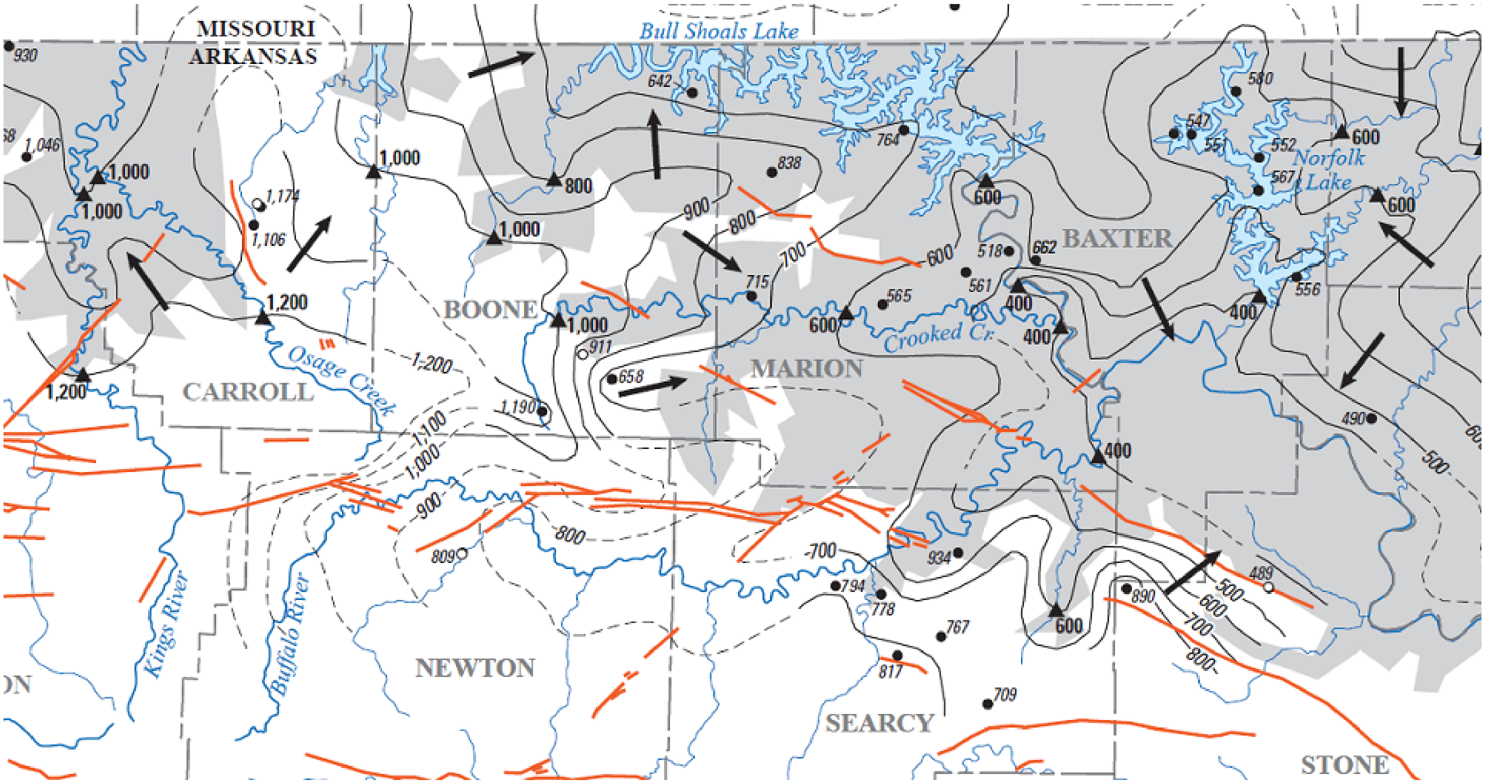
USGS
science for a changing world

Prepared in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey

Potentiometric Surface of the Ozark Aquifer in Northern Arkansas, 2010



Scientific Investigations Report 2014–5013

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

Potentiometric Surface of the Ozark Aquifer in Northern Arkansas, 2010

By John B. Czarnecki, Aaron L. Pugh, and Joshua M. Blackstock

Prepared in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey

Scientific Investigations Report 2014–5013

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

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

U.S. Geological Survey
Suzette M. Kimball, Acting Director

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

Suggested citation:
Czarnecki, J.B., Pugh, A.L., and Blackstock, J.M., 2014, Potentiometric surface of the Ozark aquifer in northern Arkansas, 2010: U.S. Geological Survey Scientific Investigations Report 2014–5013, 16 p., 1 pl., *http://dx.doi.org/10.3133/sir20145013.*

ISSN 2328-0328 (online)

Contents

Plate

Figures

Tables

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

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

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

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

Potentiometric Surface of the Ozark Aquifer in Northern Arkansas, 2010

By John B. Czarnecki, Aaron L. Pugh, and Joshua M. Blackstock

Abstract

The Ozark aquifer in northern Arkansas is composed of dolomite, limestone, sandstone, and shale of Late Cambrian to Middle Devonian age and ranges in thickness from approximately 1,100 feet to more than 4,000 feet. Hydrologically, the aquifer is complex, characterized by discrete and discontinuous flow components with large variations in permeability.

The potentiometric-surface map, based on 56 well and 5 spring water-level measurements made in 2010 in Arkansas and Missouri, has a maximum water-level altitude measurement of 1,174 feet in Carroll County and a minimum water-level altitude measurement of 120 feet in Randolph County. Regionally, the flow within the aquifer is to the south and southeast in the eastern and central part of the study area and to the west, northwest, and north in the western part of the study area. Water-level altitudes changed 0.5 feet or less in 31 out of 56 wells measured between 2007 and 2010.

Despite rapidly increasing population within the study area, the increase appears to have minimal effect on groundwater levels, although the effect may have been minimized by the development and use of surface-water distribution infrastructure, suggesting that most of the incoming populations are fulfilling their water needs from surface-water sources. The conversion of some users from groundwater to surface water may be allowing water levels in some wells to recover (rise) or decline at a slower rate in some areas such as in Benton, Carroll, and Washington Counties.

Introduction

The Ozark aquifer is the largest aquifer, both in area of outcrop and thickness, and the most important source of fresh groundwater in the Ozark Plateaus physiographic province, supplying water to large areas of northern Arkansas, southern Missouri, northeastern Oklahoma, and southeastern Kansas. Understanding the changes and trends in water levels is important for continued use, planning, and management of this important natural resource.

The U.S. Geological Survey (USGS), in cooperation with the Arkansas Natural Resources Commission (ANRC) and the Arkansas Geological Survey (AGS), conducted a study of groundwater-levels in the Ozark aquifer within Arkansas. The study is part of an ongoing effort to monitor groundwater levels in Arkansas' major aquifers. A substantial portion of the text used in this report is excerpted from an earlier study by Pugh (2008), one of the coauthors of the current report. The current report presents a potentiometric-surface map of the Ozark aquifer within the Ozark Plateaus of northern Arkansas (figs. 1 and 2), representing water-level conditions for the early spring 2010.

The study area includes 16 Arkansas counties lying completely or partially within the Ozark Plateaus of the Interior Highlands major physiographic division (Fenneman, 1938). The study area is generally bounded on the north by Missouri, on the west by Oklahoma, on the east by the Mississippi Alluvial Plain section, and on the south by the Ouachita province (fig. 1).

The potentiometric-surface map presented in this report was prepared from groundwater-level data and water-level data from springs flowing from the Ozark aquifer collected by the USGS during February and March 2010. Additionally, streambed altitudes in areas where the aquifer is unconfined and hydraulically connected to the surface were used as bounding (maximum groundwater level) values.

Methods

Personnel from the USGS collected water-level measurements during February and March 2010 from wells screened in and springs flowing from the Ozark aquifer. Well water-level measurements were made to the nearest 0.01 foot (ft) and were collected using steel or electric tapes from a measuring point of a known altitude. The steel and electric tapes were calibrated during January 2010. Spring water levels were considered to be the land-surface altitudes at which water from the Ozark aquifer emanated. Water-level altitudes were tabulated and compared with water-level measurements made in the same wells in 2007, from which differences in water-level altitudes and rates of change were calculated.

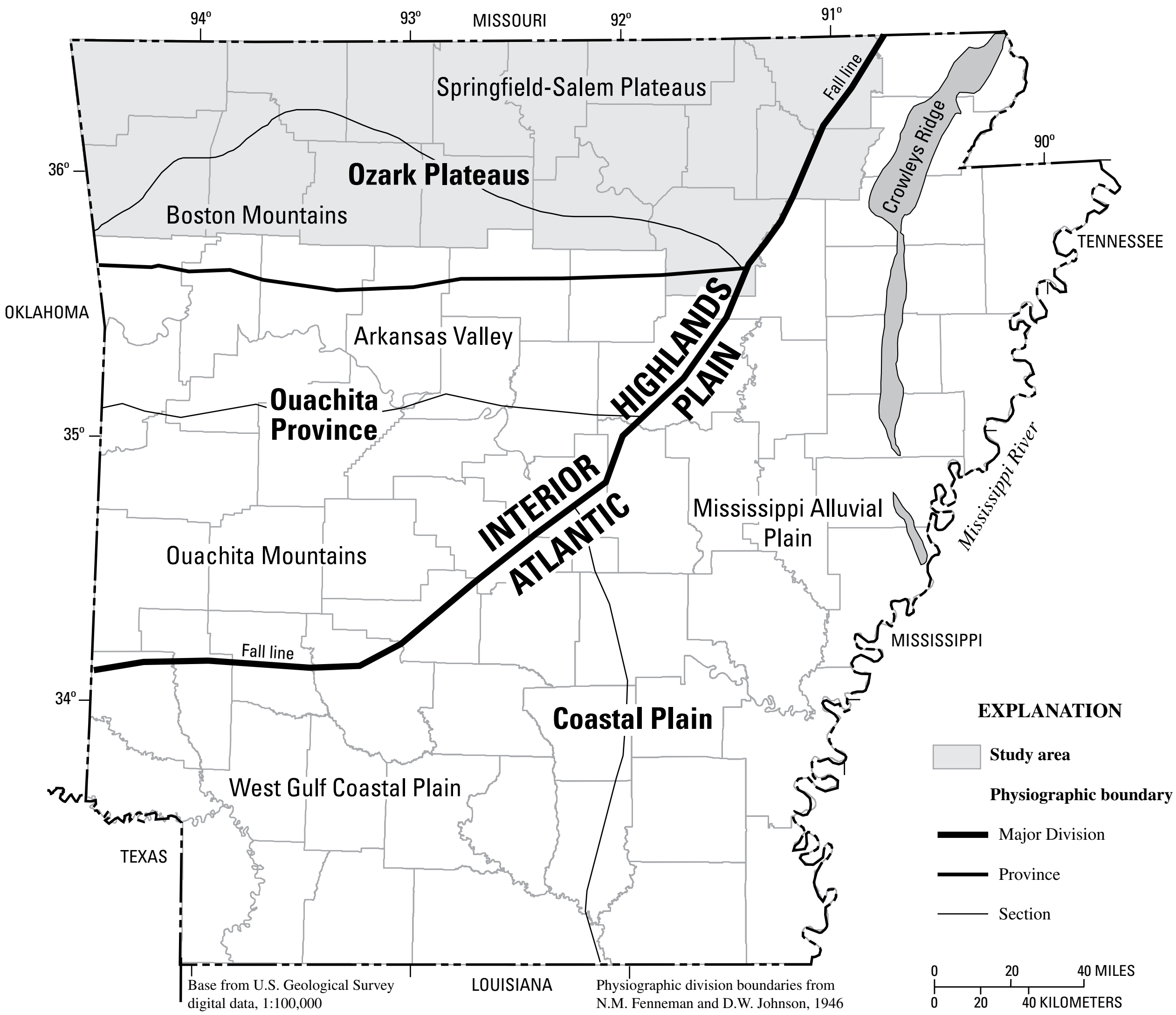


Figure 1. Location of study area.

Well and spring 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 (NAD 83). The latitude and longitude of the well or spring location were transferred to the appropriate 7.5-minute USGS topographic quadrangle map and the altitude (National Geodetic Vertical Datum of 1929 [NGVD 29]) was determined. Well and spring horizontal locations are accurate to +/- 10 ft, and the altitude of the land surface at this location also is accurate to +/- 10 ft.

The potentiometric surface was contoured using the 2010 water-level data from 56 wells and 5 springs (table 1). Additional bounding values from land-surface contours and stream altitudes were used where the Ozark aquifer is exposed at the surface. Where the Ozark aquifer is unconfined, land-surface contours and stream altitudes from a 1:500,000 scale topographic map of Arkansas (U.S. Geological Survey, 1990) were considered in the construction of the potentiometric-surface map to prevent contours from crossing streams at inappropriate locations and to reflect the general land-surface topography where appropriate. The potentiometric-surface map was constructed using a contour interval of 100 ft by initially applying an automated contouring method within ArcGIS (http://www.esri.com/software/arcgis) and subsequently making manual adjustments to the contour positions. A contour interval of 100 ft was considered the minimum value warranted by the sparseness and accuracy of the water-level altitude data.

Table 1. Information pertaining to measured wells and springs in the Ozark aquifer in northwestern Arkansas and south-central Missouri, 2010.

[NA, not applicable; Aquifer code designations are: 364STPR, St. Peter Sandstone; 364EVRN, Everton Formation; 368PWLL, Powell Dolomite; 367CTTR, Cotter Dolomite; 368JFRC, Jefferson City Dolomite; 367RBDX, Roubidoux Formation, 367GNTR, Gunter Sandstone member of the Van Buren Formation; 367POTS, Potosi Dolomite; NGVD 29, National Geodetic Vertical Datum of 1929; Horizontal coordinate information is referenced to the North American Datum of 1983]

Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Local well number	Land-surface altitude (feet above NGVD 29)	Well depth (feet below land-surface altitude)	Aquifer code of formation at depth of well	Water-level altitude (feet above NGVD 29)	Depth to water (feet)	Date of measurement	Change in water-level altitude from 2007 (feet)	Rate of water-level change since 2007 (feet per year)
Arkansas										
Baxter County										
361610	921143	19N11W31DAA1	640	193	367CTTR	556	84.41	03-01-10	-0.79	-0.26
361714	923026	19N14W29DBC1	720	1,625	367GNTR	662	58.02	02-25-10	0.37	0.12
362114	921423	20N11W35CCA1	600	295	367CTTR	567	33.08	03-01-10	-0.84	-0.28
362309	921419	20N12W23CBA1	600	550	367RBDX	552	47.98	03-01-10	37.48	12.41
362431	921912	20N13W13ABD1	620	209	367CTTR	551	69.46	03-01-10	-1.83	-0.61
362435	922026	20N13W14ABC1	580	493	367CTTR	547	32.85	03-01-10	-3.82	-1.26
362700	921558	21N12W33ACB1	610	500	367RBDX	580	30.47	03-01-10	1.00	0.33
Benton County										
362004	935553	19N28W11BAD1	1,260	1,030	367RBDX	1,073	187.13	03-02-10	-1.16	-0.39
361954	940618	19N29W07DAA1	1,210	1,659	367GNTR	1,066	144.19	03-02-10	-3.27	-1.09
362456	942723	20N33W14ACD1	1,185	1,600	367GNTR	766	418.87	03-02-10	0.79	0.26
362512	942720	20N33W14DBC1	1,230	1,614	367GNTR	803	427.12	03-02-10	0.65	0.22
362417	943607	20N34W21ABD1	1,022	380	364EVRN	995	26.57	03-02-10	0.41	0.14
362636	940138	21N29W35DDB2	1,405	1,769	367GNTR	1,054	351.46	03-02-10	-2.64	-0.88
Boone County										
361150	930258	18N19W19BCC1	1,150	1,649	367GNTR	911	239.38	02-25-10	-1.20	-0.40
361022	930050	18N19W33BBB1	1,300	2,055	367GNTR	658	642.02	02-25-10	-10.02	-3.35
362703	925503	21N18W20CCD1	880	1,415	371POTS	642	238.26	02-25-10	1.74	0.58
Carroll County										
362022	932604	19N23W04BAC1	1,365	1,587	367RBDX	1,174	190.89	03-02-10	5.08	1.69
361918	932633	19N23W08ADD1	1,355	2,300	367GNTR	1,106	248.53	03-02-10	-1.22	-0.41
362340	934458	20N26W16DCA1	1,198	1,332	367GNTR	1,068	129.55	03-02-10	7.83	2.60
362313	934253	20N26W23ACA1	1,335	1,713	371POTS	1,046	288.59	03-02-10	-0.74	-0.25
362939	934412	21N26W10CDC1	1,090	1,122	367GNTR	930	160.33	03-02-10	0.81	0.27
362921	934641	21N26W17BCC1	1,010	1,058	367RBDX	979	30.91	03-02-10	-1.70	-0.56

Table 1. Information pertaining to measured wells and springs in the Ozark aquifer in northwestern Arkansas and south-central Missouri, 2010.—Continued

[NA, not applicable; Aquifer code designations are: 364STPR, St. Peter Sandstone; 364EVRN, Everton Formation; 368PWLL, Powell Dolomite; 367CTTR, Cotter Dolomite; 368JFRC, Jefferson City Dolomite; 367RBDX, Roubidoux Formation, 367GNTR, Gunter Sandstone member of the Van Buren Formation; 367POTS, Potosi Dolomite; NGVD 29, National Geodetic Vertical Datum of 1929; Horizontal coordinate information is referenced to the North American Datum of 1983]

Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Local well number	Land-surface altitude (feet above NGVD 29)	Well depth (feet below land-surface altitude)	Aquifer code of formation at depth of well	Water-level altitude (feet above NGVD 29)	Depth to water (feet)	Date of measurement	Change in water-level altitude from 2007 (feet)	Rate of water-level change since 2007 (feet per year)
Arkansas—Continued										
Fulton County										
361707	913831	19N06W20DCA1	825	158	367CTTR	734	90.93	02-24-10	1.10	0.37
361728	913503	19N06W23AAD1	680	1,630	367GNTR	475	204.51	02-24-10	1.37	0.46
362210	914923	20N08W27ABD1	662	1,282	367GNTR	658	4.18	02-24-10	0.22	0.07
Fulton County (Spring)										
361908	913431	19N06W12BDAA1SP	400	NA	367CTTR	400	0.00	02-24-10	NA	NA
Independence County (Spring)										
354949	913959	14N06W29BCC1SP	340	NA	367CTTR	340	0.00	02-23-10	NA	NA
Izard County										
360753	920626	17N11W13AAD1	538	1,729	367RBDX	490	48.35	02-24-10	-0.66	-0.22
361323	915549	18N09W15BCB1	742	600	367CTTR	590	151.9	02-24-10	-59.76	-20.01
Marion County										
361634	923527	19N15W20ACC1	684	900	367RBDX	561	123.04	02-25-10	-20.44	-6.80
361442	924124	19N16W33CCB1	841	753	367RBDX	565	275.9	02-25-10	0.45	0.15
361512	925050	19N18W36BDC1	755	1,392	367RBDX	715	40.17	02-25-10	-1.35	-0.45
362452	923951	20N16W03BBA1	900	600	368JFRC	764	135.93	02-25-10	0.45	0.15
362225	924919	20N17W19ABC1	862	180	367CTTR	838	24.14	02-25-10	-3.43	-1.14
Newton County										
360014	931130	16N21W34ABC1	870	190	364EVRN	809	61.36	03-03-10	-0.80	-0.27
Randolph County										
361350	910944	18N02W02CAC1	361	128	368JFRC	311	50.46	02-23-10	2.86	0.96
362440	905351	20N02E06AAC1	485	900	367RBDX	120	364.96	02-23-10	2.01	0.68
362249	910959	20N02W15DAD1	440	170	367CTTR	414	25.6	02-23-10	0.61	0.21
Searcy County										
355126	923401	14N15W15AAC1	1,060	3,534	367GNTR	709	350.81	02-26-10	3.47	1.16
355520	923718	15N15W19CDD1	1,100	550	364EVRN	767	332.62	02-25-10	-6.87	-2.30
355750	924133	15N16W09BBA1	925	950	368PWLL	778	147.41	02-25-10	53.91	18.02
355416	924025	15N16W34BAD1	1,000	485	364PLTN	817	183.36	02-25-10	-0.35	-0.12
355819	924450	15N17W01CBA1	986	1,320	368PWLL	794	192.41	02-26-10	-31.05	-10.37

Table 1. Information pertaining to measured wells and springs in the Ozark aquifer in northwestern Arkansas and south-central Missouri, 2010.—Continued

[NA, not applicable; Aquifer code designations are: 364STPR, St. Peter Sandstone; 364EVRN, Everton Formation; 368PWLL, Powell Dolomite; 367CTTR, Cotter Dolomite; 368JFRC, Jefferson City Dolomite; 367RBDX, Roubidoux Formation, 367GNTR, Gunter Sandstone member of the Van Buren Formation; 367POTS, Potosi Dolomite; NGVD 29, National Geodetic Vertical Datum of 1929; Horizontal coordinate information is referenced to the North American Datum of 1983]

Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Local well number	Land-surface altitude (feet above NGVD 29)	Well depth (feet below land-surface altitude)	Aquifer code of formation at depth of well	Water-level altitude (feet above NGVD 29)	Depth to water (feet)	Date of measurement	Change in water-level altitude from 2007 (feet)	Rate of water-level change since 2007 (feet per year)
Arkansas—Continued										
Sharp County										
355812	913318	15N05W06DDD1	645	482	364EVRN	540	105.41	02-23-10	-0.68	-0.23
360233	913338	16N05W06DCC1	450	1,110	367RBDX	405	45.43	02-23-10	-1.89	-0.64
360023	913654	16N06W27ACC1	650	1,000	367CTTR	554	96.37	02-23-10	-0.54	-0.18
360818	912804	17N05W12BDC1	417	425	367CTTR	355	62.07	02-23-10	-1.65	-0.56
360604	913854	17N06W29ABC1	525	900	367CTTR	440	84.74	02-23-10	-1.14	-0.38
361325	913638	18N06W10CBC1	625	1,525	367GNTR	497	127.77	02-23-10	14.02	4.72
361813	912337	19N04W15BAA1	584	611	367RBDX	531	52.58	02-23-10	1.05	0.35
Sharp County (Springs)										
360228	913211	16N05W17AABA1SP	495	NA	364STPR	495	0.00	02-24-10	NA	NA
360325	913631	16N06W10AAA1SP	435	NA	364EVRN	435	0.00	02-24-10	NA	NA
360325	913648	16N06W10ABBA1SP	455	NA	364EVRN	455	0.00	02-24-10	NA	NA
Stone County										
355805	921352	15N12W02BCA1	980	3,420	367GNTR	489	490.61	02-24-10	1.48	0.50
355806	922402	15N13W06AC1	1,123	3,105	367RBDX	890	232.7	02-24-10	-0.60	-0.20
Washington County										
355903	941807	15N31W17BBD1	1,195	2,097	367GNTR	1,156	38.59	03-03-10	0.19	0.06
355652	941858	15N31W30CAD1	1,165	2,485	367GNTR	1,144	20.64	03-03-10	-0.83	-0.28
360509	942242	16N32W09ABD1	1,135	1,815	367GNTR	988	146.56	03-03-10	-0.43	-0.14
Missouri										
Ozark County										
363206	923609	21N15W03BAB1	805	550	367GSCD	663	142.38	03-01-10	-2.03	-0.67
Taney County										
363640	930554	23N20W27CCC1	763	350	367RBDX	666	97.31	03-02-10	-5.59	-1.87
363603	930601	23N20W33ADD1	705	410	367RBDX	654	50.61	03-02-10	-3.19	-1.05

Hydrographs with least squares linear regression trend lines were constructed for wells open to the Ozark aquifer with a minimum of 30 years of groundwater-level measurements. Least squares linear regression trend lines are a mathematical method of organizing data by plotting the data graphically and drawing a best fit straight trend line through the data by minimizing the sum of the squares of the offsets (residuals) (McCuen, 1985). Linear regression analysis was done using the regression function in Microsoft Excel on scatter point datasets, which is different than the method used in Pugh (2008). The equation of the trend line is represented by:

$$y = mx + b$$

where

- y is the dependent variable (water-level altitude, in feet)
- m is the slope of the trend line (annual rise or decline in water level, in feet per year),
- x is the independent variable (time, in years), and
- b is the y intercept value (value of y at $x = 0$).

Coefficients of variation (R^2) were calculated for each trend line to indicate statistical significance. Values less than 0.5 were considered to indicate a trend that was not statistically significant.

Aquifer Description

The Ozark Plateaus aquifer system (fig. 2) in and adjacent to the Ozark Plateaus is divided into five hydrogeologic units based on relative rock permeability and well yields. These hydrogeologic units crop out in a concentric pattern centered on the St. Francois Mountains of southeastern Missouri and dip to the southeast and south in northeastern Arkansas and to the south and southwest in north-central and northwestern Arkansas. The boundaries between these hydrogeologic units do not always conform to geologic time divisions or formation boundaries but were chosen to delineate groups of rocks having similar hydrologic properties. These hydrogeologic units consist of rocks that range in age from Cambrian to Devonian and are the St. Francois aquifer, St. Francois confining unit, Ozark aquifer, Ozark confining unit, and Springfield Plateau aquifer (Imes and Emmett, 1994). The St. Francois aquifer and St. Francois confining unit underlie the Ozark aquifer. The Ozark confining unit overlies the Ozark aquifer and the Springfield Plateau aquifer overlies the Ozark confining unit.

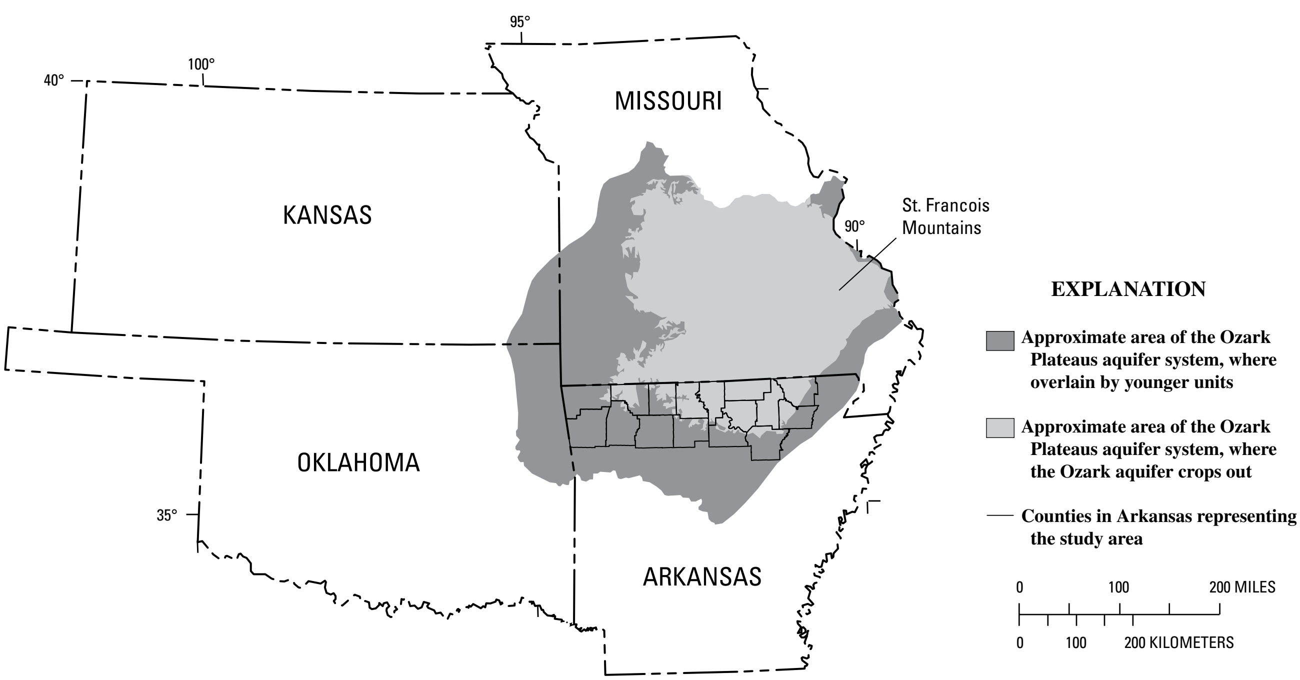


Figure 2. Location of Ozark Plateaus aquifer system.

The Ozark aquifer is underlain by the St. Francois confining unit (the uppermost geologic unit of which is the Doe Run Dolomite; table 2). The Ozark aquifer is exposed in much of southern and central Missouri and north-central Arkansas (fig. 2) where uplift of the Ozark Dome and erosion of younger rocks has formed a deeply dissected, rugged topography that is the primary recharge area of the aquifer. The aquifer is overlain by the Ozark confining unit mainly in the southern and western part of the study area (fig. 2; table 2). Within the Mississippi Alluvial Plain, east and southeast of the outcrop area (fig. 1), thick deposits of Cretaceous-, Tertiary-, and Quaternary-age sediments unconformably overlay the Ordovician-age rocks of the Ozark aquifer. Within this part of the Mississippi Alluvial Plain, major rivers receive substantial discharge from the adjacent Ozark aquifer (Mesko and Imes, 1995).

Groundwater flow and hydraulic properties within the Ozark aquifer are affected by spatial variations in hydrologic-unit thickness, fault locations and hydraulic properties, lithologic type, and degree of cementation. Values of primary porosity and permeability are small for most rock units of the Ozark aquifer, although secondary permeability resulting from fracturing, bedding planes, and dissolution of the carbonate rocks is spatially variable and ranges from moderate to large (Adamski, 1996). Hydraulic conductivity ranges from 1×10^{-3} feet per day (ft/d) to more than 1×10^{2} ft/d (Imes and Emmett, 1994). The principal recharge area for the Ozark aquifer is in central and south-central Missouri and north-central Arkansas, where the aquifer is hydraulically connected to the surface and the potentiometric surface mimics the land-surface topography.

Most wells completed in the Ozark aquifer yield between 50 and 100 gallons per minute (gal/min) although some wells may yield as much as 600 gal/min (Imes and Emmett, 1994; Adamski and others, 1995). The thick, extensive, and productive Ozark aquifer is the principal source of groundwater in northern Arkansas, except for northwestern Arkansas, which derives most of its water from Beaver Lake (Beaver Lake Water District, 2013), with the most important water-producing strata being the sandstones of the Roubidoux Formation and the Gunter Sandstone Member of the Van Buren Formation (table 2). Wells completed in the Roubidoux Formation yield an average of 60 gal/min (Adamski and others, 1995). The Gunter Sandstone Member is the principal water-yielding zone within the Ozark aquifer; wells that penetrate the unit commonly yield from 150 to 300 gal/min, and some wells yield as much as 500 gal/min. Although the Potosi Dolomite of Cambrian age is the principal source of water for municipalities in the Salem Plateau area of Missouri, in northern Arkansas, the water-yielding characteristics of this formation are poorly understood because it is located at great depths making it economically unsuited for development as a water resource. Minor water-yielding zones of the Ozark aquifer are contained within the Jefferson City, the Cotter, and the Powell Dolomites; the upper part of the Everton Formation; the St. Peter Sandstone; and the St. Clair, the Lafferty, and the Clifty Limestones (table 2). Yields from these units range from 50 to 80 gal/min (Renken, 1998).

Beneath the Mississippi Alluvial Plain (fig. 1), the rocks composing the Ozark aquifer dip at about 45 feet per mile (ft/mi) to the southeast. In the northern part of the study area, the regional dip is about 26 ft/mi southward, increasing to 175 ft/mi or more at the southern boundary of the Ozark Plateaus (Imes, 1990). The depth of the Ozark aquifer increases to more than 4,000 ft below land surface in the southern part of the study area. In this area, water quality is affected by increasing amounts of dissolved solids, fluoride, sulfide, and radium as water moves downdip, away from recharge areas (Imes and Emmett, 1994). The combination of greater depth and poorer water quality limits the viability of the Ozark aquifer as an economic source of water in the southernmost part of the study area.

Potentiometric Surface

Water-level measurements (table 1) were used to construct an updated potentiometric-surface map to the one reported by Pugh (2008). The updated potentiometric-surface map is provided in plate 1 of this report. The potentiometric-surface map indicates the altitude to which water would stand in wells completed in the Ozark aquifer and is intended to show the general configuration of the potentiometric surface. The Ozark aquifer covers a large area in Arkansas and has variable thickness and hydrologic properties that can affect water-level altitudes and hydraulic gradients. Water-level data distribution is sparse in some areas. Because of these various factors, the potentiometric-surface map should not be used to estimate exact water-level altitude or depth to water at any given location.

With few exceptions, the potentiometric-surface contours and general direction of groundwater flow are very similar to Pugh (2008). In most of the study area, the general level and shape of the potentiometric surface has changed little as mapped in previously published USGS reports in 1995 (Pugh, 1998), 2001 (Schrader, 2001), and 2004 (Schrader, 2005). Potentiometric-surface differences can be attributed to differences in hydrologic stresses (withdrawals related to changing population, differences in withdrawals for agricultural uses, or withdrawal conditions just prior to a water-level measurement) or data-collection and map-construction methods (time of year or number of water-level measurements and locations of water-level measurements used to construct maps representing different years). Local highs within the potentiometric surface occur along topographically high ridges, such as in Fulton and Izard Counties, which appear as ‘fingers’ along the 700-ft contour. Lows within the potentiometric surface occur at topographically low areas, such as along the White River, which forms the border between Stone and Izard Counties.

Table 2. Stratigraphic column with descriptions of lithologic and hydrogeologic properties of the Ozark aquifer and adjacent confining units within Arkansas (modified from Lamonds, 1972; Imes, 1990; Imes and Smith, 1990).

Era	Period	Geologic unit	Hydrogeologic unit	Lithology	Thickness (feet)	Hydrogeology
Paleozoic	Devonian	Chattanooga Shale	Ozark confining unit	Shale unit that crops out in a narrow band that outlines the Ozark aquifer and is missing where the Ozark aquifer is exposed at the surface.	0–200	Unit is relatively impermeable because of large shale content.
		Clifty Limestone	Ozark aquifer	Chert with lenses of limestone, dolomite, and cherty sandstone.	0–250	The residual cherty rubble, weathered from cherty limestone and sandstone of the unit, may yield 2 to 5 gallons per minute.
		Penters Chert				
	Silurian	Lafferty Limestone		Limestone, dolomite, sandstone, and minor amounts of shale	0–2,000	The limestones and dolomites commonly yield 5 to 10 gallons per minute from solution channels, bedding planes, and fractures. Similar yields may be obtained from the sandstone where it is porous or fractured. These units contain many springs. Yields from springs and some wells may exceed 50 gallons per minute.
		St. Clair Limestone				
		Brassfield Limestone				
	Ordovician	Cason Shale				
		Fernvale Limestone				
		Kimmswick Limestone				
		Plattin Limestone				
		Joachim Dolomite				
		St. Peter Sandstone				
		Everton Formation				
		Smithville Formation		Dolomite, dolomitic limestone, and minor amounts of sandstone and shale.	100–1,000	The solution channels and fractures in the dolomite and dolomitic limestone commonly yield 5 to 10 gallons per minute. Wells that tap large solution channels may yield more than 50 gallons per minute, but large yields are uncommon. These units yield water to several large springs.
		Powell Dolomite				
		Cotter Dolomite				
		Jefferson City Dolomite				
		Roubidoux Formation		Sandstone and sandy dolomite. Not exposed in Arkansas.	100–250	Yields of as much as 450 gallons per minute may be obtained from some wells, but yields are highly variable and generally average less than 150 gallons per minute.
		Gasconade Dolomite		Dolomite, sandy dolomite, and sandstone. Not exposed in Arkansas.	350–650	The most productive water-bearing part of this unit is the Van Buren Formation. Wells that tap into the Van Buren Formation commonly yield 150 to 300 gallons per minute and may yield as much as 500 gallons per minute.
		Gunter Sandstone member of the Van Buren Formation				
	Cambrian	Eminence Dolomite				
		Potosi Dolomite				
		Doe Run Dolomite	St. Francois confining unit	Shale and shaley dolomite, siltstone, and limestone conglomerate. Shales present both as distinct beds and disseminated throughout dolomite matrix. Not exposed in Arkansas.	0–750	Permeability is minimal to moderate. Unit is more permeable where transected by fault and fracture zones.
		Derby Dolomite				
		Davis Formation				

The 2010 water-level data indicate the highest measured water-level altitude is 1,174 ft above NGVD 29 in Carroll County. Water-level altitudes of less than 400 ft above NGVD 29 are mapped along the eastern and southeastern parts of the study area in Independence, Lawrence, Randolph, and Sharp Counties. The lowest measured water level of 120 ft above NGVD of 1929 was measured in eastern Randolph County. Of the 56 water-level altitudes measured in 2010, 24 rose and 32 declined compared to measurements made in 2007 in the same wells (table 1). The majority of wells measured (31) had rates of change with absolute values of less than 0.5 ft/yr. Water-level rises of 0.5 ft/yr or less occurred in 15 wells; declines of 0.5 ft/yr or less occurred in 16 wells. The largest rise occurred in well 15N16W09BBA1 in Searcy County with an increase in water-level altitude of 53.91 ft, or a rate of rise of 18.02 ft/yr between 2007 and 2010. The largest decline occurred in well 18N09W15BCB1 in Izard County with a decrease in water-level altitude of -59.76 ft, or a rate of decline of -20.01 ft/yr between 2007 and 2010.

Potentiometric-surface contours in Stone County differ from those presented in Pugh (2008). Pugh (2008) erroneously transposed two water-level altitudes in Stone County (631 and 748 ft) that were used in the construction of the 2007 potentiometric-surface map.

Faults within the study area likely affect water levels within the Ozark aquifer. However, faults shown on plate 1 were not used to adjust contour line positions because of the sparseness of water-level measurements. Fault traces shown represent major faults mapped by Haley and others (1993).

The potentiometric-surface map depicts the general direction of groundwater flow within the Ozark aquifer, with horizontal groundwater movement perpendicular to the potentiometric-surface contours or the direction of the horizontal hydraulic gradient. Generalized groundwater-flow directions shown on plate 1differ little from those of Pugh (2008) or the predevelopment potentiometric surface by Imes and Emmett (1994). An exception to this occurs in western Stone County, resulting from a correction to the assignment of water-level altitudes that were erroneously transposed between two measuring points in Pugh (2008). Regionally, the flow within the aquifer is to the south and southeast in the eastern and central part of the study area and to the west, northwest, and north in the western part of the study area.

The extent of the potentiometric-surface map presented on plate 1 covers approximately one-half of the area of the Ozark Plateaus in Arkansas (fig. 1). In the southern part of the study area, the aquifer is not a viable source of water because of great depths and poor water quality (Imes and Emmett, 1994). Few water wells have been constructed in this part of the study area, consequently, no data are available for contouring purposes.

Population and Water Use

The population of the 16 counties in northern Arkansas that compose the study area has increased steadily since 1960 (fig. 3). From 1960 through 2010 the population in the State of Arkansas has increased 63 percent while counties within the study area increased 201 percent. The largest increase in population was in the counties bordering Missouri and Oklahoma including Benton (510 percent), Baxter (318 percent), Washington (264 percent), Marion (176 percent), Sharp (173 percent), Carroll (143 percent), and Boone (129 percent). Lawrence and Searcy Counties experienced the smallest increases in population at 1 percent each (U.S. Census Bureau, 2013).

Estimated surface-water use fluctuated substantially during the period 1960–2010 (fig. 3). A large increase in estimated surface-water use between 1985 and 1990 is attributed mainly to changes in surface-water use data collection methods. Surface-water use associated with thermoelectric power generation at the Flint Creek Power Plant in Benton County was subtracted from the total surface-water use beginning in 1990. The Beaver Water District became operational in 1973 providing approximately 40 million gallons per day (Mgal/d) to municipal public-supply systems in Benton, Carroll, and Washington Counties (Pugh, 2008; Beaver Water District, 2013). Beaver Water District and other similar facilities across the State began to report surface-water use in 1990 when the ANRC started collecting water-use data from these facilities.

Estimated total groundwater use for the Ozark aquifer in Arkansas has varied moderately for the period from 1960 through 2010, while estimated total surface-water use has increased dramatically for the same time period for the study area (fig. 3). Estimated groundwater use from the Ozark aquifer in Arkansas peaked in 1975 at 38.29 Mgal/d and subsequently declined to 22.27 Mgal/d in 2010. Estimated surface-water use (less thermoelectric power usage) rose to 251.17 Mgal/d in 2010 (fig. 3; Terrance W. Holland, U.S. Geological Survey, written commun., 2013). Overall, groundwater use was a much smaller amount compared to that reported for surface-water use from 1990 to 2010 (fig. 3). Groundwater-use data from 2000 to 2010 are listed by county in table 3; surface-water use data are listed in table 4. Of the 16 counties in the study area, 11 experienced a decrease in groundwater use between 2005 and 2010, 4 counties experienced an increase, and 1 was unchanged (table 3). Benton and Searcy Counties had substantially more groundwater use between 2005 and 2010, with Benton County reporting the largest amount of groundwater use (5.68 Mgal/d in 2010 or a 98-percent increase over 2005 rates).

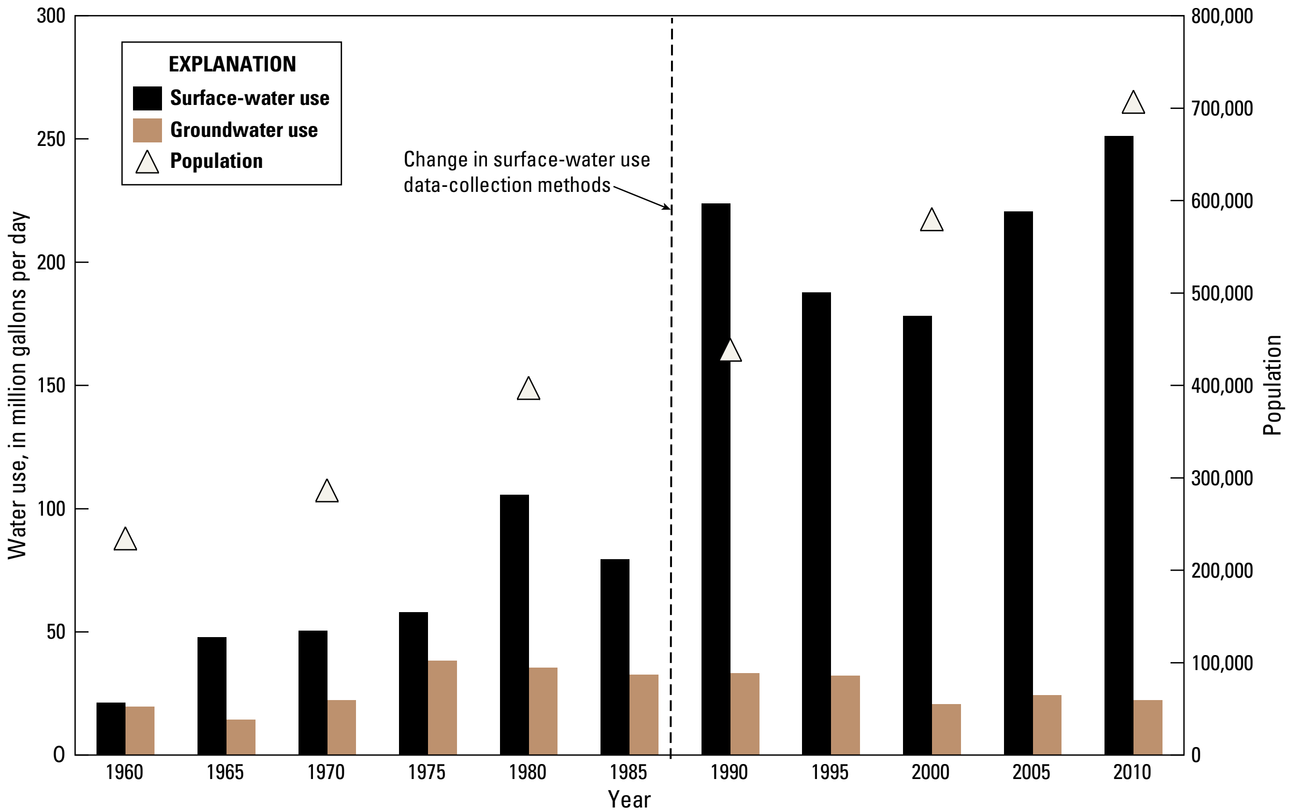


Figure 3. Total estimated groundwater and surface-water use and population for the study area in northern Arkansas, 1960–2010.

Table 3. Groundwater use for selected counties in northern Arkansas, 2000–10.

[Modified from Holland (2004, 2007). All values in million gallons per day; 2010 values are provisional (Terrance W. Holland, U.S. Geological Survey, written commun., 2013)]

County	Year			
	2000	2005	2010	Change from 2005 to 2010 (percent)
Baxter	1.95	1.95	1.37	-30
Benton	2.49	2.87	5.68	98
Boone	1.88	1.91	1.79	-6
Carroll	2.19	2.87	2.09	-27
Fulton	0.99	1.96	1.89	-4
Independence	0.00	0.00	0.00	0
Izard	2.29	1.79	1.30	-27
Lawrence	0.08	0.93	0.62	-33
Madison	1.58	1.15	0.93	-19
Marion	0.26	0.83	0.84	1
Newton	0.91	1.17	1.15	-2
Randolph	0.24	0.25	0.09	-64
Searcy	0.84	0.29	1.54	431
Sharp	1.63	4.23	1.28	-70
Stone	0.68	0.60	0.61	2
Washington	2.51	1.35	1.09	-19
Totals	20.52	24.15	22.27	-8

Table 4. Surface-water use for selected counties in northern Arkansas, 2000–10.

[Modified from Holland (2004, 2007). All values in million gallons per day; 2010 values are provisional (Terrance W. Holland, U.S. Geological Survey, written commun., 2013)]

County	Year			
	2000	2005	2010	Change from 2005 to 2010 (percent)
Baxter	4.35	3.88	3.47	-11
Benton	19.52	60.21	63.04	5
Boone	3.49	1.19	1.00	-16
Carroll	5.41	8.72	8.94	3
Fulton	1.54	0.48	0.49	2
Independence	44.34	62.74	98.59	57
Izard	0.56	3.22	3.34	4
Lawrence	30.06	32.83	18.75	-43
Madison	2.20	0.98	0.84	-14
Marion	3.29	1.21	1.19	-2
Newton	0.37	0.23	0.21	-9
Randolph	30.62	38.88	44.75	15
Searcy	0.90	0.70	0.27	-61
Sharp	1.24	0.98	2.11	115
Stone	1.08	1.84	2.12	15
Washington	29.16	2.50	2.06	-18
Totals	178.13	220.59	251.17	14

The large increase in population within the study area is not reflected by a similar increase in groundwater use from the Ozark aquifer. Although the population for the study area increased by 201 percent from 1960 to 2010, the groundwater use from the Ozark aquifer increased by only 13 percent for the same time period. The relatively small increase in groundwater use, when compared to the increase in population, is attributed to the completion of Beaver Lake in 1966, and the subsequent creation of Beaver Water Districts and other surface-water supply systems meeting the water needs of the rapidly increasing population. Surface-water usage (less thermoelectric power usage) increased 1,081 percent between 1960 and 2010 (fig. 3). For the period 2005 to 2010, surface-water usage increased by 14 percent, compared to a decrease in groundwater usage of 8 percent (tables 3 and 4).

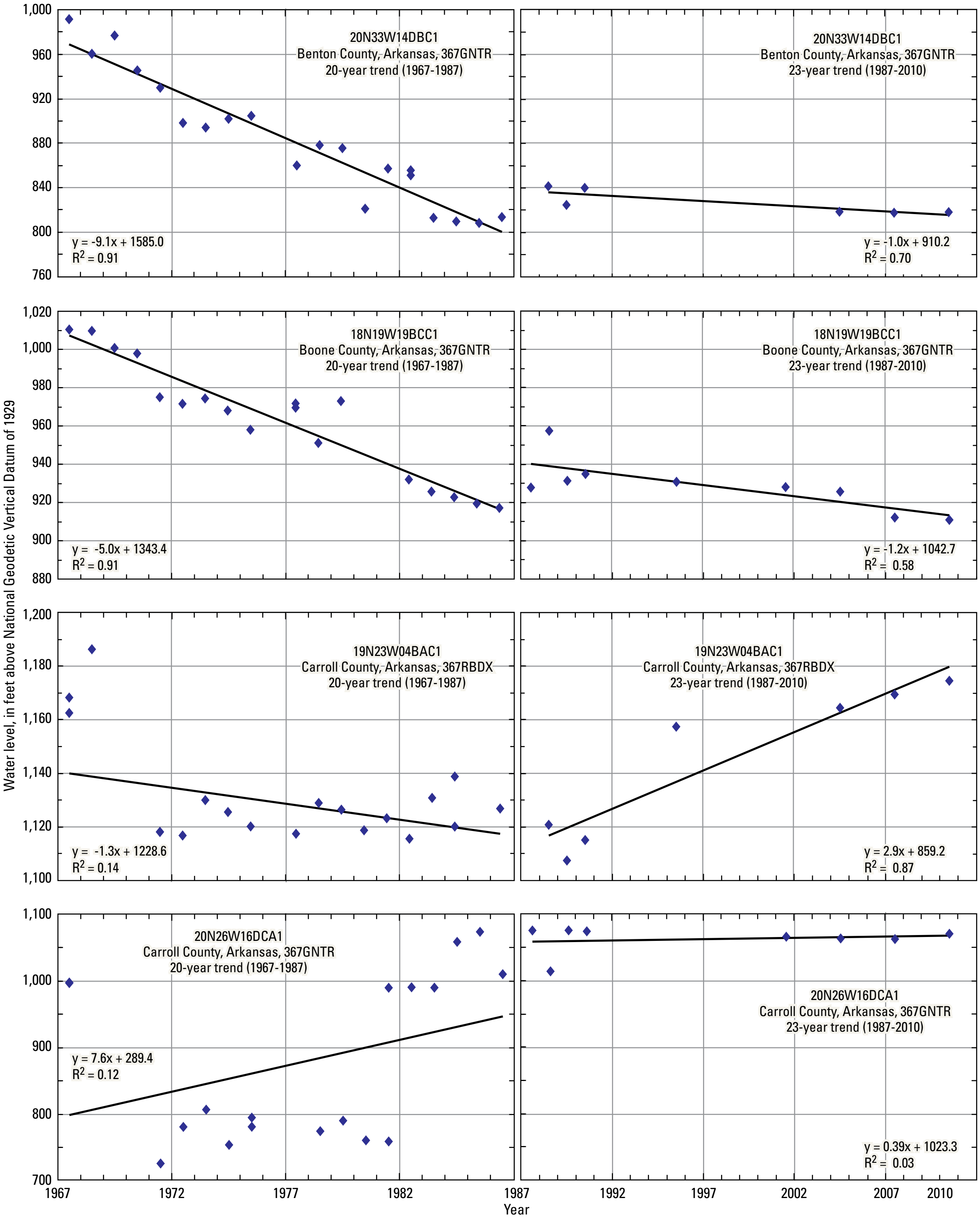
Long-Term Water-Level Trends

Hydrographs with regression trend lines were constructed for wells open to the Ozark aquifer with at least 30 years of periodically measured groundwater levels. Twenty-four hydrographs from 12 wells are presented in figure 4 and were selected to provide a relatively even geographic distribution across the study area. Hydrographs (fig. 4) are arranged in alphabetical order by county name. The minimum 30-year period of record was used to evaluate water-level trends in wells that were minimally affected by localized pumping. Trend lines, using least squares linear regression analysis, were calculated for two time periods (1967–87 and 1987–2010) to determine the rates of water-level change in each well for each time period. The year 1987 was selected as the break point in trend lines, in part, because it is about the time that estimated surface-water use increased dramatically (fig. 3).

Pugh (2008) divided water-level trends in the Ozark aquifer into two 20-year periods (1967–87 and 1987–2007) to assess the change in water-level trends. Of the 56 wells measured in the Arkansas part of the Ozark aquifer in 2010, 22 of the wells have long-term records of 30 or more years. Out of the 16 counties in the study area, 10 counties have one or more wells with long-term records. Carroll, Sharp, and Washington Counties have three or more wells with long-term records. Baxter, Independence, Lawrence, Madison, Randolph, and Searcy Counties have no wells with long-term records.

The slopes of the trend lines are an estimate of the rate of change in water levels for each time period. The fit of the trend lines to each dataset are reflected by the values of the coefficients of variation (R^2). R^2 values can vary between 0 and 1. An R^2 value of 0 may reflect a poor fit of the trend line or the absence of any slope to the trend line; an R^2 value of 1 indicates a perfect fit of the trend line to the data. Trend lines and R^2 values are shown on each hydrograph in figure 4. A statistically significant trend was considered in this study to have an R^2 value greater than 0.5. Pugh's (2008) analysis of trend lines showed that it was difficult to detect statistically significant trends in many of the hydrographs. Countywide assessments of water-level trends are hampered by lack of sufficient wells with statistically significant water-level trends. Five wells that had water-level trends that were considered statistically significant are listed in table 5. Benton, Boone, Sharp, and Washington Counties had one well each that showed declining water- level trends; Carroll County had one well with a rising water-level trend.

An examination of water-use and population data and hydrograph trends over time provides some insight into changing water levels in the Ozark aquifer. The rapidly increasing population within the study area appears to have some effect on groundwater levels. However, the effect may have been minimized by the development and use of surface-water distribution infrastructure, suggesting that most of the incoming populations are fulfilling their water needs from surface-water sources. The conversion of some users from groundwater to surface water may be allowing water levels in wells to recover (rise) or decline at a slower rate, such as in Benton, Carroll, and Washington Counties. Water levels in wells continue to decline at some locations where the users have not converted to surface water, such as in Sharp County.



Note: y is water-level altitude, in feet;
x is time, in years;
R_2 is the coefficient of variation, indicating statistical significance of the line of best fit

Figure 4. Water-level hydrographs and trends for selected wells completed in the Ozark aquifer in Arkansas.

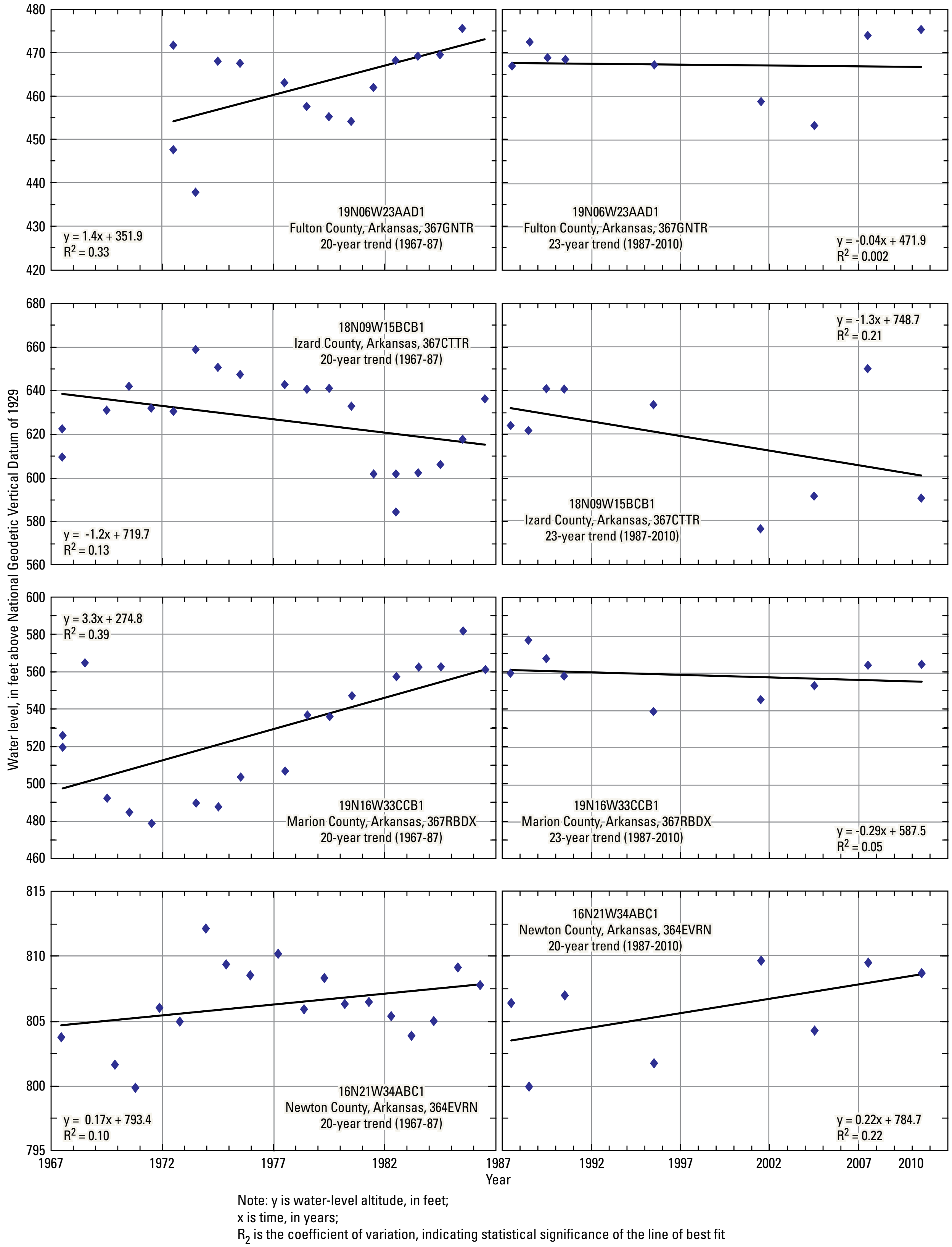
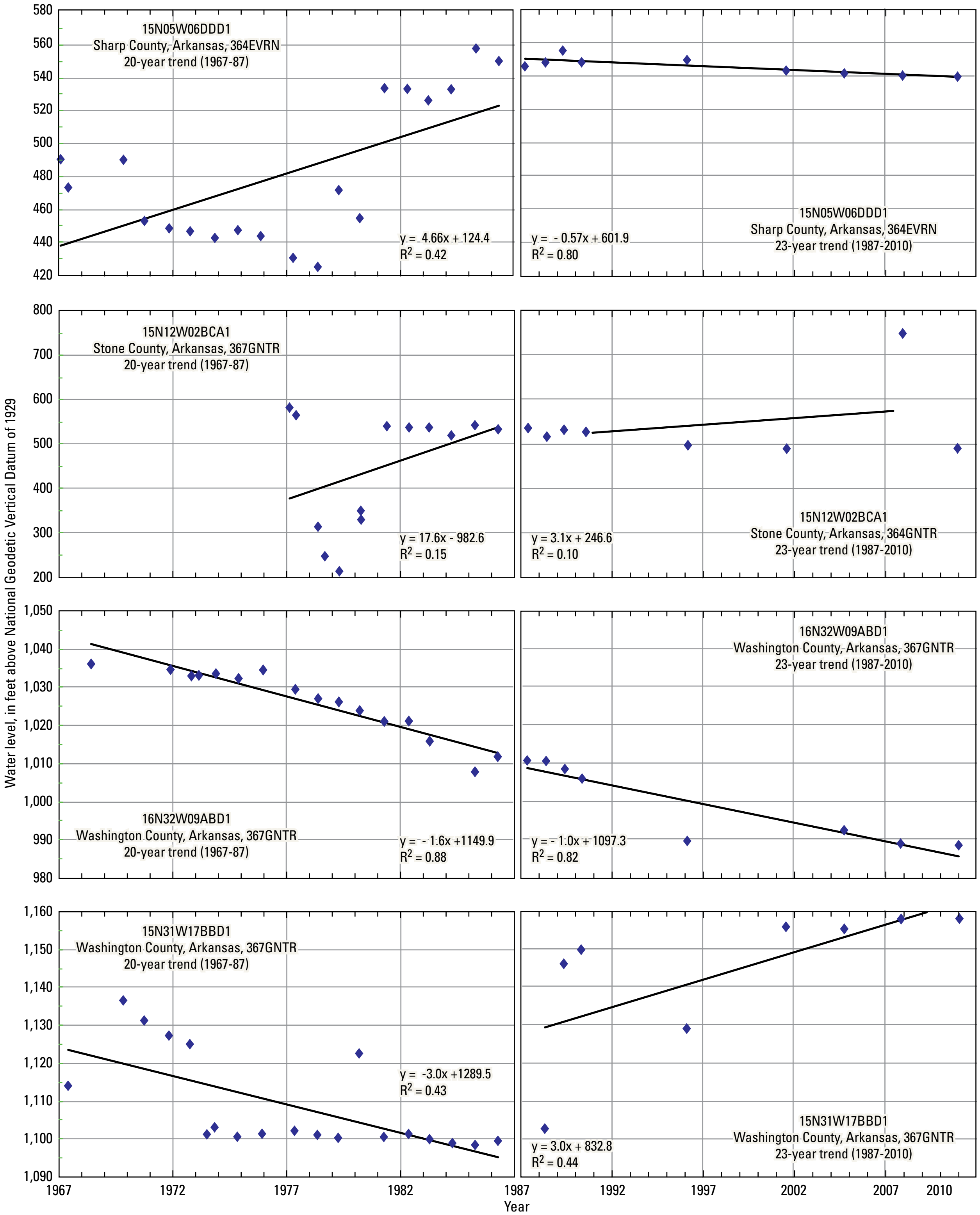


Figure 4. Water-level hydrographs and trends for selected wells completed in the Ozark aquifer in Arkansas.—Continued



Note: y is water-level altitude, in feet;
x is time, in years;
R_2 is the coefficient of variation, indicating statistical significance of the line of best fit

Figure 4. Water-level hydrographs and trends for selected wells completed in the Ozark aquifer in Arkansas.—Continued

Table 5. Statistically significant water-level trends by well.

[A statistically significant water-level trend has a coefficient of variation (R^2) value greater than 0.5; –, no value]

County	Well	Water-level rate of change (feet/year)	
		1967 to 1987	1987 to 2010
Benton	20N33W14DBC1	-9.1	-1.0
Boone	18N19W19BCC1	-5.0	-1.2
Carroll	19N23W04BAC1	–	2.9
Sharp	15N05W06DDD1	–	-0.57
Washington	16N32W09ABD1	-1.6	-1.0

Summary

During February and March 2010, groundwater levels from 56 wells and 5 springs in the Ozark aquifer in northern Arkansas and southern Missouri were measured by the U.S. Geological Survey in cooperation with the Arkansas Natural Resources Commission and the Arkansas Geological Survey. A potentiometric-surface map of the Arkansas part of the Ozark aquifer was constructed. The Ozark aquifer in northern Arkansas is composed of dolomite, limestone, sandstone, and shale of Upper Cambrian to Middle Devonian age, which dips to the south and southeast away from the St. Francois Mountains of southeastern Missouri. The aquifer is complex, characterized by discrete hydrogeologic units with large variations in permeability. The principal recharge area for the aquifer is in southern and central Missouri and north-central Arkansas where the aquifer is hydraulically connected to the surface.

A potentiometric-surface map of the Ozark aquifer in northern Arkansas for 2010 indicates the maximum measured water-level altitude is 1,174 feet (ft) above National Geodetic Vertical Datum of 1929 (NGVD 29) in Carroll County, and the minimum measured water-level altitude is 120 ft above NGVD 29 in Randolph County. The direction of regional groundwater flow generally is to the south and southeast in the eastern and central part of the study area and to the west, northwest, and north in the western part of the study area, but direction varies most in areas where the unconfined part of the aquifer is hydraulically connected to the surface. In these areas, the flow direction is affected more by local topography (flowing from high altitudes toward stream valleys). The 2010 potentiometric-surface map is very similar to prior maps. Potentiometric-surface differences can be attributed to differences in hydrologic stresses (withdrawals related to changing population, changing dependence on surface water, differences in withdrawals for agricultural uses, or withdrawal conditions just prior to a water-level measurement) or data-collection and map-construction methods (time of year or different numbers and locations of water-level measurements used to construct maps representing different years).

An examination of water-use and population data and hydrograph trends over time provides some insight into changing water levels in the Ozark aquifer. The rapidly increasing population within the study area appears to have some effect on groundwater levels. However, the effect may have been minimized by the development and use of surface-water distribution infrastructure, suggesting most of the incoming populations are fulfilling their water needs from surface-water sources. The conversion of some users from groundwater to surface water may be allowing water levels in wells to recover (rise) or decline at a slower rate, such as in Benton, Carroll, and Washington Counties. Water levels in wells continue to decline in locations where the users have not converted to surface water, such as in Sharp County.

References Cited

Adamski, J.C., 1996, Nutrients and pesticides in groundwater of the Ozark Plateaus in Arkansas, Kansas, Missouri, and Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 96–4313, 28 p.

Adamski, J.C., Petersen, J.C., Freiwald, D.A., and Davis, J.V., 1995, Environmental and hydrologic setting of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 94–4022, 69 p.

Beaver Water District, 2013, Beaver Water District: accessed April 25, 2013, at http://www.bwdh2o.org/index.php?fuseaction=p0004.&mod=11.

Fenneman, N.M., 1938, Physiography of eastern United States: New York, McGraw-Hill Book Co., Inc., 714 p.

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

Haley, B.R., Glick, E.E., Bush, W.V., Clardy B.F., Stone, C.G., Woodward, M.B., and Zachry, D.L., 1993, Geologic map of Arkansas: Arkansas Geological Survey, 1 pl.

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

Holland, T.W., 2007, Water use in Arkansas, 2005: U.S. Geological Survey Scientific Investigations Report 2007–5241, 32 p.

Imes, J.L., 1990, Major geohydrologic units in and adjacent to the Ozark Plateaus Province, Missouri, Arkansas, Kansas, and Oklahoma—Ozark aquifer: U.S. Geological Survey Hydrologic Investigations Atlas HA–711–E, 3 sheets, scale 1:750,000.

Imes, J.L., and Emmett, L.F., 1994, Geohydrology of the Ozark Plateaus aquifer system in parts of Missouri, Arkansas, Oklahoma, and Kansas: U.S. Geological Survey Professional Paper 1414–D, 127 p.

Imes, J.L., and Smith, B.J., 1990, Areal extent, stratigraphic relation, and geohydrologic properties of regional geohydrologic units, Missouri: U.S. Geological Survey Hydrologic Investigations Atlas HA–711–I, 3 sheets, scale 1:750,000.

Lamonds, A.G., 1972, Water-resources reconnaissance of the Ozark Plateaus Province, northern Arkansas: U.S. Geological Survey Hydrologic Investigations Atlas HA–383, 2 sheets, scale 1:500,000.

McCuen, R.A., 1985, Statistical methods for engineers: Englewood Cliffs, New Jersey, Prentice-Hall Inc., 439 p.

Mesko, T.O., and Imes, J.L., 1995, Discharge of ground water along the Ozark escarpment in southeastern Missouri and northeastern Arkansas: U.S. Geological Survey Water-Resources Investigations Report 95–4103, 12 p.

Pugh, A.L., 1998, Potentiometric surface of the Ozark aquifer in northern Arkansas, 1995: U.S. Geological Survey Water-Resources Investigation Report 98–4000, 7 p.

Pugh, A.L., 2008, Potentiometric surface of the Ozark aquifer in northern Arkansas, 2007: U.S. Geological Survey Scientific Investigations Report 2008–5137, 16 p.

Renken, R.A., 1998, Ground water atlas of the United States, segment 5—Arkansas, Louisiana, Mississippi: U.S. Geological Survey Hydrologic Investigations Atlas 730–F, 28 p.

Schrader, T.P., 2001, Potentiometric surface of the Ozark aquifer in northern Arkansas, 2001: U.S. Geological Survey Water-Resources Investigation Report 01–4233, 11 p.

Schrader, T.P., 2005, Potentiometric surface of the Ozark aquifer in northern Arkansas, 2004: U.S. Geological Survey Water-Resources Investigation Report 2005–5208, 10 p.

U.S. Census Bureau, 2013, State & county quickfacts: U.S. Census Bureau, accessed March 13, 2013, at http://quickfacts.census.gov/qfd/states/05000.html.

U.S. Geological Survey, 1990, State of Arkansas (topographic): U.S. Geological Survey Map Publication 34092–E1–ST–500, scale 1:500,000, 1 sheet.

Publishing support provided by
Tacoma and Lafayette Publishing Service Centers

USGS

Czarnecki and others—**Potentiometric Surface of the Ozark Aquifer in Northern Arkansas, 2010**—SIR 2014–5013

ISSN 2328-0328 (online)
http://dx.doi.org/10.3133/sir20135013