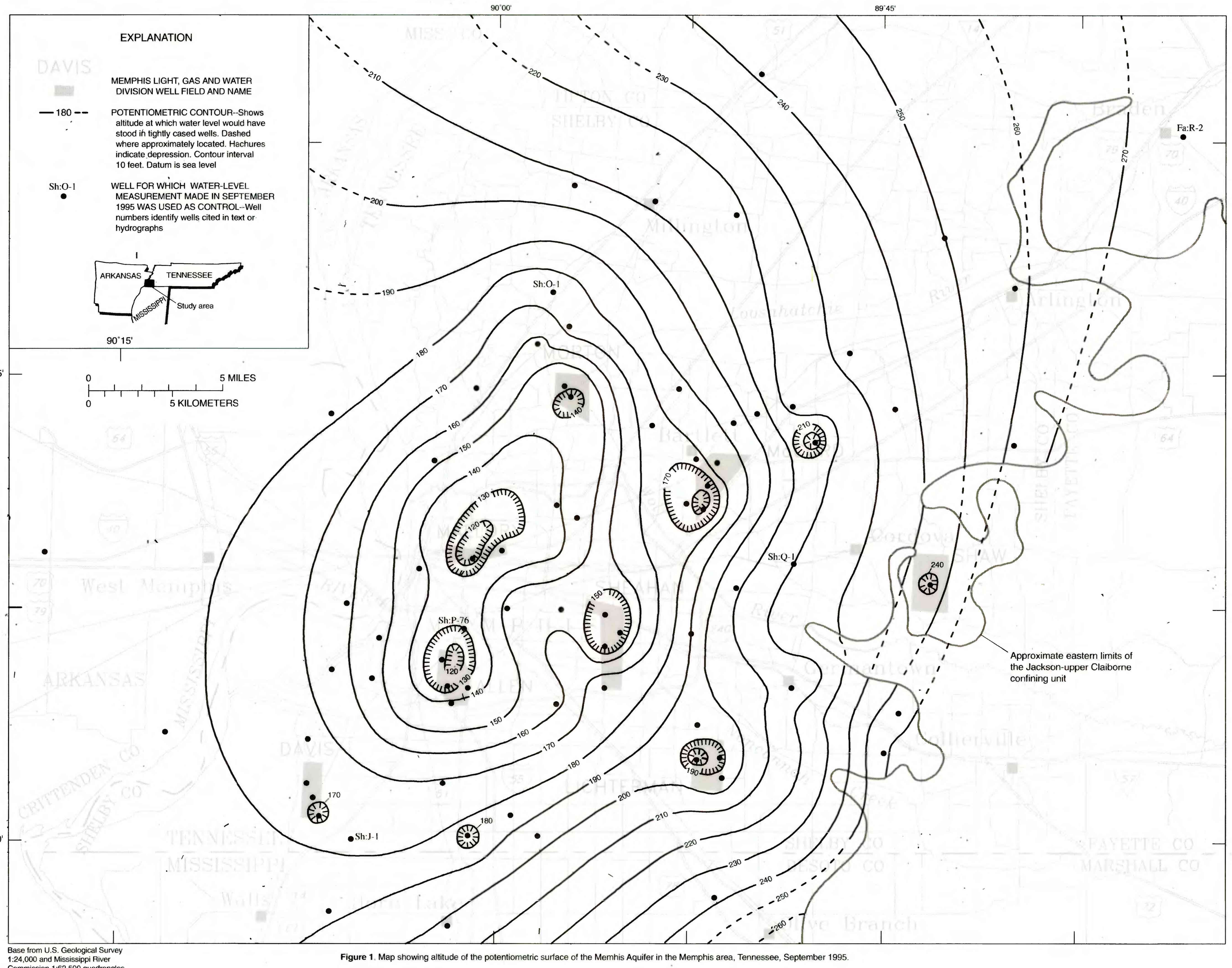
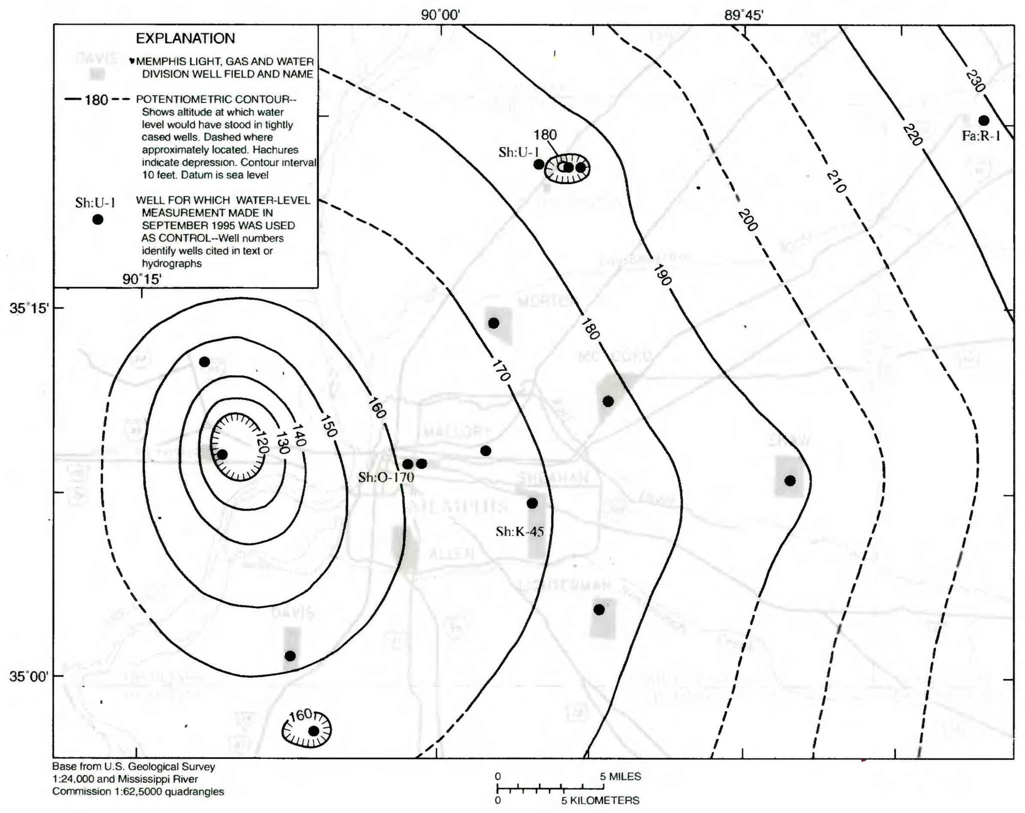
Prepared in cooperation with the
CITY OF MEMPHIS,
MEMPHIS LIGHT, GAS AND WATER DIVISION



Base from U.S. Geological Survey 1:24,000 and Mississippi River Commission 1:62,500 quadrangles

Figure 1. Map showing altitude of the potentiometric surface of the Memhis Aquifer in the Memphis area, Tennessee, September 1995.



Base from U.S. Geological Survey 1:24,000 and Mississippi River Commission 1:62,500 quadrangles

Figure 3. Altitude of the potentiometric surface of the Fort Pillow aquifer in the Memphis area, Tennessee, September 1995.

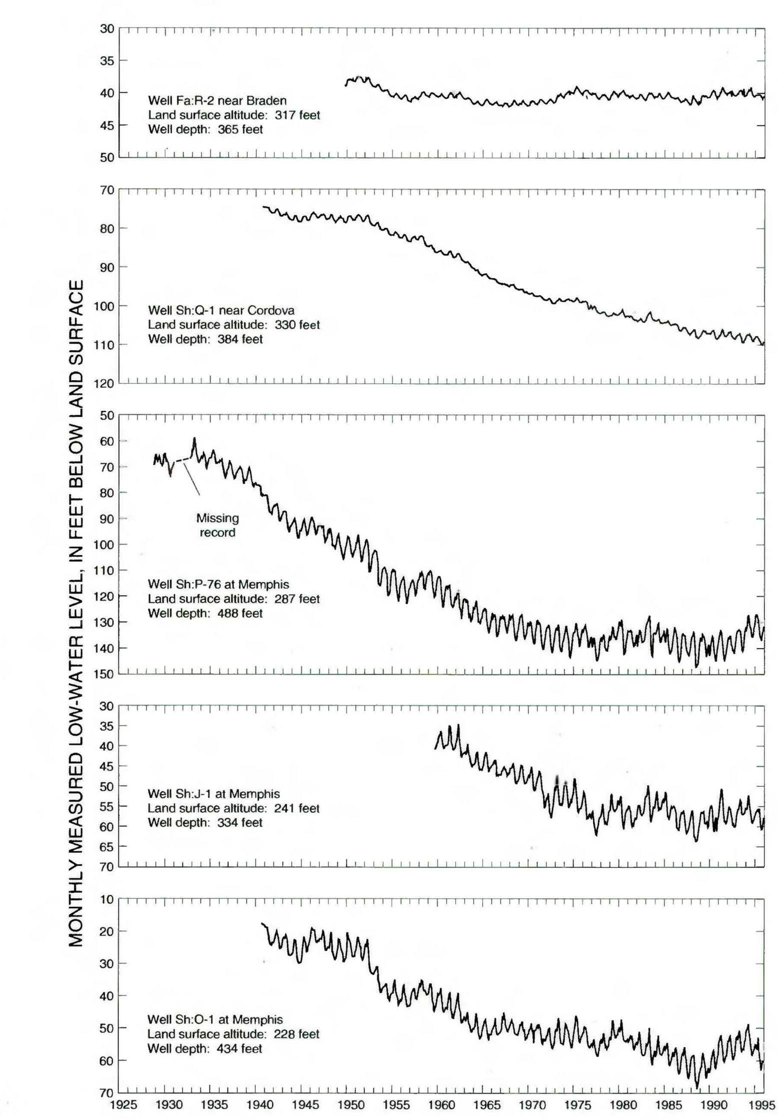


Figure 2. Historical water-level changes in selected observation wells screened in the Memphis aquifer.

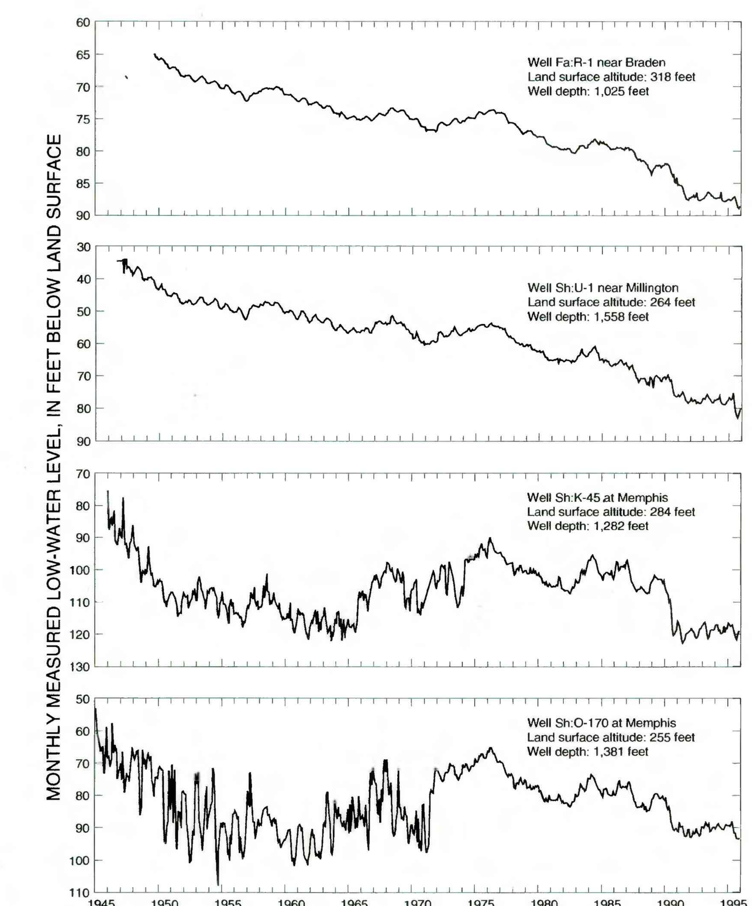


Figure 4. Historical water-level changes in selected observation wells screened in the Fort Pillow aquifer.

INTRODUCTION

The Memphis and Fort Pillow aquifers are the principal sources of water for municipal, industrial, and commercial uses in the Memphis area, Tennessee. About 190 million gallons per day (Mgal/d) were withdrawn from the Memphis aquifer, and about 10 Mgal/d were withdrawn from the Fort Pillow aquifer in 1995. The U.S. Geological Survey, in cooperation with the City of Memphis, Memphis Light, Gas and Water Division, collects water-level data for the Memphis and Fort Pillow aquifers in the Memphis area. The purpose of this report is to show the potentiometric surfaces of both aquifers based on water-level measurements made during September 1995 and to describe historical water-level changes in these aquifers in the Memphis area. The Memphis area includes about 1,500 square miles in Shelby County and parts of Tipton and Fayette Counties in Tennessee, parts of DeSoto and Marshall Counties in Mississippi, and part of Crittenden County in Arkansas (fig. 1).

MEMPHIS AQUIFER

In the Memphis area, unconsolidated Cretaceous and Tertiary sediments dip gently westward as part of the Mississippi embayment, a broad structural syncline that plunges southward with its axis roughly coincident with the Mississippi River. The Tertiary-age Memphis Sand (table 1) is a thick layer of sand with lenses of clay and silt and minor amounts of lignite present at various stratigraphic horizons. It is present in the subsurface throughout the Memphis area, and ranges from about 650 to 900 feet in thickness (Kingsbury and Parks, 1993). The Memphis Sand is thickest in the southwestern part of the Memphis area.

The Memphis Sand constitutes the Memphis aquifer. Confining clay beds above and below the aquifer cause artesian conditions within the aquifer; however, several studies have identified areas where the overlying Jackson-upper Claiborne confining unit (table 1) is thin or absent in the Memphis area (Graham and Parks, 1986; Parks, 1990; Parks and Mirecki, 1992; Parks and others, 1995). Recharge to the Memphis aquifer primarily is east of the eastern limits of the Jackson-upper Claiborne confining unit (fig.1), but some recharge occurs locally where the confining unit is thin or absent.

Potentiometric-Surface Map

The potentiometric-surface map of the Memphis aquifer was prepared using water-level measurements in 75 wells in the Memphis area (fig. 1). These measurements were made in September when water levels usually are lowest. Therefore, this map represents low water-level conditions in the aquifer for 1995. Prior to withdrawals from the Memphis aquifer in 1886, the potentiometric surface was a smooth surface with a gentle slope to the west-northwest (Criner and Parks, 1976). Since 1886, increases in the rate of water withdrawals from the aquifer have caused a large cone of depression in the potentiometric surface and several smaller cones of depression at municipal well fields in the Memphis area (fig. 1). As a result of ground-water withdrawals, the general direction of ground-water flow is toward the center of the cone of depression. Hydraulic gradients for the aquifer range from about 0.0006 foot per foot in the northeastern part of the Memphis area to about 0.0047 foot per foot near the McCord well field.

Historical Water-Level Changes

Hydrographs for selected wells away from municipal and industrial well fields show the effects of long-term pumpage on water levels in the Memphis aquifer (fig. 2). Water levels in wells near the center of the cone of depression show much larger declines than those in outlying wells, which are only minimally affected by withdrawals at Memphis. The hydrograph for well Fa:R-2 (fig. 2), located outside the large cone of depression in the potentiometric surface (fig. 1), shows a decline in water levels from about 38 feet below land surface in 1949 to a maximum low-water level of about 42 feet below land surface in the late 1960's. Since 1969, the water level in well Fa:R-2 appears to have stabilized at a level of about 40 feet below land surface. During the period of record (1949-95), the net water level decline is less than 2 feet, indicating an average rate of decline of less than 0.1 foot per year (ft/yr) (fig. 2).

Well Sh:Q-1 is located between well Fa:R-2 and the center of the cone of depression (fig.1). In contrast to the hydrograph for well Fa:R-2, the hydrograph for Sh:Q-1 shows a steady decline in water levels (fig. 2). Since 1940, the water level in well Sh:Q-1 has declined about 36 feet, an average rate of decline of about 0.7 ft/yr.

Water-level declines near the center of the cone of depression are even larger as indicated by the hydrograph for well Sh:P-76 (fig. 1). Between 1928 and 1975, the water level declined about 70 feet (fig. 2). However, since about 1975 water levels in well Sh:P-76 have not declined, indicating that water levels near the center of the cone of depression have stabilized. For the period of record (1928-95), the average rate of decline in water level is about 1 ft/yr in well Sh:P-76.

Hydrographs for wells Sh:J-1 and Sh:O-1 (fig. 2) located south and north, respectively, of the center of the cone of depression (fig. 1) show average rates of decline of about 0.5 and 0.8 ft/yr. However, the water level in both these wells show no decline from about 1990 to present. These data may indicate that the cone of depression has stabilized in the areas of these wells, but is continuing to expand eastward as indicated by the data for well Sh:Q-1. The seasonal fluctuation in water levels recorded in these observation wells (fig. 2) is a result of seasonal differences in water demand and pumpage, rather than of changes in aquifer response to recharge.

FORT PILLOW AQUIFER

The Tertiary-age Fort Pillow Sand of the Wilcox Group (table 1) composes the Fort Pillow aquifer. The Fort Pillow Sand is present in the subsurface throughout the Memphis area. It consists primarily of sand with local minor lenses of clay or silt. In the Memphis area, the Fort Pillow aquifer ranges from about 100 to 300 feet in thickness (Kingsbury and Parks, 1993), and it thickens from east to west. The Flour Island Formation, composed primarily of clay and silt, overlies the Fort Pillow Sand and serves as the upper confining unit for the aquifer and is termed the Flour Island confining unit. The Old Breastworks Formation underlies the Fort Pillow Sand and serves as part of the lower confining unit (table 1), resulting in artesian conditions in the aquifer. Recharge to the Fort Pillow aquifer primarily is east of the eastern extent of the Flour Island confining unit, outside of the Memphis area as defined for this report.

Potentiometric-Surface Map

The potentiometric-surface map of the Fort Pillow aquifer was prepared from water-level measurements in 16 wells in the Memphis area (fig. 3). These measurements were made in September when water levels are usually lowest; therefore this map represents low water-level conditions in the aquifer for 1995. Prior to withdrawals from the Fort Pillow aquifer in 1924, the shape of the potentiometric surface was probably similar to that of the Memphis aquifer with a gentle slope to the west-northwest (Criner and Parks, 1976). Withdrawals from the aquifer at West Memphis, Arkansas, account for about half of the total pumpage from the aquifer for 1995, and have caused a cone of depression in the potentiometric surface centered beneath West Memphis. Smaller cones of depression are present in the Memphis area where ground-water withdrawals from the Fort Pillow aquifer are occurring. As a result of ground-water withdrawals, the general direction of ground-water flow is to the west, toward Memphis (fig. 3). Hydraulic gradients in the Fort Pillow aquifer range from about 0.0004 foot per foot in the northeastern Memphis area to about 0.0019 foot per foot in the cone of depression at West Memphis.

Historical Water-Level Changes

Hydrographs for selected wells show the effects of long-term pumpage on water levels in the Fort Pillow aquifer (fig. 4). Although less water is withdrawn from the Fort Pillow aquifer than the Memphis aquifer, the effects of pumpage are widespread as is evident from the hydrographs of wells throughout the Memphis area.

The hydrograph for well Fa:R-1 (fig. 4), located in the northeastern part of the Memphis area (fig. 3), shows a decline in water level from about 65 feet below land surface in 1949 to about 88 feet below land surface in 1995. This is an average rate of decline of about 0.5 ft/yr.

Well Sh:U-1 is located between Fa:R-1 and the center of pumpage in the area (fig. 3). Since 1946, the water level in well Sh:U-1 (fig. 4) has declined about 49 feet, an average rate of decline of about 1 ft/yr.

The hydrograph for well Sh:O-170 (fig. 4) in the Mallory well field (fig. 3) shows the effects of pumpage from the Fort Pillow aquifer in the well field during the first half of the period of record. Water levels declined rapidly between 1945 and 1954. This decline was in response to increases in withdrawals from the aquifer from 1924 until the early 1950's. Withdrawals from the Fort Pillow aquifer reached a maximum of about 15 Mgal/d in 1951 (Criner and Armstrong, 1958) and the rate of water withdrawal remained level until 1962. Withdrawals decreased between 1962 and 1971, and MLGW stopped pumping from the aquifer in 1971 (Criner and Parks, 1976). The average rate of water-level decline for the period of record (1945 to 1995) is 0.8 ft/yr. The maximum rate of decline was 4 ft/yr between 1945 and 1954 (Parks and Carmichael, 1990).

Well Sh:K-45, located east of the Mallory well field in the Sheahan well field (fig. 3), records the same general water-level changes as well Sh:O-170; however, the early period of record does not show the large short-term fluctuations associated with nearby pumpage recorded in well Sh:O-170. In 1990, the hydrographs for all of the observation wells show a decline in water-level that may correspond to the initiation of pumping at the Shaw well field (fig. 3).

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Table 1. Post-Midway Group geologic units underlying the Memphis area, Tennessee, and their hydrologic significance

[Modified from Kingsbury and Parks, 1993]

System	Series	Group	Stratigraphic unit (and local name)	Thickness (in feet)	Lithology and hydrologic significance
Quaternary	Holocene and Pleistocene		Alluvium (alluvial deposits)	0-175	Silt, clay, sand, and gravel. Underlies the Mississippi Alluvial Plain and tributary streams. Thickest beneath the Mississippi Alluvial Plain where it is between 100-150 feet thick. Generally less than 50 feet thick elsewhere.
Quaternary	Pleistocene		Loess	0-65	Silt, with minor clay and fine sand. Principal unit at the surface in upland areas. Thickest on the bluffs that border the Mississippi Alluvial Plain; generally thins eastward. Serves as the upper confining unit for the alluvial-fluvial deposits aquifer.
Quaternary and Tertiary(?)	Pleistocene and Pliocene(?)		Fluvial deposits (terrace deposits)	0-100	Sand and gravel, with minor clay and ferruginous sandstone. Underlies the loess in upland areas, locally is absent. Thickness varies greatly because of erosional surfaces at top and base.
Tertiary	Eocene	?	Jackson Formation	0-50	Sand, silt, clay, and lignite. Because of similarities in lithology, the Jackson and Cockfield Formations cannot be reliably subdivided based on available information. Preserved sequence is mostly Cockfield, but locally is overlain by the Jackson in the northwestern part of the Memphis area. Commonly consists predominantly of fine sediments and serves as part of the upper confining unit for the Memphis aquifer.
Tertiary	Eocene	Claiborne	Cockfield Formation	0-250	
Tertiary	Eocene	Claiborne	Cook Mountain Formation	0-110	Clay, silt, and sand. Generally consists of clay and silt, but locally contains some very fine sand. Serves as part of the upper confining unit for the Memphis aquifer.
Tertiary	Eocene	Claiborne	Memphis Sand	650-900	Sand, silt, clay, and minor lignite. Consists of a thick body of sand with clay lenses at various horizons. Sand is fine to medium or medium to coarse. Upper part contains lenses of fine sand and clay. Constitutes the Memphis aquifer— the principal aquifer providing water for most domestic, commercial, industrial, and municipal supplies in the Memphis area.
Tertiary	?	Wilcox	Flour Island Formation	140-310	Clay, silt, sand, and lignite. Consists predominantly of clay and silt with lenses of fine sand. Serves as the lower confining unit for the Memphis aquifer and the upper confining unit for the Fort Pillow aquifer.
Tertiary	Paleocene	Wilcox	Fort Pillow Sand	98-300	Sand, with minor clay and silt. Sand is fine or fine to medium; clay is present as lenses. Constitutes the Fort Pillow aquifer— the secondary aquifer in the Memphis area.
Tertiary	Paleocene	Wilcox	Old Breastworks Formation[1]	180-310	Clay, silt, sand, and lignite. Serves as the lower confining unit for the Fort Pillow Sand, along with the Porters Creek Clay and the Clayton Formation of the underlying Midway Group of Tertiary age and the Owl Creek Formation of Cretaceous age.

[1]Frederiksen and others (1982) tentatively placed the Old Breastworks Formation in the Midway Group, but for the purposes of this report, the Old Breastworks Formation of the Wilcox Group is used as defined by Moore and Brown (1969).

CONVERSION FACTORS, VERTICAL DATUM, AND WELL NUMBERING SYSTEM

Multiply	By	To obtain
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
million gallons per day	0.04381	cubic meters per second

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

Tennessee District well-numbering system: Wells in Tennessee are identified according to the numbering system that is used by the U.S. Geological Survey, Water Resources Division. The well number consists of:

1. an abbreviation of the name of the county in which the well is located;
2. a letter designating the 7 1/2-minute topographic quadrangle on which the well is plotted; quadrangles are lettered from left to right across the county beginning in the southwest corner of the county; and
3. a number generally indicating the numerical order in which the well was inventoried.

For example, Sh:J-1 indicates that the well is located in Shelby County on the "J" quadrangle and is identified as well 1 in the numerical sequence.

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ALTITUDE OF THE POTENTIOMETRIC SURFACES, SEPTEMBER 1995, AND HISTORICAL WATER-LEVEL CHANGES IN THE MEMPHIS AND FORT PILLOW AQUIFERS IN THE MEMPHIS AREA, TENNESSEE

By
James A. Kingsbury
1996