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DEPARTMENT OF THE NAVY
SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND

WATER-RESOURCES INVESTIGATIONS
REPORT 95-4011
Kingsbury, J.A., and Carmichael, J.K., Hydrogeology of post-Wilcox Group stratigraphic units in the area of the Naval Air Station Memphis, near Millington, Tennessee

INTRODUCTION

The Naval Air Station (NAS) Memphis is a major training facility for the U.S. Department of the Navy (Navy). Located near the city of Millington in northwestern Shelby County, Tennessee (fig. 1), NAS Memphis consists of North and South Complexes that are divided by Navy Road and together encompass about 3,490 acres. Major operational areas at NAS Memphis include an airfield, training facilities, and a hospital in the North Complex, and housing and training facilities in the South Complex. Beginning in 1995, NAS Memphis is scheduled for realignment of its primary mission operations and partial closure under the Base Realignment and Closure Act of 1990.

As a result of the type of operations conducted at NAS Memphis, concerns have been raised regarding the release of hazardous materials to the environment; specifically, soil, ground-water, and surface-water contamination from past and present waste-management practices. Sixty-seven Solid Waste Management Units (SWMU's) have been identified at the facility pursuant to the Navy Installation Restoration Program and the Hazardous and Solid Waste Amendments (HSWA) section of the Resource Conservation and Recovery Act (RCRA) permit issued to NAS Memphis by the U.S. Environmental Protection Agency in 1986. These SWMU's presently are under investigation as part of the RCRA Corrective Action Program being conducted at the base. The objective of the Corrective Action Program is to obtain information to fully characterize the nature, extent, and rate of migration of contaminants from SWMU's and to interpret these data to determine appropriate corrective measures.

The Navy's engineering field division, Southern Division Naval Facilities Engineering Command (SOUTHDIV), is providing engineering and contract services to NAS Memphis to support compliance with the HSWA permit and the associated Corrective Action Program. The U.S. Geological Survey (USGS), in cooperation with SOUTHDIV, is providing technical assistance in an investigation of the hydrogeology at NAS Memphis under the Corrective Action Program. The purpose of this report is to summarize hydrogeologic information and geotechnical data collected from five stratigraphic test holes drilled in April 1994 near several SWMU's located within the NAS Memphis North Complex. The report briefly describes geologic and hydrologic characteristics of the strata from land surface to about 1,000 feet in depth.

HYDROGEOLOGY

NAS Memphis is located in the north-central part of the Mississippi embayment, a broad syncline that plunges southward along an axis that approximates the Mississippi River. In the NAS Memphis area, the embayment contains more than 2,500 feet of unconsolidated to semiconsolidated sediments of Cretaceous, Tertiary, and Quaternary age that overlie "bedrock" of Paleozoic age. Post-Wilcox Group stratigraphic units described in this report include, from youngest to oldest, the alluvium and loess of Quaternary age; the fluvial deposits of Tertiary(?) and Quaternary age; and the Cockfield Formation, Cook Mountain Formation, and Memphis Sand of Tertiary age (fig. 2). The description of the post-Wilcox units is based on information and data from the five stratigraphic test holes and from geophysical logs of other test holes and wells at locations within and near NAS Memphis.

Alluvium

Alluvium is present beneath the alluvial plains of streams in the NAS Memphis area. The alluvium in the Memphis area generally consists of silt and clay in the upper part and sand and gravel in the lower part (Parks, 1990). The principal stream in the NAS Memphis area is Big Creek, which forms the southern boundary of the South Complex (fig. 1). Little specific information is available concerning the stratigraphic sequence beneath the Big Creek alluvial plain in the NAS Memphis area. Sediments in about the upper 10 feet in test hole Sh:V-74 and upper 15 feet in Sh:U-99 (fig. 3) are interpreted as alluvium because these sites are near small tributaries to Big Creek. These sediments are primarily silt with some clay (fig. 2) and are similar in lithology to the loess from which they probably were reworked.

Loess

Loess is the near surface unit in upland areas of the NAS Memphis area. The loess ranges from about 15 to 45 feet in thickness and is predominantly silt and clay that contains some fine sand (fig. 2). The loess is reworked or absent beneath the alluvial plains of streams. Because of the low permeability of silt and clay, the loess retards movement of recharge water to the underlying fluvial deposits, and can serve as an upper confining unit to the fluvial deposits aquifer in the NAS Memphis area. Locally, however, the loess is saturated and contains water-bearing zones. The rate of ground-water movement in the loess is slow; wells screened in the loess are pumped dry quickly. Samples of the loess collected from three of the test holes had laboratory determined porosities ranging from 38 to about 45 percent and vertical hydraulic conductivities ranging from 3.4×10^{-4} to 1.5×10^{-3} ft/d (table 1).

Fluvial Deposits

The fluvial deposits underlie the loess in upland parts of the NAS Memphis area and consist of sand and gravel with minor amounts of clay (fig. 2). Generally, gravel and sandy gravel are present in the lower part of the formation. The gravel is predominantly chert, with some pebbles as large as 2 inches in the longest dimension. Locally, the sand and gravel may be cemented, forming thin layers of ferruginous sandstone or conglomerate. Two levels of fluvial deposits have been identified in the NAS Memphis area. The southern part of the area is underlain by deposits with a basal altitude of about 200 feet above sea level (fig. 3). This lower level of fluvial deposits ranges from about 30 to 60 feet in thickness. The northern part of the NAS Memphis area is underlain by fluvial deposits with a basal altitude of about 300 feet above sea level (fig. 3). This higher level of fluvial deposits ranges from about 10 to 35 feet in thickness. The fluvial deposits make up the fluvial deposits aquifer. The two levels of fluvial deposits could be hydraulically connected and, if so, could be considered to be a single aquifer.

Cockfield Formation

The Cockfield Formation is the uppermost unit in the Claiborne Group (fig. 2). The Cockfield Formation consists of sand, silt, clay, and lignite. Beds in the Cockfield Formation are lenticular and can be discontinuous over short distances (Parks and Carmichael, 1990a). Throughout much of the NAS Memphis area, the upper part of the Cockfield Formation consists of clay and silt and serves as a lower confining unit for the overlying fluvial deposits aquifer. Locally, however, some parts of the Cockfield Formation consist of relatively thick sections of fine and fine to medium sand. Thickness of the Cockfield Formation is variable as a result of erosional surfaces at the top and base of the formation. The thickness ranges from about 35 to 180 feet in the NAS Memphis area (fig. 3). The thickest section of the Cockfield Formation is in the northern part of the area beneath the base of the higher level fluvial deposits (section A–A′, fig. 3). Sand beds or lenses in the Cockfield Formation make up the Cockfield aquifer. Where sand beds in the Cockfield Formation underlie the fluvial deposits, the two units probably are hydraulically continuous.

Cook Mountain Formation

The Cook Mountain Formation of the Claiborne Group consists predominantly of clay and silt (fig. 2); however, minor lenses of silty fine sand may be present locally. The Cook Mountain Formation contains the most areally extensive clay in the upper part of the Claiborne Group in Shelby County (Parks, 1990). Most of the test holes drilled for this investigation did not penetrate the entire Cook Mountain Formation, but geophysical logs from other test holes and wells in the area that penetrate the entire formation indicate that the thickness ranges from about 15 to 50 feet (fig. 3). The Cook Mountain Formation serves as the lower confining unit for the Cockfield aquifer and the upper confining unit for the Memphis aquifer. Clay samples from the Cook Mountain Formation were collected in four of the test holes for mineralogical and geotechnical (table 1) analysis. Results from x-ray diffraction analysis of the <1 micron-size clay particles separated from each of the samples indicated interstratified smectite, well-crystallized kaolinite, and minor amounts of illite (B. Jones and D. Webster, USGS, written commun., 1994). Porosities of the samples ranged from about 30 to 42 percent and vertical hydraulic conductivities ranged from 8.1×10^{-6} to 1.6×10^{-4} ft/d (table 1).

Memphis Sand

The Memphis Sand (fig. 2) is a thick deposit of primarily fine to very coarse sand with lenses of clay, silt, and lignite at various stratigraphic horizons (Parks and Carmichael, 1990b). Clays and silts commonly are present in the upper part of the Memphis Sand, causing difficulty in distinguishing between the Memphis Sand and Cook Mountain Formation on geophysical logs of stratigraphic test holes (Kingsbury and Parks, 1993). In the NAS Memphis area, the Memphis Sand ranges from about 865 to 880 feet thick (fig. 2), based on test holes drilled previously at and near the facility. The Memphis Sand makes up the Memphis aquifer, which supplies water to industries and municipalities in Shelby County. Water used at NAS Memphis is withdrawn from the Memphis aquifer and the deeper Fort Pillow aquifer of the Wilcox Group (Parks and Carmichael, 1989). In 1993, about 0.8 Mgal/d were withdrawn from the Memphis aquifer and about 1.2 Mgal/d were withdrawn from the Fort Pillow aquifer for the water supply at NAS Memphis (R. Harris, NAS Memphis water plant, oral commun., 1994). As part of this investigation, two production wells screened in the Memphis aquifer at the North Complex were sampled for tritium analysis to determine if relatively young water from shallower sources has entered the aquifer through the upper confining unit. The samples essentially were free of tritium, indicating that water in the Memphis aquifer in the area of the two wells has not been affected by leakage of younger water from shallower sources.

REFERENCES CITED

Kingsbury, J.A., and Parks, W.S., 1993, Hydrogeology of the principal aquifers and relation of faults to interaquifer leakage in the Memphis area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 93-4075, 18 p.

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.

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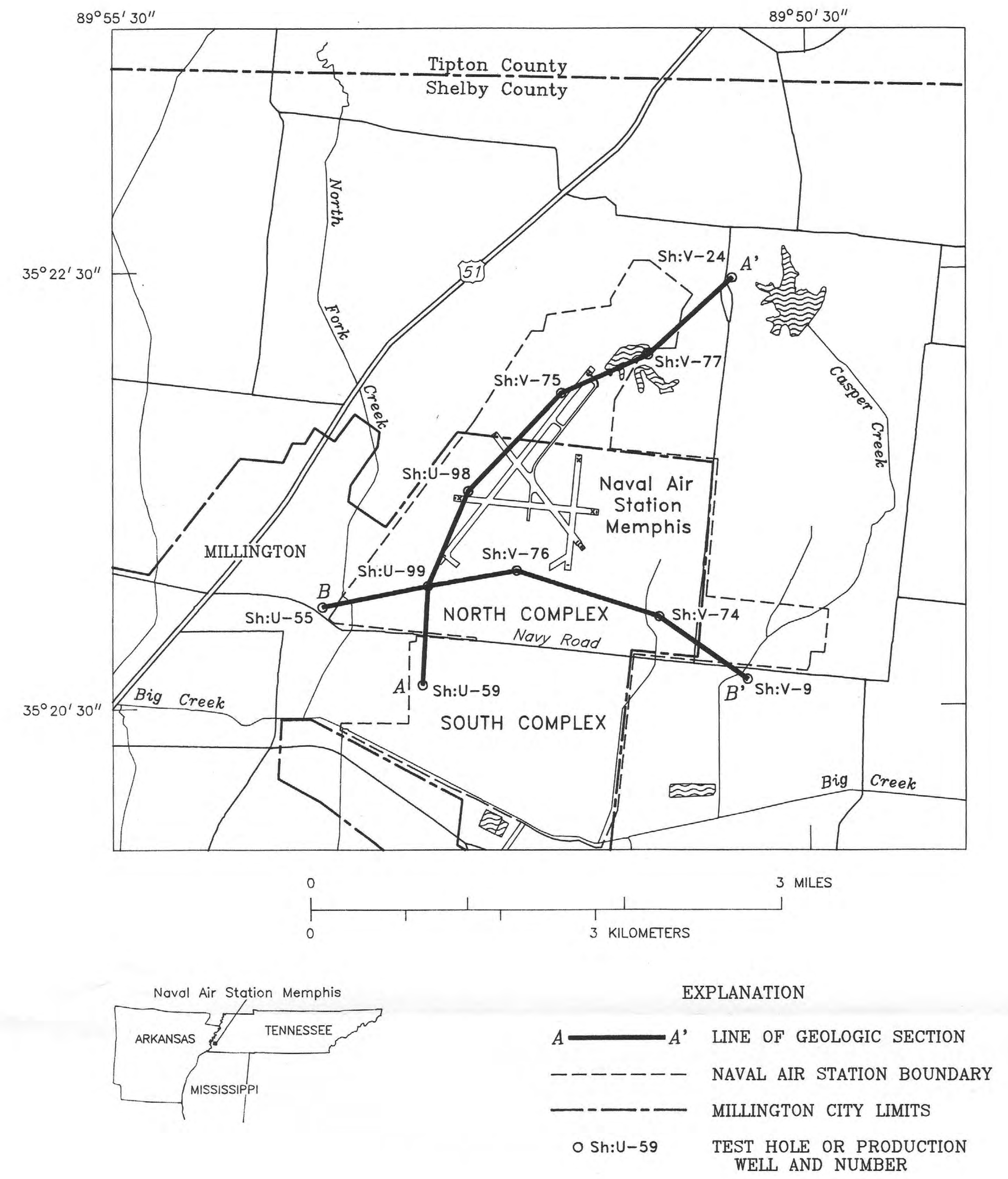

Figure 1. Locations of the Naval Air Station Memphis and geologic sections A–A′ and B–B′.

System	Series	Group	Stratigraphic unit (and local name)	Thickness (in feet)	Lithology
Quaternary	Holocene and Pleistocene		Alluvium (alluvial deposits)	0-15	Silt and clay
	Pleistocene		Loess	15-45	Silt and clay, with minor fine sand.
Quaternary and Tertiary(?)	Pleistocene and Pliocene(?)		Fluvial deposits (terrace deposits)	10-60	Sand, gravel, with minor clay and ferruginous sandstone.
Tertiary	Eocene	Claiborne	Cockfield Formation	35-180	Sand, silt, clay, and lignite.
			Cook Mountain Formation	15-50	Clay, silt, and minor sand.
			Memphis Sand	865-880	Sand, silt, clay, and minor lignite. Overlies the Flour Island Formation of the Wilcox Group.

Figure 2. Post-Wilcox Group stratigraphic units underlying the Naval Air Station Memphis area.

Table 1. Selected geotechnical properties of the loess and Cook Mountain Formation clay

[Analyses conducted by Inberg-Miller Engineers, Cheyenne, Wyoming; USGS, U.S. Geological Survey; ft, foot; lbs/ft^3, pounds per cubic foot; ft/d, feet per day; LL, liquid limit; PL, plastic limit; PI, plasticity index]

USGS and (test hole) number	Sample depth (ft)	Sample classification	Moisture content (percent)	Dry density (lbs/ft^3)	Specific gravity	Porosity (percent)	Atterberg limits LL	Atterberg limits PL	Atterberg limits PI	Vertical hydraulic conductivity (ft/d)
Loess										
Sh:V-75 (3)	11-13	Lean clay	25.5	103.3	2.71	38.9	29.6	19.0	10.6	3.4×10^{-4}
Sh:U-99 (4)	13-15	Silt	28.7	105.5	2.73	38.0	29.4	27.4	2.0	1.5×10^{-3}
Sh:V-76 (5)	11-13	Lean clay	30.9	93.7	2.73	45.1	43.6	22.2	21.4	4.5×10^{-4}
Cook Mountain Formation clay										
Sh:V-74 (1)	209-211	Lean clay	16.9	116.0	2.69	30.8	41.6	15.3	26.3	8.1×10^{-6}
Sh:U-98 (2)	199-200	Lean clay	25.5	106.9	2.73	37.2	43.5	17.4	26.1	4.5×10^{-5}
Sh:V-75 (3)	218-220	Sandy clay	35.9	97.5	2.69	42.0	37.3	14.1	23.2	1.6×10^{-4}
Sh:V-76 (5)	195-197	Fat clay	24.7	115.7	2.67	30.4	60.6	20.5	40.1	4.0×10^{-5}

CONVERSION FACTORS, VERTICAL DATUM, AND WELL-NUMBERING SYSTEM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	0.4047	square hectometer
foot per day (ft/day)	30.48	centimeter per day
million gallons per day (Mgal/d)	0.04381	cubic meters per second

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

Tennessee District well-numbering system: Wells in Tennessee are identified according to the numbering system that is used by the U.S. Geological Survey, Water Resources Division. The well number consists of 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:U-99 indicates that the well is located in Shelby County on the "U" quadrangle and is identified as well 99 in the numerical sequence.

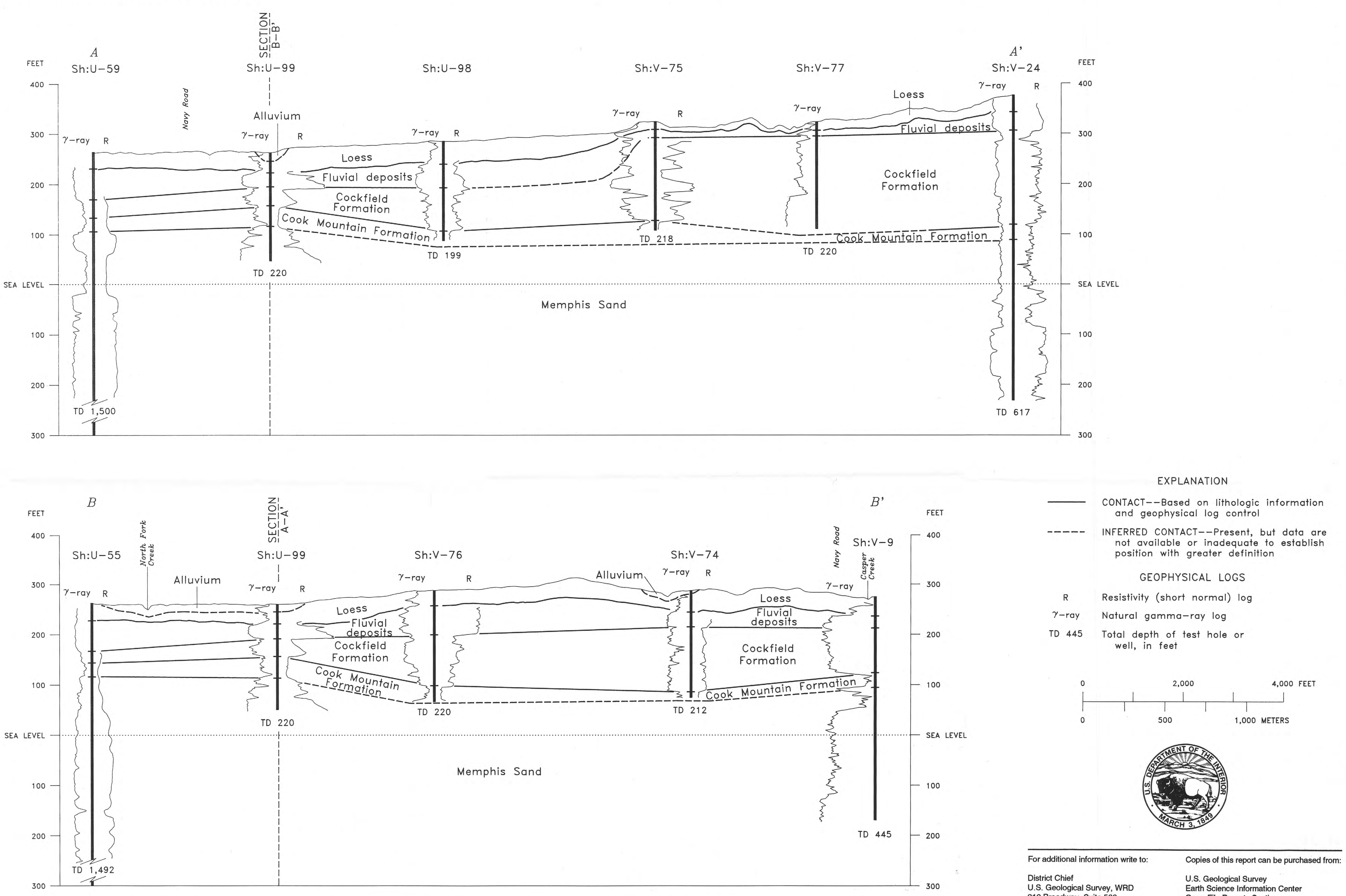

Figure 3. Geologic sections along lines A–A′ and B–B′.

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HYDROGEOLOGY OF POST-WILCOX GROUP STRATIGRAPHIC UNITS IN THE AREA OF THE NAVAL AIR STATION MEMPHIS, NEAR MILLINGTON, TENNESSEE

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