STATE OF LOUISIANA

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

OFFICE OF PUBLIC WORKS AND INTERMODAL

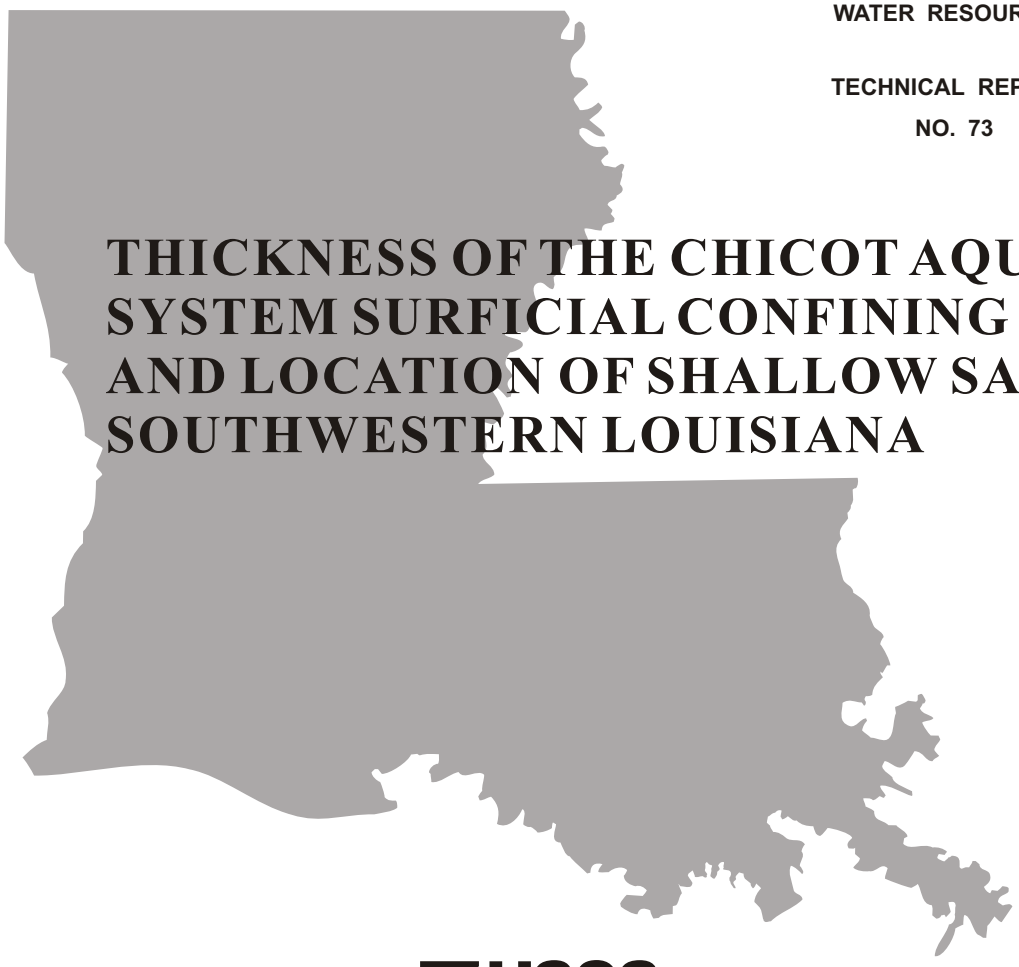
PUBLIC WORKS AND WATER RESOURCES DIVISION

WATER RESOURCES

TECHNICAL REPORT

NO. 73

THICKNESS OF THE CHICOT AQUIFER SYSTEM SURFICIAL CONFINING UNIT AND LOCATION OF SHALLOW SANDS, SOUTHWESTERN LOUISIANA



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Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1927 (NGVD 27).
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

THICKNESS OF THE CHICOT AQUIFER SYSTEM SURFICIAL CONFINING UNIT AND LOCATION OF SHALLOW SANDS, SOUTHWESTERN LOUISIANA

By B. Pierre Sargent

ABSTRACT

The Chicot aquifer system underlies an area of approximately 9,000 square miles in southwestern Louisiana and is the principal source of fresh ground water in the region. The dense surficial clays that confine the upper sands of the Chicot aquifer system in southwestern Louisiana are known as the Chicot aquifer system surficial confining unit. Although the confining unit may be relatively uniform in composition across large areas, interbedded sands that vary in areal extent and thickness are present within the confining unit. These interbedded sands are collectively known as the shallow sands of the Chicot aquifer system. The shallow sands occur irregularly throughout the confining unit and may be hydraulically connected to underlying aquifers. The shallow sands provide sufficient water for small-diameter wells that supply water for domestic, irrigation, or petroleum rig-supply purposes.

Drillers' logs and geophysical logs were used to define the thickness of the confining unit. The thickness of the surficial confining unit generally increases from north to south. In southern Vernon and Rapides Parishes, where the Chicot aquifer system crops out, the confining unit typically is less than 40 feet thick. The thickness of the confining unit generally increases southward, and generally ranges in thickness from 160 to 400 feet in coastal parishes with a maximum thickness of about 520 feet in Vermilion and St. Mary Parishes.

The locations of wells screened within the surficial confining unit and drillers' or geophysical logs showing shallow sands greater than 10 feet thick are mapped for 12 of the 15 parishes in the study area. The percentage of shallow-sand thickness in the confining unit is indicated for each log. Well-screen depths of 1,579 shallow wells used for domestic, irrigation, or petroleum rig-supply purposes were assumed to indicate the presence of productive shallow sands within the confining unit; however, only about 19 percent of the 2,098 logs analyzed indicate that shallow sands are present. The logs also indicate that the percentage of shallow-sand thickness in the confining unit can vary greatly across very short distances.

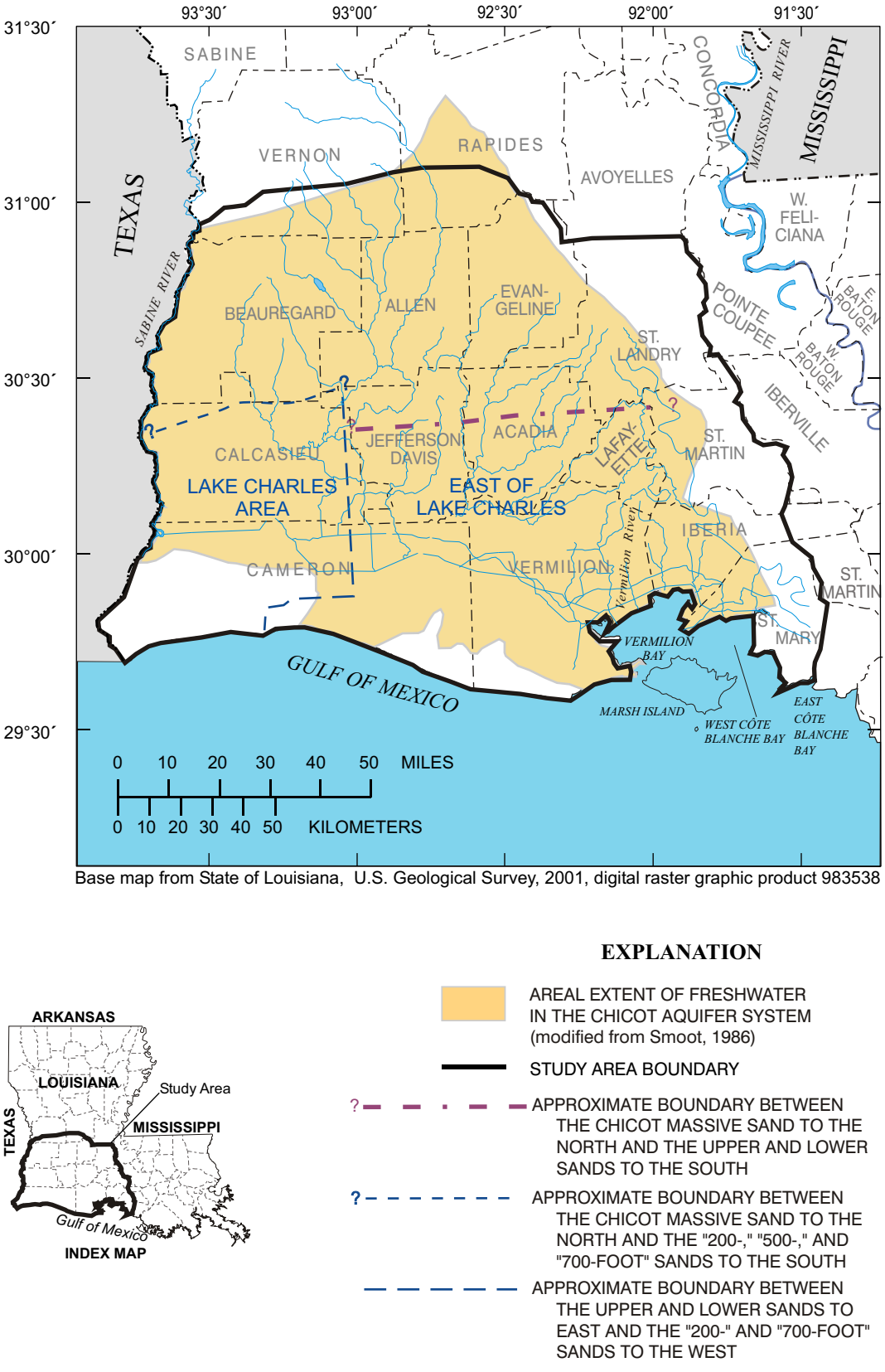
INTRODUCTION

Southwestern Louisiana is situated within the Gulf Coastal Plain Physiographic Province. The area is underlain by thick multilayered sequences of unconsolidated sedimentary deposits that alternate among gravel, sand, silt, and clay and that have a predominant dip to the south (U.S. Geological Survey, 1985, p. 229). Areally extensive zones of gravel and sand deposits, which form productive aquifer units, and the adjoining silt and clay deposits, which form confining units, are designated as the Chicot aquifer system (Nyman, 1984, p. 4). The Chicot aquifer system underlies an area of approximately 9,000 mi^2 in southwestern Louisiana (fig. 1) and is the principal source of fresh ground-water in the region (Lovelace, 1999, p. 2). In 2000, almost half of all ground-water withdrawals in Louisiana were from the Chicot aquifer system, and of this amount, more than half of the withdrawals were for rice irrigation (Sargent, 2002, p. 1). Dense surficial clays that overlie and confine the upper sands of the Chicot aquifer system makes the region ideal for rice farming by preventing major water losses through downward seepage (Lovelace, 1999, p. 2). These clays, and thin units of coarser material within the clays are known as the Chicot aquifer system surficial confining unit and will hereinafter be referred to as the confining unit.

The confining unit is composed of both Holocene- and Pleistocene-age sediments and was once thought of as an impermeable barrier to movement of contaminants from the surface to the underlying aquifers (Stanley and Maher, 1944, p. 13; Meyer, 1953, p. 2) (fig. 2). The impermeable barrier assumption has been reconsidered in recent years because of various incidents of subsurface contamination (Trudeau, 1994, p. 2). Hanor (1993) showed that the effective vertical hydraulic conductivity of surficial clay at a hazardous waste disposal site in southeastern Louisiana was as much as four orders of magnitude higher than reported laboratory measurements of clay core samples taken from the site. Hanor attributed the difference to the presence of minor sand beds and to secondary porosity and fracturing that occurred during deposition and sub-aerial weathering of the clay beds. Assuming that confining unit clays in southwestern Louisiana are similar to confining unit clays in southeastern Louisiana, the results of Hanor's research has implications for clays in the study area. Nyman and others (1990) simulated flow in the Chicot aquifer system and determined that, under 1981 conditions, vertical recharge from the land surface was now occurring throughout most of southwestern Louisiana.

Although the thickness of the confining unit may be relatively uniform across large areas, interbedded sands of varied areal extent and thickness are present within the confining unit. These sands are collectively known as the shallow sands of the Chicot aquifer system. The shallow sands occur irregularly throughout the confining unit and may be hydraulically connected to underlying aquifers. According to State well-registration records, more than 3,000 shallow, small-diameter wells that supply water for domestic, irrigation, or petroleum rig-supply purposes are screened in the shallow sands (Zahir "Bo" Bolourchi, Louisiana Department of Transportation and Development, written commun., 2002).

Little information is available on the thickness of the clay confining unit and the presence of sands within the confining unit; this information could be valuable for making land-use decisions and protecting shallow sources of ground water, as well as the deeper aquifers, from downward-moving contaminants. In 1996, the U.S. Geological Survey (USGS), in cooperation with the Louisiana Department of Transportation and Development (DOTD), began a study to document the thickness and extent of the confining unit and locations of shallow sands within the confining unit.



Base map from State of Louisiana, U.S. Geological Survey, 2001, digital raster graphic product 983538

EXPLANATION

AREAL EXTENT OF FRESHWATER IN THE CHICOT AQUIFER SYSTEM (modified from Smoot, 1986)

STUDY AREA BOUNDARY

? APPROXIMATE BOUNDARY BETWEEN THE CHICOT MASSIVE SAND TO THE NORTH AND THE UPPER AND LOWER SANDS TO THE SOUTH

? APPROXIMATE BOUNDARY BETWEEN THE CHICOT MASSIVE SAND TO THE NORTH AND THE "200-," "500-," AND "700-FOOT" SANDS TO THE SOUTH

APPROXIMATE BOUNDARY BETWEEN THE UPPER AND LOWER SANDS TO EAST AND THE "200-" AND "700-FOOT" SANDS TO THE WEST

Figure 1. Location of the study area in southwestern Louisiana.

<table>
<tr><td rowspan="3">System</td><td rowspan="3">Series</td><td colspan="3">Hydrogeologic Unit</td></tr>
<tr><td colspan="3">Southwestern Louisiana</td></tr>
<tr><td rowspan="2">Aquifer system</td><td colspan="2">Aquifer or confining unit</td></tr>
<tr><td>Lake Charles Area</td><td>East of Lake Charles</td></tr>
<tr><td rowspan="4">Quaternary</td><td>Holocene (Recent)</td><td rowspan="4">Chicot aquifer system</td><td>Shallow sand or surficial confining unit</td><td>Atchafalaya aquifer, shallow sand, or surficial confining unit</td></tr>
<tr><td rowspan="3">Pleistocene</td><td>"200-foot" sand</td><td>Upper sand</td></tr>
<tr><td>"500-foot" sand</td><td rowspan="2">Lower sand</td></tr>
<tr><td>"700-foot" sand</td></tr>
<tr><td>Tertiary</td><td>Pliocene
Miocene</td><td colspan="3">Evangeline aquifer</td></tr>
</table>

Louisiana Department of Transportation and Development-U.S. Geological Survey Water Resources Cooperative Program

Figure 2. Partial listing of hydrogeologic units in southwestern Louisiana (modified from Lovelace and Lovelace, 1995).

Purpose and Scope

This report documents the thickness of the Chicot aquifer system surficial confining unit and the location of shallow sands within the confining unit. A map is presented that shows the areal pattern of confining unit thickness for all of Acadia, Allen, Beauregard, Calcasieu, Cameron, Jefferson Davis, Lafayette, and Vermilion Parishes and parts of Evangline, Iberia, Rapides, St. Landry, St. Martin, St. Mary, and Vernon Parishes, which are located along the confining unit boundaries. Mapping of small local variations at the base of the confining unit, such as incised-stream channels was beyond the scope of this report.

The location of 2,098 drillers' or geophysical logs, and the percentage of shallow sands within the confining unit (determined from the logs) are shown on maps. The location and depth to the base of well screens of 1,579 domestic, irrigation, or petroleum rig-supply wells that are screened in the shallow sands also are shown. Wells for which log data are available and wells screened in shallow sands often are clustered along roads and in populated areas. Other areas which consist of marsh land or extensive agricultural land far from roads, may have limited amounts of available subsurface information. The quantity and quality of data were insufficient to map the areal extent of individual shallow sand units.

This report provides a basis for collection of more detailed information about the transmissivity of the confining unit and the nature of the interconnection and relation between the confining unit and the deeper hydrogeologic units of the aquifer. Knowledge about the confining unit gained as a result of this study may contribute to the understanding of hydrogeologic conditions of surficial confining units in similar coastal settings.

Description of Study Area

The study area consists of the approximate extent of freshwater in the Chicot aquifer system in southwestern Louisiana (fig. 1). Along the Gulf of Mexico well log information was available that covered Cameron and Vermilion Parishes, so the study area was expanded beyond the areal extent of freshwater in the Chicot aquifer system. Marsh Island, an area in southern Iberia Parish that is mostly marshland bounded by West Côte Blanche Bay to the north and the Gulf of Mexico to the south, was not included in the study area, and no well log information was available. The study area is bounded by the Gulf of Mexico to the south, the Louisiana-Texas State line to the west, and alluvial sediments of the Atchafalaya River to the east. The Chicot aquifer system is cut into or overlain by alluvial sediments of the Atchafalaya River and the exact boundary between the sediments is indistinct. The eastern boundary of the study area, which was based on the presence of available well log information, includes most of Evangeline Parish and parts of Iberia, St. Landry, and St. Martin Parishes. The northern boundary of the study area is located in southern Vernon and Rapides Parishes, where the aquifer system and confining units pinch out near the surface. The existence of well logs also defined the northern boundary of the study area.

Previous Investigations

Previous studies have focused on the ground-water resources of southwestern Louisiana and the occurrence of freshwater in the Chicot aquifer system. Jones and others (1956) mapped the depth to the top of first major sands of the Chicot aquifer system using drillers' logs from water wells and electric logs from petroleum-test holes. The authors also presented detailed textural and lithologic descriptions of the confining unit based on formation samples collected from water-well test holes being drilled by municipalities and private interests during the course of the study.

Jones and others (1956) described two areas where the depth to a major sand is less than 50 ft thick. One area is in southern Vernon and Rapides Parishes, where the Chicot aquifer system crops out, and the other follows the course of the Vermilion River through Lafayette, St. Martin, and Vermilion Parishes. The greatest depth to a major sand described by Jones and others (1956) was more than 700 ft in Cameron Parish. Generally, a uniform depth of about 100 ft to a major sand was indicated throughout most of Evangeline, Jefferson Davis, and Acadia Parishes, western St. Landry Parish, and western Vermilion Parish (Jones and others, 1956, p. 139). Confining unit sediments were primarily attributed to Pleistocene-age back-swamp deposits of the Mississippi and Red Rivers (Jones and others, 1956, p. 82), but also may have included younger overburden sediments near the ground surface.

Harder (1960) mapped the top of the Chicot aquifer in Calcasieu Parish and noted that shallow wells in deposits of Holocene age supply small quantities of water. He stated that, "the exact thickness and areal extent of the sand phase of the Holocene deposits has not been determined; consequently, it is difficult to estimate the hydraulic characteristics and potential yield of these deposits." He also noted that locally there are shallow sands of Pleistocene age, which provide small quantities of water for domestic and stock purposes. Drillers' logs, electrical logs, and aquifer tests were the principal bases for determining the top of the Chicot aquifer.

Whitman and Kilburn (1963) examined ground-water conditions in southwestern Louisiana and discussed the Chicot aquifer along the Gulf of Mexico. Well log information from their report was used in the study described in this report. Harder and others (1967) examined the effects of ground-water withdrawals on water levels and saltwater encroachment in southwestern Louisiana and also provided well log information that was used in this study.

Nyman (1984) mapped the top of the major sands of the Chicot aquifer system, although the focus of the report was the occurrence of high-chloride water in the Chicot aquifer system. Geophysical and driller's logs were used to create the maps. Geohydrologic sections across different parts of the study area also are presented in the Nyman report.

Williams and Duex (1995) presented a map of the top of the upper sand of the Chicot aquifer system in Lafayette Parish and two geologic sections through the parish. Well Lf-488, documented previously by Jones and others (1954), was used as a representative correlation log; and information from the logs of approximately 40 petroleum-wells, 40 municipal water-wells, and several private wells were integrated with sand-analysis reports to produce detailed top-of-sand maps for shallow sand units in Lafayette Parish.

Quaternary Deposition

The geomorphic processes of lateral planation and vertical incision by meandering and braided streams, and eustatic changes in sea level over the last 2 million years produced the deposits that make up the Chicot aquifer system (Kniffen and Hilliard, 1988, p. 35). By reviewing the pattern of Quaternary-age deposition in the study area, a foundation is provided to conceptualize the surface of the base of the confining unit.

Over the last 2 million years, continental ice sheets advanced and retreated at least five times. The melting of the ice sheets, which were north of present day Louisiana, produced glacial streams, which carried an abundance of mineral material through Louisiana on their way to the sea. During each ice advance, the sea level declined and streams began to incise channels until the ice retreated and a corresponding rise in sea level occurred. As the shoreline moved inland the incised channels filled with sediment and the pre-existing surface sediments were reworked. The glacial streams deposited more sediment than they removed, so terraces of fine-grained material were formed over time (Kniffen and Hilliard, 1988, p. 41).

Saucier and Snead (1989) delineated three terrace-like Pleistocene-age sedimentary units near the surface: the Upland, Intermediate, and Prairie Complexes. At land surface, these units have an east-to-west orientation, paralleling the Gulf of Mexico coastline. The Upland Complex is the northernmost band in the study area and consists of fluvial deposits from both glacial and non-glacial sources as well as higher fluvial terraces. South of the Upland Complex, the Intermediate Complex is composed of fluvial deposits of the Mississippi River, its tributaries, and coastal plain streams, and includes terrace deposits. The Prairie Complex is nearest to the Gulf of Mexico and includes the results of a diverse depositional sequence of the Mississippi River, its tributaries, and coastal plain streams. Saucier (1994) listed the major depositional environments for the Prairie Complex as meander belt, Red River deltaic, nearshore marine, and undifferentiated coastal plain. The net result of Quaternary-age deposition in southwestern Louisiana is a great variation in sediment size and distribution throughout the area. As a result, the surface representing the base of the confining unit is assumed to be a composite of multiple discontinuities with depressions and ridges, rather than a flat, continuous sheet. Regionally, however, the slope of this surface generally is to the south, following the orientation of the underlying aquifer units and the overlying land surface.

Acknowledgments

The author wishes to thank Flozelle C. Roberts, formerly of the USGS, who assisted in compilation of the well log information, and C. Paul Frederick of the USGS who conducted an initial review of well logs. The Louisiana Department of Natural Resources provided important geophysical information in areas where data were scarce. The author gratefully acknowledges the cooperation of Zahir "Bo" Bolourchi,

Chief of Public Works and Water Resources Division, Louisiana Department of Transportation and Development, for assistance provided during the study and preparation of the report. In addition, Louisiana Department of Transportation and Development provided well-location and well-construction information.

METHODS OF INVESTIGATION

Two sets of data were used in this study. One set included data from geophysical or drillers' logs from selected water wells or test holes. Logs that completely penetrated the confining unit were used to map the thickness of the confining unit and provide information on shallow sands within the confining unit. Data from the 2,098 well logs compiled for this study are presented in a data report by Sargent and others (in press). Well log descriptions, the thickness of the confining unit, and depths to the top and bottom of shallow sands are presented by parish and well identifier in a tabular format. The data report also includes a detailed description of the method used to categorize and compile the log data for this report.

The second set of data included the depth to the base of the screened interval of 1,579 wells, hereinafter referred to as shallow wells, which were screened in the shallow sands and used for domestic, irrigation, or petroleum rig-supply purposes. These data were mapped to indicate the presence of shallow sands. Because shallow wells did not completely penetrate the confining unit or shallow sands within the confining unit, drillers' logs from these wells were not used in this report for mapping the thickness of the confining unit or depths to the top and bottom of shallow sands. Methods used for data compilation, data analysis, and map generation are described in the following sections.

Data Compilation

Drillers' logs and/or geophysical logs with corresponding location information for the well or test hole were compiled into a data set and used to define the depth to the base of the confining unit and identify shallow sands within the unit in southwestern Louisiana. The locations of wells and test holes were obtained as latitude and longitude values from well registration forms. Drillers' logs were available for over 10,000 water wells in the study area. However, the quality and completeness of these logs vary greatly. Drillers collecting lithologic data are mainly concerned with the location of major aquifer units that are capable of supplying long-term yields to wells. When drilling through a thick confining unit, drillers may fail to note lithologic information such as thin sand beds. Therefore, the quality and completeness of each drillers' log was evaluated before it was included in the data set. Drillers' logs that typically used non-geologic terms, such as gumbo or muck, and had lithologic intervals rounded to 100 ft intervals were unacceptable and not used. Drillers' logs that included lithologic descriptions, such as particle size--sand, silt, and clay, with relatively detailed resolution, that is, lithologic intervals rounded to 10 ft intervals or less, were included in the data set.

For water wells for which both a drillers' and geophysical log were available, the driller's and geophysical logs were compared to verify thickness values. In some instances, the geophysical log did not start at the ground surface, and information from both logs was combined to create a composite log. For each location, only one value was designated as the confining unit thickness for that point.

Information from two additional sources also was utilized so that the log data from water-well or test-hole registration forms would not be the sole determinant of confining unit thickness throughout the study area. Geophysical logs from petroleum wells were used in some areas where logs from water wells were sparse or unavailable. Because the first 200 ft below the land surface typically is not logged for petroleum wells, only a small number of these could be used to delineate the thickness of the confining unit. Both drillers' and geophysical log data from published reports also were used. Reports by Jones and others (1956), Harder (1960), Harder and others (1967), Nyman (1984), and Whitman and Kilburn (1963) provided 37, 29, 7, 63, and 4 data points, respectively.

Additional information on the location of shallow sands was obtained from well-screen depths and locational data of 1,579 shallow wells used for domestic, irrigation, or petroleum rig-supply purposes. Screen depths were assumed to indicate the presence of productive shallow sands within the confining unit. This information was obtained from the DOTD well-registration data base. In some instances, a drillers' log may not record the presence of a shallow sand, but a well screened within the confining unit may indicate a shallow sand near that location. The location and depth to bottom of screen of the shallow wells are displayed on maps that also display well logs with shallow sands within the confining unit for comparison purposes. Sand thickness at shallow wells was not assumed equivalent to their screened intervals and was not determined for these wells.

Data Analysis and Map Generation

Depths to the base of the confining unit and shallow sands within the confining unit were determined for each log. The base of the confining unit was identified as the top of first massive sand unit. Massive sand units often were distinguishable not only by thickness, but by coarse basal sediments, which typify sands of the Chicot aquifer system. The thickness of the confining unit was determined by measuring the approximate depth from the ground surface to the top of the massive sand unit. In areas where a massive sand is present within the confining unit, but is directly on top of a Chicot aquifer unit, the thickness was determined from ground surface to the top of the first massive sand. Some previous investigators designated the first sand unit, irregardless as to whether it is a massive sand, as within the confining unit and thus mapped a greater depth to the base of the confining unit.

For example, in Vermilion Parish, a shallow massive sand (formerly called the Abbeville unit) is present within the confining unit (Nyman, 1984, p. 21 and fig. 11). The shallow sand ranges in thickness from 100 to 250 ft and directly overlies what is typically considered the first major aquifer unit of the Chicot aquifer system in this area, the "upper sand" (Nyman, 1984, p. 21 and fig. 11). Because the clay layer separating this sand from the upper sand is thin or missing and this sand is in direct hydraulic communication with the upper sand, the top of this sand was used as the bottom of the clay-confining unit.

Well-log data were grouped by area and the confining unit thickness values were compared for consistency within the area. For instances in which a well log showed an extreme thickness that conflicted with other logs in the same area, the outlier log was deleted from the data set. Although outlier well-log data may be valid, the mapping of local variations in the base of the confining unit, such as those created by the filling of incised channels, was beyond the scope of this report.

The depths to the tops and bottoms of shallow sand units 10 ft or more in thickness were determined from well logs. A shallow sand thickness of at least 10 ft was used to identify possible productive sand units within the confining unit. For each log, the thickness of all shallow sands (10 ft or greater) were totaled and divided by the thickness of the confining unit on the log to determine the percent sand thickness within the confining unit.

All data were entered into a geographic information system (ArcInfo) to analyze the areal distribution of logs and generate maps of the confining unit thickness, the location of wells screened in shallow sands, and the percent sand thickness within the confining unit. To generate the map of confining unit thickness, a statistically-based interpolation method, kriging, was used. Kriging provides an exact interpolation at points where data are provided, is particularly applicable for making estimates where few data points exist, and provides error estimates (Dunlap and Spinazola, 1984, p. 5). The spatial pattern of wells in the study area is such that wells are clustered in some areas, but absent in others. Drilling of new wells was beyond the scope of this study; therefore, kriging was an appropriate interpolation tool for estimating the confining unit thickness in areas were data were sparse or absent.

The thickness of the confining unit was then contoured using a 40-ft contour interval in most areas. In some coastal areas where data were sparse and the confining unit thickens rapidly, an 80-ft contour interval was used. The accuracy of the confining unit thickness contours is a function of the quality and density of the data and the power of the interpolation technique (Burrough and McDonnell, 1998). The estimated error at any point on the thickness map is plus or minus 24 ft.

The locations of wells screened in shallow sands and logs showing the percent sand thickness within the confining unit of individual parishes also were mapped. For mapping purposes, the depth to the base of the well screen was used to indicate the depth of a sand. The base-of-screen depths were grouped in intervals of less than 50 ft, 50 to 100 ft, 100 to 200 ft, and greater than 200 ft. Wells screened in shallow sands often were clustered in population centers. Many of the clustered wells were screened at a similar depth, indicating the presence of a productive sand. In some areas, wells were screened at many different depths, indicating the presence of multiple shallow sands in the area.

The percentage thickness of shallow sands within the confining unit was computed from well logs with a sand interval greater than 10 ft. Where present, percentages were grouped in intervals of 1 to 20, 20 to 40, 40 to 60, 60 to 80, and 80 to 100 percent. Only about 19 percent of the logs indicated shallow sands were present, and the percent sand thickness varied greatly across very short distances. Wells with drillers' log data showing as much as 60 percent sand and shallow wells screened in shallow sands, were often surrounded by wells with drillers' logs that did not encounter sand. These variations may be indicative of the intermittent nature of the shallow sands, but may also illustrate differences in drillers' interpretations that were recorded on logs.

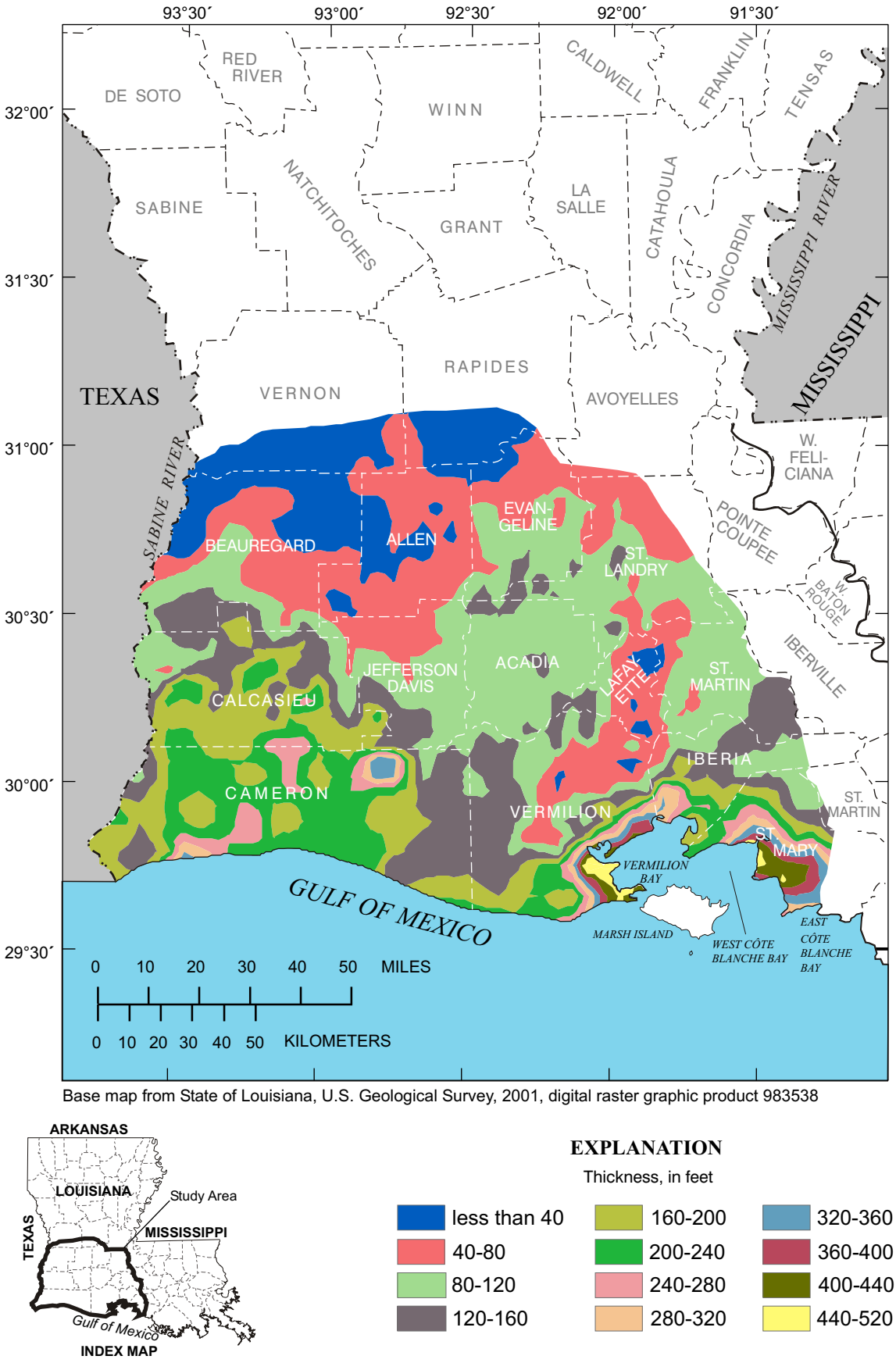
Because of poor areal distribution of well data, the varied quality of the log data, and the intermittent nature of the shallow sands, the areal extents of individual shallow sands could not be mapped. Similarly, the presence or absence of shallow sands could not be inferred for areas where well or log data are sparse or absent.

THICKNESS OF THE CHICOT AQUIFER SYSTEM SURFICIAL CONFINING UNIT

In the study area, the thickness of the Chicot aquifer system surficial confining unit ranges from less than 40 ft along the northern boundary to 520 ft in the southeastern part of the study area, along the Gulf of Mexico (fig. 3). In general, the confining unit thickens southward as its base dips toward the Gulf, conforming to the orientation and dip of the underlying aquifers (Walters, 1996, sheet 1). An exception to the southward thickening occurs in parts of Vermilion and Lafayette Parishes, along the approximate route of the Vermilion River (fig. 1), where the confining unit thins to between 40 and 80 ft thick (fig. 3). This may be evidence of an ancestral Mississippi River floodplain or delta (Kniffen and Hilliard, 1988, map 14). A few miles southeast of this area, the confining unit thickens rapidly to its greatest thickness around the southern part of Vermilion Bay and at points along the coast of East and West Côte Blanche Bays (fig. 3).

LOCATION OF SHALLOW SANDS WITHIN THE SURFICIAL CONFINING UNIT

The presence of shallow sands was documented in 12 of the 15 parishes in the study area. In the remaining three parishes, Vernon, Rapides, and St. Martin Parishes, well-log data indicated no sand intervals greater than 10 ft thick. Table 1 lists descriptive statistics by parish from rural-domestic water-supply wells screened in the shallow sands, including the total number of wells, range of depths to base of well screen, and mean depths to base of well screen. Table 1 also lists descriptive statistics by parish from



Base map from State of Louisiana, U.S. Geological Survey, 2001, digital raster graphic product 983538

Figure 3. Thickness of the Chicot aquifer system surficial confining unit, southwestern Louisiana.

well logs including total number of well logs, percentage of logs with shallow sands (sand intervals 10 ft or greater), the range and mean depths to the base of shallow sand intervals, the range and mean of shallow sand interval thickness, and the range and mean of percent shallow sand thickness of the confining unit.

A generalized east-to-west hydrogeologic section of the Chicot aquifer system surficial confining unit in northern Acadia Parish shows the location of shallow sands and wells screened within the confining unit (fig. 4). If the section is typical of the confining unit, sand and screen data indicate sands generally are not areally extensive, and may occur at various depths. Also, sand units 10 ft or greater in thickness generally constitute a small part of the confining unit. The well logs indicating no sands may be due to the actual absence of sand or the variability of drillers' interpretations of the confining unit sediments. Figures 5 through 16 show locations of well logs and wells screened in shallow sands, and the percent sand thickness within the confining unit in each of the 12 parishes.

Table 1. Descriptive statistics of the depth of wells screened in the Chicot aquifer system surficial confining unit and well logs in southwestern Louisiana

	Wells screened in surficial confining unit			Well logs (drillers' and geophysical)							
		Depth to base of screen			Logs with shallow sands[1]	Depth to base of shallow sands		Thickness of shallow sands		Percentage of shallow sands[2]	
Parish	Total number	Range (feet)	Mean (feet)	Total number of logs	(percent)	Range (feet)	Mean (feet)	Range (feet)	Mean (feet)	Range (feet)	Mean (feet)
Acadia	80	16-103	39	344	9	13-130	67	10-55	23	6-62	21
Allen	6	17-40	27	101	7	15-50	34	10-46	19	15-73	35
Beauregard	63	14-46	34	61	13	26-90	50	10-37	21	8-61	32
Calcasieu	786	4-250	63	242	42	18-247	96	10-110	35	4-71	18
Cameron	101	7-325	127	97	24	24-272	165	15-107	49	5-71	25
Evangeline	42	18-75	35	140	23	15-143	96	10-92	30	7-67	25
Iberia	59	13-270	86	93	19	35-344	116	10-60	19	3-23	12
Jefferson Davis	69	11-210	66	250	13	18-129	80	10-90	34	3-81	34
Lafayette	73	5-116	36	148	14	30-132	71	10-95	23	11-68	26
St. Landry	45	12-110	27	204	18	18-144	85	10-107	39	7-82	36
St. Mary	11	10-326	183	32	19	140-259	170	17-82	38	6-41	18
Vermilion	244	12-350	98	225	27	22-280	99	10-120	37	8-82	32

[1] Percentage of logs with sand intervals of 10 ft or greater.

[2] Percentage of confining unit composed of sand.

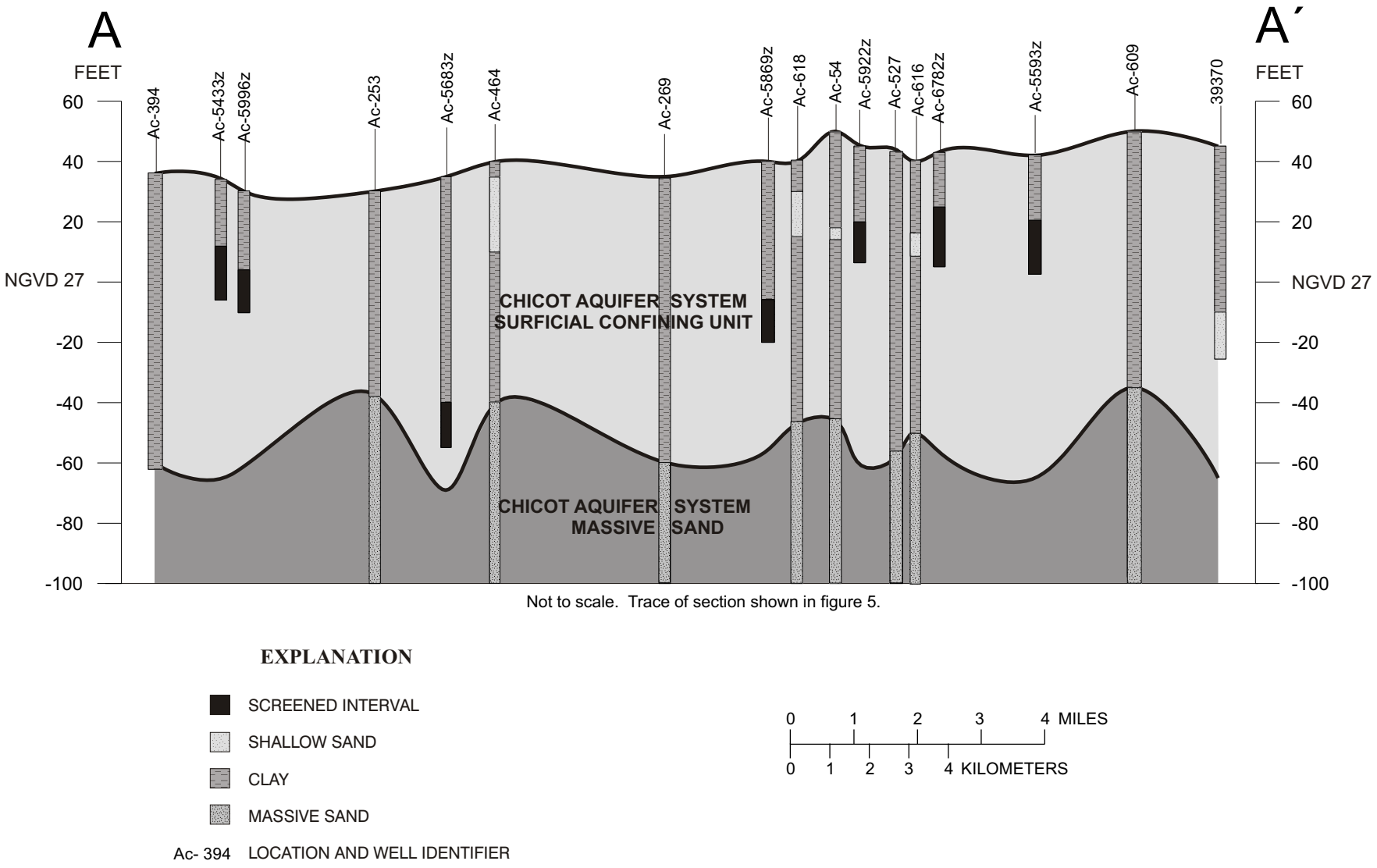


Figure 4. Generalized east-to-west hydrogeologic section in northern Acadia Parish, Louisiana.

In Acadia Parish, wells screened in shallow sands are mostly located in the northern half of the parish and are screened at depths less than 50 ft (fig. 5). Well screen depths range from 16 to 103 ft, with a mean depth of 39 ft (table 1). Five of the 80 wells had screen depths than ranged from 90 to 103 ft; the other 75 wells had screen depths that ranged from 16 to 40 ft. Approximately 9 percent of the 344 selected well logs, which were distributed throughout the parish, showed shallow sands. Well logs showing shallow sands also were mostly in the northern half of the parish.

In Allen Parish, six wells screened in shallow sands are clustered in the Oakdale area. Well screens for all the shallow wells are less than 50 ft deep (fig. 6). Well screen depths range from 17 to 40 ft, with a mean depth of 27 ft (table 1). Of 101 well logs distributed throughout the parish, only 7 percent had shallow sands. These well logs appear to be randomly distributed throughout the parish.

In Beauregard Parish, wells screened in shallow sands are clustered in the DeRidder area. Well screens for all the shallow wells are less than 50 ft deep (fig. 7). Well screen depths range from 14 to 46 ft, with a mean depth of 34 ft (table 1). Well logs in Beauregard Parish have a dispersed areal distribution. Only eight logs, mostly from wells located in the western half of the parish, indicate that shallow sands are present (fig. 7). The scarcity of shallow wells and well logs with shallow sands may indicate that shallow sands have a limited presence in the confining unit in Beauregard Parish.

In Calcasieu Parish, shallow wells screened in shallow sands are located throughout the parish. Well screens for the shallow wells vary in depth from less than 50 ft to greater than 200 ft in depth (fig. 8). Well screen depths range from 4 to 250 ft, with a mean depth of 63 ft (table 1). Fifty-five percent of the wells screened in shallow sands are screened at depths less that 50 ft, but there also are many wells screened between 50 and 200 ft (fig 8). Well logs showing shallow sands in Calcasieu Parish follow the areal distribution of the shallow wells - grouped in a line along the western border, clustered in the east-central part of the parish and scattered elsewhere. Of all of the parishes in the study area, Calcasieu Parish had the greatest percentage (42 percent) of logs showing shallow sands.

In Cameron Parish, shallow wells screened in shallow sands are located along the southern and northern border of the parish. Well screens for the shallow wells vary in depth from less than 50 ft to greater than 200 ft in depth (fig. 9). Well screen depth ranges from 7 to 325 ft with a mean depth of 127 ft (table 1). Well logs showing shallow sands generally are located near shallow wells screened in shallow sands. Few well logs and shallow wells are present in an east-to-west band through the middle of the parish, and it is not known whether shallow sands are present in this area.

In Evangeline Parish, wells screened in shallow sands are located in the southern half of the parish. Well screens for the shallow wells vary in depth from less than 50 ft to 100 ft in depth (fig. 10). Well screen depths range from 18 to 75 ft, with a mean depth of 35 ft (table 1). Most of the well logs with shallow sands also are located in the southern part of the parish. Few well logs and the absence of wells screened in shallow sands in the northern half of the parish indicate few shallow sands are present in that area.

In Iberia Parish, wells screened in shallow sands mostly are located in the western half of the parish. Eastern Iberia Parish is swampy and relatively uninhabited, so there are few rural domestic water-supply wells or well logs. Well screens for the shallow wells vary in depth from less than 50 ft to greater than 200 ft (fig. 11). Well screen depths range from 13 to 270 ft, with a mean depth of 86 ft. Well logs showing shallow sands often were located near shallow wells.

In Jefferson Davis Parish, wells screened in shallow sands are located along the southern, southwestern, and eastern borders of the parish and are absent from the south-central and northern parts of the parish. Well screens for the shallow wells vary in depth from less than 50 ft to greater than 200 ft (fig. 12). Well screen

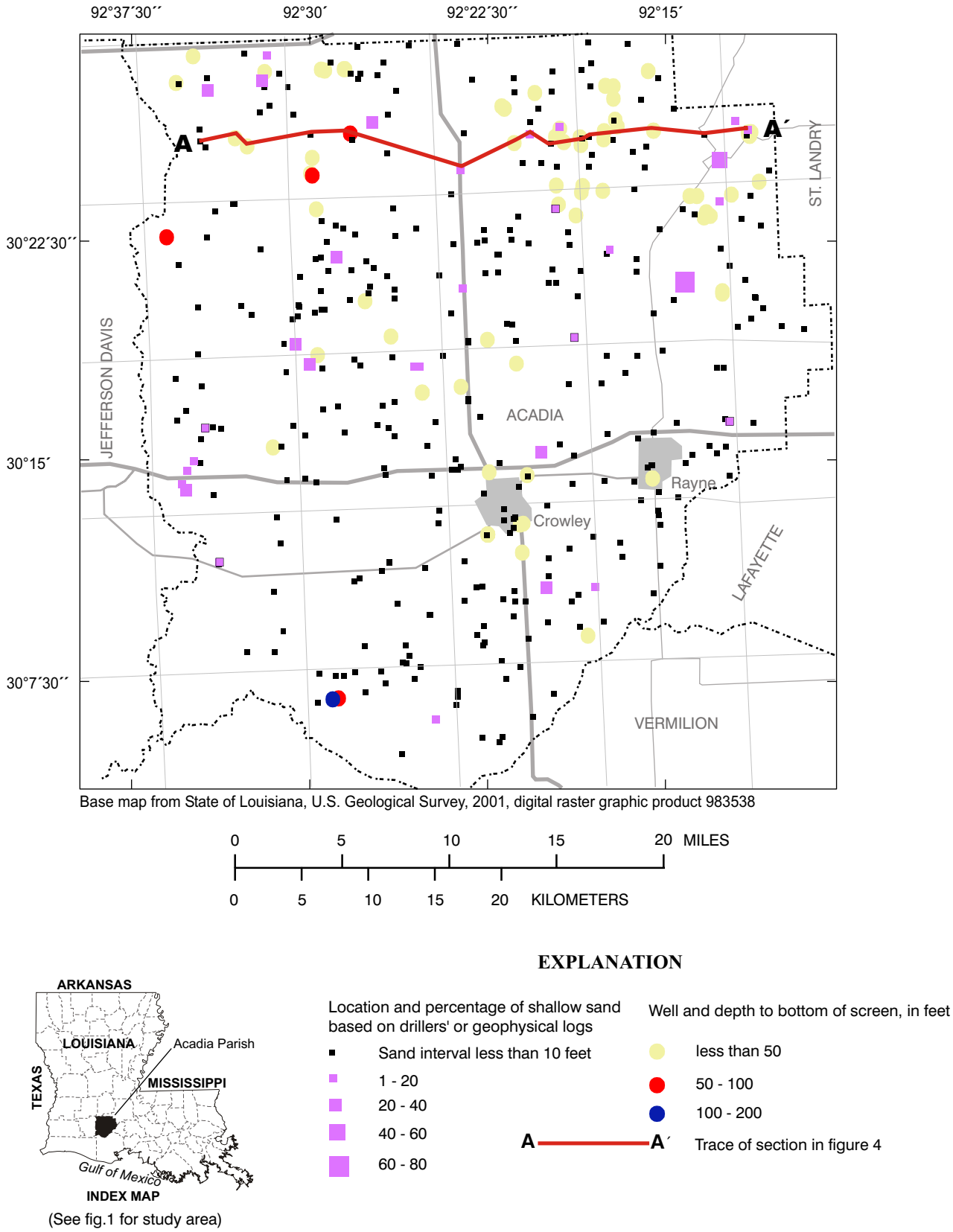


Figure 5. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Acadia Parish, southwestern Louisiana.

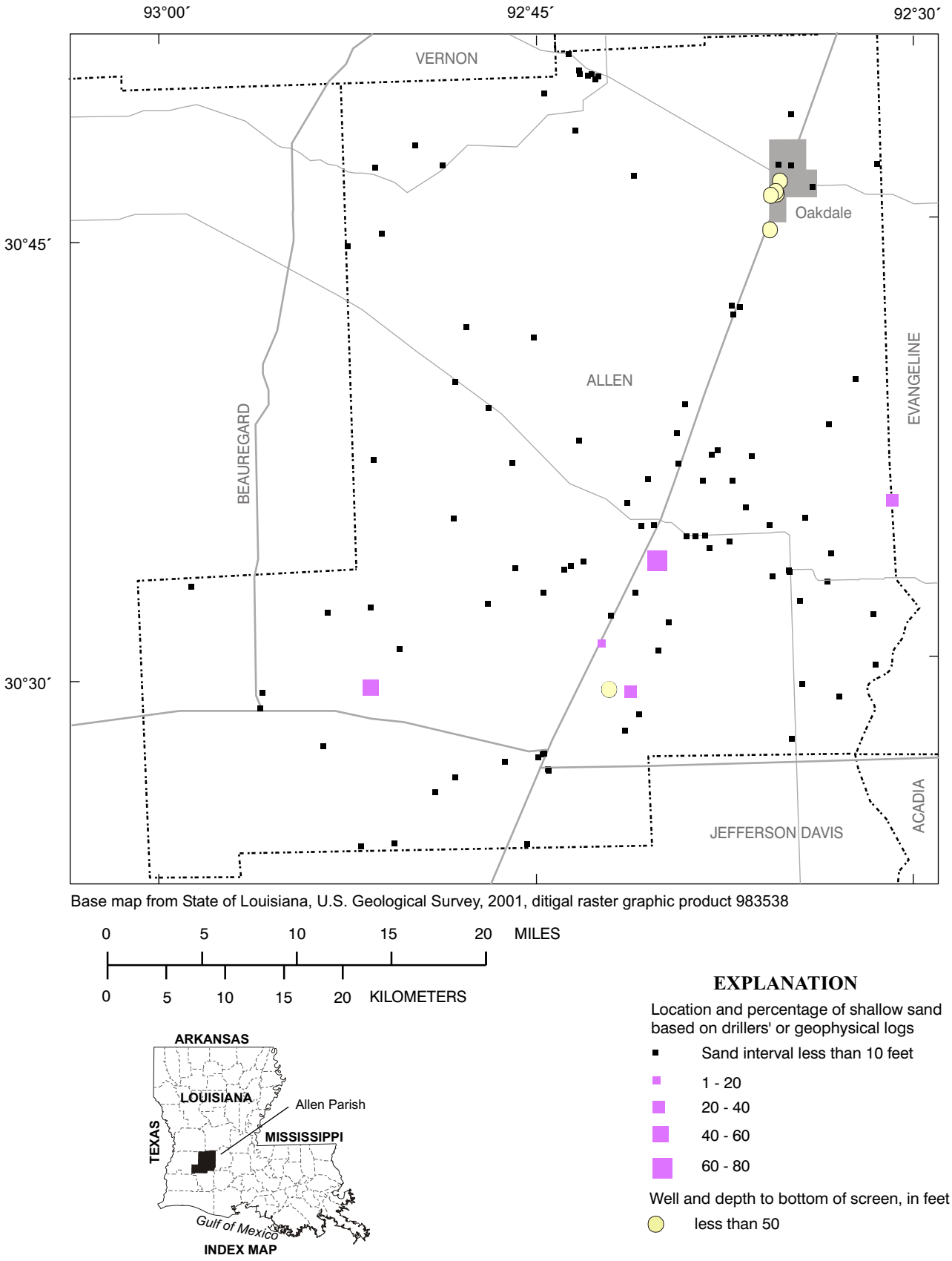


Figure 6. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Allen Parish, southwestern Louisiana.

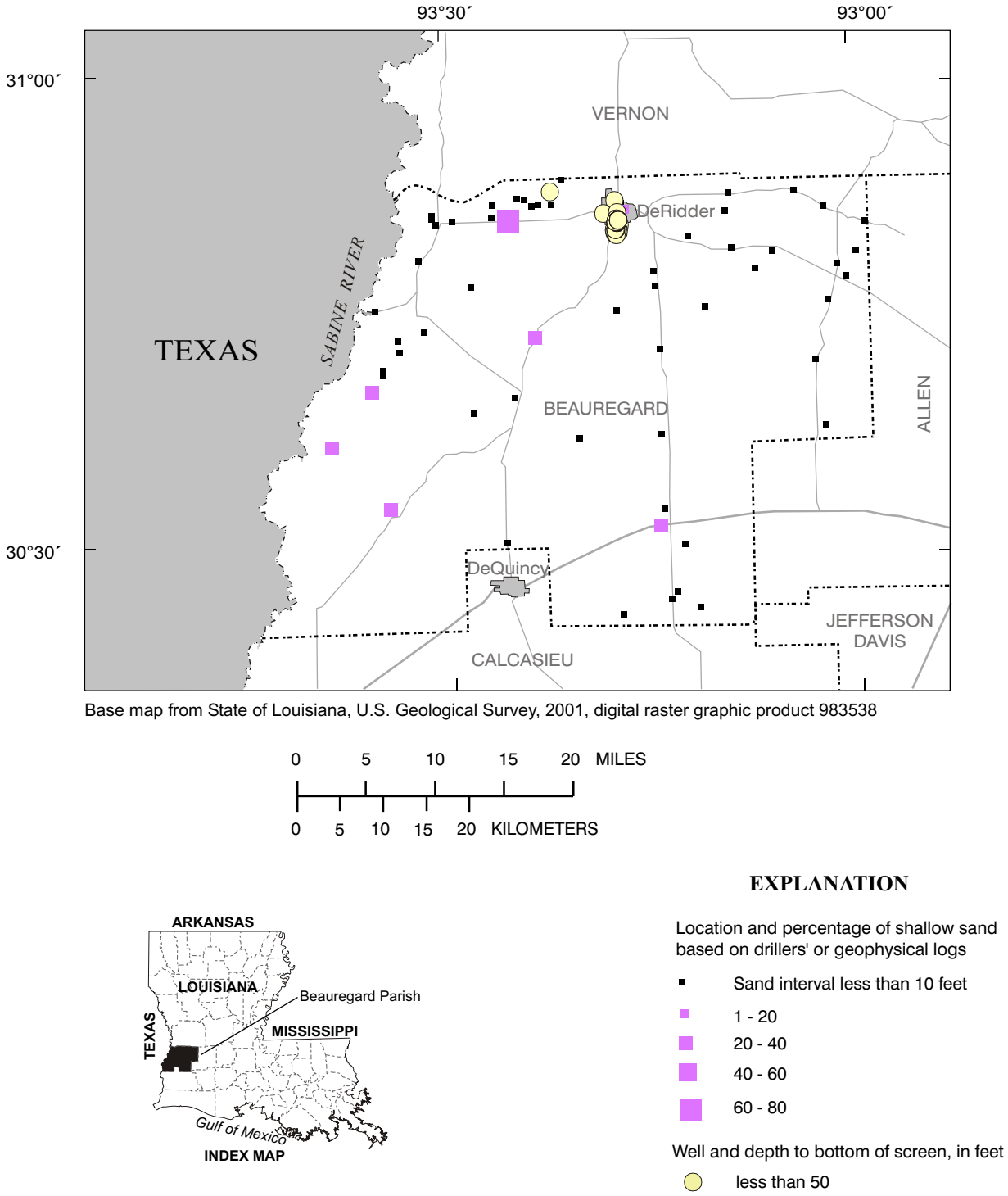


Figure 7. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Beauregard Parish, southwestern Louisiana.

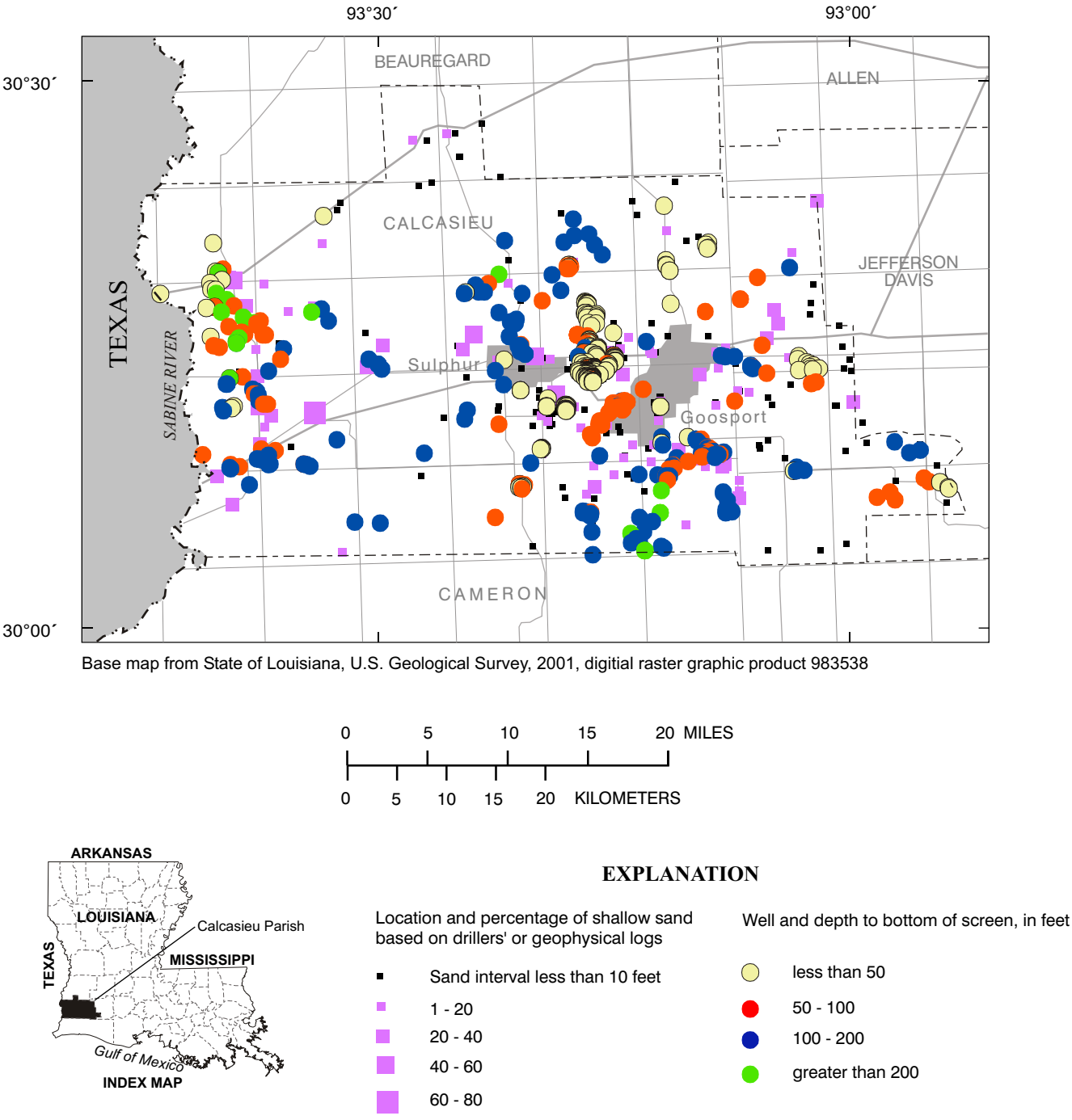


Figure 8. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Calcasieu Parish, southwestern Louisiana.

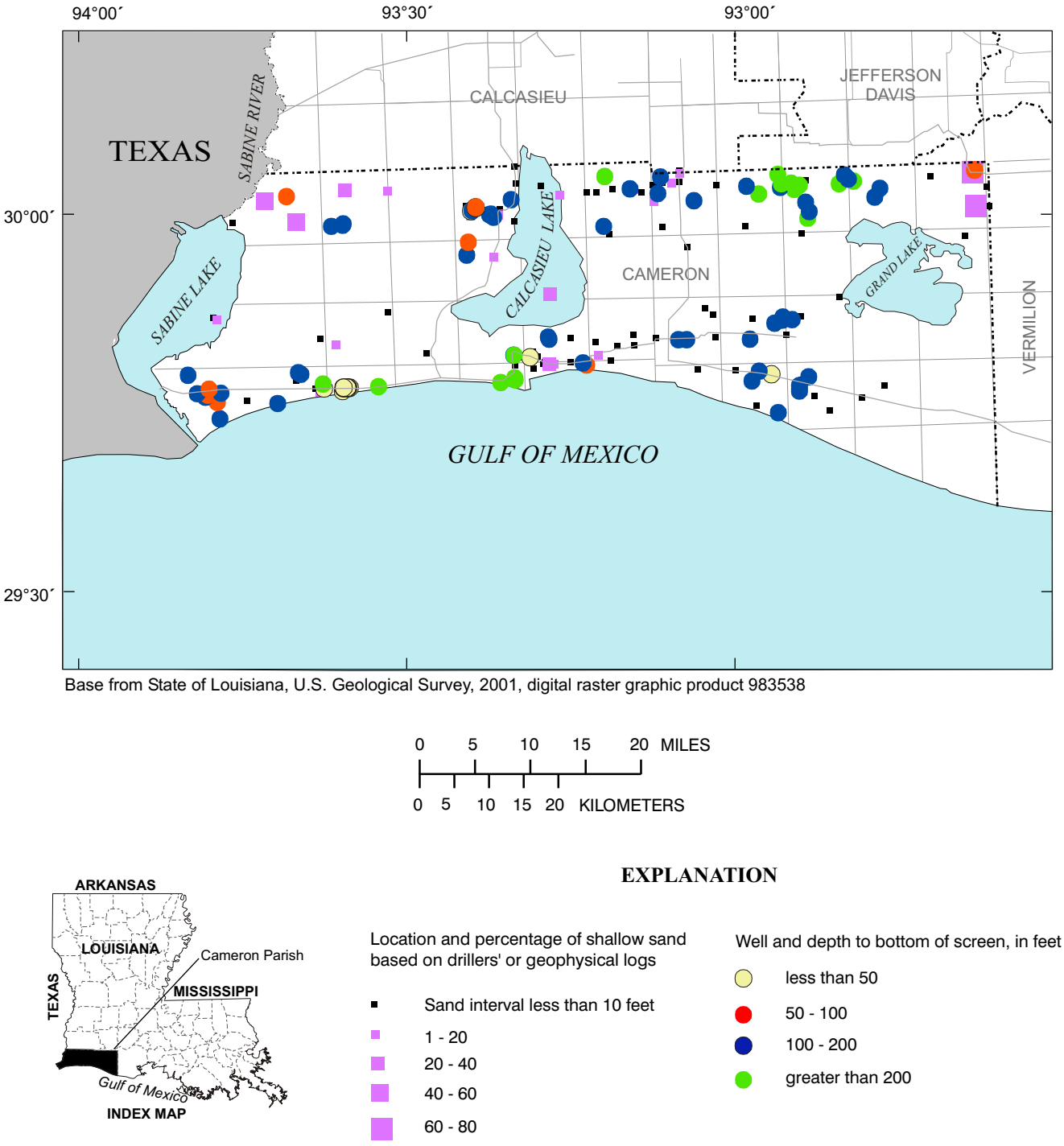


Figure 9. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Cameron Parish, southwestern Louisiana.

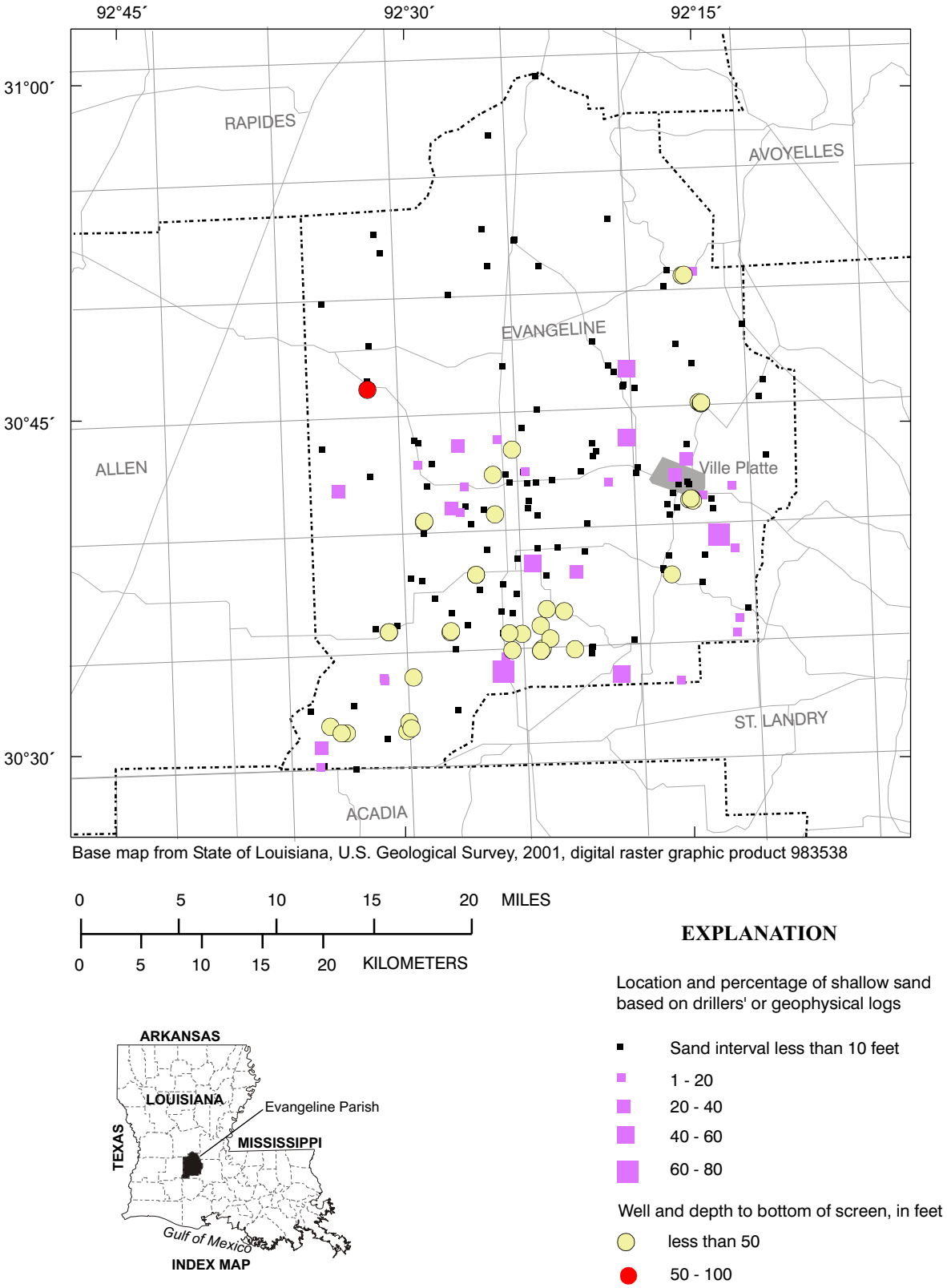


Figure 10. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Evangeline Parish, southwestern Louisiana.

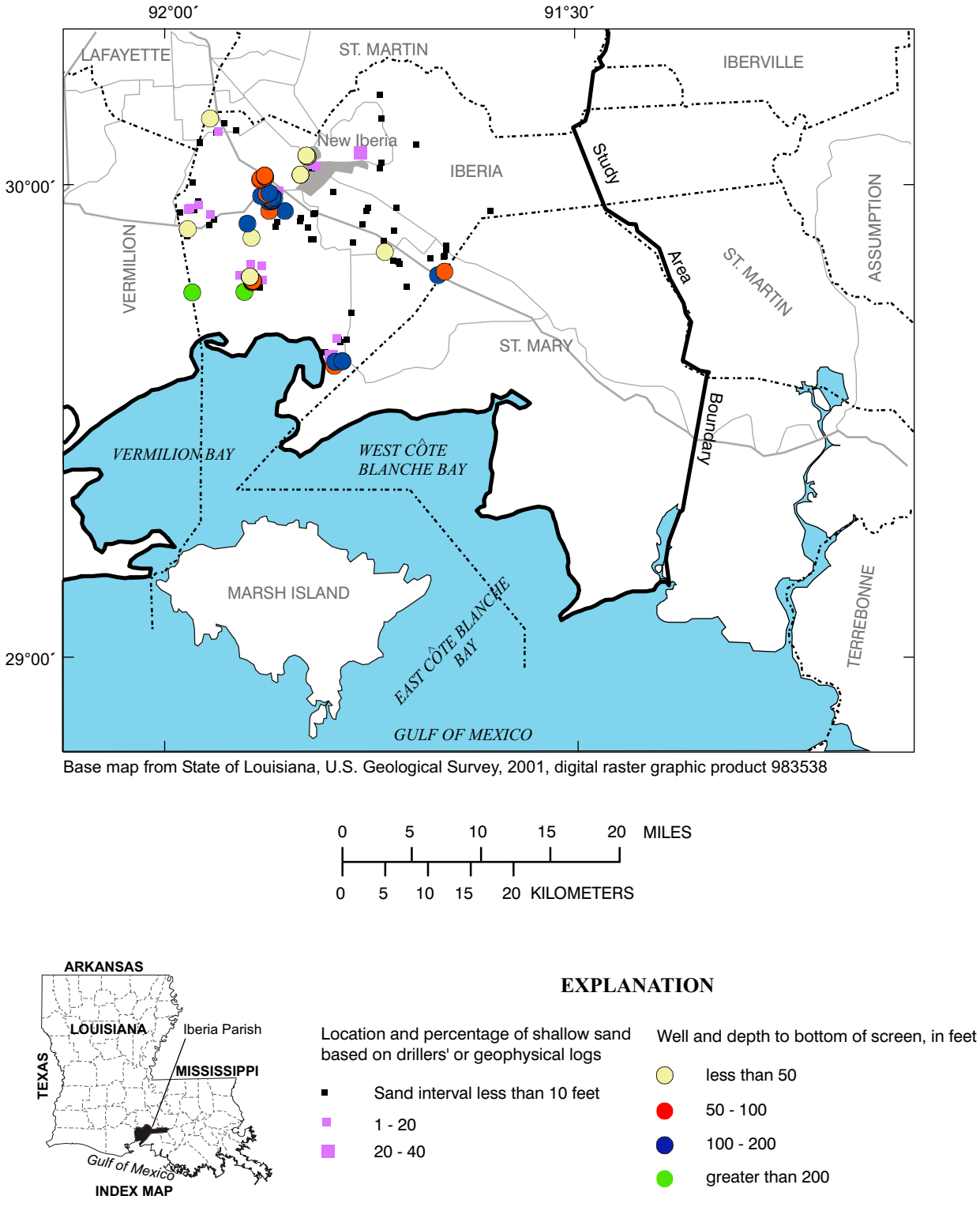


Figure 11. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Iberia Parish, southwestern Louisiana.

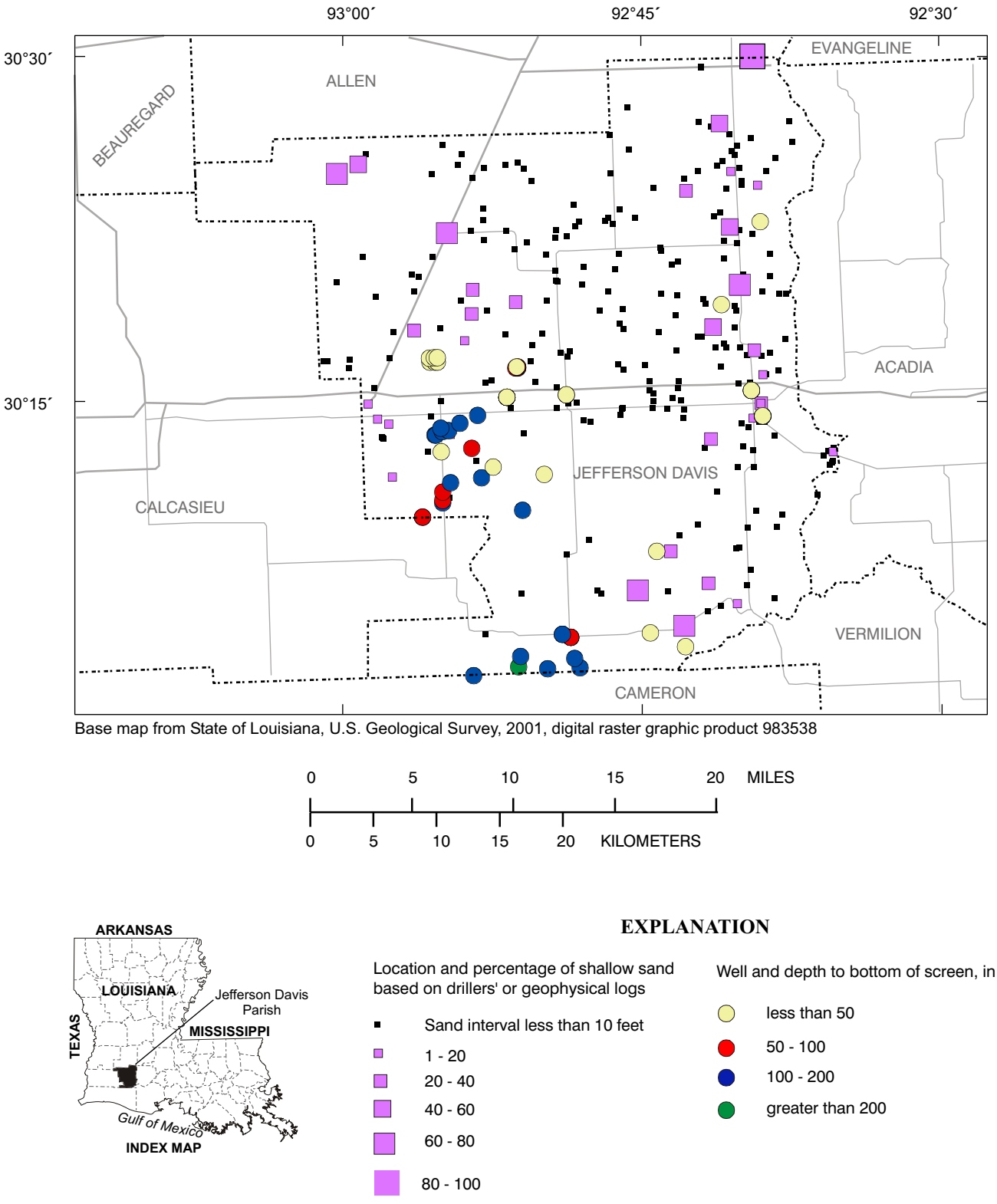


Figure 12. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Jefferson Davis Parish, southwestern Louisiana.

depths range from 11 to 210 ft, with a mean depth of 66 ft (table 1). Well logs showing shallow sands generally are located along the eastern and southern boundaries and in the northwestern corner of the parish. Shallow sands were notably absent on logs from the central and north-central parts of the parish.

In Lafayette Parish, wells screened in shallow sands are at depths less than 50 ft in the eastern and central parts of the parish, but are mostly screened between 50 and 100 ft in the western part of the parish (fig. 13). Two wells show a screen depth in the 100 to 200 ft range. Well screen depths range from 5 to 116 ft, with a mean depth of 36 ft (table 1). Well logs were evenly distributed throughout the parish, but generally only showed shallow sands in the southeastern and western parts of the parish.

In St. Landry Parish, wells screened in shallow sands are generally located in the southwestern part of the parish. Well screens for the shallow wells vary in depth from less than 50 ft to 200 ft (fig. 14). Well screen depths range from 12 to 110 ft, with a mean depth of 27 ft (table 1). Well logs are evenly distributed throughout the parish, but generally shallow sands only are evident in the western half of the parish. The logs indicate that percentage of the confining unit composed of shallow sands is highest in St. Landry Parish and averages about 36 percent (table 1).

In St. Mary Parish, wells screened in shallow sands are located in that part of the parish which is in the study area, the western half. Well screens for the shallow wells vary in depth from less than 50 ft to greater than 200 ft (fig. 15). Well screen depths range from less than 10 to 326 ft, with a mean depth of 183 ft (table 1). Little fresh ground water is available in the southern parts of St. Mary Parish (Harder and others, 1967, pl. 5), so rural domestic water-supply and petroleum rig-supply wells are generally located in the western half of the parish. Well logs that showed shallow sands generally are located in the northwestern part of the parish.

In Vermilion Parish, wells screened in shallow sands are mostly located in the eastern part of the parish. Well screens for the shallow wells vary in depth from less than 50 ft to greater than 200 ft (fig. 16). Well screen depths range from 12 to 350 ft, with a mean depth of 98 ft (table 1). Because much of western and southern Vermilion Parish is marshy and uninhabited, most wells and well logs are located in the northeastern part of the parish (fig. 16). Many of the 61 logs indicate that shallow sands compose more than 60 percent of the surficial confining unit in this area.

SUMMARY AND CONCLUSIONS

Southwestern Louisiana is located within the Gulf Coastal Plain physiographic province. The area is underlain by thick multilayered sequences of unconsolidated sedimentary deposits that alternate between gravel, sand, silt, and clay and have a predominant dip to the south. The sand and gravel deposits form productive aquifer units and they, along with adjoining clay and silt deposits, are designated as the Chicot aquifer system. The Chicot aquifer system underlies an area of approximately 9,000 square miles in southwestern Louisiana and is the principal source of fresh ground water in the region. The dense surficial clays that confine the upper sands of the Chicot aquifer system are known as the Chicot aquifer system surficial confining unit.

Although the confining unit may be relatively uniform in composition across large areas, interbedded sands of varied areal extent and thickness are present within the confining unit. These sands are collectively known as the shallow sands of the Chicot aquifer system. The shallow sands occur irregularly throughout the confining unit and may provide sufficient water for small-diameter wells that supply water for domestic, irrigation, or petroleum rig-supply purposes.

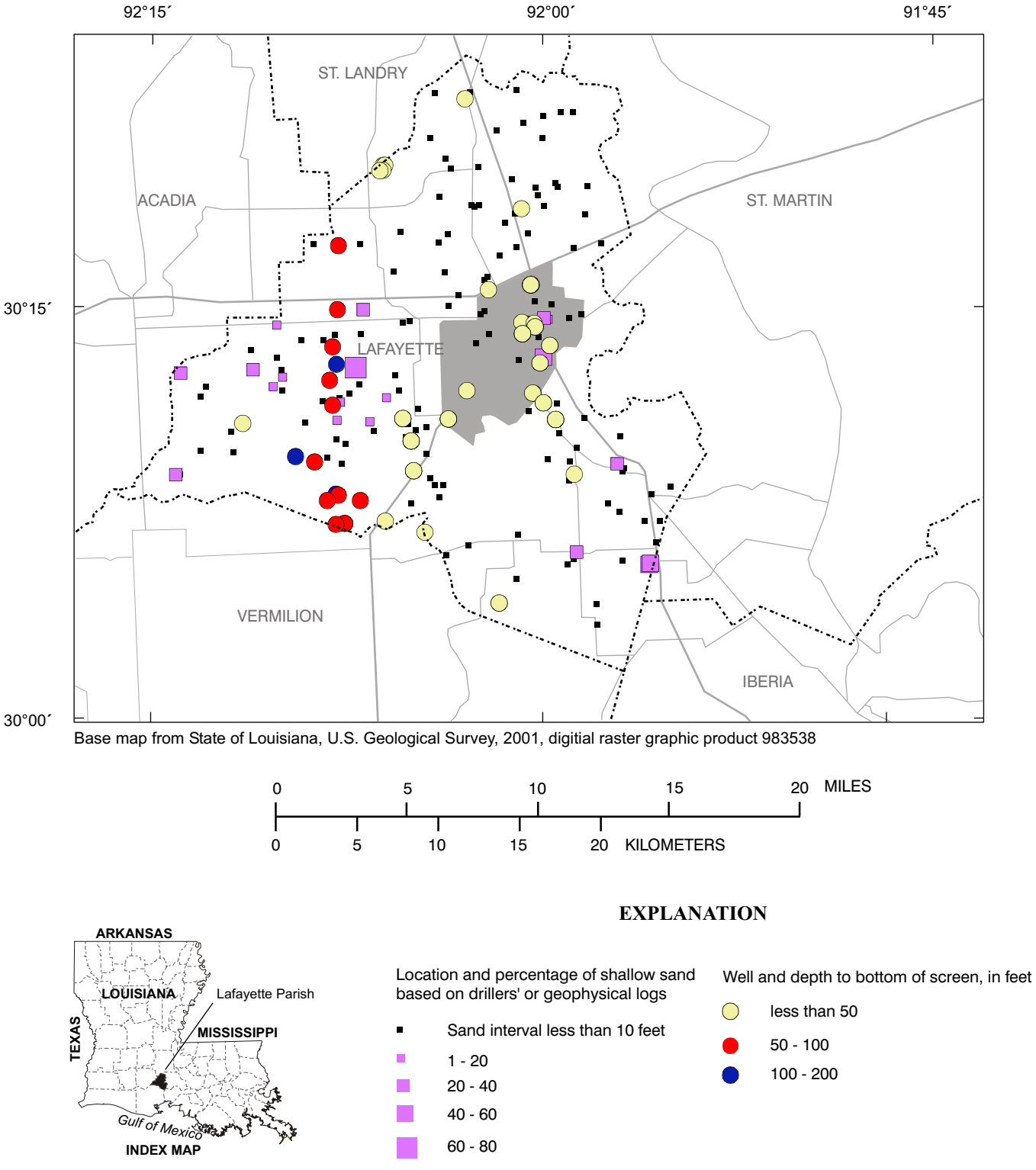


Figure 13. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Lafayette Parish, southwestern Louisiana.

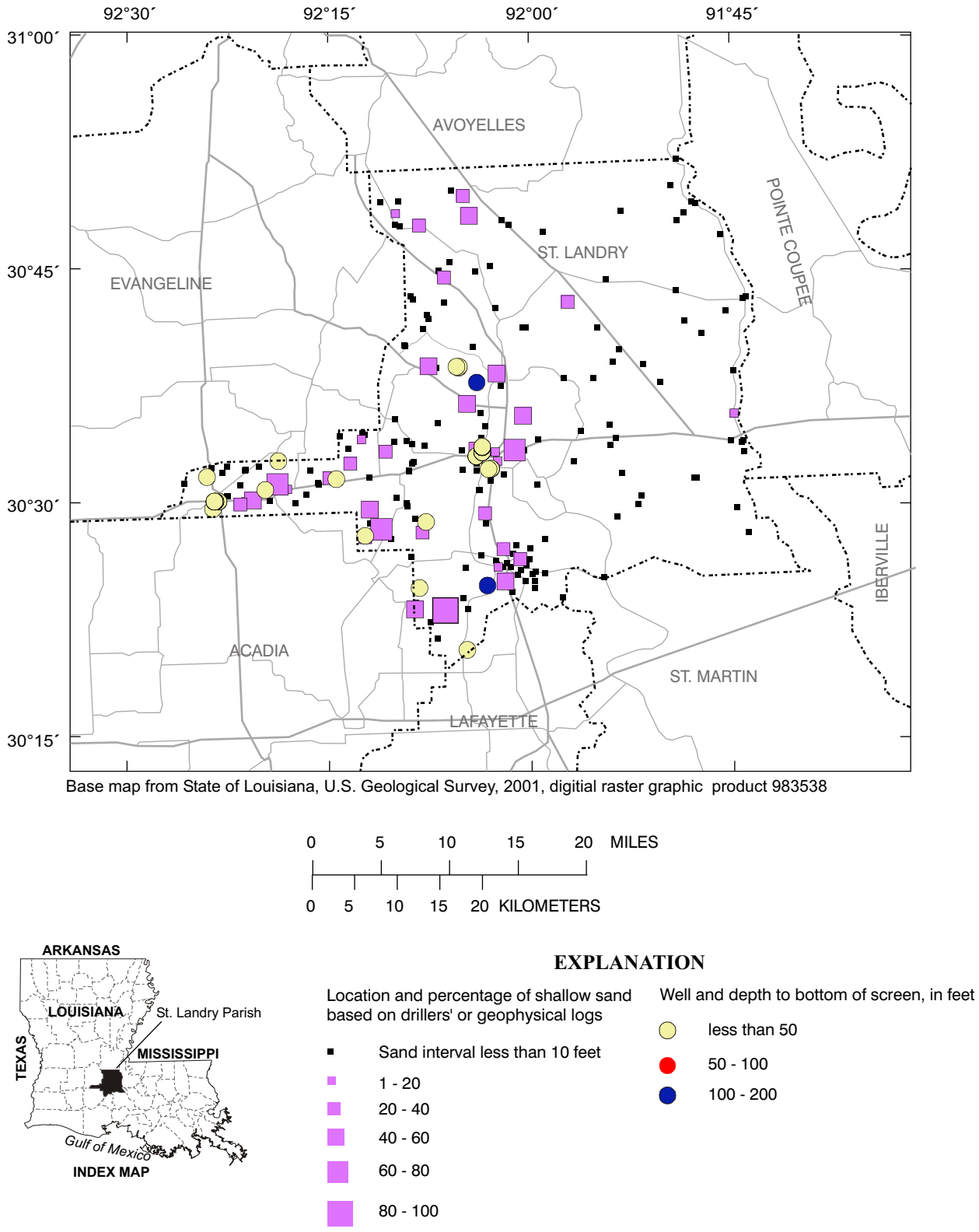


Figure 14. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in St. Landry Parish, southwestern Louisiana.

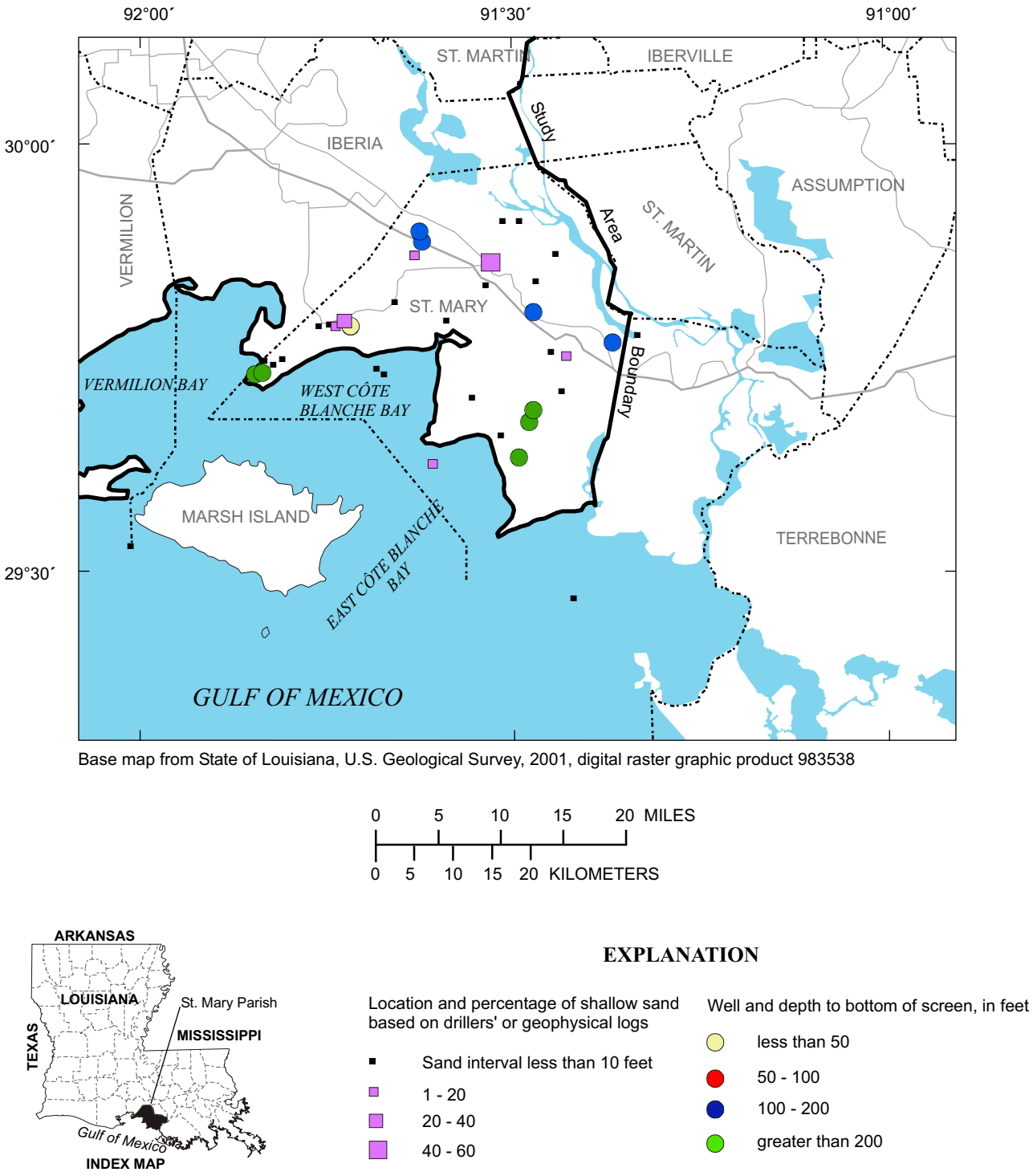


Figure 15. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in St. Mary Parish, southwestern Louisiana.

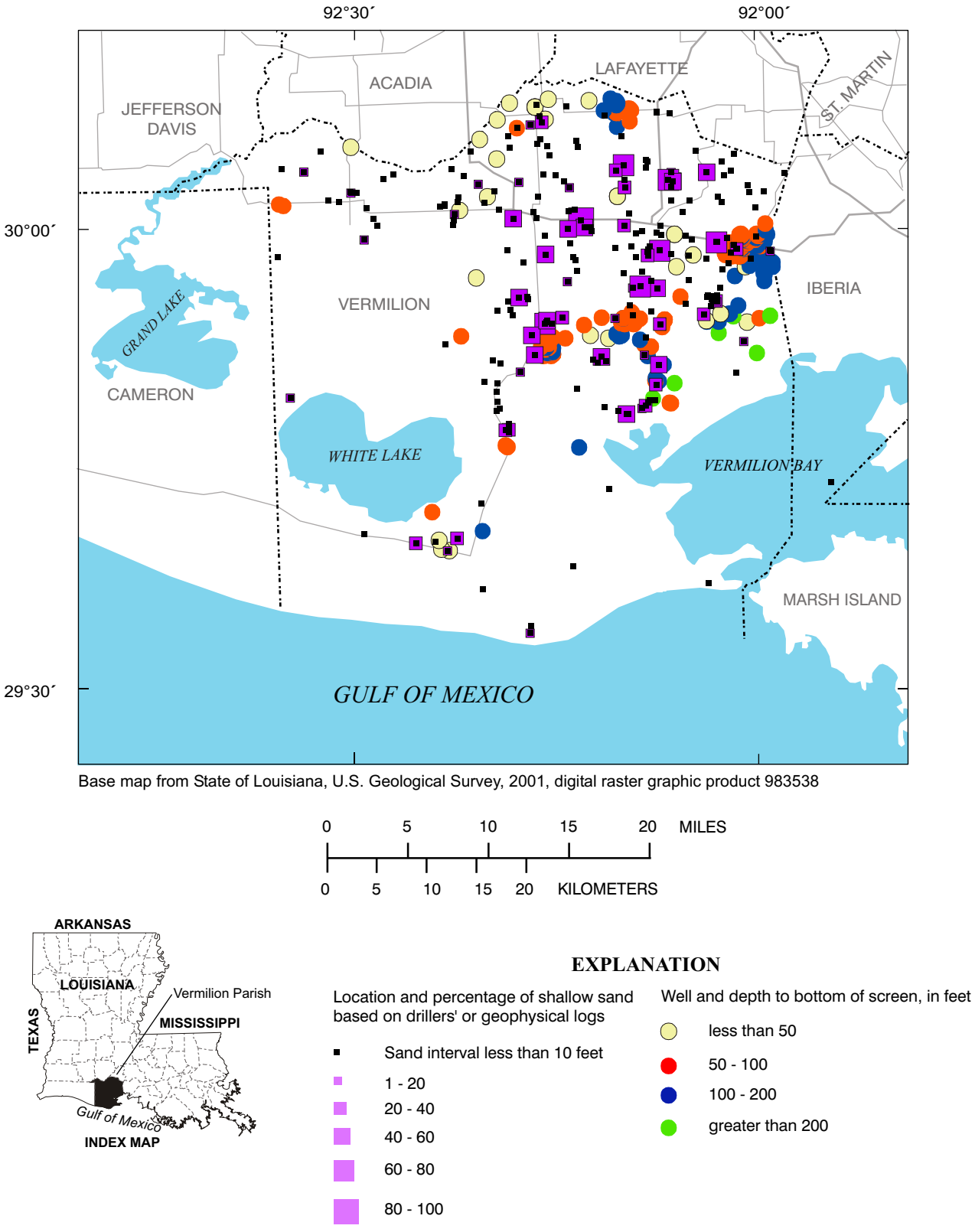


Figure 16. Location of bottom of well screens and well logs with percentage of shallow sand within the Chicot aquifer system surficial confining unit in Vermilion Parish, southwestern Louisiana.

Drillers' logs, geophysical logs, and information from shallow wells were used to define the thickness of the confining unit and locate areas of shallow sands. The thickness of the surficial confining unit generally increases from north to south. In southern Vernon and Rapides Parishes, where the Chicot aquifer system crops out, the confining unit typically is less than 40 feet thick. The thickness of the confining unit generally increases southward, and generally ranges in thickness from 160 to 400 feet in coastal parishes with a maximum thickness of about 520 feet in Vermilion and St. Mary Parishes. Because the quality of the drillers' logs varies, an analytical methodology was developed to identify the best drillers' logs and integrate higher-quality information from other sources, such as published reports.

The presence of shallow sands was documented in 12 of the 15 parishes in the study area. Well-log data from Vernon, Rapides, and St. Martin Parishes showed no shallow sands greater than 10 ft in thickness. Location and depth information of water-supply wells screened in shallow sands within the confining unit complemented the well log information with respect to the areal distribution of shallow sands. The screen depths ranged from 4 to 350 ft, and the maximum mean screen depth in a parish was 183 ft. Well location and depth to bottom of screen of the wells were mapped for the 12 parishes where shallow sands are present. The location of well logs with greater than a 10 ft sand interval and the percent shallow sand within the confining unit also were mapped for the 12 parishes in the study area. The locations of wells screened within the surficial confining unit and drillers' or geophysical logs showing shallow sands greater than 10 feet thick are mapped for 12 of the 15 parishes in the study area. The percentage of shallow-sand thickness in the confining unit is indicated for each log. Well-screen depths of 1,579 shallow wells used for domestic, irrigation, or petroleum rig-supply purposes were assumed to indicate the presence of productive shallow sands within the confining unit; however, only about 19 percent of the 2,098 logs analyzed indicate that shallow sands are present. The logs also indicate that the percentage of shallow-sand thickness in the confining unit can vary greatly across very short distances.

SELECTED REFERENCES

Alley, W.M., 1993, Geostatistical models, *in* Alley, W.M., ed., Regional ground-water quality: New York, VanNostrand Reinhold, p. 87-108.

Environmental Systems Research Institute, 2001, ARC/INFO Release 8.1: Redlands, Calif.

Battaglin, W.A., Ulery, R.L., and Vowinkel, E.F., 1989, Method of simulating water-table altitudes from stream and drainage-basin locations by use of a geographic information system, *in* Mallard, G.E., and Ragone, S.E., eds., U.S. Geological Survey Toxic Substances Hydrology Program – Proceedings of the technical meeting, Phoenix, Az., Sept. 26-30, 1988: U.S. Geological Survey Water-Resources Investigations Report 88-4220, p. 531-539.

Burrough, P.A., and McDonnell, R.A., 1998, Principles of geographical information systems: Oxford, Great Britian, Oxford University Press, p. 31-161.

Darling, M.E., and Hubbard, L.E., 1989, Application of a geographic information system for regridding a ground-water flow model of the Columbia Plateau regional aquifer system, Walla Walla River Basin, Oregon-Washington: U.S. Geological Survey Water-Resources Investigations Report 89-4179, p. 23.

Davis, J.C., 1973, Statistics and data analysis in Geology: New York, John Wiley and Sons, p. 381-390.

Delhomme, J.P., 1978, Kriging in the hydrosciences: Advances in Water Resources, v. 1, no. 5, p. 251-266.

Dunlap, L.E., and Spinazola, J.M., 1984, Interpolating water-table altitudes in west-central Kansas using kriging techniques, 1984: U.S. Geological Survey Water-Supply Paper 2238, p. 1-19.

Frink, J.W., 1940, Subsurface Pleistocene of Louisiana: Louisiana Department of Conservation, Geological Bulletin no. 19, p. 367-419.

Hanor, J.S., 1993, Effective hydraulic conductivity of fractured clay beds at a hazardous waste landfill, Louisiana Gulf Coast: Water Resources Research, v. 29, no. 11, p. 3, 691-3, 698.

Hanson, R.T., 1996, Postaudit of head and transmissivity estimates and ground-water flow models of Avra Valley, Arizona: U.S. Geological Survey Water-Resources Investigations Report 96-4045, p. 84.

Harder, A.H., 1960, The geology and ground-water resources of Calcasieu Parish, Louisiana: U.S. Geological Survey Water-Supply Paper 1488, 102 p.

Harder, A.H., Kilburn, Chabot, Whitman, H.M., and Rogers, S.M., 1967, Effects of ground-water withdrawals on water levels and saltwater encroachment in southwestern Louisiana: Department of Conservation, Louisiana Geological Survey, and Louisiana Department of Public Works Water Resources Bulletin no. 10, 56 p.

Holland, W.C., Hough, L.W., and Murray, G.E., 1952, Geology of Beauregard and Allen Parishes: Louisiana Department of Conservation and Louisiana Geological Survey, Geological Bulletin no. 27, 224 p.

Howe, H.V., Russel, R.J., McGuirt, J.H., Craft, B.C., and Stephenson, M.B., 1935, Reports on the Geology of Cameron and Vermilion Parishes: Louisiana Department of Conservation and Louisiana Geological Survey, Geological Bulletin no. 6, 242 p.

Jenks, G.F., 1963, Generalization in statistical mapping: Annuals of the Association of American Geographers, v. 53, p. 15-26.

Jones, P.H., Turcan, A.N., Jr., and Skibitzke, H.E., 1954, Geology and ground-water resources of southwestern Louisiana: Louisiana Department of Conservation Bulletin no. 30, p. 285.

Jones, P.H., Hendricks, E.L., Irelan, Burdge, and others, 1956, Water resources of southwestern Louisiana: U.S. Geological Survey Water-Supply Paper 1364, 460 p.

Kniffen, F.B. and Hilliard, S.B., 1988, Louisiana, its land and people: Baton Rouge, La., Louisiana State University Press, 213 p.

Lovelace, J.K, 1991, Water use in Louisiana, 1990: Louisiana Department of Transportation and Development Water Resources Special Report no. 6, 131 p.

Lovelace, J.K, 1999, Distribution of saltwater in the Chicot aquifer system of southwestern Louisiana, 1995-96: Louisiana Department of Transportation and Development Water Resources Technical Report no. 66, 61 p.

Lovelace, J.K., and Lovelace, W.M., 1995, Hydrogeologic unit nomenclature and computer codes for aquifers and confining units in Louisiana: Louisiana Department of Transportation and Development Water Resources Special Report no. 9, 12 p.

Meyer, R.R., 1953, Summary of ground-water conditions in southwestern Louisiana: U.S. Geological Survey Open-File Report, 7 p.

Nyman, D.J., 1984, The occurrence of high concentrations of chloride in the Chicot aquifer system of southwestern Louisiana: Louisiana Department of Transportation and Development, Office of Public Works Water Resources Technical Report no. 33, 75 p.

Nyman, D.J., 1989, Quality of water in freshwater aquifers in southwestern Louisiana: Louisiana Department of Transportation and Development Water Resources Technical Report no. 42, 22 p.

Nyman, D.J., Halford, K.J., and Martin, Angel, Jr., 1990, Geohydrology and simulation of flow in the Chicot aquifer system of southwestern Louisiana: Louisiana Department of Transportation and Development Water Resources Technical Report no. 50, 58 p.

Puente, C.E., and Bras, R.L., 1986, Disjunctive kriging, universal kriging, or no kriging--small sample results with simulated fields: Mathematical Geology, v. 18, no. 3, p. 287-305.

Sargent, B.P., 2002, Water use in Louisiana, 2000: Louisiana Department of Transportation and Development Water Resources Special Report no. 15, 133 p.

Sargent, B.P., Frederick, C.P., Roberts, F.C., 2004, Thickness data for the Chicot aquifer system surficial confining unit: Louisiana Department of Transportation and Development Water Resources Basic Records Report no. 22, 91 p.

Saucier, R.T., 1994, Geomorphology and Quaternary geologic history of the Lower Mississippi Valley: U.S. Army Corps of Engineers, v. 1, 364 p.

Saucier, R.T., and Snead, J.I., comps., 1989, Quaternary geology of the Lower Mississippi Valley: Baton Rouge, La., Louisiana Geological Survey, 2 sheets.

Smoot, C.W., 1986, Areal extent of freshwater in major aquifers in Louisiana: U.S. Geological Survey Water-Resources Investigations Report 86-4150, 1 sheet.

Sophocleous, M.A., Paschetto, J.E., and Olea, R.A., 1982, Ground-water network design for northwest Kansas, using the theory of regionalized variables: Ground Water, v. 20, no. 1, p. 48-58.

Spruill, T.B., and Candela, Lucila, 1990, Two approaches to design of monitoring networks: Ground Water, v. 28, no. 3, p. 430-432.

Stanley, T.B., Jr., and Maher, J.C., 1944, Ground-water resources of Jefferson Davis and Acadia Parishes, Louisiana: Louisiana Department of Public Works, 93 p.

Stuart, C.G., Knochenmus, Darwin, and McGee, B.D., 1994, Guide to Louisiana's ground-water resources: U.S. Geological Survey Water-Resources Investigations Report 94-4085, 55 p.

Trudeau, D.A., 1994, Geohydrology and the occurrence of selected chemical contaminants at a hazardous-waste disposal site, Calcasieu Parish, Louisiana, 1984-85: Louisiana Department of Transportation and Development, Water Resources Technical Report no. 53, 54 p.

U.S. Geological Survey, 1985, National water summary 1984: United States Geological Survey Water-Supply Paper 2275, p. 229.

Varvaro, G.G., 1957, Geology of Evangeline and St. Landry Parishes, Louisiana Department of Conservation and the Louisiana Geological Survey, Geological Bulletin no. 31, p. 295.

Walters, D.J., 1996, Louisiana ground-water map no. 11: Potentiometric surface, 1991, and water-level changes, 1985-91, of the Chicot aquifer system in southwestern Louisiana: U.S. Geological Survey Water-Resources Investigations Report 95-4044, 2 sheets.

Whitman, H.M., and Kilburn, Chabot, 1963, Ground-water conditions in southwestern Louisiana, 1961 and 1962, with a discussion of the Chicot aquifer in the coastal area: Department of Conservation, Louisiana Geological Survey, and Louisiana Department of Public Works Water Resources Pamphlet no.12, 32 p.

Williams, C.B., and Duex, T.W, 1995, A hydrogeologic study of the Chicot aquifer in Lafayette Parish, Louisiana: Gulf Coast Association of Geological Societies Transactions, v. XLV, p. 165 - 172.