Hydrogeology of the Principal Aquifers and Relation of Faults to Interaquifer Leakage in the Memphis Area, Tennessee

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Multiply	By	To obtain
foot	0.3048	meter
mile	1.609	kilometer

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 both the United States and Canada, formerly called Sea Level Datum of 1929.

Well-numbering system: In this report, wells are identified by a well number consisting 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; 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-185 indicates that the well is located in Shelby County on the "J" quadrangle and is identified as well 185 in the numerical sequence.

Wells in Crittenden County, Ark., and DeSoto County, Miss., have well numbers containing the prefixes "Ar" and "Ms," respectively. Well numbers in DeSoto County have suffixes (for example, "A-7") that are the well designations used in Mississippi.

Hydrogeology of the Principal Aquifers and Relation of Faults to Interaquifer Leakage in the Memphis Area, Tennessee

By James A. Kingsbury *and* William S. Parks

ABSTRACT

An investigation to update the hydrogeology and geologic structure of the principal aquifers in the Memphis area with emphasis on the location of faults was conducted from 1990 to 1992. The Memphis Sand and the Fort Pillow Sand of Tertiary age make up the Memphis and the Fort Pillow aquifers. These principal aquifers provide water for most domestic, commercial, industrial, and municipal supplies in the Memphis area, including the well fields of Memphis Light, Gas and Water Division of the City of Memphis. During 1990, withdrawals in the Memphis area totaled about 196 million gallons per day from the Memphis aquifer and about 6 million gallons per day from the Fort Pillow aquifer. The Memphis Sand consists primarily of a thick deposit of fine to very coarse sand with lenses of clay, silt, and lignite at various stratigraphic horizons. The Fort Pillow Sand consists primarily of fine to medium or medium to coarse sand with minor lenses of clay or silt.

Stratigraphic correlations as interpreted from 227 geophysical logs, selected from a file of more than 500 electric and natural gamma-ray logs, show that the tops of the Memphis Sand and the Fort Pillow Sand are facies-transitional and not easily identified. The upper parts of these formations locally consist of fine sand, silt, and clay similar to lithologies in the overlying Cook Mountain Formation and Flour Island Formation (both Tertiary age), respectively. The bases of the Memphis Sand and the Fort Pillow Sand commonly are distinctly recognizable and seem to overlie erosion surfaces on clay, silt, or fine sand at the tops of the underlying Flour Island Formation and the Old Breastworks Formation of Tertiary age, respectively.

Structure-contour maps showing the altitude of the tops and bases of the Memphis Sand and the Fort Pillow Sand indicate that these units dip westward toward the axis of the Mississippi embayment at rates of 10 to 20 feet per mile. These maps, along with geologic sections, show that in the Memphis area there are many normal faults with vertical displacements ranging from about 50 to 150 feet.

Faults that displace the top of the Memphis Sand in areas where the lower clay layer (Cook Mountain Formation) in the overlying confining unit is thin, locally may have contributed to the formation of "windows" in the confining unit, by exposing uplifted fault blocks to erosion. Faults also may control the shape and size of these windows. The windows are areas where downward leakage of ground water from the water-table aquifers (alluvium and fluvial deposits) to the Memphis aquifer can occur.

INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the City of Memphis, Memphis

Light, Gas and Water Division (MLGW), conducted an investigation from 1990 to 1992 to describe the hydrogeology of the Memphis aquifer and the Fort Pillow aquifer, the principal aquifers in the Memphis area (fig. 1), in more detail than was possible in the USGS Gulf Coast Regional Aquifer-System Analysis (GC RASA) investigations (Parks and Carmichael, 1989, 1990a, b). The investigation used much of the data collected during the GC RASA investigation and previous investigations in the Memphis area, but it placed emphasis on geologic structure of the principal aquifers and confining units in the Memphis area and its potential effects on the local ground-water flow system.

Public concern in recent years has focused on the possibility that the Memphis aquifer, the primary aquifer for the local ground-water public supply, may become contaminated from potential surface or near surface sources. Contaminants from these potential sources could migrate downward and enter the Memphis aquifer in the Memphis area. This migration or movement of contaminants into the Memphis aquifer could be enhanced in the Memphis area by leakage through "windows" in the overlying confining unit that separates the Memphis aquifer from the shallow water-table aquifer (Parks and Lounsbury, 1976; Graham and Parks, 1986; Parks, 1990).

Purpose and Scope

This report presents the results of an investigation to enhance the understanding of the hydrogeology and geologic structure of the principal aquifers in the Memphis area. The investigation consisted of the interpretation and correlation of geophysical logs and the preparation of structure-contour maps and geologic sections. Emphasis was placed on the identification and location of possible faults in order to determine if faults contribute to the potential for leakage of water and potential contaminants between the shallow water-table aquifer and the Memphis aquifer.

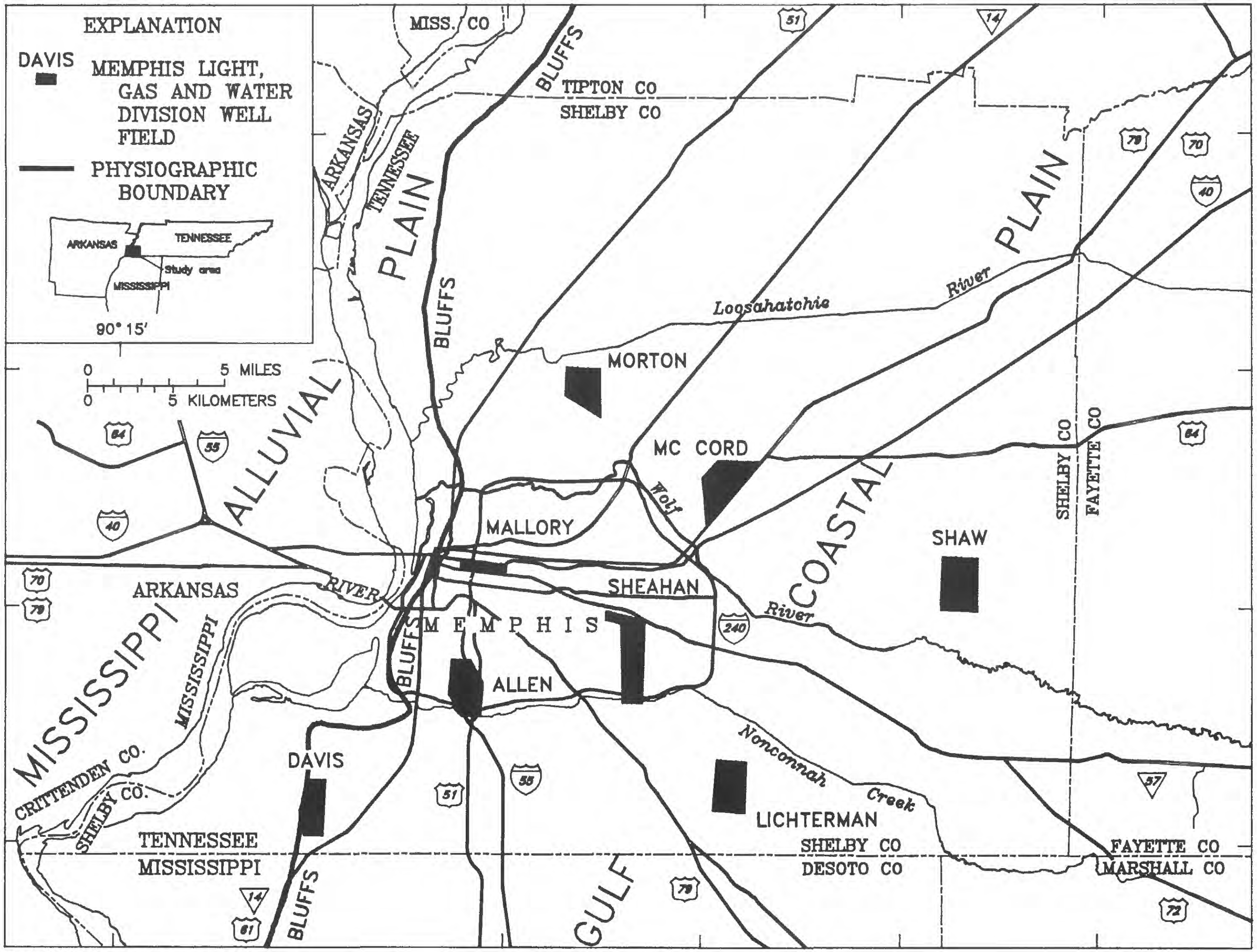
The area of investigation was limited to a 1,500-square-mile area in the vicinity of Memphis, Tennessee. The area includes Shelby County and parts of Fayette and Tipton Counties in Tennessee, parts of Crittenden County in Arkansas, and parts of DeSoto and Marshall Counties in Mississippi (fig. 1).

Previous Investigations

General information about the subsurface geology of the Memphis area has been presented by Schneider and Cushing (1948); Criner and Armstrong (1958); Criner and others (1964). More recent information on the stratigraphy of the geologic units in western Tennessee, including the Memphis area, has been presented by Parks and Carmichael (1989, 1990a, b) and Parks (1990).

The possibility that faults are present in the subsurface in the Memphis area has been suggested by several previous investigators. Fisk (1944) tentatively identified fault locations based on surface lineations and indicated a fault with a northwest strike in northern Shelby County. Criner and others (1964) suggested the existence of a fault at the mouth of Nonconnah Creek where the Mississippi River makes an abrupt bend. They also noted as much as 50 feet of displacement of the geologic units at the Lichterman well field. Moore (1965) suggested the existence of faults in southern Shelby County but did not map them because of insufficient evidence.

Stearns and Wilson (1972) located a few faults in the Memphis area primarily on the basis of surface lineations with northeast-southwest and northwest-southeast trends. In a study of the likelihood of post-Cretaceous faulting in the northern Mississippi embayment, including



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

Figure 1.--Major physiographic subdivisions in the Memphis area and locations of Memphis Light, Gas and Water Division well fields. (Modified from Brahana and others, 1987.)

western Tennessee, Stearns and Zurawski (1976) suggested that faults that displace the Tertiary formations probably are common. Parks and Carmichael (1989, 1990a, b) located several faults in the Memphis area based on stratigraphic correlations as interpreted from geophysical logs.

Approach

Geophysical logs from a USGS file of more than 500 electric and natural gamma-ray logs were interpreted and correlated. Most of the geophysical logs were made by the USGS in the Memphis area from the early 1950's to 1992. Although all of the geophysical logs were studied, 227 logs were selected for use as control for preparing the structure-contour maps and geologic sections in this report. Selection of logs was on the basis of well spacing and, when a choice could be made, on the basis of log quality.

Many of the geophysical logs were made in test holes drilled at MLGW and industrial well fields. Through the years, several wells have been drilled at some MLGW well lots to both the Memphis and Fort Pillow aquifers or as replacement wells screened in the Memphis aquifer to about the same or greater depths. Thus, the file contained as many as three logs for test holes on some lots. In addition, lots in MLGW well fields are commonly about 1,000 feet apart, necessitating a further selection of logs based on well spacing for the scale of the structure-contour maps and geologic sections.

In some instances, caving of the walls of test holes made it impossible to run geophysical logs to the total depth of the hole. For these test holes, driller's logs were used as supplemental data in preparing the structure map for the bases of the geologic units.

Geophysical-log correlations for studies of the geology and water resources in western Tennessee (Parks and Carmichael, 1989, 1990a, b) and of contamination of the Memphis aquifer in the Memphis area (Parks, 1990) served as a basis for this investigation. The stratigraphic correlations, made from interpretation of geophysical logs for these studies, were reviewed, revised where needed, and updated with additional data from more recent geophysical logs. Because of the regional scope of the Parks and Carmichael studies (1989, 1990a, b), a comparatively small number of the geophysical logs available for the Memphis area were used for those studies. However, the structure-contour maps from these reports, showing the location of some faults, provided a structural framework for a more detailed investigation of the Memphis area.

In recent years (1989-92), MLGW has had deep stratigraphic test holes drilled in the Allen, Davis, Lichterman, McCord, Morton, Shaw, and Sheahan well fields (fig.1) and in a new well field now (1992) under development. These test holes were drilled through the entire geologic section under investigation. Geophysical logs of these test holes provide information on the strata at greater depths than previously was available for these well fields. This new information made possible a refinement of the previous interpretations of the existence of faults in the Memphis area (Parks and Carmichael 1989, 1990a, b).

HYDROGEOLOGY

Generalized descriptions of post-Midway Group geologic units of Tertiary and Quaternary age in the Memphis area and their hydrologic importance as revised and updated based on information collected during this investigation are presented in table 1. Geologic units examined in detail during this investigation are the Memphis Sand and the Fort Pillow Sand of Tertiary age. Geophysical-log correlations of the tops and bases of the Memphis Sand and Fort Pillow Sand and the calculated thicknesses of these formations are given in table 2 at the back of this report.

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

[Modified from Parks and Carmichael, 1989, 1990a, b; Parks, 1990]

System	Series	Group	Stratigraphic unit (and local name)	Thickness (in feet)	Lithology and hydrologic importance
Quaternary	Holocene and Pleistocene		Alluvium (alluvial deposits)	0-175	Sand, gravel, silt, and clay. Underlies the Mississippi Alluvial Plain and the alluvial plains of streams in the Gulf Coastal Plain. Thickest beneath the Mississippi Alluvial Plain, where it commonly is between 100 and 150 feet thick and makes up the Missisippi River Valley alluvial aquifer. Generally less than 50 feet thick elsewhere. Supplies water to domestic, farm, irrigation, and industrial wells in the Mississippi Alluvial Plain.
	Pleistocene		Loess	0-65	Silt, silty clay, and minor sand. Principal unit at the surface in upland areas of the Gulf Coastal Plain, concealing the older units of Quaternary and Tertiary age at most places. Thickest on the bluffs that border the Mississippi Alluvial Plain; generally thinner eastward. Retards downward movement of water that provides recharge to the water-table aquifers (alluvium and fluvial deposits).
Quaternary and Tertiary(?)	Pleistocene and Pliocene(?)		Fluvial deposits (terrace deposits)	0-100	Sand, gravel, minor clay and ferruginous sandstone. Generally underlies the loess in upland areas, but are locally absent. Thickness varies greatly because of erosional surfaces at top and base. Provides water to many domestic and farm wells in rural areas.
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 mostly Cockfield, but locally is overlain by the Jackson in the northwestern part of the Memphis area. Thicknesses are estimates based on tentative geophysical-log correlations. The Jackson and Cockfield provide water to a few domestic wells in rural areas.
		Claiborne	Cockfield Formation	0-250	
			Cook Mountain Formation	0-110	Clay, silt, and sand. Generally consists of clay and silt, but locally may consist predominantly of fine sand. Probably averages about 60 feet in thickness. Unit can be confused with clay lenses in the lower part of the Cockfield Formation or upper part of the Memphis Sand. Serves as upper confining unit for the Memphis aquifer, along with the Cockfield and Jackson Formations.
			Memphis Sand ("500-foot" 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 very coarse. Upper part commonly contains lenses of fine sand, silt, and clay; lower part locally contains lenses of clay as thick as 50 feet. Thickest in the western part of the Memphis area; thinnest in the eastern part. The Memphis aquifer--the principal aquifer in the Memphis area--provides water for most domestic, commercial, industrial, and municipal supplies,including the well fields of Memphis Light, Gas and Water Division.
	?	Wilcox	Flour Island Formation	140-310	Clay, silt, sand, and lignite. Not an aquifer. Consists predominantly of clay and silt, but locally contains lenses of fine sand as thick as 50 feet. Serves as the lower confining unit for the Memphis aquifer and the upper confining unit for the Fort Pillow aquifer.
	Paleocene		Fort Pillow Sand ("1,400-foot" sand)	98-300	Sand and minor clay. Sand is fine to medium or medium to coarse. Thickest in the southwestern part of the Memphis area; thinnest in the southeastern part. The Fort Pillow aquifer is the second principal aquifer supplying water for the City of Memphis, used by an industry at Memphis, the City of Millington, the U.S. Naval Air Station, and the Shaw well field of Memphis Light, Gas and Water Division.
			Old Breastworks[1] Formation	180-310	Clay, silt, sand, and lignite. Not an aquifer. Consists predominantly of clay and silt. Serves as the lower confining unit for the Fort Pillow Sand, along with the Porters Creek Clay and Clayton Formation of the underlying Midway Group.

[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).

The Memphis Sand and the Fort Pillow Sand make up the Memphis aquifer and the Fort Pillow aquifer. These are the two principal aquifers in the Memphis area providing ground water for most domestic, commercial, industrial, and municipal supplies, including the well fields of MLGW. During 1990, withdrawals totaled about 196 million gallons per day from the Memphis aquifer and about 6 million gallons per day from the Fort Pillow aquifer.

The Memphis area is located in the north-central part of the Mississippi embayment, a broad structural trough or syncline that plunges southward along an axis that approximates the Mississippi River (Cushing and others, 1964). This syncline is filled with a few thousand feet of unconsolidated to semi-consolidated sediments that make up formations of Tertiary age and older. In the Memphis area, the Memphis Sand and Fort Pillow Sand of Tertiary age are part of the eastern limb of the Mississippi embayment and dip toward the axis at rates of about 10 to 20 feet per mile (plates 1-4). Faults displace these formations at many places (plates 1-5).

Memphis Sand

The Memphis Sand of Tertiary age is present in the subsurface throughout the Memphis area. It is a thick deposit of fine to very coarse sand with lenses of clay, silt, and lignite at various stratigraphic horizons. The Memphis Sand underlies the Cook Mountain Formation and overlies the Flour Island Formation (table 1). The Cook Mountain Formation, along with the Cockfield Formation and the Jackson Formation, serves as the upper confining unit for the Memphis aquifer, and the Flour Island Formation serves as the lower confining unit.

The structure-contour map of the altitude of the top of the Memphis Sand is shown on plate 1. This map is based on interpretation and correlation of 223 geophysical logs (table 2). Until recently, the top of the Memphis Sand was interpreted to be the first prominent sand below the confining unit. Parks (1990) modified the definition of the confining unit to include only the interval of sediments between the base of the water-table aquifers (alluvium and fluvial deposits) and the base of the Cook Mountain Formation (table 1). Parks (1990) recognized that the upper part of the Memphis Sand is a facies-transitional boundary that locally contains thick intervals of fine sand, silt, and clay. During this investigation, the top of the Memphis Sand was identified by correlating the base of the Cook Mountain Formation on geophysical logs.

The altitude of the base of the Memphis Sand is shown on plate 2. This structure-contour map is based on interpretation and correlation of 62 geophysical logs (table 2). Recent regional correlation of the base of the Memphis Sand in the subsurface of western Tennessee (Parks and Carmichael, 1990b) has shown that this boundary is equivalent to the base of the Claiborne Formation as mapped at the surface by Parks and Russell (1975). At the surface, the boundary between the Claiborne Formation and the underlying Wilcox Formation is an erosion surface with local relief that may be 50 feet or more (Russell and Parks, 1975, p. B28). In the subsurface of the Memphis area, comparable amounts of relief are indicated at the contact between the Memphis Sand and the Flour Island Formation at a few localities where several test holes with geophysical-log control are closely spaced. For example, at the Shaw well field, relief on this contact may be 60 to 80 feet. The contact between the Memphis Sand and underlying Flour Island Formation commonly is easy to identify on geophysical logs because of the contrast in formation characteristics caused by coarser sand in the lower part of the Memphis Sand and the underlying fine sand, silt, or clay in the upper part of the Flour Island Formation.

Structure-contour maps of the top and base of the Memphis Sand were prepared assuming a relatively constant strike and dip for the formation, particularly where control was sparse.

This strike and dip is similar to the regional strike and dip of the base of the Memphis Sand in western Tennessee shown on the structure-contour maps of Parks and Carmichael (1990b). Accuracy of the structure-contour maps (plates 1 and 2) is estimated to be about one-half a contour interval (25 feet) to one-contour interval (50 feet), depending on the proximity of test holes providing geophysical-log control. These structure-contour maps show an "average" representation of the configuration of these surfaces. Locally contour lines may not strictly honor each control point because facies changes or erosional relief would cause considerable irregularities in the mapped surface. At these places an "average" value was used for control.

Fort Pillow Sand

The Fort Pillow Sand of Tertiary age is present in the subsurface throughout the Memphis area. It consists primarily of fine to medium or medium to coarse sand with minor lenses of clay and silt. The Fort Pillow Sand underlies the Flour Island Formation and overlies the Old Breastworks Formation (table 1). The Flour Island Formation serves as the upper confining unit for the Fort Pillow aquifer, and the Old Breastworks Formation serves as part of the lower confining unit.

The structure-contour map of the altitude of the top of the Fort Pillow Sand is shown on plate 3. This map is based on the interpretation and correlation of 40 geophysical logs (table 2). The top of the Fort Pillow Sand is a facies-transitional boundary consisting of silt or clay interfingering with sand over short distances.

The altitude of the base of the Fort Pillow Sand is shown on plate 4. This structure-contour map is based on interpretation and correlation of 32 geophysical logs (table 2). The base of the Fort Pillow Sand probably overlies an erosion surface on the underlying Old Breastworks Formation that seems to be of low to moderate relief based on available geophysical-log control. For example, at the Shaw well field, relief on this contact may be as much as 30 feet. The contact between the Fort Pillow Sand and the underlying Old Breastworks Formation is distinctly recognizable on geophysical logs because of the contrast in formation characteristics caused by sand in the lower part of the Fort Pillow Sand overlying clay or silt in the upper part of the Old Breastworks Formation.

Structure-contour maps of the top and base of the Fort Pillow Sand were prepared assuming a relatively constant strike and dip for the formation, particularly where control was sparse. This strike and dip is similar to the regional strike and dip of the base of the Fort Pillow Sand in western Tennessee shown on the structure-contour maps of Parks and Carmichael (1989). Accuracy of these maps is estimated to be about one-half a contour interval (25 feet) to one-contour interval (50 feet), depending on the proximity of wells providing geophysical-log control. These structure-contour maps (plates 3 and 4) are considered to show an "average" representation of the configuration of these surfaces. Locally, contour lines may not strictly honor each control point because facies changes or erosional relief would cause considerable irregularities in the mapped surface. At these places an "average" value was used for control.

Faults

Faults (or fault zones) identified during this investigation generally have northeast-southwest and northwest-southeast strikes (plates 1-4). Orientations of the faults are similar to surface lineations mapped during previous studies (Fisk, 1944; Stearns and Wilson, 1972), but most fault locations do not coincide with lineation locations. The faults identified during this investigation are interpreted as normal faults, but it is possible that some have a component of strike-slip movement. Vertical displacement along the faults identified generally ranges from about 50 to 150 feet. Most of the faults displace both the Memphis Sand and Fort Pillow Sand (plate 5).

A few faults displace the base and top of the Fort Pillow Sand and the base of the Memphis Sand (plates 1-5) but do not displace the top of the Memphis Sand (for example, the fault north of Arlington), and displacement along most faults diminishes upward in the section. This diminished displacement indicates that movement on these faults decreased or ceased sometime during deposition of the Memphis Sand, or that displacement is small and is not detectable based on available geophysical-log control. The fault south of Millington displaces the Memphis Sand and the top of the Fort Pillow Sand, but it does not seem to displace the base of the Fort Pillow Sand. This apparent lack of displacement may be related to relief on the erosional surface at the base of the Fort Pillow Sand or to test holes that pass through the plane of a normal fault.

Identification of faults that displace the formations of Tertiary age in the Memphis area is difficult because these formations are covered by surficial deposits of Quaternary age (table 1) throughout most of the area, and faults generally cannot be observed in outcrops. Interpretation of the geologic structure is further complicated by the nature of the boundaries between the formations of Tertiary age and the limited number of wells that reach the base of the Fort Pillow Sand.

Because of the absence of a reliable stratigraphic marker in the sediments of Tertiary age, the geologic structure of the principal aquifers in the Memphis area is based on correlations of facies-transitional boundaries and erosion surfaces that can be difficult to identify. Anomalies in the altitude of one of these boundaries or surfaces might be caused by depositional features, or by miscorrelation of the contact on the geophysical log of a test hole, rather than displacement by a fault. Therefore, identifications of most faults are based primarily on recognition of comparable amounts of displacement at the tops and bases of the Memphis and Fort Pillow Sands, and displacements of these contacts that follow areal traces or lineations. Small variations in the altitudes of the tops and bases of the formations were not considered to be fault related.

Identification of faults during this investigation is highly interpretive and is subject to revision as new information becomes available. Locations and strikes of most of the faults identified are only approximate and are subject to reinterpretation.

RELATION OF FAULTS TO INTERAQUIFER LEAKAGE

Leakage (or interchange of ground water) between the water-table aquifers and the Memphis aquifer in the Memphis area has been documented in previous reports (Graham and Parks, 1986; Parks, 1990). The Cook Mountain Formation directly overlies the Memphis Sand and is the most widespread and persistent clay layer in the confining unit. Faults with displacements greater than the thickness of the Cook Mountain Formation could juxtapose sand and gravel in the water-table aquifers and sand in the Cockfield Formation with sand in the Memphis aquifer. This juxtaposition of sand and gravel or sand locally could provide "pathways" for downward leakage.

No areas were identified during this investigation where faults have displaced the Cook Mountain Formation so that sand and gravel in water-table aquifers or sand in the Cockfield Formation are in direct contact with sand in the Memphis aquifer. Displacements along most of the faults decrease upward to amounts less than the thickness of the Cook Mountain Formation, which averages about 70 feet in most of the Memphis area. However, disrupted (or "brecciated") semi-consolidated sediments along fault planes (or fault zones) locally could provide areas where leakage to the Memphis Sand might occur.

Faults identified during this investigation are shown related to previously identified areas where the upper confining unit of the Memphis aquifer is thin or absent (Parks, 1990) (fig. 2). Relative uplift of blocks bounded by faults may have resulted in erosion of the confining unit, creating windows (fig. 2) where the water-table aquifers may directly overlie the Memphis aquifer. The shape and size of these windows may also be controlled by faults. For example, the window between Sheahan and Lichterman well fields is cut by a northeast trending fault (fig. 2). This fault may limit the extent of the window, and the western boundary of the window may be coincident with the fault.

Faults with displacements more than the thickness of the Flour Island Formation, the upper confining unit of the Fort Pillow aquifer, could juxtapose sand in the Memphis aquifer with sand in the Fort Pillow aquifer. This condition locally could provide "pathways" for leakage between these aquifers. Leakage between the Memphis aquifer and the Fort Pillow aquifer as a result of fault displacement of the Flour Island Formation probably is unlikely, except along fault planes or zones. The Flour Island Formation ranges from 140 to 310 feet in thickness, and most of the faults identified have displacements that range from 50 to 150 feet. Consequently, displacement of the Memphis Sand and the Fort Pillow Sand in most of the Memphis area is not great enough to juxtapose sands in the Memphis aquifer and sands in the Fort Pillow aquifer.

SUMMARY AND CONCLUSIONS

The U.S. Geological Survey conducted an investigation from 1990 to 1992 to describe the hydrogeology and geologic structure of the principal aquifers in the Memphis area. Interpretations of more than 500 electric and natural gamma-ray logs were used to make stratigraphic correlations of the geologic formations and to prepare structure-contour maps and geologic sections.

Geologic units examined in detail during this investigation are the Memphis Sand and the Fort Pillow Sand of Tertiary age. These formations make up the Memphis aquifer and the Fort Pillow aquifer, which are the principal aquifers in the Memphis area providing ground water for most domestic, commercial, industrial, and municipal supplies. The Memphis Sand consists of a thick deposit of fine to very coarse sand with lenses of clay, silt, and lignite at various stratigraphic horizons. The Fort Pillow Sand consists primarily of fine to medium or medium to coarse sand with minor lenses of clay and silt.

Stratigraphic correlations as interpreted from geophysical logs indicate that the tops of the Memphis Sand and Fort Pillow Sand are not easy to identify because the upper part of these units locally consist of fine sand, silt, and clay similar to the lithologies in the overlying Cook Mountain Formation and Flour Island Formation, respectively. The bases of the Memphis Sand and the Fort Pillow Sand commonly are distinctly recognizable because sand in these formations probably overlie erosion surfaces on clay, silt, or fine sand at the tops of the underlying Flour Island Formation and Old Breastworks Formation, respectively.

Structure-contour maps showing the altitude of the tops and bases of the Memphis Sand and the Fort Pillow Sand indicate that these units dip westward toward the axis of the Mississippi embayment at rates of 10 to 20 feet per mile. These structure-contour maps along with geologic sections show that many faults exist in the Memphis area and have vertical displacements ranging from 50 to 150 feet. These faults are interpreted to be normal faults, but it is possible that some have a component of strike-slip movement.

No areas were identified during this investigation where faults have displaced the Cook Mountain Formation so that sand and gravel in water-table aquifers or sand in the Cockfield

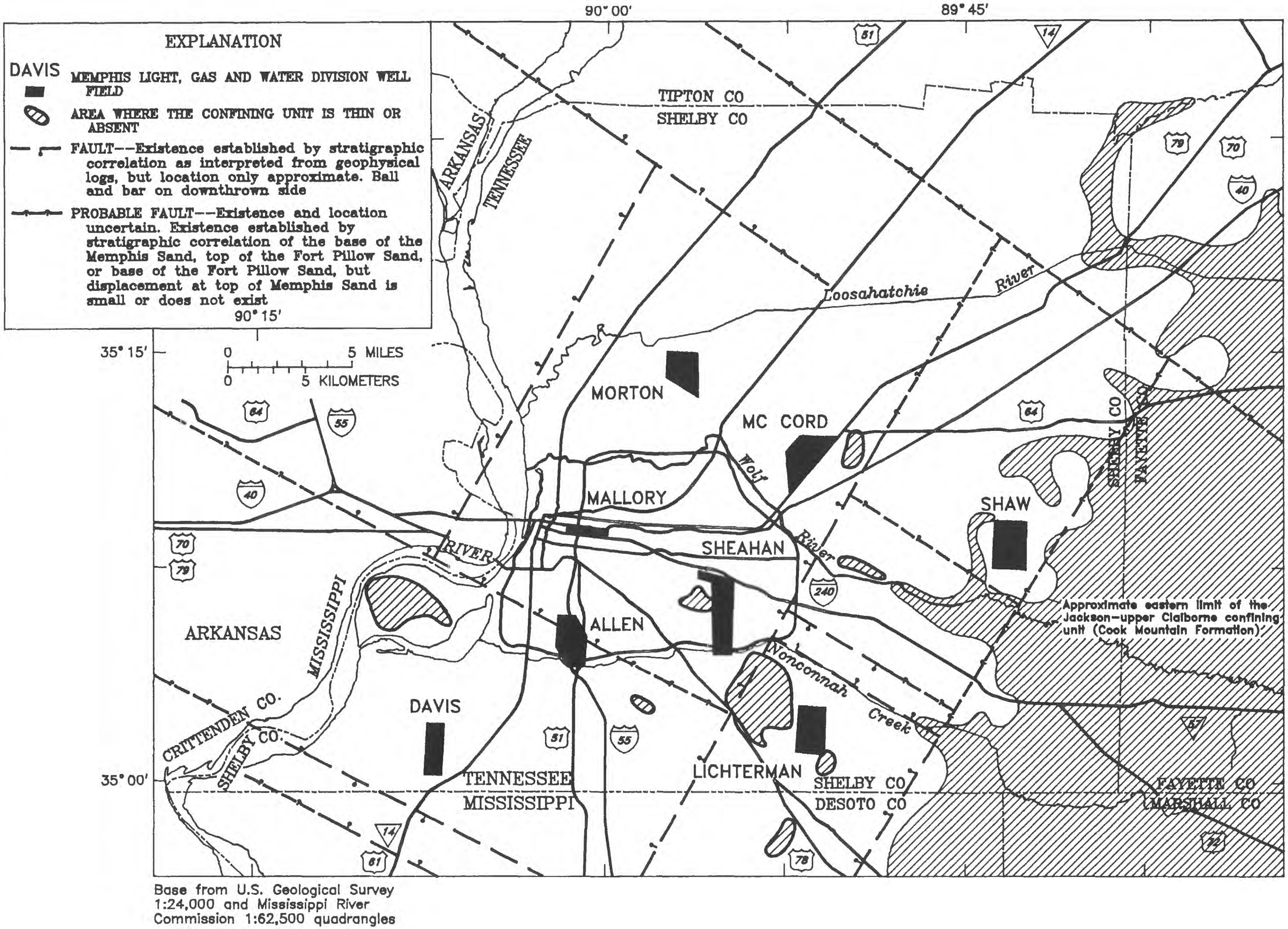


Figure 2.--Faults that displace the top of the Memphis sand and areas where the overlying confining unit is thin or absent.

Formation are in direct contact with sand in the Memphis aquifer. However, relative uplift of blocks bounded by faults may have resulted in erosion of the confining unit creating windows where the water-table aquifers may directly overlie the Memphis aquifer, and a potential exists for downward leakage of water from the water-table aquifers into the Memphis aquifer. The shape and size of these windows may also be controlled by faults.

Available geophysical logs do not indicate any areas where faults have resulted in the Memphis Sand and the Fort Pillow Sand being in juxtaposition. Such positioning would provide direct hydraulic connection for the interchange of ground water between the Memphis aquifer and the Fort Pillow aquifer.

REFERENCES CITED

Brahana, J.V., Parks, W.S., and Gaydos, M.W., 1987, Quality of water from freshwater aquifers and principal well fields in the Memphis area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 87-4052, 22 p.

Criner, J.H., and Armstrong, C.A., 1958, Ground-water supply of the Memphis area: U.S. Geological Survey Circular 408, 20 p.

Criner, J.H., Sun, P-C.P., and Nyman, D.J., 1964, Hydrology of the aquifer systems in the Memphis area, Tennessee: U.S. Geological Survey Water-Supply Paper 1779-O, 54 p.

Cushing, E.M., Boswell, E.H., and Hosman, R.L., 1964, General geology of the Mississippi embayment: U.S. Geological Survey Professional Paper 448-B, 28 p.

Fisk, H.N., 1944, Geological investigation of the alluvial valley of the lower Mississippi River: Vicksburg, Miss., U.S. Army Corps of Engineers, Mississippi River Commission, 78 p.

Frederiksen, N.O., Bybell, L.M., Christopher, R.A., Crone, A.J., Edwards, L.E., Gibson, T.G., Hazel, J.E., Repetski, J.E., Russ, D.P., Smith, C.C., and Ward, L.W., 1982, Biostratigraphy and paleoecology of lower Paleozoic, Upper Cretaceous, and lower Tertiary rocks, *in* U.S. Geological Survey New Madrid test wells, southeastern Missouri: Tulane Studies in Geology and Paleontology, v. 17, no. 2, p. 23-45.

Graham, D.D., and Parks, W.S., 1986, Potential for leakage among principal aquifers in the Memphis area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 85-4295, 46 p.

Moore, G.K., 1965, Geology and hydrology of the Claiborne Group in western Tennessee: U.S. Geological Survey Water-Supply Paper 1809-F, 44 p.

Moore, G.K., and Brown, D.L., 1969, Stratigraphy of the Fort Pillow test well Lauderdale County, Tennessee: Tennessee Division of Geology Report of Investigations 26, 1 sheet.

Parks, W.S., 1990, Hydrogeology and preliminary assessment of the potential for contamination of the Memphis aquifer in the Memphis area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 90-4092, 39 p.

Parks, W.S., and Carmichael, J.K., 1989, Geology and ground-water resources of the Fort Pillow Sand in western Tennessee: U.S. Geological Survey Water-Resources Investigations Report 89-4120, 20 p.

_____1990a, Geology and ground-water resources of the Cockfield Formation in western Tennessee: U.S. Geological Survey Water-Resources Investigations Report 88-4181, 17 p.

_____1990b, Geology and ground-water resources of the Memphis Sand in western Tennessee: U.S. Geological Survey Water-Resources Investigations Report 88-4182, 30 p.

Parks, W.S., and Lounsbury, R.W., 1976, Summary of some current and possible future environmental problems related to geology and hydrology at Memphis, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 4-76, 34 p.

Parks, W.S., and Russell, E.E., 1975, Geologic map showing Upper Cretaceous, Paleocene, and lower and middle Eocene units and distribution of younger fluvial deposits in western Tennessee: U.S. Geological Survey Miscellaneous Investigations Map I-916, scale 1:250,000.

Russell, E.E., and Parks, W.S., 1975, Stratigraphy of the outcropping Upper Cretaceous, Paleocene, and lower Eocene in western Tennessee (including descriptions of younger fluvial deposits): Tennessee Division of Geology Bulletin 75, 113 p.

Schneider, Robert, and Cushing, E.M., 1948, Geology and water-bearing properties of the "1,400-foot" sand in the Memphis area: U.S. Geological Survey Circular 33, 13 p.

Stearns, R.G., and Wilson, C.W., Jr., 1972, Relationships of earthquakes and geology in West Tennessee and adjacent areas: Knoxville, Tennessee, Tennessee Valley Authority, 302 p.

Stearns, R.G., and Zurawski, Ann, 1976, Post-Cretaceous faulting in the head of the Mississippi embayment: Southeastern Geology, v. 17, no. 4, p. 207-229.

Table 2. Tops and bases and calculated thicknesses of the Memphis Sand and the Fort Pillow Sand in the Memphis area based on geophysical-log correlations

[Latitude and longitude are in degrees, minutes, and seconds; altitude is land surface at well in feet above sea level interpolated from U.S. Geological Survey 7 1/2- minute topographic maps; top and base of units are depth in feet below land surface; values in parentheses are altitude of top and base of units in feet above (+) or below (-) sea level; thickness of units is in feet; "NR" indicates top or base of units not reached, "NL", top or base of unit not logged, "NP" indicates well is located east of the limit of the Cook Mountain Formation and the contact between the Memphis Sand and the Cook Mountain is not present; and "DL", driller's log used as supplemental information; --, no data available because contact is below the total depth of the test hole]

Well number	Latitude	Longitude	Altitude	Top of Memphis Sand	Base of Memphis Sand	Thickness of Memphis Sand	Top of Fort Pillow Sand	Base of Fort Pillow Sand	Thickness of Fort Pillow Sand
Ar:C-1	350958	0901738	209	311 (-102)	1,147 (-938)	836	NR	--	--
Ar:E-2	350519	0901810	207	313 (-106)	1,154 (-947)	841	1,390 (-1,183)	NR	--
Ar:H-2	350344	0901300	211	222 (-11)	NR	--	--	--	--
Ar:H-4	350724	0901347	214	272 (-58)	1,114 (-900)	842	1,379 (-1,165)	NR	--
Ar:N-1	350849	0900928	211	273 (-62)	NR	--	--	--	--
Ar:O-1	351349	0900628	217	285 (-68)	NR	--	--	--	--
Ar:O-2	350745	0900553	227	227 (0)	NR	--	--	--	--
Ms:A-7	345919	0900826	220	150 (+70)	NR	--	--	--	--
Ms:A-9	345731	0900911	211	204 (+7)	1,020 (-809)	816	NR	--	--
Ms:A-12	345712	0900915	210	198 (+12)	1,036 (-826)	838	1,336 (-1,126)	NR	--
Ms:A-29	345748	0900629	302	318 (-16)	1,149 (-847)	831	1,380 (-1,078)	1,660 (-1,358)	280
Ms:A-63	345831	0893806	420	NP	653 (-233)	--	902 (-482)	1,000 (-580)	98
Ms:A-103	345737	0901028	211	226 (-15)	1,060 (-849)	834	NR	--	--
Ms:B-5	345835	0900054	325	162 (+163)	NR	--	--	--	--
Ms:B-6	345740	0895945	335	161 (+174)	NR	--	--	--	--
Ms:B-7	345917	0900100	305	123 (+182)	NR	--	--	--	--
Ms:B-65	345657	0900311	289	158 (+131)	NR	--	--	--	--
Ms:C-4	345817	0895712	373	107 (+266)	NR	--	--	--	--
Ms:C-15	345812	0895851	345	144 (+201)	NR	--	--	--	--
Ms:D-3	345747	0894943	391	124 (+267)	NR	--	--	--	--
Ms:D-26	345903	0894741	402	82 (+320)	NR	--	--	--	--
Ms:D-46	345709	0895014	412	148 (+264)	NR	--	--	--	--
Ms:D-57	345820	0895142	390	101 (+289)	NR	--	--	--	--
Fa:G-1	350049	0893346	433	NP	590 (-157)	--	857 (-424)	1,005 (-572)	148
Fa:R-1	352226	0893301	318	72 (+246)	723 (-405)	651	902 (-584)	1,051 (-733)	149
Sh:E-3	345842	0895221	335	65 (+270)	NR	--	--	--	--
Sh:E-4	345943	0894802	403	153 (+250)	NR	--	--	--	--
Sh:H-1	350331	0900729	312	270 (+42)	NR	--	--	--	--
Sh:H-2	350405	0900738	215	201 (+14)	NR	--	--	--	--
Sh:H-6	350135	0900738	255	194 (+61)	NR	--	--	--	--
Sh:H-8	350157	0900742	305	246 (+59)	NR	--	--	--	--
Sh:H-9	350114	0900751	242	182 (+60)	NR	--	--	--	--
Sh:H-13	350452	0900759	238	235 (+3)	NR	--	--	--	--
Sh:J-1	350004	0900546	240	142 (+98)	NR	--	--	--	--
Sh:J-10	350501	0900239	270	193 (+77)	NR	--	--	--	--

Table 2. Tops and bases and calculated thicknesses of the Memphis Sand and the Fort Pillow Sand in the Memphis area based on geophysical-log correlations--Continued

Well number	Latitude	Longitude	Altitude	Top of Memphis Sand	Base of Memphis Sand	Thickness of Memphis Sand	Top of Fort Pillow Sand	Base of Fort Pillow Sand	Thickness of Fort Pillow Sand
Sh:J-27	350716	0900330	268	265(+3)	NR	--	--	--	--
Sh:J-32	350657	0900426	280	262(+18)	NR	--	--	--	--
Sh:J-38	350711	0900107	315	238(+77)	NR	--	--	--	--
Sh:J-41	350723	0900213	275	248(+27)	NR	--	--	--	--
Sh:J-47	350508	0900459	230	202(+28)	NR	--	--	--	--
Sh:J-49	350611	0900344	280	277(+3)	NR	--	--	--	--
Sh:J-50	350411	0900416	241	187(+54)	NR	--	--	--	--
Sh:J-59	350402	0900513	241	189(+52)	NR	--	--	--	--
Sh:J-62	350459	0900330	223	166(+57)	NR	--	--	--	--
Sh:J-65	350232	0900249	303	205(+98)	NR	--	--	--	--
Sh:J-71	350206	0900212	295	178(+117)	NR	--	--	--	--
Sh:J-74	350022	0900117	303	168(+135)	NR	--	--	--	--
Sh:J-83	350319	0900144	280	167(+113)	NR	--	--	--	--
Sh:J-84	350536	0900627	243	228(+15)	NR	--	--	--	--
Sh:J-104	350537	0900145	248	202 (+46)	1,058 (-810)	856	1,240 (-992)	1,483 (-1,235)	243
Sh:J-107	350515	0900131	245	194 (+51)	NR	--	--	--	--
Sh:J-113	350449	0900136	272	174 (+98)	NR	--	--	--	--
Sh:J-115	350553	0900223	295	262 (+33)	NR	--	--	--	--
Sh:J-119	350521	0900204	260	180 (+80)	NR	--	--	--	--
Sh:J-129	350353	0900640	290	249 (+41)	NR	--	--	--	--
Sh:J-138	350148	0900702	300	224 (+76)	NR	--	--	--	--
Sh:J-141	350114	0900703	285	220 (+65)	NR	--	--	--	--
Sh:J-142	350230	0900726	310	238 (+72)	1,124 (-814)	886	NR	--	--
Sh:J-144	350053	0900708	280	198 (+82)	NR	--	--	--	--
Sh:J-166	350611	0900205	278	210 (+68)	1,018 (-740)	808	1,278 (-1,000)	1,505 (-1,227)	227
Sh:J-167	350439	0900136	245	160 (+85)	982 (-737)	822	1,210 (-965)	1,436 (-1,191)	226
Sh:J-180	350556	0900208	257	192 (+65)	998 (-741)	806	NR	--	--
Sh:J-183	350531	0900205	285	237 (+48)	1,047 (-762)	810	1,276 (-991)	1,517 (-1,232)	241
Sh:J-185	350125	0900722	295	211 (+84)	1,108 (-813)	897	1,340 (-1,045)	1,638 (-1,343)	298
Sh:K-13	350541	0895902	295	185 (+110)	NR	--	--	--	--
Sh:K-16	350523	0895801	293	165 (+128)	NR	--	--	--	--
Sh:K-29	350258	0895929	271	135 (+136)	NR	--	--	--	--
Sh:K-31	350143	0895357	315	66 (+249)	NR	--	--	--	--
Sh:K-58	350701	0895542	301	146 (+155)	954 (-653)	808	1,200 (-899)	NR	--
Sh:K-70	350533	0895554	258	141 (+144)	NR	--	--	--	--
Sh:K-72	350509	0895553	252	106 (+146)	NR	--	--	--	--
Sh:K-73	350515	0895536	266	128 (+138)	NR	--	--	--	--
Sh:K-81	350103	0895719	380	184 (+196)	NR	--	--	--	--
Sh:K-98	350633	0895438	313	176 (+137)	NR	--	--	--	--
Sh:K-108	350153	0895259	295	74 (+221)	NR	--	--	--	--

Table 2. Tops and bases and calculated thicknesses of the Memphis Sand and the Fort Pillow Sand in the Memphis area based on geophysical-log correlations--Continued

Well number	Lati-tude	Longi-tude	Alti-tude	Top of Memphis Sand	Base of Memphis Sand	Thickness of Memphis Sand	Top of Fort Pillow Sand	Base of Fort Pillow Sand	Thickness of Fort Pillow Sand
Sh:K-113	350201	0895342	310	88 (+222)	NR	--	--	--	--
Sh:K-118	350559	0895528	285	152 (+133)	NR	--	--	--	--
Sh:K-120	350008	0895450	362	133 (+229)	NR	--	--	--	--
Sh:K-122	350434	0895739	240	116 (+124)	NR	--	--	--	--
Sh:K-125	350114	0895822	311	138 (+173)	NR	--	--	--	--
Sh:K-127	350024	0895838	320	156 (+164)	996 (-676)	840	1,236 (-916)	NR	--
Sh:K-138	350625	0895549	280	150 (+130)	926 (-646)	776	1,180 (-900)	1,410 (-1,130)DL	230
Sh:K-143	350233	0895938	281	152 (+129)	NR	--	--	--	--
Sh:K-150	350055	0895924	310	170 (+140)	987 (-677)	817	1,216 (-906)	1,424 (-1,114)	208
Sh:L-9	350504	0894828	370	127 (+243)	NR	--	--	--	--
Sh:L-12	350030	0895024	395	NL	852 (-457)	--	1,121 (-726)	1,347 (-952)	226
Sh:L-15	350412	0894530	341	74 (+267)	NR	--	--	--	--
Sh:L-17	350721	0895130	310	108 (+202)	NR	--	--	--	--
Sh:L-18	350516	0894940	320	83 (+237)	NR	--	--	--	--
Sh:L-20	350558	0895211	320	132 (+188)	NR	--	--	--	--
Sh:L-21	350540	0895211	330	151 (+179)	856 (-526)	705	NR	--	--
Sh:L-23	350519	0895212	330	155 (+175)	NR	--	--	--	--
Sh:L-25	350435	0895034	288	102 (+186)	801 (-513)	699	NR	--	--
Sh:L-27	350457	0895044	317	134 (+183)	NR	--	--	--	--
Sh:L-29	350440	0894947	325	96 (+229)	824 (-499)	728	1,094 (-769)	NR	--
Sh:L-34	350301	0895210	328	56 (+272)	770 (-442)	714	1,084 (-756)	NR	--
Sh:L-35	350248	0895200	342	93 (+249)	795 (-453)	702	NR	--	--
Sh:L-36	350218	0895117	357	82 (+275)	788 (-431)	706	NR	--	--
Sh:L-52	350024	0894722	390	120 (+270)	NR	--	--	--	--
Sh:L-57	350534	0895121	320	94 (+226)	NR	--	--	--	--
Sh:L-61	350354	0895038	272	75 (+197)	NR	--	--	--	--
Sh:L-64	350639	0895225	305	165 (+140)	NR	--	--	--	--
Sh:L-67	350447	0894826	380	136 (+244)	NR	--	--	--	--
Sh:L-68	350142	0895134	350	61 (+289)	785 (-435) DL	724	NR	--	--
Sh:L-69	350259	0895213	329	78 (+251)	806 (-477)	728	NR	--	--
Sh:L-70	350207	0895224	307	71 (+236)	785 (-478)	714	NR	--	--
Sh:L-81	350450	0894807	380	156 (+224)	846 (-466)	690	NR	--	--
Sh:L-93	350327	0895147	335	67 (+268)	782 (-447)	715	NR	--	--
Sh:L-97	350207	0895110	353	82 (+271)	782 (-429)	700	NR	--	--
Sh:L-101	350228	0895208	300	76 (+224)	787 (-487)	711	1,062 (-762)	1,305 (-1,005)	243
Sh:L-103	350234	0895156	318	66 (+252)	795 (-477)	729	1,063 (-745)	1,317 (-999)	254
Sh:M-11	350223	0894459	338	71 (+267)	NR	--	--	--	--
Sh:M-24	350653	0894215	340	82 (+258)	NR	--	--	--	--
Sh:M-26	350404	0894356	332	66 (+266)	NR	--	--	--	--
Sh:M-27	350334	0894355	355	75 (+280)	NR	--	--	--	--

Table 2. Tops and bases and calculated thicknesses of the Memphis Sand and the Fort Pillow Sand in the Memphis area based on geophysical-log correlations--Continued

Well number	Latitude	Longitude	Altitude	Top of Memphis Sand	Base of Memphis Sand	Thickness of Memphis Sand	Top of Fort Pillow Sand	Base of Fort Pillow Sand	Thickness of Fort Pillow Sand
Sh:M-37	350642	0894300	335	72 (+263)	780 (-445)	708	NR	–	–
Sh:M-38	350236	0893947	387	NP	652 (-265)	–	916 (-529)	1,076 (-689)	160
Sh:M-39	350344	0894449	363	98 (+265)	NR	–	–	–	–
Sh:M-41	350407	0894457	355	108 (+247)	852 (-497)	744	NR	–	–
Sh:O-1	351437	0900046	229	216 (+13)	NR	–	–	–	–
Sh:O-18	351034	0900243	235	209 (+26)	NR	–	–	–	–
Sh:O-67	350828	0900214	266	236 (+30)	NR	–	–	–	–
Sh:O-82	350833	0900147	288	258 (+30)	NR	–	–	–	–
Sh:O-93	350839	0900239	238	211 (+27)	NR	–	–	–	–
Sh:O-120	351050	0900035	230	184 (+46)	NR	–	–	–	–
Sh:O-169	350908	0900146	254	237 (+17)	1012 (-758)	775	1,301 (-1,047)	1,530 (-1,276)	229
Sh:O-170	350910	0900151	255	220 (+35)	994 (-739)	774	NR	–	–
Sh:O-181	350914	0900105	251	224 (+27)	1000 (-749)	776	NR	–	–
Sh:O-184	350956	0900139	251	214 (+37)	NR	–	–	–	–
Sh:O-194	350817	0900043	295	244 (+51)	NR	–	–	–	–
Sh:O-199	350846	0900311	265	239 (+26)	NR	–	–	–	–
Sh:O-202	351032	0900143	242	202 (+40)	NR	–	–	–	–
Sh:O-206	350805	0900204	272	232 (+40)	NR	–	–	–	–
Sh:O-222	350911	0900048	249	213 (+36)	993 (-744)	780	NR	–	–
Sh:O-243	350808	0900022	280	208 (+72)	NR	–	–	–	–
Sh:O-249	350919	0900019	252	204 (+48)	975 (-723)	771	1,253 (-1,001)	NR	–
Sh:P-1	351320	0895401	300	178 (+122)	NR	–	–	–	–
Sh:P-11	351028	0893050	244	160 (+84)	NR	–	–	–	–
Sh:P-14	350943	0895757	252	182 (+70)	NR	–	–	–	–
Sh:P-24	350937	0895737	260	173 (+87)	978 (-718)	805	1,217 (-957)	1,423 (-1,163)	206
Sh:P-34	350807	0895825	283	188 (+95)	NR	–	–	–	–
Sh:P-36	350950	0895833	243	182 (+61)	NR	–	–	–	–
Sh:P-39	351045	0895655	251	165 (+86)	NR	–	–	–	–
Sh:P-54	350904	0895805	255	188 (+67)	NR	–	–	–	–
Sh:P-62	350735	0895733	280	170 (+110)	NR	–	–	–	–
Sh:P-69	351220	0895525	300	182 (+118)	NR	–	–	–	–
Sh:P-71	351323	0895754	290	231 (+59)	NR	–	–	–	–
Sh:P-73	350901	0895246	250	102 (+148)	NR	–	–	–	–
Sh:P-75	351246	0895525	330	218 (+112)	NR	–	–	–	–
Sh:P-76	350735	0895932	287	211 (+76)	NR	–	–	–	–
Sh:P-85	351101	0895240	293	120 (+173)	NR	–	–	–	–
Sh:P-86	351131	0895312	275	141 (+134)	NR	–	–	–	–
Sh:P-89	351023	0895801	248	170 (+78)	NR	–	–	–	–
Sh:P-93	350831	0895656	279	191 (+88)	NR	–	–	–	–
Sh:P-94	350913	0895739	248	171 (+77)	NR	–	–	–	–

Table 2. Tops and bases and calculated thicknesses of the Memphis Sand and the Fort Pillow Sand in the Memphis area based on geophysical-log correlations--Continued

Well number	Latitude	Longitude	Altitude	Top of Memphis Sand	Base of Memphis Sand	Thickness of Memphis Sand	Top of Fort Pillow Sand	Base of Fort Pillow Sand	Thickness of Fort Pillow Sand
Sh:P-96	351435	0895300	312	224 (+88)	NR	–	–	–	–
Sh:P-103	350927	0895950	258	201 (+57)	NR	–	–	–	–
Sh:P-112	350737	0895620	315	184 (+131)	NR	–	–	–	–
Sh:P-114	351449	0895641	232	158 (+74)	NR	–	–	–	–
Sh:P-115	351327	0895658	292	214 (+78)	NR	–	–	–	–
Sh:P-117	351409	0895709	245	174 (+71)	NR	–	–	–	–
Sh:P-118	351458	0895747	265	205 (+60)	NR	–	–	–	–
Sh:P-120	351427	0895747	320	264 (+56)	NR	–	–	–	–
Sh:P-128	351450	0895713	290	230 (+60)	NR	–	–	–	–
Sh:P-131	351420	0895709	247	173 (+74)	NR	–	–	–	–
Sh:P-143	351058	0895739	228	143 (+85)	NR	–	–	–	–
Sh:P-201	351435	0895731	310	254 (+56)	1,108 (-798)	854	1,292 (-982)	1,570 (-1,260)	278
Sh:P-203	351450	0895724	270	212 (+58)	1,020 (-750)	793	1,248 (-978)	1,485 (-1,215)	237
Sh:Q-1	350900	0894822	330	103 (+227)	NR	–	–	–	–
Sh:Q-7	350940	0894504	313	101 (+212)	NR	–	–	–	–
Sh:Q-8	350901	0895113	270	144 (+126)	NR	–	–	–	–
Sh:Q-16	350909	0895153	260	121 (+139)	NR	–	–	–	–
Sh:Q-21	351215	0895127	295	172 (+123)	NR	–	–	–	–
Sh:Q-22	351144	0895044	305	136 (+169)	NR	–	–	–	–
Sh:Q-23	351138	0895207	283	132 (+151)	NR	–	–	–	–
Sh:Q-24	351315	0895150	281	137 (+144)	NR	–	–	–	–
Sh:Q-28	351054	0895155	282	162 (+120)	NR	–	–	–	–
Sh:Q-38	351124	0895156	291	138 (+153)	NR	–	–	–	–
Sh:Q-39	351128	0895130	309	152 (+157)	NR	–	–	–	–
Sh:Q-74	351223	0895221	295	154 (+141)	NR	–	–	–	–
Sh:Q-82	351326	0895046	322	163 (+159)	NR	–	–	–	–
Sh:Q-89	350737	0894856	259	49 (+210)	NR	–	–	–	–
Sh:Q-124	350822	0895003	273	60 (+213)	NR	–	–	–	–
Sh:Q-130	350835	0894994	320	81 (+239)	NR	–	–	–	–
Sh:Q-150	350804	0895037	261	57 (+204)	NR	–	–	–	–
Sh:Q-154	351112	0895125	312	178 (+134)	964 (-654)	786	1,198 (-886)	1,410 (-1,098)	212
Sh:Q-155	350934	0894825	295	124 (+171)	NR	–	–	–	–
Sh:R-5	351350	0894425	395	208 (+187)	NR	–	–	–	–
Sh:R-8	351141	0894411	372	168 (+204)	NR	–	–	–	–
Sh:R-9	351248	0894053	375	121 (+254)	NR	–	–	–	–
Sh:R-15	351239	0893943	342	85 (+257)	NR	–	–	–	–
Sh:R-21	350913	0894338	305	59 (+246)	766 (-461)	707	970 (-665)	1,166 (-861)	196
Sh:R-24	350811	0894244	330	110 (+220)	804 (-474)	694	998 (-668)	1,194 (-864)	196
Sh:R-25	350737	0894342	276	78 (+198)	796 (-520)	718	NR	–	–
Sh:R-26	351402	0893935	285	52 (+233)	NR	–	–	–	–

Table 2. Tops and bases and calculated thicknesses of the Memphis Sand and the Fort Pillow Sand in the Memphis area based on geophysical-log correlations--Continued

Well number	Latitude	Longitude	Altitude	Top of Memphis Sand	Base of Memphis Sand	Thickness of Memphis Sand	Top of Fort Pillow Sand	Base of Fort Pillow Sand	Thickness of Fort Pillow Sand
Sh:R-30	350811	0894309	325	120 (+205)	833 (-508)	713	1,003 (-678)	1,180 (-855)	177
Sh:R-33	350846	0894306	330	78 (+252)	779 (-449)	701	968 (-638)	1,204 (-874)	236
Sh:R-35	350822	0894342	322	118 (+204)	814 (-492)	696	953 (-631)	1,183 (-861)	230
Sh:R-36	350802	0894236	299	65 (+234)	764 (-465)	699	956 (-657)	1,156 (-857)	200
Sh:R-38	350833	0894239	362	106 (+256)	854 (-492)	748	1,070 (-708)	1,204 (-842)	134
Sh:R-39	350846	0894328	343	108 (+235)	820 (-477)	712	1,048 (-705)	1,198 (-855)	150
Sh:T-6	351505	0900322	290	326 (-36)	1,163 (-873)	837	NR	--	--
Sh:T-7	352040	0900154	400	420 (-20)	NR	--	--	--	--
Sh:T-13	352213	0900056	400	454 (-54)	NR	--	--	--	--
Sh:T-16	352044	0900249	355	418 (-63)	NR	--	--	--	--
Sh:T-17	351747	0900329	330	426 (-96)	NR	--	--	--	--
Sh:T-18	352127	0900107	391	432 (-41)	1,295 (-904)	863	1,540(-1,149)	1,765(-1,374)	225
Sh:U-1	352113	0895706	264	216 (+48)	NR	--	--	--	--
Sh:U-12	351705	0895320	238	171 (+67)	968 (-730)	797	1,170 (-932)	1,410 (-1,172)	240
Sh:U-22	351737	0895749	300	214 (+86)	NR	--	--	--	--
Sh:U-29	351556	0895859	242	164 (+78)	NR	--	--	--	--
Sh:U-48	352114	0895727	267	152 (+115)	NR	--	--	--	--
Sh:U-49	352023	0895627	251	155 (+96)	NR	--	--	--	--
Sh:U-52	352038	0895708	257	158 (+99)	NR	--	--	--	--
Sh:U-54	352034	0895345	265	182 (+83)	1,062 (-797)	880	1,316 (-1,051)	1,470 (-1,205)	154
Sh:U-56	351907	0895709	292	224 (+68)	NR	--	--	--	--
Sh:U-59	352009	0895253	265	160 (+105)	1,032 (-767)	872	1,260 (-995)	1,436 (-1,171)	176
Sh:V-7	351544	0894616	278	160 (+118)	NR	--	--	--	--
Sh:V-10	352010	0895036	271	163 (+108)	NR	--	--	--	--
Sh:V-16	351904	0894900	283	164 (+119)	NR	--	--	--	--
Sh:V-17	351850	0894935	282	180 (+102)	NR	--	--	--	--
Sh:V-24	352227	0895043	375	282 (+93)	NR	--	--	--	--
Sh:W-3	351750	0893943	279	67 (+212)	NR	--	--	--	--
Sh:W-7	352026	0894408	322	202 (+120)	NR	--	--	--	--
Sh:W-13	351938	0894130	320	147 (+173)	NR	--	--	--	--
Sh:W-16	351923	0894228	364	203 (+161)	NR	--	--	--	--
Tp:F-3	352517	0894124	405	272 (+133)	NR	--	--	--	--

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