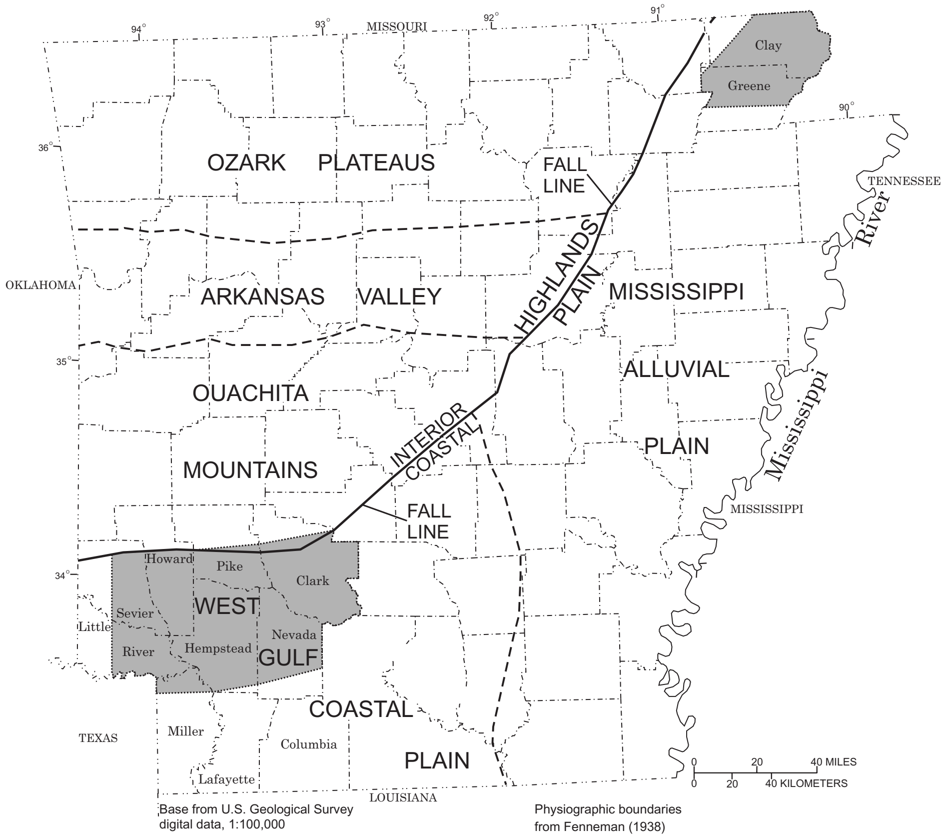
Prepared in cooperation with the

Arkansas Soil and Water Conservation Commission and the
Arkansas Geological Commission

STATUS OF WATER LEVELS IN AQUIFERS IN THE NACATOCH SAND OF SOUTHWESTERN AND NORTHEASTERN ARKANSAS AND THE TOKIO FORMATION OF SOUTHWESTERN ARKANSAS, 2002

Water-Resources Investigations Report 03-4284



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

STATUS OF WATER LEVELS IN AQUIFERS IN THE NACATOCH SAND OF SOUTHWESTERN AND NORTHEASTERN ARKANSAS AND THE TOKIO FORMATION OF SOUTHWESTERN ARKANSAS, 2002

by T.P. Schrader and Rheannon M. Scheiderer

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 03-4284

Prepared in cooperation with the

Arkansas Soil and Water Conservation Commission

and the **Arkansas Geological Commission**

Little Rock, Arkansas
2004

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information
write to:

District Chief
U.S. Geological Survey, WRD
401 Hardin Road
Little Rock, Arkansas 72211

Copies of this report can be
purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver Federal Center
Denver, Colorado 80225

CONTENTS

ILLUSTRATIONS

TABLES

Status of Water Levels in Aquifers in the Nacatoch Sand of Southwestern and Northeastern Arkansas and the Tokio Formation of Southwestern Arkansas, 2002

By T.P. Schrader and Rheannon M. Scheiderer

ABSTRACT

Aquifers in the Nacatoch Sand and Tokio Formation in southwestern Arkansas and the Nacatoch Sand in northeastern Arkansas are sources of water for industrial, public supply, domestic, and agricultural uses. Potentiometric-surface maps were constructed from water-level measurements made in 60 wells completed in the Nacatoch Sand and 48 wells completed in the Tokio Formation during January and February 2002.

In northeastern Arkansas, withdrawals from the Nacatoch Sand increased by 784 percent from 1965 to 1990 and decreased by 30 percent from 1990 to 2000. In southwestern Arkansas withdrawals from aquifers in the Nacatoch Sand and Tokio Formation increased by 125 percent and 201 percent, respectively, from 1965 to 1980 and decreased by 93 percent and 81 percent, respectively, from 1980 to 2000. Long-term hydrographs were prepared for 13 wells in the study area. Changes in water levels in some wells may be associated with changes in withdrawals from the respective aquifers.

The direction of ground-water flow in the aquifer in the Nacatoch Sand in northeastern Arkansas generally is towards the southeast. The potentiometric high is located along the north and northwestern boundaries of the subarea.

The direction of ground-water flow in the aquifer in the Nacatoch Sand in southwestern Arkansas is towards the south-southeast in Little River, Miller, and Hempstead Counties and to the east-southeast in Nevada and Clark Counties. The potentiometric high is located within the outcrop area in north-central Hempstead County. Cones of depression exist in the aquifer in the Nacatoch Sand in southeastern Hempstead County and in southwestern Clark County.

The direction of ground-water flow in the aquifer in the Tokio Formation in southwestern Arkansas generally is towards the south or southeast. The potentiometric high is located where the aquifer outcrops in the northwestern part of the study area. An area of artesian flow exists in southeastern Pike, northeastern Hempstead, and northwestern Nevada Counties. One apparent cone of depression may exist northwest of Hope in Hempstead County.

INTRODUCTION

Ground water is a renewable resource important for economic growth and quality of life. Aquifers in the Nacatoch Sand and Tokio Formation in southwestern Arkansas and the Nacatoch Sand in northeastern Arkansas are a source of water for industrial, public supply, domestic, and agricultural uses. Monitoring of ground-water levels and withdrawals provides information needed to effectively plan and manage the resource. The U.S. Geological Survey (USGS) conducted this study in cooperation with the Arkansas Soil and Water Conservation Commission and the Arkansas Geological Commission to provide potentiometric-surface maps and water-level hydrographs associated with aquifers in the Nacatoch Sand and Tokio Formation (hereinafter referred to as the Nacatoch aquifer and Tokio aquifer, respectively) in southwestern Arkansas and the Nacatoch aquifer in northeastern Arkansas.

The study area comprises parts of 10 counties in two subareas of northeastern and southwestern Arkansas. The northeastern subarea includes most of Clay and Greene Counties in the Mississippi Alluvial Plain physiographic section (fig. 1). This subarea is bounded on the north and east by the Missouri State line and on the west by the western extent of the Nacatoch aquifer. The southern boundary of this subarea was defined by the area of water use in the Nacatoch aquifer. The southwestern subarea includes parts of eight counties (Clark, Hempstead, Howard, Little River, Miller, Nevada, Pike, and Sevier) in the West Gulf Coastal Plain physiographic section (fig. 1). This subarea is bounded on the north approximately by the Fall Line separating the Interior Highlands from the West Gulf Coastal Plain, on the southwest by the Texas State line, on the west by the western extent of withdrawals in Little River and Sevier Counties, and on the east by the eastern borders of Clark and Nevada Counties. The southwestern subarea was limited to the occurrence of freshwater; the southern boundary of the subarea is defined by a freshwater/saltwater interface. To the south, the ground water is considered saline (more than 1,000 milligrams per liter of dissolved solids) and is not suitable for most uses (Boswell and others, 1965; Petersen and others, 1985).

This report presents the results of water-level measurements made in 60 wells completed in the Nacatoch aquifer and in 48 wells completed in the Tokio aquifer during January and February 2002. These measurements were used to construct potentiometric-surface maps. All water-level data are stored in the USGS Ground-Water Site Inventory (GWSI) data storage system. Long-term water-level hydrographs were prepared for selected wells. County withdrawal data collected by the USGS from 1965 to 2000 are presented and related to these hydrographs. The Tokio Formation is stratigraphically below the Nacatoch Sand and separated from it by five stratigraphic units, listed here in

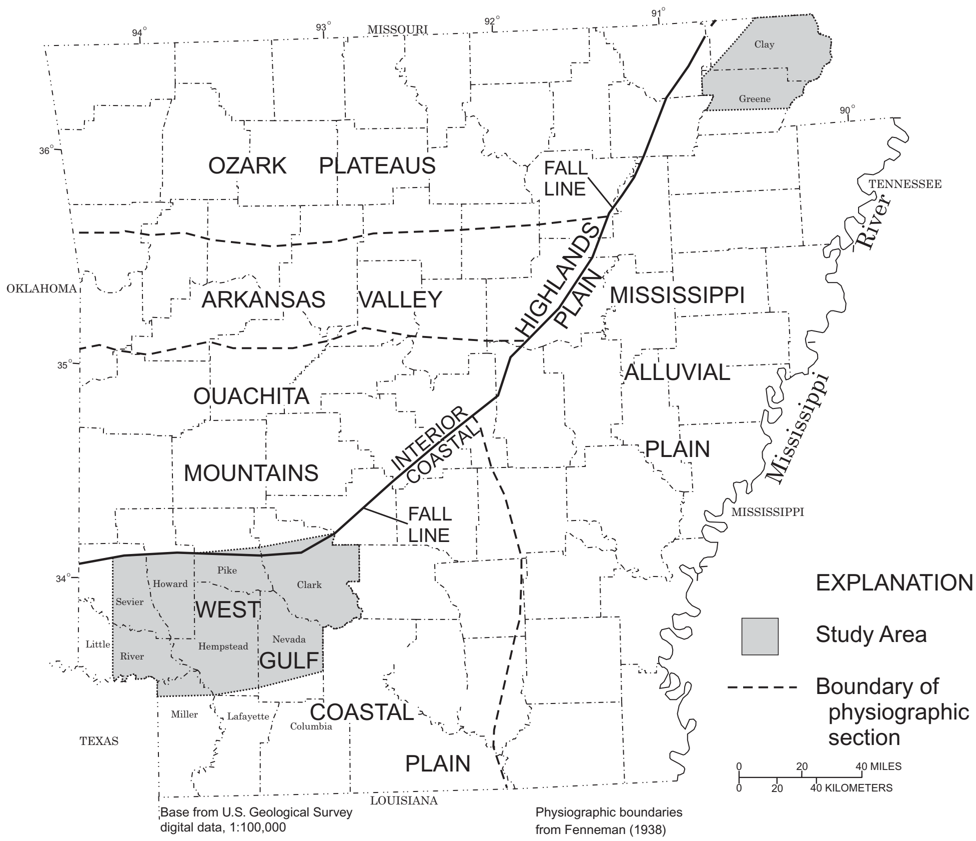


Figure 1. Location of study area.

descending stratigraphic order: Saratoga Chalk, Marlbrook Marl, Annona Chalk, Ozan Formation, and Brownstown Marl. The Saratoga Chalk, Marlbrook Marl, and Annona Chalk are non-water bearing and the five unit section can obtain a thickness of 900 feet (ft) in the study area, which hydraulically separates the Nacatoch and Tokio aquifers. These five units rarely are used as water sources and are not discussed in this report.

Cones of depression within a potentiometric surface are indicators of pumping rates that are exceeding the local recharge rates to the aquifer. During pumping, water levels are drawn down, forming a local cone of depression. Water levels will recover to static conditions if pumping rates do not exceed the recharge rates to the aquifer. Pumping rates that exceed recharge rates for an extended period of time will cause cones of depression to enlarge. Local cones of depression can intersect and coalesce, causing a regional decrease in water levels within the aquifer. Variations in climatic conditions and resulting recharge rates can result in the natural rise or decline of water levels and could account for changes shown by long-term hydrographs.

The well-numbering system used in this report is based upon the location of the wells according to the Federal land survey 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 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. 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. Wells were located using a Global Positioning System (GPS) capable of accuracy to one-tenth of a second of latitude and longitude, referenced to North American Datum 1983.

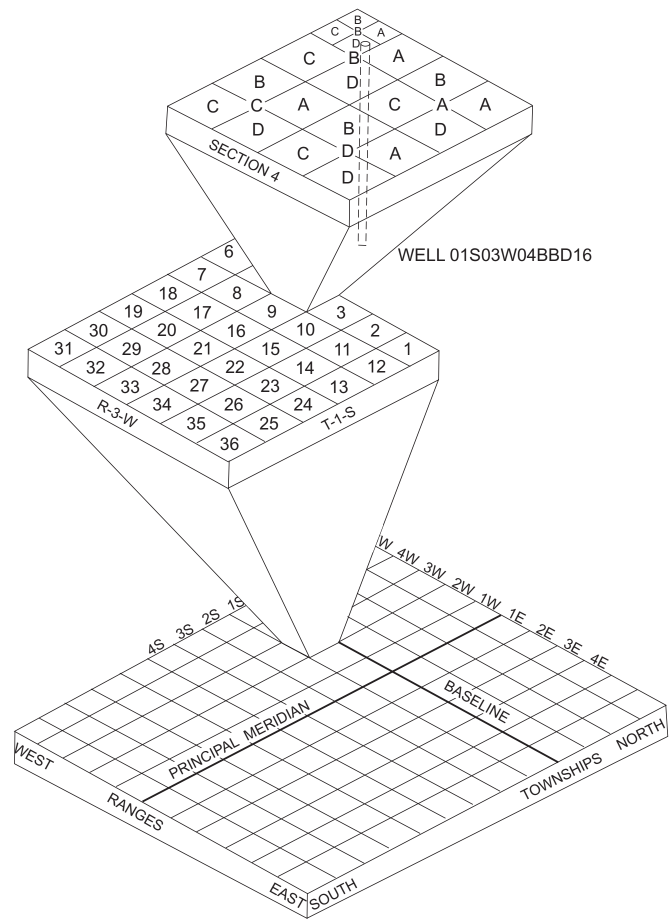


Figure 2. Well-numbering system.

METHODS

Personnel from the U.S. Geological Survey collected water-level measurements during January and February 2002 from wells screened in either the Nacatoch or Tokio aquifer. Measurements were collected using steel or electric tapes graduated in hundredths of a foot. The steel and electric tapes were calibrated during January 2002, prior to collecting measurements from wells. Well locations were measured using a Global Positioning System receiver to acquire the horizontal coordinate information, latitude and longitude, based on the North American Datum of 1983. The latitude and longitude of the well location was transferred to the topographic map and the altitude (National Geodetic Vertical Datum of 1929), was determined at the location.

NACATOCH SAND

Hydrogeologic Setting

The Nacatoch Sand of the Upper Cretaceous series is overlain by the Arkadelphia Marl and underlain by the Saratoga Chalk. In the northeastern subarea, the Nacatoch Sand subcrops beneath Quaternary alluvial and terrace deposits along the western boundary. The top of the Nacatoch Sand has an altitude of about 50 to 100 ft above the National Geodetic Vertical Datum of 1929 (NGVD of 1929) along the western boundary, dips toward the southeast (Petersen and others, 1985), and descends to about 500 ft below the NGVD of 1929 at the eastern boundary. The unit is about 100 ft thick near the subcrop and attains a maximum thickness of about 300 ft downdip.

The Nacatoch aquifer in the northeastern subarea consists of interbedded clay, limestone, and fine sand in the lower part, grading upward to loose fine quartz sand in the upper part (Petersen and others, 1985). The Nacatoch aquifer receives recharge from precipitation through the overlying alluvial and terrace deposits in western Clay and Greene Counties.

In the southwestern subarea, the Nacatoch Sand outcrops in a belt 3 to 8 miles (mi) wide extending from central Clark County southwestward to western Hempstead County. The belt continues westward as a subcrop below Quaternary alluvial and terrace deposits across Little River County (Boswell and others, 1965). The top of the Nacatoch Sand has an altitude of about 300 ft above the NGVD of 1929 in the outcrop, dips towards the southeast, and descends to about 800 ft below the NGVD of 1929 at the southern boundary of the subarea (Petersen and others, 1985). The Nacatoch Sand is about 100 ft thick near the outcrop and attains a maximum thickness of about 300 ft.

The Nacatoch Sand in the southwestern subarea consists of three distinct units. The upper unit is composed of unconsolidated, gray, fine-grained quartz sand that commonly is crossbedded. Locally, the sand is massive and contains a few hard lenses and beds of fossiliferous sandy limestone. This upper sand unit is the main water-bearing unit of the Nacatoch aquifer. The middle unit consists of a dark-green sand that contains coarse grains of glauconite and weathers to lighter shades of green. This unit generally is fossiliferous where it is glauconitic. The lower unit consists of interbedded gray clay, sandy clay and marl, dark clay-rich fine-grained sand, and hard irregular concretionary beds (Counts and others, 1955; Plebuch and Hines, 1969).

In the southwestern subarea, the Nacatoch aquifer receives recharge from precipitation in its outcrop areas in Clark, Nevada, and Hempstead Counties and through the overlying alluvial and terrace deposits in Little River County and in northeastern Texas.

The Nacatoch aquifer is used in northeastern Green County, Clay County, southern Clark County, northwestern Nevada County, central Hempstead County, northern Miller County, and southeastern Little River County. Flowing wells produce yields of 1 or 2 gallons per minute (gal/min) in the lowest stream valleys in Clark and Nevada Counties. Wells in Hempstead County and western Nevada County produce yields of 150 to 300 gal/min. The water generally is excessively saline for most uses downdip 2 to 20 mi southeast from the outcrop area in the southwestern subarea. In Miller County, eastern Nevada County, and Clark County, yields are generally small and the water may contain considerable chloride (Counts and others, 1955). Aquifer tests made using wells completed in the Nacatoch aquifer at the cities of Hope and Prescott show a transmissivity of 3,600 gallons per day per foot (gal/d/ft) (Ludwig,1972).

Water withdrawn from the Nacatoch aquifer in the northeastern subarea was estimated to be 0.25 million gallons per day (Mgal/d) in 1965 and increased to 2.21 Mgal/d in 1990, an increase of 784 percent during the 25-year period (fig. 3). The amount of water withdrawn in 2000 was 1.54 Mgal/d, a decrease of 30 percent from 1990 (Halberg and Stephens; 1966, Holland, 1993; T.W. Holland, U.S. Geological Survey, written commun., 2002).

Water withdrawn from the Nacatoch aquifer in the southwestern subarea was estimated to be 2.11 Mgal/d in 1965 and increased by 125 percent to 4.75 Mgal/d in 1980 (fig. 4). Water withdrawn from the Nacatoch aquifer in this subarea was estimated to be 0.32 Mgal/d in 2000, a decrease of 93 percent from 1980. The sharp decrease in water withdrawal rates is explained by counties in the southwestern subarea relying more on surface water during the 1980s and 1990s (Halberg and Stephens, 1966; Holland and Ludwig, 1981; T.W. Holland, U.S. Geological Survey, written commun., 2002).

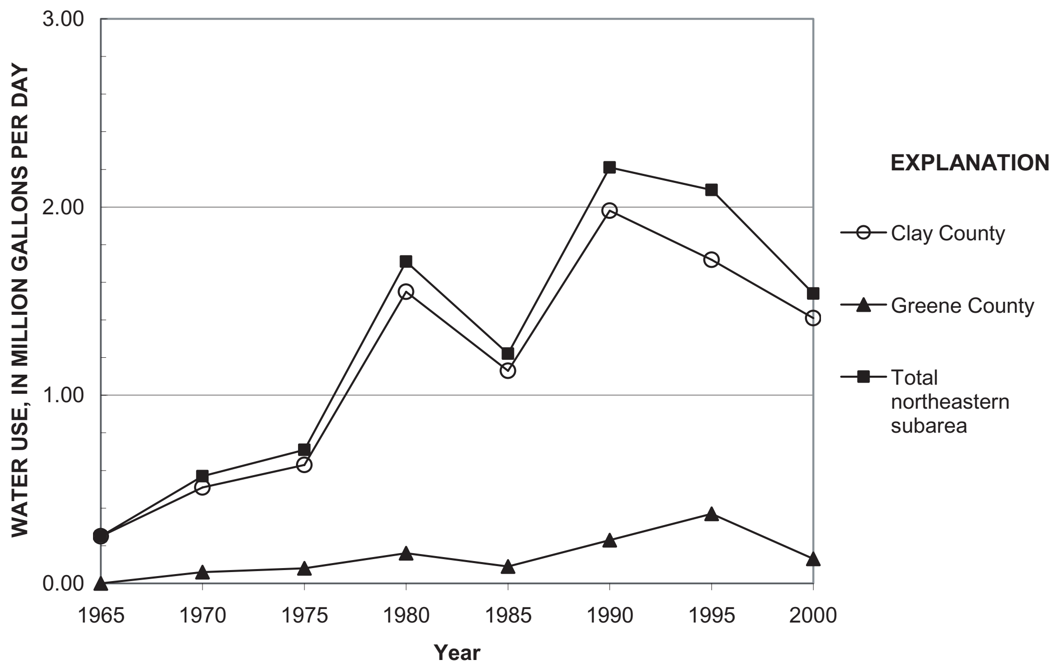


Figure 3. Estimated water use by county from the Nacatoch aquifer for the northeastern subarea.

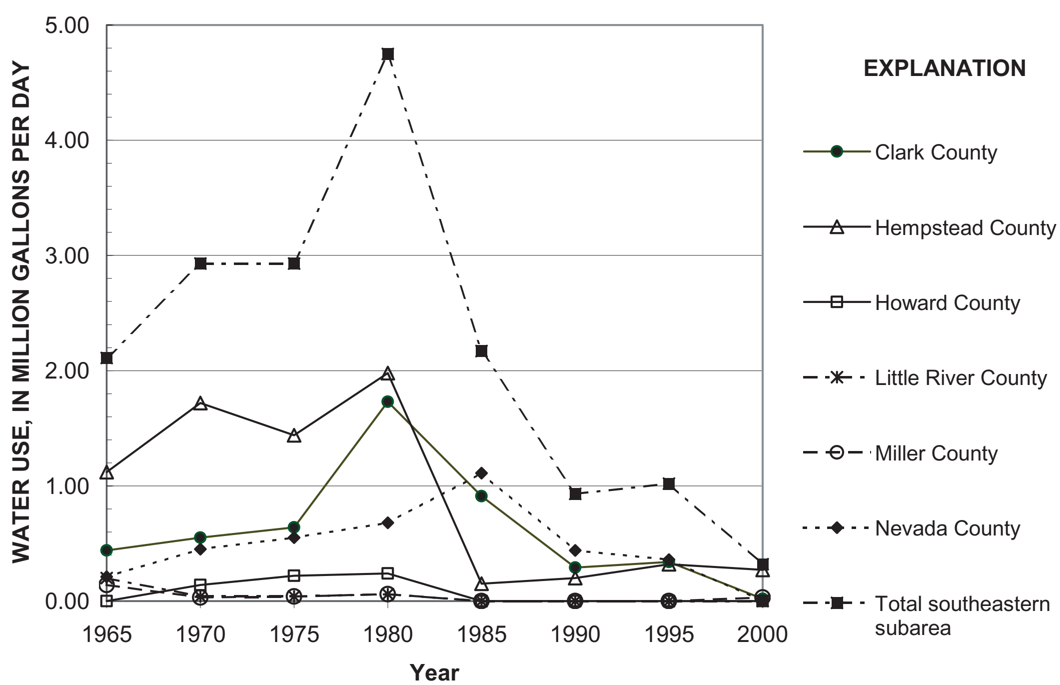


Figure 4. Estimated water use by county from the Nacatoch aquifer for the southwestern subarea.

Potentiometric Surface

Water-level measurements in 60 wells during January and February 2002 were used to construct potentiometric-surface maps for the Nacatoch aquifer (figs. 5 and 6; table 1). The surface is mapped by calculating the altitude of the water levels (table 1), plotting the values on a map, and representing the surface on the figures by contours that connect points of equal elevation. The general direction of ground-water flow is perpendicular to the contours in the direction of downward hydraulic gradient.

In the northeastern subarea, the direction of ground-water flow in the Nacatoch aquifer generally is towards the southeast (fig. 5). The potentiometric high is located along the north and northwestern boundary of this subarea. The highest water-level altitude measured was about 272 ft in northern Clay County. The lowest water-level altitude measured was about 233 ft in eastern Clay County.

In the southwestern subarea the direction of ground-water flow in the Nacatoch aquifer is generally towards the south-southeast in Little River, Miller, and Hempstead Counties and to the east-southeast in Nevada and Clark Counties (fig. 6). The direction of flow may be affected by the increase in clay content in the downdip direction and by a fault system trending northeastward from northeastern Texas across Miller, Lafayette, and Nevada Counties in Arkansas. The highest water-level altitude measured was about 445 ft in the outcrop area of north-central Hempstead County. The lowest water-level altitude measured was about 119 ft at Hope in southeastern Hempstead County.

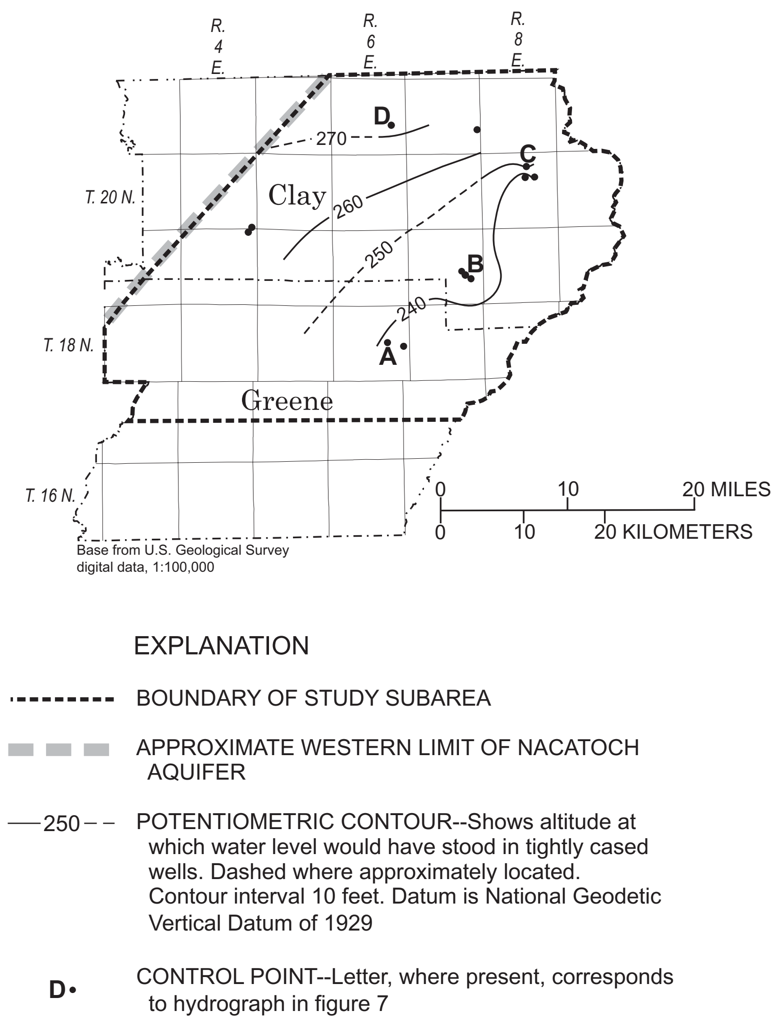


Figure 5. Potentiometric surface of the Nacatoch aquifer, northeastern Arkansas, January-February 2002.

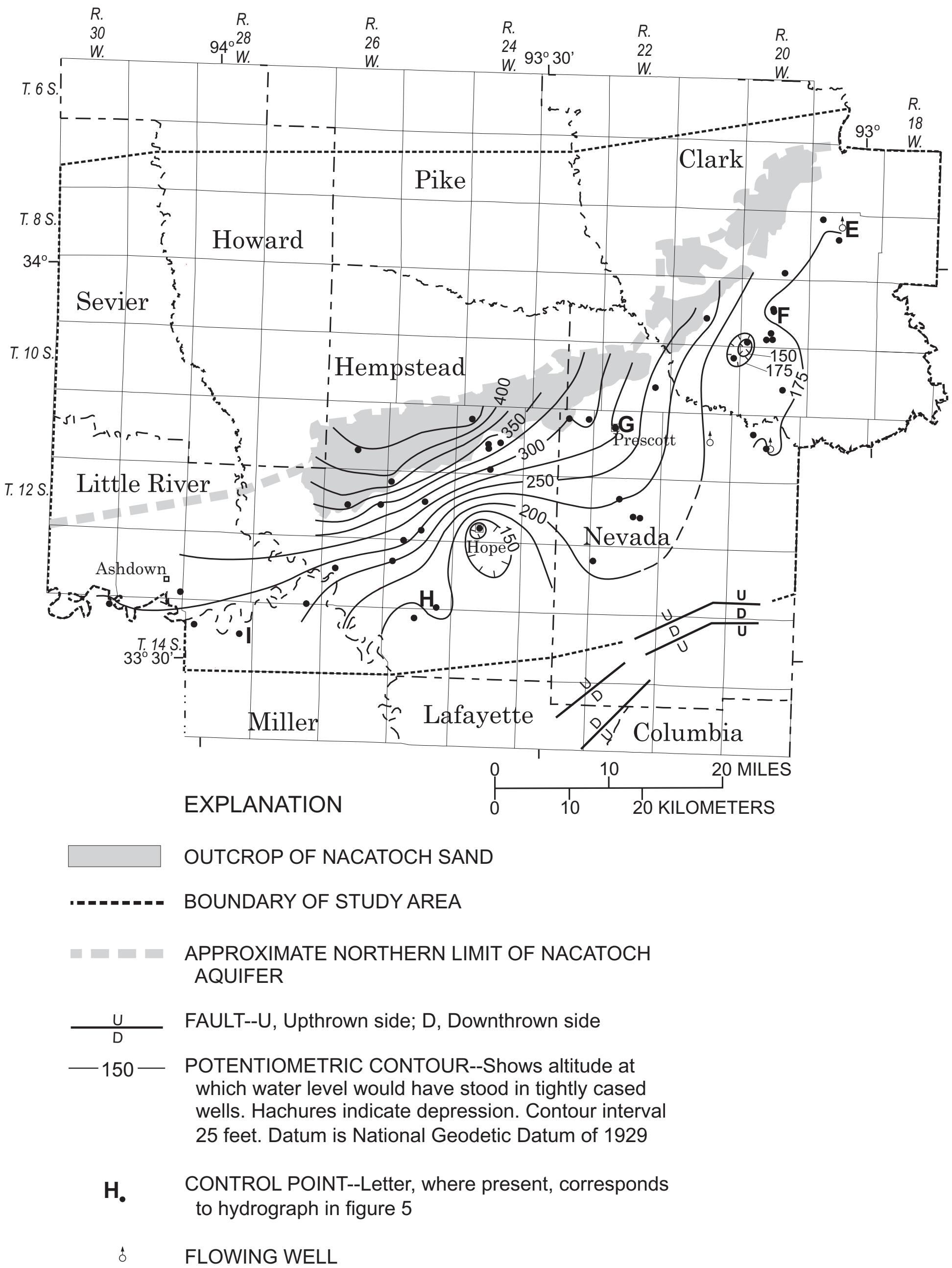


Figure 6. Hydrogeologic setting and potentiometric surface of the Nacatoch aquifer, southwestern Arkansas, January-February 2002.

Table 1. Water-level measurements and well information for wells completed in the Nacatoch aquifer

[ddmmss, degrees, minutes, seconds; NGVD of 1929 is National Geodetic Vertical Datum of 1929]

Local well number	Latitude (ddmmss)	Longitude (ddmmss)	Water-level altitude (feet above NGVD of 1929)	Depth to water level (feet below land-surface datum)	Land-surface altitude (feet above NGVD of 1929)	Date of measurement
			Clark County			
08S19W06DDA1	340401	930414	176	8.45	185	1/31/2002
08S19W09ACC1	340323	930228	178	-0.85	177	1/31/2002
08S19W16CAB1	340226	930247	171	1.89	173	1/31/2002
08S20W34DAB1	335954	930744	183	16.77	200	1/31/2002
09S20W16DBD1	335708	930847	164	76.64	241	2/01/2002
09S20W16DDC1	335657	930845	158	75.12	233	2/01/2002
09S20W28DCB1	335516	930901	184	17.53	202	1/31/2002
09S20W31CAD1	335435	931111	140	118.77	259	1/31/2002
09S20W33ABD1	335447	930852	176	32.57	209	1/31/2002
09S20W33BCD2	335446	930926	180	26.87	207	1/31/2002
09S21W21DAD1	335625	931453	242	102.84	345	1/31/2002
10S20W22DCB1	335054	930757	179	81.32	260	1/31/2002
10S21W12BAB1	335321	931225	152	69.02	221	1/31/2002
			Clay County			
19N04E01BDB1	361910	903560	268	11.78	280	2/05/2002
19N07E23BAC1	361602	901748	239	83.26	322	2/04/2002
19N07E23DBC1	361549	901730	246	36.92	283	2/04/2002
19N07E26AAA1	361532	901703	244	31.99	276	2/04/2002
20N04E36DCC1	361929	903542	264	15.09	279	2/05/2002
20N08E10ABC1	362313	901202	251	88.67	340	2/04/2002
20N08E14BAB2	362227	901120	242	43.78	286	2/05/2002
20N08E15BAA1	362224	901208	233	147.78	381	2/05/2002
21N06E23DAC1	362619	902329	272	27.79	300	2/05/2002
21N07E25AAC1	362550	901607	269	73.00	342	2/04/2002
			Greene County			
18N06E14CCD1	361115	902420	239	47.94	287	2/04/2002
18N06E24BDA1	361058	902300	234	41.59	276	2/04/2002
			Hempstead County			
11S24W08BDB1	334837	933619	445	24.89	470	1/30/2002
11S24W21ADD1	334641	933449	323	47.22	370	1/30/2002
11S24W21DDD1	334621	933447	339	32.29	371	1/30/2002
11S24W22ADD1	334647	933343	334	30.64	365	1/30/2002
11S24W34CBC1	334444	933438	297	23.44	320	1/30/2002

Table 1. Water-level measurements and well information for wells completed in the Nacatoch aquifer--Continued

[ddmmss, degrees, minutes, seconds; NGVD of 1929 is National Geodetic Vertical Datum of 1929]

Local well number	Latitude (ddmmss)	Longitude (ddmmss)	Water-level altitude (feet above NGVD of 1929)	Depth to water level (feet below land-surface datum)	Land-surface altitude (feet above NGVD of 1929)	Date of measurement
11S26W27BDD1	334611	934645	423	6.55	430	1/28/2002
12S24W28CDC1	334012	933536	119	233.66	353	1/29/2002
12S25W07ABB1	334346	934340	395	39.99	435	1/28/2002
12S25W15DBC1	334214	934036	285	25.78	311	1/28/2002
12S25W34BAC1	334002	934055	249	71.23	320	1/28/2002
12S26W21AAC1	334158	934739	366	31.73	398	1/28/2002
12S26W24ABC1	334159	934438	313	2.22	315	1/28/2002
13S25W05ABD1	333915	934232	258	23.79	282	1/28/2002
13S25W18AAB1	333740	934332	223	60.47	283	1/28/2002
13S25W35DDC1	333406	933931	188	185.26	373	1/28/2002
13S26W17DDB1	333705	934845	234	57.04	291	1/28/2002
14S25W04DDD1	333317	934132	156	103.72	260	1/28/2002
Little River County						
13S28W31BCC1	333509	940251	259	52.28	311	1/23/2002
14S30W01DAA1	333426	940904	240	42.36	282	1/23/2002
Miller County						
14S27W02AAB1	333419	935121	229	26.12	255	1/23/2002
14S28W13CCB1	333158	935727	238	27.88	266	1/23/2002
14S28W17BBC1	333240	940134	244	25.52	270	1/23/2002
Nevada County						
10S22W23DCB1	335105	931935	241	0.74	242	1/25/2002
11S20W08DCD1	334727	931037	177	4.36	181	1/25/2002
11S20W15CDC1	334622	930904	166	8.76	175	1/25/2002
11S20W22AAA1	334624	930926	176	-1.10	175	1/25/2002
11S21W14CAB1	334652	931434	197	-1.36	196	1/25/2002
11S22W08DAC2	334760	932314	262	44.08	306	1/25/2002
11S22W08DDB4	334757	932314	281	25.32	306	1/25/2002
11S23W03DCD1	334840	932726	298	86.81	385	1/25/2002
11S23W12ABB1	334837	932538	310	71.31	381	1/25/2002
12S22W09CDD1	334230	932250	225	3.71	229	1/25/2002
12S22W22ACD1	334108	932135	219	122.86	342	1/25/2002
12S22W23CBA1	334102	932057	219	109.58	329	1/25/2002
13S22W07BDC1	333744	932514	211	131.92	343	1/25/2002

A cone of depression exists at Hope in Hempstead County (fig. 6). Historical water levels indicate a decline from 185 ft above the NGVD of 1929 in 1942 to 145 ft in 1969 (Ludwig, 1972). The water-level altitude from January 2002 was 119 ft above the NGVD of 1929. This cone of depression alters local ground-water flow directions from the regional direction, with ground water flowing towards Hope from all directions. A cone of depression also exists in southwestern Clark County. This feature has not been noted in previous publications and may be caused by short-term variations in local recharge or pumping. A comparison with the 1999 potentiometric-surface maps for the Nacatoch aquifer shows no other changes over large areas in the southwestern subarea; however, the northeastern subarea shows a general decrease in water levels over the subarea (Schrader, 1999).

Long-Term Water-Level Changes

Nine hydrographs from wells completed in the Nacatoch aquifer display long-term (minimum of 20-year period) water-level altitudes (fig. 7). Linear regression was used to determine the average annual decline or rise in feet per year for the period from spring 1982 to spring 2002 for water levels in each well. The minimum 20-year period is used to decrease the influence of short-term variations in climate and localized pumping rates on water levels in a single well.

Four wells (sites A- D) are located in the northeastern subarea (fig. 5). Water levels in each of these wells generally declined over the period an average of 0.0 to 1.4 feet per year (ft/yr), with a median water-level decline of 0.8 ft/yr. The decrease in water levels may be associated with the increased withdrawal from the Nacatoch aquifer in Greene and Clay Counties (fig. 3).

Five wells with historical water-level measurements (sites E-I; fig. 7), are located in the southwestern subarea (fig. 6). Two wells (sites E and F) are located in Clark County and the other three wells are located in Hempstead (site H), Miller (site I), and Nevada (site G) Counties. The range of values for the annual rise or decline for wells in the southwestern subarea over the period from spring 1982 to 2002 was 3.8 to -0.3 ft/yr (positive values represent a water-level rise), with a median value of 0.5 ft/yr.

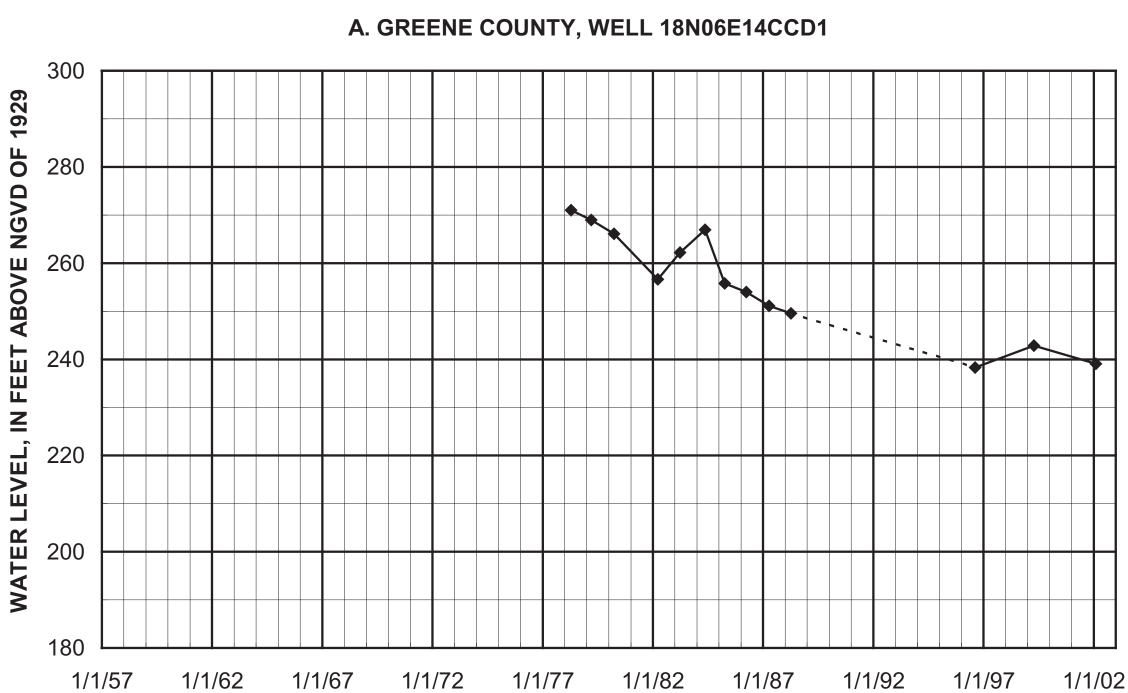
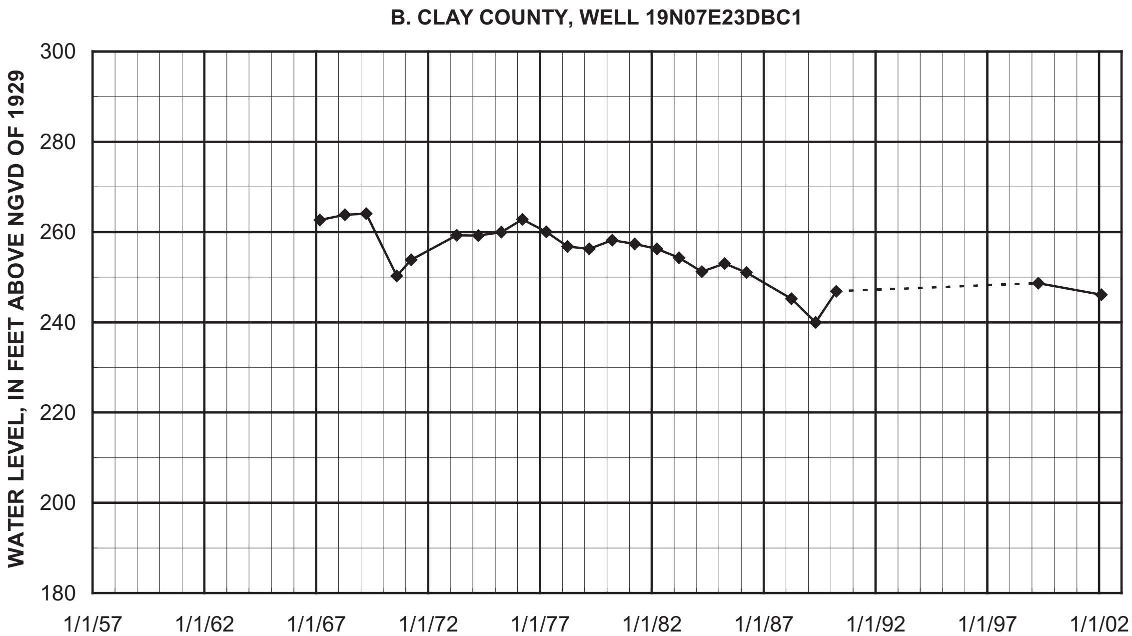


Figure 7. Water-level altitudes for selected wells completed in the Nacatoch aquifer.



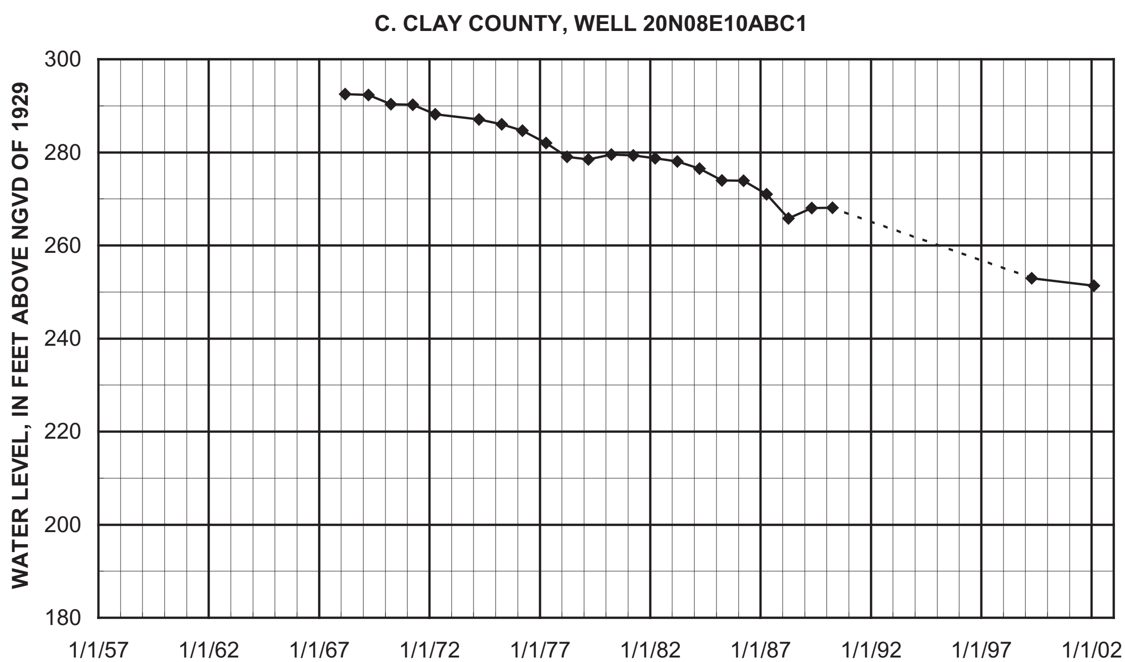
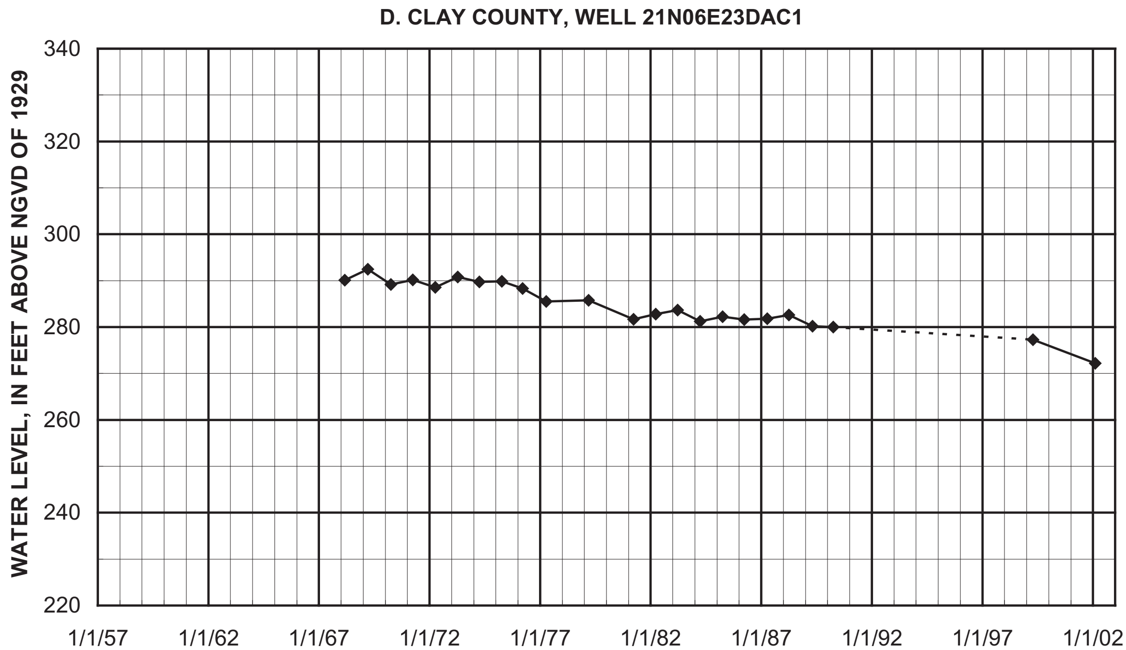


Figure 7. Water-level altitudes for selected wells completed in the Nacatoch aquifer—Continued.



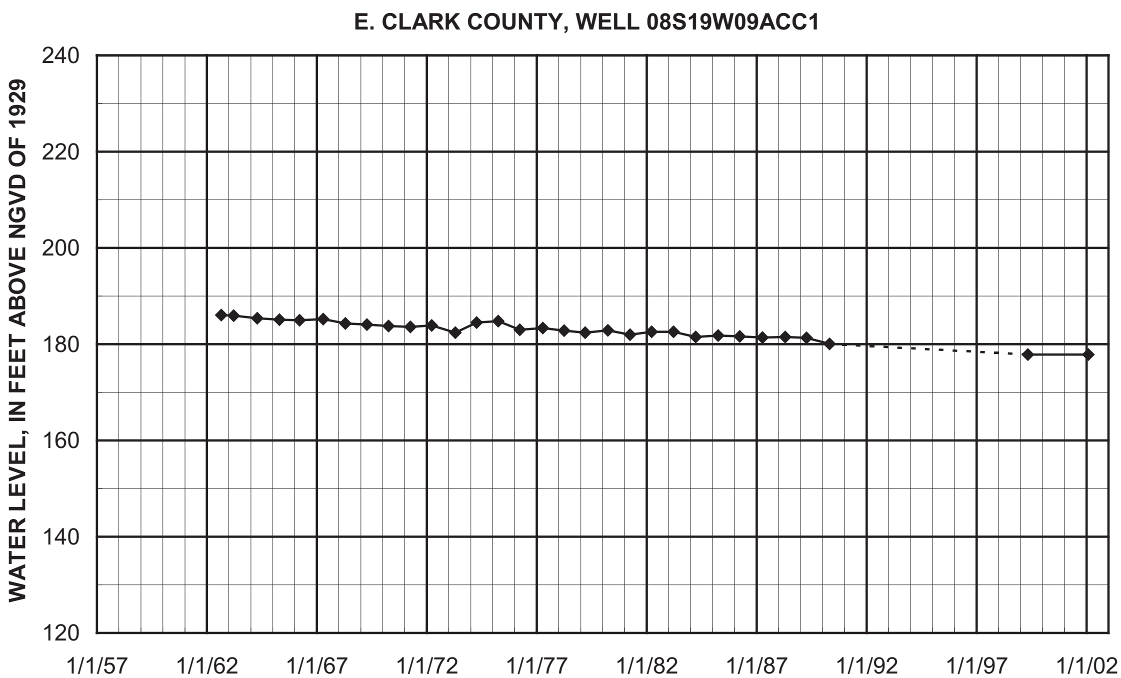
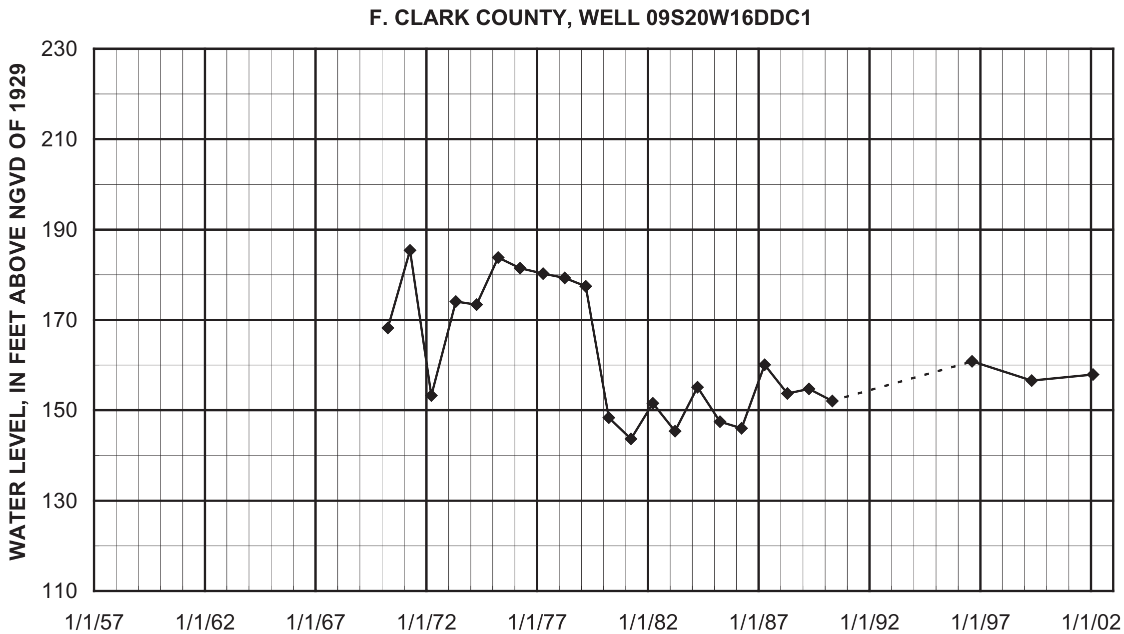


Figure 7. Water-level altitudes for selected wells completed in the Nacatoch aquifer—Continued.



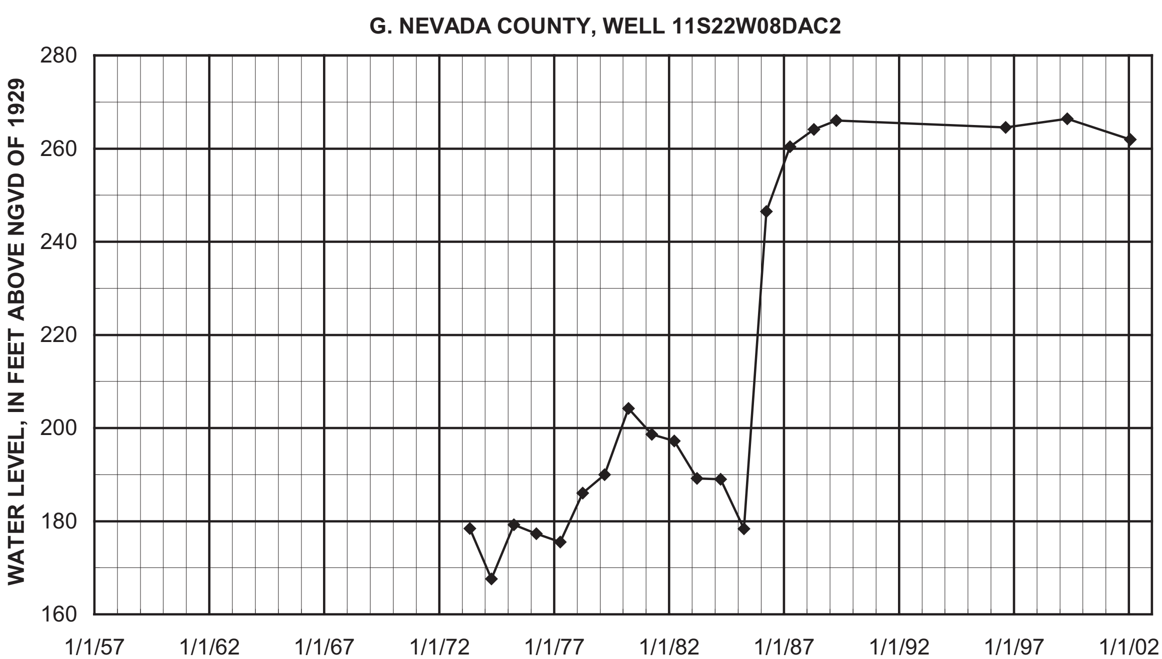
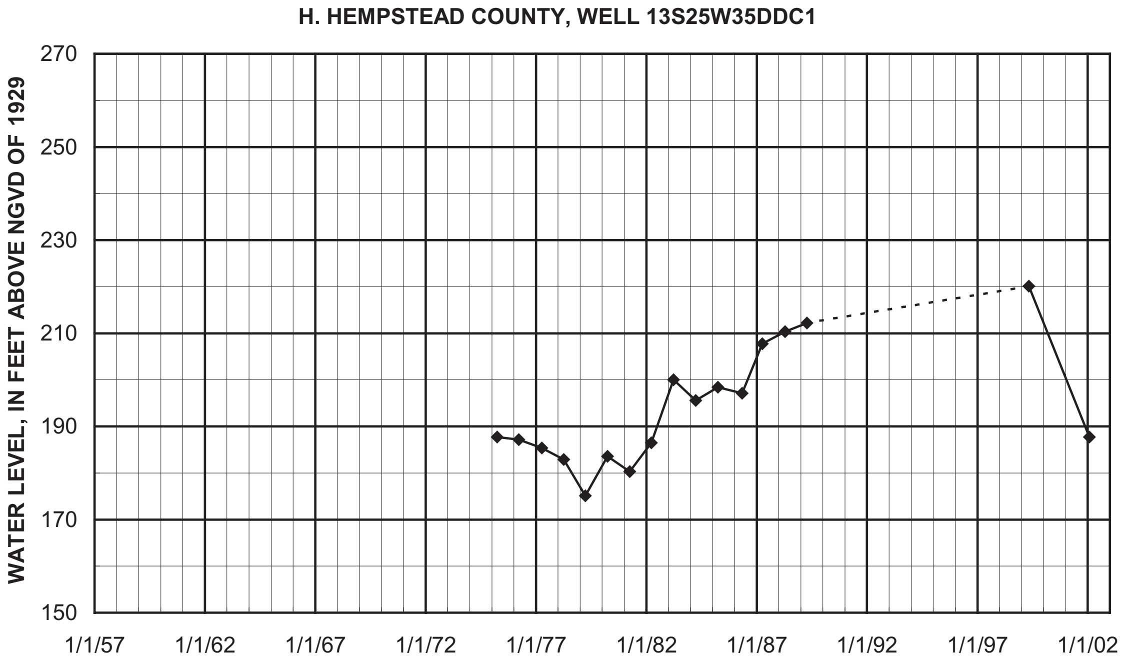


Figure 7. Water-level altitudes for selected wells completed in the Nacatoch aquifer—Continued.



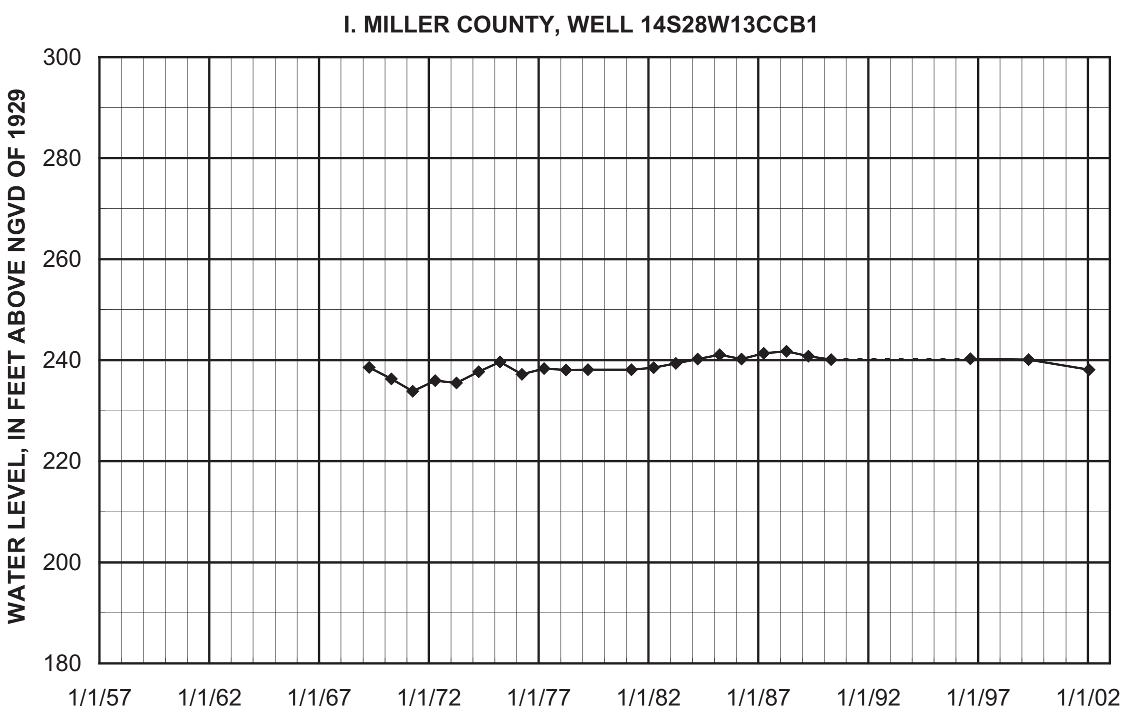


Figure 7. Water-level altitudes for selected wells completed in the Nacatoch aquifer—Continued.

Water levels in well 08S19W09ACC1 (site E, figs. 6 and 7) declined from about 186 ft above the NGVD of 1929 in 1962 to about 178 ft in 2002, an average decline of about 0.2 ft/yr. There is no apparent association between water-level changes and withdrawals. The variation in water levels in this well could result from differences in withdrawal rate changes, climatic variations, or leakage of water from overlying and underlying rock units.

Water levels in well 09S20W16DDC1 (site F, figs. 6 and 7), declined from about 184 ft above the NGVD of 1929 in 1975 to about 144 ft in 1981, which is a decline of 6.7 ft/yr. Estimated withdrawal rates from the Nacatoch aquifer in Clark County increased from 0.64 Mgal/d in 1975 to 1.73 Mgal/d in 1980, an increase of 170 percent in withdrawals (fig. 4). From 1981 to 2002, a general rise in water level was observed along with a general decrease in water use in Clark County.

Water levels in well 11S22W08DAC2 (site G, figs. 6 and 7), rose from about 179 ft above the NGVD of 1929 in 1985 to about 267 ft in 1990, an average rise of about 17.6 ft/yr. The increase in water levels occurred when the estimated withdrawal rates from the Nacatoch aquifer in Nevada County decreased from 1.11 Mgal/d in 1985 to 0.44 Mgal/d in 1990; a decrease of about 60 percent (fig. 4).

Water levels in well 13S25W35DDC1 (site H, figs. 6 and 7), declined from 188 ft in 1975 to 175 ft in 1979. Estimated withdrawal rates from the Nacatoch aquifer in Hempstead County increased from 1.44 Mgal/d in 1975 to 1.98 Mgal/d in 1980, an increase of about 38 percent (fig. 4). From 1979 to 1999, a general rise in water level was measured, but from 1999 to 2002, a sharp decrease in water level occurred. Estimated withdrawal rates from the Nacatoch aquifer in Hempstead County after 1980 fluctuated from 0.15 Mgal/d in 1985 to 0.32 Mgal/d in 1995 and decreased to 0.27 Mgal/d in 2000.

Water levels in well 14S28W13CCB1 (site I, figs. 6 and 7) ranged from 242 ft above the NGVD of 1929 to 238 ft from 1969 to 2002. The decline and rise in water levels in this well may be associated with the increased and decreased withdrawals from the Nacatoch aquifer in Clark, Hempstead, and Nevada Counties (fig. 4).

Although water levels in these nine wells may be associated with changes in withdrawals, other factors also may affect water levels. Water levels may be affected by local factors such as withdrawal rate changes, localized recharge, or changes in leakage to and from overlying and underlying rock units.

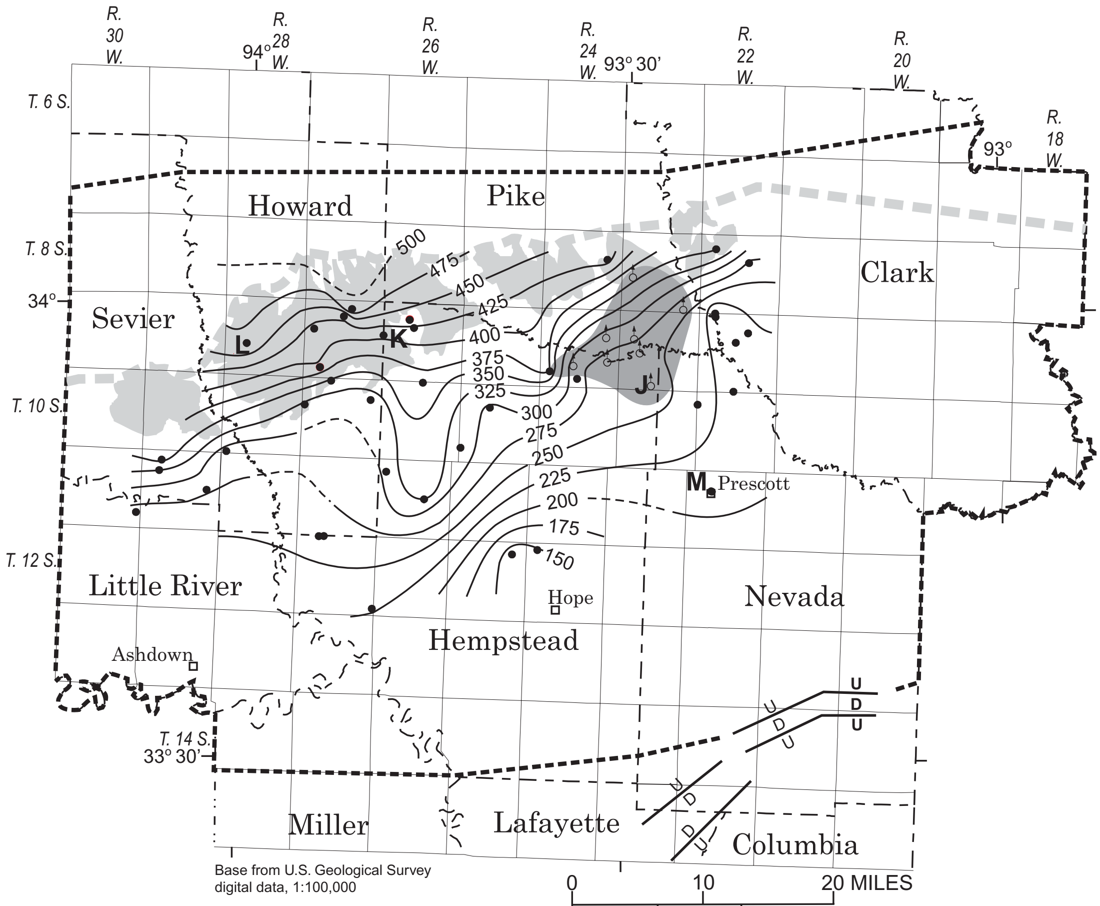
TOKIO FORMATION

Hydrogeologic Setting

The Tokio Formation of Cretaceous age underlies the Brownstown Marl and overlies consolidated rocks of Mississippian and Pennsylvanian age in Clark and northeastern Nevada Counties (Plebuch and Hines, 1969); the Trinity Group of Early Cretaceous age in Pike, Nevada, Miller, and most of Hempstead Counties (Petersen and others, 1985); and the Woodbine Formation of Late Cretaceous age in Little River, Sevier, Howard, and northwestern Hempstead Counties (Boswell and others, 1965). The Tokio Formation outcrops in a southwest-to-northeast trending mile-wide band in west-central Clark County. The outcrop attains a maximum width of about 10 mi in Howard County and continues approximately 8 mi southwest into Sevier County. In this area, the Tokio Formation is overlain in several places by alluvial and terrace deposits of Quaternary age. The unit also outcrops in northwestern Little River County, west of the study area.

The Tokio Formation ranges in thickness from about 50 ft to more than 300 ft and dips towards the southeast. The unit is composed of discontinuous, interbedded gray clay and poorly sorted, crossbedded quartz sands, lignite, and a prevalent basal gravel (Counts and others, 1955; Boswell and others, 1965; Plebuch and Hines, 1969; Petersen and others; 1985). The Tokio Formation does not occur in the northeastern subarea.

The Tokio aquifer receives recharge from precipitation where it outcrops or is overlain by permeable alluvial and terrace deposits. Salinity increases downdip to the south-southeast. The aquifer yields fresh water to within a few miles north of Ashdown in Little River County (fig. 8). The water in the Tokio aquifer becomes slightly to moderately saline downdip (southeast) from near Prescott to the fault zone trending across Nevada County. Except in its outcrop area, water in the Tokio aquifer is under artesian conditions (Petersen and others, 1985).



EXPLANATION

OUTCROP OF TOKIO FORMATION

APPROXIMATE AREA OF ARTESIAN FLOW

BOUNDARY OF STUDY SUBAREA

APPROXIMATE NORTHERN LIMIT OF TOKIO FORMATION

U/D FAULT--U, Upthrown side; D, Downthrown side

— 200 – – POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Contour interval 25 feet. Datum is National Geodetic Vertical Datum of 1929

M. CONTROL POINT--Letter, where present, corresponds to hydrograph in figure 7

FLOWING WELL

Figure 8. Hydrogeologic setting and potentiometric surface of the Tokio aquifer, southwestern Arkansas, January 2002.

The Tokio aquifer yields potable water to wells in eastern Little River County, southeastern Sevier County, southern Howard and Pike Counties, western Clark County, northern and central Hempstead County, and northwestern Nevada County. Wells penetrating the aquifer range in depth from a few feet in the outcrop area to about 1,200 ft at Hope and Prescott (Ludwig, 1972). Wells in central Hempstead County yield up to 300 gal/min. Wells flowing as much as 90 gal/min occur in the bottom-land areas adjacent to streams (Counts and others, 1955). Historic records indicate that water levels in the aquifer did not decline apprecia-bly from 1950 to 1968, and that water levels have not been greatly affected by withdrawal of water at Hope and Prescott (Ludwig, 1972).

Estimates of water withdrawn from the Tokio aquifer increased by 201 percent from 2.0 Mgal/d in 1965 to 6.02 Mgal/d in 1980 (fig. 9). Water withdrawn from the Tokio aquifer was estimated to be 1.17 Mgal/d in 2000, a decrease of 81 percent from 1980 (Halberg and Stephens, 1966; Holland and Ludwig, 1981; Holland, 1999).

Potentiometric Surface

The potentiometric surface for the Tokio aquifer shows the altitude that water would have stood in tightly cased wells screened in the aquifer (fig. 8). Water-level measurements in 48 wells in January 2002 (fig. 9; table 2) were used to construct the potentiometric-surface map. The surface is mapped by calculating the altitude of the water levels, plotting the values on a map, and representing the surface on the figures by contours that connect points of equal elevation. The general direction of ground-water flow is perpendicular to the contours in the direction of downward hydraulic gradient.

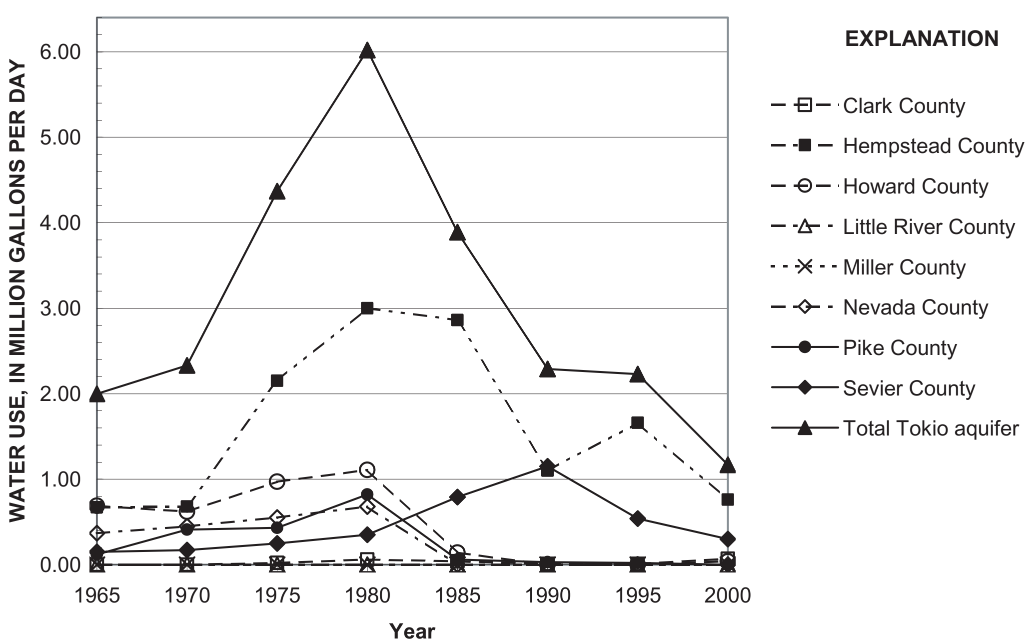


Figure 9. Estimated water use by county from the Tokio aquifer.

Table 2. Water-level measurements and well information for wells completed in the Tokio aquifer

[ddmmss, degrees, minutes, seconds; NGVD of 1929; National Geodetic Vertical Datum of 1929]

Local well number	Latitude (ddmmss)	Longitude (ddmmss)	Water-level altitude (feet above NGVD of 1929)	Depth to water level (feet below land-surface datum)	Land-surface altitude (feet above NGVD of 1929)	Date of measure-ment
Clark County						
08S22W05CCC1	340408	932255	358	31.74	390	1/30/2002
08S22W15ABB2	340313	932018	271	53.97	325	1/30/2002
09S22W05BBB1	335951	932259	205	106.59	312	1/30/2002
09S22W05BCA1	335936	932257	203	31.64	235	1/30/2002
09S22W10DBA1	335832	932021	224	138.18	362	1/30/2002
Hempstead County						
09S23W20BDA1	335710	932858	251	-1.2	250	1/30/2002
09S23W33CDA1	335457	932802	271	-0.9	270	1/29/2002
09S24W25BBB1	335633	933132	269	-0.5	268	1/29/2002
09S24W28ACC1	335617	933415	279	-2.1	277	1/29/2002
09S24W30DCC1	335556	933607	375	15.17	390	1/29/2002
09S24W33ADC1	335526	933356	284	45.07	329	1/29/2002
09S26W08ADA2	335920	934717	436	1.63	438	1/29/2002
09S26W08ADD1	335918	934717	437	0.28	437	1/29/2002
09S26W09CDC1	335846	934656	423	2.23	425	1/29/2002
09S26W18CBB1	335815	934921	403	21.91	425	1/29/2002
10S25W09CDB1	335329	934052	291	69.85	361	1/29/2002
10S25W30CCD1	335048	934310	319	69.12	388	1/28/2002
10S26W03BBA1	335507	934612	366	0.68	367	1/29/2002
11S26W08BBB1	334909	934903	302	69.56	372	1/28/2002
11S26W23BBB1	334720	934602	326	93.22	419	1/28/2002
12S24W06DAD1	334360	933701	148	206.87	355	1/29/2002
12S25W02DDD1	334341	933902	134	232.6	367	1/29/2002
12S27W04BBC1	334450	935358	262	172.66	435	1/28/2002
12S27W05AAC1	334449	935421	262	172.61	435	1/28/2002
12S27W36DBC1	333960	935006	228	32.79	261	1/28/2002
Howard County						
09S27W03DBD1	340000	935152	491	70.98	562	1/22/2002
09S27W10BCB1	335930	935231	426	108.16	534	1/22/2002

Table 2. Water-level measurements and well information for wells completed in the Tokio aquifer--Continued

[ddmmss, degrees, minutes, seconds; NGVD of 1929; National Geodetic Vertical Datum of 1929]

Local well number	Latitude (ddmmss)	Longitude (ddmmss)	Water-level altitude (feet above NGVD of 1929)	Depth to water level (feet below land-surface datum)	Land-surface altitude (feet above NGVD of 1929)	Date of measure-ment
09S27W18ADB1	335840	935452	415	77.34	492	1/22/2002
09S27W32BDB1	335606	935423	398	53.06	451	1/22/2002
09S27W32BDB2	335606	935423	370	79.98	450	1/22/2002
09S28W20DAC1	335740	940013	469	11.16	480	1/22/2002
10S27W04BBD1	335512	935329	338	53.56	392	1/22/2002
10S27W12CAB1	335356	935020	309	74.18	383	1/22/2002
10S27W18BAC1	335336	935534	317	104.81	422	1/22/2002
Little River County						
11S30W25DDC1	334618	940852	264	21.26	285	1/23/2002
Nevada County						
09S22W33DCC1	335437	932130	219	5.73	225	1/25/2002
10S23W12AAA1	335345	932421	235	20.87	256	1/25/2002
11S22W08DAC1	334758	932315	214	91.29	305	1/25/2002
11S22W08DAC8	334757	932312	215	90.39	305	1/25/2002
Pike County						
08S23W19ADC1	340213	932930	351	-0.85	350	1/24/2002
08S23W35DCA1	340004	932530	258	-1.15	257	1/24/2002
08S24W14AAC1	340324	933134	433	89.84	523	1/24/2002
09S23W17BBC2	335804	932924	282	-1.93	280	1/24/2002
09S24W14AAD1	335810	933138	287	-1.6	285	1/24/2002
Sevier County						
10S28W31DCC1	335026	940145	293	37.16	330	1/23/2002
11S29W05DCA1	334949	940653	365	115.06	480	1/23/2002
11S29W08DBB1	334907	940704	321	144.17	465	1/23/2002
11S29W13CCD1	334750	940317	278	82.22	360	1/23/2002

In the southwestern subarea, the direction of ground-water flow in the Tokio aquifer generally is towards the south or southeast. The potentiometric high is within the outcrop area in the northwestern part of the study subarea. The highest water-level altitude measured was about 491 ft above the NGVD of 1929 in Howard County. The lowest water-level altitude measured was about 134 ft above the NGVD of 1929, about 5 mi northwest of Hope in Hempstead County. An area of artesian flow exists in southeastern Pike, northeastern Hempstead, and northwestern Nevada Counties, as evidenced by eight flowing wells.

A cone of depression may exist about 5 mi northwest of Hope; the northern half of an apparent cone of depression is shown on figure 8. Water-level data in the Tokio aquifer were not available south of this area. No other cones of depression were evident in the Tokio aquifer. A comparison of the 2001 potentiometric-surface map with the 1996 and 1999 potentiometric-surface maps for the Tokio aquifer shows no substantial changes over large areas (Schrader, 1998; Schrader, 1999).

Long-Term Water-Level Changes

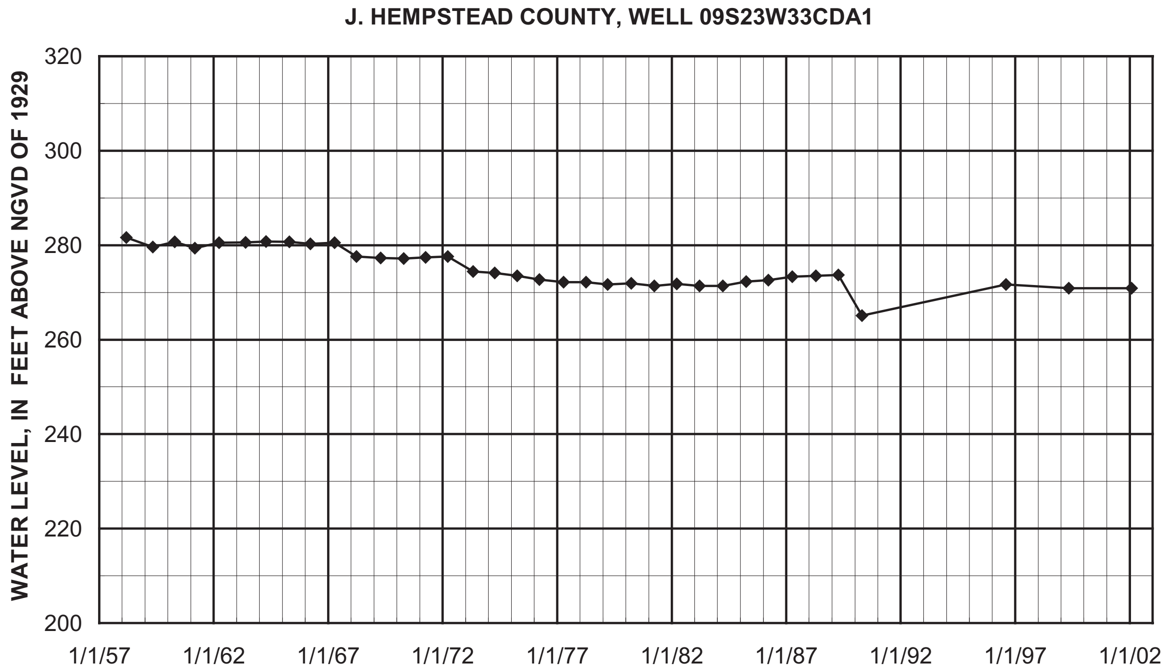
Four hydrographs from wells completed in the Tokio aquifer have long-term (minimum of 20 years) water-level altitudes. Two wells are located in Hempstead County (sites J and K) and the other two wells are located in Howard (site L) and Nevada (site M) Counties (fig. 10). Linear regression was used to determine the average annual decline or rise in feet per year for the period from spring 1982 to spring 2002 for water levels in each well. The minimum 20-year period is used to decrease the influence of short-term variations in climate and localized pumping rates on water levels in a single well.

The two hydrographs in Hempstead County show water-levels decline in one hydrograph and fluctuate over a range in the other. In well 09S23W33CDA1 (site J, figs. 8 and 10), water levels generally declined about 11 ft from 1957 to 2002. Water levels in well 09S26W18CBB1 (site K, figs. 8 and 10), fluctuated through a range of about 15 ft over a 45-year period. There does not appear to be an association between water levels in these two wells and the general decline in estimated withdrawals from the Tokio aquifer for Hempstead County (fig. 9).

In Howard County, water levels in well 09S28W20DAC1 (site L, figs. 8 and 10) range from about 476 ft to about 464 ft above the NGVD of 1929 over a 45-year period from 1957 to 2002. No significant rises or declines in water levels were observed. There does not appear to be any association between water levels in this well and estimated withdrawals from the Tokio aquifer for Howard County (fig. 9).

In Nevada County, water levels in well 11S22W08DAC1 (site M, figs. 8 and 10) declined from about 211 ft above the NGVD of 1929 in 1972 to about 150 ft in 1985, with a minimum of 135 ft in 1981. This decline averages approximately 4.7 ft/yr. Estimated withdrawal rates from the Tokio aquifer for Nevada County increased from 0.45 Mgal/d in 1970 to 0.68 Mgal/d in 1980, an increase of 51 percent (fig. 9). From 1985 to 1987, a rise in water level to about 225 ft was observed, which is approximately a 37.5 ft/yr rise. Water withdrawal rates from the Tokio aquifer for Nevada County are estimated to have decreased to zero by 1985. Water levels in the Tokio aquifer in Nevada County appear to respond to changes in withdrawal rates.

Although water levels in these four wells may be associated with changes in withdrawals, other factors also may affect water levels. Water levels may be affected by local factors such as withdrawal rate changes, climatic variations, or changes in leakage to and from overlying and underlying rock units. The range of values for the annual average rise or decline in water level for wells in the Tokio aquifer was -1.9 to 2.9 ft/yr, with a median value of 0.1 ft/yr.



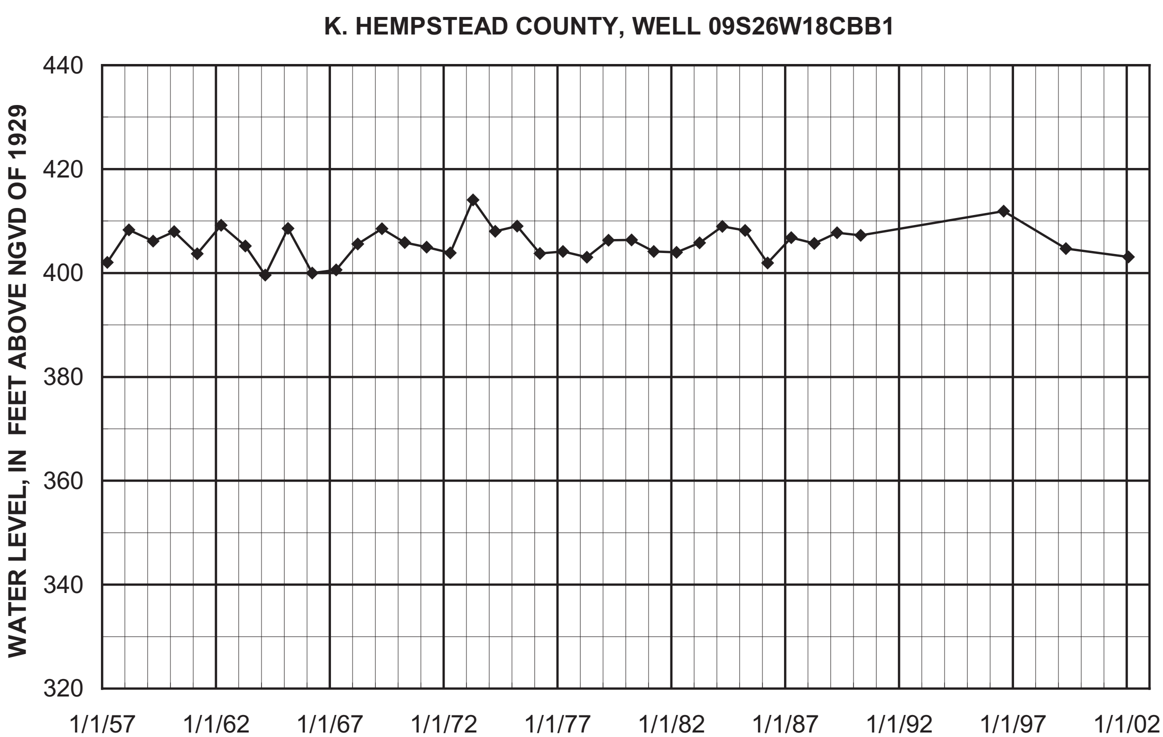
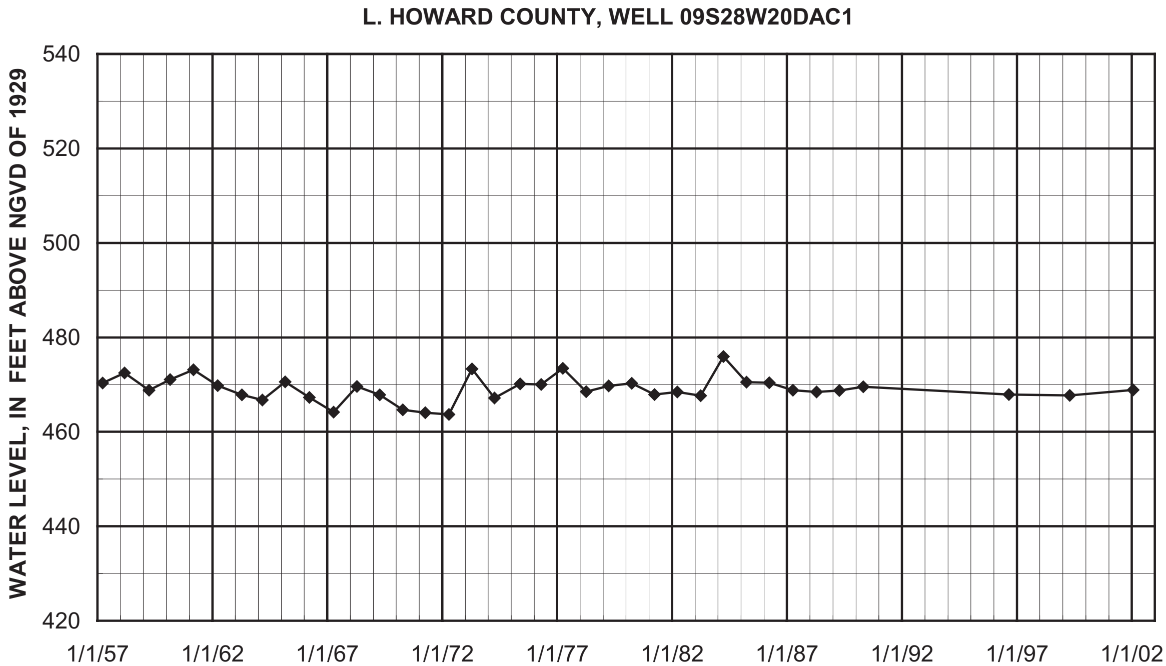


Figure 10. Water-level altitudes for selected wells completed in the Tokio aquifer.



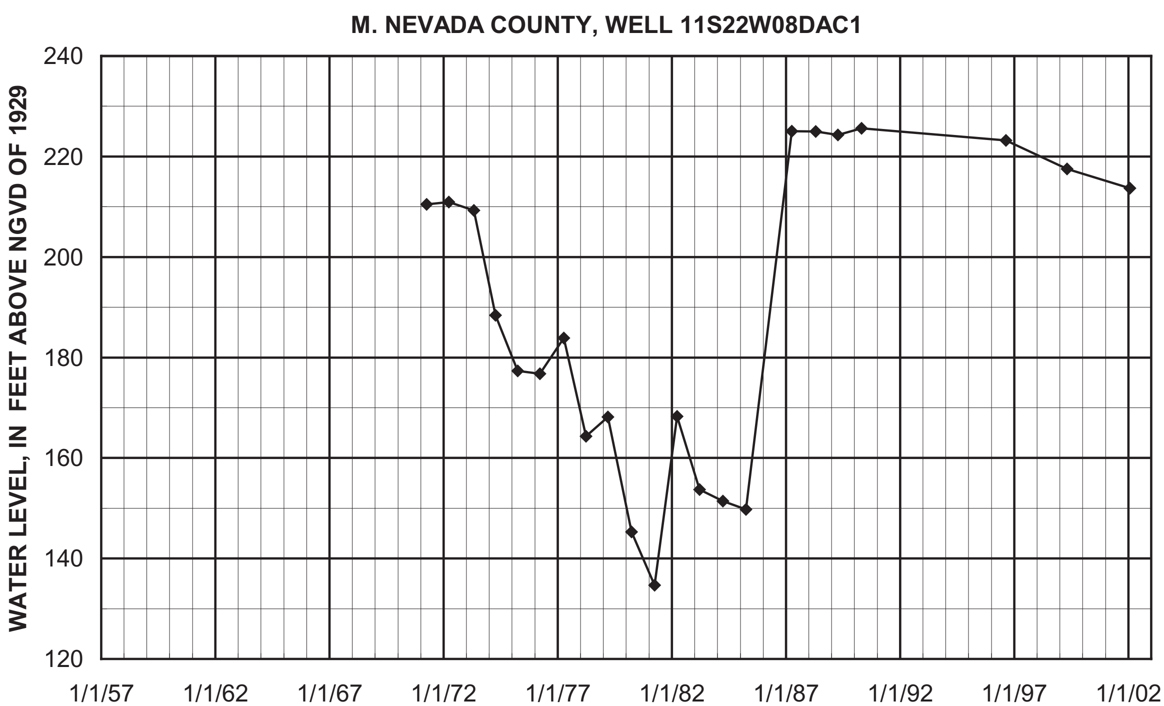


Figure 10. Water-level altitudes for selected wells completed in the Tokio aquifer—Continued.

SUMMARY

Aquifers in the Nacatoch Sand and Tokio Formation in southwestern Arkansas and the Nacatoch Sand in northeastern Arkansas are a source of water for industrial, public supply, domestic, and agricultural uses. Potentiometric-surface maps were constructed from water-level measurements made in 60 wells completed in the Nacatoch aquifer and 48 wells completed in the Tokio aquifer during January and February 2002. In northeastern Arkansas, withdrawals from the Nacatoch aquifer increased by 784 percent from 1965 to 1990 and decreased by 30 percent from 1990 to 2000. In southwestern Arkansas, withdrawals from the Nacatoch and Tokio aquifers increased by 125 percent and 201 percent, respectively, from 1965 to 1980 and decreased by 93 percent and 81 percent, respectively, from 1980 to 2000.

The direction of ground-water flow in the northeastern subarea of the Nacatoch aquifer generally is towards the southeast. The potentiometric high is located along the north and northwestern boundary of this subarea. The potentiometric low is located in eastern Clay County.

The direction of ground-water flow in the southwestern subarea of the Nacatoch aquifer is towards the south-southeast in Little River, Miller, and Hempstead Counties and to the east-southeast in Nevada and Clark Counties. The potentiometric high is located within the outcrop area in Hempstead County. Cones of depression exist in southeastern Hempstead County and in southwestern Clark County.

In the northeastern subarea of the Nacatoch aquifer, water levels in four wells declined during a period of increased withdrawals from the Nacatoch aquifer. Water levels generally declined over the period of record an average of 0.0 to 1.4 ft/yr, with a median water-level decline of 0.8 ft/yr.

In the southwestern subarea of the Nacatoch aquifer, water levels in three of five wells rose during a period of decreased withdrawal from the Nacatoch aquifer. The range of values for the annual average rise or decline for wells in the southwestern subarea (minimum of 20 years) was 3.8 to -0.3 ft/yr, with a median value of 0.5 ft/yr. The hydrograph for site E shows no apparent association between water-level changes in a well completed in the Nacatoch aquifer and withdrawals. The variation in water levels in this well could result from differences in withdrawal rate changes, climatic variations, or leakage of water from overlying and underlying rock units.

Estimates of water withdrawn from the Tokio aquifer increased from 2.0 Mgal/d in 1965 to 6.02 Mgal/d in 1980. Water withdrawn from the Tokio aquifer was estimated to be 1.17 Mgal/d in 2000, a decrease of 81 percent from 1980.

The direction of ground-water flow in the Tokio aquifer is towards the south or southeast. The potentiometric high is located where the aquifer outcrops in the northwestern part of the study area. An area of artesian flow exists in southeastern Pike, northeastern Hempstead, and northwestern Nevada Counties. One apparent cone of depression may exist northwest of Hope in Hempstead County.

The range of values for the annual average rise or decline in water level for wells in the Tokio aquifer was -1.9 to 2.9 ft/yr, with a median value of 0.1 ft/yr. Hydrographs in the Tokio aquifer in Hempstead County show water levels declined in one well and fluctuated in the other. No significant changes in water levels in Howard County were observed. In Nevada County, the hydrograph showed a decline and a rise in water levels during a period of increased, then decreased, withdrawals from the aquifer. Three hydrographs show no apparent association between water-level changes in wells completed in the Tokio aquifer and withdrawals.

REFERENCES

Boswell, E.H., Moore, G.K., MacCary, L.M., and others, 1965, Cretaceous aquifers in the Mississippi Embayment: U.S. Geological Survey Professional Paper 448-C,
37 p.

Counts, H.B., Tait, D.B., Klein, Howard, and Billingsley, G.A., 1955, Ground-water resources in a part of southwestern Arkansas: U.S. Geological Survey Water Resources Circular No. 2, 35 p.

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

Holland, T.W., 1987, Use of water in Arkansas, 1985: Arkansas Geological Commission Water Resources Summary Number 16, 27 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, Use of water in Arkansas, 1995: U.S. Geological Survey Open-File Report 99-188, 1 sheet.

Holland, T.W., and Ludwig, A.H., 1981, Use of water in Arkansas, 1980: Arkansas Geological Commission Water Resources Summary Number 14, 30 p.

Ludwig, A.H., 1972, Water resources of Hempstead, Lafayette, Little River, Miller, and Nevada Counties, Arkansas: U.S. Geological Survey Water-Supply Paper 1998, 41 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.

Plebuch, R.O., and Hines, M.S., 1969, Water resources of Clark, Cleveland, and Dallas Counties, Arkansas: U.S. Geological Survey Water-Supply Paper 1879-A, 32 p.

Schrader. T.P., 1998, Status of water levels in aquifers in the Nacatoch Sand and Tokio Formation of southwestern Arkansas, 1996: U.S. Geological Survey Water-Resources Investigations Report 98-4130, 14 p.

Schrader, T.P., 1999, Status of water levels in aquifers in the Nacatoch Sand of southwestern and northeastern Arkansas and the Tokio Formation of southwestern Arkansas, 2002: U.S. Geological Survey Water-Resources Investigations Report 99-4208A, 23 p.

Schrader, T. P., and Scheiderer, R.M.—STATUS OF WATER LEVELS IN AQUIFERS IN THE NACATOCH SAND OF SOUTHWESTERN AND NORTHEASTERN ARKANSAS AND THE TOKIO FORMATION OF SOUTHWESTERN ARKANSAS, 2002—U.S. Geological Survey Water-Resources Investigations Report 03-4284