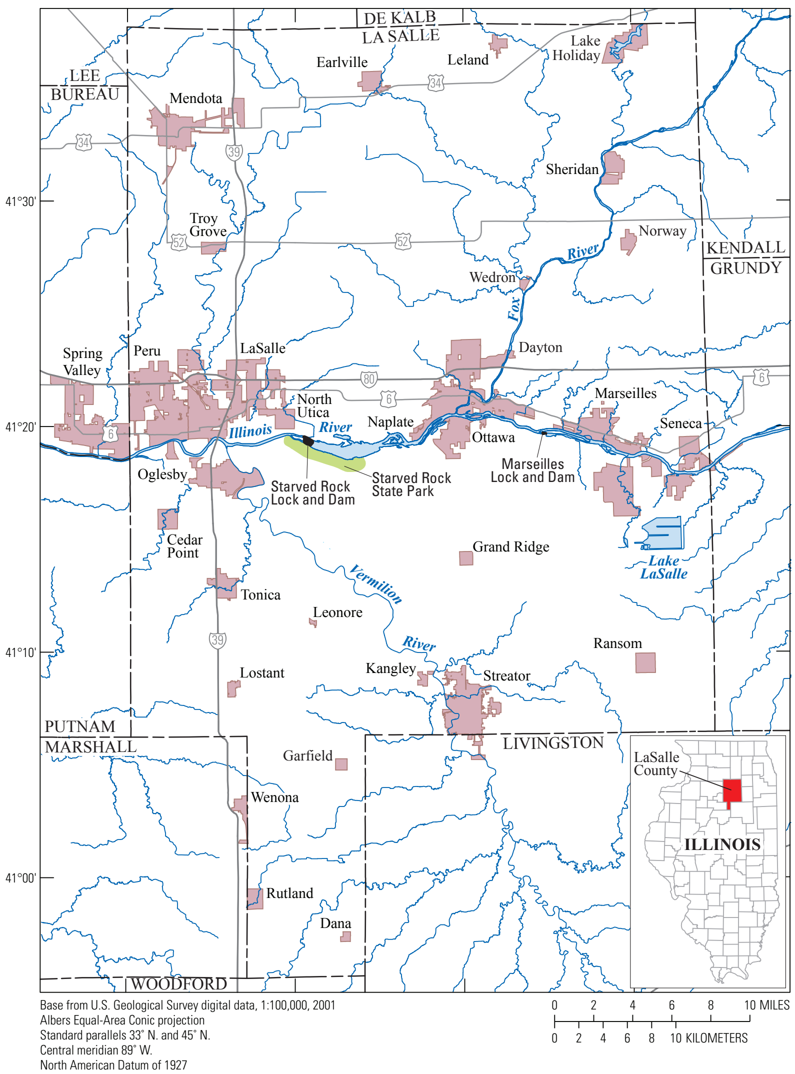
Prepared in cooperation with the LaSalle County Board and Northwestern University

Hydrogeologic Framework of LaSalle County, Illinois



Scientific Investigations Report 2016–5154

U.S. Department of the Interior
U.S. Geological Survey

Cover. Location of LaSalle County, Illinois.

Hydrogeologic Framework of LaSalle County, Illinois

By Robert T. Kay and Clinton R. Bailey

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U.S. Department of the Interior
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SALLY JEWELL, Secretary

U.S. Geological Survey
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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per day per cubic foot ([gal/d]/ft^3)	133.	liter per day per cubic meter ([L/d]/m^3)
gallon per day per square mile ([gal/d]/mi^2)	0.001461	cubic meter per day per square kilometer ([m^3/d)]/km^2)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)
	Specific capacity	
gallon per minute per foot ([gal/min]/ft)	0.2070	liter per second per meter ([L/s]/m)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Leakance	
foot per day per foot ([ft/d]/ft)	1	meter per day per meter ([m/d]/m)
inch per year per foot ([in/yr]/ft)	83.33	millimeter per year per meter ([mm/yr]/m)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83) and the North American Datum of 1927 (NAD 27).

Altitude, as used, refers to distance above the vertical datum.

Supplemental Information

Constituent concentrations are given in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Fecal coliform populations are presented in colonies per 100 milliliter (colonies/100mL).

Abbreviations

EPA	U.S. Environmental Protection Agency
HAL	health advisory level
IEPA	Illinois Environmental Protection Agency
ISWS	Illinois State Water Survey
IWQS	Illinois water quality standard
MCL	maximum contaminant level
NWIS	National Water Information System
NRWQC	national recommended water-quality criteria
PCB	polychlorinated biphenyl
SMCL	secondary maximum contaminant level
USGS	U.S. Geological Survey

Hydrogeologic Framework of LaSalle County, Illinois

By Robert T. Kay and Clinton Bailey

Abstract

Water-supply needs in LaSalle County in northern Illinois are met by surface water and groundwater. Water-supply needs are expected to increase to serve future residential and mining uses. Available information on water use, geology, surface-water and groundwater hydrology, and water quality provides a hydrogeologic framework for LaSalle County that can be used to help plan the future use of the water resources.

The Illinois, Fox, and Vermilion Rivers are the primary surface-water bodies in LaSalle County. These and other surface-water bodies are used for wastewater disposal in the county. The Vermilion River is used as a drinking-water supply in the southern part of the county. Water from the Illinois and Fox Rivers also is used for the generation of electric power.

Glacial drift aquifers capable of yielding sufficient water for public supply are expected to be present in the Illinois River Valley in the western part of the county, the Troy Bedrock Valley in the northwestern part of the county, and in the Ticona Bedrock Valley in the south-central part of the county. Glacial drift aquifers capable of yielding sufficient water for residential supply are present in most of the county, although well yield often needs to be improved by using large-diameter wells. Arsenic concentrations above health-based standards have been detected in some wells in this aquifer. These aquifers are a viable source for additional water supply in some areas, but would require further characterization prior to full development.

Shallow bedrock deposits comprising the sandstone units of the Ancell Group, the Prairie du Chien Group, dolomite of the Galena and Platteville Groups, and Silurian-aged dolomite are utilized for water supply where these units are at or near the bedrock surface or where overlain by Pennsylvanian-aged deposits. The availability of water from the shallow bedrock deposits depends primarily on the geologic unit analyzed. All these deposits can yield sufficient water for residential supply in at least some parts of the county, and sandstone deposits in the Ancell and Prairie du Chien Groups can yield sufficient water for residential or public supply in much of the county.

The Cambrian-Ordovician aquifer system comprises the most widespread, productive aquifers in northern Illinois and is used for water supply by a number of municipalities in the county. Water levels in the aquifer system have declined by as much as 300 feet in parts of LaSalle County. The aquifer contains naturally occurring concentrations of radium that are higher than established health guidelines in much of the county.

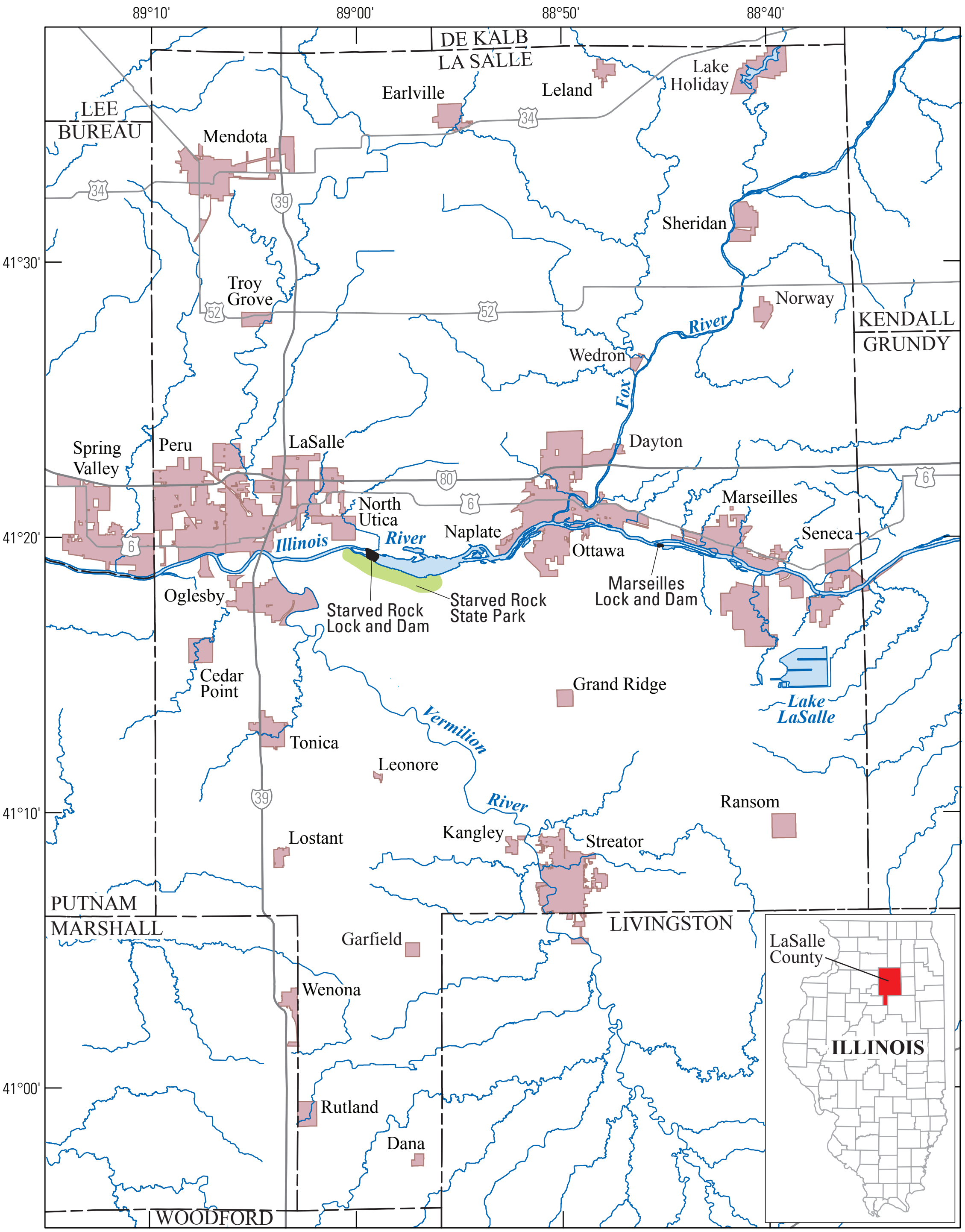
Introduction

Water-supply needs in LaSalle County in northern Illinois (fig. 1) are partly met from *groundwater*[1] derived mainly from glacial *drift* and *bedrock* aquifers open to deposits of *Cambrian, Ordovician*, *Silurian*, or *Pennsylvanian System* units. Many residences and commercial establishments rely on water from *wells* open to the glacial drift and shallow bedrock *aquifers*. Most *public-supply* wells in the county are open either to the glacial drift aquifer or to one or more aquifers of the Cambrian-Ordovician aquifer system. Water-supply needs in parts of the county also are met from *surface water* derived primarily from the Illinois, Fox, and Vermilion Rivers.

Increased groundwater withdrawals to support future population growth and economic expansion (particularly quarry operations) in LaSalle County and nearby areas increase the potential for depletion of groundwater resources in parts of the county. Additionally, water quality in some of the aquifers used for water supply within parts of LaSalle County presents challenges to meeting water needs in parts of the county.

Understanding the character of the water resources of LaSalle County can help ensure the long-term sustainability of the resource. To provide this information, the U.S. Geological Survey (USGS), in cooperation with the LaSalle County Board and Northwestern University, began an investigation of the water resources of LaSalle County in 2015. The information collected and analyzed during this investigation has increased the understanding of the water use, hydrology, and water quality of the aquifers, *semiconfining units*, and surface-water bodies in LaSalle County and can help scientists, managers, and planners to meet the needs of the population and to use the economic resources of the county in ways that minimize disruption to the water resource.

[1]Words in italics indicate the first use of words defined in the glossary of this report.



Base from U.S. Geological Survey digital data, 1:100,000, 2001
Albers Equal-Area Conic projection
Standard parallels 33° N. and 45° N.
Central meridian 89° W.
North American Datum of 1927

Figure 1. Location of LaSalle County, Illinois.

Land Use, Population, and Water Supply

Land cover data provide insight for the types of locations of demands on the water resources of LaSalle County. Analysis of the land cover presented in figure 2 indicates that LaSalle County has a total area of 1,151 square miles (mi^2), of which 1,135 mi^2 is land. About 16 mi^2 of LaSalle County is water, primarily the Illinois River and Lake LaSalle, a cooling pond for a nuclear power plant south of Seneca. Land use primarily is agricultural, which constitutes almost 80 percent of the total land use in the county (fig. 2). Natural land use, including forest and scrub (about 74 mi^2) and wetlands (about 6.3 mi^2), accounts for about 7 percent of the land use. Natural areas are present near surface-water bodies, including the Illinois, Fox, and Vermilion Rivers. Barren land associated with current or historical mining and quarry operations occupies about 3 mi^2 in the county.

Urban land use (almost 10 percent of the total; fig. 2) is focused in the vicinity of the Illinois River at Seneca, Marseilles, Ottawa, Naplate, North Utica, Oglesby, LaSalle, and Peru (fig. 1). Urbanized areas along the Fox River are Dayton, Wedron, and Sheridan in the northeastern part of the county. The communities of Lake Holiday, Leland, Earlville, Mendota, and Troy Grove are located in the northern part of the county. The communities of Streator, Kangley, Leonore, Grand Ridge, Tonica, Cedar Point, Lostant, Garfield, Wenona, Ransom, Dana, and Rutland are located in the southern part of the county.

U.S. Census Bureau data (Forstall, 1995) indicate that, from 1850 through 1900, the population of LaSalle County increased from about 18,000 residents to about 88,000 (fig. 3). From 1910 through 1960, the population increased more gradually, from about 90,000 in 1910 to about 111,000 in 1960. The population has remained stable at about 110,000 residents from 1960 through 2013, but was projected to increase to about 141,000 people by 2030 (LEAMgroup, Inc., 2008). The population increase was projected to occur primarily near the current population centers in the central and eastern parts of the county (LEAMgroup, Inc., 2008). This expansion was projected to increase the amount of land used for residential and commercial purposes in the county by almost 12.5 mi^2 and to increase demands on the water resources, particularly in the northern half of the county. At a per capita consumption rate of 80 to 100 gallons per day (gal/d; U.S. Geological Survey, undated a), the addition of about 30,000 people to the county by 2030 represents an additional water use of at least 2.4 million gallons per day (Mgal/d).

To provide context for the effects of population growth on water use, groundwater use in LaSalle County ranged from about 15 to 23 million gallons per day (Mgal/d) from 1960 through 2010 (table 1), with the majority of groundwater being used for *public supply*, *industrial self-supply*, and *domestic* self-supply. Surface water use since 1980 has been dominated by *thermoelectric power* supply, the majority of which is returned to the surface-water body from which it is taken. Public supply and *mining* withdrawals from surface-water sources also is substantial.

Because most of the water needs for the projected future population are likely to be met by groundwater through public and domestic self-supply, a projected increase of 2.4 Mgal/d is a substantial increase over recent water use. Possible increases in the area devoted to mining operations in the County also may result in an increase in groundwater use. The potential effects of increased groundwater use on water availability are highlighted by the presence of substantial decreases in water levels in some of the water-supply aquifers in northeast Illinois, including parts of LaSalle County (Abrams and others, 2015).

The u (unknown) values reported for use by public-supply systems during many of the dates listed in table 1 reflect the lack of reporting rather than an absence of use. The large variations through time in the surface-water withdrawals for mining use and power generation also may be affected by differences in the reporting as well as actual changes in surface-water use for these activities. Furthermore, is it likely that much of the surface water withdrawn for mining operations originated as groundwater flowing into the quarries so that some of this use is indicative of withdrawals from the groundwater system.

In addition to the role of water use on water availability, the future use of the water resources in the county is affected by the hydraulic properties of the geologic deposits along with surface-water and groundwater quality. Compilation of the data pertaining to these features into a hydrogeologic framework for LaSalle County is a necessary first step in ensuring the sustainable availability of the water resources for growth of the economy and population of LaSalle County.

Purpose and Scope

This report provides an assessment of the water resources of LaSalle County, Illinois. This assessment is based on an evaluation of published reports and datasets on water use, population, land use, physiography, climate, geology, surface-water hydrology, groundwater hydrology, and surface-water and groundwater quality in the county. Interpretations of the geology of the county made in this report are based on analysis of *lithologic* descriptions from more than 100 *monitoring wells* and more than 2,000 water-supply wells. Estimates of transmissivity of the uppermost bedrock (Ancell) aquifer based on nearly 900 *specific-capacity tests* performed throughout the county also are included in the report.

Methods of Investigation

Much of the information on water use, geology, hydrology, and water quality in LaSalle County was compiled from previous investigations of northern and northeastern Illinois performed by Federal and State scientific and regulatory agencies.

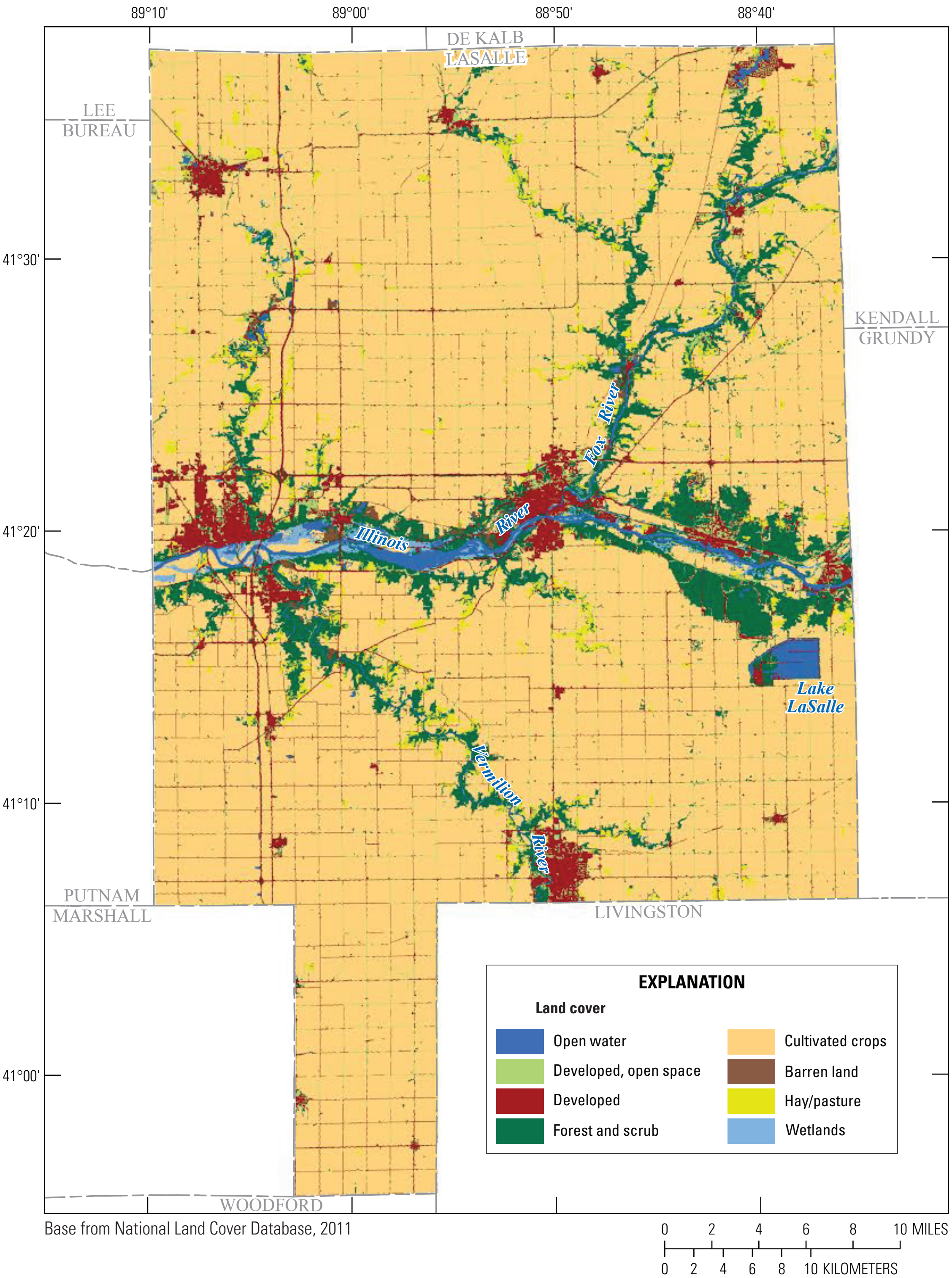


Figure 2. Land cover in LaSalle County, Illinois, in 2011.

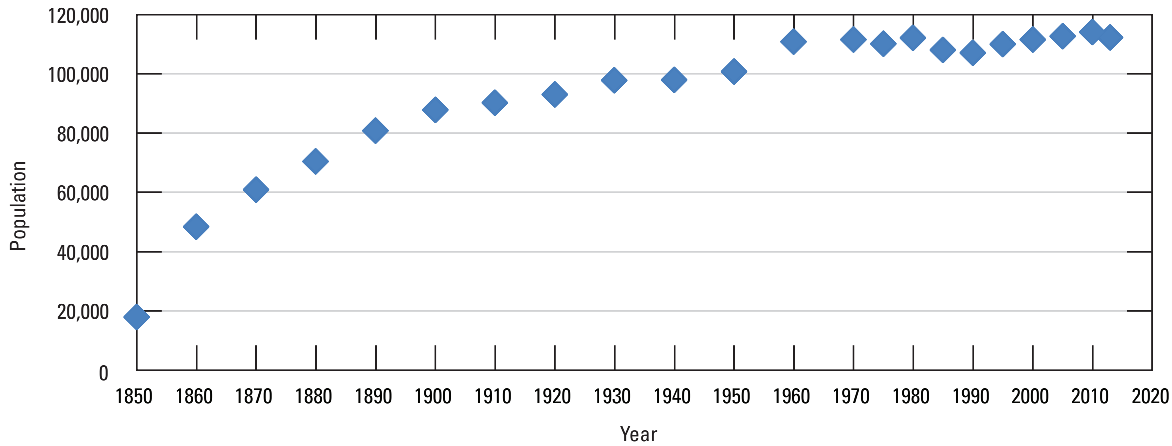


Figure 3. Population of LaSalle County, Illinois, from 1850 through 2013. Data are from U.S. Census Bureau (2015).

Water-use information collected every 2 to 5 years from 1960 through 2011 was obtained from previous investigations (Sasman and others, 1961, 1967, 1974, 1986; Kirk and others, 1979, 1982, 1985; Kirk, 1987; Avery, 1995, 1996, 1999; Hlinka and others, 2014) and from the USGS National Water Information System (NWIS) database for Illinois. These sources break water use down into several categories (including *irrigation*, *domestic supply*, *livestock*, *industrial supply*, *mining*, *thermoelectric* and *hydroelectric power generation,* and *public supply*). The volume of water extracted from each aquifer also was estimated. The completeness of these data is limited by the need to rely on the water user to report their water use.

The hydrogeologic framework for the aquifers and semiconfining units in LaSalle County is synthesized from previous investigations (Willman and others, 1942; Willman and Payne, 1943; Bergstrom and others, 1955; Suter and others, 1959; Buschbach, 1964; Emrich, 1966; Willman, 1971; Visocky and others, 1985) and by analysis of approximately 2,000 well logs on file with the Illinois State Geological Survey (ISGS) well database (http://maps.isgs.illinois.edu/ilwater/). These records include information on location (latitude, longitude, and address), well construction, lithologic description, static groundwater levels, and the geologic deposits that supply water to the well. Well location and altitude of land surface were verified by use of Google Earth® to confirm addresses

Table 1. Reported water withdrawals and water use in LaSalle County, Illinois, from 1960 to 2011.

[Data are compiled from Sasman and others (1974), Kirk and others (1979, 1982, 1985), Kirk (1987), Avery (1995, 1996, 1999), and Hlinka and others (2014). Mgal/d, Million gallons per day; u, unknown, not reported; >, greater than; GW, denotes withdrawals from groundwater; SW, denotes withdrawals from surface water]

Year	Public supply (Mgal/d)		Commercial self supply (Mgal/d)		Domestic self supply (Mgal/d)		Industrial self supply (Mgal/d)		Mining self supply (Mgal/d)		Livestock self supply (Mgal/d)		Irrigation self supply (Mgal/d)		Electric power generation (Mgal/d)	
	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW	GW	SW
1960	6.2	u	u	u	3.2	u	4.4	u	u	u	u	u	u	u	u	u
1970	8.8	u	u	u	2.6	u	4.6	u	u	u	u	u	u	u	u	u
1978	13	3.8	u	u	0.8	0	5.4	14	0.5	u	0.8	0	0	0	0.3	1,697
1980	11	u	0	0	1.6	0	4.5	0	0	0	0.8	0	0	0	1.8	1,939
1982	11	u	0	0	1.4	0	4.9	21	0	3.1	0.5	0	0.1	0	0.2	1,955
1984	10	u	0	0	0.3	0	6.2	24	0.1	12	0.4	0	0.3	0	0.5	2,209
1988	11	3.6	0	0	1.3	0	5.8	14	0	16	0.7	0	0.4	0	0.2	630
1990	11	3.4	0.1	0	1.4	0	3.2	3.9	0.2	21	0.7	0	0	0	0.2	1,329
1992	12	3.4	0	0	2.5	0	3.7	3.3	0.2	6	0.6	0	0.8	0	0.2	766
1995	14	1.8	0.1	0	2.4	0	3.4	0.1	0.3	4.9	0.4	0	0.8	0	0.2	860
2000	10	1	0	0	2.4	0	3.5	0.1	0.2	4	0.4	0	0.8	0	0.1	60
2005	13	u	0	0	2.5	0	3.5	0	0.2	19	0.3	0	3.2	0.2	0	80
2010	9.8	u	0	0	1.7	0	2.9	0	0	16	0.3	0	0.4	0.2	0	80
2011	9.3	u	0	0	u	u	3.2	u	u	u	u	0	u	u	0.1	2,454

and the presence of structures at the locations indicated on the well logs. The altitude values obtained from Google Earth® for selected wells and road intersections were compared with the values determined from well surveys and USGS topographic maps. The altitudes typically agreed to within 5 feet (ft), which is sufficiently accurate to meet the needs of the investigation. Additionally, hydrogeologic data were obtained from site-specific environmental investigations performed within the county (LandComp Corp., 1995; Dailey and Associates, 1999; Andrews Environmental Engineering, 2006, 2008; Hull and Associates, 2008; Patrick Engineering, Inc., 2011; Geosyntec Consultants, 2012).

Data on the location and characteristics of the watersheds were obtained from the USGS StreamStats program (U.S. Geological Survey, 2016a) and the NWIS database for Illinois (U.S. Geological Survey, 2016b). Discharge and stage data for the various surface-water bodies also was obtained from analysis of *streamgage* data from these water bodies stored in the NWIS database.

Surface- and groundwater-quality data were obtained from previous investigations, from the NWIS database for Illinois (U.S. Geological Survey, 2016b), from the Illinois Environmental Protection Agency (IEPA) online database (Illinois Environmental Protection Agency undated a), and IEPA offline data (Anthony Dulka, Illinois Environmental Protection Agency, written commun., 2016). These databases contain the results of periodic sampling at the location of several streamgages, in selected monitoring wells, and at public-supply wells in the county for a variety of constituents.

Physical Features of LaSalle County

Climate

The climate in LaSalle County is classified as temperate continental, with average monthly high temperatures ranging from 31 to 84 degrees Fahrenheit (°F), an average annual temperature of 50.5 °F, and an average annual precipitation of 35.6 inches (in.), according to data collected from a National Climate Data Center (undated) station at Ottawa. Precipitation varies seasonally, with monthly averages of about 1.4 to 1.5 in. in January and February, increasing to about 3.9 to 4.1 in. from May through August, and decreasing to 2.1 in. in December (table 2). More than half of all precipitation typically falls from April 1 through August 31.

Table 2. Average monthly precipitation and temperature data from 1961 to 2014 in Ottawa, LaSalle County, Illinois.

[Data are from National Climate Data Center (undated). °F, degree Fahrenheit; —, no data]

	Precipitation (inches)	Temperature (°F)	
		High	Low
January	1.50	31	15
February	1.42	36	19
March	2.44	49	29
April	3.23	62	40
May	4.09	72	51
June	3.98	81	60
July	3.86	84	64
August	3.90	83	62
September	3.27	77	54
October	2.80	65	42
November	2.95	49	30
December	2.13	36	20
Total	35.57	—	—

Physiography

LaSalle County is part of the Bloomington Ridged Plain subsection of the Till Plains section of the Central Lowland *physiographic* province (Leighton and others, 1948). The Bloomington Ridged Plain is characterized by low, broad *morainic ridges* with intervening wide stretches of flat or gently undulating *ground moraine* (Willman and Frye, 1970). From east to west, these *moraines* are the Ransom, Norway, Farm Ridge, Minonk, Mount Palatine, Mendota, Arlington, Paw Paw, and La Moille moraines (fig. 4). The mineral composition of the Norway and Farm Ridge moraines differs from that of the other moraines due to differences in the lithology of the underlying bedrock that was eroded to provide the material for these deposits (Jones and others, 1966).

In the lowlands, between the morainal ridges, were the former Lake Ottawa and parts of the former Lake Illinois, Lake Ancona, and Lake Pontiac (Willman and others, 1942; Leighton and others, 1948; Willman and Frye, 1970). These lakes formed when water from melted glaciers and other sources ponded between the ridges. Lake Pontiac and Lake Ancona occupied largely the same area at different times (fig. 4), with Lake Pontiac extending somewhat further to the west than Lake Ancona due to its higher stage (Willman and Frye, 1970). At the east-central edge of the county is part of glacial Lake Wauponsee. These lakes were present behind the Farm Ridge, Minonk, Norway, and Ransom moraines as the ice sheets that formed the moraines melted. An erosional channel associated with flow from Lake Chicago (not shown on map) bisects the county along the Illinois River, roughly along the same path as glacial Lake Illinois and the outlets of glacial Lake Wauponsee. This channel was created by the *Kankakee torrent* around 19,000 years ago and is responsible for the break in the Farm Ridge, Norway, and Ransom moraines and the draining of glacial Lakes Wauponsee, Ottawa, and Illinois (Curry and others, 2014). Smaller channels associated with drainage from Lake Ancona and Lake Pontiac also have eroded through the Farm Ridge and Minonk moraines along the lower part of the Vermilion River.

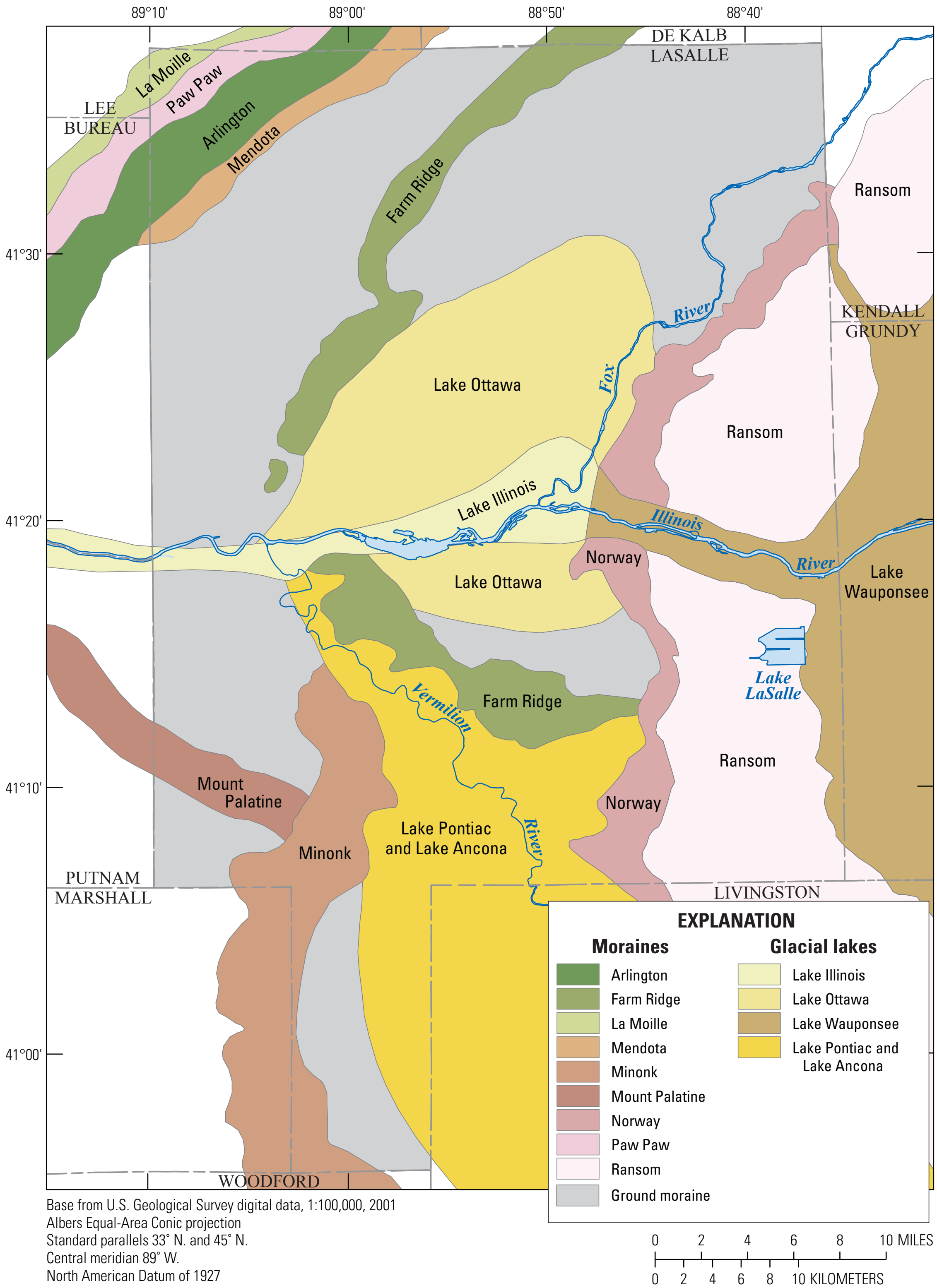


Figure 4. The physiography of LaSalle County, Illinois; modified from Willman and Frye (1970).

Topography and Watersheds

LaSalle County consists mostly of low broad morainal ridges separated by wide, flat lacustrine plains, with a few *fluvial* landforms. Land surface is elevated along ridges of the La Moille, Paw Paw, Arlington, and Mendota moraines in the northwestern part of the county near Mendota; the Farm Ridge moraine in the north-central and south-central parts of the county, the Minonk and Mount Palatine moraines in the southwestern parts of the county; and the Norway and Ransom moraines in the east-central part of the county near Marseilles (compare figs. 4 and 5). The altitude of the land surface along these ridges varies from 650 to 900 ft. Some of the moraines are disrupted by current and former river channels.

Topography defines the boundaries of the *watershed*s for the major surface-water bodies in LaSalle County. The Illinois River is the primary surface-water body in LaSalle County. The Fox and Little Vermilion Rivers are the primary tributaries to the Illinois River in the northern part of the county, and the Vermilion River is the primary tributary in the southern part of the county (fig. 6). Numerous smaller streams also are present. The boundaries for the major surface-water bodies are associated with topographic high points associated with the moraine ridges.

The Vermilion River watershed is in the south-central part of the county (fig. 6) and has a drainage area of 1,333 mi^2, according to StreamStats (U.S. Geological Survey, 2016a). The river originates in central Illinois and flows north, discharging to the Illinois River near LaSalle. The Lower Fox River watershed is located in the northeastern part of the county and has a drainage area of about 2,657 mi^2. The river originates in southeastern Wisconsin and flows to the south-southwest, discharging to the Illinois River at Ottawa. The Upper Illinois River watershed is located in the eastern part of the county upstream of the confluence of the Fox and Illinois Rivers and has a drainage area of about 8,259 mi^2. The Lower Illinois River watershed is located in the central and western part of the county in the drainage area downstream of the confluence of the Fox and Illinois Rivers (fig. 6). The Lower Illinois River watershed extends to the confluence with the Mississippi River and has a total drainage area of about 18,000 mi^2 in central and west-central Illinois (Groschen and others, 2000).

Streamflow

Active USGS streamflow-gaging stations are located on the Fox River at Dayton, the Illinois River at Marseilles, and the Vermilion River near Leonore (fig. 6). Daily discharge has been calculated from river stage beginning in *water years* 1916 at Dayton, 1919 at Marseilles, and 1972 at Leonore. Discharge of the Vermilion River at Lowell was monitored from 1931 through 1971. Annual mean stage has been calculated for several years from 1996 to 2014 at Marseilles and from 1998 to 2014 at Dayton.

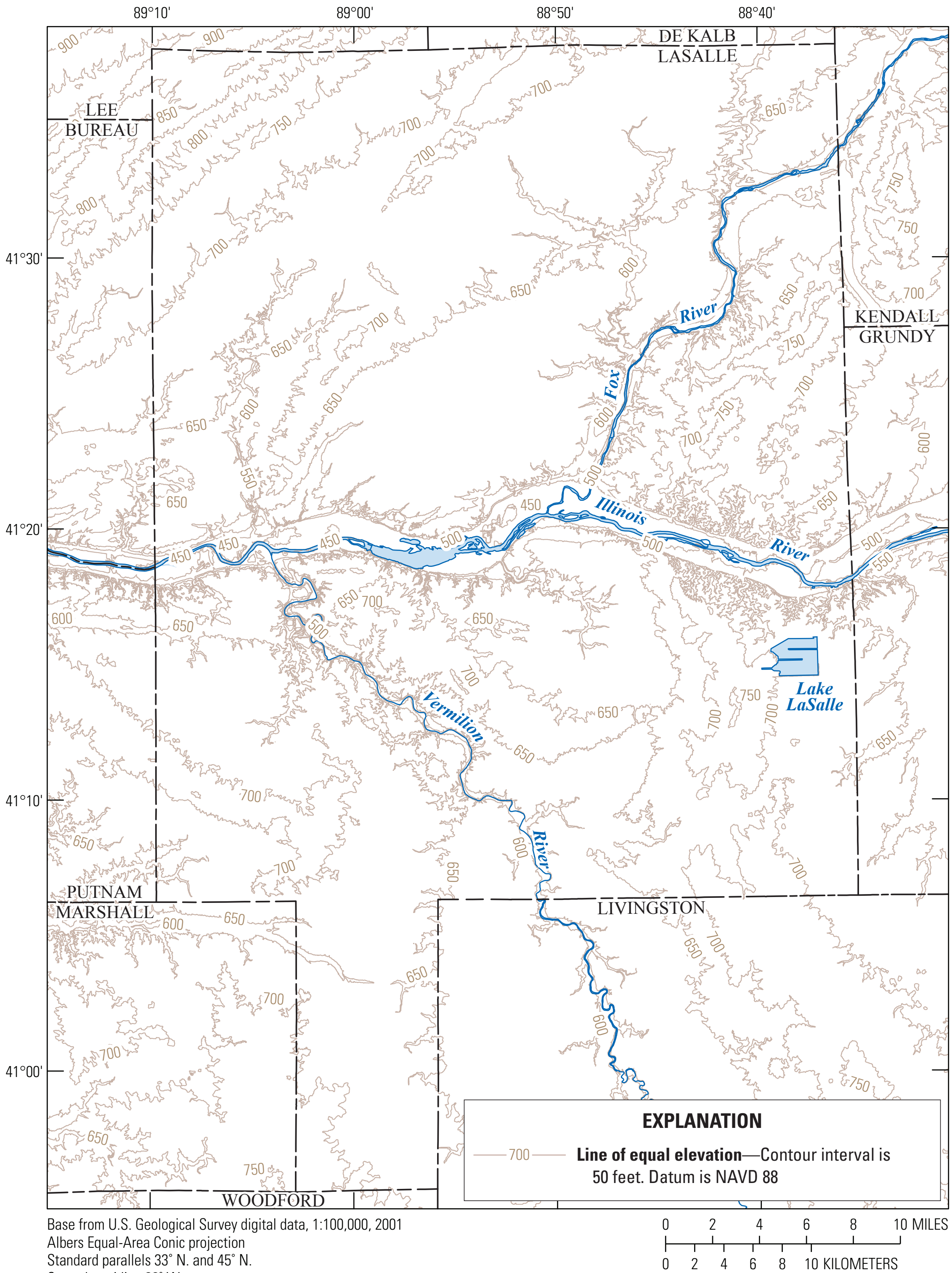
The Illinois River contains lock and dam structures at Marseilles and Starved Rock State Park (fig. 1). The Fox River also contains a lock and dam structure at Dayton. These structures are used for flood control and to facilitate navigation. As a consequence, operation of these structures can affect the *stage* and *discharge* on the river. The streamgages at Dayton and Marseilles are downstream of the dams.

The annual mean discharge of the Fox River at Dayton from 1916 through 2014 ranged from 329 ft^3/s during the drought year of 1934 to 3,940 ft^3/s in 1993 (fig. 7). The minimum mean monthly discharge of the Fox River at Dayton (fig. 8) occurs during August and September (1,040 and 1,050 ft^3/s, respectively) and the maximum occurs during March and April (3,360 and 3,350 ft^3/s, respectively). Discharge at the streamgage showed a statistically significant increase during the period of record, from 1916 to 2014. This increase may reflect the effects of dam operations on discharge, several drought years on discharge during the earlier part of the period of record, or increased surface-water runoff associated with urban or agricultural development in the basin through the years. Annual mean stream stage ranged from 470.34 to 488.4 ft NAVD 88.

The discharge data on the Vermilion River at Lowell (1932–71) and Leonore (1972–2014) were combined to provide a complete record from 1932 through 2014. The annual mean discharge of the Vermilion River from 1932 through 2014 ranged from 100 ft^3/s in 1940 to 2,419 ft^3/s in 1993 (fig. 7). The minimum monthly mean discharge of the Vermilion River (fig. 8) occurs during August (303 ft^3/s at Leonore and 197 ft^3/s at Lowell), and the maximum occurs during March and April (1,980 ft^3/s at Leonore and 1,620 ft^3/s at Lowell).

Discharge on the Illinois River was approximately an order of magnitude higher than its tributaries, with the annual mean discharge from 1920 through 2014 ranging from 5,583 ft^3/s during 1964 to 17,850 ft^3/s during 1993 (fig. 7). The minimum monthly mean discharge of the Illinois River (fig. 8) occurs during October (7,370 ft^3/s), and the maximum occurs during April (16,100 ft^3/s). From 1996 through 2014, the geometric mean annual stage of the Illinois River at Marseilles downstream of the lock and dam varied from 464.7 to 466.1 ft NAVD 88. This stage represents the approximate maximum water level on the Illinois River in most of LaSalle County.

There are 21 wastewater treatment plants that have National Pollutant Discharge Elimination System (NPDES) permits to discharge to surface water in LaSalle County (U.S. Environmental Protection Agency, undated a). Of these, 14 typically discharge more than 0.25 Mgal/d, and 7 discharge more than 1.0 Mgal/d. Numerous industrial facilities, quarries, and thermoelectric power generators also have NPDES permits to discharge stormwater runoff, noncontact cooling water, and process waters to surface waters in the county. The average allowable discharges for the various facilities as well as the receiving streams are listed in table 3.



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Central meridian 89° W.
North American Datum of 1927

Figure 5. Topography of LaSalle County, Illinois.

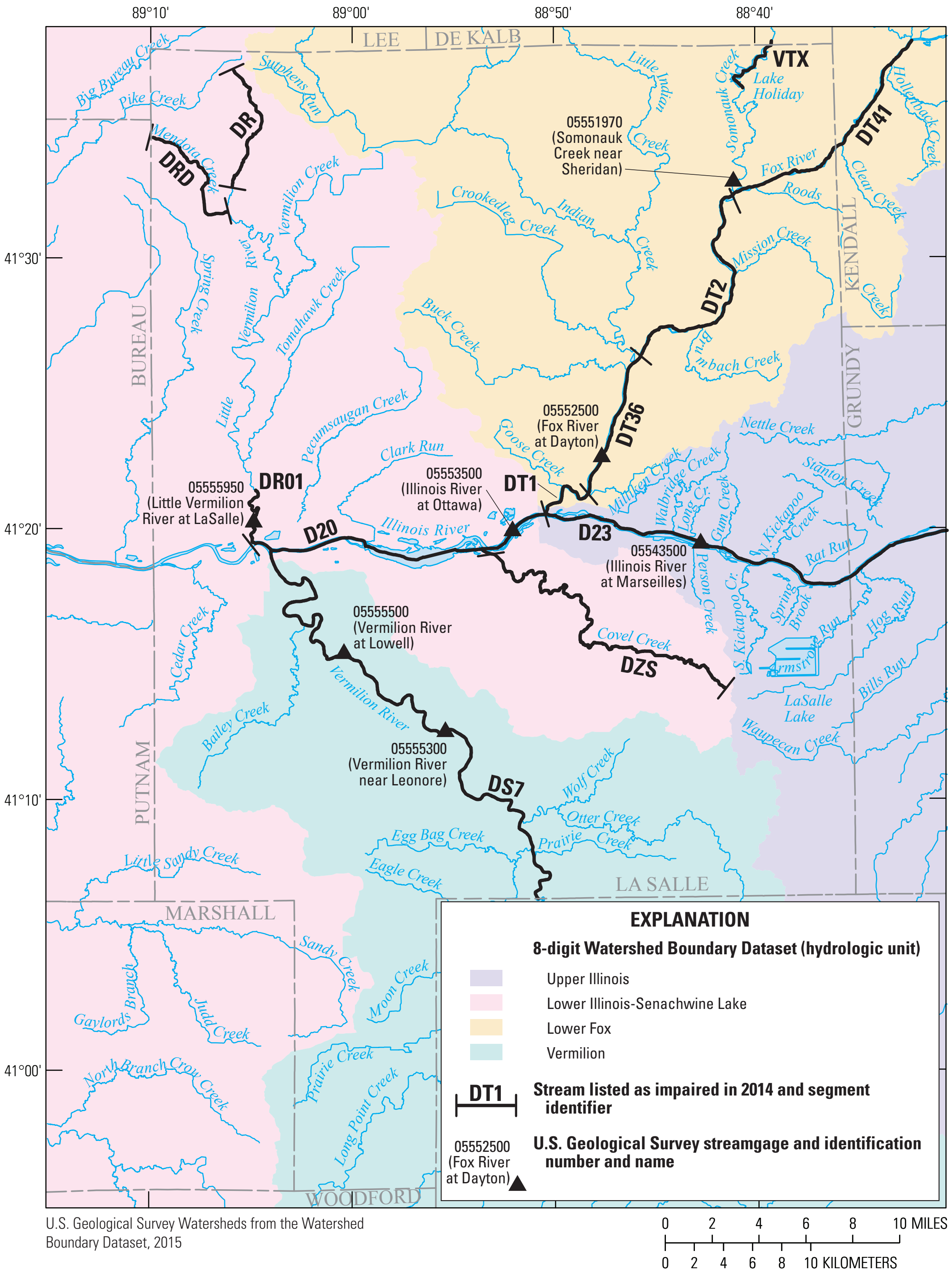

Figure 6. Watershed boundaries, streams listed as impaired by the Illinois Environmental Protection Agency under section 303(d) in 2014, and U.S. Geological Survey streamgages on or near those streams in LaSalle County, Illinois.

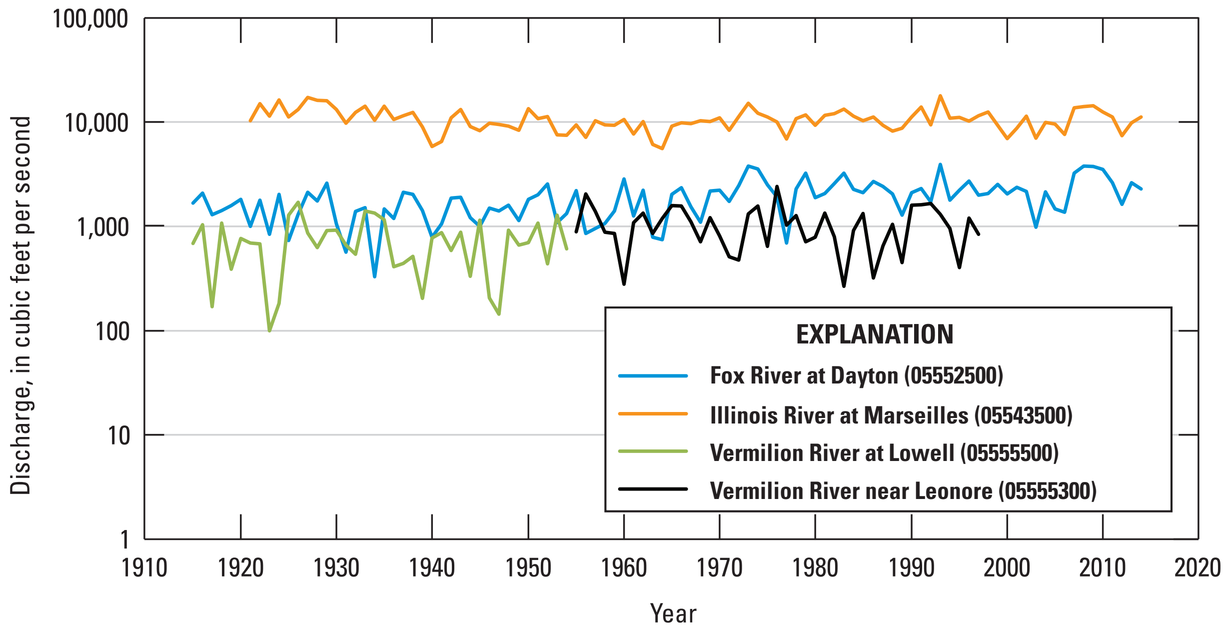

Figure 7. Annual mean discharge of the Fox River at Dayton, Vermilion River at Lowell, Vermilion River near Leonore, and Illinois River at Marseilles, Illinois, from 1915 to 2015.

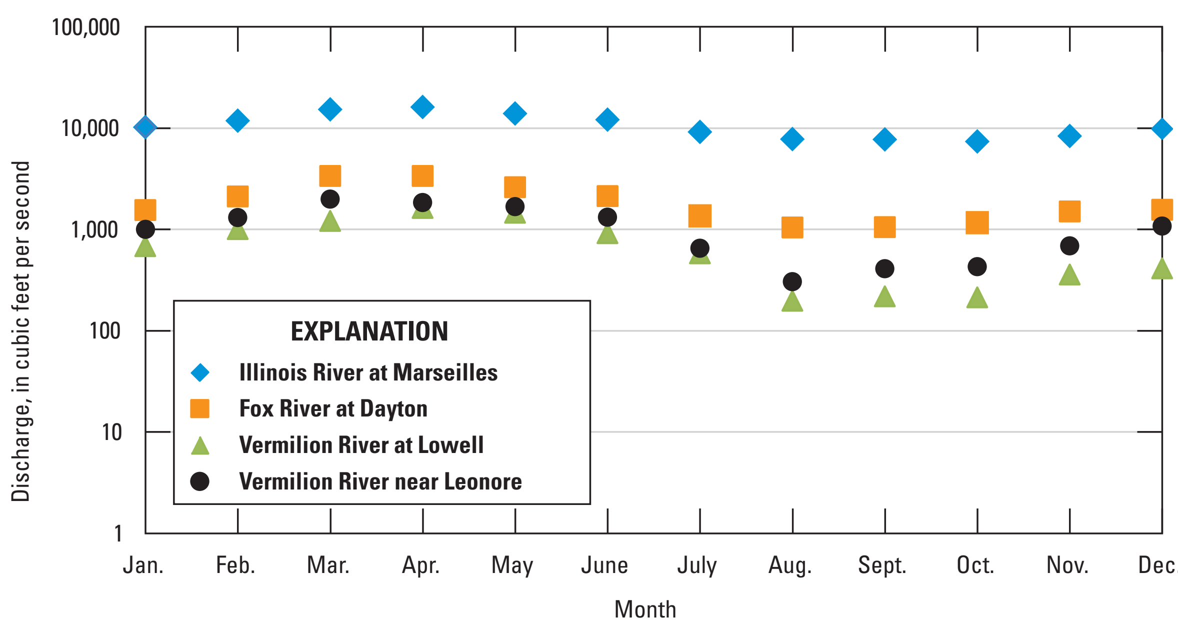

Figure 8. Monthly mean discharge at the Fox River at Dayton, Vermilion River at Lowell, Vermilion River near Leonore, and Illinois River at Marseilles, Illinois, from 1915 to 2015.

Table 3. National Pollution Discharge Elimination System permitted facilities in LaSalle County, Illinois.

[Mgal/d, million gallons per day; WWT, wastewater treatment]

Permit identification	Type of facility	Receiving body	Typical allowable discharge (Mgal/d)
IL0001708	Industrial	Illinois River	2.1
IL0078271	Industrial	Little Vermilion	0.13
IL0036595	Industrial	Vermilion	0.70
IL0001759	Quarry	Fox River, Buck Creek	6.5
IL0020877	WWT	Indian Creek	0.38
IL0030384	WWT	Illinois River	4.0
IL0031062	WWT	Fox River	0.37
IL0074098	Well	Fox River	0.075
IL0074101	Well	Fox River	0.22
ILG840084	Quarry	Somonauk Creek	Unknown
IL0064416	WWT	Fox River	0.075
ILR006834	Industrial	Pecumsaugan Creek	Unknown
IL0001325	Quarry	Illinois River, Illinois and Michigan Canal	0.78
IL0001384	Industrial	Illinois River	Unknown
IL0048151	Power generation	Illinois River	35
IL0001724	Industrial	Illinois River	0.022
IL0001741	Industrial	Clark Run	0.27
IL0001783	Industrial	Illinois River	0.002
IL0001929	Industrial	Illinois River	6.4
IL0002623	Industrial	Little Vermilion River	1.7
IL0054038	WWT	Illinois River	0.050
IL0003115	Industrial	Little Vermilion River	0.42
IL0021059	WWT	Long Creek	3.15
IL0064033	WWT	North Kickapoo Creek	0.030
IL0022446	WWT	Rat Run	0.96
IL0069281	Industrial	Illinois River	0.090
IL0023116	WWT	Clark Run	0.30
IL0023221	WWT	Mendota Creek	2.4
IL0070017	WWT	Illinois River	0.0090
IL0024996	WWT	Vermilion River	0.87
IL0071498	WWT	Illinois River	0.44
ILG840123	Quarry	Little Vermilion River	Unknown
IL0075507	WWT	Illinois River	1.0
IL0029424	WWT	Illinois River	3.3
IL0078051	Power generation	Illinois River	0.063
IL0030384	WWT	Illinois River	4.0
IL0030660	WWT	Illinois River	3.0
ILG580008	WWT	Cedar Creek	0.050
IL0035670	Industrial	Illinois River	0.0020
IL0036463	Industrial	Illinois River	Unknown
IL0038296	Industrial	Little Vermilion River	0.020
ILG640125	WWT	Waupecan Creek	0.0010
ILG840049	Quarry	Little Vermilion River	Unknown
IL0022004	WWT	Vermilion River	3.3
ILG640074	WWT	Prairie Creek	0.020
IL0065587	Quarry	Vermilion River	Unknown
IL0075671	Landfill	Illinois River tributary	0.018
IL0080047	Quarry	Pecumsaugen Creek	0.66

Geology and Structural Features

The geology of LaSalle County can be divided into the *unconsolidated deposits* of the *Quaternary* System and the underlying bedrock units of the Cambrian, Ordovician, Silurian, *Devonian*, and Pennsylvanian Systems. The *stratigraphic* framework for these units is shown in figure 9. Stratigraphic nomenclature used is that of the ISGS (Willman and others, 1975) and does not necessarily conform to usage of the USGS. Unit thickness depicted in figure 9 and elsewhere in the report are based on USGS analysis of *lithologic logs* and *isopach maps* from Willman and others (1975). Detailed information on the geologic deposits is presented in appendix 1.

The distribution of the bedrock geologic units in LaSalle County is affected by the Sandwich *Fault* Zone to the northeast and features that are part of the LaSalle *Anticlinorium* in the central and western parts of the county. Numerous smaller structural features also affect the location of the bedrock deposits in the county.

The Sandwich Fault Zone underlies most of northern Illinois and is present near the northeastern tip of LaSalle County (fig. 10). The fault zone is up to 1 mile (mi) in width. Major uplift may have occurred during the late *Mississippian* through the early Pennsylvanian period of time, with lesser uplift after the early Pennsylvanian (Kolata and others, 1978; Nelson, 1995). Uplift ended before deposition of the Quaternary materials (about 40,000 years before present). The fault zone trends approximately N60°W and is nearly vertical, with the upthrown side to the south. Displacement along the fault zone is as much as 800 ft. As a consequence of this displacement, the youngest bedrock units have been eroded in much of the northern and northeastern parts of LaSalle County so that older deposits are at the bedrock surface (figs. 9, 10, and 11).

The LaSalle Anticlinorium is a compound *anticline* consisting of a complex of anticlines (including the Ancona Anticline), *domes* (including the Troy Grove Dome), *monoclines* (such as the Peru Monocline) and *synclines* (Nelson, 1995). The LaSalle Anticlinorium trends about N20°W from Wabash County in southeastern Illinois to Ogle County in northwestern Illinois. The majority of the development of the anticlinorium and its component features in northern Illinois is in response to faulting in pre-Cambrian deposits.

The Peru Monocline is the northernmost major segment of the LaSalle Anticlinorium. The monocline is about 65 mi long, trends northwest to southeast, and extends from western Livingston County through western LaSalle County (fig. 10), before terminating in Lee County. Development of the monocline occurred after the Mississippian and into the early Pennsylvanian time period. The Peru Monocline is strongly asymmetric, *dipping* as much as 45 degrees (°) on its western flank and about 2° on its eastern flank (figs. 10 and 12). As a consequence of the location and timing of the development of the monocline, any bedrock deposit in LaSalle County accumulated prior to the Upper Pennsylvanian is present at a lower altitude along the steeply dipping western flank of the monocline than in the flatter eastern area (Nelson, 1995). Additionally, some of the younger bedrock deposits present on the western flank of the monocline have been removed by erosion in the central and eastern parts of the county.

The Troy Grove Dome (fig. 10) is an east-west trending anticline along the northern end of the LaSalle Anticlinorium present west of the town of Troy Grove (Bell, 1961; Nelson, 1995). The dome is about 5 mi long and 3 mi wide. The Cambrian deposits along the top of the dome are about 120 ft higher than in the surrounding area. The dome contains four east-west trending vertical faults that form a series of *grabens* that have a displacement ranging from about 15 to 180 ft. At any given altitude, younger rocks tend to be present on the northern (downthrown) side of the largest of these faults and older rocks are present to the south.

The Ancona Anticline (fig. 10) is a northwest-southeast trending asymmetrical anticline about 10 mi long and 3 mi wide located near Garfield in southern LaSalle County and extending into Livingston County south of Ancona (Buschbach and Bond, 1967; Nelson, 1995). The Cambrian deposits along the crest of the anticline are as much as 290 ft higher than in the surrounding area.

Water Use

Table 1 lists a breakdown of water use in LaSalle County for various categories from 1960 through 2011, the most recent date for which compiled data is available. Table 4 provides a summary of data on water use and water sources for the public-water supply systems in LaSalle County.

Categories for defining water use differed prior to 1980, from 1980 through 2010, and in 2011, so not all the categories listed in table 1 have values for all the reporting periods. In addition, the amount of water used for many categories is voluntarily reported by the water user to the Illinois State Water Survey (ISWS), who compile the data on a periodic basis. Detailed discussion of the methodology for estimating water use for public-supply facilities, mining companies, power generators, commercial, and industrial facilities is provided by Avery (1999), who notes that most water-use estimates are based on voluntary responses to questionnaires submitted to the ISWS. Estimates of water use for domestic self-supply and livestock are based on population estimates (human and livestock) and per capita water use for humans and livestock. Estimates of water use for irrigation are based on irrigated crop acreage and rainfall deficit during the growing season. The ISWS sends the compiled reported data to the USGS for their estimation of National water use during 5-year periods. These estimates undergo additional refinement for the estimates. Large differences in estimates of water use through time reported for some categories in table 1 may be partly a reflection of the changes in how the categories of use are defined, variability of voluntary reporting, or varied methods of estimation of use values between agencies and through time, rather than actual changes in water use. Water-use data from 2011 are too limited to determine an accurate total and are only discussed for those categories where results are provided.

System	Group	Formation	Regional hydrogeologic designation	County hydrogeologic designation	Thickness (feet)	Description
Quaternary			Sand and gravel aquifers and till, silt, and clay confining units	Sand and gravel aquifers and till, silt, and clay confining units	0–400	Glacial-till: alluvial silt, sand, gravel
Pennsylvanian		Mattoon Bond Shelburn-Patoka Carbondale Tradewater	Semiconfining unit	Semiconfining unit	0–500	Mainly shale, some sandstone, limestone, coal
Devonian					0–40	Limestone
Silurian			Silurian aquifer	Silurian aquifer	0–500	Dolomite, silty at base
Ordovician	Maquoketa	Neda Brainard Fort Atkinson Scales	Semiconfining unit	Semiconfining unit	0–170	Shale, locally argillaceous dolomite or limestone
	Galena		Cambrian-Ordovician aquifer system	Yields water where at bedrock surface; part of confining unit where overlain by Maquoketa deposits	0–300	Dolomite
	Platteville					
	Ancell	Glenwood		Ancell aquifer	0–285	Sandstone, shale at top
		St. Peter				Sandstone can be poorly consolidated in upper part
	Prairie du Chien	Shakopee		Middle semiconfining unit: Semiconfining unit in most of county; yields water where at bedrock surface	0–200	Dolomite
		New Richmond		Aquifer	0–160	Sandstone
		Oneota		Typically semiconfining unit; can yield water where fractured	150–200	Dolomite
		Gunter			14–25	Sandstone
Cambrian		Eminence Potosi			200–300	Dolomite and sandstone
		Franconia			110–200	Dolomite, sandstone, and shale
		Ironton		Ironton-Galesville aquifer	160–225	Sandstone
		Galesville				
		Eau Claire	Lower semiconfining unit	Lower semiconfining unit	350–450	Shale, siltstone, dolomite
			Mount Simon aquifer	Mount Simon aquifer	2,000–2,500	Sandstone (Elmhurst Member)
		Mount Simon				Sandstone

Figure 9. Stratigraphic and hydrogeologic units in LaSalle County, Illinois. Compiled from well logs and Willman and others (1975).

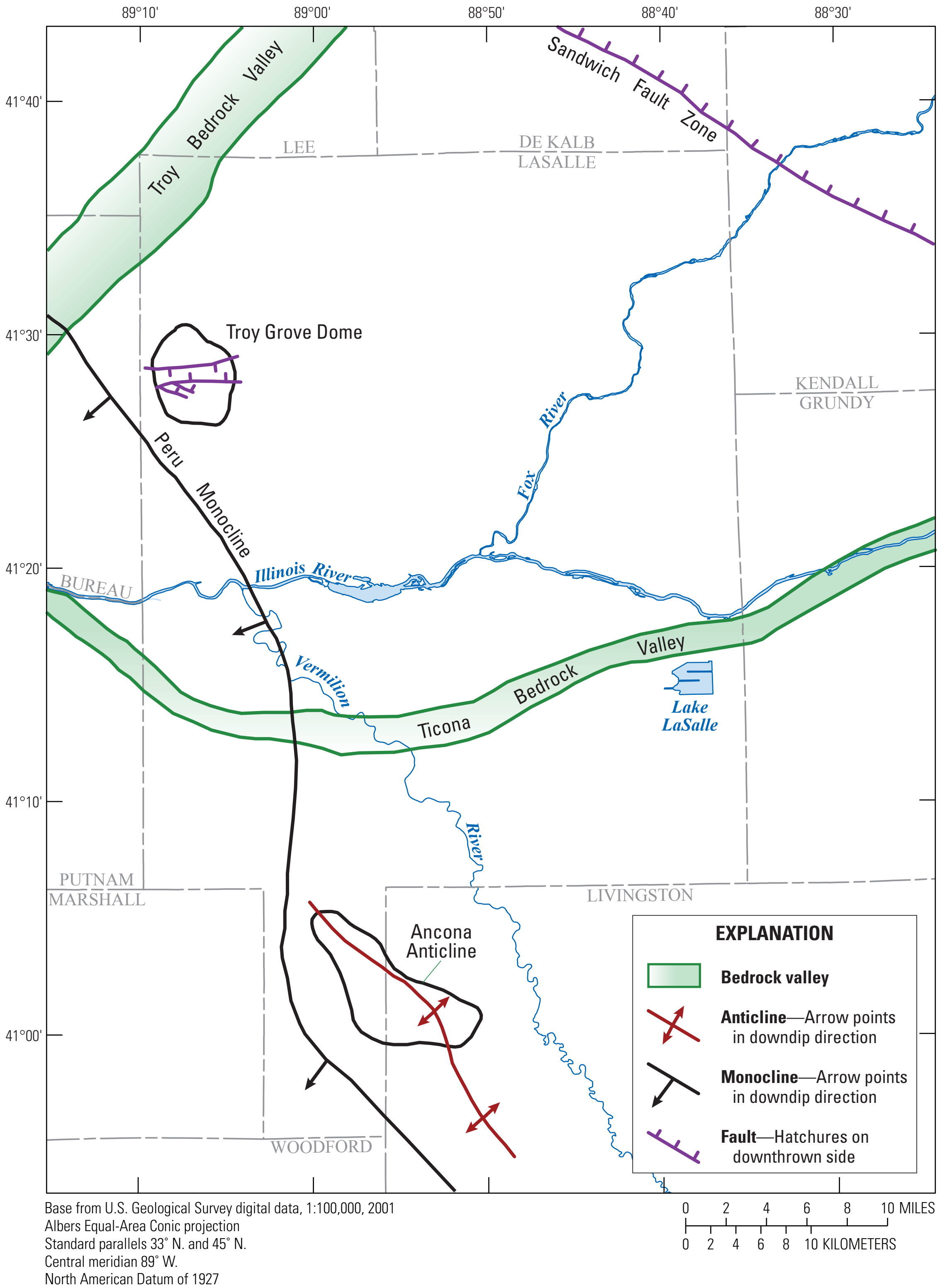

Figure 10. Selected geologic features in LaSalle County, Illinois.

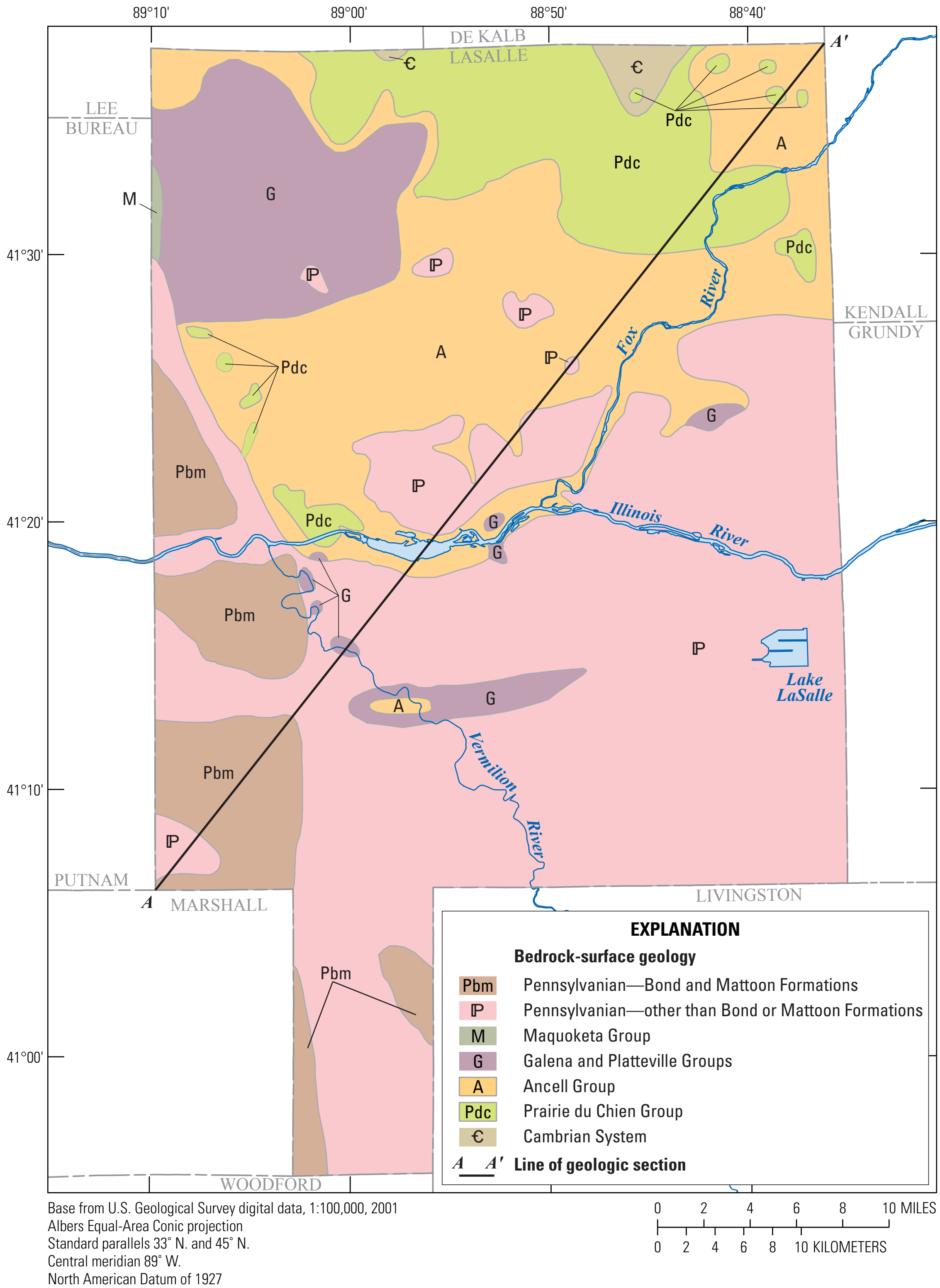

Figure 11. Geology of the bedrock surface in LaSalle County, Illinois; modified from Kolata and others (2005).

Estimates of groundwater withdrawals from 1960 through 2010 indicate that total groundwater use increased from about 14 Mgal/d in 1960 to about 20 Mgal/d for most of the period from 1978 through 2005, before decreasing to about 15 Mgal/d in 2010 (table 1; Sasman and others, 1974; Kirk and others, 1979, 1982, 1985; Kirk, 1987; Avery, 1995, 1996, 1999; Hlinka and others, 2014). The amount of groundwater withdrawn by public-supply systems for distribution to their customers (residences, industrial facilities, commercial establishments) accounted for about 60 percent of the total groundwater use from 1960 through 2011. The amount of groundwater withdrawn by homeowners who rely on private wells (domestic self-supply) accounted for about 10 percent of groundwater withdrawals in LaSalle County. The reported volume of groundwater withdrawn by industrial facilities from their private wells (industrial self-supply) was higher prior to 1990 than it has been since 1990. Estimated groundwater withdrawals for all other uses have typically been substantially less than 1.0 Mgal/d. Because water needs for the projected future population are likely to be met by groundwater for public and domestic self-supply, a projected increase of 2.4 Mgal/d has the potential to increase water use in these categories to above or near their historic maximums for these categories.

Analysis of the amount of groundwater withdrawn from the aquifers beneath LaSalle County (fig. 9) from 1960 through 2010 (Sasman and others, 1974; Kirk and others,

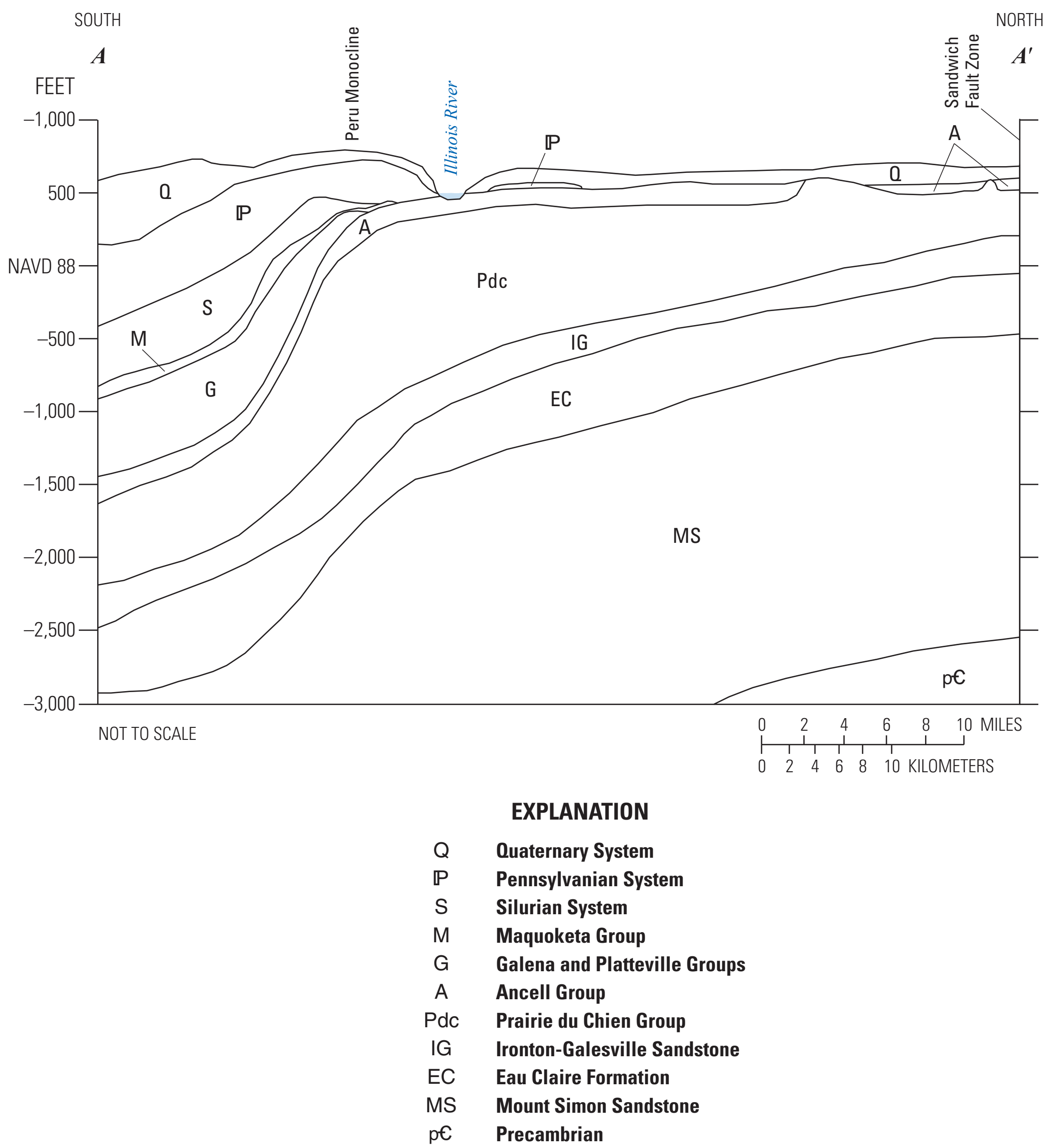

Figure 12. Geologic section *A–A′* through LaSalle County, Illinois. Line of section shown in figure 11.

Table 4. Summary of information from selected water-supply systems in LaSalle County, Illinois.

[Data are from U.S. Geological Survey (2016c), Illinois Environmental Protection Agency (undated a), and Anthony Dulka (Illinois Environmental Protection Agency, written commun., 2016). na, not applicable; --, no data]

Owner	Approximate location	Well name	Water source	Depth of well (feet)	Withdrawal for system (gallons per day)	Remarks
Cedar Point	Shown in figure 1	1	Cambrian-Ordovician	1,750	20,020	
Country Acres Mobile Home Park	South of Seneca on figure 1	1	Ancell	550	64,370 split between wells 1 and 3	
Country Acres Mobile Home Park	South of Seneca on figure 1	2	Unknown	160	--	Abandoned
Country Acres Mobile Home Park	South of Seneca on figure 1	3	Ancell	550	--	
Countryside Estates Mobile Home Park	South of Lake Holiday in figure 1	1	Ancell	200	9,000 split between wells 1 and 2	
Countryside Estates Mobile Home Park	South of Lake Holiday in figure 1	2	Ancell	192	--	
Dattis Mobile Home Park	North of Ottawa in figure 1	1	Ancell/New Richmond	508	8,000	
Earlville	Shown in figure 1	2	Ancell	150	0	Emergency supply
Earlville	Shown in figure 1	3	Cambrian-Ordovician	888	186,265 split between wells 3 and 4	
Earlville	Shown in figure 1	4	Cambrian-Ordovician	888	--	
Four Lakes Subdivision	Near Marseilles in figure 1	1	Cambrian-Ordovician	500	6,900	
Four Star Campground	Near Marseilles on figure 1	1	Ancell	460	5,760	1
Glenwood-Outback	Near Marseilles on figure 1	1	Unknown	360	2,000	Inactive
Grand Ridge	Shown in figure 1	1	Glacial	162	0	Emergency supply
Grand Ridge	Shown in figure 1	3	Glacial	190	68,150 split between wells 3 and 4	
Grand Ridge	Shown in figure 1	4	Glacial	190	--	
Illinois American Streator	Shown in figure 1	na	Vermilion River	na	2,400,000	
Illinois Prairie Estates	Near Marseilles on figure 1	1	Cambrian-Ordovician	660	4,986	
Jon’s Mobile Home Park	East of Lake Holiday in figure 1	1	Prairie du Chien	100	--	Abandoned
Jon’s Mobile Home Park	East of Lake Holiday in figure 1	2	Ancell	110	0	Emergency supply
Jon’s Mobile Home Park	East of Lake Holiday in figure 1	3	Prairie du Chien	220	8,545	
LaSalle	Shown in figure 1	3	Glacial	--	--	Abandoned
LaSalle	Shown in figure 1	4	Glacial	53	3,223,400 split between wells 4, 6, 8, 9, 10, 11 and 12	
LaSalle	Shown in figure 1	5	Glacial	--	--	Abandoned

Table 4. Summary of information from selected water-supply systems in LaSalle County, Illinois.—Continued

[Data are from U.S. Geological Survey (2016c), Illinois Environmental Protection Agency (undated a), and Anthony Dulka (Illinois Environmental Protection Agency, written commun., 2016). na, not applicable; --, no data]

Owner	Approximate location	Well name	Water source	Depth of well (feet)	Withdrawal for system (gallons per day)	Remarks
LaSalle	Shown in figure 1	6	Glacial	56	--	
LaSalle	Shown in figure 1	7	Glacial	49	0	
LaSalle	Shown in figure 1	8	Glacial	76	--	
LaSalle	Shown in figure 1	9	Glacial	68	--	
LaSalle	Shown in figure 1	10	Glacial	67	--	
LaSalle	Shown in figure 1	11	Glacial	64	--	
LaSalle	Shown in figure 1	12	Glacial	63	--	
LaSalle County Nursing Home	West of Ottawa on figure 1	1	Ancell/New Richmond	345	0	Emergency supply
LaSalle County Nursing Home	West of Ottawa on figure 1	3	Ancell/New Richmond	372	13,000	
Land and Water Association	Near Marseilles in figure 1	1	Cambrian-Ordovician	540	12,000	
Leland	Shown in figure 1	1	Prairie du Chien	230	122,400 split between wells 1 and 2	
Leland	Shown in figure 1	2	Prairie du Chien	200	--	
Leonore	Shown in figure 1	1	Glacial	40	0	Inactive
Leonore	Shown in figure 1	2	Glacial	92	8,650	--
Lostant	Shown in figure 1	3	Glacial	135	--	Abandoned
Lostant	Shown in figure 1	4	Ancell	1,881	0	Emergency supply
Lostant	Shown in figure 1	5	Ancell	1,880	44,700	
Lynnwood Water Corp.	Near Peru in figure 1	1	Cambrian-Ordovician	1,364	12,500	
Marseilles	Shown in figure 1	1	Ancell	168	--	Abandoned
Marseilles	Shown in figure 1	2	Ancell	180	--	Abandoned
Marseilles	Shown in figure 1	2	New Richmond	670	--	Abandoned
Marseilles	Shown in figure 1	3	New Richmond	850	0	Emergency
Marseilles	Shown in figure 1	4	New Richmond/Ironton-Galesville	1,450	480,000 split between wells 4 and 5	
Marseilles	Shown in figure 1	5	New Richmond/Ironton-Galesville	1,450	--	
Marseilles	Shown in figure 1	6	New Richmond/Ironton-Galesville	1,450	0	Inactive
Mendota	Shown in figure 1	3	Cambrian-Ordovician	1,354	1,100,000 split between wells 3, 4, 6, 7, and 8	

Table 4. Summary of information from selected water-supply systems in LaSalle County, Illinois.—Continued

[Data are from U.S. Geological Survey (2016c), Illinois Environmental Protection Agency (undated a), and Anthony Dulka (Illinois Environmental Protection Agency, written commun., 2016). na, not applicable; --, no data]

Owner	Approximate location	Well name	Water source	Depth of well (feet)	Withdrawal for system (gallons per day)	Remarks
Mendota	Shown in figure 1	4	Cambrian-Ordovician	1,297	--	
Mendota	Shown in figure 1	5	Cambrian-Ordovician	502	--	Abandoned
Mendota	Shown in figure 1	6	Cambrian-Ordovician	1,400	--	
Mendota	Shown in figure 1	7	Cambrian-Ordovician	519	--	Emergency
Mendota	Shown in figure 1	8	Cambrian-Ordovician	519	--	Emergency
Naplate	Shown in figure 1	1	New Richmond	420	36,134	
Naplate	Shown in figure 1	2	New Richmond	395	0	Emergency
North Utica	Shown in figure 1	1	Cambrian-Ordovician	618	325,000 split between wells 1 and 2	
North Utica	Shown in figure 1	2	Cambrian-Ordovician	1,078	--	
Oaklane Subdivision	Near Ottawa in figure 1	1	Cambrian-Ordovician	287	0	Emergency
Oaklane Subdivision	Near Ottawa in figure 1	2	Cambrian-Ordovician	504	4,400	
Oglesby	Shown in figure 1	2	Cambrian-Ordovician	2,784	--	Abandoned
Oglesby	Shown in figure 1	3	Cambrian-Ordovician	2,821	487,000 split between wells 3 and 4	
Oglesby	Shown in figure 1	4	Cambrian-Ordovician	2,795	--	
Ottawa	Shown in figure 1	7	Ironton-Galesville	1,185	--	Abandoned
Ottawa	Shown in figure 1	8	Cambrian-Ordovician	1,180	2,323,400 split between wells 8, 10, 11, 12, and 14	
Ottawa	Shown in figure 1	10	New Richmond/Ironton-Galesville	1,220	--	
Ottawa	Shown in figure 1	11	New Richmond/Ironton-Galesville	1,203	--	
Ottawa	Shown in figure 1	12	Ironton-Galesville	1,200	--	
Ottawa	Shown in figure 1	14	New Richmond/Ironton-Galesville	1,205	--	
Peru	Shown in figure 1	4	Unknown	996	0	Inactive
Peru	Shown in figure 1	5	Cambrian-Ordovician	2,576	2,523,000 split between wells 5, 6, 7, 8, and 9	
Peru	Shown in figure 1	6	Cambrian-Ordovician	2,665	--	
Peru	Shown in figure 1	7	Cambrian-Ordovician	2,591	--	
Peru	Shown in figure 1	8	Cambrian-Ordovician	2,764	--	
Peru	Shown in figure 1	9	Cambrian-Ordovician	2,759	--	
Ransom	Shown in figure 1	1	Pennsylvanian	325	0	Inactive

Table 4. Summary of information from selected water-supply systems in LaSalle County, Illinois.—Continued

[Data are from U.S. Geological Survey (2016c), Illinois Environmental Protection Agency (undated a), and Anthony Dulka (Illinois Environmental Protection Agency, written commun., 2016). na, not applicable; --, no data]

Owner	Approximate location	Well name	Water source	Depth of well (feet)	Withdrawal for system (gallons per day)	Remarks
Ransom	Shown in figure 1	2	Galena-Platteville/Ancell	831	0	Abandoned
Ransom	Shown in figure 1	3	Pennsylvanian	280	45,183 split between wells 3 and 4	
Ransom	Shown in figure 1	4	Ancell	815	--	
Rutland	Shown in figure 1	3	Glacial	65	29,353 split between wells 3 and 4	
Rutland	Shown in figure 1	4	Glacial	55	--	
Seneca	Shown in figure 1	1	Cambrian-Ordovician	700	--	Abandoned
Seneca	Shown in figure 1	2	Cambrian-Ordovician	704	250,000 split between wells 2 and 3	
Seneca	Shown in figure 1	3	Ironton-Galesville	1,500	--	
Sheridan Correctional Center	Near Sheridan in figure 1	1	Ironton-Galesville	885	172,000 split between wells 1 and 3	
Sheridan Correctional Center	Near Sheridan in figure 1	2	Prairie du Chien	298	0	Inactive
Sheridan Correctional Center	Near Sheridan in figure 1	3	Ironton-Galesville	900	--	
Tonica	Shown in figure 1	2	Glacial	193	--	Abandoned
Tonica	Shown in figure 1	3	Glacial	193	88,340 split between wells 3 and 4	
Tonica	Shown in figure 1	4	Glacial	193	--	
Lake Holiday	Shown in figure 1	1	Cambrian-Ordovician	663	341,550 split between wells 1 and 3	
Lake Holiday	Shown in figure 1	2	Cambrian-Ordovician	664	--	Abandoned
Lake Holiday	Shown in figure 1	3	Cambrian-Ordovician	745	--	
Wildlife Mobile Home Park	West of Seneca on figure 1	1	Cambrian-Ordovician	425	5,475	
Wildwood Communities	Near Lake Holiday on figure 1	1	Prairie du Chien	265	54,923	
Wildwood Communities	Near Lake Holiday on figure 1	2	Prairie du Chien	160	--	Abandoned
Wildwood Communities	Near Lake Holiday on figure 1	3	Cambrian-Ordovician	670	--	
Woodsmoke Ranch Association	North of Seneca on figure 1	2	Ancell	400	--	
Woodsmoke Ranch Association	North of Seneca on figure 1	3	Ancell	--	--	

1982, 1985; Kirk, 1987) indicates that about 15 to 30 percent is from the unconsolidated deposits, with the percentage generally decreasing through time. Less than 1 percent of groundwater withdrawals are from the Pennsylvanian deposits and the dolomite deposits of the Silurian, Galena-Platteville, and Prairie du Chien bedrock units. About 70 to 85 percent of groundwater withdrawals from 1960 through 2010 are from the Ancell or the Ironton-Galesville aquifers, with the percentage showing an overall increase through time.

Groundwater withdrawals from the Ancell aquifer in support of sandstone mining operations in the vicinity of Interstate 80 between North Utica and Ottawa (fig. 1) are expected to increase substantially in the future (LEAMgroup, Inc., 2008). This pumping is expected to occur in areas that are hydraulically upgradient of populations that rely on the Ancell aquifer in part or entirely for their water supply.

The values for surface-water withdrawals from 1978 through 2010 are highly variable for most water-use categories (table 1). The overwhelming majority of surface water was used for the generation of hydroelectric and thermoelectric power (fig. 1). This water is diverted from, and most of it is returned to, the Illinois or Fox rivers. Thermoelectric power is generated near Lake LaSalle beginning in the early 1980s. Hydroelectric power is generated at the Starved Rock Lock and Dam beginning in 1996; at the Marseilles Lock and Dam from 1911 through 1989; and on the Fox River at Dayton since 1925. Power generation at the Starved Rock facility requires using as much as 7,200 cubic feet per second (ft^3/s) of river water. Surface water has been withdrawn from the Vermilion River for public supply in Streator and Kangley since at least the early 1920s (Habermeyer, 1925). About 2.4 Mgal/d is diverted directly from the river into the drinking-water system or is diverted from the river to a nearby storage reservoir (Illinois Environmental Protection Agency, undated c). This water is filtered and chemically treated, primarily to reduce *turbidity* as well as nitrate and ammonia as needed prior to delivery to the consumer (Elizabeth Doellman, American Water Company, written commun., 2015).

Hydrogeologic Framework and Groundwater Resources

The *hydrogeologic units* of primary importance for water supply in LaSalle County are the glacial drift aquifers, composed of Quaternary-aged sand-and-gravel deposits; the Ancell, New Richmond, Galena-Platteville, and Silurian aquifers; and the Cambrian-Ordovician aquifer system, which obtains water primarily from the Ironton-Galesville Sandstone and sandstones of the Ancell Group (fig. 9). Although the Mount Simon aquifer underlies LaSalle County, it is not used for water supply in the county. The aquifers are separated by semiconfining units, which restrict groundwater flow between the aquifers.

Hydrogeology of Unconsolidated Deposits

Glacial drift aquifers are made up of sand and sand and gravel deposits. These aquifers are used for water supply in much of LaSalle County (fig. 13). However, the location, thickness, and *permeability* of these deposits are spatially variable and typically are interspersed within semiconfining units composed primarily of glacial tills. Further characterization of the aquifers and semiconfining units is required to optimize the use of the aquifers for water supply.

Location of Aquifers and Semiconfining Units

Glacial drift aquifers of sufficient thickness, continuity, and permeability to support a sustainable *yield* of 50 gallons per minute (gal/min), which is the approximate minimum required for public supply, are present in the Troy Bedrock Valley in the northwestern part of the county (fig. 10), in the Ticona Bedrock Valley in the south-central part of the county, along the Illinois River at LaSalle and perhaps near Seneca, and near the Fox River in the northeastern part of the county. Glacial drift aquifers in the Troy Bedrock Valley are used for high-capacity irrigation (Bridges and others, 2014) and residential supply. Aquifers in the Ticona Bedrock Valley are used for residential supply and for public supply by the Cities of Tonica and Grand Ridge. The glacial drift aquifer in the Illinois River Valley is used for public supply by the City of LaSalle.

Thinner, less continuous glacial drift aquifers of sufficient permeability to support a sustainable yield of about 2 to 10 gal/min are embedded in less permeable, till and silt and clay deposits in much of the county. These less permeable aquifers are pumped for residential supply primarily in the southern, eastern, and western parts of the county (fig. 13) where the Pennsylvanian deposits are thickest (fig. 1–11). These aquifers are not extensively exploited in the center of the county where the unconsolidated deposits typically are less than 100 ft thick and (fig. 1–12) and the shallow bedrock, especially the Ancell Group deposits (fig. 1–5), can be cost-effectively accessed. The yield of wells open to these thinner, less permeable aquifers is commonly improved by use of a large diameter (24-in.) borehole.

In the majority of the county, the unconsolidated deposits consist of glacial till that is composed primarily of silt and clay-sized particles or lacustrine silt and clay. These deposits have low permeability and function as semiconfining units. Semiconfining units are often present within areas where substantial glacial drift aquifers are located, such as the Troy Bedrock Valley, or overly shallow bedrock aquifers.

Semiconfining units transmit water slowly, and in small amounts, in comparison to aquifers, resulting in lower amounts of recharge to the aquifers and decreased susceptibility to surface and near-surface contamination. The slow rate of groundwater movement through the semiconfining units in LaSalle County is indicated by analysis of tritium data collected from four monitoring wells open to glacial

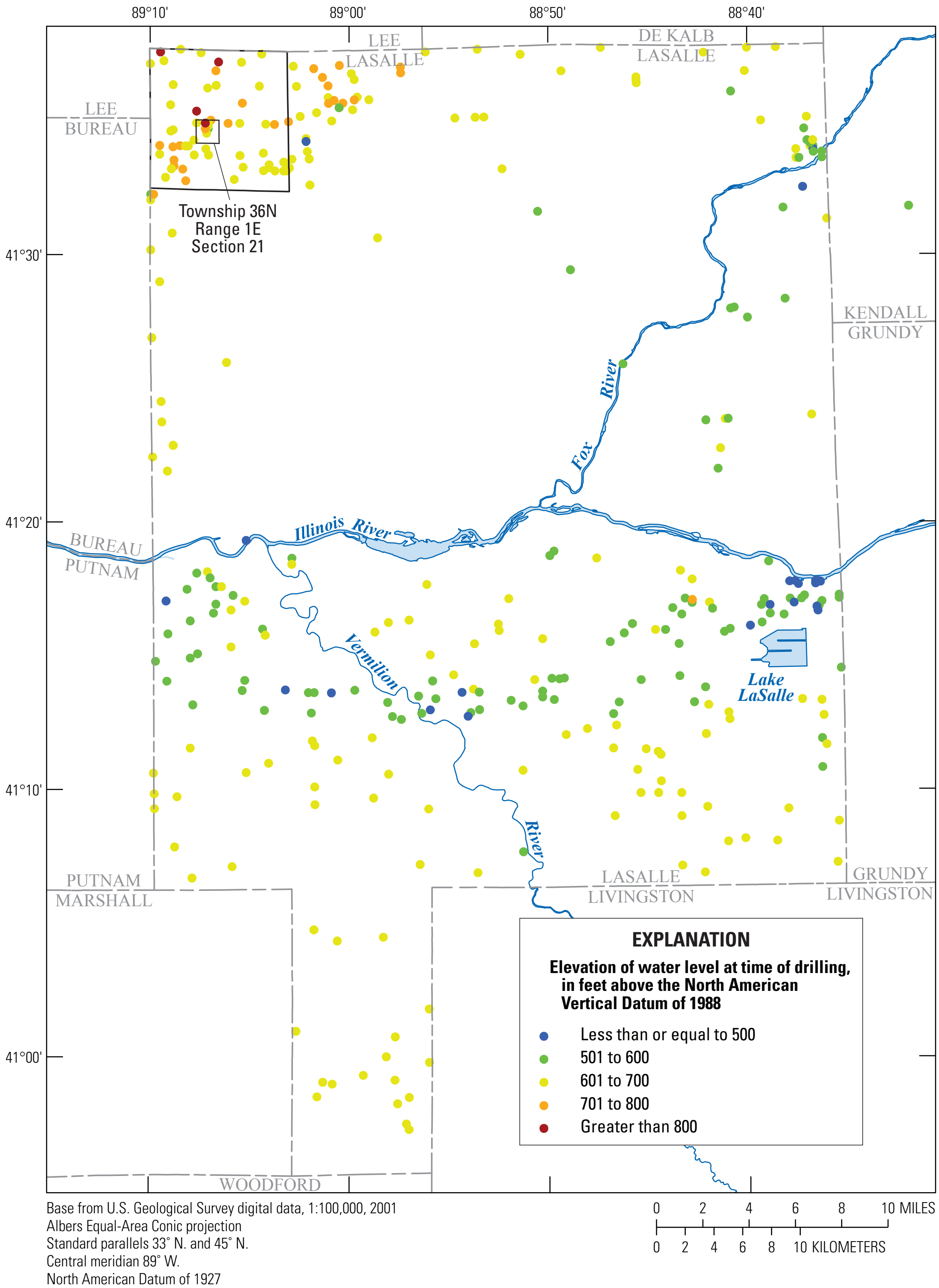

Figure 13. Approximate water-level altitude in wells open to glacial drift aquifers in LaSalle County, Illinois, at the time of drilling (about 1970 through 2014).

drift deposits in 1997; these data were obtained from the NWIS database. Tritium concentrations in an 18-ft-deep well north of Lostant (410947089044101) and a 20-ft well north of LaSalle (412442089025701) were 36 and 41 picocuries per liter (pCi/L), respectively; based on the rate of decay of tritium, these results indicated that the groundwater in these wells had infiltrated from precipitation after 1952 (Clark and Fritz, 1997). Tritium concentrations in a 33-ft deep well near Rutland (405832088592001) and in a 29-ft well north of North Utica (412136088571001) were both less than the detection limit of 5.7 pCi/L, indicating that the groundwater in these wells had infiltrated from precipitation prior to 1952. Although spatially limited, these data indicate that the vertical rate of groundwater movement through the unconsolidated semiconfining unit under prevailing hydraulic conditions is at least 0.44 foot per year (ft/yr) near Lostant and LaSalle (at least 20 ft in 45 years) and is less than about 0.67 ft/yr near Rutland and North Utica (less than about 30 ft in 45 years).

Glacial drift (and other) aquifers present within about 30 ft of the land surface in Illinois often are under *unconfined* conditions. Aquifers overlain by substantial thicknesses of low-permeability material are usually under semiconfined conditions. Unconfined aquifers are likely to receive high amounts of recharge from precipitation in comparison to semiconfined aquifers. Water levels in unconfined aquifers typically are more variable than in semiconfined aquifers, being high when precipitation is high and low when precipitation is low. Because they receive more water from recharge, unconfined aquifers tend to be less affected by pumping than semiconfined aquifers but are also more susceptible to contamination from anthropogenic compounds deposited at or near land surface (pesticides, herbicides, septic wastes). Glacial drift aquifers located in the basal deposits of the Troy and Ticona Bedrock Valleys are likely to be semiconfined. Glacial drift aquifers composed of discontinuous lenses of sand and gravel embedded within the till deposits are likely to be semiconfined on the whole but may be unconfined and susceptible to contamination where present at less than about 50 ft below land surface. Glacial drift aquifers present near the land surface in the vicinity of the Illinois and Fox Rivers may be unconfined.

Groundwater Levels and Directions of Flow

Groundwater levels in selected wells open to glacial drift aquifers in LaSalle County were compiled from water-level measurements reported on well logs at the time of drilling (fig. 13). These measurements were taken from different glacial drift aquifers at different depths at different times; therefore, figure 13 does not depict the *potentiometric surface* of the glacial drift aquifers. However, these data do provide some insight into the hydrology of these deposits.

Groundwater levels in the glacial drift aquifers typically exceed 600 ft NAVD 88 beneath most of the county, except in the Ticona Bedrock Valley (fig. 10) and to a lesser degree near (and east of) the Fox River in the northeastern part of the county. Low water levels near the Fox River may be a reflection of low surface topography and good hydraulic interconnection with the river. Low groundwater levels in the Ticona Bedrock Valley likely reflect the hydraulic isolation (semiconfined conditions) of this deep glacial drift aquifer from the shallow, near surface aquifers.

Although groundwater levels tend to be greater than 650 ft NAVD 88 in the Troy Bedrock Valley (fig. 10), partly as a reflection of the high surface topography in this area (fig. 5), the variation in water levels within specific areas can exceed 100 ft. Examination of the water levels reported on drillers logs in the Troy Bedrock Valley in Section 21 of Township 36N, Range 1E located north of Mendota (fig. 13) indicates that water levels exceed 750 ft NAVD 88 in wells that are open to glacial drift aquifers at an altitude above 730 ft NAVD 88 (table 5). Water levels in wells open to glacial drift aquifers at altitudes below 630 ft NAVD 88 in this area are reported to be between about 590 and 700 ft NAVD 88. These data are indicative of conditions in the glacial drift aquifers within the Troy Bedrock Valley in LaSalle County (and beyond) and indicate some degree of hydraulic separation between the aquifers in the upper and lower parts of the Troy Bedrock Valley.

Lateral groundwater flow in the glacial drift aquifers is from the uplands toward the Illinois, Fox, and Vermilion Rivers. It is probable that the shallowest groundwater discharges to small ditches, streams, and ponds. Vertical groundwater flow within the unconsolidated deposits is likely downward in most of the county. Upward flow may occur in areas where groundwater discharges to the larger streams and rivers (Geosyntec Consultants, 2012).

Hydraulic Properties

Data quantifying the hydraulic properties of the unconsolidated deposits in LaSalle County are sparse. Horizontal *hydraulic conductivity* values were estimated from *aquifer tests* performed at waste disposal sites in LaSalle, near Ottawa, and near Oglesby (Andrews Environmental Engineering, 2006, 2008; LandComp Corp., 1995; Dailey and Associates, 1999; Geosyntec Consultants, 2012). Estimated values of horizontal hydraulic conductivity for wells open to the till semiconfining unit range from 2.8×10^{-6} to 20 feet per day (ft/d), with a geometric mean value of 0.032 ft/d based on 19 tests. A horizontal hydraulic conductivity of 20 ft/d is high for till deposits and may reflect the presence of a sand unit in the tested well or an incorrect analysis. The vertical hydraulic conductivity of the semiconfining unit had a geometric mean value of 1.4×10^{-4} ft/d based on four tests.

Estimated *transmissivity* and horizontal hydraulic conductivity values obtained from two aquifer tests of the alluvial deposits at the Illinois River in LaSalle were about 2,200 feet squared per day (ft^2/d) and 63 ft/d, respectively (Gibb and others, 1979). Estimated horizontal hydraulic conductivity values obtained from aquifer tests in seven wells open to the alluvial deposits at the Illinois River in Spring Valley, immediately west of LaSalle County, ranged from 191

Table 5. Water levels at time of drilling in wells open to glacial drift aquifers in Section 21 of Township 36N and Range 1E, LaSalle County, Illinois, 1967–2005.

[Compiled from Illinois State Geological Survey (undated b). NAVD 88, North American Vertical Datum of 1988]

Well identification number	Land surface altitude (feet, NAVD 88)	Well depth (feet)	Water level altitude (feet, NAVD 88)	Altitude top of sand used by well (feet, NAVD 88)
1	795	72	755	732
2	810	75	760	742
3	810	78	765	732
4	810	80	770	760
5	813	81	763	739
6	810	82	760	736
7	810	88	803	737
8	805	190	699	620
9	810	219	670	595
10	813	219	673	594
11	817	261	657	597
12	810	293	695	535
13	810	310	680	540
14	810	314	630	530
15	810	321	630	493
16	795	323	665	495
17	792	330	592	492

to 4,000 ft/d, with a geometric mean value of 860 ft/d (Gibb and others, 1979). Transmissivity values determined from the tests at Spring Valley ranged from 4,900 to 29,000 ft^2/d, with a geometric mean value of 10,000 ft^2/d.

Recharge

An estimated 60 to 69 percent of the average annual precipitation that falls on LaSalle County is returned to the atmosphere by *evapotranspiration* (Sanford and Selnick, 2013). Based on this percentage, average annual precipitation available as *recharge* to groundwater is no more than about 11.0 in. More than three-quarters of all evapotranspiration occurs during the growing season from April through September (U.S. Geological Survey, 1970). During the growing season, evapotranspiration normally exceeds precipitation, depleting the available soil moisture, thereby reducing the potential for recharge to groundwater. During the nongrowing season, precipitation generally exceeds evapotranspiration, replenishing soil moisture and recharging shallow groundwater.

Streamflow records from the streamgage on the Vermilion River near Leonore (05555300) were used to refine the estimate of groundwater recharge by employing the streamflow-hydrograph separation method (Barlow and others, 2015). Most of the surficial bedrock underlying the Vermilion River watershed (fig. 6) in LaSalle County consists of Pennsylvanian deposits, which are present throughout most of southern LaSalle County (fig. 11). Recharge estimates based on the data from this streamgage are likely to be representative of the southern part of the county.

The geometric mean annual recharge for the record from 1972 to 2014 at the Leonore streamgage was calculated to be 5.2 inches per year (in/yr), which is about 14.6 percent of the average annual precipitation (table 2). Annual recharge ranged from about 0.77 in/yr in 1940 to about 16.4 in/yr in 1993, a year of greater than average precipitation in northeastern Illinois.

Groundwater recharge estimated by the streamflow-hydrograph-separation method generally is less than actual recharge because the method only represents recharge that becomes streamflow. Groundwater evapotranspiration, groundwater withdrawn by pumping and then exported from the basin, and recharge to underlying deposits are not considered in the estimate. Although the method provides a low estimate of groundwater recharge, the estimate is likely to approximate actual groundwater recharge for the studied basins in LaSalle County. Groundwater evapotranspiration is considered to be moderate in this basin. Net groundwater withdrawals from the unconsolidated deposits also are considered to be negligible because most of the water pumped for residential supply would be added back to the deposits as septic effluent. Recharge to the underlying Pennsylvanian-aged deposits also is likely to be small.

Potential Yields

Estimated *potential yields* of glacial drift aquifers in LaSalle County were estimated to be 150,000 to 200,000 gallons per day per square mile ([gal/d]/mi^2) from the Ticona Bedrock Valley and part of the Troy Bedrock Valley (fig. 14; Wehrman and others, 2003). Substantial yields also are estimated for the sand and gravel deposits in the Sheridan area, although wells in this area typically draw water from the bedrock aquifers. The less permeable glacial drift aquifers present in most of LaSalle County, are predicted to yield less than 50,000 [gal/d]/mi^2).

Hydrogeology of Bedrock Deposits

The Pennsylvanian, Silurian, Ordovician (Galena-Platteville, Ancell, Prairie du Chien) and Cambrian (Ironton-Galesville) bedrock deposits are utilized for water supply in LaSalle County. The hydrogeologic nature of these units can vary within the county based on position within the geologic sequence. The Devonian limestone deposits occupy only a small part of the extreme southern tip of the county and are omitted from this discussion. Figure 9 shows the regional hydrogeologic designation of these units.

Pennsylvanian Semiconfining Unit

Pennsylvanian deposits are used for water supply by residential wells in LaSalle County, particularly in the vicinity of the Vermilion River south of Oglesby, and for public supply at Ransom (table 4). Pennsylvanian deposits are used for water supply where glacial drift aquifers are absent or where the upper parts of the deposits are intensively fractured or comprised of sandstone (Csallany, 1966). Wells that utilize the deposits below the Pennsylvanian typically are cased through the Pennsylvanian deposits to reduce the salinity of the extracted water and to prevent borehole collapse.

The Pennsylvanian deposits as a whole function as a semiconfining unit, restricting the movement of water between the overlying unconsolidated deposits and the underlying bedrock deposits. The semiconfining nature of the Pennsylvanian deposits is demonstrated by the results of a type of single-well aquifer test (commonly referred to as a *slug test*) from wells open to weathered and unweathered shale at waste disposal sites in the county. The horizontal hydraulic conductivity of the weathered shale in the upper part of the Pennsylvanian deposits at waste disposal sites in the county ranged from 5.3×10^{-7} to 1.4 ft/d, with a geometric mean value of 6.3×10^{-4} ft/d based on testing in five wells (Dailey and Associates, 1999; Andrews Engineering, 2008; Geosyntec Consultants, 2012). The horizontal hydraulic conductivity of the unweathered Pennsylvanian shale at these sites had a geometric mean value of 4.7×10^{-5} ft/d based on tests in 13 wells (Dailey and Associates, 1999; Andrews Engineering, 2008; Geosyntec Consultants, 2012). The horizontal hydraulic conductivity of shallow coal deposits at these sites had a geometric mean value of 6.7×10^{-3} ft/d based on tests of eight rock samples.

The vertical hydraulic conductivity of the Pennsylvanian shale deposits was estimated at the landfill sites based on triaxial permeability tests from 12 shale samples and 5 coal samples. The vertical hydraulic conductivity of the shale deposits had a geometric mean value of 1.5×10^{-4} ft/d. The vertical hydraulic conductivity of the coal deposits had a geometric mean value of 4.7×10^{-2} ft/d. The total porosity of the shale deposits ranged from 7 to 43 percent, with a geometric mean value of about 22 percent. A *leakage coefficient* of 1.4×10^{-5} gallons per day per cubic foot (gal/d/ft^3) was calculated for the semiconfining unit in the southern part of the county (Hoover and Schicht, 1967). The horizontal and vertical hydraulic conductivities of the Pennsylvanian semiconfining unit may be substantially higher in areas of mine subsidence due to the formation of *fractures* in the deposits (Dailey and Associates, 1999).

Silurian Aquifer

The dolomite of the Silurian aquifer yields water from fractures and *solution openings* that are sufficient for residential supply in the west-central part of the county. Lithologic logs indicate that the Silurian dolomite has been extensively fractured near the axis of the Peru Monocline and these deposits may be capable of supporting additional withdrawals in localized areas. Because the aquifer is overlain by several hundred feet of low-permeability Pennsylvanian deposits and is restricted to a small area (fig. 9), the hydrology and water quality of the aquifer have not been characterized within the county.

Maquoketa Semiconfining Unit

The predominately shale deposits of the Ordovician Maquoketa Group function as a semiconfining unit. These deposits yield little water and are not known to be used for water supply within LaSalle County. Because the spatial extent of the semiconfining unit is restricted to the western part of the county (fig. 1–9), its effect on the hydrology of LaSalle County is limited. Where present, this semiconfining unit restricts flow from the glacial drift and Silurian aquifers to the Cambrian-Ordovician aquifer system.

Cambrian-Ordovician Aquifer System

Previous investigators working at a regional scale (Suter and others, 1959; Csallany and Walton, 1963) considered the Cambrian-Ordovician aquifer system to be composed of the deposits extending from the bottom of the Ironton-Galesville Sandstone to the top of the Galena-Platteville Dolomite. The Cambrian-Ordovician aquifer system contains some of the most productive, widespread aquifers in the upper Midwest

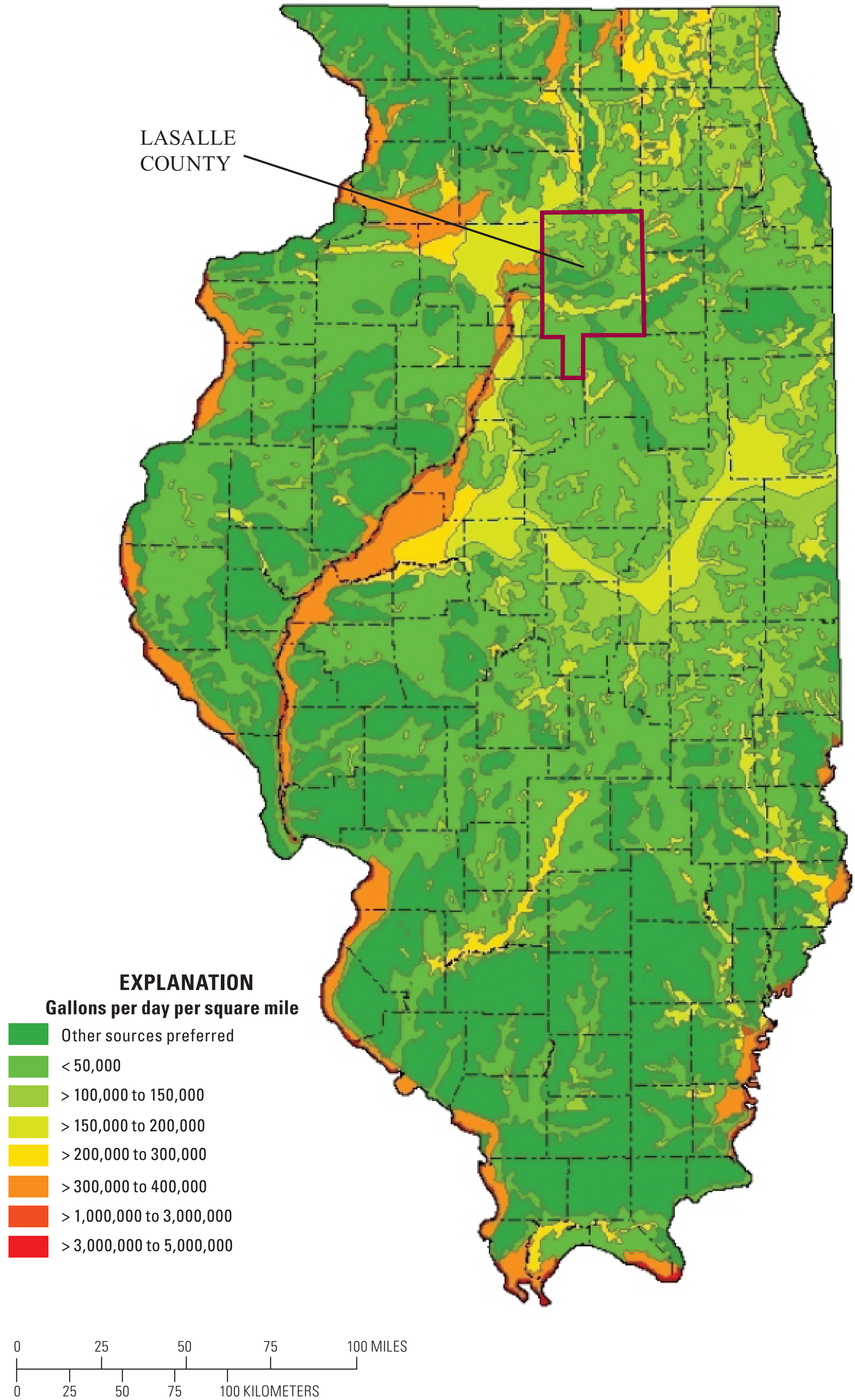

Figure 14. Estimated potential yield of sand and gravel aquifers in Illinois; from Wehrman and others (2003).

and is extensively used for public supply in northeastern Illinois, including LaSalle County (table 4). The Cambrian-Ordovician aquifer system has an average transmissivity of 2,280 ft^2/d in northeastern Illinois, with a geometric mean value of 1,500 ft^2/d in LaSalle County (Suter and others, 1959; Hoover and Schicht, 1967; Visocky and others, 1985). The geometric mean *storage coefficient* of the aquifer system in northeastern Illinois was estimated to be about 3.5×10^{-4} (Suter and others, 1959) and was estimated to be to about 6.0×10^{-4} in LaSalle County (Hoover and Schicht, 1967). The yield of wells open to the Cambrian-Ordovician aquifer system decreases in LaSalle County from greater than 500 gal/min north of the southern part of the Illinois River Valley to less than 100 gal/min south of Streator (Visocky and others, 1985).

Recharge to the Cambrian-Ordovician aquifer system in LaSalle County is derived primarily from the glacial drift deposits in areas of Lee, DeKalb, and LaSalle Counties where the deposits of the Galena, Platteville, Prairie du Chien, or Ancell Groups are at the bedrock surface and deposits of the Maquoketa Group or of Pennsylvanian age that function as semiconfining units are absent (Suter and others, 1959; Visocky and others, 1985). The recharge rate in this area was calculated to be 0.29 in/yr based on hydraulic conditions in 1963 (units converted from Hoover and Schicht, 1967). Where the Maquoketa Group, Galena-Platteville Dolomite, or Pennsylvanian-age deposits are present, recharge to the Cambrian-Ordovician aquifer system in LaSalle County was calculated to be 0.15 in/yr based on 1963 conditions.

Many of the public-supply wells are open to multiple hydrogeologic units in the Cambrian-Ordovician aquifer system to improve yield and are cased only to prevent collapse. Therefore, it can be difficult to identify the properties of the individual hydrogeologic units that make up the aquifer system. However, some information on the individual units is available.

Galena-Platteville Deposits

The Galena-Platteville Dolomite yields water from fractures and solution openings that can be sufficient for residential supply in the parts of the county where the deposits are at the bedrock surface and have been subjected to erosion and in a few wells near Peru where fracturing associated with the Peru Monocline appears to be present (figs. 9 and 1–8). Where the partly eroded Galena-Platteville Dolomite deposits are overlain by Pennsylvanian deposits (typically east of the Peru Monocline), several residential supply wells draw water from the Galena-Platteville Dolomite deposits, but most wells are open to both the Galena-Platteville Dolomite and the underlying Ancell aquifer.

The Galena-Platteville Dolomite deposits typically have few secondary permeability features where they are overlain by the Maquoketa Group in northeastern Illinois and have not been subjected to substantial erosion. Where overlain by the Maquoketa Group, the Galena-Platteville Dolomite functions as part of a semiconfining unit (Walton and Csallany, 1962; Hoover and Schicht, 1967). However, in most of LaSalle County it is considered to be part of the Cambrian-Ordovician aquifer system.

Ancell Aquifer

The sandstones of the Glenwood Formation and the St. Peter Sandstone constitute the Ancell aquifer, which is used for public supply by Cedar Point, Earlville, Lostant, Mendota, and Ransom (table 4). The Ancell aquifer also is used for residential supply in LaSalle County where the aquifer is sufficiently thick to maintain water supply during pumping. The Ancell aquifer accounts for an estimated 15 percent of the total yield of the Cambrian-Ordovician aquifer system in northeastern Illinois (Walton and Csallany, 1962).

In LaSalle County, the sandstones that constitute the upper part of the Ancell aquifer can be argillaceous or dolomitic (LandComp Corp., 1995; Andrews Environmental Engineering, 2006, 2008) and the lowermost part is shaley. As a result, the most productive part of the Ancell aquifer is typically about 60 to 80 ft thick and is present 35 to 200 ft below the top of the sandstones (Suter and others, 1959). Aquifer testing performed at waste disposal sites between Naplate and North Utica indicates that the silty sandstones in the upper part of the Ancell aquifer in this area have a geometric mean horizontal hydraulic conductivity of 7.4×10^{-4} ft/d based on slug tests in 12 wells (LandComp Corp., 1995; Andrews Environmental Engineering, 2006). Slug tests performed in 20 wells open to the deeper, less argillaceous part of the Ancell aquifer yielded a horizontal hydraulic conductivity from 0.08 to 1,500 ft/d, with a geometric mean of 0.5 ft/d (LandComp Corp., 1995; Andrews Environmental Engineering, 2006). Based on the 150-ft thickness of the Ancell aquifer in this area (fig. 1–5), the transmissivity of the aquifer (which is equal to horizontal hydraulic conductivity multiplied by thickness) is about 82 ft^2/d. The vertical hydraulic conductivity for the Ancell aquifer at these sites ranged from 7.7×10^{-4} to 0.033 ft/d, with a geometric mean of 0.005 ft/d based on triaxial permeability testing of 11 rock samples. Total porosity for the Ancell Group deposits at these sites ranged from 7 to 32 percent, with a geometric mean of 20 percent based on analysis of 20 rock samples.

Although the upper part of the Ancell aquifer is argillaceous in much of the county, there are areas where the upper part of the Ancell aquifer is poorly consolidated, becoming more cemented with depth. This increase in cementation results in decreasing horizontal hydraulic conductivity with depth (Hull and Associates, 2008). Aquifer testing at a site in Naplate indicates that the poorly consolidated sandstones in the upper part of the Ancell aquifer have a geometric mean horizontal hydraulic conductivity of 2.1 ft/d. The horizontal hydraulic conductivity of the increasingly cemented (and less porous) Ancell aquifer in the middle and lower parts of the aquifer are 1.8 and 0.65 ft/d, respectively, based on 19 slug tests (Hull and Associates, 2008).

The transmissivity of the Ancell aquifer determined from multiple-well, constant discharge aquifer tests at Naplate, Harding, Cedar Point, and east of Starved Rock State Park varied from 93 to 7,400 ft^2/d, with a storage coefficient of about 1.0×10^{-4} (Visocky and others, 1985; Hull and Associates, 2008; Patrick Engineering, Inc., 2011). On a regional scale, transmissivity values for the aquifer tend to increase where the thickness of the sandstone deposits is greatest.

Transmissivity values for the Ancell aquifer determined from analysis of specific-capacity data are presented in appendix 3. Specific-capacity tests allow the transmissivity of the Ancell aquifer to be estimated for most of the county. Appendix 3 also includes an example of how these data can be used to provide a preliminary assessment of the *drawdown* associated with hypothetical future pumping scenarios from the Ancell aquifer within the county.

Water levels measured at the time of drilling in wells that penetrate the Ancell aquifer decrease from nearly 700 ft NAVD 88 in the northern part of the county to less than 500 ft NAVD 88 near the Illinois River and less than 450 ft NAVD 88 in much of the southeastern part of the county (fig. 15). Because the direction of groundwater flow is perpendicular to the water-level contours, the overall direction of groundwater flow in the Ancell aquifer in the northern part of the county is from north to south, with components of flow toward discharge points at the Fox and Illinois Rivers, particularly in the central part of the county where the Pennsylvanian semiconfining unit is thin or absent (figs. 11 and 15). Water levels in the Ancell aquifer east of Marseilles are typically less than the mean water level in the Illinois River at Marseilles (about 465 ft NAVD 88), indicating that the Ancell aquifer and the Illinois River are hydraulically separated by the Pennsylvanian semiconfining unit in the eastern (and likely western) part of the county. Flow directions in the aquifer south of the Illinois River are complex, also due partly to the effects of the Pennsylvanian semiconfining unit, but are generally toward the southeastern part of the county.

Water levels in the Ancell aquifer near Naplate are below about 385 ft NAVD 88 due to pumping in support of mining of the St. Peter Sandstone at quarries in this area. This pumping has altered the natural direction of groundwater flow in the area. Dewatering from the quarry north of the river has created hydraulic conditions that have induced flow from the Illinois River into the aquifer, perhaps inducing groundwater flow from the south side of the river beneath the river and toward the quarry (Hull and Associates, 2008). The effects of dewatering in support of mining of Ancell Group deposits in Wedron, Troy Grove, and North Utica have not been characterized.

Water levels in the Ancell aquifer appear to be elevated in the vicinity of at least parts of the Ticona Bedrock Valley (figs. 10 and 15). Assuming water levels in these wells approximate the potentiometric surface of the Ancell aquifer, the elevated water levels indicate enhanced recharge from the glacial drift aquifers in the Ticona Bedrock Valley into the Ancell aquifer. Recharge is likely to be greatest near the Vermilion River where the Ancell Group deposits are at the bedrock surface (fig. 11) and directly underlie the Ticona Bedrock Valley (fig. 10).

Middle Semiconfining Unit

The units of the Franconia Formation, the Potosi Dolomite, and the Prairie du Chien Group form the middle semiconfining unit of the Cambrian-Ordovician aquifer system (Visocky and others, 1985). This semiconfining unit restricts flow between the underlying Ironton-Galesville aquifer and the overlying Ancell aquifer in most of the county (Hull and Associates, 2008).

The New Richmond Sandstone makes up the New Richmond aquifer and is used for residential and public supply (including by Ottawa, Marseilles, Naplate, and North Utica), where present, from the northern boundary of the county to about 3 mi south of the Illinois River (fig. 16). South of this area, the overlying Ancell aquifer is the bedrock aquifer used for residential water supply. The New Richmond Sandstone is commonly used for water supply in the northern and western parts of the county where the Ancell sandstones are thin or absent (fig. 1–4) or in the center of the county in the North Utica, Naplate, and Ottawa area where the saturated thickness of the Ancell aquifer can be thin. The transmissivity of the New Richmond aquifer determined from a multiple-well, constant discharge aquifer test northwest of Wedron was 830 ft^2/d, with a horizontal hydraulic conductivity of 11.8 ft/d and storativity of 3.3×10^{-5} (Andris Slesers, Weston Solutions, Inc., written commun., 2016).

The Franconia, Potosi, and Prairie du Chien deposits are not used as a primary source of water supply in most of northeastern Illinois, but many public-supply wells open to the Ancell Group and Ironton-Galesville Sandstone also are open to these units to increase yield. Where encountered, fractures in the Prairie du Chien Group or the Potosi Dolomite can yield substantial amounts of water to wells (Visocky and others, 1985). These deposits account for an estimated 35 percent of the yield of wells open to the Cambrian-Ordovician aquifer system (Walton and Csallany, 1962). Fractures in the weathered surface of the Shakopee Dolomite deposits allow these deposits to be used for residential supply where they are near the bedrock surface in the northeastern part of the county.

Water levels measured in wells open to the New Richmond aquifer at the time of drilling decrease from more than 650 ft NAVD 88 in the northern part of the county to less than 450 ft NAVD 88 along the Illinois River near Ottawa, Naplate, and North Utica (fig. 16). The measurements indicate that the overall direction of groundwater flow in the New Richmond aquifer (where data are present) is toward the Illinois and Fox Rivers. However, water levels in the New Richmond aquifer near Naplate were measured to be about 430 ft NAVD 88 from December 2002 through August 2003, whereas the stage of the Illinois River was about 460 ft NAVD 88 during that time (Dailey and Associates, 1999). These data indicate that pumping from the New Richmond Sandstone for public supply in the Naplate area may have induced sufficient drawdown to reverse the normal direction of flow of groundwater to surface water.

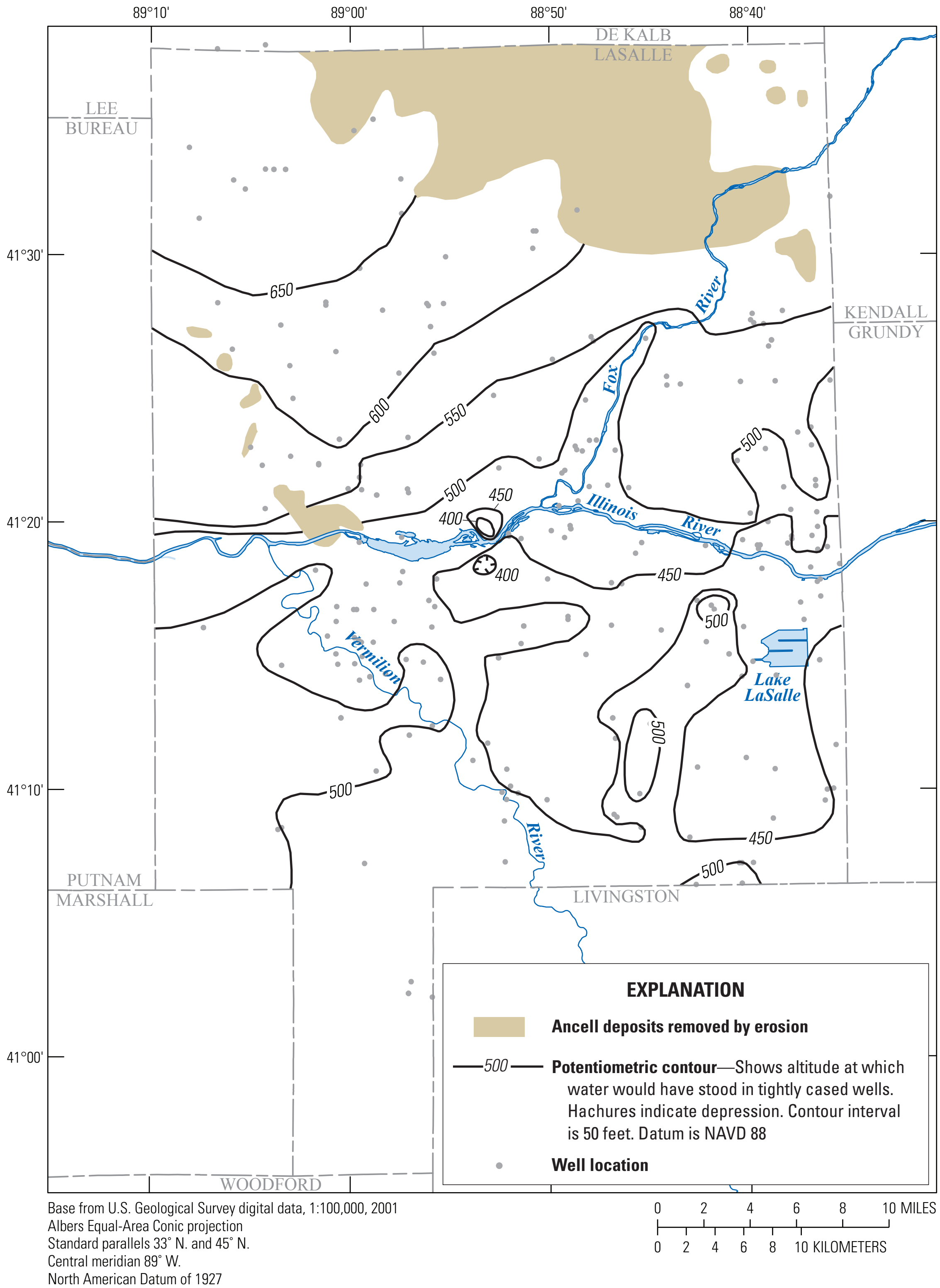

Figure 15. Approximate water-level altitude in wells open to the Ancell aquifer at the time of drilling (about 1970 through 2014) in LaSalle County, Illinois.

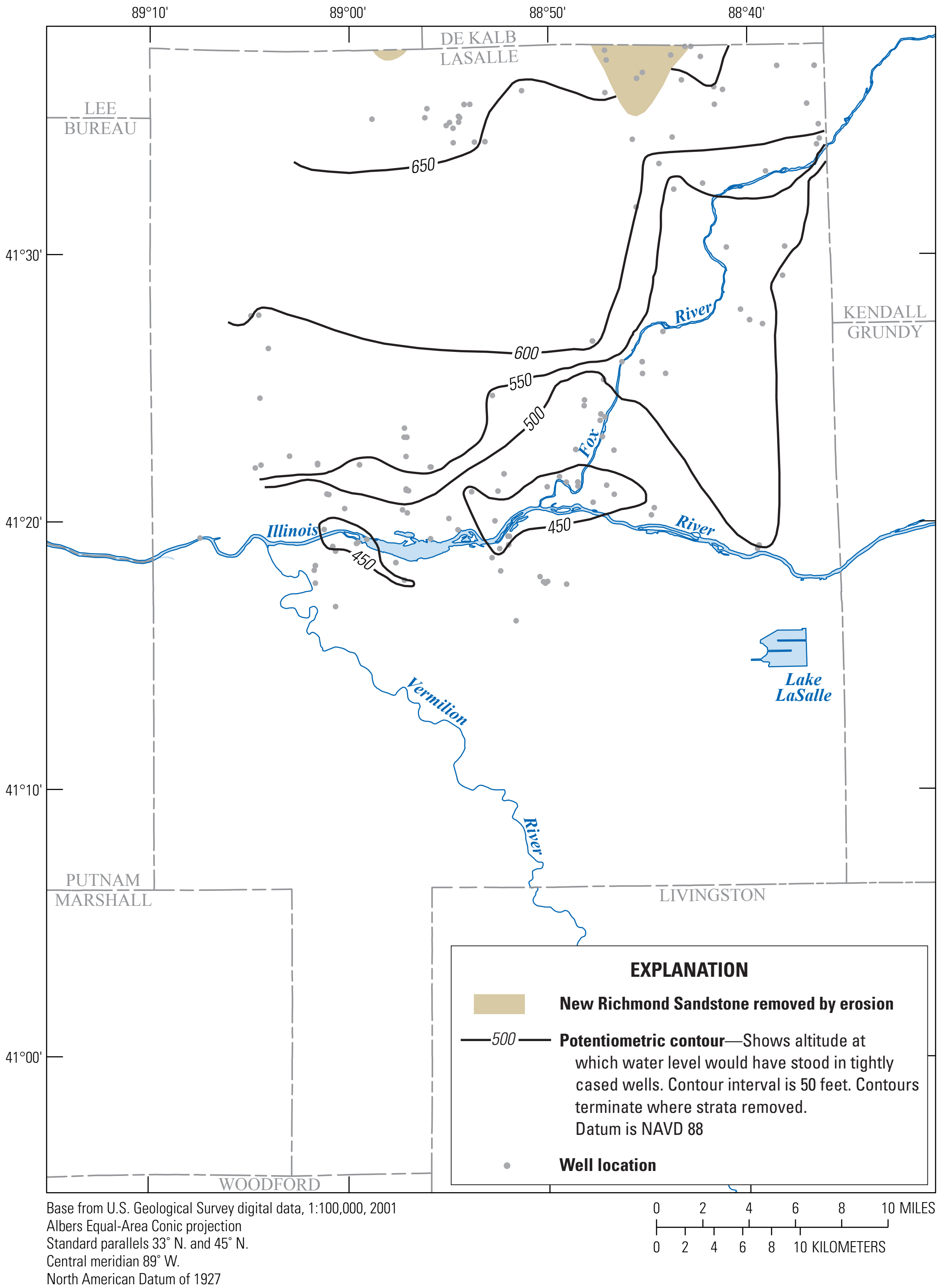

Figure 16. Approximate water-level altitude in wells open to the New Richmond aquifer at the time of drilling (about 1970 through 2014) in LaSalle County, Illinois.

Ironton-Galesville Aquifer

The Ironton-Galesville Sandstone constitutes the Ironton-Galesville aquifer (fig. 9). The Ironton-Galesville Sandstone is the most productive aquifer in northeastern Illinois, accounting for about 50 percent of the yield from the Cambrian-Ordovician aquifer system in northern Illinois (Walton and Csallany, 1962). As a consequence, dozens of municipalities in northern Illinois, including Mendota, Peru, Marseilles, Ottawa, and Oglesby in LaSalle County (table 4) and Sandwich and Somonauk in southern DeKalb County, draw water partly from the Ironton-Galesville aquifer. The aquifer is less productive south of the Illinois River due to increasing carbonate content (Emrich, 1966). The Galesville Sandstone and the Buelter Member of the Ironton Sandstone (the lowermost units in the sandstone) are considered to be the most permeable part of the aquifer (Suter and others, 1959) primarily because of the lower dolomite content of these units in comparison to the rest of the Ironton-Galesville Sandstone (Emrich, 1966).

There are no aquifer tests performed in wells that are open exclusively to the Ironton-Galesville aquifer in LaSalle County; however, conversion of permeability values based on testing of core samples collected from the Galesville Sandstone in the vicinity of the Ancona Anticline indicates that the average horizontal hydraulic conductivity of the Galesville deposits is 2.5 ft/d (Emrich, 1966). The Ironton-Galesville aquifer is less permeable in the southern part of the county than in the central and northern parts, so this horizontal hydraulic conductivity value is likely to be a minimum value for the aquifer in the county. The vertical hydraulic conductivity of the aquifer is estimated to be about 40 percent of the horizontal hydraulic conductivity (Emrich, 1966), or 1.0 ft/d. The horizontal hydraulic conductivity of the Ironton-Galesville aquifer is estimated to be between about 3.3 and 5.3 ft/d, and the transmissivity is estimated to be between 670 and 930 ft^2/d in northern Illinois (Visocky and others, 1985).

Trends in Water Levels

Prior to extensive utilization of the Cambrian-Ordovician aquifer system for water supply, which began in the 1860s in northeastern Illinois and in the 1890s in LaSalle County (Habermeyer, 1925), the potentiometric surface of the Cambrian-Ordovician aquifer system was calculated to be between about 550 and 725 ft NAVD 88 in LaSalle County (fig. 17). Flow through the aquifer system in the northern part of the county was from recharge areas in and near the northern part of the county, discharging to the Illinois River where the Ancell Group and Prairie du Chien Group deposits outcrop or are the surficial bedrock units (fig. 11). Flow in the aquifer system in the part of the county approximately between the Ticona Bedrock Valley and the Illinois River was north to the Illinois River. Flow in the part of the aquifer system approximately south of the Ticona Bedrock Valley was to the south.

Water levels in wells open to the Cambrian-Ordovician aquifer system in the Illinois River Valley during the 1890s through 1920s were above land surface, but decreased through time (Habermeyer, 1925; Burch, 2002, 2008; Hlinka and others, 2014). The water level in the aquifer system in the mid-1890s was measured to be more than 22 ft above land surface (altitude 560 ft NAVD 88) at Peru and 85 ft above land surface (altitude 506 ft NAVD 88) at Ottawa (Suter and others, 1959). The water level in a well open to the Ancell aquifer in the northern part of the county at Mendota was measured to be 45 ft below land surface (altitude 705 ft NAVD 88) during the 1890s.

Pumping from the Cambrian-Ordovician aquifer system has resulted in a decline in water levels in the aquifer system. Analysis performed by Suter and others (1959) indicated a decline in water pressure in the Cambrian-Ordovician aquifer system equivalent to 50 to 100 ft in the northern third of the county and at least 100 ft for most of the rest of the county between 1864 and 1958. This pressure decline was likely exhibited primarily in the Ironton-Galesville and New Richmond aquifers where the semiconfining units are absent and to a lesser extent throughout the of the aquifer system (including the Ancell aquifer) where the semiconfining units are present. Analysis performed by Abrams and others (2015) indicated that the Cambrian-Ordovician aquifer system exhibited less than 100 ft of drawdown from 1864 through 2014 in the northernmost part of the county, 100 to 200 ft of drawdown beneath the majority of the county, and more than 200 ft of drawdown in the east-central part of the county. Comparison of water levels reported in the 1890s with water levels measured in several water-supply wells through 2007 (the most recent date for which data from these wells are available) indicated a decrease in the potentiometric surface in the Cambrian-Ordovician aquifer system by about 50 to 120 ft at Mendota in the northwestern part of the county (fig. 1), about 70 to 160 ft at Ottawa in the center of the county, and about 100 to 300 ft at Peru along the Illinois River at the western edge of the county (fig. 18).

Associating water-level altitude in figure 18 with the altitude of the Ancell Group deposits in LaSalle County (fig. 1–6) indicated that the water levels in the aquifer system are above the top of the Ancell aquifer at Mendota and Peru, but that water levels are within the Ancell aquifer in Ottawa. If water levels in the Ottawa wells, which are open to the deeper parts of the Cambrian-Ordovician aquifer system (table 4), approximate water levels in the Ancell aquifer, this configuration indicates that the Ancell aquifer may be partly dewatered in the Ottawa area.

The decline in the potentiometric surface of the Cambrian-Ordovician aquifer system in LaSalle County can be attributed primarily to pumping from the aquifer system within LaSalle County. However, pumping from the aquifer system in the rest of northeastern Illinois also has some effect on water levels in the county.

The decline in the potentiometric surface of the Cambrian-Ordovician aquifer system from substantially above

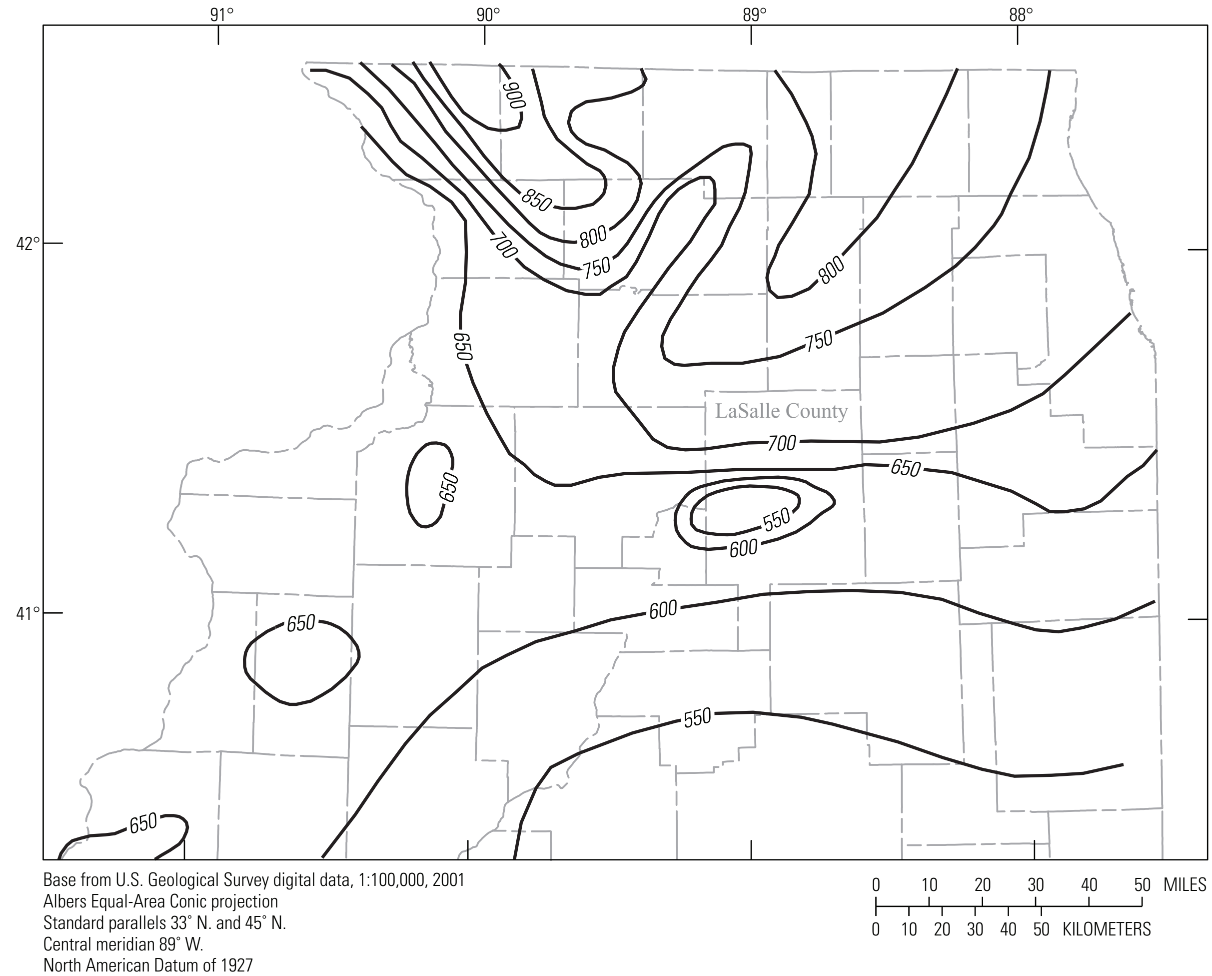

Figure 17. Potentiometric surface of the Cambrian-Ordovician aquifer system before about 1864, the time of its initial development in Illinois; modified from Visocky and others (1985).

land surface to below land surface in parts of the county, has lowered the difference in hydraulic pressure between the aquifer system and the Illinois River. Because the volume of flow between two water bodies is directly related to the difference in hydraulic pressure between them, the decreased hydraulic pressure in the aquifer system is likely to have resulted in a decrease in the amount of groundwater flow to the Illinois River and nearby wetlands in areas where the Ancell aquifer is in direct contact with the river.

Lower Semiconfining Unit

The Lombard Dolomite and the Proviso Siltstone Members of the Eau Claire Formation form a major semiconfining unit in northern Illinois. This unit, referred to as the lower semiconfining unit (fig. 9), is equivalent to the Basal Sandstone Confining Unit identified by Visocky and others (1985). The lower semiconfining unit restricts flow between the Mount Simon aquifer and the Ironton-Galesville aquifer. In northern Illinois, this semiconfining unit has an estimated vertical hydraulic conductivity of 4.7×10^{-6} ft/d (Schicht and others, 1976) and a leakage coefficient of 7.5×10^{-8} to 1.5×10^{-7} gallons per minute per cubic foot (Visocky and others, 1985).

Mount Simon Aquifer

The Elmhurst and Mount Simon Sandstones constitute the Mount Simon aquifer (fig. 9). The upper part of the Mount Simon aquifer is used for water supply in parts of north-central Illinois but the aquifer is not used for water supply in LaSalle County due to its depth and, in the southern two-thirds of the county, the high salinity of its water. The Mount Simon Sandstone is used for natural gas storage at the Troy Grove Dome and the Ancona Anticline. The Mount Simon Sandstone also is used for disposal of liquid wastes outside of LaSalle

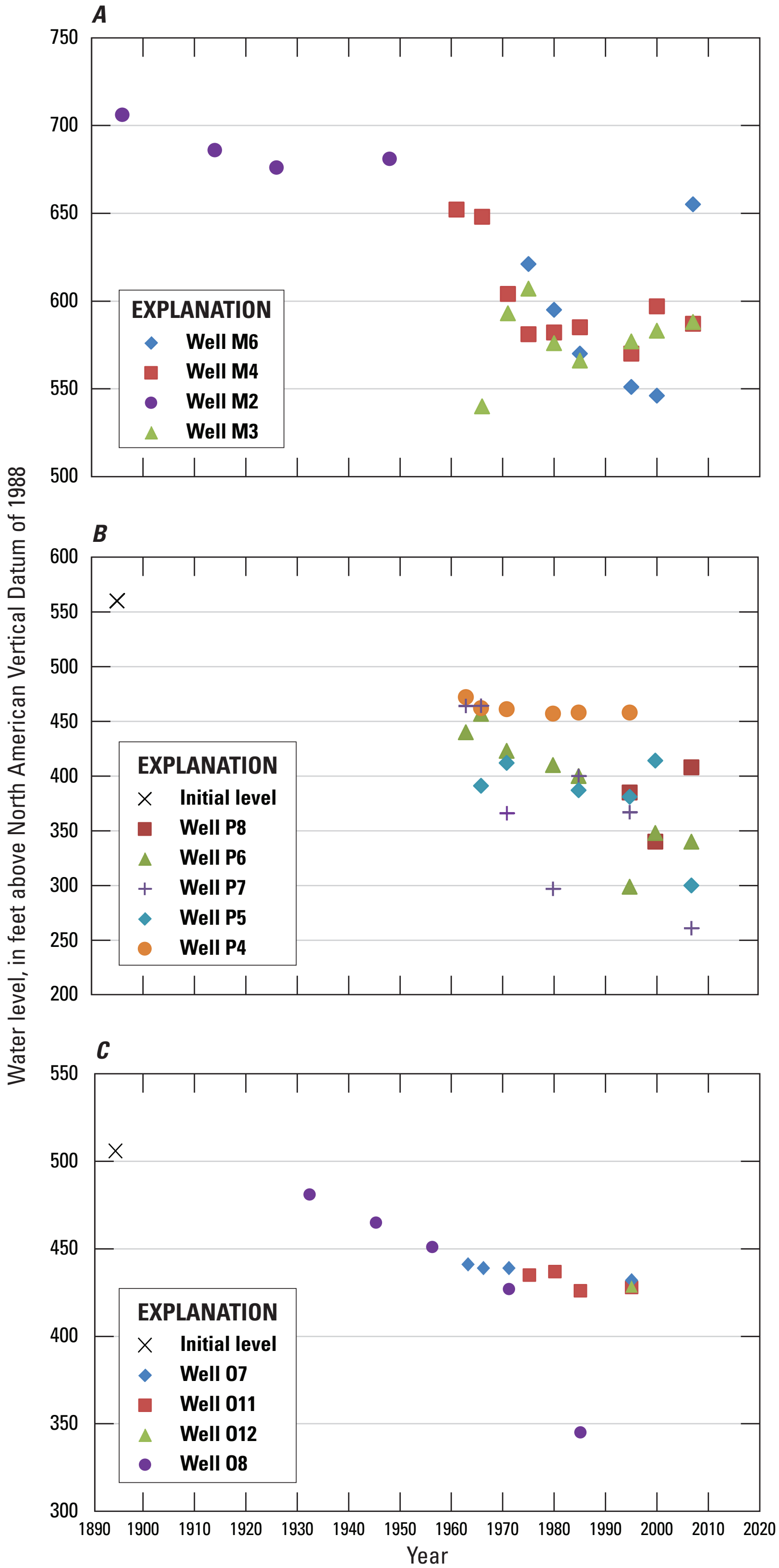

Figure 18. Static water-level altitude in selected wells open to the Cambrian-Ordovician aquifer system in LaSalle County, Illinois, from 1894 to 2007 in the towns of *A*, Mendota, *B*, Peru, and *C*, Ottawa. Towns shows in figure 1.

County. The shale and siltstone of the lower confining unit form the *cap rock* at the Troy Grove and Ancona natural gas storage facilities (Bell, 1961; Buschbach and Bond, 1967).

The Mount Simon aquifer in LaSalle County has a transmissivity of about 1,400 ft^2/d and a storage coefficient of about 1.8×10^{-4} based on the results of an aquifer test at the Ancona gas storage field (Visocky and others, 1985). The Mount Simon aquifer is estimated to have an average horizontal hydraulic conductivity of about 2.1 ft/d in northeastern Illinois (Suter and others, 1959) and an average horizontal hydraulic conductivity of 0.41 ft/d at the Troy Grove Dome and 0.70 ft/d at the Ancona Anticline based on permeability tests of core samples (Buschbach and Bond, 1967). Water levels in the Mount Simon aquifer appear to be more than 50 ft higher than in the overlying Ironton-Galesville aquifer in northeastern Illinois, indicating the potential for groundwater flow from the Mount Simon aquifer to the Ironton-Galesville aquifer (Csallany and Walton, 1963).

Water Quality

Water quality of the surface-water bodies as well as the glacial drift and bedrock aquifers of LaSalle County was evaluated by review of publicly accessible data available from studies conducted by the USGS and the ISWS (Habermeyer, 1925; Buswell, 1938, 1940; Hanson, 1950, 1958, 1961; Harmeson and Larson, 1969; Harmeson and others, 1973), from source water assessment program reports and routine sampling of public-supply wells conducted by the IEPA, and results of sampling of wells and streamgages in the NWIS database.

There are a number of standards used to determine if water quality is acceptable for various uses (table 6). Water used for drinking must meet the U.S. Environmental Protection Agency (EPA) maximum *contaminant* level (MCL) drinking-water standard (U.S. Environmental Protection Agency, 2012). The MCL is the enforceable, health-based, maximum concentration of a constituent allowed in drinking water. The EPA secondary maximum contaminant level (SMCL) is the suggested maximum concentration of a constituent in drinking water based on aesthetic considerations (odor, taste, appearance). The SMCL is not an enforceable standard. The health advisory level (HAL) is the concentration of a constituent in drinking water above which noncancer health effects are anticipated to occur for specific exposure scenarios; the HAL exposure scenario is lifetime exposure for an adult drinking 2 liters per day of water. HALs serve as informal technical guidance and are not legally enforceable.

In addition to criteria developed for drinking water, a variety of ecological screening levels have been developed for water. The ecologically based water-quality standards used are the EPA national recommended water-quality criteria (NRWQC) and the Illinois water quality standards (IWQSs) for general use (table 6). The NRWQC presented is the maximum concentration of a constituent in freshwater that will not adversely affect aquatic life (U.S. Environmental Protection Agency, 2015). The standard for many of these constituents is dependent on the values of other constituents in the water and must be calculated.

A summary of constituents detected at elevated concentrations in at least one sample from the major water-supply systems in LaSalle County is presented in table 7. These data provide a good summary of the water-quality issues for the various sources of water in the county.

Surface Water

Surface-water-quality data collected by the USGS at streamgages throughout LaSalle County was reviewed. Detailed discussion of this data is presented in appendix 2. The water-quality data from the Somonauk Creek at Sheridan streamgage (05551970; fig. 6) and the Fox River at Dayton streamgage (05552500) characterized surface-water quality in the northeastern part of the county from 1978 through 1997 (depending on the constituent). The data from the Little Vermilion River at LaSalle streamgage (05555950) characterized surface-water quality in the northwestern part of the county from 1977 through 2015. The data from the Vermilion River near Leonore streamgage (05555300) characterized the southern part of the county from 1977 through 2015. Water quality of the Illinois River was characterized in the eastern part of the county from the data of the streamgage below the dam at Marseilles (05543500) from 1974 through 2015 and in the central part of the county at Ottawa from the data at the streamgage downstream of the confluence with the Fox River (05553500) from 1997 through 2009.

An analysis of chloride in surface-water samples indicates little or no exceedance of water-quality criteria (table 8). Maximum concentrations of chloride tended to be highest in the winter (table 9), indicating the potential presence of surface-water runoff affected by road salts during these periods (Panno and others, 2009). Chloride concentrations also showed some tendency to increase through time.

Comparison of water-quality data collected from the USGS sampling sites to regulatory standards (table 6) indicates that fecal coliform exceeded the EPA MCL in all or almost all of the samples collected and exceeded the Illinois General Use criteria in at least half of the samples collected at Somonauk Creek, the Vermilion River, and the Little Vermilion River. Maximum and median populations of fecal coliform typically were highest during the spring (defined as the period from March 1 to May 31) or summer (June 1 to August 31; table 9). Elevated fecal coliform populations are attributed primarily to discharge of treated wastewater to surface water upstream of the sampling points.

Concentrations of nitrate were below the MCL of 10 milligrams per liter (mg/L) in all or nearly all the samples collected from the Illinois River and Fox River streamgages (table 8). Concentrations were equal to or exceeded the MCL

Table 6. Selected water-quality criteria used to assess water-quality data in LaSalle County, Illinois.

[Data are from U.S. Environmental Protection Agency (EPA; undated b,c). MCL, maximum contaminant level; SMCL, secondary maximum contaminant level; mg/L, milligram per liter; µg/L, microgram per liter; pCi/L, picocuries per liter; HAL, health advisory level; c/100 mL, colony per 100 milliliters]

Constituent and units	EPA MCL	EPA SMCL	Illinois general use	EPA aquatic life acute threshold	EPA aquatic life chronic threshold
Ammonia as nitrogen (mg/L)	None	None	15	17*	1.9*
Arsenic (µg/L)	10	None	360 acute impact; 190 chronic impact	340	150
Barium (µg/L)	2,000	None	5,000	None	None
Boron (µg/L)	None	None	40,100 acute; 7,600 chronic	None	None
Chloride (mg/L)	None	250	500	860	230
Chromium (total) (µg/L)	100	None	Calculated	570	74
Copper (µg/L)	1,300	1,000	Calculated	Calculated	Calculated
Dissolved oxygen (mg/L)	None	None	3.5	3.0	None
Fecal coliform (c./100 milliliter)	0 (goal)	None	200	None	None
Fluoride (mg/L)	4	None	None	1,400	None
Iron (mg/L)	None	0.3	1	None	1
Manganese (µg/L)	None	50	Calculated	1,000	None
Mercury (µg/L)	2	None	2.2 chronic; 1.1 acute	1.4	0.77
Nitrate and nitrite as nitrogen (mg/L)	10	None	None	None	None
Phosphorus (mg/L)	None	0.1 HA	0.05 (lake and reservoir)	None	None
Radium-226 plus radium-228 (pCi/L)	5	None	None	None	None
Sulfate (mg/L)	None	250	Calculated	None	None
Suspended solids (mg/L)	None	None	None	Calculated	Calculated
Uranium (pCi/L)	20.1**	None	None	None	None
Zinc (µg/L)	None	5,000	1,000	120	120
Alachlor (µg/L)	2	None	None	None	None
Atrazine (µg/L)	3	None	None	None	None
Cyanazine (µg/L)	None	1 HA	None	None	None
Metolachlor (µg/L)	None	700 HA	None	None	None
Simazine (µg/L)	4	None	None	None	None

*Assumed pH = 7.0 and temperature = 20 degrees Celsius.

**Converted from micrograms per liter using conversion factor of 0.67.

in about 3 percent of the samples from Somonauk Creek and in more than 18 percent of the samples from the Little Vermilion and Vermilion Rivers. Nitrate concentrations in samples from the Vermilion River at Streator appear to have increased from 1910 through 1995 (Keefer and others, 1996). Concentrations of phosphorous were above the SMCL or Illinois General Use criteria in virtually all of the samples collected from the Fox, Illinois, Little Vermilion, and Vermilion Rivers, about but in only about 36 percent of the samples collected form Somonauk Creek (table 8). The presence of elevated concentrations of fecal coliform, nitrate, and phosphorous in samples of surface water in LaSalle County indicate that wastewater impacts many of the streams in the county. Detections of elevated concentrations of nitrate and phosphorous, along with detection of the herbicide atrazine in many of the samples from the Illinois and Fox rivers (table 2–1), indicates that agricultural practices also are impacting surface-water quality.

The IEPA's list of impaired streams under section 303(d) of the Clean Water Act (U.S. Environmental Protection Agency, 2016) identifies water bodies in Illinois that exceed water-quality standards, ranks them from low to high priority based on the severity of the exceedance, and establishes the use and impairment of the water bodies based on the degree of contamination (fig. 6; table 10; Illinois Environmental Protection Agency, 2014). The Illinois River was listed in 2014 as being nonsupportive of *primary contact recreational use* and fish consumption due to concentrations of *polychlorinated biphenyls* (PCBs), mercury, and fecal coliform in most of LaSalle County. The Fox River was listed

Table 7. Summary of water-quality information from selected water-supply systems in LaSalle County, Illinois.

[Data are from U.S. Geological Survey (2016c), Illinois Environmental Protection Agency (undated a), and Anthony Dulka (Illinois Environmental Protection Agency, written commun., 2016). na, not applicable; --, no data]

Owner	Approximate location (on fig. 1)	Well name	Water source	Depth of well (feet)	Notable water-quality results
Cedar Point	Point on map	1	Cambrian-Ordovician	1,750	Chloride; radium
Country Acres Mobile Home Park	South of Seneca	1	Ancell	550	Radium; volatile organic compounds
Country Acres Mobile Home Park	South of Seneca	2	Unknown	160	
Country Acres Mobile Home Park	South of Seneca	3	Ancell	550	Volatile organic compounds
Countryside Estates Mobile Home Park	South of Lake Holiday	1	Ancell	200	
Countryside Estates Mobile Home Park	South of Lake Holiday	2	Ancell	192	
Dattis Mobile Home Park	North of Ottawa	1	Ancell/New Richmond	508	Radium
Earlville	Point on map	2	Ancell	150	Iron
Earlville	Point on map	3	Cambrian-Ordovician	888	
Earlville	Point on map	4	Cambrian-Ordovician	888	
Four Lakes Subdivision	Near Marseilles	1	Cambrian-Ordovician	500	
Four Star Campground	Near Marseilles	1	Ancell	460	Radium
Glenwood-Outback	Near Marseilles	1	Unknown	360	
Grand Ridge	Point on map	1	Glacial	162	Arsenic
Grand Ridge	Point on map	3	Glacial	190	Arsenic
Grand Ridge	Point on map	4	Glacial	190	Arsenic
Illinois American Streator	Point on map	na	Vermilion River	na	Nitrate
Illinois Prairie Estates	Near Marseilles	1	Cambrian-Ordovician	660	Iron; radium
Jon’s Mobile Home Park	East of Lake Holiday	1	Prairie du Chien	100	
Jon’s Mobile Home Park	East of Lake Holiday	2	Ancell	110	Nitrate
Jon’s Mobile Home Park	East of Lake Holiday	3	Prairie du Chien	220	Nitrate
LaSalle	Point on map	3	Glacial	--	
LaSalle	Point on map	4	Glacial	53	Manganese
LaSalle	Point on map	5	Glacial	--	Abandoned
LaSalle	Point on map	6	Glacial	56	
LaSalle	Point on map	7	Glacial	49	
LaSalle	Point on map	8	Glacial	76	Manganese
LaSalle	Point on map	9	Glacial	68	Manganese
LaSalle	Point on map	10	Glacial	67	Manganese
LaSalle	Point on map	11	Glacial	64	Manganese
LaSalle	Point on map	12	Glacial	63	
LaSalle County Nursing Home	West of Ottawa	1	Ancell/New Richmond	345	
LaSalle County Nursing Home	West of Ottawa	3	Ancell/New Richmond	372	Radium

Table 7. Summary of water-quality information from selected water-supply systems in LaSalle County, Illinois.—Continued

[Data are from U.S. Geological Survey (2016c), Illinois Environmental Protection Agency (undated a), and Anthony Dulka (Illinois Environmental Protection Agency, written commun., 2016). na, not applicable; --, no data]

Owner	Approximate location (on fig. 1)	Well name	Water source	Depth of well (feet)	Notable water-quality results
Land and Water Association	Near Marseilles	1	Cambrian-Ordovician	540	Radium
Leland	Point on map	1	Prairie du Chien	230	Iron
Leland	Point on map	2	Prairie du Chien	200	Iron
Leonore	Point on map	1	Glacial	40	
Leonore	Point on map	2	Glacial	92	
Lostant	Point on map	3	Glacial	135	
Lostant	Point on map	4	Ancell	1,881	Emergency supply; chloride, total dissolved solids
Lostant	Point on map	5	Ancell	1,880	Radium
Lynnwood Water Corp.	Near Peru	1	Cambrian-Ordovician	1,364	Radium
Marseilles	Point on map	1	Ancell	168	
Marseilles	Point on map	2	Ancell	180	
Marseilles	Point on map	2	New Richmond	670	
Marseilles	Point on map	3	New Richmond	850	Radium
Marseilles	Point on map	4	New Richmond/Ironton-Galesville	1,450	Radium
Marseilles	Point on map	5	New Richmond/Ironton-Galesville	1,450	
Marseilles	Point on map	6	New Richmond/Ironton-Galesville	1,450	
Mendota	Point on map	3	Cambrian-Ordovician	1,354	
Mendota	Point on map	4	Cambrian-Ordovician	1,297	Radium
Mendota	Point on map	5	Cambrian-Ordovician	502	
Mendota	Point on map	6	Cambrian-Ordovician	1,400	Radium
Mendota	Point on map	7	Cambrian-Ordovician	519	
Mendota	Point on map	8	Cambrian-Ordovician	519	
Naplate	Point on map	1	New Richmond	420	Radium
Naplate	Point on map	2	New Richmond	395	
North Utica	Point on map	1	Cambrian-Ordovician	618	Radium
North Utica	Point on map	2	Cambrian-Ordovician	1,078	Chloride, radium
Oaklane Subdivision	Near Ottawa	1	Cambrian-Ordovician	287	Radium
Oaklane Subdivision	Near Ottawa	2	Cambrian-Ordovician	504	
Oglesby	Point on map	2	Cambrian-Ordovician	2,784	
Oglesby	Point on map	3	Cambrian-Ordovician	2,821	Chloride
Oglesby	Point on map	4	Cambrian-Ordovician	2,795	Chloride
Ottawa	Point on map	7	Ironton-Galesville	1,185	
Ottawa	Point on map	8	Cambrian-Ordovician	1,180	Radium

Table 7. Summary of water-quality information from selected water-supply systems in LaSalle County, Illinois.—Continued

[Data are from U.S. Geological Survey (2016c), Illinois Environmental Protection Agency (undated a), and Anthony Dulka (Illinois Environmental Protection Agency, written commun., 2016). na, not applicable; --, no data]

Owner	Approximate location (on fig. 1)	Well name	Water source	Depth of well (feet)	Notable water-quality results
Ottawa	Point on map	10	New Richmond/Ironton-Galesville	1,220	Radium
Ottawa	Point on map	11	New Richmond/Ironton-Galesville	1,203	Radium
Ottawa	Point on map	12	Ironton-Galesville	1,200	
Ottawa	Point on map	14	New Richmond/Ironton-Galesville	1,205	
Peru	Point on map	4	Unknown	996	
Peru	Point on map	5	Cambrian-Ordovician	2,576	Radium
Peru	Point on map	6	Cambrian-Ordovician	2,665	
Peru	Point on map	7	Cambrian-Ordovician	2,591	
Peru	Point on map	8	Cambrian-Ordovician	2,764	
Peru	Point on map	9	Cambrian-Ordovician	2,759	
Ransom	Point on map	1	Pennsylvanian	325	
Ransom	Point on map	2	Galena-Platteville/Ancell	831	
Ransom	Point on map	3	Pennsylvanian	280	
Ransom	Point on map	4	Ancell	815	Chloride, radium
Rutland	Point on map	3	Glacial	65	
Rutland	Point on map	4	Glacial	55	
Seneca	Point on map	1	Cambrian-Ordovician	700	
Seneca	Point on map	2	Cambrian-Ordovician	704	
Seneca	Point on map	3	Ironton-Galesville	1,500	Radium
Sheridan Correctional Center	Near Sheridan	1	Ironton-Galesville	885	
Sheridan Correctional Center	Near Sheridan	2	Prairie du Chien	298	
Sheridan Correctional Center	Near Sheridan	3	Ironton-Galesville	900	
Tonica	Point on map	2	Glacial	193	
Tonica	Point on map	3	Glacial	193	Iron, arsenic
Tonica	Point on map	4	Glacial	193	Iron, arsenic
Lake Holiday	Point on map	1	Cambrian-Ordovician	663	Iron, beryllium
Lake Holiday	Point on map	2	Cambrian-Ordovician	664	Iron, beryllium
Lake Holiday	Point on map	3	Cambrian-Ordovician	745	Iron, beryllium
Wildlife Mobile Home Park	West of Seneca	1	Cambrian-Ordovician	425	Radium
Wildwood Communities	Near Lake Holiday	1	Prairie du Chien	265	Iron
Wildwood Communities	Near Lake Holiday	2	Prairie du Chien	160	
Wildwood Communities	Near Lake Holiday	3	Cambrian-Ordovician	670	Iron
Woodsmoke Ranch Association	North of Seneca	2	Ancell	400	Radium
Woodsmoke Ranch Association	North of Seneca	3	Ancell	--	Radium

Table 8. Comparison of surface-water-quality data collected by the U.S. Geological Survey in LaSalle County, Illinois, to regulatory standards.

[Data are shown in the format of x/y, where x is the number of samples where the concentration in the sample exceeded the water-quality criterion for the constituent and y is the number of samples analyzed. EPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; SMCL, secondary maximum contaminant level; USGS, U.S. Geological Survey; —, no standard available; ?, threshold is calculated value, exceedance unknown; mg/L, milligram per liter; µg/L, microgram per liter; c/100 mL, colony per 100 milliliters; µS/cm, microsiemens per centimeter; na, not analyzed; P, phosphorus]

Constituent and units	EPA MCL	EPA SMCL	Illinois general use	EPA aquatic life acute threshold	EPA aquatic life chronic threshold
Somonauk Creek at Sheridan, Illinois (USGS streamgage 05551970)					
Ammonia as nitrogen (mg/L)	—	—	0/165	0/165	0/165
Arsenic (µg/L)	0/5	—	0/5	0/5	0/5
Barium (µg/L)	0/5	—	0/5	—	—
Boron (µg/L)	—	—	0/5	—	—
Chromium (µg/L)	1/142	—	?	0/142	1/142
Copper (µg/L)	0/145	0/145	?	?	?
Dissolved oxygen (mg/L)	—	—	0/150	0/150	—
Fecal coliform (colonies per 100 milliliter)	124/124	—	71/124	—	—
Fluoride (mg/L)	0/4	—	—	0/4	—
Iron (µg/L)	—	101/142	31/142	—	31/142
Manganese (µg/L)	—	59/142	?	1/142	?
Mercury (µg/L)	0/5	—	0/5	0/5	0/5
Nitrate + nitrite as nitrogen (mg/L)	5/165	—	—	—	—
Total phosphorus as P (mg/L)	—	60/164	124/164	—	—
Sulfate (mg/L)	—	0/5	?	—	—
Zinc (µg/L)	—	0/140	0/140	11/140	120/140
Fox River at Dayton, Illinois (USGS streamgage 05552500)					
Ammonia as nitrogen (mg/L)	—	—	0/188	0/188	0/188
Arsenic (µg/L)	0/201	0/201	0/201	0/201	0/201
Barium (µg/L)	0/26	—	0/26	—	—
Boron (µg/L)	—	—	0/152	—	—
Chloride (mg/L)	—	0/211	0/211	0/211	0/211
Chromium (µg/L)	1/92	—	?	0/92	3/92
Copper (µg/L)	0/62	0/62	?	?	?
Dissolved oxygen (mg/L)	—	—	0/793	0/793	—
Fecal coliform (colonies per 100 milliliter)	176/176	—	68/176	—	—
Fluoride (mg/L)	0/151	—	—	0/151	—
Iron (µg/L)	—	163/208	60/208	—	60/208
Manganese (µg/L)	—	114/169	?	1/169	—
Mercury (µg/L)	0/52	—	0/52	0/52	0/52
Nitrate + nitrite as nitrogen (mg/L)	1/187	—	—	—	—
Total phosphorus as P (mg/L)	—	241/249	247/249	—	—
Sulfate (mg/L)	—	0/213	?	—	—
Zinc (µg/L)	—	0/173	0/173	20/173	20/173
Selected organic compounds:					
Atrazine (µg/L)	0/10	—	—	—	—
Cyanazine (µg/L)	—	0/10	—	—	—
Simazine (µg/L)	0/10	—	—	—	—

Table 8. Comparison of surface-water-quality data collected by the U.S. Geological Survey in LaSalle County, Illinois, to regulatory standards.—Continued

[Data are shown in the format of x/y, where x is the number of samples where the concentration in the sample exceeded the water-quality criterion for the constituent and y is the number of samples analyzed. EPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; SMCL, secondary maximum contaminant level; USGS, U.S. Geological Survey; —, no standard available; ?, threshold is calculated value, exceedance unknown; mg/L, milligram per liter; µg/L, microgram per liter; c/100 mL, colony per 100 milliliters; µS/cm, microsiemens per centimeter; na, not analyzed; P, phosphorus]

Constituent and units	EPA MCL	EPA SMCL	Illinois general use	EPA aquatic life acute threshold	EPA aquatic life chronic threshold
Illinois River at Marseilles, Illinois (USGS streamgage 05543500)					
Ammonia as nitrogen (mg/L)	—	—	0/234	0/234	19/234
Arsenic (µg/L)	0/219	—	0/219	0/219	0/219
Barium (µg/L)	0/226	—	0/226	—	—
Boron (µg/L)	—	—	0/190	—	—
Chloride (mg/L)	—	0/286	0/286	0/286	1/286
Chromium (µg/L)	1/218	—	?	0/218	3/218
Copper (µg/L)	0/201	0/201	?	?	?
Dissolved oxygen (mg/L)	—	—	0/1115	0/1115	—
Fecal coliform (colonies per 100 milliliter)	212/216	—	73/216	—	—
Fluoride (mg/L)	0/156	—	—	0/156	—
Iron (µg/L)	—	245/247	102/247	—	102/247
Manganese (µg/L)	—	189/223	?	0/223	—
Mercury (µg/L)	0/194	—	2/194 (acute)	1/194	3/194
Nitrate + nitrite as nitrogen (mg/L)	0/256	—	—	—	—
Total phosphorus as P (mg/L)	—	353/354	354/354	—	—
Sulfate (mg/L)	—	0/308	?	—	—
Zinc (µg/L)	—	0/223	0/223	35/223	35/223
Selected organic compounds:					
Alachlor (µg/L)	0/11	—	—	—	—
Atrazine (µg/L)	2/11	—	—	—	—
Cyanazine (µg/L)	—	1/11	—	—	—
Metolachlor (µg/L)	—	0/11	—	—	—
Simazine (µg/L)	0/11	—	—	—	—
Illinois River at Ottawa, Illinois (USGS streamgage 05553000)					
Ammonia as nitrogen (mg/L)	—	—	0/234	0/234	1/234
Chloride (mg/L)	—	0/286	0/286	0/286	1/286
Dissolved oxygen (mg/L)	—	—	0/1115	0/1115	—
Fluoride (mg/L)	0/67	—	—	0/67	—
Nitrate + nitrite as nitrogen (mg/L)	0/90	—	—	—	—
Total phosphorus as P (mg/L)	—	90/90	90/90	—	—
Sulfate (mg/L)	—	0/91	?	—	—
Selected organic compounds:					
Alachlor (µg/L)	0/78	—	—	—	—
Atrazine (µg/L)	10/78	—	—	—	—
Cyanazine (µg/L)	—	1/78	—	—	—
Metolachlor (µg/L)	—	0/78	—	—	—
Simazine (µg/L)	0/78	—	—	—	—

Table 8. Comparison of surface-water-quality data collected by the U.S. Geological Survey in LaSalle County, Illinois, to regulatory standards.—Continued

[Data are shown in the format of x/y, where x is the number of samples where the concentration in the sample exceeded the water-quality criterion for the constituent and y is the number of samples analyzed. EPA, U.S. Environmental Protection Agency; MCL, maximum contaminant level; SMCL, secondary maximum contaminant level; USGS, U.S. Geological Survey; —, no standard available; ?, threshold is calculated value, exceedance unknown; mg/L, milligram per liter; µg/L, microgram per liter; c/100 mL, colony per 100 milliliters; µS/cm, microsiemens per centimeter; na, not analyzed; P, phosphorus]

Constituent and units	EPA MCL	EPA SMCL	Illinois general use	EPA aquatic life acute threshold	EPA aquatic life chronic threshold
Vermilion River near Leonore, Illinois (USGS streamgage 05555300)					
Ammonia as nitrogen (mg/L)	—	—	0/123	0/123	1/123
Arsenic (µg/L)	0/5	—	0/5	0/5	0/5
Barium (µg/L)	0/13	—	0/13	—	—
Boron (µg/L)	—	—	0/145	—	—
Chloride (mg/L)	—	0/9	0/9	0/9	0/9
Chromium (µg/L)	2/150	—	?	0/150	2/150
Copper (µg/L)	0/166	0/166	?	?	?
Dissolved oxygen (mg/L)	—	—	1/213	0/213	—
Fecal coliform (colonies per 100 milliliter)	145/150	—	104/150	—	—
Fluoride (mg/L)	0/3	—	—	0/3	—
Iron (µg/L)	—	162/186	76/186	—	76/186
Manganese (µg/L)	—	88/175	?	0/175	—
Mercury (µg/L)	0/181	—	0/181	0/181	0/181
Nitrate + nitrite as nitrogen (mg/L)	76/183	—	—	—	—
Total phosphorus as P (mg/L)	—	108/118	118/118	—	—
Sulfate (mg/L)	—	0/173	?	—	—
Zinc (µg/L)	—	0/174	0/174	13/174	13/174
Little Vermilion River at LaSalle, Illinois (USGS streamgage 05555950)					
Ammonia as nitrogen (mg/L)	—	—	0/162	0/162	4/123
Arsenic (µg/L)	0/10	—	0/10	0/10	0/10
Barium (µg/L)	0/31	—	0/31	—	—
Boron (µg/L)	—	—	0/143	—	—
Chloride (mg/L)	—	0/134	0/134	0/134	0/134
Chromium (µg/L)	1/143	—	?	0/143	1/143
Copper (µg/L)	0/142	0/142	?	?	?
Dissolved oxygen (mg/L)	—	—	0/154	0/154	—
Fecal coliform (colonies per 100 milliliter)	101/111	—	57/111	—	—
Fluoride (mg/L)	0/10	—	—	0/10	—
Iron (µg/L)	—	142/164	60/164	—	60/164
Manganese (µg/L)	—	140/143	?	2/143	—
Mercury (µg/L)	0/158	—	1/158 (acute)	0/158	1/158
Nitrate + nitrite as nitrogen (mg/L)	31/163	—	—	—	—
Total phosphorus as P (mg/L)	—	88/117	114/117	—	—
Sulfate (mg/L)	—	0/164	?	—	—
Zinc (µg/L)	—	0/142	32/142	137/142	137/142

Table 9. Seasonal analysis of surface-water-quality data collected by the U.S. Geological Survey in LaSalle County, Illinois.

[Min., minimum; Med., median; Max., maximum; mg/L, milligram per liter; µg/L, microgram per liter; NO_3, nitrate; NO_2, nitrite; c/100 mL, colony per 100 milliliters; P, phosphorus; <, less than]

Constituents and units	Spring March 1–May 31			Summer June 1–August 31			Fall September 1–November 30			Winter December 1–February 28(29)		
	Min.	Med.	Max.	Min.	Med.	Max.	Min.	Med.	Max.	Min.	Med.	Max.
Fox River at Dayton, Illinois (05552500) sampling period 1978–1997												
Chloride (mg/L)	19	55	210	12	53	96	19	61	103	27	63	134
NO_3+NO_2 as nitrogen (mg/L)	0.2	3.4	7.8	0.01	2.2	8	0.1	1.5	5.4	2.3	4.2	7.1
Ammonia as nitrogen (mg/L)	0.013	0.039	0.42	0.026	0.046	0.28	0.013	0.026	0.57	0.026	0.28	0.95
Fecal coliform (c./100mL)	9	110	400,000	9	200	41,000	9	130	6,900	18	114	3,200
Total P as P (mg/L)	0.02	0.22	2.8	0.06	0.33	1.0	0.05	0.28	4.4	0.11	0.20	0.84
Dissolved P as P (mg/L)	<0.01	0.04	0.52	0.02	0.08	0.5	0.01	0.11	2.6	<0.01	0.13	0.58
Chlorophyll-*a* (µg/L)	3.6	15	158	26	39	81	29	52	94	1.4	3.0	40
Little Vermillion River at LaSalle, Illinois (05555950) sampling period 1979–1997												
Chloride (mg/L)	12	39	101	11	45	100	17	70	133	24	46	128
NO_3+NO_2 as nitrogen (mg/L)	1.3	7.5	17	0.1	5.1	14	0.3	2.2	11	2	8.3	14
Ammonia as nitrogen (mg/L)	0.013	0.15	0.90	0.013	0.17	1.9	0.039	0.27	0.90	0.039	0.35	4.8
Fecal coliform (c./100mL)	4	325	57,000	40	500	64,000	18	131	4,400	3	80	5,200
Total P as P (mg/L)	0.04	0.11	1.5	0.06	0.16	1.7	0.05	0.15	0.89	0.05	0.16	0.62
Dissolved P as P (mg/L)	0.01	0.06	0.24	0.01	0.08	0.27	0.02	0.09	0.26	0.02	0.10	0.53
Vermillion River at Leonore, Illinois (05555300) sampling period 1977–1997												
NO_3+NO_2 as nitrogen (mg/L)	5.4	11	23	<0.1	9.4	18	0.1	4.3	14	2.9	11	18
Ammonia as nitrogen (mg/L)	0.013	0.10	0.57	<0.01	0.052	0.60	<0.01	0.077	1.2	0.039	0.22	2.6
Fecal coliform (c./100mL)	42	1,000	8,800	9	290	33,000	10	370	12,000	13	630	2,200
Total P as P (mg/L)	0.06	0.18	1.0	0.08	0.27	1.0	0.11	0.24	0.95	0.06	0.20	1.2
Dissolved P as P (mg/L)	0.03	0.12	0.25	0.01	0.15	0.38	0.02	0.19	0.82	0.05	0.14	1.1
Illinois River at Marseilles, Illinois (05543500) sampling period 1974–2015												
Chloride (mg/L)	2.7	72	155	27	60	91	26	65	86	31	90	247
NO_3+NO_2 as nitrogen (mg/L)	0.04	5.4	8.9	0.4	3.2	7.9	2.1	3.6	6.4	1.1	5.3	8.9
Ammonia as nitrogen (mg/L)	0.039	0.58	4.51	0.018	0.27	1.3	0.026	0.39	3.7	0.17	1.0	4.0
Fecal coliform (c./100mL)	6	176	2,650	8	68	20,000	5	95	20,500	1.0	120	2,000
Total P as P (mg/L)	0.15	0.37	0.95	0.08	0.44	0.95	0.14	0.50	1.4	0.21	0.45	1.1
Dissolved P as P (mg/L)	0.09	0.23	0.73	0.04	0.29	0.74	0.14	0.39	0.95	0.13	0.33	0.85
Chlorophyll-*a* (µg/L)	1.9	3.9	25	1.9	6.1	9.2	2.7	10	28	1.0	1.9	4.1

Table 9. Seasonal analysis of surface-water-quality data collected by the U.S. Geological Survey in LaSalle County, Illinois.—Continued

[Min., minimum; Med., median; Max., maximum; mg/L, milligram per liter; µg/L, microgram per liter; NO_3, nitrate; NO_2, nitrite; c/100 mL, colony per 100 milliliters; P, phosphorus; <, less than]

Constituents and units	Spring March 1–May 31			Summer June 1–August 31			Fall September 1–November 30			Winter December 1–February 28(29)		
	Min.	Med.	Max.	Min.	Med.	Max.	Min.	Med.	Max.	Min.	Med.	Max.
Illinois River at Ottawa, Illinois (05553500) sampling period 1997–2004												
Chloride (mg/L)	43	90	162	36	71	118	66	81	105	67	107	232
NO_3+NO_2 as nitrogen (mg/L)	3.6	5.3	8.7	1.9	4.1	8.6	2.4	3.0	4.2	2.9	4.2	7.1
Ammonia as nitrogen (mg/L)	0.028	0.11	0.35	0.026	0.055	0.15	0.031	0.091	0.20	0.037	0.19	0.9
Total P as P (mg/L)	0.19	0.37	1.0	0.31	0.53	0.74	0.38	0.53	0.74	0.29	0.59	1.1
Dissolved P as P (mg/L)	0.09	0.21	0.81	0.15	0.30	0.69	0.32	0.52	0.90	0.15	0.48	1.0
Somonauk Creek at Sheridan, Illinois (0555197) sampling period 1979–1997												
NO_3+NO_2 as nitrogen (mg/L)	0.9	6	13	0.8	3.4	9.5	0.12	1.4	6.5	1.2	4.6	11
Ammonia as nitrogen (mg/L)	<0.01	0.084	0.99	0.013	0.058	0.64	<0.01	0.052	1.2	<0.01	0.058	1.1
Total P as P (mg/L)	<0.01	0.09	0.61	0.01	0.08	1.1	0.01	0.05	0.79	0.01	0.07	1.0
Dissolved P as P (mg/L)	<0.01	0.03	0.48	0.01	0.04	0.24	0.01	0.04	0.40	<0.01	0.03	0.34

Table 10. Streams in LaSalle County, Illinois, listed as impaired in 2014 under section 303(d) of the Clean Water Act.

Water body	Assessment identification number	Impaired use	Cause of impairment	Processes affecting impairment
Covel Creek	DZS	Fish consumption	Mercury	Unknown
Fox River	DT01	Primary contact for recreation; fish consumption	Bank erosion, flow alteration, sedimentation, suspended solids, pH, algae, polychlorinated biphenyls, fecal coliform	Streambank modification, dam or impoundment, crop production, urban runoff, other unknown causes
Fox River	DT02	Fish consumption	Polychlorinated biphenyls	Unknown
Fox River	DT36	Fish consumption	Polychlorinated biphenyls	Unknown
Fox River	DT41	Fish consumption	Polychlorinated biphenyls	Unknown
Fox River	DT46	Aquatic life, fish consumption	Flow regime alteration, sedimentation, total suspended solids, pH, mercury, polychlorinated biphenyls	Flow modification, impoundments, crop production, atmospheric deposition, other unknown sources
Illinois River	D20	Primary contact for recreation, fish consumption	Mercury, polychlorinated biphenyls, fecal coliform	Atmospheric deposition, other unknown sources
Illinois River	D23	Primary contact for recreation; fish consumption	Mercury, polychlorinated biphenyls, fecal coliform	Atmospheric deposition, other unknown sources
Lake Holiday	VTX	Fish consumption	Mercury, phosphorus	Atmospheric deposition, other unknown sources
Little Vermilion River	DR	Aquatic life	Dissolved oxygen	Unknown
Little Vermilion River	DR01	Aquatic life, primary contact for recreation	Chloride, total suspended solids, zinc, pH, phosphorus, fecal coliform	Combined sewer overflow, urban runoff, crop production, contaminated sediment, industrial land treatment, sanitary sewer overflow, other unknown sources
Mendota Creek	DRD	Aquatic life	Alteration in vegetative cover, flow alteration, dissolved oxygen, phosphorus	Channelization, combined sewer overflows, municipal point source discharge, upstream impoundments, urban runoff
Vermilion River	DS07	Fish consumption, primary contact for recreation	Mercury, fecal coliform	Atmospheric deposition, other unknown sources

as having fish-consumption impairment due to elevated PCB and mercury concentrations in LaSalle County. Segments of the Fox River in LaSalle County also were impaired for primary contact recreational use and aquatic-life use due to sedimentation, pH levels, flow alteration, or fecal coliform populations. The source of the mercury was attributed to atmospheric settling of mercury-containing particulate matter. The source of the PCBs is unknown.

The Vermilion River and Covel Creek in the southern part of the county and Lake Holiday in the northeastern part of the county also were listed in 2014 as being impaired for fish consumption due to elevated mercury concentrations. Fecal coliform populations also resulted in primary recreational use impairment for the Vermilion River. In the northwestern part of the county, Mendota Creek and segments of the Little Vermilion River were impaired for aquatic life or primary contact recreational use due to low concentrations of dissolved oxygen or elevated concentrations of phosphorus, fecal coliform, and other chemicals (table 10).

Unconsolidated Deposits

Water-quality data from 15 monitoring wells and 9 public-supply wells open to the unconsolidated deposits throughout LaSalle County were reviewed. These wells are between about 18 and 200 ft deep and are open to primarily to glacial drift aquifers, but some are open to semiconfining units. Sample collection began in 1922, with most of the samples collected from 1986 through 2010.

Selected Major Ions and Trace Elements

Samples collected from wells open to the glacial drift deposits in LaSalle County were analyzed for selected *major ions* and *trace elements* (table 11). These constituents include several elements with MCLs (arsenic, zinc, radium) as wells as indicators of the aesthetic groundwater quality (iron, fluoride, chloride, sulfate).

Analyses of major ions in groundwater from glacial drift deposits indicate waters of calcium-bicarbonate, calcium-sulfate, and sodium-bicarbonate types. Calcium tended to be the dominant cation by concentration in the northern part of the county (fig. 19). Sodium tended to be present at substantial concentrations in the southern part of the county, often being the dominant cation. Based on the alkalinity values, bicarbonate tended to be the dominant anion by concentration in the glacial drift in LaSalle County.

Chloride concentrations typically were less than 50 mg/L in LaSalle County (fig. 19), but exceeded 100 mg/L near Lostant (fig. 1) and in the alluvial deposits in along the Illinois River at LaSalle. Concentrations at Lostant may reflect road salt application or interaction with the bedrock. Concentrations in most of the samples from LaSalle are in the 50- to 100-mg/L range. However, concentrations in samples from some wells varied from 55 to 1,100 mg/L between sampling dates. The temporal variability in the chloride concentration at LaSalle may reflect variations in chloride concentrations in the Illinois River, which could infiltrate to the groundwater system under the effects of pumping. However, maximum chloride concentrations in the Illinois River were less than 250 mg/L, making flow of saline water from the surrounding Pennsylvanian deposits in response to pumping a possible source of elevated chloride (Kelly and others, 2016).

Substantial concentrations of sulfate also were present, especially in the southernmost part of the county where the SMCL for sulfate (250 mg/L as shown in table 6) was exceeded in several wells. Sulfate in the glacial drift deposits likely is formed by the oxidation of sulfide minerals such as pyrite. Pyrite can be abundant in the Pennsylvanian bedrock deposits that were eroded to partly form the glacial drift deposits. Pennsylvanian-derived drift deposits are primarily in the southern and western parts of the county. The difference in the composition of the source rock may account for some of the differences in groundwater chemistry in the glacial drift deposits in the county.

Iron concentrations in samples collected from glacial deposits in LaSalle County were above the SMCL (0.3 mg/L) in 18 of 27 samples. Manganese concentrations in samples collected from LaSalle County were at or above the SMCL (50 micrograms per liter [μg/L]) in 6 of 24 samples. Although not harmful to human health, elevated concentrations of iron or manganese are indicative of reducing geochemical conditions in the groundwater system, which can be associated with elevated concentrations of arsenic (Warner and others, 2003). Elevated concentrations of iron or manganese in water also can affect the color and taste of the water; stain laundry and dishes; and cause a buildup of mineral deposits in plumbing fixtures. As a consequence, water with high iron content is often treated before use.

Arsenic was detected above in concentrations above the MCL of 10 μg/L in samples from wells that draw water from the sand and gravel aquifers in the Ticona Bedrock Valley (fig. 19). Arsenic in these aquifers likely is derived from the oxidation of sulfide minerals in the glacial deposits and potentially the influx of water from the Pennsylvanian deposits along the sides of the valley.

Radionuclides and Volatile Organic Compounds

Data on radionuclides (radon, radium, uranium) in glacial drift aquifers in LaSalle County are available from three or five wells, depending on the analyte. Radium (MCL 5 pCi/L from table 6) and uranium (MCL 30 μg/L or 20.1 pCi/L) concentrations are below MCLs in all wells (table 11). This result is consistent with studies indicating that concentrations of these compounds in water from the glacial drift and shallow bedrock aquifers in northern Illinois are below MCLs (Gilkeson and others, 1983). Concentrations of radon in groundwater from glacial drift deposits exceed the most stringent of the proposed MCLs (300 pCi/L) in three of the five samples collected. All the radon exceedances occur in the northern part of the county.

Water samples from 10 wells open to glacial drift aquifers in LaSalle County have been analyzed for the presence of volatile organic compounds (VOCs). With the exception of well disinfection byproducts detected at low concentrations in one well, which likely are not indicative of water quality in the aquifer, VOCs were not detected in any of these wells.

Agricultural-Related Constituents

As many as 25 samples were collected from wells open to glacial drift deposits in LaSalle County and analyzed for the agricultural-related constituents nitrogen (in the form of nitrate and ammonia) and phosphorus (table 11). The concentration of nitrate (as nitrogen) exceeded the MCL of 10 mg/L in one sample, collected in 1947 from a well open to the sand and gravel aquifer beneath the Illinois River near LaSalle. Ammonia concentrations were less than 4.5 mg/L in the glacial drift deposits. Phosphorus concentrations were less than 0.25 mg/L in all samples.

A total of six samples collected from two water-table-monitoring wells, one north of LaSalle and a second near Sheridan open to the glacial drift deposits, were analyzed for insecticides and herbicides (table 11). The herbicide ′2,4-dichlorophenoxyacetic acid (2,4–D; concentration of 0.07 μg/L) was detected in a sample from a water-table monitoring well north of Lostant at concentrations substantially below the MCL (70 μg/L). The atrazine degradant 2-chloro-4-isopropylamino-6-amino-*s*-triazine (referred to as CIAT and

Table 11. Concentration of selected constituents in groundwater from unconsolidated deposits in LaSalle County, Illinois.

[Data are from U.S. Geological Survey (2016c), Illinois Environmental Protection Agency (undated a), and Anthony Dulka (Illinois Environmental Protection Agency, written commun., 2016). mg/L, milligram per liter; $CaCO_3$, calcium carbonate; µg/L, microgram per liter; pCi/L, picocurie per liter; µS/cm, microsiemens per centimeter; CIAT, deethyl atrazine; <, less than]

Constituents and units	Maximum value	Minimum value	Median value	Number of samples/wells	Period of record (yyyy–yyyy)
Alkalinity (mg/L as calcium carbonate)	544	180	341	18/13	1922–2010
Ammonia as nitrogen (mg/L)	3.7	<0.01	0.51	15/14	1986–2010
Arsenic (µg/L)	46	<1	4.0	15/14	1986–2010
Barium (µg/L)	400	16	212	11/10	1986–2010
Boron (µg/L)	1,080	20	540	11/10	1986–2010
Calcium (mg/L)	188	13	58	25/23	1922–2010
Chloride (mg/L)	1,100	2	20	27/23	1922–2010
Chromium (µg/L)	11	<1	<5	15/14	1986–2010
Copper (µg/L)	3.7	<0.8	<5	14/13	1986–2010
Fluoride (mg/L)	1.3	<0.10	0.70	25/24	1922–2010
Iron (mg/L)	3.4	0.003	3.3	25/24	1922–2010
Magnesium (mg/L)	67	5	32	26/24	1922–2010
Manganese (µg/L)	307	<5	20	15/14	1986–2010
Mercury (µg/L)	<0.10	<0.10	<0.10	10/10	1986–1987
Nitrate + nitrite as nitrogen (mg/L)	11	<0.05	1.5	25/23	1922–2010
Phosphorus as P (mg/L)	0.22	<0.004	0.03	15/14	1986–2010
Radon-222 (pCi/L)	680	<80	360	5/5	1997–1999
Radium-226 (pCi/L)	0.12	0.12	0.12	2/1	1997–2010
Sodium (mg/L)	151	4	102	26/24	1922–2010
Specific conductance (µS/cm)	1,840	685	805	15/14	1986–2010
Sulfate (mg/L)	828	5	24	26/24	1922–2010
Zinc (µg/L)	<50	<1	<1	15/14	1986–2010
Selected organic compounds:					
CIAT (µg/L)	0.012	<0.002	0.003	6/2	1997–2010
Volatile organic compounds (µg/L)	<1	<1	<1	10/10	1986–1987

also known as deethyl atrazine) was detected at concentrations of 0.004 to 0.012 µg/L. CIAT has no MCL.

Analysis of water-quality data indicates that the glacial drift deposits in parts of southern LaSalle County contain naturally occurring arsenic at concentrations above its MCL. Concentrations of naturally occurring iron, manganese, and sulfate concentrations above their SMCLs also are present in these deposits, primarily in the southern part of the county. Analysis of water-quality data also indicates that the shallow glacial drift deposits can be susceptible to contamination by agricultural chemicals. The presence of intermittent detections of low concentrations of nitrate and pesticides in the wells sampled in LaSalle may reflect the infiltration of water from the Illinois River into the nearby sand and gravel aquifer in response to pumping at these wells. Because the unconsolidated deposits have the capacity for additional water-supply development, water-quality issues should be considered prior to development.

Bedrock Aquifers

Water-quality data from more than 40 water-supply wells open to bedrock aquifers in LaSalle County were reviewed. Sample collection began in 1917, but most samples were collected from 1987 through 2008 (table 12). Although techniques for sample collection and analysis have changed through time, it is assumed that all data is accurate and can be compared across different sampling periods. The wells range in depth from about 150 to 2,800 ft and are open to shallow bedrock deposits of the Pennsylvanian System, the Ancell aquifer, New Richmond aquifer, or the deeper undifferentiated Cambrian-Ordovician aquifer system.

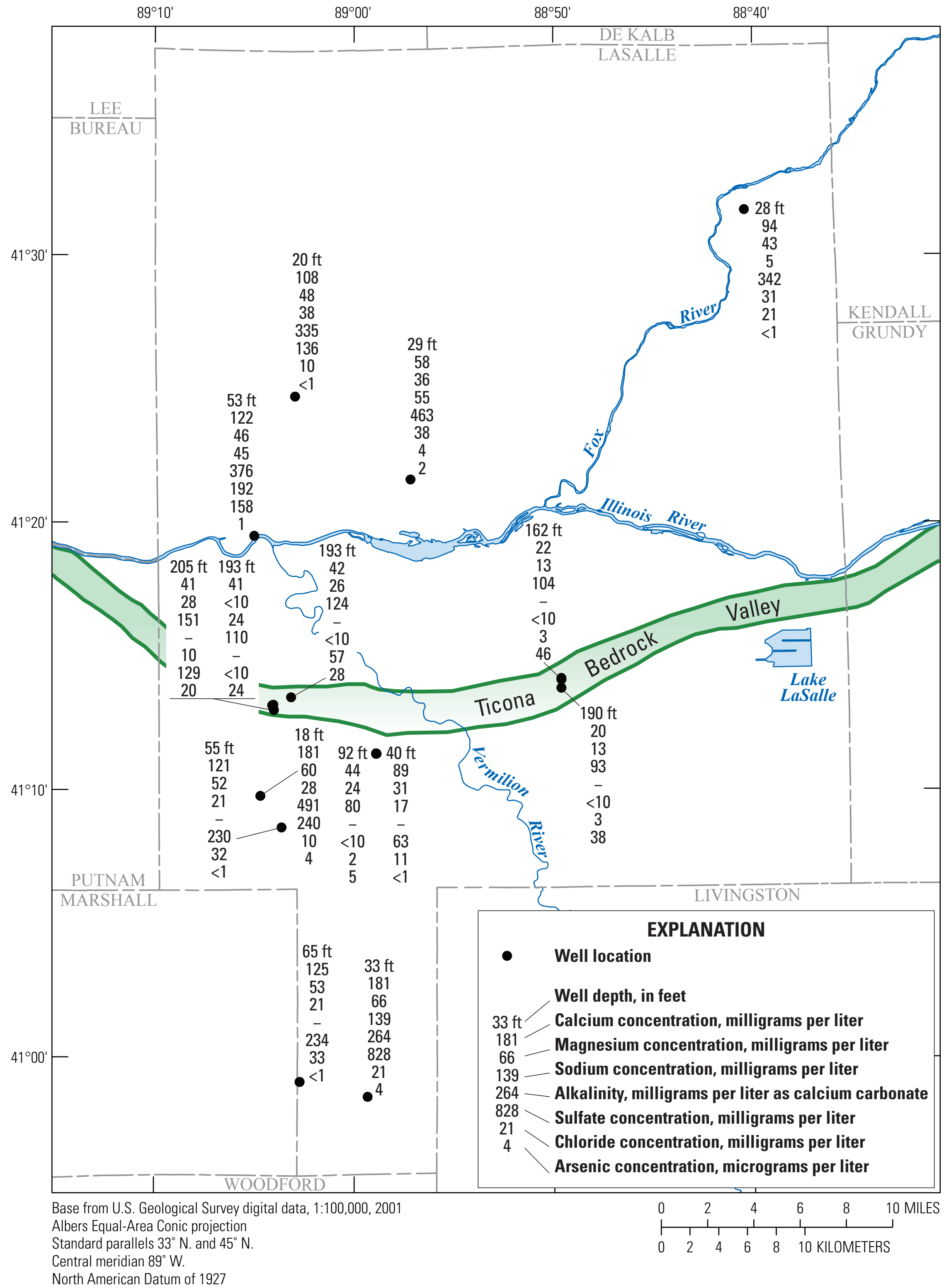

Figure 19. Concentrations of selected constituents in wells open to unconsolidated deposits in LaSalle County, Illinois, from 1980 to 2010.

Table 12. Concentration of selected constituents in groundwater from bedrock aquifers in LaSalle County, Illinois.

[Data are from U.S. Geological Survey (2016c), Illinois Environmental Protection Agency (undated a), and Anthony Dulka (Illinois Environmental Protection Agency, written commun., 2016). mg/L, milligram per liter; $CaCO_3$, calcium carbonate; µg/L, microgram per liter; pCi/L, picocurie per liter; µS/cm, microsiemens per centimeter; CIAT, deethyl atrazine; na, not available; PCE, perchlorethene; <, less than]

Constituents and units	Maximum value	Minimum value	Median value	Number of samples/wells	Period of record (yyyy–yyyy)
Alkalinity (mg/L as calcium carbonate)	512	150	308	41/24	1917–2014
Ammonia as nitrogen (mg/L)	2.6	<0.01	0.59	78/30	1920–1987
Arsenic (µg/L)	8.0	0.03	<1	46/39	1980–2013
Barium (µg/L)	400	21	200	17/16	1980–2014
Boron (µg/L)	1,400	<0.050	300	53/21	1960–2014
Calcium (mg/L)	188	21	72	85/36	1917–2014
Chloride (mg/L)	1,450	<1	90	92/41	1917–2014
Chromium (µg/L)	8.0	<0.1	<5	44/37	1987–2014
Copper (µg/L)	152	<1	<5	34/27	1980–2014
Fluoride (mg/L)	2.9	0.1	0.6	69/37	1945–2014
Iron (mg/L)	6.0	<0.05	0.75	92/29	1917–2014
Magnesium (mg/L)	72	12	31	85/35	1917–2014
Manganese (µg/L)	100	<5	10	63/26	1922–2014
Mercury (µg/L)	0.10	<0.10	<0.10	43/41	1980–2014
Nitrate + nitrite as nitrogen (mg/L)	21	0.07	<0.10	80/32	1922–2014
Phosphorus as P (mg/L)	0.25	<0.01	<0.01	41/39	1987–2014
Radon-222 (pCi/L)	310	140	225	2/2	2007–2014
Radium-226 (pCi/L)	5.7	4.7	5.2	2/2	2007–2014
Sodium (mg/L)	801	3	85	85/35	1917–2014
Specific conductance (µS/cm)	1,620	405	845	30/27	1980–2014
Sulfate (mg/L)	806	3.5	49	87/44	1920–2014
Uranium (pCi/L)	0.091	0.024	0.057	2/2	2007–2014
Zinc (µg/L)	207	6.7	<50	44/41	1987–2014
Selected organic compounds:					
CIAT (µg/L)	<0.05	<0.05	<0.05	6/5	2001–2007
Volatile organic compounds (µg/L)	3.0 (PCE)	<1	<1	43/30	1980–2013

Selected Major Ions and Trace Elements

Analyses of major ions in groundwater from the bedrock aquifers in LaSalle County indicate that waters typically are calcium-bicarbonate rich, but that substantial (greater than 200-mg/L) concentrations of sodium and chloride are present in many of the wells in the vicinity of the Illinois River and extending through the southern part of the county (fig. 20). Chloride concentrations typically were lowest in recharge areas in the northern part of the county where the Pennsylvanian or Maquoketa Group deposits are thin or absent and the Prairie du Chien or Ancell Group deposits are at the bedrock surface. Substantial concentrations of sulfate also were present, especially in the southernmost part of the county where the SMCL for sulfate was exceeded in several wells.

Chloride concentrations typically were lower in wells open only to the Ancell or New Richmond aquifers than in wells open to the Ironton-Galesville aquifer at Mendota and Marseilles. At Mendota, chloride concentrations were 4 mg/L in the Ancell aquifer and 72 to 140 mg/L in wells open to the Ironton-Galesville aquifer, and at Marseilles, concentrations were 11 mg/L in the Ancell and New Richmond aquifers and 53 mg/L in the Ironton-Galesville aquifer. These data are consistent with data from a previous investigation indicating that the dissolved solids content of the Ancell and Ironton-Galesville aquifers generally increases with depth at any location in LaSalle County (Visocky and others, 1985).

In addition to water-quality data from finished wells, samples collected from abandoned wells or collected during drilling indicated that saline water was present in the

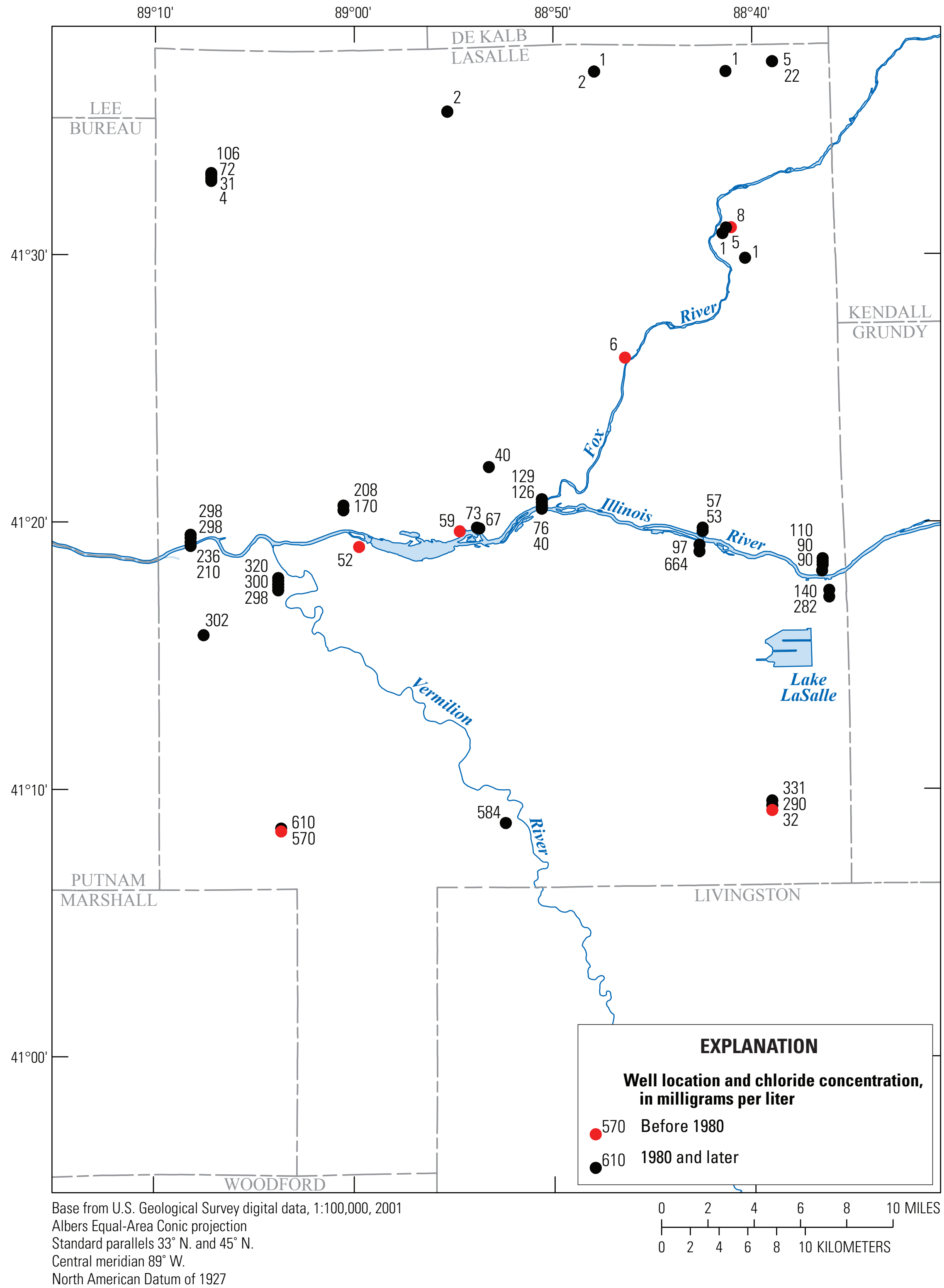

Figure 20. Concentration of chloride in wells open to the bedrock aquifers in LaSalle County, Illinois, from 1917 to 2014.

Pennsylvanian through Maquoketa Group deposits at Peru (Habermeyer, 1925), in the Pennsylvanian deposits at Ransom and Ottawa (Hanson, 1950), and perhaps in the Eau Claire Formation deposits at Ottawa (Hanson, 1950). Less saline groundwater also was present within the Cambrian-Ordovician aquifer system deposits at these locations.

The area of water with high chloride concentrations in the bedrock deposits, and particularly the Cambrian-Ordovician aquifer system, in southern LaSalle County is part of a larger area of groundwater with high chloride (greater than 150 mg/L) concentrations located in much of northern Illinois and associated with the northern part of the Pennsylvanian semiconfining unit (Buswell, 1940). This relation indicates that the downward flow of saline water from the semiconfining unit is affecting groundwater quality in the Cambrian-Ordovician aquifer system in LaSalle County. Although chloride concentrations in wells open to the Cambrian-Ordovician aquifer system in LaSalle County show no clear indications of increasing chloride concentrations through time, this rate of downward flow of saline water would be expected to increase as water levels in the aquifer system decrease in response to high-capacity pumping. Waters with chloride concentrations in excess of 150 mg/L are considered to be corrosive to pumps, necessitating more maintenance (Buswell, 1940).

Median iron concentrations in excess of 1 mg/L tended to be present in samples from wells throughout the county. Manganese concentrations exceeded the SMCL in only two samples. Concentrations of all trace elements, including arsenic, were below established MCLs (tables 6 and 11).

Radionuclides and Volatile Organic Compounds

Concentrations of combined radium-226 and radium-228 in samples collected from the bedrock aquifers exceeded the MCL of 5 pCi/L in at least one of the samples collected from numerous bedrock wells located in much of LaSalle County (fig. 21; table 4). These results are consistent with regional investigations that indicate radium naturally occurs at concentrations above its MCL in the Cambrian-Ordovician aquifer system in parts of northern Illinois (Gilkeson and others, 1983; Kay, 1999; U.S. Geological Survey, undated b). Radium concentrations are most likely to exceed the MCL where shale deposits of the Pennsylvanian System or the Maquoketa Group are present. However, radium concentrations may exceed the MCL where shale deposits are absent and may be below the MCL where they are present. Radon samples were collected by the USGS from two wells open to the bedrock deposits. Concentrations ranged from 140 to 310 pCi/L. The most stringent of the proposed MCLs for radon is 300 pCi/L (U.S. Environmental Protection Agency, 2012).

Samples from 38 wells open to bedrock aquifers in LaSalle County have been collected by the USGS or IEPA and analyzed for VOCs. Tetrachloroethene was detected at a concentration of 3 µg/L in one well open to the Prairie du Chien Group deposits in Leland in 1987. This compound was not detected during 18 subsequent sampling events in the well. Various VOCs commonly used as industrial solvents were detected during 2003 or 2014 in water-supply wells open to the Ancell aquifer south of Seneca, including vinyl chloride and carbon tetrachloride at concentrations above their MCLs. VOCs were not detected when these wells were re-sampled in 2015. Well-disinfectant byproducts (including chloroform, bromoform, and trichloromethane) were detected in several wells by the IEPA, but these detections are unlikely to be representative of conditions in the aquifer. VOC concentrations in all remaining samples were below their MCLs.

Agricultural-Related Constituents

A total of 49 water samples were collected during sampling events in 20 wells open to the bedrock aquifers and have been analyzed for the agricultural-related nutrients nitrogen (as nitrate and ammonia) and phosphorus (table 12). Concentrations of nitrate were below the MCL of 10 mg/L in all samples except for a well open to the Ancell aquifer in the North Utica area and a well open to the Prairie du Chien Group deposits east of Lake Holiday in the northeastern part of the county. Nitrate concentrations in samples collected in 1948 at Oglesby (Hanson, 1950) and from two wells east of Lake Holiday in the northeastern part of the county exceeded 9 mg/L. Ammonium was detected in almost all the samples, almost always at concentrations of less than 1 mg/L.

Bedrock wells in LaSalle County were sampled by the USGS at Ransom, Earlville, Leland, Peru, and North Utica and analyzed for insecticides and herbicides. Insecticide and herbicide compounds were not detected in these samples.

Analysis of water-quality data indicated that elevated concentrations of chloride were present in the central and southern parts of the county. The presence of elevated chloride generally corresponds to areas where the Pennsylvanian or Maquoketa semiconfining units are present, similar to elevated concentrations of radium (see “Radionuclides and Volatile Organic Compounds” section). Analysis of water-quality data also indicated that the upper bedrock aquifers can be susceptible to contamination from nitrate. Because these deposits have the capacity for additional water-supply development, water-quality issues should be considered prior to development.

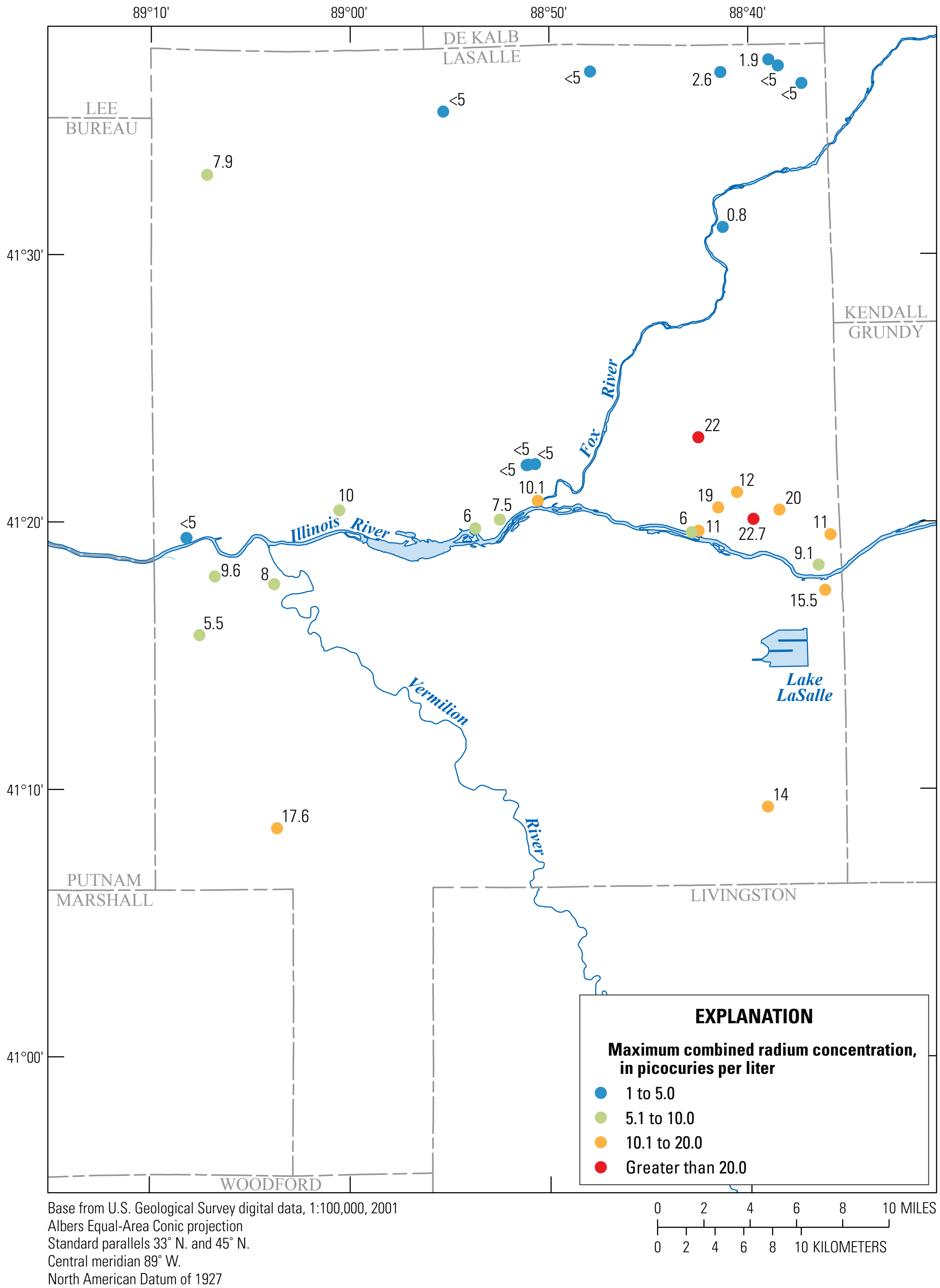

Figure 21. Combined concentration of radium-226 and radium-228 in bedrock wells in LaSalle County, Illinois.

Potential for Groundwater Contamination

Aquifers, particularly those within about 50 ft of land surface, are susceptible to contamination by a variety of anthropogenic compounds, including agricultural-related constituents and septic and industrial wastes applied at or near the land surface (Kolpin and others, 1993, 1994; Keefer, 1995; Mills and McMillan, 2004). The susceptibility of an aquifer to contamination increases where overlying low permeability materials are thin (thickness less than about 50 ft) or absent. Other lithologic and hydrologic factors that can enhance the leaching potential of soils and, thus, susceptibility of groundwater to contamination include well-drained to excessively drained soils (as classified by the U.S. Department of Agriculture [1993]), available water capacity of soil layers (amount of water that a soil can store that is available for use by plants), absence of a fragic horizon (dense soils that greatly restrict flow of water), soils with slopes less than about 15 percent, and soils with comparatively thick profiles (that may contain crop-related macropores; Keefer, 1995). For some contaminants, such as organic compounds, the amount of organic carbon in the overlying material also affects the susceptibility of an aquifer to contamination (Keefer, 1995). The susceptibility of shallow glacial drift aquifers and the uppermost bedrock aquifers (Galena-Platteville, Ancell, and New Richmond, depending on which deposits are at the bedrock surface) to groundwater contamination has been determined in LaSalle County on the basis of these hydrologic and lithologic factors. It is generally preferable to avoid putting shallow water-supply wells in areas that are highly susceptible to contamination, particularly if contaminant sources (landfills or areas of pesticide application) are located nearby.

Four State-scale susceptibility maps have been prepared by the ISGS (Berg and others, 1984; Keefer and others, 1990; Keefer, 1995) and include a detailed description of the susceptibility categories. Areas of the county that are susceptible to groundwater contamination are depicted in State-wide maps showing the potential for aquifer recharge (Keefer and others, 1990), aquifer sensitivity to contamination by nitrate leaching (Keefer, 1995), aquifer sensitivity to contamination by pesticide leaching (Keefer, 1995), and the potential for contamination of shallow aquifers from land burial of municipal wastes (Berg and others, 1984). These maps indicate that the aquifers are most susceptible to contamination in the vicinity of the Illinois, Fox, and Little Vermilion Rivers (fig. 22). In these areas, glacial drift aquifers tend to be within about 20 ft of land surface (Keefer, 1995) or the unconsolidated deposits are less than 50 ft thick (fig. 1–12). The potential for aquifer contamination is most limited at scattered locations throughout the county but particularly in the eastern part of the county where thick (up to 200 ft) sequences of low permeability till or Pennsylvanian shale are present.

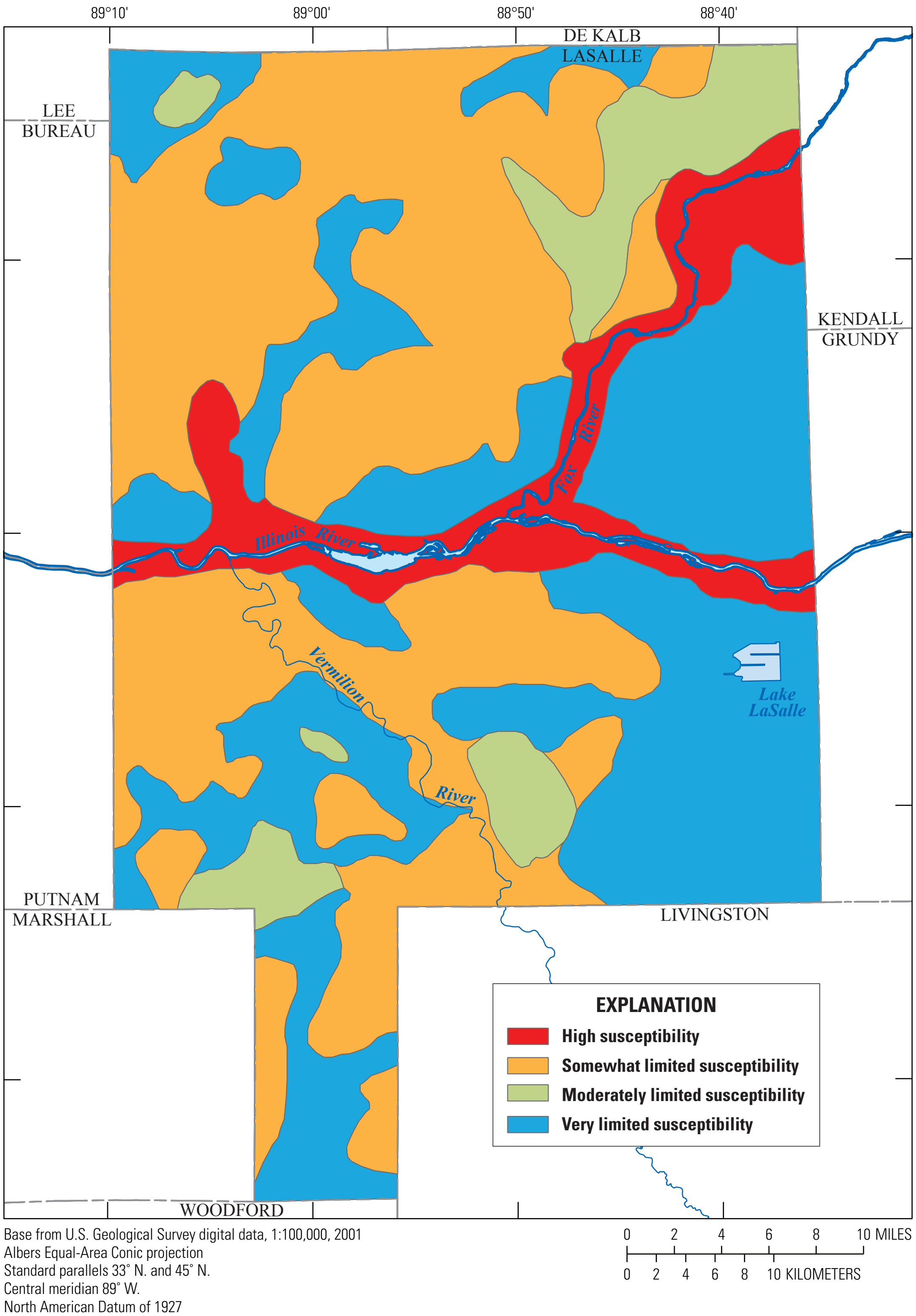

Figure 22. Susceptibility of aquifers to contamination from near-surface sources in LaSalle County, Illinois; modified from Keefer (1995).

Summary and Conclusions

Increased water use to meet the needs of an expanding population as well as the needs of growing commercial, industrial, irrigation, and mining operations in LaSalle County has the potential to result in the overutilization of the water resources in parts of the county, particularly the groundwater resources. Data on surface- and groundwater hydrology and water quality in LaSalle County were assessed by the U.S. Geological Survey, in cooperation with the LaSalle County Board and Northwestern University, to help determine the long-term sustainability of the water resource.

Total groundwater withdrawals in LaSalle County increased from about 14 million gallons per day in 1960 to about 20 million gallons per day for most of the period from 1978 through 2005 before decreasing to about 15 million gallons per day in 2010 and at least 12.5 million gallons per day in 2011. Population growth is expected to result in a daily increase in water use of at least 2.4 million gallons by the year 2030. Future mining operations in parts of the county also have the potential to increase withdrawals from groundwater.

The primary surface-water bodies in LaSalle County are the Vermilion, Little Vermilion, Fox, and Illinois Rivers. Surface-water quality appears to be affected by application of agricultural chemicals and road salt as well as the disposal of treated wastewater.

The geology of LaSalle County consists of unconsolidated units of the Quaternary System and the underlying bedrock units of the Cambrian, Ordovician, Silurian, and Pennsylvanian Systems. Glacial drift aquifers of sufficient thickness and permeability to support public supply may be present in the Troy and Ticona Bedrock Valleys as well as near the Illinois River at LaSalle. The unconsolidated deposits can contain elevated concentrations of naturally occurring arsenic in parts of the county.

The Pennsylvanian deposits are used for residential and public supply by a few wells but function as a semiconfining unit as a whole. Water in the Pennsylvanian deposits can be saline, which can affect the ability to use the Pennsylvanian deposits and can impact water quality in adjacent deposits.

The Cambrian-Ordovician aquifer system is used for water supply by a number of municipalities in LaSalle County. Water from the sandstone units of the Cambrian-Ordovician aquifer system has elevated concentrations of radium in areas where the aquifer system is overlain by Pennsylvanian or Maquoketa Group shale deposits. Water from the aquifer system also has elevated concentrations of chloride where overlain by Pennsylvanian shale deposits.

The potentiometric surface of the Cambrian-Ordovician aquifer system has declined by as much as 120 feet at Mendota, by as much as 300 feet at Peru, and by as much as 170 feet at Ottawa since about 1890. These declines are attributed to pumping near these wells as well as from the aquifer system throughout northeastern Illinois.

The Lombard Dolomite and Proviso Siltstone Members of the Eau Claire Formation form the lower semiconfining unit. This semiconfining unit overlies the Mount Simon aquifer. The Mount Simon aquifer is not used for water supply in LaSalle County because of its depth and the salinity of the water it yields. The aquifer is used for the storage of natural gas in the county at the Troy Grove Dome and the Ancona Anticline.

Assessment of the water resources of LaSalle County would be improved by the timely collection of accurate water-use data. The utility of this information would be enhanced by the collection of real-time, continuous water-level and specific-conductance data in areas of interest so that the effects of water use can be quickly identified and mitigated (if necessary). To the extent practical, multiple-well, constant discharge aquifer tests should be performed at the proposed locations of future high-capacity groundwater extraction. The aquifer properties identified from these tests should be used to calculate the impacts of realistic pumping scenarios (pumping rate, pumping volume, and pumping duration) at the wells on water levels in the surrounding aquifer. The data compiled, and suggested for future collection, should be used to develop and periodically update a model of the groundwater system to allow a quantitative depiction of the effects of future water-use scenarios on the water resources of LaSalle County.

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Glossary

A

alluvial Pertaining to or composed of alluvium, or deposited by a stream or running water.

anticline A fold that is convex (downward curving) and has its oldest beds at its core.

anticlinorium A system of anticline folds.

aquifer test A test to determine hydraulic properties of the aquifer involving the withdrawal of measured quantities of water from or addition of water to a well and the measurement of resulting changes in water level in the aquifer both during and after the period of discharge or additions.

aquifer A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield appreciable quantities of water to wells and springs.

argillaceous Rocks that contain clay minerals.

arkose Sandstone deposit containing notable quantities of the mineral feldspar.

axis With reference to folds, such as anticlines and synclines, an imaginary plane that intersects the crest or trough of a fold.

B

bedrock The solid rock that lies below soil and other loose surface materials.

C

Cambrian system Period of geologic time extending from about 542 to 488 million years before the present.

cap rock A layer of impervious rock overlying a deposit of oil or gas, often sealing it in.

chert A rock type composed primarily of cryptocrystalline silica.

chlorophyll Molecule found in algae and plants that is critical in the process of photosynthesis.

clay Detrital particles less than 1/256 millimeter (mm) in size or an unconsolidated detrital sedimentary deposit composed primarily of particles less than 1/256 mm in size.

conformably Rock layers that were deposited in sequence without episodes of erosion between deposition of layers.

contaminant An undesirable substance that is not normally present naturally or that is present at concentrations higher than would occur due to natural processes.

D

Devonian system Period of geologic time extending from about 416 to 359 million years before the present.

dewater To remove sufficient water from part or all of a deposit so that the pore spaces in the deposit are not completely filled with water.

dip A measure of the angle between the flat horizon and the slope of a sedimentary layer, fault plane, metamorphic foliation, or other geologic structure.

discharge The volume of water that passes a given location within a given period of time.

disconformity A break in a sedimentary sequence not involving a difference in inclination between the strata.

dolomite Rock composed of calcium and magnesium carbonate.

dome An uplift that is circular or elliptical in map view, with beds dipping away in all directions from a central area.

domestic self-supply Water supplied by a well serving one household and used for household purposes.

drawdown The decline in water level at a point caused by the withdrawal of water from a hydrogeologic unit, typically by pumping.

drift All glacial and glaciofluvial deposits left after the retreat of glaciers and ice sheets.

drusy A cavity in a rock or mineral vein into which euhedral crystals of the minerals forming the rock or vein project.

E

end moraine Till deposited by a glacier at its edge.

evapotranspiration The combined loss of water from a given area by evaporation from the land and transpiration from plants.

F

fault A fracture in rock along which there has been an observable amount of displacement.

fluvial Of, relating to, or living in a stream or river.

formation Aggregation of related strata distinguishable from beds above and below and of mappable extent.

fracture Breakage in the rock not related to the crystalline structure of the minerals that compose the rock, often having a preferred orientation.

G

glauconitic Containing the mineral glauconite, a type of mica generally formed in place with the development of sea beds.

grabens An elongate bed of rock downdropped along roughly parallel faults.

granite A coarse-grained igneous rock consisting essentially of quartz (20 to 40 percent) and alkali feldspar.

granodiorite A coarse-grained igneous rock consisting of quartz (20 to 40 percent) calc-alkali feldspar, and various ferromagnesian minerals.

gravel Coarse-grained particles between 2 and 4 mm in size. Loosely used to denote unconsolidated detrital sedimentary deposits composed primarily of particles greater than 2 mm in size.

ground moraine Till deposited beneath a glacier and back from its edge or end.

groundwater Subsurface water that fills available openings in rock or soil materials to the extent they are considered saturated by water.

group The lithostratigraphic unit higher in rank above formation, consisting partly or entirely of two or more adjacent formations having prominent features in common.

H

hydraulic conductivity A proportionality constant relating hydraulic gradient to specific discharge, which for an isotropic medium and homogeneous fluid equals the volume of water at the prevailing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

hydraulic head The height above a datum plane (such as sea level) of the column of water that can be supported by the hydraulic pressure at a given point in a groundwater system. For a well, the hydraulic head is equal to the distance between the water level in the well and the datum plane.

hydroelectric power water use The use of water in the generation of electricity at plants where the turbine generators are driven by falling water.

hydrogeologic unit Any soil or rock unit that, by virtue of its hydraulic properties, has a distinct effect on the storage or movement of groundwater.

I

industrial water Water used for industrial purposes in such industries as steel, chemical, paper, and petroleum refining. Nationally, water for industrial uses comes mainly (80 percent) from self-supplied sources, such as a local wells or withdrawal points in a river, but some water comes from publicly supplied sources, such as a county or city water department.

irrigation The controlled application of water for agricultural purposes through anthropogenic systems to supply water requirements not satisfied by rainfall.

isopach map Illustration of variations in the thickness of a layer or stratum by use of contour lines of equal thickness of the unit or stratum in an area.

K

Kankakee torrent A catastrophic flood that occurred approximately 19,000 years ago, resulting from the breach of a large glacial lake in northeastern Illinois.

L

lacustrine Pertaining to lakes.

laminae Thin, discrete layers in rock.

leakage coefficient The rate of flow across a unit area of a semipervious layer into or out of an aquifer under one unit of *head* difference across the layer.

lens An irregular-shaped formation consisting of a porous, permeable sedimentary deposit surrounded by impermeable rock.

limestone Sedimentary rock composed primarily of calcium carbonate.

lithologic log Description of the geologic deposits encountered during drilling.

lithology The description of rocks on the basis of color, structure, mineral composition, and grain size; the physical character of a rock.

livestock water supply Water used to meet the needs of livestock for drinking and other needs.

M

major ions Cations and anions typically present at the highest concentrations in water, consisting primarily of calcium, magnesium, sodium, chloride, sulfate, and bicarbonate.

member Units of lesser rank in a heterogeneous formation that are lithologically distinct.

mica A mineral with a layered structure created by linked sheets of tetrahedra.

mining water supply Water used to dewater mining and quarry operations and used in the processing of mining products.

Mississippian System A period in time from 359 to 318 million years before present.

monitoring well A well that is used to obtain water quality samples or to measure groundwater levels.

monocline A step-like bend or fold in rock strata consisting of a zone of steeper dip within an otherwise horizontal or gently dipping sequence of deposits.

moraine A mound, ridge, or other distinct accumulation of glacial drift, predominantly till, deposited chiefly by direct action of glacial ice in a variety of topographic landforms that are independent of control by the surface on which the drift lies.

morainal ridge Long, narrow elevation of land composed of material deposited by ice after being transported, generally by a glacier.

O

oolite A spherical or subspherical rock particle that has grown around a nucleus.

Ordovician System Period of geologic time extending from about 488 to 443 million years before the present.

outcrop Visible exposure of a geologic deposit at the surface of the Earth.

P

Pennsylvanian System Period of geologic time extending from about 318 to 299 million years before the present.

permeability A measure of the relative ease with which a porous medium can transmit a fluid under a potential gradient and is a property of the medium alone.

physiography The study and classification of the surface features of the Earth on the basis of similarities in geologic structure and the history of geologic changes.

polychlorinated bipheynl A group of manmade chemicals that were widely used in electrical equipment, hydraulic fluids, lubricants, and plasticizers; banned for use in the United States in 1979 due to health concerns.

porosity The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium.

potential yield The maximum amount of groundwater that can be extracted from wells and well fields without resulting in water levels low enough to prevent efficient pumping or exceeding groundwater recharge rates in the area contributing water to the well.

potentiometric surface An imaginary surface representing the static head of groundwater and defined by the level to which water will rise in a tightly cased well.

Precambrian Period of geologic time extending prior to about 542 million years before present.

primary contact recreational use Water use that results in direct contact of water with skin, such as swimming or water skiing.

public supply System for the provision to the public of water for human consumption with at least 15 service connections or that regularly serves at least 25 individuals.

Q

quartz Mineral consisting of silicon dioxide.

Quaternary The latest period of geologic time represented in Illinois by accumulations of glacial (Pleistocene) and postglacial (Holocene) deposits that were deposited above the Pliocene series.

R

recharge The process of addition of water to the saturated zone or a well.

rhyolite Fine grained to glassy volcanic rocks.

S

sand Typically a silicate mineral between 1/16 and 2 mm in size or an unconsolidated detrital sedimentary deposit composed of particles between 1/16 and 2 mm in size.

sandstone Detrital sedimentary rocks composed primarily of silicate minerals that typically vary in size between 1/16 and 2 mm.

semiconfining unit A unit that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs but may serve as a storage unit for groundwater.

shale Detrital sedimentary rock composed primarily of particles less than 1/256 mm in size.

silt Particle between 1/256 and 1/16 mm in size or an unconsolidated detrital sedimentary deposit composed primarily of particles between 1/256 and 1/16 mm in size.

siltstone Detrital sedimentary rocks composed primarily of particles between 1/256 and 1/16 mm in size.

Silurian System Period of geologic time extending from about 443 to 416 million years before the present.

slug test A particular type of aquifer test where water is quickly added or removed from a groundwater well, and the change in hydraulic head is monitored through time, to determine the near-well aquifer characteristics.

solution opening A large cavity in a rock formed by chemical dissolution.

specific-capacity test The quantity of water a well can produce per unit of drawdown.

stage The water level in a surface-water body with respect to a chosen datum.

storage coefficient The volume of water an aquifer releases from storage per unit surface area of the aquifer per unit change in head.

stratigraphy The study, definition, and description of major and minor natural divisions of rocks, particularly the study of their form, arrangement, geographic distribution, chronologic succession, classification, correlation, and mutual relationships of rock strata.

streamgage An active, continuously functioning measuring device in the field for which a mean daily streamflow is computed or estimated and quality assured for at least 355 days of a water year or a complete set of unit values are computed or estimated and quality assured for at least 355 days of a water year; also known as a gage or streamgaging station.

surface water Natural water that has not penetrated below the ground surface, such as a river, lake, pond, or reservoir.

syncline A downward fold in stratified rocks from whose central axis the beds rise upward and outward with the youngest beds at its core.

T

thermoelectric power supply Water used in the generation of thermoelectric power, typically for cooling.

till Unsorted, unstratified material deposited beneath glacial ice or deposited from melting glacial ice.

trace element A chemical element present in minute quantities.

transmissivity The rate at which water of the prevailing kinematic viscosity is transmitted through the unit width of the aquifer under a unit hydraulic gradient. It is equal to an integration of the hydraulic conductivities across the saturated part of the aquifer perpendicular to the flow paths.

turbidity The amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter. Thus, turbidity makes the water cloudy or even opaque in extreme cases.

U

unconfined aquifer An aquifer that has a water table.

unconformably Feature of strata that do not succeed the underlying rocks in immediate order of age or in parallel position. A general term applied to any strata deposited directly upon older rocks after an interruption in sedimentation, with or without any deformation or erosion of the older rocks.

unconsolidated deposit Geologic material that has not been lithified.

W

watershed an area or ridge of land that separates waters flowing to different rivers, basins, or seas.

water year The 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year beginning October 1, 1977, and ending September 30, 1978, is referred to as water year 1978.

well An artificial excavation used to access underground water, oil, gas, or brine.

Y

yield Volume of water supplied to a receptor per unit time.

Appendix 1. Assessment of Geologic Deposits, LaSalle County, Illinois

The geologic deposits in LaSalle County are divided into bedrock and Quaternary-aged deposits.

Bedrock Deposits

Precambrian rocks beneath northern Illinois are composed primarily of *granite, granodiorite*, and *rhyolite* (Willman and others, 1975; McBride and others, 2010). The altitude of the top of the Precambrian rocks beneath LaSalle County is less than –4,000 ft[1] at the southeastern and southwestern parts of LaSalle County and is greater than –3,000 ft in the northern part of the county (Beck, 1965; Buschbach and Kolata, 1991; Kolata and others, 2005; McBride and others, 2010).

The Mount Simon *Sandstone unconformably* overlies the Precambrian rocks (figs. 6 and 9). The Mount Simon Sandstone is present throughout Illinois and consists predominately of fine- to coarse-grained *quartz* sandstone (Willman and others, 1975; Visocky and others, 1985). As much as 350 ft of the bottom of the unit is *arkosic* and discontinuous. *Micaceous shale* beds up to 15 ft thick are present in the upper 300 ft and lower 600 ft of the unit. The thickness of the Mount Simon Sandstone increases from about 2,000 ft beneath the western part of LaSalle County to about 2,500 ft beneath the eastern part (Visocky and others, 1985). The sandstone has a *porosity* ranging from 15 to 18 percent near Troy Grove (Bell, 1961) and 12 percent at the Ancona Anticline (Buschbach and Bond, 1967). The altitude of the top of the Mount Simon Sandstone (fig. 1–1) decreases from about –500 ft NAVD 88 in the northeastern part of LaSalle County near the Sandwich Fault Zone to less than –2,800 ft NAVD 88 in the southwestern part of the county along the western flank of the Peru Monocline, with localized high points near the top of the Troy Grove Dome and along the crest of the Ancona Anticline (Roy, 2008).

The Eau Claire *Formation conformably* overlies the Mount Simon Sandstone (fig. 9; Willman and others, 1975). The Eau Claire Formation is divided into three *members*, from oldest to youngest: the Elmhurst Sandstone, the Lombard *Dolomite*, and the Proviso *Siltstone*. The Elmhurst Sandstone consists of fine- to medium-grained fossiliferous sandstone with interbedded grey shale. The Lombard Dolomite consists of *glauconitic*, sandy dolomite with interbedded, greenish-gray shale in most of northeastern Illinois. The Proviso Siltstone consists of sandy, dolomitic siltstone with pink or red shale in most of northeastern Illinois. The Eau Claire Formation is described as predominately dolomitic, fine- to medium-grained grey sandstone, containing beds of siltstone and dolomite in the northwestern part of LaSalle County and predominately dolomitic siltstone and shale in the remainder of the county (Willman and others, 1975; Visocky and others, 1985). The thickness of the individual members of the Eau Claire Formation typically is not described on the lithologic logs for LaSalle County, but their combined thickness typically is about 400 to 500 ft (Willman and others, 1975). A few lithologic logs near the Ancona Anticline describe the Elmhurst Sandstone (fig. 9) as being about 40 to 60 ft thick, indicating that the Lombard Dolomite and Proviso Siltstone deposits are about 350 to 450 ft thick. The altitude of the top of the Eau Clare Formation is estimated to decrease from about 0 ft NAVD 88 in the northeastern part of LaSalle County to less than –2,000 ft NAVD 88 on the western flank of the Peru Monocline, with localized high points at the Troy Grove Dome and along the crest of the Ancona Anticline.

The Eau Claire Formation is conformably overlain by the Galesville Sandstone, a white, fine-grained, well-sorted, slightly dolomitic sandstone composed primarily of well-rounded quartz grains (Willman and others, 1975: Visocky and others, 1985). The average porosity of the Galesville sandstone at the Ancona Anticline is 22 percent (Emrich, 1966). The Galesville Sandstone is overlain by the Ironton Sandstone, a medium- to coarse-grained, partly dolomitic, moderately to poorly sorted sandstone. From top to bottom, the Ironton Sandstone is subdivided into the Mooseheart, Marywood, Fox Valley, and Buelter Members. The Mooseheart Member consists of dolomitic and glauconitic, coarse-grained, poorly sorted sandstone. The Marywood Member consists of sandstone that is less dolomitic and finer grained than the Mooseheart and Fox Valley Members. The Fox Valley Member consists of dolomitic, poorly sorted, medium- to coarse-grained sandstone with beds of sandy dolomite. The Buelter Member consists of medium-grained, moderately to poorly sorted sandstone with small amounts of dolomite. The Ironton and Galesville sandstones (hereafter referred to as the Ironton-Galesville Sandstone) is about 160 to 200 ft thick in much of the northeastern and central parts of the county and is about 200 to 225 ft thick beneath the most of the remainder of the county (fig. 1–2). The altitude of the top of the sandstone ranges from about 200 ft NAVD 88 beneath the northeastern edge of the county to more than –1,900 ft NAVD 88 along the western flank of the Peru Monocline, with localized high points along the crest of the Ancona Anticline and the top of the Troy Grove Dome.

The Ironton Sandstone is conformably overlain by the Franconia Formation (fig. 9). In northern Illinois, the Franconia Formation is composed of fine-grained, *argillaceous*, silty, glauconitic sandstone and dolomite with variable amounts of shale (Willman and others, 1975; Visocky and others, 1985). The altitude of the top of the Franconia Formation exceeds

[1]Negative values for altitude denote feet below the North American Vertical Datum of 1988 (NAVD 88).

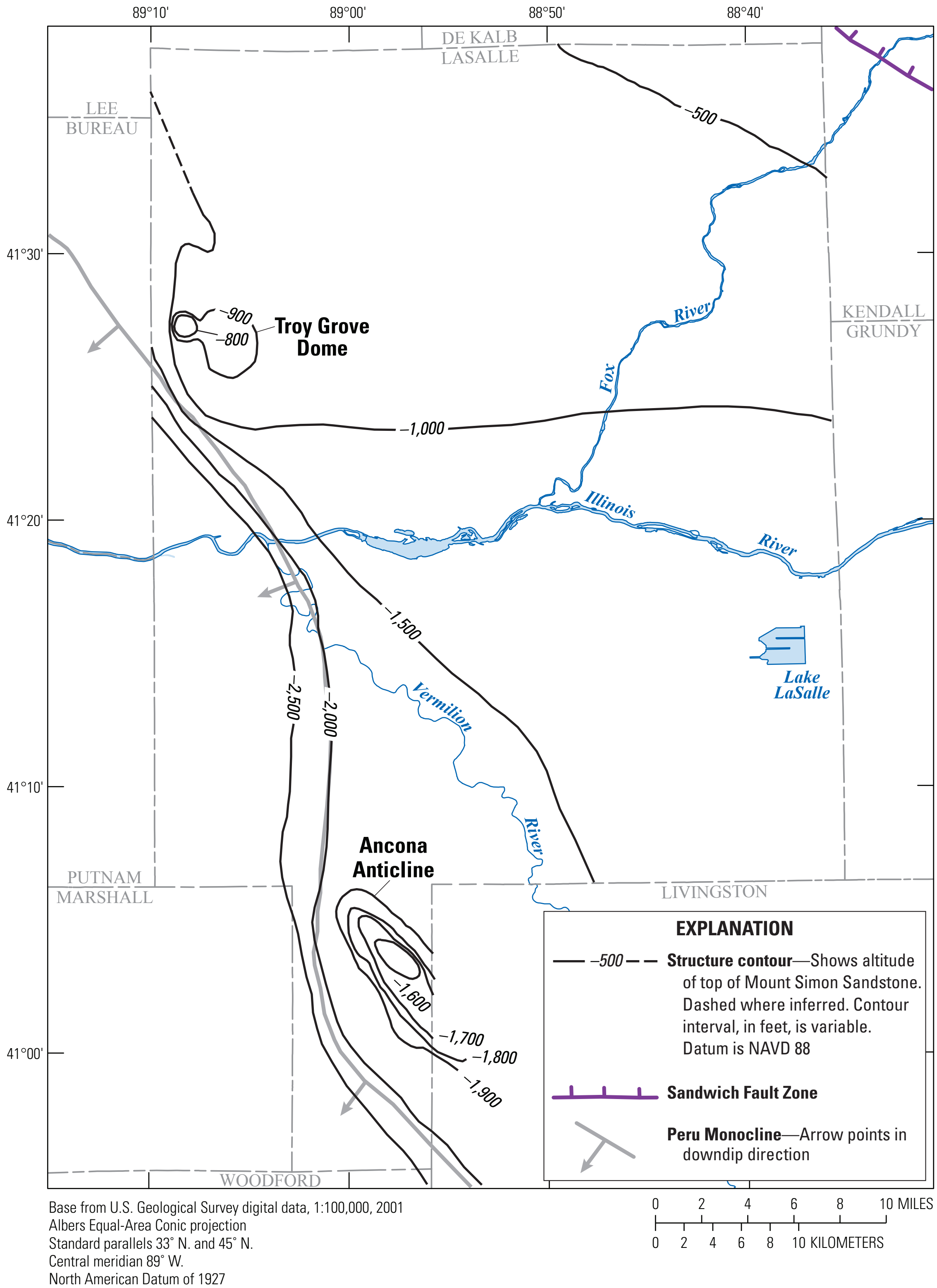

Figure 1–1. Altitude at the top of the Mount Simon Sandstone in LaSalle County, Illinois.

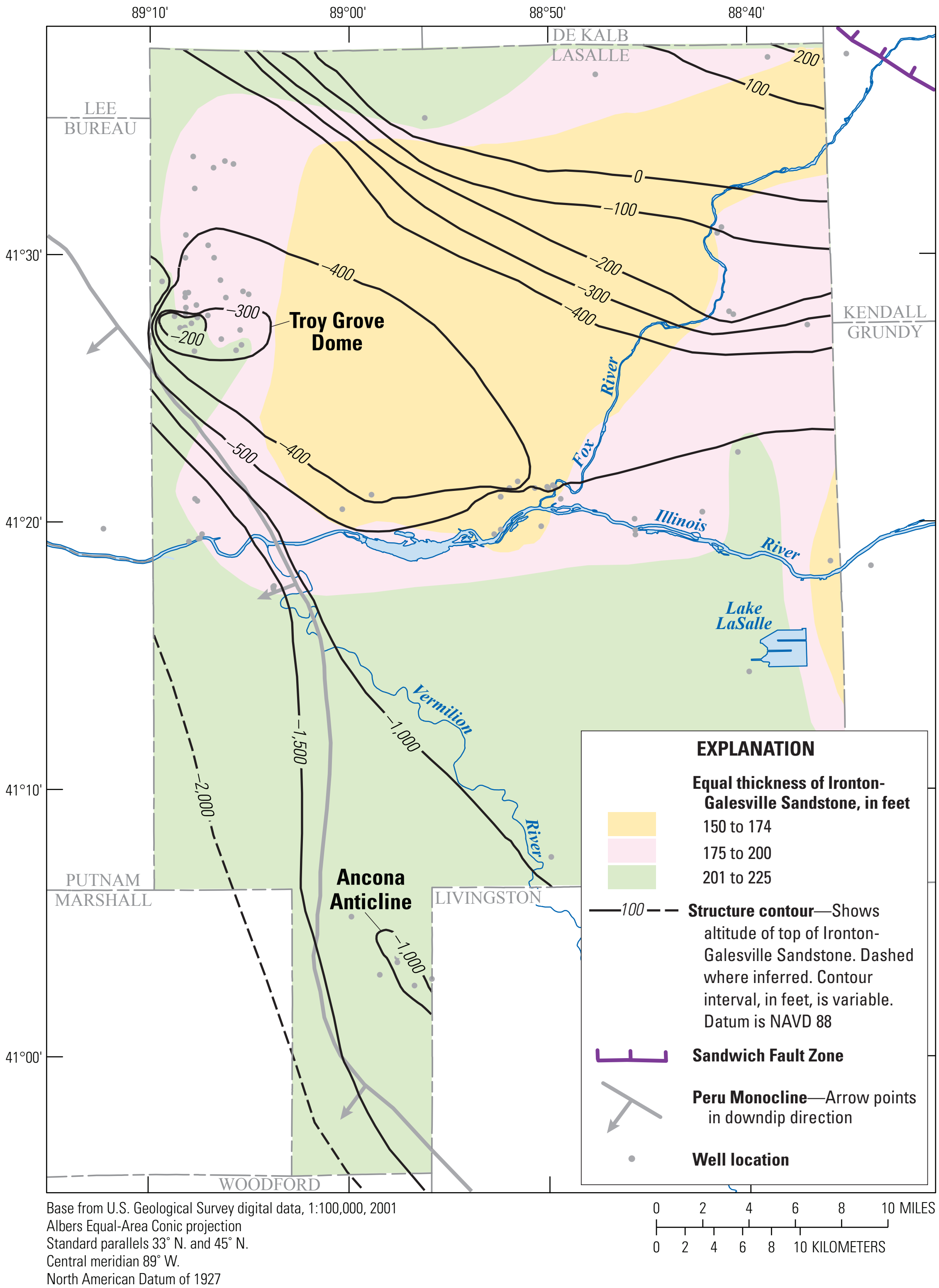

Figure 1–2. Altitude at the top and thickness of the Ironton-Galesville Sandstone in LaSalle County, Illinois.

100 ft NAVD 88 in the northern part of the county and is less than –1,500 ft NAVD 88 on the western flank of the Peru Monocline. The altitude of the top of the Franconia Formation exceeds 0 ft NAVD 88 at the top of the Troy Grove Dome and is about –700 ft NAVD 88 along the crest of the Ancona Anticline. The Franconia Formation increases in thickness from about 110 to 125 ft in the northern part of the county to about 200 ft in the southern tip.

The Franconia Formation is conformably overlain by a Formation referred to by the ISGS as the Potosi Dolomite (fig. 9). The Potosi Dolomite is composed of finely crystalline, slightly argillaceous, pinkish-gray to brown dolomite (Willman and others, 1975: Visocky and others, 1985). The deposit is characterized by *drusy* quartz covering the surfaces of small cavities in the dolomite. Glauconite is present at the top and the base of this unit. The Potosi Dolomite is described at only a few boreholes in LaSalle County but is estimated to range from about 150 ft thick beneath the northern boundary of the county to about 200 ft thick at its southern tip (Willman and others, 1975).

The Potosi Dolomite is conformably overlain by the Eminence Formation (fig. 9), which is composed of light gray, brown, or pink, sandy, fine- to medium-grained dolomite. *Oolitic chert* and thin sandstone beds also may be present. The Eminence Formation is described at only a few boreholes in LaSalle County but is estimated to be about 50 ft thick beneath the northern part of the county and nearly 100 ft thick beneath the southern part (Willman and others, 1975). Undifferentiated deposits of Cambrian age are present at the bedrock surface in parts of the northern edge of the county (fig. 11).

The Eminence Formation is overlain *disconformably* by the Prairie du Chien *Group* (fig. 9), which is composed of cherty dolomite with interbedded sandstones. Deposits of the Prairie du Chien Group have been removed by erosion in areas within the far northern part of the county (fig. 11) and *outcrop* along the Fox River in the northeastern part of the county near Sheridan (Willman and others, 1942; Frankie and others, 1995; East and others, 2006; Nelson and others, 1997) and are at the bedrock surface in much of the northern part of LaSalle County and at isolated locations in the western part of the county near the crest of the Peru Monocline (Willman and others, 1967; Kolata and others, 2005). The thickness of these deposits is variable because of erosion where they are at the bedrock surface in the northern part of the county and because of erosion during the Ordovician Period throughout northern Illinois. Where overlain by younger bedrock, deposits of the Prairie du Chien Group range from about 300 ft thick beneath the northern part of the county to almost 600 ft thick beneath the southern tip of the county (Willman and others, 1975). The altitude of the top of the deposits of the Prairie du Chien Group exceeds 500 ft NAVD 88 in the northern part of the county where these deposits are at the bedrock surface and at the peak of the Troy Grove Dome; is between 500 and 0 ft NAVD 88 in most of the center of the county; is about 100 ft NAVD 88 along the crest of the Ancona Anticline; and is less than –1,000 ft NAVD 88 along the flank of the Peru Monocline.

The Prairie du Chien Group is subdivided into four formations. From oldest to youngest, these formations are the Gunter Sandstone, Oneota Dolomite, New Richmond Sandstone, and Shakopee Dolomite (fig. 9). The Gunter Sandstone is composed of medium- to fine-grained, poorly sorted sandstone. The Gunter Sandstone was identified in wells at Peru, North Utica, and Seneca, where it is described as being 14 to 25 ft thick (Willman and others, 1975). The Oneota Dolomite is composed of coarse-grained, light gray and pink dolomite with some sand and oolitic chert nodules. The altitude of the top of the Oneota Dolomite in LaSalle County is not defined south of the Illinois River due to a paucity of logs describing this deposit, but the altitude of the top of the Formation exceeds 450 ft NAVD 88 in the northern part of the county, is less than –50 ft NAVD 88 in the vicinity of Seneca, and is less than –1,000 ft NAVD 88 along the flank of the Peru Monocline. The Oneota Dolomite is between about 150 and 200 ft thick beneath much of the county, but typically is greater than 200 ft in the center of the county.

The New Richmond Sandstone is composed of moderately sorted, medium-grained sandstone with interbedded sandy dolomite. It has been removed by erosion in areas beneath the far northern part of the county and possibly in a small area in Mendota. Where present, the thickness of the New Richmond Sandstone exceeds 100 ft along a several mile long band from the northeastern to the southwestern part of the county, with thickness decreasing to the east and west (fig. 1–3). Where present, the altitude of the New Richmond Sandstone exceeds 500 ft NAVD 88 in the northern part of the county, is less than 0 ft NAVD 88 in the Seneca area, and is less than –1,000 ft NAVD 88 along the flank of the Peru Monocline (fig. 1–4). These deposits are not described at the Ancona Anticline or the Troy Grove Dome.

The Shakopee Dolomite is composed of fine-grained, sandy dolomite with oolitic chert and thin beds of sandstone and shale. It underlies most of LaSalle County, but has been removed by erosion in areas within the northern part of the county and is partly eroded in several small areas near the crest of the Peru Monocline from North Utica to the Troy Grove Dome (Willman and others, 1942, 1975). The Shakopee Dolomite, where present, is less than 100 ft thick north of a line from about Seneca to the northwestern corner of the county and is more than 200 ft thick south of a line from about Garfield to the intersection of the Illinois River and the western boundary of the county (Willman and others, 1975).

The Prairie du Chien Group is overlain unconformably by the St. Peter Sandstone and the Glenwood Formation of the Ancell Group (fig. 9). The Ancell Group is the surficial bedrock deposit in much of LaSalle County north of the Illinois River but has been removed by erosion in much of the northernmost part of the county (fig. 11). The Ancell Group is composed, by thickness, of about 80 percent of deposits of the St. Peter Sandstone.

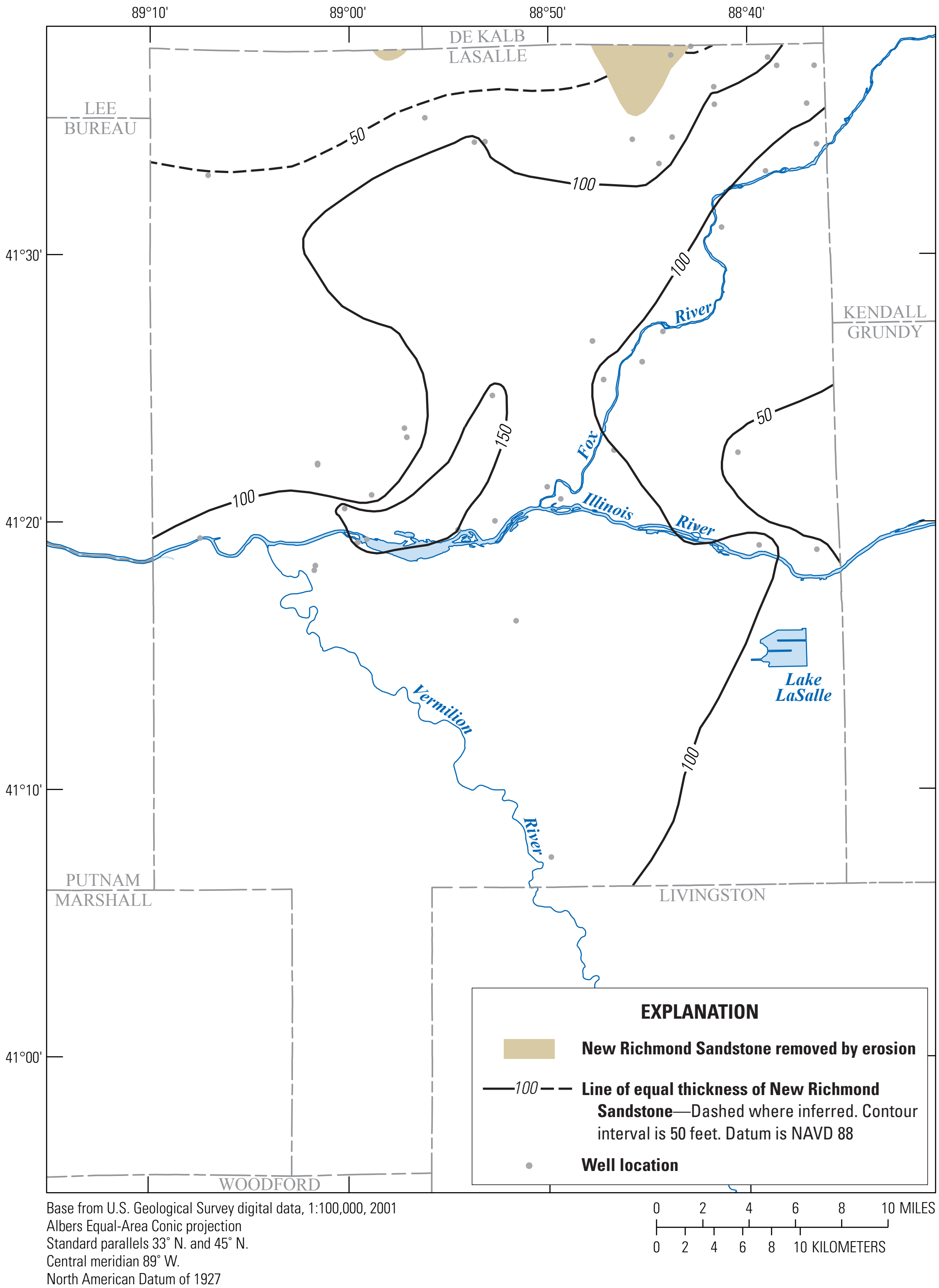

Figure 1–3. Thickness of the New Richmond Sandstone in LaSalle County, Illinois.

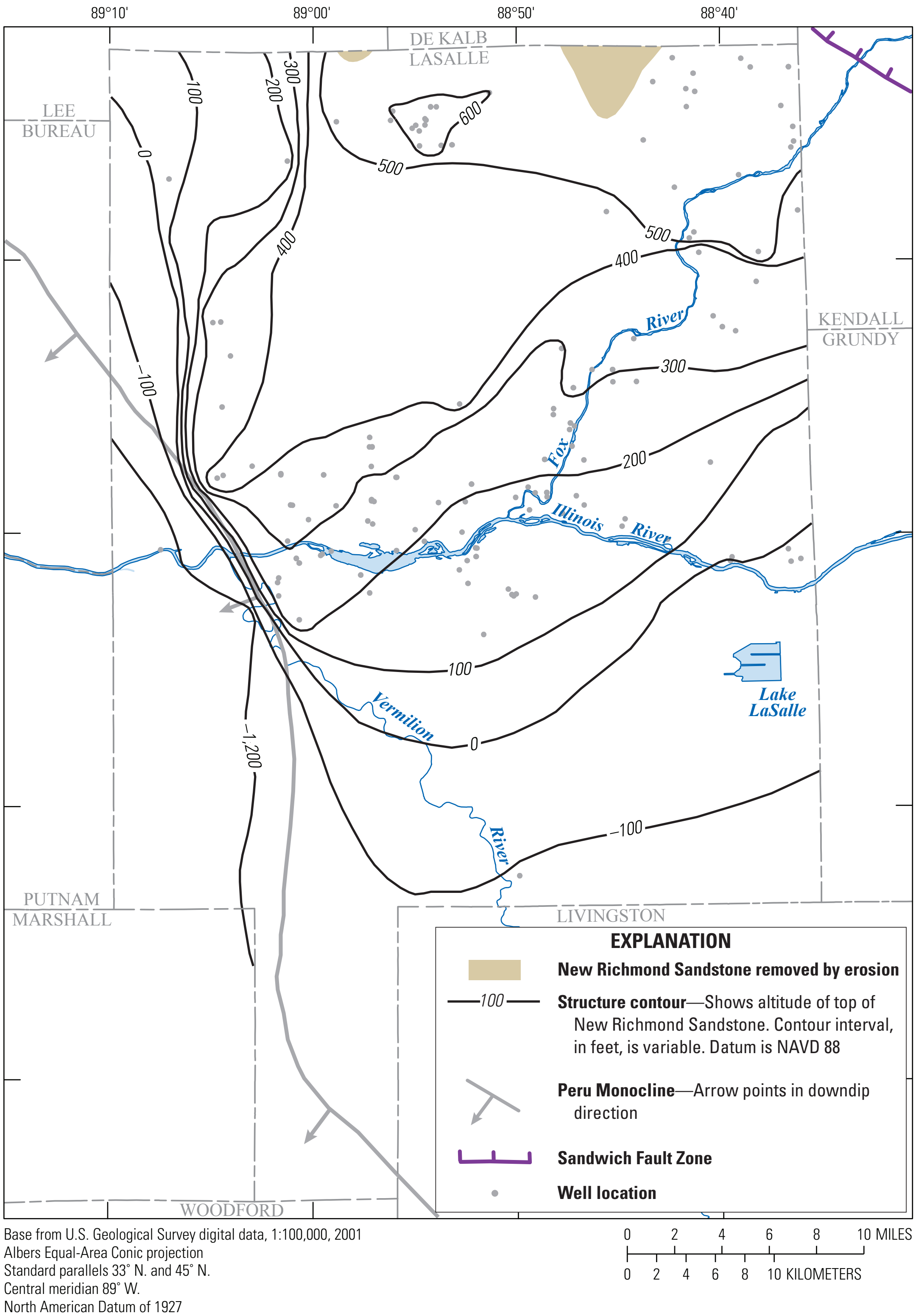

Figure 1–4. Altitude at the top of the New Richmond Sandstone in LaSalle County, Illinois.

The St. Peter Sandstone outcrops along the lower reaches of the Fox River and along the Illinois River from the confluence with the Fox River to just east of the confluence with the Vermilion River (Willman and Payne, 1943). The St. Peter Sandstone is extensively quarried in LaSalle County for use in glass manufacture and hydraulic fracturing.

The St. Peter Sandstone is composed of a lower unit, the Kress Member, which consists of chert conglomerate with beds of red and green shale and medium- to coarse-grained sandstone (Willman and others, 1975). The remainder of the St. Peter Sandstone is composed of well-rounded, well-sorted, medium- to coarse-grained sandstone of the Tonti and Starved Rock Members. The upper part of the St. Peter Sandstone is poorly consolidated in parts of the county, becoming more consolidated with depth.

The Glenwood Formation is composed of a mixture of dolomite, sandstone, and shale. The total porosity for the sandstones of the Ancell Group based on 20 samples from the Naplate area ranged from 7 to 32 percent with a geometric mean value of 20 percent (LandComp Corp., 1995; Andrews Environmental Engineering, 2006).

Where present, the deposits of the Ancell Group typically are between about 100 and 200 ft thick beneath LaSalle County (fig. 1–5). However, the deposits are less than 100 ft thick in the western part of the county near Troy Grove and North Utica and exceed 200 ft in the east-central and southern parts of the county. The variation in the thickness of the deposits of the Ancell Group is attributed to differential erosion of the top of the deposit where it is at the bedrock surface as well as conforming to the erosional surface of the underlying Prairie du Chien Group. The altitude of the top of the Ancell Group exceeds 500 ft NAVD 88 in most of the northern part of LaSalle County, decreasing to less than 0 ft NAVD 88 in the southeastern part of the county and to less than –1,000 ft NAVD 88 along the flank of the Peru Monocline (fig. 1–6). The altitude of the top of the deposits exceeds 600 ft on the southern part of Troy Grove Dome (where the deposits of the Ancell Group are at the bedrock surface) and is more than 200 ft NAVD 88 along the *axis* of the Ancona Anticline.

The Ancell Group is overlain by the Platteville and Galena Groups. The Galena and Platteville Groups are similar lithologically and commonly are referred to as the Galena-Platteville Dolomite. The Galena-Platteville Dolomite is composed of pure to argillaceous dolomite with some *limestone* (Willman and others, 1975). The Galena-Platteville Dolomite has been removed by erosion in much of the northern and central parts of the county and has been partly eroded in much of the southeastern and northwestern parts of the county (figs. 1–7 and 1–8). The dolomite is at the bedrock surface in the northwestern part of the county near Mendota and in small areas between Grand Ridge and Oglesby (fig. 11). The Galena-Platteville Dolomite is less than 50 ft thick in most of the areas adjacent to where is has been removed by erosion but its thickness increases to more than 300 ft thick in the southeastern and southwestern parts of the county (fig. 16). The altitude of the top of the Galena-Platteville Dolomite exceeds 600 ft NAVD 88 at the northern part of the Troy Grove Dome, where it is at the bedrock surface, decreasing to less than 300 ft NAVD 88 in the southeastern part of the county and less than -600 ft NAVD 88 in the southwestern part of the county (fig. 1–8). The Galena-Platteville Dolomite also is present along the axis of the Ancona Anticline.

The Galena-Platteville Dolomite is overlain unconformably by the Maquoketa Group in the western part of LaSalle County (fig. 8). The Maquoketa Group is composed primarily of dolomitic shale and argillaceous dolomite and limestone (Willman and others, 1975). The basal unit of the group is the Scales Formation, a predominately dolomitic shale with interbedded dolomite. Overlying the Scales Formation is the Fort Atkinson Formation, which is composed primarily of pure to argillaceous dolomite and limestone with some interbedded shale. Overlying the Fort Atkinson Formation is the Brainard Formation, a dolomitic shale with some dolomite and limestone. The Maquoketa Group is present along the flank of the Peru Monocline (fig. 1–9) at an altitude of less than –500 ft NAVD 88 on the western flank to about 350 to 380 ft NAVD 88 on the eastern edge and surrounding the axis of the Ancona Anticline. The Maquoketa deposits have a typical thickness of about 170 ft in LaSalle County.

The Maquoketa Group is overlain unconformably by Silurian dolomites of the Alexandrian and Niagaran Series. The base of the Alexandrian Series is composed of argillaceous dolomite, and the remaining deposits in the series are composed of dolomite with varying amounts of shale and chert (Willman and others, 1975). The Silurian deposits have been removed by erosion beneath most of the county, but are more than 500 ft thick along the flank of the Peru Monocline (fig. 1–10). The altitude of the Silurian deposits is about 100 ft NAVD 88 along the eastern edge of the Peru Monocline and about –100 to –170 ft NAVD 88 along the western flank.

Approximately south of a line through Rutland and Dana (fig. 1), Middle Devonian limestone deposits are depicted as being present (Kolata and others, 2005). These deposits are estimated to be about 40 ft thick based on regional studies (Willman and others, 1975).

The uppermost bedrock deposits in most of central and southern LaSalle County consist of Pennsylvanian-aged deposits belonging to the Tradewater, Carbondale, Shelburn, Patoka, Bond, and Mattoon Formations (figs. 9 and 11; Willman and others, 1975; Kolata and others, 2005). Deposits of the Carbondale Formation are present at the bedrock surface beneath most of the southeastern part of the county and where the Pennsylvanian deposits are present in the north-central part of the county. Deposits of the Shelburn and Patoka Formations are present at the bedrock surface near Marseilles and Seneca and beneath much of the southern and western parts of the county. The Tradewater, Carbondale, and Shelburn and Patoka Formations underlie the Bond and Mattoon Formations along the western flank of the Peru Monocline where the Bond and Mattoon Formations are at the bedrock surface. Depending on the location within the county, the Pennsylvanian deposits unconformably overlie the Silurian, Maquoketa,

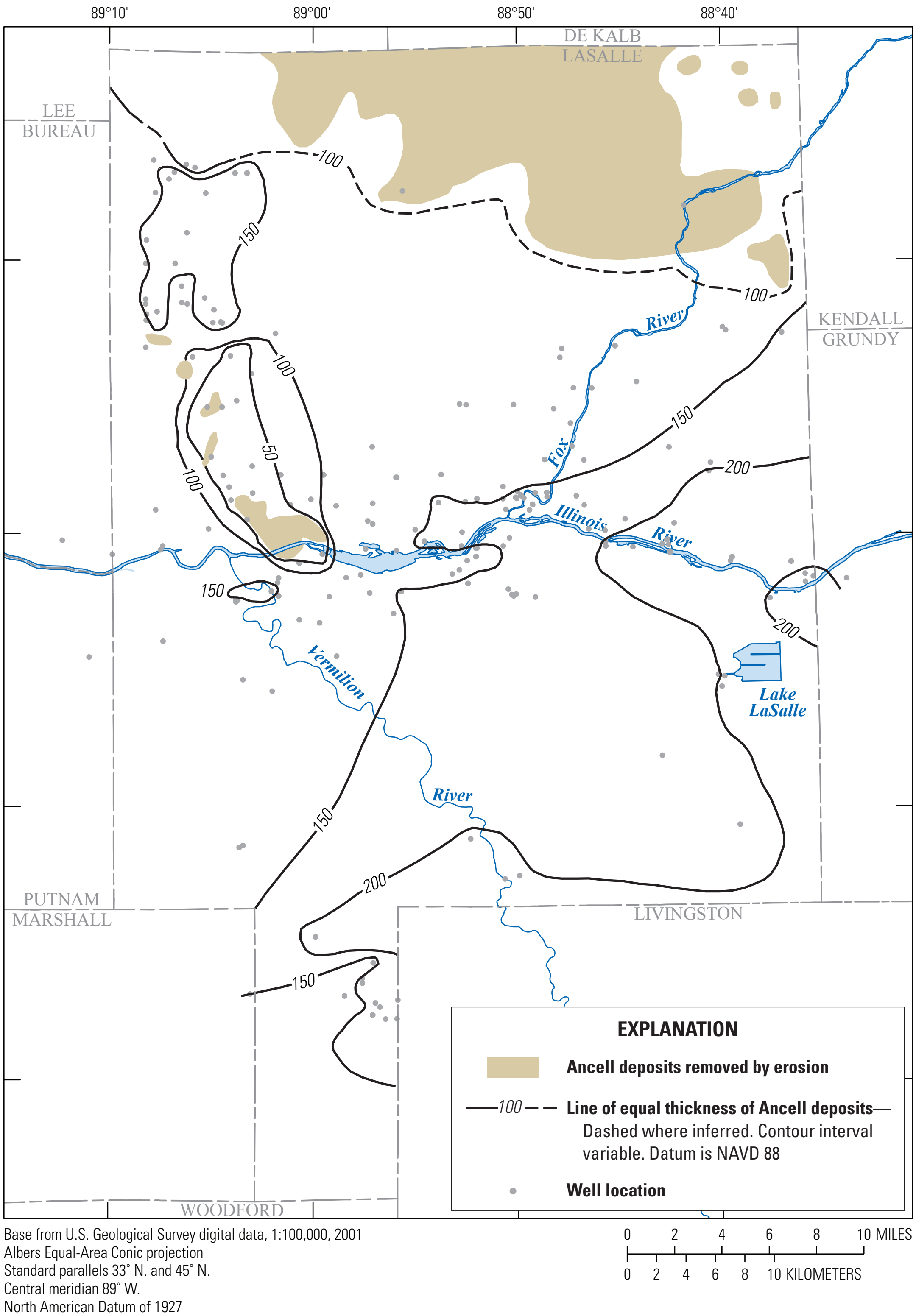

Figure 1–5. Thickness of the deposits of the Ancell Group in LaSalle County, Illinois.

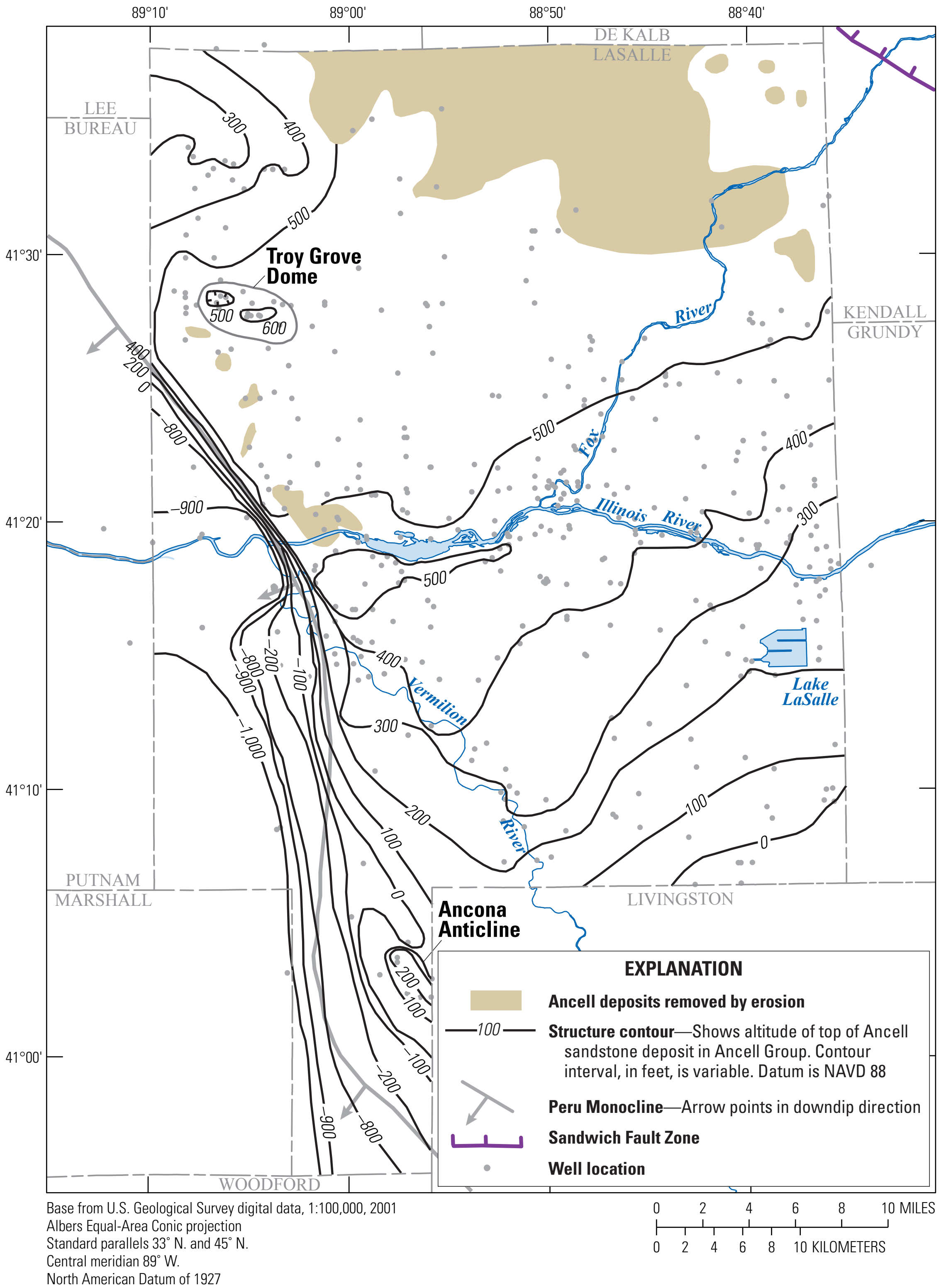

Figure 1–6. Altitude at the top of the sandstone deposit in the Ancell Group in LaSalle County, Illinois.

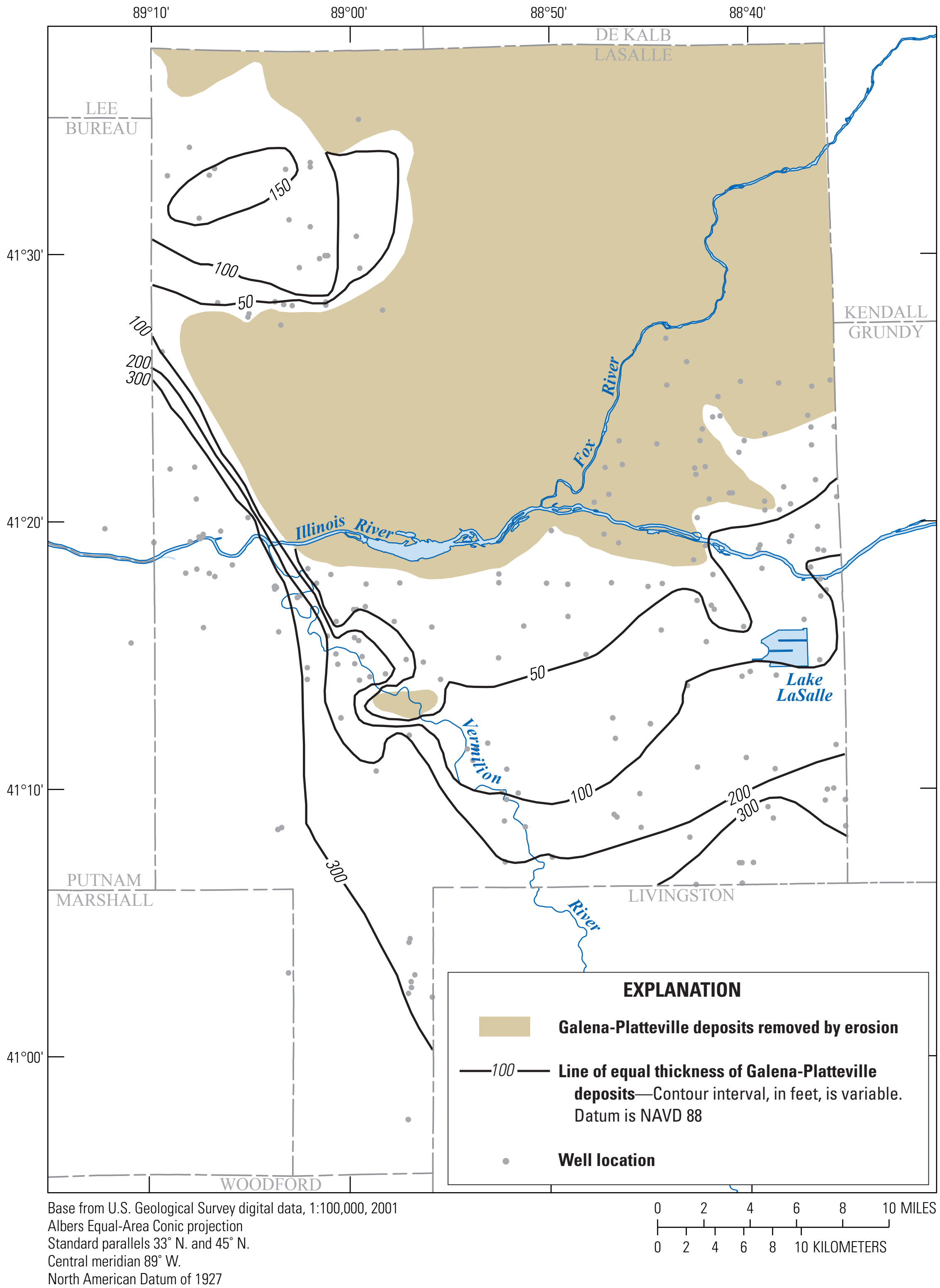

Figure 1–7. Thickness of the deposits of the Galena and Platteville Groups in LaSalle County, Illinois.

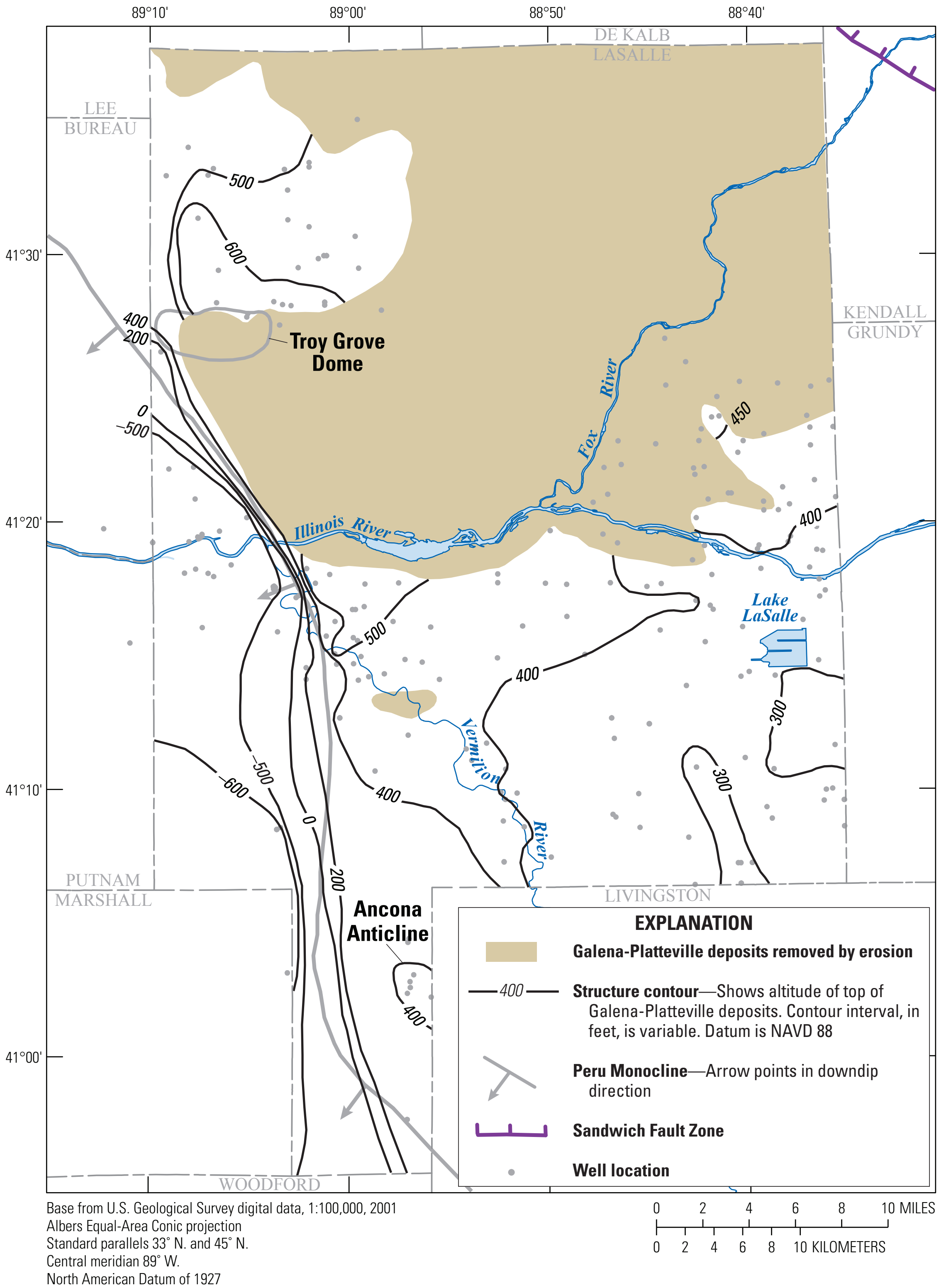

Figure 1–8. Altitude at the top of the deposits of the Galena and Platteville Groups in LaSalle County, Illinois.

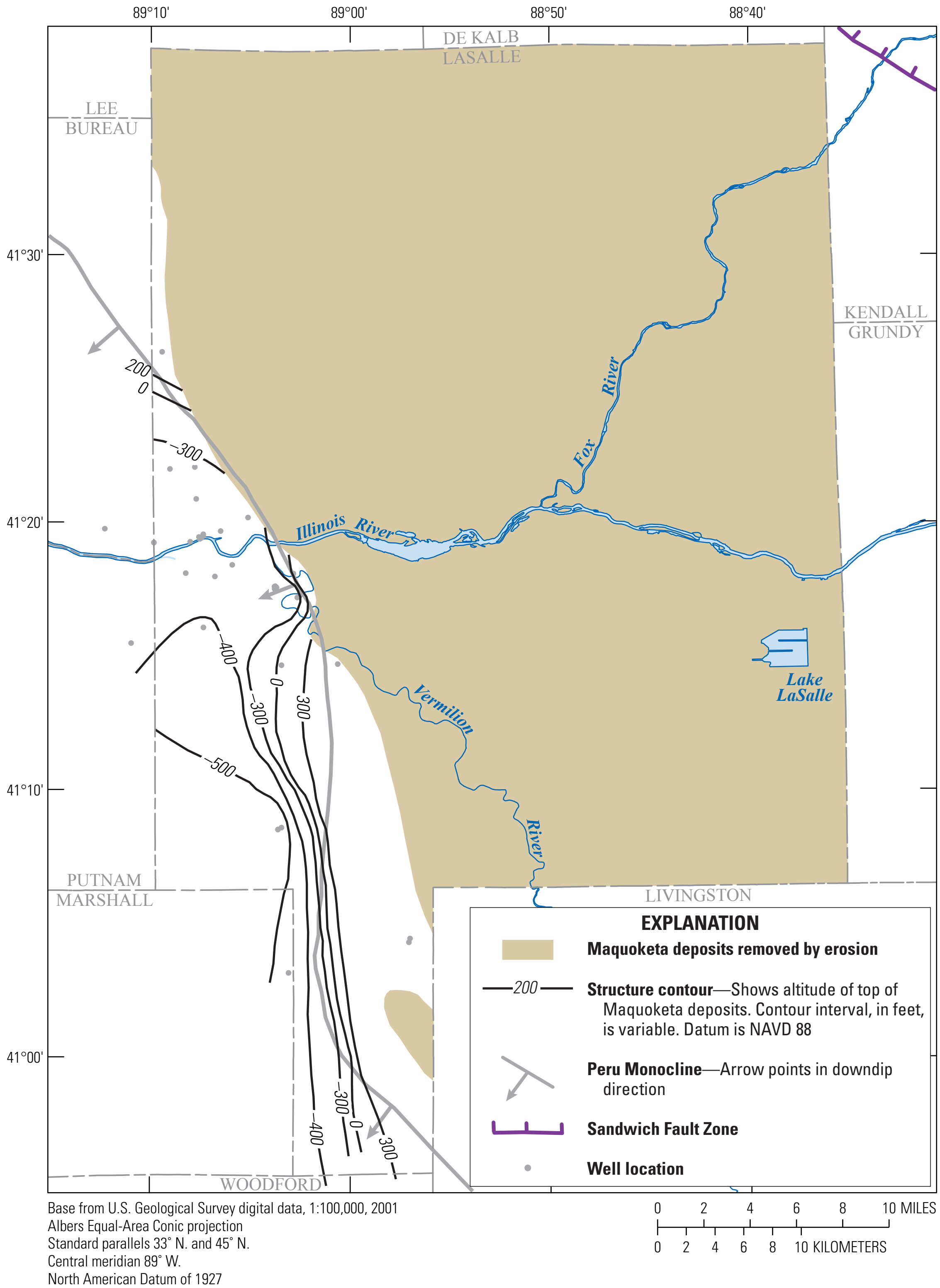

Figure 1–9. Altitude at the top of the deposits of the Maquoketa Group in LaSalle County, Illinois.

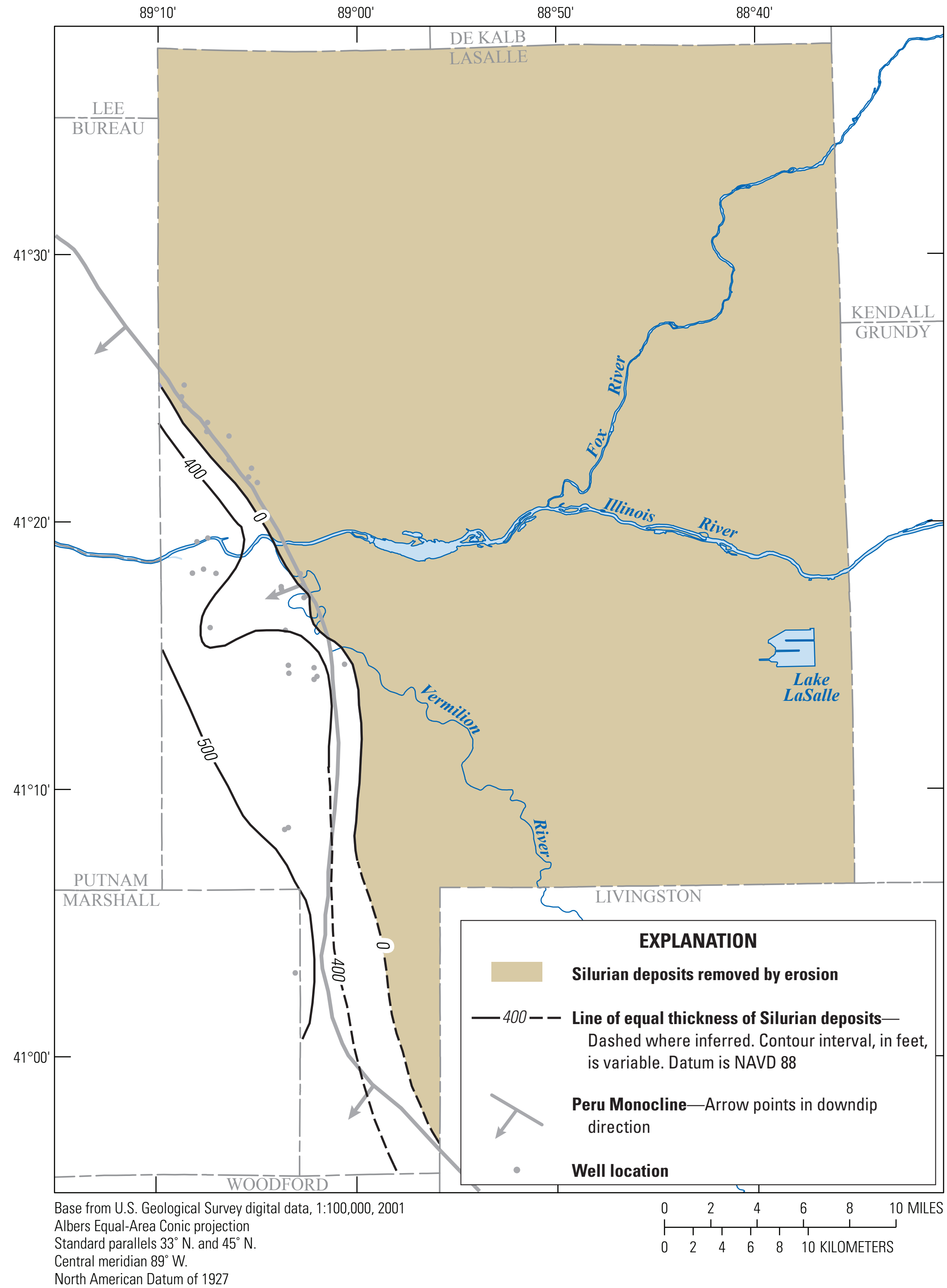

Figure 1–10. Thickness of Silurian-aged deposits in LaSalle County, Illinois.

Galena-Platteville, or Ancell deposits. The Pennsylvanian-aged formations consist of varying amounts of shale (10 to 50 percent, depending on the formation), argillaceous sandstone (10 to 20 percent), limestone (10 to 60 percent), and coal (less than 5 to 10 percent). The economically important Danville, Herrin, Springfield, and Colchester Coal Members have been mined in central and southern LaSalle County (Illinois State Geological Survey, 2015). Land subsidence has been observed in the vicinity of at least one of these abandoned underground mines (Dailey and Associates, 1999). Where present, the Pennsylvanian deposits typically are less than 200 ft thick beneath LaSalle County (fig. 1–11), but they may be more than 500 ft thick in the southwestern part of the county where the Bond and Mattoon Formations are present.

Quaternary Deposits

The surficial geologic deposits in most of LaSalle County are unconsolidated deposits of Quaternary age. These deposits are of primarily glacial origin and produced the various *end moraines* and associated ground moraines that are present beneath most of the county (fig. 4). Moraine deposits are composed primarily of *till*. Thin (generally less than 10 ft thick), discontinuous *lenses* of sorted *sand* and *gravel* may be present in localized areas within the till units.

Unconsolidated deposits typically are less than 50 ft thick in the center of the county near the Illinois River and in the Streator area, are from 50 to 200 ft thick in most of the northern and southern parts of the county, exceed 200 ft in the south-central part of the county in the Ticona Bedrock Valley (Willman and others, 1975; Larson, 1994) and may be as much as 400 ft thick where morainic deposits overlie the Troy Bedrock Valley in the northwestern part of the county (compare figs. 5 and 21). Unconsolidated deposits are absent and bedrock is exposed in and near various reaches of the Illinois, Fox, and Vermilion Rivers (Willman and others, 1942; Walls, 2004).

Unconsolidated deposits of *alluvial* and *lacustrine* origin also are present in parts of the county. Lacustrine deposits consist primarily of *silt* and *clay* deposited in the glacial lakes in the center of the county (fig. 4; Willman and Frye, 1970). Thick (greater than 10 ft), generally continuous, alluvial sand and gravel deposits are located in the Troy and Ticona bedrock valleys (figs. 10, 1–12, and 1–13) and in the vicinity of the Fox River near Sheridan (East and others, 2006).

Although absent in areas, alluvial deposits of mixed composition (sand, gravel, silt, clay) are present in much of the Illinois River Valley (Hart, 2002; Walls, 2004; Shields and others, 2005; Thomason, undated). These deposits are not well characterized but appear to be comparatively thin east of LaSalle. Sand and gravel deposits are reported to be about 30 ft thick at LaSalle (Habermeyer, 1925).

Troy Bedrock Valley Deposits

The Troy Bedrock Valley underlies northwestern LaSalle County (figs. 10 and 1–13). The deposits within the Troy Bedrock Valley are a mixture of interbedded sand and gravel and silt and clay till. Lithologic logs indicate that generally continuous sand and gravel deposits are present on the bedrock surface as well as in the middle part of the unconsolidated deposits (Vaiden and others, 2004). The basal sand and gravel deposits typically are less than 30 ft thick. Sand and gravel deposits in the middle and upper parts of the valley typically are less than 20 ft thick. As the result of interfingering of the various unconsolidated deposits, focused investigation would be necessary to locate specific sand and gravel deposits capable of exploitation for high-capacity water withdrawals.

Ticona Bedrock Valley Deposits

The Ticona Bedrock Valley is located south of the Illinois River from the southern part of Seneca, through Grand Ridge, north of Tonica, and into Putnam County (fig. 1–13). The valley was the location of a regional glacial drainage that eroded into the Pennsylvanian, Galena-Platteville, and the upper part of the St. Peter deposits (Larson, 1994) prior to diversion of the drainage to the path of the Illinois River during the Kankakee Torrent. The valley is about 1 mi wide and 200 ft deep (Willems and others, 2007). Lithologic logs and surface geophysical investigations indicate that 50 to 100 ft of continuous sand and gravel deposits overlie the bedrock within the Ticona Bedrock Valley. These deposits are overlain by more than 100 ft of till material deposited after drainage was diverted to the Illinois River.

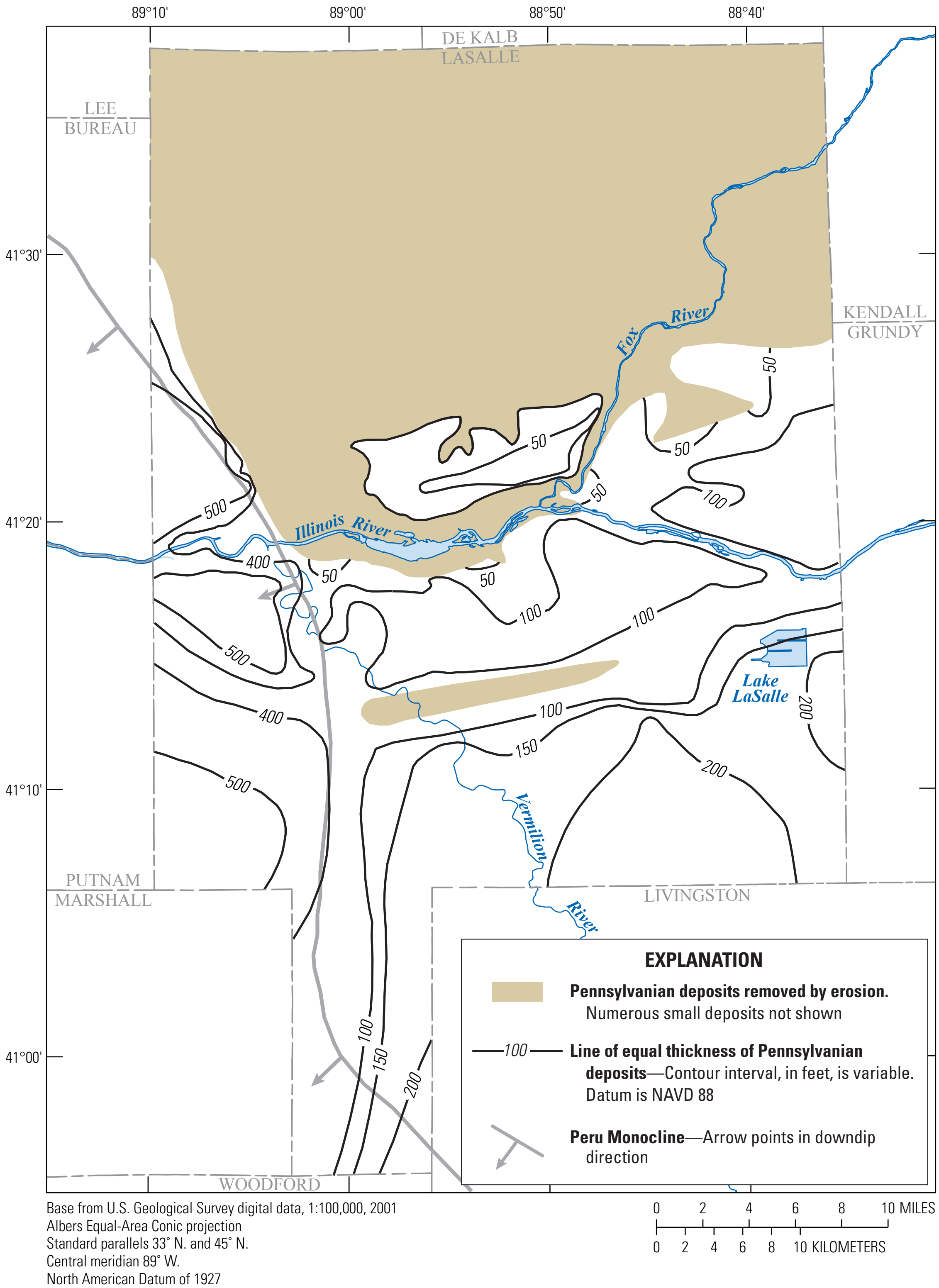

Figure 1–11. Thickness of Pennsylvanian-aged deposits in LaSalle County, Illinois.

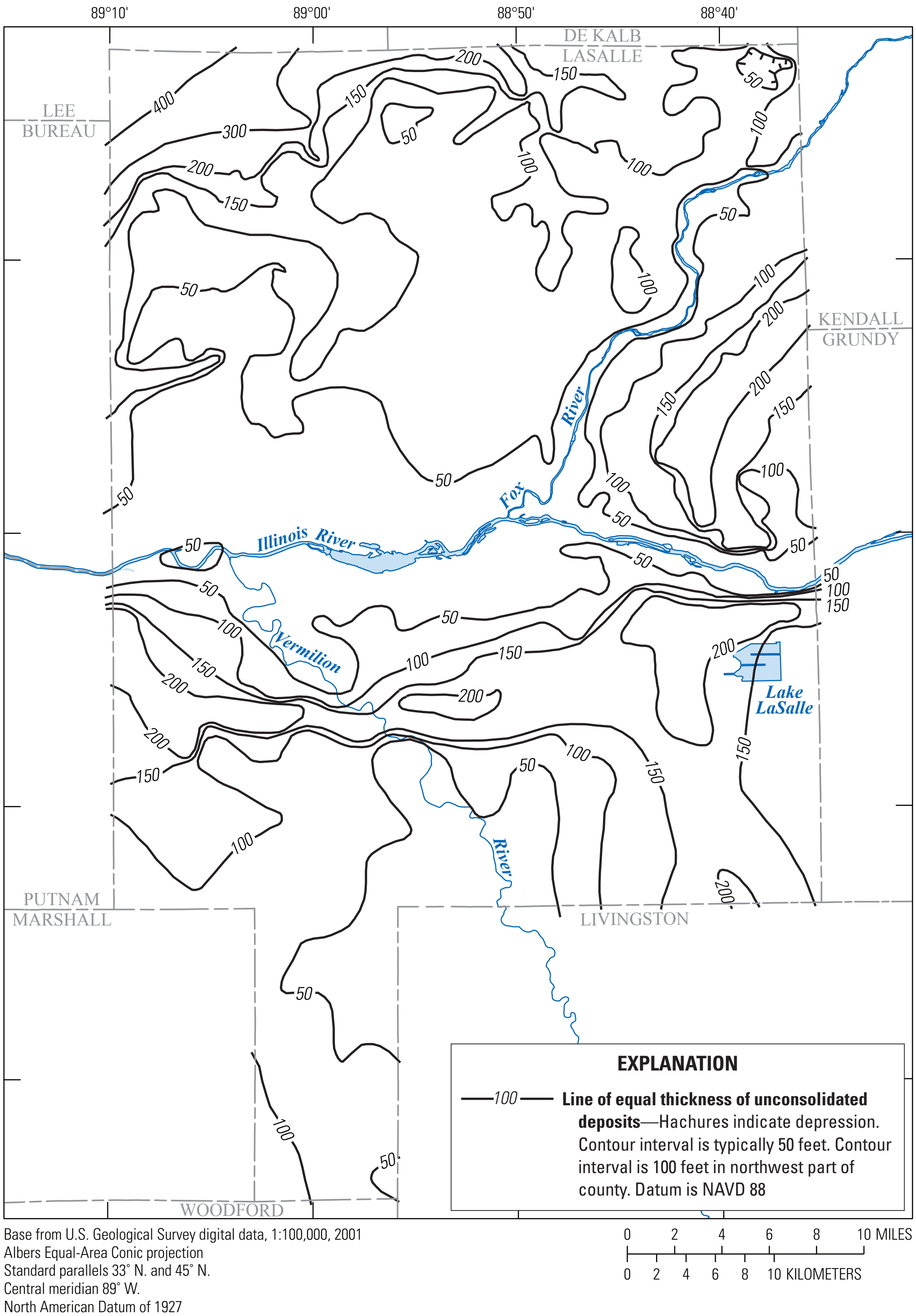

Figure 1–12. Thickness of unconsolidated deposits in LaSalle County, Illinois.

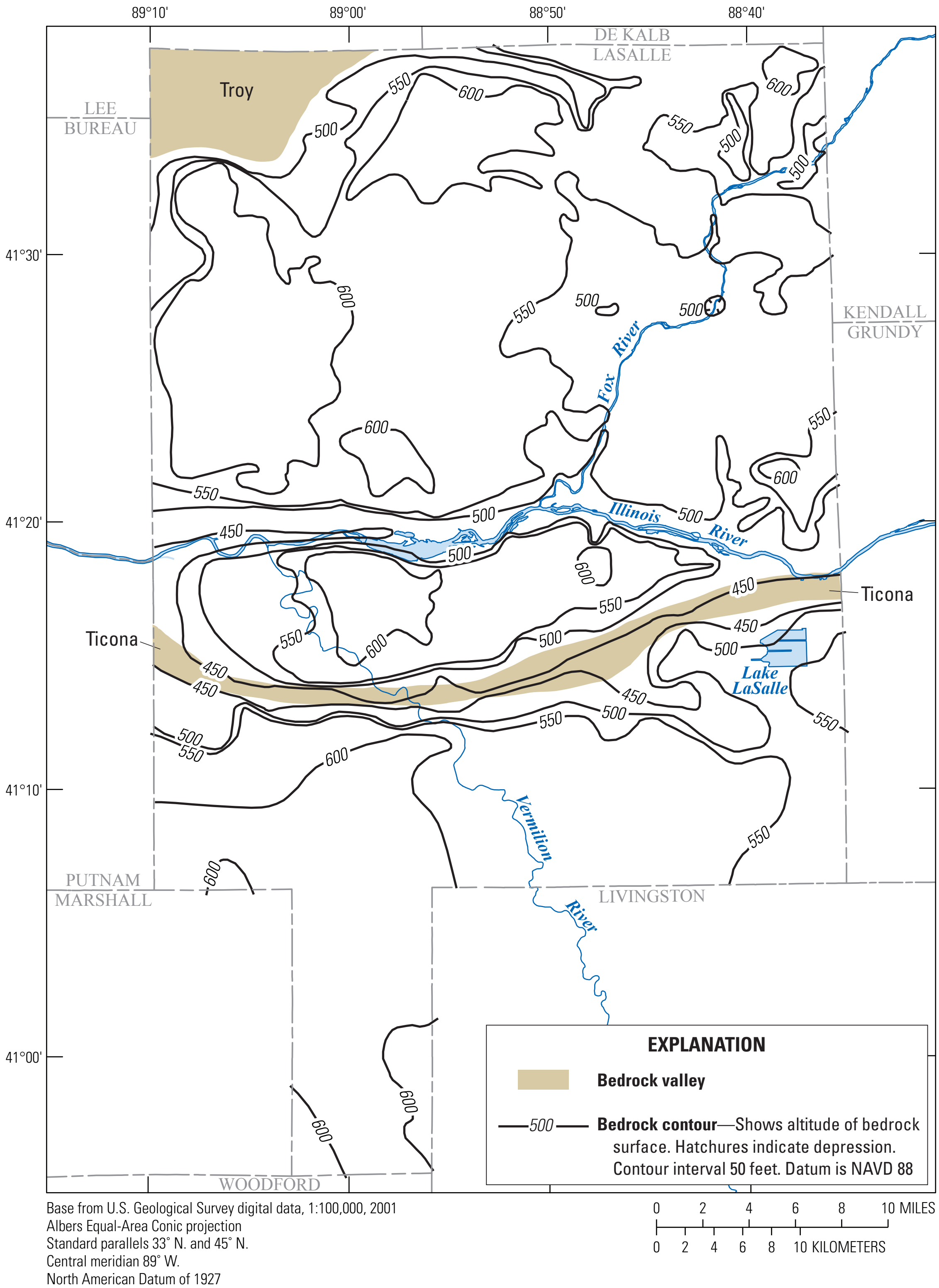

Figure 1–13. Altitude of bedrock surface in LaSalle County, Illinois.

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Appendix 2. Surface-Water-Quality Data, LaSalle County, Illinois

Samples were collected from the Fox River at Dayton (fig. 6) approximately monthly from 1956 to 1961 by the Illinois State Water Survey (ISWS; Harmeson and Larson, 1969; Harmeson and others, 1973). The median concentration of chloride in these samples was 21 milligrams per liter (mg/L), and the median concentration of nitrate was 7.6 mg/L. The MCL for nitrate was exceeded in 28 percent of these samples. The median concentration of dissolved phosphorus, which was only sampled for in 1960 and 1961, was 0.9 mg/L. Every sample contained phosphorus concentrations above the IWQS general use criterion (table 6). Seasonal trends were not apparent in these data.

Samples were collected approximately monthly from the Vermilion River at Lowell (fig. 6) from 1957 to 1961 and from 1966 to 1971 by the ISWS (Harmeson and Larson, 1969; Harmeson and others, 1973). Median nitrate concentrations in these samples were above the MCL, at 11.3 mg/L from 1957 to 1961 and 31.4 mg/L from 1966 to 1971, and typically were substantially lower from August through October or November than the rest of the year (Harmeson and others, 1973). The median concentration of chloride was 14 mg/L from 1957 to 1961 and 22 mg/L from 1966 to 1971. The median concentration of dissolved phosphorus was 0.36 mg/L from 1966 to 1971.

Surface-water quality in LaSalle County also has been characterized by multiyear sampling at several streamgages by the USGS (table 2–1). Discussion of surface-water-quality data for the rest of this report is based exclusively on the data from USGS sampling.

Populations of fecal coliform exceeded drinking-water standards as well as the IWQS criterion for general use (200 colonies per 100 milliliters [colonies/100 mL]) in numerous samples at all the streamgages at which fecal coliform was sampled (table 7). Median populations were highest on the Vermilion River near Leonore (630 colonies/100 mL), followed by Somonauk Creek at Sheridan (240 colonies/100 mL), the Little Vermilion River at LaSalle (200 colonies/100 mL), the Fox River at Dayton (130 colonies/100 mL), and the Illinois River at Marseilles (100 colonies/100 mL; table 2–1). Maximum populations exceeded 100,000 colonies/100mL in the Fox River at Dayton (400,000 colonies/100 mL) and Somonauk Creek at Sheridan (120,000 colonies/100 mL). At the remaining streamgages, except the Illinois River at Ottawa where it was not analyzed, maximum populations of fecal coliform exceeded 1,000 colonies/100 mL.

Nitrogen compounds such as nitrate, nitrite, and ammonia are common components of agricultural fertilizers in rural watersheds. Elevated levels of nitrogen compounds can also be detected in surface waters within urban and mixed watersheds. Common contributors of nitrogen within urban watershed include fertilizers applied to lawns and golf courses, emissions from automobiles, discharge from electric powerplants, and effluents from wastewater treatment facilities (U.S. Geological Survey, 1999). The elevated concentrations of these compounds in surface water can stimulate excessive algal growth, which can adversely affect aquatic habitat, increase water treatment costs, and may be harmful to humans who come into contact with the water (U.S. Environmental Protection Agency, 2015a).

Because nitrate is the primary compound in nitrate plus nitrite analyses in the majority of surface water bodies (U.S. Geological Survey, 1999), nitrate plus nitrite data are referred to as nitrate. The U.S. Environmental Protection Agency (EPA) drinking-water MCL of 10 mg/L for nitrate (table 6) is determined from the collection of a filtered water sample. Data for dissolved nitrate were only collected at a limited number of surface-water streamgages, including those located on the Illinois River at Marseilles and Ottawa as well as the Fox River at Dayton. Most of the surface-water samples collected by the USGS in LaSalle County were analyzed for total nitrate. In order to include the total nitrate data collected at the other major and minor tributaries in LaSalle County, the filtered (dissolved nitrate) or unfiltered (total nitrate) data obtained from the NWIS database were provided in tables 7, 8, and 2–1, depending on which analyses were available. This decision was based on comparing differences in median concentrations of filtered (dissolved) and unfiltered (total) nitrate of samples collected from the Fox River at Dayton and the Illinois River at Marseilles. At both sites, median concentrations for total and dissolved nitrate were calculated using only sample dates where both constituents were sampled side by side. On the Illinois River, median concentrations for unfiltered nitrate were 4.3 mg/L compared to 4.2 mg/L for the filtered samples collected from 1979 through 2015. Similarly, the unfiltered (total) median nitrate concentrations calculated from the Fox River samples were 3.0 mg/L compared to 2.9 mg/L calculated from the filtered (dissolved) samples. These differences were considered to be negligible for the purposes of this study.

Ammonia is a form of nitrogen that is commonly associated with agricultural fertilizers and effluent from wastewater treatment facilities. Ammonia can occur naturally in the environment; however, concentrations exceeding 0.1 mg/L are considered to be anthropogenically influenced (U.S. Geological Survey, 1999). Samples for ammonia exceeded the EPA aquatic life chronic threshold in at least one sample from streamgages on the Illinois River at Marseilles and Ottawa as well as the Vermilion and Little Vermilion Rivers (table 6). Median concentrations of ammonia measured on the Illinois River at Marseilles (0.49 mg/L) were higher than at any of the other streamgages and more than six times greater than the median concentration recorded downstream on the Illinois River at Ottawa (0.08 mg/L; table 2–1). Excluding the Illinois River at Marseilles, seasonal median and maximum ammonia concentrations were highest during the winter (table 8). The seasonal pattern in ammonia concentration can most likely be attributed to a decline in the biological utilization of the nutrient during this period (U.S. Geological Survey, 1999).

Table 2–1. Surface-water quality data in LaSalle County, Illinois.

[mm/yy, month/year; USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; µg/L, microgram per liter; c/100 mL, colony per 100 milliliters; na, not analyzed; <, less than]

Constituents and units	Maximum value	Minimum value	Median value	Number of samples	Period of record (mm/yy–mm/yy)
Somonauk Creek at Sheridan, Illinois (USGS streamgage 05551970)					
Ammonia as nitrogen (mg/L)	0.93	<0.01	0.04	165	7/79–4/97
Arsenic (µg/L)	3	<1	1.5	5	5/82–1/83
Barium (µg/L)	118	18	62	126	10/80–4/97
Boron (µg/L)	100	<5	<50	142	3/81–4/97
Chemical oxygen demand (mg/L)	120	1.0	12.5	134	7/79–8/93
Chloride (mg/L)	na	na	na	na	na
Chromium (µg/L)	203	<5	<5	142	3/81–4/97
Copper (µg/L)	20	<5	<5	145	7/79–4/97
Dissolved oxygen (mg/L)	16.2	6.5	10.8	150	11/79–4/97
Fecal coliform (colonies per 100 milliliter)	120,000	6	240	124	11/79–4/97
Fluoride (mg/L)	0.20	0.20	0.20	5	5/82–1/83
Iron (µg/L)	19,000	110	410	142	3/81–4/97
Manganese (µg/L)	1,030	20	50	142	3/81–4/97
Mercury (µg/L)	<0.1	<0.1	<0.1	5	5/82–1/83
Nitrate + nitrite as nitrogen (mg/L)	13	0.12	4.0	165	7/79–4/97
Total phosphorus as P (mg/L)	1.1	0.004	0.07	163	7/79–4/97
Sulfate (mg/L)	58	22	52	5	5/82–1/83
Total suspended solids (mg/L)	930	1	17	165	7/79–4/97
Zinc (µg/L)	460	<5	<100	140	3/81–4/97
Selected organic compounds:					
Alachlor (µg/L)	na	na	na	na	na
Atrazine (µg/L)	na	na	na	na	na
Cyanazine (µg/L)	na	na	na	na	na
Metolachlor (µg/L)	na	na	na	na	na
Simazine (µg/L)	na	na	na	na	na
Fox River at Dayton, Illinois (USGS streamgage 05552500)					
Ammonia as nitrogen (mg/L)	1.7	<0.01	0.05	188	3/78–4/97
Arsenic (µg/L)	8	1	2	201	3/78–4/97
Barium (µg/L)	300	100	100	26	3/81–11/95
Boron (µg/L)	700	<50	80	152	3/78–4/97
Chemical oxygen demand (mg/L)	210	8.8	35.5	170	3/78–4/97
Chloride (mg/L)	210	12	56	211	3/78–4/97
Chromium (µg/L)	419	<5	5.5	92	3/78–4/97
Copper (µg/L)	50	<5	10	62	3/78–4/97
Dissolved oxygen (mg/L)	19.9	4.0	12.2	793	3/78–4/97
Fecal coliform (colonies per 100 milliliter)	400,000	9	130	176	4/78–4/97
Fluoride (mg/L)	0.70	0.10	0.30	151	8/81–4/97
Iron (µg/L)	32,200	60	595	206	3/78–4/97
Manganese (µg/L)	1,150	10	70	169	3/78–4/97
Mercury (µg/L)	0.50	<0.1	<0.1	52	3/78–4/97
Nitrate + nitrite as nitrogen (mg/L)	14	<0.01	3.0	187	3/78–4/97
Total phosphorus as P (mg/L)	4.4	<0.01	0.26	249	3/78–4/97
Sulfate (mg/L)	135	11	58	213	3/78–4/97
Total suspended solids (mg/L)	2,500	<1	55	191	3/78–4/97
Zinc (µg/L)	340	<5	120	173	3/78–4/97
Selected organic compounds:					
Atrazine (µg/L)	1.7	.031	0.1005	10	5/96–1/97
Cyanazine (µg/L)	0.44	<0.004	0.038	10	5/96–1/97
Simazine (µg/L)	0.1	0.009	0.018	10	5/96–1/97

Table 2–1. Surface-water quality data in LaSalle County, Illinois.—Continued

[mm/yy, month/year; USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; µg/L, microgram per liter; c/100 mL, colony per 100 milliliters; na, not analyzed; <, less than]

Constituents and units	Maximum value	Minimum value	Median value	Number of samples	Period of record (mm/yy–mm/yy)
Illinois River at Marseilles, Illinois (USGS streamgage 05543500)					
Ammonia as nitrogen (mg/L)	3.9	<0.01	0.49	234	10/77–4/97
Arsenic (µg/L)	5	<1	2	219	12/74–8/15
Barium (µg/L)	127	<5	34	226	10/77–4/97
Boron (µg/L)	240	53	140	190	10/80–8/15
Chemical oxygen demand (mg/L)	200	9.0	22	171	1/78–10/93
Chloride (mg/L)	247	2.7	69	286	11/74–8/15
Chromium (µg/L)	170	0.89	10	218	12/74–8/15
Copper (µg/L)	220	3.7	10	201	12/74–8/15
Dissolved oxygen (mg/L)	19.7	4.0	9.7	1,115	8/75–7/98
Fecal coliform (colonies per 100 milliliter)	20,500	<1	100	216	11/74–12/96
Fluoride (mg/L)	1.2	0.10	0.44	156	11/74–8/15
Iron (µg/L)	17,600	240	870	247	12/74–8/15
Manganese (µg/L)	300	30	60	223	12/74–8/15
Mercury (µg/L)	1.4	<0.1	<0.1	194	10/70–4/97
Nitrate + nitrite as nitrogen (mg/L)	8.3	0.34	4.2	256	11/74–7/98
Total phosphorus as P (mg/L)	1.4	0.08	0.44	354	11/74–8/15
Sulfate (mg/L)	173	24	90	308	11/74–8/15
Total suspended solids (mg/L)	416	<1	30	224	12/77–4/97
Zinc (µg/L)	410	2.9	<100	223	12/74–8/15
Selected organic compounds:					
Alachlor (µg/L)	0.13	0.007	0.017	11	4/96–7/98
Atrazine (µg/L)	6.2	0.11	0.54	11	4/96–7/98
Cyanazine (µg/L)	2.8	0.019	0.132	11	4/96–7/98
Metolachlor (µg/L)	3.2	0.079	0.27	11	4/96–7/98
Simazine (µg/L)	0.08	0.012	0.026	11	4/96–7/98
Illinois River at Ottawa, Illinois (USGS streamgage 05553000)					
Ammonia as nitrogen (mg/L)	0.70	<0.02	0.08	90	2/97–8/04
Arsenic (µg/L)	na	na	na	na	na
Barium (µg/L)	na	na	na	na	na
Boron (µg/L)	na	na	na	na	na
Chemical oxygen demand (mg/L)	na	na	na	na	na
Chloride (mg/L)	232	36	81	90	2/97–8/04
Chromium (µg/L)	na	na	na	na	na
Copper (µg/L)	na	na	na	na	na
Dissolved oxygen (mg/L)	15.6	6.4	10	95	2/97–9/09
Fecal coliform (colonies per 100 milliliter)	na	na	na	na	na
Fluoride (mg/L)	0.73	0.21	0.37	67	2/97–8/01
Iron (µg/L)	na	na	na	na	na
Manganese (µg/L)	na	na	na	na	na
Mercury (µg/L)	na	na	na	na	na
Nitrate + nitrite as nitrogen (mg/L)	8.7	<0.05	4.7	90	2/97–8/04
Total phosphorus as P (mg/L)	1.1	0.19	0.51	90	2/97–8/04
Sulfate (mg/L)	110	41	72	91	2/97–9/09
Total suspended solids (mg/L)	na	na	na	na	na
Zinc (µg/L)	na	na	na	na	na
Selected organic compounds:					
Alachlor (µg/L)	0.31	<0.005	0.011	78	2/97–8/04
Atrazine (µg/L)	10.6	0.066	0.44	78	2/97–8/04
Cyanazine (µg/L)	3.0	<0.004	<0.018	78	2/97–8/04
Metolachlor (µg/L)	2.8	0.009	0.12	78	2/97–8/04
Simazine (µg/L)	0.41	<0.005	0.023	78	2/97–8/04

Table 2–1. Surface-water quality data in LaSalle County, Illinois.—Continued

[mm/yy, month/year; USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; µg/L, microgram per liter; c/100 mL, colony per 100 milliliters; na, not analyzed; <, less than]

Constituents and units	Maximum value	Minimum value	Median value	Number of samples	Period of record (mm/yy–mm/yy)
Vermilion River near Leonore, Illinois (USGS streamgage 05555300)					
Ammonia as nitrogen (mg/L)	2.0	<0.01	0.070	123	10/82–4/97
Arsenic (µg/L)	<1	<1	<1	5	12/77–5/78
Barium (µg/L)	300	<1	100	13	2/81–7/96
Boron (µg/L)	900	40	100	145	12/77–4/97
Chemical oxygen demand (mg/L)	140	1	16	155	10/77–10/93
Chloride (mg/L)	45	16	29	9	12/77–4/81
Chromium (µg/L)	485	<5	<5	150	12/77–4/97
Copper (µg/L)	340	<5	<5	166	12/77–4/97
Dissolved oxygen (mg/L)	22.7	3.4	9.6	213	10/77–9/15
Fecal coliform (colonies per 100 milliliter)	33,000	9	630	150	10/77–9/15
Fluoride (mg/L)	0.34	0.30	0.32	3	8/80–4/81
Iron (µg/L)	28,000	90	700	186	12/77–4/97
Manganese (µg/L)	520	<5	50	175	12/77–4/97
Mercury (µg/L)	0.60	<0.01	<0.10	181	12/77–4/97
Nitrate + nitrite as nitrogen (mg/L)	23	<0.1	9.2	183	10/77–4/97
Total phosphorus as P (mg/L)	1.2	0.06	0.24	118	1/78–4/97
Sulfate (mg/L)	207	16	76	173	12/77–4/97
Total suspended solids (mg/L)	876	1	29	182	10/77–4/97
Zinc (µg/L)	900	<5	<50	174	12/77–4/97
Selected organic compounds:					
Alachlor (µg/L)	na	na	na	na	na
Atrazine (µg/L)	na	na	na	na	na
Cyanazine (µg/L)	na	na	na	na	na
Metolachlor (µg/L)	na	na	na	na	na
Simazine (µg/L)	na	na	na	na	na
Little Vermilion River at LaSalle, Illinois (USGS streamgage 05555950)					
Ammonia as nitrogen (mg/L)	3.7	<0.01	0.16	162	10/82–4/97
Arsenic (µg/L)	5.0	1.0	2.0	10	4/89–9/90
Barium (µg/L)	500	100	100	31	2/81–6/96
Boron (µg/L)	290	30	80	143	2/81–4/97
Chemical oxygen demand (mg/L)	200	1	14	134	7/79–8/93
Chloride (mg/L)	133	11	48	164	7/79–4/97
Chromium (µg/L)	250	<5	<5	143	2/81–4/97
Copper (µg/L)	60	<5	<5	142	7/79–4/97
Dissolved oxygen (mg/L)	15.7	5.7	9.8	154	11/79–4/97
Fecal coliform (colonies per 100 milliliter)	64,000	3	200	111	10/77–9/15
Fluoride (mg/L)	0.50	0.20	0.35	10	4/89–9/90
Iron (µg/L)	35,100	<50	620	164	7/79–4/97
Manganese (µg/L)	1,950	30	130	143	2/81–4/97
Mercury (µg/L)	1.1	<0.01	<0.10	158	7/79–4/97
Nitrate + nitrite as nitrogen (mg/L)	17	0.10	6	163	7/79–4/97
Total phosphorus as P (mg/L)	1.7	0.04	0.15	117	2/84–4/97
Sulfate (mg/L)	152	17	71	164	8/79–4/97
Total suspended solids (mg/L)	1,840	1	25	164	7/79–4/97
Zinc (µg/L)	4,700	<100	605	142	2/81–4/97
Selected organic compounds:					
Alachlor (µg/L)	na	na	na	na	na
Atrazine (µg/L)	na	na	na	na	na
Cyanazine (µg/L)	na	na	na	na	na
Metolachlor (µg/L)	na	na	na	na	na
Simazine (µg/L)	na	na	na	na	na

There is currently no EPA enforceable health standard for phosphorus in rivers and streams. However, an EPA secondary MCL goal of 0.1 mg/L and an IWQS criterion for lakes and reservoirs of 0.05 mg/L have been established (table 6) due to the negative effects of phosphorus on aquatic life (U.S. Environmental Protection Agency, 2015b). Phosphorus is the limiting nutrient to the growth of many species of algae.

Total phosphorus concentrations exceeded the IWQS criterion for lakes and reservoirs (0.05 mg/L) in all or nearly all the samples collected from every sampling site except Somonauk Creek, where approximately 75 percent of the samples exceeded the standard (table 7). Total phosphorus concentrations exceeded the SMCL (0.1 mg/L) in the majority of samples at every streamgage except for Somonauk Creek. Median total phosphorus concentrations varied by no more than a factor of two between seasons at any streamgage and showed no consistent seasonal variation (table 8).

The median concentrations of nitrate and total phosphorus in samples collected by the USGS from the Fox River at Dayton and the Vermilion River near Lowell from 1978 to 1997 (table 2–1) tended to be about one-third to an order of magnitude lower than the median concentrations of nitrate and dissolved phosphorus in samples collected by the ISWS from these rivers from 1956 to 1961 and 1966 to 1971 (Harmeson and Larson, 1969; Harmeson and others, 1973). The median concentration of chloride in samples from these rivers was higher during the USGS sampling than during the ISWS sampling. These trends indicate that changes in fertilizer application and wastewater treatment have resulted in an improvement in nutrient concentrations through time but that increased application of road salts has resulted in increased chloride concentrations.

Chlorophyll concentrations were monitored on the Illinois River at Marseilles and on the Fox River at Dayton from October 1987 through September of 1990 (table 8). The limited sampling period makes interpreting long-term temporal trends in chlorophyll difficult. However, median chlorophyll concentrations for the monitoring period from 1987 to 1990 were higher on the Fox River (18 micrograms per liter [μg/L]) than on the Illinois River at Marseilles (4.1 μg/L). Seasonal trends in concentration were apparent on both the Illinois and Fox Rivers. Median concentrations were highest during fall (September 1 to November 11) and lowest during winter (table 8). Excessive concentrations of chlorophyll in surface water can be attributed to a number of factors, including increased nutrient levels, low stream velocities, and warm water temperatures.

The herbicides alachlor, atrazine, cyanazine, metolachlor, prometon, and simazine and the pesticide diazinon were detected in more than 50 percent of the samples collected as part of a subset of the sampling effort in the Fox River at Dayton and the Illinois River at Marseilles and Ottawa. Other herbicide and pesticide compounds were detected in the samples from these streamgages at a lower frequency of detection. Pesticides and herbicides were not analyzed at the remaining streamgages. Concentrations of atrazine exceeded the MCL of 3 μg/L in 10 of the 78 samples collected at Ottawa and in 2 of the 11 samples collected at Marseilles (table 7). HALs also were exceeded for cyanazine at Marseilles and Ottawa. The presence of herbicides and pesticides in these waters indicates they are affected by agricultural processes.

Maximum and median chloride concentrations measured on the Illinois River at Marseilles and Ottawa were marginally higher than chloride concentrations measured on the Fox River at Dayton and substantially higher than those measured on the Vermilion and Little Vermilion Rivers (table 2–1). Median concentrations of chloride varied by less than a factor of two over the course of a year at each streamgage but were highest during the spring and winter at Ottawa and Marseilles (table 8). Median chloride concentrations measured on the Fox River and Little Vermilion River showed little seasonal variation, with only small increases during the fall. Most of the sites show maximum chloride concentrations occurring during spring or winter (table 8). Chloride concentrations were below water-quality standards in almost every sample from every site (table 7).

In addition to exceeding water-quality standards for fecal-coliform, various nutrients, and herbicides in a substantial number of samples, concentrations of total chromium, iron, manganese, and zinc exceeded the water-quality criteria in at least one sample at each streamgage (table 7). With the exception of iron, manganese, and zinc, these exceedances typically were detected in fewer than five samples. The concentrations of these elements in the samples likely reflect natural processes.

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Appendix 3. Specific-Capacity Analysis for Wells Open to the Ancell Aquifer, LaSalle County, Illinois

Specific-capacity (Q/s) data from more than 870 water-supply wells were used to determine the transmissivity (T) in the Ancell aquifer in LaSalle County. T was calculated by solving the following equation modified from Walton (1962) for T:

$$\frac{Q}{s} = \frac{T}{264 \times \log\left(\frac{T't}{2{,}693 r_w^2 S}\right) - 65.5}, \tag{1}$$

where

Q	is the discharge, in gallons per minute
s	is the drawdown, corrected for partial penetration of the well, in feet
T	is the transmissivity, in gallons per day per foot, then converted into units of feet squared per day,
T'	initial estimate guess of transmissivity value, in gallons per day per foot, value is correct when T equal to T'
t	is the time of measurement from the time pumping was initiated, in minutes,
r_w	is the nominal well radius, in feet, and
S	is the storage coefficient of the aquifer (dimensionless).

The values for Q, s, r_w, and t were obtained from the construction logs for the wells provided by the driller, which are located in the Illinois State Geological Survey well database (Illinois State Geological Survey, undated). These values are assumed to be accurate. The storage coefficient for the Ancell aquifer was 1.0×10^{-4} based on the results of a multiple well, constant discharge aquifer test of the Ancell aquifer in the Naplate area (Hull and Associates, 2008). This test was used because it provided the only field-based S value for the Ancell aquifer in LaSalle County.

Specific-capacity analysis is based on the Theis (1935) equation

$$drawdown = \frac{Q}{4\pi T} \times \left[-0.5572 - \ln(u) + u - \frac{u^2}{2 \times 2!} + \frac{u^3}{3 \times 3!} - \ldots\right], \tag{2}$$

where the following assumptions are made:

- the aquifer is homogeneous, isotropic, of constant thickness, and of infinite areal extent,
- the aquifer is overlain and underlain by impermeable strata,
- the pumped well is of infinitesimal diameter, penetrates the entire thickness of the aquifer, is 100-percent efficient, and is pumped at a constant rate, and
- the aquifer remains fully saturated.

With the exception of a 100-percent efficient well that fully penetrates the aquifer, these conditions were met or approximated for these tests. The effects of partial penetration of the pumping well on drawdown were corrected using the drawdown equation from Butler (1957, eq. 3):

$$s = Cpp \times spp \tag{3}$$

where

Cpp	is a partial penetration constant for the pumped well, as a fraction, and
spp	is the observed drawdown for partial penetration conditions, in feet.

The value of Cpp is related to the fraction of the aquifer penetrated by the pumped well (α) and a factor (x) related to the well configuration and the aquifer properties, measured as follows:

$$x = \frac{r_w}{\sqrt{b\left(\frac{K_v}{K_h}\right)}}, \quad (4)$$

where

b is the thickness of the aquifer, in feet,

K_v is the vertical hydraulic conductivity of the aquifer, in feet per day, and

K_h is the horizontal hydraulic conductivity of the aquifer, in feet per day.

When assessing the effects of partial penetration, the aquifer thickness at the well was approximated in 50-foot increments (100, 150, and 200 feet) based on the thickness of the Ancell Group sandstone deposits (fig. 14). The ratio of K_v to K_h for the aquifer was 9.1×10^{-3} based on results of aquifer testing in the Naplate area (Hull and Associates, 2011). Data presented in Walton (1962) indicate that the value of *Cpp* is approximately equal to α plus a constant of 0.02.

Plotting specific capacity for the wells open to the Ancell aquifer in LaSalle County in gallons per minute per foot against the calculated value of transmissivity for that well in feet squared per day yields a relation as follows:

$$T = 266\frac{Q}{s} - 51.11, \quad (5)$$

with a Pearson product moment correlation (R^2) of 0.99 (fig. 3–1).

The maximum transmissivity from the specific-capacity tests in LaSalle County was calculated to be 5,800 ft^2/d, the minimum was 13 ft^2/d, and the geometric mean of all tests was 333 ft^2/d. These values are consistent with the range of values determined from constant discharge aquifer tests and slug tests in the county (table 3–1; Visocky and others, 1985; Hull and Associates, 2008; Patrick Engineering, Inc., 2011). Comparison of *T* values obtained from slug and constant discharge aquifer tests at a location with the geometric mean of the *T* values obtained from analysis of specific-capacity tests in wells near that location shows agreement within a factor of five (table 3–1). Agreement in *T* values between the methods was best for areas with lower transmissivity, with *T* values from the specific-capacity analysis typically being higher than the values from the slug and constant discharge test. This moderate level of agreement between testing methods indicates that specific capacity tests, on the whole, yield reasonably accurate *T* values.

Calculated *T* values in the Ancell aquifer can display variation of more than an order of magnitude between adjacent residences. Because the Ancell aquifer is considered to be homogenous and isotropic, *T* values should vary by less than about a factor of five within distances of a few thousand feet. It is likely that some of the variation in *T* values within an area can be related to factors such as erroneous measurement of specific capacity, depth of well penetration, degree of well development, and the integrity of the casing seal. Because the *T* value from any individual specific-capacity test may be

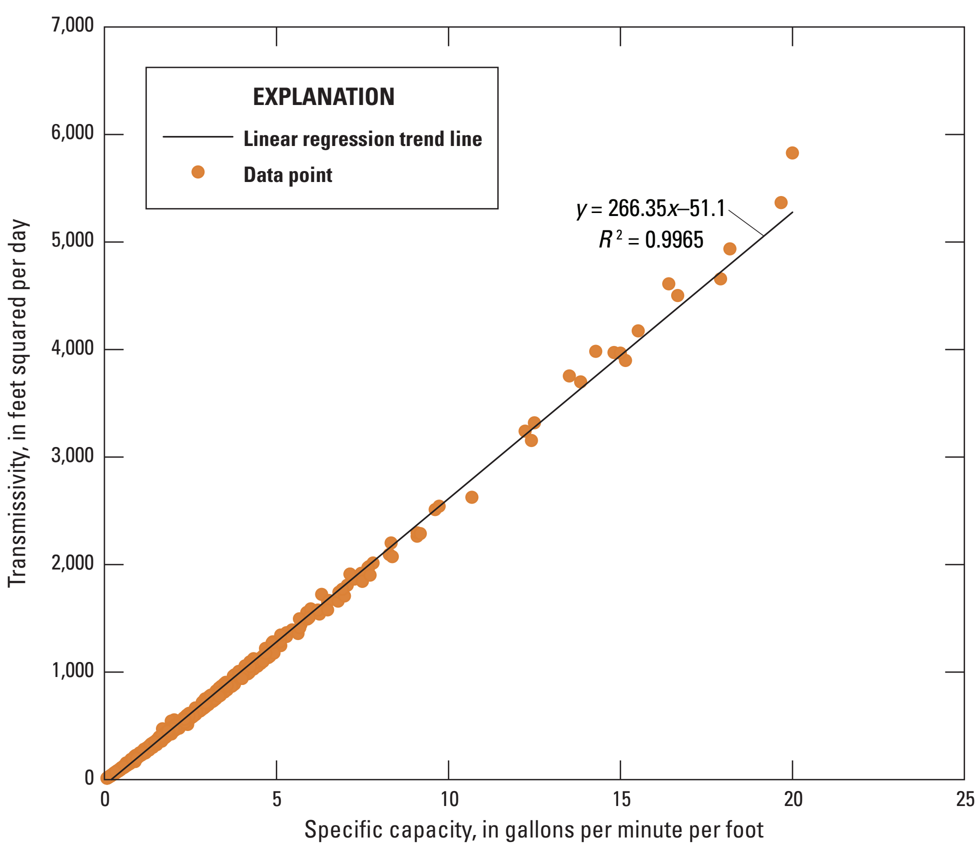


Figure 3–1. Relation between specific capacity and transmissivity of the Ancell aquifer in LaSalle County, Illinois.

inaccurate, obtaining the geometric mean from several wells in an area, including the county as a whole, is likely to produce the most accurate *T* value for the aquifer. Plotting summary information regarding *T* values obtained from specific-capacity testing from wells open to the Ancell aquifer within the various township and range divisions in LaSalle County indicates that geometric mean transmissivity values are above 500 ft^2/d in the northwestern part of the county (fig. 3–2). Geometric mean values less than 200 ft^2/d tend to be located in the southern part of the county.

Calculation of Potential Effects From Future Pumping Using Transmissivity Estimates From Specific-Capacity Tests.—T values can be used to calculate the amount of drawdown at a point in space and time that would be caused by pumping at a constant rate from a location in LaSalle County by entering the transmissivity for that location (fig. 3–2) and other parameters into an equation appropriate to the aquifer conditions. For ease of demonstration we will assume pumping from a part of the Ancell aquifer that is under confined conditions. Drawdown under these conditions can be calculated using a Theis equation calculator, such as the one available from the USGS (Keith Halford, U.S. Geological Survey, written commun., 2016) that can be obtained from the author by request. Other (non-USGS) versions of the Theis equation calculator can be accessed online. The Theis equation calculator can be used to calculate the effect that pumping from the Ancell aquifer at any pumping rate will have at any distance from the pumped well at any time since the start of pumping. For example, pumping at a rate of 100 gal/min (or any other pumping rate) in Township 34N, Range 2E, Section 32, the drawdown that this pumping would induce at a well 1,000 ft (or any other distance) from the pumped well after 1 year of pumping (or any other time) can be calculated by assuming that *T* is 480 ft^2/d (fig. 3–2) and *S* is 0.0001 (in this scenario the aquifer is not dewatered, if it was dewatered an different equation and a storage coefficient of 0.20 would be required). Using these inputs, the calculated drawdown is about 26 ft. An approximation to the Theis equation given by Cooper and Jacob (1946) also can be used to estimate the drawdown:

$$drawdown = \frac{Q}{4\pi T} \times \left(-0.5572 - ln\frac{r^2 S}{4Tt} \right), \qquad (6)$$

as long as *r* is relatively small and *t* is large. In the case described above,

$$drawdown = \frac{0.2232\frac{ft^3}{s}}{12.6 \times 0.00555\frac{ft^2}{s}} \times \left(-0.5572 - ln\frac{(1{,}000\ ft)^2 \times 0.0001}{4 \times 0.00555\frac{ft^2}{s} \times 31536000\,s} \right) \cong 26.5 \text{ ft},$$

where

Q	= 100 gal/min	= 0.2232 ft^3/s,
T	= 480 ft^2/d	= 0.00555 ft^2/s, and
t	= 365 days	= 3,1536,000 seconds.

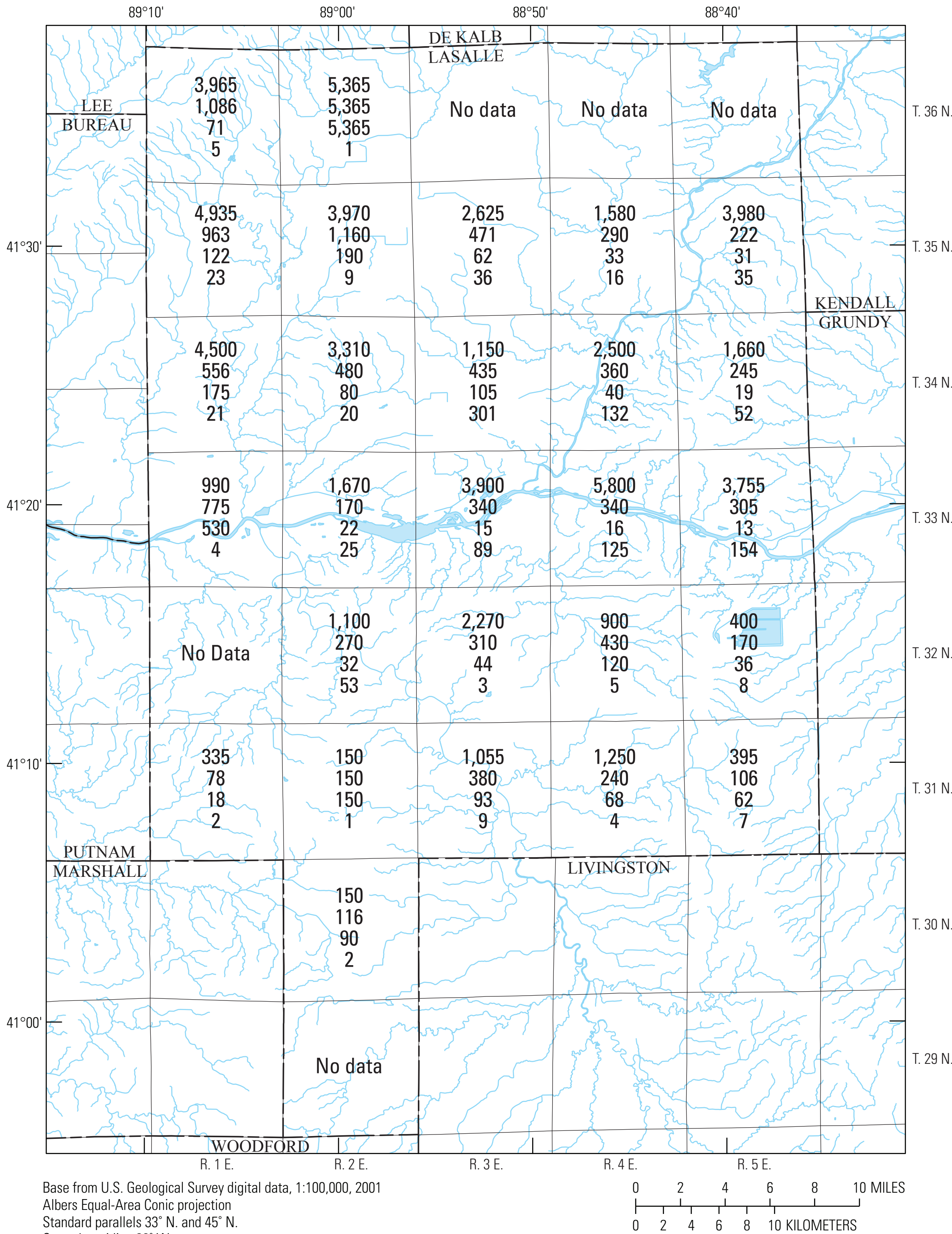
This calculation does not account for the effects of recharge from precipitation, surface water bodies, and overlying geologic units, the effects of discontinuous pumping, and the effects of partial or total dewatering of the aquifer. However, this process can be used to provide a preliminary indication of the (likely) maximum impacts of pumping from various points in the Ancell aquifer on the surrounding aquifer. A more refined understanding of the effects of pumping from the Ancell aquifer on drawdown in the surrounding aquifer, including when the aquifer is dewatered, requires more complex tools (Barlow and Moench, 2011).

Table 3–1. Comparison of transmissivity values from specific-capacity and constant discharge aquifer tests of the Ancell aquifer, LaSalle County, Illinois.

[na, not available]

Location	Transmissivity from constant discharge aquifer (feet squared per day)	Transmissivity from specific capacity (feet squared per day)
Cedar Point	1,869	na
East of Starved Rock State Park	93	226
Harding	362	612
Kangely	255	406
Naplate	1,300	282
Waste-disposal sites[1]	88	400

[1]Calculated from slug-test data.



EXPLANATION

150 **Maximum transmissivity value, in feet squared per day**
116 **Geometric mean transmissivity value, in feet squared per day**
90 **Minimum transmissivity value, in feet squared per day**
2 **Number of tests**

Figure 3–2. Summary of transmissivity values based on specific-capacity tests in the Ancell aquifer in LaSalle County, Illinois.

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