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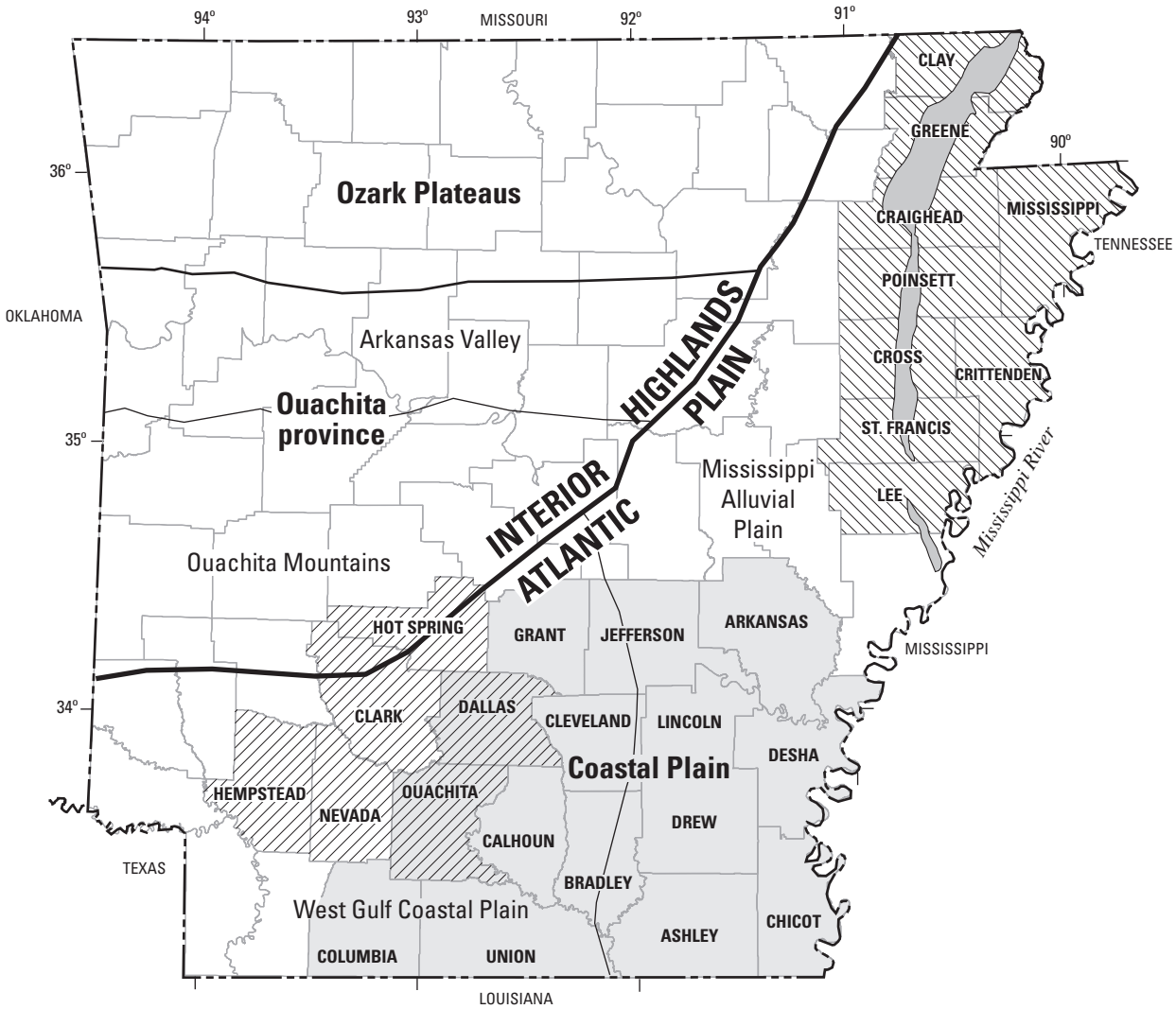
Potentiometric Surfaces and Water-Level Trends in the Cockfield and Wilcox Aquifers of Southern and Northeastern Arkansas, 2006



Scientific Investigations Report 2007–5218

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

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
foot per year (ft/yr)	0.3048	meter per year (m/yr)
gallon per minute (gal/m)	0.6308	liter per second (L/s)
million gllons 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 x ˚C) + 32

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

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

Potentiometric Surfaces and Water-Level Trends in the Cockfield and Wilcox Aquifers of Southern and Northeastern Arkansas, 2006

By T.P. Schrader

Abstract

The Cockfield Formation of Claiborne Group and the Wilcox Group contain aquifers that provide sources of ground water in southern and northeastern Arkansas. In 2000, about 9.9 million gallons per day was withdrawn from the Cockfield Formation of Claiborne Group and about 22.2 million gallons per day was withdrawn from the Wilcox Group. Major withdrawals from the aquifers were for industrial and public water supplies.

A study was conducted by the U.S. Geological Survey in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey to determine the water level associated with the aquifers in the Cockfield Formation of Claiborne Group and the Wilcox Group in southern and northeastern Arkansas. During February and March 2006, 56 water-level measurements were made in wells completed in the Cockfield aquifer and 59 water-level measurements were made in wells completed in the Wilcox aquifer, 16 in southwestern and 43 in northeastern Arkansas. This report presents the results as potentiometric-surface maps and as long-term water-level hydrographs.

The regional direction of ground-water flow in the Cockfield Formation of Claiborne Group generally is towards the east and southeast, away from the outcrop, except in areas of intense ground-water withdrawals, such as western Drew County, southeastern Lincoln County, southwestern Calhoun County, and near Crossett in Ashley County. There are three cones of depression indicated by relatively low water-level altitudes in southeastern Lincoln County, southwestern Calhoun County, and near Crossett in Ashley County. The lowest water-level altitude measured was 44 feet above the National Geodetic Vertical Datum of 1929 in Lincoln County; the highest water-level altitude measured was 346 feet above the National Geodetic Vertical Datum of 1929 in Columbia County at the outcrop area. Hydrographs from 40 wells with historical water levels from 1986 to 2006 were evaluated using linear regression to calculate the annual rise or decline. Calhoun and Cleveland Counties have mean annual rises from 0.01 to 0.07 feet per year. Arkansas, Ashley, Bradley, Chicot, Columbia, Drew, Lincoln, and Union Counties have mean annual declines from 0.4 to 0.55 feet per year. Desha County has a mean annual decline of about 1.35 feet per year.

The direction of ground-water flow in the southwestern study area of the Wilcox Group generally is south and east. The lowest water-level altitude measured in southwestern Arkansas was 147 feet above the National Geodetic Vertical Datum of 1929 near the Ouachita River in Clark County; the highest water-level altitude measured was 397 feet above the National Geodetic Vertical Datum of 1929 in the outcrop area of Hempstead County. The direction of ground-water flow in the northeastern study area of the Wilcox Group generally is south and east. The lowest water-level altitude measured in northeastern Arkansas was 120 feet above the National Geodetic Vertical Datum of 1929 near West Memphis in Crittenden County; the highest water-level altitude measured was 368 feet above the National Geodetic Vertical Datum of 1929 on Crowleys Ridge in Clay County. Hydrographs from 28 wells with historical water levels from 1986 to 2006 were evaluated using linear regression to calculate the annual rise or decline. All 28 wells showed an annual decline from 1986 to 2006. Craighead, Greene, Mississippi, and Poinsett Counties have mean annual declines from 0.27 to 1.00 feet per year. Crittenden, Lee, and St. Francis Counties have mean annual declines from 1.39 to 1.64 feet per year.

Introduction

The Cockfield Formation of Claiborne Group and the Wilcox Group contain aquifers that provide sources of ground water in southern and northeastern Arkansas, where in 2000 about 9.9 million gallons per day (Mgal/d) was withdrawn from the Cockfield Formation of Claiborne Group and about 22.2 Mgal/d was withdrawn from the Wilcox Group (Holland, 2004). Major withdrawals from the aquifers were for industrial and public water supplies, with lesser but locally important withdrawals for domestic and livestock uses.

A study was conducted by the U.S. Geological Survey (USGS) in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey to determine the water level associated with the aquifers in the Cockfield Formation of Claiborne Group and the Wilcox Group (hereafter the respective aquifers are referred to as the Cockfield aquifer and the Wilcox aquifer) in southern and northeastern Arkansas. During February and March 2006, 56 water-level measurements were made in wells completed in the Cockfield aquifer and 59 water-level measurements were made in wells completed in the Wilcox aquifer, 16 in southwestern and 43 in northeastern Arkansas. This report presents the results as potentiometric-surface maps and as long-term water-level hydrographs.

The study areas of the Cockfield and Wilcox aquifers (fig. 1) include much of the West Gulf Coastal Plain and the Mississippi Alluvial Plain in Arkansas. The study area of the Cockfield aquifer in southeastern Arkansas is bounded on the east by the Mississippi River and on the south by the Louisiana State line. The western boundary is defined by the western extent of the outcrop and subcrop (Hosman, 1982) of the Cockfield Formation. The northern boundary is defined by the locations of observation wells. The study area boundary of the Wilcox aquifer in southwestern Arkansas is defined by the outcrop of the Wilcox Group and the locations of observation wells in Clark, Hempstead, Hot Spring, Nevada, and Ouachita Counties. The study area of the Wilcox aquifer in northeastern Arkansas is bounded on the north by the Missouri State line and on the east by the Mississippi River. The western and southern boundaries of the study area are defined by the extent of the outcrop at or near Crowleys Ridge, and by the location of observation wells that penetrate the Wilcox aquifer.

This report is the fourth in a triennial series of reports discussing the potentiometric surfaces of the Cockfield and Wilcox aquifers. Earlier reports in 2003, 2000, and 1996-1997 can be referenced through Yeatts (2004), Schrader and Joseph (2000), and Joseph (1998), respectively. The potentiometric surfaces for 1991 were published in a map report (Westerfield, 1994). In the report by Yeatts (2004), 55 and 56 wells completed in the Cockfield and Wilcox aquifers, respectively, were measured for water levels.

Methods

The well-numbering system used in this report is based upon the location of the wells according to the Public Land Survey System used in Arkansas. The component parts of a well number are the township number, the range number, the section number, three letters which indicate, respectively, the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section in which the well is located, and a sequence number. 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. 2) is located in Township 1 South, Range 3 West, and 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.

The horizontal coordinate information of wells was determined using a global positioning system (GPS) referenced to the North American Datum of 1983 (NAD 83), with accuracy to about one-tenth of a second of latitude and longitude (approximately 10-20 feet). The vertical coordinate information was determined with accuracy to about 5 feet (ft) from topographic maps referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 1929). Herein all altitudes are referenced to NGVD of 1929.

Water levels were measured by USGS personnel at public water supply, industrial, commercial, domestic, and observation wells open to the Cockfield or Wilcox aquifers. Water levels were measured at least 1 hour after pumping from the well had ceased. Measurements were recorded after consecutive measurements, with a 5-minute interval, differed by no more than 0.02 ft. Measurements were made using steel or electric tapes graduated to hundredths of a foot. The steel and electric tapes used by USGS personnel were calibrated during January 2006 prior to collecting measurements from wells. Calibration of steel and electric tapes was performed by comparing the field steel or electric tape to a standardized steel tape used only for calibration of field tapes.

There are five assumptions 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).

Linear regression can be used with a hydrograph of water level versus time to calculate the annual rise or decline in water level. Another method for calculating the annual rise or decline is to take the difference between the final and initial water levels and divide by the period of time. This method is determined from two measurements and calculated values are dependent solely on the final and initial water levels. Linear regression includes all the measurements to determine the trend line, resulting in a value that is dependent on all water levels during the period of record. The slope, $ß_1$, of the line is the annual rise or decline in water level. The intercept, $ß_0$, would be the water level in the year 1900, the origin for the graph. This requires the assumption that the pumping rate would be constant throughout the period of pumping. This condition is not commonly met or the data are not available to demonstrate that this has occurred. The predevelopment water level will not be discussed as this condition can not be demonstrated. The R^2 term is used as an indicator of the variability of the water-level data. Values of R^2 can range from 0.00 to 1.00.

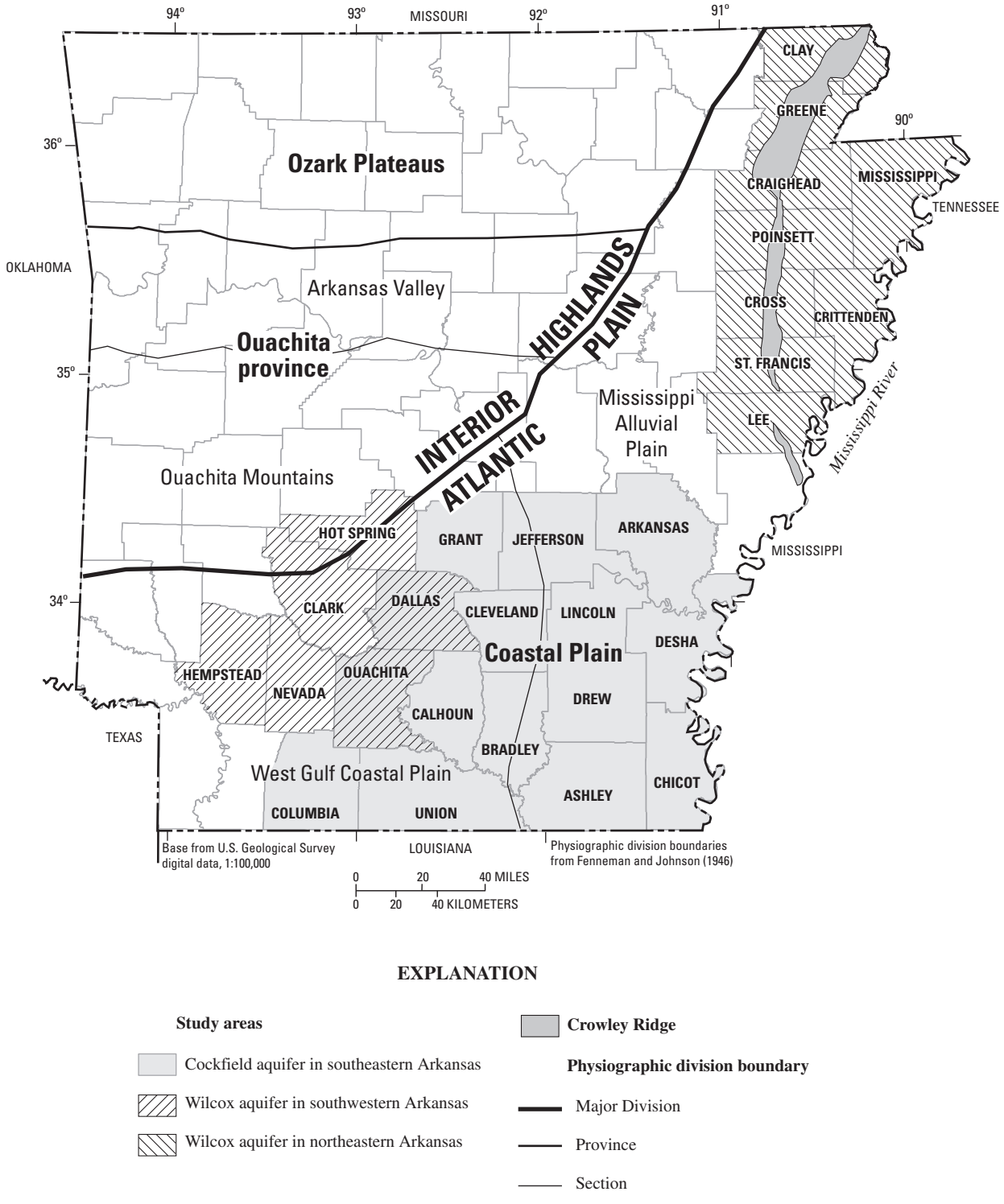

Figure 1. Location of study areas.

A high value of R^2 can indicate a linear change in water level. A low value of R^2 can indicate sporadic change in water level.

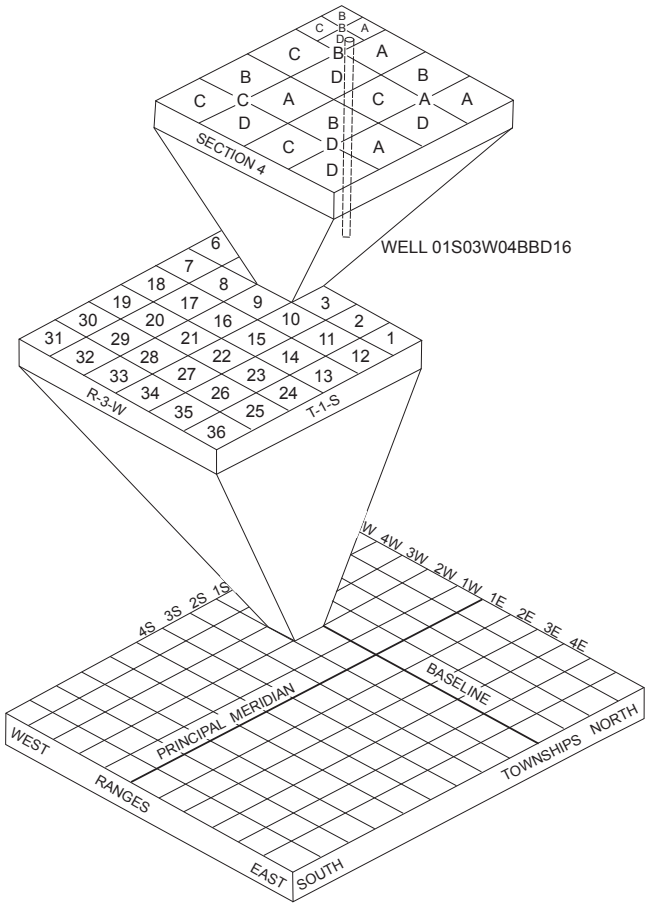

Figure 2. Well-numbering system.

Cockfield Formation

Hydrogeologic Setting

The Cockfield Formation of Claiborne Group (hereafter referred to as the Cockfield Formation) is Eocene age and generally consists of discontinuous fine- to medium-grained sand units interbedded with silt, clay, and lignite, all of nonmarine origin, in southeastern Arkansas. Most of the sand beds constitute the Cockfield aquifer and are found near the base of the Cockfield Formation. The Cockfield Formation generally ranges from 100 to 400 ft thick near the outcrop area and thickens downdip of the outcrop area reaching 625 ft thick in northeastern Chicot County (Onellion and Criner, 1955). Total sand thickness in the Cockfield Formation generally ranges from 20 to 150 ft. The Cockfield Formation is underlain throughout the study area by calcareous and sandy marl, limestone, and carbonaceous clay of the Cook Mountain Formation of Claiborne Group. The Cockfield Formation is overlain by silty clays of the Jackson Group throughout much of southeastern Arkansas. In the confined part of the aquifer, the potentiometric surface can be near or above land surface. Sand beds at the base of the overlying Jackson Group in parts of southeastern Arkansas may be in hydraulic connection with the Cockfield aquifer (Ackerman, 1987). The Cockfield aquifer comprises the water-yielding strata within the Cockfield Formation.

The Cockfield Formation outcrops in Grant, Dallas, Cleveland, Calhoun, Bradley, Columbia, and Union Counties and dips southeastward. In the subcrop area, the Cockfield Formation is overlain by terrace deposits and alluvium of Quaternary age. The terrace deposits may attain a thickness of 40 ft, and as much as 60 ft of alluvium overlies the Cockfield Formation in some of the larger river valleys.

Most recharge to the Cockfield aquifer occurs by infiltration of rainfall on the upland outcrop areas and by inflow from the overlying alluvium; most discharge is to rivers in outcrop areas, to vertically adjacent units where the Cockfield aquifer is confined, and to wells (Ackerman, 1987). Well depths are shallow and yields of most wells in the outcrop areas are small, less than 30 gallons per minute (gal/min), but in other areas downdip of the outcrop, wells screened the full thickness of the aquifer often yield 100 to 500 gal/min (Westerfield, 1994).

Withdrawals from the Cockfield aquifer in the study area during 2000 totaled about 9.9 Mgal/d (Holland, 2004) (fig. 3). Withdrawals from the Cockfield aquifer generally increased from 1975 to 2000, the exception being a decrease in 1985, producing 5.2 Mgal/d in 1975, 7.2 Mgal/d in 1980, 5.0 Mgal/d in 1985, 8.1 Mgal/d in 1990, and 9.8 Mgal/d in 1995 (Halberg, 1977; Holland and Ludwig, 1981; Holland, 1987, 1993, 1999, 2004). Most wells completed in the Cockfield aquifer study area provide small volumes of water for domestic and livestock use. In some locations, the Cockfield aquifer yields volumes large enough to supply industrial and public supply systems.

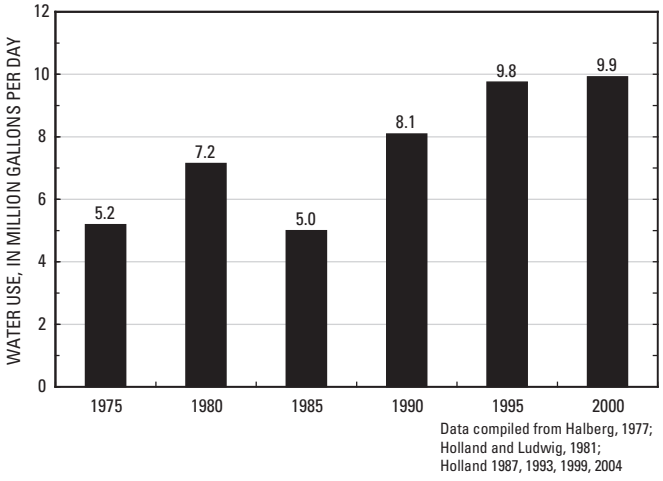

Figure 3. Water use from the Cockfield aquifer, 1975-2000.

Adjacent to Arkansas, the State of Mississippi pumped about 27 Mgal/d from the Cockfield aquifer in 1999 (D.E. Burt, U.S. Geological Survey, written commun., 2003). Immediately across the Arkansas/Mississippi State line, the city of Greenville, Mississippi, pumped about 11 Mgal/d from the Cockfield aquifer in 1999 (D.E. Burt, U.S. Geological Survey, written commun., 2003), or about 11 percent more than all of Arkansas pumped from the Cockfield aquifer in 2000. The large amount of withdrawal from Greenville probably contributes to lower water levels in Arkansas (Ackerman, 1987; Joseph, 1998; Schrader and Joseph, 2000).

Potentiometric Surface

The potentiometric-surface map shows the altitude of the water surface in 56 tightly cased wells in the Cockfield aquifer (fig. 4) during February and March 2006, in southeastern Arkansas (table 1). The potentiometric surface was constructed by determining the water-level altitude at wells, and constructing contour lines along points of equal water-level altitude. The direction of ground-water flow is perpendicular to the contours in the direction of decreasing water level.

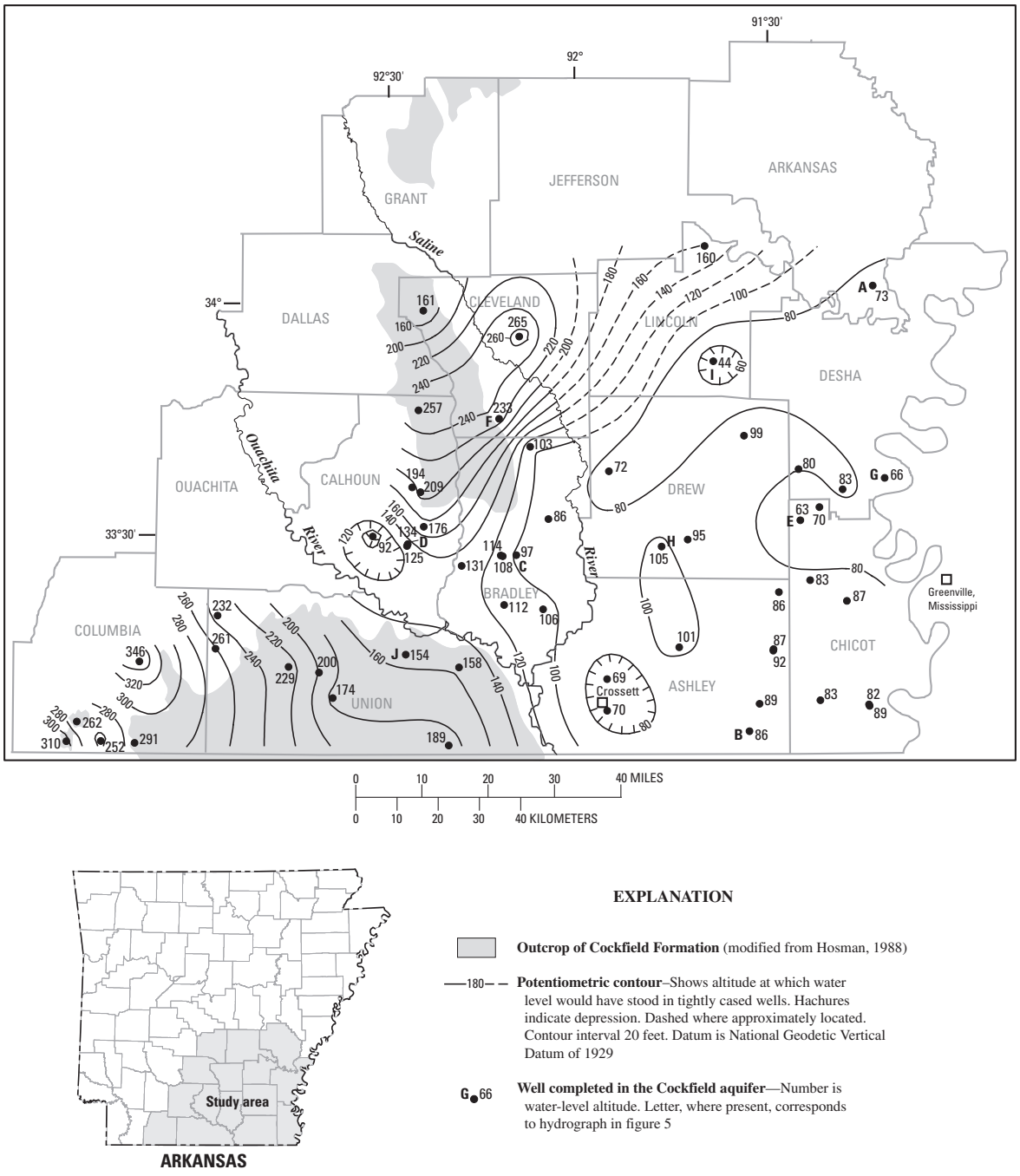

Figure 4. Potentiometric surface of the Cockfield aquifer in southeastern Arkansas, 2006.

Table 1. Water-level data collected from wells completed in the Cockfield aquifer in southeastern Arkansas, 2006.

[Horizontal datum is NAD of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929; --, missing data]

Station Name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Arkansas County							
08S02W04ACA1	340139	911406	73	91.62	165	453	3/10/2006
Ashley County							
15S04W26CBC1	332144	912932	86	41.88	128	409	3/02/2006
17S04W10BCD2	331417	913030	87	38.18	125	340	3/02/2006
17S04W10CBA1	331406	913033	92	33.30	125	360	3/02/2006
17S06W07ADA1	331442	914510	101	72.85	174	426	3/02/2006
18S04W19DAA2	330710	913247	89	26.89	116	356	3/02/2006
18S08W04BBC1	331038	915627	69	80.30	149	314	3/02/2006
18S08W29DDD2	330630	915629	70	69.80	140	--	3/02/2006
19S05W12CAC1	330336	913425	86	29.38	115	320	3/02/2006
Bradley County							
12S10W10BCA1	334108	920807	103	124.15	227	425	3/01/2006
14S10W01BAD1	333139	920522	86	144.55	231	540	3/01/2006
14S10W31DBA1	332658	921025	97	96.47	193	349	3/01/2006
14S11W35CAB1	332656	921251	114	75.89	190	320	3/01/2006
14S11W35DAC1	332650	921233	108	65.68	174	345	3/01/2006
15S12W11CAB1	332536	921858	131	23.94	155	225	3/01/2006
16S10W11DCB1	331951	920619	106	45.51	152	152	3/02/2006
16S11W11ACA1	332027	921223	112	29.36	141	140	3/02/2006
Calhoun County							
11S13W15BBC1	334560	922534	257	53.18	310	70	3/01/2006
13S13W09CBD1	333555	922638	194	38.03	232	147	3/01/2006
13S13W15DBA1	333517	922520	209	23.40	232	122	3/01/2006
14S13W11CAC1	333045	922451	176	28.55	205	105	3/01/2006
14S13W29ADA1	332829	922722	134	26.02	160	81	3/01/2006
14S13W29DAC1	332815	922729	125	14.24	139	--	3/01/2006
14S14W21ACB1	332931	923249	92	40.27	132	160	3/01/2006

Table 1. Water-level data collected from wells completed in the Cockfield aquifer in southeastern Arkansas, 2006.—Continued

[Horizontal datum is NAD of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929; --, missing data]

Station Name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Chicot County							
13S03W26BBB1	333247	912301	70	69.34	139	422	3/02/2006
14S03W05BBA1	333106	912602	63	75.69	139	510	3/02/2006
15S03W21ABA1	332314	912438	83	38.91	122	400	3/02/2006
16S02W04BAC1	332027	911857	87	38.07	125	330	3/02/2006
18S02W24CDB1	330652	911547	82	47.07	129	364	3/02/2006
18S02W25ABB3	330640	911541	89	46.27	135	332	3/02/2006
18S03W14CCC1	330731	912319	83	14.86	98	320	3/02/2006
Cleveland County							
08S13W34BDA1	335902	922444	161	87.02	248	181	3/06/2006
09S10W17CDD1	335534	920942	265	4.73	270	361	3/06/2006
11S11W23BBD1	334449	921258	233	42.03	275	148	3/06/2006
Columbia County							
17S20W35BBD1	331313	930914	346	14.91	361	--	2/28/2006
19S20W34ADC1	330233	930958	291	22.37	313	39.8	2/28/2006
19S21W17CBB1	330520	931857	262	44.12	306	54.8	2/28/2006
19S21W35ADC1	330247	931513	252	3.54	256	30.1	2/28/2006
19S22W36DBB1	330245	932034	310	41.15	351	68.6	2/28/2006
Desha County							
12S01W32DCA1	333628	911245	66	69.87	136	495	3/06/2006
12S03W30ADC1	333747	912611	80	72.99	153	280	3/06/2006
13S02W08CAA1	333504	911921	83	64.48	147	515	3/06/2006
Drew County							
11S05W35DDB1	334216	913438	99	81.08	180	500	3/03/2006
12S08W33AAB1	333750	915551	72	101.02	173	543	3/03/2006
14S06W21BDC1	332846	914339	95	120.62	216	--	3/03/2006
14S07W26BAB1	332754	914744	105	125.04	230	440	3/03/2006

Table 1. Water-level data collected from wells completed in the Cockfield aquifer in southeastern Arkansas, 2006.—Continued

[Horizontal datum is NAD of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929; --, missing data]

Station Name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Lincoln County							
07S06W14BBC1	340709	914026	160	22.22	182	483	3/06/2006
10S05W06CAC1	335204	913918	44	126.30	170	550	3/06/2006
Union County							
16S18W22DCD1	331913	925704	232	14.71	247	36	2/28/2006
17S12W27DCA1	331219	921929	158	11.91	170	24	3/01/2006
17S13W17DDC1	331402	922746	154	38.67	193	156	2/28/2006
17S15W31DCA2	331144	924116	200	52.99	253	110	3/01/2006
17S16W33BBA2	331229	924601	229	25.54	255	31	2/28/2006
17S18W15CDA1	331453	925723	261	28.82	290	35	2/28/2006
18S15W21DAC1	330824	923909	174	26.13	200	40	3/01/2006
19S12W28CBA1	330207	922109	189	10.73	200	25	3/01/2006

The regional direction of ground-water flow generally is towards the east and southeast, away from the outcrop, except in areas of intense ground-water withdrawals, such as western Drew County, southeastern Lincoln County, southwestern Calhoun County, and near Crossett in Ashley County (Schrader and Joseph, 2000). There are three cones of depression indicated by relatively low water-level altitudes in southeastern Lincoln County, southwestern Calhoun County, and near Crossett in Ashley County. The cones of depression in southeastern Lincoln and southwestern Calhoun Counties were not evident in the 2003 potentiometric-surface map (Yeatts, 2004) but more data or different wells were available for 2006. Some local ground-water flow in the outcrop area is toward rivers that have eroded into the Cockfield Formation and deposited alluvium in southern Bradley and Calhoun Counties (Ouachita River), and in north Dallas County (Saline River). The lowest water-level altitude measured was 44 ft in Lincoln County; the highest water-level altitude measured was 346 ft in Columbia County at the outcrop area.

Water-Level Trends

Water-level trends in the Cockfield aquifer are illustrated by plotting the water levels in hydrographs, and evaluating the change in water level over a period of time. Hydrographs from 41 wells with historical water levels from 1986 to 2006 were evaluated using linear regression to calculate the annual rise or decline, in feet per year, for each well and grouped by county (table 2). Table 2 shows the number of wells with a minimum 20 years of record, the range of annual rise or decline, and the mean and median annual rise or decline by county. Arkansas, Desha, Drew, and Lincoln Counties only had one well with a minimum 20 years of record. Calhoun and Cleveland Counties have mean annual rises from 0.01 to 0.07 ft/yr. Arkansas, Ashley, Bradley, Chicot, Columbia, Drew, Lincoln, and Union Counties have mean annual declines from 0.04 to 0.55 ft/yr. Desha County has a mean annual decline of about 1.35 ft/yr. Historical water-level data from ten wells (wells A-J, fig. 4) in the Cockfield aquifer were plotted to illustrate the water-level trend in selected areas of southeastern Arkansas (fig. 5). The hydrographs were selected with an annual rise or decline near the mean annual rise or decline for the respective county.

Table 2. Range, mean, and median of annual rise/decline in water level by county for wells in the aquifer, 1986-2006.

[Annual rise or decline in water level for each well is calculated using linear regression]

County	Number of wells	Range or value 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[1]	1	-0.55	-0.55	-0.55	0.33
Ashley	6	-0.55 to 0.00	-0.33	-0.33	0.01 to 0.87
Bradley	5	-0.55 to 0.22	-0.24	-0.29	0.07 to 0.94
Calhoun	5	-0.22 to 0.18	0.01	0.15	0.01 to 0.76
Chicot	5	-0.84 to -0.11	-0.42	-0.29	0.14 to 0.84
Cleveland	2	-0.11 to 0.26	0.07	0.07	0.42 to 0.47
Columbia	5	-0.40 to 0.29	-0.04	-0.01	0.01 to 0.49
Desha[1]	1	-1.35	-1.35	-1.35	0.94
Drew[1]	1	-0.47	-0.47	-0.47	0.97
Lincoln[1]	1	-0.33	-0.33	-0.33	0.10
Union	9	-0.80 to 0.55	-0.13	-0.15	0.06 to 0.92

[1]County produced one hydrograph of 20 years or more.

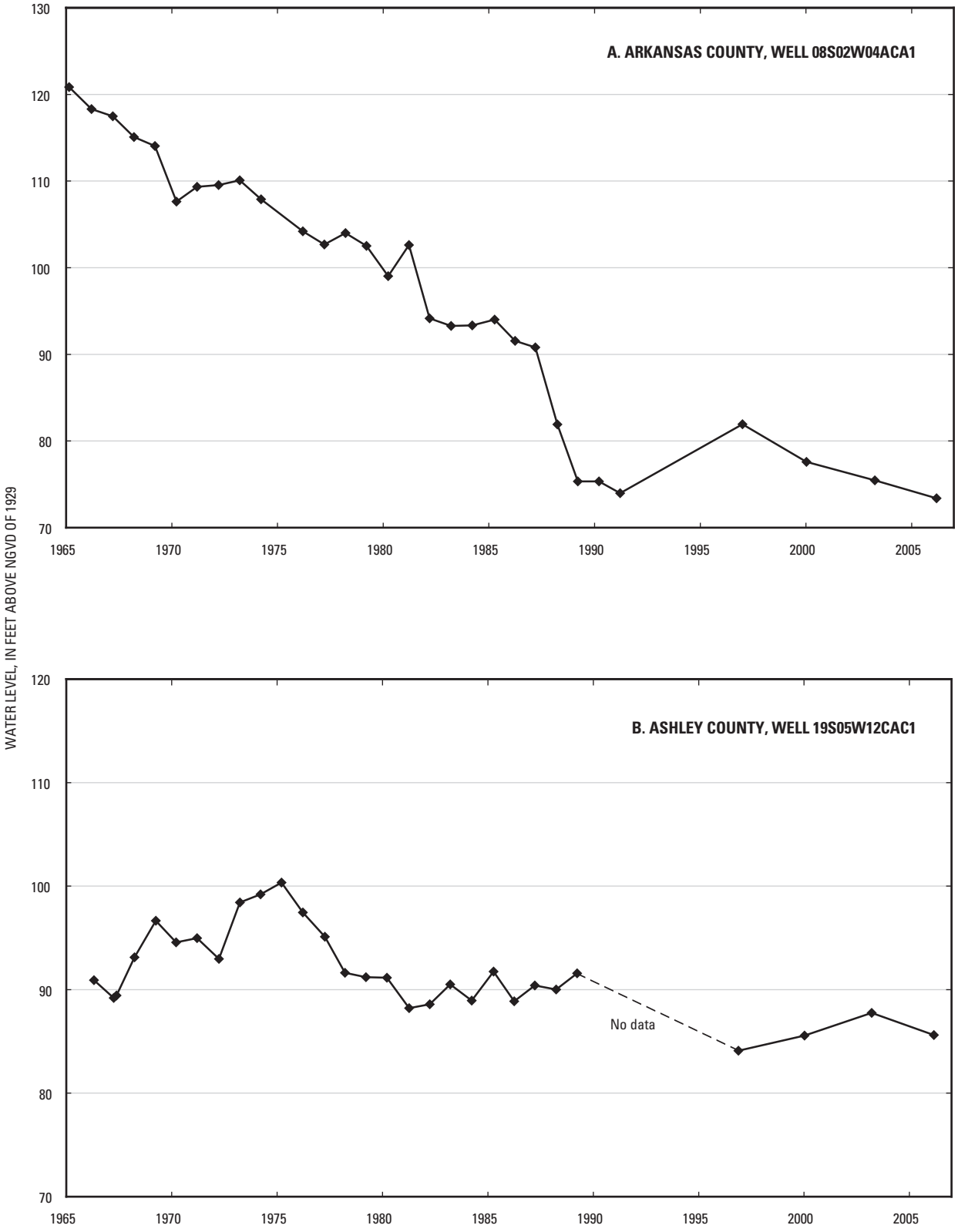

Figure 5. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southeastern Arkansas.

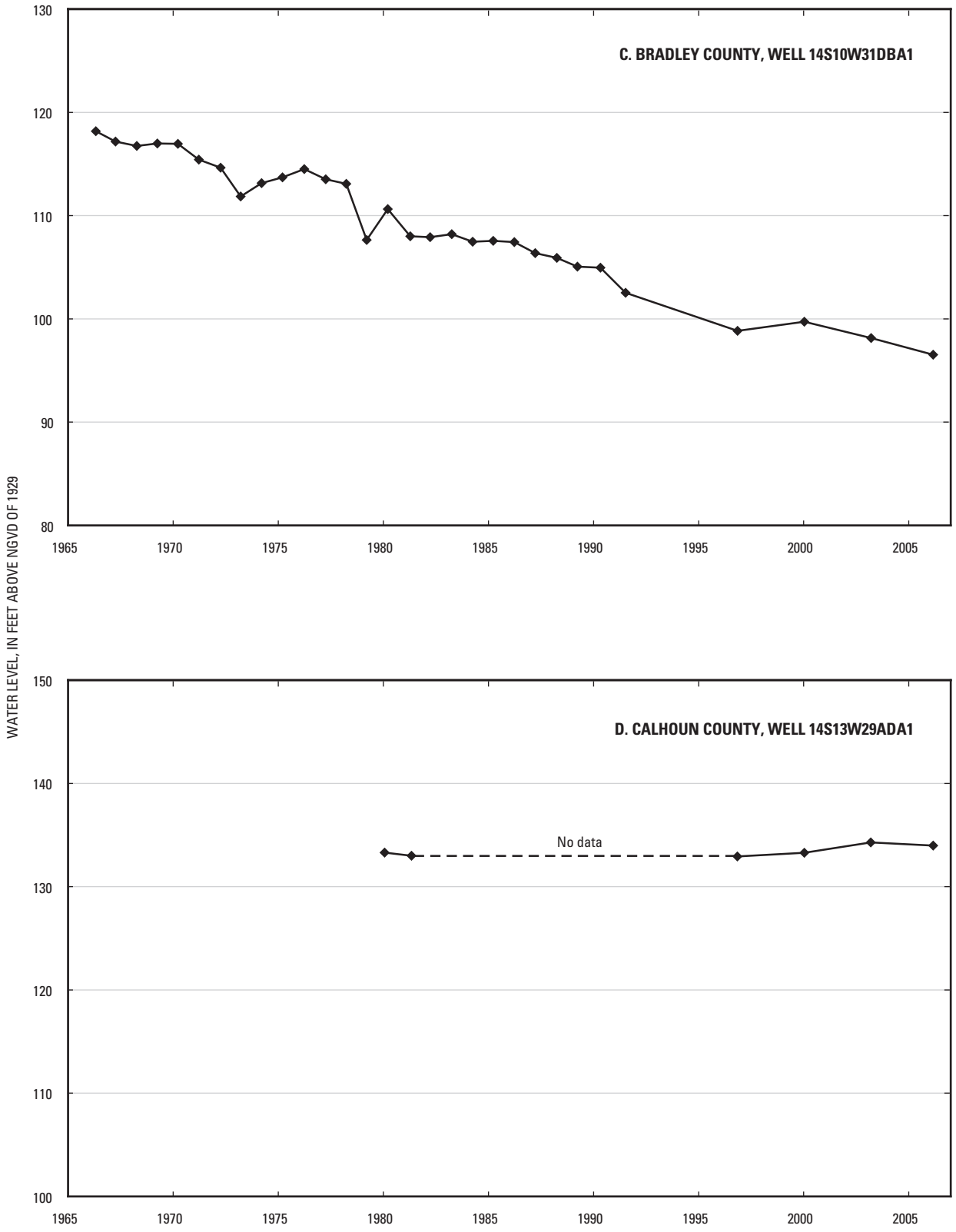

Figure 5. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southeastern Arkansas.—Continued

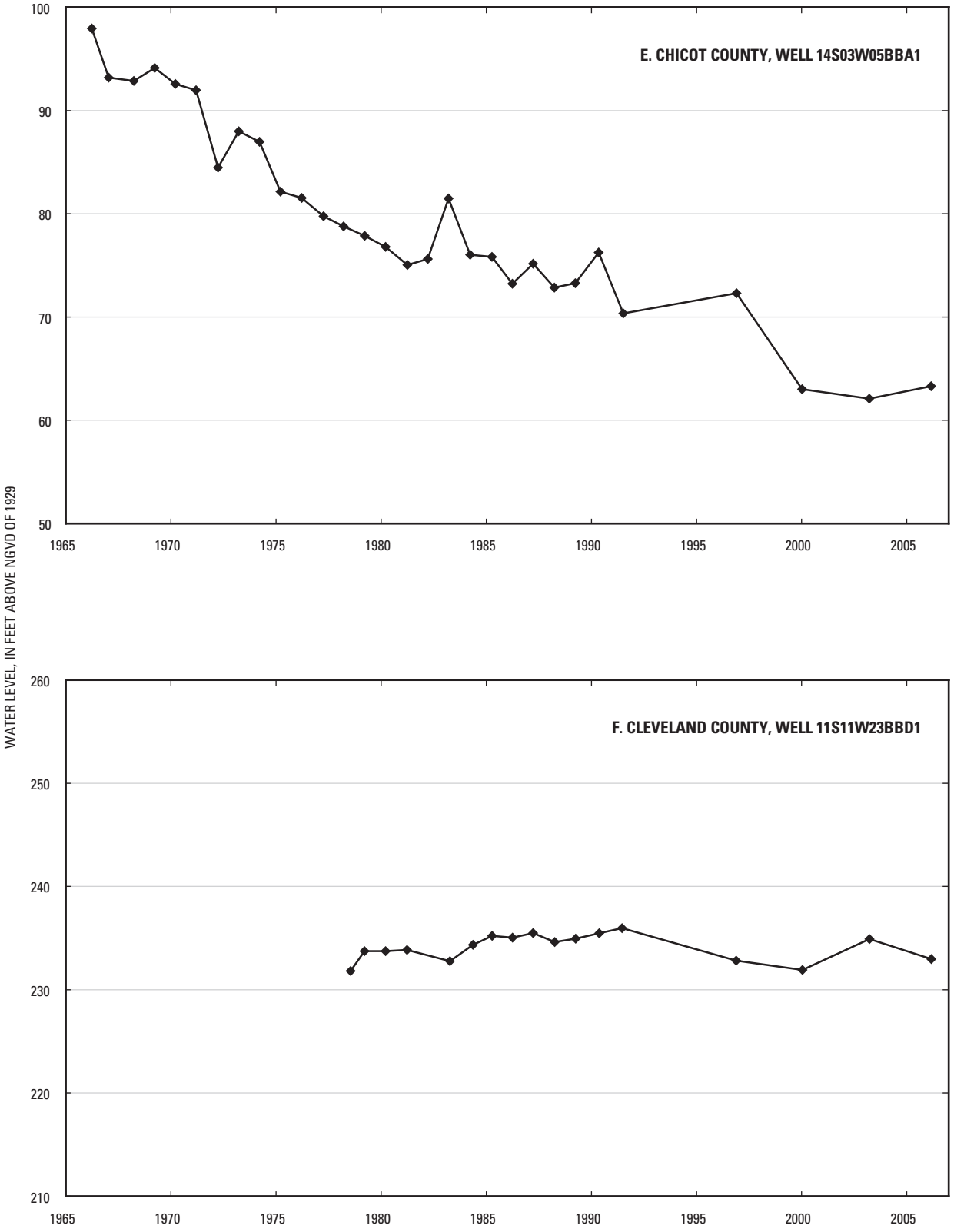

Figure 5. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southeastern Arkansas.—Continued

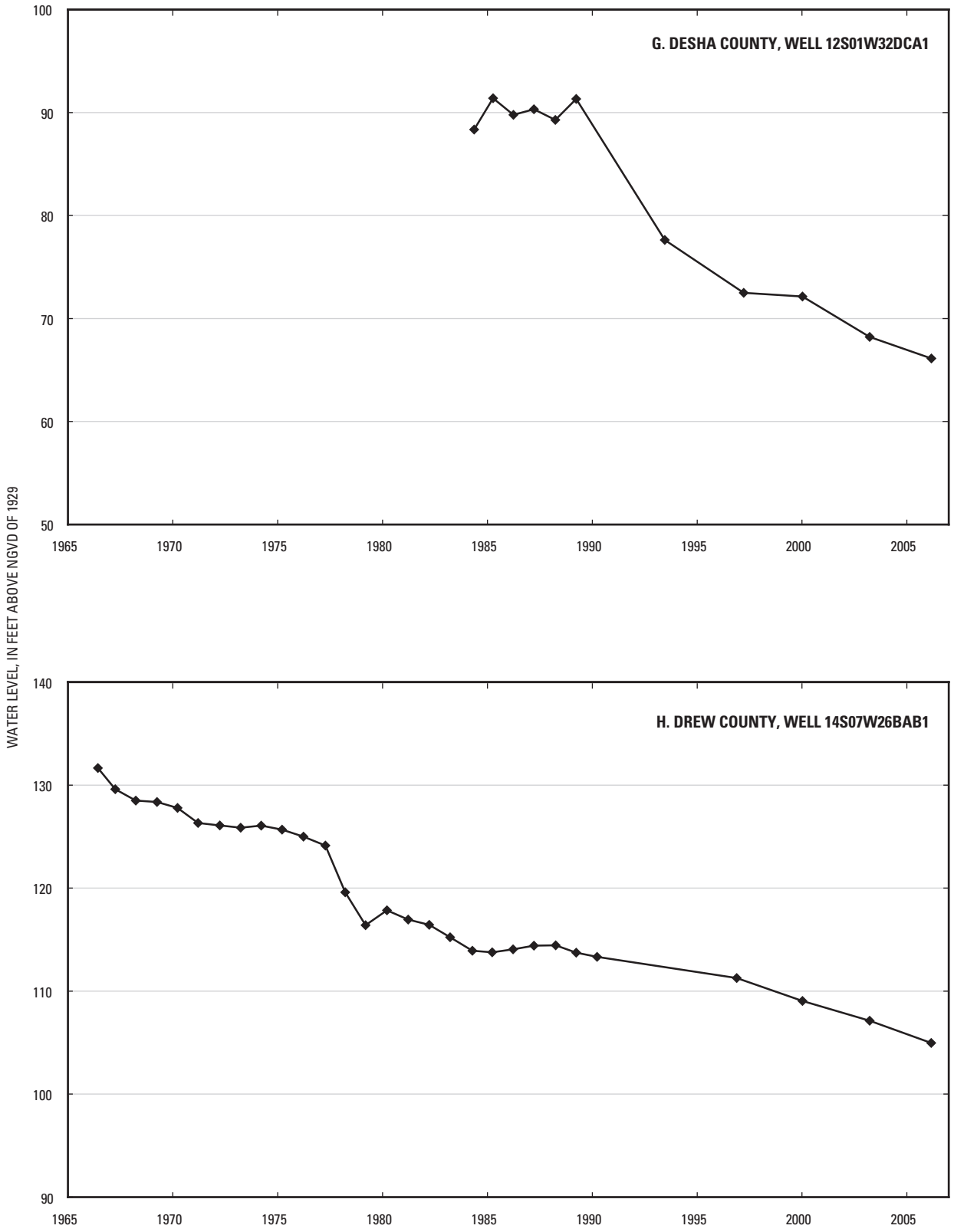

Figure 5. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southeastern Arkansas.—Continued

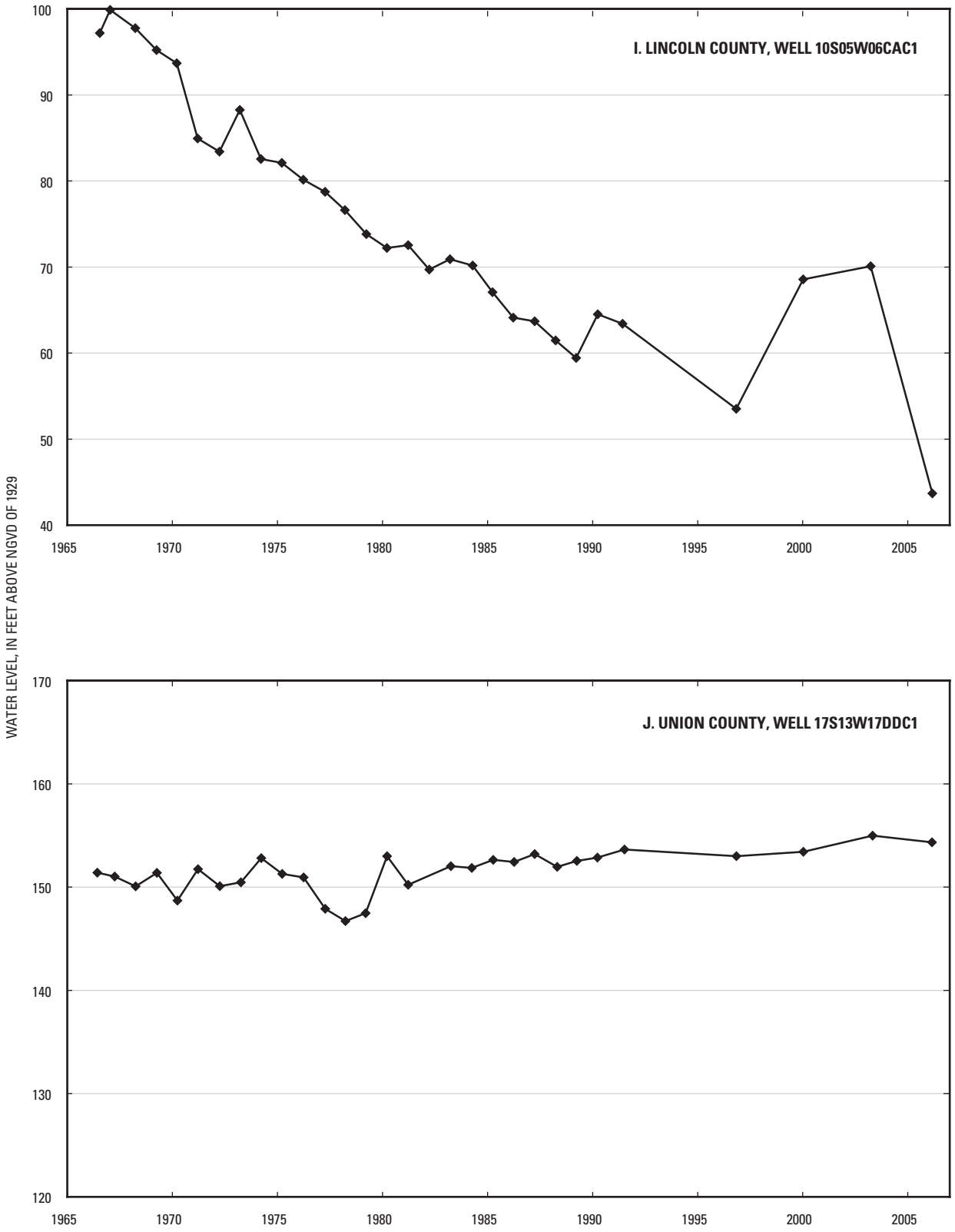

Figure 5. Water-level hydrographs for selected wells completed in the Cockfield aquifer in southeastern Arkansas.—Continued

Wilcox Group

Hydrogeologic Setting

The Wilcox Group of Eocene and Paleocene age is located throughout most of southern and eastern Arkansas. The Wilcox aquifer comprises water-yielding strata within the Wilcox Group in two study areas in the southwestern and northeastern portions of Arkansas. The Wilcox aquifer in central Arkansas is not extensively used, and water-level data are insufficient to determine the potentiometric surface.

The Wilcox Group in the southwestern study area consists of interbedded layers of clay, sandy clay, sand, and lignite. Formations in the southwestern study area are undifferentiated. Sand beds generally are thin and are not continuous over large areas. In most of the southwestern study area, the Wilcox Group overlies the Midway Group and is overlain by terrace deposits and alluvium of Quaternary age or crops out in discontinuous bands that are 1 to 3 miles wide. The Wilcox Group becomes progressively thicker downslope from the outcrop, ranging in thickness from a few feet in the outcrop to about 750 ft in northeastern Bradley County (Albin, 1964).

Recharge to the southwestern study area occurs by infiltration of rainfall in the outcrop areas and by inflow from overlying terrace and alluvial deposits; discharge flows to streams in the outcrop, to overlying formations where the aquifer is confined, and to wells (Westerfield, 1994). Well depths are shallow and well yields range from 10 to 100 gal/min (Schrader and Joseph, 2000).

The Wilcox Group in most of the northeastern study area consists of thin interbedded layers of lignitic sand and clays. The Wilcox Group outcrops at or near Crowleys Ridge in Clay, Greene, and Craighead Counties (Broom and Lyford, 1981). East of Crowleys Ridge, the middle to lower part of the Wilcox Group contains a sand bed of 200 ft or more in thickness (Petersen and others, 1985) referred to as the "1,400-foot sand" (Ryling, 1960; Plebuch, 1961) or the "lower Wilcox aquifer" (Hosman and others, 1968). The Wilcox aquifer in the northeastern study area is confined above by a clay bed of the Wilcox Group and underlain below by a clay bed of the Wilcox Group or the Midway Group.

Recharge to the northeastern study area occurs by infiltration of rainfall in the outcrop areas along the western side of Crowleys Ridge; discharge occurs by wells and by flow beneath the Mississippi River into Mississippi (Westerfield, 1994). Well depths range from 157 ft on Crowleys Ridge in Clay County to 1,885 ft in Lee County. Well yields range from 100 to 2,000 gal/min (Schrader and Joseph, 2000).

Withdrawals from the Wilcox aquifer in the study areas totaled about 22.2 Mgal/d during 2000, most of which came from the northeastern study area (Holland, 2004) (fig. 6). Withdrawals from the Wilcox aquifer generally increased from 1975 to 1995, the exception being a decrease in 1985, producing 24.3 Mgal/d in 1975, 25.7 Mgal/d in 1980, 21.0 Mgal/d in 1985, 30.9 Mgal/d in 1990, and 41.0 Mgal/d in 1995 (Halberg, 1977; Holland and Ludwig, 1981; Holland, 1987, 1993, 1999). In the southern study area, the primary use of water from the aquifer was for domestic supplies, usually from wells on or near the outcrop areas. In the northeastern study area, the primary use of water from the aquifer was for public supplies, but the aquifer is also a source of water for some commercial, domestic, and industrial users.

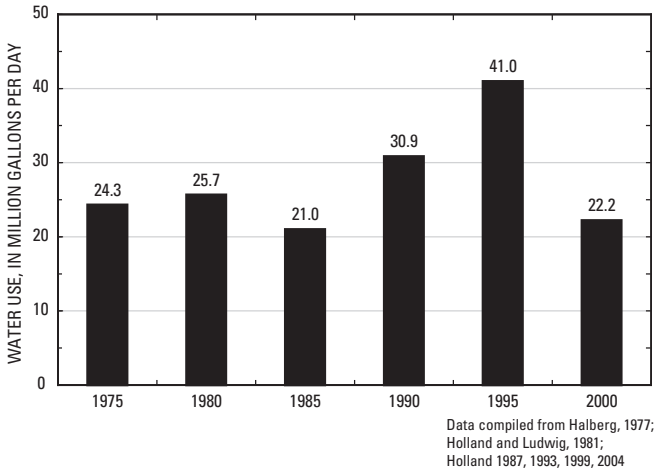

Figure 6. Water use from the Wilcox aquifer, 1975-2000.

Potentiometric Surface

The potentiometric-surface maps show the altitude of the water surface in tightly cased wells screened in the Wilcox aquifer (figs. 7 and 8). The maps are based upon water-level data collected from 59 wells during February and March 2006, 16 wells in the Wilcox aquifer southwestern study area and at 43 wells in the Wilcox aquifer northeastern study area (tables 3 and 4). The potentiometric surface was constructed by determining the water-level altitude in wells and constructing contour lines along points of equal water-level values. The direction of ground-water flow is perpendicular to the contours in the direction of decreasing water level.

The direction of ground-water flow in the southwestern study area generally is south and east, except in Clark County where flow is towards the Ouachita River, which has eroded into the Wilcox Group and deposited alluvium. The lowest water-level altitude measured in southwestern Arkansas was 147 ft near the Ouachita River in Clark County; the highest water-level altitude measured was 397 ft in the outcrop area of Hempstead County.

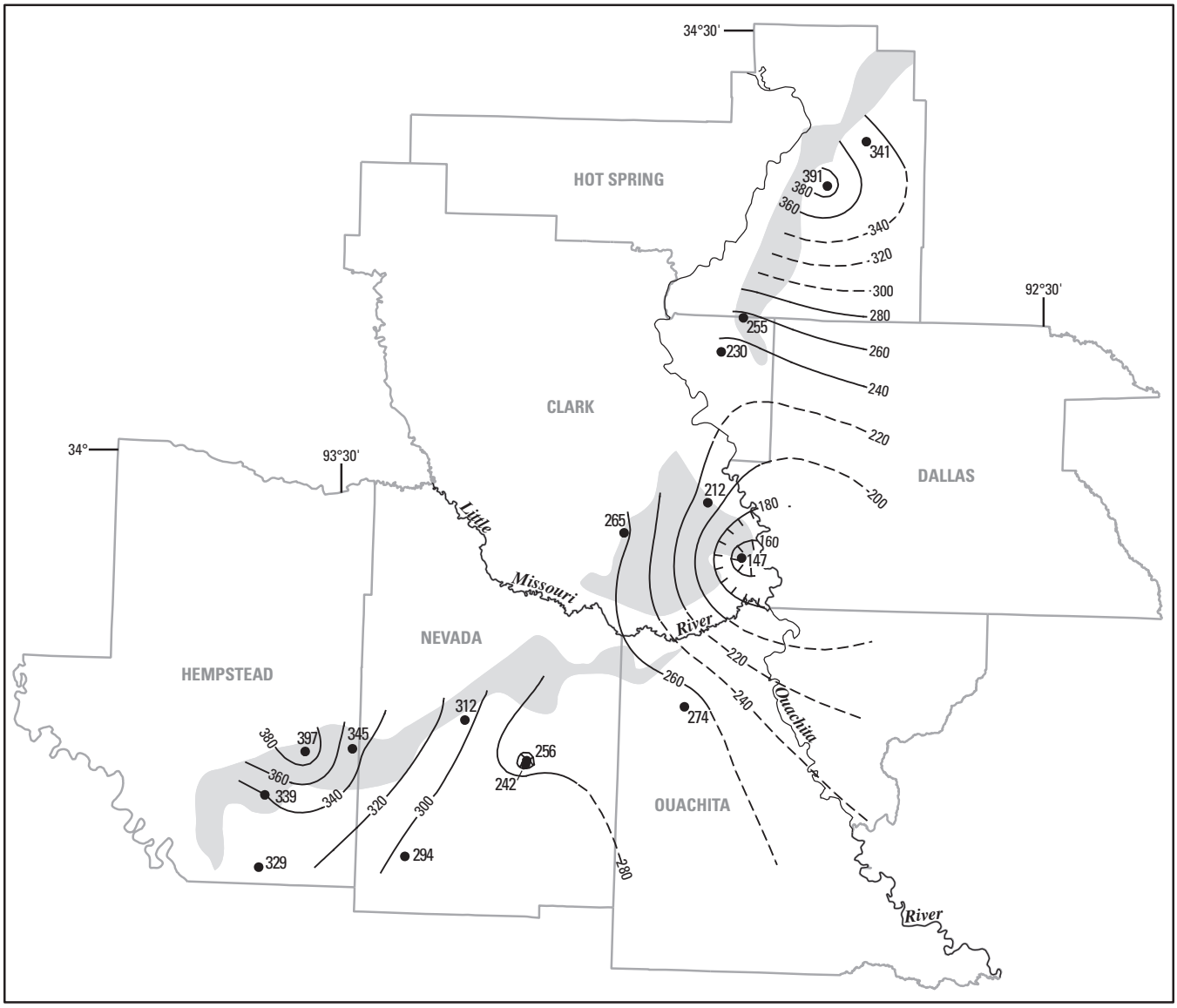

Figure 7. Potentiometric surface of the Wilcox aquifer in southern Arkansas, 2006.

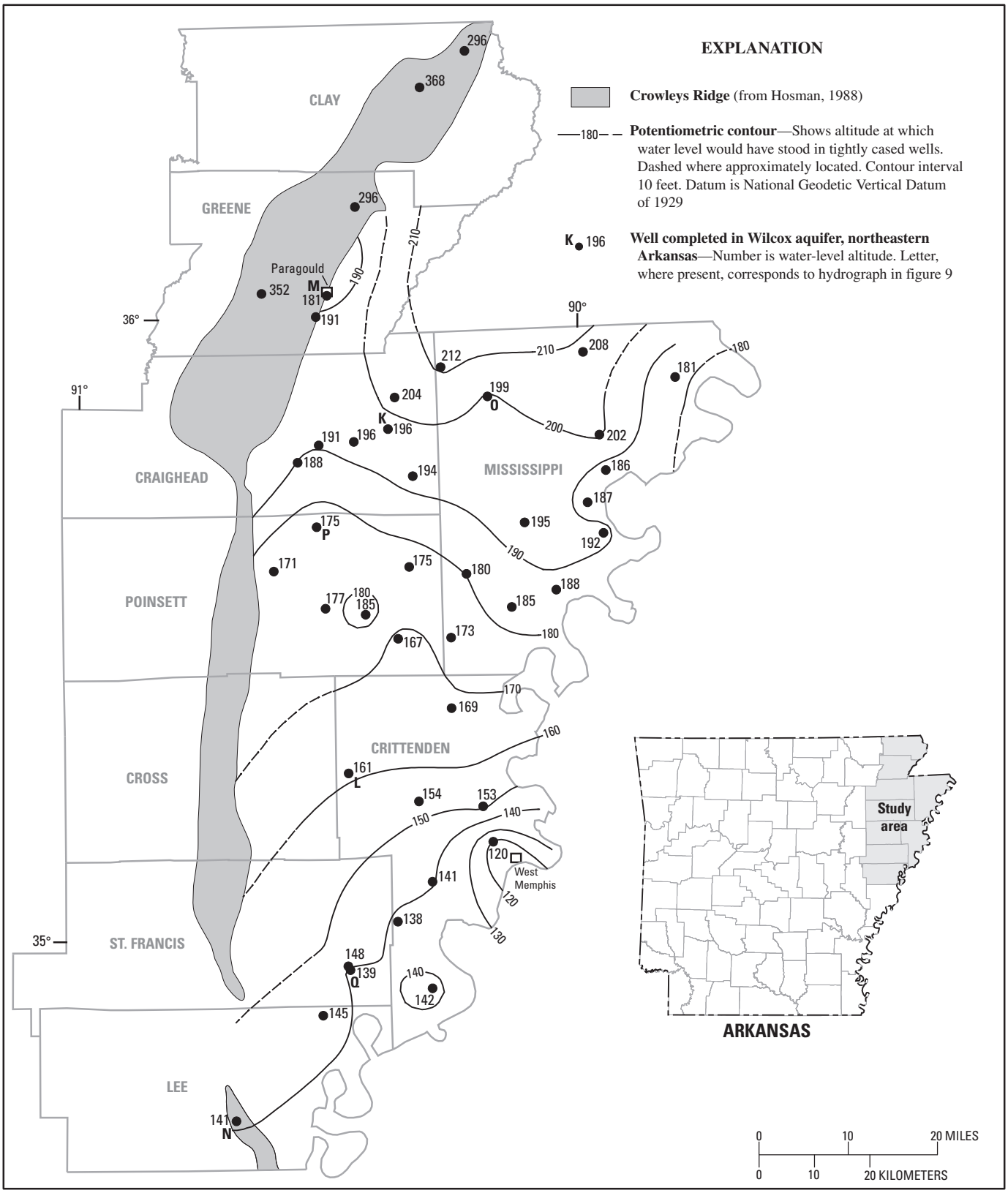

Figure 8. Potentiometric surface of the Wilcox aquifer in northeastern Arkansas, 2006.

Table 3. Water-level data collected from wells completed in the Wilcox aquifer in southwestern Arkansas, 2006.

[Horizontal datum is NAD is NAD of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929; --, no data]

Station Name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Clark County							
07S18W03BBD1	340917	925604	255	14.72	270	47	2/27/2006
07S18W20ABB2	340652	925757	230	11.63	242	18.5	2/27/2006
09S18W20CBB1	335611	925905	212	18.03	230	25.5	2/27/2006
10S18W10DDB1	335216	925613	147	48.31	195	215	2/27/2006
10S20W01BAC1	335403	930612	265	30.26	295	53	2/27/2006
Hempstead County							
13S23W04BDD1	333842	932911	345	4.91	350	14.2	2/28/2006
13S24W02DCA2	333829	933311	397	48.90	446	63	2/28/2006
13S24W29ACC1	333524	933635	339	31.60	371	60.2	2/28/2006
14S24W29BCA1	333017	933704	329	25.68	355	30.5	2/28/2006
Hot Spring County							
04S16W20CBB1	342144	924532	341	4.25	345	18.2	2/27/2006
05S17W10AAC1	341836	924853	391	18.85	410	26	2/27/2006
Nevada County							
12S22W24CDA1	334046	931941	312	32.01	344	41.2	2/27/2006
13S21W02DCC1	333754	931426	256	59.31	315	240	2/27/2006
13S21W11BDA1	333738	931432	242	26.07	268	--	2/27/2006
14S22W19AAA1	333105	932443	294	43.28	337	75	2/27/2006
Ouachita County							
12S19W11DCD1	334144	930105	274	13.82	288	533	3/1/2006

Table 4. Water-level data collected from wells completed in the Wilcox aquifer in northeastern Arkansas, 2006.

[Horizontal datum is NAD is NAD of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929]

Station Name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Clay County							
20N07E01CBB1	362347	901703	368	92.25	460	200	3/07/2006
21N08E14CBB1	362716	901126	296	83.53	380	157	3/07/2006
Craighead County							
13N07E14BBA2	354526	901911	194	26.89	221	1,028	3/08/2006
14N05E25DCB1	354843	903029	191	42.24	233	890	3/08/2006
14N05E34DDD1	354737	903209	188	41.37	229	874	3/08/2006
14N06E27ACB2	354858	902613	196	30.98	227	999	3/08/2006
14N07E17DCB1	355008	902202	196	35.57	232	1,070	3/08/2006
15N07E33BAD1	355315	902107	204	28.00	232	1,034	3/08/2006
Crittenden County							
04N07E36ADB1	345449	901828	142	59.09	201	1,638	3/09/2006
05N07E29ACC1	350129	902225	138	61.52	200	1,700	3/09/2006
06N07E01ABB1	350520	901807	141	66.06	207	1,541	3/09/2006
06N09E07CAC1	350907	901042	120	90.44	210	1,470	3/09/2006
07N07E14CCC1	351318	901930	154	68.93	223	1,584	3/09/2006
07N08E24CAB1	351238	901148	153	68.37	221	1,540	3/09/2006
08N06E33CBD1	351614	902752	161	53.96	215	1,750	3/09/2006
09N08E29ADD1	352225	901516	169	56.03	225	1,564	3/09/2006
Greene County							
16N05E13BAB1	360123	903026	191	99.32	290	545	3/07/2006
17N04E36BCA1	360348	903658	352	152.52	505	311	3/07/2006
17N06E31DCB1	360328	902902	181	104.00	285	462	3/07/2006
18N06E10DCD1	361209	902520	296	23.77	320	120	3/07/2006
Lee County							
01N04E09DCC1	344209	904220	141	62.62	204	1,885	3/09/2006
03N05E01BAB1	345413	903136	145	51.18	196	1,702	3/09/2006

Table 4. Water-level data collected from wells completed in the Wilcox aquifer in northeastern Arkansas, 2006.—Continued

[Horizontal datum is NAD is NAD of 1983; NGVD of 1929, National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929]

Station Name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Water-level altitude (feet above NGVD of 1929)	Depth to water (feet below land-surface datum)	Land-surface datum (feet above NGVD of 1929)	Well depth (feet)	Date of measurement
Mississippi County							
10N08E17ADD1	352923	901505	173	52.40	225	1,521	3/08/2006
11N08E10AAC2	353538	901301	180	40.07	220	1,380	3/08/2006
11N09E33AAB1	353214	900739	185	52.29	237	1,560	3/08/2006
11N10E20ADA1	353349	900213	188	47.07	235	1,417	3/08/2006
12N09E11DBB1	354033	900548	195	35.23	230	1,452	3/08/2006
12N11E17CDD1	353917	895618	192	52.79	245	1,500	3/08/2006
13N11E08DDA1	354528	895547	186	59.03	245	1,445	3/08/2006
13N11E31C-CCC1	354221	895807	187	53.51	241	1,500	3/08/2006
14N11E20CCA1	354859	895626	202	37.88	240	1,518	3/08/2006
15N08E08DBC3	355607	901527	212	25.59	238	1,060	3/08/2006
15N09E31ACD1	355306	900952	199	40.69	240	1,158	3/08/2006
15N10E01ADC1	355712	895806	208	39.93	248	1,350	3/08/2006
15N12E23DBC1	355426	894701	181	56.59	238	1,491	3/08/2006
Poinsett County							
10N07E16CBB2	352925	902129	167	51.03	218	1,500	3/07/2006
11N05E06CCD1	353622	903618	171	42.72	214	992	3/07/2006
11N05E36AAA1	353234	903009	177	37.38	214	1,175	3/07/2006
11N06E35CDA3	353152	902520	185	30.48	215	1,301	3/07/2006
11N07E03BDD1	353629	901955	175	41.03	216	1,456	3/07/2006
12N05E13BBB1	354038	903059	175	47.28	222	1,071	3/07/2006
St. Francis County							
04N06E16CCB1	345712	902830	148	54.36	202	1,615	3/09/2006
04N06E21BAD2	345649	902815	139	61.81	201	1,740	3/09/2006

The direction of ground-water flow in the northeastern study area generally is south and east. Larger ground-water withdrawals may have altered the natural direction of flow near the centers of pumping at Paragould and West Memphis (Joseph, 1998). The lowest water-level altitude measured in northeastern Arkansas was 120 ft near West Memphis in Crittenden County; the highest water-level altitude measured was 368 ft on Crowleys Ridge in Clay County. Crowleys Ridge represents an erosional remnant elevated as high as 200 ft above the Mississippi Alluvial Plain. Water levels measured in wells on Crowleys Ridge are higher because of the higher altitude of the Wilcox Group and influence of direct recharge to outcrops and subcrops on the ridge. The water levels on Crowleys Ridge were not included in the construction of the potentiometric surface because of few control points (only four wells).

Water-Level Trends

Water-level trends in the Wilcox aquifer northeastern study area are illustrated by plotting the water levels in hydrographs, and evaluating the change in water level over a period of time. Hydrographs from 28 wells with historical water levels from 1986 to 2006 were evaluated using linear regression to calculate the annual rise or decline, in feet per year, for each well and grouped by county (table 5). Table 5 shows the number of wells with a minimum of 20 years of record, the range of annual rise or decline, and the mean and median annual rise or decline by county. Lee and St. Francis Counties only had one well with a minimum of 20 years of record. All 28 wells showed an annual decline from 1986 to 2006. Craighead, Greene, Mississippi, and Poinsett Counties have mean annual declines from 0.27 to 1.00 ft/yr. Crittenden, Lee, and St Francis Counties have mean annual decline of from 1.39 to 1.64 ft/yr. Historical water-level data from seven wells (wells K-Q, fig. 8) in the Wilcox aquifer were plotted to illustrate the water-level trend in selected areas of northeastern Arkansas (fig. 9). The hydrographs were selected with an annual rise or decline near the mean annual rise or decline for the respective county. Hydrographs are not shown for wells in the southwestern study area, because the wells did not have 20 years of historical data.

Table 5. Range, mean, and median of annual rise/decline in water level by county for wells in the Wilcox aquifer in the northeastern study area, 1986-2006.

[Annual rise or decline in water level for each well is calculated using linear regression]

County	Number of wells	Range or value of annual decline (-) in water level (feet/year)	Mean annual decline (-) in water level (feet/year)	Median annual decline (-) in water level (feet/year)
Craighead	3	-0.84 to -0.69	-0.77	-0.77
Crittenden	8	-1.83 to -0.99	-1.39	-1.39
Greene	2	-0.47 to -0.07	-0.27	-0.27
Lee[1]	1	-1.64	-1.64	-1.64
Mississippi	9	-1.68 to -0.58	-1.00	-0.84
Poinsett	4	-1.53 to -0.17	-0.82	-0.79
St. Francis[1]	1	-1.57	-1.57	-1.57

[1]County produced one hydrograph of 20 years or more.

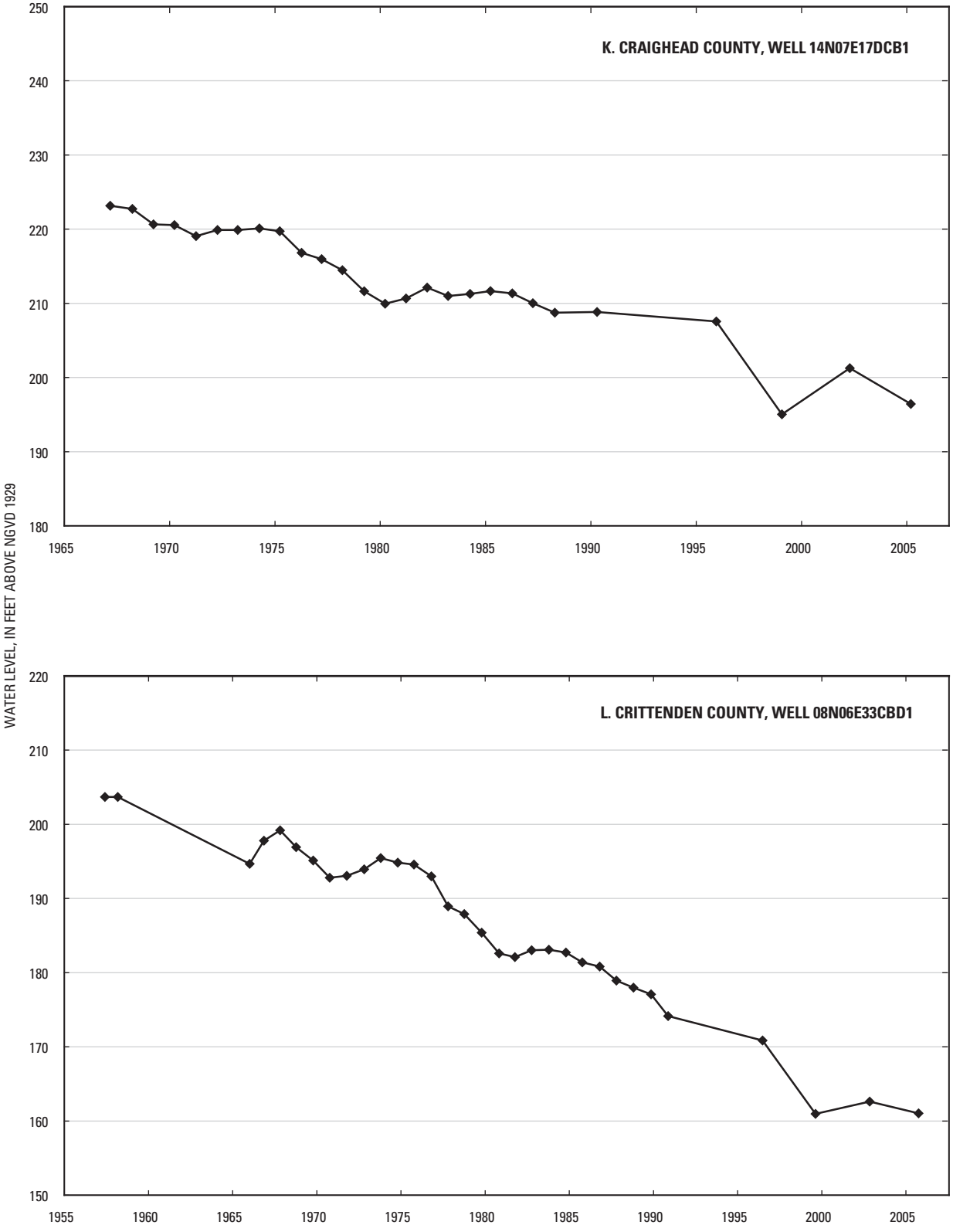

Figure 9. Water-level hydrographs for selected wells completed in the Wilcox aquifer in northeastern Arkansas.

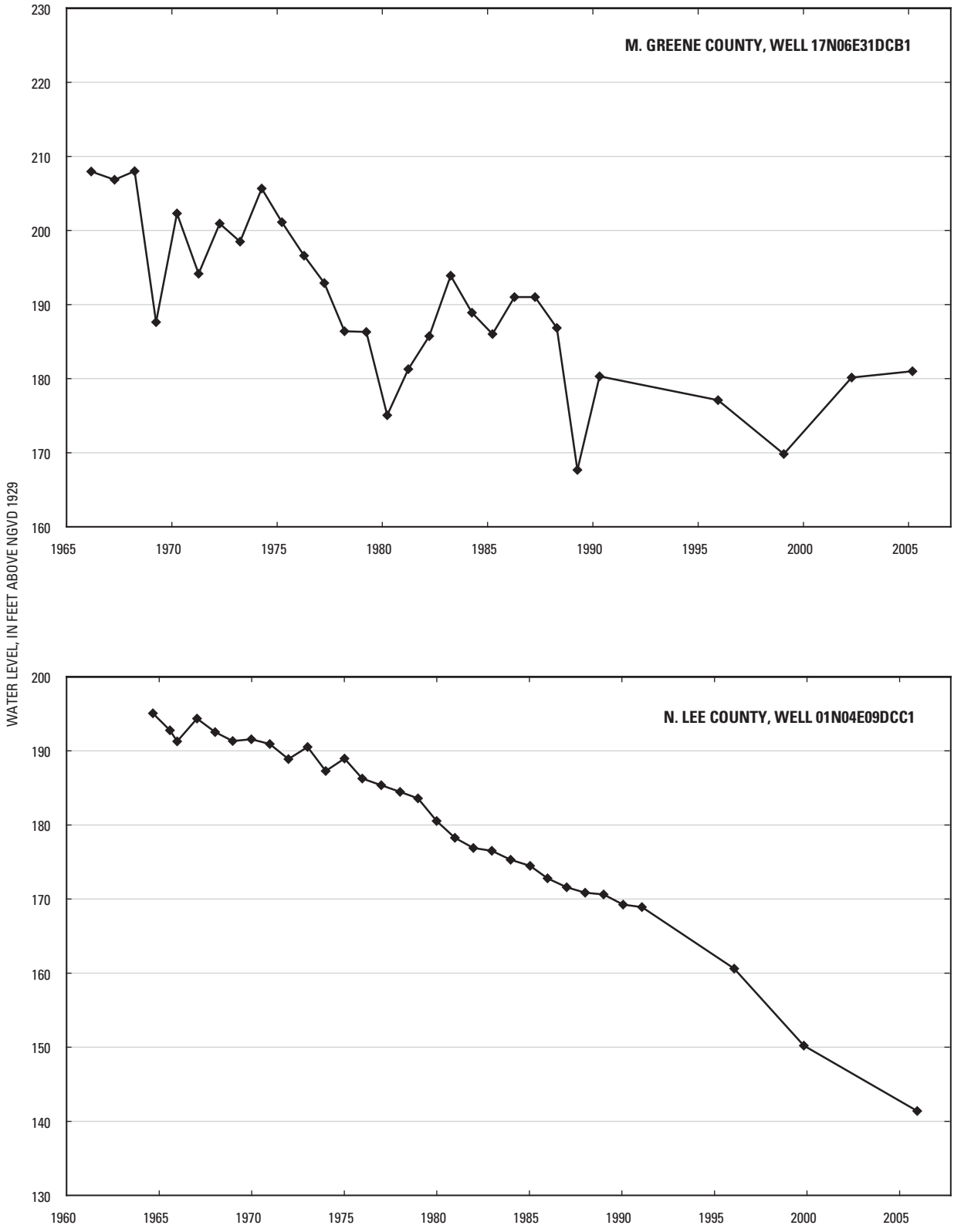

Figure 9. Water-level hydrographs for selected wells completed in the Wilcox aquifer in northeastern Arkansas.—Continued

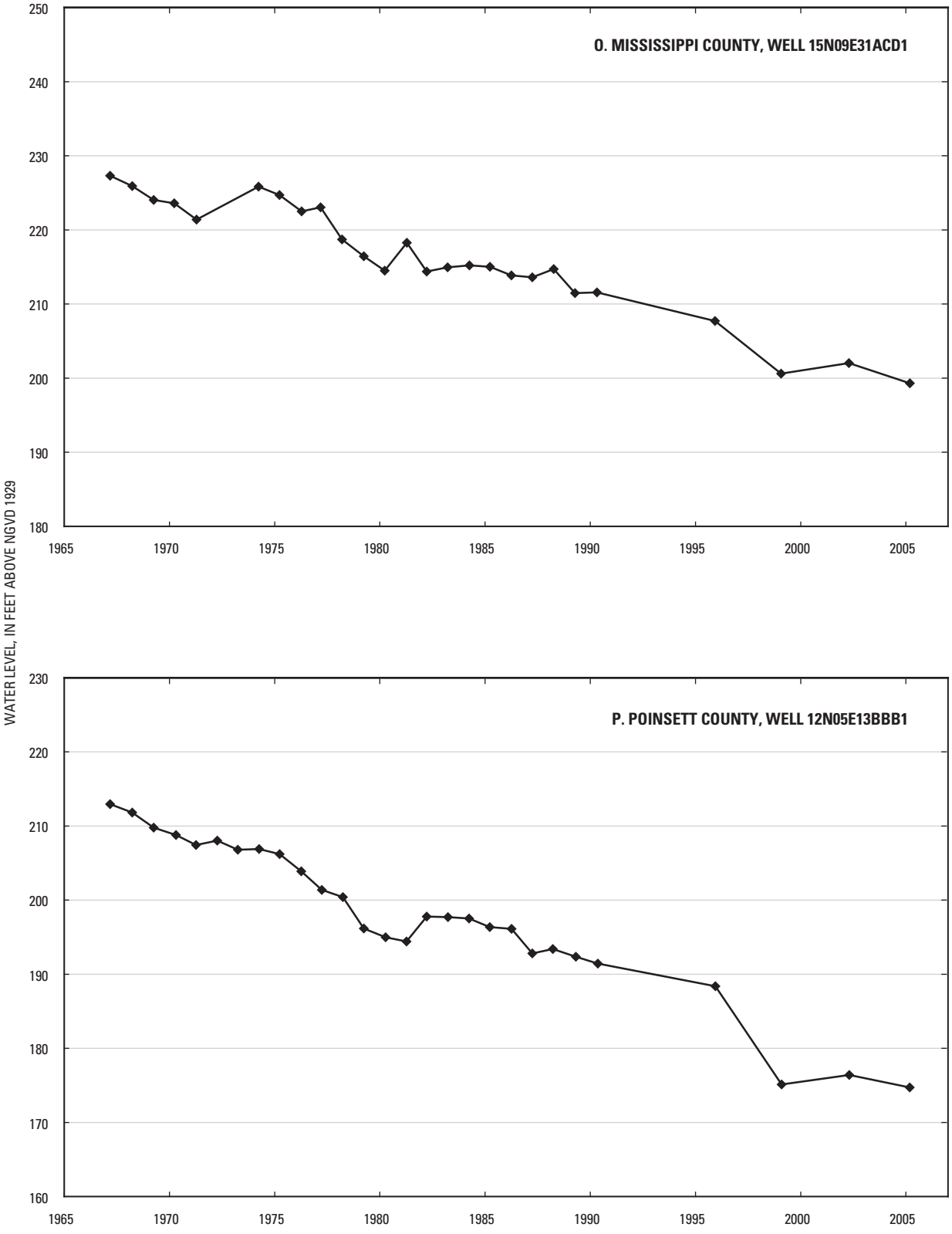

Figure 9. Water-level hydrographs for selected wells completed in the Wilcox aquifer in northeastern Arkansas.—Continued

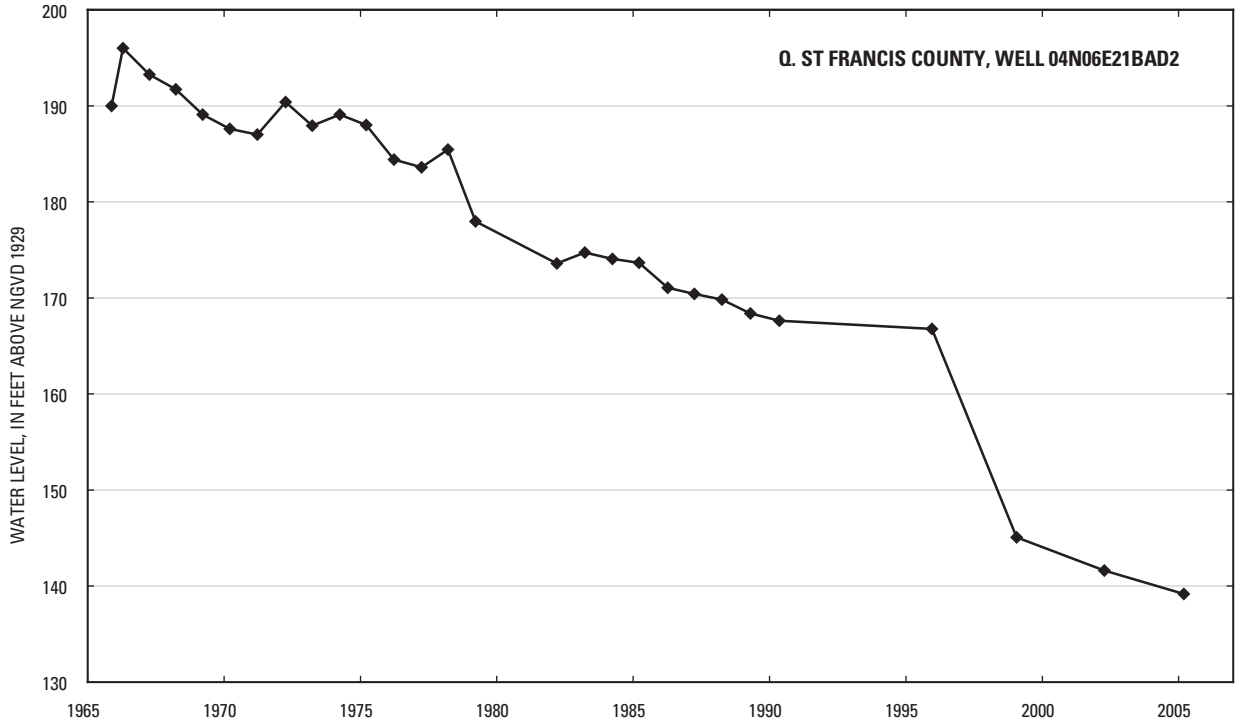

Figure 9. Water-level hydrographs for selected wells completed in the Wilcox aquifer in northeastern Arkansas.—Continued

Summary

The Cockfield aquifer and the Wilcox aquifer provide sources of ground water in southern and northeastern Arkansas. In 2000 about 9.9 Mgal/d was withdrawn from the Cockfield aquifer and about 22.2 Mgal/d was withdrawn from the Wilcox aquifer. Major withdrawals from the aquifers were for industrial and public water supplies, with lesser but locally important withdrawals for domestic and livestock uses.

A study was conducted by the U.S. Geological Survey in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey to determine the water level associated with the Cockfield aquifer and the Wilcox aquifer in southern and northeastern Arkansas. During February and March 2006, 56 water-level measurements were made in wells completed in the Cockfield aquifer and 59 water-level measurements were made in wells completed in the Wilcox aquifer, 16 in southwestern and 43 in northeastern Arkansas. This report presents the results as potentiometric-surface maps and as long-term water-level hydrographs.

The Cockfield Formation is Eocene age and generally consists of discontinuous fine- to medium-grained sand units interbedded with silt, clay, and lignite, all of nonmarine origin, in southeastern Arkansas. Most of the sand beds constitute the Cockfield aquifer and are near the base of the Cockfield Formation. The Cockfield Formation generally ranges from 100 to 400 ft thick near the outcrop area and thickens downdip of the outcrop area reaching 625 ft thick in northeastern Chicot County. Total sand thickness in the Cockfield Formation generally ranges from 20 to 150 ft. Withdrawals from the Cockfield aquifer in the study area during 2000 totaled about 9.9 Mgal/d. Withdrawals from the Cockfield aquifer generally increased from 1975 to 2000, the exception being a decrease in 1985, producing 5.2 Mgal/d in 1975, 7.2 Mgal/d in 1980, 5.0 Mgal/d in 1985, 8.1 Mgal/d in 1990, and 9.8 Mgal/d in 1995. Most wells completed in the Cockfield aquifer study area provide small volumes of water for domestic and livestock use.

The potentiometric-surface map shows the altitude of the water surface in tightly cased wells screened in the Cockfield aquifer. The regional direction of ground-water flow generally is towards the east and southeast, away from the outcrop, except in areas of intense ground-water withdrawals, such as western Drew County, southeastern Lincoln County, southwestern Calhoun County, and near Crossett in Ashley County. There are three cones of depression indicated by relatively low water levels in southeastern Lincoln County, southwestern Calhoun County and near Crossett in Ashley County. The cones of depression in southeastern Lincoln and southwestern Calhoun Counties were not evident in the 2003 potentiometric-surface map. The lowest water-level altitude measured

was 44 ft in Lincoln County; the highest water-level altitude measured was 346 ft in Columbia County, at the outcrop area.

Hydrographs from 40 wells with historical water levels from 1986 to 2006 were evaluated using linear regression to calculate the annual rise or decline, in feet per year. Calhoun and Cleveland Counties have mean annual rises from 0.01 to 0.07 ft/yr. Arkansas, Ashley, Bradley, Chicot, Columbia, Drew, Lincoln, and Union Counties have mean annual declines from 0.04 to 0.55 ft/yr. Desha County has a mean annual decline of about 1.35 ft/yr.

The Wilcox Group of Eocene and Paleocene age is located throughout most of southern and eastern Arkansas. There are two study areas in the southwestern and northeastern portions of Arkansas for which potentiometric surfaces of the Wilcox aquifer were made. The Wilcox Group in the southwestern study area consists of interbedded layers of clay, sandy clay, sand, and lignite. Formations in the southwestern study area are undifferentiated. Sand beds generally are thin and are not continuous over large areas. In most of the southwestern study area, the Wilcox Group overlies the Midway Group and is overlain by terrace deposits and alluvium of Quaternary age or crops out in discontinuous bands that are 1 to 3 miles wide. The Wilcox Group becomes progressively thicker downslope from the outcrop, ranging in thickness from a few feet in the outcrop to about 750 ft in northeastern Bradley County.

The Wilcox Group in most of the northeastern study area consists of thin interbedded layers of lignitic sand and clays. The Wilcox Group outcrops at or near Crowleys Ridge in Clay, Greene, and Craighead Counties. East of Crowleys Ridge, the middle to lower part of the Wilcox Group contains a sand bed of 200 ft or more in thickness referred to as the "1,400-foot sand" or the "lower Wilcox aquifer". The Wilcox aquifer in the northeastern study area is confined above by a clay bed of the Wilcox Group and confined below by a clay bed of the Wilcox Group or the Midway Group.

Withdrawals from the Wilcox aquifer in the study areas totaled about 22.2 Mgal/d during 2000, most of which came from the northeastern study area. Withdrawals from the Wilcox aquifer generally increased from 1975 to 1995, the exception being a decrease in 1985, producing 24.3 Mgal/d in 1975, 25.7 Mgal/d in 1980, 21.0 Mgal/d in 1985, 30.9 Mgal/d in 1990, and 41.0 Mgal/d in 1995.

The potentiometric-surface maps show the altitude of the water surface in tightly cased wells screened in the Wilcox aquifer. The direction of ground-water flow in the southwestern study area generally is south and east, except in Clark County where flow is towards the Ouachita River that has eroded into the Wilcox Group and deposited alluvium. The lowest water-level altitude measured in southwestern Arkansas was 147 ft near the Ouachita River in Clark County; the highest water-level altitude measured was 397 ft in the outcrop area of Hempstead County.

The direction of ground-water flow in the northeastern study area generally is south and east. Ground-water withdrawals may have altered the natural direction of flow near the centers of pumping at Paragould and West Memphis. The lowest water-level altitude measured in northeastern Arkansas was 120 ft near West Memphis in Crittenden County; the highest water-level altitude measured was 368 ft on Crowleys Ridge in Clay County.

Hydrographs from 28 wells in the northeastern study area with 20 years of historical water levels from 1986 to 2006 were evaluated using linear regression to calculate the annual rise or decline, in feet per year, for each well and grouped by county. All 28 wells showed an annual decline from 1986 to 2006. Craighead, Greene, Mississippi, and Poinsett Counties have mean annual declines from 0.27 to 1.00 ft/yr. Crittenden, Lee, and St Francis Counties have mean annual declines from 1.39 to 1.64 ft/yr. The wells in the southwestern study area did not have 20 years of historical data.

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