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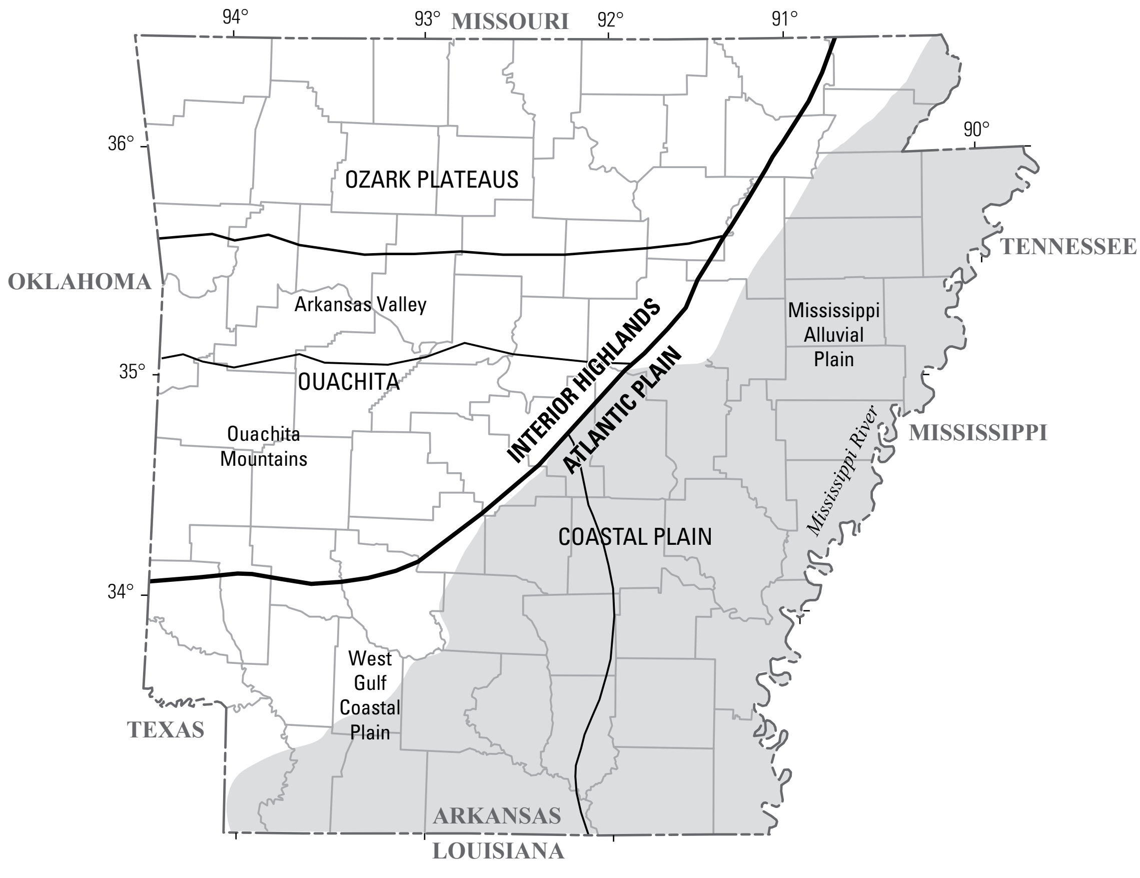
Water Levels and Water Quality in the Sparta-Memphis Aquifer (Middle Claiborne Aquifer) in Arkansas, Spring–Summer 2011



Scientific Investigations Report 2014–5044

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

U.S. Geological Survey
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U.S. Geological Survey, Reston, Virginia: 2014

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Contents

Plates

[In pocket]

Figures

Tables

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.029329	cubic meter (m^3)
	Flow rate	
foot per year (ft/yr)	0.3048	meter per year (m/yr)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

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

°F=(1.8×°C)+32

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

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

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

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

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Water Levels and Water Quality in the Sparta-Memphis Aquifer (Middle Claiborne Aquifer) in Arkansas, Spring–Summer 2011

By T.P. Schrader

Abstract

The U.S. Geological Survey, in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey, has monitored water levels in the Sparta Sand of Claiborne Group and Memphis Sand of Claiborne Group (herein referred to as "the Sparta Sand" and "the Memphis Sand," respectively) since the 1920s. Groundwater withdrawals have increased while water levels have declined since monitoring was initiated. Herein, aquifers in the Sparta Sand and Memphis Sand will be referred to as "the Sparta-Memphis aquifer" throughout Arkansas. During the spring of 2011, 291 water levels were measured in wells completed in the Sparta-Memphis aquifer and used to produce a regional potentiometric-surface map. During the summer of 2011, groundwater-quality samples were collected and measured from 61 wells for specific conductance, pH, and temperature.

In the northern half of Arkansas, the regional direction of groundwater flow in the Sparta-Memphis aquifer is generally to the south-southeast and flows east and south in the southern half of Arkansas. The groundwater in the southern half of Arkansas flows away from the outcrop area except where affected by large depressions in the potentiometric surface. The highest and lowest water-level altitudes measured in the Sparta-Memphis aquifer were 326 feet above and 120 feet below National Geodetic Vertical Datum of 1929 (NGVD 29), respectively.

Five depressions are located in the following counties: Arkansas, Cleveland, Jefferson, Lincoln, and Prairie; Union; Cross, Poinsett, St. Francis, and Woodruff; Columbia; and Bradley. Two large depressions, centered in Jefferson and Union Counties, are the result of large withdrawals for industrial, irrigation, or public supply. The depression centered in Jefferson County has expanded in recent years into Arkansas and Prairie Counties as a result of large withdrawals for irrigation and public supply. The lowest water-level altitude measured in this depression is approximately 20 feet (ft) higher in 2011 than in 2009. The area enclosed within the 40-ft contour on the 2011 potentiometric-surface map has decreased in area, shifting north in Lincoln County and west in Arkansas County when compared with the 2009 potentiometric-surface map.

The depression in Union County is roughly circular within the -60-ft contour. The lowest water-level altitude measurement was 157 ft below NGVD 29 in 2009, with a 37-ft rise to 120 ft below NGVD 29 in 2011. The depression in Union County has diminished and encloses a smaller area than in recent years. In 1993, the -60-ft contour enclosed 632 square miles (mi^2). In 2011, the -60-ft contour enclosed 375 mi^2, a decrease of 41 percent from 1993. The lowest water-level altitude measurement during 2011 in the center of the depression in Union County represents a rise of 79 ft since 2003. The area enclosed by the lowest altitude contour, 120 ft below NGVD 29, on the 2011 potentiometric-surface map is less than 10 percent of the area enclosed by that same contour on the 2009 potentiometric-surface map.

A broad depression in western Poinsett and Cross Counties was first shown in the 1995 potentiometric-surface map. In 2011, the lowest water-level altitude measurement in this depression, 129 ft above NGVD 29, is 2 ft lower than in 2009. The 140-ft contour has extended southwest into northwestern St. Francis and east-central Woodruff Counties in 2011. In Columbia County in 2011, the area of the depression has decreased, with water levels rising about 1 ft since 2005 in the well with the lowest water-level altitude measurement. The depression in Bradley County in 2011 has decreased in area compared to 2007.

A water-level difference map was constructed using the difference between water-level measurements made during 2007 and 2011 at 247 wells. The differences in water level between 2007 and 2011 ranged from -17.3 to 45.4 ft, with a mean of 4.1 ft. Water levels generally declined in the northern half of the study area and generally increased in the southern half of the study area. Areas with a general decline in water levels include Lonoke and western Prairie Counties; northern Arkansas County; Miller County; and Craighead, Poinsett, Cross, and Woodruff Counties. Areas with a general rise in water levels include Lafayette, Columbia, Union, Calhoun, and Bradley Counties; Grant, Jefferson, southern Arkansas, Lincoln, Drew, and Desha Counties; and Phillips County.

Hydrographs from 183 wells with a minimum of 25 years of water-level measurements were constructed. During the period 1987–2011, county mean annual water levels generally declined. Mean annual declines were between 0.5 foot per year (ft/yr) and 0.0 ft/yr in Ashley, Chicot, Crittenden, Drew, Grant, Jefferson, Lafayette, Mississippi, Monroe, Ouachita, Phillips, Pulaski, St. Francis, and Woodruff Counties. Mean annual declines were between 1.0 ft/yr and 0.5 ft/yr in Bradley, Calhoun, Cleveland, Craighead, Cross, Desha, Lonoke, Miller, Poinsett, and Prairie Counties. Mean annual declines were between 1.5 ft/yr and 1.0 ft/yr in Arkansas, Lee, and Lincoln Counties. The county mean annual water level rose in Columbia, Dallas, and Union Counties about 0.3 ft/yr, 0.1 ft/yr, and 1.2 ft/yr, respectively.

Water samples were collected in the summer of 2011 from 61 wells completed in the Sparta-Memphis aquifer and measured onsite for specific conductance, temperature, and pH. Although there is a regional increase in specific conductance to the east and south, anomalous increases occur in some parts of the study area. Specific conductance ranged from 35 microsiemens per centimeter (µS/cm) in Ouachita County to 1,380 µS/cm in Monroe County. Relatively large specific conductance values (greater than 700 µS/cm) occur in samples from wells in Arkansas, Ashley, Clay, Monroe, Phillips, and Union Counties.

Introduction

The U.S. Geological Survey (USGS), in cooperation with the Arkansas Natural Resources Commission (ANRC) and the Arkansas Geological Survey, has monitored water levels in the Sparta Sand of Claiborne Group and Memphis Sand of Claiborne Group (herein referred to as "the Sparta Sand" and "the Memphis Sand," respectively) since the 1920s. Groundwater withdrawals generally have increased while water levels generally have declined since monitoring was initiated. Since 1980, the USGS has produced reports, at various intervals, that describe groundwater conditions in the Sparta Sand and Memphis Sand aquifers in Arkansas. These reports are the products of a continuing project that includes the USGS groundwater monitoring effort for the State of Arkansas to provide information for management of this valuable resource.

The study area (fig. 1) in Arkansas is bounded on the north by the Missouri State line, on the east by the Tennessee and Mississippi State lines, and on the south by the Louisiana State line. The western boundary is defined as the western extent of the outcrop and subcrop (Hosman, 1982) of the Sparta Sand and the Memphis Sand. The Sparta Sand and Memphis Sand underlie the physiographic provinces of the Mississippi Alluvial Plain and the West Gulf Coastal Plain of

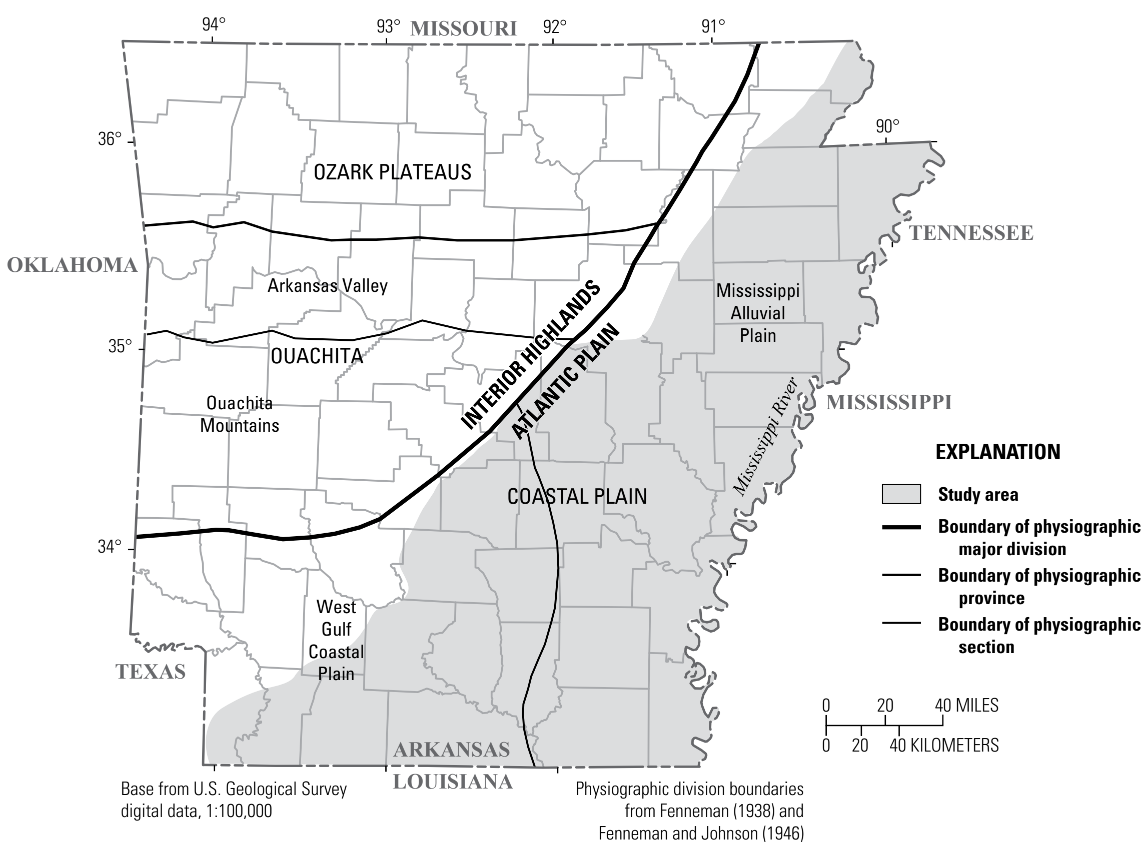

Figure 1. Location of study area.

the Coastal Plain physiographic division (Fenneman, 1938; Fenneman and Johnson, 1946). The Sparta Sand and Memphis Sand (Eocene) are a sequence of alternating marine and continental deposits (Hosman and Weiss, 1991). Water levels in the aquifer in the Sparta Sand generally correlate with those in the aquifer in the Memphis Sand; therefore, the water-bearing formations are considered to be one hydrologic unit (Stanton, 1997).

Purpose and Scope

This report presents water-level and water-quality conditions in the aquifers in the Sparta Sand and the Memphis Sand in Arkansas. Herein, aquifers in the Sparta Sand and Memphis Sand will be referred to as “the Sparta-Memphis aquifer.” Groundwater levels were measured in the spring of 2011 in 291 wells completed in the Sparta-Memphis aquifer. These measurements were used to describe the potentiometric surface of the Sparta-Memphis aquifer. During the summer of 2011, groundwater-quality samples were collected and measured from 61 wells for specific conductance, pH, and temperature. Information in this report includes (1) groundwater levels for spring 2011, (2) a potentiometric-surface map, (3) a water-level difference map comparing water levels from 2007 to 2011, (4) selected water-level hydrographs, and (5) a groundwater-quality data table for samples collected in the summer of 2011.

Water Use

Water use in the Sparta-Memphis aquifer in Arkansas generally increased from 1965 to 2000 (fig. 2). In 1965, water use in the Sparta-Memphis aquifer was about 112 million gallons per day (Mgal/d), increasing to 142 Mgal/d in 1970, 144 Mgal/d in 1975, and 185 Mgal/d in 1980 (Halberg and Stephens, 1966; Halberg, 1972, 1977; Holland and Ludwig, 1981). In 1985, water use declined to about 157 Mgal/d (Holland, 1987). Water use in the Sparta-Memphis aquifer was about 223 Mgal/d in 1990 and 284 Mgal/d in 1995 (Holland, 1993, 1999). In 2000, water use in the Sparta-Memphis aquifer was about 287 Mgal/d (Holland, 2004), an increase of about 156 percent from 1965. In 2005, water use in the Sparta-Memphis aquifer declined to about 170 Mgal/d (Holland, 2007).

The majority of water used from the Sparta-Memphis aquifer in 2005 was shared among three primary categories—irrigation, public supply, and industrial. Irrigation used about 61.0 Mgal/d (35.9 percent), public supply used about 58.9 Mgal/d (34.6 percent), and industrial used about 48.0 Mgal/d (28.2 percent). Agriculture and power generation each accounted for less than 1 percent of the water use in the Sparta-Memphis aquifer in Arkansas in 2005. The agriculture category includes all farm use except domestic use for a home and irrigation. Major pumping centers that use the Sparta-Memphis aquifer for public supply and industry

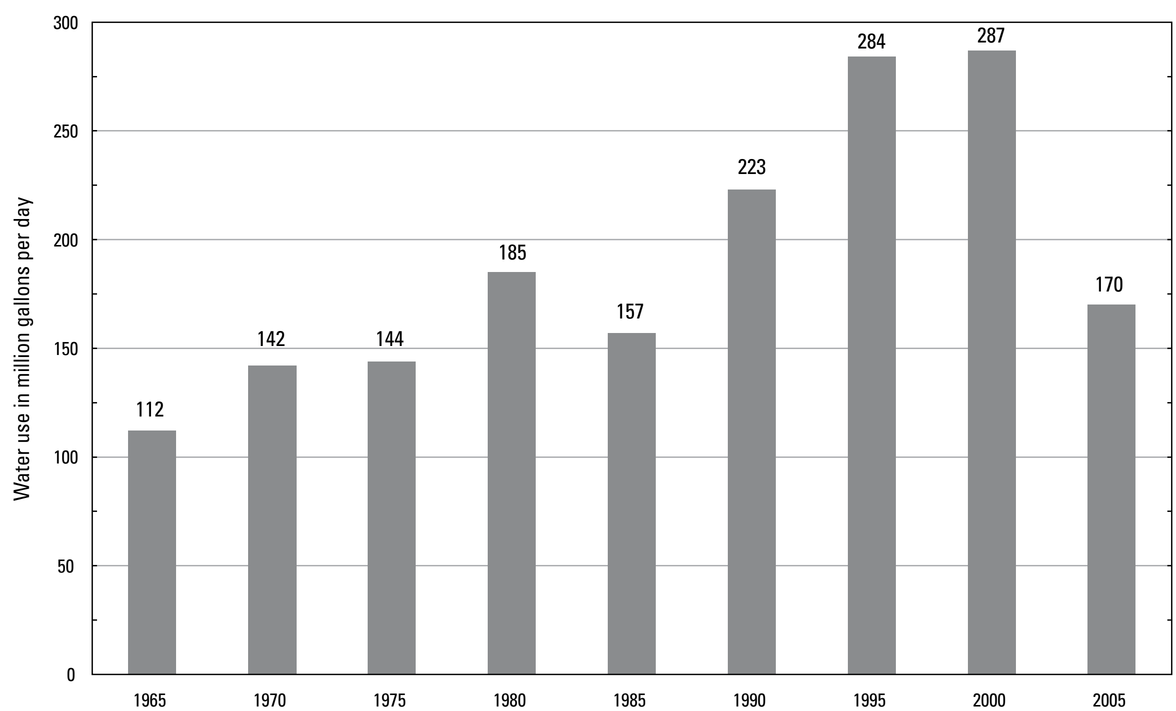

Figure 2. Water use in the Sparta-Memphis aquifer in Arkansas, 1965–2005.

occur in Columbia, Jefferson, and Union Counties. Arkansas, Craighead, Cross, Desha, Lonoke, Monroe, Phillips, and Prairie Counties accounted for the majority of the water withdrawn for irrigation from the Sparta-Memphis aquifer in 2005 (Holland, 2007).

Well-Numbering System

The well-numbering system used in this report is based upon the Public Land Survey System used in Arkansas. The component parts of a well number are the township designation; the range designation; the section number; three-letter designation that indicates, respectively, the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section in which the well is located; and the sequence number of the well in the quarter-quarter-quarter section. The letters are assigned counterclockwise, beginning with "A" in the northeast quarter or quarter-quarter or quarter-quarter-quarter section in which the well is located. For example, well 01S03W04BBD16 (fig. 3) is located in Township 1 South, Range 3 West, in the southeast quarter of the northwest quarter of the northwest quarter of section 4. This well is the 16th well in this quarter-quarter-quarter section of section 4 from which data were collected.

Methods

Water levels were measured by USGS and ANRC personnel from March to May 2011 from wells completed in the Sparta-Memphis aquifer. Measurements were made using steel or electric tapes graduated in hundredths of a foot. Water levels were collected according to USGS procedural documentation (Cunningham and Schalk, 2011). The steel and electric tapes were calibrated prior to collecting water-level measurements. Calibration was performed by comparing the steel or electric tapes to a standardized steel tape used only for calibration. Tape calibrations are performed annually.

Well locations were verified using Global Positioning System (GPS) receivers to acquire the horizontal-coordinate information, latitude and longitude, based on the North American Datum of 1983. The latitude and longitude of the wells in Arkansas were recorded from a GPS receiver accurate to one-tenth of a second of latitude and longitude (approximately 10–20 feet [ft]). The latitude and longitude of each well were transferred to topographic maps and the altitude of each well (National Geodetic Vertical Datum of 1929 [NGVD 29]) was determined from the topographic contours at the location on the map. Altitude is accurate to about 2.5 to 5 ft, or half the contour interval on the map.

Two methods are used for calculating the annual rise or decline of water levels. One method is to take the difference between the final and initial water levels and divide by the period of time. This method uses two measurements, and calculated values are dependent solely on the final and initial water levels. A second method uses the linear regression of water levels and time of measurement to calculate the annual rise or decline of water levels. Linear regression is more robust because all measurments are included to determine the trend line, resulting in a value that is dependent on all water levels during the period of record. The slope, β (equation 1), of the line is the annual rise or decline of water levels. The intercept, β_0, is the water level in the year 1900, the origin for the graph. The predevelopment water level will not be discussed as this condition cannot be demonstrated. The equation of the regression line or line of best fit, Y = aX+b, may be written as:

$$h = \beta t + \beta_0 \tag{1}$$

where

- h is water-level altitude, in feet;
- β is the slope of the line, in feet per year;
- t is time, in years; and
- β_0 is the y-intercept or water-level altitude at time equal to the year 1900.

Five assumptions are associated with linear regression: (1) Y is linearly related to X, (2) data used to fit the linear regression are representative of data of interest, (3) variance of the residuals is constant and does not depend on X or on anything else, (4) the residuals are independent, and (5) the residuals are normally distributed. The assumption of a normal distribution is involved only when testing hypotheses, requiring the residuals from the regression equation to be normally distributed (Helsel and Hirsch, 1992).

The R^2 term is the coefficient of determination, the correlation coefficient, or the fraction of variance explained by the regression. The R^2 value gives the proportions of the total variability that can be accounted by the independent variable (Helsel and Hirsch, 1992). Values of R^2 can range from 0.00 to 1.00. A large value of R^2 can indicate a linear change in water level. A low value of R^2 can indicate a sporadic change in water level.

Water-quality samples were collected for specific conductance, pH, and temperature using the procedures described in the "National Field Manual for the Collection of Water-Quality Data" (U.S. Geological Survey, variously dated). Wells were purged a minimum of three casing volumes, at a pumping rate that ranged from 100 to 500 gallons per minute (Fishman and Friedman, 1989). The purge process is important to obtain a water-quality sample that is representative of the aquifer conditions without the effects of the borehole environment. Casing volumes for the wells were calculated from the well casing diameter, depth to water, and well depth. The cross-sectional area of the casing was calculated from the casing diameter, and the height of the water column was determined by subtracting the depth to water from the well depth. The cross-sectional area and the height of the water column were multiplied for a casing volume in cubic feet and converted to gallons. The calculated purge volume at each well was then divided by the pumping rate to determine the minimum pumping time for purging.

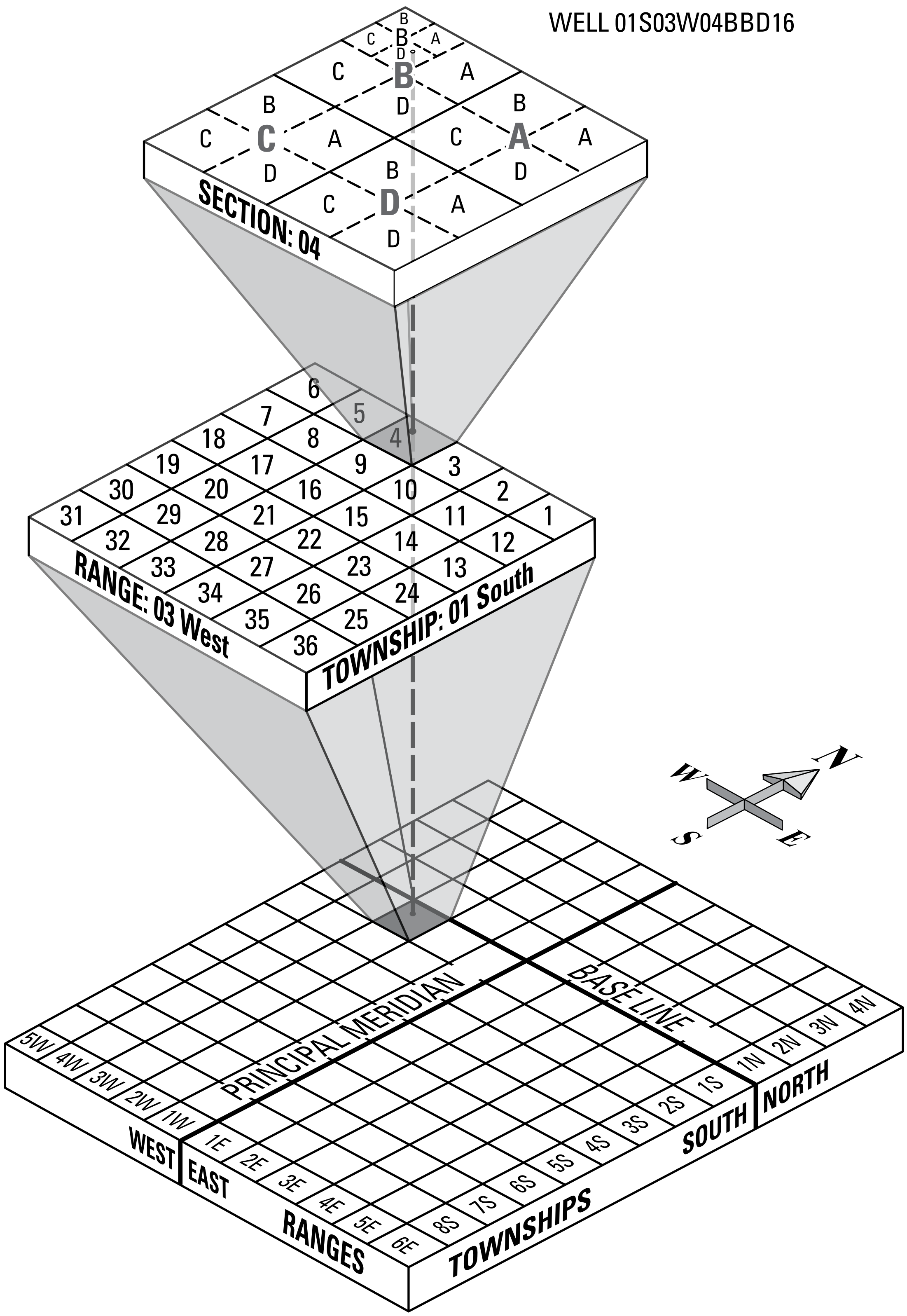

Figure 3. Diagram showing well-numbering system.

During the purge process, specific conductance, pH, and temperature were measured from selected wells until measurements stabilized (Fishman and Friedman, 1989), by using specific-conductance and pH meters with temperature compensation. A field meter was calibrated twice daily by comparing the measurement of two specific conductance and pH calibration standards. Specific conductance is a measure of the electrical conductance of a solution normalized to 25 degrees Celsius (°C), an indicator of the presence of charged ionic species or dissolved solids. As the ion concentration increases in groundwater, the conductivity of the groundwater increases. The pH is a measure of the acidity of the water, an indicator of the hydrogen ion concentration and activity (Hem, 1985).

Sparta-Memphis Aquifer

In Arkansas, the Sparta Sand and Memphis Sand (table 1) of Eocene age mainly consist of fine to medium sand with some silt, clay, and lignite in the upper parts. Sands in the Sparta Sand were deposited by shifting streams on a deltaic-fluvial flood plain (Payne, 1968). These sands mostly are interconnected, but separately identifiable sands can be traced for short distances (Snider and others, 1972). The Cook Mountain Formation of Claiborne Group overlies the Sparta Sand and Memphis Sand and serves as an upper confining unit (table 1). The permeable units of the Sparta Sand and the Memphis Sand compose the Sparta and Memphis aquifers.

The Sparta Sand is composed of a sequence of alternating sand and clay beds between the massive clays of the overlying Cook Mountain Formation and the underlying Cane River Formation of Claiborne Group confining units (Hosman and others, 1968) (table 1). The Sparta Sand is in the southern part of the study area (south of about 35 degrees latitude, pl. 1) where the Cane River Formation is composed predominantly of clay. The Memphis Sand is in the northern part of the study area (north of about 35 degrees latitude) where the Cane River Formation or equivalent facies is composed predominantly of sand. Moving south to north in the area, the Cane River Formation undergoes a facies change northward at about 35 degrees latitude, and the marine clays become sand. The transitional zone of interfingering sands and clays is narrow. The northern sand facies of the Cane River Formation is the middle part of the Memphis Sand (Hosman and others, 1968). In the southern area, the Claiborne Group is subdivided into the Carrizo Sand, Cane River Formation, Sparta Sand, Cook Mountain Formation, and the Cockfield Formation (table 1). The equivalent section in the northern area is subdivided into the Memphis Sand, the Cook Mountain Formation, and the Cockfield Formation. The Memphis Sand in the northern area is equivalent to the Carrizo Sand, the Cane River Formation, and the Sparta Sand in the southern area. The Memphis Sand is underlain by a thick layer of clay in the upper part of the Wilcox Group (Hosman and others, 1968). The Mississippi River Valley Alluvium is the surficial aquifer in the Mississippi Alluvial Plain province (fig. 1). The Mississippi River Valley Alluvium is up to 250 ft thick and overlies the Jackson Group. The Jackson Group overlies the Claiborne Group. In the northern half of the area, the Jackson Group may be missing, having been eroded away, and the Mississippi River Valley alluvial aquifer can be directly connected to the Memphis Sand (Schrader, 2010).

There are variations in the thickness of the Sparta Sand. Within the outcrop area (along the western limit), the Sparta Sand is 50 to 200 ft and thickens easterly to nearly 900 ft. The Memphis Sand subcrops beneath other formations in the study area and thickens easterly to more than 900 ft (Petersen and others, 1985). The Memphis Sand and Sparta Sand contain freshwater throughout most of their extent in Arkansas; however, saltwater is present in the extreme southeastern part of the State in parts of Ashley, Chicot, and Union Counties (Payne, 1968). The Sparta Sand and Memphis Sand generally thicken and groundwater increases in salinity as depth increases to the southeast.

Table 1. Stratigraphic correlation in the northern and southern parts of Arkansas.

[Table constructed from Petersen and others (1985); Hart and others (2008); confining units shaded in grey]

<table>
<tr><th>Series</th><th>Group</th><th>Formations in the south part of Arkansas</th><th>Formations in the north part of Arkansas</th><th colspan="2">Hydrogeological units</th></tr>
<tr><td rowspan="6">Eocene</td><td>Jackson</td><td>Undifferentiated</td><td>Undifferentiated</td><td colspan="2">Vicksburg-Jackson confining unit</td></tr>
<tr><td rowspan="5">Claiborne</td><td>Cockfield Formation</td><td>Cockfield Formation</td><td colspan="2">Upper Claiborne aquifer</td></tr>
<tr><td>Cook Mountain Formation</td><td>Cook Mountain Formation</td><td colspan="2">Middle Claiborne confining unit</td></tr>
<tr><td>Sparta Sand</td><td rowspan="3">Memphis Sand</td><td></td><td rowspan="3">Middle Claiborne aquifer (Sparta-Memphis)</td></tr>
<tr><td>Cane River Formation</td><td>Lower Claiborne confining unit</td></tr>
<tr><td>Carrizo Sand</td><td>Lower Claiborne aquifer</td></tr>
<tr><td rowspan="2">Paleocene</td><td>Wilcox</td><td>Wilcox Group</td><td>Wilcox Group</td><td colspan="2">Lower Wilcox aquifer</td></tr>
<tr><td>Midway</td><td>Undifferentiated</td><td>Undifferentiated</td><td colspan="2">Midway confining unit</td></tr>
</table>

Water Levels

Water-level measurements in wells screened in the Sparta-Memphis aquifer (appendix 1) were used to produce a regional potentiometric-surface map (pl. 1), a map showing the area enclosed in 2011 by a depression in southern Arkansas for comparisons to depression areas from recent years (fig. 4), water-level difference map (pl. 2), and hydrographs (fig. 5). Water levels measured during the spring of 2011 were used to construct a potentiometric-surface map (pl. 1), then subtracted from water levels measured during the spring of 2007 at selected Sparta-Memphis aquifer wells and used to create the water-level difference map (pl. 2). Hydrographs were generated for 183 wells (that have water-level measurements with a minimum 25-year period of record) and compiled by county; hydrographs for 25 of the wells are shown in figure 5. The water levels shown in the hydrographs indicate long-term changes in hydrologic conditions. Long-term water-level declines shown in the hydrographs reflect the response of the groundwater-flow system to stresses caused by groundwater pumping.

Potentiometric-Surface Map

A potentiometric-surface map was constructed by using 291 water-level measurements (appendix 1) from wells completed in the Sparta-Memphis aquifer during spring 2011. Hydrologic principles, water-use data, and historical information were used in conjunction with the water-level data to delineate the potentiometric-surface contours. The number and location of wells used to construct potentiometric-surface maps differ from year to year.

The potentiometric-surface map of the Sparta-Memphis aquifer shows the altitude at which water would have stood in tightly cased wells completed in the aquifer (pl. 1). The surface is mapped by determining the altitude of the water levels measured in the wells and is represented on the map by contours that connect points of equal water-level altitude. The general direction of groundwater flow in the Sparta-Memphis aquifer is perpendicular to the contours in the direction of decreasing hydraulic gradient.

In the northern half of Arkansas, the regional direction of groundwater flow in the Sparta-Memphis aquifer is generally to the south-southeast and flows east and south in the southern half of Arkansas. The groundwater in the southern half of Arkansas flows away from the outcrop area except where affected by large depressions in the potentiometric surface. The direction of groundwater flow in 2011 is towards each of three large depressions. Parts of the study area not affected by these three large depressions exhibit a regional direction of groundwater flow to the east and south, away from the outcrop area. The highest water-level altitude measured in the Sparta-Memphis aquifer was 326 ft above NGVD 29, located in Grant County in the outcrop at the western boundary of the study area; the lowest water-level altitude was 120 ft below NGVD 29 in Union County near the southern boundary of the study area.

Depressions usually are caused by withdrawal rates that exceed recharge rates within the aquifer over an extended period of time. When a well is pumped, the water level in and around the well declines, creating a depression in the potentiometric surface. Groundwater flows toward the depression at a rate that is proportional to the slope of the depression and the transmissivity of the aquifer (Schrader and Jones, 2007). Five depressions (represented by closed contours) are located in Arkansas; three large depressions are in the following counties: Arkansas, Cleveland, Jefferson, Lincoln, and Prairie; Union; and Poinsett, Cross, St. Francis, and Woodruff. The first depression is located in Arkansas, Cleveland, Jefferson, Lincoln, and Prairie Counties in the center of the study area, the second is in Union County in the southern part of the study area, and the third is in western Cross and Poinsett Counties in the northern half of the study area. Small depressions exist in Columbia and Bradley Counties. Two large depressions, centered in Jefferson and Union Counties, are the result of large withdrawals for industrial, irrigation, or public supply. The depression centered in Jefferson County has expanded in recent years into Arkansas and Prairie Counties as a result of large withdrawals for irrigation and public supply. The lowest water-level altitude measured in this depression is approximately 20 ft higher in 2011 than in 2009 (Schrader, 2013). The area enclosed within the 40-ft contour on the 2011 potentiometric-surface map has decreased in area, shifting north in Lincoln County and west in Arkansas County when compared with the 2009 potentiometric-surface map (Schrader, 2013).

The lowest water-level altitude measurement during 2011 in the center of the depression in Union County represents a rise of 79 ft since 2003 (Schrader, 2006). The lowest water-level altitude measurement was 157 ft below NGVD 29 in 2009 (Schrader, 2013), with a 37-ft rise to 120 ft below NGVD 29 in 2011. The location of the lowest water-level altitude can vary through time. Changes in pumping rates and well efficiency can affect the location of the lowest water-level altitude. The lowest water-level altitude measurement in 2011 is from the same well as the lowest water-level altitude measurement in 2003.

The depression in Union County has diminished and is roughly circular within the -60-ft contour and encloses a smaller area than in recent years. The -60-ft contour is shown in figure 4 for 1993, 2003, 2007, and 2011. The area enclosed within the -60-ft contour for each year is shown in table 2. In 1993, the -60-ft contour enclosed 632 sqaure miles (mi^2). In 2003, the -60-ft contour enclosed 767 mi^2, an increase of 21 percent from 1993. In 2007, the -60-ft contour enclosed 699 mi^2, an increase of 10 percent from 1993. In 2011, the -60-ft contour enclosed 375 mi^2, a decrease of 41 percent from 1993. The -60-ft contour on the 2011 potentiometric-surface map has moved away from the Arkansas-Louisiana State border. The area enclosed by the lowest altitude contour, 120 ft below NGVD 29, on the 2011 potentiometric-surface map is less than 10 percent of the area enclosed by that same contour on the 2009 potentiometric-surface map (Schrader, 2013). The lowest altitude contour on the 2009 potentiometric-surface map (Schrader, 2013), 140 ft below NGVD 29, is not present on the 2011 potentiometric-surface map.

A broad depression, first shown in the 1995 potentiometric-surface map (Stanton, 1997), in western Poinsett and Cross Counties has both increased and decreased in size since 1995. The depression expanded in area in 1997 and 1999 and then decreased in area in 2003 and 2005. In 1997, the depression covered most of the western half of Poinsett County (Joseph, 1998). In 1999, the 150-ft contour of the depression extended from Poinsett County through Cross County into St. Francis County (Joseph, 2000; Schrader, 2004). In 2003, the depression covered most of the western half of Poinsett County (Schrader, 2006). In 2005, the depression covered part of western Poinsett County and extended into northwestern Cross County. In 2007, the 140-ft contour expanded northeast to the Poinsett-Craighead County line, farther east, and the farthest extent south into Cross County (Schrader and Jones, 2007). In 2009, the 140-ft contour had extended south across two-thirds of Cross County. In 2011, the lowest water-level altitude measurement in this depression, 129 ft above NGVD 29, was 2 ft lower than in 2009. The 140-ft contour extended southwest into northwestern St. Francis and east-central Woodruff Counties in 2011.

Unlike other depressions in the Sparta-Memphis aquifer, the depression in Poinsett, Cross, St. Francis, and Woodruff Counties primarily is caused by withdrawals for irrigation, instead of withdrawals for public supply and industrial uses. The Mississippi Embayment Regional Aquifer Study project has identified an area in Poinsett, Cross, and St. Francis Counties where the Sparta-Memphis aquifer and the Mississippi River Valley alluvial aquifer (herein referred to as the “alluvial aquifer”) are hydrologically connected. Borehole geophysical logs show that the Jackson Group, the unit that underlies the alluvial aquifer; the Cockfield Formation of Claiborne Group; and the Cook Mountain Formation of Claiborne Group, the unit that confines the Sparta-Memphis aquifer, are absent in this area (Hart and others, 2008). Irrigation withdrawals from the alluvial aquifer have resulted in water-level declines in the Sparta-Memphis aquifer (Schrader, 2008).

Two other depressions located in Columbia and Bradley Counties are shown on the 2011 potentiometric surface. The depression in Columbia County was first shown on the 1996–97 potentiometric-surface map (Joseph, 1998). In 2011, the area decreased, with water levels rising about 1 ft since 2005 in the well with the lowest water-level altitude measurement. The depression in Bradley County was first shown in 2007 (Schrader, 2009). In 2011, this depression decreased in area.

Table 2. Area within the -60-foot contour in Union County, Arkansas in 1993, 2003, 2007, and 2011.

Year	Area (square miles)	Area (square kilometers)
1993	632	1,018
2003	767	1,234
2007	699	1,124
2011	375	604

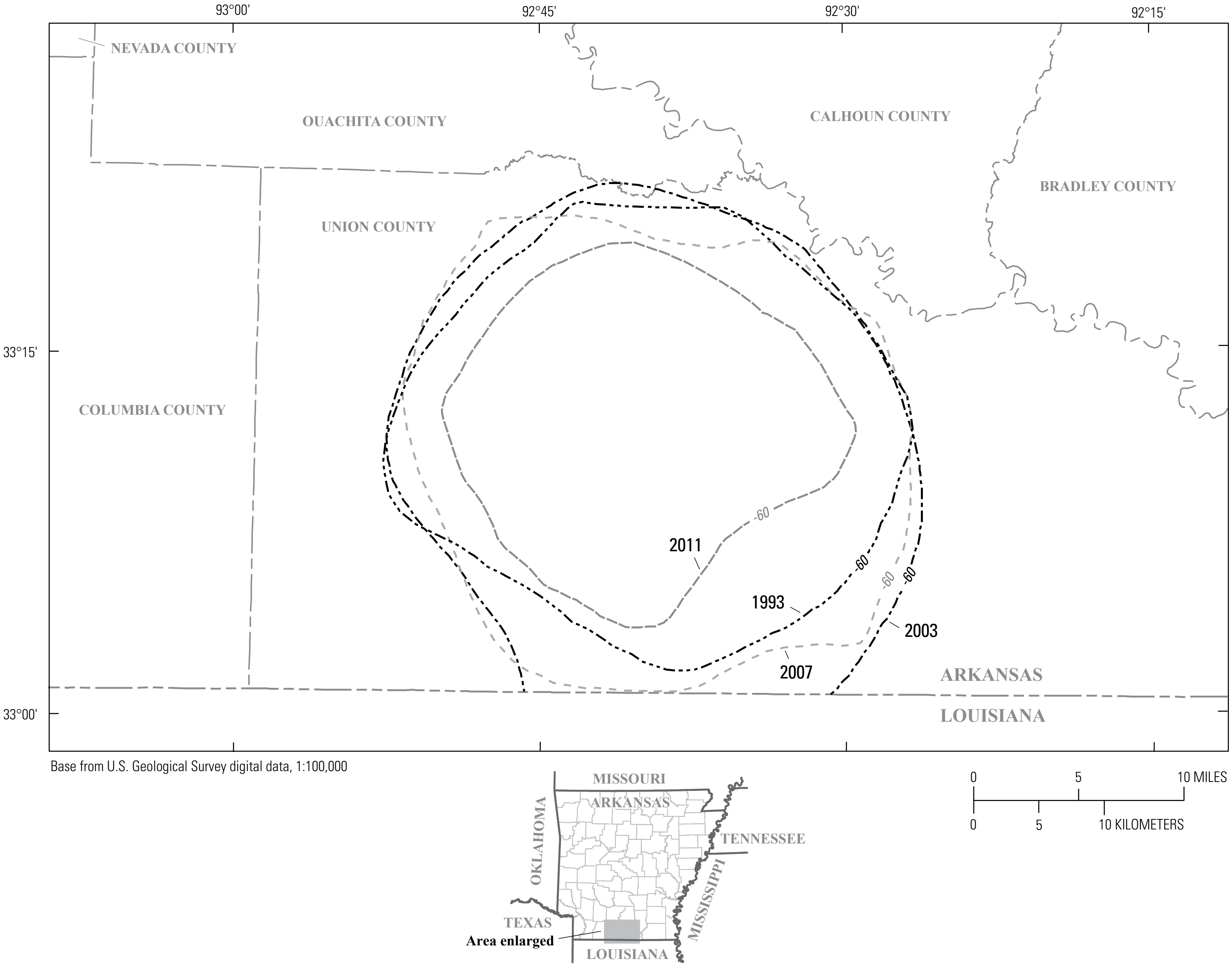

Figure 4. Change in the depression in southern Arkansas, 1993–2011.

Water-Level Difference from 2007 to 2011

A water-level difference map (pl. 2) was constructed using the difference between water-level measurements made during 2007 and 2011 at 247 wells (appendix 2). The difference in water levels was calculated by subtracting the 2011 depth-to-water level from the 2007 depth-to-water level. Positive values shown on plate 2 indicate a rise, and negative values indicate a decline in water level. Rises in water level are indicated on plate 2 with blue triangles pointing upward; declines in water level are indicated with red triangles pointing downward. Triangles are scaled to the relative value of the rise or decline. Water-level differences do not necessarily indicate a long-term water-level trend but are intended to show where water levels have increased or decreased from 2007 to 2011.

The differences in water levels between 2007 and 2011 ranged from -17.3 to 45.4 ft, with a mean of 4.1 ft. The largest measured decline (-17.3 ft) in water level was in eastern Union County. The largest measured rise (45.4 ft) in water level was in central Union County. In central Union County (pl. 2), water levels in seven wells rose 20 ft or more, with an average annual rise of 5 ft or more. The rising water levels in central Union County coincide with water conservation measures initiated in 1999 and the conversion of large industrial water users from groundwater to surface water from the Ouachita River beginning in December 2004 (Scheiderer and Freiwald, 2006).

Water levels generally declined in the northern half of the study area and generally increased in the southern half of the study area. Areas with a general decline in water levels include Lonoke and western Prairie Counties; northern Arkansas County; Miller County; and Craighead, Poinsett, Cross, and Woodruff Counties. Areas with a general rise in water levels include Lafayette, Columbia, Union, Calhoun, and Bradley Counties; Grant, Jefferson, southern Arkansas, Lincoln, Drew, and Desha Counties; and Phillips County (pl. 2).

Long-Term Hydrographs

Hydrographs from 183 wells with a minimum of 25 years of water-level measurements were constructed. Selected hydrographs are shown in figure 5 with locations indicated on plate 1. The minimum 25-year period of record is used to evaluate long-term trends not dominated by variations in climate and localized pumping rates on water levels in a single well. A trend line using linear regression was calculated for the period from 1987 to 2011 to determine the slope in feet per year (ft/yr) for water levels in each well. The slope of the trend line represents the typical annual decline or rise in water level during the 25-year period. A statistical summary of the number of wells; the range, mean, and median of the annual rise or decline in water level; and the range of the R^2 values for each county are listed in table 3. Negative values denote a decline in water level. During the period 1987–2011, county mean annual water levels generally declined. Mean annual declines were between 0.5 ft/yr and 0.0 ft/yr in Ashley, Chicot, Crittenden, Drew, Grant, Jefferson, Lafayette, Mississippi, Monroe, Ouachita, Phillips, Pulaski, St. Francis, and Woodruff Counties (table 2). Mean annual declines were between 1.0 ft/yr and 0.5 ft/yr in Bradley, Calhoun, Cleveland, Craighead, Cross, Desha, Lonoke, Miller, Poinsett, and Prairie Counties. Mean annual declines were between 1.5 ft/yr and 1.0 ft/yr in Arkansas, Lee, and Lincoln Counties. The county mean annual water level rose in Columbia, Dallas, and Union Counties, about 0.3 ft/yr, 0.1 ft/yr, and 1.2 ft/yr, respectively.

Table 3. Number of wells, range, mean, median, and correlation coefficient (R^2) of annual rise-decline in water level by county for wells in the Sparta-Memphis aquifer, 1987–2011.

[Annual rise or decline in water level for each well is calculated using linear regression; negative value indicates decline; positive value indicates rise]

County	Number of wells	Range of annual rise-decline in water level (feet/year)	Mean annual rise-decline in water level (feet/year)	Median annual rise-decline in water level (feet/year)	Range of R^2 values for trend line
Arkansas	26	-1.42 to -0.26	-1.02	-1.11	0.14 to 0.78
Ashley	6	-0.55 to -0.04	-0.32	-0.38	0.10 to 0.87
Bradley	4	-1.35 to 0.29	-0.68	-0.84	0.23 to 0.96
Calhoun	2	-0.69 to -0.69	-0.69	-0.69	0.35 to 0.35
Chicot	1	-0.21 to -0.21	-0.21	-0.21	0.37 to 0.37
Cleveland	4	-0.99 to -0.26	-0.66	-0.69	0.19 to 0.88
Columbia	13	-1.10 to 3.07	0.31	-0.07	0.10 to 0.93
Craighead	1	-0.80 to -0.80	-0.80	-0.80	0.80 to 0.80
Crittenden	3	-0.37 to 0.40	-0.07	-0.26	0.58 to 0.92
Cross	5	-1.10 to -0.44	-0.85	-0.91	0.54 to 0.87
Dallas	8	-0.47 to 1.72	0.05	-0.11	0.00 to 0.95
Desha	6	-1.31 to -0.35	-0.69	-0.57	0.17 to 0.81
Drew	5	-0.80 to 0.15	-0.40	-0.47	0.11 to 0.97
Grant	8	-1.10 to -0.07	-0.35	-0.26	0.18 to 0.81
Jefferson	18	-2.52 to 7.38	-0.31	-1.02	0.11 to 0.93
Lafayette	2	-0.04 to -0.01	-0.03	-0.03	0.10 to 0.10
Lee	2	-1.39 to -0.84	-1.11	-1.11	0.86 to 0.94
Lincoln	6	-2.70 to -0.77	-1.41	-1.21	0.66 to 0.88
Lonoke	5	-1.21 to 1.17	-0.66	-1.10	0.38 to 0.99
Miller	2	-0.88 to -0.15	-0.51	-0.51	0.12 to 0.51
Mississippi	1	-0.40 to 0.40	-0.40	-0.40	0.20 to 0.20
Monroe	5	-0.95 to -0.04	-0.35	-0.29	0.15 to 0.90
Ouachita	13	-1.64 to 1.79	-0.00	-0.07	0.11 to 0.85
Phillips	6	-0.62 to 0.29	-0.05	-0.02	0.15 to 0.78
Poinsett	2	-1.17 to -0.69	-0.93	-0.93	0.40 to 0.94
Prairie	10	-1.53 to 0.62	-0.89	-1.06	0.17 to 0.96
Pulaski	2	-0.47 to -0.22	-0.35	-0.35	0.45 to 0.50
St. Francis	1	-0.11 to -0.11	-0.11	-0.11	0.16 to 0.16
Union	29	-0.95 to 8.55	1.17	0.40	0.11 to 0.95
Woodruff	1	-0.03 to -0.03	-0.03	-0.03	0.23 to 0.23

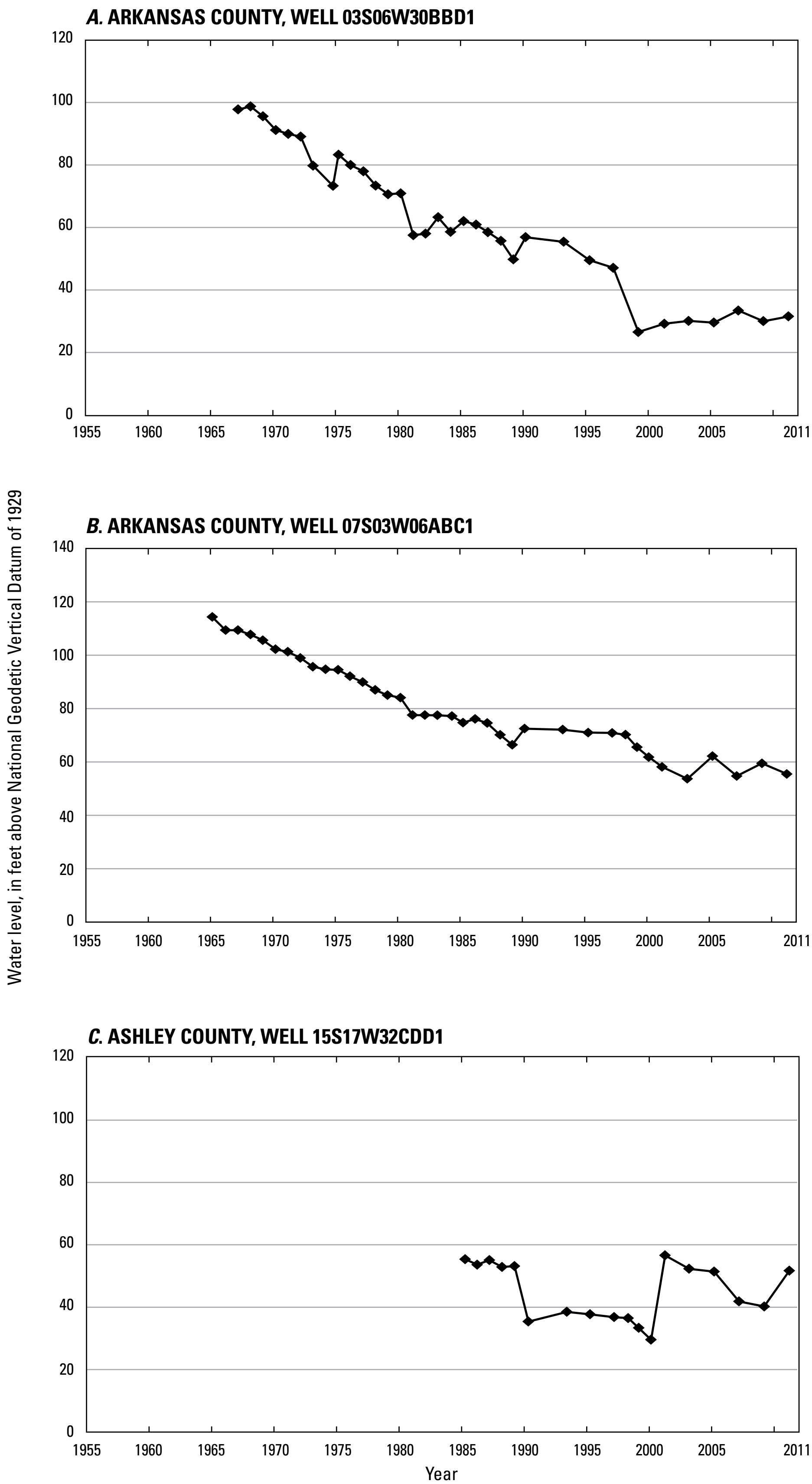

Figure 5. Water levels for selected wells completed in the Sparta-Memphis aquifer in Arkansas.

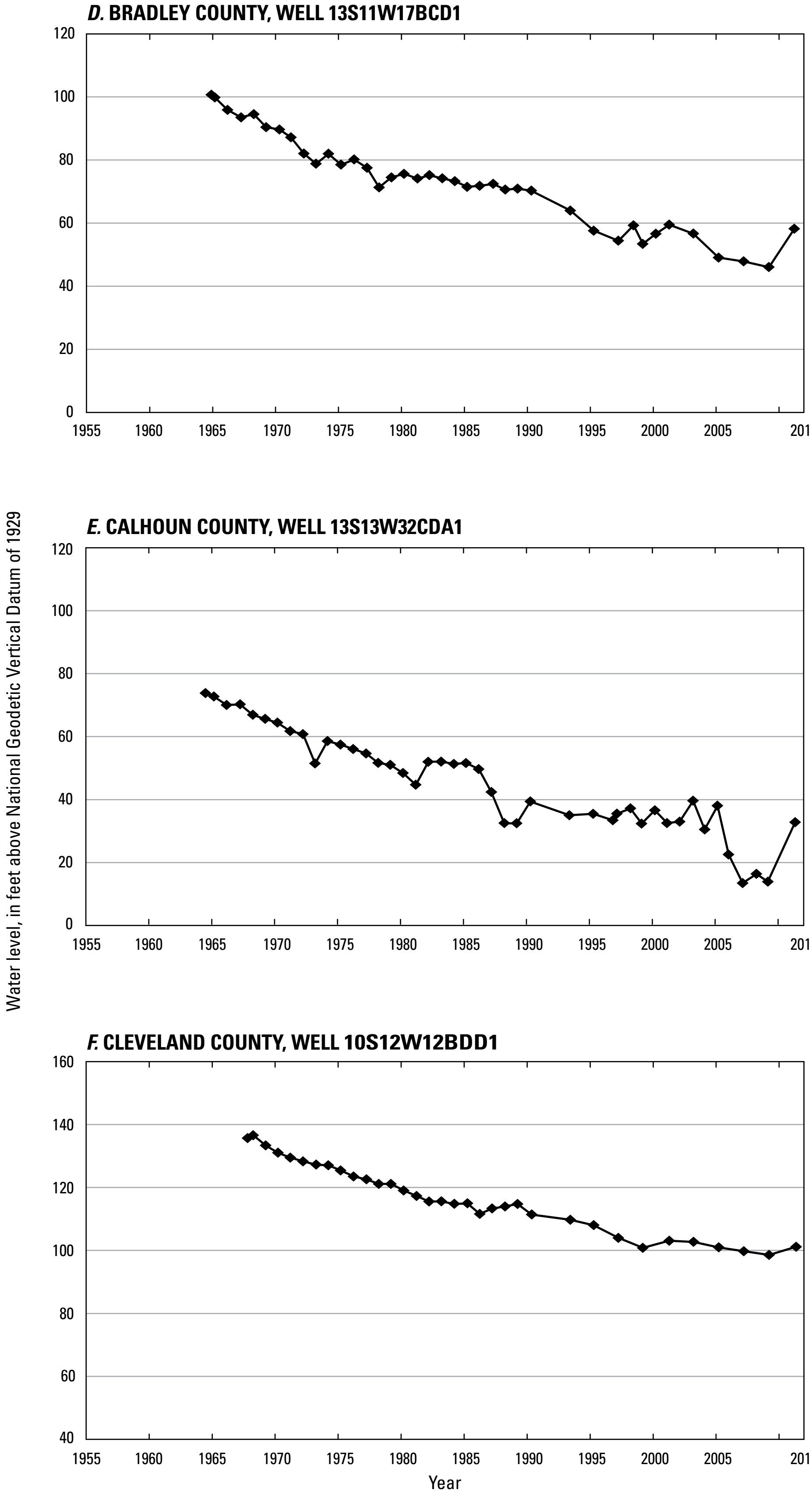

Figure 5. Water levels for selected wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

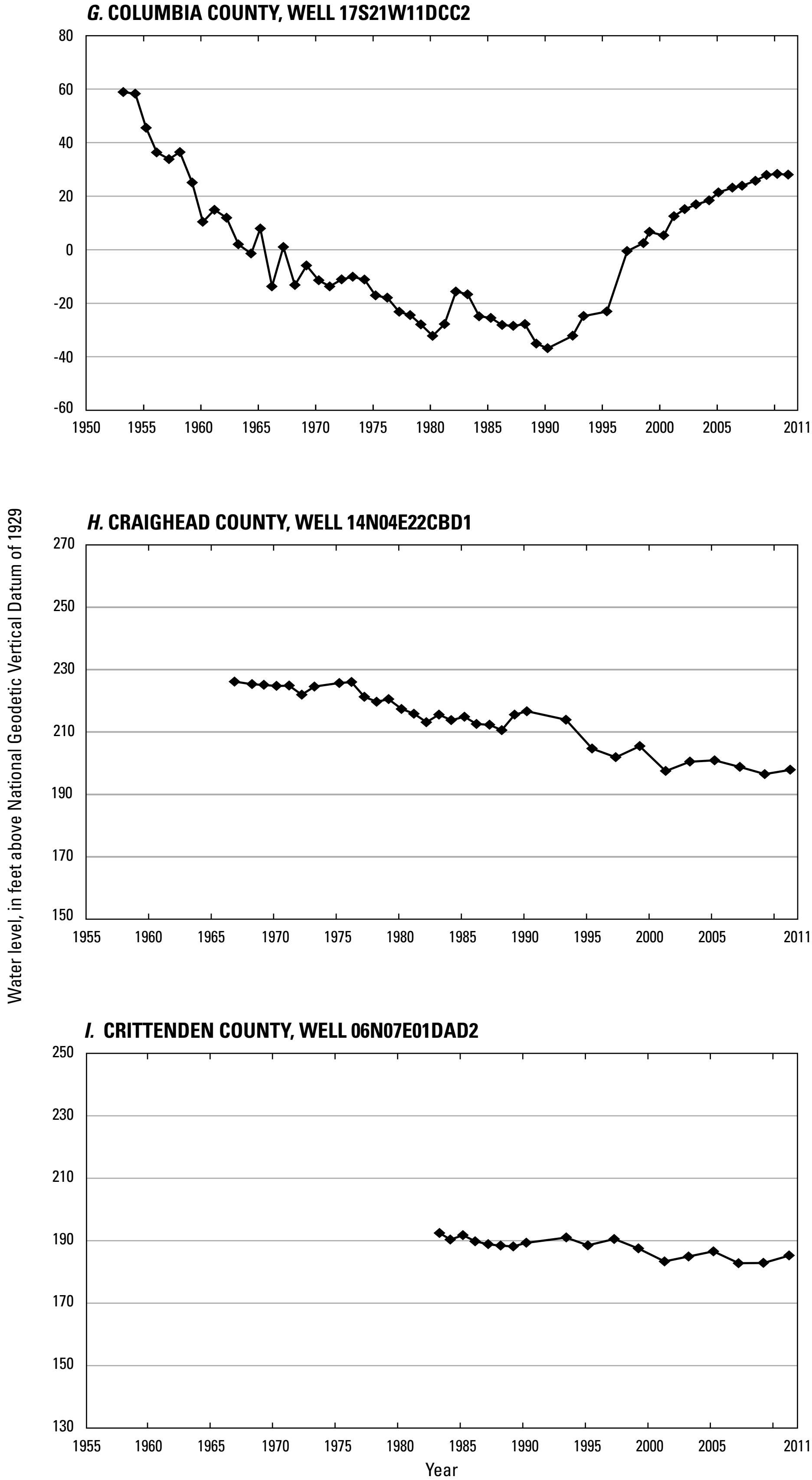

Figure 5. Water levels for selected wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

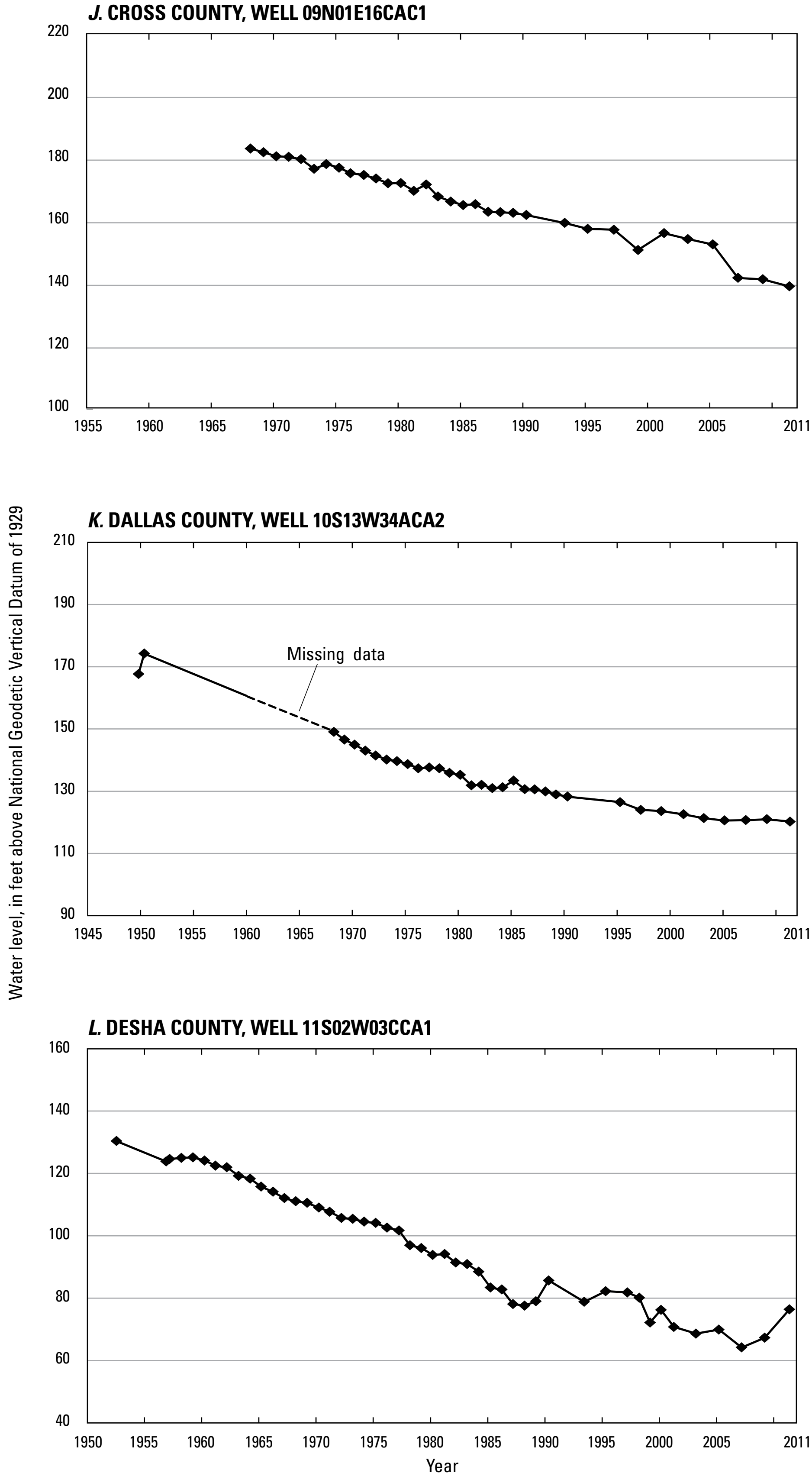

Figure 5. Water levels for selected wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

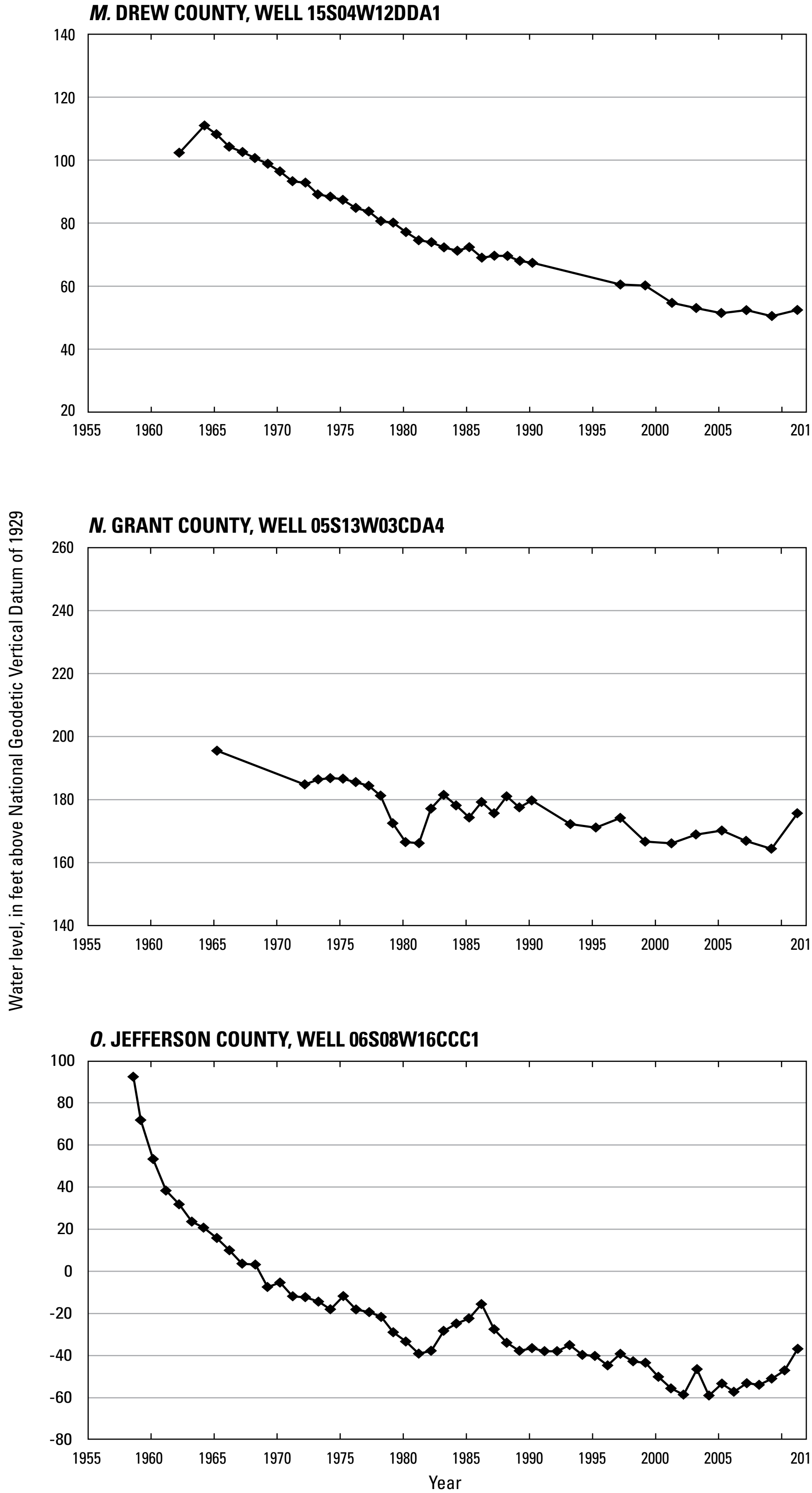

Figure 5. Water levels for selected wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

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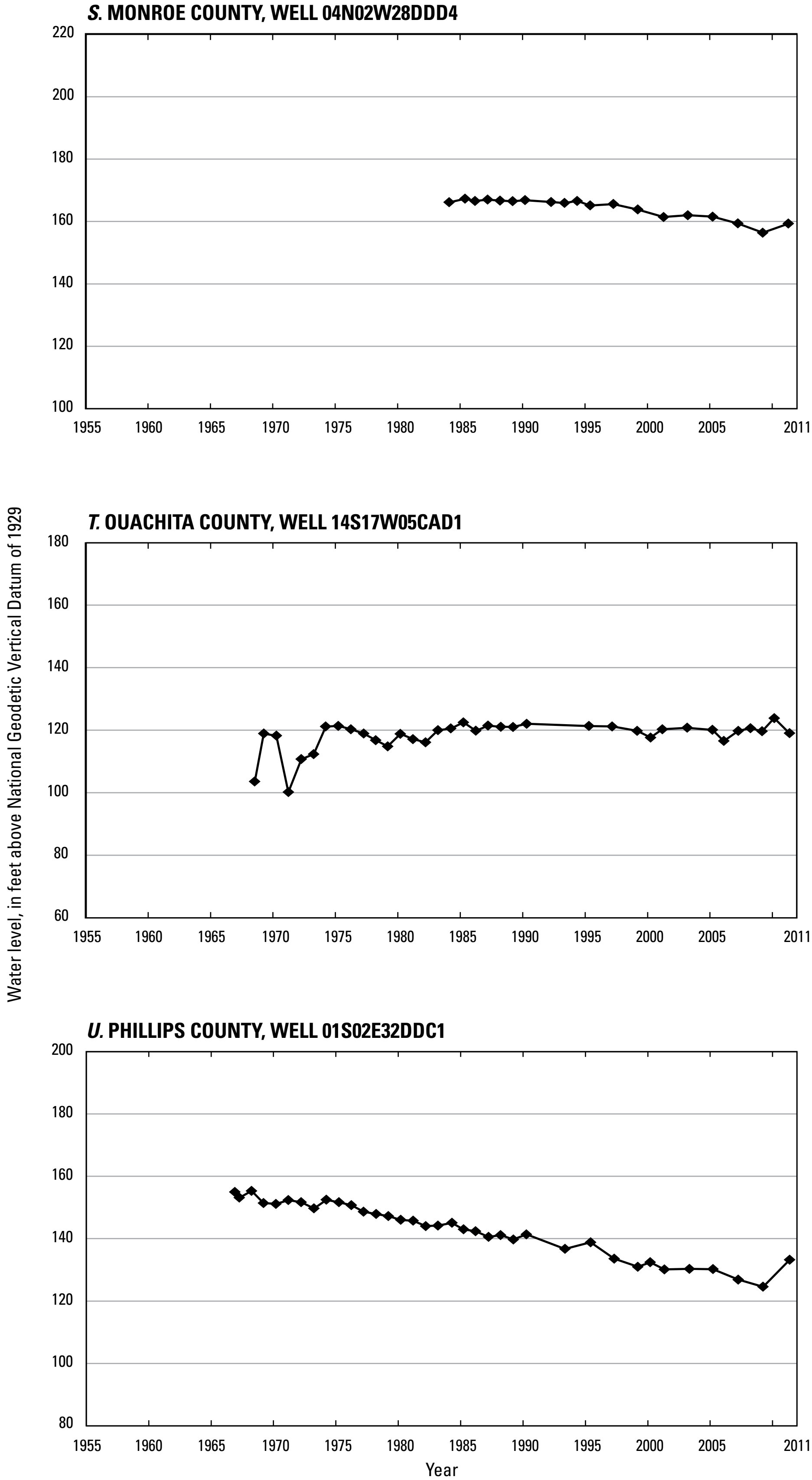

Figure 5. Water levels for selected wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

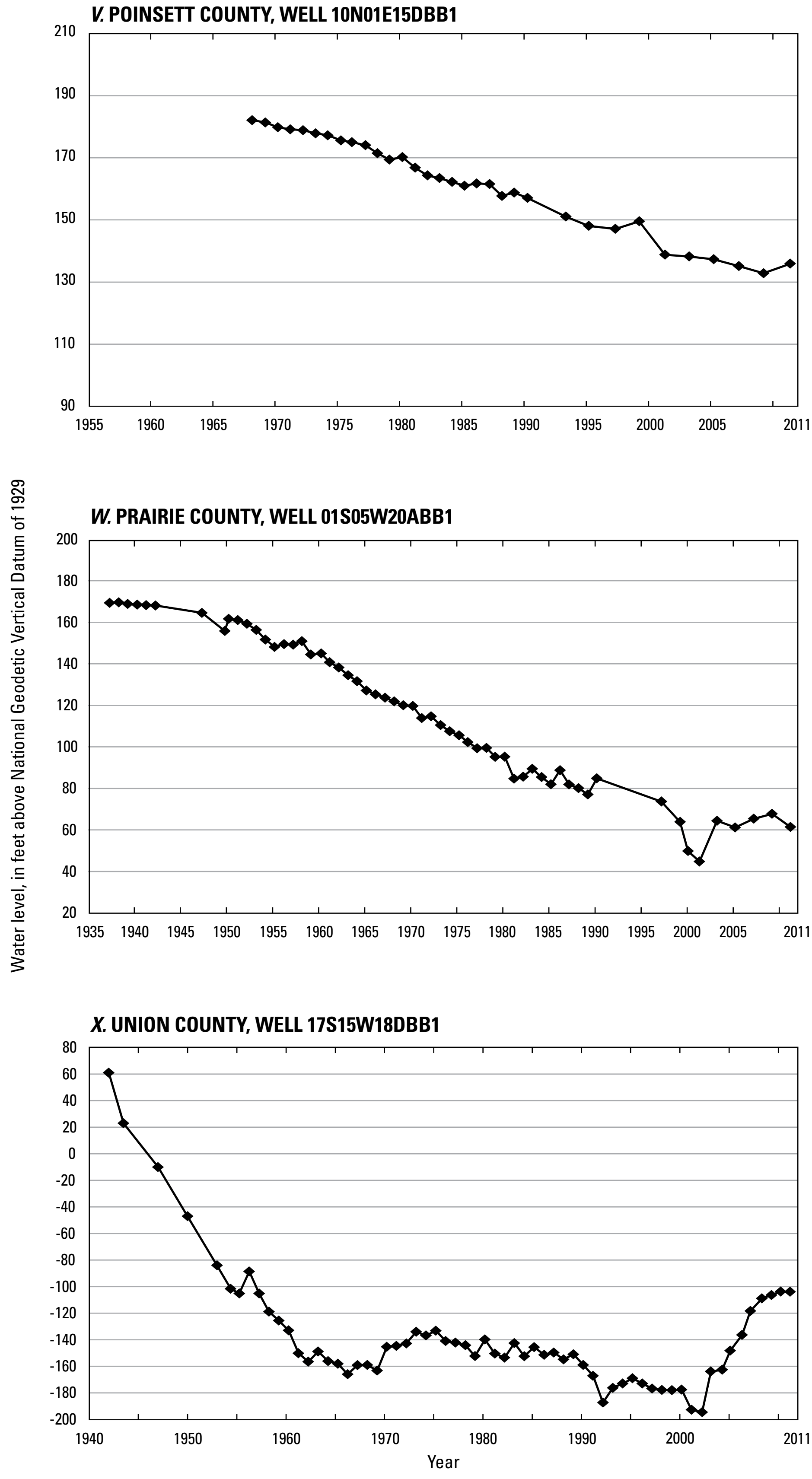

Figure 5. Water levels for selected wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

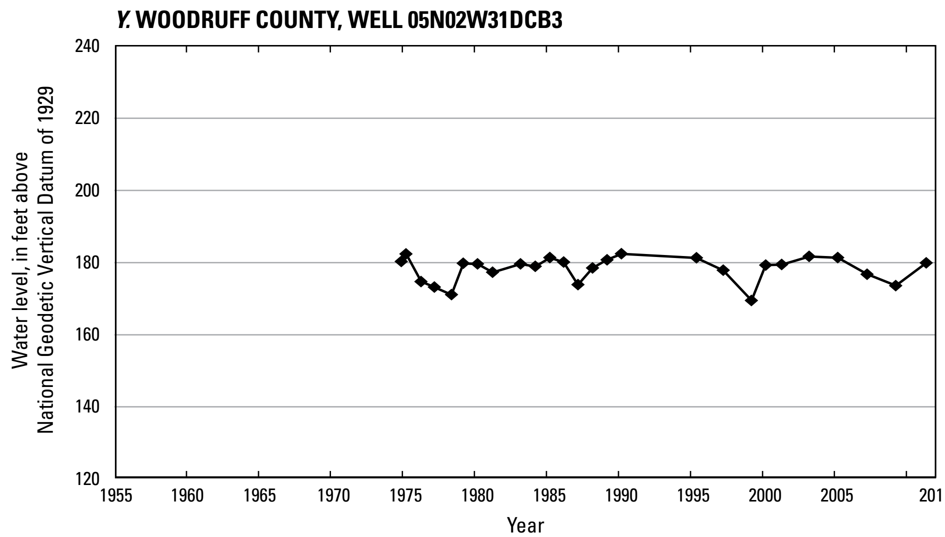

Figure 5. Water levels for selected wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

Water-Quality Conditions

Water samples were collected in the summer of 2011 from 61 wells completed in the Sparta-Memphis aquifer and measured onsite for specific conductance, pH, and temperature (app. 3). Specific conductance ranged from 35 microsiemens per centimeter at 25 degrees Celsius (µS/cm) in Ouachita County to 1,380 µS/cm in Monroe County. Relatively large specific conductance values (greater than 700 µS/cm) occur in samples from wells in Arkansas, Ashley, Clay, Monroe, Phillips, and Union Counties. Large specific conductance values occur near the water-level depression (pl. 1) in Union County and increase eastward toward Ashley County; several specific-conductance values greater than 2,000 µS/cm for groundwater from the Sparta aquifer in Union County have been documented (Broom and others, 1984).

Although there is a regional increase in specific conductance to the east and south, anomalous increases occur in some parts of the study area. Morris and Bush (1986) and Broom and others (1984) cited upward leakage of saltwater from the Nacatoch Formation of Cretaceous age into the Sparta aquifer through a fault or abandoned oil and gas wells as possible explanations for these anomalies.

Specific conductance values from samples collected in 2009 and 2011 generally were less than 400 µS/cm. The histograms of specific conductance data for 2009 (64 samples) (Schrader, 2013) and 2011 (61 samples) are shown in figure 6. The mean specific conductance was 392 µS/cm in 2009 and 391 µS/cm in 2011. Both histograms have a right skew. Eighty-four percent of the wells sampled in 2009 and 2011 had specific conductance values less than 600 µS/cm. The largest category for both years is the 201–400 µS/cm range. The 201–400 µS/cm range included 53 percent of the samples in 2009 and 36 percent of the samples in 2011. The lowest range, 1–200 µS/cm, increased from 15 percent of the samples in 2009 to 26 percent of the samples in 2011. The small change in the mean specific conductance and the distribution of data from 2009 to 2011 may indicate a change in water quality or be the result of the distribution of sampling locations.

Temperature ranged from 18.0 °C in Ouachita County to 26.7 °C in Nevada County. The mean temperature was 23.0 °C. The pH ranged from 5.4 in Ouachita County to 8.8 in Calhoun, Drew, and Union Counties. The pH had a mean of 7.7.

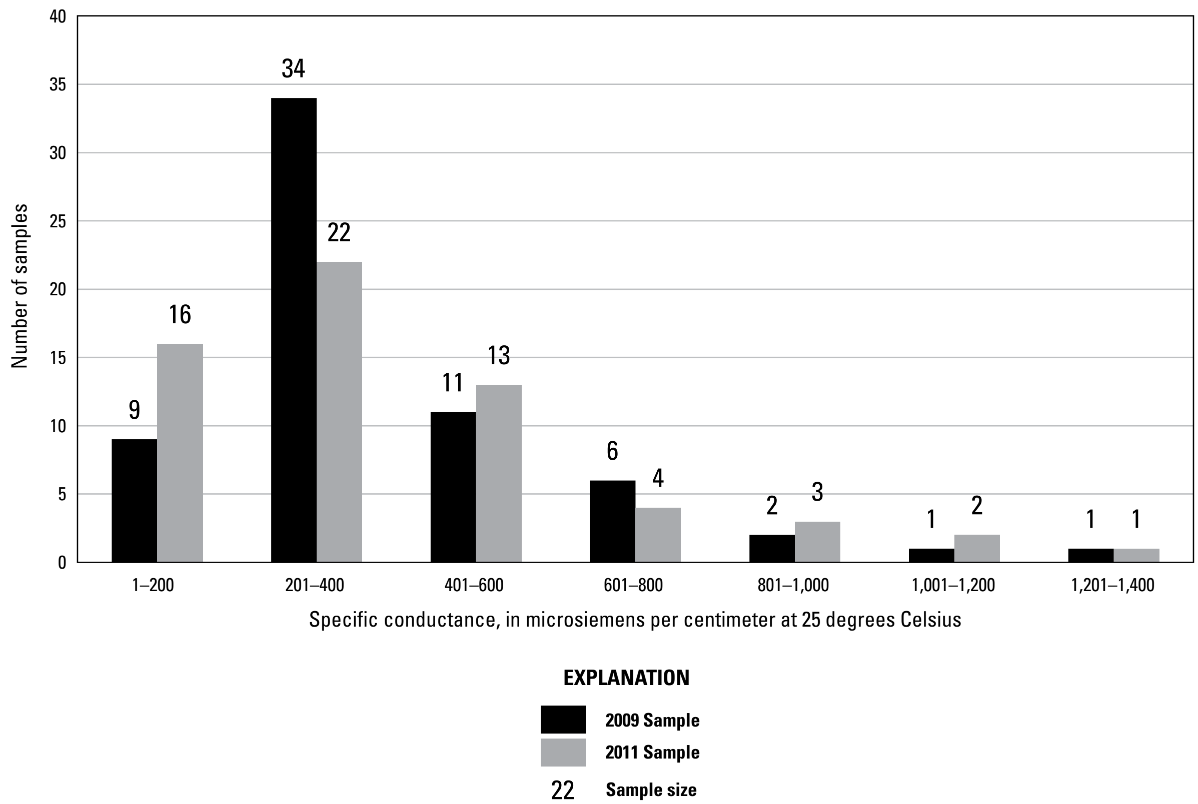

Figure 6. Distribution of specific conductance in samples from the Sparta-Memphis aquifer in 2009 and 2011.

Summary

The U.S. Geological Survey, in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey, has monitored water levels since the 1920s. Groundwater withdrawals have increased while water levels have declined since monitoring was initiated. During the spring of 2011, 291 water levels were measured in wells completed in the Sparta-Memphis aquifer. During the summer of 2011, 61 water-quality samples were collected and measured for specific conductance, temperature, and pH from wells completed in the Sparta-Memphis aquifer.

Water use in the Sparta-Memphis aquifer in Arkansas generally increased from 1965 to 2000. In 2000, water use in the Sparta-Memphis aquifer was about 287 million gallons per day (Mgal/d), an increase of about 156 percent from 1965. In 2005, water use in the Sparta-Memphis aquifer declined to about 170 Mgal/d.

The Sparta Sand is composed of a sequence of alternating sand and clay beds between the massive clays of the overlying Cook Mountain Formation and the underlying Cane River Formation confining units. The Sparta Sand is in the southern part of the study area (south of about 35 degrees latitude). The Memphis Sand is in the northern part of the study area (north of about 35 degrees latitude). The Memphis Sand is underlain by a thick layer of clay in the upper part of the Wilcox Group.

The regional direction of groundwater flow in the Sparta-Memphis aquifer is generally to the south-southeast in the northern half of Arkansas and flows east and south in the southern half of Arkansas. The groundwater in the southern half of Arkansas flows away from the outcrop area except where affected by large depressions in the potentiometric surface. The highest water-level altitude measured in the Sparta-Memphis aquifer was 326 feet (ft) above the National Geodetic Vertical Datum of 1929 (NGVD 29) in the outcrop at the western boundary of the study area in Grant County; the lowest water-level altitude was 120 feet (ft) below NGVD 29 in Union County.

Five depressions are located in the following counties: Arkansas, Cleveland, Jefferson, Lincoln, and Prairie; Union; Cross, Poinsett, St. Francis, and Woodruff; Columbia; and Bradley. Two large depressions, centered in Jefferson and Union Counties, are the result of large withdrawals for industrial, irrigation, or public supply. The depression centered in Jefferson County has expanded in recent years into Arkansas and Prairie Counties as a result of large withdrawals for irrigation and public supply. The lowest water-level altitude measured in this depression is approximately 20 ft higher in 2011 than in 2009. The area enclosed within the 40-ft contour on the 2011 potentiometric-surface map has decreased in area, shifting north in Lincoln County and west in Arkansas County when compared with the 2009 potentiometric-surface map.

The depression in Union County is roughly circular within the -60-ft contour. The lowest water-level altitude measurement was 157 ft below NGVD 29 in 2009, with a 37-ft rise to 120 ft below NGVD 29 in 2011. The depression in Union County has diminished and encloses a smaller area than in recent years. In 1993, the -60-ft contour enclosed 632 square miles (mi^2). In 2003, the -60-ft contour enclosed 767 mi^2, an increase of 21 percent from 1993. In 2007, the -60-ft contour enclosed 699 mi^2, an increase of 10 percent from 1993. In 2011, the -60-ft contour enclosed 375 mi^2, a decrease of 41 percent from 1993. The lowest water-level altitude measurement during 2011 in the center of the depression in Union County represents a rise of 79 ft since 2003. The area enclosed by the lowest altitude contour, 120 ft below NGVD 29, on the 2011 potentiometric-surface map is less than 10 percent the area enclosed by that same conour on the 2009 potentiometric-surface map.

A broad depression, first shown in the 1995 potentiometric-surface map, in western Poinsett and Cross Counties has both increased and decreased in size since 1995. In 2011, the lowest water-level altitude measurement in this depression, 129 ft above NGVD 29, is 2 ft lower than in 2009. The 140-ft contour extended southwest into northwestern St. Francis and east-central Woodruff Counties in 2011. In Columbia County in 2011, the area of the depression decreased, with water levels rising about 1 ft since 2005 in the well with the lowest water-level altitude measurement. The depression in Bradley County in 2011 declined in area compared to 2007.

A water-level difference map was constructed using the difference between water-level measurements made during 2007 and 2011 at 247 wells. The differences in water level between 2007 and 2011 ranged from -17.3 ft to 45.4 ft, with a mean of 4.1 ft. In central Union County, water levels in seven wells rose 20 ft or more, with an average annual rise of 5 ft or more. Water levels generally declined in the northern half of the study area and generally increased in the southern half of the study area. Areas with a general decline in water levels include Lonoke and western Prairie Counties; northern Arkansas County; Miller County; and Craighead, Poinsett, Cross, and Woodruff Counties. Areas with a general rise in water levels include Lafayette, Columbia, Union, Calhoun, and Bradley Counties; Grant, Jefferson, southern Arkansas, Lincoln, Drew, and Desha Counties; and Phillips County.

Hydrographs from 183 wells with a minimum of 25 years of water-level measurements were constructed. During the period 1987–2011, county mean annual water levels generally declined. Mean annual declines were between 0.5 ft/yr and 0.0 ft/yr in Ashley, Chicot, Crittenden, Drew, Grant, Jefferson, Lafayette, Mississippi, Monroe, Ouachita, Phillips, Pulaski, St. Francis, and Woodruff Counties. Mean annual declines were between 1.0 foot per year (ft/yr) and 0.5 ft/yr in Bradley, Calhoun, Cleveland, Craighead, Cross, Desha, Lonoke, Miller, Poinsett, and Prairie Counties. Mean annual declines were between 1.5 ft/yr and 1.0 ft/yr in Arkansas, Lee, and Lincoln Counties. The county mean annual water level rose in Columbia, Dallas, and Union Counties, about 0.3 ft/yr, 0.1 ft/yr, and 1.2 ft/yr, respectively.

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Selected References

Broom, M.E., Kraemer, T.F., and Bush, W.V., 1984, A reconnaissance study of saltwater contamination in the El Dorado aquifer, Union County, Arkansas: U.S. Geological Survey Water-Resources Investigations Report 84–4012, 47 p.

Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater technical procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods book 1, chap. A1, 151 p.

Edds, Joe, and Fitzpatrick, D.J., 1985, Maps showing altitude of the potentiometric surface and changes in water levels of the Sparta Sand and Memphis Sand aquifers in eastern Arkansas, spring 1984: U.S. Geological Survey Water-Resources Investigations Report 85–4223, 1 sheet.

Edds, Joe, and Fitzpatrick, D.J., 1989, Altitude of the potentiometric surface and changes in water levels in the Sparta-Memphis aquifer in eastern and southern Arkansas, spring 1986: U.S. Geological Survey Water-Resources Investigations Report 88–4042, 1 sheet.

Fenneman, N.M., 1938, Physiography of eastern United States: New York, McGraw-Hill Book Co., Inc., 689 p.

Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States (Map): Washington, D.C., U.S. Geological Survey, scale 1:7,000,000.

Fishman, M.J., and Friedman, L.C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

Halberg, H.N., 1972, Use of water in Arkansas, 1970: Arkansas Geological Commission, Water Resources Summary Number 7, 17 p.

Halberg, H.N., 1977, Use of water in Arkansas, 1975: Arkansas Geological Commission, Water Resources Summary Number 9, 28 p.

Halberg, H.N., and Stephens, J.W., 1966, Use of water in Arkansas, 1965: Arkansas Geological Commission, Water Resources Summary Number 5, 12 p.

Hart, R.M., Clark, B.R., and Bolyard, S.E., 2008, Digital surfaces and thicknesses of selected hydrogeologic units within the Mississippi Embayment Regional Aquifer Study (MERAS): U.S. Geological Survey Scientific Investigations Report 2008–5098, accessed March 9, 2009, at http://pubs.usgs.gov/sir/2008/5098/.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: New York, N.Y., Elsevier Science Publishing Co., 522 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water Supply Paper 2254, 263 p.

Holland, T.W., 1987, Use of water in Arkansas, 1985: Arkansas Geological Commission Water Resources Summary Number 14, 30 p.

Holland, T.W., 1993, Use of water in Arkansas, 1990: U.S. Geological Survey Open-File Report 93–48, pamphlet.

Holland, T.W., 1999, Water use in Arkansas, 1995: U.S. Geological Survey Open-File Report 99–188, 1 sheet.

Holland, T.W., 2004, Estimated water use in Arkansas, 2000: U.S. Geological Survey Scientific Investigations Report 2004–5230, 31 p.

Holland, T.W., 2007, Water use in Arkansas, 2005: U.S. Geological Survey Scientific Investigations Report 2007–5241, 31 p.

Holland, T.W., and Ludwig, A.H., 1981, Use of water in Arkansas: Arkansas Geological Commission, Water Resources Summary Number 14, 30 p.

Hosman, R.L., 1982, Outcropping Tertiary units in southern Arkansas: U.S. Geological Survey Miscellaneous Investigations Series I–1405, 1 sheet.

Hosman, R.L., Long, A.T., Lambert, T.W., and others, 1968, Tertiary aquifers in the Mississippi Embayment: U.S. Geological Survey Professional Paper 448–D, 29 p.

Hosman, R.L., and Weiss, J.S., 1991, Geohydrologic units of the Mississippi Embayment and Texas Coastal Uplands aquifer systems, South-Central United States: U.S. Geological Survey Professional Paper 1416–B, 19 p.

Joseph, R.L., 1998, Potentiometric surface of the Sparta aquifer in eastern and south-central Arkansas and north-central Louisiana, and the Memphis aquifer in east-central Arkansas, October 1996–July 1997: U.S. Geological Survey Water-Resources Investigations Report 97–4282, 19 p.

Joseph, R.L., 2000, Status of water levels and selected water-quality conditions in the Sparta and Memphis aquifers in eastern and south-central Arkansas, 1999: U.S. Geological Survey Water-Resources Investigations Report 00–4009, 34 p.

Morris, E.E., and Bush, W.V., 1986, Extent and source of saltwater intrusion into the alluvial aquifer near Brinkley, Arkansas, 1984: U.S. Geological Survey Water-Resources Investigations Report 85–4322, 123 p.

Payne, J.N., 1968, Hydrologic significance of the lithofacies of the Sparta Sand in Arkansas, Louisiana, Mississippi, and Texas: U.S. Geological Survey Professional Paper 569–A, 17 p.

Petersen, J.C., Broom, M.E., and Bush, W.V., 1985, Geohydrologic units of the Gulf Coastal Plain in Arkansas: U.S. Geological Survey Water-Resources Investigations Report 85–4116, 20 p.

Schrader, T.P., 2004, Status of water levels and selected water-quality conditions in the Sparta-Memphis aquifer in Arkansas and the Sparta aquifer in Louisiana, spring-summer 2001: U.S. Geological Survey Scientific Investigations Report 2004–5055, 52 p.

Schrader, T.P., 2006, Status of water levels and selected water-quality conditions in the Sparta-Memphis aquifer in Arkansas, spring-summer, 2003: U.S. Geological Survey Scientific Investigations Report 2006–5021, 43 p.

Schrader, T.P., 2008, Potentiomentric surface in the Sparta-Memphis aquifer of the Mississippi Embayment, spring 2007: U.S. Geological Survey Scientific Investigations Map 3014, 1 pl.

Schrader, T.P., 2009, Water levels and selected water-quality conditions in the Sparta-Memphis aquifer (middle Claiborne aquifer) in Arkansas, spring–summer 2007: U.S. Geological Survey Scientific Investigations Report 2009–5207, 50 p.

Schrader, T.P., 2010, Water levels and selected water-quality conditions in the Mississippi River Valley alluvial aquifer in eastern Arkansas, 2008: U.S. Geological Survey Scientific Investigations Report 2010–5140, 71 p.

Schrader, T.P., 2013, Water levels and water-quality in the Sparta-Memphis aquifer (middle Claiborne aquifer) in Arkansas, spring–summer 2009: U.S. Geological Survey Scientific Investigations Report 2013–5100, 53 p.

Schrader, T.P., and Jones, J.S., 2007, Status of water levels and selected water-quality conditions in the Sparta-Memphis aquifer in Arkansas and the status of water levels in the Sparta aquifer in Louisiana, spring 2005: U.S. Geological Survey Scientific Investigations Report 2007–5029, 66 p.

Scheiderer, R.M., and Freiwald, D.A., 2006, Monitoring the recovery of the Sparta aquifer in southern Arkansas and northern Louisiana: U.S. Geological Survey Fact Sheet 2006–3090, 4 p.

Snider, J.L., Calandro, A.J., and Shampine, W.J., 1972, Water resources of Union Parish, Louisiana: Department of Conservation, Louisiana Geological Survey, and Louisiana Department of Public Works Water Resources Bulletin no. 17, 68 p.

Stanton, G.P., 1997, Potentiometric surface and specific conductance of the Sparta and Memphis aquifers in eastern and south-central Arkansas, 1995: U.S. Geological Survey Water-Resources Investigations Report 97–4119, 16 p.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1–A9. [Also available at http://pubs.water.usgs.gov/twri9A.]

Westerfield, P.A., 1995, Potentiometric surface of the Sparta and Memphis aquifers in eastern Arkansas, April through July 1993: U.S. Geological Survey Water-Resources Investigations Report 95–4000, 1 sheet.

Appendixes 1–3

Appendix 1. Water-level data collected during spring 2011 from wells completed in the Sparta-Memphis aquifer in Arkansas.

[NGVD 29, National Geodetic Vertical Datum of 1929; horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
			Arkansas County			
02S04W06CDB1	34°33′12″	91°28′49″	39	173.13	212	03/28/2011
02S04W23DAA1	34°30′44″	91°23′55″	64	143.67	208	04/01/2011
02S04W33BBB1	34°29′22″	91°27′03″	39	166.19	205	04/01/2011
02S05W16CBB1	34°31′44″	91°33′19″	36	177.38	213	03/28/2011
02S05W34BDA1	34°29′25″	91°31′48″	30	186.45	216	03/28/2011
02S05W35AAB1	34°29′30″	91°30′35″	41	175.31	216	03/28/2011
03S04W02CCB1	34°27′48″	91°24′58″	50	151.95	202	04/01/2011
03S04W26CDA1	34°24′21″	91°24′38″	60	142.52	203	04/04/2011
03S05W02AAB1	34°28′42″	91°30′34″	40	169.82	210	03/28/2011
03S05W13BDC1	34°26′31″	91°30′05″	36	173.60	210	03/28/2011
03S05W15CBB1	34°26′33″	91°32′29″	29	176.74	206	03/28/2011
03S05W18CAB1	34°26′29″	91°35′25″	34	161.90	196	03/28/2011
03S05W28DAB1	34°24′47″	91°32′40″	22	181.68	204	04/04/2011
03S06W21ACB1	34°25′54″	91°39′27″	42	157.81	200	03/28/2011
03S06W30BBD1	34°25′16″	91°42′16″	32	159.30	191	04/04/2011
04S01W04CBD1	34°22′25″	91°08′08″	86	110.13	196	04/05/2011
04S01W28BAA1	34°19′27″	91°07′48″	87	102.71	190	04/05/2011
04S04W11BCC1	34°21′57″	91°25′02″	36	161.55	198	03/31/2011
04S04W19CBB1	34°20′04″	91°29′29″	33	162.49	195	03/31/2011
04S04W22DAA1	34°20′07″	91°25′15″	41	153.66	195	03/31/2011
04S05W01BAA1	34°23′22″	91°29′56″	36	160.44	196	03/28/2011
04S05W05ACC1	34°23′03″	91°34′13″	29	156.72	186	03/21/2011
04S05W15AAA1	34°21′32″	91°31′33″	37	164.44	201	03/28/2011
04S05W36DCC1	34°17′52″	91°30′04″	37	158.97	196	03/31/2011
05S01W17BAA1	34°15′51″	91°07′45″	86	90.08	176	04/05/2011
05S03W04ADB1	34°17′34″	91°20′07″	41	147.43	188	04/04/2011
05S04W26ACA1	34°13′58″	91°24′34″	51	136.58	188	03/31/2011
05S05W36DAA1	34°12′45″	91°29′47″	38	141.61	180	03/31/2011
06S02W06ABB1	34°12′28″	91°16′20″	65	115.90	181	03/31/2011
06S02W17ADA1	34°10′23″	91°14′53″	78	110.50	188	03/31/2011
06S02W22CDB1	34°09′04″	91°13′31″	78	108.18	186	03/31/2011
06S03W27BAA1	34°08′59″	91°20′09″	64	117.34	181	03/31/2011
07S02W28ABA1	34°03′40″	91°14′11″	79	102.13	181	03/31/2011
07S03W06ABC1	34°07′02″	91°22′48″	55	129.53	185	03/31/2011
08S02W09BCC1	34°00′31″	91°14′48″	76	97.79	174	03/31/2011
			Ashley County			
15S07W32CDD1	33°21′18″	91°51′01″	52	138.41	190	03/29/2011
17S09W15ACC1	33°13′34″	92°01′16″	77	22.83	100	03/29/2011
			Bradley County			
12S09W31CCB1	33°37′11″	92°04′44″	47	184.12	231	03/29/2011
13S09W06ACB2	33°36′47″	92°04′17″	40	168.24	208	03/29/2011
13S11W17BCD1	33°34′54″	92°16′07″	58	191.89	250	03/29/2011
15S11W31DDD1	33°21′42″	92°16′21″	29	102.40	131	03/01/2011
16S12W21CAA1	33°18′39″	92°20′52″	22	78.36	100	03/29/2011

Appendix 1. Water-level data collected during spring 2011 from wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
			Calhoun County			
13S13W32CDA1	33°32′27″	92°27′42″	33	175.50	208	05/19/2011
14S13W03CAB1	33°31′45″	92°25′51″	33	169.08	202	05/19/2011
14S13W05BBD1	33°32′07″	92°28′02″	38	151.42	189	05/19/2011
14S13W12CCB1	33°30′40″	92°24′04″	40	165.18	205	05/19/2011
			Chicot County			
13S03W22DAD1	33°33′12″	91°23′08″	64	70.74	135	03/29/2011
15S03W07BCC1	33°24′45″	91°27′23″	64	65.35	129	03/29/2011
			Cleveland County			
09S11W01DCA1	33°57′29″	92°11′34″	42	183.03	225	05/18/2011
09S11W11CDB1	33°56′23″	92°12′51″	72	160.64	233	05/18/2011
10S09W23CDC1	33°49′18″	92°00′21″	52	167.84	220	05/18/2011
10S09W35ACD1	33°47′58″	91°59′57″	54	164.96	219	05/18/2011
10S12W12BDD1	33°51′33″	92°17′43″	101	118.83	220	05/18/2011
11S11W16AAB1	33°45′43″	92°14′23″	100	202.97	303	05/18/2011
			Columbia County			
15S20W20CCB1	33°24′53″	93°12′15″	156	216.45	372	03/24/2011
16S20W08DCC1	33°21′14″	93°11′41″	87	315.03	402	03/25/2011
16S21W14CBB1	33°20′49″	93°15′17″	77	203.83	281	03/21/2011
16S21W20DAD1	33°19′55″	93°17′36″	96	254.43	350	03/21/2011
16S22W22CCD1	33°19′48″	93°22′25″	207	132.97	340	03/14/2011
17S19W15AAB1	33°15′46″	93°03′18″	41	277.31	318	03/22/2011
17S19W17ACA1	33°15′38″	93°05′36″	31	271.86	303	03/24/2011
17S19W18CBD1	33°15′17″	93°06′56″	-5	310.11	305	03/24/2011
17S19W19BCA1	33°14′33″	93°07′05″	30	271.36	301	03/22/2011
17S19W30ABB1	33°14′06″	93°06′50″	32	215.52	248	03/22/2011
17S20W13BCD1	33°15′32″	93°08′07″	33	307.02	340	03/24/2011
17S20W17CDA1	33°15′20″	93°12′01″	20	305.21	325.1	03/24/2011
17S20W36ABC1	33°13′07″	93°07′55″	42	293.06	335	03/23/2011
17S21W01BBC1	33°17′43″	93°14′24″	55	250.37	305	03/21/2011
17S21W08DCA1	33°16′13″	93°17′58″	91	208.90	300	03/22/2011
17S21W11DCC2	33°16′09″	93°14′49″	28	271.97	300	03/22/2011
17S21W11DCC3	33°16′09″	93°14′49″	22	275.71	298	03/22/2011
17S21W17BAB1	33°16′08″	93°18′20″	88	198.95	287	03/22/2011
17S22W21ABD1	33°15′17″	93°23′04″	214	81.45	295	03/22/2011
17S22W22ABB1	33°15′22″	93°22′10″	185	135.75	321	03/23/2011
17S22W23BBB1	33°15′21″	93°21′37″	191	148.78	340	03/22/2011
18S20W06DDC1	33°11′43″	93°12′49″	1	299.43	300	03/22/2011
18S20W08CBC1	33°11′15″	93°12′27″	-9	272.02	263	03/23/2011
18S20W10CAA1	33°10′54″	93°10′16″	19	271.29	290	03/23/2011
19S20W08DAB1	33°05′58″	93°11′56″	53	274.62	328	03/02/2011
19S20W09CBD1	33°05′55″	93°11′29″	69	262.52	332	03/23/2011
19S20W34BDD1	33°02′39″	93°10′31″	83	206.98	290	03/23/2011

Appendix 1. Water-level data collected during spring 2011 from wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
			Columbia County—Continued			
19S21W16DBB1	33°05′17″	93°17′24″	111	172.62	284	03/23/2011
19S23W10ABD1	33°06′44″	93°28′33″	199	43.41	242	03/24/2011
19S23W11CDA2	33°06′09″	93°27′44″	197	51.07	248	03/24/2011
19S23W11DDB1	33°06′05″	93°27′22″	194	51.85	246	03/24/2011
19S23W14BAB2	33°05′55″	93°27′52″	199	44.52	244	03/24/2011
20S22W11ACD1	33°01′09″	93°21′33″	164	106.95	271	03/23/2011
			Craighead County			
13N03E23CDD1	35°44′04″	90°44′33″	155	93.16	248	04/28/2011
14N04E22CBD1	35°49′29″	90°39′21″	198	58.28	256	04/28/2011
14N05E34ADD1	35°47′48″	90°34′14″	212	17.77	230	04/27/2011
14N05E36CBC1	35°47′51″	90°31′00″	206	13.62	220	04/27/2011
15N05E29DBB1	35°53′60″	90°34′33″	232	25.95	258	04/28/2011
15N06E18ACA1	35°55′44″	90°28′58″	211	19.21	230	04/27/2011
			Crittenden County			
06N07E01DAD2	35°09′58″	90°17′38″	185	23.85	209	04/27/2011
06N09E08DCC1	35°08′50″	90°09′22″	211	3.58	215	04/27/2011
06N09E23AAB1	35°07′45″	90°05′53″	175	46.56	222	04/27/2011
09N07E21BBB1	35°23′41″	90°21′31″	191	25.12	216	04/27/2011
			Cross County			
06N04E06ACA1	35°10′04″	90°42′38″	155	202.83	358	05/31/2011
07N05E04ADD1	35°15′38″	90°33′30″	176	33.43	209	05/31/2011
08N02E18BDB1	35°19′08″	90°55′38″	140	87.89	228	05/31/2011
09N01E16CAC1	35°24′05″	90°59′51″	139	94.80	234	05/31/2011
09N03E22AAB2	35°24′04″	90°45′18″	147	130.12	277	05/31/2011
09N03E22AAD1	35°24′03″	90°45′12″	150	127.55	278	05/31/2011
09N04E30DCA1	35°22′32″	90°42′18″	153	276.63	429.32	05/31/2011
			Dallas County			
07S14W31AAA1	34°04′25″	92°33′34″	217	113.48	330	05/17/2011
07S16W20CAB1	34°05′55″	92°45′45″	296	25.72	322	05/17/2011
08S15W34BDC1	33°58′59″	92°37′30″	212	28.07	240	05/17/2011
08S16W18ACC1	34°01′52″	92°46′39″	233	19.22	252	05/17/2011
09S13W35CCD1	33°53′09″	92°24′13″	127	72.75	200	05/17/2011
09S14W01BDC1	33°57′54″	92°29′19″	224	41.05	265	05/17/2011
09S16W19CAA1	33°56′05″	92°47′01″	253	7.40	260	05/17/2011
10S13W34ACA2	33°48′29″	92°24′58″	120	151.86	272	05/17/2011
10S14W27CDB1	33°49′08″	92°31′38″	239	30.99	270	05/17/2011
10S15W11DBB1	33°52′01″	92°36′32″	238	57.21	295	03/03/2011
10S15W18BCC1	33°51′20″	92°41′20″	252	76.18	328	05/17/2011
			Desha County			
09S02W26AAC1	33°53′46″	91°15′21″	86	67.50	153	05/26/2011
09S04W28DDD1	33°53′10″	91°30′07″	48	116.54	165	05/26/2011
10S02W26CCC2	33°47′50″	91°16′24″	78	70.07	148	05/26/2011

Appendix 1. Water-level data collected during spring 2011 from wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
			Desha County—Continued			
10S04W11CBC1	33°50′34″	91°29′05″	59	101.53	161	05/26/2011
11S02W03CCA1	33°46′16″	91°17′11″	76	62.54	139	05/26/2011
12S03W26CBB1	33°37′49″	91°22′59″	55	88.10	143	05/26/2011
12S03W34DAD1	33°36′43″	91°23′05″	70	77.31	147	05/26/2011
			Drew County			
11S04W02ACA2	33°46′32″	91°28′27″	60	93.46	153	03/30/2011
11S04W25DAA1	33°42′49″	91°27′07″	60	87.81	148	03/30/2011
11S06W11DBC1	33°46′07″	91°41′22″	52	150.54	203	03/30/2011
12S06W30BBD1	33°38′07″	91°45′43″	46	224.80	271	03/30/2011
12S06W32DAD1	33°36′49″	91°44′02″	52	162.85	215	03/30/2011
13S05W36ACB1	33°31′51″	91°34′08″	77	91.73	169	03/30/2011
15S04W12DDA1	33°24′29″	91°27′24″	61	63.92	125	03/30/2011
			Grant County			
03S13W12AAA1	34°28′46″	92°21′06″	231	129.79	361	04/14/2011
03S15W26DAA1	34°26′01″	92°34′47″	326	10.90	337	04/14/2011
05S13W03CAA1	34°18′44″	92°24′00″	176	83.79	260	04/14/2011
05S13W03CDA4	34°18′38″	92°24′02″	176	105.17	281	04/14/2011
05S13W07ADB1	34°18′10″	92°26′50″	190	79.76	270	04/14/2011
05S14W06DCC1	34°18′43″	92°33′27″	208	85.47	293	04/14/2011
05S15W05ABD1	34°19′24″	92°38′27″	222	14.47	236	04/14/2011
06S11W05ACD1	34°13′41″	92°14′13″	80	189.02	269	04/15/2011
06S15W26ACA1	34°10′22″	92°35′38″	216	63.64	280	04/14/2011
07S12W21BDB1	34°05′58″	92°19′53″	218	4.60	223	04/15/2011
			Jefferson County			
03S08W19BAD1	34°26′24″	91°54′44″	48	169.28	217	04/12/2011
03S08W19BBD1	34°26′28″	91°55′05″	52	162.78	215	04/12/2011
03S10W14CAD1	34°26′59″	92°03′30″	107	114.48	221	04/12/2011
03S10W27AAD1	34°25′02″	92°04′34″	76	145.83	222	04/12/2011
03S11W22ABC1	34°26′51″	92°10′58″	140	170.37	310	04/07/2011
04S07W17BCC1	34°21′40″	91°47′42″	34	166.29	200	04/12/2011
04S08W35BBD1	34°19′09″	91°50′56″	-15	215.40	200	04/12/2011
04S09W11BAA1	34°23′09″	91°57′02″	67	142.86	210	04/12/2011
04S10W29ADB1	34°20′25″	92°06′25″	50	217.06	267.55	04/07/2011
04S11W14BAD1	34°22′20″	92°10′00″	80	320.46	400	04/07/2011
05S08W30ADB1	34°14′52″	91°54′40″	-55	276.43	221	04/19/2011
05S09W24DBD1	34°15′30″	91°55′56″	-52	259.74	208.17	04/18/2011
05S10W16DBB1	34°16′35″	92°05′43″	1	313.86	315	04/07/2011
06S08W16CCC1	34°11′43″	91°55′17″	-37	239.21	202.42	04/18/2011
06S08W25ADC1	34°10′25″	91°51′16″	-12	215.09	203.48	04/18/2011
06S09W17CAD1	34°11′59″	92°02′07″	-22	255.30	233	04/13/2011
06S09W17CCA1	34°11′52″	92°02′21″	-16	250.79	234.34	04/13/2011
06S10W23ACA2	34°11′23″	92°05′04″	17	217.55	235	04/19/2011
06S10W23ACD1	34°11′16″	92°05′08″	11	228.10	239	04/18/2011

Appendix 1. Water-level data collected during spring 2011 from wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
Jefferson County—Continued						
06S10W23DBA1	34°11′05″	92°05′06″	19	232.62	252	04/19/2011
07S07W24BAB1	34°06′33″	91°45′23″	27	160.68	188	04/19/2011
07S10W24CAC1	34°05′49″	92°04′21″	46	264.83	311	04/18/2011
Lafayette County						
16S23W12CAD1	33°21′43″	93°26′09″	261	61.49	322	03/14/2011
16S24W26AAC1	33°19′50″	93°33′03″	210	56.72	267	03/14/2011
17S23W19ACC1	33°15′20″	93°31′28″	238	53.27	291	03/14/2011
17S24W23BBD1	33°15′26″	93°34′03″	227	33.61	261	03/14/2011
18S23W29ACC1	33°09′11″	93°30′39″	238	17.49	255	03/14/2011
19S23W29BDB1	33°03′52″	93°31′03″	210	39.96	250	03/14/2011
20S23W05ADB1	33°02′23″	93°30′36″	204	37.56	242	03/14/2011
Lee County						
01N04E09CDD1	34°42′10″	90°41′19″	141	66.61	208	04/26/2011
Lincoln County						
07S07W30CDC1	34°04′44″	91°50′43″	36	172.32	208	06/02/2011
08S08W35DBB1	33°58′58″	91°52′22″	32	217.66	250	03/30/2011
09S07W07DAD1	33°56′34″	91°51′28″	21	274.74	296	03/30/2011
Lonoke County						
01N07W03BCC1	34°44′25″	91°45′03″	87	136.20	223	03/10/2011
01S08W02DBD1	34°38′55″	91°49′60″	102	108.41	210	03/11/2011
02N07W06ACD1	34°49′39″	91°47′37″	116	124.51	241	03/10/2011
02N07W09AAA1	34°49′06″	91°45′00″	129	102.77	232	03/10/2011
02N07W22DBA1	34°46′51″	91°44′26″	92	135.45	227	03/10/2011
02N07W24DAC1	34°46′50″	91°42′09″	80	150.94	231	03/10/2011
02N07W32DDD1	34°44′53″	91°46′19″	86	139.74	226	03/10/2011
02S07W08DCC1	34°32′35″	91°47′00″	60	141.71	202	03/11/2011
02S08W16BDA1	34°32′28″	91°52′32″	90	126.40	216	03/10/2011
03N07W03CAA1	34°54′45″	91°44′26″	153	81.70	235	03/11/2011
03N07W23CCC1	34°51′44″	91°43′50″	136	92.29	228	03/11/2011
03N08W11ACD1	34°54′03″	91°49′35″	152	96.43	248	03/11/2011
03N08W22DAD1	34°52′05″	91°50′24″	134	98.99	233	03/11/2011
03N08W22DAD2	34°52′05″	91°50′24″	133	99.66	233	03/11/2011
03N08W22DDD2	34°51′52″	91°50′25″	137	98.14	235	03/11/2011
Miller County						
17S25W18CDB1	33°16′05″	93°44′02″	208	12.20	220	05/16/2011
19S27W10BBA1	33°07′19″	93°53′45″	303	17.17	320	05/16/2011
Monroe County						
01N01W15DBC2	34°41′39″	91°05′42″	123	62.00	185	04/27/2011
01N03W14CCB1	34°41′44″	91°18′01″	98	74.30	172	04/26/2011
03N02W26DAB1	34°50′42″	91°10′26″	142	49.54	192	04/26/2011
04N02W28DDD4	34°55′35″	91°12′21″	159	32.73	192	04/26/2011
04N02W30BAC1	34°56′17″	91°15′04″	166	15.58	182	04/26/2011
04N02W30BAD1	34°56′17″	91°15′15″	155	20.98	176	04/26/2011

Appendix 1. Water-level data collected during spring 2011 from wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
			Ouachita County			
11S15W27ABD1	33°44′41″	92°37′26″	130	69.72	200	05/20/2011
11S17W14CAC1	33°46′31″	92°49′27″	126	19.90	146	05/20/2011
11S17W36CCA1	33°43′41″	92°48′34″	125	7.94	133	05/17/2011
12S15W09BBA1	33°42′23″	92°39′22″	165	47.83	213	05/20/2011
12S16W25BDC1	33°39′29″	92°42′11″	105	35.25	140	05/24/2011
12S16W26ABD1	33°39′46″	92°43′04″	105	32.23	137	05/24/2011
12S18W19CDC1	33°40′14″	92°59′51″	202	32.87	235	03/22/2011
12S18W25CAB1	33°39′37″	92°54′42″	108	78.51	187	05/16/2011
12S19W09BAB1	33°42′51″	93°03′52″	275	14.79	290	05/17/2011
12S19W35BDD1	33°39′01″	93°01′46″	193	156.69	350	05/16/2011
13S16W28ADD1	33°34′16″	92°44′51″	79	27.40	106	05/20/2011
13S18W06BBA1	33°38′19″	93°00′06″	167	114.60	282	03/03/2011
13S18W31BDD1	33°33′43″	92°59′56″	210	31.77	242	05/19/2011
13S19W28BCD1	33°34′34″	93°04′18″	192	37.55	230	05/16/2011
14S16W32BDB1	33°28′16″	92°46′40″	187	43.79	231	03/21/2011
14S17W03CBA1	33°32′34″	92°50′55″	123	16.70	140	03/03/2011
14S17W05CAD1	33°32′38″	92°52′55″	119	38.20	157	03/03/2011
14S17W19DBB1	33°30′02″	92°53′45″	229	29.70	259	03/21/2011
14S17W32CAD1	33°28′03″	92°52′51″	141	79.04	220	05/24/2011
14S19W29ABB1	33°29′41″	93°05′13″	192	88.38	280	05/16/2011
15S15W32DBB2	33°22′34″	92°40′27″	-40	159.17	119	05/19/2011
15S16W23DAC1	33°24′17″	92°43′14″	44	126.21	170	05/19/2011
15S18W36ADD1	33°23′11″	92°54′36″	69	91.14	160	05/19/2011
15S19W10DCC1	33°26′18″	93°03′18″	140	69.83	210	05/24/2011
15S19W21CDD2	33°24′38″	93°04′32″	84	188.10	272	03/03/2011
			Phillips County			
01S02E32DDC1	34°33′24″	90°54′55″	133	77.81	211	05/25/2011
02S02E01ADC1	34°33′23″	90°50′56″	143	32.82	176	05/25/2011
02S04E02DAA1	34°32′43″	90°38′44″	169	89.76	259	05/25/2011
02S04E02DBA1	34°32′43″	90°39′07″	158	91.83	250	05/25/2011
02S05E29CCC1	34°28′51″	90°36′35″	164	15.06	179	05/25/2011
03S03E30DAA1	34°24′03″	90°49′15″	135	37.28	172	05/25/2011
04S02E25CCC1	34°18′24″	90°51′21″	137	29.23	166	05/25/2011
			Poinsett County			
10N01E12BDC1	35°30′26″	90°56′30″	130	104.40	234	04/28/2011
10N01E15DBB1	35°29′31″	90°58′25″	136	96.14	232	06/01/2011
10N01E33ABA1	35°27′25″	90°59′24″	138	82.62	221	04/28/2011
10N03E02BCD1	35°31′39″	90°44′47″	137	113.82	251	04/28/2011
10N03E23CAC1	35°28′50″	90°44′32″	143	115.27	258	04/28/2011
11N02E16CCC1	35°34′48″	90°53′21″	129	113.65	243	04/28/2011
11N03E25BDD	35°33′28″	90°43′23″	149	127.60	277	04/29/2011
11N03E25BDD1	35°33′25″	90°43′23″	145	124.03	269	04/29/2011

Appendix 1. Water-level data collected during spring 2011 from wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
			Poinsett—Continued			
12N03E35BCC1	35°37′45″	90°44′56″	141	102.98	244	04/28/2011
12N03E35DDA1	35°37′27″	90°43′53″	141	106.42	247	04/28/2011
			Prairie County			
01N05W19CDC1	34°41′13″	91°35′05″	66	146.47	212	04/06/2011
01N06W34CBB1	34°39′43″	91°38′46″	63	162.87	226	04/05/2011
01S05W06BCB1	34°39′04″	91°35′32″	63	157.39	220	04/05/2011
01S05W20ABB1	34°36′40″	91°33′52″	61	158.62	220	04/05/2011
01S06W01BDD2	34°38′59″	91°36′13″	63	162.73	226	04/05/2011
01S06W11DBD1	34°37′49″	91°36′54″	48	177.72	226	04/05/2011
01S06W12BAB2	34°38′26″	91°36′13″	57	171.28	228	03/17/2011
02N04W19ACB1	34°46′49″	91°28′02″	150	60.82	211	04/06/2011
02N05W21CBB2	34°46′49″	91°33′00″	115	110.02	225	03/22/2011
02N05W24BCA4	34°46′59″	91°29′37″	121	103.58	225	03/22/2011
02N06W04DBB1	34°49′28″	91°38′52″	129	106.05	235	04/06/2011
02N06W19AAB1	34°47′18″	91°40′50″	83	152.69	236	04/06/2011
02N06W20BCB1	34°47′07″	91°40′33″	87	149.24	236	04/06/2011
02N06W21DAD1	34°46′44″	91°38′29″	103	128.86	232	04/06/2011
02N06W22BDD1	34°46′54″	91°38′01″	103	130.44	233	04/06/2011
02N06W24CAA2	34°46′51″	91°35′51″	112	120.93	233	03/22/2011
03N05W03ADA2	34°54′52″	91°30′43″	144	61.08	205	04/06/2011
03N05W20CCC1	34°51′45″	91°33′56″	142	71.28	213	04/06/2011
03N06W20CDD1	34°51′40″	91°40′04″	139	85.70	225	04/06/2011
			St. Francis County			
03N01W33CDD1	34°54′46″	91°06′35″	139	70.91	210	04/27/2011
04N04E18BAB1	34°57′43″	90°43′19″	154	65.52	220	04/27/2011
			Union County			
16S14W15CAB1	33°19′44″	92°32′18″	-40	133.56	94	03/15/2011
16S16W02ABC1	33°22′06″	92°43′29″	-42	158.27	116	04/20/2011
17S12W31DDD1	33°12′06″	92°22′26″	11	209.24	220	03/17/2011
17S12W32BBC1	33°12′02″	92°22′19″	-16	247.39	231	03/17/2011
17S13W31BAC1	33°12′00″	92°29′16″	-62	278.07	216	03/17/2011
17S14W22BAB1	33°13′54″	92°32′24″	-76	276.92	201	04/20/2011
17S15W08CDD1	33°15′05″	92°40′27″	-95	270.36	174.92	03/15/2011
17S15W18DBB1	33°14′39″	92°41′29″	-104	286.84	182.93	03/25/2011
17S16W01BAA1	33°16′49″	92°42′33″	-74	262.65	188.84	03/15/2011
17S16W24BDB1	33°13′57″	92°42′48″	-120	324.99	205	03/15/2011
17S17W25DBA2	33°12′56″	92°48′38″	-71	320.58	250	03/25/2011
17S17W30DCD1	33°12′57″	92°53′56″	-24	303.86	280	03/17/2011
18S11W09ABC1	33°10′12″	92°14′43″	33	102.46	135	03/16/2011
18S12W33BBB1	33°06′50″	92°21′20″	-24	138.40	114	03/16/2011
18S15W03DAB1	33°11′04″	92°38′02″	-88	328.10	240	03/16/2011
18S15W33ADA1	33°06′59″	92°38′58″	-79	332.36	253	03/16/2011

Appendix 1. Water-level data collected during spring 2011 from wells completed in the Sparta-Memphis aquifer in Arkansas.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD 29)	Depth to water (feet below land surface)	Land-surface datum (feet above NGVD 29)	Date of measurement
			Union County—Continued			
18S15W35DAC1	33°06′36″	92°37′07″	-61	261.91	201	03/16/2011
18S16W10CDD1	33°10′00″	92°44′45″	-91	272.75	182	03/15/2011
18S16W11DAC1	33°10′11″	92°43′16″	-95	367.36	272	03/16/2011
18S16W12ACB1	33°10′29″	92°42′32″	-98	399.92	302	03/16/2011
19S10W16CBC1	33°03′29″	92°09′04″	-5	86.55	82	03/16/2011
19S11W23ACA1	33°02′55″	92°12′29″	-9	151.17	142	03/17/2011
19S11W25AAA1	33°02′18″	92°11′13″	-10	145.49	135	03/16/2011
19S12W13AAA1	33°04′11″	92°17′17″	31	159.66	191	03/16/2011
19S18W14ADA1	33°04′52″	92°56′08″	52	190.81	243	03/17/2011
			Woodruff County			
05N01W11ABA1	35°04′26″	91°04′07″	150	61.17	211	05/27/2011
05N01W17DBB1	35°03′11″	91°07′27″	163	46.74	210	05/27/2011
05N02W31DCB3	35°00′27″	91°14′56″	180	13.09	193	05/27/2011
06N01W13ABA1	35°08′52″	91°02′54″	138	73.51	212	05/27/2011
06N01W13ADC1	35°08′27″	91°02′47″	142	70.11	212	05/27/2011
07N01W12BCB1	35°14′42″	91°03′26″	154	68.43	222	05/27/2011
08N01W12CDA1	35°19′34″	91°03′11″	147	77.89	225	05/27/2011
08N02W26ADC1	35°17′26″	91°10′04″	185	27.06	212	05/27/2011

Appendix 2. Difference in water level from 2007 to 2011 in the Sparta-Memphis aquifer in Arkansas.

[Horizontal datum is the North American Datum of 1983; negative values denote a decline; 2007 depth-to-water level from Schrader (2009)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2007 depth to water (feet below land-surface datum)	2011 depth to water (feet below land-surface datum)	Difference in water level from 2007 to 2011 (feet)
			Arkansas County		
02S04W06CDB1	34°33′12″	91°28′49″	159.24	173.13	-13.9
02S04W23DAA1	34°30′44″	91°23′55″	144.91	143.67	1.2
02S04W33BBB1	34°29′22″	91°27′03″	168.78	166.19	2.6
02S05W16CBB1	34°31′44″	91°33′19″	172.95	177.38	-4.4
02S05W34BDA1	34°29′25″	91°31′48″	180.13	186.45	-6.3
02S05W35AAB1	34°29′30″	91°30′35″	174.89	175.31	-0.4
03S04W02CCB1	34°27′48″	91°24′58″	153.4	151.95	1.5
03S04W26CDA1	34°24′21″	91°24′38″	147.52	142.52	5.0
03S05W02AAB1	34°28′42″	91°30′34″	173.32	169.82	3.5
03S05W13BDC1	34°26′31″	91°30′05″	183.01	173.6	9.4
03S05W15CBB1	34°26′33″	91°32′29″	179.22	176.74	2.5
03S05W28DAB1	34°24′47″	91°32′40″	172.86	181.68	-8.8
03S06W30BBD1	34°25′16″	91°42′16″	157.4	159.3	-1.9
04S01W04CBD1	34°22′25″	91°08′08″	113.42	110.13	3.3
04S01W28BAA1	34°19′27″	91°07′48″	106.52	102.71	3.8
04S04W11BCC1	34°21′57″	91°25′02″	155.1	161.55	-6.5
04S04W19CBB1	34°20′04″	91°29′29″	163.58	162.49	1.1
04S04W22DAA1	34°20′07″	91°25′15″	159.48	153.66	5.8
04S05W01BAA1	34°23′22″	91°29′56″	156.85	160.44	-3.6
04S05W05ACC1	34°23′03″	91°34′13″	159.4	156.72	2.7
04S05W15AAA1	34°21′32″	91°31′33″	167.55	164.44	3.1
04S05W36DCC1	34°17′52″	91°30′04″	166.15	158.97	7.2
05S01W17BAA1	34°15′51″	91°07′45″	93.46	90.08	3.4
05S03W04ADB1	34°17′34″	91°20′07″	140.31	147.43	-7.1
05S04W26ACA1	34°13′58″	91°24′34″	140.06	136.58	3.5
05S05W36DAA1	34°12′45″	91°29′47″	145.24	141.61	3.6
06S02W06ABB1	34°12′28″	91°16′20″	115.17	115.9	-0.7
06S02W17ADA1	34°10′23″	91°14′53″	115.11	110.5	4.6
06S02W22CDB1	34°09′04″	91°13′31″	112.18	108.18	4.0
06S03W27BAA1	34°08′59″	91°20′09″	119.92	117.34	2.6
07S02W28ABA1	34°03′40″	91°14′11″	106.08	102.13	4.0
07S03W06ABC1	34°07′02″	91°22′48″	130.28	129.53	0.8
08S02W09BCC1	34°00′31″	91°14′48″	100.92	97.79	3.1
			Ashley County		
15S07W32CDD1	33°21′18″	91°51′01″	148.25	138.41	9.8
17S09W15ACC1	33°13′34″	92°01′16″	17.59	22.83	-5.2
			Bradley County		
12S09W31CCB1	33°37′11″	92°04′44″	194.72	184.12	10.6
13S09W06ACB2	33°36′47″	92°04′17″	179	168.24	10.8
13S11W17BCD1	33°34′54″	92°16′07″	202.22	191.89	10.3
16S12W21CAA1	33°18′39″	92°20′52″	79.02	78.36	0.7

Appendix 2. Difference in water level from 2007 to 2011 in the Sparta-Memphis aquifer in Arkansas.—Continued

[Horizontal datum is the North American Datum of 1983; negative values denote a decline; 2007 depth-to-water level from Schrader (2009)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2007 depth to water (feet below land-surface datum)	2011 depth to water (feet below land-surface datum)	Difference in water level from 2007 to 2011 (feet)
			Calhoun County		
13S13W32CDA1	33°32′27″	92°27′42″	194.83	175.5	19.3
14S13W03CAB1	33°31′45″	92°25′51″	167.59	169.08	-1.5
14S13W05BBD1	33°32′07″	92°28′02″	156.8	151.42	5.4
14S13W12CCB1	33°30′40″	92°24′04″	171.6	165.18	6.4
			Chicot County		
13S03W22DAD1	33°33′12″	91°23′08″	70.1	70.74	-0.6
15S03W07BCC1	33°24′45″	91°27′23″	65.11	65.35	-0.2
			Cleveland County		
09S11W01DCA1	33°57′29″	92°11′34″	206.97	183.03	23.9
09S11W11CDB1	33°56′23″	92°12′51″	162.62	160.64	2.0
10S09W23CDC1	33°49′18″	92°00′21″	164.12	167.84	-3.7
10S09W35ACD1	33°47′58″	91°59′57″	156.42	164.96	-8.5
10S12W12BDD1	33°51′33″	92°17′43″	120.26	118.83	1.4
11S11W16AAB1	33°45′43″	92°14′23″	204.31	202.97	1.3
			Columbia County		
16S20W08DCC1	33°21′14″	93°11′41″	319.33	315.03	4.3
17S19W15AAB1	33°15′46″	93°03′18″	275.73	277.31	-1.6
17S19W19BCA1	33°14′33″	93°07′05″	268.97	271.36	-2.4
17S20W17CDA1	33°15′20″	93°12′01″	313.96	305.21	8.8
17S20W36ABC1	33°13′07″	93°07′55″	292.66	293.06	-0.4
17S21W11DCC2	33°16′09″	93°14′49″	276.11	271.97	4.1
17S21W11DCC3	33°16′09″	93°14′49″	277.89	275.71	2.2
19S20W09CBD1	33°05′55″	93°11′29″	263.22	262.52	0.7
19S21W16DBB1	33°05′17″	93°17′24″	175.3	172.62	2.7
19S23W10ABD1	33°06′44″	93°28′33″	45.57	43.41	2.2
19S23W11CDA2	33°06′09″	93°27′44″	53.07	51.07	2.0
19S23W11DDB1	33°06′05″	93°27′22″	53.82	51.85	2.0
19S23W14BAB2	33°05′55″	93°27′52″	52.58	44.52	8.1
20S22W11ACD1	33°01′09″	93°21′33″	108.04	106.95	1.1
			Craighead County		
13N03E23CDD1	35°44′04″	90°44′33″	88.76	93.16	-4.4
14N04E22CBD1	35°49′29″	90°39′21″	57.38	58.28	-0.9
14N05E36CBC1	35°47′51″	90°31′00″	12.4	13.62	-1.2
15N05E29DBB1	35°53′60″	90°34′33″	23.89	25.95	-2.1
15N06E18ACA1	35°55′44″	90°28′58″	17.26	19.21	-2.0
			Crittenden County		
06N07E01DAD2	35°09′58″	90°17′38″	26.28	23.85	2.4
06N09E23AAB1	35°07′45″	90°05′53″	54.51	46.56	7.9
09N07E21BBB1	35°23′41″	90°21′31″	24.87	25.12	-0.3
			Cross County		
06N04E06ACA1	35°10′04″	90°42′38″	206.34	202.83	3.5
07N05E04ADD1	35°15′38″	90°33′30″	35.51	33.43	2.1
09N01E16CAC1	35°24′05″	90°59′51″	92.09	94.8	-2.7

Appendix 2. Difference in water level from 2007 to 2011 in the Sparta-Memphis aquifer in Arkansas.—Continued

[Horizontal datum is the North American Datum of 1983; negative values denote a decline; 2007 depth-to-water level from Schrader (2009)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2007 depth to water (feet below land-surface datum)	2011 depth to water (feet below land-surface datum)	Difference in water level from 2007 to 2011 (feet)
Cross County—Continued					
09N03E22AAB2	35°24′04″	90°45′18″	127.98	130.12	-2.1
09N03E22AAD1	35°24′03″	90°45′12″	133.06	127.55	5.5
09N04E30DCA1	35°22′32″	90°42′18″	271.73	276.63	-4.9
Dallas County					
07S14W31AAA1	34°04′25″	92°33′34″	111.07	113.48	-2.4
07S16W20CAB1	34°05′55″	92°45′45″	28.46	25.72	2.7
08S15W34BDC1	33°58′59″	92°37′30″	26.67	28.07	-1.4
08S16W18ACC1	34°01′52″	92°46′39″	16.86	19.22	-2.4
09S13W35CCD1	33°53′09″	92°24′13″	71.62	72.75	-1.1
09S14W01BDC1	33°57′54″	92°29′19″	82.92	41.05	41.9
09S16W19CAA1	33°56′05″	92°47′01″	7.31	7.4	-0.1
10S13W34ACA2	33°48′29″	92°24′58″	151.38	151.86	-0.5
10S14W27CDB1	33°49′08″	92°31′38″	33.44	30.99	2.5
10S15W18BCC1	33°51′20″	92°41′20″	79.05	76.18	2.9
Desha County					
09S02W26AAC1	33°53′46″	91°1521″	72.64	67.5	5.1
09S04W28DDD1	33°53′10″	91°30′07″	115.48	116.54	-1.1
10S02W26CCC2	33°47′50″	91°16′24″	75.97	70.07	5.9
10S04W11CBC1	33°50′34″	91°29′05″	105.61	101.53	4.1
11S02W03CCA1	33°46′16″	91°17′11″	74.73	62.54	12.2
12S03W26CBB1	33°37′49″	91°22′59″	100.29	88.1	12.2
12S03W34DAD1	33°36′43″	91°23′05″	82.21	77.31	4.9
Drew County					
11S04W02ACA2	33°46′32″	91°28′27″	96.09	93.46	2.6
11S04W25DAA1	33°42′49″	91°27′07″	88.18	87.81	0.4
11S06W11DBC1	33°46′07″	91°41′22″	150.59	150.54	0.1
12S06W30BBD1	33°38′07″	91°45′43″	226.62	224.8	1.8
12S06W32DAD1	33°36′49″	91°44′02″	177.16	162.85	14.3
13S05W36ACB1	33°31′51″	91°34′08″	92.23	91.73	0.5
15S04W12DDA1	33°24′29″	91°27′24″	63.68	63.92	-0.2
Grant County					
03S13W12AAA1	34°28′46″	92°21′06″	132.41	129.79	2.6
03S15W26DAA1	34°26′01″	92°34′47″	11.02	10.9	0.1
05S13W03CAA1	34°18′44″	92°24′00″	88.26	83.79	4.5
05S13W03CDA4	34°18′38″	92°24′02″	113.93	105.17	8.8
05S13W07ADB1	34°18′10″	92°26′50″	81.75	79.76	2.0
05S14W06DCC1	34°18′43″	92°33′27″	87.64	85.47	2.2
05S15W05ABD1	34°19′24″	92°38′27″	14.29	14.47	-0.2
06S11W05ACD1	34°13′41″	92°14′13″	216.06	189.02	27.0
06S15W26ACA1	34°10′22″	92°35′38″	72.77	63.64	9.1
07S12W21BDB1	34°05′58″	92°19′53″	4.12	4.6	-0.5

Appendix 2. Difference in water level from 2007 to 2011 in the Sparta-Memphis aquifer in Arkansas.—Continued

[Horizontal datum is the North American Datum of 1983; negative values denote a decline; 2007 depth-to-water level from Schrader (2009)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2007 depth to water (feet below land-surface datum)	2011 depth to water (feet below land-surface datum)	Difference in water level from 2007 to 2011 (feet)
			Jefferson County		
03S08W19BAD1	34°26′24″	91°54′44″	173.95	169.28	4.7
03S08W19BBD1	34°26′28″	91°55′05″	181.23	162.78	18.4
03S10W14CAD1	34°26′59″	92°03′30″	120.6	114.48	6.1
03S10W27AAD1	34°25′02″	92°04′34″	136.63	145.83	-9.2
03S11W22ABC1	34°26′51″	92°10′58″	176.45	170.37	6.1
04S07W17BCC1	34°21′40″	91°47′42″	205.35	166.29	39.1
04S08W35BBD1	34°19′09″	91°50′56″	215.5	215.4	0.1
04S11W14BAD1	34°22′20″	92°10′00″	313.67	320.46	-6.8
05S08W30ADB1	34°14′52″	91°54′40″	298.66	276.43	22.2
05S09W24DBD1	34°15′30″	91°55′56″	279.23	259.74	19.5
05S10W16DBB1	34°16′35″	92°05′43″	312.25	313.86	-1.6
06S08W16CCC1	34°11′43″	91°55′17″	255.56	239.21	16.4
06S08W25ADC1	34°10′25″	91°51′16″	225.35	215.09	10.3
06S09W17CAD1	34°11′59″	92°02′07″	263.78	255.3	8.5
06S09W17CCA1	34°11′52″	92°02′21″	257.38	250.79	6.6
06S10W23ACD1	34°11′16″	92°05′08″	230.84	228.1	2.7
06S10W23DBA1	34°11′05″	92°05′06″	248.12	232.62	15.5
07S07W24BAB1	34°06′33″	91°45′23″	170.85	160.68	10.2
07S10W24CAC1	34°05′49″	92°04′21″	258.8	264.83	-6.0
			Lafayette County		
16S23W12CAD1	33°21′43″	93°26′09″	77.88	61.49	16.4
16S24W26AAC1	33°19′50″	93°33′03″	57.61	56.72	0.9
17S23W19ACC1	33°15′20″	93°31′28″	53.95	53.27	0.7
17S24W23BBD1	33°15′26″	93°34′03″	35.42	33.61	1.8
18S23W29ACC1	33°09′11″	93°30′39″	13.26	17.49	-4.2
19S23W29BDB1	33°03′52″	93°31′03″	43.16	39.96	3.2
20S23W05ADB1	33°02′23″	93°30′36″	40.96	37.56	3.4
			Lee County		
01N04E09CDD1	34°4210″	90°41′19″	62.21	66.61	-4.4
			Lincoln County		
07S07W30CDC1	34°04′44″	91°50′43″	190.05	172.32	17.7
08S08W35DBB1	33°58′58″	91°52′22″	228.88	217.66	11.2
09S07W07DAD1	33°56′34″	91°51′28″	279.86	274.74	5.1
			Lonoke County		
01N07W03BCC1	34°44′25″	91°45′03″	131.22	136.2	-5.0
01S08W02DBD1	34°38′55″	91°49′60″	98.31	108.41	-10.1
02N07W06ACD1	34°49′39″	91°47′37″	125.85	124.51	1.3
02N07W09AAA1	34°49′06″	91°45′00″	101.45	102.77	-1.3
02N07W22DBA1	34°46′51″	91°44′26″	131.71	135.45	-3.7
02N07W24DAC1	34°46′50″	91°42′09″	149.65	150.94	-1.3
02S07W08DCC1	34°32′35″	91°47′00″	143.4	141.71	1.7
03N07W03CAA1	34°54′45″	91°44′26″	79.98	81.7	-1.7
03N08W11ACD1	34°54′03″	91°49′35″	93.65	96.43	-2.8

Appendix 2. Difference in water level from 2007 to 2011 in the Sparta-Memphis aquifer in Arkansas.—Continued

[Horizontal datum is the North American Datum of 1983; negative values denote a decline; 2007 depth-to-water level from Schrader (2009)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2007 depth to water (feet below land-surface datum)	2011 depth to water (feet below land-surface datum)	Difference in water level from 2007 to 2011 (feet)
			Lonoke County—Continued		
03N08W22DAD1	34°52′05″	91°50′24″	97.42	98.99	-1.6
03N08W22DAD2	34°52′05″	91°50′24″	99.53	99.66	-0.1
03N08W22DDD2	34°51′52″	91°50′25″	101.98	98.14	3.8
			Miller County		
17S25W18CDB1	33°16′05″	93°44′02″	7.04	12.2	-5.2
19S27W10BBA1	33°07′19″	93°53′44″	1.48	17.17	-15.7
			Monroe County		
01N03W14CCB1	34°41′44″	91°18′01″	75.96	74.3	1.7
03N02W26DAB1	34°50′42″	91°10′26″	49.02	49.54	-0.5
04N02W28DDD4	34°55′35″	91°12′21″	32.68	32.73	-0.0
04N02W30BAC1	34°56′17″	91°15′04″	11.8	15.58	-3.8
04N02W30BAD1	34°56′17″	91°15′15″	15.07	20.98	-5.9
			Ouachita County		
11S15W27ABD1	33°44′41″	92°37′26″	69.34	69.72	-0.4
11S17W14CAC1	33°46′31″	92°49′27″	22.32	19.9	2.4
11S17W36CCA1	33°43′41″	92°48′34″	9.43	7.94	1.5
12S15W09BBA1	33°42′23″	92°39′22″	52.9	47.83	5.1
12S16W25BDC1	33°39′29″	92°42′11″	32.42	35.25	-2.8
12S16W26ABD1	33°39′46″	92°43′04″	34.63	32.23	2.4
12S18W19CDC1	33°40′14″	92°59′51″	30.63	32.87	-2.2
12S18W25CAB1	33°39′37″	92°54′42″	78.56	78.51	0.0
12S19W35BDD1	33°39′01″	93°01′46″	160.25	156.69	3.6
13S16W28ADD1	33°34′16″	92°44′51″	33.28	27.4	5.9
13S18W31BDD1	33°33′43″	92°59′56″	71.18	31.77	39.4
13S19W28BCD1	33°34′34″	93°04′18″	38.21	37.55	0.7
14S17W05CAD1	33°32′38″	92°52′55″	37.54	38.2	-0.7
14S17W32CAD1	33°28′03″	92°52′51″	79.06	79.04	0.0
14S19W29ABB1	33°29′41″	93°05′13″	88.16	88.38	-0.2
15S15W32DBB2	33°22′34″	92°40′27″	169.42	159.17	10.3
15S16W23DAC1	33°24′17″	92°43′14″	126.15	126.21	-0.1
15S18W36ADD1	33°23′11″	92°54′36″	94.4	91.14	3.3
15S19W10DCC1	33°26′18″	93°03′18″	69.86	69.83	0.0
15S19W21CDD2	33°24′38″	93°04′32″	198.82	188.1	10.7
			Phillips County		
01S02E32DDC1	34°33′24″	90°54′55″	84.17	77.81	6.4
02S02E01ADC1	34°33′23″	90°50′56″	35.17	32.82	2.4
02S04E02DAA1	34°32′43″	90°38′44″	132.52	89.76	42.8
02S04E02DBA1	34°32′43″	90°39′07″	129.19	91.83	37.4
02S05E29CCC1	34°28′51″	90°36′35″	23.56	15.06	8.5
03S03E30DAA1	34°24′03″	90°49′15″	35.05	37.28	-2.2
04S02E25CCC1	34°18′24″	90°51′21″	37.67	29.23	8.4

Appendix 2. Difference in water level from 2007 to 2011 in the Sparta-Memphis aquifer in Arkansas.—Continued

[Horizontal datum is the North American Datum of 1983; negative values denote a decline; 2007 depth-to-water level from Schrader (2009)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2007 depth to water (feet below land-surface datum)	2011 depth to water (feet below land-surface datum)	Difference in water level from 2007 to 2011 (feet)
			Poinsett County		
10N01E12BDC1	35°30′26″	90°56′30″	100.38	104.4	-4.0
10N01E15DBB1	35°29′31″	90°58′25″	99.23	96.14	3.1
10N01E33ABA1	35°27′25″	90°59′24″	79.5	82.62	-3.1
10N03E02BCD1	35°31′39″	90°44′47″	111.68	113.82	-2.1
10N03E23CAC1	35°28′50″	90°44′32″	113.12	115.27	-2.1
11N02E16CCC1	35°34′48″	90°53′21″	108.69	113.65	-5.0
11N03E25BDD	35°33′28″	90°43′23″	126.96	127.6	-0.6
11N03E25BDD1	35°33′25″	90°43′23″	121.45	124.03	-2.6
12N03E35BCC1	35°37′45″	90°44′56″	100.53	102.98	-2.5
12N03E35DDA1	35°37′27″	90°43′53″	102.95	106.42	-3.5
			Prairie County		
01N05W19CDC1	34°41′13″	91°35′05″	145.15	146.47	-1.3
01N06W34CBB1	34°39′43″	91°38′46″	169.7	162.87	6.8
01S05W06BCB1	34°39′04″	91°35′32″	177.2	157.39	19.8
01S05W20ABB1	34°36′40″	91°33′52″	154.65	158.62	-4.0
01S06W11DBD1	34°37′49″	91°36′54″	177.82	177.72	0.1
02N04W19ACB1	34°46′49″	91°28′02″	66.13	60.82	5.3
02N06W04DBB1	34°49′28″	91°38′52″	106.45	106.05	0.4
02N06W19AAB1	34°47′18″	91°40′50″	150.58	152.69	-2.1
02N06W20BCB1	34°47′07″	91°40′33″	147.18	149.24	-2.1
02N06W21DAD1	34°46′44″	91°38′29″	132.92	128.86	4.1
02N06W22BDD1	34°46′54″	91°38′01″	127.9	130.44	-2.5
03N05W03ADA2	34°54′52″	91°30′43″	59.9	61.08	-1.2
03N05W20CCC1	34°51′45″	91°33′56″	71.89	71.28	0.6
03N06W20CDD1	34°51′40″	91°40′04″	85.88	85.7	0.2
			St. Francis County		
04N04E18BAB1	34°57′43″	90°43′19″	65.29	65.52	-0.2
			Union County		
16S14W15CAB1	33°19′44″	92°32′18″	149.7	133.56	16.1
16S16W02ABC1	33°22′06″	92°43′29″	162.53	158.27	4.3
17S12W31DDD1	33°12′06″	92°22′26″	228.07	209.24	18.8
17S12W32BBC1	33°12′02″	92°22′19″	241.54	247.39	-5.8
17S13W31BAC1	33°12′00″	92°29′16″	309.04	278.07	31.0
17S14W22BAB1	33°13′54″	92°32′24″	297.61	276.92	20.7
17S15W08CDD1	33°15′05″	92°40′27″	289.65	270.36	19.3
17S15W18DBB1	33°14′39″	92°41′29″	301.33	286.84	14.5
17S16W01BAA1	33°16′49″	92°42′33″	271.73	262.65	9.1
17S16W24BDB1	33°13′57″	92°42′48″	343.85	324.99	18.9
17S17W25DBA2	33°12′56″	92°48′37″	336.42	320.58	15.8
17S17W30DCD1	33°12′57″	92°53′56″	323.53	303.86	19.7
18S11W09ABC1	33°10′12″	92°14′43″	94.64	102.46	-7.8
18S12W33BBB1	33°06′50″	92°21′20″	139.56	138.4	1.2
18S15W03DAB1	33°11′04″	92°38′02″	346.05	328.1	17.9

Appendix 2. Difference in water level from 2007 to 2011 in the Sparta-Memphis aquifer in Arkansas.—Continued

[Horizontal datum is the North American Datum of 1983; negative values denote a decline; 2007 depth-to-water level from Schrader (2009)]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	2007 depth to water (feet below land-surface datum)	2011 depth to water (feet below land-surface datum)	Difference in water level from 2007 to 2011 (feet)
			Union County—Continued		
18S15W33ADA1	33°06′59″	92°38′58″	359.87	332.36	27.5
18S15W35DAC1	33°06′36″	92°37′07″	283.78	261.91	21.9
18S16W10CDD1	33°10′00″	92°44′45″	314.68	272.75	41.9
18S16W11DAC1	33°10′11″	92°43′16″	412.75	367.36	45.4
18S16W12ACB1	33°10′29″	92°42′32″	433.04	399.92	33.1
19S10W16CBC1	33°03′29″	92°09′04″	88.33	86.55	1.8
19S11W23ACA1	33°02′55″	92°12′29″	152.44	151.17	1.3
19S11W25AAA1	33°02′18″	92°11′13″	151.2	145.49	5.7
19S12W13AAA1	33°04′11″	92°17′17″	142.37	159.66	-17.3
19S18W14ADA1	33°04′52″	92°56′08″	192.57	190.81	1.8
			Woodruff County		
05N01W11ABA1	35°04′26″	91°04′07″	60	61.17	-1.2
05N01W17DBB1	35°03′11″	91°07′27″	47.36	46.74	0.6
05N02W31DCB3	35°00′27″	91°14′56″	16.24	13.09	3.1
06N01W13ABA1	35°08′52″	91°02′54″	68.46	73.51	-5.1
06N01W13ADC1	35°08′27″	91°02′47″	68.38	70.11	-1.7
07N01W12BCB1	35°14′42″	91°03′26″	67.94	68.43	-0.5
08N01W12CDA1	35°19′34″	91°03′11″	74.86	77.89	-3.0
08N02W26ADC1	35°17′26″	91°10′04″	33.83	27.06	6.8

Appendix 3. Specific conductance, temperature, and pH data from wells completed in the Sparta-Memphis aquifer in Arkansas, 2011.

[Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83); µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Date	Specific conductance (µS/cm)	Temperature (degrees Celsius)	pH (standard units)
			Arkansas County			
07S03W06ABC1	34°07′02″	91°22′48″	06/23/2011	195	24.5	8.3
04S01W04CBD1	34°22′25″	91°08′08″	06/24/2011	868	25.4	7.8
02S04W06CDB1	34°33′12″	91°28′49″	06/27/2011	464	24.0	7.2
			Ashley County			
15S07W32DCC1	33°21′08″	91°50′44″	06/23/2011	834	26.1	8.6
			Bradley County			
13S09W06ABD3	35°36′52″	92°04′13″	06/23/2011	403	26.4	8.3
			Calhoun County			
14S13W12CCB1	33°30′40″	92°24′04″	07/05/2011	437	24.5	8.5
14S13W03CAB1	33°31′45″	92°25′51″	06/22/2011	445	22.7	8.8
11S14W12CAC3	33°46′30″	92°29′28″	06/22/2011	185	21.9	6.5
			Clark County			
09S20W31CAD1	33°54′35″	93°11′11″	06/30/2011	486	22.2	7.8
			Clay County			
20N08E14BAB2	36°22′27″	90°11′20″	06/29/2011	712	25.4	8.2
			Cleveland County			
11S11W16AAB1	33°45′43″	92°14′23″	06/23/2011	350	25.2	8.3
09S09W04BBD1	33°58′20″	92°02′37″	06/22/2011	179	25.8	7.1
			Columbia County			
19S20W09CBD1	33°05′55″	93°11′29″	07/05/2011	227	23.5	8.6
17S20W17CDA1	33°15′20″	93°12′01″	07/05/2011	382	23.2	8.6
16S20W18ACD1	33°20′53″	93°12′37″	06/30/2011	366	22.8	8.4
15S20W20CCB1	33°24′53″	93°12′15″	06/30/2011	630	26.1	7.6
			Craighead County			
14N04E28DBD1	35°48′37″	90°39′53″	06/29/2011	180	19.6	6.4
			Crittenden County			
06N09E23AAB1	35°07′45″	90°05′53″	06/29/2011	263	19.7	6.6
			Cross County			
07N05E04ADD1	35°15′38″	90°33′30″	06/28/2011	207	20.8	7.1
09N04E30DCA1	35°22′32″	90°42′18″	06/28/2011	474	21.9	7.3
09N01E16CAC1	35°24′05″	90°59′51″	06/28/2011	492	18.5	7.4
			Dallas County			
10S13W34ACA2	33°48′29″	92°24′58″	06/22/2011	254	23.9	7.2
07S14W31AAA1	34°04′25″	92°33′34″	06/22/2011	133	22.1	6.5
			Desha County			
12S03W34DAD1	33°36′43″	91°23′05″	06/23/2011	365	25.6	8.5
09S02W26AAC1	33°53′46″	91°15′21″	06/23/2011	244	22.2	8.7

Appendix 3. Specific conductance, temperature, and pH data from wells completed in the Sparta-Memphis aquifer in Arkansas, 2011.—Continued

[Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83); µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Date	Specific conductance (µS/cm)	Temperature (degrees Celsius)	pH (standard units)
			Drew County			
13S05W36ACB1	33°31′51″	91°34′08″	06/23/2011	335	24.6	8.6
11S05W21CDC1	33°43′52″	91°37′24″	06/23/2011	288	21.9	8.8
			Grant County			
06S15W26ACA1	34°10′22″	92°35′38″	06/22/2011	55	19.8	5.4
05S14W06DCC1	34°18′43″	92°33′27″	06/27/2011	96	20.9	6.1
			Jefferson County			
06S10W23DBA1	34°11′05″	92°05′06″	06/27/2011	154	24.0	7.4
04S08W35BCC1	34°19′08″	91°50′55″	06/27/2011	144	25.6	7.0
04S07W17BCC1	34°21′40″	91°47′42″	06/27/2011	140	25.9	7.1
04S11W14BAD1	34°22′20″	92°10′00″	06/27/2011	82	23.9	6.2
			Lafayette County			
20S23W05ADB1	33°02′23″	93°30′36″	06/20/2011	273	21.1	7.5
			Lincoln County			
09S07W07DAD1	33°56′34″	91°51′28″	06/23/2011	196	26.6	7.6
08S05W35ACC1	33°59′07″	91°33′37″	06/23/2011	232	22.0	8.3
07S06W33BAA1	34°04′45″	91°41′40″	06/23/2011	194	24.9	8.3
			Lonoke County			
02N07W32DDD1	34°44′53″	91°46′19″	06/27/2011	450	20.5	7.1
02N07W09AAA1	34°49′06″	91°45′00″	06/27/2011	354	21.6	7.1
			Mississippi County			
11N09E33AAB1	35°32′14″	90°07′39″	06/29/2011	208	25.8	7.9
			Monroe County			
01N03W14CCB1	34°41′44″	91°18′01″	06/27/2011	917	21.8	7.3
04N02W30BAC1	34°56′17″	91°15′04″	06/28/2011	1,380	18.2	7.7
			Nevada County			
14S21W20AAB1	33°30′50″	93°17′23″	06/23/2011	338	26.7	8.2
14S21W04CCB1	33°32′51″	93°17′08″	06/30/2011	144	20.8	6.6
			Ouachita County			
15S19W10DCC1	33°26′18″	93°03′18″	06/20/2011	186	22.0	6.6
12S16W26BAA1	33°39′48″	92°43′04″	07/05/2011	223	19.9	6.9
12S19W14AAA1	33°41′43″	93°01′05″	06/30/2011	35	18.0	5.4
			Phillips County			
04S02E25CCC1	34°18′24″	90°51′21″	06/24/2011	1,190	22.9	8.3
			Poinsett County			
10N01E15DBB1	35°29′31″	90°58′25″	06/28/2011	499	18.6	7.4
			Prairie County			
02N06W20BCB1	34°47′07″	91°40′33″	06/27/2011	342	21.6	6.9

Appendix 3. Specific conductance, temperature, and pH data from wells completed in the Sparta-Memphis aquifer in Arkansas, 2011.—Continued

[Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83); µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Station name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Date	Specific conductance (µS/cm)	Temperature (degrees Celsius)	pH (standard units)
			Union County			
19S16W35DDC1	33°01′09″	92°43′26″	07/05/2011	546	24.6	8.7
19S11W25AAA1	33°02′18″	92°11′13″	07/05/2011	1,060	23.1	8.8
19S15W01CCA1	33°05′35″	92°36′45″	06/22/2011	315	26.6	8.0
18S14W06CCD1	33°10′39″	92°35′31″	06/21/2011	722	24.1	8.6
17S13W31BAD1	33°12′04″	92°29′07″	07/05/2011	723	26.2	8.8
17S17W30DCD1	33°12′57″	92°53′56″	07/05/2011	317	26.2	8.4
17S16W24BDB1	33°13′57″	92°42′48″	07/05/2011	413	23.2	8.6
16S18W34ABC2	33°18′06″	92°57′09″	06/21/2011	324	21.4	8.2
16S15W20DAA1	33°18′60″	92°39′58″	06/21/2011	498	24.6	8.0
16S16W01DDD1	33°21′14″	92°42′11″	06/21/2011	450	21.9	8.7
			Woodruff County			
05N02W31DCB3	35°00′27″	91°14′56″	06/28/2011	230	18.0	7.4

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