GROUND-WATER RESOURCES OF THE UPPER WHITE RIVER BASIN IN ARKANSAS

By John M. Kilpatrick and A.H. Ludwig

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (continued)

TABLES

CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units, rather than the inch-pound units used in this report, the following conversion factors may be used:

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallon per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallon per day (Mgal/d)	3,785	cubic meter per day (m^3/d)
cubic foot per second (ft^3/s)	2.832	liter per second (L/s)
cubic foot per second (ft^3/s)	2.832	cubic decimeter per second (dm^3/s)
cubic foot per second(ft^3/s)	0.02832	cubic meter per second (m^3/s)

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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ABSTRACT

The upper White River basin in Arkansas lies almost entirely within the Ozark Plateaus physiographic province, which consists of deeply dissected plateaus underlain by limestone, shale, and dolomite. Significant water-yielding units within the upper White River basin include the Eminence and Potosi Dolomites, the Roubidoux Formation, the Gasconade Dolomite and the Van Buren Formation, outcrops of undifferentiated Paleozoic rocks, the Nacatoch Sand, and Quaternary deposits. Water in the Quaternary deposits is the most heavily used, but areally, other units are significant sources of ground water for domestic and rural use. The quality of ground water withdrawn from the various units generally is suitable for most uses, although ground water in the study area is typically very hard. Iron concentrations commonly exceed allowable limits.

Yields from the different water-yielding units are highly variable. The Eminence and Potosi Dolomites lie between 2,000 and over 3,500 feet below land surface, are virtually unused, and are known to yield as much as 230 gallons per minute. Nearer the surface, the Gunter Sandstone Member of the Van Buren Formation yields as much as 500 gallons per minute and is used by many public supply systems. Above the Gunter Sandstone, but still 300 feet below land surface, the Roubidoux Formation yields as much as 450 gallons per minute to wells. In contrast to the high yields from these deeper units, the outcrops of Paleozoic rocks commonly yield less than 10 gallons per minute. Yields from the Nacatoch Sand are unknown, because it is not currently used as a source of water in the study area. The Quaternary deposits yield as much as 2,500 gallons per minute of very hard water.

High nitrate concentrations that exceed U.S. Environmental Protection Agency primary drinking-water standards and bacterial contamination have occurred in some areas. These concentrations probably result from deteriorated well bore seals and perforated casings that allow wastes from barnyards and septic tanks to enter the well bore at or near the surface. In addition, saline water occurs in the Quaternary deposits near Bald Knob and Cord, Arkansas. Potential sources of contamination include two Resource Conservation and Recovery Act sites, two Superfund sites, and numerous landfills and surface impoundments.

INTRODUCTION

This report was prepared in cooperation with the U.S. Army Corps of Engineers to describe the ground-water resources of the upper White River basin in Arkansas. The contents of this report will be incorporated by the Arkansas Soil and Water Conservation Commission (ASWCC) into the 1986 Arkansas State Water Plan. The 1986 Arkansas State Water Plan is intended to update the first State Water Plan published by ASWCC in 1975, and serve as the basic document for defining water policy for the protection, development, and management of water resources in the State. ASWCC's specific objectives in revising the first State Water Plan are to incorporate more recent data and research, evaluate new and existing problems, and present solutions and recommendations.

The study area consists of the upper White River basin in Arkansas (fig. 1), most of which lies in the Ozark Plateaus physiographic province. The area is dominated by deeply dissected plateaus which are as much as 2,400 feet (ft) above sea level in the south (Brewster and Williams, 1951). The rocks underlying the Ozark Plateaus range in age from Ordovician to Pennsylvanian (fig. 2). They are composed primarily of nearly horizontal beds of limestone, shale, dolomite, sandstone, and chert. The beds dip gently to the south at the rate of about 50 feet per mile (ft/mi). The dip increases gradually toward the Arkansas Valley on the south. Small quantities of ground water, generally less than 10 gallons per minute (gal/min), are available at shallow depths in these units from secondary openings such as joints, fractures, and solution cavities. Yields of as much as 500 gal/min are possible from three deeply buried limestone and dolomite units; which are regionally important sources of ground water. These units occur at depths ranging from 300 to more than 3,500 ft below land surface.

A small part of the southeastern corner of the study area lies in the Arkansas Valley section of the Ouachita province. This area is described by Fenneman (1938) as being little different from the southern Ozark Plateaus.

A narrow strip along the eastern edge of the study area, ranging from 10 to 20 miles in width, lies in the Mississippi Alluvial Plain section of the Coastal Plain province. This area is characterized by nearly flat topography and is underlain by as much as 155 ft of Quaternary alluvial sediments composed of gravel, sand, silt, and clay. These deposits are the most productive ground-water source in the study area. Properly constructed wells in these deposits yield as much as 2,500 gal/min of water. The Quaternary deposits lie unconformably on a sequence of older, unconsolidated deposits that dip gently to the east-southeast. These deposits are composed of sand, clay, marl, and chalk of Tertiary and Cretaceous ages. Sand units within this sequence are thought to be capable of yielding several hundred gallons per minute to wells in the study area, downdip from their outcrop areas (Lamonds and others, 1969).

Information concerning the lithology and water-yielding characteristics of each of the geologic units in the study area is contained in the stratigraphic column (table 1).

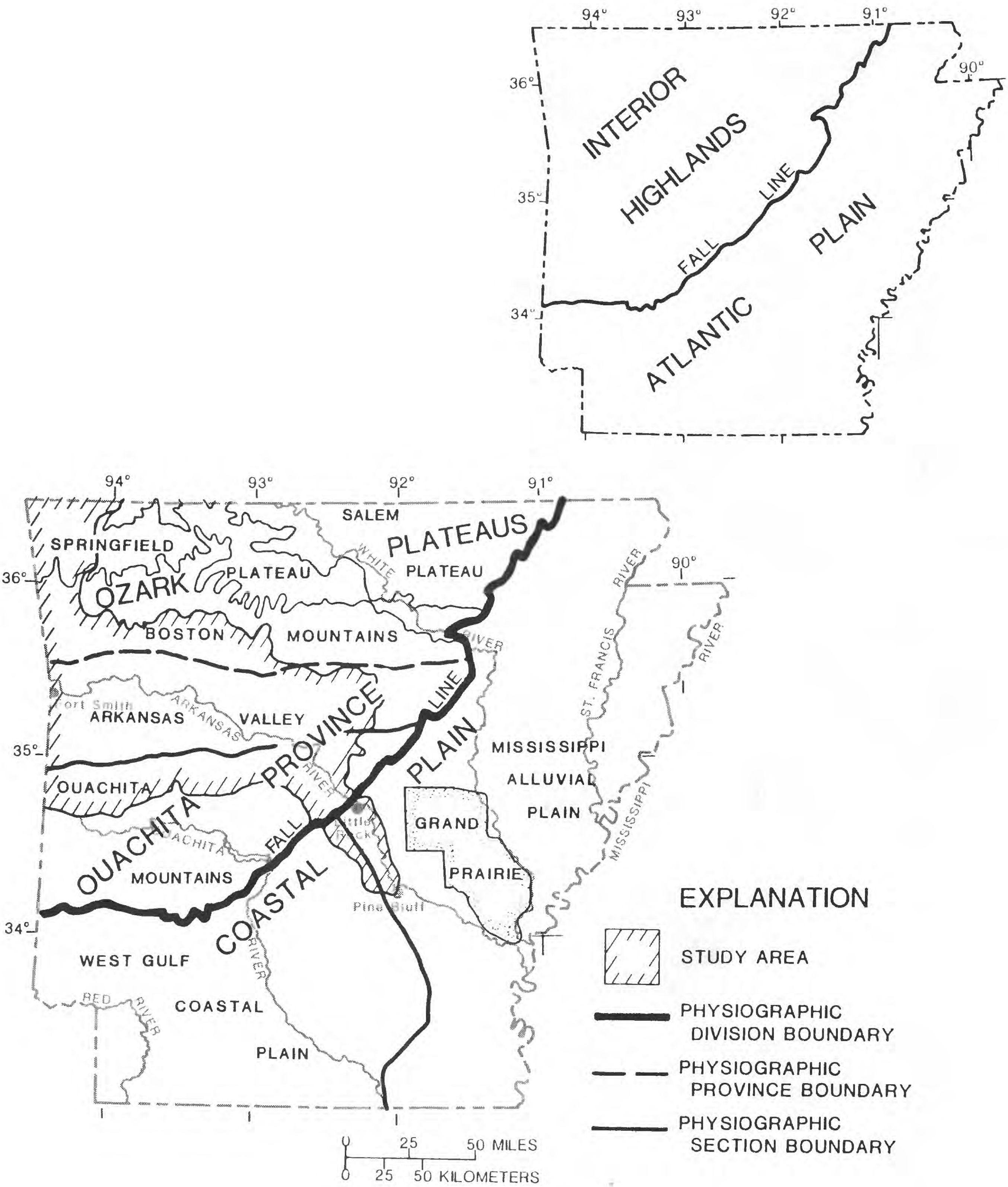

Figure 1.--Location and physiography of the study area (modified from Lamonds, 1972).

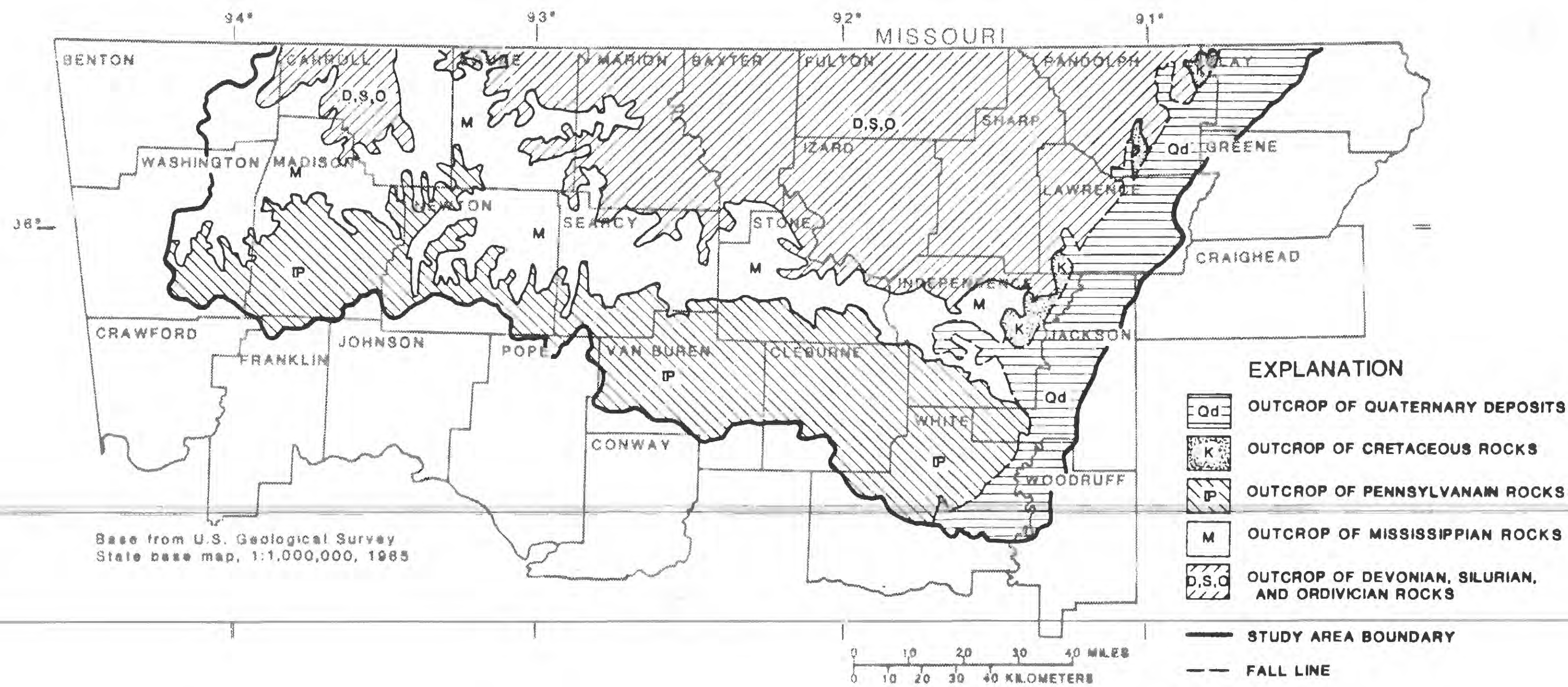

Figure 2.--Geology of the upper White River basin, in Arkansas (modified from Haley, 1976).

Table 1.--Generalized stratigraphic column for the study area

(modified from Caplan, 1957; Caplan, 1960; and Albin and others, 1967)

Erathem	System	Geologic unit	Thickness in feet	Description	Water-yielding characteristics
Cenozoic	Quaternary	Alluvial and terrace deposits	0-155	Sand, fine- to very coarse-grained, and gravel; contains much silt and clay near surface	Can yield as much as 2,500 gal/min from a large-diameter well
Cenozoic	Tertiary	Wilcox Group	0-200	Sand, silt, and clay, gray and greenish to dark brown	Not considered a potential source of water in the study area
Cenozoic	Tertiary	Midway Group	0-380	Clay, silty, in part, with minor quantities of sandy, fossiliferous limestone at the base	Not considered sources of water in the study area
Mesozoic	Cretaceous	Arkadelphia Marl	0-30	Clay, silty and sandy in part, interbedded light and dark gray, lignitic in part	
Mesozoic	Cretaceous	Nacatoch Sand	0-300	Sand, medium- to coarse-grained, clayey in part, glauconitic, phosphatic, maroon to brown, contains minor layers of reddish-brown clay	Utilized in the study area only for domestic purposes in the outcrop
Mesozoic	Cretaceous	Saratoga Chalk	0-117	Upper unit - clay; middle unit - interbedded sand and clay; lower unit - chalk	Not considered a source of water in the study area
Paleozoic	Pennsylvanian	Atoka Formation	0-4,600	Sandstone, medium-grained, interbedded with dark shale	Yields small quantities of water to wells in the weathered zones in the outcrop area. Most wells yield 2 to 5 gal/min. In some areas, fracture zones and bedding planes may yield up to 25 gal/min.
		Bloyd Shale	0-628	Shale, dark, fissile; contains beds of of sandy, gray limestone	
		Hale Formation	0-980	Upper part - massive limestone, shaly layers; lower part - shale, fissile, dark	
	Mississippian	Pitkin Limestone	0-219	Limestone, crystalline, gray-black	
		Fayetteville Shale	0-297	Shale, dark; black sandstone beds near top	
		Batesville Sandstone	0-457	Sandstone, medium-grained with basal limestone	
		Ruddell Shale		Shale, fissile, dark gray-green	
		Moorefield Formation		Shale, platy, gray-black	
		Boone Formation (including St. Joe Limestone Member)	0-388	Chert, dense, or cherty limestone; contains a basal pink to maroon, finely crystalline limestone	Weathered rubble of limestones yield 2 to 5 gal/min to wells. Wells tapping solution channels can yield as much as 25 gal/min.
		Chattanooga Shale	0-70	Shale, black, bituminous, with basal sandstone	
	Devonian	Penters Chert	0-260	Chert, gray to black, with interbedded limestone	

Table 1.--Generalized stratigraphic column for the study area -- Continued

(modified from Caplan, 1957; Caplan, 1960; and Albin and others, 1967)

Erathem	System	Geologic unit	Thickness in feet	Description	Water-yielding characteristics
Paleozoic	Silurian	Lafferty Limestone	0-254	Limestone, earthy, thinly bedded, red to gray	Commonly yield 5 to 10 gal/min from solution channels, bedding planes, and fractures. Yields from some wells may exceed 50 gal/min.
		St. Clair Limestone		Limestone, pinkish-gray	
		Brassfield Limestone		Limestone, light gray, containing vugs	
	Ordovician	Cason Shale	0-57	Shale, platy to fissile, black and gray	
		Fernvale Limestone	0-108	Limestone, coarsely crystalline, white, gray, pink	
		Kimmswick Limestone	0-400	Limestone, sacchroidal, white to gray, fossiliferous	
		Plattin Limestone		Limestone, dense, light gray to blue gray	
		Joachim Dolomite	0-117	Dolomite, silty, gray to brown, some sandstone	
		St. Peter Sandstone	0-158	Sandstone, medium-grained, white, frosted grains	
		Everton Formation	0-1,180	Dolomite, dense, gray to brown, and sandstone	
		Powell Dolomite	0-404	Dolomite, silty, shaly; sandstone and sandy dolomite	Solution channels and fractures yield 5 to 10 gal/min. Yields in some wells may exceed 50 gal/min.
		Cotter Dolomite	0-527	Dolomite, light gray to brown, cherty	
		Jefferson City Dolomite	100-496	Dolomite, cherty, silty, gray to brown. Minor beds of sandstone	
		Roubidoux Formation	132-455	Dolomite, dolomitic sandstone, and chert	Average yield is less than 150 gal/min but as much as 450 gal/min is possible
		Gasconade Dolomite and Van Buren Formation (including Gunter Sandstone Member)	319-600	Dolomite, cherty, light brown-gray. Basal Gunter Sandstone Member, white to gray quartz sandstone.	Wells commonly yield 150 to 300 gal/min. Can yield as much as 500 gal/min.
	Cambrian	Eminence and Potosi Dolomites	307-389	Dolomite, cherty, light colored	Little is known about water yields of these formations in Arkansas. With the exception of the Eminence and Potosi, these formations yield less than 50 gal/min in southern Missouri. The Eminence and Potosi have reportedly yielded as much as 230 gal/min in a Benton County well.
		Derby and Doe Run Dolomites	---	Dolomite, granular, cherty, sandy, silty	
		Davis Formation		Dolomite, sandy, shaly	
		Bonneterre Dolomite	0-71	Dolomite, light gray, glauconitic	
		Lamotte Sandstone	0-59	Quartzose sandstone, locally arkosic	
	Precambrian	Igneous Rocks			

PURPOSE AND SCOPE

The purposes of this report are to (1) describe the ground-water resources and general geologic characteristics of the basin in Arkansas, (2) describe the significant water-yielding units in more detail, and (3) examine specific ground-water problems and potential problems. General physiographic and geologic characteristics of the study area including topography, geologic structure, and lithologies present, are described in this report. In addition, general hydrologic characteristics of the study area including ground-water availability, ground-water use, and ground-water quality, are described. Several regionally important water-yielding units are described in more detail. These units included the Eminence and Potosi Dolomites, the Gasconade Dolomite and the Van Buren Formation, the Roubidoux Formation, and outcrops of Paleozoic rocks in the Plateaus, and the Nacatoch Sand and Quaternary deposits in the Coastal Plain. The availability and quality of water from each of these units are discussed in detail. Ground-water availability and quality problems in the study area also are described in detail.

The study area includes all of the upper White River basin in Arkansas. For convenience, ground-water use data were assembled by county for the 17-county area shown in figure 3. The 17-county area approximates but does not correspond exactly to the study area.

GENERAL HYDROLOGY OF THE STUDY AREA

Ground water is available from nearly all of the geologic units in the study area. However, many of the units do not yield enough water for domestic use. Several subsurface Paleozoic units yield large amounts of water in the Ozark Plateaus, but the depth of these units makes drilling expensive. In the Plateaus, the most commonly used ground-water sources are the Paleozoic units which crop out, but they commonly yield less than 10 gal/min. In the Coastal Plain, the Quaternary deposits at the surface yield as much as 2,500 gal/min of water suitable for most uses.

Ground-water withdrawals in the 17-county area approximating the study area totaled 304 million gallons per day (Mgal/d) in 1985 of which almost 92 percent (278 Mgal/d) was withdrawn from the Quaternary alluvial deposits which crop out along the eastern edge of the basin in Independence, Lawrence, Randolph, and White Counties (Holland, 1987). Pumpage from the Paleozoic rocks that underlie the majority of the 17-county area accounted for the remaining 8 percent (25 Mgal/d) of the total water withdrawn.

Although most of the ground water withdrawn in the 17-county area is pumped from wells in Quaternary deposits, the aquifers in the Paleozoic rocks are far more significant areally; in most areas, they provide the only source of ground water (table 2). Additional information on ground-water use in the 17-county area is contained in tables 3 and 4.

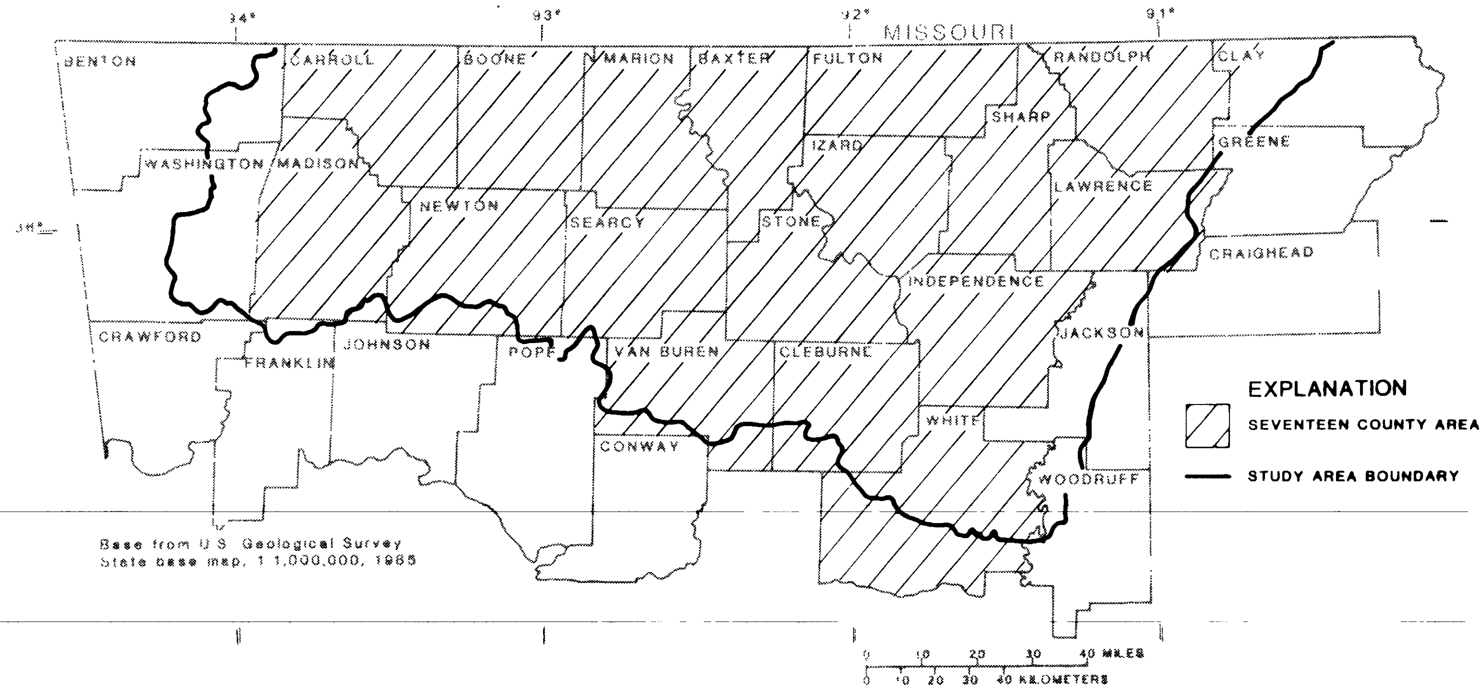

Figure 3.--Location of the 17-county area used for ground-water use data compilation.

Table 2.--Withdrawals of ground water from aquifers in the study area in 1985

[Holland, 1987; withdrawals in million gallons per day]

County	Rocks of Paleozoic age, undifferentiated	Deposits of Quaternary age	County total
Baxter	2.31	---	2.31
Boone	2.66	---	2.66
Carroll	2.82	---	2.82
Cleburne	1.23	---	1.23
Fulton	.94	---	.94
Independence	1.79	32.55	34.34
Izard	1.49	---	1.49
Lawrence	.16	153.39	153.55
Madison	1.49	---	1.49
Marion	4.75	---	4.75
Newton	.89	---	.89
Randolph	.44	42.03	42.47
Searcy	.92	---	.92
Sharp	1.89	---	1.89
Stone	.84	---	.84
Van Buren	.83	---	.83
White	---	50.48	50.48
Area total	25.45	278.45	303.90

Table 3.--Use of water in the study area, by county and use category

[Withdrawals in million gallons per day]

County	Public supply						Self-supplied industry					
	[a]1960	[b]1965	[c]1970	[d]1975	[e]1980	[f]1985	[a]1960	[b]1965	[c]1970	[d]1975	[e]1980	[f]1985
Baxter	0.20	0.34	0.46	0.38	0.55	0.46	0.01	0.07	0.25	0.28	0.14	0.39
Boone	.61	.02	.05	1.94	1.98	1.22	.0	.01	1.65	.0	.05	.0
Carroll	.07	.55	1.11	1.42	1.46	1.75	.01	.0	.01	.01	.01	.0
Cleburne	.0	.02	.05	.05	.12	.13	.01	.04	.12	.09	.13	.44
Fulton	.08	.12	.16	.29	.38	.34	1.30	.0	.0	.0	.02	.0
Independence	.04	.04	.10	.59	1.17	1.13	.25	.0	.03	.04	.09	.04
Izard	.14	.11	.17	.64	1.22	.86	.0	.0	.0	.01	.01	.02
Lawrence	.39	.71	.86	1.20	1.28	1.43	1.0	.0	.0	.01	.01	.01
Madison	.0	.0	.0	.01	.02	.02	.0	.0	.01	.0	.01	.16
Marion	.02	.08	.19	.41	.56	.5	.07	.07	.04	.08	.22	.32
Newton	.0	.0	.03	.08	.1	.09	.0	.0	.04	.12	.17	.12
Randolph	.0	.0	.06	.1	.16	.21	.0	.02	.01	.01	.01	.04
Searcy	.11	.11	.17	.15	.25	.24	.09	.0	.0	.0	.01	.01
Sharp	.05	.09	.98	1.05	1.42	1.30	.0	.0	.0	.0	.01	.0
Stone	.05	.09	.0	.0	.02	.02	.0	.01	.01	.03	.05	.01
Van Buren	.0	.0	.1	.02	.04	.04	.01	.0	.0	.0	.01	.0
White	.43	.33	.28	.3	.55	.49	.15	.04	.05	.05	.04	.02
Total	2.19	2.61	4.77	8.63	11.28	10.23	2.90	.26	2.22	.73	.99	1.58

County	Rural						Irrigation[g]					
	[a]1960	[b]1965	[c]1970	[d]1975	[e]1980	[f]1985	[a]1960	[b]1965	[c]1970	[d]1975	[e]1980	[f]1985
Baxter	0.38	0.31	0.77	0.92	1.13	1.46	0.0	0.06	0.07	0.05	0.0	0.0
Boone	.45	.48	.76	1.34	1.09	1.44	.0	.03	.05	1.87	.11	.0
Carroll	.61	.50	.79	1.27	.80	1.07	.0	.01	.03	.0	.0	.0
Cleburne	.35	.41	.73	.71	.78	.66	.0	.01	.01	.0	.0	.0
Fulton	.27	.26	.42	.84	.58	.60	.0	.0	.0	.0	.0	.0
Independence	1.12	.71	1.15	.83	1.13	1.52	1.5	2.05	4.70	7.08	17.44	31.65
Izard	.33	.27	.43	.66	.53	.58	.0	.0	.01	.0	.09	.03
Lawrence	.45	.46	.58	.81	.68	1.77	19.61	16.72	23.33	75.34	152.14	150.34
Madison	.87	.60	.96	1.43	1.13	1.31	.0	.21	.19	.0	.0	.0
Marion	.23	.25	.34	.77	.63	3.93	.0	.03	.0	3.46	3.97	.0
Newton	.25	.28	.42	.65	.56	.68	.0	.03	.01	1.73	.0	.0
Randolph	.35	.37	.56	1.00	.79	1.14	3.16	2.97	3.57	18.16	42.32	41.08
Searcy	.29	.33	.45	.80	.66	.67	.0	.0	.0	.0	.0	.0
Sharp	.24	.20	.22	.35	.46	.55	.0	.0	.01	.0	.0	.04
Stone	.36	.26	.46	.78	.76	.81	.0	.0	.01	.04	.02	.0
Van Buren	.38	.32	.52	.56	.66	.77	.0	.0	.0	.0	.02	.02
White	1.02	1.08	1.85	1.99	1.65	2.54	1.42	2.87	4.66	13.59	50.21	47.43
Total	7.95	7.09	11.41	15.71	14.02	21.50	25.69	24.99	36.65	121.32	266.32	270.59

[a] Stephens and Halberg, 1961

[b] Halberg and Stephens, 1966

[c] Halberg, 1972

[d] Halberg, 1977

[e] Holland and Ludwig, 1981

[f] Holland, 1987

[g] Includes fish and minnow farms

Table 4.--Total ground-water use from the study area, by county, 1960 through 1985

[Withdrawals in million gallons per day]

County	Total ground-water use					
	[a]1960	[b]1965	[c]1970	[d]1975	[e]1980	[f]1985
Baxter	0.59	0.78	1.55	1.63	1.82	2.31
Boone	1.06	.54	2.51	5.15	3.23	2.66
Carroll	.69	1.06	1.94	2.70	2.27	2.82
Cleburne	.36	.48	.91	.85	1.03	1.23
Fulton	1.65	.38	.58	1.13	.98	.94
Independence	2.91	2.80	5.98	8.54	19.83	34.34
Izard	.47	.38	.61	1.31	1.85	1.49
Lawrence	21.45	17.89	24.77	77.36	154.11	153.55
Madison	.87	.81	1.16	1.44	1.16	1.49
Marion	.32	.43	.57	4.72	5.38	4.75
Newton	.25	.31	.5	2.58	.83	.89
Randolph	3.51	3.36	4.20	19.72	43.28	42.47
Searcy	.49	.44	.62	.95	.92	.92
Sharp	.29	.29	1.21	1.40	1.89	1.89
Stone	.41	.36	.48	.85	.85	.84
Van Buren	.39	.32	.62	.58	.73	.83
White	3.02	4.32	6.84	15.93	52.45	50.48
Area total	38.73	34.95	55.05	146.39	292.61	303.90

[a] Stephens and Halberg, 1961

[b] Halberg and Stephens, 1966

[c] Halberg, 1972

[d] Halberg, 1977

[e] Holland and Ludwig, 1981

[f] Holland, 1987

Ground-water withdrawals from the Paleozoic rocks in the 17-county area have recently decreased while withdrawals from Quaternary deposits have consistently increased. Ground-water withdrawals from Paleozoic rocks, after increasing for 15 years, peaked in 1980 and decreased 16 percent between 1980 and 1985. Withdrawals in 1985 decreased 9 percent compared to the withdrawals in 1975 (fig. 4). In contrast, withdrawals from Quaternary deposits in the 17-county area increased 136 percent during the same period. Pumpage from Quaternary deposits increased only 4 percent between 1980 and 1985.

In 1985, 89 percent (270.59 Mgal/d) of the water withdrawn in the 17-county area was used for irrigation. More than 99 percent of this water was pumped from the Quaternary deposits in four counties along the eastern edge of the 17-county area. This is the only part of the 17-county area where substantial irrigation occurs. Rural use accounted for the majority of ground

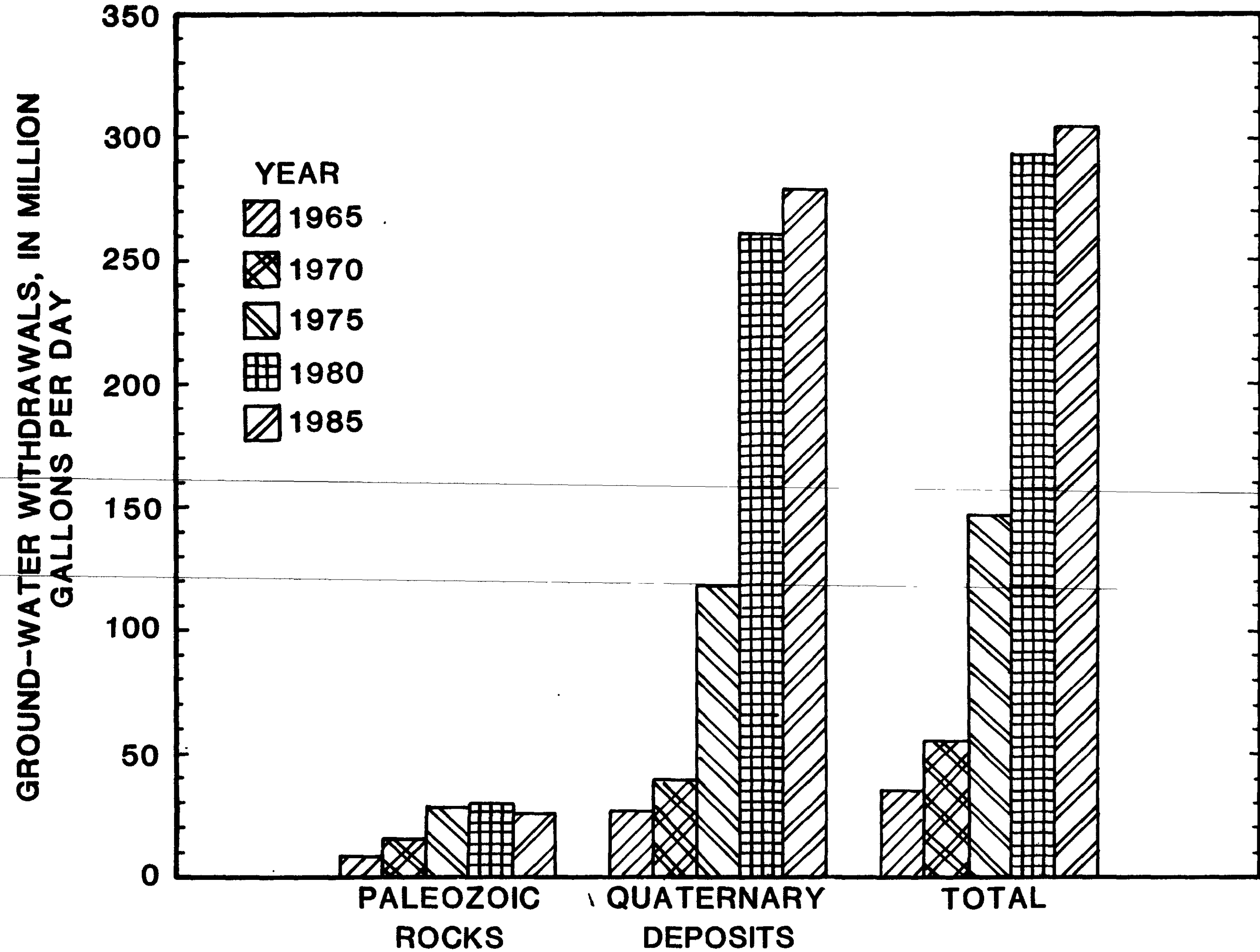

Figure 4.--Ground-water withdrawals 1965 to 1985.

water withdrawn in the remaining counties. Self-supplied industry accounted for only 0.5 percent (1.53 Mgal/d) of the ground water withdrawn in the 17-county area in 1985. Fluctuations in pumpage in each of these categories over the past 25 years are shown in figure 5.

Water-use data for the Ozark Plateaus, which are overlain by consolidated rocks, are undifferentiated as to source unit. The uncertainty of source unit occurs because wells in the consolidated rocks generally are uncased, except at the surface. As a result, water withdrawn from a well may have been contributed by any unit exposed to the well bore.

Ground-water quality in the Ozark Plateaus in the study area is closely related to the mineral content of the Paleozoic geologic units. The ground water at shallow depths in the Plateaus is primarily of the calcium- and magnesium-bicarbonate type (Lamonds and others, 1969) and generally contains excessive amounts of iron and is very hard (Lamonds, 1972). Ground water in the Plateaus generally is usable without treatment for rural, domestic, and some industrial uses; but requires softening and removal of iron to be made acceptable for public supplies and most industrial uses (Lamonds and others, 1969).

The Quaternary deposits of the Mississippi Alluvial Plain yield a hard to very hard, calcium-magnesium-bicarbonate water (Lamonds and others, 1969). Ground water from these deposits also is characterized by excessive iron concentrations. Locally high chloride concentrations have been observed in ground water from these deposits near Cord and Bald Knob (Bryant and others, 1985).

Ground-water quality data are listed by geologic unit in table 5. The recommended limits for several of these constituents, as established under the Safe Drinking Water Act (U.S. Environmental Protection Agency, 1986a; 1986b), can be found in tables 6 and 7. The Arkansas Department of Health uses the National Primary Standards to set State standards for public water-supply systems.

GROUND-WATER RESOURCES OF MAJOR WATER-YIELDING UNITS

Eminence and Potosi Dolomites

Geology

These formations are undifferentiated and occur only in the subsurface at a depth of between 2,000 ft and over 3,500 ft below land surface. The Eminence Dolomite marks the top of the Cambrian section in Arkansas. These formations consist of more than 300 ft of light-colored, crystalline dolomite with some associated chert.

Hydrology

The Eminence and Potosi Dolomites are important sources of ground water in southern Missouri, but ground water from these formations is seldom used in Arkansas because of the availability of water from the overlying Roubidoux Formation and Gunter Sandstone Member of the Van Buren Formation. Only a few

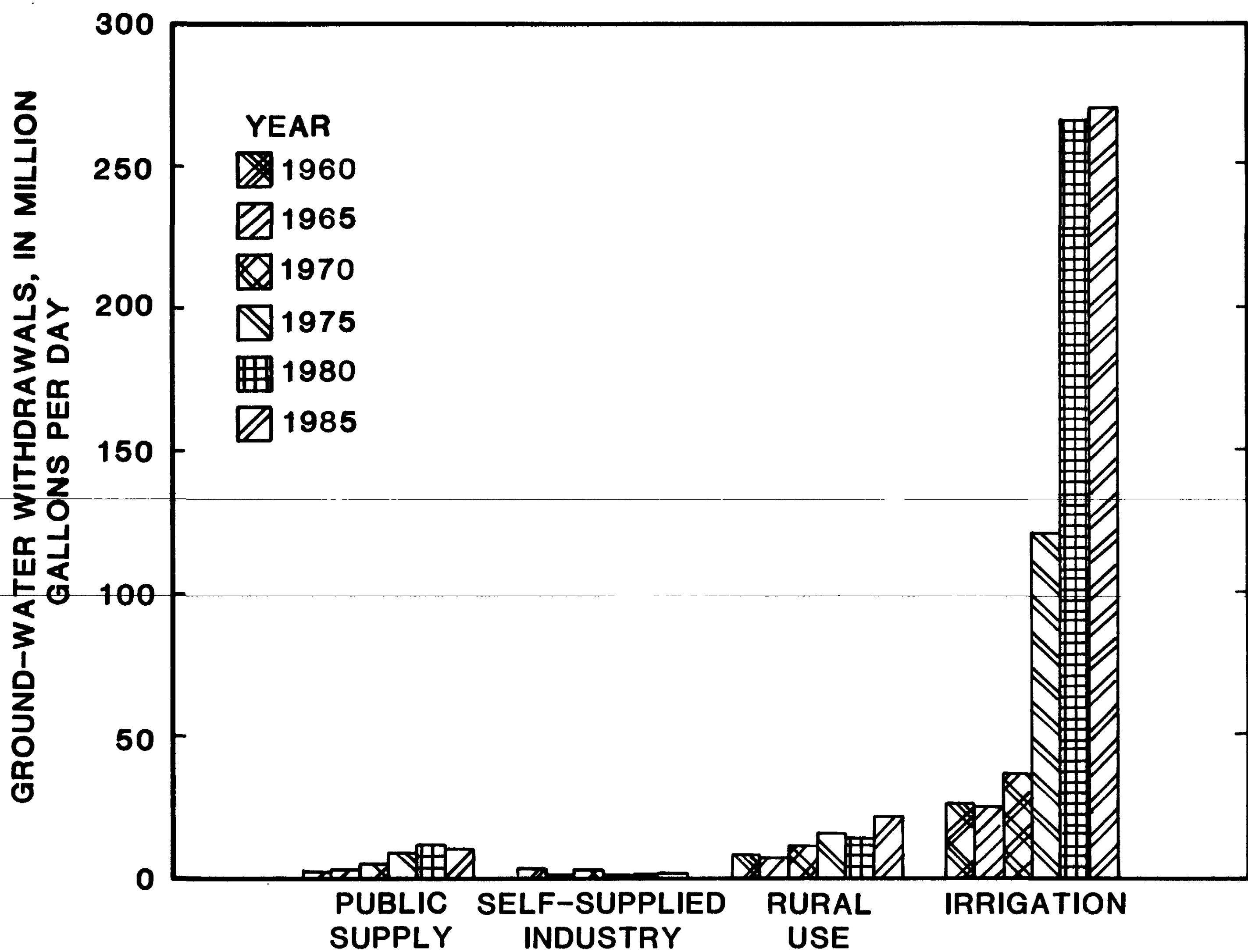

Figure 5.--Ground-water withdrawals for each use category, 1960 to 1985.

Table 5.--Ground-water quality in the various geologic units

[Values are means; °C = degrees Celsius; pcu = platinum-cobalt units; mg/L = milligrams per liter; µg/L = micrograms per liter; µS = microsiemens per centimeter at 25 degrees Celsius]

Geologic unit	Temperature (°C) (00010)	Color (pcu) (00080)	Specific conductance (µS) (00095)	pH (00400)	Bicarbonate (mg/L as HCO_3) (00440)	Carbonate (mg/L as CO_3) (00445)	Carbonate hardness (mg/L as $CaCO_3$) (00410)	Total hardness (mg/L as $CaCO_3$) (00900)	Dissolved calcium (mg/L as Ca) (00915)	Dissolved magnesium (mg/L as Mg) (00925)	Dissolved iron (µg/L as Fe) (01046)
Quaternary deposits	17.3	5.0	895	7.2	200	---	168	184	52.2	13.1	2,822
Cretaceous rocks	19.0	---	695	7.7	450	---	368	390	85.0	42.0	---
Paleozoic rocks, undifferentiated	16.4	3.3	460	7.3	235	1	187	206	59.0	14.2	43
Gunter Sandstone	16.2	4.1	440	7.8	264	0	225	190	42.4	22.6	504
Roubidoux	15.5	5.3	420	7.8	288	0	231	248	50.7	26.3	56
Eminence-Potosi	---	5.0	450	8.0	255	0	212	258	39.2	52.5	30

Geologic unit	Dissolved sodium (mg/L as Na) (00930)	Sodium absorption ratio (00931)	Dissolved potassium (mg/L as K) (00935)	Dissolved chloride (mg/L as Cl) (00940)	Dissolved sulfate (mg/L as SO_4) (00945)	Dissolved fluoride (mg/L as F) (00950)	Dissolved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dissolved nitrate (mg/L as N) (00618)
Quaternary deposits	23.0	0.75	2.77	[a] 202.5	22.1	0.17	30.4	290	1.46
Cretaceous rocks	32.0	.70	2.10	18.0	56.0	.10	16.0	447	0.
Paleozoic rocks, undifferentiated	14.8	.66	2.52	14.8	20.9	.22	11.3	310	1.52
Gunter Sandstone	21.4	1.57	2.44	12.1	15.5	.45	9.6	294	1.19
Roubidoux	14.4	.55	2.21	11.2	18.6	.71	8.2	266	2.79
Eminence-Potosi	8.7	.27	1.90	13.2	17.5	.24	9.9	270	3.01

[a] The median value was 18 mg/L, and more than 75 percent of the values are less than 100 mg/L.

Table 6.--National interim primary drinking-water regulations[1]

[Data in milligrams per liter; tu = turbidity; pCi/L = picocurie per liter; mrem = millirem (one thousandths of a rem)]

Constituent	Maximum concentration
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05
Fluoride	4.0
Turbidity	1.5 tu
Coliform bacteria	1/100 mL (mean)
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP (silvex)	0.01
Total trihalomethanes [The sum of the concentrations of bromodichloromethane, dicromochloromethane, tribromomethane (bromoform) and trichloromethane (chloroform)]	0.10
Radionuclides:	
Radium 226 and 228 (combined)	5 pCi/L
Gross alpha particle activity	15 pCi/L
Gross beta particle activity	4 mrem/year

[1]U.S. Environmental Protection Agency, 1977; 1986a

Table 7.--National secondary drinking-water regulations[1]

[Data in milligrams per liter unless otherwise specified]

Constituent	Maximum concentration
Chloride	250
Color	15 color units
Copper	1
Corrosivity	Noncorrosive
Dissolved solids	500
Foaming agents	0.5
Iron	300 µg/L
Manganese	0.05
Odor	3 (threshold odor number)
pH	6.5-8.5 units
Sulfate	250
Zinc	5

[1] Modified from U.S. Environmental Protection Agency, 1986b

wells in the study area are producing from these formations. Melton (1976) reports a well producing from the Eminence and Potosi Dolomites in Benton County with a yield of 230 gal/min. U.S. Geological Survey files contain the record of two additional wells in these formations in Carroll and Boone Counties, each with a yield of approximately 260 gal/min. These two wells range in depth from 1,400 to 2,100 ft. This information suggests that the Eminence and Potosi Dolomites can yield significant amounts of water in the northwestern part of the study area in Benton, Carroll, and Boone Counties. Elsewhere, these formations contain saline water or are inaccessible because of their great depth.

Little information concerning which horizons in the Eminence and Potosi Dolomites yield water is available. Melton (1976) maintains that production is from the Potosi, the lower of the two formations. This assertion is supported by the fact that many wells penetrate the top of the Eminence without any increase in yield. In addition, in southern Missouri, where water from these formations is heavily used, the Potosi yields more water than the Eminence.

Water levels in wells penetrating the Eminence and Potosi Dolomites have risen as much as 190 ft between 1981 and 1986. These large increases are indicative of the extreme variability in water levels in these formations. Depth to water ranges from 210 to 450 ft below land surface depending on the altitude of the well.

Water Quality

All available water-quality data for the Eminence and Potosi Dolomites are summarized in table 8. The tabulation includes six sample analyses from Benton, Boone, and Carroll Counties. The limited number and distribution of samples precludes an accurate evaluation of the quality of water from the Eminence and Potosi Dolomites throughout the entire study area. However, these data do indicate that the water quality is suitable in at least some areas in the northwestern part of the study area. The only constituent exceeding or approaching National Primary Drinking Regulations (U.S. Environmental Protection Agency, 1986a) is nitrate. One sample had nitrate levels at the limit, 10 mg/L as nitrogen, but other samples had little or no nitrate, indicating that high nitrate levels probably are local problems that do not occur throughout the entire extent of the aquifer.

Gasconade Dolomite and Van Buren Formation

Geology

These Ordovician formations are undifferentiated in Arkansas, and consist chiefly of light-colored dolomites with associated chert. The only exception to this description is the Gunter Sandstone Member at the base of the Van Buren Formation which has been described as both a dolomitic sandstone (Melton, 1976) and a sandy dolomite (Caplan, 1960). The Gasconade Dolomite and the Van Buren Formation are from approximately 300 to 600 ft thick excluding the Gunter Sandstone Member, which ranges in thickness from 20 to 100 ft (fig. 6).

Hydrology

Most of the water withdrawn from the Gasconade and Van Buren interval is from the basal Gunter Sandstone Member. Yields of wells penetrating the Gunter Sandstone in the study area average greater than 100 gal/min, with yields locally of over 500 gal/min (Melton, 1976). The dolomites that make up the rest of the interval yield water in smaller quantities (Caplan, 1960). Recent measurements (1987) indicate that water levels in the Gunter Sandstone range from 14 to 485 ft below land surface (Freiwald and Plafcan, 1987). Water levels fluctuate from year to year in the Gunter. Water levels declined as much as 60 ft in three wells in the study area between 1985 and 1986 (Edds and Remsing, 1986). The rate of change of water levels also varies areally. Although some wells had water levels almost 100 ft higher in 1986 than 1981, others declined more than 40 ft during the same 5-year period (Edds and Remsing, 1986). The variation in water levels probably is related to temporal variations in pumpage from the formation.

Table 8.-- Ground-water quality in the Eminence and Potosi Dolomites

[No. = number; °C = degrees Celsius; pcu = platinum-cobalt units; mg/L = milligrams per liter; µg = micrograms per liter; µS = microsiemens per centimeter at 25 degrees Celsius]

County		Temperature (°C) (00010)	Color (pcu) (00080)	Specific conductance (µS) (00095)	pH (00400)	Bicarbonate (mg/L as HCO_3) (00440)	Carbonate (mg/L as CO_3) (00445)	Carbonate hardness (mg/L as $CaCO_3$) (00410)	Total hardness (mg/L as $CaCO_3$) (00900)	Dissolved calcium (mg/L as Ca) (00915)	Dissolved magnesium (mg/L as Mg) (00925)
Benton	No. samples	0	1	1	2	1	1	1	3	3	2
	Minimum	--	5	450	7.6	220	0	184	180	37.0	21.0
	Maximum	--	5	450	7.8	220	0	184	680	43.0	140.0
	Mean	--	5	450	7.7	220	0	184	347	40.0	80.5
Boone	No. samples	0	1	0	1	1	1	1	2	1	1
	Minimum	--	5	--	8.1	290	0	240	120	49.0	30.0
	Maximum	--	5	--	8.1	290	0	240	250	49.0	30.0
	Mean	--	5	--	8.1	290	0	240	185	49.0	30.0
Carroll	No. samples	0	0	0	1	0	0	0	1	1	1
	Minimum	--	--	--	8.4	--	--	--	140	27.0	19.0
	Maximum	--	--	--	8.4	--	--	--	140	27.0	19.0
	Mean	--	--	--	8.4	--	--	--	140	27.0	19.0

County		Dissolved iron (µg/L as Fe) (01046)	Dissolved sodium (mg/L as Na) (00930)	Sodium absorption ratio (00931)	Dissolved potassium (mg/L as K) (00935)	Dissolved chloride (mg/L as Cl) (00940)	Dissolved sulfate (mg/L as SO_4) (00945)	Dissolved fluoride (mg/L as F) (00950)	Dissolved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dissolved nitrate (mg/L as N) (00618)
Benton	No. samples	1	1	1	1	3	3	2	1	1	3
	Minimum	20.0	12.0	0.4	1.9	21.0	13.0	0.20	9.9	222.0	0.0
	Maximum	20.0	12.0	.4	1.9	25.0	19.0	.38	9.9	222.0	10.0
	Mean	20.0	12.0	.4	1.9	22.7	16.0	.29	9.9	222.0	3.4
Boone	No. samples	1	1	1	0	2	2	2	0	1	2
	Minimum	40.0	11.0	.3	--	2.5	20.0	.20	--	318.0	.01
	Maximum	40.0	11.0	.3	--	5.0	21.0	.23	--	318.0	5.00
	Mean	40.0	11.0	.3	--	3.8	20.5	.22	--	318.0	2.51
Carroll	No. samples	0	1	1	0	1	1	1	0	0	0
	Minimum	--	3.0	.1	--	3.5	16.0	.20	--	--	--
	Maximum	--	3.0	.1	--	3.5	16.0	.20	--	--	--
	Mean	--	3.0	.1	--	3.5	16.0	.20	--	--	--

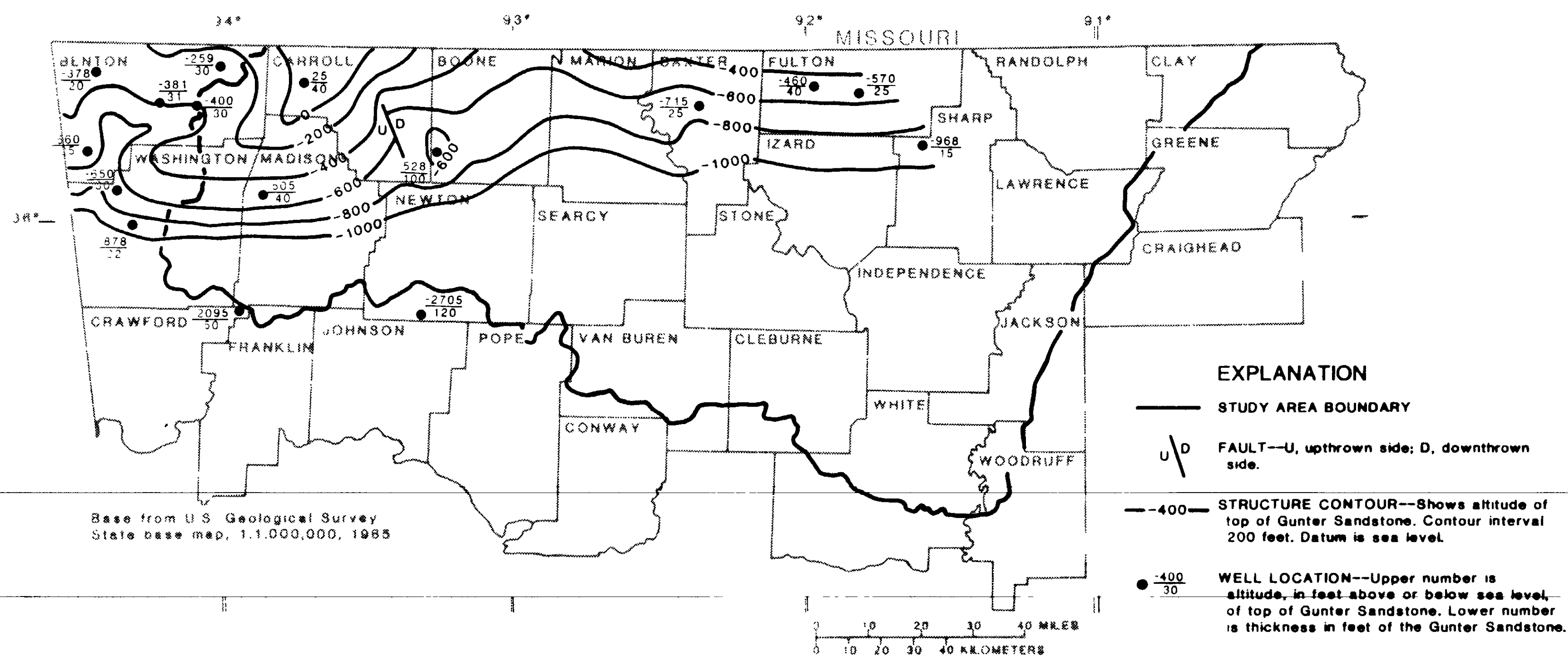

Figure 6.--Structure of the top of the Gunter Sandstone, member of the Van Buren Formation (modified from Lamonds, 1972).

Water Quality

Analyses of water samples from wells penetrating the Gunter Sandstone Member indicate that water in this unit is hard to very hard, and calcium-magnesium-bicarbonate in ionic composition. Hard water is defined as having a hardness range of 121 to 180 mg/L of calcium carbonate. Water with hardness greater than 180 mg/L as calcium carbonate is described as very hard (Hem, 1985). A summary of the available water-quality data is given in table 9.

Roubidoux Formation

Geology

The Roubidoux Formation, of Ordovician age, exists only in the subsurface in the study area. It crops out in southern Missouri and dips to the south (fig. 7). The Roubidoux ranges from approximately 130 to 455 ft in thickness and consists chiefly of dolomite, dolomitic sandstone, and chert (Caplan, 1960). The top of the formation ranges from 1,100 ft below land surface near the Arkansas-Missouri State line to about 3,500 ft below land surface at the boundary between the Boston Mountains and Arkansas Valley physiographic sections.

Hydrology

Recharge to the Roubidoux occurs primarily in the outcrop area in Missouri. The formation can yield as much as 450 gal/min but generally yields less than 150 gal/min.

The hydrograph of a well completed in the Roubidoux Formation, (fig. 8) owned by the city of Yellville, indicates the considerable variability of water levels from year to year. Water levels in other wells completed in the Roubidoux rose as much as 180 ft and declined by as much as 28 ft between 1985 and 1986. This variability probably results from changes in pumping. Because of the large temporal variations in depth to water and large spatial variations due to topographic relief, the depth to water can vary greatly. Water levels in the Roubidoux are generally nearest (less than 50 ft) to land surface near the Arkansas-Missouri State line and deepest (more than 200 ft) in wells penetrating the Roubidoux on the crest of the Boston Mountains.

Water Quality

Analyses of water samples from the Roubidoux Formation indicate that it is a hard to very hard calcium-magnesium-bicarbonate water. A complete summary of the available water-quality data can be found in table 10. One sample in Baxter County contained an iron concentration exceeding the Primary Drinking Water Standard (U.S. Environmental Protection Agency, 1986b), although all other samples from the Roubidoux had iron concentrations well below the recommended limit. Nitrate concentrations exceeding the allowable limit have been found in at least one sample from a well in Marion County, but other samples from the Roubidoux have shown little or no nitrate. This seems to indicate that high nitrate concentrations in ground water from the Roubidoux

Table 9.--Ground-water quality in the Van Buren Formation, Gunter Sandstone Member

[No. = number; °C = degrees Celsius; pcu = platinum-cobalt units; mg/L = milligrams per liter; µg/L = micrograms per liter; µS = microsiemens per centimeter at 25 degrees Celsius]

County		Temperature (°C) (00010)	Color (pcu) (00080)	Specific conductance (µS) (00095)	pH (00400)	Bicarbonate (mg/L as HCO_3) (00440)	Carbonate (mg/L as CO_3) (00445)	Carbonate hardness (mg/L as $CaCO_3$) (00410)	Total hardness (mg/L as $CaCO_3$) (00900)	Dissolved calcium (mg/L as Ca) (00915)	Dissolved magnesium (mg/L as Mg) (00925)
Baxter	No. samples	0	0	0	1	1	0	0	2	2	2
	Minimum	--	--	--	7.5	380	--	--	260	50.0	33.0
	Maximum	--	--	--	7.5	380	--	--	290	60.0	35.0
	Mean	--	--	--	7.5	380	--	--	275	55.0	34.0
Benton	No. samples	0	1	0	0	0	0	0	1	1	1
	Minimum	--	5	--	--	--	--	--	170	37.0	18.0
	Maximum	--	5	--	--	--	--	--	170	37.0	18.0
	Mean	--	5	--	--	--	--	--	170	37.0	18.0
Boone	No. samples	1	1	2	4	4	4	4	5	4	4
	Minimum	16.0	2	353	7.3	210	0	170	36	33.0	19.0
	Maximum	16.0	2	370	8.1	220	0	182	190	42.0	22.0
	Mean	16.0	2	362	7.7	215	0	175	149	39.3	20.3
Carroll	No. samples	0	1	0	2	0	0	0	4	2	2
	Minimum	--	5	--	8.2	--	--	--	150	34.0	16.0
	Maximum	--	5	--	8.4	--	--	--	230	48.0	27.0
	Mean	--	5	--	8.3	--	--	--	195	41.0	21.5
Fulton	No. samples	3	3	4	4	2	2	4	4	4	4
	Minimum	15.0	0	428	7.7	290	0	234	23	6.2	1.8
	Maximum	18.0	2	479	8.2	320	0	270	250	52.0	29.0
	Mean	16.7	1	452	7.9	305	0	250	186	38.8	21.5
Madison	No. samples	0	2	0	0	0	0	0	2	1	1
	Minimum	--	5	--	--	--	--	--	130	34.0	19.0
	Maximum	--	5	--	--	--	--	--	160	34.0	19.0
	Mean	--	5	--	--	--	--	--	145	34.0	19.0
Marion	No. samples	0	0	0	1	0	0	0	1	1	1
	Minimum	--	--	--	7.7	--	--	--	280	58.0	33.0
	Maximum	--	--	--	7.7	--	--	--	280	58.0	33.0
	Mean	--	--	--	7.7	--	--	--	280	58.0	33.0
Newton	No. samples	0	2	0	1	0	0	0	3	2	2
	Minimum	--	5	--	7.5	--	--	--	130	37.0	18.0
	Maximum	--	5	--	7.5	--	--	--	230	54.0	23.0
	Mean	--	5	--	7.5	--	--	--	177	45.5	20.5

Table 9.--Ground-water quality in the Van Buren Formation, Gunter Sandstone Member -- Continued

County		Temperature (°C) (00010)	Color (pcu) (00080)	Specific conductance (μS) (00095)	pH (00400)	Bicarbonate (mg/L as HCO_3) (00440)	Carbonate (mg/L as CO_3) (00445)	Carbonate hardness (mg/L as $CaCO_3$) (00410)	Total hardness (mg/L as $CaCO_3$) (00900)	Dissolved calcium (mg/L as Ca) (00915)	Dissolved magnesium (mg/L as Mg) (00925)
Searcy	No. samples	1	0	1	1	0	0	1	1	1	1
	Minimum	15.0	--	550	7.7	--	--	320	180	44.0	18.0
	Maximum	15.0	--	550	7.7	--	--	320	180	44.0	18.0
	Mean	15.0	--	550	7.7	--	--	320	180	44.0	18.0
Sharp	No. samples	0	0	0	0	0	0	0	2	1	1
	Minimum	--	--	--	--	--	--	--	260	52.0	30.0
	Maximum	--	--	--	--	--	--	--	280	52.0	30.0
	Mean	--	--	--	--	--	--	--	270	52.0	30.0
Stone	No. samples	0	1	0	0	0	0	0	1	1	1
	Minimum	--	10	--	--	--	--	--	130	28.0	15.0
	Maximum	--	10	--	--	--	--	--	130	28.0	15.0
	Mean	--	10	--	--	--	--	--	130	28.0	15.0

County		Dissolved iron (μg/L as Fe) (01046)	Dissolved sodium (mg/L as Na) (00930)	Sodium absorption ratio (00931)	Dissolved potassium (mg/L as K) (00935)	Dissolved chloride (mg/L as Cl) (00940)	Dissolved sulfate (mg/L as SO_4) (00945)	Dissolved fluoride (mg/L as F) (00950)	Dissolved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dissolved nitrate (mg/L as N) (00618)
Baxter	No. samples	1	2	2	1	2	2	2	0	1	0
	Minimum	3,600	1.0	0.0	6.1	2.8	14.0	0.2	--	370.0	--
	Maximum	3,600	5.0	.1	6.1	3.0	14.0	1.0	--	370.0	--
	Mean	3,600	3.0	.05	6.1	2.9	14.0	.6	--	370.0	--
Benton	No. samples	0	0	0	0	1	1	1	0	0	1
	Minimum	--	--	--	--	7.5	16.0	.32	--	--	0.02
	Maximum	--	--	--	--	7.5	16.0	.32	--	--	.02
	Mean	--	--	--	--	7.5	16.0	.32	--	--	.02
Boone	No. samples	2	2	2	2	5	4	5	2	1	3
	Minimum	40	3.3	.1	1.6	1.3	7.7	.10	8.5	216.0	0.0
	Maximum	1,100	5.1	.2	1.7	9.4	20.0	.50	8.8	216.0	.23
	Mean	570	4.2	.15	1.65	3.7	14.18	.28	8.65	216.0	.11

Table 9.--Ground-water quality in the Van Buren Formation, Gunter Sandstone Member -- Continued

County		Dis-solved iron (µg/L as Fe) (01046)	Dis-solved sodium (mg/L as Na) (00930)	Sodium absorp-tion ratio (00931)	Dis-solved potassium (mg/L as K) (00935)	Dis-solved chloride (mg/L as Cl) (00940)	Dis-solved sulfate (mg/L as SO_4) (00945)	Dis-solved fluoride (mg/L as F) (00950)	Dis-solved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dis-solved nitrate (mg/L as N) (00618)
Carroll	No. samples	0	2	2	0	4	4	3	0	0	2
	Minimum	--	2.0	.1	--	2.2	11.0	.2	--	--	1.0
	Maximum	--	2.0	.1	--	4.0	24.0	.2	--	--	5.0
	Mean	--	2.0	.1	--	3.0	16.0	.2	--	--	3.05
Fulton	No. samples	4	4	4	4	2	2	4	4	4	0
	Minimum	0	1.2	0.0	0.7	1.6	2.0	0.0	8.4	205.0	--
	Maximum	17	170.0	16.0	3.2	74.0	8.2	.4	11.0	453.0	--
	Mean	[a] 9	43.7	4.0	1.5	20.1	4.45	[b] .16	9.45	285.3	--
Madison	No. samples	1	0	0	0	2	2	2	0	0	2
	Minimum	2	--	--	--	3.0	20.0	0.22	--	--	.23
	Maximum	2	--	--	--	110.0	49.0	3.2	--	--	4.0
	Mean	2	--	--	--	56.5	34.5	1.71	--	--	2.12
Marion	No. samples	0	0	0	0	2	1	1	0	0	1
	Minimum	--	--	--	--	9.2	7.0	.2	--	--	.07
	Maximum	--	--	--	--	9.2	7.0	.2	--	--	.07
	Mean	--	--	--	--	9.2	7.0	.2	--	--	.07
Newton	No. samples	1	0	0	0	2	3	3	0	0	3
	Minimum	70	--	--	--	3.6	17.0	.21	--	--	.2
	Maximum	70	--	--	--	12.0	28.0	.85	--	--	.68
	Mean	70	--	--	--	7.8	23.33	.44	--	--	.43
Searcy	No. samples	1	1	1	1	1	1	1	1	1	0
	Minimum	190	53.0	2.0	4.1	17.0	17.0	.8	12.0	330.0	--
	Maximum	190	53.0	2.0	4.1	17.0	17.0	.8	12.0	330.0	--
	Mean	190	53.0	2.0	4.1	17.0	17.0	.8	12.0	330.0	--
Sharp	No. samples	0	0	1	0	2	2	1	0	0	0
	Minimum	--	11.0	.3	--	1.5	3.0	.2	--	--	--
	Maximum	--	11.0	.3	--	3.0	16.0	.2	--	--	--
	Mean	--	11.0	.3	--	2.3	9.5	.2	--	--	--
Stone	No. samples	0	0	0	0	1	1	1	0	0	1
	Minimum	--	--	--	--	2.5	22.0	.76	--	--	3.4
	Maximum	--	--	--	--	2.5	22.0	.76	--	--	3.4
	Mean	--	--	--	--	2.5	22.0	.76	--	--	3.4

[a] This mean value included one < 10 vslue that was changed to 5.0.
[b] This mean value included one < 0.1 value that was changed to 0.05.

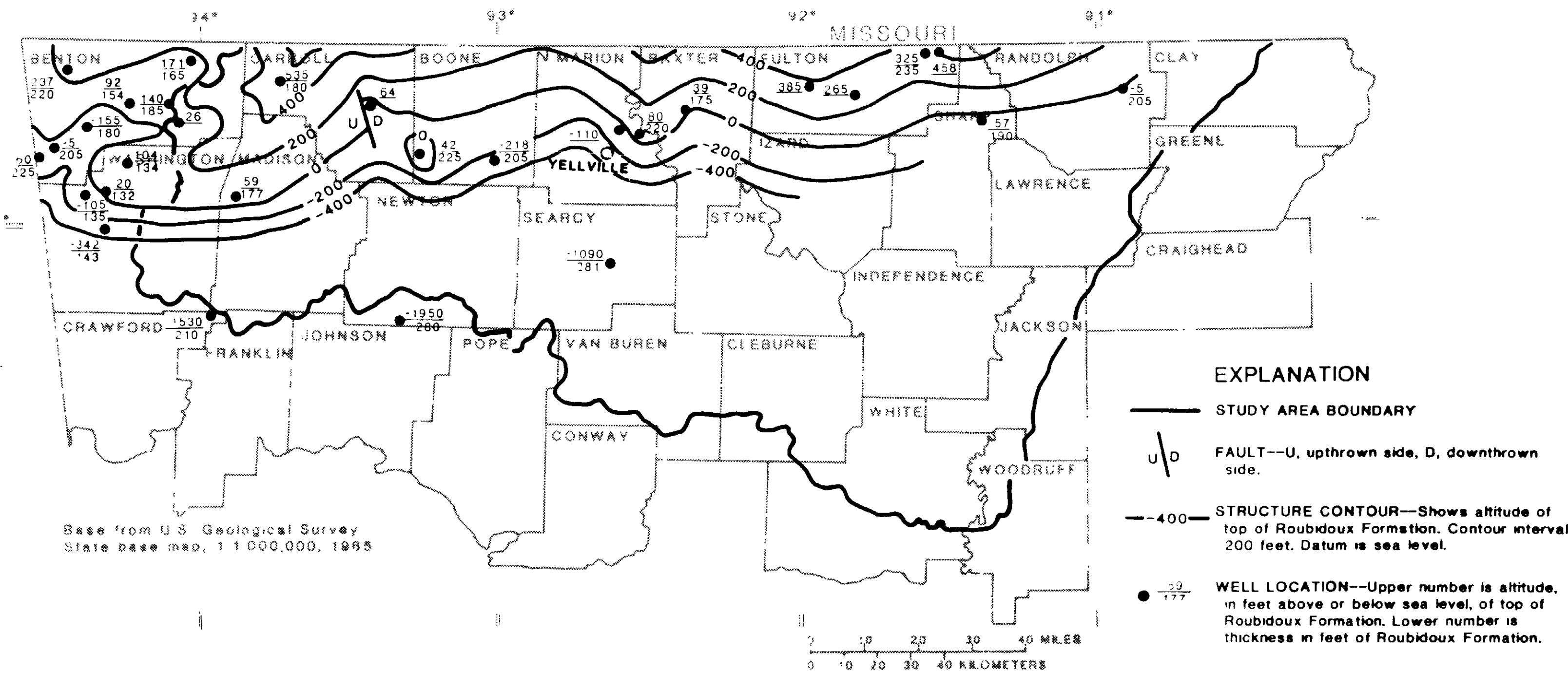

Figure 7.--Structure of the top of the Roubidoux Formation (modified from Lamonds, 1972).

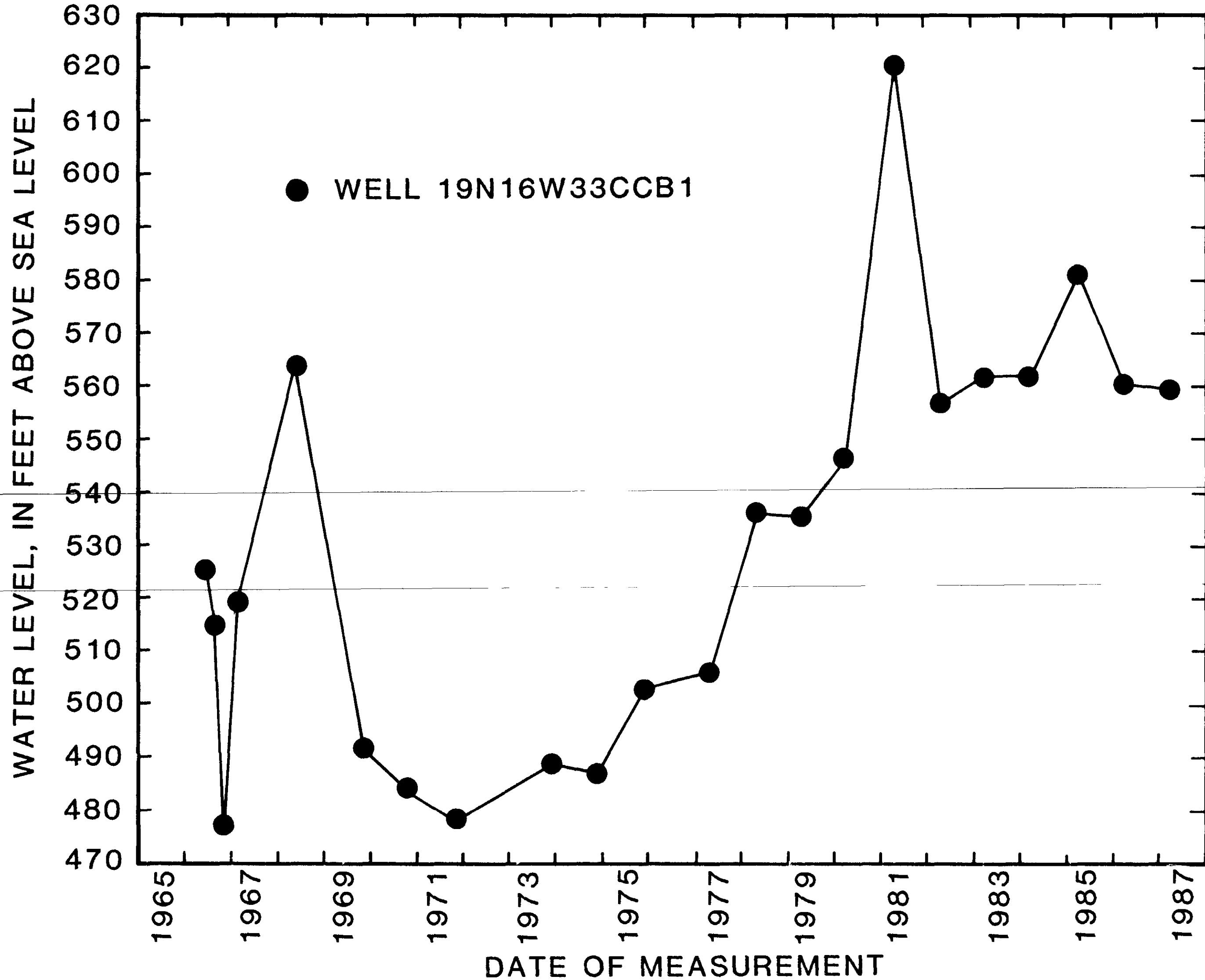

Figure 8--Hydrograph of a well penetrating the Roubidoux Formation near Yellville.

Table 10.--Ground-water quality in the Roubidoux Formation

[No. = number; °C = degrees Celsius; pcu = platinum-cobalt units; mg/L = milligrams per liter; µg/L = micrograms per liter; µS = microsiemens per centimeter at 25 degrees Celsius]

County		Temperature (°C) (00010)	Color (pcu) (00080)	Specific conductance (µS) (00095)	pH (00400)	Bicarbonate (mg/L as HCO_3) (00440)	Carbonate (mg/L as CO_3) (00445)	Carbonate hardness (mg/L as $CaCO_3$) (00410)	Total hardness (mg/L as $CaCO_3$) (00900)	Dissolved calcium (mg/L as Ca) (00915)	Dissolved magnesium (mg/L as Mg) (00925)
Baxter	No. samples	0	2	0	0	0	0	0	4	2	3
	Minimum	--	5	--	--	--	--	--	100	30.0	6.8
	Maximum	--	20	--	--	--	--	--	400	51.0	21.0
	Mean	--	13	--	--	--	--	--	223	40.5	15.6
Benton	No. samples	0	0	0	1	0	0	0	2	2	2
	Minimum	--	--	--	8.4	--	--	--	110	43.0	1.0
	Maximum	--	--	--	8.4	--	--	--	190	43.0	21.0
	Mean	--	--	--	8.4	--	--	--	150	43.0	11.0
Boone	No. samples	0	0	0	3	3	3	3	3	3	3
	Minimum	--	--	--	7.3	230	0	190.0	210	45.0	25.0
	Maximum	--	--	--	8.1	310	0	250.0	470	50.0	83.0
	Mean	--	--	--	7.8	277	0	227.3	310	48.0	46.0
Carroll	No. samples	0	1	0	1	0	0	0	2	2	2
	Minimum	--	1	--	8.3	--	--	--	250	54.0	28.0
	Maximum	--	1	--	8.3	--	--	--	280	58.0	34.0
	Mean	--	1	--	8.3	--	--	--	265	56.0	31.0
Fulton	No. samples	3	2	4	4	3	3	3	4	4	4
	Minimum	15.0	0	380	7.3	270	0	180.0	190	38.0	22.0
	Maximum	16.0	1	439	7.8	300	0	242.0	240	48.0	35.0
	Mean	15.5	1	422	7.5	287	0	214.3	223	42.5	27.8
Izard	No. samples	0	1	0	1	0	0	0	2	2	1
	Minimum	--	5	--	8.4	--	--	--	270	7.3	33.0
	Maximum	--	5	--	8.4	--	--	--	300	55.0	33.0
	Mean	--	5	--	8.4	--	--	--	285	31.2	33.0
Madison	No. samples	0	1	1	1	1	1	1	1	1	1
	Minimum	--	1	402	8.1	240	0	197.0	140	31.0	14.0
	Maximum	--	1	402	8.1	240	0	197.0	140	31.0	14.0
	Mean	--	1	402	8.1	240	0	197.0	140	31.0	14.0
Marion	No. samples	0	3	2	3	1	1	1	4	3	2
	Minimum	--	1	10	7.4	370	0	301.0	290	58.0	35.0
	Maximum	--	20	634	7.8	370	0	301.0	390	79.0	39.0
	Mean	--	9	322	7.5	370	0	301.0	330	69.0	37.0
Newton	No. samples	0	1	0	1	0	0	0	3	1	1
	Minimum	--	5	--	8.3	--	--	--	110	32.0	14.0
	Maximum	--	5	--	8.3	--	--	--	140	32.0	14.0
	Mean	--	5	--	8.3	--	--	--	127	32.0	14.0

Table 10.--Ground-water quality in the Roubidoux Formation -- Continued

County		Temperature (°C) (00010)	Color (pcu) (00080)	Specific conductance (µS) (00095)	pH (00400)	Bicarbonate (mg/L as HCO_3) (00440)	Carbonate (mg/L as CO_3) (00445)	Carbonate hardness (mg/L as $CaCO_3$) (00410)	Total hardness (mg/L as $CaCO_3$) (00900)	Dissolved calcium (mg/L as Ca) (00915)	Dissolved magnesium (mg/L as Mg) (00925)
Randolph	No. samples	0	0	0	0	0	0	0	1	0	0
	Minimum	--	--	--	--	--	--	--	320	--	--
	Maximum	--	--	--	--	--	--	--	320	--	--
	Mean	--	--	--	--	--	--	--	320	--	--
Searcy	No. samples	1	2	2	2	2	2	2	2	2	2
	Minimum	15.5	0	478	7.3	250	0	207.0	230	67.0	4.9
	Maximum	15.5	7	487	7.5	290	0	239.0	250	91.0	16.0
	Mean	15.5	4	483	7.4	270	0	223.0	240	79.0	10.5
Sharp	No. samples	0	2	1	2	1	1	1	4	3	4
	Minimum	--	4	502	7.9	330	0	272.0	260	46.0	7.6
	Maximum	--	5	502	8.5	330	0	272.0	380	76.0	46.0
	Mean	--	5	502	8.2	330	0	272.0	300	79.0	30.4

County		Dissolved iron (µg/L as Fe) (01046)	Dissolved sodium (mg/L as Na) (00930)	Sodium absorption ratio (00931)	Dissolved potassium (mg/L as K) (00935)	Dissolved chloride (mg/L as Cl) (00940)	Dissolved sulfate (mg/L as SO_4) (00945)	Dissolved fluoride (mg/L as F) (00950)	Dissolved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dissolved nitrate (mg/L as N) (00618)
Baxter	No. samples	1	1	1	0	5	4	4	0	0	2
	Minimum	300	58.00	3.00	--	2.0	7.0	0.20	--	--	0.20
	Maximum	300	58.00	3.00	--	10.0	52.0	2.00	--	--	.74
	Mean	300	58.00	3.00	--	4.6	25.0	.90	--	--	.47
Benton	No. samples	0	1	1	0	2	2	2	0	1	0
	Minimum	--	8.00	0.30	--	4.0	13.0	0.22	--	202	--
	Maximum	--	8.00	.30	--	17.0	18.0	.51	--	202	--
	Mean	--	8.00	.30	--	10.5	15.5	.37	--	202	--
Boone	No. samples	0	3	3	0	2	3	3	0	0	1
	Minimum	--	1.50	0.00	--	2.0	11.0	0.20	--	--	0.90
	Maximum	--	11.00	.30	--	5.0	40.0	.25	--	--	.90
	Mean	--	7.50	.20	--	3.5	23.7	.23	--	--	.90
Carroll	No. samples	0	1	1	0	2	2	2	0	1	2
	Minimum	--	2.00	0.00	--	2.8	11.0	0.20	--	337	0.04
	Maximum	--	2.00	.00	--	10.0	32.0	.25	--	337	2.30
	Mean	--	2.00	.00	--	6.4	21.5	.23	--	337	1.17

Table 10.--Ground-water quality in the Roubidoux Formation -- Continued

County		Dis-solved iron (µg/L as Fe) (01046)	Dis-solved sodium (mg/L as Na) (00930)	Sodium absorp-tion ratio (00931)	Dis-solved potassium (mg/L as K) (00935)	Dis-solved chloride (mg/L as Cl) (00940)	Dis-solved sulfate (mg/L as SO_4) (00945)	Dis-solved fluoride (mg/L as F) (00950)	Dis-solved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dis-solved nitrate (mg/L as N) (00618)
Fulton	No. samples	3	4	4	4	4	4	3	3	4	0
	Minimum	<10	1.50	0.00	1.3	1.5	1.2	0.00	8.5	185	--
	Maximum	90	1.90	.10	1.9	3.3	2.4	.00	11.0	298	--
	Mean	a34	1.73	.05	1.6	2.1	1.8	b .03	10.2	237	--
Izard	No. samples	0	1	1	0	2	2	2	0	0	1
	Minimum	--	2.00	0.00	--	1.0	12.0	0.2	--	--	0.14
	Maximum	--	2.00	.00	--	2.0	13.0	.2	--	--	.14
	Mean	--	2.00	.00	--	1.5	12.5	.2	--	--	.14
Madison	No. samples	0	1	1	1	1	1	1	1	1	1
	Minimum	--	36.00	1.00	5.2	7.7	14.0	1.2	7.9	214	0.0
	Maximum	--	36.00	1.00	5.2	7.7	14.0	1.2	7.9	214	.0
	Mean	--	36.00	1.00	5.2	7.7	14.0	1.2	7.9	214	.0
Marion	No. samples	2	1	1	1	5	3	3	1	1	4
	Minimum	10	2.50	0.10	3.8	2.5	8.0	0.0	8.5	360	0.05
	Maximum	20	2.50	.10	3.8	10.0	23.0	2.0	8.5	360	29.00
	Mean	15	2.50	.10	3.8	7.2	16.3	.7	8.5	360	9.41
Newton	No. samples	2	1	1	0	3	3	3	0	0	3
	Minimum	1	100.0	4.0	--	41.0	34.0	2.5	--	--	0.40
	Maximum	110	100.0	4.0	--	120.0	44.0	3.2	--	--	.45
	Mean	56	100.0	4.0	--	69.0	38.3	2.9	--	--	.42
Randolph	No. samples	1	0	0	0	1	1	1	0	0	1
	Minimum	30	--	--	--	10.0	25.0	0.2	--	--	4.0
	Maximum	30	--	--	--	10.0	25.0	.2	--	--	4.0
	Mean	30	--	--	--	10.0	25.0	.2	--	--	4.0
Searcy	No. samples	1	2	2	2	2	2	2	2	2	2
	Minimum	10	5.80	0.20	1.0	5.5	16.0	0.1	0.8	286	0.11
	Maximum	10	13.00	.40	2.3	11.0	36.0	.8	9.0	294	.72
	Mean	10	9.40	.30	1.7	8.3	26.0	.5	4.9	290	.42
Sharp	No. samples	1	2	2	1	4	4	4	1	1	4
	Minimum	30	1.10	0.00	1.2	1.0	10.0	0.0	8.7	287	0.03
	Maximum	30	2.00	.10	1.2	6.2	12.0	2.0	8.7	287	8.00
	Mean	30	1.55	.05	1.2	4.1	11.3	.6	8.7	287	2.65

[a]This mean value includes one <10 value that was changed to 5.0.
[b]This mean value includes two <0.1 values that were changed to 0.05.

are a local problem. In general, the Roubidoux Formation yields good quality freshwater in the northernmost counties in the study area.

Outcrops of Paleozoic Rocks, Undifferentiated

Geology

Paleozoic rocks ranging in age from Ordovician to Pennsylvanian crop out in the study area. Almost all sedimentary lithologies are represented but limestones and dolomites predominate. These units dip to the south and are overlain by successively younger units in the direction of dip.

Hydrology

Ground water in these rocks occurs mostly in secondary openings such as fractures, joints, bedding planes, and solution channels. These secondary openings generally are larger and more numerous near land surface. Consequently, the quantity of ground water in these units generally decreases with depth (Lamonds, 1972). Wells in these units generally are less than 300 ft deep and yield less than 10 gal/min. The yield of a well depends on the number and size of openings penetrated by the well bore. The depth to water ranges from 5 to 25 ft below land surface and fluctuates primarily in response to variations in precipitation. No long-term water-level declines have been observed. Water levels in these units form a subdued reflection of the land surface, and are closest to the land surface in the valleys (Lamonds, 1972).

Numerous perennial springs issue from the limestone formations, primarily the Boone Formation, in the Springfield-Salem Plateaus. The largest spring is Mammoth Spring which has an average discharge of 330 ft^3/s and is used as the source of water for the town of Mammoth Springs. In the study area 27 springs have average discharges greater than 1 ft^3/s. Many of the smaller springs have been developed as water supplies for rural homes or for livestock. In addition, the discharges from the many springs provide the sustained base flow for several streams in the study area.

Water Quality

The outcrops of Paleozoic rocks yield a hard to very hard, calcium-bicarbonate water. The quality of this water varies with the lithology of the units, but the water generally is suitable for most uses. Ground-water quality also varies spatially within the units. Local concentrations of dissolved solids, nitrate, chloride, iron, and sulfate may exceed allowable limits in some areas within the study area. Low pH values and color are problems in other areas. These problems are all of a local nature. Additional quality data are summarized in table 11.

Table 11.--Ground-water quality in the outcrops of Paleozoic rocks

[No. = number; °C = degrees Celsius; pcu = platinum-cobalt units; mg/L = milligrams per liter; µg/L = micrograms per liter; µS = microsiemens per centimeter at 25 degrees Celsius]

County		Temperature (°C) (00010)	Color (pcu) (00080)	Specific conductance (µS) (00095)	pH (00400)	Bicarbonate (mg/L as HCO_3) (00440)	Carbonate (mg/L as CO_3) (00445)	Carbonate hardness (mg/L as CaCO) (00410)	Total hardness (mg/L as $CaCO_3$) (00900)	Dissolved calcium (mg/L as Ca) (00915)	Dissolved magnesium (mg/L as Mg) (00925)
Baxter	No. samples	1	1	1	2	1	1	1	3	3	3
	Minimum	19.0	3	932	7.4	370	40	371	290	56.0	37.0
	Maximum	19.0	3	932	8.7	370	40	371	520	92.0	71.0
	Mean	19.0	3	932	8.1	370	40	371	383	70.3	50.3
Boone	No. samples	118	1	118	118	69	69	115	118	117	117
	Minimum	11.0	5	132	6.2	55	0	45	51	18.0	0.8
	Maximum	24.0	5	790	8.2	410	0	338	390	120.0	50.0
	Mean	15.7	5	417	7.3	200	0	172	197	60.6	10.9
Carroll	No. samples	2	0	2	2	1	1	2	2	2	2
	Minimum	17.0	--	478	7.0	230	0	192	220	58.0	18.0
	Maximum	22.0	--	480	7.5	230	0	202	220	59.0	19.0
	Mean	19.5	--	479	7.3	230	0	197	220	58.5	18.5
Cleburne	No. samples	1	1	1	1	1	1	1	1	1	1
	Minimum	16.5	5	311	6.3	20	0	16	120	33.0	10.0
	Maximum	16.5	5	311	6.3	20	0	16	120	33.0	10.0
	Mean	16.5	5	311	6.3	20	0	16	120	33.0	10.0
Fulton	No. samples	2	2	2	2	1	1	2	2	2	2
	Minimum	20.0	1	364	6.7	230	0	180	190	39.0	22.0
	Maximum	21.0	3	370	7.8	230	0	185	190	41.0	23.0
	Mean	20.5	2	367	7.3	230	0	183	190	40.0	22.5
Independence	No. samples	14	17	18	18	18	18	18	18	18	18
	Minimum	14.0	0	21	5.4	2	0	2	4	0.5	0.3
	Maximum	17.0	10	3,320	8.5	610	15	502	550	100.0	72.0
	Mean	15.9	4	492	7.2	190	1	158	147	40.0	11.5
Izard	No. samples	0	0	0	1	0	0	0	2	1	1
	Minimum	--	--	--	8.6	--	--	--	190	46.0	24.0
	Maximum	--	--	--	8.6	--	--	--	210	46.0	24.0
	Mean	--	--	--	8.6	--	--	--	200	46.0	24.0
Jackson	No. samples	1	1	1	1	1	1	0	1	1	1
	Minimum	15.5	2	32	5.9	6	0	--	270	110.0	0.3
	Maximum	15.5	2	32	5.9	6	0	--	270	110.0	.3
	Mean	15.5	2	32	5.9	6	0	--	270	110.0	.3
Lawrence	No. samples	4	5	4	4	4	4	4	5	3	5
	Minimum	17.0	0	530	6.9	410	0	335	230	53.0	24.0
	Maximum	21.5	30	700	7.3	500	0	408	420	100.0	40.0
	Mean	20.3	6	614	7.1	450	0	368	350	79.6	36.2

Table 11.--Ground-water quality in the outcrops of Paleozoic rocks -- Continued

County		Temperature (°C) (00010)	Color (pcu) (00080)	Specific conductance (µS) (00095)	pH (00400)	Bicarbonate (mg/L as HCO_3) (00440)	Carbonate (mg/L as CO_3) (00445)	Carbonate hardness (mg/L as $CaCO_3$) (00410)	Total hardness (mg/L as $CaCO_3$) (00900)	Dissolved calcium (mg/L as Ca) (00915)	Dissolved magnesium (mg/L as Mg) (00925)
Newton	No. samples	0	1	0	1	0	0	0	2	2	2
	Minimum	--	5	--	8.3	--	--	--	140	48.0	3.9
	Maximum	--	5	--	8.3	--	--	--	150	50.0	7.0
	Mean	--	5	--	8.3	--	--	--	145	49.0	5.5
Randolph	No. samples	8	8	8	8	7	7	8	8	8	8
	Minimum	18.5	0	470	6.9	330	0	272	280	64.0	30.0
	Maximum	23.5	0	780	7.4	470	0	560	500	100.0	59.0
	Mean	20.9	0	580	7.2	414	0	368	371	80.9	41.1
Searcy	No. samples	1	3	3	3	3	3	2	3	3	3
	Minimum	15.0	5	585	7.5	240	0	197	48	9.8	5.7
	Msximum	15.0	7	2,840	8.2	1,720	0	284	400	88.0	43.0
	Mean	15.0	6	1,405	7.8	770	0	241	246	59.9	22.9
Sharp	No. samples	2	1	2	2	2	1	1	2	2	1
	Minimum	9.0	7	419	7.4	200	0	251	190	45.0	11.0
	Maximum	15.0	7	457	7.5	310	0	251	250	82.0	18.0
	Mean	12.0	7	438	7.5	255	0	251	220	63.5	14.5
Van Buren	No. samples	1	1	1	1	1	1	1	1	1	1
	Minimum	19.0	0	202	6.6	120	0	99	75	15.0	9.1
	Maximum	19.0	0	202	6.6	120	0	99	75	15.0	9.1
	Mean	19.0	0	202	6.6	120	0	99	75	15.0	9.1
White	No. samples	17	1	17	2	1	1	1	2	2	2
	Minimum	17.0	3	62	6.6	86	0	71	54	11.0	6.5
	Maximum	22.0	3	1,260	6.8	86	0	71	120	34.0	9.5
	Mean	18.7	3	500	6.7	86	0	71	87	22.5	8.0

County		Dissolved iron (µg/L as Fe) (01046)	Dissolved sodium (mg/L as Na) (00930)	Sodium absorption ratio (00931)	Dissolved potassium (mg/L as K) (00935)	Dissolved chloride (mg/L as Cl) (00940)	Dissolved sulfate (mg/L as SO_4) (00945)	Dissolved fluoride (mg/L as F) (00950)	Dissolved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dissolved nitrate (mg/L as N) (00618)
Baxter	No. samples	1	2	2	1	3	3	2	1	1	1
	Minimum	150	2.0	0.00	0.90	1.0	9.0	0.20	10.0	612	3.20
	Maximum	150	20.0	0.40	.90	25.0	120.0	.20	10.0	612	3.20
	Mean	150	11.0	0.20	.90	10.3	46.2	.20	10.0	612	3.20
Boone	No. samples	102	117	117	117	118	118	21	20	20	98
	Minimum	1	1.0	0.00	0.05	0.5	1.5	<0.10	8.7	70	<0.04
	Maximum	[a]440	24.0	0.80	[b]9.30	81.0	[c]75.0	[d].90	14.0	345	[e]11.20
	Mean	21	4.4	0.15	2.33	7.6	14.8	.13	10.3	199	1.6

Table 11.--Ground-water quality in the outcrops of Paleozoic rocks -- Continued

County		Dis-solved iron (µg/L as Fe) (01046)	Dis-solved sodium (mg/L as Na) (00930)	Sodium absorp-tion ratio (00931)	Dis-solved potassium (mg/L as K) (00935)	Dis-solved chloride (mg/L as Cl) (00940)	Dis-solved sulfate (mg/L as SO_4) (00945)	Dis-solved fluoride (mg/L as F) (00950)	Dis-solved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dis-solved nitrate (mg/L as N) (00618)
Carroll	No. samples	2	2	2	2	2	2	0	0	0	2
	Minimum	4	6.1	0.20	3.50	6.0	17.0	--	--	--	2.01
	Maximum	8	6.4	0.20	3.90	8.7	17.0	--	--	--	3.24
	Mean	6	6.3	0.20	3.70	7.4	17.0	--	--	--	2.63
Cleburne	No. samples	1	1	1	1	1	2	1	1	1	1
	Minimum	0	4.7	0.20	0.90	2.8	110.0	0.10	10.0	228	0.23
	Maximum	0	4.7	0.20	.90	2.8	110.0	.10	10.0	228	.23
	Mean	0	4.7	0.20	.90	2.8	110.0	.10	10.0	228	.23
Fulton	No. samples	2	2	2	2	2	2	2	2	2	1
	Minimum	4	1.2	0.00	1.4	1.4	0.4	0.10	7.9	181	1.30
	Maximum	1,300	2.0	0.10	1.8	4.1	1.4	.10	11.0	199	1.30
	Mean	652	1.6	0.05	1.6	2.8	.9	.10	9.5	190	1.30
Independence	No. samples	3	17	17	17	17	17	17	17	16	18
	Minimum	20	1.3	0.10	0.20	0.5	0.0	0.00	4.8	24	0.00
	Maximum	200	640.0	21.00	16.00	270.0	1,000.0	.90	24.0	2,480	4.70
	Mean	107	56.1	2.22	3.60	30.0	66.4	.21	11.8	336	1.11
Izard	No. samples	0	1	1	0	2	2	1	0	0	0
	Minimum	--	54.0	2.00	--	5.0	1.0	0.20	--	--	--
	Maximum	--	54.0	2.00	--	9.2	3.0	.20	--	--	--
	Mean	--	54.0	2.00	--	7.1	2.0	.20	--	--	--
Jackson	No. samples	0	1	1	1	1	1	1	1	1	0
	Minimum	--	2.0	0.10	1.10	4.5	1.2	0.00	12.0	27.0	--
	Maximum	--	2.0	.10	1.10	4.5	1.2	.00	12.0	27.0	--
	Mean	--	2.0	.10	1.10	4.5	1.2	.00	12.0	27.0	--
Lawrence	No. samples	0	4	4	4	5	5	5	4	4	5
	Minimum	--	1.3	0.0	1.0	1.4	1.0	.1	9.1	345	0.0
	Maximum	--	6.7	.1	7.4	20.0	14.0	.3	17.0	433	1.86
	Mean	--	3.5	.08	3.13	6.8	8.7	.2	12.5	386	.63
Newton	No. samples	0	2	2	0	2	2	2	0	0	1
	Minimum	--	7.8	0.3	--	6.5	7.0	.2	--	--	.25
	Maximum	--	21.0	.8	--	7.0	10.0	.2	--	--	.25
	Mean	--	14.4	.55	--	6.8	8.5	.2	--	--	.25
Randolph	No. samples	1	8	8	8	8	8	8	8	8	7
	Minimum	200	3.1	.1	.9	1.4	1.0	.1	11.0	324	.38
	Maximum	200	13.0	.3	3.4	26.0	21.0	.3	20.0	532	4.7
	Mean	200	6.1	.15	1.74	10.4	7.9	.18	13.4	398	2.3

Table 11.--Ground-water quality in the outcrops of Paleozoic rocks -- Continued

County		Dis-solved iron (µg/L as Fe) (01046)	Dis-solved sodium (mg/L as Na) (00930)	Sodium absorp-tion ratio (00931)	Dis-solved potassium (mg/L as K) (00935)	Dis-solved chloride (mg/L as Cl) (00940)	Dis-solved sulfate (mg/L as SO_4) (00945)	Dis-solved fluoride (mg/L as F) (00950)	Dis-solved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dis-solved nitrate (mg/L as N) (00618)
Searcy	No. samples	3	3	3	3	3	3	3	3	3	2
	Minimum	0.0	11.0	.2	1.6	17.0	10.0	.5	2.3	387	.07
	Maximum	40.0	700.0	45.0	22.0	100.0	100.0	3.0	9.4	1,770	.09
	Mean	27.0	241.7	15.2	8.43	45.0	68.7	1.33	5.2	878	.08
Sharp	No. samples	1	2	2	2	2	2	2	2	2	1
	Minimum	0.0	1.5	0.0	1.0	1.5	4.4	.1	9.5	238	.14
	Maximum	.0	12.0	.4	1.6	17.0	21.0	.1	9.9	261	.14
	Mean	.0	6.8	.2	1.3	9.3	12.7	.1	9.7	250	.14
Van Buren	No. samples	0	1	1	1	1	1	1	1	1	1
	Minimum	--	13.0	.7	1.0	1.6	4.2	.2	15.0	121	.11
	Maximum	--	13.0	.7	1.0	1.6	4.2	.2	15.0	121	.11
	Mean	--	13.0	.7	1.0	1.6	4.2	.2	15.0	121	.11
White	No. samples	2	2	2	1	17	2	1	1	2	1
	Minimum	0	12.0	.7	1.5	5.0	3.4	.2	25.0	108	.43
	Maximum	860	34.0	1.0	1.5	260.0	3.4	.2	25.0	217	.43
	Mean	430	23.0	.85	1.5	56.0	3.4	.2	25.0	163	.43

[a] This mean value includes two <3 values, two <2 values, and two <4 values which were changed to 1.5, 1.0, and 2.0, respectively.
[b] This mean value includes one <1.0 value that was changed to 0.5.
[c] This mean value includes 17 values of <3.0 which were changed to 1.5.
[d] This mean value includes 16 values of <0.1 which were changed to 0.05.
[e] This mean value includes 6 values of <0.04 which were changed to 0.02.

Nacatoch Sand

Geology

The Nacatoch Sand crops out along the Fall Line and underlies the Quaternary deposits in the eastern part of the study area. The formation dips to the southeast at the rate of about 40 ft/mi (Lamonds and others, 1969). The Nacatoch Sand consists chiefly of medium-grained, glauconitic sand and is as much as 300 ft thick.

Hydrology

The importance of the Nacatoch Sand is in its potential as a source of suitable quality water. Little is known concerning the hydrologic characteristics of the Nacatoch Sand in the study area, but a study by Boswell and others (1965) indicates that the formation may be a potential source of water in the easternmost counties in the study area. The Nacatoch yields substantial amounts of water in eastern Clay County. Lamonds and others (1969) suggest that a well drilled in the Nacatoch downdip from the outcrop area would be artesian and could yield several hundred gallons per minute.

The Nacatoch Sand is not used as a source of ground water in the study area except for domestic wells in its small outcrop area. However, east of the study area, in eastern Clay County, the Nacatoch is used extensively as a source of water for public supply.

Water Quality

Little is known concerning the quality of water in the Nacatoch Sand, but south of the Lawrence-Jackson County line water in the Nacatoch is highly mineralized. Electric logs indicate dissolved-solids concentrations are over 3,000 mg/L in Jackson County (Petersen and others, 1985).

Quaternary Deposits

Geology

The Quaternary deposits in the study area crop out east of the Fall Line and range in thickness from zero at the Fall Line to as much as 155 ft thick at the eastern edge of the basin (Albin and others, 1967). These deposits are chiefly composed of silt and clay to a depth of about 30 ft below land surface, and of sand increasing in coarseness from the bottom of the clay cap to gravel at the base of the unit.

Hydrology

Recharge to Quaternary deposits is principally from precipitation. Wells in Quaternary deposits commonly yield 1,000 gal/min, but yields as high as 2,500 gal/min have been reported.

Water levels in these deposits fluctuate from year to year due to pumping and climatic effects, but over a long period of time, water levels appear to be relatively constant. Water levels generally are less than 20 ft below land surface. The potentiometric surface in the Quaternary deposits is shown in figure 9.

Use of water from the Quaternary deposits in 1985 totaled 278.45 Mgal/d (fig. 10). This is over ten times the use in 1965 (25.45 Mgal/d). Almost all of this water was withdrawn for irrigation and rural use. The current withdrawal rate appears to have little long-term effect on water levels in the Quaternary deposits in the study area.

Water Quality

The Quaternary deposits in the study area yield a hard to very hard, calcium-magnesium-bicarbonate water. Water-quality data for wells penetrating Quaternary deposits are summarized in table 12. Iron concentrations often exceed the allowable limit, and in some limited areas, dissolved solids, nitrate, chloride, and sulfate concentrations also may exceed recommended limits. The water from these deposits is unsuitable for public supply without treatment, but it is commonly used without treatment for domestic supply, irrigation, aquaculture, and some industrial purposes (Lamonds and others, 1969).

GROUND-WATER PROBLEMS

In many areas ground-water yields are insufficient for public supply or the quality of the available water is not suitable for use.

Quantity

Shallow wells in the Ozark Plateaus commonly yield less than 10 gal/min. Much deeper and more expensive wells can yield as much as 500 gal/min in the northernmost counties in the study area. Only these deeper wells can yield adequate amounts of water to public-supply systems. East of the Fall Line the Quaternary deposits yield as much as 2,500 gal/min.

Quality

The most common water-quality problems in the study area are hardness and high iron concentrations, but locally other constituents also may exceed established drinking-water standards. Several wells with nitrate concentrations exceeding established standards are located within the study area. The contamination of these wells may be due to deteriorated well bore seals and perforated well casings. If wells are not properly sealed to prevent the shallow surface drainage from entering the well, the wells can become contaminated.

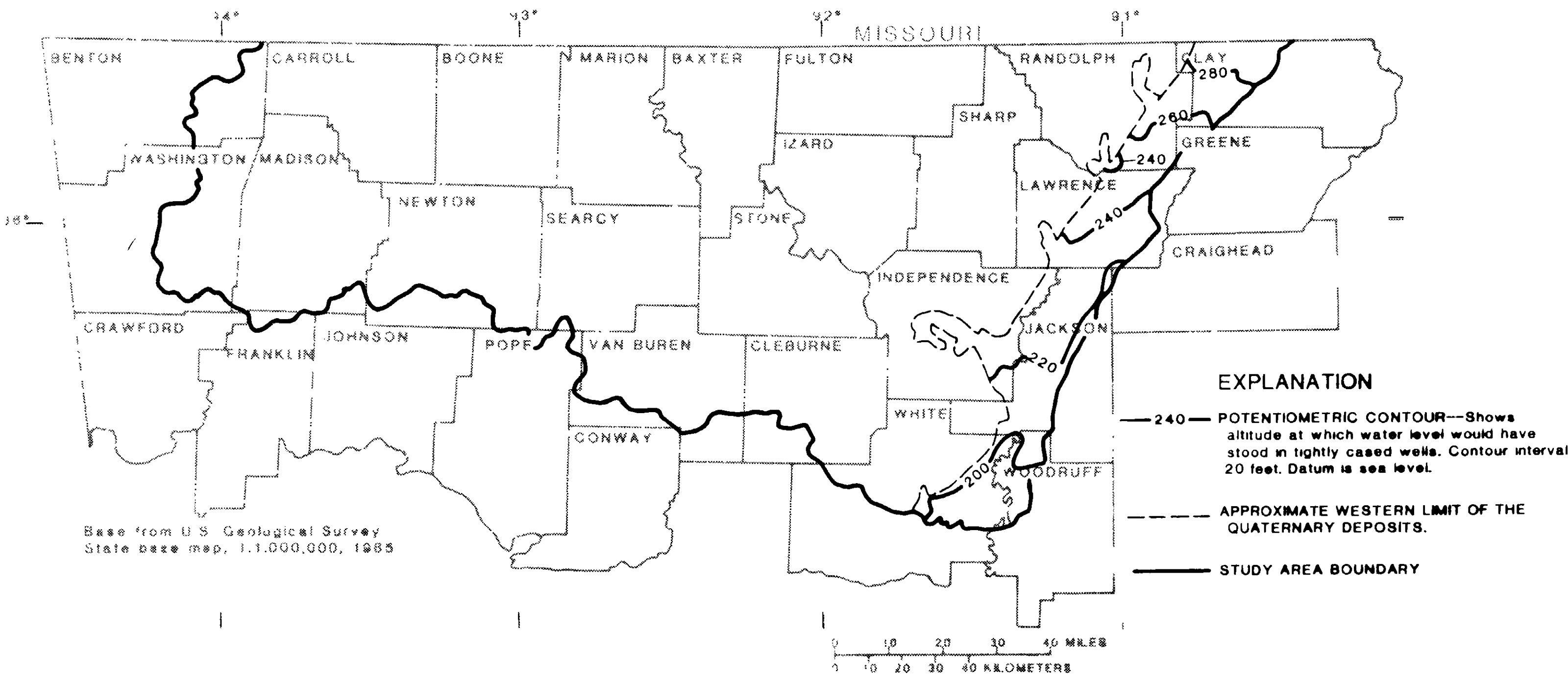

Figure 9.--Potentiometric surface in the Quaternary deposits in 1985 (modified from Plafcan and Fugitt, 1987).

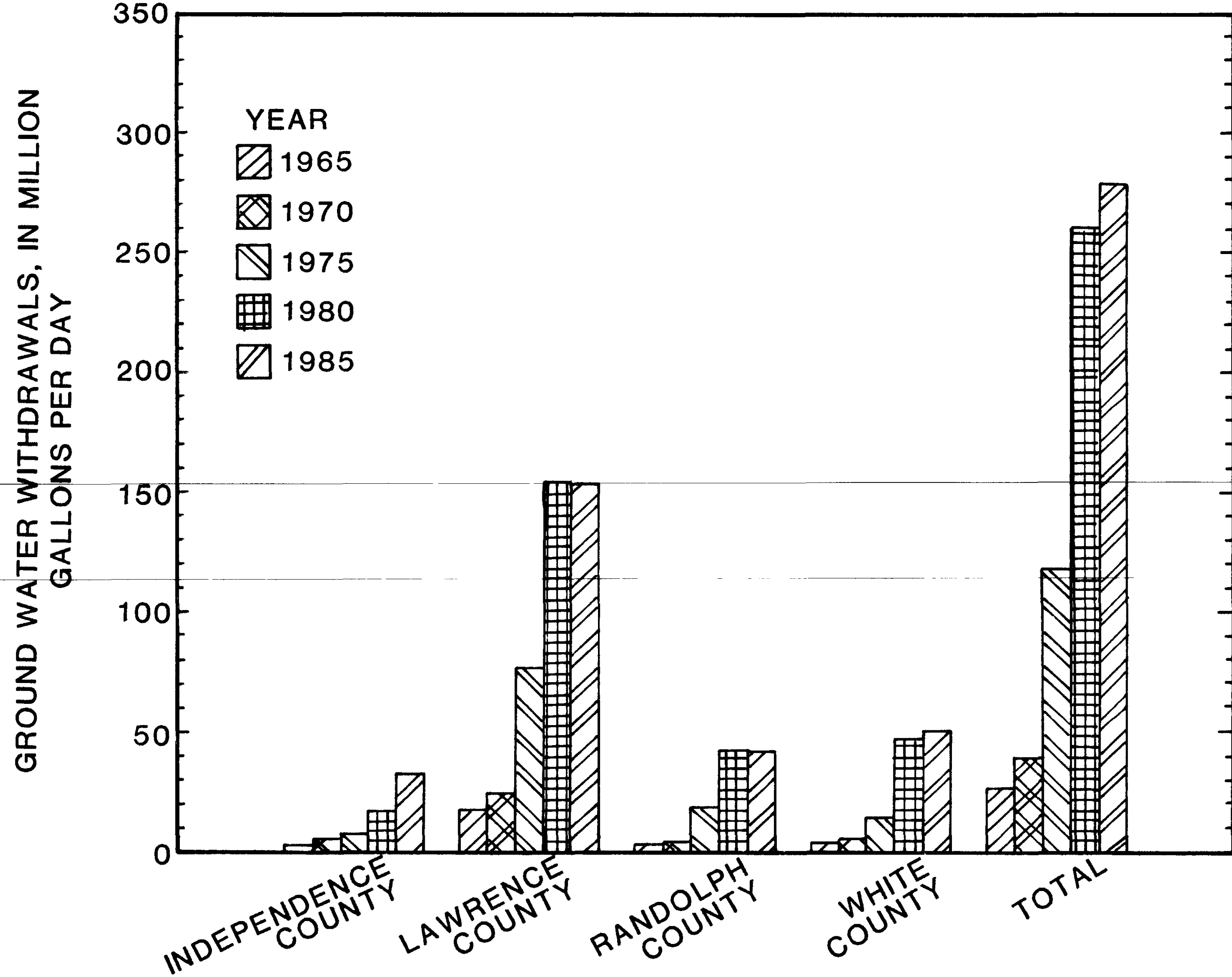

Figure 10.--Ground-water withdrawals from Quaternary deposits, 1965 to 1985.

Table 12.--Ground-water quality in the Quaternary deposits

[No. = number; °C = degrees Celsius; pcu = platinum-cobalt units; mg/L = milligrams per liter; µg/L = micrograms per liter; µS = microsiemens per centimeter at 25 degrees Celsius]

County		Temperature (°C) (00010)	Color (pcu) (00080)	Specific conductance (µS) (00095)	pH (00400)	Bicarbonate (mg/L as HCO_3) (00440)	Carbonate (mg/L as CO_3) (00445)	Carbonate hardness (mg/L as $CaCO_3$) (00410)	Total hardness (mg/L as $CaCO_3$) (00900)	Dissolved calcium (mg/L as Ca) (00915)	Dissolved magnesium (mg/L as Mg) (00925)
Clay	No. samples	8	7	10	9	9	9	9	8	8	8
	Minimum	15.0	1	146	7.1	66	0	54	56.0	15	4.5
	Maximum	16.5	10	694	7.8	290	0	238	230.0	69	15.0
	Mean	15.6	5	381	7.4	200	0	163	159.5	48	9.7
Greene	No. samples	2	0	2	0	0	0	0	0	0	0
	Minimum	15.5	--	420	--	--	--	--	--	--	--
	Maximum	15.5	--	500	--	--	--	--	--	--	--
	Mean	15.5	--	460	--	--	--	--	--	--	--
Independence	No. samples	15	4	15	5	5	5	4	4	4	4
	Minimum	15.0	0	302	6.8	110	0	87	98.0	25	8.6
	Maximum	18.0	5	2,750	8.0	360	0	292	360.0	89	33.0
	Mean	16.2	2	854	7.4	282	0	224	244.5	65	20.1
Jackson	No. samples	28	16	32	25	24	23	24	22	21	21
	Minimum	15.5	0	128	6.5	28	0	33	55.0	11	6.6
	Maximum	18.5	8	600	8.0	300	0	244	270.0	78	18.0
	Mean	16.5	3	381	7.3	176	0	161	161.9	47	10.9
Lawrence	No. samples	19	16	28	22	20	20	21	20	20	20
	Minimum	15.0	0	263	6.7	120	0	100	130.0	37	7.1
	Maximum	23.5	30	1,030	8.0	450	0	369	530.0	150	45.0
	Mean	17.3	7	472	7.4	252	0	206	231.5	67	15.8
Randolph	No. samples	12	8	11	8	9	9	9	9	9	9
	Minimum	14.5	1	170	6.2	30	0	25	50.0	12	4.8
	Maximum	22.5	7	460	7.9	270	0	221	210.0	64	19.0
	Mean	17.1	3	348	7.1	169	0	138	148.6	40	11.6
White	No. samples	46	10	48	11	11	11	11	11	11	11
	Minimum	16.0	3	66	5.1	6	0	5	17.0	4	0.8
	Maximum	25.0	13	10,200	8.2	450	0	366	600.0	150	53.0
	Mean	18.5	6	1,793	6.9	177	0	145	194.6	51	15.8
Woodruff	No. samples	2	1	3	3	3	3	3	3	3	3
	Minimum	17.0	13	143	6.7	68	0	56	58.0	16	4.5
	Maximum	17.0	13	207	7.7	120	0	97	99.0	29	6.4
	Mean	17.0	13	166	7.3	88	0	72	73.7	21	5.4

Table 12.--Ground-water quality in the Quaternary deposits -- Continued

County		Dis-solved iron (µg/L as Fe) (01046)	Dis-solved sodium (mg/L as Na) (00930)	Sodium absorp-tion ratio (00931)	Dis-solved potassium (mg/L as K) (00935)	Dis-solved chloride (mg/L as Cl) (00940)	Dis-solved sulfate (mg/L as SO_4) (00945)	Dis-solved fluoride (mg/L as F) (00950)	Dis-solved silica (mg/L as SiO_2) (00955)	Dissolved solids (mg/L residue at 180°C) (70300)	Dis-solved nitrate (mg/L as N) (00618)
Clay	No. samples	7	8	8	8	8	8	8	8	9	6
	Minimum	30	4.6	0.2	1.4	2.7	0.0	0.0	14.0	114	0.0
	Maximum	5,000	54.0	2.0	3.1	74.0	36.0	.2	40.0	406	.41
	Mean	2,653	19.5	.74	2.36	20.21	12.5	.15	28.9	238	.08
Greene	No. samples	0	0	0	0	0	0	0	0	0	0
	Minimum	--	--	--	--	--	--	--	--	--	--
	Maximum	--	--	--	--	--	--	--	--	--	--
	Mean	--	--	--	--	--	--	--	--	--	--
Independence	No. samples	3	4	4	4	14	4	4	4	4	3
	Minimum	10	5.0	.1	.8	5.5	10.0	.1	15.0	177	0.0
	Maximum	4,700	430.0	10.0	21.0	700.0	31.0	1.1	22.0	1,460	2.1
	Mean	2,170	116.8	2.85	7.83	142.25	16.3	.43	18.5	564	1.02
Jackson	No. samples	20	23	21	21	26	22	21	21	23	18
	Minimum	30	6.0	.2	1.0	2.5	0.0	0.0	8.7	157	0.0
	Maximum	20,000	29.0	1.0	4.5	35.0	65.0	.3	46.0	362	8.6
	Mean	4,262	13.9	.5	2.11	10.31	20.3	.17	33.6	243	1.06
Lawrence	No. samples	20	23	20	20	23	20	20	20	23	14
	Minimum	20	3.7	.1	1.1	1.1	1.6	0.0	6.4	178	0.0
	Maximum	13,000	42.0	1.0	21.0	70.0	270.0	.4	42.0	737	10.0
	Mean	2,458	13.5	.38	3.1	14.05	34.3	.16	31.2	311	.78
Randolph	No. samples	9	8	8	8	9	8	8	8	8	8
	Minimum	0	6.9	.2	1.0	2.5	1.8	0.0	19.0	153	0.0
	Maximum	20,000	27.0	1.0	3.8	28.0	43.0	.2	43.0	316	6.1
	Mean	4,943	12.8	.51	1.74	14.02	14.8	.1	32.9	227	2.08
White	No. samples	11	11	11	3	48	11	3	3	11	11
	Minimum	0	5.1	.5	2.5	4.8	.6	.1	5.6	48	0.0
	Maximum	620	100.0	3.0	3.7	3,000.0	100.0	.2	25.0	1,010	38.0
	Mean	114	42.4	1.46	3.07	492.62	21.9	.13	15.5	376	3.79
Woodruff	No. samples	3	3	3	3	3	3	3	3	3	3
	Minimum	140	4.4	.2	1.0	2.5	8.2	0.0	21.0	112	.02
	Maximum	350	7.0	.3	2.4	4.2	12.0	.3	43.0	152	.14
	Mean	280	5.3	.27	1.93	3.07	10.1	.13	30.7	125	.07

The occurrence of bacterial contamination in shallow wells and springs has increased as human and animal populations have increased in the study area. Fractures and solution channels in rock outcrops, particularly limestone and dolomite, are conduits for ground-water contamination because the fractures allow rapid infiltration of fecal bacteria from a variety of sources including septic tanks, landfills, poultry and cattle operations, and runoff from pastures.

Another water-quality problem in the study area is the occurrence of saline water in the Quaternary deposits. In two areas in the eastern part of the study area (near Cord and Bald Knob), the Quaternary deposits contain saline water (fig. 11).

The Quaternary deposits also have been contaminated from surface sources. Chesney (1979) reported the contamination of water in these deposits at Newport in 1977 when dilute sulfuric acid leaked from holding ponds and affected a nearby water supply. At Augusta, water from industrial monitoring wells in the Quaternary deposits had lead concentrations that exceeded established drinking-water standards.

Critical Use Areas

Critical ground-water use areas have been defined by the Arkansas Soil and Water Conservation Commission for both water-table and artesian aquifers using the following criteria:

Water-Table Aquifers

1. Less than 50 percent of the thickness of the aquifer is saturated
2. Average annual declines of 1 ft or more have occurred for the preceding 5-year period
3. Ground-water quality has been degraded or trends indicate probable future degradation that would render the water unusable as a drinking-water source or for the primary use of the aquifer

Artesian Aquifers

1. The potentiometric surface is below the top of the aquifer
2. Average annual declines of 1 ft or more have occurred for the preceding 5 years
3. Ground-water quality has been degraded or trends indicate probable future degradation that would render the water unusable as a drinking-water source or for the primary use of the aquifer.

If even one of these criteria is met by an aquifer in part of the study area, then that part of the study area is considered to be a critical use area for that aquifer.

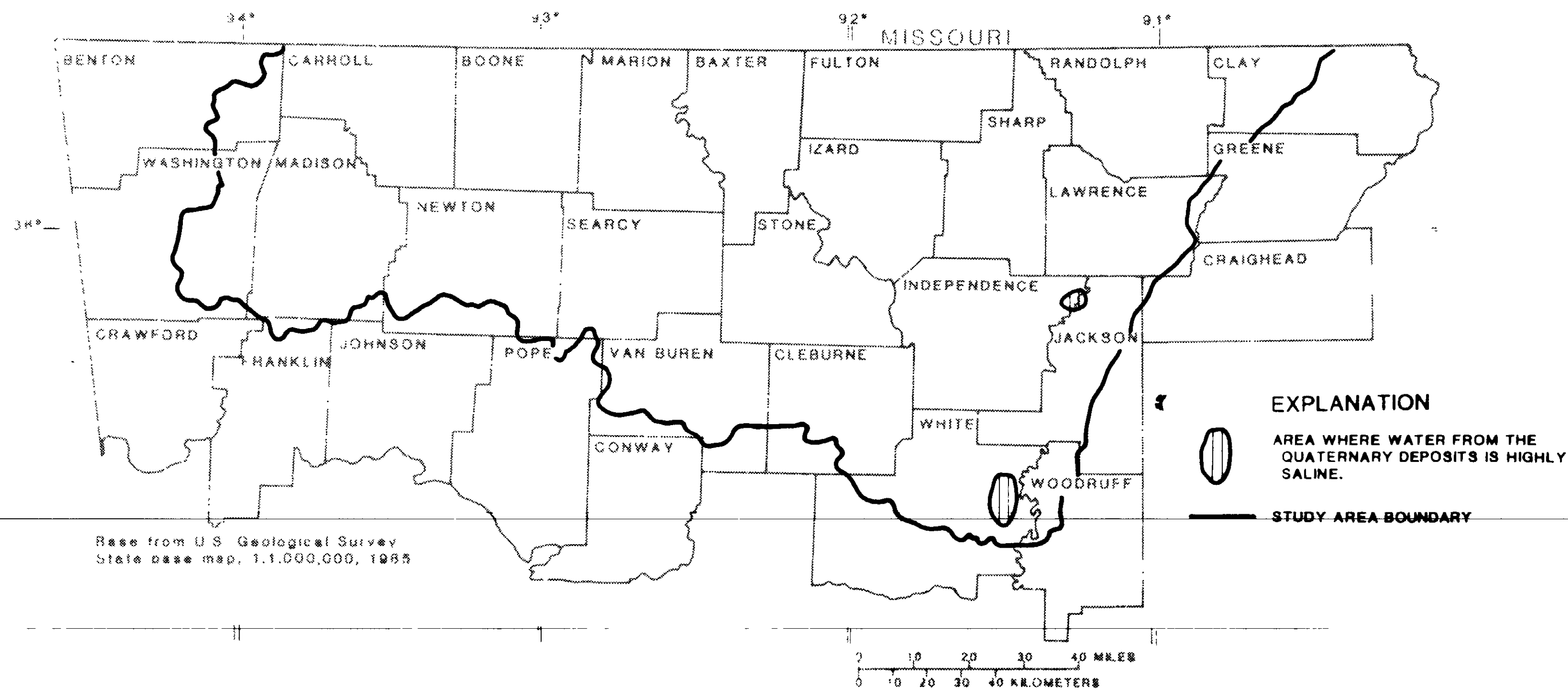

Figure 11.--Areas of saline water in the Quaternary deposits (modified from Bryant and others, 1985).

The aquifers in the subsurface Paleozoic formations, namely the Eminence and Potosi Dolomites, Gasconade Dolomite and Van Buren Formation, and the Roubidoux Formation, are all considered to be artesian aquifers in the study area. Water levels in wells penetrating these units indicate no long-term declines and most water-quality problems appear to be of a local nature. The ground water from these units generally is extremely hard, and iron concentrations commonly exceed secondary drinking-water regulations (U.S. Environmental Protection Agency, 1986b). The quantity and quality problems of available ground water are due primarily to natural constraints. On the basis of available data, no areas in these deep Paleozoic formations are critical use areas.

The outcropping Paleozoic units exist under water-table conditions. Well yields in these units are low because of natural constraints, and water levels indicate no long-term declines. Water-quality problems generally are of a local nature and are unrelated to pumping rates. Therefore, no critical areas exist in these units in the study area.

The Nacatoch Sand exists under water-table conditions in its outcrop area and under artesian conditions downdip. There is no known use in the study area and limited water-quality data are available. On the basis of the limited data available, no areas in the Nacatoch Sand in the study area are critical use areas.

Quaternary deposits exist under water-table conditions in their outcrop areas in the study area. Iron concentrations are a common problem in these deposits and other isolated water-quality problems exist. Water levels in many areas actually rose in these deposits between 1981 and 1986, while in other areas water levels declined less than 2 ft. No critical use areas exist in the Quaternary deposits in the study area.

In general, the ground-water resources of the study area, with the exception of the Quaternary deposits, are not being used to a large extent. Water use in the Quaternary deposits, although significant, does not appear to be causing water levels to decline at a rate high enough to meet the criteria for a critical use area. Quality problems generally are limited to individual wells, although some natural problems are more widespread. Therefore, no critical use areas were designated in the study area.

POTENTIAL GROUND-WATER PROBLEMS

The potential for ground-water contamination exists throughout the study area. Potential hazards include landfills, surface waste impoundments, hazardous waste operations, storage tanks, septic tanks, and saline water intrusion. The probability of contamination of ground water varies from area to area depending largely on the permeability of the surface materials.

Permeable materials that allow water to recharge aquifers also will allow contaminants to enter the ground-water system. Figure 12 shows the recharge potential of the study area in different zones. Zones shown on figure 12 as having high recharge potential are outcrop areas of Paleozoic limestones. Zones with medium recharge potential are outcrops of Paleozoic sandstones and shales and low interstream terraces of Quaternary deposits. Zones with low recharge potential are high interstream terraces of Quaternary deposits. The greatest potential for contamination is in zones with high recharge potentials.

At least 61 open landfills and dumps exist in the study area (fig. 12). The contents of the majority of these landfills and dumps are virtually unknown. Hazardous materials may be stored in these areas and could be leaking into the shallowest aquifer. At least one Resource Conservation and Recovery Act (RCRA) site and at least two Superfund sites exist in the study area.

Surface waste impoundments also may be considered potential hazards to ground water. Chesney (1979) inventoried 7,640 impoundments at 872 sites. A small number of these impoundments (518) were selected for assessment of contamination potential. The assessment conducted by Chesney included a complete description of the impoundments including size in acres, age, amount and type of wastes present, type of liner, and the presence of monitoring wells. In addition, the geologic formations underlying the impoundments were rated according to the ease with which contaminants could penetrate surface layers. By using these data, the impoundments were then assessed for ground-water contamination potential, which is expressed as a numerical rating with a low of 1 and a high of 29. Surface waste impoundments with a hazard rating of 16 or above are shown in figure 12.

Additional sources of potential ground-water contamination include storage tanks, septic tanks, waste-injection wells, mining activities, pipelines, and waste spilled in transport.

Another potential problem involves the development of ground-water resources to such an extent that water levels decline steadily and ground-water availability is threatened.

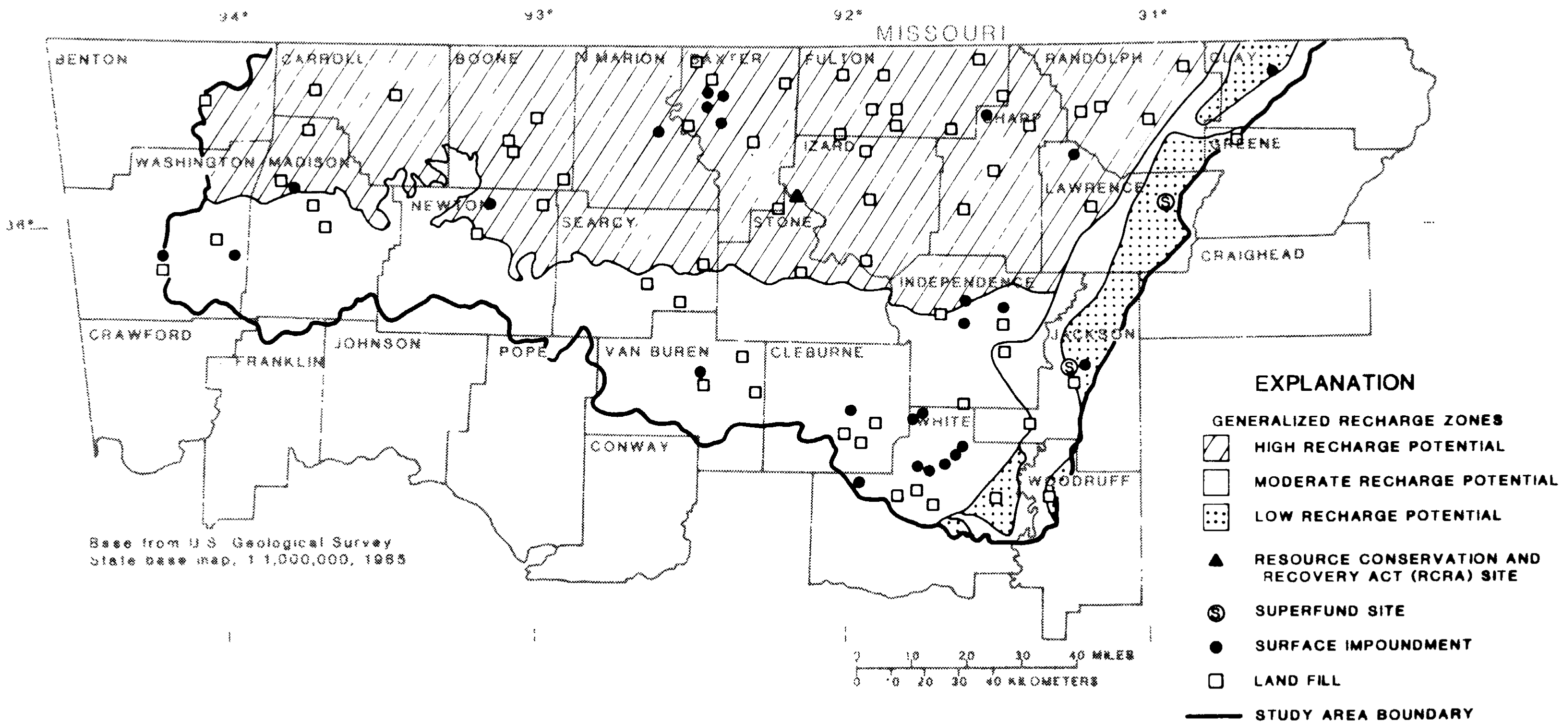

Figure 12.--Generalized recharge zones and potential ground-water contamination sources (modified from Bryant and others, 1985).

SUMMARY AND CONCLUSIONS

Ground water is available from nearly all the geologic units in the study area in different amounts. Most of these units, such as the surficial Paleozoic units, are important only because they are readily accessible. However, several of the units are important regional sources of water. These include the Eminence and Potosi Dolomites, the Gasconade Dolomite and Van Buren Formation, and the Roubidoux Formation in the Ozark Plateaus and the Nacatoch Sand and Quaternary deposits in the Coastal Plain.

Although most of the ground water withdrawn in the 17-county area that approximates the study area is from Quaternary deposits, the aquifers in the Paleozoic rocks are far more significant areally.

Yields from the different water-yielding units are highly variable. The Eminence and Potosi Dolomites yield as much as 230 gal/min, although few wells are known to penetrate these formations in Arkansas. Overlying these formations, the Gunter Sandstone Member of the Van Buren Formation and the Roubidoux Formation, which overlies the Gunter Sandstone, yield as much as 500 gal/min. Although these deeper units can yield large volumes of water, the outcrops of Paleozoic rocks commonly yield less than 10 gal/min. In the Coastal Plain, the Quaternary deposits can yield as much as 2,500 gal/min.

Ground water in the Ozark Plateaus generally is usable without treatment for rural, domestic, and some industrial uses; but requires softening and removal of iron to be made acceptable for municipal supplies and most industrial uses. The Quaternary deposits of the Coastal Plain also yield a very hard water.

Nitrate concentrations exceeding drinking-water standards, have occurred in some areas, probably as a result of deteriorated well bore seals or perforated casings that allow wastes from barnyards and septic tanks to enter the well bore. In addition, saline water occurs in the Quaternary deposits near Bald Knob and Cord, Arkansas.

In general the ground-water resources of the study area, with the exception of the Quaternary deposits, are not being used to a great extent. Ground-water quality problems generally are limited to individual wells, although some natural problems are more widespread. Therefore, no critical use areas, as defined by the Arkansas Soil and Water Conservation Commission, were designated in the study area.

The potential for ground-water contamination exists throughout the study area. Potential hazards include landfills, surface impoundments, hazardous waste operations, storage tanks, and saline water intrusion.

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