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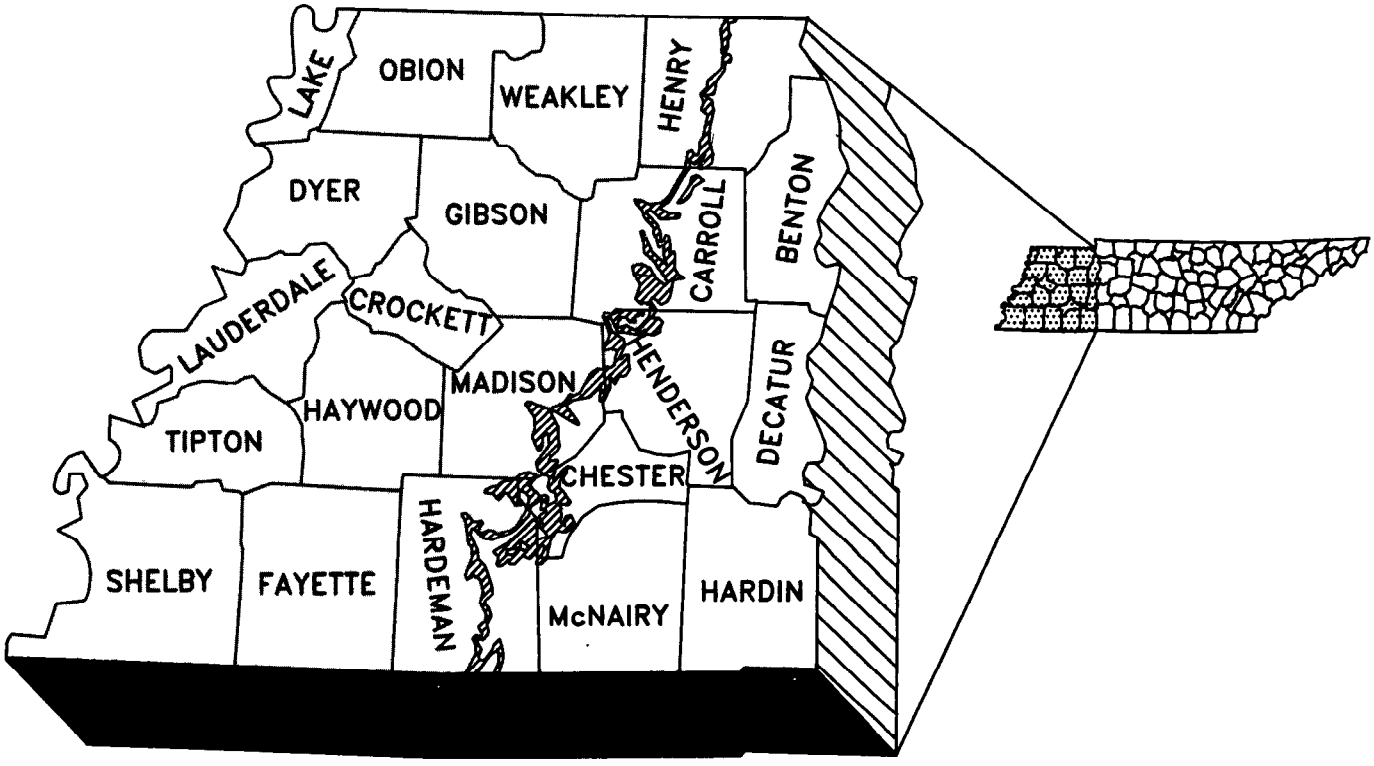
# GEOLOGY AND GROUND-WATER RESOURCES OF THE FORT PILLOW SAND IN WESTERN TENNESSEE

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# GEOLOGY AND GROUND-WATER RESOURCES OF THE FORT PILLOW SAND IN WESTERN TENNESSEE

By W.S. Parks and J.K. Carmichael

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 89-4120


Memphis, Tennessee
1989

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## CONVERSION FACTORS

Factors for converting inch-pound units used in this report to metric units are as follows:

| Multiply inch-pound units | By | To obtain metric units |
|---|---|---|
| foot (ft) | 0.3048 | meter (m) |
| foot per year (ft/yr) | 30.48 | centimeter per year (cm/yr) |
| foot per mile (ft/mi) | 0.1894 | meter per kilometer (m/km) |
| mile (mi) | 1.609 | kilometer (km) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| gallon (gal) | 0.00379 | cubic meter ($m^3$) |
| gallon per minute (gal/min) | 0.06309 | liter per second (L/s) |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second ($m^3/s$) |
| foot squared per day ($ft^2/d$) | 0.0929 | meter squared per day ($m^2/d$) |

*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."

*Well-Numbering System*: Wells are identified according to the numbering system used by the U.S. Geological Survey throughout Tennessee. The well number consists of three parts: (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; and (3) a number generally indicating the numerical order in which the well was inventoried. The symbol Md:G-45, for example, indicates that the well is located in Madison County on the "G" quadrangle and is identified as well 45 in the numerical sequence. Quadrangles are lettered from left to right, beginning in the southwest corner of the county.

# GEOLOGY AND GROUND-WATER RESOURCES OF THE FORT PILLOW SAND IN WESTERN TENNESSEE

W. S. Parks and J. K. Carmichael


## ABSTRACT

*The Fort Pillow Sand of the Wilcox Group of Tertiary age underlies approximately 7,700 square miles in western Tennessee. The formation consists primarily of very fine to very coarse sand that locally contains minor lenses or beds of clay or silt. The Fort Pillow Sand ranges from 0 to 350 feet in thickness. In the Memphis area, where many wells have been drilled through the formation, the Fort Pillow Sand ranges from about 90 to 240 feet in thickness, but commonly it is about 200 feet thick. The Fort Pillow Sand would yield water to wells in most of the area of occurrence in western Tennessee and, where saturated, makes up the Fort Pillow aquifer.*

*Recharge to the Fort Pillow aquifer is from precipitation on the outcrop, a narrow belt across western Tennessee, and by downward infiltration of water from the overlying fluvial deposits of Tertiary(?) and Quaternary age and alluvium of Quaternary age or, where the upper confining unit is absent, from the overlying Memphis aquifer of Tertiary age. Long-term data (1945-83) from four observation wells in areas affected by pumping indicate that water levels in these areas have declined at average rates ranging from 0.4 to 0.9 foot per year. The rate of decline was as large as 4.0 feet per year between 1945 and 1954 in one well in an intensely pumped area at Memphis.*

*Water from the Fort Pillow aquifer generally is a sodium bicarbonate type but near the outcrop-recharge area, it locally is a calcium bicarbonate type. The water contains low concentrations of most major constituents and generally is suitable for most uses. Dissolved-solids concentrations range from 20 to 143 milligrams per liter.*

*Results from 20 aquifer tests made at Memphis and 4 made at Jackson during the period 1932-61 indicate that transmissivities average about 13,100 feet squared per day at Memphis and about 10,000 feet squared per day at Jackson. Storage coefficients from these tests average about 0.0002 and 0.0015, respectively.*

*The Fort Pillow aquifer provides moderate to large quantities of water to several public and industrial well fields and small quantities of water to numerous domestic and farm wells along a belt just downdip from the outcrop area in western Tennessee. The aquifer also provides part of the water supply for an industry and a municipality in the Memphis area. Withdrawals for public and industrial supplies in western Tennessee in 1983 averaged about 10.6 million gallons per day. The*

*Fort Pillow aquifer is widespread, virtually untapped, and has much potential for future use.*

## INTRODUCTION

This report was prepared by the U.S. Geological Survey as part of the Gulf Coast Regional Aquifer-System Analysis (GC RASA) program. The GC RASA study area covers about 230,000 $mi^2$ onshore in Louisiana and parts of Alabama, Arkansas, Florida, Illinois, Kentucky, Mississippi, Missouri, Tennessee, and Texas. About 60,000 $mi^2$ offshore on the continental shelf also are included because the aquifers extend beyond the coast line beneath the Gulf of Mexico. The study is limited to the Coastal Plain sediments of Tertiary and younger age, except for an area in the Mississippi embayment where Upper Cretaceous sediments supply ground water in parts of several States. The objectives of the GC RASA study are to define the geohydrologic framework, to describe the chemistry of the ground water, and to analyze the regional ground-water flow system (Grubb, 1984).

### Background Information

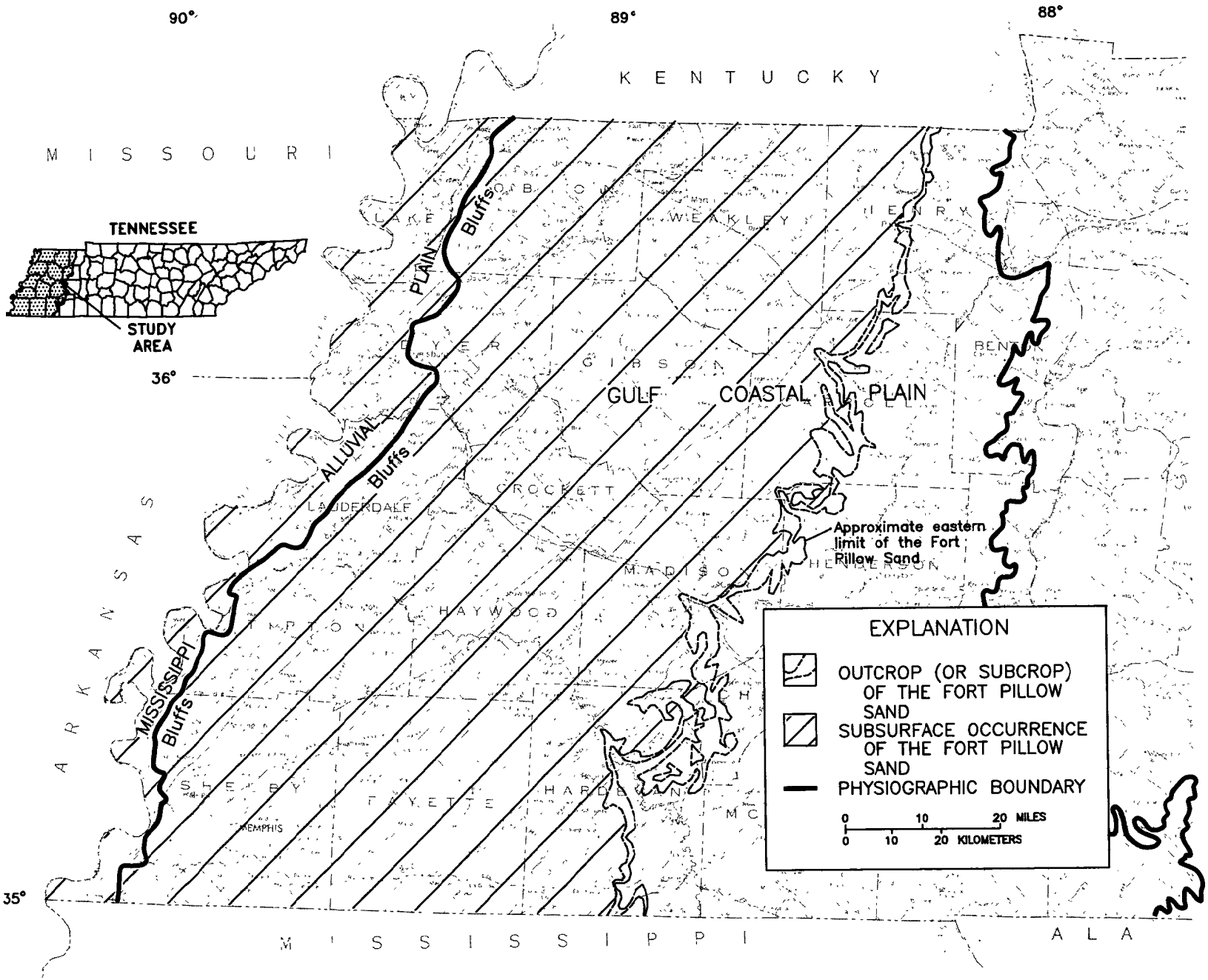
Information interpreted or compiled for the aquifers in Tertiary sediments in western Tennessee as a part of the GC RASA study, included: (1) geophysical-log correlations of the stratigraphic and geohydrologic units, (2) thicknesses of sand and clay beds in the geohydrologic units, (3) maps of the water-table and potentiometric surfaces in the aquifers, (4) data showing long-term water-level changes, (5) historic pumpage from the aquifers, (6) hydraulic characteristics of the aquifers, (7) water-quality data, and (8) locations of pumping centers. Much of this information was interpreted or compiled from existing geophysical logs, water-level data, pumpage inventories, aquifer-test records, and water-quality analyses. New data collected for GC RASA include: (1) water-quality data from about 40 wells, (2) water-level measurements in about 70 wells, (3) location of currently used public and industrial water-supply wells, and (4) field verification of the locations of wells for which important historic data are available.

### Purpose and Scope

This report summarizes and interprets the information and data collected on the geology and ground-water resources of the Fort Pillow Sand in western Tennessee as part of the larger GC RASA investigation. Similar reports were prepared for the Cockfield Formation and Memphis Sand (Parks and Carmichael, in press, a,b). Reports also were prepared to show the altitude of the potentiometric surfaces in the Memphis and Fort Pillow aquifers for the the fall of 1985 and to describe historic water-level changes in these aquifers (Parks and Carmichael, in press, c,d).

## GEOLOGY

The Fort Pillow Sand (Moore and Brown, 1969) of the Wilcox Group of Tertiary age underlies approximately 7,700 $mi^2$ in the Gulf Coastal Plain of western Tennessee (fig. 1). The formation crops out in a narrow belt across western Tennessee. The Wilcox Group in the area includes the underlying Old Breastworks Formation and the overlying Flour Island Formation (Moore and Brown, 1969). At many places, the outcrop of the Fort Pillow Sand is overlain by the fluvial deposits of Tertiary(?) and Quaternary age and the alluvium of Quaternary age. Post-Cretaceous geologic units in western Tennessee and their hydrologic significance are given in table 1.




Base from U.S. Geological Survey, State base map, 1:500,000, 1973

Figure 1.——Occurrence of the Fort Pillow Sand as related to major physiographic subdivisions in western Tennessee.

Table 1.--*Post-Cretaceous geologic units underlying western Tennessee and their hydrologic significance*

| System | Series | Group | Stratigraphic unit | Thickness (in feet) | Lithology and hydrologic significance |
|---|---|---|---|---|---|
| Quaternary | Holocene and Pleistocene | | Alluvium (alluvial deposits) | 0-200 | Sand, gravel, silt, and clay. Underlies the Mississippi Alluvial Plain and the alluvial plains of streams in the Gulf Coastal Plain upland areas. Thickest beneath the Mississippi Alluvial Plain where it commonly is between 100 and 150 feet thick and makes up the Mississippi River Valley alluvial aquifer. Generally less than 50 feet thick elsewhere. Provides water to farm and domestic wells and to some industrial and irrigation wells in the Mississippi Alluvial Plain. |
| | Pleistocene | | Loess | 0-70 | Silt, silty clay, and minor sand. Principal unit at the surface in upland areas of the Gulf Coastal Plain, concealing the older Quaternary and Tertiary units at most places. Thickest on the bluffs that border the Mississippi Alluvial Plain; generally thinner eastwards. Retards downward movement of the water that provides recharge to the water-table aquifers. |
| Quaternary and Tertiary(?) | Pleistocene and Pliocene(?) | | Fluvial deposits (terrace deposits) | 0-100 | Sand, gravel, minor clay and ferruginous sandstone. Generally underlie the loess in upland areas, but are locally absent. Thickness varies greatly because of erosional surfaces at top and base. Provides water to farm and domestic wells in rural areas. |
| Tertiary | Eocene | ?<br>Claiborne | Jackson Formation<br>?<br>Cockfield Formation<br>?<br>Cook Mountain Formation<br>? | 0-150<br><br>0-270<br><br>40-200 | Sand, silt, clay, and lignite. Because of similarities in lithology, the Jackson and Cockfield cannot be reliably subdivided based on available information. Preserved sequence mostly Cockfield, but locally is overlain by the Jackson. Thicknesses are estimates based on tentative geophysical log correlations The Jackson and Cockfield provide water to farm and domestic wells in rural areas and the Cockfield provides water for some public and industrial supplies.<br><br>Clay, silt, and sand. Generally consists of clay and silt, but locally may consist predominately of fine sand. Probably averages about 70 feet in thickness. Unit can be confused with clay lenses in the lower part of the Cockfield or upper part of the Memphis Sand. Serves as upper confining unit for the Memphis Sand. |
| | | | Memphis Sand ("500-foot" sand) | 400-890 | Sand, silt, clay, and minor lignite. Consists of a thick body of sand with clay lenses at various horizons. Sand is fine to very coarse Upper part commonly contains fine sediments, particularly north of the Hatchie River where it is generally necessary to drill to the middle or lower parts of the aquifer to install large capacity wells. Thickest in Shelby County where it is the principal aquifer supplying water to the City of Memphis. Major aquifer providing water for most public and industrial supplies in the western part of western Tennessee. |
| | ? | Wilcox | Flour Island Formation | 0-310 | Clay, silt, sand, and lignite. Not an aquifer. Consists predominantly of clay and silt. Where present, serves as lower confining unit for the Memphis Sand and the upper confining unit for the Fort Pillow Sand. |
| | Paleocene | | Fort Pillow Sand ("1400-foot" sand) | 0-350 | Sand and minor clay. Sand is fine to very coarse. Thickest in the Dyer-Lake County area. Once used as the second principal aquifer to supply water for the City of Memphis; now used by an industry at Memphis and the City of Millington. Provides water for some municipal and industrial supplies just downdip from its outcrop belt. Major aquifer in rudimentary stage of development. |
| | | | Old Breastworks Formation[1] | 0-310 | Clay, silt, sand, and lignite. Not an aquifer Consists predominantly of clay and silt. Where present, serves as the lower confining unit for the Fort Pillow Sand along with Porters Creek Clay and Clayton Formation. |
| | | ?<br>Midway | Porters Creek Clay | 40-320 | Clay and minor sand. Consists of a widespread and generally thick body of clay with local interbeds or lenses of fine sand. Serves as the major confining unit between the Fort Pillow Sand of Tertiary age and the McNairy Sand of Cretaceous age. |
| | | | Clayton Formation | 40-110 | Clay, sand, and limestone. Generally consists of clay with local interbeds or lenses of fine sand and limestone. North of Hardeman County in a narrow belt paralleling and including the outcrop area, the Clayton is predominantly sand and provides water to some farm and domestic wells. Underlain by the Owl Creek Formation and McNairy Sand 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 Beastworks Formation of the Wilcox Group as defined by Moore and Brown (1969) is used.

## Stratigraphy

The sequence of strata equivalent to the Fort Pillow Sand was referred to as the "1,400-foot" sand in many early reports, particularly those for the Memphis area (Klaer, 1940; Kazmann, 1944; Schneider and Cushing, 1948; Criner and Armstrong, 1958; Criner and others, 1964). The informal name "1,400-foot" sand originated at Memphis where wells tapping the Fort Pillow Sand had an "average" depth of about 1,400 feet. The geology and water-bearing properties of the "1,400-foot" sand in the Memphis area were described in detail by Schneider and Cushing (1948). Additional information on the "1,400-foot" sand was subsequently published in reports concerning the ground-water supply of the Memphis area (Criner and Armstrong, 1958) and the hydrology of the aquifer systems in the Memphis area (Criner and others, 1964).

Hosman and others (1968), in a report on the Tertiary aquifers in the Mississippi embayment, included strata equivalent to the "1,400-foot" sand in their description of the lower Wilcox aquifer. Moore and Brown (1969) in their study of the stratigraphy of the Fort Pillow Sand at a test well in Lauderdale County, Tenn., divided the Wilcox Group into, in ascending order, the Old Breastworks Formation, the Fort Pillow Sand, and the Flour Island Formation. These formations were correlated in the subsurface across western Tennessee on a geologic section.

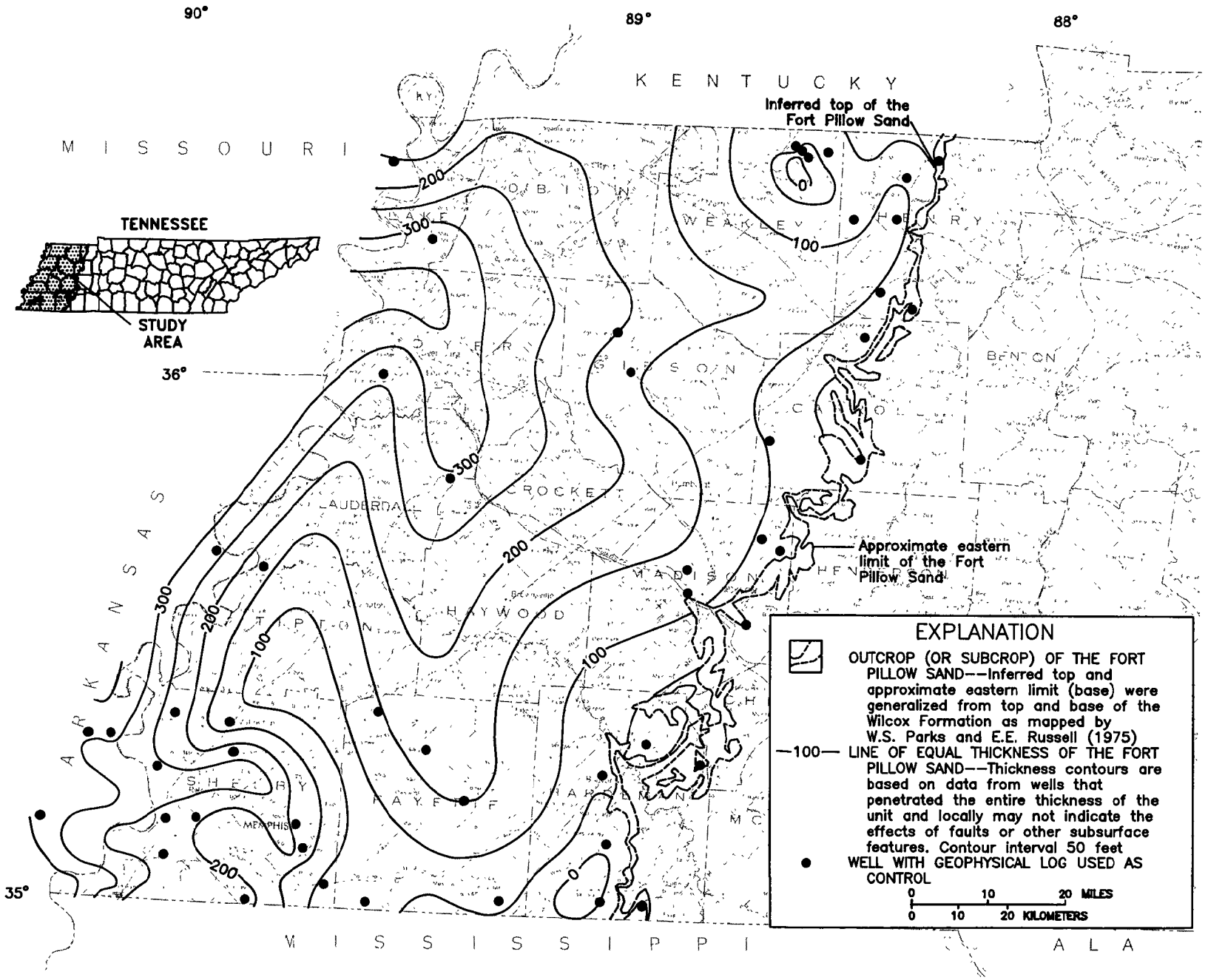
The outcrop belt of the Wilcox Formation in western Tennessee, as mapped by Parks and Russell (1975), locally includes strata equivalent to the Fort Pillow Sand. The Wilcox was mapped as a formation by Parks and Russell (1975) because of the uncertainty as to the equivalence of surface strata with the Old Breastworks Formation, Fort Pillow Sand, and Flour Island Formation of the Wilcox Group in the subsurface as divided and described by Moore and Brown (1969). In a report on the stratigraphy of the outcropping Cretaceous, Paleocene, and lower Eocene in western Tennessee, Russell and Parks (1975) described the Wilcox Formation as a heterogeneous body of sand, silt, and clay, having no sequence laterally persistent over any great distance. The cleaner, better sorted sand, which may be equivalent to the Fort Pillow Sand, was described as being predominant in only a few areas. Stratigraphic and structural information collected during this investigation indicates that the Wilcox Formation at the surface and in the subsurface just downdip from the outcrop belt may include any combination of the formations that make up the Wilcox Group in the subsurface.

The Fort Pillow Sand is underlain by the Old Breastworks Formation, except where the Fort Pillow Sand overlaps the Old Breastworks Formation and overlies the Porters Creek Clay. The Fort Pillow Sand is overlain by the Flour Island Formation, except where the Memphis Sand overlaps the Flour Island Formation and overlies the Fort Pillow Sand (table 1).

## Lithology and Thickness

The Fort Pillow Sand consists primarily of sand that locally contains minor lenses or beds of clay or silt. The sand ranges from very fine to very coarse, but commonly it is locally fine to medium or medium to coarse. In Shelby County, the sand generally is fine to medium and well sorted (Criner and others, 1964, p. O15). Descriptions of sand from test holes in Carroll, Fayette, Hardeman, Henry, Lauderdale, and Madison Counties show that locally it ranges from very fine to very coarse (Milhous, 1959, p. 121-123, 278-279; Moore and Brown, 1969; Russell and Parks, 1975, p. B48-B53).

The generalized thickness of the Fort Pillow Sand is shown in figure 2. The thickness contours are based on data from wells that penetrated the entire thickness of the unit and




Base from U.S. Geological Survey, State base map, 1:500,000, 1973

Figure 2.--Generalized thickness of the Fort Pillow Sand.

locally may not indicate the effects of faults or other subsurface features.

The Fort Pillow Sand ranges from 0 to about 350 feet in thickness. Regionally, the formation is thinnest along the outcrop and is thickest downdip in the western tier of counties along the Mississippi River. Locally, the thickness varies because of an erosional boundary at the base of the formation and a gradational boundary at the top. In the Memphis area, where many wells have been drilled through the formation, the Fort Pillow Sand ranges from about 90 to 240 feet in thickness, but commonly it is about 200 feet thick.

### Geologic Structure

In western Tennessee, the base of the Fort Pillow Sand dips westward at 25 to 50 ft/mi, and it is faulted at many places (plates 1 and 2). Identification and location of faults that displace the Tertiary formations are difficult because they are covered at most places by Quaternary surficial deposits and subsurface information is sparse. A study of the likelihood of post-Cretaceous faulting in the northern Mississippi embayment, including western Tennessee, has shown that faults that displace the Cretaceous and Tertiary formations probably are relatively common (Stearns and Zurawski, 1976). Correlation and interpretation of geophysical logs made in test holes drilled in Lauderdale County, Tenn., indicate several faults that displace the upper part of the Memphis Sand and the Cook Mountain and Cockfield Formations (Parks and others, 1985).

Faults identified during this investigation that displace the base of the Fort Pillow Sand are shown in plate 1. Most of these faults are based on an interpretation of the geologic structure using correlations of geophysical logs of wells. Faults in Lake County, however, are based partly on the interpretation of seismic reflection profiles by Zoback (1979) and Hamilton and Zoback (1982). The geophysical log correlations are highly interpretive but are supported by paleontological evidence from the Fort Pillow test well in Lauderdale County, Tenn. (Moore and Brown, 1969), and the New Madrid test wells in New Madrid County, Mo. (Frederiksen and others, 1982).

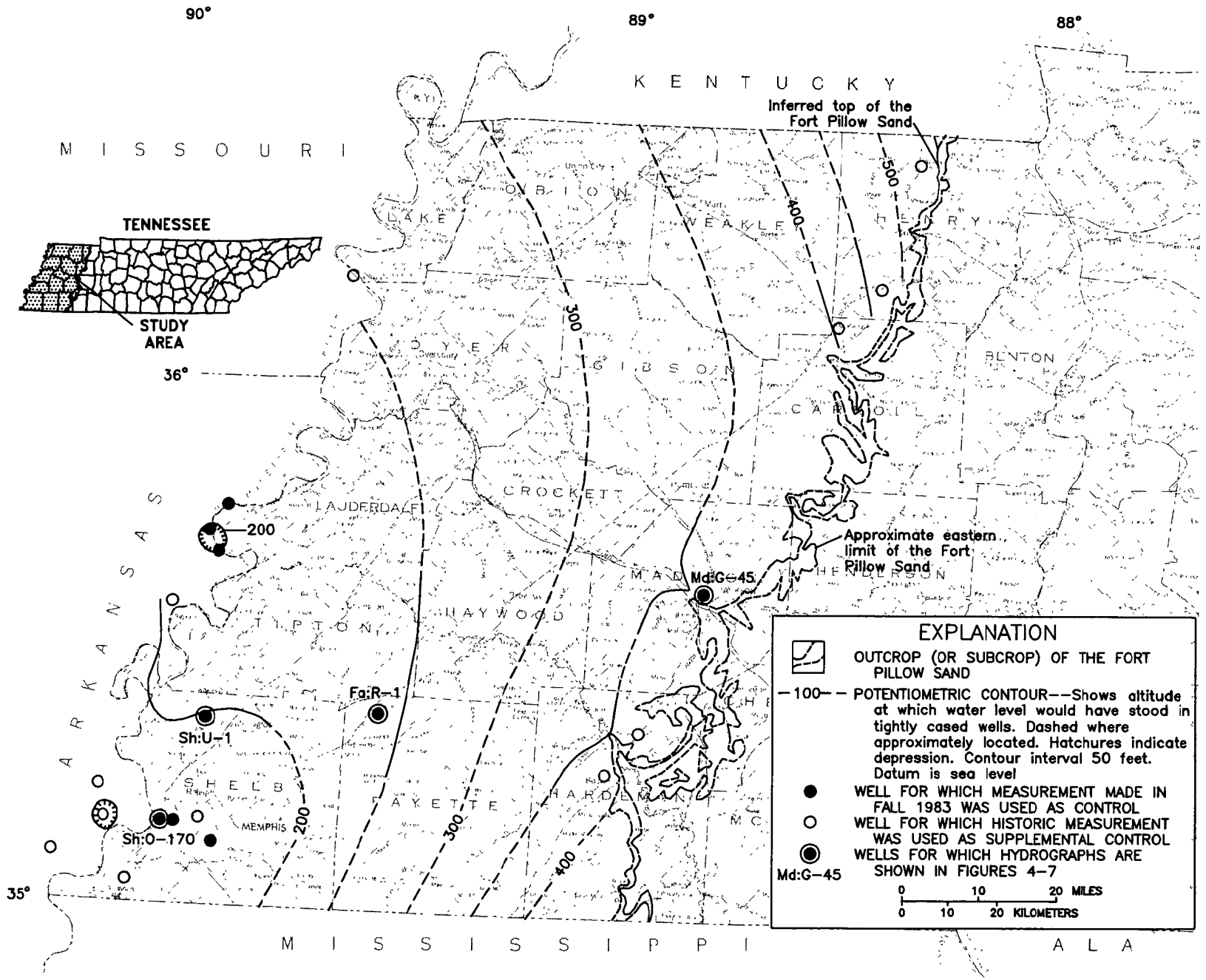
## HYDROLOGY

The Fort Pillow Sand would yield water to wells in most of the area of occurrence in western Tennessee and, where saturated, makes up the Fort Pillow aquifer. In the larger, multistate GC RASA investigation, the Fort Pillow aquifer is included in the lower Wilcox aquifer for purposes of studying the regional aspects of the ground-water system (Grubb, 1986).

### Recharge and Potentiometric Surface

Recharge to the Fort Pillow aquifer occurs along the narrow outcrop belt across western Tennessee (fig. 3). Recharge is from precipitation on the outcrop and downward infiltration of water from the overlying fluvial deposits and alluvium. Along this outcrop-recharge belt and in the subsurface just downdip, the Flour Island Formation, which serves as the upper confining unit for the Fort Pillow aquifer, is absent at places and the Memphis Sand directly overlies the Fort Pillow Sand. At these places, the Fort Pillow and Memphis aquifers have common recharge areas.

In the outcrop-recharge belt, the Fort Pillow aquifer is under water-table conditions (unconfined); and the configuration of the potentiometric surface (fig. 3), whether in the Fort Pillow Sand or in the overlying fluvial deposits and alluvium, generally conforms to the topography. Seeps and springs occur where the land surface intercepts the water table. In the




Base from U.S. Geological Survey, State base map, 1:500,000, 1973

Figure 3.--Generalized potentiometric surface in the Fort Pillow aquifer, fall 1983.

outcrop-recharge belt, water moves westward down the dip of the Fort Pillow Sand and also toward the major streams that drain the area. Part of the water that flows toward the major streams passes through the alluvium, discharges to the channels, and sustains base flows.

In the subsurface to the west of the outcrop-recharge belt where the Fort Pillow aquifer is confined by the Flour Island Formation, the potentiometric surface slopes gently westward (fig. 3), and the water moves slowly in that direction. In the downdip western tier of counties, the Flour Island Formation locally is displaced by faults, and the Fort Pillow and Memphis aquifers are in direct hydraulic connection, as in Lake County (plate 2). At these places, vertical interchange of water may occur between these aquifers. The depression in the potentiometric surface in the Memphis area (fig. 3) is the result of past pumping at Memphis Light, Gas and Water Division (MLGW) well fields (1924-74), and past and present pumping at an industrial well field at Memphis, and the municipal well field at West Memphis, Ark.

The Old Breastworks Formation of the Wilcox Group and the Porters Creek Clay and Clayton Formation of the Midway Group make up the lower confining unit for the Fort Pillow aquifer, separating it from the deeper McNairy aquifer of Cretaceous age. This confining unit is thick, widespread, and consists predominantly of clay. Consequently, interchange of water between the Fort Pillow and McNairy aquifers probably is minimal.

### Historic Water-Level Changes

Historic water-level changes in the Fort Pillow aquifer are evident from long-term records of water-level measurements in observation wells. Hydrographs for four observation wells in the Fort Pillow aquifer are shown in figures 4-7; their locations are shown in figure 3. The wells are in areas where water levels are affected by pumping. Well Md:G-45, in Madison County, was near public and industrial well fields at Jackson (fig. 3). A water-level recorder installed on this well in late 1958 was operated until early 1973 when the well was destroyed. The water level in well Md:G-45 declined about 13.1 feet in 14 years (1958-72), an average rate of about 0.9 ft/yr (fig. 4).

Key observation wells in the Memphis area show the long-term effects of pumping on water levels in the Fort Pillow aquifer. Well Fa:R-1, in northwestern Fayette County, is the farthest of these wells from the center of the depression in the potentiometric surface in the Memphis area (fig. 3). The water level in well Fa:R-1 declined about 13.6 feet in 34 years (1949-83), an average rate of about 0.4 ft/yr (fig. 5). Well Sh:U-1, in northern Shelby County, is downgradient from Fa:R-1 and at an intermediate distance between well Fa:R-1 and the center of the depression (fig. 3). The water level in well Sh:U-1 declined about 25.2 feet in 36 years (1947-83), an average rate of about 0.7 ft/yr (fig. 6).

Well Sh:O-170 is near the center of the depression in the potentiometric surface in the Memphis area (fig. 3). This observation well is in the Mallory well field of MLGW, where prior to 1972, nearby wells were pumping from the Fort Pillow aquifer. The early part of the hydrograph for this well shows extreme fluctuations of monthly low-water levels (fig. 7). The record from this well, however, is the best information available on which to base an average rate of decline of water levels in a much larger and deeper depression in the potentiometric surface that developed when MLGW was pumping from this aquifer. The early part of this hydrograph shows a maximum water-level decline of about 4 ft/yr between 1945 and 1954. This decline was in response to increases in pumping rates from the aquifer beginning in 1924. In 1951, withdrawals from the aquifer in the Memphis area reached a maximum at an average rate of 15.1 Mgal/d, and

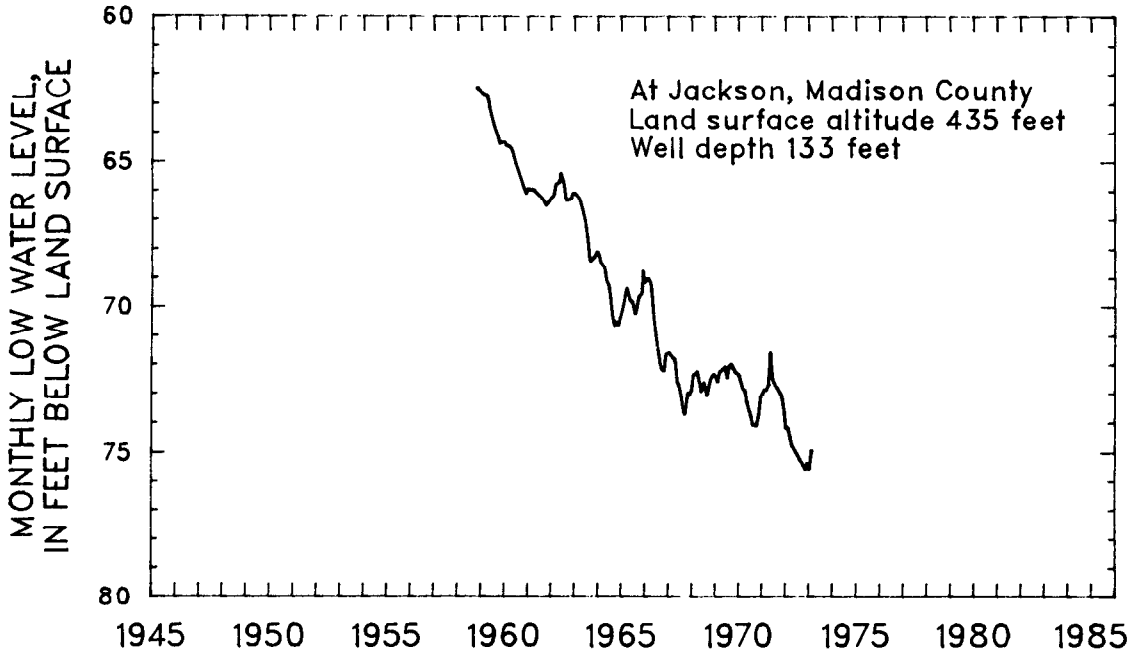



Figure 4.--Water levels in observation well Md:G-45.

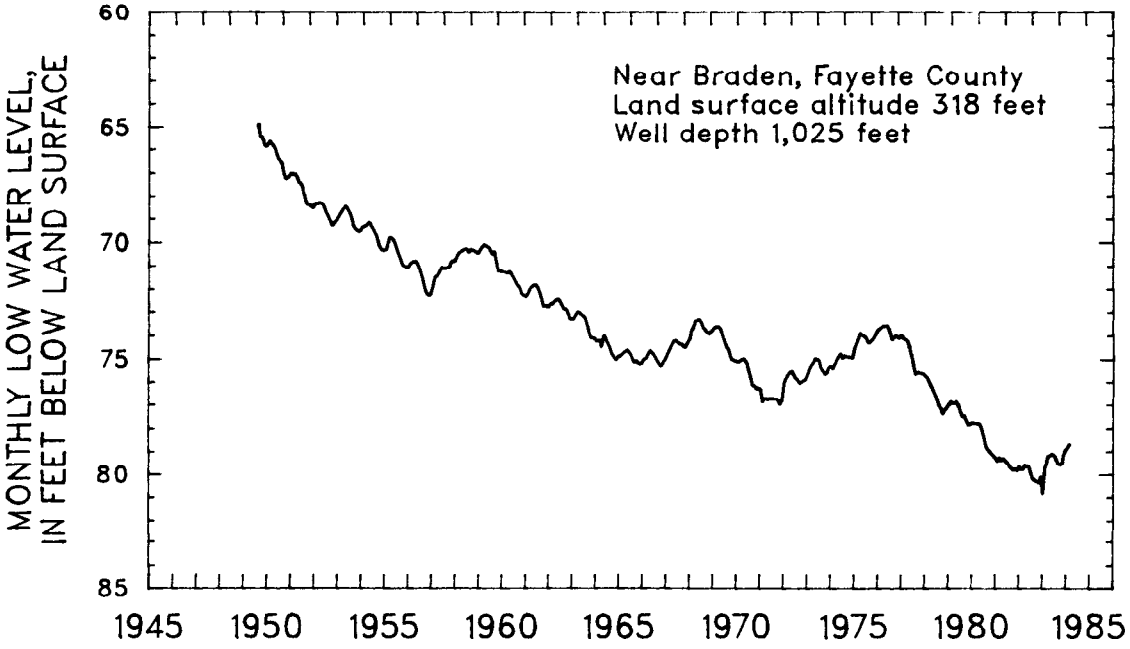



Figure 5.--Water levels in observation well Fa:R-1.

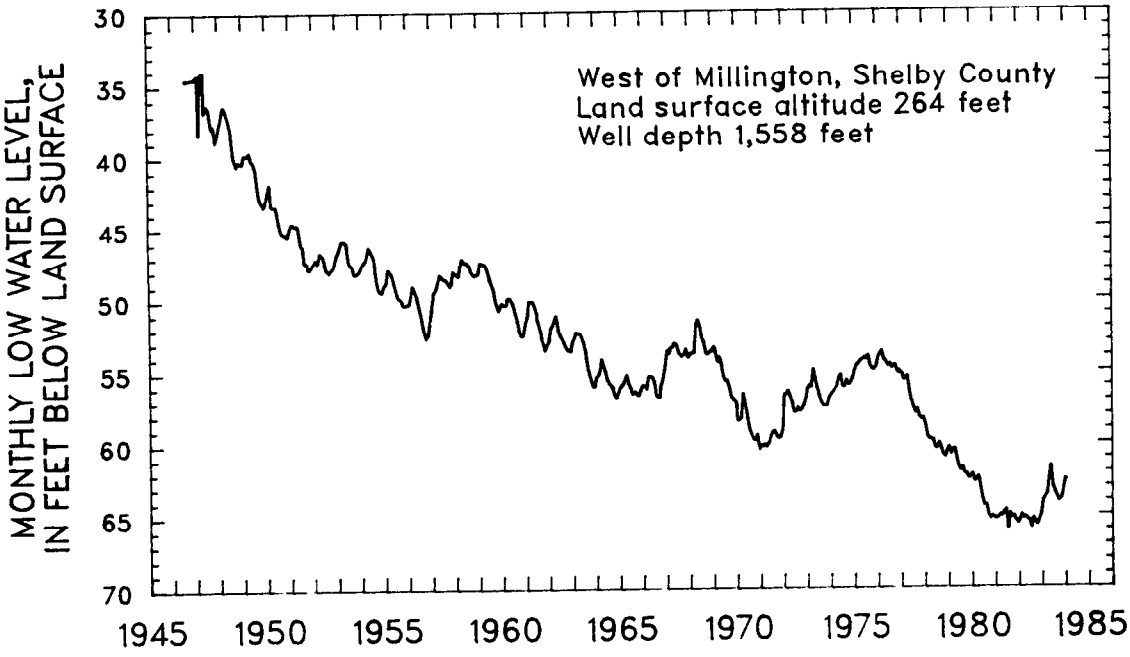



Figure 6.--Water levels in observation well Sh:U-1.

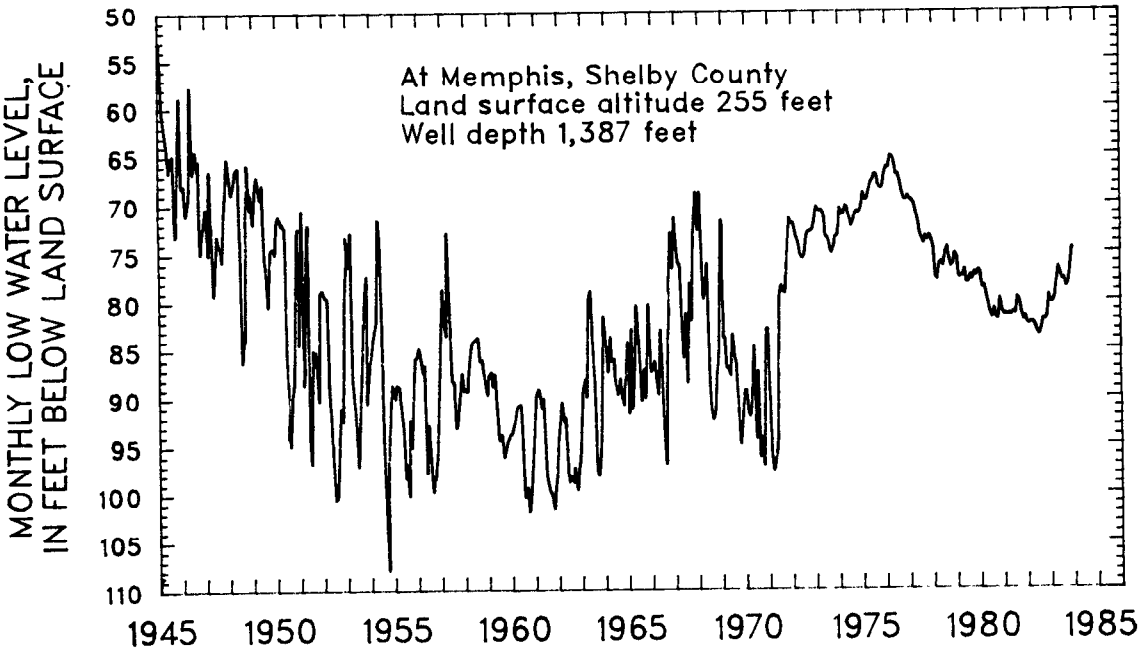



Figure 7.--Water levels in observation well Sh:O-170.

then declined slightly (Criner and Armstrong, 1958, table 1). Pumping rates remained fairly constant between 1954 and 1962, but gradually declined between 1962 and 1971 (Criner and Parks, 1976, table 2). In 1971, MLGW ceased pumping from the Fort Pillow aquifer in the well field. As a consequence, between 1971 and 1976 the water level in well Sh:O-170 rose about 28 feet. The lowest level in 1976 was about 3 feet higher than the lowest water level measured in 1945. Since 1976, the water level in well Sh:O-170 has shown a declining trend as a result of continued pumping from the Fort Pillow aquifer in an industrial well field at Memphis, and in the municipal well field at West Memphis, Ark.

### Water Quality

Water from the Fort Pillow aquifer generally is a sodium bicarbonate type, but near the outcrop-recharge area in Henry and Madison Counties, it locally is a calcium bicarbonate type (table 2). The water contains low concentrations of most major constituents and generally is suitable for most uses. Dissolved-solids concentrations range from 20 to 143 milligrams per liter (mg/L) with a median of 104 mg/L. Hardness ranges from soft (minimum--5 mg/L as $CaCO_3$) to moderately hard (maximum--70 mg/L) but is generally soft (median--10 mg/L). Iron concentrations range from 0 to 2,400 micrograms per liter (µg/L) with a median of 585 µg/L. Temperature of the water ranges from 15.0 to 23.0 degrees Celsius ($^{o}C$) with a median of 21 $^{o}C$.

Water quality in the Fort Pillow aquifer varies areally in western Tennessee. Although water-quality data are not available for the greater part of the area of occurrence of the aquifer, some differences in water quality can be distinguished between the outcrop-recharge area--Carroll, Hardeman, Henry, and Madison Counties--and the downdip Memphis area--Shelby County (table 2). In general, mineralization of the water increases westward from the outcrop-recharge area to the Memphis area. Iron concentrations also commonly increase from the outcrop-recharge to the Memphis area. Hardness, however, commonly is greater in the outcrop-recharge area. Temperature of the water increases with increasing well depth and distance from the outcrop-recharge area.

Trace constituents in the water from the Fort Pillow aquifer include arsenic, barium, chromium, copper, lead, mercury, strontium, and zinc (table 3). Most of these constituents are present in very low concentrations, and all are less than the maximum concentrations recommended by the U.S. Environmental Protection Agency (1986a,b) for drinking-water supplies.

### Aquifer Characteristics

Aquifer tests were made using wells in the Fort Pillow aquifer at Memphis and Jackson during the period 1932-61. Although many of these tests were conducted under less than ideal conditions, the results provide reasonably accurate estimates of transmissivities and storage coefficients for this aquifer. From 20 tests made at Memphis, transmissivities averaged about 13,100 $ft^2/d$, and the storage coefficients averaged about 0.0002 (Hosman and others, 1968, p. D9). The hydraulic characteristics of the Fort Pillow aquifer, as determined from seven tests in three well fields at Memphis, cover a rather narrow range (Criner and others, 1964, p. 37):

| | Minimum | Maximum |
|---|---|---|
| Transmissivity | 12,000 $ft^2/d$ | 18,700 $ft^2/d$ |
| Storage coefficient | .00015 | .0004 |

From four tests made at Jackson, transmissivities averaged about 10,000 $ft^2/d$, and from three of these tests, the storage coefficients

Table 2.--*Minimum, median, and maximum values for selected major constituents and properties of water from the Fort Pillow aquifer*

[mg/L, milligrams per liter; µg/L, micrograms per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter; values given as 0 (zero) or (less than) indicate that the constituent was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent; --, median values not determined for less than three wells]

| | Specific conductance µS/cm at 25 °C) | pH (units) | Temperature (°C) | Color (platinum cobalt units) | Hardness (mg/L as $CaCO_3$) | Calcium, dissolved (mg/L as Ca) | Magnesium, dissolved (mg/L as Mg) | Sodium, dissolved (mg/L as Na) | Potassium, dissolved (mg/L as K) |
|---|---|---|---|---|---|---|---|---|---|
| **Carroll County** | | | | | | | | | |
| Minimum | 29 | 5.4 | 15.5 | <1 | 8 | 2.1 | 0.2 | 2.2 | 0.6 |
| Median | 31 | 6.0 | 16.0 | 3 | 8 | 2.5 | 0.7 | 2.6 | 0.9 |
| Maximum | 33 | 6.9 | 16.5 | 6 | 10 | 2.7 | 1.0 | 3.2 | 1.2 |
| Number of wells | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **Hardeman County** | | | | | | | | | |
| Minimum | 27 | 5.7 | 15.0 | <1 | 6 | 1.4 | 0.6 | 2.3 | 0.4 |
| Median | 47 | 5.9 | 16.5 | 2 | 10 | 2.3 | 1.0 | 2.8 | 1.0 |
| Maximum | 80 | 6.5 | 16.5 | 7 | 32 | 6.7 | 3.7 | 3.2 | 1.4 |
| Number of wells | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| **Henry County** | | | | | | | | | |
| Minimum | 65 | 5.6 | 16.0 | 1 | 10 | 2.5 | 0.9 | 2.7 | 0.4 |
| Median | -- | -- | 16.5 | -- | 16 | 3.6 | 1.6 | 3.8 | 0.8 |
| Maximum | 67 | 5.7 | 16.5 | 5 | 18 | 4.5 | 1.7 | 8.7 | 1.3 |
| Number of wells | 2 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 3 |
| **Madison County** | | | | | | | | | |
| Minimum | 30 | 5.0 | 16.0 | <1 | 5 | 1.5 | 0.4 | 1.0 | 0.4 |
| Median | 94 | 5.4 | 16.0 | 3 | 43 | 11 | 4.0 | 5.5 | 2.3 |
| Maximum* | 240 | 5.5 | 17.0 | 4 | 70 | 20 | 5.8 | 15 | 3.8 |
| Number of wells | 5 | 4 | 4 | 5 | 6 | 6 | 6 | 6 | 5 |
| **Shelby County** | | | | | | | | | |
| Minimum | 145 | 6.9 | 21.0 | 9 | 8 | 1.8 | 0.7 | 31 | 1.2 |
| Median | 177 | 7.6 | 21.5 | 25 | 10 | 2.2 | 0.9 | 40 | 1.6 |
| Maximum | 186 | 7.9 | 23.0 | 60 | 17 | 4.0 | 1.9 | 46 | 3.0 |
| Number of wells | 13 | 18 | 18 | 11 | 18 | 18 | 18 | 18 | 8 |
| **All Counties** | | | | | | | | | |
| Minimum | 27 | 5.0 | 15.0 | <1 | 5 | 1 4 | 0.2 | 1.0 | 0.4 |
| Median | 160 | 7.2 | 21.0 | 6 | 10 | 2.4 | 1.0 | 33 | 1.2 |
| Maximum | 240 | 7.9 | 23.0 | 60 | 70 | 20 | 5.8 | 46 | 3.8 |
| Number of wells | 27 | 31 | 32 | 25 | 34 | 34 | 34 | 34 | 23 |

Table 2.--*Minimum, median, and maximum values for selected major constituents and properties of water from the Fort Pillow aquifer*--Continued

| | Alkalinity (mg/L as $CaCO_3$) | Carbon dioxide, dissolved (mg/L as $CO_2$) | Sulfate, dissolved (mg/L as $SO_4$) | Chloride, dissolved (mg/L as Cl) | Fluoride, dissolved (mg/L as F) | Silica, dissolved (mg/L as $SiO_2$) | Solids, residue at 180 °C (mg/L) | Iron (µg/L as Fe) | Manganese (µg/L as Mn) |
|---|---|---|---|---|---|---|---|---|---|
| **Carroll County** | | | | | | | | | |
| Minimum | 8 | 62 | 0.3 | 0.8 | 0 | 9.2 | 30 | 0 | 1 |
| Median | 10 | -- | 0.4 | 1.5 | <0 1 | 12 | 30 | 14 | -- |
| Maximum | 12 | 62 | 1.1 | 1.7 | 0.1 | 14 | 30 | 50 | 1 |
| Number of wells | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **Hardeman County** | | | | | | | | | |
| Minimum | 8 | 31 | 0.3 | 1.3 | 0 | 13 | 29 | <3 | <1 |
| Median | 13 | -- | 1.0 | 2.6 | <0.1 | 16 | 32 | 6 | -- |
| Maximum | 34 | 37 | 2.3 | 3.4 | 0.1 | 20 | 69 | 2,400 | 7 |
| Number of wells | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 2 |
| **Henry County** | | | | | | | | | |
| Minimum | 8 | 44 | 2.6 | 2.2 | 0 | 13 | 50 | 10 | 3 |
| Median | 9 | -- | 2.8 | 5.5 | -- | 14 | 52 | 11 | -- |
| Maximum | 17 | 44 | 3.5 | 7.5 | <0.1 | 17 | 56 | 1,190 | 3 |
| Number of wells | 3 | 1 | 3 | 3 | 2 | 3 | 3 | 3 | 1 |
| **Madison County** | | | | | | | | | |
| Minimu | 5 | 136 | 0 | 2.0 | 0 | 3.4 | 20 | 0 | 4 |
| Median | 18 | -- | 26 | 6.2 | <0.1 | 8.1 | 80 | 5 | -- |
| Maximum | 29 | 136 | 44 | 14 | 0.1 | 16 | 143 | 700 | 4 |
| Number of wells | 6 | 1 | 6 | 6 | 5 | 6 | 6 | 6 | 1 |
| **Shelby County** | | | | | | | | | |
| Minimum | 79 | 12 | 4.2 | 0.8 | 0 | 8.5 | 99 | 240 | 0 |
| Median | 87 | -- | 4.9 | 1.5 | 0.1 | 10 | 114 | 905 | 37 |
| Maximum | 100 | 21 | 6.4 | 2.5 | 0.3 | 12 | 120 | 1,700 | 50 |
| Number of wells | 17 | 2 | 18 | 18 | 8 | 13 | 18 | 18 | 9 |
| **All Counties** | | | | | | | | | |
| Minimum | 5 | 12 | 0 | 0.8 | 0 | 3.4 | 20 | 0 | 0 |
| Median | 79 | 37 | 4.7 | 1.9 | <0.1 | 12 | 104 | 585 | 22 |
| Maximum | 100 | 136 | 44 | 14 | 0.3 | 20 | 143 | 2,400 | 50 |
| Number of wells | 33 | 7 | 34 | 34 | 22 | 29 | 34 | 34 | 14 |

Table 3.--*Minimum, median, and maximum values for selected trace constituents, in water from the Fort Pillow aquifer*

[Concentrations in micrograms per liter, values given as (less than) indicate the concentration was below the level of detection for the analytical method used and do not indicate the presence or absence of a constituent; --, median values not determined for less than three wells]

| | Arsenic, dissolved (as As) | Barium, dissolved (as Ba) | Cadmium, dissolved (as Cd) | Chromium, dissolved (as Cr) | Copper, dissolved (as Cu) | Lead, dissolved (as Pb) | Mercury, dissolved (as Hg) | Strontium, dissolved (as Sr) | Zinc, dissolved (as Zn) |
|---|---|---|---|---|---|---|---|---|---|
| **Carroll County** | | | | | | | | | |
| Minimum | <1 | 70 | <1 | <10 | <10 | 4 | <0.1 | -- | 12 |
| Median | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maximum | <1 | 70 | <1 | <10 | <10 | 4 | 0.1 | -- | 12 |
| Number of wells | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| **Hardeman County** | | | | | | | | | |
| Minimum | <1 | 28 | <1 | <10 | <10 | <1 | <0.1 | 11 | 7 |
| Median | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maximum | <1 | 29 | <1 | 10 | 10 | 1 | 0.2 | 41 | 14 |
| Number of wells | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **Henry County** | | | | | | | | | |
| Minimum | <1 | 60 | <1 | <10 | <10 | 4 | <0.1 | -- | 5 |
| Median | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maximum | <1 | 60 | <1 | <10 | <10 | 4 | <0.1 | -- | 5 |
| Number of wells | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| **Madison County** | | | | | | | | | |
| Minimum | 1 | 120 | <1 | <10 | <10 | 3 | <0.1 | -- | 24 |
| Median | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maximum | 1 | 120 | <1 | <10 | <10 | 3 | <0.1 | -- | 24 |
| Number of wells | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| **Shelby County** | | | | | | | | | |
| Minimum | <1 | 31 | <1 | <10 | <10 | <1 | <0.1 | 76 | <3 |
| Median | <1 | 39 | -- | -- | -- | -- | -- | -- | -- |
| Maximum | <5 | 42 | <1 | <10 | <10 | <1 | <0.1 | 79 | 4 |
| Number of wells | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **All Counties** | | | | | | | | | |
| Minimum | <1 | 28 | <1 | <10 | <10 | <1 | <0.1 | 11 | <3 |
| Median | <1 | 40 | <1 | <10 | <10 | 1 | <0.1 | 58 | 7 |
| Maximum | <5 | 120 | <1 | 10 | 10 | 4 | 0.2 | 79 | 24 |
| Number of wells | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 4 | 7 |

averaged about 0.0015 (Hosman and others, 1968, p. D9).

### Water Use

The area of present use of the Fort Pillow aquifer is limited to a relatively narrow belt along the eastern limits of occurrence of the aquifer in Carroll, Hardeman, Henry, and Madison Counties, and in the Memphis area in Shelby County (fig. 8). Withdrawals from this aquifer for public and industrial supplies in western Tennessee during 1983 averaged about 10.6 Mgal/d (table 4). Public and industrial wells range from 124 to 1,478 feet deep, and well yields range from 125 to 1,700 gal/min. The aquifer also provides small quantities of water to numerous domestic and farm wells in the belt along the eastern limits.

The Fort Pillow aquifer has the potential to supply additional water to wells throughout most of the area of occurrence in western Tennessee (fig. 8). The Fort Pillow aquifer is widespread, virtually untapped, and has much potential for future use. This aquifer provides water for public and industrial supplies in adjacent areas in eastern Arkansas, southeastern Missouri, and northwestern Mississippi. In these areas, the Fort Pillow aquifer is a preferred source of water for public and industrial supplies because it provides water that requires less treatment than water from shallower aquifers.

## SUMMARY AND CONCLUSIONS

The Fort Pillow Sand underlies approximately 7,700 $mi^2$ in the Gulf Coastal Plain of western Tennessee. It consists primarily of sand that locally contains minor lenses or beds of clay or silt. The sand ranges from very fine to very coarse, but commonly it is locally fine to medium or medium to coarse. The Fort Pillow Sand ranges from 0 to 350 feet in thickness. It is thinnest along the outcrop belt and is thickest downdip in

Table 4.--*Public and industrial water supplies from the Fort Pillow aquifer in western Tennessee, 1983*

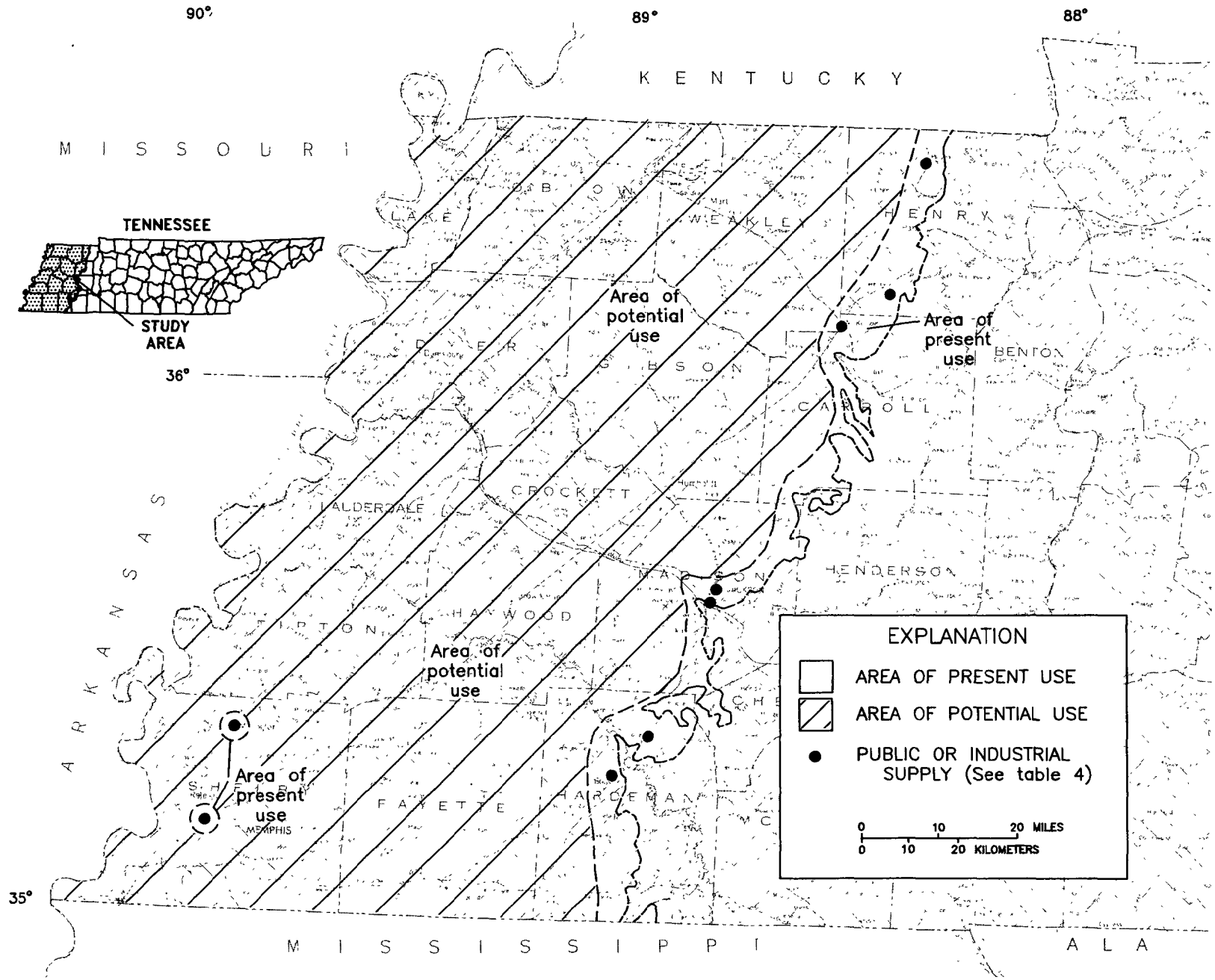
| County | Water user (U D - utility district) | Number of wells in use | Reported depth of wells (ft) | Reported pumping rates of wells (gal/min) | Reported average daily withdrawal in 1983 (thousand gallons) | Technical data available: Chemical analysis R-recent H-historic | Geophysical log[1] E-electric G-gamma ray | Aquifer test(s) Year of test |
|---|---|---|---|---|---|---|---|---|
| Carroll | McKenzie | 3 | 340- 360 | 500-1,500 | 756 | H-R | G(286) | -- |
| Hardeman | Toone | 3 | 124- 131 | 125 | 182 | R | | -- |
| | Western Mental Health Inst. | 2 | 282- 298 | 620-750 | 196 | R | E-G(316) | -- |
| Henry | Henry | 2 | 182- 190 | 175-250 | 80 | H | G(176) | -- |
| | Puryear | 2 | 135- 141 | 150 | 72 | R | G(128) | -- |
| Madison | Jackson U D (south field)[2] | 13 | 124- 168 | 644-1,304 | 1,000[3] | H-R | E-G(515) | 1961 |
| | Self-supplied industry | 11 | 149- 249 | 300-800 | 5,725 | H | | -- |
| Shelby | Millington | 2 | 1,466-1,478 | 850-1,000 | none[4] | R | E-G(1,492) | -- |
| | Self-supplied industry | 3 | 1,386-1,456 | 1,200-1,700 | 2,605 | H-R | E(1,583) | 1947 |

[1]More than one geophysical log may be available for each well field; number in parentheses indicates the maximum depth, in feet, logged by either electric or gamma-ray methods.

[2]Jackson Utility District has north and south well fields. Wells in the south field pump from the Fort Pillow aquifer; the north field is in an area where the Memphis Sand directly overlies the Fort Pillow Sand, and the wells may be in either the lower part of the Memphis aquifer or upper part of the Fort Pillow aquifer. For this report, water pumped at the north field is considered to be from the Memphis aquifer.

[3]Withdrawal shown is from the Fort Pillow aquifer; part of supply is from the Memphis aquifer.

[4]Wells installed in 1984 in the Fort Pillow aquifer; withdrawal in 1983 was totally from the Memphis aquifer.




Base from U.S. Geological Survey, State base map, 1:500,000, 1973

Figure 8.——Areas of present and potential use of the Fort Pillow aquifer in western Tennessee.

the western tier of counties along the Mississippi River. The base of the Fort Pillow Sand generally dips westward from 25 to 50 ft/mi, but it is faulted at many places. The Fort Pillow Sand would yield water to wells in most of the area of occurrence and, where saturated, makes up the Fort Pillow aquifer.

Recharge to the Fort Pillow aquifer is from precipitation on its outcrop and by downward infiltration of water from the overlying fluvial deposits and alluvium or, where the upper confining unit is absent, from the overlying Memphis aquifer. In the outcrop-recharge belt, the Fort Pillow aquifer is unconfined, and the configuration of the water table generally conforms to the topography. To the west of the outcrop-recharge belt where the Fort Pillow aquifer is confined, the potentiometric surface slopes gently westward, and the water moves slowly in that direction. Long-term data (1945-83) from four observation wells in areas affected by pumping indicate that water levels in these areas have declined at average rates of 0.4 to 0.9 ft/yr. The greatest rate of decline was about 4.0 ft/yr, which occurred between 1945 and 1954 in a then intensely pumped area at Memphis.

Water from the Fort Pillow aquifer generally is a sodium bicarbonate type but, near the outcrop-recharge area, it is locally a calcium bicarbonate type. The water contains low concentrations of most major constituents and generally is suitable for most uses. Dissolved-solids concentrations range from 20 to 143 mg/L, hardness ranges from soft (5 mg/L as $CaCO_3$) to moderately hard (70 mg/L), and iron concentrations range from 0 to 2,400 μg/L. Temperature of the water ranges from 15.0 to 23.0 °C. In general, mineralization of the water increases westward from the outcrop-recharge area downdip to the Memphis area.

From 20 aquifer tests made at Memphis, transmissivities averaged about 13,100 $ft^2/d$, and storage coefficients averaged about 0.0002. From four tests made at Jackson, transmissivities averaged about 10,000 $ft^2/d$, and storage coefficients averaged about 0.0015.

The Fort Pillow aquifer provides moderate to large quantities of water to several public and industrial well fields, and small quantities of water to numerous domestic and farm wells in a relatively narrow belt along the eastern limits of occurrence. It also provides water to an industry and a municipality in the Memphis area. Withdrawals for the public and industrial supplies in western Tennessee in 1983 averaged about 10.6 Mgal/d. Public and industrial wells range from 124 to 1,478 feet deep, and well yields range from 125 to 1,700 gal/min. The area of potential use of the Fort Pillow aquifer includes most of the area of its occurrence in western Tennessee. This aquifer is widespread, virtually untapped, and has much potential for future use.

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