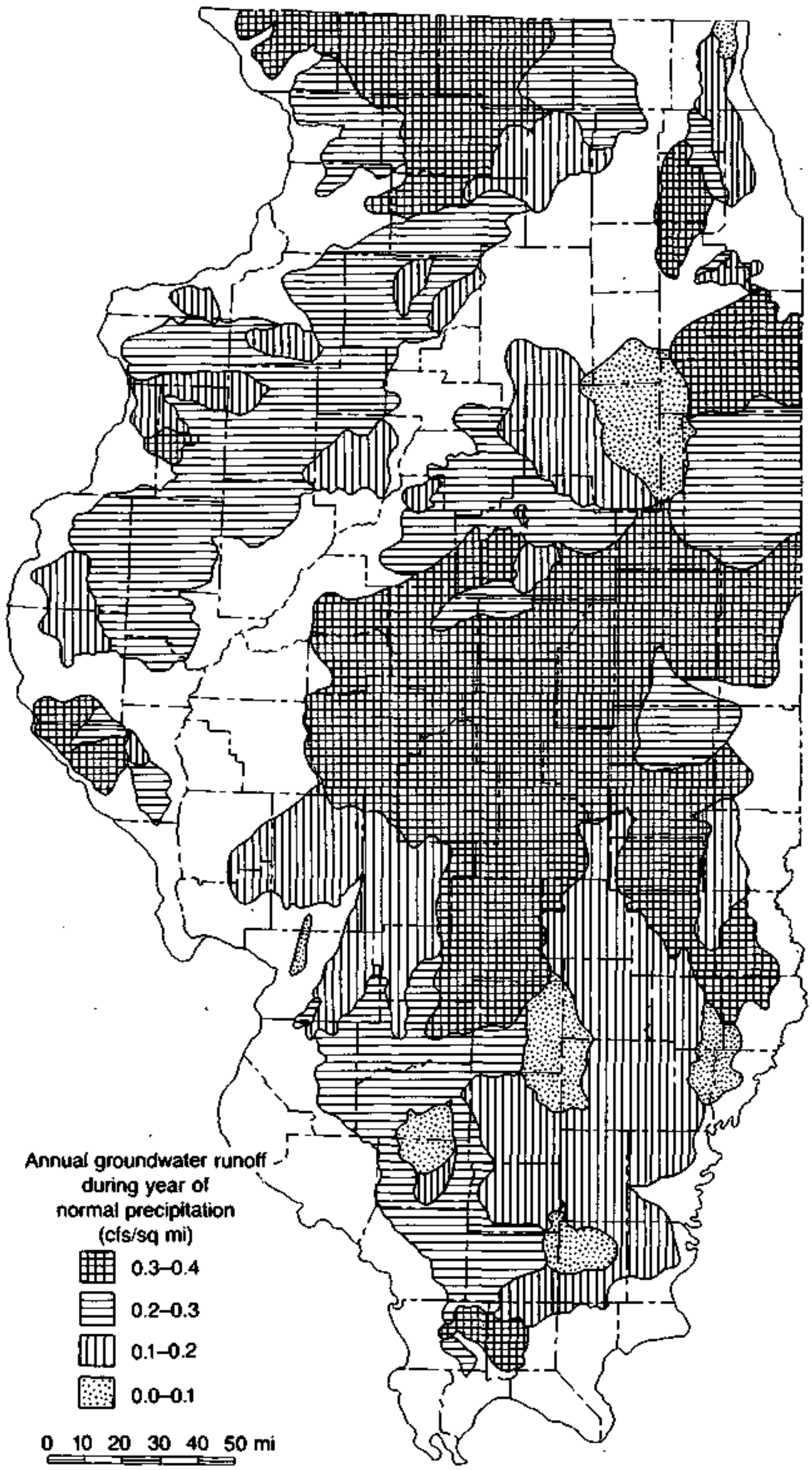


Figure 17 Distribution of annual groundwater runoff in Illinois during a year of normal precipitation (from Walton 1965).

Table 3 Summary of selected water-quality parameters.

Aquifer	Total dissolved minerals (mg/L) Range	Mean	Hardness as $CaCO_3$ (mg/L) Range	Mean	Alkalinity as $CaCO_3$ (mg/L) Range	Mean	Dissolved iron (mg/L) Range	Mean
Henry or Wedron Formation	366-1,273	539	295-938	436	233-536	379	0.02 - 9.61	2.75
Glasford Formation	438- 605	507	254-473	376	433-612	491	0.97 - 5.32	2.74
Banner Formation	317-1,290	541	208-749	347	375-636	432	0.005-38.9	3.60

concentrations for total dissolved minerals, hardness, alkalinity, and iron in the Glasford Formation aquifers as 507 mg/L, 376 mg/L, 491 mg/L, and 2.74 mg/L and in the Banner Formation as 541 mg/L, 347 mg/L, 432 mg/L, and 3.6 mg/L, respectively.

SUMMARY

Data are available in sufficient quantity and quality to provide a preliminary regional assessment of the groundwater resources. They are not, of the overall quality, detail, or distribution to provide site-specific evaluation in some areas and there is a need for verification throughout the area. The data distribution is shown on plate 1. The actual thickness and distribution of the lower Glasford Formation aquifer and the Mahomet-Sankoty Sand is in question for the region because of the lack of wells penetrating the lower Glasford Formation aquifer, as well as the Mahomet-Sankoty Sand (see pl. 1 and figs. 11-15).

From a geologic perspective, there is rather convincing evidence that the thick Mahomet-Sankoiy Sand is present throughout large areas of eastern Tazewell County, smaller portions of western and southwestern McLean County and northern De Witt County (fig. 18). Only a few dozen wells or tests penetrate the entire thickness (to bedrock) of the Mahomet-Sankoty Sand, and many of these are bunched (e.g. test holes and wells in Normal). However, from the data that are available, the general uniformity of thickness and character of the sand are sufficient to extrapolate its general distribution.

Figure 18 and plate 4, therefore, represent an interpretation of the available data showing the probability of occurrence of the Mahomet-Sankoty Sand and its potential as an aquifer. The map combines information on the distribution, thickness, and character of the sand with the information available on specific well production. As indicated by the cross sections (figs. 11-15) and an overall evaluation of the data, the Mahomet-Sankoty Sand should be a highly productive aquifer in most of map area 1 shown on plate 4 and figure 18, and locally highly productive in map area 2. Although less substantive data exist for areas designated as map area 3, there is a good probability that, within a few miles, the sand should be present and have similar characteristics to those in the adjacent map areas. Similarly, where map area 3 is adjacent to area 4, aquifer conditions could be less promising. The least potential for developing large groundwater supplies appears exists in map area 4. It should be recognized that the placement of all map boundaries are somewhat arbitrary. The decisions, were made on the basis of the data distribution shown on the database map (pl. 1) and on our best geologic judgment. We believe that any error is on the conservative side.

The Glasford Formation aquifers are encountered in the area but are relatively thin, except in local channels, and are not always present. There are generally insufficient data from wells penetrating these aquifers to map them with great confidence. Most wells do not entirely penetrate the principal producing aquifer. However, given sufficient additional data, the

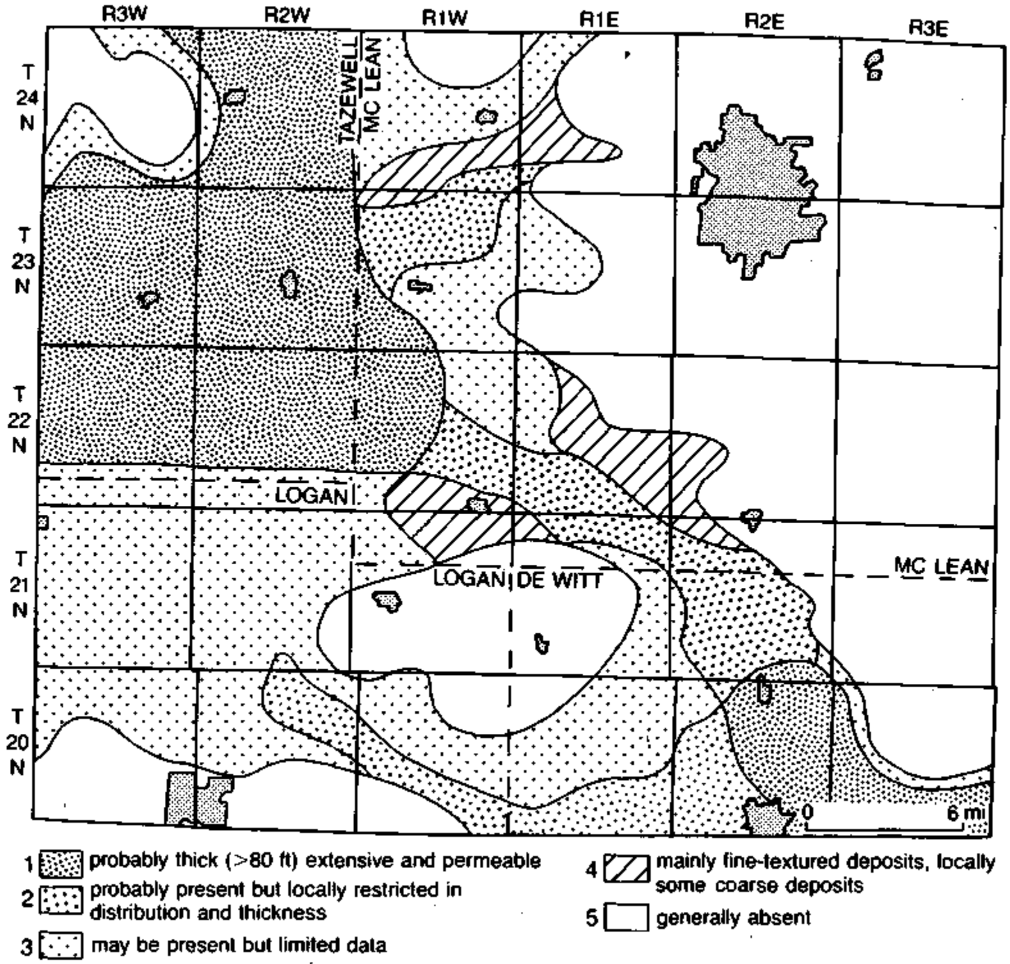


Figure 18 Occurrence of the Mahomet-Sankoty Sand in the study area as a guide for further groundwater exploration (see pl. 4; numbers on legend refer to map areas on pl. 4).

distribution and thickness of at least the lower Glasford Formation aquifer is mappable. Other shallow aquifers within the Glasford Formation, aquifers associated with the Wedron Formation and the Henry Formation, should be considered as local sources of small groundwater supplies.

The greatest limitation to the data, geologically, is that it is mainly limited to drillers' descriptions of the materials encountered. Although generally suitable for identifying marker horizons and making major distinctions between coarse and fine-textured materials, these descriptions cannot be used for identifying or characterizing specific geologic units. Furthermore, the spotty distribution of wells leaves numerous large areas devoid of specific data (pl. 1).

From a hydrologic perspective, a few production tests have been conducted on wells tapping several of the aquifers of the area. Only a few of the aquifer tests have been conducted under long-term controlled conditions on wells finished in the Mahomet-Sankoty Sand. However, there are enough data to suggest that the Mahomet-Sankoty Sand in the prime areas of its occurrence (area 1, fig. 18, pl. 4) is likely to be highly productive. The lower Glasford Formation aquifer, where associated with the Mackinaw Valley in western Tazewell County, is not well characterized hydrologically. In this area, it appears to be tapped by many farm and domestic wells. Its overall productivity cannot be evaluated with the data available. Neither can its significance to recharge to the underlying Sankoty Sand Member nor the impact of heavy pumpage of the Sankoty Member on the lower Glasford Formation water levels be determined without better definition of the aquifer geologically and hydrologically.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY AND EXPLORATION

This preliminary reassessment of the hydrogeologic conditions in the confluence area of the Mahomet and Mackinaw Bedrock Valleys has provided additional insights into the distribution, thickness, and character of the sand and gravel aquifers of the region and the order of magnitude of groundwater availability. Because groundwater is a renewable resource, its wise and effective development and use should allow for its availability to all users.

Conclusions

° Enough hydrogeologic data are available to ensure that a significant sand and gravel aquifer (Mahomet-Sankoty Sand) is present within the Mahomet-Mackinaw Bedrock Valley System in southwestern McLean and eastern Tazewell counties. Therefore, further exploration and development are warranted.

° Distribution of the Mahomet Sand Member within the Mahomet Bedrock Valley in southwestern McLean County is not as extensive as earlier studies had projected. Considerable exploration and testing may be required to adequately determine its extent and productivity.

° Our preliminary assessment, based on hydrologic analysis, suggests that up to 75 mgd might be developed from the major aquifers of the area, primarily the Mahomet-Sankoty Sand.

° Shallower aquifers above the Mahomet-Sankoty Sand, including the basal Glasford Formation aquifer and those in Wedron and Henry Formations, should be used where locally present and practical.

° The database needs considerable enhancement to verify the geologic and hydrologic conditions and conclusions, particularly in areas where data are sparse and where additional data could resolve specific geologic and/or hydrologic questions.

Recommendations

Because existing data are limited, planning for future exploration and development should include data collection from and detailed studies of some of the more promising areas identified in this and other recent studies. This approach will verify the presence of the aquifers and provide the data necessary for well-field design and projections for long-term production capabilities.

Several specific objectives will need to be addressed in such a program. These include verifying the distribution and hydrologic properties of the Mahomet Sand Member in southwestern McLean County, establishing the thickness distribution and aquifer properties of the lower Glasford Formation aquifer in eastern Tazewell County and its relationship to the Mahomet-Sankoty Sand, and determining the impact of heavy pumpage from the Mahomet-Sankoty Sand on nearby wells finished in that aquifer and in the overlying aquifers.

A program of geologic verification, exploration and aquifer mapping and testing will lead to better prediction of aquifer occurrence, distribution, properties, and yields. Such a program would include (1) test drilling, sampling, and geophysically logging and collecting hydrologic data at selected sites within area 1 to verify that conditions are suitable for developing large capacity wells; (2) developing an exploration program (geophysical and test drilling) in areas 2 and 3, areas with limited data and/or limited thickness and distribution of aquifer indicated, to locate areas for potential development; (3) selecting the most suitable areas for well fields and for designing a detailed test drilling, sampling, and logging program to map all geologic units and detail aquifer dimensions, characteristics and properties; (4) developing test wells in proposed well field area(s) to determine hydraulic properties of aquifer's leading to design of wells, well spacing and estimate production capability; and (5) plan development of well field based on data collected from test wells.

REFERENCES

Bergstrom, R. E., Kemal Piskin, and L. R. Follmer, 1976, Geology for Planning in the Springfield-Decatur Region, Illinois: Illinois State Geological Survey, Circular 497, 76 p.

Boulton, N. S., 1963, Analysis of data from nonequilibrium pumping tests allowing for delayed yield from storage: Proceedings of the Institution of Civil Engineers, v. 26, no. 6693, p. 469-482.

Cooper, H. H., Jr., and C. E. Jacob, 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Transactions of the American Geophysical Union, v. 27, no. 4, p. 526-534.

Ferris, J. G., 1959, Groundwater, *in* C. O. Wisler, and E. F. Brater, editors, Hydrology: John Wiley and Sons, New York, p. 198-272.

Foster, J. W., 1953, Significance of Pleistocene deposits in the groundwater resources of Illinois: Economic Geology, v. 48, no. 7, p. 568-573.

Foster, J. W., and M. B. Buhle, 1951, An integrated geophysical and geological investigation of aquifers in glacial drift near Champaign-Urbana, Illinois: Economic Geology, v. 46, no. 4, p. 367-397; Illinois State Geological Survey, Report of Investigations 155, 31 p.

Freeze, R. A., and J. A. Cherry, 1979, Groundwater: Prentice-Hall, Englewood Cliffs, NJ, 230 p.

Hanson, Ross, 1950, Public Ground-Water Supplies in Illinois: Illinois State Water Survey, Bulletin 40, 1036 p. and supplements.

Hantush, M.S., 1956, Analysis of data from pumping tests in leaky aquifers: Transactions of the American Geophysical Union, v. 36, no. 1, p. 95-100.

Hantush, M. S., and C. E. Jacob, 1955, Nonsteady radial flow in an infinite leaky aquifer: Transactions of the American Geophysical Union, v. 36, no. 1, p. 95-100.

Horberg, Leland, 1945, A Major Buried Valley in East-Central Illinois and Its Regional Relationships: Geology, v. 53, no. 5, p. 349-359; Illinois State Geological Survey, Report of Investigations 106, 11 p.

Horberg, Leland, 1950, Bedrock Topography of Illinois: Illinois State Geological Survey, Bulletin 73,111 p.

Horberg, Leland, 1953, Pleistocene Deposits Below the Wisconsin Drift in North-eastern Illinois: Illinois State Geological Survey, Report of Investigations 165, 61 p.

Hunt, C. S., and J. P. Kempton, 1977, Geology for Planning in De Witt County, Illinois: Illinois State Geological Survey, Environmental Geology Notes 83, 42 p.

Kempton, J. P., W. H. Johnson, K. Cartwright, and P. C. Heigold, 1991, Mahomet Bedrock Valley in east-central Illinois; topography, glacial drift stratigraphy and hydrogeology, *in* W. N. Melhorn, and J. P. Kempton, editors, Geology and Hydrogeology of the Teays-Mahomet Bedrock Valley System: Geological Society of America, Special Paper 258, p. 91-124.

Kempton, J. P., W. J. Morse, and W. H. Johnson, 1980, Stratigraphy and regional distribution of Illinoian and pre-Illinoian deposits of east-central Illinois: Geological Society of America Abstracts with Programs, v. 12, no. 5, p. 230-231.

Kempton, J. P., W. J. Morse, and A. P. Visocky, 1982, Hydrogeological Evaluation of Sand and Gravel Aquifers for Municipal Groundwater Supplies in East-Central Illinois: Illinois State Geological Survey and Illinois State Water Survey, Cooperative Groundwater Report 8, 59 p.

Kempton, J. P., and V. L. Poole, 1985, Geology and Distribution of the Aquifers West of Normal, Illinois, an Update: Illinois State Geological Survey, Open File Report, 13 p.

Kempton, J. P., and A. P. Visocky, 1991, Regional Groundwater Resources in Western McLean and Eastern Tazewell Counties with Emphasis on the Mahomet Bedrock Valley, Plates 1-4: Illinois State Geological Survey, Open File Series 14, scale 1:62,500.

Larson, T. H., and V. L. Poole, 1989, Geophysical exploration for potential groundwater resources near Bioomington, iiiinois: Illinois State Geological Survey, Contract/Grant Report 1898-2, 51 p.

Lineback, J. A., 1979, Quaternary Deposits of Illinois: Illinois State Geological Survey Map, scale 1:500,000.

Lineback, J. A., 1981, Quartenary Deposits of Illinois: Illinois State Geological Survey Map, page-sized map.

Morse, W. J., J. P. Kempton, and A. C. Sternberg, 1980, Stratigraphic definition and areal distribution of sand and gravel aquifers, east-central Illinois: Geological Society of America Abstracts with Programs, v. 12, no. 5, p. 252.

Neuman, S. P., 1975, Analysis of pumping test data from anisotropic unconfined aquifers considering delayed gravity response: Water Resources Research, v. 11, no. 2, p. 329-342.

Piskin, Kemal, and R. E. Bergstrom, 1975, Glacial Drift in Illinois: Thickness and Character: Illinois State Geological Survey, Circular 490, 35 p.

Poole, V. L, and P. C. Heigold, 1981, Geophysical Assessment of Aquifers Supplying Groundwater to Eight Small Communities in Illinois: Illinois State Geological Survey, Environmental Geology Notes 91, 61 p.

Prickett, T. A., 1965, Type-curve solution to aquifer tests under water-table conditions: Ground Water, v. 3, no. 3, p. 5-14.

Richards, S. S., and A. P. Visocky, 1982, A Reassessment of Aquifer Conditions West of Normal, Illinois: Illinois State Water Survey, Circular 153, 33 p.

Sanderson, E. W., 1971, Ground-water Availability in Piatt County: Illinois State Water Survey, Circular 107, 83 p.

Sanderson, E. W., and E. Zewde, 1976, Ground-Water Availability in Champaign County: Illinois State Water Survey, Circular 124, 139 p.

Selkregg, L. F., and J. P. Kempton, 1958, Groundwater Geology in East-Central Illinois. A preliminary geology report: Illinois State Geological Survey, Circular 248, 36 p.

Smith, H. F., 1950, Groundwater Resources in Champaign County: Illinois State Water Survey, Report of Investigation 6, 44 p.

Stephenson, D. A., 1967, Hydrogeology of Glacial Deposits of the Mahomet Bedrock Valley in East-central Illinois: Illinois State Geological Survey, Circular 409, 51 p.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Transactions of the American Geophysical Union 16th Annual Meeting, part 2.

Todd, D. K., 1980, Groundwater Hydrology, 2nd ed.: John Wiley and Sons, New York, 535 p.

Vaiden, R. C, and J. P. Kempton, in preparation, Hydrogeological Investigations for a Supplemental Groundwater Supply for the Town of Normal, Illinois: Illinois State Geological Survey, Open File Report.

Visocky, A. P., and R. J. Schicht, 1969, Groundwater Resources of the Buried Mahomet Bedrock Valley: Illinois State Water Survey, Report of Investigation 62, 52 p.

Visocky, A. P., H. A. Wehrmann, K. L. Kim, and R. W. Ringler, 1978, Assessment of Public Groundwater Supplies in Illinois: Illinois State Water Survey, Contract Publication 209, 195 p.

Walton, W. C, 1962, Selected Analytical Methods for Well and Aquifer Evaluation: Illinois State Water Survey, Bulletin 49, 82 p.

Walton, W. C, 1965, Ground-water Recharge and Runoff in Illinois: Illinois State Water Survey, Report of Investigation 48, 55 p.

Wehrmann, H. A., A. P. Visocky, C. B. Burris, R. W. Ringler, and R. D. Brower, 1980, Assessment of Eighteen Public Groundwater Supplies in Illinois: Illinois State Water Survey, Contract Report 237, 185 p.

Willman, H. B., and J. C. Frye, 1970, Pleistocene Stratigraphy of Illinois: Illinois State Geological Survey, Bulletin 94, 204 p.

Woller, D. M., 1975, Public Ground-Water Supplies in Champaign County: Illinois State Water Survey, Bulletin 60-15, 55 p.

Zeizel, A. J., W. C. Walton, R. T. Sasman, and T. A. Prickett, 1962, Ground-Water Resources of Du Page County, Illinois: Illinois State Water Survey and Geological Survey, Cooperative Ground-Water Report 2, 103 p.