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GROUND-WATER RESOURCES OF WESTERN TENNESSEE

BY
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WITH A DISCUSSION OF THE
CHEMICAL CHARACTER OF THE WATER

BY
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GROUND-WATER RESOURCES OF WESTERN TENNESSEE

By Francis G. Wells

ABSTRACT

The area treated in this report is that part of Tennessee that lies west of the northward reflex of the Tennessee River. Most of the area falls within the eastern flank of the Gulf embayment, a basin of Paleozoic rocks filled with unconsolidated sand and clay of Cretaceous and Eocene age. The floor of the basin and the overlying sediments dip to the west at 15 to 30 feet to the mile. Paleozoic rocks ranging in age from Ordovician to Mississippian crop out as a narrow band along the eastern boundary. The unconsolidated sand and clay form the surface over the remainder of western Tennessee. These deposits range in thickness from about 3,000 feet at Memphis to the vanishing point in the eastern part of the area.

The Wilcox group, the McNairy sand member of the Ripley formation, and the Eutaw formation are the principal water-bearing beds. They consist of sand of varying sizes of grain with intercalated lenses of clay and yield large quantities of water. Laboratory tests of 113 samples of sand taken throughout the area show a wide range in physical properties, but most of the sands are composed predominantly of grains coarser than 0.25 millimeter in diameter; the average porosity is 40.3, and the average coefficient of permeability 737. The thickness of these sand formations, which reaches 1,900 feet for the Wilcox group, 400 feet for the McNairy sand member, and 250 feet for the Eutaw formation, and the physical properties of the sand indicate that large quantities of ground water can be developed throughout the area.

Analyses of samples of water taken throughout western Tennessee indicate that except for the presence of considerable iron the water is of good quality for all purposes. The waters are soft, and the total dissolved solids are usually less than 100 parts per million. Except in a few places the water contains sufficient iron to precipitate out on standing or when the water is boiled. The iron is readily removed, however, by aeration followed by sedimentation or filtration for removal of the precipitate.

Large ground-water developments are few in western Tennessee. There are 40 public water supplies, but not more than 10 pump 500,000 gallons or more a day. Bored wells are the most numerous throughout the area, but drilled wells for domestic use are becoming more common. There are, however, very few domestic water systems. The county reports show the types, depth, method of pumping, and other data for typical wells throughout each county.

The largest ground-water development in western Tennessee is at Memphis. All water used in the city is derived from the Wilcox group. The maximum pumpage from the upper and middle Wilcox was reached about 1920; in this year an estimated average of 37,575,000 gallons a day was pumped. In 1928 the average daily pumpage from the upper and middle Wilcox was about 33,984,000

gallons, a decrease from 1920 of 3,591,000 gallons. This decrease of pumpage from the Wilcox formations instead of the increase that would normally be expected resulted from cuts in pumpage by industrial plants due to many causes but chiefly to the smaller quantity of water used in condensing after the introduction of spray systems of cooling water and to the development of the lower Wilcox by the Memphis Artesian Water Department, which pumped an average of 4,616,000 gallons a day from this formation in 1928.

The static level at Memphis varies with the pumpage and the stage of the Mississippi River. Originally it was about 230 feet above mean sea level. The average static level for 1928 at the Auction Avenue plant was 202 feet above mean sea level, which was about 28 feet lower than the original level. This gives a yield of about a million gallons a day for each foot of drawdown. The drawdown is not excessive, and additional pumpage can be developed without undue lowering of head.

INTRODUCTION

Purpose and scope of investigation.—Of fundamental importance to any community is an adequate supply of good water. There are three possible sources of water—direct collection of rain, surface water, and ground water. The first of these sources is suitable only for small supplies. The second is capable of very large development, but the cost of development is high, and sanitary control is necessary. This leaves ground-water supplies as the cheapest and most sanitary source of water for towns and scattered rural populations and, under certain favorable conditions, for large cities. Consequently data on the ground-water conditions—the depth at which water can be obtained, the quantity of water that can be developed, and the quality of the water—should be available to the inhabitants of any region. As these features are all related to the physiography and geology of a region, the study of them is a specialized problem requiring a familiarity with the geology of the region as well as a knowledge of existing ground-water supplies. It was the purpose of the investigation whose results are here set forth to collect all the data available on ground-water conditions, to synthesize these data in a logical manner, to correlate them with the geology of the region, and finally to present them in such a manner that an individual, industry, or municipality could find the information necessary for the solution of its water problems in a satisfactory and economical way. Obviously this is for any region a difficult task. In many places the necessary data are unavailable, and the data are not always amenable to simple exposition.

The field work for this report was carried on for five months during the summer and fall of 1928 and 4½ months during the summer of 1929. With the aid of an automobile it was possible to cover the area rather thoroughly. The laboratory work and writing of the report were done during the winters and springs of 1928–29 and 1929–30.

Location of area.—The area studied is commonly designated western Tennessee. With the exception of the eastern part of Hardin County, it lies west of the Tennessee River and is bounded on the north by the Kentucky State line, on the south by the Mississippi State line, and on the west by the Mississippi River. It comprises about 11,000 square miles. The location of the area as well as of other parts of Tennessee that have been covered by similar reports is shown in Plate 3.

Previous investigations.—The principal earlier reports treating of the geology and ground water of western Tennessee are listed below.

Safford, J. M., Geology of Tennessee, 1869.

Glenn, L. C., Underground waters of Tennessee and Kentucky west of the Tennessee River: U. S. Geol. Survey Water-Supply Paper 164, 1906.

Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, vol. 4, pp. 150–181, Tennessee Geol. Survey, 1914.

Wade, Bruce, The fauna of the Ripley formation on Coon Creek, Tenn.: U. S. Geol. Survey Prof. Paper 137, 1926.

Dunbar, C. O., Stratigraphy and correlation of the Devonian of western Tennessee: Tennessee Geol. Survey Bull. 21, 1919.

Wade, Bruce, Recent studies of the Upper Cretaceous of Tennessee: Tennessee Geol. Survey Bull. 23, pp. 51–64, 1920.

Roberts, J. K., and Collins, R. L., The Tertiary of west Tennessee: Am. Jour. Sci., 5th ser., vol. 12, pp. 235–243, 1926.

Roberts, J. K., Tertiary stratigraphy of west Tennessee: Geol. Soc. America Bull., vol. 39, pp. 435–446, 1928.

Berry, E. W., Revision of the lower Eocene Wilcox flora of the Southeastern States: U. S. Geol. Survey Prof. Paper 156, 1930.

Roberts, J. K., Tertiary and Quaternary sediments of west Tennessee and their economic geology (in preparation).

Acknowledgments.—This investigation was carried on under the supervision of O. E. Meinzer, geologist in charge of the division of ground water, United States Geological Survey, and W. F. Pond, State geologist of Tennessee. Analyses were made by Margaret D. Foster, of the Federal Geological Survey, who collaborated in the preparation of the discussion of the chemical character of the waters. D. C. Farrar, of the State geological survey, made some of the analyses. To these and other colleagues of the two organizations the writer wishes to express thanks for their assistance and advice. He also desires to acknowledge his indebtedness for cooperation and assistance in assembling the data to J. K. Roberts, who kindly put at his disposal his unpublished report on the Tertiary and Quaternary sediments of western Tennessee, the material of which has been freely used; to J. J. Sheehan, superintendent, W. D. Lanham, J. J. Ryan, and other members of the Memphis Artesian Water Department, who

helped the writer in many ways and placed the records of this department at his disposal; to the well drillers of the area, who generously furnished detailed information about the wells they had drilled; and to municipal authorities and owners of wells, who courteously gave the information which is the basis of much of this report.

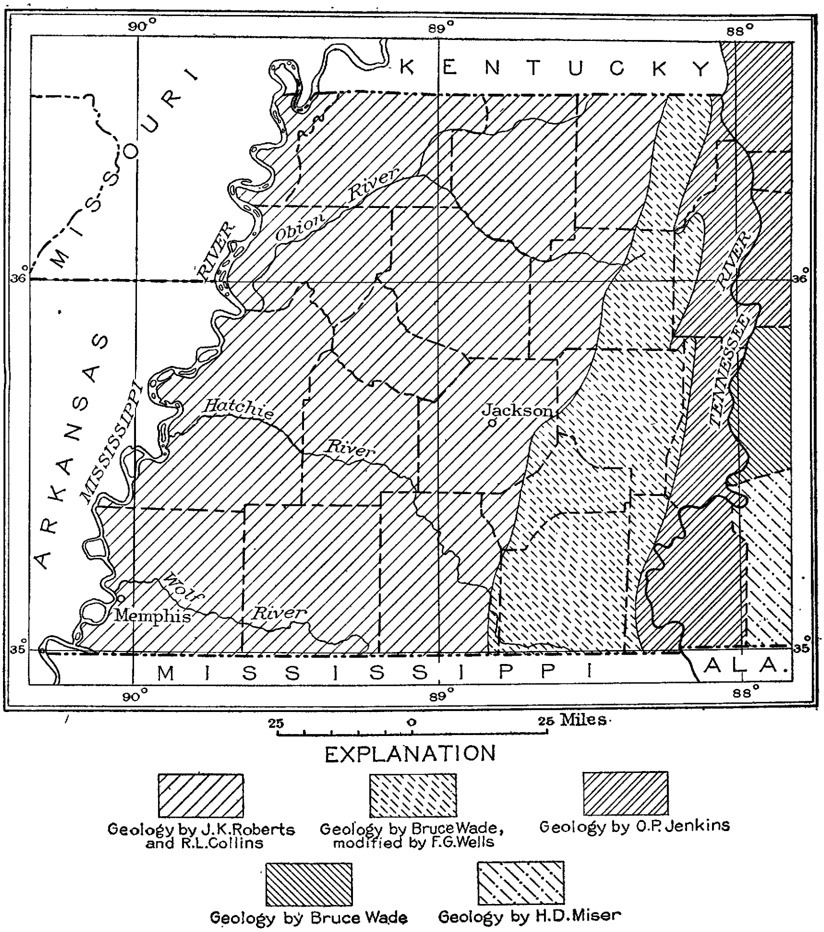


FIGURE 1.—Index map of western Tennessee showing sources from which the geologic map was compiled

Geologic and hydrologic maps.—The geology of the area covered by this report is shown in Plate 1. This map, except for changes in the mapping of the Cretaceous and Tertiary, is taken from the geologic map of Tennessee, edition of 1923. Figure 1 shows the sources from which the data were compiled. As explained on page 75, the distribution of the Selma clay and the Coon Creek tongue of the Ripley formation was mapped incorrectly on the geologic map of the State. The Selma formation does not extend north of central Henderson

County as such but either pinches out by overlap of the Coon Creek tongue or is represented from Henderson County northward by beds lithologically like the Coffee sand member of the Eutaw formation. The two narrow bands previously mapped by Wade as Selma formation and Coon Creek tongue of the Ripley formation from Henderson County northward together constitute the northward extension of the Coon Creek tongue. Coon Creek fossils have been found in beds mapped as far north as a point 4 miles north of Camden, Benton County. The Tertiary has been remapped by Roberts and Collins and correlated with the Clayton, Porters Creek, Holly Springs, and Jackson formations of Mississippi.

The location of wells described in the text is shown on Plate 2. The wells are numbered consecutively in each county, beginning with No. 1 and following the United States land survey system of numbering sections.

The method of locating the wells depended on the county maps available. Good county maps made by the State geological survey on the scale of 1 inch to the mile and showing much detail were available for Benton, Carroll, Chester, Decatur, Fayette, Gibson, Hardeman, Henry, McNairy, and Shelby Counties. Wells could be located with considerable accuracy on such maps. Blueprints of maps on the same scale, started many years ago but never completed, were available for Hardin and Henderson Counties. The distances given in the tables of wells for all these counties were scaled from the county maps. A soil map on a scale of 1 inch to the mile was available for Madison County,[1] and distances used in descriptions of well locations were scaled from it. Post-route maps were the only ones available for Crockett and Haywood Counties. These maps are not accurate, but the location of villages and of such roads as are shown is fair. Some of the distances given in the tables for these counties were scaled from the county maps; others are the readings of the speedometer on an automobile. The only maps available for Dyer, Lauderdale, Obion, Tipton, and Weakley Counties were blueprints of sketch maps made by the Tennessee Department of Health. Unfortunately these maps were not drawn to scale, and though they showed all roads, villages, schools, and churches, the locations were not accurate. All distances given in the well tables for these counties were obtained from readings of a speedometer (front-wheel type). As the distances traversed by an automobile are never in a straight line, this introduces some error. It is also probable that there are errors in the location of the towns as shown on the base map of the State. The wells were transferred from the county maps to the State maps by the method of squares. The

[1] Lyman, W. S., and Lendon, W. E., Soil survey of Madison County, Tenn.: U. S. Dept. Agr. Bur. Soils Field Operations, 1906.

result has been that for some wells the locations on the State map do not show the proper relation to some of the towns, but the general location in the county is correct.

GEOGRAPHY

SURFACE FEATURES

PHYSIOGRAPHIC POSITION

The Tennessee River almost coincides with the boundary between two of the great physiographic provinces of the United States, the interior low plateaus, in central Tennessee called the Highland Rim, and the coastal plain. Thus the area under discussion, with the exception of the eastern part of Hardin County, falls within the coastal plain. The Highland Rim is a typical plateau country which has an altitude in its eastern portion of about 1,200 feet, but which slopes down to about 500 feet at its western boundary, where it grades without a break into the slope of western Tennessee. This region has reached a submature state of erosion. In Hardin County the streams flow west or northwest to the Tennessee in narrow V-shaped valleys that are as much as 150 feet lower than the intervening flat-topped ridges, the remnants of the plateau surface. These ridges are utilized for road sites, for they furnish the only flat places in this rough terrain.

The western valley of the Tennessee—the low-lying land along the river below its northward reflex—has an average width of 10 to 11 miles and includes the lowlands along the tributaries in this area. At its low-water stage the Tennessee is 350 feet above mean sea level where it crosses the Alabama line in its northward course and 302 feet at the Kentucky line. The distance along the river between these two points is 153 miles and the river gradient is thus less than one-third of a foot to the mile.

The part of the interior low plateaus which falls within the area here described has been called by Safford [2] the plateau or slope of western Tennessee. This surface can be visualized as a plain sloping northwestward until it ends abruptly at the bluffs overlooking the Mississippi flood plain. In its northern portion it rises slightly toward the Mississippi bluffs. This plateau is about 700 feet above sea level in the eastern part and descends to an altitude of 300 to 390 feet at its western margin. The plateau has been dissected and in its eastern portion is hilly; toward the west the streams have cut broad valleys, and the intervening uplands are gently rolling. The resulting features are residual ridges, hills of erosion, and the Tennessee-Mississippi divide.

[2] Safford, J. M., Geology of Tennessee, p. 110, 1869.

SURFACE FORMS

Residual ridge.—Extending northward from Mississippi into southwestern McNairy County, Tenn., is a ridge about half a mile wide. It is in the region where Ripley sands and clays come to the surface and owes its preservation to the "ironstone" that is abundant in this region. The ridge dies out toward the north.

Tennessee-Mississippi divide.—The Tennessee-Mississippi divide is the high land just west of the Tennessee River. It forms the highest part of western Tennessee and represents the remnant of the original plateau surface. This divide separates the eastward-flowing rivers that empty into the Tennessee from the westward-flowing rivers that empty into the Mississippi. The eastward-flowing streams are short and steep, but those flowing to the west have low gradients and broad valleys.

Hills of erosion.—Extending from the western part of Hardeman County northward to Henry County is an unusually hilly belt composed of Holly Springs sand. The flat tops of many of these hills are parts of the old plateau surface. Owing to the sandy, porous nature of the ground, rain water readily sinks into the permeable sands and has not yet eroded them. Any slopes formed by stream cutting are subject, however, to rapid erosion. The loose sand washes easily, and the slopes are quickly eaten away. Thus the flat tops of the hills remain unaltered, while the slopes are steep and deeply incised.

The general surface forms of western Tennessee are the result of stream erosion on loose sand and clay. The behavior of sand has just been described; the clay, however, erodes more uniformly, for it sheds the water and develops the usual type of erosion surfaces. The history of the formation of the present surface is part of the geologic history of the area and is set forth on pages 24–25. A surface feature of the area which is of recent development is the badland topography. Throughout western Tennessee there are areas which have been so completely dissected by gullies that they resemble the badlands of the Dakotas. (See pl. 4.) Another expression of this action is found in the great gullies, 50 feet or more deep, that in many places hem the country roads on both sides. These surface features are due to the washing of the sandy soil as soon as the vegetation is removed. With proper attention cultivated fields can be kept from washing, but too often no attempt has been made to prevent this form of erosion. Thus since the advent of the white man large tracts have become barren.

Alluvial region.—Lying at the foot of the Chickasaw Bluffs, the western boundary of the slope of western Tennessee, is the Mississippi flood plain, a low tract much of which is covered by the extreme high waters of the Mississippi River. Nowhere in western Tennessee is this plain very wide. Its greatest width in Tennessee, some 10 miles, is in the north, but in the south it dwindles to nothing where the Mississippi River washes the foot of the bluffs.

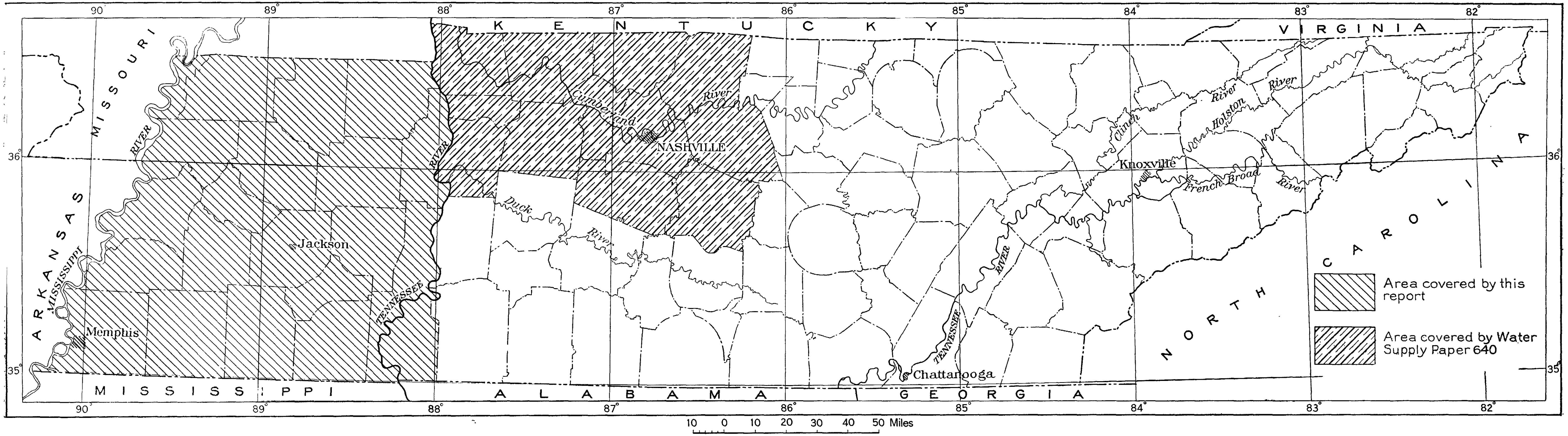
DRAINAGE

The eastern part of Hardin County drains westward into the Tennessee by means of Horse, Indian, and Hardin Creeks. These creeks are short, rapid streams. The longest, Indian Creek, is about 30 miles long, and much of its course lies outside of this area. There are not enough known altitudes in the region to give even approximate gradients for these streams; all that can be said is that they are swift streams with falls and cascades.

The Tennessee-Mississippi divide separates the region west of the Tennessee River into two very unequal drainage areas. The east versant has a width of 9 to 25 miles. Besides the major streams, the Beach and Big Sandy Rivers and Hurricane Creek, there are a few short creeks that drain this slope. All these streams have fairly steep grades, and numerous springs insure their permanency throughout the year. The west versant of the divide is from 98 to 105 miles in width and is drained by long streams of low gradient. From north to south these streams are the Obion, Forked Deer and its Middle and South Forks, Hatchie, Loosahatchie, and Wolf Rivers and Nonconnah Creek. The longest of these is the Hatchie River, which has a length of 120 miles. With the exception of the Obion River, which flows southwest though its major tributary flows northwest, all these rivers flow in a direction north of west to points within a few miles of the Mississippi River, where they swing to the southwest. Along their lower reaches their valleys are broad and flat and in large part swampy and subject to flooding during high water. The streams meander through these swampy areas in tortuous channels. In some places drainage of the bottoms has been effected by trenching the streams and thereby shortening their courses. These streams are all perennial.

DEVELOPMENT

The difference between the broad valleys and gently rolling uplands of the western part of western Tennessee and the rough lands of the eastern part has had a strong influence on settlement and industrial development. The counties bordering the Mississippi River (Obion, Lake, Dyer, Lauderdale, Tipton, and Shelby) and those adjacent to them (Weakley, Gibson, Crockett, Haywood, Fayette, and Madison) are the most populous. These counties have a population of 46 to 92 persons to the square mile except Shelby County, which contains the city of Memphis and has 383 persons to the square mile. In contrast to this are the eastern counties, with a density of 24 to 42 persons to the square mile. The only large city in the area, Memphis, with a population of 253,143, is on the Mississippi River. The next largest city,



INDEX MAP OF TENNESSEE SHOWING AREAS COVERED BY GROUND-WATER REPORTS

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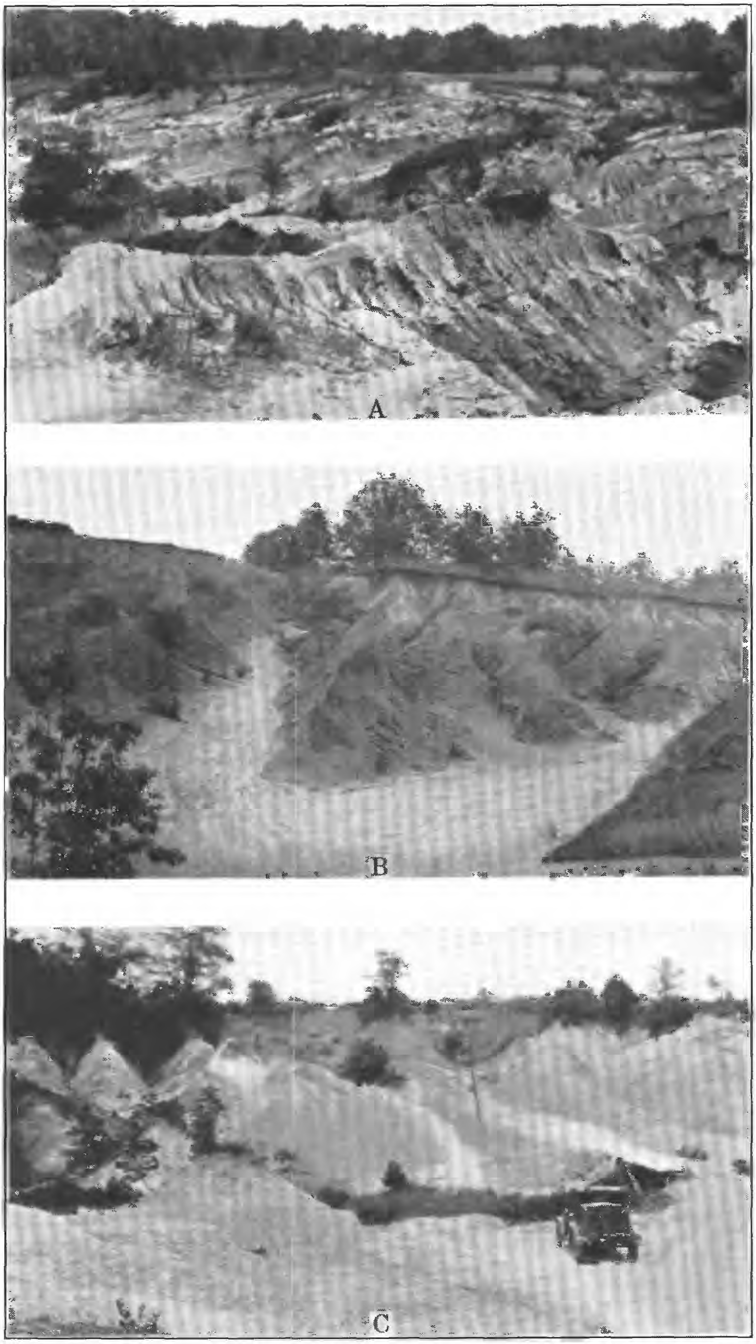


VIEWS SHOWING EROSION

A, Early stages, southern Carroll County, upland surface in background; B, advanced stages, southwestern Hardeman County; C, erosion of a clay lens, southern Weakley County.

Jackson, with a population of 22,172, is the county seat of Madison County. The other six cities with a population in 1930 that exceeded 3,200 are Dyersburg, Paris, Union City, Covington, and Brownsville, the county seats of Dyer, Henry, Obion, Tipton, and Haywood Counties respectively, and Humboldt, the largest city in Gibson County. In the eastern part of the area there are only a few small towns.

Agriculture and lumbering.—Agriculture is the principal activity of the region, and the major crop both in acreage and in value is cotton. According to the census of 1925, 250,281 bales of cotton were grown in western Tennessee in 1924. Corn ranked second in importance, the yield being 722,595 bushels, and 203,755 tons of hay of all kinds was grown. Except in the western counties dairying is not important, but the agricultural department of the State is encouraging this branch of farming, and as time goes on dairying will become more prevalent. Spring vegetables and small fruits are grown for northern markets. Tomatoes and strawberries are the principal ones, but there is a considerable acreage in cabbage and spinach. Gibson County is the center of the truck gardening.

In the hilly parts of the eastern counties there is still considerable timber standing, and lumbering is actively carried on. In the west the land has been mostly cleared, but some lumbering is done in the swampy river bottoms.

Industries.—The industries of the region are those consequent on agriculture and lumbering. Cotton gins are scattered over the area, and cottonseed-oil plants and canneries are found in the largest towns. There are a few cotton-spinning mills. Sawmills are common, and at Memphis there are many factories for the fabrication of wood. At present all the clay produced in the area comes from northwestern Tennessee, though in the past southwestern Tennessee produced considerable clay of all grades—ball, sagger, wad, potters, and common brick clay.[3] The finer grades were shipped to other States, but brick and some of the cheaper wares were fabricated in the region. Practically all of the 45,593 tons of ball clay produced in Tennessee during 1928 came from Henry County.[4] All of this clay, with the exception of a little used for the local manufacture of jugs and churns, is shipped to potteries outside of the State. Fire clay is mined at several localities in the area and used in the local brick kilns.

Routes of communication.—The lower gently rolling land of western Tennessee furnishes the natural passageway for railroads seeking an outlet to the south. Consequently this part of the area is well served with railroads. Hardin County is the only county in the area that

[3] Nelson, W. A., Clay deposits of west Tennessee: Tennessee Geol. Survey Bull. 5, 1911.
[4] U. S. Bur. Mines Mineral Resources, 1928, pt. 2, p. 192, 1930.

has no railroad within its boundaries. At the present time the State and counties are actively engaged on a comprehensive program of highway construction which will cover the area with a network of hard-surfaced highways built in conformity to the specifications of the United States Bureau of Public Roads. In addition, the principal towns of each county will be connected by graveled roads. At present this condition prevails in Shelby County, but in the other counties the roads are still very poor, and during certain seasons of the year they are almost impassable for automobiles. Formerly the Mississippi and Tennessee Rivers formed the main routes of transportation in western Tennessee. At present the traffic on the Mississippi River is small, and that on the Tennessee has dwindled to occasional shipments of bulky materials.

RESOURCES

Minerals.—The mineral resources of the area are scanty. Deposits of clay are worked as stated above. Though the present clay production is limited to Henry County, there are clay deposits in other parts of western Tennessee which, with changes in economic conditions, will probably be worked again, and there are undoubtedly deposits that have never been developed.[5]

The sand deposits of western Tennessee are very large and of all kinds, and the quantity of building sands is almost unlimited.[6] Road material is plentiful in much of the area. The cherts of Devonian and Mississippian age that occur in Benton, Decatur, and Hardin Counties form good road metal.[7] The terrace gravel in the valley of the Tennessee and the Pliocene gravel also form good road material.[8]

Low-grade phosphate rock occurs in Decatur County,[9] and tripoli, a weathering product of the Fort Payne chert and St. Louis limestone, is found in Hardin County. Although iron ore has been worked in Decatur County,[10] it is doubtful whether the quantity and quality warrant exploitation by modern methods. Some of the limestones of the area might be used as polished stone, and others could be used in the manufacture of cement. Deposits of these raw materials are so abundant throughout the United States, however, that exploitation depends largely on the proximity of markets or of cheap transportation.

[5] Nelson, W. A., op. cit. Schroeder, R. A., Ball clays of west Tennessee: Resources of Tennessee, 1919, pp. 88–191. Roberts, J. K., Tertiary and Quaternary sediments of west Tennessee and their economic geology (in preparation).

[6] Roberts, J. K., op. cit. Nelson, W. A., Some building sands of Tennessee: Resources of Tennessee, vol. 2, pp. 389–397, 1912.

[7] Ashley, G. H., The Camden chert; an ideal road material: Resources of Tennessee, vol. 1, pp. 34–43, 1911.

[8] Wade, Bruce, Gravels of west Tennessee: Resources of Tennessee, vol. 7, pp. 55–89, 1917.

[9] Maynard, T. P., White phosphate rocks of Decatur County: Resources of Tennessee, vol. 3, pp. 161–169, 1913.

[10] Miser, H. D., Mineral resources of the Waynesboro quadrangle, Tennessee: Tennessee Geol. Survey Bull. 26, p. 118, 1921.

Timber.—Although most of the hardwood in the area under discussion has been cut, there is still considerable lumbering. Oak, ash, hickory, poplar, gum, and cypress are being cut. In Hardin County the cutting of pine logs for telegraph poles is actively carried on. No figures either of the present production of timber or of the timber resources of the area are available. Memphis is a large lumber center and is the site of many factories that fabricate hardwood articles such as wheel spokes, kegs, poles, shafts, and furniture.

CLIMATE

Rainfall.—Western Tennessee is a region of abundant rainfall. A map showing the location of rainfall stations and the areas of equal

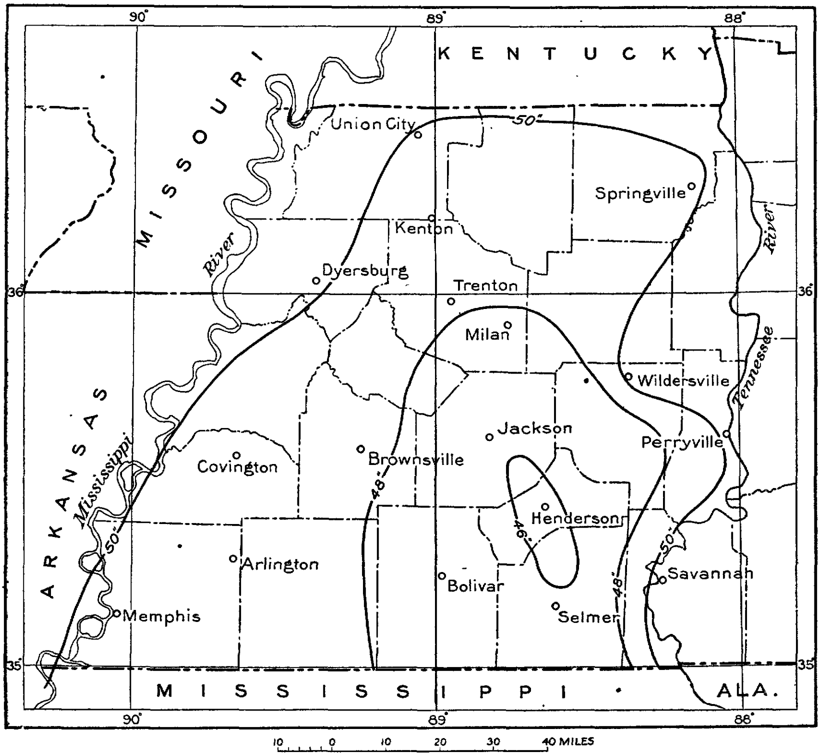


FIGURE 2.—Map of western Tennessee showing stations at which observations are made for the United States Weather Bureau and mean annual precipitation

rainfall is given in Figure 2, and the annual precipitation at each of the rainfall stations since its establishment is given in the following table. The station with the largest annual precipitation is Savannah with an average of 51.9 inches; the station with the lowest is Center Point, with an average of 44.01 inches. The record at Center Point is short, however, and the average is probably too low to represent the long-time average. The average of the mean annual rainfall of 14

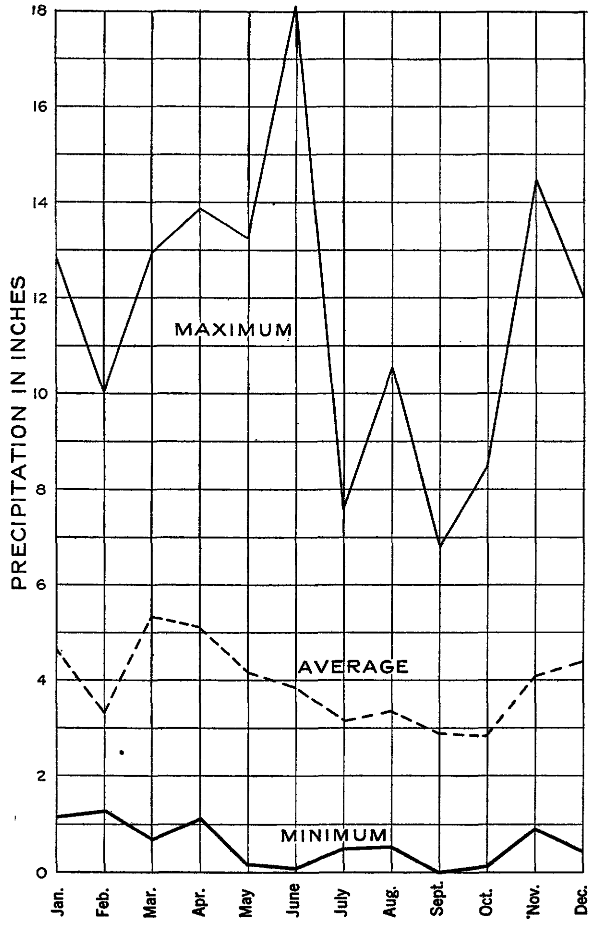


FIGURE 3.—Maximum, average, and minimum monthly precipitation at Memphis, 1870–1927

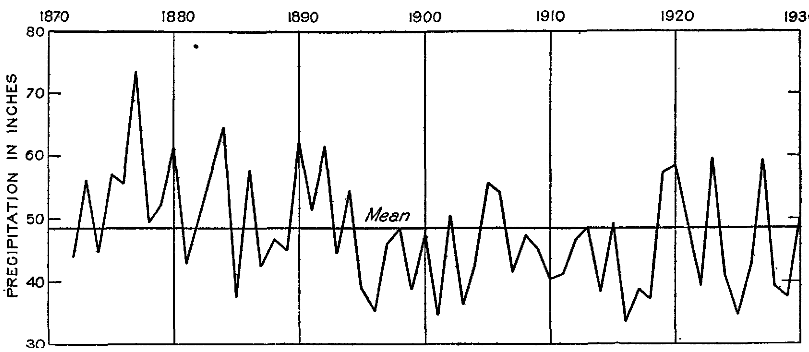


FIGURE 4.—Annual precipitation at Memphis, 1872–1930

stations scattered throughout the area is 48.74 inches. This insures the permanent flow of the many rivers and springs in the region. The most rain falls in the winter and spring; the driest time is in the late summer and autumn, when droughts lasting 15 to 30 days are not uncommon. Heavy downpours of 2.5 inches or more in 24 consecutive hours occur occasionally. The seasonal distribution of precipitation is clearly demonstrated by the graph of the average monthly precipitation in Figure 3. Though the deviation from the mean as shown by the curves for minimum and maximum monthly precipitation is large, the maximum and minimum curves show the same seasonal trend.

Annual precipitation in western Tennessee, 1883–1928

[From publications of U. S. Weather Bureau. The precipitation at Memphis in 14 years prior to 1883 ranged from 42.84 to 73.50 inches and averaged 54.29 inches]

Year	Arlington	Bolivar	Brownsville	Center Point	Covington	Dresden	Dyersburg	Henderson	Huntingdon	Jackson	Kenton	Lexington	Memphis	Milan	Moscow	Newbern	Paris	Perryville	Savannah	Selmer	Springville	Tiptonville	Trenton	Union City	Wildersville
1883													57.14						57.80						
1884		54.10											64.69	57.99					58,20				72,65		
1885		39.38			29.19								37,41	40.46					40.45				43.66		
1886					49.61								57.72	52.20					56.26				49.55		
1887					39.19								42.52	40.90					47.76				40.95		
1888					44.61								46.82	43.53					44.68				44.20		
1889					45.58								44.67	42.87					46.85				45.94		
1890					73.62								68.28						66.54				63.99		
1891					54.08								51.31						49.49				60.00	42.00	
1892					64.74					57.31			61.46						60.45						
1893					48.70					37.92			44.45						44.04						
1894					54.15					37.79			54.52						48.57						
1895	38.97	36.18			40.99					40.26			38.59						39.14				34.50		
1896	37.07	38.45			38.12					46.43			35.00						50.76				48.67	49.23	
1897		42.55			40.93					42.23			46.03					40.71	43.46				39.78	43.24	
1898		48.42			47.10					50.54			48.58					48.81	43.32				61.06	55.30	
1899		40.32		41.02	30.88								38.99					48.43	46.52				39.08		51.91
1900		53.30		51.17	45.62								47.22					63.85	66.38				48.51		55.37
1901		35.52		38.85	36.45								34.58					45.32	46.69				38.63		64.14
1902		52.90		47.56	51.88								50.32					53.66	63.11				50.74		41.60
1903		39.32		40.49	46.54					38.73	40.30		36.17					37.17	46.17		45.69		46.24		58.05
1904		40.07		41.33	45.24					38.17	38.64		42.56					44.13	44.33		37.10		42.24		
1905		55.67		52.78	51.67		50.46				47.80		55.85					55.33	43.53		49.91		49.90		47.93
1906		56.14	51.51	51.78	62.60		63.80			57.53	58.92		54.31					53.40	50.93		58.60		52.16	58.54	48.90
1907		49.17	46.65	44.22	47.55		55.40			43.97	59.37		41.55						53.33		57.34		48.41		
1908		42.56	43.92	43.45	40.66		46.05			42.29	47.02		47.46	36.32				49.56	50.26		43.54		43.86		
1909		43.76	47.35		51.38		48.22				52.71		45.29						49.51		52.03		50.83	48.00	
1910		46.21	48.74	41.40	42.28		46.22				49.03		40.41	40.28					41.29		45.44		42.80	42.53	53.57
1911		49.89	49.28		47.98		46.69			60.53	52.20		41.12	55.30					63.62		50.18		45.04	36.97	33.34
1912		59.33	51.12		53.15		46.82				46.21		46.80	52.99				66.71	58.54		53.93		42.22		60.67
1913		52.79	51.71		46.49		50.18			51.34	47.88		48.93	45.09				58.83	61.75		50.82		47.23	50.78	51.45
1914		39.71	37.49		41.77		42.03			34.33	36.54		38.34	38.88				44.47	40.16		37.12		36.37	48.04	
1915		59.42	58.52		60.08		61.92				47.93		49.23	51.95				55.55			54.48		54.29	53.26	
1916	43.90	46.65	39.60		43.31		49.22			42.42	48.96		33.44	47.77				52.82	52.41		51.31		50.47	50.80	
1917	40.00	41.85	46.07		44.00		42.20			39.77	45.67		38.98	44.33					50.75		44.00		43.85	41.29	
1918	42.52	33.34	40.76		45.04		43.43	36.87	40.00	39.26	44.97		37.16	40.91					39.42		41.39		48.59	46.55	
1919	63.04	60.33	61.65		65.70		67.08	71.61	74.68	59.07	65.04		57.75	58.98					62.93		70.47		64.97	61.63	
1920		53.06	51.40		63.15	50.01	50.01	54.00	52.88	42.91	53.57		58.30	50.31				56.76	57.20		53.77			58.03	

1921			49.02		57.81		44.06	54.86	55.77	50.22	41.66		49.53	49.57	59.64			49.61	53.60		51.15			45.96	
1922			46.71		49.71		57.37	57.58	48.32	45.14	37.13		39.26	45.84	66.43			55.73	55.37		48.97			43.59	
1923			68.65		74.12					55.05	57.22		59.79	67.70	56.23		68.97	51.73	62.28						
1924			44.34		35.11					41.42	41.01		40.91	34.82	40.60		34.62	45.09	42.05	43.53		43.53		49.66	
1925			43.06		45.99	47.54				39.73	40.66		34.67	41.10	45.54	37.49		34.60	45.46	36.78		38.87		39.41	
1926			48.50		53.47	52.73				50.82	51.49	59.41	41.98	58.29	46.30	48.77		50.83	50.71	45.23		46.71		50.09	
1927		63.05	68.66		65.80	70.06				63.85	63.85	76.70	59.14	59.14	67.57	60.54	64.07	49.77	56.07	57.60		70.24		65.39	
1928		49.96	46.33		54.65	55.90				46.77	56.22		39.05	46.06	44.64	45.58		44.99	50.12	44.69		56.04		51.43	
Average	48.46	47.45	49.61	44.01	49.33	55.25	50.62	54.98	54.33	46.27	48.96		48.47	47.83	53.37	48.10	55.88	50.31	51.16	45.57	49.86	51.08	48.12	49.29	50.58
Number of years	6	30	23	11	44	5	18	5	5	28	26		60	26	8	4	3	25	45	5	20	5	34	23	14

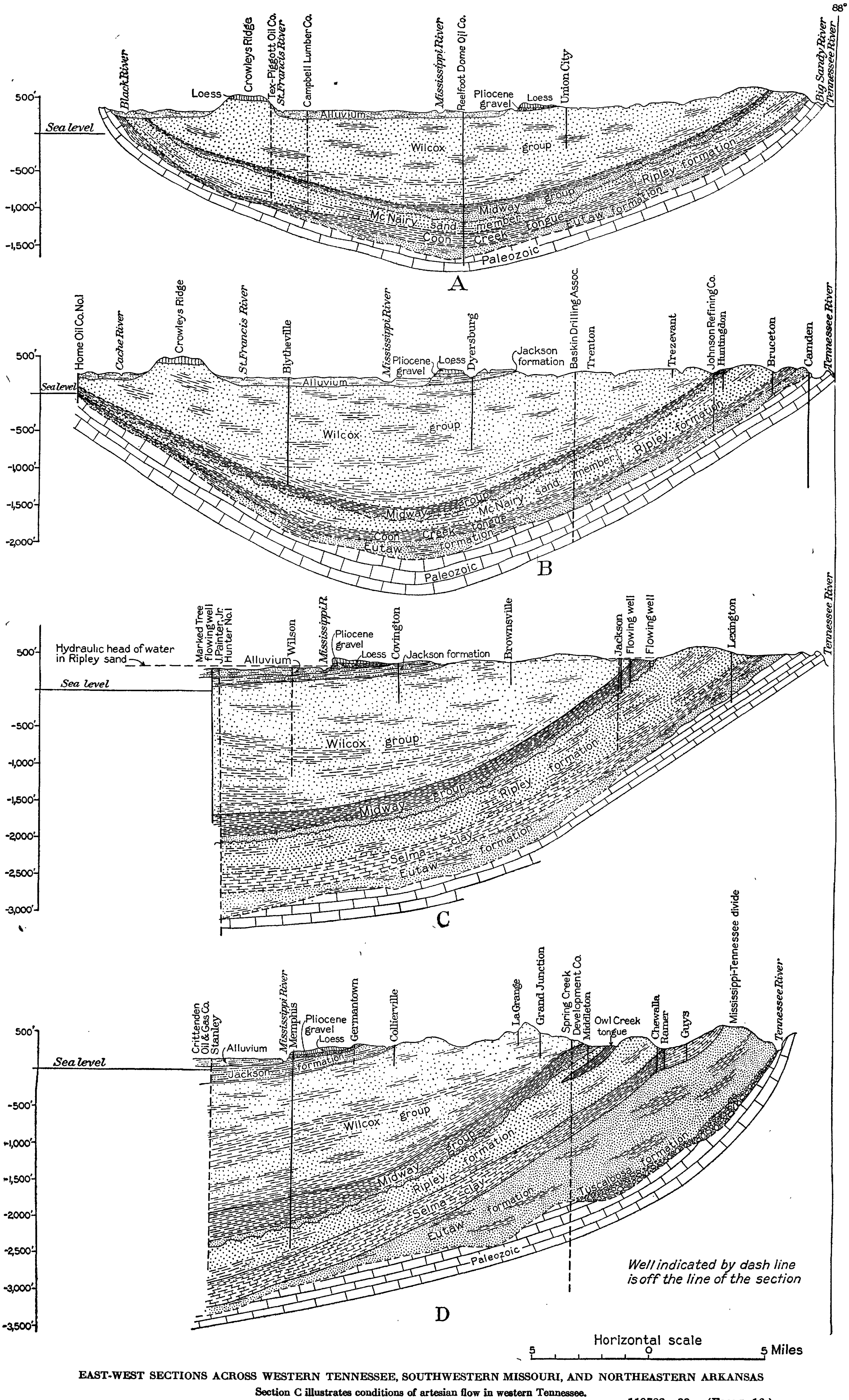
Temperature.—The climate is mild and not subject to such sudden and decided changes in temperature as are suffered in the Northern and Northeastern States. The highest temperature recorded at Memphis in 48 years is 104° F., and the lowest is 9° below zero. The annual mean maximum and minimum temperatures, however, are 70° and 53.3°. The crop-growing season is long. The average date of the last killing frost in spring is April 6, and of the first in autumn October 24. The winters are not cold, and the ground is practically never frozen.

GEOLOGY

SUMMARY OF STRATIGRAPHY

Western Tennessee is situated in that part of the Gulf Coastal Plain which is commonly called the Mississippi embayment. This embayment is a down-warped trough of Paleozoic rocks pitching gently to the south, whose upper end is in southern Illinois and whose axis roughly parallels the Mississippi River but lies a few miles west of it. This trough has been filled with sediments of Cretaceous and Eocene age, which rest unconformably on the older rock floor. The Paleozoic rocks crop out around the periphery of the trough. An east-west section across the embayment is shown in Plate 5, *A*.

The oldest formation that crops out in western Tennessee is the Hermitage formation, which is of Middle Ordovician age. The Upper Ordovician is represented by the Arnheim and Fernvale formations. The Ordovician rocks are cherty and argillaceous limestones containing some shale members. The Brassfield limestone (of early Silurian (Albion) age) rests unconformably on the Ordovician and is separated from the overlying Middle Silurian (Niagaran) rocks by an unconformity. The subdivisions of Niagaran age, from older to younger, are the Osgood limestone, Laurel limestone, Waldron clay, Lego limestone, Dixon limestone, Beech River limestone, Bob limestone, and Lobelville limestone. The topmost Silurian formation, the Decatur limestone, is of late Silurian (Cayugan) age. The Lower and Middle and probably the Upper Devonian are represented in the stratigraphic column of western Tennessee. The Lower Devonian rests unconformably on the late Silurian Decatur limestone. It has been divided into the following units, named in ascending order: Rockhouse shale, Ross limestone, Bear Branch limestone, Flat Gap limestone, Birdsong shale, Decaturville chert, Quall limestone, and Harriman chert. The Middle Devonian is represented by the Camden chert and the overlying Pegram limestone. The Upper Devonian, if present in western Tennessee, is represented by the 20 feet, more or less, of black carbonaceous shale known as the Chattanooga shale. This shale, however, is considered by some geologists to be of Mississippian age. It rests unconformably on the Middle Devonian rocks. The Mississippian is



EAST-WEST SECTIONS ACROSS WESTERN TENNESSEE, SOUTHWESTERN MISSOURI, AND NORTHEASTERN ARKANSAS

Section C illustrates conditions of artesian flow in western Tennessee.

represented by the Ridgetop shale and Fort Payne chert, of lower Mississippian age, and the St. Louis limestone, of upper Mississippian age. This completes the Paleozoic column in western Tennessee.

On the eroded surface of the above-mentioned Paleozoic rocks rests the Tuscaloosa formation, of Upper Cretaceous age, which occurs only in a few scattered outcrops. The Eutaw formation, mainly the Coffee sand member, also of Upper Cretaceous age, is found as a belt of sand and clay covering the Paleozoic rocks in the eastern part of the area. Overlying the Eutaw formation are the Selma and Ripley formations, also Upper Cretaceous.

The Eocene is separated from the Cretaceous by a marked unconformity. The Midway group is represented in western Tennessee by the Clayton formation and the Porters Creek clay. In the southern part of the State the lower part of the Clayton formation is an impure limestone, and the upper part a glauconitic sand. Toward the north the limestone soon thins out, but the glauconitic sand can be traced into central Madison County. It is rarely found in outcrop. The Porters Creek clay, a uniform clay formation, overlies the Clayton. The basal formation of the Wilcox group, the Ackerman, does not crop out in western Tennessee, though it probably underlies all the counties in the western part of the area. The overlying sand, the middle formation of the Wilcox group, consists of about 450 feet of unconsolidated sand with intercalated lenses of clay. The Grenada, or upper formation of the Wilcox group, resembles the Holly Springs sand in lithologic characteristics, and the contact between the two formations can not be determined in the field. There is a break between the Wilcox group and the overlying Jackson formation, of upper Eocene age. The Jackson outcrop occurs in the Chickasaw Bluffs only.

On the eroded surface of the Eocene formations are deposits of terrace gravel of Pliocene age. These are most common on the high land bordering the flood plains of the Mississippi and Tennessee Rivers. Overlying the gravel and forming the tops of the bluffs along the Mississippi is loess of Pleistocene age.

Generalized section of the geologic formations of western Tennessee

Era	System	Series	Subdivisions		Thickness (feet)	Physical character	Water-bearing capacity and kind of water
Cenozoic.	Quaternary.	Recent.	Alluvium.		0–150±	Gravel, sand, and mud of fluviatile origin.	Abundantly water bearing; in places yields hard water of high iron content, particularly in the western part of the area.
		Pleistocene.	Loess.		0–100	Gray and yellowish-brown loess with some concretions and a sparse fauna of land shells.	No water.
	Tertiary.	Pliocene.	Gravel (some of the terrace may be Pleistocene).		0–50	Chert, gravel, and sand.	Abundantly water bearing; yields hard water where overlain by loess, soft where not.
		Eocene.	Jackson formation.		100–200±	Thin-bedded fine sand, clay, and lignite.	Little water; sand too fine to be checked by strainers.
			Wilcox group.	Grenada formation.	600–1,900±	Varicolored medium to fine cross-bedded sand with intercalated lenses of clay.	Abundantly water bearing; yields soft water of low mineral content.
				Holly Springs sand.		Many-colored medium-fine and coarse sand with intercalated lenses of clay.	
				Ackerman formation.		Does not crop out in Tennessee. In Mississippi, gray, more or less lignitic clay, lignite, and sand. Probably present in western part of area.	Some water.
			Midway group.	Porters Creek clay.	140–373	Dove-gray clay showing distinctive hackly structure.	No water.
				Clayton formation.	0–121±	A thin 7-foot layer of limestone at base, overlain by layers of glauconitic sand and gray clay; the limestone, disappearing toward the north, contains a marine fauna.	Little water, reported to be of high mineral content.

Mesozoic.	Cretaceous.	Upper cretaceous.	Ripley formation.	Owl Creek tongue.		Micaceous sand and marl containing marine fauna.	Little water, of high iron content.
				McNairy sand member.	350–600±	Cross-bedded variegated sand containing intercalated lenses of clay. In some places induration has produced very hard sandstone or quartzite.	Abundantly water bearing; yields soft water of low mineral content.
				Coon Creek tongue.		Ferruginous, carbonaceous, glauconitic marl, containing marine fauna.	No water.
			Selma clay.		0–210	Gray to white chalky clay containing marine fauna.	No water.
			Eutaw formation.	Coffee sand member.	0–536(?)	Cross-bedded micaceous fine and interlaminated with clay of various colors, in places carbonaceous.	Yields soft water of low mineral content in outcrop area; harder water at greater depths.
				Tombigbees and member.		Cross-bedded and massive more or less glauconitic fine to medium sand.	Yields soft water of low mineral content.
			Tuscaloosa formation.		0–100±	Well-rounded waterworn pebbles of chert and some quartz, 1 to 6 inches in diameter.	Abundantly water bearing; yields soft water of low mineral content.
Paleozoic.	Carboniferous.	Mississippian.	St. Louis limestone.		(?)	Gray cherty limestone exposed as residual cherty rubble.	Little water, hard.
			Fort Payne chert.		0–200.	Dark calcareous chert exposed as yellow cherty rubble.	Abundant soft water of very low mineral content in outcrop area; water from deep wells has higher mineral content.
			Ridgetop shale.		0–110±	Gray to black siliceous shale.	Little water; hard.
	Carboniferous or Devonian.	Mississippian or Upper Devonian.	Chattanooga shale.		0–22	Black fissile shale; hard sandstone (Hardin sandstone member) at base, 0 to 15 feet.	No water.
		Middle Devonian.	Pegram limestone.		0–6±	Pure white limestone. Not exposed in this area.	Is believed to contain but little water; hard.
			Camden chert.		0–240	White to buff hard, brittle chert resembling novaculite; weathers to buff rubble; fossiliferous.	Abundant soft water of low mineral content in outcrop area.

Generalized section of the geologic formations of western Tennessee—Continued

Era	System	Series	Subdivisions			Thickness (feet)	Physical character	Water-bearing capacity and kind of water
Paleozoic.	Devonian.	Lower Devonian.	Harriman chert.			0–55	Chert similar to Camden chert.	Abundant soft water of low mineral content in outcrop area; water from greater depth is harder and more highly mineralized.
			Quall limestone.			0–10±	Light-gray siliceous chert.	Little water, hard.
			Linden group.	Decaturville chert.		0–10±	Porous yellow to gray chert.	Some water, hard.
				Birdsong shale.		0–70	Bluish calcareous shale and thin bands of crystalline limestone.	Yields some hard water in wells less than 300 feet deep; at greater depths water is high in mineral content.
				Olive Hill formation.	Flat Gap limestone member.	0–55	Massive coarsely crystalline or granular white or pink limestone.	
					Bear Branch limestone member.	0–45	Impure coarse-grained limestone and oolitic hematite.	
					Ross limestone member.	0–80	Dark-gray compact, thin-bedded siliceous and cherty limestone.	
				Rockhouse shale.		0–15	Greenish-gray calcareous shale; some bands of limestone.	
	Silurian.		Decatur limestone.			0–70	Thick-bedded light-gray, rather pure limestone.	
			Brownsport formation.	Lobelville shaly limestone member.		0–40	Thin-bedded shaly limestone and yellowish shale.	
				Bob crystalline limestone member.		0–42	Massive light-gray coarsely crystalline limestone; some cherty limestone.	
				Beech River shaly limestone member.		0–106	Shaly, cherty greenish-gray and pink limestone and purplish shale.	

Paleozoic.	Silurian.		Wayne formation.	Dixon earthy limestone member.	0–44	Argillaceous red limestone and red or purplish shale.	Yields some hard water in wells less then 300 feet deep; at greater depths water is high in mineral content.
				Lego limestone member.	0–46	Compact pinkish or bluish gray sub-crystalline limestone.	
				Waldron clay member.	0–4	Light-gray shaly limestone.	
				Laurel limestone member.	0–28	Massive purple and reddish limestone.	
				Osgood earthy limestone member.	0–15	Thin-bedded reddish argillaceous limestone.	
			Brassfield limestone.		0–25	Finely crystalline light-gray limestone.	
	Ordovician.	Upper Ordovician (Cincinnatian).	Fernvale formation.		0–40	Green shale underlain by coarse-grained gray phosphatic limestone.	
			Arnheim limestone.		0–3	Coarse-grained phosphatic and cherty limestone.	
		Middle Ordovician (Mohawkian).	Hermitage formation.		0–70±	Dark bluish-gray compact argillaceous limestone interbedded with fissile blue shale.	

HISTORICAL GEOLOGY

Paleozoic time.—The geologic history of western Tennessee as recorded in the exposed rocks of the area begins with Mohawkian time, or the middle of the Ordovician period. Then the land lay to the east, its western edge just crossing the eastern boundary of the State. Western Tennessee formed part of an inland sea that covered much of the interior United States. The rivers from the low-lying land to the east brought to this sea limy mud, which the currents and waves spread out in broad flat layers over the sea floor, forming the limestones and shales of to-day. In late Ordovician time the Cincinnati arch began to form. This was a low dome that extended from Cincinnati to Nashville. As a result of this arching the region southwest of Nashville was also gently raised above sea level, and it remained as a low-lying land mass until Silurian time, when the sea once more covered its comparatively level surface.

A long period of deposition followed, in Niagaran time. Owing to slight movements of the earth's surface minor oscillations in the shore line took place, and from time to time different parts of the area were lifted slightly above sea level and then were submerged again. Hence the beds of limestone and shale that were laid down in Niagaran time are not continuous over the area, and their thickness varies from place to place. The material brought to the sea in Niagaran time did not differ very much from that of the Ordovician period.

At the end of the Silurian period the region was raised slightly above sea level and subjected to moderate erosion, so that the sea returning in early Devonian time spread over an extremely flat limestone country, depositing newer limestone on the old. Throughout the Devonian period gentle warping caused the sea to change its position at intervals. Early in Devonian time the submerged portion of western Tennessee rose above water, but toward the end of the Lower Devonian the water from the Appalachian trough inundated the area. Then followed another brief emergence, and again the waters swept in from the south. Another period of emergence and erosion followed and was terminated when the Chattanooga sea spread over Tennessee. During much of the Mississippian epoch the area was submerged. Throughout Devonian and Mississippian time the rivers that brought sediment to the sea covering this area had low gradients and drained a base-leveled land. This old land furnished very little clastic material to the streams, the erosion being due mostly to solution.[11] Hence the deposits were chiefly limestones and cherts, and only rarely shales.

Some time after the end of the Mississippian epoch the region was lifted above sea level and remained land until Cretaceous time.

[11] Twenhofel, W. H., Treatise on sedimentation, p. 384, 1926.

During this long geologic interval the land was reduced to a peneplain, which has been called by Hayes [12] the Cumberland peneplain. Shaw [13] gives evidence to show that the Cumberland peneplain of Hayes is not concordant with the rock surface under the Cretaceous and younger rocks.

Cretaceous time.—It was not until Upper Cretaceous time that downwarping of the land along an axis approximately coincident with the present Mississippi River allowed the sea, which had already covered the southern part of the Gulf States, to submerge this region. The downwarping caused a tilting of the land mass to the southwest, thus increasing the gradient of the streams, which began to erode rapidly the deeply weathered land and carry much coarse material toward their mouths. The drainage was to the southwest, following the structural folds. Along the shore where these streams debouched they built deltas, which constitute what is known as the Tuscaloosa formation. The coarse material was dropped near the land, and the finer material was carried seaward. The Cretaceous Tennessee River [14] was the largest of these streams and contributed much material to the Tuscaloosa delta. Continued warping caused the sea to gradually transgress the land. The coarser materials were deposited farther and farther up the valleys, and finer sediments were deposited over the gravel downstream. So Tuscaloosa time changed into Eutaw time. More of the land was covered by the sea. During the Tuscaloosa and Eutaw epochs western Tennessee was never deeply submerged, and much of the deposition was subaerial, but later, in Salema time, the sea covered the area to a shallow depth. The rivers were no longer active and flowed to the northwest. In the shallow waters marine life swarmed, and the deposits then formed consist of argillaceous limestone containing abundant fossil remains. Minor warping caused oscillations in the shore line, so that conditions of sedimentation were locally different. A slight elevation of the area followed, and the waters became so shallow that waves could reach and erode the bottom. The sands that washed to the sea were swept from place to place, so that they show much cross-bedding. This condition prevailed during all except the early part of Ripley time.

Eocene time.—The great diastrophic movements that convulsed much of North America at the end of the Cretaceous period did not greatly disturb the embayment region. It was gently elevated above sea level and exposed to erosion. Some of the material that had been

[12] Hayes, C. W., The physiography of the Chattanooga district: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, pp. 23-28, 1899.

[13] Shaw, E. W., The Pliocene history of northern and central Mississippi: U. S. Geol. Survey Prof. Paper 108, pp. 149-151, 1918.

[14] Berry, E. W., Upper Cretaceous floras of the eastern Gulf region in Tennessee, Mississippi, and Georgia: U. S. Geol. Survey Prof. Paper 112, pp. 26-30, 1919.

deposited during Cretaceous time was removed. When in Eocene time the sea crept up the embayment it inundated a relatively level surface and penetrated as far north as southern Illinois. The region was submerged to only moderate depth; in southern Tennessee limestones were deposited but toward the north glauconitic sands were formed. This phase gave place to the deposition of fine clay. Shark teeth have been found in this clay from well drillings at Jackson. The sea receded at the end of Midway time, and a period of erosion followed, of which good evidence is found in the basal clay conglomerates of the Holly Springs formation. (See pl. 6.)

The sea returned in lower Wilcox time but did not reach as far up the embayment nor attain as great a depth as it had in the Midway. Littoral and estuarine conditions prevailed, and the sand and clay brought in by the streams were swept along by strong currents and laid down in irregular cross-bedded deposits. These conditions prevailed until the end of Wilcox time, when the region once more became land.[15] During Jackson time swamp conditions existed over the area south and west of Tennessee and covered the westernmost part of this State. Sand, clay, and lignite were deposited.

Eocene to Recent time.—By the end of Eocene time all of Tennessee was dry land, and the rivers began to erode the recently deposited sand and clay. As these deposits were unconsolidated they yielded readily to the erosive action of the streams, and thus much of the material was carried away. Marbut[16] has shown that at this time the Mississippi River flowed west of Crowleys Ridge, the Ohio flowed in what is now the valley of the Mississippi River,[17] and the Tennessee followed its present channel as far north as Kentucky. Though erosion was active from the end of the Eocene epoch until Pliocene time, the area was not reduced to a peneplain, and therefore the subsequent formation was laid down on an irregular surface.

Some time during the Pliocene epoch the land was sufficiently lowered to allow the heavily loaded streams that came from surrounding highlands to cover the area with sand and gravel. The exact conditions of deposition are not known, but it is probable that the material was derived from high land where erosion was active and was carried by streams of high gradient and large transporting power. It was dropped as a subaerial deposit on the low-lying lands where the flow of the streams was checked and their transporting power greatly reduced.[18]

In Pleistocene time the northern part of the United States was covered by continental ice sheets, which advanced and retreated in

[15] Berry, E. W., Erosion intervals in the Eocene of the Mississippi embayment: U. S. Geol. Survey Prof. Paper 95, pp. 81–82, 1916.

[16] Marbut, C. F., The evolution of the northern part of the lowlands of southeastern Missouri: Missouri Univ. Studies, vol. 1, No. 3, pp. 47–63, 1912.

[17] Stephenson, L. W., and Crider, A. F,. Geology and ground waters of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, p. 129, 1916.

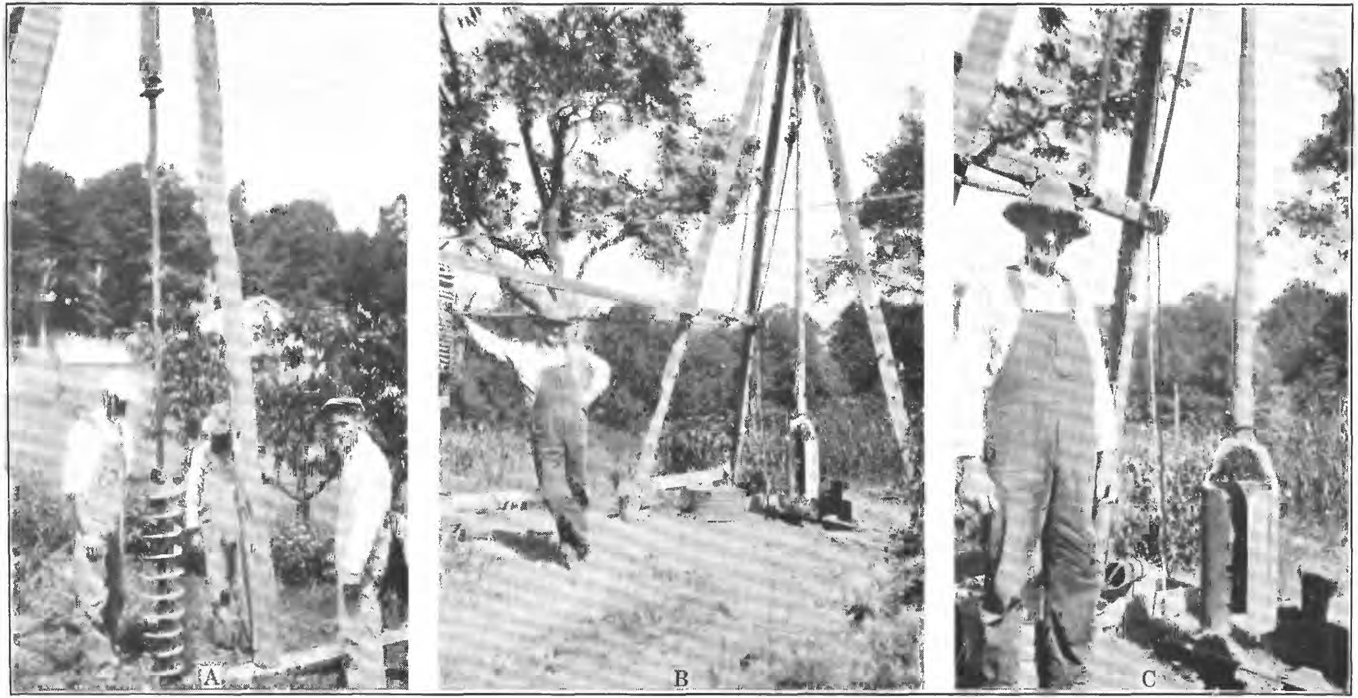
[18] Idem, pp. 126–127.

A. CLAY CONGLOMERATE IN LOWER PART OF HOLLY SPRINGS SAND, HARDEMAN COUNTY

On old road between Bolivar and Hornsby, just east of Hatchie River.

B. PORTERS CREEK CLAY ON DOG TAIL BRANCH, 1 MILE WEST OF HORNSBY, HARDEMAN COUNTY

Photograph by J. K. Roberts.



APPARATUS USED BY WELL DRILLERS IN WESTERN TENNESSEE

A, Boring rig, showing tripod and auger; B, punching rig, driller leaning against winding drum; C, close view of punch.

accordance with the changes in climate. The great quantities of water liberated by the melting ice carried large amounts of glacial débris, which was spread out as outwash plains or carried down the rivers and deposited on their flood plains. When these deposits were dry the wind lifted the fine silty material and dropped it on adjacent regions. Such wind-transported material, called loess, was laid down in the land bordering the Ohio (now the Mississippi) in western Tennessee. Erosion had been resumed in this area after the deposition of the Pliocene gravel, and it was on an irregular erosion surface that the loess was deposited.

The heavily loaded Mississippi River of late Pleistocene time built up its valley to a higher altitude than the valley of the Pleistocene Ohio River, as is clearly shown by the old terraces at Cape Girardeau and on Crowleys Ridge. At the end of the Pleistocene epoch active erosion cut through the loess deposits in many places.[19]

The streams soon adjusted their channels, but in comparatively recent time a slight uplift has caused them to intrench themselves a few feet and by lateral cutting to remove and redeposit the old alluvium, leaving along the edges of the river valleys only narrow remnants of the older valley bottoms, which are called second bottoms.

GEOLOGIC STRUCTURE

FOLDING OF PALEOZOIC ROCKS

The Paleozoic rocks exposed in the eastern part of the area in general lie flat, although they have been elevated and depressed many times. However, the beds show slight flexures, the axes of which are irregular but seem to have a northeast trend.[20]

Dunbar,[21] in describing these folds, says:

> They [the sedimentary strata] are in many places thrown into low open folds, on the limbs of which the dip may reach a maximum of 8° to 10°. In the southern half of the valley (valley of the west Tennessee) faulting is not uncommon, and the throws range from a few feet to 150 feet. The strongest disturbance observed is in the vicinity of Clifton, where the structure is transected and beautifully shown along the Tennessee River. The town is located on the crest of the anticline, from which the rocks dip very gently away to the east and west for a mile in either direction. The height of the arch if restored would be fully 250 feet, and the south limb is broken down by a fault which has a throw of about 125 feet, bringing the mid-Ordovician Hermitage limestone up in contact with the mid-Silurian Dixon. Just below Grandview the river cuts across another low arch some 2 miles wide and fully 100 feet high at its crest, while the preserval of the big Devonian section at Olive Hill is due to a syncline of similar magnitude. Considerable faulting has ocurred just below the Cerro Gordo, where a section of the bluff 200 or 300 yards long composed of Devonian limestone dipping 8° to

[19] Matthes, F. E., oral communication.

[20] Wade, Bruce, Geology of Perry County and vicinity: Resources of Tennessee, vol. 4, p. 175, 1914.

[21] Dunbar, C. O., Stratigraphy and correlation of the Devonian of west Tennessee: Tennessee Geol. Survey Bull. 21, pp. 13–15, 1919.

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10° to the north intervenes between these bluffs formed of horizontal mid-Silurian strata. Faulting is also seen in the bluff above Pyburns. Just below the mouth of Bluff Creek the strata dip westward at an angle of about 8° and the top of the Devonian is over 50 feet above water level. The dip decreases and the strata are nearly horizontal half a mile to the west, where the bluff drops away to the valleys of Anderson's and Johnson's branches; and the top of the Devonian is but little above water level. West of these valleys the previous section is repeated, the dip being to the west again, and the top of the Devonian about 50 feet above the river. A fault with a throw of between 25 and 30 feet, therefore, occurs somewhere in the intervening valley.

While the dips are invariably slight and the folds broad and low in the limestone and shale formations of the valley, the hard, brittle Camden and Harriman cherts are extremely fractured and frequently crumpled by small sharp folds with dips at all angles up to vertical. It is characteristic of these chert formations that the bedding plains are seldom horizontal for more than a short distance, even though the underlying shales and limestones bear no appearance of disturbance. This character is well shown at the boat landing at Saltillo, which is situated on a rather sharp anticline. Above the landing the massive Decatur limestone may be seen dipping downstream at an angle of about 25°. Some 200 yards below it appears again, dipping upstream at an equal angle. Aside from the dip, the limestone shows no obvious results of deformation. The Harriman chert formation, which succeeds the Decatur, is well exposed by a ravine which enters the river at the landing. The chert is thoroughly fractured and crumpled into a series of small sharp folds, frequently reaching 80° or more. Some of these folds are broken and others slightly overturned. Since the older limestones and shales could not have escaped the same compressive stresses to which the chert has been subjected, the contrast in their structure must be attributed to their different physical character. The heavy limestones were stout and tough enough to carry the stresses into broad open folds, while the shale was soft and weak enough to yield by mashing and to accommodate itself between the harder formation. The thin-bedded chert, on the contrary, being too hard to yield by mashing and too brittle to carry the strain into broad folds, has been thoroughly fractured and crumpled.

Detailed mapping would undoubtedly show other folds and faults. To those mentioned above might be added an anticlinal fold at Old Dunbar and another at Dry Creek.

The age of this deformation is uncertain. The overlying Cretaceous beds are not involved, and inasmuch as all the older rocks are deformed, the age of the major disturbance may be placed between the Mississippian and the Cretaceous. As the Pennsylvanian also is faulted in Illinois it seems probable that the deformation occurred in Permian time, when the entire Appalachian mountain system was elevated.[22]

REGIONAL DIP OF CRETACEOUS AND TERTIARY FORMATIONS

Glenn[23] has likened the shape of the rock floor of the upper Mississippi embayment to that of a spoon, with the tip extending northward into Illinois and the east half underlying Tennessee and Kentucky.

[22] Dunbar, C. O., op. cit.

[23] Glenn, L. C., Underground waters of Tennessee and Kentucky west of the Tennessee River: U. S. Geol. Survey Water Supply Paper 164, p. 10, 1906.

The younger sediments, of Cretaceous and Eocene age, were deposited in successive layers on this surface, and the slope of these beds is that of the underlying floor. In the area under discussion this slope is toward the west and southwest. Near their outcrops the formations dip about 30 feet to the mile. This dip lessens considerably toward the west and may reach a minimum of 15 feet to the mile. (See pl. 5.) Few drill holes penetrate the Paleozoic rocks west of their outcrop area and the logs that are available are too general for precise correlation, but it is probable that the axis of the basin lies about 15 miles west of the Mississippi River. Logs of two oil tests from the files of well logs in the Arkansas Geological Survey are given below. No change has been made in the lithologic descriptions as given by the driller, and the data are not such as to permit accurate correlation.

Log of well No. 1 of J. Painter, jr., on farm of Page M. Patterson, northwest corner sec. 35, T. 9 N., R. 7 E., Crittenden County, Ark.

	Thickness (feet)	Depth (feet)
Black surface clay	5	5
Sand and gravel	35	40
Sand and lignite	32	72
White coarse sand and gravel	40	112
Sandy gravel	18	130
Hard sand	14	144
Gumbo	12	156
Hard sand	14	170
Big gravel	2	172
Hard sand	23	195
Gumbo	5	200
Hard sand	5	205
Gumbo	25	230
Hard sand	78	308
Coarse gravel	34	342
Hard sand	32	374
Sand and gravel	26	400
Hard sand	15	415
Gumbo	5	420
Hard sand	30	450
Gumbo	28	478
Hard sandrock	5	483
Gumbo	17	500
Hard sand	20	520
Gumbo	10	530
Sand and boulder	40	570
Hard broken sand	160	730
Hard sand rock	10	740
Broken sand	8	748
Hard sand	16	764
Soft sand	12	776
Hard sand	12	788
Sand mixed with ozarthite and dead oil?	20	808
Hard sand	17	825
Soft sand	11	836
Broken sand	39	875
Hard sand	19	894
Sand and gas and oil showing	18	912
Soft sand	8	920
Brown gumbo	22	942
Broken sand	17	959
Pack sand	10	969
Sand	20	989
Hard sand and oil	12	1,001
Hard sand	9	1,010
Broken sand	80	1,090
Tough gumbo	10	1,100
Hard sand	20	1,120
Gumbo	10	1,130
Hard sand	22	1,152
Gumbo	11	1,163
Sand, very sharp	27	1,190
Gumbo	18	1,208
Sand	22	1,230
Gumbo	10	1,240
Sand	3	1,243
Broken gumbo	43	1,286
Hard broken sand	212	1,498
Soft sand	6	1,504
Sand mixed with okerite and dead oil?	14	1,518
Some gas showing	13	1,531
Greasy lime	3	1,534
Hard lime	14	1,548
Soft sandy lime	19	1,567
Hard sand	3	1,570
Oil and gas showing at 894, 989, and 1,570 feet.		
Soft sand showing gas	13	1,583
Hard sand	12	1,595
Broken sand	41	1,636
Soft sand showing gas	82	1,718
Gumbo; water at 1,742 feet from water well at 2.563 feet	24	1,742
White sand; fine water well	28	1,770
Shale, gummy	2	1,772
Gumbo	11	1,783
Sand and shale [Arkadelphia]	189	1,972
Hard rock	2	1,974
Sandy shale	38	2,012
Limerock	3	2,015
Sticky shale	39	2,154
Broken shale and lime	39	2,193
Shale	4	2,197
Gas showing	12	2,209
Broken shale and lime	61	2,270
Broken lime and gumbo	21	2,291
Tough gumbo	20	2,311
Sand	25	2,336
Sand and gumbo	20	2,356
Graphite	24	2,380
Sand and shale	138	2,518
Lime and some sand	6	2,524
Sand and shale	8	2,532
Gypsum	10	2,542
Hard broken lime	9	2,551
Mixed black lime	1	2,552
White lime	2	2,554
Hard brown lime	1	2,555
Hard lime and sand	5	2,560
Hard sandrock	3	2,563

Log of well No. 1 of J. Painter, jr., on farm of Page M. Patterson, northwest corner sec. 35, T. 9 N., R. 7 E., Crittenden County, Ark.—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Hard sand shale, showing water	7	2,570	Broken sand	46	2,916
Shale	24	2,594	Gumbo	27	2,943
Hard shale	8	2,602	Broken sand, shale, and gravel	52	2,995
Sandy shale	21	2,623	Gumbo	9	3,004
Rock	1	2,624	White shale	12	3,016
Tough gumbo	26	2,650	Chalk and sand mixed with fossils	13	3,029
Shale and gumbo	30	2,680	Sand	12	3,031
Shale and strips of rock	30	2,710	Shale and lime	21	3,052
Rock [starting in Nacatoch sand]	2	2,712	Shale, lime, and chalk	24	3,076
Sandy shale	19	2,731	Chalk	10	3,086
Sand and rock	7	2,738	Shale and chalk	78	3,164
Shale, gumbo, and rock	14	2,752	Hard shale and pyrites	45	3,219
Hard rock and sand	10	2,762	Shale	17	3,236
Soft sand	8	2,770	Hard shale and pyrites	26	3,262
Green sticky sand	35	2,807	Sand, gravel, and pyrites	14	3,276
Soft sand	7	2,814	Hard lime	14	3,290
Hard sand pyrites	1	2,815	Shale and lime	26	3,316
Hard sandrock	3	2,818	Hard lime	4	3,320
Soft sand and shale	6	2,824	Rock	2	3,322
Hard sand	1	2,825	Broken rock	1	3,333
Soft sand	6	2,831	Sand	18	3,351
Hard sand	15	2,846	Mixed shale and chalk	25	3,376
Gumbo	4	2,850	Hard chalk	39	3,415
Sand	7	2,857	Hard lime mixed with sand	4	3,419
Hard sand	1	2,858	Hard chalk and lime	34	3,453
Soft sand	7	2,865	Chalk and shale	37	3,490
Hard sand	1	2,866	Hard chalk	26	3,516
Soft sand	2	2,868	Hard lime; hole abandoned at 3,516 feet.		
Hard sand	2	2,870			

Log of well No. 1 of J. Painter, jr., on Hunter farm, sec. 24, T. 7 N., R. 8 E., Crittenden County, Ark.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface clay	10	10	Hard shale	57	1,340
Sand and gravel	28	38	Hard sand	1	1,441
Lignite	3	41	Hard packed sand	47	1,488
Sand and gravel	129	170	Sand; broken formation	4	1,492
Rock	1	171	Hard packed sand	42	1,534
Gray gumbo	69	240	Hard sand	61	1,595
Sand and gravel	130	370	Gumbo	5	1,600
Sandy shale	37	407	Soft sand	25	1,625
Sand and gravel	35	442	Sand and shale	23	1,648
Sand with hard streaks	53	495	Hard sand	27	1,675
Gumbo	60	535	Gumbo	20	1,695
Hard sand	22	557	Sandy shale	25	1,720
Hard broken sand	75	632	Gumbo	6	1,726
Sand	118	750	Sandy shale	51	1,777
Hard sand (gas at 865 feet)	144	894	Water sand	12	1,789
Rock	2	896	Shale, lignite; cored at 1,792 feet	32	1,821
Sand	4	900	Soft sand and shale	44	1,865
Hard sand	20	920	Shell rock; cored at 1,867 feet; no		
Brown shale	15	935	water; soft sand	1	1,866
Hard sand	15	950	Soft sand	4	1,870
Gumbo	30	980	Rock	1	1,871
Sand	10	990	Fine sand and shale; cored	15	1,886
Water sand	35	1,025	Rock	1	1,887
Rock	5	1,030	Sandy shale; cored	85	1,972
Gumbo	15	1,045	Sandy shale	28	2,000
Rock and pyrites of iron	4	1,049	Gumbo	10	2,010
Brown shale	11	1,060	Sandy lime and shale; gas showing	20	2,030
Hard sand	9	1,069	Gummy shale	245	2,275
Packed sand	6	1,075	Broken lime and shale	25	2,300
Hard packed sand	55	1,130	Gummy shale	50	2,350
Sandrock	5	1,135	Chalky shale	100	2,450
Blue gumbo	37	1,172	Gummy shale	50	2,500
Sandrock	5	1,177	Chalky shale	40	2,540
Gumbo	95	1,272	Black shale	20	2,560
Sand shale	8	1,280	Black sandy lime	18	2,578
Hard sand	2	1,282	Gray water sand	5	2,583
Fresh-water sand	1	1,283	Gray water sand; fresh water, hot	27	2,610

Log of well No. 1 of J. Painter, jr., on Hunter farm, sec. 24, T. 7 N., R. 8 E., Crittenden County, Ark.—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale	35	2,645	Sandy lime	20	3,085
Sandy lime	15	2,660	Chalk	45	3,130
Shale	70	2,730	Chalky shale	90	3,220
Lime and shale	30	2,760	Shale and shells	25	3,245
Water sand	40	2,800	Sand; cored; no water at 3,250 feet	20	3,265
Hard sand and pyrites	120	2,920	Chalky shale	20	3,285
Hard sandy shale	40	2,960	Shale and lime, broken	50	3,335
Chalky shale	60	3,020	Hard lime	250	3,585
Chalk rock	45	3,065	Paleozoic (abandoned)	29	3,614

Mr. Spooner [24] places the base of the Wilcox at 2,000 to 2,030 feet and the base of the Midway (base of Eocene) at 2,578 feet. The writer places the base of the Midway at 2,371 feet.

An analysis of these well logs shows unconsolidated deposits of sand and clay to a depth of about 3,300 feet and hard consolidated rock below this. The log of the well on the Hunter farm states that the well was in the Paleozoic at a depth of 3,614 feet, where the work was abandoned. On the assumption that the transition from unconsolidated or soft materials to hard limestone represents the contact between the Cretaceous and Paleozoic this contact can be placed at about 3,300 feet. This is the greatest depth to the Paleozoic floor in this latitude, and the site of the axis of the basin can be assumed to be at this point.

SURFACE WARPING

The plateau of western Tennessee has a general slope to the northwest, but in the northwestern part of the area the land rises again, forming the high tract in the western part of Obion County. Surface warping has elevated this tract until its general level is about 100 feet higher than the general surface level to the south. This is near the area of maximum disturbance of the New Madrid earthquake of 1811 and 1812. That this earthquake formed Reelfoot Lake and caused changes in level of parts of the land surface has been shown by McGee[25] and Shepard.[26] Uplift sufficient to give a difference of 100 feet could not have occurred at the time of the New Madrid earthquake, for ponding of the drainage would have resulted. It seems possible, however, that this warping could have been effected in recent times by successive small disturbances similar to the New Madrid earthquake.

SLUMPING

Small faults, the displacement on which does not exceed a few feet, occur in the Porters Creek clay. A good example of these faults is

[24] Spooner, W. C., personal communication.
[25] McGee, W J, A fossil earthquake: Geol. Soc. America Bull., vol. 4, pp. 411–414, 1893.
[26] Shepard, C. M., The New Madrid earthquake: Jour. Geology, vol. 13, pp. 45–62, 1865.

seen three-quarters of a mile west of Middleton, in Hardeman County, on the south side of the Southern Railway. Here three small faults are exposed, of which the largest has a displacement of 8 feet. Another fault, forming a small graben, is well exposed in a road cut on highway 15 just east of the Hatchie River, in Hardeman County. These small faults were probably caused by slumping, and as the overlying Holly Springs formation seems not to be affected the slumping probably took place at the end of Midway time.

GROUND WATER

SOURCE AND OCCURRENCE

Of the rain that falls in any region a part returns to the atmosphere by direct evaporation either from the land surface or from objects on the surface, a part flows directly to the streams and is carried away, and another part seeps into the soil or rocks. Some of this last part is withdrawn by evaporation from the soil and transpiration of plants and some penetrates downward through the cracks, crevices, and interstices until it reaches the water table, or upper surface of the zone of saturation, below which all openings are saturated with water. Above the water table is the zone of aeration, where the water is suspended against gravity by molecular forces. The zone of aeration is not saturated but is moist.

Nearly all rock formations contain some openings through which water will pass. Some formations, such as clean gravel and clean coarse sand, are very porous and permeable; others, such as dense granite and metamorphic rocks, may be impermeable except as they are traversed by joints and fissures through which water may percolate. Limestone may consist of very dense material but may contain a system of solution channels that will carry water freely. In general the most impermeable formations are those composed of clay, which is itself impermeable and is too soft to have open joints or fissures. The rocks of western Tennessee can be divided on the basis of the nature of the openings in them into two distinct classes—the consolidated rocks of Paleozoic age and the relatively unconsolidated Cretaceous, Eocene, and Quaternary deposits.

WATER IN THE CONSOLIDATED PALEOZOIC ROCKS

OPENINGS IN SOLID ROCKS

The openings in the indurated Paleozoic rocks can be divided into four classes—major fractures, minor or joint fractures, anastomosis, and solution channels. The formation of a particular class depends on the stresses at work and on the physical and chemical nature of the rocks. Thus under compressive stresses shales will tend to flow and cherts to shatter; solutions carrying carbon dioxide will vigorously attack limestones but have no influence on shales.

Major fractures caused by profound structural stresses, such as faults and large fissures, may extend horizontally and vertically for hundreds or thousands of feet and may traverse many formations. The width of the fissures may attain several feet. They may contain large volumes of water and furnish channels along which water can move easily for considerable distances. Such fissures are not common in this area but are found in conjunction with the folds. (See pp. 25–26.)

The jointing in limestones and shales is largely due to cubical expansion and contraction, especially during drying and settling.[27] The jointing may be greater in one bed than in another and does not pass from formation to formation but is most common at the contacts of the different beds. Contraction and expansion take place in consolidated beds as a result of temperature changes, absorption of moisture, and other factors of weathering. These weathering processes bear a relation to the surface, and joints caused by them are more numerous at the surface and diminish with depth. Frost action and the pressure of growing roots open the joints, so that their width also shows a relation to the surface. Bedding planes are surfaces of weakness, and joints are likely to form along them. Folding of the beds may produce tension and compression joints.[28]

Owing to their brittle nature the cherts in this area were completely shattered by the slight folding they have undergone, and circulating ground waters have removed by solution their lime content, until the remaining mass is cut by a labyrinth of irregular solution cavities. The innumerable interlocking openings permit water to move freely in all directions, instead of being restricted to definite channels as is usual in impermeable rocks. Such a condition has been called anastomosis by Martel,[29] who defines it as follows:

> When the fissures are smaller and more numerous * * * in place of true currents one is in the presence of a network of conduits arranged in a more or less regular checkerboard and joined in every way, anastomosed—that is, communicating with each other by chance according to the laws of hydrostatic equilibrium.

Meteoric waters carry carbon dioxide, which in solution is a solvent for calcium carbonate. Hence meteoric waters percolating downward through jointed or fissured limestones dissolve some of the wall rock and thereby enlarge the openings. This process takes place largely above the zone of saturation, where the movement of water is rapid; it is generally negligible at any considerable depth below the water table. With some possible exceptions the value of this process as a reservoir former is confined to regions where the limestone formations have stood above the ground-water level until caverns were formed and then have subsided so that these caverns were lowered below the level of

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[27] Leith, C. K., Structural geology, p. 33, 1923.
[28] Idem, pp. 47–48.
[29] Martel, E. A., Nouveau traité des eaux souterrains, p. 111, 1921.

saturation. In this area there are no large solution channels in the Paleozoic limestones below the water table, but caves exist above the ground-water level, and many surface streams disappear into such caves, to come to the surface farther down their courses. These underground streams do not everywhere represent the true ground-water level.

From what has been said about the relation of joints, fissures, and solution channels to the surface it follows that these openings are much more numerous within the zone of weathering than at greater depth. The geologic column (pp. 18–21) shows that none of the limestone or shale formations in western Tennessee exceed 100 feet in thickness and that most of them are less than 50 feet. Hence a well in these rocks from 150 to 300 feet in depth will traverse several formations of varying character in the zone where they are most highly fractured. If water is not encountered above a depth of 300 feet the chances of obtaining a successful well by drilling to greater depths are not good, and it is generally advisable to start a new hole.

WATER IN LIMESTONES

The Paleozoic rocks of western Tennessee are limestones, shales, and cherts. The limestones of this area vary considerably in composition and texture and in the amount of jointing. Some beds, such as the Decatur limestone, are massive crystalline limestone, which has relatively few joints, no bedding planes, and few fissures. Other limestones are argillaceous and grade into shale. These formations are in many places thin bedded. The bedding planes are lines of weakness and are the sites for the formation of numerous horizontal fissures. Also these formations were more subject to jointing during deposition than the pure limestones, and they are traversed by numerous cracks. The influence of folding and of solution on limestones has been described (p. 31) and applies to all the limestones in the area. The argillaceous limestones are less soluble than the others and may serve to deflect percolating waters, so that immediately above them horizontal solution channels are found.

WATER IN SHALES

Many shales are essentially impervious and do not yield water but serve as barriers to its movement. As they are relatively plastic they are likely to yield to stresses by flowing instead of breaking, so that even when folded they remain unbroken and impervious. The pure shales of the region, such as the Chattanooga shale, are of this nature and generally do not yield water to wells. Most of the shales of the area, however, are impure, containing sand or calcium carbonate. They have many bedding planes and are cut by numerous fissures. They form better sources of water than the massive limestones.

WATER IN CHERTS

The cherts of this area are calcareous and brittle. The slight folding they have undergone has shattered them, and near their outcrops circulating waters have removed the calcium carbonate by solution. The solution cavities and the numerous fractures make these rocks highly porous and permeable. They are excellent water-bearing beds in localities where they crop out.

WATER IN THE RELATIVELY UNCONSOLIDATED CRETACEOUS, TERTIARY, AND QUATERNARY DEPOSITS

The relatively unconsolidated sediments of Cretaceous age consist of sand, silt, and clay. The classification of gravel, sand, and clay, expressed in millimeters, used in the hydrologic laboratory of the United States Geological Survey,[30] is as follows:

Gravel, greater than 5.	Fine sand, 0.25 to 0.1.
Gravel, 5 to 2.	Very fine sand, 0.1 to 0.05.
Fine gravel, 2 to 1.	Silt, 0.05 to 0.005.
Coarse sand, 1 to 0.5.	Clay, less than 0.005.
Medium sand, 0.5 to 0.25.	

The clays are arenaceous near their contact, and these parts will yield a little water, but the massive clays are not water bearing. The silts yield only a little water, but the sands are excellent water bearers. The properties that determine the water-yielding capacities of sand are those which hold for any granular deposit—namely, porosity, specific retention, specific yield, and permeability.

POROSITY

A granular deposit consists of solid grains and the intervening open spaces. The percentage of the open spaces to the total volume determines the porosity of the deposit. To investigate the porosity of granular deposits Slichter [31] considered an "ideal soil" consisting of spherical grains of equal size. He demonstrated mathematically that the ratio of the volume of the intergranular space to the volume of the spheres, or the porosity of such a soil, ranged from a maximum when the arrangement of the spheres was such that lines joining the centers of the spheres made angles of 90° to each other to a minimum when the center lines formed rhombohedra with interfaced angles of 60° and 120° respectively. As the packing of grains changed from the maximum cubical or open packing to the minimum or closed packing the porosity ranged between the limits of 47.64 and 29.95 per cent. The pores through such an ideal soil are capillary tubes of approximately triangular cross section, which enlarge slightly in area and then diminish again as they follow the surfaces of the spherical soil grains.

[30] Stearns, N. D., Laboratory tests of physical properties of water-bearing material: U.S. Geol. Survey Water-Supply Paper 596, p. 127, 1928.

[31] Slichter, C. S., Theoretical investigation of the motion of ground water: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, pp. 305–328, 1899.

It can be mathematically demonstrated that the pore space of such an ideal soil is independent of the size (diameter) of the constituent grains, the porosity being a function of the arrangement of these grains only.

In a soil consisting of spheres of many sizes the relationship above set forth no longer holds true. It is obvious that a large sphere fills the space that would otherwise be occupied by many small ones, thus diminishing the number of voids, or the smaller spheres may be considered as lying in the spaces between the larger ones, thereby reducing the void space. In such a soil the factor that controls the porosity is largely the degree of assortment—that is, the difference in sizes of grain and the proportion of the material that is of each size. Such a soil can have a porosity less than the limiting porosity of an ideal soil. Most clastic deposits are made up of grains of many sizes, and the porosity of clastic deposits is determined largely by the degree of assortment.

Another factor that determines the porosity of granular material is the shape of the constituent grains, for the grains are not true spheres but may have any shape. Angular and lath-shaped grains generally give greater porosity, for they generally have a chaotic arrangement, whereas tabular grains deposited by running water tend to be laid down with the short dimensions of the different grains parallel, causing such materials to be much less porous. The shape of the grains depends on the minerals from which they are derived, the size of the grains, and the amount of abrasion to which they have been subjected. Grains derived from minerals with strong cleavage will have shapes determined by the cleavage—for instance, mica grains are platy—and as the grains are reduced in size they will tend to maintain the same shape. Minerals without cleavage give fragments of irregular shape, which may be rounded by abrasion, and as the grains diminish in size they become more nearly round. Fine sands, however, are often found to be very angular. This can be explained by the fact that grains of less than a certain size are unable to abrade or be abraded, as they are unable to inflict a blow of sufficient force. Hence very small angular fragments smaller than this limiting size are not rounded. The limiting size of abrasion is dependent upon the specific gravity of the material and the conditions of transportation. In a general way it may be said that fine grains are likely to be angular. The sands of western Tennessee are composed largely of quartz, a mineral with no cleavage, which has been worn until it is subangular in shape.

Many methods of determining porosity have been used, as described by Meinzer.[32] The present method used in the hydrologic labora-

[32] Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, pp. 11-17, 1923. See also Stearns, N. D., Laboratory tests on physical properties of water-bearing materials: U. S. Geol. Survey Water-Supply Paper 596, pp. 131-134, 1928.

tory of the United States Geological Survey was developed by P. G. Nutting and is described in a memorandum prepared by A. M. Piper as follows:

The method of determining porosity which is at present in use in the hydrologic laboratory differs from the method described by Mrs. Stearns in Water-Supply Paper 596 in three respects—(1) the fluid used is tetrahydronaphthalene instead of water; (2) a Babcock milk or cream testing bottle is used in place of the Johnston and Adams pycnometer; (3) the determination is made at room temperature. The revised method has long been used in the Bureau of Standards laboratory in determining the porosity of paint pigments.

Tetrahydronaphthalene is sold under the commercial name tetraline. It is a colorless fluid of low volatility, boiling point 204° C., density 0.975 at 21° C, and is very soluble in alchohol or ether and practically insoluble in water. Furthermore, its coefficient of thermal expansion is very low, and it is fairly stable. It is sufficiently miscible with water to displace the small amount of moisture absorbed by the mineral grains during determination. Parahyde is more effective than tetraline in displacing absorbed moisture but is distinctly inferior in that it is more volatile. Toluene is much too volatile to be satisfactory.

The stem of a Babcock cream test bottle is larger in diameter than that of the milk test bottle. Hence, with the cream test bottle the sand sample can be inserted more easily, but the determination is uncertain in the hundredths of 1 per cent. With the milk test bottle and refined technique, the determination is certain at least to hundredths of 1 per cent. As much as 15 grains of sand can be placed in either the milk or the cream bottle.

Each Babcock bottle must first be standardized by weighing the quantity of water required to fill it to the lower part of the scale (which is graduated on the stem of the bottle) and reading the volume on the scale at two or three temperatures between 0° and 35° C. The volume must be read after the bottle has been brought to equilibrium in a constant-temperature bath. A similar series of readings is taken with enough water to fill each bottle nearly to the top of the scale. From these data can be computed (1) the volume of the bottle below the mere mark of the scale at 0° C., (2) the volume represented by each scale graduation, (3) the coefficients of volume expansion of the bottle and of the stem.

The tetraline used is then standardized by repeating the set of observations outlined in the preceding paragraph with tetraline rather than water. From these data can be computed the density of tetraline at standard temperature and the coefficient of change in density with temperature.

The determination of porosity is made thus:

1. The bottle is cleaned, dried in the oven, and weighed.

2. The sample of sand is placed in the bottle and its weight determined by difference between the weight of the empty bottle and the total weight of bottle and sample.

3. Enough tetraline is placed in the bottle to cover the sample, and the bottle is held in an inclined position and rotated slowly in the hands until the air trapped in the sample has been displaced. Usually the air is displaced rapidly, and there is a well-defined cessation of the escape of air bubbles.

4. More tetraline is added to bring the fluid level up into the graduated stem, and the weight of the tetraline is determined by difference.

5. The bottle is corked to prevent evaporation or entrance of foreign particles and allowed to stand until it and its contents have come to temperature equilibrium. The scale rating of the fluid level is then noted and the fluid temperature read from a thermometer inserted in the stem of the bottle. For convenience, steps 1 to 4 are usually performed in the late afternoon, and the bottles are

allowed to stand over night on a pad or other poor conductor of heat in a place that is protected from the direct radiation of light, and the volume and temperature readings are made early the following morning. Even in heated buildings the changes in temperature during the night are not so rapid that the bottle will not come to equilibrium.

From the known weights of the sample and the tetraline, the total volume of sample and tetraline, the temperature, and the thermal coefficients of bottle and tetraline, the porosity can be computed.

The results of 117 porosity determinations (see pp. 82, 96–97, 101–102) made on samples collected from all the sand formations in western Tennessee, both from outcrops and from well drillings, show a high porosity. The average is 39.9 per cent; the maximum 49 per cent (sample 911, p. 102); the minimum 22.4 per cent (sample 855, p. 82). The range of porosity is relatively small, almost falling within the range possible in an ideal soil due to differences of packing.

SPECIFIC YIELD AND SPECIFIC RETENTION

Although in an ideal soil the grain size does not affect the porosity it does affect the amount of water that such a soil when saturated will yield under force of gravity. This is due to forces acting between liquids and solids in contact with each other which cause a film of liquid to adhere to the surface of a solid. These forces are proportional to the surface area, and with an increase of area the quantity of liquid held is increased. As the surface of spheres varies directly as the square of their diameters and the number of spheres of equal size in a given volume varies inversely as the cube of the diameters, the aggregate surface of the spheres in a given volume increases with diminishing grain size, which hence results in an increase in the quantity of liquid held. Surface tension manifests itself in small tubes by capillarity. The height of a column of liquid that a capillary tube will hold varies inversely as the diameter. The interstices between grains in a granular mass can be considered irregular tubes. The size of the tubes between the grains decreases as the diameter of the grains decreases, but the number of tubes increases. Hence the smaller the grains the more liquid will be held by capillarity. If a sand saturated with water is allowed to drain, a certain amount of the water will be retained in the sand by the force of surface tension. The percentage by volume of the water retained by a sand is called the specific retention of the sand; the percentage which is occupied by gravity water (water that will drain out under gravitational pull) is called the specific yield. From the discussion of surface tension it is obvious that the specific retention varies inversely with size of grain, being greater the smaller the grain. The sum of these two percentages equals the porosity.

Various methods for determining the specific retention and specific yield have been employed.[33] One method of determining the specific

[33] Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, pp. 67–77, 1923.

yield is the moisture-equivalent method, which consists in determining the amount of water retained by a saturated sample of sand after it has been subjected in a centrifuge to a pull 1,000 times the pull of gravity. The technique employed in making this determination in the hydrologic laboratory of the United States Geological Survey is described by Mrs. Stearns.[34]

The moisture-equivalent determinations made on 144 samples (see pp. 82, 96–97, 101–102) from the Eutaw, Ackerman, Ripley, Holly Springs, Grenada, and Jackson formations at outcrops and from wells in western Tennessee are low. The highest is 12.70 per cent (sample 859, p. 96); the lowest is 0.50 per cent (sample 1071, p. 101); and the average is 3.32 per cent. The mechanical analysis of sample 859 shows that the sand contains 2.3 per cent of clay and 4.1 per cent of silt and is all less than 0.5 millimeter in size. From the discussion of specific retention it is obvious that the moisture equivalent will increase with increasing content of silt and clay, but these samples include materials which are as much as 83 per cent very fine sand (on 0.125-millimeter sieve), and by definition finer material does not fall within the sand size. Therefore these determinations probably represent the range in moisture equivalent of the sand formations of western Tennessee.

PERMEABILITY

Specific yield and specific retention are of interest when a rock is considered as a reservoir, for they indicate how much water a given volume of a rock will yield. If a formation is to be considered as a conduit for carrying water from one point to another, the capacity of the formation for transmitting water under pressure, rather than the water content of the formation, is of primary importance. This capacity is called permeability and is defined as the rate at which a formation will transmit water through a given cross section under a given difference of pressure per unit of distance. The permeability of a granular deposit is determined by the resistance that the deposit offers to the passage of water through it. In a deposit composed of very fine grains (less than 0.005 millimeter), the surface tension is so great that water can not be forced through the deposit, and it is said to be impermeable. In deposits composed of larger grains the resistance offered to the flow of water depends on the diameter of the openings. Slichter[35] has demonstrated that in an ideal soil the permeability varies as the square of the diameters of the grains. In a natural deposit no definite relation exists between size of grain and permeability, but grain size is a very influential factor, and poorly sorted coarse-grained material may have greater permeability than uniform

[34] Stearns, N. D., Laboratory tests on physical properties of water-bearing materials: U. S. Geol. Survey Water-Supply Paper 596, pp. 134-139, 1928.

[35] Slichter, C. S., op. cit., pp. 301–323.

material of a grain size equal to the average grain size of the coarse material.

Meinzer [36] has devised a laboratory method for measuring the permeability, the result being expressed as a coefficient of permeability. The coefficient of permeability is the number of gallons of water a day, at 60° F., that is conducted laterally through each mile of the water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed and for each foot per mile of hydraulic gradient. A description of this method and a discussion of its limitations are given by Mrs. Stearns.[37] A method of measuring permeability of a formation in place is discussed in the present paper on page 306.

Permeability determinations were made on 113 samples (see pp. 82, 96–97, 101–102) collected both from outcrops and from well drillings from the Eutaw, Ripley, Ackerman, Holly Springs, and Grenada formations throughout western Tennessee. The results show a wide range, from a maximum of 3,936 (sample 1039) to a minimum of 9 (sample 862). The average, 750, is high and indicates that the sands of western Tennessee are relatively permeable.

MECHANICAL ANALYSIS

The preceding discussion has shown that the properties of porosity, specific retention, specific yield, and permeability are dependent upon either the grain size or the degree of uniformity of grain size, or both. Mechanical analysis is a simple laboratory analysis which will give comparative data on the grain size and on the variations of grain size of a sand. The mechanical analysis of a sand is determined by sieving a sample through a series of screens having mesh of different sizes and weighing the material retained on each screen. The weight of the material retained on each screen divided by the weight of the whole sample and multiplied by 100 gives the percentage of the material by weight held on each screen. If the percentage of the material that passes through each screen is plotted against the logarithm of the size of opening of the screen and the points connected by a curve, the shape of this curve gives an indication of the degree of assortment. The more nearly uniform the material the steeper will be the slope of the curve; with completely uniform material the curve is a vertical straight line.

Hazen [38] expressed the degree of assortment of a deposit by what he called the uniformity coefficient, which is the ratio of the diameter of a grain that is coarser than 60 per cent of the sample to the diameter of a

[36] Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 596, pp. 144–149, 1928.

[37] Stearns, N. D., Laboratory tests on physical properties of water-bearing materials: U. S. Geol. Survey Water-supply Paper 596, pp. 144–149, 1928.

[38] Hazen, Allen, Experiments upon the purification of sewage and water at the Lawrence Experiment Station: Massachusetts Board of Health Twenty-third Ann. Rept., for 1891, pp. 429–431, 1892.

grain that is coarser than 10 per cent of the sample. If the grains are all of one size the coefficient will be 1; as the difference in grain sizes increases the coefficient increases. Hazen [39] also states that the size larger than 10 per cent of the material and smaller than 90 per cent gives as good an idea of the nature of the sand as can be condensed into a single figure, and he calls this size the effective size.

A description of the technique employed in making these measurements is given by Mrs. Stearns.[40] In many experiments where the sand contained no silt or clay and was composed predominantly of coarse grains it was deemed advisable to follow another technique. One hundred grams of sand was weighed out and sieved in a nest of five screens, the openings ranging from a width of 1 millimeter down to 0.0625 millimeter, and those in each screen being half the size of the preceding. The nest of screens was agitated in a machine which gyrated them and tapped them periodically for 10 minutes, after which the material on each screen was weighed and the percentages determined. A torsion balance weighing to 0.1 gram was used throughout this test. This procedure is called the second method.

Mechanical analyses of 134 samples collected from the Eutaw, Ripley, Holly Springs, and Grenada formations throughout western Tennessee are listed on pages 82–83, 96–98, 101–102, 104. These analyses show considerable variation in the character of the sand, both in size of grain and in uniformity of grain size. The uniformity coefficient ranges from 1.31 (sample L. & N. I) to 9.50 (sample 906), but the average is 2.61, which is rather low. These determinations indicate that in general terms the sands of western Tennessee are very uniform in grain size.

PROBLEMS OF SAMPLING

A discussion of the limitations of these experiments is beyond the scope of this paper. There is one point, however, that should be mentioned. The porosity, moisture equivalent, and permeability are dependent on the arrangement of the grains. It is impossible to duplicate in the laboratory the arrangement of a heterogeneous sand in place. Therefore it is never possible to obtain an absolutely correct laboratory determination of these factors, but the laboratory result is of the same order of magnitude as the true field condition.

Of greater importance than the above is the question whether the sample is truly representative of the formation. This has two parts—whether the sample accurately represents the formation at the place where it was taken and whether the formation at that particular place accurately represents the whole formation. The method of sampling an outcrop and the accuracy of this method is discussed by Mrs. Stearns.[41] If the sample is taken from drillings the accuracy

[39] Hazen, Allen, op. cit., p. 431.
[40] Stearns, N. D., op. cit. (Water-Supply Paper 596), pp. 121–176.
[41] Idem, pp. 22–23.

depends on the method of drilling. When the rotary process is used a fair sample can be obtained from the drillings, provided sufficient care is observed in taking the sample and no sludge is used in the drilling process. When a sludge is used in drilling it is necessary to remove the sludge from the sample. A clay sludge can be removed by careful washing, but any silt and clay that belongs to the sample will be removed with the sludge. In the samples taken from outcrops throughout western Tennessee the silt and clay content ranges from 11.9 to 2.2 per cent. The error resultant upon removing this silt and clay from the sample can not be avoided. If the sludge is carelessly washed out some of the fine sand will be removed at the same time, thereby introducing a greater error.

The degree in which the sample represents the whole formation depends on the uniformity of the formation, which in turn is determined by the source of the material and the environment under which the formation was deposited. Materials that have undergone several cycles of erosion and deposition may have been subject to various types of sorting. If the same environment of sedimentation is repeated the material will attain a very definite character; if the environment is varied succeeding reworking may serve to mix the sorting previously imposed on the material. Marine conditions of sedimentation where reworked and sorted materials are being brought to the sea by streams are likely to produce deposits that are uniform in character over large areas. Deposits laid down by torrential streams bringing in heterogeneous material, however, will be extremely variable, and no sample or group of samples will give adequate data on which to base conclusions as to their water-yielding qualities. These are extreme conditions, neither of which is found in western Tennessee. In the sections on porosity, specific retention, permeability, and mechanical analysis it has been shown that the physical properties of the sands found in any one formation in western Tennessee range between fairly wide limits. Also lenses of clay occur irregularly distributed throughout the formations. Though with adequate data it might be possible to determine the physical properties for the formations as a whole, it is obviously impossible to predict how much clay and sand of different grades will be encountered in any one well. It is probable, however, that almost invariably in any well as much as 50 feet of sand can be found which will have a porosity, moisture equivalent, and permeability equal to the averages of these physical properties as determined from the samples collected from each formation.

RELATION OF GROUND WATER TO LAND FORMS

In this area the water table, or level below which the ground is saturated, follows in a general way the configuration of the surface; it rises under the hills and sinks under the valleys. The slope of the water table is nearly everywhere less than that of the land; therefore, the depth to water ranges from nothing where the water table comes to the surface at the streams in the valleys to a maximum on the highest hills. Not only does the topography influence the depth to the water table, but variations in the permeability of the underlying rocks modify its position. An impervious layer may bring the water table to the surface on a hillside, whereas high porosity will cause it to stand at considerable depths. In the valleys of western Tennessee the water table commonly stands from 10 to 20 feet below the surface, but in the hills of the Wilcox group it is from 60 to 125 feet below the surface. Local impervious layers of "hardpan" that stand above the main water table may form small basins of perched water. (See fig. 5.) Such basins are most common in the Holly Springs and Grenada sand or at the base of the Pliocene gravel.

The fissuring of the Paleozoic rocks is greatest at the surface and diminishes with depth. The same thing is true of the leaching of the

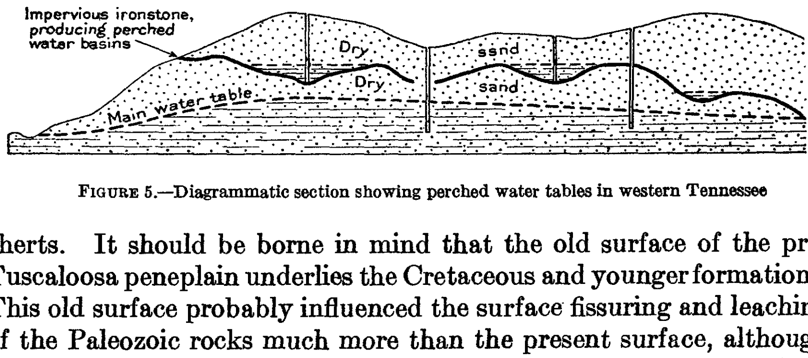

FIGURE 5.—Diagrammatic section showing perched water tables in western Tennessee

cherts. It should be borne in mind that the old surface of the pre-Tuscaloosa peneplain underlies the Cretaceous and younger formations. This old surface probably influenced the surface fissuring and leaching of the Paleozoic rocks much more than the present surface, although this pre-Tuscaloosa surface fissuring and leaching has been modified by later fissuring and leaching due to weathering from the present surface. Therefore, even where the Paleozoic rocks are covered by a mantle of younger deposits the top 100 feet or so of the Paleozoic rocks may be traversed by fissures and solution channels produced when these rocks stood at the surface. Hence wells seeking water in Paleozoic rocks that are so covered are most likely to strike water within the first 100 feet below the Paleozoic rock surface.

RELATION OF GROUND WATER TO GEOLOGIC STRUCTURE

The Paleozoic rocks of the area under discussion were gently folded sometime after the Mississippian epoch. The folding was not intense enough to fracture the flexible limestones and slates greatly, but it severely fractured the brittle cherts. Hence in the areas of folding the cherts are more permeable than elsewhere. On the crests of the anticlines the limestone has been somewhat fractured, and along the fractures there has been considerable solution, resulting locally in the formation of caves, as at Dry Creek, Hardin County.

The only structure in the younger formations other than surface slumping is a monoclinal dip to the west of 20 to 30 feet to the mile. In areas where water is obtained from the outcropping formation this dip does not influence the water table. However, when deeper artesian formations are to be penetrated this dip must be considered, for the depth to a given formation increases toward the west. The dip also has a very important bearing on artesian conditions, discussed below.

ARTESIAN CONDITIONS.

According to Meinzer [42] artesian water is ground water that is under sufficient hydrostatic pressure to rise in a well above the zone of saturation.

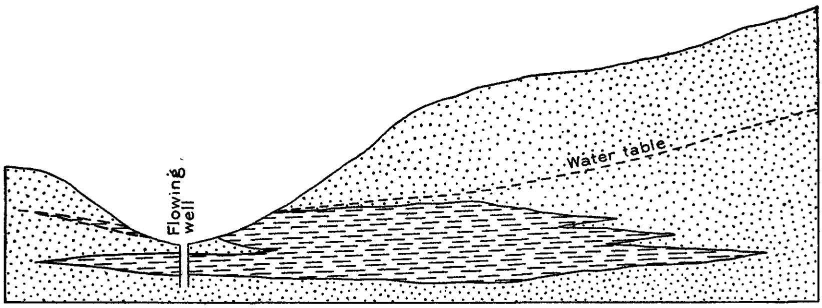

FIGURE 6.—Artesian flow caused by local clay lens.

If it rises above the surface the well is called a flowing well. In general the following conditions are fulfilled in artesian water-bearing beds—an inclined pervious bed lying between two impervious beds and having its outcrop at a height greater than the water table at the well, an outcrop favorable to absorption, a rainfall sufficient to furnish the necessary supply, and the absence of extensive leakage. It has been found that these conditions are nonessential. Fuller [43] has shown that in porous formations, even where the grains of the formation are of uniform size, there may be artesian flow if the permeability of the formation in a direction parallel to the bedding is greater than the permeability in a direction across the bedding.

In western Tennessee artesian conditions are found in the Eutaw and Ripley sands west of their outcrop area and are shown diagrammatically in Plate 5, *C*. The confining beds are the Selma and Porters Creek clay, respectively, and the Eutaw and Ripley formations crop out in the hilly region in the eastern part of the area.

[42] Meinzer, O. E., Outline of ground water hydrology: U. S. Geol. Survey Water-Supply Paper 494, p. 39, 1923.

[43] Fuller, M. L., Artesian flows from unconfined strata: Engineering News, vol. 53, pp. 329–330, 1905.

Water in the sandy layers of the Ackerman formation is under artesian pressure, being confined by the clayey upper beds of the formation. In the extreme western part of the State artesian conditions exist in the Holly Springs and Grenada formations, as at Memphis, being due to a bed of blue clay that forms a continuous layer in the Jackson formation or the upper part of the Grenada formation in the extreme west. Local artesian conditions are also found where a sloping clay lens that crops out on a hilltop may trap the water below it, so that a well located at the lower level and passing through the lens may obtain an artesian flow. (See fig. 6.)

QUALITY OF GROUND WATER

By Francis G. Wells and Margaret D. Foster

Samples of ground water from 176 sources were collected by Mr. Wells in the course of the field seasons of 1928 and 1929. About half of these samples were analyzed in the laboratory of the United States Geological Survey, Washington, D. C., and the remainder were analyzed in the laboratory of the Tennessee Geological Survey. Five analyses of water representing the treated water of such city supplies as treat the well water before distributing it and one analysis of the water representing the water supply of Tiptonville, which is derived from Reelfoot Lake, were made. These analyses are listed in tables according to counties, each table being included with the county description.

CHEMICAL CHARACTER OF NATURAL WATERS

The amount and character of the mineral matter dissolved in a water depend on the chemical composition and physical structure of the rocks with which it has been in contact, the temperature, the pressure, the duration of the contact, and the materials already in solution. The character of a water may, however, be altered by various polluting agencies. Usually the materials thus added are organic matter or its decomposition products. The treatment of a water for municipal or industrial use may also affect its chemical character.

The most noticeable characteristic of most natural waters is their appearance as to color or turbidity, and the removal of color and turbidity is one of the first considerations of any plant for the purification of water for a public supply. Much of the apparent color may be due to clay or other colored matter carried in suspension in water that is, of itself, colorless. In technical discussions of water problems the term "color" is usually confined to the true color caused by dissolved or colloidal material largely derived from decaying leaves or other organic matter, so finely divided that it is not removed by sedimentation or ordinary filtration. It is most pronounced in water from swamps and is usually not noticeable in waters that have been in contact only with rock, sand, or gravel. In some regions colored waters are obtained from deep wells that penetrate beds of lignite or other deeply buried organic material. Ground waters are, as a rule, practically colorless; surface waters are in general noticeably colored even when quite free of suspended matter.

The turbidity and suspended matter in a water may be caused by suspended silt or other inorganic matter or, in industrial and well-populated areas, by the suspended solids of sewage and industrial wastes. Ground waters are normally free from suspended matter except as iron may be precipitated on exposure to air. Suspended matter is an important factor in determining the value of a water for most uses. Its removal is necessary to make water satisfactory as a public supply or suitable for many industrial uses.

The mineral constituents of natural waters considered here are those usually found in quantities sufficient to have a practical effect upon the value of the water for ordinary uses.

The waters of western Tennessee vary considerably in the amount of mineral matter which they carry in solution. In some the mineral content is very low—25 or 30 parts per million; a few others contain almost 1,000 parts per million, but 300 or 400 parts per million of dissolved mineral matter is high for most of the ground waters of this area.

Calcium (Ca) is dissolved to some extent from practically all rocks and may be dissolved in large quantities from limestone, dolomite, and gypsum. Calcium carbonate, the essential mineral of limestone, is but slightly soluble in pure water but dissolves readily in water containing carbon dioxide in solution. Of the unconsolidated deposits of western Tennessee the only formations containing appreciable quantities of calcium carbonate are the Selma clay, the Coon Creek tongue of the Ripley formation, the Clayton formation, and the loess. Ground water from these formations or from the top part of the formations immediately underlying them may have a high content of calcium carbonate.

Water from dolomite or dolomitic limestone usually contains considerable magnesium; other rocks furnish smaller quantities. Magnesium is one of the abundant constituents of sea water and is found in appreciable quantities in water contaminated with sea water or with salts or brines embedded in deposits laid down in the sea in past ages.

Calcium and magnesium are the chief cause of hardness in water. They are also the principal basic constituents of the scale formed in boilers or other vessels in which water is heated or evaporated.

Sodium is a normal constituent of all natural waters. Traces of sodium are found in practically all rocks. It may also be present in a water as a result of pollution by sewage or of contamination with sea water or salts or brines inclosed in marine sediments. The quantity in solution ranges from a few parts per million in most waters in humid regions to several thousand parts in waters from the alkali rocks and soils of the semiarid regions of the Southwest. In some waters the sodium content has apparently been increased by the exchange of the calcium and magnesium in solution for sodium by certain clays capable of such exchange. Moderate quantities of sodium have little effect upon the suitability of a water for ordinary uses. Water containing sodium in excess of 100 parts per million, however, may cause foaming in steam boilers unless precautions are taken to prevent it. Waters that contain large quantities of sodium salts injure crops, and some waters contain so much sodium that they are unfit for nearly all uses.

Potassium is usually present in waters in smaller quantities than sodium, although many rocks contain more potassium than sodium. Approximately equal quantities of sodium and potassium are found in many waters in which the quantities of these two constituents combined amount to less than 10 parts per million. With larger amounts of sodium, however, the proportion of potassium is less. Few waters contain more than 100 parts per million of potassium. In many analyses the sodium and potassium are reported together as sodium. The two elements have practically the same effect in the use of the water.

Carbonate is not present in appreciable amounts in most natural waters. The carbonate of the rocks is held in solution as bicarbonate through the action of carbon dioxide. Waters that come from relatively insoluble rocks may contain less than 10 parts per million of bicarbonate. Waters from limestone or dolomite generally contain from 100 to 500 parts per million of bicarbonate, although some limestone waters contain less than 100 parts. Calcium and magnesium bicarbonate make up the greater part of the dissolved mineral matter of many natural waters. The bicarbonate as such has comparatively little effect upon the use of a water.

Sulphate is derived from various sources in the soil and rocks and from materials added by human agencies—from gypsum, from sulphates resulting from the oxidation of metallic sulphides or organic compounds, or from fertilizers containing sulphates. The waters of some public supplies contain additional sulphate from the aluminum sulphate used in treating the water. In mines, where pyrite (iron sulphide) is exposed to the action of air and water, the oxidation of sulphide and the formation of sulphuric acid is so extensive that serious damage results. Hardness due to calcium or magnesium sulphate may increase the cost of softening, and it makes the scale formed in boilers much more troublesome. If present in sufficient quantity, sulphate may impart a bitter taste to the water.

Chloride is dissolved in small quantities from rock materials. Waters that are contaminated with sea water or that come from deep wells which penetrate brines or salt deposits inclosed in the old marine sediments contain large quantities of chloride. Sodium chloride is a characteristic constituent of sewage, and any appreciable pollution of a water is accompanied by a measurable increase in chloride. The presence of chloride in more than "normal" quantities can not, however, be taken alone as a definite indication of pollution, because of the many other sources from which chloride may be derived. Chloride gives a salty taste to water if present in quantities greater than 300 parts per million.

Nitrate may be leached from rocks, although few rocks contain appreciable amounts of nitrate except in regions where there are nitrate deposits. It may be washed from the soil, especially in areas where nitrate fertilizer is used. Nitrate in water is usually, however, considered a final oxidation product of nitrogenous organic material. Many waters contain less than 1 part per million of nitrate, although as much as 100 parts per million is sometimes found. The interpretation of the presence of abnormal amounts of nitrate with reference to the sanitary condition of a water should be made with extreme caution and only after due consideration of the chloride content, the sanitary surroundings of the source of the water, and the nature of the rock formation from which it is derived. The quantities of nitrate usually found in water have no effect upon the value of the water for ordinary uses.

The mineral constituents considered above are those which are in chemical equilibrium in water. The mineral matter dissolved in a natural water is not a collection of random quantities of several constituents. In practically all waters the quantities of the basic radicles—calcium, magnesium, sodium, and potassium—are together chemically equivalent to the sum of the acid radicles—bicarbonate, sulphate, chloride, and nitrate. If the quantities in solution of all but one are known the quantity of the missing radicle may be calculated to complete the analysis. In addition to these constituents that are in chemical equilibrium with each other all waters contain iron, aluminum, and silica, which are generally supposed to be present in the colloidal state as oxides.

Iron is dissolved from many rocks and may be dissolved from water pipes in sufficient quantities to be objectionable. Some of the waters of western Tennessee contain much iron in solution. In the limestones, shales, and cherts of Paleozoic age the source of the iron is either the oxides or sulphides of iron, which are present in small amounts in these formations. In the Cretaceous and Tertiary formations the iron is dissolved from the oxides and sulphides of iron or from the mineral glauconite. The sulphides of iron are associated with the clays of these formations and are most abundant in the carbonaceous clays. Oxides of iron coat the sand grains of all the unconsolidated sediments in outcrop. It is difficult to determine whether part of the iron oxide was formed on the sand grains at the time of deposition and part formed at the outcrop by the oxidation and precipitation of the iron dissolved in the ground water, but it is certain that much of the iron oxide that now coats and cements the sand grains has been formed at the outcrop. On the other hand, as any iron oxide laid down with the sediments would be dissolved when the formation was buried and reducing conditions existed, it is probable that iron oxides have contributed iron to the ground water. Glauconite is an iron-potassium silicate formed on the sea bottom at shallow depths. It is a common mineral in sediments formed in this habitat. Glauconite is dissolved by ground waters and contributes iron to the solution. From what has been said it follows that the Eutaw formation and the Owl Creek tongue of the Ripley formation give waters with high iron content, but water from the vicinity of lenses of carbonaceous clay in any formation is likely to be high in iron. Small quantities of iron in water are more objectionable than much larger quantities of other constituents. If iron is in solution in excess of about 1 part per million some of it may separate out as the reddish hydrated oxide when the water is exposed to air. It is this precipitated oxide which forms the reddish sediment in many spring and well waters and which causes the reddish stain on white enameled or porcelain plumbing fixtures. A water that contains more than 0.5 part per million of iron is objectionable for laundry work. Many of the waters of western Tennessee have sufficient iron in solution to make them poor for industrial or domestic use. The excess of iron may be removed from most waters by simple aeration and sedimentation or filtration, but a few require the addition of lime or some other substance.

Aluminum is usually present in waters in quantities decidedly less than 1 part per million. It appears to have no particular effect on the use of the water where only normal quantities are present. Its determination was omitted in the analyses made for this report.

Silica is dissolved from practically all rocks. In most waters it is found in quantities of 10 to 30 parts per million. The silica separates with other scale-forming constituents in steam boilers and not only adds to the amount of the scale but makes it harder than it would be without it. Otherwise silica is of no significance in regard to the use of a water.

The hardness or soap-consuming power of a water is due chiefly to the salts of calcium and magnesium. A few waters contain enough iron, aluminum, zinc, or other metal to produce measurable hardness, but such waters are rare. Hardness was formerly differentiated as "temporary" and "permanent". Temporary hardness was that part of the hardness removed by boiling and was approximately the hardness caused by the carbonate and bicarbonate of calcium and magnesium. Permanent hardness was not removed by boiling and was caused by sulphate or other strong acid salt of calcium or magnesium. These terms were not definite and have been replaced by the definite terms "carbonate" and "noncarbonate" hardness. Hardness in general is expressed as the quantity of calcium carbonate equivalent to the calcium and magnesium present. Water having a hardness of less than 50 parts per million is considered soft, and its treatment for the removal of hardness is rarely justified. Hardness between 50 and 150 parts per million does not seriously interfere with the use of the water for most purposes but it does increase the consumption of soap. Its removal by softening processes is profitable for laundries and other industries using soap in large quantities. Treatment of such water for the prevention of scale is also necessary for the successful operation of steam boilers. More than 150 parts per million of hardness is noticed by everyone. If the water contains more than 200 parts per million it is common practice to soften the water for household use or to install a cistern to collect rain water.

Water from some of the wells in the Paleozoic rocks and water from many springs throughout the area contains hydrogen sulphide (H_2S). This is derived from the pyrite which is found in the shale and clay. Hydrogen sulphide imparts an unpleasant odor to water, and its presence in water renders the water unsatisfactory for domestic use.

Carbon dioxide is derived from the atmosphere by the rain and from the oxidation of carbonaceous material in the soil. Carbon dioxide in solution increases the solvent power of water. Many of the ground waters of western Tennessee contain considerable free carbon dioxide. As long as the water remains under the conditions of temperature and pressure that existed underground the carbon dioxide is retained in solution. But on exposure to the air, where different conditions of temperature and pressure prevail, much of it escapes, precipitating iron and sometimes calcium which were held in solution through its action. Water containing free carbon dioxide in solution actively attacks iron pipes.

The chemical character of the ground waters of western Tennessee is shown by the analyses given in tables with the county descriptions. The analyses were studied in regard to the source of the waters in order to compare the chemical character of waters from the same formation. The results are discussed in the descriptions of the geologic formations. The conclusions are general and indicate only the probable quality of the water to be found in the formations considered. The discussions are concerned with the characteristics imparted to the waters by the mineral matter dissolved from the rocks, and it should be understood that the analysis of water for its mineral constituents gives little indication of the sanitary condition of the water.

EXPRESSION OF RESULTS

The analyses made for this report are expressed in parts per million of the radicles determined, in accordance with the long established custom of the United States Geological Survey and the usage of most water analysts. Results given in parts per million may be converted to grains per United States gallon by multiplying by 0.058 or dividing by 17.12.

If one basic and one acid radicle make up the greater part of the dissolved mineral matter it is customary and helpful to refer to the water as characterized by the name of the compound made up of these radicles. A large proportion of the waters from limestone can properly be called calcium carbonate or calcium bicarbonate waters; calcium and bicarbonate together may make up 70 to 90 per cent of the dissolved mineral matter. A brine is a sodium chloride water. If, however, the quantities of several of the acid or basic radicles are of about the same magnitude, it is unjustifiable and misleading to characterize the water by the name of a single compound.

It is not possible to put down the names of the compounds that are dissolved in a water. The hypothetical combinations in which analyses are sometimes reported represent the salts and their quantities that would make up a solution chemically identical with the water.

The composition of some of the waters is shown graphically by diagrams made according to the method used for some years in the United States Geological Survey.[44] The heights of the several sections correspond to the quantities of the radicles, expressed in terms of combining weights rather than in parts per million. One unit of height corresponds to 20 parts per million of calcium, 12 of magnesium, 23 of sodium, 39 of potassium, 61 of bicarbonate, 48 of sulphate, 35.5 of chloride, 62 of nitrate, and 50 of hardness as calcium carbonate. The total hardness is measured to the top of the magnesium. If the bicarbonate block extends above the magnesium block all the hardness is carbonate hardness, but if the top of the bicarbonate is lower than the top of the magnesium, part of the hardness is due to sulphate or even to chloride, if the chloride extends down below the top of the magnesium.

REMOVAL OF IRON AND CARBON DIOXIDE

Many of the waters of western Tennessee contain sufficient iron and carbon dioxide in solution to make them poor for industrial or domestic use. Iron will precipitate from solution, thereby clogging water

[44] Collins, W. D., Graphic representation of water analyses: Ind. and Eng. Chemistry, vol. 15, No. 4, p. 394, 1923.

systems. It stains plumbing fixtures, vessels, and clothes. Carbon dioxide in solution vigorously corrodes iron pipe.

Excessive carbon dioxide is removed from solution by aeration. Aeration will also precipitate iron. The air-lift method of pumping serves this purpose. Spraying, allowing water to fall over a set of tiers, or any system whereby the water is brought into contact with the air is effective in precipitating the iron. Another method of precipitating iron is by the addition of small amounts of lime. After the iron is precipitated it must be removed from the water. At Paris, Tenn., this is effected by allowing the water to flow slowly through a series of tanks in which baffles are inserted in such a manner that the water must flow under and over successive baffles. This method of sedimentation is very efficient. Many other cities in western Tennessee have rapid sand filters, which remove the iron effectively. Sometimes a small dose of alum is added to the water to coagulate the iron hydroxide and make filtration more effective.

A simple system of treating water can be installed for a few thousand dollars. Such a system is easy to operate and gives good results. The simplicity of installation, low cost, and ease of maintenance bring such systems within the reach of the smallest municipalities, and they are feasible for any consumer who uses more than 10,000 gallons of water a day.

UTILIZATION

Dug wells.—Several types of wells are found in western Tennessee. The type used depends on the depth to ground water, the physical character of the underlying formations, the quantity of water desired, and the amount the owner can afford to pay. Formerly dug wells were very common, but they have nearly all been replaced by wells of better types except in chert areas or in districts where a thin water-bearing bed at shallow depth is the only source of water within a depth of 200 feet. The reason for using dug wells in chert areas is that the small fragments of chert cause the bit of the drill to jam and give a great deal of difficulty in drilling but can be readily dug with pick and shovel. A well of small diameter has but small reservoir capacity. A dug well, however, of 3 feet or larger diameter has a storage capacity sufficient to meet the requirements of the average household at any one time. In parts of Shelby and Tipton Counties a bed of Pliocene gravel 2 or 3 feet thick that yields water slowly is found below 30 or 40 feet of loess and is underlain by 100 feet or more of clay or very fine sand. As drilled wells in these areas would have to be sunk to a depth of several hundred feet to reach a coarse sand and would be expensive, dug wells are very largely used. In western Tennessee dug wells are generally 3 feet in diameter and from 20 to 60 feet deep and are curbed with wood, brick, or glazed tile. Shallow wells are very liable to contamination by surface drainage, owing to disintegration of curbing or lack of water-tight curbing below the water table, also by the introduction of foreign material either on the bucket or because the well is not tightly covered and thus may become unsanitary. For this reason, wherever possible, shallow wells should be replaced by drilled wells, and where this is not feasible great care should be exercised in the location of the well with reference to possible pollution from waste water; curbing that is not subject to decay should be used and so installed that it is water tight; a pump should replace the bucket; and the top of the well should be carefully sealed, so that no refuse can gain access to the well.

Wells bored with augers.—Throughout the areas where the Eutaw, Ripley, and Wilcox crop out and where the water table stands from 40 to 110 feet below the surface bored wells are the most commonly used. The unconsolidated sand and clay of these formations are easily bored with an auger, and bored wells are relatively cheap and yield sufficient water for domestic needs. Bored wells are also preferred because they can be equipped with buckets. Though this method of lifting water from the well is a means by which contamination is frequently introduced into the well, in many places the well bucket is used in preference to the lift pump, because the water standing in the pump barrel acquires an iron taste and grows warm, so that it must be pumped off before fresh cold water can be obtained. Long cylindrical buckets with a check valve in the bottom are generally used. Bored wells are 6, 8, or 10 inches in diameter and are usually curbed with cypress or gum. Oak is rarely used for curbing, as it imparts an unpleasant taste to the water. Sometimes tile is employed for lining the well but it is not very popular because it is easily broken. As wood curbing is subject to decay, can not be maintained water-tight, and hence permits the entrance of shallow ground water which may be contaminated, it should be replaced by tile or concrete.

The wells are bored with a steel auger 6, 8, or 10 inches in diameter and 45 inches long. The pitch of the spiral is 5 inches. The surface of the blade is flat, and the cutting lip is sharpened and sometimes has a "toe" of sharp thin steel affixed at its outer edge. This toe is bent down slightly so as to dig into the dirt. A steel rod 1 inch square and 10 feet long is put through the hollow center of the shank of the spiral, and the auger is keyed on. This leaves about 6 feet of rod projecting above the spiral. In use the auger is attached to a rope and lifted and dropped into the hole by means of the rope, which is fastened to a windlass.

A lever 5 feet long with a square boss in the center which fits on the auger shaft is used to rotate the auger. In starting a hole the auger is lifted until it swings freely and then lowered until it touches the ground. If the ground is uneven at this point it is levelled off with a shovel. These precautions are necessary in order to start and keep the hole straight. While operating, one man stands at the windlass and slowly lowers the auger, always having just enough tension to hold the auger vertical, while two men rotate the bit by standing on opposite sides of the lever bar and walking around the hole. When the auger is full of dirt it is hoisted out of the hole and cleaned off. The auger fills for every 30 inches of lowering of the bit. As the hole is deepened additional lengths of rod are screwed on to the original auger shaft. The soil is usually sufficiently moist to adhere to the auger and be hoisted out. As soon as the auger reaches the zone of saturation a pump bucket or sand pump is used for deepening the hole. Such a hole can generally be drilled in one or two days. The auger can be used effectively for holes as much as 125 feet deep, but some wells as much as 175 feet deep are made by this process. Plate 7, *A*, shows such a boring rig.

Punched wells.—Another method used in western Tennessee to make wells in soft unconsolidated materials is punching. A punch has two parts—the cutting barrel and the stem. The cutting barrel consists of a steel cylinder 1 to 2 feet long, split along one side and slightly spread. The lower portion of the cylinder is very slightly expanded, sharpened, and tempered into a cutting edge. This cylinder is fastened to the stem, a heavy pipe 10 feet long, by means of a fork, the shoulder of which is welded to the top of the cylinder and screwed to the end of the pipe. A rope is fastened to the end of the stem, run through a shive at the top of a tripod, and fastened to a drum. The punch is raised from the hole by winding up the rope on the drum, which is rotated by a mule, until the punch reaches the top, when the drum is released by a trip and the punch drops to the bottom of the hole. As the punch enters the clastic material it is spread slightly so that it holds the material by squeezing. The punch is then hoisted out of the hole, the sand or clay removed, and the operation repeated. The hardness of the sand or clay that is being penetrated determines the distance the punch must be dropped. A punch works in moist sand as well as in clay; dry sand must be slightly moistened but not saturated. A punch is shown in Plate 7, *B* and *C*. Wells as much as 150 feet deep are made by this method. Such wells are usually curbed with wood, and the water is drawn by a cylindrical bucket.

Wells sunk by means of bailers.—Another method used for sinking wells in unconsolidated material is by means of a bailer or sand pump. Water is poured into a hole and a bailer is worked up and down in the bottom of the hole. The sand is loosened and forms a thick sludge with the water, and the sludge is then removed by bailing. The bailer consists of a section of tubing 6 to 8 feet long and somewhat smaller in diameter than the well. It has an iron valve at the bottom, either of the flat pattern or the ball and tongue pattern. (See fig. 7.)

Sometimes a sand pump is used which in addition to the bottom valve has a plunger that is worked like the plunger of a water pump and thus sucks the mud into the tubing. This method is very simple and efficient where the materials are loose, but it will not work in hard sand or tough clay. Wells as much as 250 feet deep are made in this way. These wells are 2 or 3 inches in diameter and are usually cased with standard galvanized-iron pipe.

Wells sunk by jetting process.—Jetting, or what is locally called "washing down," is an effective and common method of making wells of small diameter 100 to 300 feet deep in unconsolidated or only slightly consolidated sand and clay. Veatch[45] describes the method as follows:

> In the jetting process the material is loosened and the drillings are elevated to the surface by means of water under pressure. * * * The water is conducted into the well by means of pipes of relatively small diameter, called wash pipes, jet pipes, or drill pipes, and is directed downward near the bottom of the well by means of a suitable bit. The drill is turned from time to time by means of a clamp or wrench and so keeps the hole true and aids the water in wearing away more resistant masses of clay or like substances.

This method is best suited to unconsolidated material but is also used successfully in penetrating consolidated material if not too hard. In this area such wells are usually less than 6 inches in diameter and 300 feet in depth.

Driven wells.—Along the flood plains or "bottoms" of the streams the depth to water is in many places less than 25 feet and driven wells are largely used. A drive point is fastened to the end of a strainer, which is put on a pipe, and this is driven into the ground. When the strainer is below the water table a suction "pitcher" pump is put on the end of the pipe and the well is pumped until all the fine sand and clay has been washed out of the sand surrounding the strainer. Such driven wells are very simple to make.

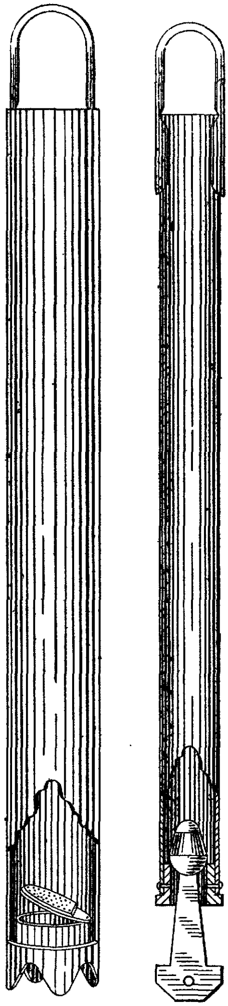

FIGURE 7.—Sand bucket

Wells sunk by hydraulic rotary process.—The hydraulic rotary process is coming into more general use for drilling small wells throughout western Tennessee and in the past has been used almost exclusively in Memphis and elsewhere in the State for drilling wells 6 inches or more in diameter and several hundred feet deep. In this process drilling is accomplished by rotating a string of drill pipe at the lower end of which

[45] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, p. 103, 1906.

is a toothed cutting shoe or a fishtail-shaped bit; when hard rock formations are to be penetrated the fishtail bit is replaced by a rock-roller bit. During the drilling operation mud fluid, which is pumped down the drill pipe under pressure, issues from holes in the bit and returns to the surface between the outside of the drill pipe and the wall of the hole. The mud fluid serves to carry the drillings to the surface, to mud up the walls of the hole, and to form a column of high density both buoying the string of casing and exerting a pressure against the walls of the well to prevent their caving. Unless difficulty from caving is experienced, the hole is not cased until the water-bearing formation is reached. Because of the sealing effect of a high column of mud fluid, the water-bearing sand is sometimes penetrated by the use of a sand pump instead of continuing the drilling with the fishtail bit. For a detailed description of the hydraulic rotary process reference should be made to publications on well-drilling methods.[46]

Often in drilling wells "hardpan" is encountered, and sometimes a well is abandoned because it seems impossible to penetrate the hard layer. The hardpan is never more than a foot or two thick and with proper tools can be penetrated. In most places in western Tennessee coarse sand can be found within a depth of 200 feet, and such sand is readily checked by a strainer. In some places, however, the depth to coarse sand is as much as 350 feet. The cost of a well of this depth is considerable and may represent a capital outlay greater than the small farmer can afford.

Screens.—Some form of screen should be used in wells that end in loose sand, in order to exclude the sand and offer as large an open area as possible to the inflow of water. Screens are made of many materials and are of several types, each type offering some advantage of cost, strength, resistance to corrosion, area of opening, etc. The commonest type consists of metal cylinders containing perforations, which may be of any shape but are most generally circular holes or rectangular slot openings. The slot type is gradually replacing the circular-hole type, as it has many advantages, the chief of which are that the greatest strength with the largest percentage of opening can be obtained with longitudinally cut slots;[47] the slots are less liable to complete clogging, for, as can be readily seen, one large grain of sand can completely close a smaller circular hole, whereas it is very difficult to close a slot completely; and the milling of slots of narrow width is more easily effected than the drilling of holes of the same diameter.

It is desirable to have the width of the slot increase from the outer edge toward the interior of the screen in order that a grain of such a size that it just passes the outer edge may not catch but freely move

[46] Bowman, Isaiah, Well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, pp. 70–75, 1911. Petroleum engineering methods, pp. 53–144, Los Angeles, Petroleum World, 1930. Jeffery, W. H., Well drilling, pp. 232–318, Houston, Gulf Publishing Co., 1925.

[47] Petroleum engineering handbook, p. 151, 1930.

on. This is effected in screens with thin walls by cutting the slot from the inside out; in screens of thicker walls the slot is undercut. The undercutting must not be great, otherwise the wall at the outer edge of the slot is so thin that it is readily worn off. The trade furnishes screens of the slot type made of seamless brass tubing with slots cut either longitudinally or at right angles to the length. One type of brass screen is made of a brass wire of special cross section that is wound in a spiral; the turns of wire interlock with one another to form a screen with a continuous slot. Such screens are available in various diameters and with slots that range in width from 0.06 inch to 0.125 inch.

Another type of screen is made by drilling large holes in a pipe which is either covered with fine woven screen or else wrapped with wire, the size of opening being determined by the spacing of the wire. In wire-wrapped screens wire of various cross sectional shapes, such as triangular or trapezoidal, is used to prevent clogging.

Iron is readily attacked by most waters, and screens made of it will not give long service. As most waters will not corrode brass this metal is widely used in screens. Some waters, however, are chemically very active and rapidly corrode most metals and alloys. To cope with such waters concrete screens with slot openings have been made.

Concrete is also used in strainers in which the water flows through the concrete. A concrete in which the sand and gravel grains are grouted together is very permeable, and yet the pores in the outer surface are small. One screen of this type consists of sectors filled with grouted sand and gravel. The finest sand is at the periphery, and each succeeding layer is coarser than the preceding. This is grouted with cement. Another screen is made of chert gravel about one-eighth of an inch in diameter. This gravel is grouted together, and the permeability of the screen, which is designed to be the same as the permeability of the sand in which it is used, is determined by the amount of cement used in grouting.

The openings in a screen should be as large as possible, for the smaller the openings the greater the resistance offered to the flow of water. The experimental work of Tickell and Coberly on the relation between sand grain size and size of screen opening is summarized by Lake[48] as follows:

> Some excellent experiments on the screening effect of various dimensioned slots on various sized grains and assortments of sands have been made by Prof. F. G. Tickell at Stanford University, from which the following conclusions have been drawn:
>
> 7. If an oil sand is poorly sorted, large grains will form a bridge against the slot and will prevent the passage of finer grains through the slot.
>
> 8. The size of grains capable of bridging the slot depends on the differential pressure at the slot.

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[48] Lake, F. W., Petroleum engineering handbook, p. 152, 1930.

9. If the sand grains are slightly larger than one-half the slot width, they will not pass through at low pressure but will pass through at pressures in the neighborhood of 1,000 pounds.

10. If the sand grains are one-half the slot width or smaller, they will pass through at low pressure.

Additional and more detailed experiments have been conducted by Clarence J. Coberly, of Los Angeles, which have substantiated the conclusions of Professor Tickell. It was found that if the slot opening was more than about three times the diameter of the sand grains they passed through readily, that if the slot opening was less than approximately twice the diameter of the grains they were bridged by the slot, and that in between these ratios there was an unstable condition in which the sand tended to pass through but not readily. In numerous tests on sands composed of various sized grains fairly well assorted, it was found that successively larger slot openings were bridged as the percentage of the larger grains increased. From the tests so far conducted it was reasonable to conclude that in a well-assorted sand such as is the usual occurrence, a slot which would be bridged by those larger grains existing in the amount of between 25 and 30 per cent of the total sand volume would be sufficiently small to retain all of the sand after an initial sorting and arranging of the grains about the slot.

Wells that end in sand are usually developed by back washing, by surging, by pumping, by the use of compressed air, or by a combination of these methods. Bridging of the sand particles across the screen openings is thus overcome, and the fine sand is removed from that portion of the water-bearing formation adjacent to the screen or to the gravel pack around the screen in wells that are finished with a gravel wall. Formerly it was considered that the purpose of a screen was to prevent all sand from entering the well, and hence very small screen openings were used. Within recent years screens having relatively large openings have come into general use, for it is recognized that wells of larger capacity are obtained by removing, during the development process, the fine sand in the water-bearing formation around the well. However, the screen openings should not be too large, for the small grains may abrade the openings as they pass through, allowing slightly larger grains to pass through, and thus a screen may be abraded until it will not check even the largest grains in a sand.

In order to increase the production of wells in fine sands a system of surrounding the screen with a layer of gravel called a gravel wall, is sometimes used. This is most generally used in wells less than 300 feet deep; for greater depths the method is likely to be costly. Various methods of putting in a gravel wall are used. One company employs the following technique. First a test hole is drilled to determine the depth and thickness of the water-bearing bed; then a well 24 to 36 inches in diameter is drilled by means of the hydraulic rotary method to the top of this bed. This hole is cased. Then a screen, the lower 3 feet of which is flared so as to fit the 24 to 36 inch casing, is lowered into the hole on a string of casing, and a few feet of gravel is put in the hole between the inner and outer casing. Bailing is started inside the screen, and the screen is slowly lowered as bailing continues. Gravel is added as the screen is lowered. In this way a wall of gravel is formed around the screen. When the well is finished the outer casing is pulled.

Another company employs a different method. First a well is sunk to the depth planned for the finished well. This well is large, the initial diameter being as much as 6 feet, but diminishes in diameter as the progress of sinking the well necessitates. The excavation is done by an orange-peel bucket, and men may work in the well if necessary. The casing follows upon the excavating, in the same way as a caisson. When the desired depth is reached the well strainer and casing are lowered into the well. Then gravel is added, and the outer casing is pulled slowly so that a foot or two of gravel remains between the inner and outer casing.

Ground-water developments.—All towns in western Tennessee with a population in excess of 800 and some of the smaller towns have public water supplies. All these towns obtain water from one or more deep wells. The wells are usually 6 or 8 inches in diameter, though larger wells are in use. They are equipped with pumps of many types. A few public supplies are pumped directly into the mains, but in general an elevated tank holding 25,000 or 50,000 gallons is used, and this may be supplemented with a reservoir. Except for the iron content, which is objectionable, the waters are good. The larger municipalities precipitate the iron either by a system of aeration or else by treating the water with lime and alum, after which the iron is removed by filtration or sedimentation. The smaller communities do not treat the water, though aeration and filtration cost but little and would eliminate the troubles caused by the iron. More detailed information about each municipal water supply is given in the county descriptions, and the water supply of Memphis is described in a separate section.

The industries both in Memphis and in other parts of the area obtain water from wells, for it is very easy to obtain water in sufficient quantity for industrial use in all parts of the area. In general the water is good for boiler use, neither scaling nor foaming.

The railroads usually obtain boiler water from the numerous perennial streams, for water from the streams whose drainage basins lie within the coastal plain area is very low in dissolved solids and is slightly better for boiler use than well water. The water of the Mississippi and Tennessee Rivers, however, is inferior to well water in quality, the yearly average of the Mississippi River at Memphis being about 200 parts per million total dissolved solids and of the Tennessee

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River at Gilbertsville, Ky., about 100 parts per million,[49] whereas the average of the total dissolved solids in samples from 130 representative wells in western Tennessee was 80 parts per million. The railroads use well water at Memphis and at other places throughout the area where the distance between streams necessitates intermediate watering points.

Practically all farm houses are supplied from wells. Bored wells are the most common though 2, 3, or 4 inch wells sunk by jetting or a rotary drill are employed, and some dug wells are still in use. Very few farmers have power-driven pumps, and relatively few are equipped with water systems. The automatically controlled pump and pressure tank systems operated by electricity or gasoline engines are gradually coming into more general use.

WATER-BEARING FORMATIONS

The geologic formations of western Tennessee fall into two groups, different in age and markedly different in lithologic character. The older, or Paleozoic rocks, crop out over the small part of the area that is contiguous to the Tennessee River. These formations consist of limestone, shale, and chert. The limestones are but poor water-bearing formations, yielding small supplies of hard water; the shales range from the calcareous shales that yield only a little water to the pure shales that yield no water; the cherts, however, yield abundant supplies of water.

Though the Paleozoic rocks are found in outcrop only in the eastern part of the area, they underlie all the region to the west. Any one formation may locally be absent, but there can be no doubt that the general geologic section is continuous. Whatever is said of the different formations in the succeeding description applies to these formations in their general outcrop area and can not safely be applied to the formations where they are deeply buried. It is known that the water derived from these formations where they are buried is very poor in quality, containing considerable sulphide, sulphates, and various salts. These formations also have fewer openings with depth and therefore will yield less water. This is especially true of the chert, which may not be fractured in the western part of the area and is certainly unweathered there, whereas in its outcrop area it owes its condition of anastomosis to fracturing and weathering.

The formations of Cretaceous and Tertiary age are quite different form the Paleozoic rocks. They consist of unconsolidated sand and clay. Loose sands form the commonest type of deposit, and limestone is almost entirely lacking. The formations have a wide distribution and as a rule yield very large supplies of good water. In con-

[49] Clarke, F. W., The composition of the river and lake waters of the United States: U. S. Geol. Survey Prof. Paper 135, pp. 52, 90, 1924.

sidering the unconsolidated deposits the danger of extrapolating the descriptions beyond the outcrop area should be borne in mind. These deposits may thicken toward the west, or other formations may come in. They are known to vary from place to palce and may show a progressive change toward the west; sand formations may give place to clay, coarse sand to fine sand, and vice versa. This is especially true along the southern boundary of the State.

PALEOZOIC ROCKS

ORDOVICIAN SYSTEM

HERMITAGE FORMATION

The oldest geologic formation that crops out in western Tennessee is the Hermitage formation, which is exposed at several places in Hardin County and is visible during periods of very low water in the bed of the Tennessee River at Savannah. Its best as well as its most northerly exposure is at Clifton, where 70 feet of it crops out. It probably underlies the whole area, although only one well in the western part of the area is known to have penetrated it—the well of the Spring Creek Development Co., in Hardeman County. The thickness of the Hermitage in this area is unknown, but in two wells at Iron City, [50] Wayne County, that pass through it the thickness is 126 feet. This formation consists of equal quantities of limestone and shale, which alternate with marked regularity. The limestone is dark bluish gray and fine grained and occurs in layers 2 to 6 inches thick. The shale is blue and fissile.

The Hermitage probably will yield some water. Near its outcrop the quantity of water would be larger. The one analysis of water from the Hermitage formation (Hardin County, No. 35a) is probably not representative, as the sample probably contained a mixture of Tennessee River water, and the high nitrate content indicates pollution. As reported by users, the water from the formation is of poor quality, containing large amounts of hydrogen sulphide and having in solution a large amount of dissolved solids. Near its outcrop the water is of fair quality but is very hard.

ARNHEIM LIMESTONE

The Arnheim formation ranges in thickness from a feather edge to 3 feet. It is a coarse-grained phosphatic cherty limestone and has no importance as a source of water. Except for an outcrop in the vicinity of Decaturville reported by Pate and Bassler, the Arnheim is not known to occur in the area.

[50] Miser, H. D., Mineral resources of the Waynesboro quadrangle, Tenn.: Tennessee Geol. Survey Bull. 26, pp. 27-37, 1921.

FERNVALE FORMATION

The Fernvale formation crops out in the northern part of Hardin County along the Tennessee River. Both the Arnheim and Fernvale formations were partly removed by erosion before the deposition of the Silurian, so they may be missing at any place. The Fernvale ranges from 20 to 40 feet in thickness and consists of two equal parts, the lower limestone and the upper shale. The limestone is light gray and coarsely crystalline. The shale is soft, green, and fissile or platy. Small quantities of water can be obtained from the Fernvale formation. Near the outcrop area the water is of fair quality, but where the formation is buried it is high in dissolved solids and is a poor water. A more detailed discussion of the quality of water from limestone is given on page 62.

SILURIAN SYSTEM

Silurian rocks are found in the valley of Horse Creek in southeastern Hardin County and are widely exposed in the northeastern part of the same county. Most of the exposed rocks of eastern Decatur County are of this age. The most northerly exposure of Silurian rocks is at Allen Mills, 5 miles northeast of Holladay, Benton County, and Silurian rocks probably underlie the whole area. The total thickness of the Silurian rocks is about 200 feet, but in no one place in the area is such a thickness exposed. The Silurian rocks are mostly limestone and argillaceous limestone, though there is some shale. In general they yield but small supplies of hard water. In their outcrop area these rocks yield sufficient water for domestic use, although the water is somewhat hard. Where they are buried the water derived from them is of very poor quality. The discussion of water in limestone on page 62 shows that it is never advisable to drill deeper than 150 to 200 feet in limestone formations. If water has not been encountered at this depth it is better to start a new hole.

BRASSFIELD LIMESTONE

The Brassfield limestone, of early Silurian (Albion) age, occurs at the surface, so far as known, only in the northern part of Hardin County. At one place on Indian Creek a thickness of 25 feet is exposed, but as a rule the formation is much thinner. It is finely crystalline and light gray, is in thin layers of uniform thickness, and contains many small grains of glauconite. It has no importance as a source of water.

WAYNE FORMATION

The middle Silurian or Niagaran rocks in the western valley of the Tennessee River are divided into the Wayne formation below and the Brownsport formation above, each of which has been subdivided into several named members. The members of the Wayne formation are described below.

Osgood earthy limestone member.—The Osgood limestone is not known to crop out in the area described, though it is found on the east bank of the Tennessee River at Clifton. It is a thin-bedded reddish argillaceous limestone which contains some layers of pure limestone and is 15 feet in maximum thickness. This member yields some water.

Laurel limestone member.—The Laurel limestone is found at the surface in the northern part of Hardin County along the Tennessee River and the lower part of Indian Creek. It is in general massive, though it contains some thin layers. Its thickness ranges from 28 feet to the vanishing point. The limestone is purple and reddish. It is differentiated from the Lego limestone with difficulty. The Laurel limestone is not a good source of water, though here and there it contains water-yielding fissures.

Waldron clay member.—The Waldron is a thin member, having a maximum thickness of 4 feet. It is a fossiliferous indurated shaly limestone, usually gray, but in places pink. It yields no water.

Lego limestone member.—The Lego limestone is widely distributed throughout Hardin County, being found along much of the length of Horse and Indian Creeks as well as along the Tennessee River in the northern part of the county. It is also exposed in Decatur County but, as far as known, does not occur at the surface north of Decaturville. The Lego has a maximum thickness of 46 feet and is usually more than 25 feet thick wherever it is exposed. Lithologically it is a compact but subcrystalline pinkish or bluish-gray limestone much of which contains small crystals of pyrite. It occurs in layers from a few inches to 2 feet thick. The Lego limestone is a fair water-bearer.

Dixon earthy limestone member.—What has been said of the distribution of the Lego limestone is true for the Dixon, which conformably overlies the Lego. The Dixon forms ledges along many of the streams where it is well exposed. It consists of argillaceous red limestone and red or purplish shale. It has a maximum thickness of 44 feet and yields some water.

BROWNSPORT FORMATION

The type locality for the Brownsport formation is Brownsport Furnace, in southeastern Decatur County. Pate and Bassler[51] describe the section, which has a thickness of 109 feet. The Brownsport formation is widely distributed in eastern Decatur County and is found in northern and northeastern Hardin County. It has been divided into three members, which are described in ascending order below.

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[51] Pate, W. F., and Bassler, R. S., The late Niagaran strata of west Tennessee: U. S. Nat. Mus. Proc., vol. 34, pp. 407–432, 1908.

Beech River shaly limestone member.—The Beech River member occurs at the surface in many places in central, eastern, and northeastern Hardin County and is extensively exposed in southeastern Decatur County. It is composed mostly of shaly fossiliferous cherty greenish-gray and pink limestone and fossiliferous purplish shale and ranges in thickness from a feather edge to 106 feet. Practically everywhere that the Beech River limestone crops out it forms glades—barren patches of white or light-gray clay and limestone rubble on which is a scanty vegetation of dwarf cedars, bushes, and weeds. The surfaces of many of these glades are covered with well-preserved fossils, which have been weathered out of the limestone.

Bob crystalline limestone member.—The Bob limestone is patchy and irregular in distribution in central, northeastern, and eastern Hardin County but is extensively exposed in southeastern Decatur County. The thickest section exposed in the area is at Bob, where a maximum of 42 feet is found. The Bob limestone is a massive coarsely crystalline light-gray fossiliferous limestone but in places it contains beds of cherty limestone. It is a poor source of water.

Lobelville shaly limestone member.—The general distribution of the Lobelville is the same as that of the Bob member. The Lobelville is a gray, shaly limestone and yellowish shale. It is very fossiliferous, containing many different corals, and is invariably thin-bedded. It has a maximum thickness of 40 feet and furnishes some water.

DECATUR LIMESTONE

The Decatur limestone is widely distributed over the northern and eastern parts of Hardin County, but in the southeast it crops out only in small patches along Horse Creek. It crops out throughout eastern Decatur County, where it finds its typical development. It forms prominent bluffs, such as those on the Beech River north of Decaturville, its type locality. Its most northern exposure is at Allen Mills, 5 miles northeast of Holladay, Benton County, where 20 feet of Decatur limestone occurs at the foot of the bluff. In thickness it ranges from 50 to 70 feet. This formation is massive, occurring in thick layers of coarsely crystalline fine-grained light-gray limestone. The Decatur limestone is a poor water-bearing formation, though water can be found in the few large fissures.

QUALITY OF WATER IN LIMESTONES

Water from the Decatur limestone is similar in quality to that from other limestones in western Tennessee. In this area a few wells derive water from limestone at depths of less than 300 feet, but none derive water from limestone at depths exceeding 300 feet. Hence very few analyses of water from limestones are available, and these give data about water from shallow wells only. Of the analyses made of waters from shallow wells in limestone (Benton County, No. 34; Decatur County, Nos. 27c, 31a, 49; Hardin County, Nos. 35a, 59; Henry County, No. 28) only two can be taken as representative. These are predominantly calcium bicarbonate waters with low content of all other constituents. The other samples show such a high content of nitrate and chloride that they indicate contamination with surface drainage. Water from the well at Savannah (Hardin County, No. 35a), which has a mineral content of less than 100 parts per million, is probably a mixture of Tennessee River water and ground water. Some of the waters from the limestones contain enough iron to make separation by aeration followed by sedimentation or filtration desirable. If the water comes from depths exceeding 200 feet it may contain hydrogen sulphide, which gives the water an unpleasant taste and smell. (See analysis No. 33, Benton County.)

DEVONIAN SYSTEM

Rocks of Devonian age are found in small outcrops in southeastern Hardin County in the valleys of Horse and Indian Creeks but are extensively exposed in eastern, central, and northern Decatur County. In Benton County Devonian rocks occur at the surface over large areas, especially along the valleys of Birdsong Creek and its tributaries, in the environs of Camden, and in the east. They also crop out in Henry County along the west side of the Big Sandy River. The conditions of sedimentation during Devonian time were such that the boundaries of the formations deposited were irregular, and intraformational erosion added to the irregularity of their distribution. This is especially true of the Linden group, of Helderberg (Lower Devonian) age. The formations of this group are spotty in distribution and very irregular in thickness. With the exception of the Decaturville chert they consist of limestone and shale. The maximum thickness of the Linden group is found at Olive Hill, where a section of 174 feet is exposed.[52] Most other outcrops show sections of only 20 to 55 feet. It is not advisable to drill wells deeper than 150 to 200 feet in formations of this group, for the reasons given on page 32. Brief descriptions of the formations of the Linden group follow in ascending order.

ROCKHOUSE SHALE

The Rockhouse shale, which occurs in the southern part of Hardin County, is a calcareous greenish-gray shale interbedded here and there with layers of light-gray crystalline limestone, which are thicker and more numerous toward the base. Its thickness is from 10 to 15 feet. It crops out in only three places in southern Hardin County. Some water of very poor quality is derived from it.

[52] Dunbar, C. O., Stratigraphy and correlation of the Devonian of western Tennessee: Tennessee Geol. Survey Bull. 21, pp. 119-121, 1919.

OLIVE HILL FORMATION

The beds above the Rockhouse shale and below the Birdsong shale have been named Olive Hill formation and separated into several members, described below, in ascending order.

Ross limestone member.—The Ross limestone is an impure dark-gray siliceous and cherty limestone occurring in layers 2 to 5 inches thick. The limestone is hard and commonly forms cliffs. It has a maximum thickness of 80 feet. It is widely distributed in Hardin County, being conspicuously exposed along the Tennessee River at Grand View, and is found along upper Horse Creek at Rockhouse. Some water is procurable from the Ross limestone, but it is not a good source.

Bear Branch limestone member.—The Bear Branch limestone is found in a small area in the northeastern part of Hardin County. It consists of impure coarse-grained limestone and oolitic hematite. It occurs in layers 2 to 12 inches thick and ranges in color from gray to dark red. It is unimportant as a source of water.

Flat Gap limestone member.—The Flat Gap limestone ranges in thickness from a feather edge to 55 feet. It has about the same distribution as the Bear Branch member. It is a thick-bedded, coarsely crystalline or granular white or pink limestone that contains but few fossils. Like the Bear Branch, it is unimportant as a source of water.

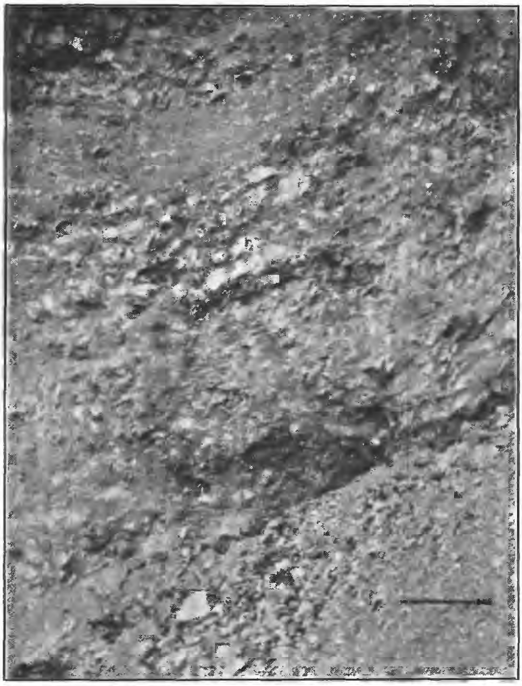
BIRDSONG SHALE

The Birdsong shale, which overlies the Olive Hill formation, is most extensively exposed in Benton County. Its northernmost outcrop is at the steel bridge about 4 miles above the mouth of the Big Sandy River, where 22½ feet of it is exposed. About a mile upstream from the steel bridge is another exposure of the formation, showing a thickness of 35 feet. There are many other exposures in Benton County. The Birdsong shale is also well developed in Decatur County but thins to the south and is not found south of Saltillo. It consists of interbedded bluish calcareous shale and thin bands of crystalline limestone. The lower few feet of the formation consists of limestone, which becomes less abundant higher up. The shale is very fossiliferous and gives rise to the glades of this area. It ranges in thickness from 70 feet to the vanishing point. At Allen Mills, Benton County, the Birdsong shale rests unconformably on the Decatur limestone, the other formations of the Linden group being absent. It is probable that the older Devonian rocks were eroded away in the northern part of the area. The Birdsong has no importance as a source of water but in its outcrop area would probably yield very small supplies.

DECATURVILLE CHERT

The Decaturville chert is found as far north as southern Benton County, where it crops out in the valley of Birdsong Creek. It occurs

A. GRAVEL PIT IN CAMDEN CHERT, CAMDEN



B. CLOSE VIEW OF CHERT, SHOWING ITS ANGULAR FRAGMENTAL NATURE

on Saltillo, Grandview, and Dry Creeks, in Hardin County, and is widely distributed over Decatur County. However, it may be locally absent due to intraformational erosion. The Decaturville is a yellow to gray chert, in places stained by iron oxide. It is thin-bedded and porous, and the upper 6 inches of the formation is very fossiliferous. It is generally from 5 to 6 feet in thickness, though locally it probably attains a maximum of 10 feet. This formation yields medium-sized supplies of water. The water derived from it varies considerably in chemical character and in this respect is similar to the water from the Camden chert. (See p. 66.)

QUALL LIMESTONE

In Hardin County the Quall limestone unconformably overlies the Decaturville chert, the top formation of the Linden group, and unconformably underlies the Harriman chert. It consists of thick-bedded dense cherty gray limestone, nowhere more than about 10 feet thick. The Quall limestone and Harriman chert are of Oriskany (Lower Devonian age). The Quall formation occurs in patches so small that it has no importance as a source of water.

HARRIMAN CHERT

Above the Quall limestone is the Harriman chert, which is nearly white on fresh exposure but weathers to shades of yellow and buff. It is exposed in layers from a few inches to a foot in thickness and is very hard and brittle. In its outcrop it is thoroughly fractured and forms a rubble of small angular fragments. It ranges in thickness from 30 to 55 feet. It is extensively exposed in Benton County and forms chert hills in northern Decatur County but is not found to the south except at Grandview and Cerro Gordo. In Decatur County the Harriman chert furnishes good supplies of water, which shows the same variation in chemical character as the water from the Camden chert. (See p. 66.)

CAMDEN CHERT

The Camden chert, of Middle Devonian (Onondaga) age, is a white to buff-yellow flinty, hard, brittle chert, resembling novaculite. It occurs in thin layers usually from 1 to 3 inches thick, rarely as much as 8 to 10 inches. These layers are commonly separated by soft gritty clay along the bedding planes. In some places the chert is calcareous, and in many places it contains considerable clay. Locally there are irregular more or less vertical pockets of white powdered silica, the result of leaching along ground-water channels. Where the formation contained considerable clay leaching has removed the lime, leaving the clay as a filling around nodules of chert. In some localities the chert content is low and large lenses of almost pure clay are found. The chert is everywhere extremely fractured, so that any face is seen to consist of a mosaic of irregular blocks, which quickly break down to form a rubble slope. (See pl. 8, *A*, *B*.)

The Camden chert has a maximum thickness of 240 feet. It forms most of the chert hills that occur in Benton County and is exposed in a few places in Henry County along the west side of the Big Sandy River. It is found in northern Decatur County but does not extend as far south as Persons or Perryville. It may occur under the younger deposits to the west. It is difficult to differentiate between the Camden and Harriman cherts in the field, for they are very similar in their weathered forms, and the only safe criterion is the evidence afforded by fossils. The Camden is an excellent water-bearing formation in this region. It is the source of many springs.

Eight samples of water from the Camden chert, at varying depths, were analyzed (Benton County, Nos. 10a, 10b, 32, 35; Carroll County, No. 17; Decatur County, No. 2; Henry County, No. 28, 46). These waters vary widely in mineral content and chemical character. In the following table No. 1 is a water of high mineral content in which sodium predominates, with practically equivalent amounts of bicarbonate and sulphate; No. 2 is a calcium bicarbonate water of moderate mineral content; No. 3 is a water of low mineral content that can not be said to be characterized by any particular constituent. The waters from the Camden range from very soft water, such as No. 3 of the following table, to water containing about 200 parts per million of total hardness. The analyses indicate that the deeper well waters are more highly mineralized than the shallow well waters. This may be due to the greater leaching of the lime from the chert near the surface. The content of iron in waters from shallow wells is usually sufficiently low to be unobjectionable, but water from deeper wells generally should be treated by aeration followed by sedimentation or filtration for the removal of the excess iron. Water from the Camden chert at depths of a few hundred feet may contain considerable hydrogen sulphide. The waters from the Decaturville and Harriman cherts are similar in chemical character to the water from the Camden chert.

Analyses of waters from the Camden chert

[Parts per million]

	1	2	3
Silica (SiO_2)	12	6.2	13
Iron (Fe)	.15	1.5	.11
Calcium (Ca)	19	75	3.1
Magnesium (Mg)	3.7	5	1.3
Sodium (Na)	167	2 (Na + K)	2.9
Potassium (K)	5.0		.8
Bicarbonate radicle (HCO_3)	194	202	5.0
Sulphate radicle (SO_4)	151	40	4.9
Chloride radicle (Cl)	84	3	2.5
Nitrate radicle (NO_3)	1.9	.4	7.5
Total dissolved solids	542	240	42
Total hardness as $CaCO_3$ (calculated)	63	208	13
Date of collection	June 19, 1929	June 22, 1929	Sept. 29, 1928
Analyst [a]	M. D. F.	D. F. F.	M. D. F.

[a] M. D. F.—Margaret D. Foster, U. S. Geological Survey, Washington, D. C.; D. F. F.—D. F. Farrar, Tennessee Geological Survey, Nashville, Tenn.
1. Water with high mineral content from well 1,000 feet deep (No. 9c, Benton County, p. 120).
2. Water with medium mineral content from depth of 270 feet in well 31a, Benton County (p. 120).
3. Water with low mineral content from well 20 feet deep (No. 2, Decatur County, p. 147).

PEGRAM LIMESTONE

The Pegram limestone, also of Middle Devonian (Onondaga) age, is found in four exposures in the western part of Tennessee, none of which lie within the area of this report, but it is believed to be present in places. It is a pure-white thick-bedded limestone and because of its spotty distribution is of no value as a source of water.

DEVONIAN OR CARBONIFEROUS SYSTEM

CHATTANOOGA SHALE

The Upper Devonian, if present in western Tennessee, is represented by the Chattanooga shale. Some geologists, however, consider this formation to be of Mississippian age. It crops out in the valleys of southeastern Hardin County, on the hillsides of southeastern Decatur County, and at scattered localities in northeastern Benton County. It probably underlies much of the area, but it is not continuous in its distribution and may be lacking in places. It consists of a basal member, the Hardin sandstone, and the shale proper. The Hardin member is nowhere very thick, in this area ranging from 2 to 15 feet, but a maximum of 22 feet is reported from Wayne County. The shale is a black fine-grained fissile shale, which splits like slate into very thin flat sheets. It gives a petroliferous odor when hit with a hammer and contains much pyrite. The Chattanooga shale yields very little water, which is of poor quality. The overlying Fort Payne chert contains abundant water. The impervious Chattanooga shale deflects the downward circulation of water in the Fort Payne, with the result that along the valleys where the Chattanooga crops out springs are very abundant. The valley of upper Horse Creek is a good example of this. The Hardin sandstone is usually from a few inches to 3 or 4 feet thick but has a maximum development at Olive Hill, where it attains a thickness of 15 feet. It is very irregular in distribution. It consists of a single massive bed of fine-grained muddy-gray sandstone. Its thinness and small, irregular extent preclude its being of value as a source of water.

CARBONIFEROUS SYSTEM

MISSISSIPPIAN SERIES

The formations of unquestioned Mississippian age that occur in the area under discussion are, in ascending order, the Ridgetop shale, ths Fort Payne chert, and the St. Louis limestone. As the St. Louie has only a very sparse distribution and in its weathered outcrop is similar to the Fort Payne, no attempt will be made to differentiate it in this report.

RIDGETOP SHALE

The Ridgetop shale is a gray to black siliceous shale that directly underlies the Fort Payne chert in Hardin County. It is not a good water bearer, and as the Fort Payne is present wherever the Ridgetop is found it has no importance as a source of water.

FORT PAYNE CHERT

The Fort Payne chert occurs along the sides of the valleys in southeastern Hardin County, and most of the large springs in this area issue from it. It covers the uplands of northeastern Decatur County, occurs at the surface over most of eastern Benton County, forms a narrow band along the eastern boundary of Henry County, and probably underlies the younger formations to the west. The Fort Payne is a dark calcareous chert in beds 1 to 4 inches thick which have been broken by folding into angular blocks a few inches square. It weathers to a yellow color and when exposed is full of solution pores. Its outcrops consist of rubble composed of loose angular fragments. In some places it has been weathered to form tripoli. No exact figures on the thickness of the Fort Payne in this area are available. It may attain a thickness of 200 feet in some places, but its usual thickness is from 50 to 100 feet.

The Fort Payne is the source of many large springs, which furnish excellent water. Wells sunk into the fractured weathered portion of the Fort Payne formation obtain water in abundance.

The waters from the Fort Payne formation (Benton County, Nos. 8, 15, 53; Hardin County, Nos. 28, 71), which vary extremely in quantity and character of dissolved mineral matter, can be divided into three groups on the basis of their mineral content—water containing less than 100 parts per million of total dissolved solids, water containing less than 1,000 parts per million, and water containing more than 1,000 parts per million. These groups are determined by the amount of ground-water circulation that takes place in the formation. Where the Fort Payne chert is the surface formation and is thoroughly leached by rapidly circulating ground water, it yields soft water of low mineral content, which falls in the first group and except for the iron content, which may need to be removed by aeration followed by sedimentation or filtration, is of excellent quality for all uses. The analysis of a representative sample is given in the following table. Most of the waters derived from the Fort Payne formation in the area covered by this report fall in the first group.

Waters of the second group are obtained from the Fort Payne chert where it occurs at shallow depths and is sufficiently fractured to allow some circulation of ground water. The mineral content of waters of this group ranges from 100 to 1,000 parts per million. An average of 14 analyses is given in the following table and represents a calcium bicarbonate water containing about 200 parts per million of dissolved mineral matter. The third group comprises waters obtained from the Fort Payne formation at depths where there is very little movement of ground water. These waters are high in total dissolved solids and unlike those of the other groups contain predominant calcium sulphate and sodium chloride. It is probable that these waters are modified connate waters. The high content of calcium sulphate is probably brought about by solution of the gypsum present in the argillaceous portions of the formation. These waters have too high a mineral content to be suitable for any use. An average of 5 analyses from this group is given in the following table:

Analyses of waters from the Fort Payne chert

[Parts per million]

	1	2	3		1	2	3
Silica (SiO_2)	4.3	14	17	Sulphate (SO_4)	11	20	1,883
Iron (Fe)	1.3	.47	7.5	Chloride (Cl)	6	6.7	700
Calcium (Ca)	9	52	591	Nitrate (NO_3)	.3	1.0	1.6
Magnesium (Mg)	2	11	135	Total dissolved solids	52	207	3,970
Sodium (Na) and potassium (K)	4	8.7	646	Total hardness as $CaCO_3$ (calculated)	31	------	------
Bicarbonate (HCO_3)	24	195	173				

1. Representative analysis of waters containing less than 100 parts per million of total dissolved solids (Benton County, No. 52, p. 120).
2. Average of 14 analyses containing between 100 and 1,000 parts per million of total dissolved solids. Piper, A. M., Ground water in north-central Tennessee: U. S. Geol. Survey Water-Supply Paper 640, p. 122, 1932.
3. Average of 5 analyses containing more than 1,000 parts per million o fdissolved solids. Piper, A. M., op. cit., p. 122.

ST. LOUIS LIMESTONE

The St. Louis limestone is found at the surface over a small area in northeastern Henry County between the Big Sandy and Tennessee Rivers. It is a gray porous limestone containing considerable chert. It does not crop out but weathers to form a clayey rubble containing angular fragments of yellow fossiliferous chert. In Henry County large springs issue from it at the foot of the hills. The chemical character of the water from the St. Louis limestone in this area is similar to that of the water from the Fort Payne chert.

MESOZOIC ROCKS

CRETACEOUS SYSTEM

TUSCALOOSA FORMATION

The Tuscaloosa formation as described at its type locality consists of sand, clay, and gravel. Berry [53] has shown that this is a delta formation which thins toward the north and becomes prevailingly gravelly. The Tuscaloosa probably covered all of this area at one time, but most of it has been removed by erosion, and now only iso-

[53] Berry, E. W., Upper Cretaceous floras of the eastern Gulf region in Tennessee, Mississippi, Alabama, and Georgia: U. S. Geol. Survey Prof. Paper 112, p. 13, 1919.

lated remnants are to be found. It occurs only in southeastern Hardin County in the area under consideration, though it crops out east of the Tennessee River in Decatur County.[54] No good sections were encountered, and its thickness in Hardin County can not be accurately given but probably ranges from 10 to 100 feet.

The Tuscaloosa formation consists of well-rounded waterworn pebbles most of which are 1 inch in diameter, although many are larger, as much as 6 inches. The pebbles consist mostly of chert derived from the Mississippian and Devonian chert formations. The formation shows some stratification of the coarse and fine pebbles. In most outcrops there is very little sand present, but in some it is more abundant. In places the pebbles have been cemented by iron oxide, forming a very hard conglomerate.

The Tuscaloosa forms an excellent source of water wherever it occurs at or near the surface. Usually water is found running out of it along the sides of the valleys and ravines where it is exposed, and as in its area of outcrop the population is sparse these springs furnish all needs. Its small areal extent precludes large water developments from it, but supplies of as much as a few thousand gallons a day could be obtained in favorable localities. No analyses of water from the Tuscaloosa were obtained, but the users report that it is of excellent quality, being low in dissolved mineral matter.

EUTAW FORMATION

The Eutaw formation in western Tennessee is divided into the Tombigbee sand member below and the Coffee sand member above. These two members are nowhere sharply demarked, and it is probable that the Tombigbee sand grades into the Coffee sand.[55] These deposits were laid down by a transgressing sea, the Coffee sand representing the shallow-water stage of deposition and hence being slightly younger than the Tombigbee sand.

The Tombigbee sand caps the hills of eastern Hardin County. Near Burnsville, Miss., it contains a small marine fauna, and fossils perhaps from the same horizon have been collected in Hardin County, about 5 miles east of Nixon on the Florence road. The remainder of the Eutaw formation in western Tennessee belongs to the Coffee sand member. Owing to the difficulty of differentiating the Tombigbee sand from the Coffee sand the two members will not be treated separately but the formation will be discussed as a unit.

[54] Wade, Bruce, The gravels of west Tennessee Valley: Resources of Tennessee, vol. 7, pp. 55–89, Tennessee Geol. Survey, 1917.

[55] Wade, Bruce, The fauna of the Ripley formation on Coon Creek, Tennessee: U. S. Geol. Survey Prof. Paper 137, p. 6, 1926.

DISTRIBUTION AND THICKNESS

The Eutaw formation is found at the surface over the eastern part of the area under discussion as a belt several miles wide in the south but diminishing to almost nothing at the Kentucky line. It forms the tops of all ridges and hills in Hardin County, occurs in the western half of Decatur County, occupies a narrow strip 1 to 3 miles wide along the eastern boundary of McNairy and Henderson Counties, and continually decreases in width as it passes north through central Benton County to eastern Henry County. As it dips toward the west at the rate of 20 to 30 feet to the mile, it is found at progressively greater depths below all the region to the west. The Eutaw lies on the slightly uneven surface of the Paleozoic rocks; in some places it has been removed by erosion, but it covers most of the above-mentioned area with a mantle of sand and clay that ranges in thickness from 20 feet in the vicinity of Dulac, northeastern Henry County, to a maximum of 250 feet at the western edge of its outcrop area in southern Hardin County. West of its outcrop area the only well that is surely known to pass through the Eutaw formation is the one on the Sain farm, 5 miles south of Bolivar. (See p. 76.) The record of this well shows the Eutaw to have a thickness of 218 feet here, and it is probable that the formation thickens to the west. Whether well 25 at Memphis (p. 284) penetrates the Eutaw is questionable, as the log that was obtained is not sufficiently accurate to serve as a basis for definite correlation. From a study of the log of the test well of the Ira T. Johnson Co. near Ridgely, Obion County (p. 235), it seems probable, however, that the Eutaw was penetrated at a depth of about 2,500 feet.

LITHOLOGIC CHARACTER

Although the Eutaw formation is dominantly sandy, clay is always found with the sand. The most usual condition is a series of rapidly alternating layers of sand and clay, the sand occurring in laminae from a quarter of an inch to 6 inches thick with sheets of white, dark-gray, or black clay one-sixteenth to one-half inch thick. The clay layers thicken laterally into lenses several feet in thickness, which in turn give place to the thin sheets. Almost every outcrop of the Eutaw shows the condition just described, but in some localities solid beds of clay are found. These clay beds are dark brown to black and are composed of fissile paper-thin laminae. Their carbonaceous content is high, in places being enough to form argillaceous lignite. Fragments of leaves and wood are abundant, and marcasite is common. The best exposure of the Eutaw formation in western Tennessee is found at Coffee Bluffs, on the west side of the Tennessee River about 4 miles north of Savannah, Hardin County. Here a section of more than 215 feet is exposed. The section as given by Glenn[56] is as follows:

Section of Coffee sand member at Coffee Bluff, Tenn.

	Feet
1. Back half a mile west of the bluff red and yellow chert gravels of Pliocene age with overlying reddish sandy clay	15
2. Along descending slope of road from above point to edge of the bluff are poorly exposed light-colored sands and leaden-colored clays interbedded in thin layers which are usually minutely laminated	120
3. At top of bluff light-colored sands similar in color, texture, and structure to those below	13
4. Dark slate-colored clay in thin laminae, usually a very pure and fine-grained clay but in places with thin sandy layers. It contains small fragments of indistinct plants and showed at its base local unconformity with the underlying beds	25
5. Fine gray sand interbedded with slaty or leaden-colored clay in fissile papery laminae. The sand and clay are often interlaminated and more or less cross-bedded; in places a relatively pure bed of sand or clay several feet thick grades over along the bedding plane into the other within a few yards. On the surface of the thin fissile shales are indistinct leaf impressions. The sand and clay alike carry more or less lignitized wood, which is in small pieces except in the lower part of this division where logs of it are found. Decomposing pyrite is associated with the lignite. Two logs of petrified wood projected from this sand and clay when Safford made the measurements recorded on page 412 of his Geology of Tennessee. These have since disappeared by the recession of the bluffs from undercutting by the river. Some of the sand is flecked with fine mica particles. In places a tendency to induration is noticeable in the sands, though generally they are rather soft. The cross-bedding is always on a small scale, and frequent reversals of direction are to be seen	40
6. Sand varying in color from light gray to canary-yellow, micaceous	3
7. Sand, gray and lignitic, with much decomposing pyrite, to water's edge	15

The sand of the Eutaw formation is composed dominantly of subangular quartz and chert grains. Muscovite is a universal accessory mineral and in some places is so abundant that the sand sparkles in the sun as if made up entirely of this mineral. Much of the muscovite occurs in definite layers a fraction of an inch thick. The sands are of variegated color but usually are red, yellow, or buff, though some white sand is found. The red coloration is due to a surface coating of iron oxide which covers all the grains. This staining may have resulted from the oxidation of the iron in the percolating water,

[56] Glenn, L. C., Underground waters of Tennessee and Kentucky west of the Tennessee River: U. S. Geol. Survey Water-Supply Paper 164, pp. 24–25, 1906.

which takes place near the surface of the ground and may be absent in depth. The sands show small-scale cross-bedding. In the central part of Decatur County, in the vicinity of Parsons and Decaturville, the basal part of the Eutaw contains irregular lenses of fine chert and quartz gravel, some of them several feet thick. This material has not been found elsewhere. In northern Decatur County and in Benton County a bed of black lignitic clay about 20 feet thick occurs near the base of the Eutaw formation in many outcrops.

WATER-BEARING PROPERTIES

The laboratory analysis of four samples from the Eutaw formation shows that they are fine grained, being composed largely of material less than 0.25 millimeter in diameter. The uniformity coefficient has a wide range, from greater than 6.1 to 1.5, which is very low. The porosity is high, ranging from 516 to 398. The coefficient of permeability ranges from 379 to 104. These factors indicate that the sandy parts of the Eutaw are fair water bearers and compare favorably with the other sands. It must be borne in mind, however, that the presence of interlaminated clays in the deposits makes the Eutaw sand a poorer source of water than any other in the region. Also the Eutaw changes abruptly from place to place, and intercalated with it are large masses of clay. It is difficult to find a section of clay-free sand more than 10 feet thick, and even such a section may have some clay seams that give trouble. At any one place it may be difficult to find a layer of sand in which to end a well, but a change of site should solve this difficulty. The Eutaw will furnish ample water for farm wells, but it will be difficult to develop wells in this formation with a capacity of more than 300 gallons a minute.

The logs of the Spring Creek Development Co.'s well, in Hardeman County; the Ira T. Johnson Oil Co.'s oil test well, in Obion County; and the deep well at Memphis afford scanty and imperfect data but seem to show that the sandy parts of the formation continue to the west and are present in about the same relative amounts as in their outcrop area.

The pressure-indicating surface in the Eutaw formation in its outcrop area depends on topographic position. To the west of the outcrop area there are no data available with the exception of the log of the deep well at Memphis, which has not been definitely correlated. The static level in this well is 360 feet above mean sea level.

QUALITY OF WATER

Twelve samples of water from the Eutaw formation were analyzed. These analyses, as well as 48 analyses from the Eutaw formation in Mississippi,[57] indicate that the waters from this formation vary

[57] Stephenson, L. W., Logan, W. N., and Waring G. A., The ground-water resources of Mississippi: U. S. Geol. Survey Water-Supply Paper 576, pp. 35–36, 1928.

considerably in the amount and character of the dissolved material. The waters from the Eutaw in Tennessee can be divided into three groups, examples of each of which are given in the following table. One group includes waters from the outcrop area of the Eutaw formation and is represented by seven analyses (Benton County, No. 60; Hardin County, Nos. 3, 35b, 36; Henderson County, No. 11a; McNairy County, Nos. 5, 17). Three of these analyses show high nitrate and chloride, which may be obtained from surface sources. The other four samples, which may be taken as representative of the formation, are soft waters of low mineral content varying considerably in character. Some of the waters contain enough iron to make its removal by aeration followed by sedimentation or filtration necessary. Analysis 1 in the following table represents a water from this group. A second group includes waters derived from the Eutaw formation to the west of its outcrop area but at depths less than 1,000 feet. The content of total dissolved solids in waters from this group for which analyses are available (Henderson County, No. 14; McNairy County, Nos. 3, 11b, 12, 14) range from 193 to 290 parts per million except in one sample, which contains 875 parts per million and which is probably derived from a sandy layer of the base of the Selma formation and should not be included in this group. The other samples of this group are all calcium bicarbonate waters of low sodium and chloride content, but with varying amounts of sulphate. Some of these waters should be treated to make them satisfactory for laundry use and for use in steam boilers, and in some the iron content is sufficiently high to necessitate its removal. Analysis 2 in the table represents water of this group.

Though the water from the Eutaw formation in its outcrop area is fairly soft and has a moderately low content of dissolved solids, the water obtained from deep wells that penetrate the Eutaw in Mississippi [57a] contains over 1,000 parts per million total dissolved solids and is characterized by sodium chloride.

Analyses of waters from the Eutaw formation

[Parts per million]

	1	2	3	4
Silica (SiO_2)	6.2	19	16	16
Iron (Fe)	.8	.27	.40	1.7
Calcium (Ca)	14	52	3.2	5.5
Magnesium (Mg)	2	20	1.0	1.8
Sodium (Na)	10	7.7	432	269
Potassium (K)	1	5.1		
Bicarbonate (HCO_3)	20	208	[a] 1,068	[b] 494
Sulphate (SO_4)	23	55	1.8	2.4
Chloride (Cl)	18	2.8	16	142
Nitrate (NO_3)	1.3	1.0	.02	0
Total dissolved solids	86	260	1,026	692
Total hardness as $CaCO_3$ (calculated)	43	212	12	21

[a] Includes 71 parts per million of carbonate (CO_3).
[b] Includes 14 parts per million of carbonate (CO_3).

1. Analysis of water from the Eutaw formation in its outcrop area (Benton County, No. 59, p. 120).
2. Analysis of water from the Eutaw formation to the west of its outcrop area, but at depths less than 1,000 feet (McNairy County, No. 11b, p. 233).
3. Analysis of water from the 2,656-foot well at Memphis (analysis 10, p. 287).
4. Analysis of water from Eutaw formation in Clay County, Miss. U. S. Geol. Survey Water-Supply Paper 576, p. 132, 1928.

[57a] Stephenson, L. W., Logan, W. N., and Waring, G. A., op. cit., pp. 35-36.

SELMA CLAY

The Selma clay crosses the area in a direction a little east of north, forming a belt that diminishes in width from 8 miles at the southern boundary to the vanishing point in central Henderson County. Formerly [58] the Selma formation was believed to continue north into Kentucky, but recent work indicates that the supposedly northward continuation of the Selma formation is the Coon Creek tongue of the Ripley formation.[59] The most northerly outcrop in Tennessee known to contain fossil shells is in central Henderson County, on the old Lexington-Parsons road 2.2 miles west and a little north of Chesterford. Here the road crosses a creek and goes up an abrupt hill. Where the road has worn away the surface soil, typical black marl of the Coon Creek, is exposed and fossil shells are abundant. Stephenson [59] identifies this fauna as Coon Creek. The most northerly exposures of the supposed Selma contain only fossil molds, the shells having been weathered out. Though no systematic collections of these molds were made, the fossils recognized were more characteristic of the Coon Creek than of the Selma, and the lithologic characteristics of the material also indicate that the bed belongs with the Coon Creek rather than with the Selma formation. Unmistakable Selma fossils have been found at several outcrops in southern Henderson County. As it is impossible to differentiate the Selma from the Coon Creek in the usual well log in this report, any Coon Creek that may be present in a well is included in the material classified as Selma. A study of the microfauna of the Selma formation and the Coon Creek tongue of the Ripley formation made by Cushman [60] has revealed a rich fauna, which furnishes a basis for the accurate correlation of these formations from well drillings. Like the Eutaw formation, the Selma dips from 20 to 30 feet to the mile toward the west and underlies all of the region west of its outcrop. In southern McNairy County it has a thickness of about 210 feet, but by the time it reaches central Henderson County it has thinned out. The well of the Spring Creek Development Co., in Hardeman County, 25 miles west of the western edge of the Selma outcrop, shows a thickness of about 172 feet for this formation. The deep well at Memphis (p. 284) gives no positive data. The top of the Cretaceous is believed to be at 2,371 feet, but how much of the material below this belongs to the Selma and how much to the Ripley formation can not be determined, though most of it is certainly Ripley.

The Selma clay was deposited under marine conditions in water of sufficient depth to keep the bottom free from wave action. Though much of the lime has the characteristics of chemically precipitated

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[58] Wade, Bruce, Recent studies of the Upper Cretaceous: Tennessee Geol. Survey Bull. 23, p. 58, 1920.

[59] Stephenson, L. W., oral communication.

[60] Cushman, J. A., A preliminary report on the Foraminifera of Tennessee: Tennessee Geol. Survey Bull. 41, 1931.

calcium carbonate, fragments of shells from the numerous marine organisms that swarmed in these waters formed a part of the sediment, and the large shells of *Inoceramus* and *Exogyra* are very conspicuous throughout the formation. Clay and sand were brought to this sea and were deposited along with the lime, so that the formation consists of chalky clay and argillaceous sand. Specks of glauconite are found throughout the formation but are very abundant near its base, where the Selma consists of a glauconitic sand indurated by lime. The unweathered clay when wet is slate-blue and is locally known as "blue dirt." Its weathered surfaces are from grayish white to gray and are strewn with fossils.

Though the Selma is slightly porous it is not a water-bearing formation. Very small quantities of water will seep out of it, but the water is highly charged with mineral matter, has an unpleasant taste, and is poor water for any purpose.

RIPLEY FORMATION

DISTRIBUTION AND THICKNESS

West of the Selma clay and paralleling it in trend is a broad band of sand and clay of the Ripley formation, which ranges in width from 18 miles in the south to 8 miles at the northern boundary of Tennessee. This formation is found at the surface over most of McNairy, Chester, and Henderson Counties, the western part of Benton County, and the eastern half of Carroll and Henry Counties. It has a maximum thickness of 600 feet in southern McNairy County but thins to about 350 feet at the Kentucky line. It dips 30 feet to the mile toward the west and underlies all the younger formations.

The well of the Spring Creek Development Co., 5 miles south of Bolivar, in Hardeman County, furnishes the only precise measurements of thickness and the only detailed description of lithology of the Ripley formation west of its outcrop area. The log of this well is as follows:

Log of well of Spring Creek Development Co., Hardeman County

Geologic age	Formation		Thickness (feet)	Depth (feet)
Eocene.	Holly Springs sand.	Soil, sandy loam	2	2
	Porters Creek clay.	Soapstone	14	16
		Quicksand	6	22
		Lime, soft, gray	82	104
		Sand, green; water	16	120
		Sandstone, soft, blue	9	129
	Clayton formation.	Lime, soft, blue	17	146
		Lime, soft, gray	104	250

Log of well of Spring Creek Development Co., Hardeman County—Continued

Geologic age	Formation			Thickness (feet)	Depth (feet)
Cretaceous.	Ripley formation	Owl Creek tongue.	Marl, sandy, gray	10	260
			Shale, black, hard	51	311
			Sand, pepper and salt; water	69	370
			Shale, black, hard	42	412
			Sand, coarse, brown; shells	6	418
		McNairy sand member.	Marl, sandy, gray	16	434
			Sand, brown; water	16	450
			Marl, sandy, blue	30	480
			Sand, gray; water	71	551
			Lime, hard, white	4	555
			Sand, green; water	57	612
			Lime, hard, gray	3	615
			Marl, sandy, blue	45	660
			Sand, gray; water	58	718
			Lime, hard, gray	2	720
			Sand, white; water	28	748
			Lime, hard, gray	2	750
			Sand, hard; water	33	783
			Marl, sandy, blue	18	801
			Lime, hard, white	3	804
			Sand, gray; water	16	820
		Coon Creek tongue.	Marl, sandy, black	30	850
			Lime, soft, blue	22	872
			Shale, black, hard	8	880
			Marl, sandy, black	60	940
	Selma clay.		Lime, "blue rock," soft	52	992
			Lime, shells, blue	9	1,001
			Lime, "blue rock," soft	14	1,015
			Lime, shells, blue	36	1,051
			Shale, black, hard	15	1,066
			Lime, soft, white	23	1,089
			Sand, gray; water	17	1,106
			Lime, hard, gray	1	1,107
			Sand, brown	2	1,109
			Lime, soft, blue	3	1,112
	Eutaw formation.		Sand, gray, mica; water	10	1,124
			Clay beds, sand intervene	80	1,204
			Sand, white, mica; water	76	1,280
			Clay, medium, hard, gray	10	1,290
			Shale, blue, black	40	1,330
	Tuscaloosa formation.		Gravel, sand, gray	10	1,340
Carboniferous and Devonian.			Sandstone, gray, hard	5	1,345
			Lime, white, hard	49	1,394
			Sandstone, gray, hard	11	1,405
			Lime, brown, hard	23	1,428
			Sandstone, gray, hard	10	1,438
			Lime, gray, hard	12	1,450
			Sandstone, white, hard	13	1,463
			Lime, gray, hard	85	1,548
			Lime, blue, hard	87	1,635
			Sandstone, gray, hard	35	1,670
			Lime, blue, hard	7	1,677
			Sand, gray, dry	3	1,680
			Lime, sandy, gray	30	1,720
			Lime, white, hard	10	1,730
			Shale, gray, hard	10	1,740
Silurian.			Lime, bluish, hard	90	1,830
			Lime, shaly, gray, hard	65	1,895
			Sandstone, gray, hard	80	1,975
			Lime, gray, hard	20	1,995
			Lime, shaly, gray, hard	75	2,070
			Lime, bluish, hard	95	2,165
			Shale, gray, hard	12	2,177
			Lime, shaly, gray, hard	90	2,267
			Sandstone, white, hard	13	2,280
			Lime, shaly, gray, hard	60	2,340
			Lime, white, hard	55	2,395
			Shale, bluish, hard	20	2,415
			Lime, blue, hard	12	2,427

Log of well of Spring Creek Development Co., Hardeman County—Continued

Geologic age	Formation		Thickness (feet)	Depth (feet)
Ordovician.		Lime, blue-gray, hard	92	2,519
		Shale, blue-gray, medium hard	20	2,539
		Lime, gray, hard	21	2,560
		Lime, blue-gray, hard	45	2,605
		Sand, dark-gray, dry	2	2,607
		Shale, blue-black, hard	38	2,645
		Sandstone, gray, hard	70	2,715
		Lime, white, hard	80	2,795
		Lime, bluish, very hard	40	2,835
		Lime, shaly, gray, hard	62	2,897
		Sandstone, gray, medium hard	9	2,906
		Lime, blue, hard	89	2,995
		Lime, gray, hard	73	3,068
		Shale, blue, hard	22	3,090
		Lime, bluish-gray, hard	70	3,160
		Sand, dark-gray; water	18	3,178
		Lime, bluish-gray, hard	22	3,200
		Lime, gray, hard	5	3,205
		Lime, shaly, blue, hard	5	3,210

Though the deep well at Memphis (see p. 284) penetrates the Ripley formation, the log is so vague that it is impossible to determine whether it passes through the formation.

Since the time of Safford [61] this formation has been correlated with the Ripley formation in Mississippi. Because of the lithologic dissimilarity of the sand and clay in Tennessee to the typical materials of the Ripley formation, Stephenson [62] used the name McNairy sand member to designate the upper part of the Ripley formation in Tennessee. Wade [63] retained the name Ripley formation for the whole series but subdivided it into three lithologic and faunal units—in descending order the Owl Creek tongue, McNairy sand member, and Coon Creek tongue.

LITHOLOGIC CHARACTER

The Coon Creek tongue consists in the southern part of this area of black to bluish-green marl. The marl is composed of quartz, sand grains, glauconite, small flakes of mica, and fragments of shells cemented together by fine calcareous material. Pieces of lignitic wood and small nodular masses of pyrite are common but not abundant. The lime and clay content are variable. Scattered through this matrix are numerous fossil shells. Toward the north the lime content decreases, mica becomes more abundant, and the material becomes greenish gray, in places stained brown with iron oxide. Fossils are no longer present, though molds may be found in the material; but irregular nodular masses composed largely of limonitic material and

[61] Safford, J. M., On the Cretaceous and superior formations of west Tennessee: Am. Jour. Sci., vol. 37, pp. 360–372, 1864; Geology of Tennessee, p. 550, plates and map, 1869.

[62] Stephenson, L. W., Cretaceous deposits of the eastern Gulf region: U. S. Geol. Survey Prof. Paper 81, pp. 17–18, pl. 10, 1914.

[63] Wade, Bruce, The fauna of the Ripley formation on Coon Creek, Tennessee: U. S. Geol. Survey Prof. Paper 137, pp. 7–8, 1926.

vaguely resembling organic forms are conspicuous features of any outcrop. The large and beautiful fauna of well-preserved marine fossils in the type locality has been described by Wade.[64] The northern extension of the Coon Creek tongue was formerly considered to belong to the Selma clay, but although there is no fossil evidence in northern Tennessee on which to base a correlation, the lithologic nature of the material would place it in the Coon Creek.

Wade[65] describes the ferruginous clay portion of the Coon Creek tongue as follows:

> The ferruginous clay portion of the Coon Creek tongue of the Ripley is well exposed in a cut on the Mobile & Ohio Railroad just south of Falcon, in McNairy County. It consists of a series of stratified micaceous clays about 100 feet thick containing numerous concretions of limonite, which are very conspicuous on the eroded slopes in the central part of McNairy County. A scant and dwarfed marine fauna has been obtained from this clay in the southern part of the State. Toward the north this clay becomes sandy, loses its identity, and merges into the McNairy sand.

The McNairy sand member is predominantly sand, though clay lenses from 10 to 20 feet thick are found throughout the member. The sand consists chiefly of fine to coarse subrounded quartz grains. Mica is present but is less abundant than in the Eutaw formation. Glauconite occurs in small amounts. The sands are variegated in color—red, white, brown, yellow, pink, and purple—but in the outcrop are predominantly a deep red to brown owing to the oxidation of the iron in the waters of this member, which probably contain more iron than those of any other formation in western Tennessee. When exposed to the oxidizing influence of the air the iron is precipitated and forms a coating of red ferric oxide on the surface of the sand grains. In places the ferric oxide cements the grains together, forming hard sandstone. Locally this is found as large tabular masses, as near Dollar and Hollow Rock, Carroll County, or in fluted columns, as at Big Cut, McNairy County. The sands are in many places strongly cross-bedded but elsewhere show parallel bedding. Here and there the sands contain interlaminated layers of clay, from a fraction of an inch to several inches in thickness. In other places large lenses of thinly laminated clays are found. The clays are gray, dove-gray, or black. Leaves and fragments of leaves are found in the clays, and fragments of lignitic wood are common. The following section of the Ripley at a deep cut on the Southern Railway 1½ miles west of Cypress station, Tennessee, is given by Glenn:[66]

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[64] Wade, Bruce, The fauna or the Ripley formation on Coon Creek, Tenn.: U. S. Geol. Survey Prof. Paper 137, 1926.

[65] Idem, p. 8.

[66] Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River: U. S. Geol. Survey Water-Supply Paper 164, p. 29, 1906.

Section of Ripley formation near Cypress

	Feet
[Residuum:]	
1. Red casehardened Lafayette sand and clay with a few broken pieces of ferruginous sandstone and scattering quartz pebbles marking the contact with the underlying Ripley	8
[Ripley:]	
2. Fine red sand and clay with rolled clay pellets and thin streaks of white clay	20–25
3. Concretionary tabular and ironstone in single pipes or in masses of parallel ones with soft sand cores	2–8
4. Fine variegated sand, having as a whole a light-grayish color, but showing in detail red, white, brown, yellow, and purple streaks or mottling. Casehardened so that it breaks off in large masses	20
5. Ferruginous sandstone pipes and flutes massed as above	0–5
6. Fine sand and clay interbedded in thin laminae; yellow, brown, cream, or gray; sands micaceous; leaf and other plant markings common but indistinct and unidentifiable, exposed down to 15 feet below track level	35

Another place where the Ripley is well exposed is just south of the Carroll County line in northeastern Henderson County, 1 mile east of Holly Springs Church. Here a series of gullies about 60 feet deep show in one place the following section:

Section 1 mile east of Holly Springs Church, Henderson County

	Feet
Soil	0–1
Very coarse sand and gravel as much as 3 millimeters in diameter	1–6
White sand and clay	6–7
Medium-grained white sand, irregularly stained with iron oxide	7–21
White thinly laminated sandy clay with stocks of clay and clay balls scattered through sand	21–23
Medium-grained white cross-bedded sand	23–28
Medium-grained white and pink sand showing distinct bedding with a few thin layers of clay. To the west the sand gradually changes to white plastic clay by the interfingering of layers of clay 1 to 6 inches thick	28–55

The bottom of the McNairy sand is, in general, white and very fine grained. High banks of this fine white sand are found at Zacks, Benton County, in southwestern Benton County, just east of Lexington, and southwest of Selmer. Though this belt of fine sand has not been traced uninterruptedly across the State, it probably forms a fairly continuous layer representing a certain phase of sedimentation. Sand samples 925 and 809 are typical of this sand. Above it occur many lenses of very coarse sand. Though any particular outcrop in this belt may not show coarse sand, yet in general coarse sands are present. Sand samples 865 and 914 represent this coarse sand.

Stratigraphically above the McNairy sand member in southwestern McNairy County and eastern Hardeman County is the Owl Creek tongue. This is a series of micaceous sands and marls about 168 feet in thickness in Tennessee that contain a portion of the Owl Creek marine fauna. This northern extension of the Owl Creek does not extend far into Tennessee.

The Ripley formation was deposited by a sea that receded and then advanced again. The shallow marine conditions that are represented by the Coon Creek tongue gave way to shallow-water and littoral conditions of the McNairy sand, which in turn were followed by the shallow marine conditions of the Owl Creek.

PHYSICAL PROPERTIES

In order to determine the physical properties of the sands of the Ripley formation 24 samples were collected in the outcrop area. These samples were taken, as far as possible, along east-west lines at right angles to the strike of the formation. Two such series were collected, one across southern Carroll County and one along highway 15, which crosses central McNairy County. Besides these two series other samples were taken at good outcrops. Owing to the facts that the outcrops are not large or continuous and that the formation is extremely variable, it is impossible to determine what proportion of the total formation each grade of sand makes. It may be said, however, that the measurements of the thickness of the sands of different size in different outcrops are approximately the same, and if it is assumed that the chance distribution of outcrops is such that the various grades of sand are represented by samples in proportion to their relative abundance in the formation, the properties of the average sample give a fair average for the formation as a whole.

Physical properties of sands from outcrop area of the Ripley formation of Tennessee

[Laboratory determinations by V. C. Fishel]

Laboratory No.[a]	Apparent specific gravity of oven-dried sample	Mechanical composition (per cent)							10 per cent size (millimeters)	Uniformity coefficient	Porosity (per cent)	Moisture equivalent (per cent by volume)	Porosity minus moisture equivalent (per cent by volume)	Coefficient of permeability
		2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.10 mm	Residue on pan	Silt	Clay						
851 [b]	1.69	------	------	------	------	------	------	------	0.19	2.21	39.9	1.09	38.0	717
852	1.78	4.57	52.4	28.91	11.98	1.48	.7	0	.184	3.75	39.7	0.61	39.1	996
853	1.78	8.52	40.9	40.0	8.9	.9	0.	0	.240	2.46	40.1	1.29	38.8	759
854	1.44	.9	3.2	28.4	64.1	1.4	1.2	0	.118	2.62	25.0	5.76	19.2	370
855	1.55	2.4	4.9	21.5	61.0	1.4	3.5	4.6	.102	2.10	22.4	9.0	13.4	175
865	1.83	9.6	64.1	17.7	4.6	.9	1.4	1.0	.27	2.70	32.0	4.7	27.3	2,060
864	1.60	None.	.3	1.0	80.1	9.2	6.1	2.2	.058	2.79	37.3	11.0	26.3	237
925	1.59	None.	.5	2.4	96.0	.7	.4	0	.110	1.60	42.4	5.5	36.9	70
915	1.66	64.7	11.9	11.4	1.3	5.1	4.3	1.0	.094	1.35	34.5	3.0	31.5	1,821
916	1.56	3.7	45.1	36.7	3.9	4.3	5.9	.6	.084	6.78	46.0	6.1	39.9	608
917	1.63	.2	15.8	54.6	25.2	3.0	1.6	.6	.123	3.00	39.4	2.2	37.2	598
918	1.76	6.9	26.5	49.3	12.5	.6	1.7	.6	.165	1.85	39.4	2.2	37.2	475
914	1.75	79.5	11.6	2.9	1.1	2.1	1.8	1.0	.53	2.66	36.0	2.6	33.4	2,347
913	1.78	20.4	33.1	32.9	6.5	1.6	4.0	.8	.165	4.06	34.0	3.3	31.7	947
919	1.48	.4	1.8	15.8	66.3	7.3	7.7	1.8	.052	3.54	47.0	10.0	37.0	37
809	1.87	.1	.5	1.6	73.4	18.5	[b] 6.5	------	.058	2.67	39.1	10.9	28.2	29.5
808	2.00	.0	2.0	43.0	49.6	.7	4.8	------	.082	3.60	33.2	3.6	29.6	143
812	1.99	3.2	47.2	30.8	9.2	2.7	7.0	------	.10	5.90	32.7	6.4	26.3	182
813	1.56	None.	.8	46.6	48.4	1.1	3.1	------	.113	1.51	47.2	2.1	45.1	------
814	1.56	.3	28.4	50.2	16.0	2.6	2.7	------	.13	2.30	41.5	3.5	38.0	443
805	1.50	None.	.2	1.7	59.3	30.2	8.5	------	.052	2.65	49.4	7.4	42.0	505
815	1.59	6.6	15.0	40.3	34.8	1.1	2.2	------	.123	2.97	48.4	1.6	46.8	391
866	1.63	2.3	41.0	43.0	8.2	4.6	1.0	------	.165	3.21	45.9	1.0	44.9	652
867	1.49	.1	9.3	35.0	42.0	7.8	3.4	.8	.082	2.93	46.5	5.8	40.7	572

[a] Samples listed in order across formation from bottom up.

[b] For mechanical analysis see next table.

Mechanical analyses of sands from the Ripley formation of Tennessee, made according to second method

[See p. 39]

Laboratory No.[a]	Mechanical composition (per cent)					Residue on pan
	2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.125 mm	0.125-0.062 mm	
851	9.0	18.0	58.5	15.6	0.5	0.3
852	1.1	49.1	41.5	6.1	.8	.4
853	6.0	43.8	45.9	3.5	.4	.2
854	.9	3.1	41.6	52.3	1.5	.8
855	1.2	8.7	52.5	33.7	1.6	1.6
865	4.0	68.0	26.0	1.5	.4	.5
864	.3	1.0	9.0	73.0	9.0	6.4
925	None.	.3	6.7	81.9	9.3	.9
915	66.5	16.5	11.0	2.0	1.0	2.5
916	3.5	54.5	40.0	1.0	.5	.5
917	----------	14.0	78.0	7.0	.5	1.0
918	5.0	32.0	59.0	5.0	.5	.5
914	59	34.5	4.0	1.6	1.0	2.5
913	23.3	47.0	26.5	1.0	.5	.9
919	2.6	2.0	31.0	54.0	8.0	2.0
866	1.1	34.7	55.8	4.2	1.7	.6
867	None.	4.5	48.8	29.0	13.2	3.5

[a] Samples listed in order across formation from bottom up.

851. Gully 0.25 mile south ofBuchanan, Henry County. Altitude of top of gully 500 feet. Section from top down: 0–9 feet, red sandy clay, some gravel; 9–9.5 feet, impure white clay; 9.5–15 feet, alternating bands of red and white sand about 3 inches thick, white sand coarser grained, red sand contains some clay; 15–23 feet, cross-bedded white sand of varying coarseness, lenses of purple spots accentuating bedding. Sample taken 23 feet below top of section.

852. Same as 851; 21 feet below top of section.

853. Same as 851; 19 feet below top of section.

854. Same as 851; 17 feet below top of section.

855. Same as 851; 15 feet below top of section.

865. Gully 1.5 miles east of Mansfield and 1 mile south of New Hope Church, Henry County, on south side of road. Altitude of top of gully 470 feet. Section from top down: 0–15 feet, red sandy clay; 15–25 feet, alternating 3 to 12 inch bands of red and white fine-grained sand; 25–27 feet, coarse cross-bedded white and brown sand. Sample taken 26 feet below top of section.

864. Same as 865; 20 feet below top of section.

925. Sand pit on west side of State highway 1, Zacks, Benton County. A 30-foot bank of fine white sand. Sample taken 15 feet above level of railroad track.

915. Gully 6.2 miles southeast of Yuma and 1 mile east of Holly Springs Church, Henderson County, just south of Carroll County line. Altitude of top of gully 580 feet. Section from top down: 0–1 foot, soil; 1–6 feet, very coarse sand and gravel as much as 3 millimeters in diameter, in channels; 6–7 feet, white sandy clay; 7–21 feet, medium-grained sand stained irregularly with iron oxide; 21–23 feet, white, thinly laminated clay with some stocks of clay and clay balls scattered through sand; 23–28 feet, medium-grained white cross-bedded sand; 28–55 feet, medium to fine grained white and pink sand with some layers of clay. Sample taken 5 feet below top of section.

916. Same as 915; 20 feet below top of section.

917. Same as 915; 28 feet below top of section.

918. Same as 915; 54 feet below top of section.

914. Gully on south side of Yuma-Cavia road 3.4 miles east of Yuma, Carroll County. Approximate altitude at top of gully 490 feet. Section from top down: 0–7 feet, bedded medium-grained sand with lumps of clay; 7–22 feet, coarse sand. Sample taken 16 feet below top of section.

913. Gully on south side of Yuma-Cavia road 1.9 miles east of Yuma, Carroll County. Approximate altitude of top of gully 440 feet. Section from top down: 0–6 feet, soil grading within a few inches into very coarse sand; 6–12 feet, very coarse sand showing bedding at angle to the preceding; 12–17 feet, very coarse sand, as much as 3 millimeters in diameter; 17–20 feet, white and pink thinly laminated clay.

919. Hillside 2.8 miles south of Clarksburg on east side of highway 44, Carroll County. Approximate altitude of top of hill 390 feet. Section from top of hill down: 0–5 feet, argillaceous sand; 5–35 feet, dark-red, partly cemented fine sand; 35–50 feet, micaceous thin-bedded red sand; 50–53 feet, thin-bedded carbonaceous clay. Sample taken 45 feet below top of section.

809. Gully 1 mile east of Lexington on highway 20 (old road), Henderson County, north side of road. Fine-grained white micaceous sand.

808. Gully 0.5 mile east of Lexington on highway 20 (old road), north side of road. Variegated dark-brown, yellow, and white sand.

812. Road cut on highway 15, 0.25 mile west of Selmer Courthouse, McNairy County. Cut 20 feet deep. Medium-grained quartz sand streaked with red.

813. Road cut 0.5 mile west of Selmer Courthouse on highway 15, McNairy County. Cross-bedded black, brown, red, yellow, and white sand.

814. Road cut 5.0 miles west of Selmer on highway 15, McNairy County. Cut 20 feet deep. Coarse-grained sand in shades of yellow and red.

805. Road cut 6.2 miles east of Selmer on highway 15, McNairy County. Cut 20 feet deep. Fine white micaceous sand.

815. Road cut 5 miles east of Hornsby on highway 15, McNairy County. Cut 20 feet deep. Coarse-grained variegated red and yellow sand.

866. Big cut on Southern Railway 1.5 miles west of Cypress. Section from top down: 0–15 feet, dove-gray and white finely interbedded clay, at the top of which are some fluted iron oxide sandstone formations; 15–17.5 feet, finely laminated dove-gray and white clay, also some layers of sand; 17.5–28.3 feet, coarse white and brown cross-bedded sand; 28.3–32.4 feet, interbedded gray and white plastic clay in 1-inch groups composed of layers 1/16 to 1/8 inch thick; 32.4–40.3 feet, coarse brown and white cross-bedded sand. Clay covered with talus. Sample taken 24.8 feet below top of section.

867. Same as 866 ;36.5 feet below top o fsection.

An examination of these analyses shows a wide range in the physical properties. Sample 914 shows 79.5 per cent of the sand coarser than 1 millimeter; sample 925 shows 96 per cent on the 0.1-millimeter screen. The samples range from very uniform material, such as sample 923, with a uniformity coefficient of 1.31, to variable material, such as sample 916, with a coefficient of 6.78. The average uniformity coefficient is 2.96. The coarse sands are as a rule less uniform than the fine sands, but there are exceptions. The porosity is high and ranges from 22.4 to 49.4 per cent, with 39.1 per cent as the average. There seems to be no relation between grain size and porosity. The moisture equivalent is low, ranging from 0.61 to 11, with 4.61 as the average. The coefficient of permeability has a wide range, from 29.5 to 2,347, and averages 670.

WATER-BEARING PROPERTIES

The Coon Creek tongue and the Owl Creek tongue of the Ripley formation yield little water, but the McNairy sand member is a good water bearer. In its outcrop area this member is predominantly sand, and though clay lenses may be encountered in it these can be readily drilled through. The sand is usually sufficiently coarse to finish a well in, though the very fine sand would not be checked by strainers of the usual type. Very few data are available concerning the Ripley formation to the west of its outcrop area. Three wells that are within 10 miles of the western boundary of the outcrop area and pass completely through the Ripley formation show that the formation is about half sand at these points. It is reasonable to assume that farther to the west the proportion of sand decreases. Evidence furnished by the deep wells at Memphis (p. 284) and in Crittenden County, Ark. (p. 27), bears this out. If it is assumed that at Memphis the Ripley is encountered at 2,371 feet, the amount of sand below this is less than 33 per cent and the proportion of sand found in the oil tests in Crittenden County is even less. Furthermore, the sand is here partly cemented and indurated and probably has a lower porosity and permeability. It seems probable, however, that some sand will be found in the Ripley wherever it occurs. Large supplies of water can be developed from the Ripley formation, but the quantity is not inexhaustible. As larger quantities of water are developed from it there will be a lowering of the head, and wells that now flow will cease to flow. For this reason waste of water should be stopped, flowing wells that are not used should be shut off, and the flow of wells that yield much more water than is needed should be cut down. In this way the greatest use can be made of the water with the least loss of head.

The static level of the water in the Ripley formation in the area where it crops out depends on topographic position. To the west of the outcrop area the static levels in different wells are as follows:

Paris, 392 feet above mean sea level (based on railroad altitude); Huntington, 405 feet; McKenzie, 403 feet; Pinson, 390 feet; Middleton, 381 feet; Memphis, 360 feet. This gives an average altitude of the static level at the western edge of the outcrop area of 400 feet. The loss in head is about 0.5 foot to the mile toward the west, the minimum head being about 360 feet.

QUALITY OF WATER

The McNairy sand member and the Owl Creek tongue of the Ripley formation yield waters of different chemical composition. Most of the waters from the McNairy sand (see analyses—Benton County, No. 31; Carroll County, Nos. 33, 40, 58, 69, 71, 74; Chester County, Nos. 1, 3, 4; Henderson County, Nos. 1, 5b, 8a; Henry County, Nos. 7, 15, 64, 68, 79; Madison County, Nos. 15c, 31) are low in mineral content, usually containing less than 100 parts per million of total dissolved solids, and they are generally soft, containing less than 50 parts per million of hardness. They are usually characterized by calcium bicarbonate. Water from the Ripley formation at Memphis (sample 10, p. 287), however, has a high mineral content, containing 1,026 parts per million of total dissolved solids, and is characterized by sodium bicarbonate. This water is not fit for domestic or industrial use. It is probable that the change from water such as is found in the outcrop area of the Ripley formation to the water obtained at Memphis is gradual, but data are not available to show the western boundary of good water. The change from a calcium to a sodium bicarbonate water is effected by certain clay minerals in the formations. This change with increasing depth is also observed in waters from Ripley sand in Mississippi.[67] Analyses of waters having high, low, and medium mineral content are given in

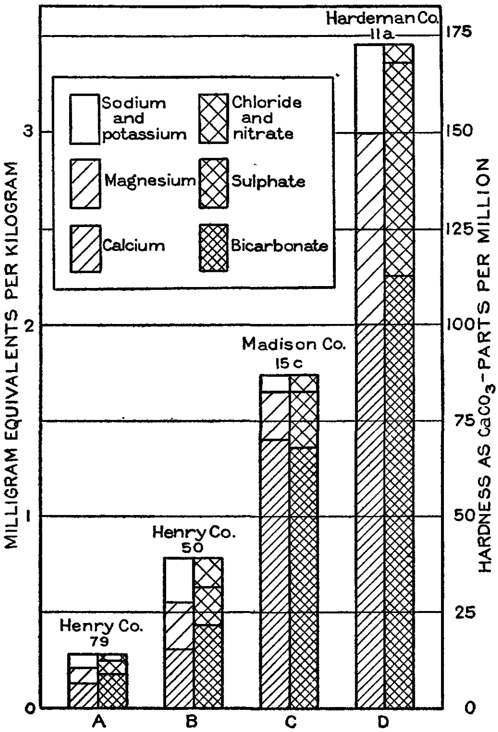

FIGURE 8.—Analyses of water from the Ripley formation

[67] Stephenson, L. W., Logan, W. N., and Waring, G. A., op. cit., p. 43.

Figure 8, as well as an analysis of water from the Ripley formation at Memphis.

Water from the upper portion of the Ripley formation, the Owl Creek tongue, yields water of higher mineral content. The six waters analyzed (Hardeman County, Nos. 11a, 15a, 15b, 17, 22; Madison County, No. 17) range in total dissolved solids from 148 to 217 parts per million and are of moderate hardness, ranging from 90 to 150 parts per million. They are all calcium bicarbonate in character, but some contain considerable sulphate. The difference in sulphate content may be due to local variations in the mineral composition of the formation.

The waters from both divisions of the Ripley formation are likely to be high in iron. The iron can be easily removed by some method of aeration followed by filtration or sedimentation.

CENOZOIC ROCKS

TERTIARY SYSTEM

EOCENE SERIES

MIDWAY GROUP

Safford [68] proposed the name Porters Creek for the clays that are well exposed along Porters Creek, a small tributary of the Hatchie River in southeastern Hardeman County. Later [69] he differentiated a lower Eocene formation consisting of fossiliferous argillaceous, glauconitic sandstone and other undescribed beds lying between the Porters Creek clay and the Ripley formation, and called it the "Middleton formation." This formation is included in the Clayton formation of the present report. Harris [70] correlated the Porters Creek clay and the "Middleton formation" of Safford with other formations throughout the Gulf embayment area, demonstrated that they were of early Eocene age, and applied the name Midway to all these formations. Glenn [71] regarded the "Middleton" and Porters Creek as one formation and grouped them as Porters Creek.

Roberts [72] has correlated the basal part of the Midway in southern Tennessee with the Clayton limestone of Mississippi and retained the name Porters Creek for the characteristic clays of the upper formation of the Midway group.

The Midway group is distinctly marine, as indicated by its fauna. It lies unconformably on the Ripley formation, of Upper Cretaceous age. This group crops out in a band that strikes a little east of north and is about 7 miles wide in Hardeman County but narrows to 1 mile

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[68] Safford, J. M., On the Cretaceous and superior formations of west Tennessee: Am. Jour. Sci., vol. 37, p. 368, 1864.

[69] Safford, J. M., Notes on the Middleton formation of Tennessee, Mississippi, and Alabama: Geol. Soc. America Bull., vol. 3, pp. 511-512, 1892; Am. Geologist, vol. 9, pp. 63-64, 1792.

[70] Harris, G. D., The Midway stage: Bull. Am. Paleontology, vol. 1, pp. 18-22, 1896.

[71] Glenn, L. C., Underground waters of Tennessee and Kentucky, west of Tennessee River: U. S. Geol. Survey Water-Supply Paper 164, p. 32, 1906.

[72] Roberts, J. K., Tertiary stratigraphy of westTennessee: Geol. Soc. America Bull., vol. 39, p. 436, 1928.

at the Kentucky line. It is encountered in all wells west of its outcrop area that penetrate the Cretaceous.

CLAYTON FORMATION

The Clayton formation unconformably overlies the Ripley formation from the Mississippi-Tennessee State line to a point 2 miles north of Beech Bluff, though not continuously exposed. Its maximum exposed thickness probably does not exceed 60 feet. According to Cooke[73] the Clayton is thickest in eastern Alabama and thins to the west. Whether the Clayton thins out to the west in Tennessee is not known, but the presence in Jackson County, Ark., and as far north as Dunklin County, Mo.,[74] of calcareous fossiliferous Midway that is considered to be equivalent to the Clayton formation indicates that the Clayton probably underlies much of Tennessee west of the outcrop of the Cretaceous-Eocene contact. The logs of the deep wells at Memphis and in Crittenden County, Ark., are not sufficiently detailed to determine whether the Clayton is present or not, but if present it certainly is not a limestone. At its best exposure, near Trim's mill, in southeastern Hardeman County, about 4 miles southeast of Middleton, the limestone phase of the Clayton shows a section of 7 feet of limestone containing characteristic Midway fossils. This is overlain by 30 feet of glauconitic sand and clay, showing imperfect impressions of leaves. The limestone is coarse grained, consisting of a heterogeneous mass of shells cemented by glauconite and calcite. It is gray with a yellow tone. The weathered portions are porous and stained with iron. Toward the north the limestone disappears and the Clayton is composed entirely of a loose medium-grained sand consisting of two-thirds quartz and one-third green sand, with a little mica and amphibole. It varies in color from that of the scattered sand—medium green when dry or dark green when wet—to the light green or brown of the weathered material, but in some places so little glauconite is present that the sand is gray. The sand grains are subrounded or angular, and there is very little clay present.

The limestone phase of the Clayton is not a good water bearer. Mechanical analyses of two samples of green sand show it to range from coarse to medium grain and to have a low uniformity coefficient. The artesian wells in the vicinity of Hornsby, which obtain water from the Clayton formation, have large yields considering the slight head the water must be under.

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[73] Cooke, Wythe, Correlation of the Eocene formations in Mississippi and Alabama: U. S. Geol. Survey Prof. Paper 140, p. 134, 1925.

[74] Stephenson, L. W., and Crider, A. F., Geology and ground water of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, p. 51, 1916. Berry, E. W., Northernmost extension of marine Eocene beds in Mississippi embayment: Pan Am. Geologist, vol. 37, pp. 75–76, 1922.

PORTERS CREEK CLAY

Nowhere in southwestern Tennessee does the width of the outcrop of Porters Creek Clay exceed 5 miles, and locally it is found only in a small band less than a mile in width. Its greatest thickness in outcrop is 250 feet, but it thins toward the north, being 140 feet thick at Paris. The deep wells at Memphis (p. 284) and in Crittenden County, Ark. (p. 27), pass through the Porters Creek clay but are not sufficiently detailed to permit definite correlation. Dr. J. A. Cushman [74a] has identified diagnostic Midway fossils in core from the S. J. Bradshaw oil test well No. 1, in southwestern Obion County, at a depth of 2,080 to 2,094 feet. Material from depths of 1,785 to 2,100 feet lithologically resembles the Midway. In Mississippi the transition from Wilcox to Porters Creek, as found in wells, is gradational, and no sharp division can be made, though in its lower part the Porters Creek is fossiliferous and can be differentiated from the underlying Cretaceous. Hence it is at present impossible to determine the top and bottom of the Porters Creek clay, but most of this material undoubtedly belongs to that formation. At the Mississippi River the Porters Creek clay is probably as much as 350 feet thick, thus showing a slight thickening to the west. The formation has an average dip from Middleton to Memphis of 19 feet to the mile, but farther east it dips 30 feet to the mile. The Porters Creek Clay is lead-gray to dove-gray when dry but becomes dove-gray to black on wetting. It is homogeneous, smooth, and plastic, with a greasy feel. These properties explain its local appellation "soapstone." It is dissected into small cubical or rectangular blocks by innumerable joints intersecting at right angles, and upon weathering it parts along these lines, the mass thus acquiring a hackly structure. The fresh dry clay has a conchoidal fracture. (See pl. 5, *B*.) In certain areas where the Porters Creek is exposed it is cut by sandstone dikes from a fraction of an inch to 22 feet thick; they show no systematic orientation and many of them intersect one another. The material forming the dikes consists of sand of uniform size, fragments of Porters Creek clay, and a few foraminifers and gastropods. The sand contains muscovite, limonite, and some green sand. Glenn [75] ascribes the formation of these dikes to earthquake disturbances in Eocene time that opened fissures into which the underlying sand was injected.

Owing to its fine texture and clay composition the Porters Creek clay is impervious to water. It furnishes a confining bed for the waters in the underlying Ripley sands, creating artesian conditions to the west.

[74a] Personal communication.
[75] Glenn, L. C., op. cit., p. 31.

WILCOX GROUP

Berry[76] has shown that the "La Grange formation" of Glenn[77] included the Wilcox group, of lower Eocene age, and the Jackson formation, of upper Eocene age, the intervening Claiborne group, of middle Eocene age, apparently being absent. As the Wilcox formations and the Jackson are now differentiated in western Tennessee, there is no longer need for the inclusive name "La Grange." Roberts and Collins[78] have identified, in the Wilcox group as exposed in Tennessee, the two upper formations of the group, the Holly Springs sand and the overlying Grenada formation. The two formations are lithologically very much alike, so that it is impossible to differentiate them except on the basis of the fossil floras. For this reason no precise correlation of well drillings can be made. In this report whenever it is definitely known which formation is being considered the formation name will be used; in case of doubt the group name will be employed.

ACKERMAN FORMATION

In Mississippi the Wilcox group includes at its base the Ackerman formation, but the Ackerman does not crop out in Tennessee, its most northerly exposure being found in the northwestern part of Tippah County, Miss., where it disappears beneath the Holly Springs sand by overlap. On account of the northward strike of the Ackerman formation in Mississippi it seems probable, however, that the Ackerman continues to the north beneath the Holly Springs formation and would be encountered in depth beneath the counties bordering the Tennessee River. This assumption furnishes the best explanation of the thickening of the Wilcox group observed in the S. J. Bradshaw oil test well No. 1. (See p. 235.) The thickness of the Ackerman formation in Mississippi is 300 to 500 feet.[78a] It probably is much thinner than this along its eastern margin in Tennessee but along the Tennessee River may exceed the maximum thickness given.

The Ackerman formation rests unconformably on the surface of the Porters Creek clay. According to Berry[78b] this is an erosional surface.

In outcrop the formation consists of stratified gray, more or less lignitic clay with many interbedded layers of lignite. Many of the

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76 Berry. E. W., The lower Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 91, pp. 29–30, 45, 1916; The middle and upper Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 92, pp. 96, 98, 1924.

77 Glenn, L. C., op. cit., pp. 33–40.

78 Roberts, J. K., and Collins, R. L., The Tertiary of west Tennessee: Am. Jour. Sci., 5th ser., vol. 12, pp. 238–241, 1926.

78a Stephenson, L. W., Logan. W. N., and Waring, G. A., The ground-water resources of Mississippi. U. S. Geol. Survey Water-Supply Paper 576, p. 45, 1928.

78b Berry, E. W., Erosion intervals in the Eocene of the Mississippi embayment: U. S. Geol. Survey Prof: Paper 95, pp. 73–78, 1916.

clay layers are more or less sandy, and some beds of sand are interstratified with the clay. The character of the Ackerman formation in Tennessee is not known except at Memphis, where material encountered by deep wells between 1,300 and 1,900 feet and in this report correlated with the Ackerman (see p. 284) is predominantly clay, though it contains some beds of good sand as much as 100 feet thick. The physical properties of this sand are shown by 7 complete and 14 partial analyses. The samples were taken from drillings obtained by the hydraulic rotary process. They were carefully washed and the silt and clay decanted. This introduced an error, for the silt and clay of the sample were lost, but it is believed that the silt and clay content was so small that its loss would not materially alter the physical properties of the sand.

The sand is medium grained and very uniform, having an average uniformity coefficient of 2.02. The average porosity is 40.2 per cent. The average moisture equivalent, 2.2, is very low and may be explained in part by the absence of the silt and clay removed from the sample by washing. The average permeability coefficient is 802, which shows that the formation will yield considerable water to wells.

Physical properties of sands from wells in the Ackerman formation of Tennessee

[Laboratory determinations by V. C. Fishel]

Laboratory No.[a]	Apparent specific gravity of oven-dried sample	Mechanical composition (per cent)						
		2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.1 mm	Residue on pan	Silt	Clay
978	1.47	0.5	0.9	1.4	89.2	7.5	0.6	0
979	1.47	.3	.3	23.3	75.4	.5	.2	0
980	1.51	----------	1.7	51.0	46.3	.2	.6	-------
981	1.52	0	2.1	32.	65.3	.3	.2	-------
982	1.51	0	1.3	28.7	69.4	.3	.2	-------
828	1.59	----------	5.0	56.8	37.5	.2	.6	-------
829	1.56	----------	7.7	55.9	34.5	1.3	.6	-------

Laboratory No.[a]	10 per cent size (millimeters)	Uniformity coefficients	Porosity (per cent)	Moisture equivalent by volume (per cent)	Porosity minus moisture equivalent	Coefficient of permeability
978	0.104	1.62	42.0	2.6	39.4	335
979	.113	1.82	44.0	1.6	42.4	904
980	.120	2.50	40.0	1.6	38.4	894
981	.114	2.02	42.0	1.4	40.6	919
982	.113	1.95	43.0	1.4	41.6	842
828	.125	2.20	38.7	1.7	37.0	918
929	.168	1.81	40.8	1.1	39.7	132

[a] Listed in order of depth.

Physical properties of sands from wells in the Ackerman formation of Tennessee, as determined by the second method

[See p. 39. Laboratory determinations by V. C. Fishel]

Laboratory No.[a]	Mechanical composition (per cent)					
	2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.125 mm	0.125-0.062 mm	Residue on pan
978	0.3	1.0	44.0	46.0	7.0	0.4
1072	.2	1.0	40.6	51.5	5.0	.6
1073	.2	.5	88.5	10.0	.3	.1
979	.1	.3	91.7	7.0	.7	.3
1074	.1	.5	91.0	7.0	1.0	.3
1075	.2	.5	88.0	10.2	1.0	.3
1076	.2	.5	87.5	11.0	1.0	.2
1077	.1	.7	87.0	12.0	.5	.2
1078	.3	.5	89.0	10.0	.4	.1
980	.1	1.0	93.0	5.3	.3	.1
1079	.1	1.0	91.0	7.0	1.0	.1
1080	0	1.0	88.0	10.0	.5	.1
1081	0	.8	88.0	11.0	.6	.2
982	0	.8	83.0	14.8	1.2	.3
1082	0	2.0	82.0	16.0	1.0	.1
1083	0	.7	83.0	15.0	1.0	.1
1084	0	1.0	89.0	9.5	.7	.1
981	0	1.0	87.0	10.0	.7	.1
1085	.1	2.0	88.0	9.0	.8	.2

[a] Listed in order of depth.

978. Well 51 of Memphis Artesian Water Department, on Southern Avenue West of West Tennessee State Normal School; depth 1,215 feet.
1072. Same as 978; depth 1,220 feet.
1073. Same as 978; dzth 1,225 feet.
979. Same as 978; depth 1,230 feet.
1074. Same as 978; depth 1,235 feet.
1075. Same as 978; depth 1,240 feet.
1076. Same as 978; depth 1,245 feet.
1077. Same as 978; depth 1,250 feet.
1078. Same as 978; depth 1,255 feet.
980. Same as 978; depth 1,260 feet.
1079. Same as 978; depth 1,265 feet.
1080. Same as 978; depth 1,270 feet.
1081. Same as 978; depth 1,275 feet.
982. Same as 978; depth 1,280 feet.
1082. Same as 978; depth 2,285 feet.
1083. Same as 978; depth 1,290 feet.
1084. Same as 978; depth 1,295 feet.
981. Same as 978; depth 1,305 feet.
1085. Same as 978; depth 1310-1315 feet.
828. Well 33, Memphis Artesian Water Department, about 4 miles west of well 51; depth 1,290-1,383 feet.
829. Well of western State hospital, Bolivar, Tenn.; depth 615-654 feet.

The sample of water from the 1,400-foot well at Memphis is the only sample available from the Ackerman formation in Tennessee. This water (see analysis 9, p. 287) is a sodium bicarbonate water; it is soft but contains sufficient iron to make necessary some form of treatment for its removal. In Mississippi water from the Ackerman formation [78c] near its outcrop is a calcium bicarbonate water, but with increasing depth the water changes to a water characterized by sodium bicarbonate. The water from the 1,200-foot well at Tutwiler, Miss.,[78d] very closely resembles the water from the 1,400-foot well at Memphis.

HOLLY SPRINGS SAND

Distribution and thickness.—The Holly Springs sand rests unconformably on the surface of the Porters Creek clay, which is probably an erosional surface.[79] The formation crops out as a broad band which is 20 miles wide at the southern boundary of the State and

[78c] Stephenson, L. W., Logan W. N., and Waring, G. A., The ground-water resources of Mississippi: U. S. Geol. Survey Water-Supply Paper 576, pp. 45-46, 1928.

[78d] Idem, p. 443.

[79] Berry, E. W., Erosion intervals in the Eocene of the Mississippi embayment: U. S. Geol. Survey Prof. Paper 95, pp. 73-78, 1916.

8 miles wide at the Kentucky line and which trends slightly east of north. It is the surface formation over most of Hardeman and Madison Counties, the western half of Carroll and Henry Counties, and the southeast corners of Fayette, Haywood, Gibson, and Weakley Counties. In southern Fayette County it probably has a thickness of 450 feet but thins to 250 feet at the north. This formation dips 20

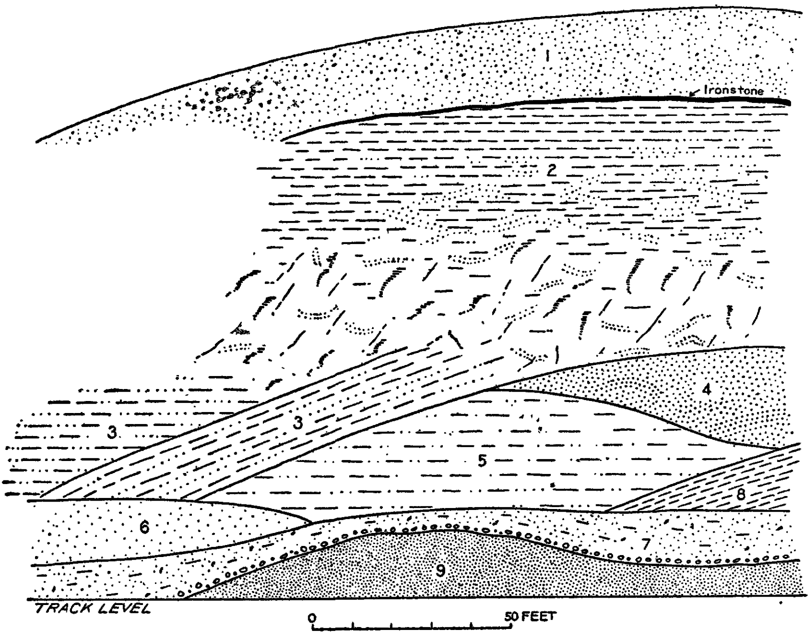


FIGURE 9.—Diagrammatic section of the north end of the east side of the big cut on the Gulf, Mobile & Northern Railroad near Pine Top, Hardeman County. 1, Angular sand with scattered small lenses of clean white sand, 0-25 feet; 2, yellow sandy clay with fossil plants, grading downward into dark-gray, very irregularly bedded sand and clay, more or less concealed by slumping, about 95 feet; 3, laminated sandy clay; 4, sand; 5, gray sandy clay; 6, massive sand; 7, argillaceous lignitic sand with plants, small quartz pebbles, and bauxite, 0-5 feet; 8, clay; 9, massive greenish-gray fine micaceous sand

to 30 feet to the mile toward the west and underlies all the younger formations west of its outcrop area.

Lithologic character.—The formation consists predominantly of sand, strongly cross-bedded and of all sizes from small gravel to the finest of sand, which is in many places mixed with clay. It is questionable whether these sands of various sizes occur in continuous beds rather as irregular masses that may have considerable lateral extent but eventually pinch out. This is especially true of the very coarse sands. Locally the sands of various sizes are disposed in irregular masses which show the greatest confusion of arrangement, as is well illustrated in the big cut on the Gulf, Mobile & Northern Railroad near Pine Top, Hardeman County. (See fig. 9.)

What appear to be thick beds of homogeneous sand are found on close examination to consist of a successive series of thin lenses from a fraction of an inch to 10 inches in thickness. (See pl. 9, *A*.) Although these lenses show enough difference in grain size and arrangement to form distinguishable layers, yet a series of them may be coarse, giving rise to a coarse bed of considerable thickness, whereas the overlying bed may consist of a series of lenses of fine sand. The individual lenses may show slight differences in color, but usually the whole bed is of one color and the succeeding bed is of another. Lenses of clay are intercalated with the sand. The clay is of three types—white plastic clay free from grit, dark to black lignitic clay, parts of which contain an abundant flora, and a sandy white clay locally called pipe clay. The clay lenses show the greatest variety in size and shape, ranging from those a few square feet in area and a foot or two thick to some covering several acres and 100 or more feet in thickness, and from long, thin lenses to short, thick ones. The picture of the Wade clay pit (pl. 9, *B*) gives an idea of the extent of some of these clay lenses.

In some exposures the base of the Holly Springs is a clay conglomerate composed of pebbles of varying size, from 8 or 9 inches down. The pebbles are all rounded, although some of them have a longer dimension. There is no sorting or orientation. The matrix is a clay which is sandy in some places. These conglomerates were probably formed by gully filling and give evidence of erosional activity in early Wilcox time. (See pl. 6, *A*.)

In order to understand such variation and abrupt change both horizontally and vertically in the physical character of the sediments of Holly Springs age, it is necessary to visualize the conditions under which the deposits were formed. In middle Wilcox time the Gulf of Mexico extended up to the present mouth of the Ohio River, forming a shallow marine embayment sloping gently to the southwest. The surrounding land rose slightly above the gulf, forming low-lying shores of unconsolidated sediments, a continuation of the gently sloping gulf bottom. Conditions were favorable for the maximum development of the littoral zone. The tides swept over this gently dipping bottom, churning up the loose materials and carrying them from place to place. Strong undertows and currents also served to carry and sort the materials. Along some parts of the shore barrier beaches were built, and into the quiet waters protected by these beaches streams of low gradient brought only the finest sediment. Leaves from the forests along the shore fell into the water and were buried with the fine silt. Thus were formed the lenses of clay that occur in these sediments. Slight sinking allowed the sea water to sweep over these clay lenses and cover them with sand. Currents formed channels and scour holes, while farther on bars and islands were built up. The rapid succession of conditions of strong and weak currents and of quiet waters gave rise to the lateral and vertical variations in size of grains which are exhibited in these deposits.

The best section of the Holly Springs formation to be found in the area here described is at La Grange, where, just south of the town, there are gullies and ravines from 100 to 150 feet deep. Glenn [80] gives the following section measured at this locality:

Section at La Grange, Tenn.

	Feet
1. Soft loose light-yellow to light-gray sands, cross-bedded	15–18
2. Soil layer, dark with organic matter	1
3. Massive bed of brick-red sand, casehardened, showing even top but very irregular lower surface and resting unconformably on the underlying sand	4–15
4. [Holly Springs sand:] Soft cross-bedded sands, mostly fine but in places coarse, of various light colors such as nearly white, light yellow, faint pink, and faint purplish, with a few thin crusts and small rounded or short tabular concretions of sand ironstone in place. Near the top there is a clay lens of irregular shape ranging up to 8 or 10 feet thick	100

Although there is a wide range in the size of the Holly Springs sands, the sand in any one layer is fairly uniform. The large grains are subrounded and show some frosting and pitting. The small grains are angular and have fresh surfaces. The sands are variegated, shades of gray, black, brown, red, pink, purple, and yellow being found, as well as white. The prevailing color, however, is gray, and next in order is yellowish brown. The coloring is a surface stain and can be removed by abrasion. Quartz is the most abundant mineral, and weathered chert is present in varying amounts. Mica is sometimes noticeable. Other accessory minerals are hornblende, rutile, tourmaline, and zircon.

GRENADA FORMATION

Overlying the Holly Springs sand and cropping out west of it is the Grenada formation, which occupies a belt 20 miles wide at the south and about 22 miles at the north. Its maximum thickness is 600 feet. The Grenada, like the Holly Springs, consists largely of cross-bedded sand of various colors, intercalated with which are lenses of clay, comparable in size and shape to those in the Holly Springs and having the sand mode of occurrence. Toward the west the lenses of clay probably increase in number and in horizontal extent. The sands are more uniform in grain size and on the whole finer than those in the Holly Springs formation and are of fewer colors. Limonite concretions of two types occur in the Grenada—cylindrical concretions from

[80] Glenn, L. C., op. cit., p. 36.

2 to 4 inches in length and as much as a quarter of an inch in diameter, some of which are hollow, and round flat concretions consisting of a limonite shell with a clay center.

The clays of the Grenada are either smooth white or dove-colored to brown clays of fine texture or gritty light-colored clays. In many places they are fossiliferous, and it was on the basis of their contained flora that the division of the Wilcox was made. A characteristic feature of the clay is the presence in it of numerous small crystals of selenite, which average 2 to 3 millimeters in length. The conditions of sedimentation that prevailed during Grenada time were much the same as those of Holly Springs time but on the whole were more uniform. At the base of the Grenada the sands are prevailingly coarse, but the basal sand bed is absent in places. The other sands are finer than the sands of the Holly Springs. Also they are of uniform size and, as would be expected, are rather angular. The most prevalent color is gray, but white and pink are common. Quartz is the most abundant mineral, forming 90 per cent of the sand. The accessory minerals are hornblende, rutile, zircon, and mica; the mica in places forms as much as 4 per cent of the sand and is very noticeable. Though the porosity and specific yield of these sands is high, the difficulty of finishing wells in them and the presence of better sands at greater depth has hindered their use.

The Grenada formation is well exposed in Haywood County on the north bank of the Hatchie River a quarter of a mile west of the Brownsville-Somerville road. Here a gullied bluff about 100 feet high shows the following beds:

	Feet
Red fine-grained sand	0–30
Layers of finer gray sand, average thickness 1 inch, interbedded with layers of white plastic clay about 1 inch thick	30–82
Bedded white clay	82–100

PHYSICAL PROPERTIES OF SANDS

The results of laboratory tests of 48 samples collected throughout the outcrop area of the Wilcox group of formations are listed in the following table. Besides a few samples collected at random, these samples comprise three groups taken as far as outcrops would allow across the strike of the formation. Those of one group (samples 858 to 862) were collected across northern Henry County from a point southeast of Puryear to College Grove. Those of another group (samples 920 to 922 and 885 to 874) were taken across southwestern Carroll County and southeastern Gibson County; those of the third group (samples 886–908) were collected along the line of the Southern Railway across southwestern Hardeman County and southeastern Fayette County.

Physical properties of sands from the outcrop area of the Wilcox group

[Laboratory determinations by V. C. Fishel]

Laboratory No.[a]	Apparent specific gravity of oven-dried sample	Mechanical composition (per cent)							10 per cent size (millimeter)	Uniformity coefficient	Porosity (per cent)	Moisture equivalent by volume (per cent)	Porosity minus moisture equivalent	Coefficient of permeability
		2-1 mm	1-0.5 mm	0 5-0.25 mm	0.25-0.1 mm	Residue on pan	Silt	Clay						
858	1.67	0	1.4	50.9	42.1	1.7	2.2	1.6	0.110	2.68	44.3	5.4	38.9	285
857	1.69	9.2	10.0	48.6	28.7	.6	.9	1.1	.126	2.94	40.0	3.5	36.5	356
856	1.96	.4	14.9	63.3	17.1	.6	3.2	1.8	.126	2.94	33.9	6.0	27.9	448
861	1.65	.1	14.3	60.0	19.0	.5	3.6	1.7	.116	3.20	37.7	8.7	29.0	439
860	1.82	13.7	26.4	20.7	30.9	3.3	4.3	1.7	.105	4.57	37.4	6.3	31.1	233
859	1.78	0	.3	64.3	28.7	.3	4.1	2.3	.110	1.95	34.6	12.7	21.9	308
863	1.74	0	0	.8	96.3	1.7	.9	0	.105	1.50	33.6	3	30.6	130
862	1.66	0	0	.6	62.4	27.3	9.7	0	.051	2.74	40.8	9.7	31.1	9
920	1.79	4.1	15.2	40.0	37.3	1.6	1.3	.5	.116	3.01	38.0	1.7	36.3	388
921	1.65	1.4	47.7	37.9	6.7	2.1	2.0	.5	.210	2.76	44.0	2.2	41.8	822
922	1.68	7.1	42.3	38.7	9.2	.8	1.6	.4	.20	3.35	37.3	1.7	35.6	586
885	1.45	0	.2	2.6	94.1	2.7	1.3	.4	.108	1.94	43.0	3.2	39.8	475
884	1.45	0	.2	2.3	95.0	1.3	1.6	.5	.108	1.76	43.0	3.2	39.8	726
883	1.47	.2	.6	3.3	91.6	2.5	2.9	.6	.106	1.79	43.0	5.3	37.7	357
882	1.47	6.7	21.9	53.2	12.9	.9	4.5	.8	.130	3.31	43.0	4.0	39.0	670
881	1.47	1.9	12.8	65.0	16.3	.5	3.7	.7	.135	2.82	45.0	4.4	40.6	1,100
880	1.52	4.5	20.0	54.6	18.6	.6	1.7	.8	.140	2.93	42.0	4.3	37.7	1,590
879	1.51	2.6	13.4	53.6	15.5	.4	1.9	.8	.273	1.58	43.0	4.3	38.7	1,400
878	1.51	.2	4.3	44.0	48.3	2.3	1.7	1.2	.110	2.55	39.0	11.8	27.2	810
877	1.40	1,0	11,9	52.5	21.3	1.0	6.8	5.0			45.0	9.1	35.9	430
876	1.50	5.0	10.1	51.0	20.5	2.6	7.0	.7	.093	4.03	42.0	.9	41.1	313
875	1.37	0	1.0	37.9	44.8	2.0	12.2	1.0	.033	7.58	47.0	1.6	45.4	260
874	1.35	.25	2.3	29.5	51.8	1.4	14.6	.9	.027	7.78	49	1.5	47.5	268
899	1.79	6.0	11.6	28.4	47.4	2.7	.9	2.6	.108	2.73	34.1	2.0	32.1	367
900	1.64	.6	31.4	40.8	17.8	.9	7.5	0	.10	6.70	35.3	5.1	30.2	338
897	1.78	2.4	17.6	42.4	34.4	1.2	1.3	.5	.115	2.82	33.8	2.8	31.0	791
898	1.5	.3	3.5	26.4	58.7	8.1	2.2	.4	.094	2.32	43.4	3.4	40.0	712
901	1.73	14.8	43.4	18.2	13.9	7.6	2.1	0	.150	3.93	37.0	1.3	35.7	370
902	1.69	19.9	22.6	36.3	13.1	3.8	.4	0	.110	4.04	42.3	2.0	40.3	340
896	1.82	1.1	14.3	32.1	44.4	7.1	1.1	.5	.102	2.84	31.3	2.5	28.8	346
895	1.74	2.4	10.4	25.1	50.8	8.9	1.6	.4	.091	2.67	35.2	2.1	33.1	264
894	1.74	.1	6.3	35.8	55.0	.8	1.9	.4	.111	1.86	34.1	2.7	31.4	576
893	1.80	.2	4.2	20.3	66.7	7.3	1.8	.5	.100	2.00	32.7	3.4	29.3	359
892	1.79	13.4	24.7	25.4	30.0	4.3	1.9	.3	.110	4.27	31.0	1.9	29.1	723
891	1.74	1.5	10.1	29.0	45.1	7.4	6.6	.5	.066	3.86	34.0	8.7	25.3	258
890	1.53	.4	7.5	29.1	52.0	6.9	4.2	.4	.088	2.67	40.0	6.2	33.8	430
889	1.40	.6	27.9	49.5	13.2	3.4	2.9	2.5	.108	3.80	48.0	4.2	43.8	932
888	1.69	.3	1.4	27.9	59.5	6.4	3.2	1.9	.084	2.50	30.0	5.2	24.8	206

886	1.55	0	0.3	7.2	83.4	6.8	1.7	1.0	.100	1.73	42.7	2.5	40.2	134
903	1.66	1.0	27.5	64.2	6.6	.8	----------	0	.258	1.74	44.0	.7	43.3	800
905	1.65	0	1.1	89.7	7.6	.5	1.0	0	.252	1.45	39.7	1.6	38.1	554
904	1.62	0	.2	85.1	9.8	.2	3.3	0	.180	2.03	40.5	1.8	38.7	1,050
906	1.94	49.2	18.7	8.6	17.3	3.7	2.0	.8	.120	9.50	0	3.1	----------	632
907	1.58	0	7.7	88.9	2.4	.2	.7	0	.280	2.14	3.1	1.8	28.2	125
801	1.60	.4	.7	26.8	66.7	1.5	[b] 4.4	----------	.115	1.85	42.7	2.0	40.7	179
802	1.68	8.7	35.7	35.4	17.7	.8	[b] 1.5	----------	----------	----------	40.7	4.5	35.8	220
803	1.55	.6	5.2	21.2	57.4	8.8	[b] 6.9	----------	.075	2.88	46.5	3.5	43.0	209
804	1.81	.4	1.7	14.7	65.3	11.0	[b] 7.0	----------	.07	2.60	33.0	3.9	29.1	163
816	1.73	1.0	4.4	27.1	62.7	1.6	[b] 3.2	----------	.130	1.81	34.0	.9	33.1	----------

[a] Samples listed in order across the formation from bottom to top.

[b] Silt and clay not separated but expressed as silt.

Mechanical analyses of sands from the outcrop area of the Wilcox group, made according to the second method

[See p. 39]

Laboratory No.[a]	Mechanical composition (per cent)					
	2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.125 mm	0.125-0.062 mm	Residue on pan
858	0.2	0.9	60.0	36.0	1.0	1.0
857	6.0	18.0	57.0	17.0	.8	.7
856	0	7.8	83.0	9.0	.3	.3
861	0	16.5	79.5	2.5	.6	.4
860	13.0	41.0	29.0	14.0	2.0	.5
859	0	.3	83.2	14.0	.8	1.0
863	0	.05	8.6	83.8	6.1	.8
862	.1	1.4	4.3	35.2	35.0	22.0
920	1.0	15.5	54.5	17.0	2.0	1.5
921	0	38.5	57.5	2.5	1.5	1.5
922	2.0	38.0	53.5	5.0	1.5	1.5
885	0	.5	74.0	23.0	2.0	.5
884	.3	.6	62.5	35.0	1.5	.8
883	.3	1.0	61.5	35.2	1.0	1.0
882	2.5	18.8	72.0	4.5	1.0	1.0
881	1.4	15.5	81.0	2.0	.2	.3
880	4.0	29.0	65.0	1.0	.3	.3
879	2.0	21.0	74.2	1.0	.2	.3
878	0	4.5	84.0	11.5	.5	.5
877	.9	10.2	74.3	12.0	2.0	1.8
876	4.5	16.0	70.0	6.0	1.0	.5
875	.3	6.0	88.0	3.0	1.0	1.5
874	.3	5.5	83.0	8.0	1.0	2.0
899	.7	28.4	42.5	20	1.5	.6
900	1.2	36.8	52.7	6.1	.4	.4
897	1.0	17.5	74.0	7.0	1.0	.8
898	.5	4.5	75.0	16.0	4.0	1.0
901	10.7	53.4	26.5	6.0	4.9	4.9
902	19.2	30.4	41.7	5.5	1.2	1.2
896	.5	12.5	66.8	15.5	5.5	.5
895	1.0	11	62	19	6.0	1.5
894	0	7.0	74.5	18.0	1.0	1.0
893	0	5.0	56.0	35.5	4.0	.5
892	10.0	30.3	42.0	13.8	4.0	1.0
891	.8	11.0	68.8	14.0	2.7	2.5
890	.3	7.5	62.0	24.5	5.0	1.0
889	.3	41.0	55.9	2.5	1.0	1.0
888	.3	2.5	52.5	38.6	4.5	3.0
886	0	.7	11.5	68.8	16.0	4.0
903	.2	17.0	79.3	3.0	.4	.4
905	0	.08	92.5	4.9	.7	.5
904	1.3	23.5	71.3	1.6	.1	.1
906	0	.3	96.6	2.0	.2	.2
907	71.7	24.5	3.6	1.2	.9	1.0
830	0	10.4	67.1	20.4	1.8	---------
831	0	2.4	72.1	22.6	2.9	---------
832	1.4	30.8	56.6	10.4	.9	---------
833	3.1	43.5	46.1	6.8	.5	---------
834	5.8	50.6	40.6	3.0	.0	---------
835	32.7	38.9	24.4	3.1	1.0	---------
836	2.8	62.3	34.0	.9	0	---------
837	0	32.1	43.8	21.6	1.9	---------
838	0	9.5	6.0	27.6	37.9	19.0
839	0	0	37.5	55.0	7.4	0
840	0	1.2	75.2	19.7	3.9	0
841	0	2.6	72.5	23.4	2.5	0
842	0	4.4	62.2	29.7	3.7	0

[a] Samples listed in order across formations from bottom up.

858. Gully 5 miles south and a little east of Puryear, Henry County, on east side of old road from Paris to Hazel. Section from top down: 0-27 feet, red soil and sand with irregular streaks of gravel; 27-30 feet, mottled red and white sand with irregular cross-bedding; 30 feet to talus, medium to fine white sand showing shades of pink. Sample taken 40 feet below top of gully.

857. Same as 858; 5 feet below top of gully.

856. Same as 858; 30 feet below top of gully.

861. Clay pit 2.3 miles south and a little west of Puryear, Henry County. Section from top down: 0-7 feet, red sandy soil; 7-17 feet, sand and gravel, 3 feet of clean gravel; 17-42 feet, red and buff banded sand, some interstratified layers of coarse at bottom; 42-45 feet, black, thinly laminated clay. Sample taken 32 feet below top.

860. Same as 861; 27 feet below surface.

859. Same as 861; 22 feet below surface.

863. Cottage Grove, Henry County; gully on west side of village. Section from top down: 0–7 feet, red sandy soil; 7–50 feet, white, very fine grained sand showing markings in delicate pink. On weathering a distinct bedding is revealed, showing beds from 2 to 13 inches thick. Sample taken 40 feet below top.
862. Same as 863; 15 feet below the top.
920. Gully 4 miles east of Lavinia, Carroll County, on Milan-Lexington road. Shows 12 feet of medium-grained white sand. Sample taken at bottom.
921. Creek bank 1.8 miles east of Lavinia, in Carroll County. Shows 15 feet of medium-grained sand. Sample taken at bottom.
922. Bank 1.5 miles east of Lavinia, on right side of road. Section from top down: 0–10 feet, medium-grained sand stained and cemented by iron oxide; 10–13 feet, white sandy clay; 13–18 feet, medium-grained yellow sand. Sample taken 16 feet below top.
885. Bored well of T. M. Meads, 0.3 mile south of highway 5, Gibson County, on Madison County line. Section from top down: 0–30 feet, red sand, clay streak at 30 feet; 30–60 feet, coarse brown sand; 60–86 feet, fine white sand. Sample taken 85 feet below top.
884. Same as 885; 80 feet below top.
883. Same as 885; 75 feet below top.
882. Same as 885; 70 feet below top.
881. Same as 885; 65 feet below top.
880. Same as 885; 60 feet below top.
879. Same as 885; 55 feet below top.
878. Same as 885; 50 feet below top.
877. Same as 885; 45 feet below top.
876. Same as 885; 40 feet below top.
875. Same as 885; 35 feet below top.
874. Same as 885; 30 feet below top.
899. Gully 8 miles east of Rogers Springs and 0.5 mile north of Southern Railway, Hardeman County. Section from top down: 0–14 feet, coarse and medium-grained sand, stained red by iron oxide, weathered product of underlying sand; 14–27 feet, white sand, cross-bedded, mostly coarse with some streaks containing pebbles 5 millimeters in diameter; 29–30 feet, fine white and red sand. Sample taken 29 feet below top.
900. Same as 899; 15 feet below top.
897. Bank 3 miles east of Saulsbury on south side of Southern Railway, Hardeman County, shows 10 feet of white medium-grained sand grading into soil at the top. Sample taken 25 feet below top.
898. Bank 1,000 yards west of 897. Shows 15 feet of brown medium-grained sand. Sample taken 13 feet below top.
901. Gully 1.5 miles east and a little south of Saulsbury on Old State Line Road, Hardeman County, showing great variation in its different branches. At one place 15 feet of coarse white sand overlain by fine sand. Sample from fine sand.
902. Bank on roadside 200 yards west of 901. Red, brown, and white cross-bedded coarse sand.
896. Durden sand pit, on east edge of Saulsbury, on south side of Southern Railway, Hardeman County. Shows 55 feet of white cross-bedded medium to coarse grained sand. Wide bands of white sand showing cross-bedding at high angles separated by red layers a few feet thick showing horizontal bedding. Sample taken 45 feet below top.
895. Same as 896; 40 feet below top.
894. Same as 896; 35 feet below top.
893. Same as 896; 30 feet below top.
892. Same as 896; 25 feet below top.
891. Same as 896; 20 feet below top.
890. Same as 896; 15 feet below top.
889. In creek bank 3.4 miles east of Grand Junction on road to Saulsbury, Hardeman County. Shows 12 feet of interlaminated medium to coarse grained red and white sand. Sample taken 8 feet below top.
888. Bank 200 yards west of 889. Shows 20 feet of white and red medium-grained sand. Sample taken 16 feet below top.
886. On Southern Railway 2.4 miles east of Grand Junction, Hardeman County. Section from top down: 0–6 feet, sandy soil stained dark red by iron oxide, at bottom rubble of angular fragments of iron oxide and pebbles; 6–26 feet, interlaminated coarse red sand; 26–55 feet, interlaminated fine-grained, slightly micaceous white sand with plastic clay, from half an inch to 6 inches in thickness. Sample taken 55 feet below top.
903. Bank on Grand Junction-La Grange road at Fayette-Hardeman County line. Shows 15 feet of medium-grained sand with usual weather staining. Sample taken 11 feet below surface.
905. Sand pit 0.5 mile east of La Grange and 0.5 mile south of Southern Railway, Fayette County. Shows 50 feet of irregularly bedded medium-grained white sand. Sample taken at bottom.
904. Same as 905; 30 feet below top.
906. Gully on north side of Southern Railway 1.5 miles west of La Grange, Fayette County. Section from top down: 0–20 feet, medium-grained white sand; 20–25 feet, coarse sand; 25— feet, clay. Sample taken 23 feet below top.
907. Same as 906; 13 feet below top.
801. Gully 0.5 mile south of railroad bridge on Main Street, La Grange, Hardeman County. Medium to fine-grained sand.
802. Same as 801; 40 feet higher up gully.
803. Bank on Old State Line Road 1.1 miles southeast of Saulsbury, Hardeman County.
804. Bank at crossing of Brownsville-Somerville road and Nashville, Chattanooga & St. Louis Railway track, Fayette County.
816. Road cut on State highway 15.3 miles west of Hornsby, Hardeman County. Shows 22 feet of white and pink fine-grained sand. Sample taken 19 feet below top.
830. Well 654 feet deep at Western State Hospital, Bolivar, Hardeman County. Sample from depth of 10–20 feet.
831. Same as 830; depth 20–30 feet.
832. Same as 830; depth 30–40 feet.
833. Same as 830; depth 40–50 feet.
834. Same as 830; depth 50–65 feet.
835. Same as 830; depth 65–80 feet.
836. Same as 830; depth 80–90 feet.
837. Same as 830; depth 90–100 feet.
839. Same as 830; depth 207–232 feet.
840. Same as 830; depth 232–256 feet.
841. Same as 830; depth 256–276 feet.
842. Same as 830; depth 276–316 feet.

It is impossible to say whether the samples represent the relative abundance of the different grades of sand in the formation as a whole, but there is little doubt that they indicate the range of sands present in the formation. The maximum, minimum, and average figures are as follows:

	Maximum	Minimum	Average
Coefficient of permeability	1,488	9	514
Uniformity coefficient	9.50	1.50	3.05
Porosity per cent	48.0	30.0	39.3
Porosity minus moisture equivalent do	47.5	21.9	35.5

The coefficient of permeability shows a wide range, but there is only one sample that is close to the minimum, and it is probable that sand of that grade is rather sparsely distributed. There is also a wide range in the uniformity coefficient, but samples showing high values are rare. The porosity is limited in range.

A comparison of these figures with the following results of similar tests made on 26 samples obtained from wells drilled throughout the area is of interest. Of these samples 7 came from wells in different parts of the area and 19 from wells in Memphis. Nos. 1039, 1040, 1042, 1048, 1052, 1056, 1059, 1061, 1064, 1068, and 1071 are complete analyses made on representative samples selected from 33 samples obtained from well 50 of the Memphis Artesian Water Department. These 33 samples were taken one every 5 feet. The samples were sieved, and a sample for complete analysis was taken from each layer of sand that had a distinctive mechanical composition. The 11 complete analyses represent the character of 190 feet of sand. A log of well 50 is given below.

Log of well 50, Memphis Artesian Water Department

[Authority, W. G. Lanham]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Loess: Yellow clay	27	27	Wilcox group—Continued.		
Pliocene gravel: sand and gravel	58	85	Rock	1	195
Jackson formation:			Clay	17	212
Blue clay	50	135	Rock	1	213
Very soft mucky sandy clay	27	162	Clay	72	285
Wilcox group:			Sand, water-bearing	58	343
Yellow sand	13	175	Clay	19	362
Clay	15	190	Rock	1	363
Rock	1	191	Clay	31	394
Clay	3	194	Sand, water-bearing	19	513

Physical properties of sands from the upper part of the Wilcox group of Memphis, Tenn.

[Samples from well 50 of the Memphis Artesian Water Department. Laboratory determinations by V. C. Fishel]

Laboratory No.[a]	Apparent specific gravity of oven-dried sample	Mechanical composition (per cent)						
		2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.1 mm	Residue on pan	Silt	Clay
1039	1.64	8.6	73.6	15.9	0.5	0.1	0.1	0
1040	1.65	.2	3.8	42.1	44.6	8.4	.4	0
1042	1.58	.2	10.6	60.1	27.5	.8	.1	0
1048	1.60	0	7.1	59.0	29.7	2.2	.8	0
1052	1.56	0	12.1	51.4	31.9	3.5	.5	0
1056	1.56	0	18.5	59.7	20.0	1.0	.1	0
1059	1.52	0	18.9	74.5	5.2	.5	.3	0
1061	1.65	0	23.0	8.4	64.0	3.5	.2	0
1064	1.59	0	20.1	59.8	18.6	1.2	.2	0
1068	1.56	0	4.4	9.1	81.2	4.8	.2	0
1071[b]	---	---	---	---	---	---	---	---

Laboratory No.[a]	10 per cent size (millimeter)	Uniformity coefficient	Porosity (per cent)	Moisture equivalent by volume (per cent)	Porosity minus moisture equivalent	Coefficient of permeability	Depth (feet)
1039	0.375	1.84	38.1	0.75	38.0	3,936	162-175
1040	.106	2.23	38.3	1.65	36.6	529	295
1042	.138	2.36	40.5	1.44	39.1	1,664	300
1048	.125	2.48	38.9	1.97	36.9	851	330
1052	.115	2.61	42.0	1.74	40.3	1,263	405
1056	.150	2.33	41.2	1.54	39.7	1,640	425
1059	.260	1.46	43.7	1.24	42.5	2,279	440
1061	.110	1.78	32.3	1.65	30.6	563	450
1064	.150	1.37	40.4	2.42	38.0	1,647	465
1068	.106	1.59	41.0	3.2	37.8	538	485
1071[b]	.203	2.21	25.4	.5	24.9	1,836	560

[a] Arranged in order of increasing depth. [b] For mechanical analysis see next table.

Mechanical analyses of sands from well 50 of the Memphis Artesian Water Department, as determined by the second method

[See p. 39. Laboratory determinations by V. C. Fishel]

Laboratory No.[a]	Mechanical composition (per cent)						Depth (feet)
	2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.125	0.125-0.62 mm	Residue on pan	
1039	2.4	84.0	13.8	0.1	0	0	162-175
1040	.8	4.0	69.7	21.0	3.8	1.0	290
1041	.9	4.0	75.0	18.0	2.0	.5	295
1042	.5	7.0	81.6	10.1	.7	.1	300
1043	.5	8.7	82.0	8.0	.6	.1	305
1044	.1	13.0	77.5	9.0	1.0	.2	310
1045	.1	11.0	78.0	10.0	1.0	.1	315
1046	.1	12.1	78.8	8.0	.2	.1	320
1047	.2	3.9	75.0	8.9	1.5	.9	325
1048	.2	5.2	82.3	12.0	.2	.1	330
1049	.2	3.8	80.0	15.0	.8	.3	335
1050	.4	3.7	80.9	13.4	1.2	.8	340
1051	0	3.2	77.0	18.8	.9	.1	400
1052	.1	9.1	78.5	10.8	1.4	.6	405
1053	.1	8.0	80.2	10.0	1.2	.5	410
1054	.1	8.0	77.5	12.0	2.0	1.0	415
1055	0	7.0	86.5	6.0	.5	.2	420
1056	0	9.5	87.0	3.9	.1	0	425
1057	0	9.5	88.0	2.1	.2	.1	430
1058	0	6.0	89.5	4.0	.2	.1	435
1059	0	6.0	92.5	1.5	.1	0	440
1060	0	10.0	82.8	7.0	.2	.1	445
1061	0	17.0	30.0	48.9	3.1	.2	450
1062	0	18.0	35.0	44.0	2.9	.2	455
1063	0	18.0	40.0	39.5	2.5	.2	460
1064	0	8.0	83.5	8.0	.8	.2	465
1065	0	7.0	81.5	10.6	1.0	.2	470
1066	.1	7.5	81.8	9.1	1.5	.2	475
1067	0	2.8	59.5	30.5	6.0	1.0	480
1068	0	3.9	60.0	30.0	5.5	1.1	485
1069	0	4.0	58.0	32.0	5.0	1.0	490
1070	.2	5.0	60.0	29.0	5.0	1.0	495
1071	.2	4.4	69.0	22.8	2.8	.8	500

[a] Arranged in order of increasing depth.

Physical properties of sands obtained from wells in the Wilcox group

[See p. 103. Laboratory determinations by V. C. Fishel]

Laboratory No.	Apparent specific gravity of oven-dried sample	Mechanical composition (per cent)						
		2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.1 mm	Residue on pan	Silt	Clay
817	1.69	1.9	19.9	51.2	24.1	2.2	0.7	0
819	1.65	5.0	56.6	33.2	4.6	0	.5	0
821	1.67	1.4	16.9	54.7	25.6	2.1	.4	0
822	1.68	.7	53.4	39.9	5.3	0	.7	0
823	1.63	37.4	37.1	23.2	2.4	0	0	0
824	1.65	1.1	31.7	48.0	17.6	1.4	.3	0
825	1.68	.8	33.3	50.2	14.7	.8	.2	0
826	1.57	.3	.9	12.6	69.5	15.9	.8	0
827	1.66	2.8	6.3	16.9	66.4	6.6	1.0	0
870	1.63	1.7	8.9	40.8	41.0	3.1	2.7	1.1
871	1.69	17.4	30.6	29.0	20.8	.6	1.1	1.1
872	1.69	43.4	40.7	7.0	7.7	1.3	.1	1.1
873	1.59	6.0	21.3	44.2	25.7	.4	.6	1.2
910	1.48	6.9	88.3	2.1	.1	.2	1.1	.1
911	1.41	7.5	84.6	2.6	.2	.1	2.8	.4
924	1.71	27.1	43.0	18.7	10.2	.7	.4	0
L. & N. I	----------	.0	4.5	67.5	26.0	2.0	0	0
L. & N. II	----------	1.4	6.5	64.1	26.0	2.0	0	0
L. & N. III	----------	2.0	23.1	63.0	11.0	1.0	0	0
L. & N. IV	----------	1.8	30.1	60.1	7.4	.6	0	0

Laboratory No.	10 per cent size (millimeters)	Uniformity coefficients	Porosity (per cent)	Moisture equivalent by volume (per cent)	Porosity minus moisture equivalent	Coefficient of permeability
817	0.17	2.19	44.5	----------	----------	----------
819	.34	1.71	47.2	----------	----------	----------
821	.17	2.19	48.1	----------	----------	513
822	.30	1.84	45.4	----------	----------	1,539
823	.38	2.48	39.0	0.7	66.4	2,435
825	.21	2.23	44.7	.5	44.2	1.036
826	.08	2.02	46.4	1.6	44.8	529
827	.14	1.56	43.6	1.7	41.9	1,518
870	.11	1.93	43.2	6.6	36.6	348
871	.14	4.25	41.9	2.3	39.6	675
872	.24	4.38	41.7	2.3	39.4	1,100
873	.13	1.73	44.9	2.9	42.0	682
910	.54	1.44	43.0	1.4	41.6	2,000
911	.52	1.50	49.0	2.9	46.1	----------
924	.25	3.28	35.0	1.2	33.8	----------
L. & N. I	.23	1.31	----------	----------	----------	----------
L. & N. II	.24	1.32	----------	----------	----------	----------
L. & N. III	.23	1.91	----------	----------	----------	----------
L. & N. IV	.26	1.88	----------	----------	----------	----------

Mechanical analyses of sands obtained from wells in the Wilcox group, as determined by second method

[See p. 39. Laboratory determinations by V. C. Fishel]

Laboratory No.	Mechanical composition (per cent)					
	2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.125 mm	0.125-0.062 mm	Residue on pan
870	1.0	11.0	62.0	24.0	1.0	0.6
871	20.0	48.0	26.0	4.8	.3	.2
872	25.0	58.0	12.5	3.0	.5	.8
873	3.0	20.5	58.5	16.5	.5	.5
910	4.0	90.0	6.0	0.4	.1	0
911	7.0	88.0	3.5	1.0	.3	.1
924	37.5	42.5	16.0	3.0	.5	.2

817. From well of Baptist Hospital, Madison and Dudley Streets, Memphis, drilled October, 1928; depth 446 feet.
819. From well 20 of Memphis Artesian Water Department, Memphis; depth 301–320 feet.
821. Same as 819; depth 350–390 feet.
822. Same as 819; depth 390 feet.
823. From well 32 of Memphis Artesian Water Department, Memphis; depth 421–495 feet.
824. From well 33 of Memphis Artesian Water Department, Memphis; depth 300–402 feet.
825. Same as 824; depth 419–500 feet.
826. Same as 824; depth 760–825 feet.
827. Same as 824; depth 1035–1090 feet.
870. From well of T. E. Sanford, 3 miles west of Medina, Gibson County; depth 113 feet.
871. 2.4 miles north of Sharon, Weakley County, on east side of highway 5; depth 250 feet.
872. From well 37c, city of Martin, Weakley County; depth 320 feet.
873. 2.8 miles north of Sharon, Weakley County, on east side of highway 5; depth 230 feet.
910. From well 35, city of Dyersburg, Dyer County; depth 784 feet.
911. Same as 910; depth 650 feet.
924. Western State Hospital, 2.3 miles from Bolivar, Hardeman County; depth 110 feet.
L. & N. I. From well of Louisville & Nashville Railroad at Leewood yard, Memphis, drilled in 1917; sample from 113 to 132 feet below mean sea level.
L. & N. II. Same as I; 132 to 148 feet below mean sea level.
L. & N. III. Same as I; 148 to 168 feet below mean sea level.
L. & N. IV. Same as I; 168 to 184 feet below mean sea level.

The maximum, average, and minimum results are as follows:

	Maximum	Average	Minimum
Coefficient of permeability	3,936	1,295	348
Uniformity coefficient	4.38	2.11	1.31
Porosity per cent	73.9	43.7	25.4
Porosity minus moisture equivalent do	72.3	41.3	24.9

The figures for the coefficient of permeability are much larger than the corresponding figures for samples from the outcrop area. This difference can be explained in either of two ways. The samples from the wells are carefully washed to remove sludge, and in this washing the silt and clay that belong to the sample are removed. The average silt and clay content of samples from the outcrop area, however, is only 3.8 per cent, and the removal of that much material would not make so great a difference as the figures show. A more probable explanation is that a large number of the samples from wells represent only the coarsest and most permeable material encountered in drilling. Also some of the finer sands containing clay included in the samples from the outcrop area would be classed as clay in drilling, and so they are not present in the well samples to drag down the general average. This explanation can be tested by studying the physical properties of sands from well 51 of the Memphis Artesian Water Department. This well passes completely through the upper and middle Wilcox, as shown by the following log:

Log of well 51 of Memphis Artesian Water Department

[Authority, W. G. Lanham]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Loess: Yellow clay	28	28	Wilcox group—Continued.		
Pliocene gravel: Sand and gravel	60	88	Rock	1	645
Jackson formation: Clay	182	270	Clay	37	682
Wilcox group:			Sand	43	735
Sand	51	321	Clay	251	986
Clay	69	390	Rock	1	987
Sand	80	470	Clay	3	990
Sand, extra good water-bearing	65	535	Rock	1	991
Sand	35	570	Clay	219	1,210
Clay	74	644	Sand	160	1,370

Physical properties of sands from the Wilcox group at Memphis, Tenn.

[Samples from well 51, Artesian Water Department. Laboratory determinations by V. C. Fishel]

Laboratory No.[a]	Apparent specific gravity of oven-dried sample	Mechanical composition (per cent)						
		2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.1 mm	Residue on pan	Silt	Clay
983	1.49	0	1.0	57.4	40.1	0.2	1.1	0
984	1.51	0	1.1	62.9	35.7	.1	.1	0
986	1.62	6.6	28.1	37.7	27.4	.9	.2	0
985	1.52	0	1.3	61.3	37.4	.2	.8	0
987	1.62	3.2	19.1	43.9	32.2	1.3	.3	0
988	1.68	15.6	45.9	24.1	13.3	.7	1.6	0
989	1.62	3.5	20.5	38.0	35.1	2.7	.1	0
990	1.54	1.3	2.9	10.7	83.6	1.2	.5	0
991	1.52	1.1	1.9	13.5	82.0	.8	.1	0
992	1.65	0	.5	26.0	71.6	1.8	.1	0
993	1.47	.2	.2	4.1	93.1	2.0	.4	0
994	1.47	.3	.7	4.8	90.3	3.2	.7	0

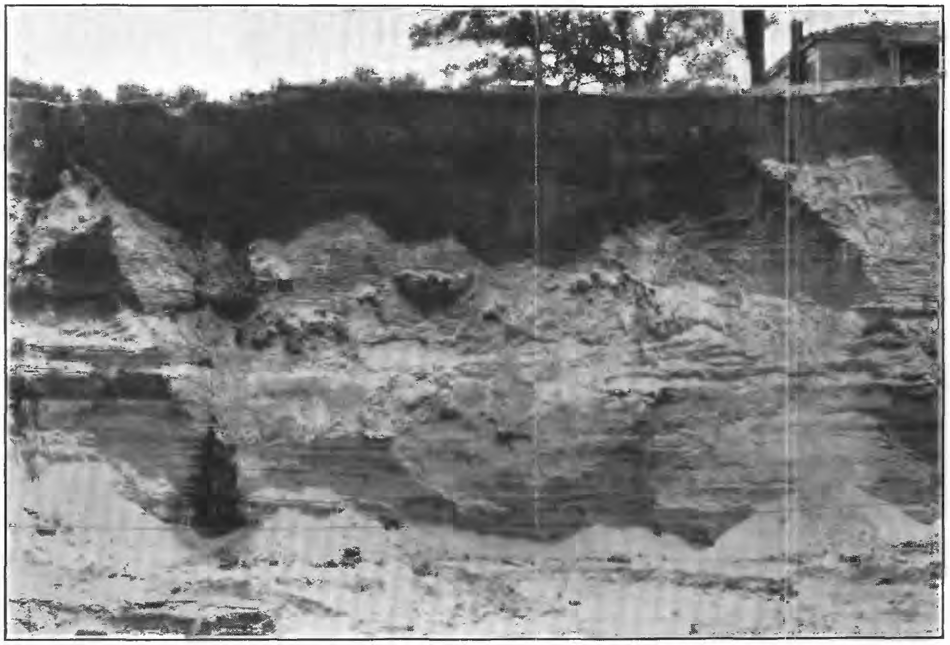
Laboratory No.[a]	10 per cent size (millimeter)	Uniformity coefficient	Porosity (per cent)	Moisture equivalent by volume (per cent)	Porosity minus moisture equivalent	Coefficient of permeability	Depth (feet)
983	0.12	2.58	41.5	1.23	40.3	1,181	445
984	.12	2.38	41.4	.86	40.5	1,019	455
986	.135	3.30	35.6	1.21	34.4	951	500
985	.125	2.56	40.1	1.79	38.3	996	475
987	.125	2.04	36.2	1.20	35.0	672	520
988	.150	3.53	35.3	2.02	33.2	1,154	530
989	.12	3.17	39.0	2.14	36.9	855	540
990	.11	1.73	42.0	1.54	40.5	640	550
991	.11	1.77	42.9	1.65	41.2	585	560
992	.11	1.91	37.8	1.65	36.1	835	690
993	.11	1.65	43.9	1.76	42.1	688	710
994	.11	1.64	43.7	1.63	42.1	503	720

[a] Arranged in order of increasing depth.

Mechanical analyses of sands from well 51 of the Memphis Artesian Water Department, as determined by the second method

[See p. 39. Laboratory determinations by V. C. Fishel]

Laboratory No.	Mechanical Composition (per cent)						Depths (feet)
	2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.125 mm	0.125-0.062 mm	Residue on pan	
983	0	0.5	93.0	6.2	0.2	0.1	445
995	0	.5	91.0	8.5	.1	0	450
984	0	.5	93	6.2	.1	.1	455
996	0	.3	89.3	10.0	.2	.1	460
997	0	.5	90	9	.2	.1	465
998	0	.5	90.5	8	.1	0	470
985	0	.3	88.0	11.7	.2	.1	475
999	0	.5	90.7	8.3	.3	.1	480
1000	0	.4	87.0	12.5	.3	.1	485
1025	0	.5	89.0	10.3	.1	0	495
986	1.2	34.0	61.0	8.0	.2	.1	500
1026	1.0	27.0	56.5	13.3	1.0	.3	505
1027	1.0	26.3	59.0	12.5	.8	.2	510
988	6.0	53.2	38.2	2.2	.1	0	530
1030	.7	4.7	46.0	48.0	2.0	.1	535
989	.8	22.5	62.0	13.3	.7	.7	540
990	1.0	4.5	75.0	18.0	1.0	.1	550
1031	1.0	8.0	65.0	25.0	1.0	.1	555
991	.4	2.0	76.0	19.0	1.0	.5	560
1032	.8	3.0	80.0	15.0	.5	.1	565
1033	2.0	6.5	64.0	26.0	1.0	.1	570
1034	0	.3	78.0	21.0	.5	.1	685
992	0	.4	81.5	17.0	1.0	.2	690
1035	0	.5	74.0	24.0	1.0	.1	695
1036	.3	.8	69.0	28.0	1.5	.1	705
993	.2	.5	74.0	24.3	1.2	.1	710
1037	.1	.5	69.0	28.0	2.6	.4	715
994	.5	1.0	49.5	45.0	4.0	.5	720
1038	.4	1.0	60.0	32.0	6.0	.9	725

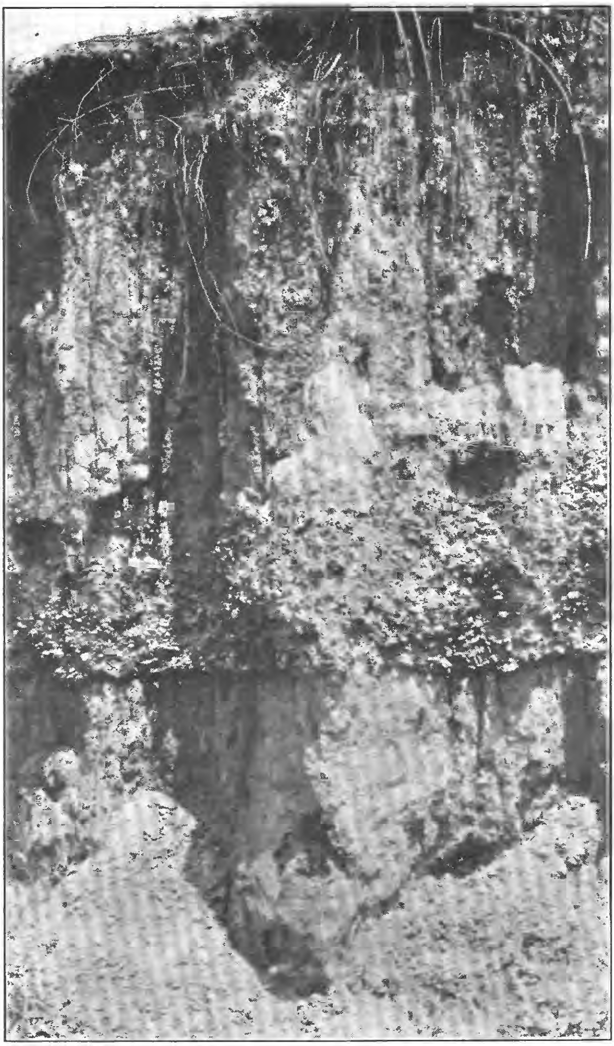


A. DURDEN SAND PIT AT SAULSBURY, HARDEMAN COUNTY

The bedding is shown in the lower part and the alternating gray and brown sand laminae near the top. Photograph by J. K. Roberts.

B. WADE PIT NO. 4, 3½ MILES NORTHWEST OF WITTOCK, HENRY COUNTY

The pit indicates the areal extent of clay lenses in the Holly Springs sand of the Wilcox group. Photograph by J. K. Roberts.



LOESS AND PLIOCENE GRAVEL AND SAND IN RAILROAD CUT, 1 MILE EAST OF BRUNSWICK, SHELBY COUNTY

Photograph by J. K. Roberts.

Samples of sand were taken one every 5 feet, and these were sieved. A sample for complete analysis was selected from each successive group of samples that were similar in mechanical composition. This series of selected samples gives an idea of the physical properties of what the driller terms sand throughout the section of the upper and middle Wilcox at Memphis. The maximum, average, and minimum physical properties of sands from well 51 are as follows:

	Maximum	Average	Minimum
Coefficient of permeability	1,181	840	503
Uniformity coefficient	3.53	2.37	1.64
Porosity per cent	43.9	40.0	35.3
Porosity minus moisture equivalent do	42.1	38.4	33.3

This indicates that the average physical properties of samples from well 51 and of samples from the outcrop area represent approximately the upper and middle Wilcox sands as a whole.

The maxima and minima given above for the well samples are very different from the maxima and minima of the sands from the outcrop area, but the averages are fairly comparable. The average physical properties of sands from well 51, however, are much less than the average for samples taken from wells throughout the area. In conclusion it can safely be said that the physical properties of the sands from the Wilcox group taken as a whole correspond to those of the samples of sand taken from outcrops. In any section sands coarser, more uniform, more permeable, and more porous than the average will probably be found, as well as sands that are less so, but sand having physical properties corresponding to the average can be confidently expected in any section.

WATER-YIELDING PROPERTIES

Taken as a whole the upper and middle Wilcox is an excellent source of water. Although it contains clay lenses they are not of great extent and form but a small part of the group, and it is always possible to pass through them by deeper drilling or to avoid them by changing the location of a well. The very fine clay sands, "pipe clay," are also not water bearing, and these form a larger part of the group than the clays. Although no figures can be given for the percentage of the Wilcox that will not yield water, it may safely be placed under 50 per cent. The fine sands are good water bearers. Although it may be difficult to finish a well in them, this is a well driller's problem and does not lessen their water-bearing properties. The coarse sands of this formation are found in layers as much as 50 feet thick and form the finest kind of water-bearing beds, in which wells can be finished without any difficulty. The laboratory tests of the coarse sand show it to have high porosity, specific yield, and permeability. These results are borne out by well tests.

QUALITY OF WATER

The upper and middle Wilcox yield waters that are uniformly low in mineral content. Most of the 90 samples analyzed from this group [81] contained less than 100 parts per million of dissolved mineral matter, and many contained less than 50 parts. In many of these waters two or more of the principal acidic and basic constituents are present in amounts so nearly equivalent that the waters can not be characterized by naming a single compound, as calcium bicarbonate or sodium sulphate. The greater mineral content of several of the few samples that contained more than 100 parts per million of dissolved solids may be attributed to contamination, indicated by unusually high chloride and nitrate content. In others the increase is in calcium bicarbonate, an increase which seems to bear no relation to locality or depth. The iron content of the waters is variable. Some of the samples analyzed contain as much as 6 or 7 parts per million of iron, others as little as 0.05 part. This variation is dependent on the contact of the waters with lenses of clay that contain iron sulphide. Aside from the high iron content of some of the waters, which can be removed by aeration, most of them are excellent for all industrial and domestic uses, if proper precautions are taken to guard against pollution.

JACKSON FORMATION

Distribution and thickness.—The upper Eocene is represented in western Tennessee by the Jackson formation, which is separated from the underlying Grenada and the overlying Pliocene gravel by unconformities. The Jackson crops out in the Chickasaw Bluffs along the Mississippi River and probably extends eastward under the loess covering, but except for an outcrop at Raleigh it is not found at the surface in any place east of the bluffs. The formation is well exposed at Maybury Leap, Richardson's Landing, and Fort Pillow and in Obion County. Owing to the paucity of outcrops and the fact that the eastern contact or base of the Jackson is not exposed, there is a great uncertainty as to the thickness of the formation. At Yazoo City, about 75 miles south of the Tennessee-Mississippi line, the formation is 600 feet thick.[82] Stephenson [83] gives the thickness in north-

[81] Carroll County, Nos. 10, 28, 30, 45, 62; Chester County, No. 2; Crocker County, Nos. 5a, 8, 12, 25, 28, 30, 39; Dyer County, Nos. 14, 26, 35a, 35b, 35c, 53; Fayette County, Nos. 4c, 10a, 11, 12, 13, 14, 15; Gibson County, Nos. 9, 15, 20, 30, 42, 58, 62, 64, 78, 81; Hardeman County, Nos. 2, 4a, 5c, 9b, 10b, 23, 24a; Haywood County, Nos. 8, 11, 18, 25, 27, 36a, 36b, 40; Henry County, Nos. 22, 33, 38, 75; Lake County, Nos. 11a, 11b; Lauderdale County, Nos. 12, 21, 38b; Madison County, Nos. 1c, 15a, 19b, 21g, 34b, 36a; Obion County, Nos. 1, 17, 17b, 24, 38, 57; Shelby County, Nos, 5, 6a, 8a, 21, 38b; Tipton County, Nos. 6, 9a, 9b, 23b, 44; Weakley County, Nos. 4, 7, 23, 36, 37, 41, 41a, 58, 70.

[82] Cooke, C. W., Correlation of the deposits of Jackson and Vicksburg age in Mississippi and Alabama: Washington Acad. Sci. Jour., vol. 7, p. 188, 1918.

[83] Stephenson, L. W., and Crider, A. F., Geology and ground waters in northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, p. 75, 1916.

eastern Arkansas as 200 feet. If the blue clay which is found underlying all of Memphis and which is reported by all drillers throughout Shelby, Tipton, Lauderdale, and Dyer Counties and parts of Obion County is correlated with the Jackson, the formation at Memphis would be 150 to 200 feet thick.

Lithologic character.—The Jackson formation as found in outcrop consists of sand, clay, and lignite. The sand is very fine grained and uniform in grain size and is either of a gray color or speckled from grains of lignite. The sand shows marked lamination. The clay occurs in beds that are continuous throughout the length of outcrop, and if they are lenticular they thin out very gradually. The Jackson is peculiar among the formations of western Tennessee in that it contains layers of lignite which attain a maximum thickness of several feet. These lignite beds contain marcasite and pyrite concretions.

The lower part of the Jackson formation as revealed by well drillings is largely blue clay. Drillers' reports vary, but they are consistent in describing its blue color. In some logs the clay is said to be sandy, and in others it is described as hard. The logs of about 200 wells of the Memphis Artesian Water Department drilled throughout Memphis furnish the best information. These logs show that the formation is predominantly hard blue clay containing some layers or lenses of fine sand. There can be little doubt that the clay forms an essentially continuous bed over most of the counties bordering the Mississippi River, and it is to this confining bed that the artesian head of the water at Memphis and Dyersburg is due. No attempt has been made in this report to differentiate the Jackson from the underlying Grenada.

Although the sands of Jackson age are slightly water bearing, they are not used as sources of water. The lignite beds render the water adjacent to them unpalatable. Also the water is liable to have a high iron and sulphur content, which is derived from the marcasite and pyrite in the lignite. As the sands are very fine it is difficult to finish wells in them. These factors have prevented this formation being drawn upon by wells.

Quality of water.—It is impossible to recognize definitely the Jackson formation from well logs or drillings, and its outcrop along the bluffs does not afford enough information to determine its extent and thickness definitely. In areas where it probably occurs, however, wells that end a short distance below the Pliocene gravel obtain water that varies considerably in the amount of dissolved mineral matter, ranging from 170 to more than 400 parts per million. (See analyses—Dyer County, Nos. 1, 37; Lauderdale County, Nos. 6, 9, 38a; Obion County, Nos. 19a, 33, 53; Weakley County, No. 24.)

The waters from the Jackson formation are usually calcium bicarbonate in character, although some of them are typically dolomitic, and they range in hardness from 120 to 360 parts per million, which is sufficient to necessitate treatment for most industrial uses and to be objectionable for many household purposes. The iron content is usually high enough to justify its removal by aeration. Diagrams of analyses of two representative samples are shown in Figure 10.

PLIOCENE SERIES

GRAVEL

Outcropping in the Chickasaw Bluffs and on the uplands adjacent to the Tennessee River occur deposits of gravel and sand. These deposits, with the mantle of coarse ferruginous sand that covers the uplands of western Tennessee, were formerly considered to be one formation and were called "Lafayette." [84] Berry [85] has shown that the "Lafayette" of Hilgard and McGee is of various ages, ranging from Cretaceous to Recent, and that at the type locality it is Eocene. After a careful study of the Pliocene of northern Mississippi Shaw [86] came to the conclusion that this so-called formation was in reality nothing but the weathered portion of the underlying formations plus such larger material as was left behind in the process of erosion; for this material he suggested the name "residuum." The writer believes that the mantle of coarse ferruginous sand that covers the uplands of western Tennessee is also residuum formed from the underlying formations by the usual process of erosion and soil formation. The true gravels are terrace deposits which rest unconformably on the Jackson and Wilcox in the western part of the area and on the Cretaceous deposits in the eastern part. Along the Mississippi they are of Pliocene age. Wade [87] believes that only the highest of the terraces along the Tennessee River is of Pliocene age, the others being Pleistocene. In this report they will be discussed together.

Distribution and thickness.—The Pliocene gravel and sand are well exposed in the bluffs along the Mississippi River and are found below the loess on the uplands wherever gullies or roads have cut through the loess throughout Shelby County (pl. 10), the western edge of Fayette County, Tipton, and Lauderdale Counties, and Dyer and Obion Counties west of a line connecting Dyersburg and Union City. The gravel and sand have a maximum thickness of 50 feet, but 20 feet is the usual thickness in the west, and they thin out toward the east. Along the Tennessee the gravel is most extensively developed on the

[84] McGee, W J, The Lafayette formation: U. S. Geol. Survey Twelfth Ann. Rept., pt. 1, pp. 461–466, 1891. Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River: U. S. Geol. Survey Water-Supply Paper 164, pp. 40–43, 1906.

[85] Berry, E. W., The age of the type exposure of the Lafayette formation: Jour. Geology, vol. 19, pp. 249–256, 1911.

[86] Shaw, E. W., The Pliocene history of northern and central Mississippi: U. S. Geol. Survey Prof. Paper 108, pp. 125–164, 1918.

[87] Wade, Bruce, The gravels of west Tennessee Valle.: Resources of Tennessee, vol. 7, No. 2, p. 70, Tennessee Geol. Survey, 1917.

uplands of Hardin, McNairy, Decatur, Benton, and Henry Counties, though some occurs in Hardeman, Chester, Henderson, and Carroll Counties. The maximum thickness of any of the terraces along the Tennessee River is 50 feet.

Lithologic character.—The deposits range from gravel with very little interstitial sand through gravel filled with sand to sand containing a small number of pebbles. In some localities the gravel occurs as irregular-shaped bodies in sand. The pebbles may show some regular distribution, but usually the distribution is chaotic; likewise the pebbles may be fairly regular in size or may vary considerably. The pebbles average less than 2 inches in diameter but reach more than 5½ inches, and a few cobbles that measured as much as 8 inches have been found. The pebbles are rounded or subrounded and may be flattened or tabular. They consist of quartz, chert, sandstone, quartzite, and a few recorded fossils from the Paleozoic. The pebbles are coated with iron oxide. The deposits are loose and unconsolidated except where they form thin layers of pebbles cemented by iron oxide, which makes very hard material.

The gravel is as a whole a good source of water. Where it underlies the loess it is the formation from which most small domestic supplies are obtained. The gravel that is found locally in the area around Memphis will yield from 200 to 400 gallons a minute. In the hilly regions gravel overlying sand lies above the water table, but gravel overlying impervious formation is a valuable source of water for small supplies.

Quality of water.—The waters from the gravel can be divided into two distinct groups on the basis of the amount and character of the dissolved solids. (See analyses—McNairy County, Nos. 1, 10, 16; Obion County, No. 35; Shelby County, Nos. 21a, 28; Tipton County, Nos. 25, 33, 39, 45.) The chemical character of these two groups is determined by the geologic location of the gravel. Where the gravel forms the surface formations the water derived from it is low in dissolved solids, unless contaminated by surface drainage, is fairly soft, and is usually low in iron content. These waters are excellent. An example is given in diagram E, Figure 10.

In the counties bordering the Mississippi River the Pliocene gravel is covered with a mantle of loess. Meteoric water percolating down through the loess dissolves considerable quantities of various mineral constituents, particularly calcium carbonate. Most of the waters from the gravel where these conditions exist are calcium carbonate waters of moderate mineral content. The waters are hard, the total hardness ranging from 115 to more than 400 parts per million. The iron content is also high enough to cause trouble if the water is used for some purposes. A representative analysis is shown in diagram F, Figure 10.

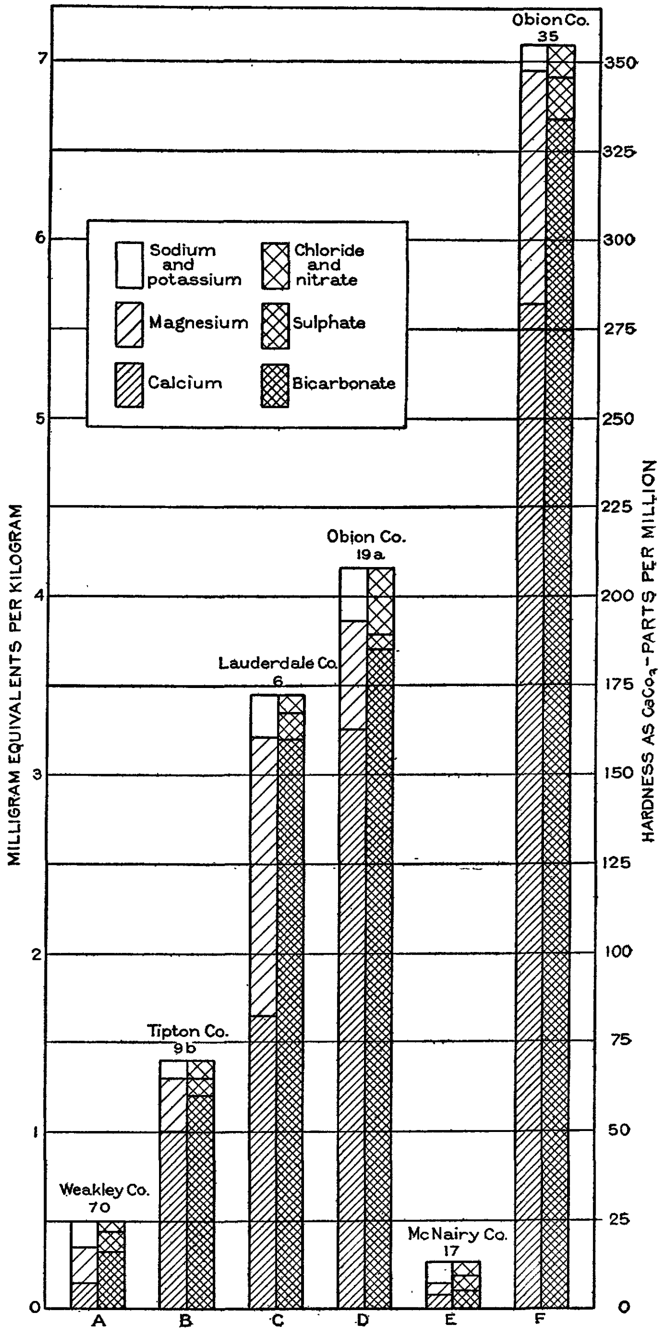


FIGURE 10.—Analyses of water from the Wilcox group (A, B), Jackson formation (C, D), and Pliocene gravel (E, F)

QUATERNARY SYSTEM

PLEISTOCENE SERIES

LOESS

The loess of western Tennessee is of Pleistocene age. It forms a belt about 20 miles wide that borders the Mississippi River. The loess has its greatest thickness at the river, where it is excellently exposed in the bluffs at Memphis, Richardson's Landing, and Randolph. The thickness exposed in the bluffs is from 50 to 100 feet, but it thins to a feather edge toward the east. The vertical jointing and lack of bedding are very distinctive features of the loess in its outcrop and impart to it the characteristic of standing with vertical face. This feature is diagnostic. The loess can be divided into two parts on the basis of color. The lower part is gray and the upper part is buff, but both parts vary in hue from place to place. Fossils are more abundant in the lower part.

The loess is very uniform in composition, consisting of fine material. Ten mechanical analyses by Roberts [88] show that over 90 per cent of the material is under 200 mesh, and microscopic examination shows much of the material to be very fine. The particles are angular and are predominantly quartz, though feldspar and clay are abundant. Some calcium carbonate is present.

The basal loess contains some gravel and in places is found to grade down into Pliocene gravel. The loess also contains irregular concretions.

There has been considerable controversy concerning the method of deposition of the loess, but it is now generally conceded that the material was brought down by the rivers from the melting glaciers and deposited on their flood plains. During periods of low water wind picked up the dry fine silt and dropped it on the adjacent uplands to form deposits that were thickest near the streams and thinnest away from them.

Water probably seeps through the loess very slowly, but the material has a very high specific retention and will not yield water.

LOAM

A thin deposit of loam forms the surface over much of western Tennessee. The deposit is a yellowish or brownish loam in most of the area of its occurrence, though in some places it becomes a soft sand with very little argillaceous material. This phase is found mainly to the east of the loess as a thin veneer derived from the underlying formations and resting upon and partly concealing them. It is rarely over 10 to 12 feet thick and is in many places not more than half that thickness. It thins out to the east and disappears before the eastern

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[88] Roberts, J. K., Tertiary and Quaternary sediments of west Tennessee and their economic geology (in preparation).

edge of the embayment deposits has been reached. The loam is probably in large part the equivalent of the loess, though in some places a few feet of loam overlies the loess. Its age is Pleistocene and recent. The loam has no importance as a source of water.

RECENT SERIES

ALLUVIUM

The flood plains or bottoms of the present streams are composed of alluvium, the most recent deposit in the area. The region has been recently elevated, and the alluvium of the present bottoms represents in part the reworked alluvium of the older flood plains, which now exist as narrow terraces or second bottoms along the margins of the stream valleys. The alluvium consists of material derived from the adjacent land by erosion and is the same in composition, being made up of the reworked sand, gravel, and clay derived from the Cretaceous and Tertiary deposits. It has the characteristics of river deposits, showing rapid vertical and horizontal variation. The deposits may be lenticular. The alluvium in the valley of the Mississippi attains a depth of 100 to 150 feet. Its character is clearly shown in the well log given on page 211. The alluvium in the other stream valleys is less than 100 feet thick, the thickness being dependent on the size of the stream and the depth to which it can cut. The variable character of the alluvium makes it a poor source of water for large supplies, but small supplies of water can be developed in it almost everywhere.

The waters from the alluvium are variable in chemical character. (See analyses—Fayette County, No. 12; Haywood County, No. 35a; Lake County, No. 5; Lauderdale County, No. 26; McNairy County, No. 10.) During flood stages the streams are probably influent into the alluvium, and during periods of low stage ground water flows from the alluvium into the streams; the chemical character of the water in the alluvium is therefore dependent upon both the character of the stream water and that of the ground water. In addition, the character of the water is locally changed by the presence of lenses of clay rich in organic matter containing much sulphur and iron. From this material the water dissolves hydrogen sulphide, carbon dioxide, and considerable iron. These constituents make the water unpalatable and give it an unpleasant smell. Water from the alluvium of the Mississippi River flood plain predominates in calcium bicarbonate, is moderately high in total dissolved solids and iron content, and is hard. An analysis of such a water is given in the following table and for comparison with it an average analysis of water from the Mississippi River at Memphis. One sample of water from the alluvium in the flood plains of the streams whose drainage basins lie within the areas of outcrop of the Cretaceous and Eocene formations is low in total dissolved solids and very soft. The iron content is high enough to make removal by aeration and sedimentation or filtration desirable. The analysis of this water is also given in the table.

Analyses of waters from alluvium and from Mississippi River at Memphis

[Parts per million]

	1	2	3		1	2	3
Silica (SiO_2)	8	24	24	Sulphate radicle (SO_4)	15	43	5.8
Iron (Fe)	1.4	.61	.65	Chloride radicle (Cl)	8	8.6	11
Calcium (Ca)	88	36	3.8	Nitrate radicle (NO_3)	.7	1.7	.77
Magnesium (Mg)	10	12	1.5	Total dissolved solids	291	202	72
Sodium (Na)	5	19	10	Total hardness as $CaCO_3$ (calculated)	261	--------	16
Potassium (K)			.7				
Bicarbonate radicle (HCO_3)	296	129	19				

1. Representative analysis of water from the alluvium of the Mississippi River flood plain. Lake County No. 5.
2. Mean of analyses of Mississippi River water taken at intervals throughout the year at Memphis, Tenn. Clarke, F. W., Composition of river and lake waters of the United States: U. S. Geol. Survey Prof. Paper 135, p. 52, 1924.
3. Representative analysis of water from alluvium of Hatchie River. Haywood County, No. 35.

GROUND-WATER RESOURCES BY COUNTIES

BENTON COUNTY

[Area 456 square miles. Population 11,237]

GEOGRAPHY

Benton County is a long, narrow county, of which the eastern boundary is the Tennessee River and about two-thirds of the western boundary is the Big Sandy River. A ridge runs northward through the middle of the county, dividing the drainage to the east into the Tennessee River from that to the west into the Big Sandy River. Of the eastward-flowing streams Cypress and Birdsong Creeks are the largest; of the streams flowing west, Ramble and Rushing Creeks. The central ridge has been cut into many hills by the creeks and their tributaries. The tributaries form V-shaped valleys, and the flood plains or bottoms of the larger creeks are narrow, attaining a maximum width of 2 miles.

The Mississippi River at low water at Johnsonville is 322 feet above mean sea level. A bench mark opposite the railroad station at Camden has an altitude of 392.60 feet, and the high point on the Louisville & Nashville Railroad 2.2 miles south of Camden is 471.7 feet. Probably altitudes of 600 feet are attained in the southwestern part of the county, and the average is between 400 and 500 feet.

GEOLOGY

The boundary between the Paleozoic rocks and the unconsolidated Cretaceous formations runs north through the middle of Benton County. The Paleozoic rocks form the surface in the eastern part of the county, and though the upper part of the central ridge is covered by the Cretaceous deposits the large creeks have cut through them into the underlying Paleozoic rocks. The Paleozoic formations that crop out in Benton County are, from younger to older, the Fort Payne chert, of Mississippian age; the Chattanooga shale, of Mississippian or Devonian age; and the Camden and Harriman cherts and Birdsong shale, of Devonian age. The Fort Payne formation is a limestone that contains considerable chert and weathers to a chert rubble, which is the surface expression of the formation. Its thickness in Benton County is not known, but at Paint Rock, a few miles to the east, it has a maximum thickness of 200 feet. Below the Fort Payne chert occurs the Chattanooga shale. It crops out in only a few areas and yields small amounts of sulphur water.

The Camden chert is widely distributed throughout the northern and southeastern parts of the county. Its maximum thickness is exposed at Camden, the type locality. In outcrop it consists of a rubble of iron-stained angular fragments of chert. The Harriman chert resembles the Camden chert and can be differentiated from it only by means of the inclosed fossils. The combined thickness of the Camden and Harriman cherts does not exceed 275 feet.

The Eutaw formation covers the top of the ridge that runs through the middle of the county. It occurs as a band about a mile wide and is not more than 90 feet thick in the southern part of the county and 20 feet thick at the northern boundary. In many outcrops it shows at its base a layer of black carbonaceous thin-bedded clay from 10 to 15 feet thick. The remainder of the formation consists of fine sand and interlaminated clay.

Overlying the Eutaw and cropping out just west of it is a band of the Coon Creek tongue of the Ripley formation. The Coon Creek is an argillaceous glauconitic sand containing some mica. It contains indurated casts of fossils cemented by hydrous iron oxide, which give a characteristic appearance to any outcrop. The thickness of the Coon Creek ranges from about 120 feet in the south to 80 feet in the north.

The outcrop area of the overlying McNairy sand member of the Ripley is confined to the southwestern part of the county. Here high hills have been cut out of the formation and deep gullies have been formed. Though the McNairy contains some coarse sand in Benton County it is predominantly fine grained.

GROUND WATER

There are no towns with public water supplies in Benton County, and as there are no industries ground-water developments are confined to farm needs. As stock is watered from the numerous perennial streams, the farm wells supply only the small amount of water needed for domestic use. The type of well employed depends on the nature of the formation from which the water is to be obtained. In the chert areas dug wells are used, for the fractured chert can be dug easily but can be drilled only with great difficulty. Of the 62 wells listed in the following table, 51 are dug, and they have an average depth of 29 feet. Where the Cretaceous formations are the source of water both dug and bored wells are used, but the latter are the more common. The 11 bored wells listed in the table have an average depth of 61 feet.

Three deep wells have been drilled in Benton County, but the information concerning them is so meager that very little can be said about the formations they penetrate. It is reported that the water from well 9c at Big Sandy comes from a depth between 250 and 300 feet; the water from the Eva well, No. 33, from depths of 130 to 140 feet and 263 feet; and the water from the well at Camden from a depth of 275 to 300 feet. Very small amounts of water were encountered below these depths. This would indicate that practically no water can be developed below 300 feet and this probably means below the Devonian. The cherts of Mississippian and Devonian age yield abundant water, and where they are 100 feet or more thick supplies of several thousand gallons a day could be developed.

Both dug and bored wells are used in the Eutaw area, but as a rule the water is poor. The Coon Creek yields but little water. In areas where the Eutaw or Coon Creek crops out many cisterns are used.

In the region of the Ripley outcrop bored wells are most common. As the region is high and the formation porous, the water table is as much as 100 to 120 feet deep in the high hills, and wells must go below this depth to obtain water. In general the Ripley sands in Benton County are fine grained and cause much trouble in screened wells. In the northern part of the county, where Pliocene gravel occurs, dug wells finished in the gravel afford sufficient water.

In the northern part of Benton County dug wells are used extensively. These wells obtain water from the Fort Payne or the Camden chert and the Pliocene gravel. Eutaw sand covers some of the hills, but it is not very thick, and good water can be found below it. The Chattanooga shale is found in certain areas. This formation does not exceed 15 feet in thickness and water is found below it. At the foot of the ridge that forms the eastern boundary of the valley of the Big Sandy River many large springs issue from the Camden chert.

LOCAL SUPPLIES

The city of Big Sandy has a public well. This is a 6-inch well which was drilled to a depth of 965 feet and is cased to 165 feet. No log was available, but it was reported that very little water comes from beds below 300 feet. The water level is 4 feet below the surface. The well is equipped with an electric pump that delivers water into a small tank, from which it can be drawn. All the houses in Big Sandy are supplied from shallow dug wells obtaining water from the Camden chert.

Camden has a public well which is 8 inches in diameter and 1,565 feet deep. No log of this well is available. The well is cased to a depth of 250 feet, where the well is reported to have passed through a cave. Water is derived from a depth of less than 300 feet and comes from the Camden chert. (See analysis 31a.) The public well supplies only a small group of buildings around the courthouse. Most of the houses have cisterns; the remainder have wells ending in the Camden chert, which furnishes sufficient water.

At Eva dug wells obtain water from Devonian chert. To the west the Chattanooga shale is encountered, and wells must pass through this to the underlying chert.

Holladay is situated in the outcrop area of Eutaw sand. As the water from the sand is highly charged with hydrogen sulphide and is unpalatable, cisterns are used. Deeper wells penetrating the Devonian chert and casing off the higher water would obtain potable water.

At Zach bored wells obtain water from Ripley sand. As Zach is situated in a valley, at an altitude of 421.6 feet, the wells are shallow, not exceeding 25 feet, but just to the north in the hilly section they are more than 100 feet deep.

Records of wells in Benton County

No	Location	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (feet)		Water-bearing bed		Depth to which well is cased (feet)	Water level		Method of lift	Use of water
						Top	Bottom	Character of material	Geologic horizon		Below surface (feet)	Date of measurement (1929)		
1	8.5 miles northeast of Big Sandy.	Leo Askew	Hilltop	Dug	23	3	3	Shale	Chattanooga.	0	12	June 19	Bucket	Domestic.
2	7.1 miles northeast of Big Sandy.	V. K. Stockdale	Hillside	do	18	3	3	do	do	0	12	do	do	Do.
3	6.8 miles north of Big Sandy.	School	do	do	45	3	3	Chert	Camden	0	37	June 21	do	Do.
4	4 miles north of Big Sandy.	T. D. Cooper	Valley	do	24	3	3	do	do	24	10	do	do	Do.
5	5.7 miles northeast of Big Sandy.	J. A. Clement	do	do	17	3	3	do	do	0	13	June 19	do	Do.
6	3.8 miles northeast of Big Sandy.	J. F. Dowdy	Hilltop	do	44	3	3	Gravel	Pliocene	0	30	do	do	Do.
7	Faxon	G. A. Robbins	Valley	do	18	3	3	Chert	Fort Payne	18	15	do	do	Do.
8	3.3 miles east of Big Sandy.	H. C. Giles	do	Spring		3		do	do		(a)	do		Do.
9a	Big Sandy	George Dowdy	do	Dug	11	3	3	do	Camden	11	7	do	Bucket	Do
9b	do	H. F. Cantrell	do	Driven	20	[b] 1½	[b] 1½	do	do	20	14	June 18	do	Do.
9c	do	City of Big Sandy	do	Drilled	1,000	[b] 6	[b] 6			165	4	do	do	Public supply.
10	1.9 miles south of Big Sandy.	I. T. Cantrell	Upland	Dug	40	3	3	Chert	Camden	12	34	do	do	Domestic.
11	3 miles southeast of Big Sandy.	T. W. Brewer	Hillside	do	30	3	3	do	Fort Payne		15	do	do	Do.
12	5 miles southeast of Big Sandy.	W. H. Berry	do	do	18	3	3	do	do	0	13	do	do	Do.
13	6.5 miles southeast of Big Sandy.	O. E. Pattrich	Valley	do	15	3	3	do	do	0	9	do	do	Do.
14	Claud	A. H. Ball	do	do	24	3	3	do	do	0	14	do	do	Do.
15	6.5 miles southeast of Big Sandy.	D. Cagle	Upland	do	22	3	3	Sand	Eutaw	0	19	June 21	do	Do.
16	4 miles south of Big Sandy.	M. C. Farrist	Hilltop	do	21	3	3	do	do	21	7	June 18	do	Do.
17	5.8 miles southwest of Big Sandy.	G. R. Bains	Hillside	do	22	3	3	do	Ripley	22	16	June 21	do	Do.
18	6 miles southwest of Big Sandy.	School	do	do	19	3	3	do	Eutaw	19	4	do	do	Do.
19	5.8 miles south of Big Sandy.	J. D. Markham	Hilltop	do	28	3	3	do	do	28	23	June 18	do	Do.

[a] Flowing 1 gallon a minute.

[b] Inches.

Records of wells in Benton County—Continued

No.	Location	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (feet)		Water-bearing bed		Depth to which well is cased (feet)	Water level		Method of lift	Use of water
						Top	Bottom	Character of material	Geologic horizon		Below surface (feet)	Date of measurement (1929)		
20	7 miles northwest of Camden.	J. H. Hall	Hilltop	Dug	23	3	3	Sand	Ripley	23	20	June 21	Bucket	Domestic.
21	4.8 miles north of Camden.	J. P. Rushing	do	do	50	3	3	do	Eutaw	50	44	June 19	do	Do.
22	8.3 miles southeast of Big Sandy.	T. J. Berry	do	do	30	3	3	Chert	Fort Payne	30	26	June 18	do	Do.
23	9.1 miles northeast of Camden.	D. Farmer	Hillside	do	24	3	3	do	do	24	11	do	do	Do.
24	7.3 miles northeast of Camden.	W. E. Milton	Valley	do	12	3	3	do	do	12	9	do	do	Do.
25	5.8 miles northeast of Camden.	W. D. Pafford	Hilltop	do	21	3	3	Clay	do	21	17	do	do	Do.
26	3.5 miles northeast of Camden.	A. P. Lashlee	Hillside	do	42	3	3	Chert	Camden	42	36	do	do	Do.
27	2.4 miles north of Camden.	M. E. Hudson	do	do	31	3	3	Sand	Eutaw	31	16	June 19	do	Do.
28	3.4 miles north of Zach	Lester Presson	Valley	do	18	3	3	do	Ripley	18	16	June 21	do	Do.
29	0.8 mile northwest of Zach.	W. A. Presson	Hilltop	Bored	116	6	6	do	do	110	92	June 22	do	Do.
30	Zach (Sawyer's Mill)	E. Bonds	Hillside	do	17	6	6	do	do	17	7	June 21	do	Do.
31a	Camden, north side of court house.	City of Camden	do	Drilled	1,565	8	8			250	45	Rept.	Lift pump	Public supply.
31b	Camden, Paris St	Wm. Morris	Hilltop	Dug	62	3	3	Chert	Camden	62	45	June 21	Bucket	Domestic.
32	1.6 miles east of Camden	J. L. Davis	Valley	do	17	3	3	do	do	17	12	June 18	do	Do.
33	5.8 miles east of Camden	Benton County Oil & Gas Co.	do	Drilled	1,463	c 10	c 10					do		
34a	5.1 miles east of Camden	Troy Milton	Hillside	Dug	21.5	3	3	Chert	Devonian	21.5	20	do	Bucket	Do.
34b	5 miles east of Camden	L. Milton	Hilltop	do	35	3	3	do	do	0	28	do	do	Do.
35	2.2 miles southeast of Camden.	Zack Clayton	do	do	30	3	3	do	Camden	0	20	June 20	do	Do.
36	2.2 miles south of Camden on highway 69.	E. H. Harris	Valley	do	25	3	3	do	Devonian	25	15	June 17	do	Do.
37	4.6 miles southwest of Camden.	D. B. White	Hilltop	do	40	3	3	Sand	Eutaw		36	June 20	do	Do.
38	4 miles south of Camden on highway 69.	W. H. Garrett	do	Bored	42	6	a 6	do	do	42	38	June 18	do	Do.
39	3.7 miles southeast of Camden.	A. L. Walker	do	Dug	45	3	3	Chert	Camden	0	30	do	do	Do.

40	4 miles southeast of Camden on highway 1.	O. P. Lashlee	Hillside	do	60	3	3	do	do	0	12	June 20	do	Do.
41	6.6 miles southeast of Camden on highway 1	do	Bottom	do	45	3	3	Sand	Alluvium	45	37	do	do	Do.
42	5.7 miles south of Camden on highway 69.	L. F. Harrington	Valley	do	18	3	3	Chert	Devonian	0	15	June 17	do	Do.
43	6.9 miles southwest of Camden.	R. E. Hedge	Hilltop	Bored	30	6	6	Sand	Ripley	30	27	June 20	do	Do.
44	8.8 miles southwest of Camden.	W. W. Smothers	do	do	90	6	6	do	do	90	84	do	do	Do.
45	6.6 miles south of Camden on highway 69.	W. M. Smith		Dug	45	3	3	do	Eutaw	45	40	June 17	do	Do.
46	7.2 miles southeast of Camden.	B. W. Warren	Hilltop	do	37	3	3	Chert	Fort Payne	37	26	do	do	Do.
47	8.6 miles southeast of Camden.	Nancy Terry	Valley	do	11½	3	3	do	do	11½	6	do	do	Do.
48	8.8 miles south of Camden.	M. F. Miller	Hilltop	Bored	75	6	6	Sand	Ripley	75			do	Do.
49	10.4 miles southwest of Camden.	B. H. Norwood	Hillside	do	60	6	6	do	do	60	50	June 20	do	Do.
50	2.3 miles north of Camden.	A. D. Baker	Valley	Dug	8	3	3	Chert	Devonian	0	2	June 17	do	Do.
51	1.8 miles west of Coxburg.	E. H. Thornton	Hillside	do	45	3	3	do	Fort Payne	45	40	do	do	Do.
52	Coxburg	F. T. Trout	Valley	do	27	3	3	do	do	27	15	do	do	Do.
53	0.2 mile east of Coxburg	A. Fry	Bottom	do	14	3	3	do	do	0			do	Do.
54	3.4 miles northeast of Sugar Tree.	Oscar Bell	Hilltop	do	17	3	3	do	do	0	12	June 20	do	Do.
55	1.5 miles north of Sugar Tree.	J. B. Odle	Valley	do	18	3	3	do	Devonian	18	10	do	do	Do.
56	4.6 miles southeast of Holladay.	H. E. Cox	Hilltop	do	27	3	3	Sand	Eutaw	27	25	do	do	Do.
57	3.5 miles east of Holladay.	School	do	Bored	30	6	6	do	do	30			do	Do.
58	1.6 miles east of Holladay.	J. F. Prince	do	do	55	6	6	do	do	55	50	June 17	do	Do.
59	Holladay	D. Holladay	Hillside	Dug	35	3	3	do	do	35	24	do	do	Do.
60	1 mile north of Holladay	H. S. Wilson	Hilltop	do	60	3	3	Limestone		60	45	do	do	Do.
61	1.5 miles northwest of Holladay.	Harrison Barnes	do	Bored	90	6	6	Sand	Eutaw	90	84	June 20	do	Do.

[a] Flowing 1 gallon a minute.

[c] Flowing 28,800 gallons a day.

Analyses of waters from Benton County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyses 7, 9c, 9a, and 30 by Margaret D. Foster; the rest by D. F. Farrar]

	7	9c	9a	14	30
Silica (SiO_2)	8.8	12	16	4.5	11
Iron (Fe)	.12	.15	.13	1.1	.14
Calcium (Ca)	4.8	19	12	8	2.8
Magnesium (Mg)	2.4	3.7	4.6	1	1.5
Sodium (Na)	6.0	167	14	3	2.5
Potassium (K)	2.9	5.0	3.0		1.1
Bicarbonate (HCO_3)	13	194	14	17	12
Sulphate (SO_4)	14	151	23	9	4.0
Chloride (Cl)	4.5	84	30	5	3.0
Nitrate (NO_3)	7.2	1.9	4.0	.4	1.1
Total dissolved solids	57	542	123	39	33
Total hardness as $CaCO_3$ (calculated)	22	63	49	24	13
Date of collection, 1929	June 19	June 19	June 19	June 18	June 20

	31a	33	34a	52	59
Silica (SiO_2)	6.2	4.3	7.3	4.3	6.2
Iron (Fe)	1.5	.4	1.3	1.3	.8
Calcium (Ca)	75	60	17	9	14
Magnesium (Mg)	5	8	2	2	2
Sodium (Na)	2	7	11	4	10
Potassium (K)			1		1
Bicarbonate (HCO_3)	202	202	17	24	20
Sulphate (SO_4)	40	18	35	11	23
Chloride (Cl)	3	8.5	17	6	18
Nitrate (NO_3)	.4	.2	.8	.3	1.3
Total dissolved solids	240	204	106	52	86
Total hardness as $CaCO_3$ (calculated)	208	182	51	31	43
Date of collection, 1929	June 22	June 19	June 18	June 17	June 17

CARROLL COUNTY

[Area 619 square miles. Population 26,132]

GEOGRAPHY

Carroll County is situated in the northeastern part of the area. The Mississippi-Tennessee divide cuts across the county in a direction east of north, dividing the drainage areas into two unequal parts. About one-third of the county drains east to the Tennessee through the Big Sandy River and its tributaries; the remaining two-thirds drains to the west through the tributaries of the South Obion and Forked Deer Rivers. In the southern part of the county the Mississippi-Tennessee divide is formed by an area of very hilly, high country, the northward extension of the hills of erosion. Another area of high hills is in the southeast corner of the county. The highest precisely determined altitude in the county is 514.39 feet, at a point 4.4 miles west of Huntingdon on the road to McLemoresville, but the hilly areas above mentioned probably rise above 600 feet. The lowest known altitude is 393.5 feet, at a point 1.8 miles west of Huntingdon on the road to McLemoresville, but the valley of the South Obion River is lower than this at the western boundary of the county.

GEOLOGY

Underlying the whole of Carroll County but not cropping out are the Eutaw formation and the Coon Creek tongue of the Ripley formation. The Eutaw formation rests on the Paleozoic rocks, which consist of chert, limestone, and shale. The surface of the Paleozoic rocks dips gently to the west at about 20 feet to the mile. It is at a depth of 300 feet at the east edge of the county and 1,000 feet at the west edge. The Eutaw formation is about 80 feet thick and is composed predominantly of clay but contains some layers of sand. The Eutaw is not a very good water bearer, although some water can be obtained from it.

Overlying the Eutaw formation occurs the Coon Creek tongue of the Ripley formation. It is a glauconitic, argillaceous sand or fossiliferous marl, with a maximum thickness of 120 feet. The Coon Creek does not yield water.

The oldest rocks outcropping in Carroll County are those of the McNairy sand member of the Ripley formation, which forms a band 11 miles wide and crosses the eastern part of the county in a direction a little north of east. It has a maximum thickness of 425 feet and dips toward the west at the rate of 20 to 30 feet to the mile. The Ripley is predominantly a sandy formation with intercalated lenses of clay. There is a persistent layer of coarse sand which crops out in the hills along the eastern edge of the county. The formation as a whole is a good source of water.

The Porters Creek clay, which overlies the Ripley formation, is a plastic dove-gray clay with a characteristic hackly structure. It does not yield water, and where it crops out wells must pass through it to the underlying Ripley formation. It has a thickness of about 170 feet.

Throughout the western half of Carroll County the Holly Springs sand forms the surface. The Holly Springs formation consists of sand of varying size and color with intercalated layers and lenses of clay. The formation dips to the west at a rate of 20 to 30 feet to the mile. At the western edge of the county the Holly Springs has a thickness of 400 feet. Water is readily obtained from this formation.

WATER RESOURCES

The numerous streams in Carroll County serve for watering stock. Along the foot of the hills are many springs, and those that are conveniently located are used for domestic purposes. Except for the narrow band of Porters Creek clay, which has a maximum width of 4 miles but is usually not more than a mile wide, the formations at the surface throughout Carroll County consist of unconsolidated sand. This material can be bored easily, and the depth to water ranges from 15 feet in the valleys to 150 feet on the highest hills. Consequently bored wells are most widely used for domestic purposes, though a few dug wells are still in use. The average depth of the 64 wells listed in Carroll County is 72.5 feet. Where large supplies of water are needed or where clay lenses are found at shallow depths or in the outcrop area of the Porters Creek clay deeper wells are used, and these are drilled. In the table, 17 drilled wells are listed, averaging 211 feet in depth. Such wells develop water supplies sufficient for any present needs. The Porters Creek clay serves as a confining bed for the waters in the Ripley sands. To the west of its outcrop area water will rise to an altitude of 400 feet above sea level in wells that pass through the Porters Creek to the Ripley formation.

LOCAL SUPPLIES

At Atwood (altitude 447.6 feet) the water table stands at a depth of about 90 feet. Bored wells 90 to 120 feet deep are used almost exclusively. (See analysis 45b.)

Bruceton (altitude 417.8 feet) has a public water supply owned by the Tennessee Property Co. (See analysis 17a.) A drilled well 298 feet deep obtains water from Eutaw sand. A log of the well is as follows:

Log of Tennessee Property Co.'s well, Bruceton, Tenn.

	Thickness (feet)	Depth (feet)
Ripley formation (McNairy sand member):		
Red sand	60	60
Fine white sand (quicksand)	108	168
Coon Creek tongue of Ripley formation: Black mud	110	278
Eutaw formation:		
Rock	4	282
Black mud	4	286
Black sand, water bearing	12	298
Paleozoic: Rock.		

The water company does not supply water to the houses south of the State highway. These houses are equipped with bored wells from 90 to 120 feet deep. The Junction City Ice & Coal Co. obtains 40,000 gallons a day from Ripley sands, and further developments should be able to obtain ample water from these sands.

Buena Vista is underlain by considerable clay, and wells must pass through this to obtain water. The depth of the wells ranges from 90 to 150 feet, depending on topographic position.

In Clarksburg bored wells can obtain water from the Ripley sands at depths of 35 to 60 feet. It is necessary to go to 100 feet to reach a sand suitable for finishing a drilled well.

Hollow Rock (altitude 423 feet) is in a valley, and shallow bored wells about 30 feet deep obtain sufficient water for domestic purposes.

Huntingdon (altitude 414.7 feet) is in the outcrop area of the Porters Creek clay, which has a thickness of 75 to 90 feet. The Porters Creek is covered by a layer of residuum about 40 feet thick so that wells must penetrate at least 130 feet to reach the underlying Ripley. The city is supplied with water by the Kentucky-Tennessee Light & Power Co. (See analyses 33a, 33b.) Water is obtained from two 6-inch wells and one 10-inch well, ranging from 213 to 270 feet in depth. The wells are all connected by a suction centrifugal pump situated in a pit and having a capacity of 100 gallons a minute. The static level is at the bottom of the pit. A small amount of lime is added to the water on its way to the rapid sand filters to accelerate the precipitation of the iron. From the filters, where the iron is removed, the water passes to a reservoir with a capacity of 65,000 gallons. The total daily consumption of water at Huntingdon is about 75,000 gallons. Analyses of the raw and treated water are given in the table on page 130. The ice plant is equipped with a 6-inch well 235 feet deep.

The log of a test hole drilled 1.8 miles west of Huntingdon on the old McLemoresville road is as follows:

Log of Johnson Refining Co.'s well, Huntingdon, Tenn.

	Thickness (feet)	Depth (feet)
Holly Springs sand:		
Soil	13	13
Red quicksand	10	23
Red mud	7	30
Quicksand	10	40
Porters Creek clay:		
Tough gray clay	105	145
McNairy sand member of Ripley formation:		
Varicolored quicksand	41	186
Thinly laminated clay	3	189
Fine sand with thinly laminated clay	14	203
Brown micaceous sand	3	206
Sand and thinly laminated hard clay	54	260
Sand containing pyrites	4	264
Sand and decayed vegetation	38	302
Hard flaky clay	2	304
Brown flaky clay and well-preserved pieces of wood	66	370
Quicksand	10	380
Hard gray clay	15	395
Quicksand and thinly laminated clay	16	511
Hard gray clay	4	515
McNairy sand member of Ripley formation—Continued.		
Coarse sand and a little clay	41	856
Brown flaky clay	2	558
Quicksand	12	570
Hard gray clay	6	576
Quicksand	8	584
Flaky clay and sand	14	598
Thinly laminated flaky clay	6	604
Quicksand	8	612
Coon Creek tongue of Ripley formation:		
Hard black clay	13	625
Hard gray clay, thin bedded	31	656
Hard blue clay	44	700
Thin-bedded clay	6	706
Eutaw formation:		
Quicksand	4	710
Hard gray clay	6	716
Thin-bedded clay	3	719
Quicksand and mud	8	727
Paleozoic:		
Slate, small shells, and quicksand	33	760
Slate	15	775

At Lavina there is a perched water table, and wells from 60 to 80 feet deep obtain water from it. These wells go dry during dry weather. To obtain a permanent water supply wells must penetrate to the true water table, which is from 90 to 160 feet in depth.

McKenzie has a public water supply owned by the Kentucky Tennessee Power & Light Co. Water is obtained from three wells, one 8-inch well 335 feet deep, one 8-inch well 340 feet deep, and one 10-inch well 330 feet deep. These wells end in the Holly Springs sand and obtain water of excellent quality. (See analysis 10b.) All three wells are pumped by compressed air. The water flows into a 200,000-gallon reservoir and is pumped from the reservoir into an overhead tank of 50,000 gallons capacity. The average consumption is 700,000 gallons a day. The Nashville, Chattanooga & St. Louis Railway, Louisville & Nashville Railroad, and McKenzie Ice Co. have similar wells.

Log of well of Nashville, Chattanooga & St. Louis Railway, McKenzie, Tenn.

	Thickness (feet)	Depth (feet)
Holly Springs sand:		
Soil	10	10
Red sand	26	36
White sand	11	47
Red sand	20	67
Fine white sand	34	101
White sand and pipe clay mixed	50	151
Holly Springs sand—Continued.		
Gray pipe clay	74	225
Dark pipe clay	38	263
Yellow sand	10	273
White sand	38	311
Coarse white sand	12	323

The log of the Louisville & Nashville Railroad well, which penetrates the Ripley formation, is given below.

Log of well of Louisville & Nashville Railroad, McKenzie, Tenn.

[Authority, chief engineer]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil (loam and clay)	10	10	Holly Springs sand—Continued.		
Holly Springs sand:			Fine white sand	16	340
Red sand	26	36	Pipe clay	8	348
White sand	11	47	Fine white sand, pipe clay	4	352
Red sand	20	67	Fine white sand	16	368
Fine white sand	34	101	Porters Creek clay:		
White sand and pipe clay	50	151	Gray pipe clay	122	490
Gray pipe clay	74	225	Dark pipe clay	47	537
Dark pipe clay	38	263	Ripley formation:		
Yellow sand	10	273	Fine white sand	6	543
White sand	38	311	Soapstone, good water bearing	20	563
Coarse white sand	9	320	Coarse white sand	84	647
Pipe clay	4	324			

At McLemoresville (altitude 422 feet) bored wells are used; they range from 40 to 50 feet in depth.

At Trezevant (altitude 464 feet) the city-owned public water supply (analysis 28) obtains water from two 6-inch wells 120 feet deep, which end in Holly Springs sand. Both wells are pumped by lift pumps that deliver the water to an elevated tank of 50,000 gallons capacity.

At Yuma the water table is only 8 to 15 feet below the surface, and dug and bored wells 13 to 25 feet deep obtain sufficient water for domestic needs from the Ripley sands.

Records of wells in Carroll County

No.	Location	Owner	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface	Water level: Date of measurement (1929)	Method of lift	Use of water
1	Vale, 4.5 miles north of Hollow Rock.	A. C. Crews	Valley bottom	Bored	30	6	Sand	Ripley	30	25	June 29	Bucket	Domestic.
2	6 miles north of Hollow Rock on road to Paris.	J. W. Barton	Hillside	Dug	87	36	do	do	87	77	do	do	Do.
3	5 miles north of Hollow Rock on road to Paris.	A. T. Rigsby	Hilltop	Bored	72	6	do	do	72	68	do	do	Do.
4	Mixie, 7 miles northwest of Hollow Rock.	L. G. Symons	Hillside	do	58	6	do	do	58	50	do	do	Do.
5	6 miles northwest of Hollow Rock.	V. W. Rice	Valley	do	45	6	do	do	45	35	do	do	Do.
6	7.5 miles northwest of Hollow Rock.	A. Harder	Foot of hill	Spring				Porters Creek		(a)	do		Do.
7	8.5 miles north of Huntingdon.	S. T. Sparks	Hilltop	Bored	100	6	do	Holly Springs	100	70	do	Force pump	Domestic and stock.
8a	Macedonia, 8.5 miles north of Huntingdon.	A. O. Milam	do	Dug	22	36	do	Residuum	22	19	do	Bucket	Domestic.
8b	Macedonia	do	do	Drilled	100	2	do	Holly Springs				Lift pump	Do.
9	2 miles east of McKenzie.	B. Kemp	do	Bored	90	6	do	do	90			Bucket	Do.
10a	Main Street and Nashville, Chattanooga & St. Louis Ry.	Kentucky-Tennessee Power & Light Co.	Hillside	Drilled	340	8	do	Ripley	340	90	Rept	Air lift [b]	Public supply.
10b	do	do	do	do	335	8	do	do	335	90	do	do	Do.
10c	do	do	do	do	330	10	do	do	330	90	do	do	Do.
10d	Cedar Street, McKenzie.	McKenzie Ice Co.	do	do	347	6	do	do	347	90	do	Force pump	Industrial.
11a	Christmasville, 55 miles north of Trezevant.	Christmasville School	Upland	do	90	2	do	Holly Springs	90	65	July 2	do	Domestic.
11b	Christmasville	Mrs. C. E. Lawler	Hilltop	Bored	114	6	do	do	114	99	do	Bucket	Do.
12	Hinkleville	W. S. Houston	Hillside	do	70	6	do	do	70	60	do	do	Do.
13	3 miles southwest of McKenzie.	D. Bowden	Hilltop	do	65	6	do	do	65	54	do	do	Do.
14	3.8 miles southeast of McKenzie on highway 22.	Leon Currin	do	do	54	6	do	do	54	44	June 29	do	Do.

[a] Flowing 1 gallon a minute.

[b] Reported pumpage, 700,000 gallons a day.

Records of wells in Carroll County—Continued

No.	Location	Owner	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface	Water level: Date of measurement (1929)	Method of lift	Use of water
15	7.5 miles northeast of Huntingdon.	Lester Presson	Foot of hill	Spring				Ripley					Domestic.
16	3.5 miles northwest of Hollow Rock junction (Bruceton).	J. E. Vick	Hillside	Bored	45	6	Sand	do	45	40	June 29	Bucket	Do.
17a	Bruceton	Tennessee Property Co.	do	Drilled	298		Chert	Devonian	375			Air lift [c]	Public supply.
17b	do	Junction City Ice & Coal Co.	do	do	125	6	Sand	Ripley	125			Force pump [d]	Industrial.
17c	Bruceton, north of highway 1.	H. H. Warmack	do	Bored	90	6	do	do	90	85	June 28	Bucket	Domestic.
18a	Hollow Rock, south side of Main Street.	R. A. Webb	Valley bottom	do	26	6	do	do	26	2	June 28	do	Do.
18b	Hollow Rock, north side of highway 1.	H. Pinkston	Hillside	do	28	6	do	do	26	21	do	do	Do.
19	4.5 miles north of Huntingdon.	G. W. Britts	River bottom	Drilled		2½	do	do					Domestic and stock.
20	3.4 miles north of Huntingdon on old Paris road.	I. C. Enocks	do	do	104	2½	do	Clayton	104	(e)			Stock.
21	2.8 miles northwest of Huntingdon on highway 22.	John Ransome	Hilltop	Bored	43	6	do	Holly Springs	43	39	June 29	Bucket	Domestic.
22	5.4 miles southwest of McKenzie.	L. M. Flippin	Hillside	do	60	6	do	do	60	48	July 2	do	Do.
23	4.1 miles north of Trezevant.	F. G. Blaylock	Valley	do	60	6	do	do	60	50	do	do	Do.
24	2.7 miles north of Trezevant.	J. D. Smothers	do	do	43	6	do	do	43	40	do	do	Do.
25	2.2 miles northwest of Trezevant.	G. L. Pratt	Hillside	do	57	6	do	do	57	52	do	do	Do.
26	3.2 miles west of Trezevant.	Chester Hampton	Hilltop	do	90	6	do	do	90	87	do	do	Do.
27	27 miles north of Atwood.	N. Walker	Hillside	do	60	6	do	do				do	Do.
28a	Trezevant, east of railroad track, 1,000 feet northwest of station.	City of Trezevant	Upland	Drilled	120	6	do	do	120	[f]100	Rept.	Force pump	Public supply.
28b	do	do	do	do	120	6	do	do	120	100		do	Do.

	.5 miles east of Trezevant on road to McLemoresville.	D. B. Traywich	Hilltop	Bored	110	6	do	do	110	95	July 1	Bucket	Domestic.
30	McLemoresville, north side of highway 77.	H. L. Carter	Hillside	do	40	8	do	do	40	24	do	do	Do.
31	2.5 miles east of McLemoresville on highway 77.	C. Cannon	do	do	32	6	do	do	32	16	do	do	Do.
32	5.2 miles east of McLemoresville on highway 77.	C. R. Williamson	do	do	51	6	do	do	51	45	do	do	Do.
33a	Huntingdon	Kentucky-Tennessee Light & Power Co.		Drilled	213	6	do	Ripley				Centrifugal	Public supply.
33b	do	do		do	265	6	do	do				do	Do.
33c	do	do		do	270	10	do	do		(g)		do	Do.
33d	do	Huntingdon Ice Co.		do	235	6	do	do		(h)		Lift pump	Industrial.
34	1.2 miles south of Huntingdon on highway 22.	A. B. Pettigrew	Valley	do	64	2	do	Clayton	64	(i)	June 24		Domestic.
35	1 mile east of highway 1 on road to Buena Vista.	J. D. Porter	Hilltop	Bored	55	6	do	Ripley	55	44	June 29		Do.
36	3.6 miles east of highway 1 on road to Buena Vista.	C. Churchwell	Valley	do	32	6	do	do	32	18	do		Do.
37	2.4 miles south of Hollow Rock.	W. Marbin	Upland	do	70	6	do	do	70	60	June 28		Do.
38	2.5 miles southeast of Bruceton.	H. C. Nwese	Hilltop	do	70	6	do	do	70	64	June 24		Do.
39	4.3 miles south of Bruceton.	W. N. Allan	do	do	71	6	do	do	71	59	June 29		Do.
40a	1,000 feet west of Buena Vista.	J. E. Riding	do	do	144	6	do	do	144	135	Rept		Do.
40b	Buena Vista	L. K. Frinkley	Valley	do	85	6	do	do	85	73	June 28		Do.
41	2.4 miles south of Huntingdon on highway 22.	A. C. Johnson	do	do	28	6	do	do	28	10	June 24	Bucket	Do.
42	3 miles southwest of Huntingdon on highway 1.	M. C. Twyman	Foot of hill	Spring			do	Holly Springs		(h)	July 4		Do.
43	1.8 miles south of McLemoresville.	J. A. Bramley	Hilltop	Dug	35	36	do	do	35	30	do	Bucket	Do.
44	2 miles south of Trezevant.	J. Morris	do	Bored	136	6	do	do	136	114.5	Rept	do	Do.
45a	Atwood, just west of railroad station.	Bellow Gin Co.	Upland	Drilled	110	2½	do	do	110	82	do	Force pump	Industrial.

[c] Capacity of pump, 250 gallons a minute; reported pumpage, 150,000 gallons a day.
[d] Capacity of pump, 35 gallons a minute.
[e] Flowing 40 gallons a minute.
[f] Estimated pumpage, 50,000 gallons a day.
[g] Pumpage, 65,000 gallons a minute.
[h] Pumpage, 50 gallons a day.
[i] Flowing 2 gallons a minute.

Records of wells in Carroll County—Continued

No.	Location	Owner	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface	Water level: Date of measurement (1929)	Method of lift	Use of water
45b	Atwood, north section of intersection of railroad and Main Street.	Town of Atwood	Hillside	Bored	100	6	Sand	Holly Springs	100	82	July 2	Bucket	Domestic.
46	4.2 miles south of McLemorsville.	J. E. Lawrence	do	do	55	6	do	do	55	40	July 4	do	Do.
47	Leach	E. M. Goodrum	Hilltop	do	65	6	do	do	65	58	July 3	do	Do.
48	4 miles southwest of Huntingdon on highway 1.	R. E. Foust	Upland	do	90	6	do	Clayton	90			do	Do.
49	4.5 miles south of Huntingdon on highway 22.	R. L. Anderson	Hillside	do	41	6	do	Ripley	41	29	June 24	do	Do.
50	5.3 miles southeast of Huntingdon.	H. F. Horn	do	do	31	6	do	do	31	28	June 29	do	Do.
51	7.2 miles southeast of Huntingdon.	Hugh Smith	Upland	do	75	6	do	do	75	64	June 28	do	Do.
52	3.6 miles north of Westport.	W. T. Smith	Hilltop	do	123	6	do	do	123	110	do	do	Do.
53	2.5 miles southeast of Buena Vista.	J. Butler	do	do	70	6	do	do	70			do	Do.
54	3 miles east of Buena Vista.	J. E. Butler	do	do	49	6	do	do	49	44	June 28	do	Do.
55	Dollar	A. O. Thomas	do	do	65	6	do	do	65	59	June 29	do	Do.
56	4.8 miles east of Westport.	J. C. Brinkley	do	do	90	6	do	do	90	72	do	do	Do.
57	1.8 miles southeast of Westport.	B. A. Medaris	do	do	135	6	do	do	135	110	do	do	Do.
58a	Westport	Mrs. E. M. Joyner.	do	do	61	6	do	do	61	52	do	do	Do.
58b	do	J. T. Merrick	do	do	27	6	do	do	27	19	do	do	Do.
59	6 miles south of McLemoresville.	J. Parker	Hillside	do	20	6	do	Holly Springs	20	12	July 4	do	Do.
60	7.8 miles south of Trezevant.	W. A. Little	Hilltop	do	125	6	do	do	125	110	do	do	Do.
61	4.2 miles north of Lavina.	W. T. Little	Hillside	Drilled	50	2	do	do	50	45	do	do	Do.
62	1.7 miles west of Lavina.	W. H. Manning	Hilltop	Bored	140	6	do	do	140	135	July 3	do	Do.

63a	Lavina	R. L. Gowan	Hillside	do	110	6	do	do	110	98	do	do	Do.
63b	do	W. H. Hickman	do	do	100	6	do	do	100	92	do	do	Do.
64	2.5 miles northwest of Cedar Grove.	W. Holmes	Upland	do	71	6	do	do	71	62	July 4	do	Do.
65	0.5 mile northeast of Cedar Grove on highway 1.	W. H. Bray	Hilltop	do	80	6	do	do	80	75	July 3	do	Do.
66	1 mile northeast of Cedar Grove, 0.2 mile west of road.	E. Evans	Foot of hill	Spring						(i)	July 4		Do.
67	3.3 miles southwest of Leach on highway 1.	W. T. Howler	Hilltop	Bored	57	6	Sand	Holly Springs	57	53	July 3	Bucket	Do.
68	3 miles southeast of Leach.	J. Pendigrass	Foot of hill	Dug	18	36	do	Ripley	18	2	July 4	do	Do.
69a	Clarksburg	J. H. Pritchard	Hilltop	Washed	120	2	do	do	120	90	Rept.	Force pump	Do.
69b	do	A. D. Jerrett	Hillside	Bored	40	6	do	do	40	34	June 24	Bucket	Do.
70	1.4 miles east of Clarksburg.	J. H. Darnell	Hilltop	do	112	6	do	do	112	92	do	do	Do.
71a	Yuma, 500 feet north of station on east side of track.	C. E. Bolen	do	Dug	13	24	do	do	13	9	do	do	Do.
71b	Yuma	I. T. Blunt	do	Bored	18	6	do	do	18	15	July 4	do	Do.
72	2.2 miles east of Yuma	O. T. Horn	Upland	do	83	6	do	do	83	77	June 24	do	Do.
73	5 miles east of Yuma	Sear Hatch	Hilltop	Drilled	150	2	do	do	150			Force pump	Do.
74a	Cavia	Mrs. Ira Belan	do	Bored	60	6	do	do	60	46	June 24	Bucket	Do.
74b	do	S. J. Wilson	do	do	50	6	do	do	50	42	do	do	Do.
75	3.8 miles south of Lavina.	W. B. Reynolds	do	do	168	6	do	Holly Springs	168	150	Rept.	do	Do.
76	2.3 miles east of Lavina	H. Seavers	do	do	100	6	do	do	100	95	July 3	do	Do.
77	2 miles southwest of Cedar Grove on highway 1.	H. M. Clark	Hillside	do	46	6	do	do	46	34	do	do	Do.

i Flowing 80 gallons a minute.

Analyses of waters from Carroll County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyses 17a, 33a (raw), 45, 69, and 71, by D. F. Farrar; the rest by Margaret D. Foster]

	10b	17a	28	30	33a		40a
					Treated	Raw	
Silica (SiO_2)	11	9	16	12	11	5	13
Iron (Fe)	.07	1.4	.21	.14	.13	1.1	.18
Calcium (Ca)	2.0	72	15	14	24	13	4.9
Magnesium (Mg)	1.4	7	5.9	14	3.2	4	2.8
Sodium (Na)	1.3	6	14	33	4.9	2	4.6
Potassium (K)	.9		1.8	6.4	1.4		1.2
Bicarbonate (HCO_3)	13	194	28	22	60	8	16
Sulphate (SO_4)	2.5	47	40	27	32	41	12
Chloride (Cl)	.9	9	15	62	1.6	3	4.4
Nitrate (NO_3)	.39	.2	10	44	.05	.2	3.3
Total dissolved solids	27	276	142	237	107	72	57
Total hardness as $CaCO_3$ (calculated)	11	209	62	92	73	49	24
Date of collection, 1929	June 29	July 3	July 1	July 1	Oct. 12	July 3	June 29

	45b	58a	63a	69a	71b	74b
Silica (SiO_2)	5	11	14	7	4.4	14
Iron (Fe)	.7	.42	.34	1.4	.8	.07
Calcium (Ca)	7	3.1	2.6	12	12	2.7
Magnesium (Mg)	2	1.8	1.1	3	2	3.1
Sodium (Na)	17	1.0	2.9	2	17	8.6
Potassium (K)	1	.8	1.1		2	1.6
Bicarbonate (HCO_3)	20	11	12	48	17	8.0
Sulphate (SO_4)	5	4.7	2.5	.6	22	3.3
Chloride (Cl)	28	1.3	2.7	4	28	13
Nitrate (NO_3)	1.2	2.5	3.9	.3	1.3	14
Total dissolved solids	73	36	41	56	93	72
Total hardness as $CaCO_3$ (calculated)	26	15	11	42	38	19
Date of collection, 1929	July 2	June 27	July 3	July 4	July 4	June 24

CHESTER COUNTY

[Area 313 square miles. Population 10,603]

GEOGRAPHY

Chester County, which lies in the eastern part of the area, is of unusually irregular outline. Its area is only 313 square miles. The larger part of the county is drained by the South Fork of the Forked Deer River and its tributaries, Sugar, Turkey, Clark, and Jacks Creeks, which flow to the north and west. The remainder is drained by Middletown, Threemile, and White Oak Creeks, which flow slightly east of south. These two systems are separated by the Tennessee-Mississippi divide, an area of high land running in a northeasterly direction across the east-central part of the county. The valley of the South Fork is broad and fertile. The western portion of the county is hilly, wooded, and sparsely settled.

GEOLOGY

The Eutaw formation, of Cretaceous age, does not crop out in Chester County but underlies the whole county. The oldest exposed formation is the Selma clay, which occurs at the surface along the eastern boundary of the county in a strip 4 miles wide at the south and 3 miles wide at the north. It ranges in thickness from 230 to 250 feet. West of the Selma the Ripley formation crops out. The basal part of the Ripley formation is a black clay marl which is mostly fossiliferous. This is known as the Coon Creek tongue of the Ripley formation. The Coon Creek can not be differentiated from the Selma in well logs and is often included in the Selma. The Ripley formation is about 500 feet thick and crosses the county in a broad north-south band 15 miles wide. It consists of sands of different size and intercalated lenses of clay. The Ripley in turn is overlain by the Clayton formation, which is here a glauconitic sand of uncertain thickness but does not exceed 25 feet. The Porters Creek clay, which crops out just west of the Clayton, is nowhere wider than 3 miles and is about 275 feet thick. The Holly Springs sand crops out in the extreme western part of the county. All these formations dip 20 to 30 feet to the mile toward the west. Pliocene sand and gravel are found in some places, and the usual mantle of residuum covers all the upland surface.

WATER RESOURCES

The county is well watered by streams and springs, which furnish in most localities a sufficient supply of water for stock. Wells supply domestic needs. The Selma clay does not yield water. Where it comes to the surface water is obtained from the overlying residuum or else from wells that pass through the Selma into the Eutaw. Wells in the residuum will not furnish large quantities of water and are subject to drying up during dry weather. The Ripley formation is an excellent source of water, and many springs are found in the area of its outcrop, but on hilltops the water table is likely to stand as much as 100 feet below the surface. In the areas of Porters Creek outcrop conditions are similar to those where the Selma is the surface formation, but good supplies of water can be obtained by drilling through the Porters Creek clay into the underlying Ripley. The Holly Springs sand is an excellent water bearer.

LOCAL SUPPLIES

At Deanburg bored wells obtain water from the Holly Springs sand at depths of 50 to 80 feet.

At Enville, on the western contact of the Selma clay, dug wells 25 feet deep are used for domestic supplies. Some wells about 250 feet deep go through the Selma into the Ripley formation.

Henderson (altitude 421 feet) is located in the Ripley formation, which has a thickness of 250 feet at this place. Here the Ripley consists of interbedded sand and clay with some thin seams of lignite that contain marcasite. The lignite gives an unpleasant taste to water, and the oxidizing marcasite gives the water a high iron content. The logs of wells at Henderson show marked variations, as indicated by the two given below.

Logs of wells of West Tennessee Power & Light Co., Henderson, Tenn.

[Authority, driller]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	23	23	Yellow clay	20	20
Gray muddy sand	16	39	Yellow sand	83	103
Dark mud	3	42			
Black mud	8	50			
Streaked sand	2	52			
Mud and sand	6	58			
Light mud	33	91			
Sand	15	106			
Hard sand	5	111			
Mud	22	133			
Sand mixed with mud	15	148			

These wells are within 160 feet of each other. Wells of different depths from 60 to 250 feet have been used, but none gave entire satisfaction. The present water supply of Henderson is furnished by the West Tennessee Power & Light Co. (See analysis 4b.) This system consists of seven wells. Five 3-inch wells 60 feet deep and one 8-inch well 90 feet deep are pumped by an electrically driven Worthington triplex pump located in a pit 12 feet deep which delivers the water to a 70,000-gallon elevated tank. The capacity of this battery of wells is 84 gallons a minute. The water level in these wells is 20 feet below the surface. The latest addition to the plant is a recently completed well 8 inches in diameter and 103 feet deep, which has a gravel wall screen 17 inches in diameter. The well is equipped with a turbine centrifugal pump capable of delivering 225 gallons a minute.

About 20 years ago a deep well was drilled at Henderson to a depth of about 600 feet but was abandoned because no good sand was encountered. It is probable that fair sands were encountered, but the driller was inexperienced and failed to realize this fact. No log of this well could be obtained, but the driller stated that the well did not reach the Paleozoic rocks.

At Jacks Creek (altitude 430 feet) the depth of the wells ranges from 25 to 125 feet, depending on their topographic position. Deep wells are bored.

Mifflin is in the area where the Ripley formation comes to the surface. Water is obtained from dug wells 30 to 40 feet deep.

At Montezuma, which is just east of the eastern edge of the Porters Creek outcrop area, water is obtained from dug or bored wells 25 to 85 feet deep.

In the Porters Creek belt water is obtained by drilling through the "soapstone" to the underlying sand. The wells are as much as 280 feet deep. Some intermittent shallow wells are used but are unsatisfactory.

Records of wells in Chester County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
1	Mifflin	Earl Butler	Upland		Dug	33	36	Sand	Ripley	33	29	July 28	Bucket	Domestic.
2	Deanburg	J. W. Hearn	Hillside	550	Bored	65	10	do	Holly Springs		60	July 30	do	Do.
3	2.3 miles west of Montezuma on road to Deanburg.	A. F. Jones	Hilltop	490	Drilled	277	2	do	Ripley	277			Lift pump, gas motor.	Domestic and stock.
4a	Henderson 300 feet north of railroad station.	O. Fay & Sons	Valley bottom	430	do	76	4	do	do	76	22	Rept.	Lift pump, electric.[a]	Industrial.
4b	Henderson, South Franklin Street.	Western Power & Light Co.	Valley	430	do	103	8	Sand and clay.	do	103	20	do	Turbine centrifugal.[b]	Public supply.
4c	do	do	do	430	do	60	3	Gray sand	do	60	20	do	Lift pump, electric.	Do.
4d	do	do	do	430	do	60	3	do	do	60	20	do	do	Do.
4e	do	do	do	430	do	60	3	do	do	60	20	do	do	Do.
4f	do	do	do	430	do	90	8	Sand	do	90	20	do	do	Do.

[a] Reported pumpage 36,000 gallons a day.

[b] Reported pumpage 288,000 gallons a day.

Analyses of waters from Chester County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyses 1 and 4b by D. F. Farrar; 2 and 3 by Margaret D. Foster]

	1	2	3	4b
Silica (SiO_2)	2.0	17	22	6
Iron (Fe)	.1	.21	47	1.2
Calcium (Ca)	15	2.6	4.8	8
Magnesium (Mg)	2	1.1	1.9	2
Sodium (Na)	9	1.9	2.8	5
Potassium (K)		.8	.3	
Carbonate (CO_3)	0	0	0	0
Bicarbonate (HCO_3)	47	6.0	22	17
Sulphate (SO_4)	4	2.5	4.9	12
Chloride (Cl)	15	2.6	1.2	8
Nitrate (NO_3)	.3	5.3	.0	1
Total dissolved solids	76	47	52	54
Total hardness as $CaCO_3$ (calculated)	46	11	20	28
Date of collection, 1928	July 31	June 30	June 30	Aug. 13

CROCKETT COUNTY

[Area 267 square miles. Population 17,359]

GEOGRAPHY

Crockett County lies just west of the center of western Tennessee. The county is small and has a very irregular boundary. The Gulf, Mobile & Northern Railroad (Dyersburg branch) crosses the middle of the county in a northwesterly direction, and the Louisville & Nashville Railroad parallels the southeastern boundary. Though Crockett County is served by two railroads it is but slightly developed. The two largest towns—Alamo, the county seat, and Bells—have a population of less than 1,000 each. Bells is at the junction of the two railroads and is the largest town. Agriculture is the only activity, and cotton exceeds all other crops in both acreage planted and value of product; corn is second, and some early vegetables and small fruits, especially strawberries, are grown. Dairying is carried on to a certain extent.

The whole of Crockett County lies within the Mississippi drainage area. The two major streams, which are also in part the boundaries of the county, are the Middle Fork and South Fork of the Forked Deer River; these streams flow to the northwest. The flood plain or bottom of the Middle Fork is fairly wide, and its southwest side is in Crockett County. Where the South Fork forms the southwest boundary of Crockett County it flows against the northeast side of its valley so that the land rises abruptly from the river.

A ridge of high, hilly country running west through the middle of the eastern part of the county divides the drainage to the north and southwest. In the western part of the county Pond Creek flows to the northwest, and on each side of it there are low divides which have been cut into low hills. The ground surface of the county is gently rolling. The highest known altitude is 442 feet, at a point 1.4 miles west of Gadsden. The lowest point is probably in the northwest corner of the county.

GEOLOGY

Except in a small strip of land along the western boundary the Grenada formation of the Wilcox group crops out throughout Crockett County. This is underlain by the Holly Springs sand and probably the Ackerman formation of the same group, below which is the Porters Creek clay. The Grenada and Holly Springs are both sand formations but contain thin layers or lenses of clay. The sand varies from very fine to coarse. The clay lenses may be as much as 100 feet thick; such lenses, however, are not more than 100 or 200 feet wide. In the northwestern part of the county beds of lignite or lignitic clay are found in the upper part of the Grenada formation. The thickness of the Wilcox at the eastern boundary of the county is about 700 feet, but it increases to 1,100 feet at the western edge. Throughout this thickness there are many sand layers in which wells can obtain sufficient water for any purpose.

The Porters Creek clay is about 275 feet thick in Crockett County. This formation is underlain by the McNairy sand member, which yields water. The water in the McNairy sand member will rise to about 360 feet above mean sea level.

The western part of Crockett County is covered with a mantle of loess, a buff fine-grained structureless deposit which stands in almost vertical banks. The loess has a maximum thickness of 10 feet in Crockett County. It does not yield water.

WATER RESOURCES

As there are but few permanent streams in Crockett County stock is usually watered from shallow ponds dug in low ground. Springs are not common and have but weak flow. The water table stands at a maximum depth of 125 feet below the surface in the high area in the vicinity of Gadsden. Throughout most of the county, however, the depth to water is much less, the average depth recorded in wells being 38 feet. The Grenada formation can be readily bored, and therefore bored wells are used as a general rule. They have an average depth of 44 feet. Even the drilled wells are not very deep, averaging 105 feet.

LOCAL SUPPLIES

Alamo (altitude 367 feet) has a public water supply owned by W. C. Mount. Water is obtained from a 4-inch well 98 feet deep (analysis 28b) by a force pump that delivers the water to an elevated tank. A good water-bearing sand is found everywhere in Alamo at a depth of about 97 feet.

Bells is furnished with water by the Bells Light & Water Co., which has three 4-inch wells 165 feet deep. Two of these wells are pumped with turbine centrifugal pumps sunk in a sump 25 feet deep; the other well is pumped by a triplex pump. The water is delivered to an elevated tank of 10,000 gallons capacity. The average daily consumption is 15,000 gallons. The depth to water is 15 feet.

The sand encountered at a depth of 100 feet is coarse, but it is reported to yield a water of high iron content. The sand at 165 feet is coarse, and the water from it is good. (See analysis 39.)

At Chestnut Bluff both bored and drilled wells are used. The bored wells are from 50 to 70 feet deep; the drilled wells from 90 to 110 feet. There are many springs at the foot of the hills but they are seldom used.

At Gadsden (altitude 428 feet) the depth to water is 100 feet. A very coarse sand is found at this depth. Bored and drilled wells range from 110 to 160 feet in depth. East of Gadsden the country is higher, the depth to water is greater, and the wells range from 160 to 210 feet in depth.

At Friendship city water is furnished by the Friendship Light & Power Co., a log of whose well is as follows:

Log of well of Friendship Light & Power Co.

	Thickness (feet)	Depth (feet)
Red clay	25	25
Red sand	15	40
Yellow sand and pipe clay	31	71
Fine sand and some clay (water)	10	81

At 81 feet a thick layer of tough clay is encountered. Several years ago a well was drilled to a depth of 950 feet, and it is reported that this well passed through nothing but clay. The driller was probably mistaken, because there are good water-bearing sands in the Wilcox group. Undoubtedly good sand could be found within 600 feet. The Friendship Light & Power Co. has five 3-inch wells 81 feet deep. They are all pumped by force pumps which deliver the water into an elevated tank of 3,800 gallons. The average daily consumption of the town is 10,000 gallons. The water contains sufficient iron to cause trouble if used for some purposes. (See analysis 5a.)

At Maury City both bored and drilled wells are used; the bored wells are from 30 to 60 feet in depth and the drilled wells from 50 to 90 feet.

Records of wells in Crockett County

No.	Location [a]	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Use of water
1	5.8 miles northeast of Friendship on Eaton road.	W. B. Hay		Bored	33	6	Sand	Grenada	33	30	Aug. 31	Bucket	Domestic.
1a	do	do		Drilled	100	2	do	do	100			Lift pump	Do.
2	4.2 miles north and a little east of Friendship.	Mrs. Jesse Clark	Lowland	Bored	30	6	do	do	30	25	Aug. 31	Bucket	Do.
3	2.5 miles northeast of Friendship.	J. W. Sewell	Hillside	do	50	6	do	do	50	45	do	do	Do.
4	1 mile northwest of Friendship on highway 20.	S. J. Jones	Lowland	do	25	6	do	do	25	19	Aug. 30	do	Do.
5a	Friendship	Friendship Mill	Upland	Drilled	87	3	do	do	87			Lift pump	Industrial.
5b	do	Friendship Light & Water Co.	do	do	81	3	do	do					Public supply.
6	Old Saunders, 4.5 miles east of Friendship.	E. Warren	Lowland	Bored	20	12	do	do	20	10	Aug. 31	Bucket	Domestic.
7	5.5 miles north and a little west of Alamo.	J. W. Saunders	Upland	do	36	6	do	do	36	28	Aug. 30	do	Do.
8	Crockett Mills, 5 miles east and a little south of Friendship.	W. O. Redman	Lowland	do	35	6	do	do	35	20		Suction pump	Do.
9	2.2 miles east and a little south of Friendship	S. L. Privett	Upland	do	30	6	do	do	30		Sept. 3	Bucket	Do.
10	1.7 miles southwest of Friendship.	F. D. Schmidt	do	do	42	6	do	do	42	32	Aug. 31	do	Do.
11	4 miles southwest of Friendship.	Wilson Spence	Hillside	Dug	31	36	do	do	31	26	do	do	Do.
12	Chestnut Bluff	W. T. Nun	Upland	Drilled	96	2	do	do	96			Lift pump	Do.
13	2 miles south and a little east of Chestnut Bluff.	D. Brown	Lowland	Bored	25	6	do	do	25	18	Aug. 31	Bucket	Do.
14	2.4 miles southeast of Chestnut Bluff.	R. H. Mitchell	Hillside	Drilled	70	2	do	do	70			Lift pump	Do.
15	3 miles east and a little south of Chestnut Bluff.	W. M. Climer	Hill	do	88	2	do	do	88	80	Rept.	do	Do.
16	5 miles east of Chestnut Bluff.	Mrs. J. Cales	Upland	Bored	88	6	do	do	88	70	Aug. 31	Bucket	Do.
17	4.7 miles northwest of Alamo.	J. A. Taylor	do	do	90	14	do	do	90	85	Sept. 3	do	Do.
18	3.2 miles north of Alamo.	Old Nance School.	Lowland	Drilled	68	2	do	do	68	40	Aug. 30	Lift pump	Do.
19	4.2 miles northeast of Alamo.	Ira Porter	do	Bored	20	6	do	do	20	13	do	Bucket	Do.

[a] Distances given scaled from county post-route map.

Records of wells in Crockett County—Continued

No.	Location	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Use of water
20	5.6 miles northeast of Alamo.	J. B. Kincard	Hillside	Bored	60	6	Sand	Grenada	60	55	Aug. 30	Bucket	Domestic
21	3.4 miles north and a little west of Gadsden.	J. C. Mitchell	Lowland	do	42	6	do	do	42	35	do	do	Do.
21a	do	L. T. Poole	Hillside	Drilled	165	2	do	do	165			Lift pump	Do.
22	2.6 miles northeast of Gadsden, 1,000 feet east of Louisville & Nashville R. R.	T. H. Humphey	Upland	do	90	2	do	do	90			do	Do.
23	1.9 miles east and a little north of Gadsden.	R. S. Medlin	Hilltop	Bored	80	6	do	do	80			Bucket	Do.
24	1.8 miles east of Gadsden	Griggs Bros.		Drilled	187	2½	do	do	187	125	Rept.	Lift pump	Do.
25	Gadsden	Clyde Richardson	Upland	do	120	2	do	do	120			do	Do.
26	2 miles west and a little south of Gadsden.	J. B. Follis	do	Dug	38	36	do	do	38	32	Aug. 30	Bucket	Do.
27	2.6 miles east of Alamo	William Brassfield	do	Bored	45	6	do	do	45			do	Do.
28a	Alamo	N. W. Darden	do	Drilled	97	2	do	do	97			Lift pump	Do.
28b	do	W. C. Mount	do	do	98	4	do	do	98			Force pump	Public supply.
29	2.5 miles east of Alamo on highway 20.	R. J. Robbins	do	Bored	32	6	do	do	32	28	Aug. 30	Bucket	Domestic.
30	Maury City	Town	do	do	35	6	do	do	35	19	Aug. 31	do	Do.
30a	do	School	do	Drilled	90	2	do	do	90			Lift pump	Do.
31	4.1 miles south and a little east of Chestnut Bluff.	J. C. Elmore	do	Bored	60	6	do	do	60	52	Aug. 31	Bucket	Do.
32	6 miles southeast of Chestnut Bluff.	J. J. Chaney	do	do	60	6	do	do	60	54	do	do	Do.
33	7.6 miles southeast of Chestnut Bluff.	J. A. Agee	do	do	32	6	do	do	32	26	do	do	Do.
34	3.4 miles southeast of Maury City.	Johnson School	do	Drilled	87	2	do	do	87			Lift pump	Do.
35	3 miles south and a little west of Alamo.	Cross Roads School.	do	do	85	2	do	do	85	50	Rept.	do	Do.
36	3.2 miles north of Bells on highway 20.	J. R. Midgett	Hillside	Bored	34	6	do	do	34	24	Aug. 30	Bucket	Do.
37	Fruitvale, 4 miles northeast of Bells on Louisville & Nashville R. R.	J. O. Boyd	Lowland	Drilled	65	2	do	do	65			Lift pump	Do.
38	2.8 miles east of Bells on highway 20.	H. G. Nelson	Hillside	Bored	60	6	do	do	60	55	Aug. 30	Bucket	Do.
39a	Bells	Bells Light & Water Co.		Drilled	165	4	do	Holly Springs	165	17	Rept.	Force pump	Public supply.
39b	do	do		do	165	4	do	do	165	17	do	Web cut	Do.
39c	do	do		do	165	4	do	do	165	17	do	do	Do.

Analyses of waters from Crockett County

Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analysis 39 by Margaret D. Foster; the rest by D. F. Farrar]

	5b	8	12	25	28b	30a	39
Silica (SiO_2)	7	4	8	6	6	6	38
Iron (Fe)	2.4	1	1.3	1.3	.4	.2	.05
Calcium (Ca)	26	17	12	24	15	8	6.8
Magnesium (Mg)	2	5	2	2	2	2	2.5
Sodium (Na)	65	63	4	2	15	2	13
Potassium (K)		1					1.6
Bicarbonate (HCO_3)	56	58	44	48	54	28	42
Sulphate (SO_4)	47	7	1	27	3	3	6.0
Chloride (Cl)	84	100	6	3	22	4	8.0
Nitrate (NO_3)	1.2	2.3	.3	.3	.2	.2	4.4
Total dissolved solids	252	218	60	104	87	44	104
Total hardness as $CaCO_3$ (calculated)	73	63	38	68	46	28	27
Date of collection, 1929	Sept. 3	Sept. 3	Sept. 3	Aug. 30	Aug. 30	Sept. 3	Aug. 13

DECATUR COUNTY

[Area 288 square miles. Population 10,106]

GEOGRAPHY

Decatur County is on the eastern edge of the area under consideration. It is a long, narrow county running north and south and bounded on the east by the Tennessee River. The high land in the western part of the county has an altitude of 550 to 600 feet. It is almost flat in places remote from the small streams that drain it, but along the streams the surface has been cut by erosion into hills. Though the eastern part of the county is lower it is thoroughly dissected into narrow V-shaped valleys that are as much as 150 to 200 feet deep. This region is very rugged and sparsely populated.

The county is drained by many short, rapid streams, the largest of which—Big and Little Lick, Club, Turkey, Rushing, Lost, Whites, and Turmbo Creeks, Sulphur Fork, and the Beech River—flow in a generally easterly direction to the Tennessee River. These streams are perennial. The valley of the Beech River ranges from 1 to 2 miles in width and forms the only valley of any size in the area.

Such a region contains very little land suitable for farming. Grazing is the most common means of livelihood. Most of the timber has been cut, but some lumbering is still carried on.

Parsons, the largest town in the county, has a population of 915. Decaturville, the county seat, has a population of 419, and Perryville a population of 128.

GEOLOGY

Paleozoic rocks are exposed throughout the eastern half of the county and are found in the valley of the Beech River within a mile of the western boundary. The oldest rocks exposed are of Silurian age. These are limestones and limy shales; the limestones are the more abundant. These rocks are described in detail on pages 60–63. In the areas in which the Paleozoic rocks are covered by the Eutaw formation the depth to them is not great, ranging from a few feet to a maximum of 200 feet at the southwestern boundary. The Silurian rocks have a maximum thickness of 245 feet but in most places are thinner than this.

Overlying the Silurian rocks are rocks of Devonian age. Like the Silurian, the formations of the Linden group, of Lower Devonian age, consist of limestones and limy shales, with the exception of the top formation, the Decaturville chert. The Decaturville is a thin-bedded gray chert from 5 to 6 feet thick. It has been fractured and rendered porous by solution and though thin is a good water bearer. It crops out on the hillsides of the valley of Big Lick Creek in north-central Decatur County. It is absent at Perryville but is found around Decaturville and farther south near Thurmans.

The Harriman chert is the only formation of Oriskanian age that is present in Decatur County. This formation is a hard, brittle chert resembling novaculite, which has been thoroughly fractured and forms talus slopes of angular rubble. It has a thickness of 30 to 75 feet. It is extensively exposed from Parsons to the northern boundary of the county, forming the cherty hilltops of this area. The Harriman is an excellent source of water.

The Pegram limestone, of the Middle Devonian, does not occur in Decatur County, and the Camden chert is only scatteringly exposed in the northern part of the county. The Camden chert resembles the Harriman chert. It is a brittle chert resembling novaculite, thoroughly fractured and forming a rubble of angular fragments. This formation ranges in thickness from 150 to 240 feet. It is a good water bearer.

The Chattanooga shale is a dark carbonaceous shale with a thickness of 13 feet. In Decatur County it is found on the hillsides in the southeast. It will not yield water.

The Fort Payne chert and St. Louis limestone are found in the northern part of the county and on the hilltops in the southeast. The weathered chert and the St. Louis limestone form good water bearers. They range in thickness from a feather edge to a maximum of 200 feet.

The Eutaw formation is predominantly composed of medium to fine grained sand with which are intercalated some lenses of clay. In places the clay is disposed as thin interlaminated beds, and much of it contains considerable carbonaceous material. It has a maximum thickness in the south of 200 feet but thins to about 90 feet in the north. The Eutaw is a good source of water.

The Coon Creek tongue of the Ripley formation, which crops out in the northwest corner of the county, is an argillaceous glauconitic sand containing some mica and casts of fossils. It has a thickness of 140 feet. The Coon Creek does not yield water.

In the southwest quarter of the county Pliocene gravel forms terraces on many of the uplands and hilltops. These gravel deposits are good sources of water.

WATER RESOURCES

Decatur County is well watered. The county is full of perennial streams which furnish water for stock. Springs are also common, occurring at the foot or sides of the hills at the contact of the Eutaw formation and the underlying Paleozoic rocks. In the northern part of the county, where the hills are composed of chert, springs issue from the chert formations. Although some springs are found in the Paleozoic rocks they are not very large. In an oil test of the Chester County Oil Co. (well No. 44) water was encountered in Paleozoic rocks to a depth of 200 feet but below this the well yielded no water until a flow of water containing considerable hydrogen sulphide was penetrated at 943 feet. Sulphur springs occur in the valley of Sulphur Fork, in southeastern Decatur County. The sulphur water is derived from the Paleozoic rocks. An oil well (No. 42) drilled in the Silurian and Ordovician rocks of this area had an artesian flow of sulphur water.

In the areas where limestone and shale crop out springs are used if available. Otherwise drilled wells furnish small supplies of water. Wells in limestone and shale obtain water from fissures in these rocks. As these fissures are more numerous near the surface, wells should not be drilled deeper than 200 feet. If water is not obtained within this depth a new hole should be started. Bored wells 5 inches in diameter are the usual type of well in the limestone and shale. The average depth of the wells in these formations listed in the table is 74 feet. In the northeastern part of the county dug wells obtain good supplies of water from chert, from wells that average 40 feet in depth. In the western part of the county bored or dug wells obtain water from Eutaw sand at an average depth of 45 feet. If water is not found in the Eutaw it is not advisable to drill more than 10 or 20 feet into the underlying rocks unless they are cherts. It is better to start a new hole, but as a rule water is easily found in the Eutaw.

Water can not be obtained from the Selma clay. In the northeast corner of Decatur County, where the Selma crops out, it is necessary to drill through the Selma to the underlying Eutaw formation. The greatest depth necessary would be 200 feet.

LOCAL SUPPLIES

Bath Springs is in a region where Silurian limestones are exposed. Water is obtained from wells drilled in the limestone or from springs. In some places it has been necessary to drill two or three holes to get water, and the supply was meager.

Silurian limestones and shales crop out in the region around Brownsport Landing. Drilled wells from 50 to 125 feet in depth yield scant supplies of water.

At Colwick bored wells find ample water in the Eutaw formation. The depth to water is 30 to 50 feet.

At Decaturville the Eutaw formation crops out but does not exceed 15 feet in thickness. It is underlain by 15 feet of Harriman chert, 4 feet of Decaturville chert, and 10 feet of Birdsong shale, which is underlain by the Decatur limestone, the intervening Olive Hill formation and Rockhouse shale being absent. Most of the wells are of the dug type and derive their water from either the Harriman or the Decaturville chert. There are a few drilled wells, which penetrate the Decatur limestone and obtain water from this formation. The chert formations yield sufficient water for domestic use. It is difficult to obtain wells in the Decatur limestone. Southwest of Decaturville bored wells in the Eutaw formation furnish domestic water supplies.

The hilltops in the region around Jeanette consist of Harriman and Decaturville cherts. Dug wells obtain ample water from these formations. In the valleys the Silurian rocks crop out, and water is obtained either from springs or from drilled wells.

The surface formation at Parsons is the Eutaw, which has a thickness of 40 feet. It contains many layers of clay, which may impart an unpleasant taste to the water, but the base of the Eutaw contains gravel and is a good water bearer. The Eutaw is underlain by the Harriman and Decaturville cherts. No well at Parsons has penetrated these formations, so their thickness is not known, but from their thickness 1 mile to the east it should be at least 30 feet. These cherts should be good sources of water. There is no town supply at Parsons. Domestic needs are furnished from dug wells from 25 to 40 feet deep. The Nashville, Chattanooga & St. Louis Railway has a well at Parsons 12 feet in diameter and 30 feet deep, with the static level 6 feet below the collar. On pumping at the rate of 70 gallons a minute for 5 hours the drawdown is 9 feet. This demonstrates the low permeability of the Eutaw formation at this point and indicates that no large supply of water could be developed from it.

At Perryville wells drilled in the Decatur limestone (Silurian) furnish the small quantities of water required for domestic use.

Scotts Hill is on the western boundary of the county. Bored wells in this region obtain water from the Eutaw formation. In the immediate vicinity of Scotts Hill the Eutaw contains a great deal of carbonaceous clay, and it is difficult to obtain good water.

At Sugartree and in the area to the south and east dug wells obtain water from the Camden or Harriman chert. The water is of excellent quality. Springs are also used for domestic supply when conveniently located.

At Swallow Bluffs drilled wells obtain small supplies of water from Silurian limestones. To the northeast of Swallow Bluffs bored wells obtain water from the Eutaw formation or Pliocene gravel.

Records of wells in Decatur County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
1	Oak View on Hogs Creek	A. H. Mills	Foot of hill	400	Dug	11	36	Fractured chert.	Devonian		8	Sept. 29	Bucket	Domestic.
2	Sugartree	H. B. Mcilwain	do	360	do	20	36	do	Fort Payne		14	do	do	Do.
3	1.8 miles south of Sugartree on Parsons road.	R. Riley	do	450	do	30	36	do	do		13	do	do	Do.
4	Holladay	Clift Brothers	Hilltop	500	Bored	55	6	Sand	Eutaw	55	49	Sept. 28	do	Do.
5	3.5 miles south of Sugartree on Parsons road.	W. C. Moore	do	530	Dug	36	36	Fractured chert.	Devonian		32	Sept. 29	do	Do.
6	8.5 miles south of Hogs Creek School.	H. E. Frazier	Foot of hill	350	do	20	36	do	do		8	do	do	Do.
7	1.8 miles south of Hogs Creek School.	Mrs. R. E. Cotham	Hillside	330	do	32	36	do	do	32	25	do	do	Do.
8	3.1 mile south of Jeanette on Ferry road.	J. T. Walker	Hilltop	460	do	55	36	do	do		49	Sept. 27	do	Do.
9	0.5 mile east of Cedar Hill Church.	L. C. Bowman	Foot of hill	450	Spring			Sand	Eutaw		(a)	Sept. 28		Do.
10	0.2 mile east of county on old Lexington road.	A. C. Evans	Upland	470	Bored	44	6	do	do	34	40	do	Bucket	Do.
11	1.7 miles northeast of Bible Hill on old Lexington road.	N. H. Arnold	do	500	do	43	6	do	do	43	40	do	do	Do.
12	Jeanette	J. W. Cottrell	Hilltop	530	do	20	6	do	do	20	17	Sept.	do	Do.
13	1 mile north of Jeanette on Sugartree road.	E. L. Baugas	Valley	380	Dug	24	36	Limestone	Silurian		20	Sept. 29	do	Do.
14	Cliffs Landing	N. E. Prince	Hillside	400	Drilled	185	6	do	Silurian (Decatur).	185	155	do	do	Do.
15	Bussel Town	Stella Horner	Hilltop	550	Bored	137	6	do	do		100	Oct. 1	do	Do.
16	Bells Store	J. H. Bell	do	540	Drilled	50	6	do	do	50	32	do	do	Do.
17	5 miles east of Parsons on Bussel Town road.	S. T. Churchill	Gully	480	Dug	25	36	Fractured chert.	Devonian	25	21	do	do	Do.
18	2.7 miles north of Parsons on Sugartree road	A. J. Dailey	Upland	510	do	35	36	Sand	Eutaw	26.5	23	Sept. 28	do	Do.
19	Bible Hill	O. H. Hurst	Hilltop	470	Bored	26½	6	do	do	26.5	23	do	do	Do.
20	3 miles northwest of Parsons on road to Bible Hill.	W. T. Hayes	do	480	do	37	6	do	do	30	34	do	do	Do.
21	1.1 miles northwest of Parsons on road to Bible Hill.	E. Carrington	do	560	do	47	6	do	do	47	40	do	do	Do.

[a] Flowing 23,680 gallons a day.

Records of wells in Decatur County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
22	1.4 miles north of Parsons on Sugartree road.	B. Morris	Hilltop	550	Bored	41	6	Sand	Eutaw	41	38	Sept. 30	Bucket	Domestic.
23	6 miles west of Decaturville on Lexington road.	E. W. Ham	Valley	420	do	62	8	do	do	62	37	July	do	Do.
24a	200 feet east and 30 feet south from railroad station, Parsons.	W. D. Colwick	Upland	485	Dug	25	36			5–20	17	Oct. 2	Lift pump	Do.
24b	200 feet east and 100 feet south from railroad station, Parsons.	M. L. Houston	do	487	do	33	36			22	17	do	Lift pump, electric.	Do.
24c	Parsons	Nashville, Chattanooga & St. Louis Ry.	do	487	do	30	144			30	18	do	Steam plunger	Railroad.
24d	0.25 mile east of railroad station, Parsons.	J. J. Odel	do	505	Drilled	45	6			45	41	do	Bucket	Domestic.
24e	500 feet east and 100 feet north from railroad station, Parsons.	Southern Cities Power Co.	do	487	Dug	40	36	Sand	Eutaw	40	18	do	Lift pump, electric.	Industrial.
25	1.6 miles east of Parsons on Perryville road.	C. N. Townsend	Hilltop	460	do	30	36	Fractured chert.	Devonian	30	21	Oct. 1	Bucket	Domestic.
26	On highway 69 south of Parsons, opposite Mount Tabor.	Wm. Graves		380	do	38	36	do	do	38	25	Oct. 2	do	Do.
27a	400 feet north of railroad station Perryville.	J. A. Ready	Hillside	400	Bored	44	5	Limestone	Silurian (Decatur)	16	28	Sept. 22	do	Do.
27b	Perryville	Thomas Young	do	400	Dug	20	36	Gravel	Pliocene	20	17	do	do	Do.
27c	200 feet north of railroad station, Perryville.	Town of Perryville	do	390	Drilled	72	5	Limestone	Silurian (Decatur).	12	42	do	do	Do.
28	5 miles east of Decaturville	J. E. Reynolds	do	410	do	78	5	do	Silurian	23	54	do	do	Do.
29	1.5 miles east of Fishers Landing.	J. F. Dellenger	Hilltop	470	do	70	6	do	do	70	65	Oct. 1	do	Do.
30	3 miles east of Decaturville	W. G. Lacy	Valley	410	do	40	5	do	do		28	Sept. 22	do	Do.
31a	200 feet south of courthouse, Decaturville.	Mrs. O. L. Duncan	Hilltop	520	Dug	30	36	Fractured chert.	Devonian (Harriman).	30	30	Oct. 1	do	Do.
31b	do	J. H. Stout	do	520	do	25	36	do	do	25	20	do	Lift pump, electric.	Do.

31c	500 feet south of high school, Decaturville.	do	do	520	Drilled	38	6	Shaly limestone.	Devonian	30	23	do	Bucket	Do
31d	0.5 mile southeast of courthouse, Decaturville.	Walter Johnson	Hillside	500	do	107	6	Limestone	Silurian (Decatur).	51	75	do	do	Do.
32	On highway 69 at intersection of Scotts Hill road.	Myrn C. Smith	Upland	490	Bored	38	6	Sand	Eutaw	38	30	Sept. 22	do	Do.
33	6.4 miles northeast of Scotts Hill on Decaturville road.	W. T. Wright	Foot of hill	500	do	16	6	do	do	16	13	do	do	Do.
34	3.4 miles northeast of Scotts Hill on Decaturville road.	A. J. Brown	Hillside	530	do	85	6	do	do	85	71	do	do	Do.
35	4.1 miles south of Decaturville on highway 69.	J. B. West	Hilltop	540	Drilled	54	6	Limestone	Silurian		36	Sept. 21	do	Do.
36	6.0 miles south of Decaturville on highway 69.	R. W. Haney	do	550	Bored	58	6	Gravel	Pliocene	50	46	do	do	Do.
37	Brownsport	T. S. Hassel	Hillside	440	Drilled	125	5	Limestone	Silurian (Decatur).			Oct. 1	do	Do.
38	On Vice Landing road, 3 miles south of branch to Fishers Landing.	W. I. Thomson	Hilltop	440	do	67	6	do	do		30	do	do	Do.
39	1.1 miles northwest of Vice Landing on road.	Mrs. Kate Smith	do	490	do	86	8	do	do	30	64	do	Hand pump	Do.
40	4.5 miles north of Bath Springs on highway 69.	N. T. Shelton	Hillside		Spring			Gravel	Pliocene		(b)	Sept. 21		Do.
41	2.3 miles north of both springs on highway 69.	J. W. Pikins	Lowland		Drilled	1,100	6	Limestone			(c)			
42	2.2 miles north of Bath springs on highway 69.	do	Hillside	500	Spring			do	Silurian		(d)	Sept. 21		Do.
43	Dunbar	B. B. Keaton	Hilltop	600	Bored	67	6	Sand	Eutaw	67	60	Sept. 27	Bucket	Do.
44	3.3 miles northwest of Bath Springs.	Chester County Oil Co.	Upland		Drilled	2,141	10			200	(e)			
45	4.7 miles north of Thurman on Scotts Hill road.	E. J. Scotts	Ridgetop	520	Bored	44	6	Sand	Eutaw	44	39	Sept. 22	Bucket	Do.
46	1.7 miles north of Thurman on Scotts Hill road.	Molly Eason	Hilltop	420	do	39	6	do	do	39	31	do	do	Do.
47	Thurman	W. M. White	do	460	Dug	62	36	do	do	42	38		do	Do.
48	3 miles north of highway 69 on road to Old Dunbar.	E. R. Maners	do	500	do	60	36	do	do	60	47	Sept. 27	do	Do.
49	200 feet north of post office at Bath Springs.	W. E. Lancaster	Hillside		Drilled	60	3	Limestone	Silurian (Decatur).	18	44	Sept. 21	do	Do.
50	1.3 miles east of branch of highway 69 on road to Clifton.	Illinois Tie Co.	Valley		Dug	20	36	do	Silurian		6		do	Do.
51	3.1 miles east of Tennessee River at Clifton, on highway 69.	Elmer Brawley	Hillside		Spring			do	Dixon					Do.

b Flowing 8,640 gallons a day.
c Small flow of strong, sulphur water.
d Flowing 14,400 gallons a day.
e Base of Cretaceous at 90 feet. Water found to a depth of 200 feet. Sulphur water at 943 feet.

Records of wells in Decatur County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed		Depth to which well is cased (feet)	Water level		Method of lift	Use of water
								Character of material	Geologic horizon		Below surface (feet)	Data of measurement (1928)		
52	1.3 miles north of Tennessee River on highway 69.	W. S. Howard	Hillside		Dug	42	36	Sand	Eutaw	42	38		Bucket	Domestic.
53	2.2 miles south of Bath Springs on highway 69.	G. T. Tucker	Hill	410	Bored	56	6	Limestone	Silurian		54		do	Do.
54	0.1 mile south of highway 69 on Swallow Bluffs road.	Mrs. F. E. Boggan	Hillside	370	Dug	26	36	do	do		10		do	Do.
55	1.0 mile north of highway 69 on Old Dunbar road.	L. White	Hilltop	510	Spring	37	36	Sand	Eutaw		30		do	Do.
56	2 miles northwest of Swallow Bluffs Landing on highway 69.	O. C. Simmons	Hill	480	do	87	36	do	do	30	75		do	Do.

Analyses of waters from Decatur County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table Analyzed by Margaret D. Foster]

	2	27c	31a	31d	49
Silica (SiO_2)	13	12	15	18	13
Iron (Fe)	.11	.45	.18	.32	.11
Calcium (Ca)	3.1	158	69	24	96
Magnesium (Mg)	1.3	16	5.6	22	4.4
Sodium (Na)	2.9	21	3.3	111	2.5
Potassium (K)	.8	3.4	.7	3.1	1.4
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	5.0	344	222	48	296
Sulphate (SO_4)	4.9	57	4.7	2.8	3.2
Chloride (Cl)	2.5	63	2.8	200	4.0
Nitrate (NO_3)	7.5	94	14	86	7.9
Total dissolved solids	42	609	224	516	276
Total hardness as $CaCO_3$ (calculated)	13	461	195	150	258
Date of collection 1928	Sept. 29	Sept. 22	Oct. 1	Oct. 1	Sept. 22

DYER COUNTY

[Area 500 square miles. Population 31,405]

GEOGRAPHY

Dyer County lies in the northwestern part of the area under consideration. It is bounded on the west by the Mississippi River and on the south by the Forked Deer River and its South Fork. Two lines of the Illinois Central Railroad enter the county at the north boundary, meet at Dyersburg, and one continues southward. The Dyersburg branch of the Gulf, Mobile & Northern Railroad enters the county from the southeast. Agriculture is the principal occupation, cotton and corn being the major crops, and dairying is important. On the bottom land of the Mississippi lumbering is still carried on. Some cotton mills are located at Dyersburg, the third largest city in western Tennessee, with a population of 8,733.

Dyer County is drained by three large streams—the Obion River, the Forked Deer River, and the South Fork of the Forked Deer. These streams have low gradients and are building up their flood plains, which are rather wide. The area between the rivers is gently rolling with the exception of the region just south of the Obion in the western part of its course, before it crosses the flood plain of the Mississippi. Here the land surface rises abruptly from the river, forming bluffs. The upland surface has been somewhat dissected and is hilly. The western part of the county belongs to the flood plain of the Mississippi River, which is from 4 to 10 miles in width, is low and in places swampy, and is subject to the overflow of the Mississippi at very high water. Most of this area is wooded, and here lumbering is still actively carried on.

GEOLOGY

The river bottoms are composed of alluvium. The alluvium along the Mississippi River is about 100 feet deep and is typical alluvium, being very changeable and lenticular, lenses of fine and coarse sand, clay, and gravel succeeding one another both horizontally and vertically.

The upland of Dyer County is everywhere covered with a mantle of loess. The loess is about 60 feet thick at the bluffs but thins to 25 feet in the eastern part of the county. Pliocene gravel underlies the loess in the upland section in the northwestern part of the county but is not found elsewhere. Under this gravel and in other places under the loess occurs the Jackson formation, which is underlain by the Grenada, Holly Springs, and Ackerman formations of the Wilcox group. The Jackson and the upper part of the Grenada are very similar and can not be differentiated in well logs. The Jackson consists of fine sand, in places silty, and clay; lignite is characteristic of the formation, and organic matter is common. The clay occurs in beds that are continuous over large areas. The Jackson formation is not a good source of water, for the beds of sand are too thin and the sand is too fine grained. (See p. 106.) What has been said of the Jackson is true of the upper part of the Grenada formation, but in depth the Grenada sands may be coarser and the clay occurs in lenses that are nowhere more than a few hundred feet long. The Holly Springs formation consists of coarse and fine sand in which occur lenses of clay. Both the lower part of the Grenada and the Holly Springs contain layers of coarse sand which are excellent sources of water. The combined thickness of the Jackson formation and Wilcox group is about 1,800 feet.

The Wilcox group is underlain by the Porters Creek clay, which is about 200 feet thick. It is a hard clay, impervious to water, and forms an effective confining bed to the water in the Ripley formation below. The Ripley formation contains layers of sand that yield water. The static head of water from the Ripley is 300 feet above mean sea level. This is below the level of the lowlands, and wells in the lowlands that end in the Ripley will flow.

WATER RESOURCES

Springs are not common in Dyer County, although they are found at the foot of the bluffs in the northwestern part of the county south of the Obion River. In this hilly region cisterns are used extensively. The loess that forms the surface is easily dug, but, as the water immediately below the loess is hard the inhabitants prefer cistern water. Deep wells, however, would obtain good water. In the remainder of the uplands both drilled and bored wells are in use; the drilled wells listed have an average depth of 157 feet, and the bored wells average 39 feet. The top of the Jackson and the top of the Grenada contain but few layers of sand sufficiently coarse to be checked by a strainer. In the river bottoms driven wells are used almost exclusively. They average 38 feet in depth and derive their water from the alluvium. Better water could be obtained at greater depths.

LOCAL SUPPLIES

Bogota is on the alluvial plain of the Obion River. Driven wells 15 to 30 feet deep obtain fair water.

Dyersburg is on the North Fork of the Forked Deer River. The city-owned public water supply (see analyses 35a, 35b) is on the lowland and derives water from three wells. Well 1 is 820 feet deep and is pumped by air lift, yielding 250 gallons a minute. Well 2, drilled in 1922, is 10 inches in diameter at the bottom and 650 feet deep. This well showed a flow of 128 gallons a minute at a depth of 206 feet, and it flows at a depth of 650 feet. The well is pumped by air lift. Well 3 is 10 inches in diameter and 633 feet deep. It is pumped by a turbine centrifugal pump. The water from these wells enters two settling tanks of 26,000 gallons capacity each and flows from these tanks to a rapid sand filter, making several drops in transit, thus being aerated. Analyses of the treated and raw water are given in the table, Nos. 35b and 35d. After passing through the filter the water is pumped by two centrifugal pumps which deliver 700 and 1,000 gallons a minute into a 214,000-gallon standpipe. Distribution is effected by gravity. The average daily consumption is 1,000,000 gallons.

The original static head at Dyersburg was 282.9 feet above mean sea level. This is higher than the ground level, and the well flowed. The first layer of sand coarse enough to be checked by a strainer and thick enough to finish a well in is found between depths of 585 and 666 feet, but the depth and thickness of the sand differ from place to place. It is from this horizon that the city and the Dyersburg Coal & Ice Co. obtain water. The Phoenix Compress Co. used to obtain water from this sand but now taps a deeper sand at 950 feet. The log of well 3 of the Dyersburg Water Department is as follows:

Log of well 3 of Dyersburg Water Department, Dyersburg

[Well in alley between Chicago, Memphis & Gulf Railroad and Forked Deer River. Authority, S. R. Blakeman]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	25	25	Hard rock	1	566
Fine clay	30	55	Clay	3	569
White water-bearing sand	11	66	Hard rock	1	570
Lignite	3	67	White clay	13	583
White and gray sand mixed	12	81	Medium-hard rock	1	584
Mixed lignite and blue clay	1	82	Clay	5	589
Fine dark sand mixed with clay	93	175	Medium-hard rock	.6	589.6
Fine white sand mixed with clay	26	201	Pipe clay, white and hard	9.4	599
Gray clay	39	240	Medium-hard rock	1	600
Fine brown sand	10	250	Hard white clay	4	604
Gray clay	20	270	Coarse water sand	29	633
Clay and sand mixture	40	310	Medium sand and clay mixed with sand	17	650
Light-colored clay	45	355	Fine sand	10	660
Hard clay	3	358	Hard dry clay	40	700
Soft rock	2	360	Fine sand and clay	38	738
Pipe clay	83	423	Water sand (doubtful as to quality of sand)	30	768
Hard white clay	73	496	Shale	76	784
Brown sand	6	502			
Hard rock	1	503			
Hard white clay	3	565			

The log of the Phoenix Compress Co.'s well is recorded as clay and sand for 715 feet; from 715 to 850 feet, good-looking sand, but only 125 gallons a minute could be developed; 850 to 851 feet, sandrock; 851 to 950 feet, good water sand.

The log of a drilled well on the Forest Ferguson farm, 2 miles southwest of Dyersburg, is as follows:

Log of well on Forest Ferguson farm, Dyer County

[Authority, Carloss Well Supply Co. Water level 39 feet below collar of well]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	36	36	Clay	32	222
Sand	14	50	Fine sand; water	11	233
Clay	24	74	Blue clay	59	292
Sand	73	87	Hardpan	2	294
Big gravel and sand	14	101	Blue clay	10	304
White clay	19	120	Hardpan	3	307
Soft sandy clay	39	159	Blue clay	13	320
Black silty sand	21	180	Good coarse sand	200	520
Hard clay	10	190	Clay	29	549

Water from a depth of 600 feet is less highly mineralized than that from a depth of 950 feet, as can be seen by comparing analyses 35a and 35d. Both are calcium bicarbonate waters, but the water from the deep well is hard, whereas the water from the 600-foot well is soft.

At Finley the depth to water is 20 feet. Driven or drilled wells are used and average 33 feet in depth but range from 18 to 60 feet.

At Lenox, just west of the bluffs on the Obion River bottom, driven wells are mostly used, and they are from 30 to 60 feet deep. The log of a drilled well is as follows:

Log of well of J. W. Anderson at Lenox, Dyer County

[Authority, J. W. Anderson]

	Thickness (feet)	Depth (feet)
Clay and sand	20	20
Limestone (?)	21	41
Yellow sand mixed with clay	18	58
Black sandy clay with lignite	40	98
Fine sand	69	167
Yellow coarse sand	40	207

Newbern has a municipally owned public water supply. Water is obtained from two wells—one 10-inch well 160 feet deep and one 8-inch well 260 feet deep. Water from the deep well is somewhat softer than that from the shallow well, as can be seen by comparing analyses 14a and 14b (p. 154). The 10-inch well is pumped by a turbine centrifugal pump and the 8-inch well by a lift pump. The water flows into a 138,000-gallon reservoir, from which it is pumped into a 75,000-gallon standpipe by a centrifugal pump. The average daily consumption is 100,000 gallons. A log of the 8-inch well is as follows:

Log of well at Newbern

	Thickness (feet)	Depth (feet)
Clay	45	45
Hard, tough bluish-gray clay	10	55
Hard clay	45	100
Fine silty sand	60	160
Very fine sand	70	230
Coarse gray sand	30	260

In the uplands west of Newbern drilled wells are used. The following log of a well owned by N. W. Colcaltt 8 miles west of Newbern shows the general conditions.

Log of Colcaltt well, 8 miles west of Newbern

	Thickness (feet)	Depth (feet)
Yellow clay loess	50	50
Blue clay loess	40	90
Sand and gravel (Pliocene)	12	102
Quicksand with some gravel	54	156

Tigrett is in a valley. Bored wells are largely used and are from 25 to 40 feet deep. A layer of lignite is encountered at about 20 feet. The drilled well of W. L. Moore, which is 125 feet deep, has a slight flow.

At Trimble bored wells 30 to 50 feet deep are mostly used, although there are a few drilled wells 80 to 90 feet deep. A test well drilled 3 miles east of Trimble, on the farm of M. A. Gauldin, had the following log:

Log of well 3 miles east of Trimble, on farm of M. A. Gauldin

	Thickness (feet)	Depth (feet)
Wilcox group:		
Surface	4	4
Red clay	20	24
Water sand	40	64
Blue clay	20	84
Gumbo	12	96
Water sand	40	136
Blue clay	40	176
Gravel (?)	80	256
Water sand	70	326
Lignite	8	334
Blue clay	40	374
Sand	20	394
Gravel (?)	120	514
Blue clay	20	534
Dry sand	20	554
Gravel (?)	80	634
Clay	20	654
Lignite	10	664
Dry sand	20	684
Gravel (?)	40	724
Hard sand	40	764
Wilcox group—Continued.		
Gumbo	20	784
Iron pyrites	10	794
Water sand	5	799
Iron pyrites	15	814
Broken formation	40	854
Shale	60	914
Rock sand	10	924
Dry sand	18	942
Boulder	5	947
Rock sand	10	957
Gumbo	20	977
Sandrock	40	1,017
Iron pyrites	4	1,021
Sandrock	40	1,061
Blue gumbo	40	1,101
Sandy shale	80	1,181
Rock, broken	15	1,196
Gumbo	40	1,236
Rock sand	22	1,258
Blue shale	32	1,286
Rock	4	1,290

It is questionable if the material called gravel is truly gravel. Sand cemented by iron oxide drills like gravel, and the driller might readily so classify drillings from such material.

Records of wells in Dyer County

No.	Location	Owner or name	Topographic situation	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface or bench mark (feet)	Water level: Date of measurement (1929)	Method of lift	Capacity of pump (gallons a minute)	Use of water
1	Trimble	R. O. Fisher		Drilled	82	3	Sand	Jackson	82	30	Rept.	Lift pump		Domestic.
2	1.8 miles south of Trimble	E. Tarks	Hilltop	do	100	2	do	Wilcox	100			do		Do.
3	2.7 miles southwest of Trimble	Daulton Scobey	do	do	95	2	do	Jackson	95			do		Do.
4	6 miles southwest of Trimble	Sam Town	Lowland	do	135	2	do	do	135			do		Do.
5	1 mile southeast of Lane	John Beach	Second bottom.	do	135	2	do	do	135			do		Do.
6	2.5 miles northeast of Miston	J. T. Bratton	Bottom	Driven	84	1¼	do	Alluvium	84			do		Do.
7	1.8 miles west of Miston	do	do	do	20	1¼	do	do	20			Suction pump		Do.
8	Miston	W. Horner	do	do	60	1¼	do	do	60			Lift pump		Do.
9	Bogota, 2.5 miles east of Miston	J. J. Riley	do	do	23	1¼	do	do	23			Suction pump		Do.
10a	5.5 miles west of Newbern	William Robbins	Hilltop	Bored	92	6	do	Jackson	92	88	Aug. 28	Bucket		Do.
10b	do	G. M. Tickle	do	Drilled	300	3	do	Wilcox	300			Lift pump		Do.
11	4 miles west of Newbern	County School	do	Dug	65	36	Gravel	Pliocene		60	Aug. 28	Bucket		Do.
12	3.6 miles west of Newbern	J. W. Wynne	Upland	Drilled	116	2	Sand	Jackson		75	do	Lift pump		Do.
13	2 miles northeast of Newbern on highway.	H. C. Brooks	Hillside	Bored	33	6	do	do	33	16	do	Bucket		Do.
14a	Newbern	City of Newbern	Upland	Drilled	260	8	do	Wilcox	260	80	Rept.	Lift pump	150	Public supply.
14b	do	do	do	do	160	10	do	Jackson	160	80	do	Centrifugal	250	Do.
15	2.5 miles east of Newbern	H. P. Tigrett	do	do	119	2	do	do	119			Lift pump		Domestic.
16	5.4 miles east of Newbern	E. C. Gregory	do	do	65	2	do	Wilcox	65			do		Do.
17	6 miles east of Newbern	E. M. McCorkley	do	do	150	2	do	do	150	45		do		Do.
18	6.5 miles southeast of Newbern(?)	H. E. Austin	do	Bored	52	6	do	do	52	37	Aug. 27	Bucket		Do.
19	3.6 miles southeast of Newbern	J. C. Balthrop	do	do	40	6	do	Jackson	40	30	do	do		Do.
20	2.5 miles south of Newbern	A. G. Harris	do	Drilled	160	2	do	Wilcox	160	80	Rept.	Lift pump		Do.
21	7.3 miles northeast of Dyersburg on highway 3	W. Brown	do	Bored	35	6	do	Jackson	35	29	Aug. 28	Bucket		Do.
22	4.9 miles northeast of Dyersburg on highway 3.	J. O. Owen	Lowland	Drilled	97	2	do	do	97			Lift pump		Do.
23a	4 miles north of Dyersburg	Guy Fairbanks	do	do	25	2	do	do	25	10	Rept.	Suction pump		Do.
23b	do	N. W. Colcaltt	do	do	156	2	do	Wilcox	156			Lift pump		Do.
24	4.5 miles northwest of Dyersburg	W. E. McGuire	Hilltop	do	140	2	do	Jackson	140			do		Do.
25	3 miles west of Lenox	D. Lumley	Bottom	do	127	1½	do	do	127	10	Rept.	Suction pump		Do.
26a	Lenox	J. W. Anderson	do	Washed	207	2	do	Wilcox	207	20	do	Lift pump		Do.
26b	do	G. W. Smith	do	Driven	50	2	do	Alluvium	50			do		Do.
27	3.5 miles north of Dyersburg	L. Gobb	Lowland	Dug	44	36	do	Jackson	44			Suction pump		Do.

28	1.5 miles north of Dyersburg	Ferguson School	do	do	35	36	do	do	35	30	Aug. 28	Bucket		Do.
29	2.8 miles northeast of Dyersburg on highway 3.	J. A. Greer	Upland	Drilled	115	2	do	Wilcox	115			Lift pump		Do.
30	6.5 miles east and a little north of Dyersburg.	C. W. Copeland	Hilltop	do	193	2	do	do	193	100	Rept	do		Do.
31	10.7 miles east of Dyersburg	H. Williams	Lowland	Driven	35	2	do	do	35	7	do	Suction pump		Do.
32	9 miles east of Dyersburg	W. J. Hendrix		Bored	50	6	do	do	50	40	Aug. 27	Bucket		Do.
33a	6 miles east of Dyersburg	E. M. Hobday	Valley	do	40	8	do	Jackson	40	30	do	do		Do.
33b	do	P. J. Strickland	Hilltop	do	60	6	do	do	60			do		Do.
34	2.5 miles east of Dyersburg	W. Condray	Bottom	Drilled	90	2	do	do	90			Lift pump		Do.
35a	Well 1, Dyersburg	City of Dyersburg	do	do	810	10	do	Wilcox	810			Air lift	250	Public supply.
35b	Well 2, Dyersburg	do	do	do	650	10	do	do	650	(a)	Rept	do	523	Do.
35c	Well 3, Dyersburg	do	do	do	633	10	do	do	633	(a)	do	do	650	Do.
35d	Dyersburg	Phoenix Compress Co.	Lowland	do	950	8	do	do	950			Centrifugal	400	Industrial.
36	3.2 miles west of Dyersburg on highway 20.	W. L. Tansil	Bottom	do	65	2	do	Jackson	65			Lift pump		Domestic.
37	Finley	R. C. Finlay	do	Driven	53	1	do	do	53	20	Rept	Suction pump		Do.
38	9.5 miles west of Dyersburg	T. R. Jackson	do	do	38	2	do	Alluvium	38			do		Do.
39	16 miles west of Dyersburg	J. Mechell	do	do	40	2	do	do	40			Lift pump		Do.
40	17 miles west of Dyersburg	Harris Walker	do	do	30	1	do	do	30			Suction pump		Do.
41	14 miles west and a little south of Dyersburg.	J. K. White	do	do	30	1	do	do	30			do		Do.
42	11 miles west and a little south of Dyersburg.	Dyer Delta Co.	do	Bored	100	1	do	do	100			Lift pump		Do.
43	Richwood, 2.5 miles south of Finley.	E. W. Moody	do	Driven	30	1¼	do	do	30			Suction pump		Do.
44	7.5 miles southwest of Finley	J. J. Parker	do	do	18	1¼	do	do	18			do		Do.
45	11.2 miles southwest of Finley	L. R. Sentell	do	do	28	1¼	do	do	28			do		Do.
46	Chic, 11.5 miles southwest of Finley.	W. T. Connell	do	do	32	1¼	do	do	32			do		Do.
47	Tigertail	J. Moore	do	do	40	1¼	do	do	40			do		Do.
48	6.5 miles south and a little west of Dyersburg.	County School	Upland	Drilled	85	2	do	Jackson	85			Lift pump		Do.
49	3.7 miles south of Dyersburg on highway 3.	A. C. Smith	do	do	85	2	do	do	85			do		Do.
50	.5 miles south of Dyersburg on highway 3.	H. W. Welch	do	do	70	2	do	do	70			do		Do.
51	2.7 miles east of highway 3 on highway 20.	M. C. Vear	do	Bored	35	6	do	do	35			Bucket		Do.
52	5 miles east of highway 3 on highway 20.	J. H. Putnam	do	do	36	6	do	do	36			do		Do.
53	Tigertail, 9 miles southeast of Dyersburg.	W. L. Moore	Lowland	Drilled	125	2	do	Wilcox	125	(a)				Do.
54	1.4 miles north of Chestnut Bluffs	A. T. Hattsford	do	Bored	27	6	do	Jackson	27	14	Sept. 3	Bucket		Do.
55	2.5 miles north of Chestnut Bluffs	J. B. Freano	Upland	do	37	6	do	do	37	14	do	do		Do.

[a] Flow.

Analyses of waters from Dyer County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyses 35a, 35, and 35d by Margaret D. Foster; the rest by D. F. Farrar]

	1	14a	14b	26	35a
Silica (SiO_2)	6	4	5	5	14
Iron (Fe)	.8	.8	.7	.6	5.9
Calcium (Ca)	53	27	31	148	12
Magnesium (Mg)	6	5	6	9	6.9
Sodium (Na)	2	3	7	3	6.2
Potassium (K)					1.4
Bicarbonate (HCO_3)	180	98	91	484	79
Sulphate (SO_4)	7	7	22	7	8.6
Chloride (Cl)	4	5	13	5	1.6
Nitrate (NO_3)	.2	.1	.3	.4	.05
Total dissolved solids	173	105	140	426	84
Total hardness as $CaCO_3$ (calculated)	157	89	102	406	58
Date of collection 1929	Aug. 28	Aug. 28	Aug. 28	Aug. 29	Sept. 9

	35 [a]	35d	37	53
Silica (SiO_2)	11	26	6.7	8
Iron (Fe)	.49	9.5	.6	1.3
Calcium (Ca)	13	43	115	26
Magnesium (Mg)	7.3	19	18	5
Sodium (Na)	4.7	6.5	2	2
Potassium (K)	1.4	4.1		
Bicarbonate (HCO_3)	76	238	400	102
Sulphate (SO_4)	7.0	7.1	30	1
Chloride (Cl)	1.6	1.6	3	3
Nitrate (NO_3)	.05	.0	.2	.2
Total dissolved solids	80	210	387	101
Total hardness as $CaCO_3$ (calculated)	62	185	361	85
Date of collection	Sept. 9, 1929	Mar. 24, 1930	Aug. 29, 1929	Sept. 3, 1929

[a] Treated water from wells at Dyersburg.

FAYETTE COUNTY

[Area 618 square miles. Population 28,891]

GEOGRAPHY

Fayette County is in the southwestern part of the area. It approximates a square in outline, being 28 miles long and 25 miles wide, and has an area of 618 square miles. Two large streams flow across the county from east to west. The Wolf River enters the southeast corner from the State of Mississippi, and after flowing north for 2 miles it turns sharply and flows slightly north of west across the county. It has a wide valley, of which the first bottom, some 2 miles in width, is swampy and uncultivated. The Loosahatchie River flows completely across the northern part of the area from east to west. It has a fairly broad valley and, like the Wolf River, a swampy first bottom. Muddy Creek, in the northeastern part of the county, flows in a northwesterly direction into Haywood County. These streams have been ditched in order to drain the bottoms and carry off flood waters.

In the eastern part of the county between these rivers is an area of high country cut into numerous hills and gullies. This area is covered with timber and with the exception of a few farms is uninhabited. The surface between the rivers in the western part of the county is also broken and hilly. The sandy formations of this area are readily washed by the rains, forming deep gullies. For example, just south of La Grange steep gullies have been cut to a depth of 150 feet. These gullies afford the best exposure of Holly Springs sand in the region.

GEOLOGY

The Holly Springs and Grenada formations of the Wilcox group cover the entire county. These two formations are similar in their main physical features, and as their water-bearing properties are similar they will be discussed together. Along the eastern border of Fayette County the depth to the underlying Porters Creek clay is 200 to 250 feet in the valleys 300 feet above sea level and as much as 650 feet on the high ridges that reach an altitude of 600 feet. The Holly Springs and Grenada formations dip from 25 to 30 feet to the mile toward the west, and at the western boundary of the county they have attained a thickness of 750 feet. These formations are composed of sand of varying coarseness with interbedded lenses of clay. The clay lenses make up a small part of the total. Both the Holly Springs and the Grenada are excellent water-bearing formations, and there is no difficulty in obtaining water throughout the county. In the hilly areas the water table stands as much as 150 feet below the surface during dry weather, and in these areas wells must exceed this depth to be permanent. In some places, however, there are perched water tables that will yield water above the true water level. Such perched water tables are formed by basin-shaped impervious layers of clay at the base of the Pliocene gravel or by hardpan consisting of sand and gravel cemented by iron oxide. (See p. 41.) They are irregularly distributed, and their presence can not be predicted. As they are of small area they will furnish only small supplies, which will run dry in summer.

WATER RESOURCES

Bored wells are most commonly used in this county, especially on high ground. In the valleys where the water table stands within 20 feet of the surface dug wells are common. Where large quantities of water are needed drilled wells are used. Stock is watered from stock ponds or streams or from the few springs.

LOCAL SUPPLIES

At Braden (318 feet above sea level) water can be obtained at depths of 30 to 60 feet by bored or dug wells. Drilled wells are not feasible at shallow depths because the sand encountered is so fine. At a depth of 225 feet coarser sand is found, which becomes increasingly coarser to a depth of 350 feet. There is no difficulty in finishing wells in this sand.

Galloway (277 feet above sea level), being in the valley of the Loosahatchie, obtains water from shallow wells 20 to 30 feet deep. The water comes from the valley alluvium. It has an unpleasant taste and attacks boilers, and for this reason cisterns are mostly used. Good water, however, can be obtained from wells at a depth of 190 feet.

Hickory Withe and environs are in a region of dissected uplands at an altitude of 410 feet. Water is obtained either from the Pliocene gravel at a depth of 60 to 90 feet or from the Grenada formation at a depth of 130 to 230 feet. The shallow wells obtain water from a perched water table and are not permanent. The water table in this area falls as low as 125 feet in the late summer and fall. For this reason drilled wells are largely used, although some bored wells are found. A typical well log from the locality is as follows:

Log of well of W. A. Weber, Hickory Withe

[Authority, R. D. Leah, driller, from memory]

	Thickness (feet)	Depth (feet)
Sandy loam	6	6
Red dry sand	39	45
Red sand	24	69
White clay	32	112
White medium-grained quartz sand	45	157

At Laconia wells range from 50 to 125 feet in depth, but most of them exceed 75 feet. Bored wells are almost exclusively used. Water is good and abundant. (See analysis 10.)

La Grange is situated in the high region in southeastern Fayette County and southwestern Hardeman County where the ridges are remnants of the old plateau surface. The altitude of La Grange is 534 feet, and the ridge to the north probably reaches 600 feet. In some places shallow wells obtain small supplies of water, but usually it is necessary to drill from 200 to 300 feet for a permanent supply.

The region around Macon is rolling upland. Water is obtained at depths of 80 to 125 feet according to topographic position. The water is of fair quality but somewhat harder than most of the other waters of this region. (See analysis 11.)

Moscow (352 feet above sea level) is in the valley of the Wolf River. Simple driven wells with suction pumps are used, and the water is of excellent quality. (See analysis 13.) In case it were found desirable for reasons of sanitation to go to greater depths, water would be found almost anywhere between 50 and 280 feet. At shallow depths quicksand is reported. It is difficult to keep this fine sand out of a well, and its passage through the strainers erodes them rapidly. With proper handling, however, this sand can usually be shut out. Coarser sand can be found at greater depths.

Rossville is in the valley of the Wolf River at an altitude of 310 feet. Water is found at a depth of 15 feet in the valley alluvium. Simple driven wells with suction pumps are exclusively used. The water is of excellent quality for any use. (See analysis 12.)

Somerville (altitude 345 feet) has a water supply owned by the city. The water is obtained from four 4-inch wells in the valley of the Loosahatchie River, spaced 9 feet apart in a north-south line and 74 feet deep. A log of one of them is given below.

Log of well of City Waterworks, Somerville

[Authority, J. L. Saunders, superintendent]

	Thickness (feet)	Depth (feet)
Silt	2	2
Blue clay	8	10
Fine sand	7	17
Increasingly coarser sand ending in gravel ¾ inch in diameter	57	74

The four wells are connected in battery and pumped by two electric centrifugal pumps, each with a capacity of 250 gallons a minute, that deliver the water to an elevated 50,000-gallon tank from which it is distributed by gravity. The water is of good quality but contains enough iron to make its removal by aeration followed by sedimenatation or filtration desirable. (See analysis 10a.)

Records of wells in Fayette County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Capacity of pump (gallons a minute)	Use of water
1	6 miles north of Somerville on Brownsville road.	Elizabeth Homer Estate.	Hilltop	420	Drilled	140	2	Sand	Grenada	140			Lift pump, gas motor.		Domestic and stock.
2a	Braden, 200 feet east of railroad station.	H. L. McGraw	Hillside	325	Bored	40	6	do	do	40	25	July	Bucket		Domestic.
2b	Braden, 2,000 feet from station on road going west.	do	do	325	Drilled	283	3	do	do	283	40	Rept.	Gas motor		Do.
3a	Galloway, east of railroad station at sawmill.	P. D. Clack	Valley bottom.	277	do	190	2	do	do	190	20	do	do		Do.
3b	Galloway, west of railroad, 500 feet north of station.	T. A. Watson	do	277	Dug	20	36	do	Alluvium	20	10	July	Bucket		Do.
4a	Hickory Withe, 2,000 feet north of crossroads.	A. V. Luck	Ridgetop	410	Drilled	230	2½	do	Grenada				Lift pump, gas motor.		Do.
4b	Hickory Withe, 200 feet north of crossroads 200 feet west.	W. A. Weber	do	410	do	153	2½	do	do	153	123	Rept.	do		Do.
4c	Hickory Withe, 1,000 feet west of crossroads.	A. Weber & Co.	do	410	do	135	4	do	do	135	125	do	Steam plunger pump.		Industrial.
5	9.6 miles west of Somerville on highway 15.	Tennessee Highway Department.	Valley	340	do	157	6	do	do	157	25	Aug. 23	Lift pump, gas motor.		Do.
6a	Oakland, on highway 15	V. M. Umble	Upland	387	Bored	100	6	do	do	100	93	do	Bucket		Domestic.
6b	Oakland, 500 feet east of railroad station, 25 feet north of track.	Mathews & Murrull Gin Co.	do	387	do	119	3	do	do	119			Steam plunger	45	Industrial.
7	Warren, 200 feet west of railroad station, 100 feet south of track.	E. W. McKinstry.	do	400	do	125	6	do	do	125	117	Aug. 23	Bucket		Domestic.
8	3.4 miles west of Somerville on highway 15.	do	do	420	do	100	6	do	do	100	97	do	do		Do.
9a	Somerville, opposite railroad station.	City of Somerville.	Valley bottom.	345	Washed	75	4			75	15	July	Electric plunger.	(a)	Public supply.

[a] Reported yield 110,000 gallons a day.

Records of wells in Fayette County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed		Depth to which well is cased (feet)	Water level		Method of lift	Capacity of pump (gallons a minute)	Use of water
								Character of material	Geologic horizon		Below surface (feet)	Date of measurement (1928)			
9b	Somerville, 1,000 feet southwest of railroad station.	Somerville Ice Co	Hill slope	355	Washed	94	4			94	17	Rept.	Lift pump, oil engine.	[b] 6	Industrial.
10	Laconia, 500 feet east and 100 feet north from railroad station.	Morrison Saw Mill.		428	Bored	125	6	Sand	Holly Springs	125			Steam		Do.
11	Macon	T. D. Boswell	Upland	430	do	125	3	do	Grenada	125	95	Rept.	Lift pump, gas motor.		Domestic.
12	Rossville	Town	Valley bottom.	310	Washed	28	1¼	do	Alluvium	28	20	do	Lift pump		Domestic and stock.
13	Moscow	do	do	355	Driven	50	2	do		50	18	do	Hand pump		Domestic.
14	La Grange, on highway 0.1 mile east of crossroads.	John Hamil	Hilltop	540	Drilled	240	2	do	Holly Springs	240			Lift pump, gas motor.		Do.

[b] Yield 8,400 gallons a day, Aug. 23, 1928.

Analyses of waters from Fayette County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyses 4c and 9a by D. F. Farrar; the rest by Margaret D. Foster]

	4c	9a	10	11	12	13	14
Silica (SiO_2)	6	11	16	21	18	12	14
Iron (Fe)	.2	1.2	.23	.30	.21	.19	.23
Calcium (Ca)	13	10	1.9	12	3.6	3.0	2.6
Magnesium (Mg)	3	3	1.2	5.1	1.7	.9	1.1
Sodium (Na)	9	9	2.5	22	7.6	9.0	6.0
Potassium (K)			.9	1.6	1.0	.4	.8
Carbonate (CO_3)	0	0	0	0	0	0	0
Bicarbonate (HCO_3)	45	28	11	80	18	30	24
Sulphate (SO_4)	4	10	2.8	3.0	3.1	1.6	1.9
Chloride (Cl)	17	16	1.4	14	11	3.0	1.4
Nitrate (NO_3)	.1	.5	1.5	18	1.5	.23	2.9
Total dissolved solids	77	78	33	142	58	49	43
Total hardness as $CaCO_3$ (calculated)	45	37	9.7	51	16	11	11
Date of collection, 1928	July 27	Aug. 23	Aug. 22	July 3	July 3	July 6	Aug. 20

GIBSON COUNTY

[Area 633 square miles. Population 46,528]

GEOGRAPHY

Gibson County lies just north of the center of the area under discussion. It is bounded on the north by the South Fork of the Obion River and on the south by the Middle Fork of the Forked Deer River. The county is served by three railroads—the Illinois Central, the Louisville & Nashville, and the Mobile & Ohio. Agriculture is the predominating activity, and the major crop is cotton, though much corn is raised, and dairying is actively carried on. Gibson County is the center of the spring vegetable section of western Tennessee; large quantities of strawberries, cabbages, and tomatoes are shipped from this county to northern markets every year. Humboldt and Milan are the principal shipping points. Though agriculture is the main activity there is some manufacturing in Gibson County. Cotton and shoe mills are located at Humboldt and Milan.

The entire surface of Gibson County lies within the drainage area of the Mississippi River. The South Fork and Rutherford Fork of the Obion River and the North Fork and Middle Fork of the Forked Deer are the major streams. They all flow toward the northwest and as they have low gradients are building up their flood plains. The surface of Gibson County is level or gently rolling and slopes to the northwest. The highest precisely determined altitude in the county is 505 feet above mean sea level at a point in Medina, and the lowest is 271.7 feet at a point on the road between Forks of River and Tatumville.[89] The county probably averages about 350 feet above mean sea level.

GEOLOGY

The Wilcox group occurs at the surface throughout the county. The Holly Springs sand crops out along the eastern edge of the county,

[89] Spirit leveling in Tennessee: U. S. Geol. Survey Bull. 519, op. 33, 16, 1912.

but except for a narrow band of loess in the western part the Grenada is the surface formation in the remainder of the county. The Grenada consists of sand with thin interstratified layers or intercalated lenses of clay. As a rule the sand of the Grenada is fine grained, although some coarse sands are found, especially at the base of the formation. Small beds of lignite occur in the formation at some places. A more detailed description of the Wilcox group can be found on pages 89-106. The total thickness of the group ranges from 450 feet at the eastern boundary to 1,100 feet at the western edge of the county. The Wilcox is underlain by the Porters Creek clay, which has a thickness of 220 feet. Below the Porters Creek lies the Ripley formation, which may contain considerable beds of sand, but according to the log of the Baskins Drilling Association well, given below, the Ripley seems to be predominantly clay.

Log of well of Baskins Drilling Association, 2 miles southeast of Dyer, just west of Mobile & Ohio Railroad

	Thickness (feet)	Depth (feet)
Wilcox group:		
Soil	20	20
Sand	4	24
Clay	3	27
Blue clay	20	47
Sand	30	77
Pipe clay	20	97
Sand; water	90	187
Pipe clay	20	207
Sand; water	40	247
Clay	5	252
Sand; water	75	327
Clay, pink and white	40	367
Sand; water	37	404
Clay	10	414
Pack sand, coarse	67	481
Blue clay	20	501
Pink sand; artesian flow	8	509
Sticky clay	14	523
Black sand	116	639
Gumbo	61	700
Blue shale	5	705
Sandrock	2	707
Gumbo	28	735
Blue shale	20	755
Sandrock	2	757
Sand	19	776
Shale	12	788
Sandrock	1	789
Shale	28	817
Red sandrock	3	820
Blue gumbo	15	835
Red sandrock	5	840
Gumbo	3	843
Sandrock	2	845
Blue shale	28	873
Sandrock	1	874
Shale	9	883
Gumbo	10	893
Blue shale	8	901
Gumbo	50	951
Sandrock	1	952
Shale	12	964
Sand	1	965
Porters Creek clay:		
Blue shale	20	985
Gumbo	5	990
Shale	5	995
Porters Creek clay—Continued.		
Gumbo	3	998
Blue shale	19	1,017
Gumbo	1	1,018
Hard blue shale	40	1,058
Blue shale	10	1,068
Rock	2	1,070
Rock shale	12	1,082
Rock	1	1,083
Gumbo	8	1,091
Black shale and shells	68	1,159
Black gumbo	46	1,205
Cretaceous:		
Hard sand	10	1,215
Shale	2	1,217
Sand; water	3	1,220
Gumbo, black	16	1,236
Sand	26	1,262
Hard blue shale	20	1,287
Gumbo	18	1,300
Rock	4	1,304
Gumbo	10	1,314
Rock	2	1,316
Shale	8	1,324
Gumbo	6	1,330
Rock	3	1,333
Gumbo, white	18	1,351
Lime	4	1,355
Sand	126	1,481
Hard sand and shale	116	1,597
Lime, hard, and pyrites of iron (very hard, possibly chert)	22	1,619
Lime; oil show	4	1,623
Sand	103	1,726
Sand	24	1,750
Limy hard gray rock	8	1,758
Gray rock	9	1,767
Sandy shale	28	1,795
Gumbo	3	1,798
Paleozoic:		
Black shale	6	1,804
Hard lime	3	1,807
Black shale and gumbo	40	1,847
Hard sand; gas show	70	1,917
Gumbo and black shale; gas show	80	1,997
Sandy lime	30	2,027

Corrected depth by tape-line measurement, 2,009 feet.

An examination of the above log shows that there are many sand layers in the Wilcox group at depths between 20 and 639 feet. These will yield abundant water.

A thin mantle of loess covers the western part of the county. The loess is a structureless fine-grained buff deposit which does not yield water.

WATER RESOURCES

The numerous streams throughout the county provide most of the water for stock. Where these are not handy watering ponds are dug in any swale. The small springs that are found at the edges of the bottoms are not used to any extent. Though a few dug wells are still used in Gibson County, bored wells are the most common. They average 67 feet in depth. Wherever the depth to water is much more than 100 feet or where a large supply is wanted drilled wells are used. In the river bottoms the water comes almost to the surface, but in the hills the water table stands as much as 140 feet below the surface. The average depth to water in the wells listed is 52 feet. The great thickness of the Wilcox group is predominantly sand.

LOCAL SUPPLIES

Bradford (368 feet above sea level) has a municipal water supply, obtained from one 8-inch well 272 feet deep. The well is pumped by a lift pump that delivers the water to a reservoir; thence it is pumped into a 50,000-gallon overhead tank by a turbine centrifugal pump yielding 500 gallons a minute. The daily consumption averages 120,000 gallons. The water is of excellent quality. (See analysis 15.) Bradford is underlain by about 100 feet of black clay. Below this is 125 feet of fine sand, which in turn gives place to coarse sand.

At Cades (367 feet above sea level) wells from 70 to 90 feet deep end in a fine white sand. Coarse sand can be found at and below 130 feet.

At Dyer (372 feet above sea level) a 6-inch well owned by the city is 296 feet deep and is pumped by air lift. The water flows into an 80,000-gallon reservoir from which it is pumped into a 40,000-gallon overhead tank by a three-cylinder duplex pump yielding 750 gallons a minute. The daily consumption averages 50,000 gallons. (See analysis 20.)

To the southeast of Dyer wells encounter a layer of lignitic clay 15 feet thick at a depth of 40 to 55 feet. Water obtained near this layer is unpalatable. Coarse sand is found below the lignite.

Eaton (310 feet above sea level) is located on the second bottom. Shallow bored wells 25 to 40 feet obtain enough water for domestic use.

In and around Gibson (396 feet above sea level) both bored and drilled wells are used. The bored wells are from 55 to 75 feet deep; the drilled wells go as deep as 150 feet.

Humboldt (345 feet above sea level) is the largest city in Gibson County, having a population of 4,613. The public water supply, which is owned by the city, is equipped with three 8-inch wells 440 feet deep and two 8-inch wells 285 feet deep. The wells are connected in a battery and are pumped by a centrifugal pump having a capacity of 750 gallons a minute, located in the bottom of a 16-foot pit, which delivers the water to a 212,000-gallon overhead tank. The average daily consumption is 450,000 gallons. The water is soft and of excellent quality. (See analysis 81.) It is not necessary to go deeper than 170 feet to find a water-bearing sand. The water level is 342 feet above mean sea level. A well drilled at Humboldt in 1912 to a depth of 880 feet passed through the Porters Creek clay into the Ripley formation and is reported to have flowed for a few hours. Water in the Ripley formation should have sufficient head to flow at the pumping plant in Humboldt.

Medina (505 feet above sea level) is on the high land in the southeast corner of the county. The water table stands at a depth of 118 feet, or 387 feet above sea level. Drilled wells in this vicinity range from 116 to 179 feet in depth, according to their topographic position. The sand in this vicinity is very coarse, and good wells are easily made.

Concerning Milan (423 feet above sea level) Glenn [90] makes the following statement:

Milan is underlain by 20 to 22 feet of red Lafayette sand, below which in a part of the town is found a pipe clay 43 feet thick, while elsewhere, especially in the eastern part of the town, instead of pipe clay a very dark lignitic clay is struck. This black clay occurs 3 or 4 miles north of the town and for the same distance south. It reaches a thickness in places of 70 to 80 feet. Under it are 2 to 7 feet of yellow clay, then a 3 or 4 inch ironstone crust easily broken by an iron bar. Below either the pipe clay or ironstone is found a soft sand which varies in texture but often contains in its upper part some fine gravel. This sand is water-bearing and has been explored to a depth of 200 feet from the surface.

The town corporation has three wells—one 8-inch well 110 feet deep, one 10-inch well 120 feet deep, and one 10-inch well 135 feet deep. The 110-foot well is pumped by an air lift pump; the other two are pumped by deep-well turbine pumps. The water flows into an 85,000-gallon reservoir, from which it is pumped directly into the mains by a centrifugal pump. The average daily consumption is about 225,000 gallons. (See analysis 58.)

At Rutherford (318 feet above sea level) the town corporation has two wells—one 8-inch well 271 feet deep and one 10-inch well 286 feet deep. They are both pumped by air lift. The water flows from the wells into a 100,000-gallon reservoir from which it is picked up by a turbine yielding 300 gallons a minute and delivered to a 50,000-gallon elevated tank. The average daily consumption is 40,000 gallons. (See analysis 9.)

At Trenton (321 feet above sea level) the wells owned by the city are in the bottoms of the North Fork of the Forked Deer River. At this point the static level is 316 feet, and the wells flow, the altitude of the collar being 315 feet. The city has four wells—two 8-inch wells 165 feet deep, one 10-inch well 165 feet deep, and one 12-inch well 450 feet deep. All four are pumped by compressed air, and the water flows into a 150,000-gallon reservoir, from which it is pumped directly into the mains. The average daily consumption is 150,000 gallons. The log of the 450-foot well is as follows:

Log of well of the city of Trenton

[Authority, Mr. Cunningham]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	14	14	Lime rock (?)	6	233
Fine sand	160	174	Clay	103	336
Clay	53	227	Fine sand	114	450

The water obtained from these wells is of excellent quality. (See analysis 42.)

At Yorkville pipe wells about 80 feet deep are used. The town is underlain by a layer of lignitic clay from 100 to 158 feet in depth and wells drilled into it obtain very poor water. Deeper wells, however, would obtain good water.

[90] Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U. S. Geol. Survey Water-Supply Paper 164, p. 75, 1906.

Records of wells in Gibson County

No.	Location [a]	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Capacity of pump (gallons a minute)	Use of water
1	5 miles east-northeast of Rutherford.	J. W. Allen	Second bottom.	Bored	38	6	Sand	Alluvium	38	14	Aug. 10	Bucket		Domestic.
2	3.6 miles north-northeast of Rutherford.	P. E. Jenkins	Hillside	do	53	10	do	Grenada	53	47	do	do		Do.
3	2.9 miles east-northeast of Rutherford.	W. S. Lawrence	Upland	do	40	6	do	do	40	33	do	do		Do.
4	5 miles east-northeast of Rutherford.	J. B. Barton	do	do	85	6	do	do	85	63	do	do		Do.
5	2.3 miles northeast of Bradford	J. P. Knott	do	do	55	6	do	do	55	44	Aug. 2	do		Do.
6	2.3 miles north of Bradford on highway 42.	E. Smith	Second bottom.	do	35	6	do	Alluvium	35	20	do	do		Do.
7	10.5 miles northeast of Trenton on road to Greenfield.	F. Emerson	do	do	30	6	do	do	30	19	Aug. 3	do		Do.
8	9.7 miles northeast of Trenton on road to Greenfield.	W. T. Shortt	Upland	do	50	6	do	Grenada	50	46	do	do		Do.
9a	Rutherford, east of railroad well 1.	City of Rutherford	Lowland	Drilled	271	8	do	do	271			Air lift		Public supply.
9b	Same, well 2	do	do	do	286		do	do	286			do	(b)	Do.
10	9.7 miles west of Dyer on highway 77.	H. H. Huie	Upland	do	66	2	do	do	66	48	Rept.	Lift pump		Domestic.
11	Yorkville	W. M. Baker	do	Driven	80	2	do	do	80			do		Do.
12	2 miles north-northeast of Dyer on highway 5.	W. E. Porter	do	Dug	50	36	do	do	50	40	Aug. 9	Bucket		Do.
13	7.8 miles northeast of Trenton on road to Greenfield.	R. A. Milton	do	Bored	100	6	do	do	100	90	Aug. 3	do		Do.
14a	2 miles west of Bradford	Kate Lannom	Valley	Dug	30	36	do	do	30	27	do	do		Do.
14b	do	E. P. Lannom	Hilltop	Bored	66	6	do	do	66	62	do	do		Do.
15	100 feet west of Bradford, 50 feet north of railroad station.	City of Bradford	Lowland	Drilled	272	8	do	Holly Springs	272	40	Rept.	Lift pump	[c] 60	Public supply.
16	3 miles east-northeast of Bradford.	E. S. Flippin	Upland	Bored	98	6	do	Grenada	98	92	Aug. 2	Bucket		Domestic.
17	5.5 miles east-southeast of Bradford.	O. Blankinship	do	do	103	6	do	do	103	95	Aug. 3	do		Do.
18	2.3 miles southeast of Bradford	C. H. Bruff	Hilltop	do	142	6	do	do	142	134	do	do		Do.
19	6 miles northeast of Trenton on road to Greenfield.	W. F. Cash	Second bottom.	do	50	6	do	do	50	40	do	do		Do.

[a] Distances scaled from county map. [b] Pumpage, 40,000 gallons a day. [c] Pumpage, 120,000 gallons a day.

Records of wells in Gibson County—Continued

No.	Location	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Capacity of pump (gallons a minute)	Use of water
20	On east side of railroad at Dyer, 200 feet north of station.	City of Dyer	Upland	Drilled	296	6	Sand	Grenada	296	60	Rept	Air lift	[d] 250	Public supply.
21	1.9 miles west of Dyer on highway 77.	G. M. Fisher	Hillside	Bored	37	6	do	do	37	25	Aug. 9	Bucket		Domestic.
22	4 miles west of Dyer on highway 77.	Ray Wilson	do	Dug	35	36	do	do	35	21	do	do		Do.
23	6 miles west of Dyer on highway 77.	J. H. Strong	Valley	Bored	40	8	Gravel	Pliocene	40		do	do		Do.
24	8.5 miles west-southwest of Dyer.	J. W. Airce	Upland	Drilled	175	2	Sand	Grenada	175	65	Rept	Lift pump		Do.
25	7.7 miles west-southwest of Dyer.	E. E. Jetton	do	Bored	21	6	do	do	21	15	Aug. 9	Bucket		Do.
26	1.5 miles west-southwest of Dyer.	United Brethren Camp.	Valley	Spring						(e)				Do.
27	2.5 miles southeast of Dyer on highway 5.	O. M. Goodman	Upland	Bored	90	6	Sand	Grenada	90	81	Aug. 9	Bucket		Do.
28a	Laneview, 4 miles northeast of Trenton.	Mrs. N. Carthcart	do	do	85	6	do	do	85					Do.
28b		Laneview group of citizens.	do	Drilled	326	2	do	Holly Springs	326	126	Rept	Lift pump		Do.
29	3 miles west of Idlewild	J. Y. Proctor	Second bottom.	Washed	85	2	do	Grenada	85			do		Do.
30	Idlewild	A. Powell	Lowland	Bored	24	6	do	do	24	14	Aug. 2	Bucket		Do.
31	5.5 miles east of Idlewild	Gerald Flippin	Upland	do	60	6	do	Holly Springs	60	41	do	do		Do.
32	Gann, 2.1 miles northeast of Cades.	G. S. Mayo	do	do	80	6	do	Grenada	80	76	do	do		Do.
33	Avery, 3 miles southwest of Idlewild.	J. E. Carr	Hill	Drilled	175	2	do	do	175			Lift pump		Do.
34	2.2 miles northwest of Trenton on highway 5.	W. L. George		Bored	25	6	do	do	25	21	Aug. 9	Bucket		Do.
35	10.2 miles west-northwest of Trenton.	Robert Freeman	Bottom	do	20	6	do	Alluvium	20	9	Aug. 5	do		Do.
36	14.5 miles west of Trenton	H. D. Evans	do	Driven		1¾	do	do				Pump suction		Do.
37	Central, 10.3 miles west of Trenton.	Z. K. Hunt	Upland	Bored	35	6	do	Grenada	35	29	Aug. 5	Bucket		Do.
38	8.6 miles west-northwest of Trenton.	L. E. Williams	Second bottom.	do	32	6	do	do	32	26	do	do		Do.

39	7.2 miles west of Trenton	R. J. Jones	Upland	do	56	6	do	do	56	44	do	do		Do.
40	5.6 miles west of Trenton	A. M. McCree	Valley	do	35	6	do	do	35	22	do	do		Do.
41	2.4 miles west of Trenton	J. T. Grisp	Upland	Drilled	125	2	do	do	125			Lift pump		Do.
42a	Trenton	City of Trenton	Lowland	do	450	12	do	do	450		Flows	Air lift		Public supply.
42b	do	do	do	do	165	10	do	do	165		do	do		Do.
42c	do	do	do	do	165	8	do	do	165		do	do		Do.
43	2.7 miles east of Trenton on highway 77.	W. A. Thompson	Valley	Dug	30	36	do	Alluvium	30	11	Aug. 3	Bucket		Domestic.
44	5 miles east of Trenton on highway 77.	Albert Elder	Hilltop	Drilled	125	2	do	Grenada	125			Lift pump		Do.
45	3 miles west-northwest of Cades.	C. Hassell	Upland	Bored	165	6	do	do	165	155	Aug. 3	Bucket		Do.
46	1.8 miles west of Cades on highway 77.	J. Connell	Lowland	do	45	6	do	do	45	42	do	do		Do.
47	3.1 miles east-northeast of Cades.	Wiley Belew	Hilltop	do	130	6	do	do	130	102	Aug. 2	do		Do.
48a	Cades	G. A. Watson	Upland	Drilled	160	2	do	Holly Springs	160			Lift pump		Do.
48b	do	L. M. Reeves	do	Bored	70	6	do	Grenada	170	60	Aug. 2	Bucket		Do.
49	2 miles northwest of Milan	J. B. Peeks	do	do	50	6	do	do	50	40	Aug. 3	do		Do.
50	4.8 miles west-northwest of Milan.	C. T. Cole	Lowland	Dug	30	36	do	do	30	26	do	do		Do.
51	4 miles southeast of Trenton	R. C. Burns	do	Bored	40	6	do	do	40	25	do	do		Do.
52	6.3 miles west-southwest of Trenton.	A. N. Freeze	Upland	do	82	6	do	do	82	62	Aug. 5	do		Do.
53	13 miles west of Trenton	C. C. Essary	Second bottom.	do	30	14	do	do	30	26	do	do		Do.
54	Eaton	G. A. Hoover	do	do	40	6	do	do	40	34	do	do		Do.
55	2 miles south-southeast of Eaton.	Miss A. Bechett	Bottom	do	20	6	do	do	20	17	do	do		Do.
56	3.2 miles south of Trenton on highway 5.	Ray Hicks	Hillside	Drilled	57	2	do	do	57	45	Rept.	Lift pump		Do.
57	1.9 miles northeast of Gibson	C. C. Langford	do	do	120	2	do	do	120			do		Do.
58a	Milan, west of Jackson Street, east of Louisville & Nashville R. R.	City of Milan	Upland	do	120	10	do	Holly Springs	120			Centrifugal	350	Public supply.
58b	175 feet east of 58a	do	do	do	135	10	do	do	135			do	225	Do.
58c	Milan	do	do	do	110	8	do	do	110	60	Rept.	Force pump	180	Do.
58d	75 feet west of 58a	Milan Ice & Fuel Co.	do	do	150	6	do	do	150			do		Industry.
59	2.8 miles east of Milan on highway 77.	J. P. McClemore	do	Bored	55	6	do	do	55	45	Aug. 1	Bucket		Domestic.
60	3.6 miles southeast of Milan	C. H. Foster	Hilltop	do	110	6	do	do	110	100	do	do		Do.
61	2.7 miles south-southwest of Milan.	J. E. Wood	Upland	do	140	6	do	do	140	131	Aug. 2	do		Do.
62	Gibson, Main Street, 200 feet east of railroad track.	J. H. Bass	do	do	68	6	do	Grenada	68	52	Aug. 1	do		Do.
63	2.6 miles west of Gibson	E. Coleman	do	Drilled	150	2	do	do	150			Lift pump		Do.
64a	Fruitland, 75 feet north of railroad station, east of track.	G. W. Dedman	do	do	202	4	do	Holly Springs	202			do		Do.
64b	Fruitland, 200 feet south of railroad station, west of track.	do	do	Bored	102	6	do	Grenada	102	62		Bucket		Do.
65	Edison, 2 miles west of Fruitland.	F. Culp	do	Drilled	213	2	do	do				Lift pump		Do.

[d] Pumpage, 50,000 gallons a day.

• Flowing 3 gallons a minute, Aug. 10, 1929.

Records of wells in Gibson County—Continued

No.	Location	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed		Depth to which well is cased (feet)	Water level		Method of lift	Capacity of pump (gallons a minute)	Use of water
							Character of material	Geologic horizon		Below surface (feet)	Date of measurement (1929)			
66	4.4 miles west of Fruitland	A. J. Mitchell	Upland	Bored	44	6	Sand	Grenada	44	32		Bucket		Domestic.
67	Frog Jump, 5.6 miles southwest of Trenton on highway 54.	W. R. Collins	Hillside	do	31	10	do	do	31	21		do		Do.
68a	Brazil, 3.5 miles west of Frog Jump.	Norwell and Harrington.	Upland	Drilled	70	2	do	do	70	35		Lift pump		Do.
68b	do	Town of Brazil	do	Bored	40	6	do	do	40	31		Bucket		Do.
69	6 miles west of Frog Jump	G. Thompson	Lowland	do	40	6	do	do	40	33	Aug. 5	do		Do.
70	5.3 miles southwest of Frog Jump.	M. Dinwiddy		do	49	6	do	do	49	41	do			Do.
71	Gibson Wells, 9.2 miles southwest of Trenton on highway 54.	Watt and Diel		do	33	14	do	do	33	16	do			Do.
72	1.4 miles south of Gibson Wells	Mrs. L. Richardson.	Upland	do	64	6	do	do	64	56	do			Do.
73	2.4 miles north of Humboldt on highway 5.	Mrs. H. Barrix	Hilltop	do	94	6	do	do	94	73	Aug. 3			Do.
74	Sitka, 4 miles south of Milan on highway 43.	S. P. Chapman	Upland	do	108	6	do	Holly Springs	98	96	Aug. 2			Do.
75	4.8 miles northeast of Medina	J. R. Killen	Hilltop	do	127	6	do	do	127	120	Aug. 1			Do.
76	5.5 miles south of Milan on highway 43.	E. L. West	Upland	do	100	6	do	do	100	67	Aug. 2			Do.
77	2.7 miles northeast of Medina	W. P. Grogan	Hillside	do	65	6	do	do	65	45	Aug. 1			Do.
78	Medina	City of Medina	Upland	do	155	6	do	do	155	118	Aug. 2			Do.
79	1.6 miles west of Medina	R. Witt	do	do	92	6	do	do	92	80	do			Do.
80	4.3 miles west of Medina	J. B. Roe	do	do	100	2	do	do	100			Lift pump		Do.
81a	Humboldt	City of Humboldt	Lowland	do	440	8	do	do	440			Centrifugal pump	750	Public supply.
81b	do	do	do	do	285	8	do	do	285			do		

Analyses of waters from Gibson County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyses 9b, 20, 42, and 81 by Margaret D. Foster; the rest by D. F. Farrar]

	9b	15	20	30	42
Silica (SiO_2)	11	7	13	5	28
Iron (Fe)	.51	.2	1.6	1	.02
Calcium (Ca)	14	10	8.9	25	3.6
Magnesium (Mg)	5.8	2	3.9	3	2.2
Sodium (Na)	10	3	5.0	27	5.9
Potassium (K)	1.6		1.6	2	1.3
Bicarbonate (HCO_3)	88	34	50	25	33
Sulphate (SO_4)	4.9	2	5.2	46	3.3
Chloride (Cl)	1.8	6	2.8	46	1.6
Nitrate (NO_3)	.0	.1	.0	3.2	.0
Total dissolved solids	90	52	65	164	63
Total hardness as $CaCO_3$ (calculated)	59	33	38	75	18
Date of collection, 1929	Aug. 10	Aug. 2	Aug. 8	Aug. 2	Aug. 12

	58a	62	64b	78	81
Silica (SiO_2)	6	8	6	4	12
Iron (Fe)	.3	.4	1.1	.6	.02
Calcium (Ca)	10	15	10	7	2.8
Magnesium (Mg)	2	3	1	1	1.6
Sodium (Na)	7	27	1	4	5.7
Potassium (K)		1			1.2
Bicarbonate (HCO_3)	30	48	36	23	16
Sulphate (SO_4)	4	3	.5	.5	4.3
Chloride (Cl)	13	46	1	7	5.2
Nitrate (NO_3)	.1	1.6	.1	.3	4.5
Total dissolved solids	55	120	34	39	49
Total hardness as $CaCO_3$ (calculated)	33	50	29	22	14
Date of collection, 1929	Aug. 1	Aug. 1	Aug. 1	Aug. 2	Aug. 12

HARDEMAN COUNTY

[Area 697 square miles. Population 22,193]

GEOGRAPHY

With the exception of the drainage basin of Indian Creek, a small stream in the southwest corner of Hardeman County, the whole county is drained by the Hatchie River and its tributaries. This river enters the county at the southeast corner, flows in a northerly direction for 15 miles, turns northwestward, and leaves the county a few miles east of the northwest corner. The valley of the Hatchie is broad, having wide first and second bottoms. The first bottom is in part swamp, and most of it is covered in periods of high water, but it is very fertile. Three large tributaries flow into the Hatchie from the northeast—Clover, Piney, and Little Hatchie Creeks—besides the shorter streams, Mill, Grays, and Hayes Creeks and Wade Branch. The large tributaries from the southwest are Spring, Porters, and Muddy Creeks. Much smaller are Hickory, Clear, Short, and Club Creeks, the Pleasant River, and Cypress Branch.

This drainage clearly shows the distribution of the high ground, to the northeast in the region around Pinetop and to the southwest around Middleburg and in the area between Spring and Muddy

Creeks. The country around Pinetop, which probably reaches an altitude of 600 feet, is very hilly and well timbered. A few hill farms are scattered over the area. In the southwestern part of the country the tops of the ridges, which are remnants of the old plateau surface, must exceed 600 feet in altitude. Locally this region is called the dividing ridge, and from the highest points the country can be seen sloping away toward the east and west. The surface is very irregular and hilly. Much of the timber has been cut, but the area is only thinly populated.

GEOLOGY

Five formations crop out in Hardeman County—the Ripley formation, the Clayton formation, the Porters Creek clay, the Holly Springs sand, and Pliocene gravel. These formations, with the exception of the Pliocene gravel, strike slightly east of north and dip toward the west at the rate of 20 to 30 feet to the mile.

Along the south half of the east boundary of Hardeman County is an area of Ripley outcrop in which the formation attains a maximum width of 4 miles. The top part of the Ripley, called the Owl Creek tongue, is composed of calcareous and micaceous sand, clay, and marl of marine origin, with a thickness of 50 to 200 feet. Most of the Ripley exposed in Hardeman County belongs to the Owl Creek tongue. The sandy parts of the Owl Creek will yield water of poor quality, but most of the Owl Creek is clay and is not water bearing. The remainder of the Ripley formation consists of sand with some clay lenses, attains a thickness of 500 feet, and is an excellent source of water. (See well log, p. 77.)

The Clayton formation rests unconformably on the Ripley formation and is found along its western margin in scattered outcrops. The Clayton has a maximum thickness of 37 feet at the southern boundary of the county. Of this thickness the lower 7 feet is fossiliferous limestone, which is overlain by 30 feet of glauconite sand and clay. The limestone thins out rapidly toward the north, giving place to glauconite sand. Water from the Clayton formation is of poor quality, owing to its high content of iron derived from grains of glauconite, an iron-potassium silicate which makes up a considerable percentage of the sand.

The Porters Creek clay, locally called soapstone, crops out in a band 4 miles in maximum width which traverses the eastern part of the county in a direction east of north. Its maximum thickness is 250 feet. This formation yields no water. In places it may be overlain by a thin cover of Pliocene sand and gravel, and shallow wells bottoming in the Pliocene yield intermittent supplies of poor "soap water." Water can be obtained in the area where the Porters Creek is the surface formation by drilling through this formation, which is nowhere more than 250 feet thick, to the underlying Ripley sands. The water from the Ripley has a static head of 410 feet above sea level, hence in the area of Porters Creek outcrop or farther west, where the altitude is less than 410 feet, wells tapping the underlying Ripley will flow. Examples of this are the flowing wells around Hornsby.

Though the Ackerman formation of the Wilcox group does not crop out in this county, owing to overlap of the Holly Springs formation, it probably underlies the western part of the county. It is largely a lignitic clay but contains some sand beds that yield water of fair quality.

The region west of the outcrop of the Porters Creek formation comprises the outcrop area of the Holly Springs sand of the Wilcox group, which ranges in thickness from a feather edge at its eastern contact to 300 feet at the southwest margin of the county and 500 feet at the northwest margin. The Holly Springs is composed largely of sand but contains a few clay lenses. A more detailed description of this formation is given on pages 91–94. On the ridges it may be necessary to go as deep as 150 feet to penetrate below the water table, or locally fine sand or clay lenses may necessitate even deeper wells, but good water and an abundant supply can be obtained anywhere in this formation. Within a distance of 4 or 5 miles of the eastern contact of the Holly Springs sand it may not be possible to develop large water supplies because the water-bearing bed has not sufficient depth and area. In such places by drilling through the Porters Creek to the Ripley ample water can be obtained.

The Pliocene gravel has its usual character and is found on the uplands ranging in thickness from 10 to perhaps 40 feet. This formation is used as a source of water where it is sufficiently thick in the area of outcrop of the Porters Creek. It is not satisfactory, however, as it yields "soap water" of poor quality.

WATER RESOURCES

The county is well watered, and no part of it is far from streams. The flow of the streams is fairly constant, as most of the water comes from sandy formations that furnish an almost unfailing supply. There are many springs throughout the area, at the foot of the hills, and they are used almost exclusively to water stock.

LOCAL SUPPLIES

The city of Bolivar (altitude 449 feet) has a municipal water supply. At present water is obtained from three wells—one 6-inch well 71 feet deep, one 8-inch well 73 feet deep, and one 6-inch well 195 feet deep. The water is of good quality, being soft and low in iron, but the high nitrate content indicates that it is being contaminated by surface drainage. (See analysis 10b.) The log of the 195-foot well, which was drilled to 495 feet but was ended at 195 feet, is as follows:

Log of well of city of Bolivar

[Authority, Oliver Sain]

	Thickness (feet)	Depth (feet)
Soil (red clay)	20	20
Holly Springs sand:		
Sand and clay	40	60
Sand	15	75
Pipe clay	5	80
Shale	95	175
Good coarse salt-and-pepper sand	20	195
Porters Creek clay:		
Tough clay (soapstone)	300	495
Rock.		

It is probable that the rock at the bottom represented the hard layer which usually occurs at a contact and that the Clayton was immediately below.

The 71-foot well is pumped by an electrically driven plunger pump, the 73-foot well by an electric turbine centrifugal, and the 195-foot well by a vertical centrifugal. The water is pumped directly into the mains, but a 60,000-gallon elevated tank is used for a reserve to handle peak loads. The daily consumption is 120,000 gallons. The 195-foot well obtains water from the base of the Holly Springs formation, the eastern contact of which lies 3 miles to the east, so it is improbable that the present supply from this formation can be greatly augmented without excessive lowering of head. New wells should be drilled through the Porters Creek, 300 feet thick, to the Ripley. Allowing 195 feet of Holly Springs, 300 feet of Porters Creek, and 100 feet of Ripley would make the total depth of these wells 550 to 650 feet. Water would stand at 40 feet below the surface of the ground.

About 2½ miles northwest of Bolivar is the Western State Hospital, which has an average daily water consumption of 250,000 gallons, supplied by two wells called No. 3 and No. 5. Well 3 is 116 feet deep and 10 inches in diameter. Well 5 (see analysis 9b) is 100 feet deep and 24 inches in diameter, has 13 feet of 12-inch strainer, and is finished with a gravel wall. Each well is pumped by an electrically driven turbine centrifugal pump yielding 200 gallons a minute. The drawdown in well 3 when pumped at 200 gallons a minute is 23 feet. In addition to these two wells are wells 1 and 2, of approximately the same depth, which are not operated. Well 4, which is 654 feet deep, penetrates the Ripley formation. Owing to the fairly high iron content the water is not used. A log of the well is as follows:

Log of well 4, Western State Hospital, near Bolivar

[Authority, F. G. Wells, from saved samples]

	Thickness (feet)	Depth (feet)
Clay loam	10	10
Residuum:		
Medium-grained quartz sand, water bearing	10	20
Slightly finer red quartz sand, water bearing	10	30
Holly Springs sand:		
Medium-grained white quartz sand, water bearing	10	40
Coarse white sand, water bearing	25	65
Very coarse sand, as much as 3 millimeters in diameter, water bearing	25	90
Medium grained white sand, water bearing	10	100
Coarse white sand with pebbles as much as 3 centimeters long by 1½ centimeters in diameter (possibly coarser in well), water bearing	8	108
Very fine white sand grading into clay, containing some muscovite, water bearing	12	120
Slightly finer sand, water bearing	30	150
Brown micaceous sandy clay	22	172
Dove-gray clay	35	207
Fine-grained yellowish sand, water bearing	25	232
Fine-grained white sand, water bearing	24	256
Dirty-gray medium-grained sand, water bearing	60	316
Porters Creek clay:		
Dark-gray clay	229	545
Clayton formation:		
Medium-grained salt and pepper sand, water bearing	5	550
Gray speckled argillaceous sand, water bearing	65	615
Ripley formation (Owl Creek tongue):		
Salt and pepper medium-grained argillaceous sand streaked with brown, water bearing	39	654

Cedar Chapel is situated in a hilly area in the northwest corner of the county. The depth to water is more than 100 feet, and cisterns are used exclusively.

Grand Junction (altitude 580 feet) is supplied by a privately owned water system. Water is obtained from three wells 163 feet deep, two of which are 4½ inches in diameter and one 6 inches. All three wells are pumped by electrically driven reciprocating pumps, which deliver the water into a 10,000-gallon elevated tank, from which it is distributed by gravity. The daily consumption of water is 20,000 gallons. The water is derived from the Holly Springs formation and is of excellent quality. (See analysis 23.) The water table is 130 feet below the surface.

Hickory Valley (altitude 566 feet) is in the high hilly country of Holly Springs outcrop, where the water table stands at considerable depth. Drilled wells 90 to 150 feet in depth are used. (See analysis 18.)

Hornsby, being in the area of Porters Creek clay near its eastern edge, obtains water from the underlying Ripley formation. As the land is lower than the pressure head, the wells flow. The thickness of the Porters Creek formation at Hornsby is from 125 to 145 feet. The clay stands up in the wells, which are therefore not cased. All wells are 2 inches in diameter. Their flow ranges from 1 to 18 gallons a minute. The water has a very high iron content, one analysis (No. 15a) giving 55.66 parts per million, which quickly precipitates out on exposure to the air. The water can not be used in cooking, and it stains all containers. Precipitation of iron also takes place in the well, with the result that the flow is gradually diminished and ultimately stopped. The water is moderately hard, containing on analysis 140 parts per million of $CaCO_3$. Similar flowing wells are found in the lowland west and southwest of Hornsby. They are progressively deeper toward the west, and in the drilled wells larger flows have been obtained. The largest flow recorded to date is 24 gallons a minute.

Middleburg (altitude 529 feet) obtains water from the Pliocene gravel and Holly Springs formation. Wells drawing water from the Pliocene gravel attain a depth of 40 feet. The supply is not permanent, being derived from a perched water table. Wells in the Holly Springs are about 100 feet deep and end in sand after passing through a clay lens. These wells are not satisfactory, owing to the method of finishing them. A pipe is driven down to the sand, but no strainer is used. Proper finishing of wells would solve the difficulty, as the water is of good quality.

At Middleton (altitude 411 feet) some water is obtained from the thin covering of residuum, which nowhere exceeds 25 feet in depth. This is surface "soap water," is not permanent, tastes strong, and is entirely unsatisfactory. In order to penetrate the underlying Ripley sands it is necessary to drill through the Porters Creek clay, which has a thickness of 250 feet. The water from the Ripley is of fair quality, but the iron content gives some trouble, staining all containers yellow. (See analysis 22.)

Pinetop is in the hilly forested area in the northeastern part of Hardeman County. Sufficient water for domestic use can be obtained from shallow wells in the thin cover of Holly Springs sand that overlies the Porters Creek clay. For larger supplies it is necessary to drill through the Porters Creek; water can be reached at a depth of 275 feet.

Pocahontas (altitude 400 feet) is in the valley of the Hatchie River. Abundant water is obtained from dug wells 20 to 35 feet deep. They pass through a thin layer of red sand and some clay into coarse white sand.

Rogers Springs is at the foot of some hills, and springs are plentiful. Wells obtain water at depths of 15 to 30 feet.

At Saulsbury (altitude 543 feet), in a hilly region of Holly Springs sand, the water table is 60 feet of more below the surface. Bored and drilled wells obtain water of good quality. (See analysis 24a.)

The Illinois Central Railroad well at Shandy, on the Hatchie River bottom, is 134 feet deep and 10 inches in diameter. It is pumped by a steam head and yields 200 gallons a minute.

At Silerton most of the wells are in the residuum and are shallow and not very satisfactory. A few wells have been drilled through the Porters Creek clay into the Ripley formation, and these furnish permanent supplies of water.

Teague, in the valley of Clover Creek, obtains water from shallow wells 30 feet deep. Springs occurring along the foot of the hills are used for stock and in a few places for domestic supply.

At Toone (altitude 392 feet) the wells in the lowland are about 40 feet deep, but those in the hilly areas attain depths of 65 feet. Bored wells are largely used. The water, which comes from the Holly Springs formation, is of good quality.

At Vildo, in the valley of the Hatchie River, bored wells 40 feet deep are in use. (See analysis 2.)

Whiteville (altitude 500 feet) has a municipal supply owned by the city. Water is obtained from two wells, each 180 feet deep. Well 1, 6 inches in diameter, is equipped with a reciprocating pump having a capacity of 80 gallons a minute. Well 2 is 4½ inches in diameter and is equipped with a reciprocating pump capable of delivering 30 gallons a minute. Water from the wells is pumped into an elevated tank, from which it is distributed by gravity. The average daily consumption is 25,000 gallons. The water is derived from the Holly Springs formation and is of excellent quality. (See analysis 4a.)

Records of wells in Hardeman County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Capacity of pump (gallons per minute)	Use of water
1a	Teague	Illinois Central R. R. (section house).	Hillside	378	Bored	25	6	Sand	Holly Springs	25	18	Aug. 22	Bucket		Domestic.
1b	Teague, 0.1 mile east of railroad and road crossing.	T. J. Keller	Foot of hill	370	Spring			do	do		(a)				Do.
2	Vildo	Miss Olive Camp	Hillside		Bored	40	8	do	do				Bucket		Do.
3	2.0 miles north of Whiteville.	F. W. Hasse			Drilled	644	3	do	Ripley	644					Do.
4a	Whiteville	City of Whiteville.		500	do	180	6	do	Holly Springs	180			Electric plunger	[b] 30	Public supply.
4b	do	do		500	do	180	4½	do	do	180			do	[b] 80	Do.
4c	Whiteville, 1,000 feet northeast of railroad along track.	R. Norment		500	Bored	147	4	do	do	147	47	Rept.	Steam plunger	18	Industrial.
5a	Toone	Toone Baptist Church.		395	do	30	6	do	do	30			Bucket		Domestic.
5b	do	M. R. Kelly		450	do	65	6	do	do	65	53	Aug. 22	do		Do.
5c	1,200 feet west of depot at Toone.	F. P. Yarborough.		450	do	80	6	do	do	80	50	Rept.	Plunger gas motor.	7	Do.
6	Silerton	J. D. Siler		380	Drilled	209	2½	do	Ripley	209	5	do	Lift pump		Do.
7	Pineton	R. G. Kennedy		560	do	275	3	do	do	35	30	do	Steam lift pump		Industrial.
8	Shandy	Illinois Central R. R.		350	do	134	10	do	Holly Springs	134			do	[c] 140	Railroad.
9a	2.3 miles northwest of Bolivar, well 1.	Western State Hospital.	Hilltop	470	do	116	10	do	do	116	90	Rept.	Electric plunger	200	Domestic.
9b	2.3 miles northwest of Bolivar, well 5.	do	do	470	do	100	24	do	do	100	16	do	do	200	Do.
9c	2.3 miles northwest of Bolivar, well 4.	do	do	470	do	654	8	do	Ripley						Do.
10a	75 feet east of railroad, 10 feet north of Union Street, Bolivar.	City of Bolivar	Upland	443	do	73	8	do	Holly Springs	73	65	Rept.	Turbine centrifugal.	125	Public supply.
10b	50 feet east of railroad, 50 feet north of Union Street, Bolivar.	do	do	443	do	71	6	do	do	71	65	do	Electric plunger	45	Do.

[a] Flowing 14,400 gallons a day.
[b] Reported pumpage, 12,500 gallons a day.
[c] Reported pumpage, 50,000 gallons a day.

Records of wells in Hardeman County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Capacity of pump (gallons per minute)	Use of water
10c	50 feet east of railroad, 50 feet north of Union Street, Bolivar.	City of Bolivar	Upland	443	Drilled	195	8	Sand	Holly Springs	195			Turbine centrifugal.	320	Public supply.
11a	2.9 miles east of Bolivar	Hugh Carter		385	do	230	2	do	Ripley		(d)	June 13			Stock.
11b	do	D. R. Breeden		385	do	230	2	do	do	25	(d)	do			Domestic.
12	4 miles west of Hornsby	E. & R. Mitchell		400	do			do	do		(e)				
13	2 miles west of Hornsby	Mrs. H. Brint	River bottom	380	do	130	2	do	do		(f)	June 14			Do.
14	Hooper	Hooper	do		do	120	2	do	do		12	Rept.	Lift pump		Do.
15a	Hornsby, west edge of town.	H. E. Millstead	do		do	142	2	do	do	34	(g)	June 20			Do.
15b	Hornsby, at bank	J. P. Mitchell	do		do	140	2	do	do	60	(f)	June 14			Do.
16	5 miles south of Bolivar	Spring Creek Development Co.	Second bottom.	400	do	3,210				3,210	(e)				
17	3 miles southeast of Bolivar on Grand Junction road, 0.5 mile east of road.	Clifft Bros.	Upland	500	do	585	2	Sand	Ripley	400	40	Rept.	Lift pump, gas motor.		Do.
18	Hickory Valley	R. H. Scott	do	545	do	150	3	do	Holly Springs	150	30	do			Do.
19	0.8 mile northeast of Locust Grove Church.	W. Harris	do	515	do	345	6	do	Ripley	40	60	do	Lift pump		Do.
20	0.8 mile south of Vaughn's store.	Henry McKinney	Valley bottom	430	do	140	2½	do	do		(h)	June 16			Do.
21	Locust Grove Church	L. T. Watson	Upland	515	do	326	2	do	do				Lift pump		Do.
22	1 mile south of New Church.	W. T. Rogers	do	520	do	412	6	do	do	50	160	Rept.	do		Do.
23	Grand Junction	A. B. Martin		580	do	163	6	do	Holly Springs	163	130	do	Lift pump, electric.[i]		Public supply.
24a	Saulsbury	C. W. Press	Hillside	580	do	130	2	do	do	130			Lift pump, wind.		Domestic.
24b	do	H. E. Dowdy	Hilltop	565	Bored	77	8	do	do	77	60	Aug. 20	Bucket		Do.
25	Rogers Springs	J. H. Shelly	Bottoms		Drilled	317	2	do	Ripley		75	Rept.	Lift pump		Do.
26a	Middleton	Judson Lambett		445	do	233	3	do	do	120			do		Do.
26b	do	E. Rogers			do	166	3	do	do	33	55	Rept.	do		Do.
26c	do	J. W. Whaley			do	220	3	do	do	60	30	do	do		Do.
27	Pocahontas	J. W. Wardlow	Valley	400	do	160	4	do	do	40	20	do	do		Do.

[d] Flowing 31,680 gallons a day.
[e] Flowing 7,200 gallons a day.
[f] 14,400 gallons a day.
[g] Flowing 2,880 gallons a day.
[h] Flowing 21,600 gallons a day.
[i] Pumpage, 20,000 gallons a day.

Analyses of waters from Hardeman County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analysis 24a by D. F. Farrar; the rest by Margaret D. Foster]

	2	4a	5c	9b	10b	11a
Silica (SiO_2)	16	18	14	15	19	27
Iron (Fe)	.26	.38	.08	.02	.07	.35
Calcium (Ca)	7.3	4.8	1.6	13	15	40
Magnesium (Mg)	4.9	1.7	.7	4.2	6.6	12
Sodium (Na)	15	10	2.7	7.0	19	6.6
Potassium (K)	1.8	1.0	.5	1.8	2.3	4.9
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	8.0	16	10	12	11	137
Sulphate (SO_4)	3.7	2.6	2.1	24	17	54
Chloride (Cl)	24	10	1.3	16	30	2.7
Nitrate (NO_3)	36	14	.31	10	48	.0
Total dissolved solids	131	80	26	104	176	217
Total hardness as $CaCO_3$ (calculated)	38	19	6.9	50	65	149
Date of collection, 1928	July 5	July 4	Aug. 22	Aug. 21	June 23	June 22

	15a	15b	17	22	23	24a
Silica (SiO_2)	42	40	23	26	13	3
Iron (Fe)	56	36	.30	.01	.07	.1
Calcium (Ca)	40	25	29	33	2.8	4
Magnesium (Mg)	9.7	6.7	9.7	13	1.2	1
Sodium (Na)	3.0	2.8	11	7.5	2.0	2
Potassium (K)	3.7	2.8	4.8	4.0	.9	
Carbonate (CO_3)	0	0	0	0	0	0
Bicarbonate (HCO_3)	89	64	164	185	10	15
Sulphate (SO_4)	65	42	3.3	6.0	2.3	2
Chloride (Cl)	3.2	2.6	.8	1.6	2.0	2.5
Nitrate (NO_3)	.0	.0	.77	.37	3.2	.2
Total dissolved solids	216	157	157	176	32	24
Total hardness as $CaCO_3$ (calculated)	140	90	112	136	12	14
Date of collection, 1928	June 22	June 22	Aug. 20	June 22	June 21	Aug. 20

HARDIN COUNTY

[Area 582 square miles. Population 16,213]

GEOGRAPHY

Hardin County is in the southeast corner of the area described. The Tennessee River in its northward reflex cuts the county into two unequal and dissimilar parts. The area east of the river, being part of the Highland Rim, partakes of its nature and consists of narrow flat-topped ridges, remnants of the old peneplain. These ridges are separated by narrow V-shaped valleys about 200 feet deep, which are occupied by swift perennial streams with high gradients. Horse and Indian Creeks with their tributaries drain the area. They flow northeastward into the Tennessee River. The valleys of these streams widen near their mouths, and their small flood plains form part of the valley of the Tennessee.

The Tennessee River forms a flood plain which reaches a maximum of 4 miles in width in the central part of the county but wedges out in the northern part. This flood plain is a flat surface about 20 feet above the average river level, but in time of flood it is completely inundated. The streams draining the area west of the river broaden their valleys near their mouths. The land on this side rises rapidly to a level 200 to 300 feet above the river.

Southeastern Hardin County is very sparsely settled, but the western part supports a larger population. Here are Savannah and Saltillo, population 1,129 and 365, respectively, the only towns in the county containing more than 150 persons. The county as a whole has a density of population of 28 persons to the square mile.

There is no railroad in Hardin County. Formerly the Tennessee River was the means of transportation, but river traffic has practically ceased, being superseded by automobile trucking. Farming is the main activity. The hardwood has almost all been cut, but considerable lumbering of pine for poles is carried on.

GEOLOGY

Paleozoic rocks form the surface of northeastern Hardin County and occur along the valleys in the southeastern part of the county. Except for a small area of Ordovician limestone along the Tennessee River in the northern part of the county, the oldest rocks that crop out are Silurian limestone and shale which are widely exposed in the northeast and along the valleys of Indian and Horse Creeks. The average thickness of the Silurian rocks is 150 feet. They are unimportant as sources of water. Rocks of Lower and Middle Devonian age crop out only in the vicinity of Olive Hill, Walnut Grove, and Saltillo. They consist of limestone, shale, and chert, but only the chert is a good water-bearing formation. The maximum thickness of Devonian rocks is a section of 200 feet, exposed at Olive Hill. At Grand View the section is only 100 feet thick, and this is probably an average section. The Chattanooga shale crops out in the valleys of Hardin, Indian, and Horse Creeks. It is a fissile carbonaceous shale and does not yield water. Silurian and Devonian rocks underlie the whole of Hardin County. Where buried these rocks yield waters high in dissolved solids and in places quite unpotable.

The Fort Payne chert of Mississippian age is a dark-gray calcareous chert which on weathering changes to a soft yellow porous chert. It is found on the hillsides in the northeastern part of the county and forms the valley slopes of Horse Creek and its tributaries to the southeast. The thickness of the entire formation ranges from 100 to 200 feet. It is an excellent source of water in its outcrop area.

The St. Louis limestone, a cherty limestone which on weathering forms rubble slopes of chert, overlies the Fort Payne chert and crops out in the same localities. Its thickness ranges from 50 to 200 feet. It is difficult to differentiate the St. Louis limestone from the Fort Payne chert in weathered outcrops, and no attempt has been made to do so in this report.

The Tuscaloosa formation crops out as isolated remnants in southeastern Hardin County, much of it having been removed by erosion. It consists of 10 to 100 feet of gravel and sand.

The tops of all the ridges and hills of Hardin County consist of the Eutaw formation, which ranges in thickness from a thin veneer covering the Paleozoic rocks in the northeast to a maximum of 250 feet at the western boundary. This formation consists of sand and clay and is a good source of water.

The Selma clay crops out along the northwestern boundary of the county. It is a calcareous clay containing many large fossils, which are conspicuous in the weathered outcrop. The Selma ranges in thickness from a feather edge to 150 feet. It does not yield water, and in its outcrop area water can be obtained only by drilling through the Selma to the underlying Eutaw formation.

Pliocene or Pleistocene terrace gravel overlies much of the Eutaw and Selma formations, especially on the high land bordering the Tennessee River. Wade [91] has described four terraces—one around the 600-foot contour, one at 500 feet, one at 420 feet, and the fourth about 10 to 25 feet above present high water on the second bottom. The terraces range in thickness from 20 to 30 feet and consist of gravel intermixed with sand.

WATER RESOURCES

All of Hardin County is well watered by perennial streams. Springs are very abundant, issuing from the Pliocene gravel, the Eutaw formation, or the Fort Payne chert. The Fort Payne gives rise to many large springs, as, for example, in the valley of Hollands Branch. In the areas where the Fort Payne crops out springs are exclusively used for domestic supplies. A few springs issue from the limestone, but they are small. On the uplands throughout the area water is obtained from wells, which derive water from the Eutaw formation or the Pliocene gravel. Ample supplies of water are obtained from dug wells, which are used almost exclusively. The average depth of wells is 40 feet. In one or two places drilled wells have been put down, but there is no well more than 128 feet in depth in the county. In the area southeast and east of Hardin County the Fort Payne formation probably underlies the Eutaw formation at altitudes above 500 feet. Wells drilled in this formation would obtain large supplies of water. There are very few wells in the Paleozoic limestone and shale. In these formations it is unadvisable to drill to depths exceeding 300 feet, because the chances of encountering a fissure grow less with depth and because the deeper formations yield water that is so high in hydrogen sulphide and dissolved salts that it is unfit for domestic or industrial use. This is borne out by the water from the "sulphur spring" southwest of Saltillo. No log of this flowing well is available, but it is known to have a depth of 100 feet and starts in the Eutaw, probably passes through the Devonian (Devonian

[91] Wade, Bruce, The gravels of West Tennessee Valley: Tenn. Geol. Survey, Res. Tenn. vol. 7, pp. 55-89, 1917.

rocks crop out at Saltillo), and may end in Silurian or Ordovician rocks. The water is very high in dissolved sulphur and forms a precipitate along the banks of the stream flowing from the well. The water from a deep well at Collinwood,[92] Wayne County, at a depth of 270 feet, is low in dissolved solids, whereas the water from 1,512 feet is high in sulphur. Water from a well at Iron City,[93] Wayne County, at 300 feet had 3,857 parts per million of total dissolved solids. Further evidence is given by the numerous sulphur and chalybeate springs found in the area. The water feeding these springs probably rises along fissures or faults that penetrate to deeper formations, as is indicated by the proximity of springs yielding sulphur water, iron water, and water containing neither iron nor sulphur.

LOCAL SUPPLIES

At Lowryville a spring in Silurian limestone furnishes the few houses with water. To the south of Lowryville springs issuing from the Fort Payne chert furnish large quantities of good water.

In the vicinity of Morris Chapel wells range in depth from 25 to 75 feet, the depth depending on whether they are located on hilltops or in valleys. Water is derived from either Eutaw sand or Pliocene gravel.

The Fort Payne chert crops out on the hillsides around Olive Hill, and most of the wells obtain water from it. East of Olive Hill, in the valley of Indian Creek, shallow wells 10 to 25 feet deep obtain water from the alluvium.

At Pittsburg Landing, in Shiloh National Park, wells pass through about 30 feet of Pliocene into Eutaw sand. Sufficient water for domestic use is found at depths of 40 to 70 feet. South and west of Pittsburg Landing dug wells obtain water from the Eutaw formation or Pliocene gravel at depths of 40 to 50 feet.

Springs are common in the vicinity of Pyburns, issuing from the Fort Payne chert or Tuscaloosa gravel. Shallow wells dug in the weathered chert or gravel are also used.

At Saltillo dug wells are used. These obtain water in Eutaw sand, at depths of 25 to 35 feet. In case larger supplies of water were needed deeper drilling would encounter the Harriman and Decaturville cherts, which have a combined thickness in this vicinity of 40 feet.

At Savannah there is 20 to 40 feet of Pliocene gravel underlain by 25 to 45 feet of Eutaw sand. This rests on limestones of middle and lower Silurian age which have a thickness of 63 feet. Most of the wells at Savannah obtain water from the Pliocene gravel or Eutaw formation at depths of 35 to 65 feet. Dug wells yield as much as 2,000 or 3,000 gallons a day. E. P. Churchill has a drilled well 128 feet deep which obtains water from Ordovician limestone. (See analysis 35a.)

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[92] Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee Geol. Survey Bull. 26, p. 154, 1921.

[93] Idem, p. 156.

Records of wells in Hardin County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
1	On Swallow Bluffs road	S. E. Smith	Hilltop	510	Dug	30	36	Gravel	Pliocene		24	Sept. 17	Bucket	Domestic.
2	6 miles north of Cerro Gordo.	E. L. Russell	do	450	do	25	36	do	do		22	do	do	Do.
3	Saltillo	White & Son	Valley	370	do	30	36	Sand	Eutaw	30	23	Sept. 20	do	Do.
4	5.2 miles west of Saltillo	County School	Hilltop	510	Bored	56	7	do	do	56			do	Do.
5	7.2 miles west of Saltillo	J. C. Bridges	Hillside	410	do	24	6	Gravel	Pliocene	24			do	Do.
6	2 miles west of highway 69, southeast of Saltillo.	J. T. Spencer	Hilltop	410	do	52	6	Sand	Eutaw	52	45	Sept. 20	do	
7	2.7 miles southwest of Saltillo.	Jame- Craven	Second bottom.		Drilled						([a])	do		Do.
8	4.5 miles north of Cerro Gordo on Saltillo road.	J. M. Browns	Ridgetop		Bored	59	6	Shale	Ordovician		20	Sept. 17	Bucket	Do.
9	2 miles northeast of Swift.	G. F. Cary	Foot of hill	470	Spring			Limestone	Silurian		([b])			Do.
10	Swift	E. Bryant	Hilltop	500	Dug	40	36	Gravel	Pliocene	40	35	Sept. 17	Bucket	Do.
11	2.2 miles north of Cerro Gordo.	R. White	Ridgetop	530	do	35	36	Sand	Eutaw	35	32		do	Do.
12	3.7 miles south of Saltillo on highway 69.	A. B. Copeland	Upland	400	do	52	36	do	do	52	48	Sept. 20	do	Do.
13	On highway 69, 6.1 miles north of its junction with highway 17.	Mrs. H. Allen	Valley	370	do	23	36	do	do		20		do	Do.
14	On highway 69, 4.4 miles south of junction with highway 17.	J. F. Lane	Upland	450	Bored	40	8	Gravel	Pliocene	40	37	Sept. 20	do	Do.
15	On highway 69, 2.6 miles north of junction with highway 17.	D. H. Gary	Hilltop	480	Dug	40	36	Sand	Eutaw	40	35	do	do	Do.
16	1.5 miles east and 1.7 miles north from Morris Chapel.	C. A. Jones	do	450	do	23	36	do	do	23	21	Sept. 18	do	Do.

[a] Flowing 8,640 gallons a day.

[b] Flowing 770 gallons a day.

Records of wells in Hardin County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed		Depth to which well is cased (feet)	Water level		Method of lift	Use of water
								Character of material	Geologic horizon		Below surface (feet)	Date of measurement (1928)		
17	1.3 miles east of Morris Chapel.	D. M. Haynes	Hilltop	430	Bored	35	10	Sand	Eutaw	35	29	Sept. 19	Bucket	Domestic.
18	Morris Chapel	School	do	510	Dug	72	36	do	do	72	67	do	do	Do.
19	0.9 mile east of Morris Chapel on highway 17.	J. M. White	Valley bottom.	430	do	20	36		Alluvium	20	10	do	do	Do.
20	2.5 miles southeast of Morris Chapel on highway 17.	J. H. Taylor	Hilltop	610	do	28	36	Sand	Eutaw	28	25	do	do	Do.
21	3.3 miles east of Morris Chapel on highway 17.	J. V. Hughes	do	550	Driven	60	6	do	do	60	47	do	do	Do.
22a	0.4 mile north and 0.1 mile west from Cerro Gordo.	John H. Pitts	do	520	Dug	42	36	do	do	10	36		do	Do.
22b	Cerro Gordo	do	Hillside	430	do	40	36	Limestone	Silurian		37		do	Do.
23	On Steel Branch, 3 miles west of Bethlehem Chapel.	James Gerratt	Cliffside		Spring			do	do		(c)			
24	0.6 mile west of Bethlehem Chapel.	F. Baugers	Hilltop	520	Dug	65	36	Chert	Mississippian (Fort Payne).		59		Bucket	Do.
25	1.2 miles north of highway 15 on road to Bethlehem Chapel.	Mrs. J. A. Harber	do	570	do	37	36	do	do		25		do	Do.
26	On highway 15 at east county line.	J. F. White	Valley bottom.		do	14	36	Sand	Alluvium		5		do	Do.
27	1 mile south of highway 15 on Steel Branch.	Amos Lowd	Hillside		do	45	36	Sandstone	Devonian (Harriman).		38		do	Do.
28	Olive Hill	W. G. Baird	Hilltop	570	do	30	36	Chert	Mississippian (Fort Payne).		26		do	Do.
29	4.2 miles west of Olive Hill on highway 15.	J. T. Jarrolds	Valley bottom.		Spring			do	do		(d)			
30	5 miles west of Olive Hill on highway 15.	do	Foot of hill		do			do	do					
31	5.6 miles east of Savannah on highway 15.	G. A. Freeman	Hillside	440	Dug	15	36	Gravel	Pliocene	15	11		Bucket	Do.

32	4.1 miles northeast of Savannah on Cerro Gordo road.	W. A. Kinchen	Hilltop	470	do	28	36	Sand	Eutaw		24		do	Do.
33	4 miles east of Savannah on highway 15.	G. S. McKnight	do	440	do	20	36	do	do	20	11		do	Do.
34	2 miles north of Savannah on Cerro Gordo road.	J. R. Kerr	Upland	440	do	30	36	do	do		27		do	Do.
35a	Savannah	E. P. Churchill & Sons.	Hilltop	440	Drilled	128	3	Limestone	Oodovician (Hermitage).	65	65	Rept	Lift pump, electric.	Do.
35b	do	F. H. Fariss	do	440	Dug	42	36	Sand	Eutaw	42	[e]34	Sept. 15	do	Do.
35c	do	Savannah Ice Co.	Hillside	440	do	60	36	do	do	60	[f]51	Rept	Lift pump, oil engine.	Industrial.
36	Crump	County School	Upland	470	do	65	36	do	do	65	41		Bucket	Domestic.
37	1.2 miles north of Crump.	T. C. Philips	do	460	do	22	36	do	do	22	20		do	Do.
38	3.2 miles northwest of Crump.	N. B. Littfield	Hilltop	510	do	36	36	Gravel	Pliocene	36	32		do	Do.
39	3 miles south of Crump	E. C. Delaney	do	510	do	50	36	Sand	Eutaw	50			Lift pump	Do.
40	1 mile south of Crump on highway 17.	Fletcher Gattis	do	500	do	30	36	Gravel	Pliodene	30	26		Bucket	Do.
41	1.4 miles south of Savannah on Pittsburg Landing road.	Horace Briley	Upland	460	do	50	36	do	do		37	Sept. 13	do	Do.
42a	4 miles south of Savannah on Lowryville road.	G. M. Conners	Hilltop	500	Drilled	100	6	Limestone	Silurian				Dry hole	
42b	3.5 miles southeast of Savannah on Hamburg road.	Perry Kurr	Foot of hill	440	Spring			Sand	Eutaw					Do.
42c	do	Mrs. Jackson Prince.	Hilltop	465	Dug	40	36	do	do	20	37	Sept. 15	Bucket	Do.
43	2.8 miles southeast of Savannah on Pinhook road.	M. A. Jowers	Hillside	450	do	22	36	Gravel	Pliocene				do	Do.
	4.2 miles southeast of Savannah on Pinhook road.	Wm. S. Bivins	do	500	do	49	36	Sand	Eutaw		44	Sept. 15	do	Do.
45	7.2 miles southeast of Savannah on Pinhook road.	Wm. Jerrolds	Valley	500	do	21	36	do	do		18	do	do	Do.
46	9 miles east of Savannah.	W. C. Kelley	Foot of hill		Spring			Chert	Mississippian (Fort Payne).		([g])	do		Domestic and stock.
47	8.5 miles southeast of Savannah.	H. Smith	do		do			Limestone			([h])	do		Domestic.

[c] Flowing 25,920 gallons a day.
[d] Flowing 21,600 gallons a day.
[e] Reported pumpage 1,000 gallons a day.
[f] Reported pumpage 2,160 gallons a day.
[g] Flowing 432,000 gallons a day.
[h] Flowing 770 gallons a day.

Records of wells in Hardin County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
48	5.5 miles south of highway 15 at Union Chapel, on road to Gilleses Mills.	Frank Wilkson	Valley	620	Spring			Chert	Mississippian (Fort Payne).		(i)	Sept. 25		Domestic.
49	3.2 miles south of Savannah on Florence road.	Lee Davis		475	Dug	20	36	Sand	Eutaw		6	Sept. 13	Bucket	Do.
50	6 miles south of Savannah on Hamburg Landing road.	Offe Austin	Hilltop	480	do	65	36	do	do	65	59	do	do	Do.
51	6.8 miles south of Savannah on Florence road.	G. W. Roberts	do	490	do	35	36	do	do	30	23	Sept. 25	do	Do.
52	1.3 miles south of Gilleses Mills.	G. B. Harrison	Creek bottom.		Spring			Gravel			(i)	do		Do.
53	Gilleses Mills	T. N. Stricklan	Foot of hill		do			Limestone	Devonian (Ross)					Domestic and stock.
54	1 mile east of Gilleses Mills on Horse Creek.	E. Franks	Ravine		do			do	do					Domestic.
55a	2.8 miles east of Gilleses Mill on Horse Creek.	T. N. Stricklan	Valley	680	do			Chert	Mississippian (Fort Payne).		(i)	Sept. 25		Domestic and stock.
55b	do	H. A. Butter	Hillside	700	Dug	33	36	do	do		28	do		Domestic.
56	2.5 miles south of Gilleses Mills.	Dickson Brown	Foot of hill	600	Spring			do	do		(a)	do		Do.
57	3.6 miles east of Lowryville on Fort Creek.	Oscar Shelby	Gully	650	do			do	do		(a)	do		Do.
58	Cherry School	Cherry School	Foot of hill	600	do			do	do		(k)	do		Do.
59	Lowryville	Mrs. Molly Franks.	Valley	580	do			Limestone	Ross		(a)	do		Do.
60	11 miles south of Savannah on Florence road.	H. L. Porter	Ravine	510	do			Chert	Mississippian (Fort Payne).		(l)	Sept. 14		Do.
61	Pyburn	J. G. Crotts	Hilltop	530	Dug	60	36	Gravel	Pliocene		57	Sept. 13	Bucket	Do.
62	2.1 miles north of Pyburn on Savannah road.	Oscar Qualls	do	540	do	55	36	do	do		57	do	do	Do.
63	Hamburg	C. M. Durbin	River bottom.	400	do	25	36	Sand	Alluvium	30	23	Sept. 25	do	Do.
64	Counce	T. J. Atkins	Hilltop	610	do	63	36	do	Eutaw	30	57	Sept. 26		Do.
65	3 miles south of Pickwick.	E. A. Cresop	Upland		do	37	36	do	do	8	32	do	Bucket	Do.

66	Red Sulphur Spring	Indiana Tie Co.	Gully		Spring			Shale	Mississippian (Ridgetop).		(m)	do		Do.
67	1 mile west of White Sulphur Spring.	J. D. Byrd	Hilltop	510	Dug	22	48	Sand	Eutaw		17	Sept. 27		Do.
68	White Sulphur Spring	First National Bank, Jackson	Foot of hill	430	Spring			Gravel	Pliocene		(n)	Sept. 25		
69	0.8 mile north of Duncans Landing.	O. A. Paulk	Valley bottom.	495	Dug	30	48	do		30	22	Sept. 13	Bucket	Do.
70	4.5 miles east of Walnut Grove.	E. H. Milligan	Hilltop		do	22	48	Sand	Eutaw		16			Do.
71		J. M. Austin	Foot of hill	600	Spring			Chert	Mississippian (Fort Payne).		(o)	Sept. 14		Domestic and stock.

[a] Flowing 8,640 gallons a day.
[i] Flowing 5,760 gallons a day.
[j] Flowing 28,800 gallons a day.
[k] Flowing 57,600 gallons a day.
[l] Flowing 1,440 gallons a day.
[m] Flowing 360 gallons a day.
[n] Flowing 8,640 gallons a day. Water contains considerable hydrogen sulphide.
[o] Flowing 64,800 gallons a day.

Analyses of waters from Hardin County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table Analyzed by Margaret D. Foster]

	3	28	35a	35b	36	59	71
Silica (SiO_2)	13	12	11	8.3	9.1	13	8.1
Iron (Fe)	.13	.36	.07	.29	.11	.06	.01
Calcium (Ca)	6.6	5.8	10	24	.4	29	1.0
Magnesium (Mg)	4.4	4.0	4.7	10	.3	3.4	.6
Sodium (Na)	66	6.7	10	56	13	1.5	1.0
Potassium (K)	2.3	1.5	1.7	4.4	1.5	.6	.7
Carbonate (CO_3)	0	0	0	0	0	0	0
Bicarbonate (HCO_3)	4.0	8.0	10	28	10	98	6.0
Sulphate (SO_4)	2.2	20	1.7	21	7.4	3.3	1.6
Chloride (Cl)	88	6.0	22	104	8.0	1.8	1.5
Nitrate (NO_3)	60	8.0	27	33	6.3	.89	.05
Total dissolved solids	263	74	98	290	53	100	17
Total hardness as $CaCO_3$ (calculated)	35	27	40	101	2.2	86	5.0
Date of collection, 1928	Sept. 20	Sept. 18	Sept. 24	Sept. 28	Sept. 24	Sept. 25	Sept. 14

HAYWOOD COUNTY

GEOGRAPHY

[Area 508 square miles. Population 26,063]

Haywood County, which is in the west-central part of the area on its northern boundary, is roughly quadrilateral though irregular in outline, and comprises an area of 508 square miles. Along the southeastern boundary there is a region of hills, but the rest of the county is gently rolling and slopes either northward toward the Hatchie River or southward toward the South Fork of the Forked Deer River. The Hatchie flows in a westerly direction to the Mississippi. Its valley is broad, in places more than 3 miles in width, and the lower bottom is swampy and wooded. The South Fork of the Forked Deer River, which forms most of the northern boundary of Haywood County, flows to the northwest. Its valley is not as broad as that of the Hatchie but is otherwise similar.

GEOLOGY

Except for a triangular patch comprising some 44 square miles of Holly Springs sand in the southeast corner, the county is underlain by the Grenada formation. The Holly Springs and Grenada, which with the Ackerman formation constitute the Wilcox group, are lithologically alike and as they have similar water-yielding properties they can be treated as one. They are sandy formations with intercalated lenses of clay, some of which attain a thickness of 100 or 200 feet. At the eastern boundary of the county these formations have a combined thickness of about 400 feet, and at the western boundary they attain their maximum thickness of 700 to 750 feet. In the northwest corner of the county these formations are overlain by a thin cover of loess, which thickens toward the west. The Jackson formation is found in the northwestern part of the county. It contains beds of lignite and lignitic clay. The thickness of the Jackson is unknown but probably does not exceed 30 feet. The usual mantle of residuum is found the high areas.

WATER RESOURCES

Surface water is not abundant in Haywood County, and springs are very rare. Stock is usually watered from stock ponds. Dug wells were formerly most commonly used, and some of them attained a depth of 100 feet, but these are being superseded by bored wells, and there are a few drilled wells. The Holly Springs and Grenada are excellent sources of water. Locally clay lenses may give trouble, but water of good quality can be found everywhere. Differences in the depth of drilled and bored wells are largely due to the fact that bored wells, having no strainer, do not have to end in coarse sand, whereas drilled wells, using strainers, must bottom in sand sufficiently coarse to be checked by the strainer. Of the 62 wells listed in the table 28 are bored and have an average depth of 67 feet and 27 are drilled and average 208 feet in depth.

LOCAL SUPPLIES

At and near Allen (altitude 364 feet) both bored wells and drilled wells are used. The bored wells range in depth from 50 to 60 feet. They end in fine sand, which in the course of a few years fills the wells. Drilled wells range from 100 to 150 feet in depth.

Brownsville (altitude 344 feet) has a municipal water supply. (See analysis 25a.) The plant consists of a 6-inch well 142 feet deep and an 8-inch well 250 feet deep. The two wells are pumped by an electrically driven 3-cylinder reciprocating pump having a capacity of 200 gallons a minute. The water is pumped into a 100,000-gallon elevated tank, from which it is distributed by gravity. Further storage is furnished by a 110,000-gallon reservoir. The daily consumption is 210,000 gallons. At the ice plant of the Western Tennessee Power & Light Co. there is a 6-inch well 228 feet deep, in which the water level stands 51 feet below the surface. Another deep well at Brownsville is the well of the Louisville & Nashville Railroad, an 8-inch well 310 feet deep, with the water level 50 feet below the surface and a drawdown of 11 feet when pumped at 150 gallons a minute. The well is pumped by air lift, and the total daily pumpage is 200,000 gallons. A log of this well is as follows:

Log of Louisville & Nashville Railroad well, Brownsville

[Authority, chief engineer]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
No record	5	5	White sand streaked with clay	121	211
Red clay	10	15	Coarse sand	51	262
Hard white clay	8	23	Very hard clay	9	271
Dry red sand	8	31	Medium-grade white water-bearing sand	39	310
Sand and clay	9	40			
Blue clay with sand	25	65			

The region west of Brownsville is underlain by a bed of fine sand and blue clay, which extends to a depth of about 275 feet. As it is difficult to finish a well so that it will hold out this fine sand, drilled wells penetrate to the coarser sands below. These wells attain depths of 290 to 323 feet. The bored wells, however, obtain sufficient water from depths of 40 to 100 feet.

Log of well of Columbus Hinkle, 6 miles west of Brownsville

	Thickness (feet)	Depth (feet)
Clay and sand, variegated, mixed	60	60
Sand, fine, with water	18	78
Lignite	4	82
Clay, blue	158	240
Sand, coarse, gray, water bearing (penetrated)	7	247

To the north of Brownsville deep wells end in a good sand at depths of 175 to 250 feet. The log of such a well is as follows:

Log of well of G. Pond, 6.5 miles north of Brownsville

[Authority, William Kimmerling]

	Thickness (feet)	Depth (feet)
Brown clay	25	25
Brown sand	10	35
Soapstone	115	150
Gray, silty sand	25	175
Coarse sand with some pebbles	5	180
Coarse white sand	15	195

Log of well of P. H. Bell, 2.4 miles northeast of Brownsville

[Authority, P. H. Bell]

	Thickness (feet)	Depth (feet)
Clay loam	20	20
Fine sand with interstratified white "pipe clay"	120	140
Coarse gray water sand	13	153

Southeast of Brownsville bored wells are most common and range from 50 to 100 feet in depth; a few drilled wells go to 170 feet.

Log of well at schoolhouse, Sunny Hill, 4.1 miles south of Brownsville

[Authority, D. B. Mann (from memory)]

	Thickness (feet)	Depth (feet)
Loamy clay	20	20
Medium-grained red sand	80	100
Black clay	5	105
White sand, increasingly coarse with depth	45	150

The country around Dancyville is hilly. On the hilltops the depth to water is considerable, being as much as 95 feet in some places. Bored wells from 60 to 130 feet deep are in use. The water is of good quality. (See analysis 39.)

At Forked Deer there are only a few springs, and wells 40 to 60 feet deep yield hard water. Good soft water is obtained at depths of 100 to 150 feet in sand beneath blue clay.

Log of G. W. Pearson well, Forked Deer

	Thickness (feet)	Depth (feet)
Loess: Surface sand and clay	40	40
Grenada:		
Sand, water bearing	5	45
Clay, blue	95	140
Sand, coarse, water bearing, entered	10	150

As its name would indicate, Hillville is in the high, hilly country in the southeastern part of the county. Drilled and bored wells from 80 to 150 feet in depth furnish sufficient water for domestic use.

Jones (altitude 325 feet) is on the edge of the valley of the South Fork of the Forked Deer River. On the bottom shallow wells 30 feet deep yield abundant water. In higher country to the east and southeast bored or drilled wells must go down from 60 to 140 feet to obtain a permanent supply of water.

The wells in the neighborhood of Keeling are usually bored and run from 30 to 50 feet in depth. At 60 feet there is a bed of lignite, and deep wells have to go below this. The gin at Keeling obtains sufficient water from a 3-inch well 106 feet deep.

Near Randolph, on the edge of the Forked Deer bottom, a 2-inch well of the Hatchie Lumber Co. passed through tough alluvial clay 32 feet, fine sand 5 feet, lignite 4 feet, blue clay 24 feet, and coarse sand with soft water 5 feet.

Shepards (altitude 290 feet) is in the valley of the Hatchie River. Domestic needs are supplied by driven wells 1¼ inches in diameter and 30 feet deep. This type of well is found throughout the bottoms. The Louisville & Nashville Railroad has a watering station at Shepards where water is obtained from a 12-inch well 172 feet deep. (See analysis 35b.) The water level is 9 feet below the surface and draws down 10 feet when the well is pumped at 400 gallons a minute. The well is equipped with a duplex steam pump with a capacity of 300 gallons a minute. The log of this well is as follows:

Log of Louisville & Nashville Railroad well at Shepards

[Authority, chief engineer]

	Thickness (feet)	Depth (feet)
Yellow clay	7	7
Red sand	72	79
Red clay	17	96
Coarse sand	95	191

At Stanton (altitude 314 feet) clay lenses have been encountered in drilling. One hole was abandoned at a depth of 300 feet after traversing 200 feet of clay without passing through it. As these clay lenses are local, moving a few hundred yards away will usually insure passing beyond their limits. If, however, it is necessary to put down a well in a particular spot abundant water may be obtained by drilling through the clay lens. Bored wells in this region range from 70 to 113 feet in depth, according to topographic position; drilled wells range from 150 to 325 feet.

Log of well of R. L. Baxter, Stanton

[Authority, R. L. Baxter, driller (from memory)]

	Thickness (feet)	Depth (feet)
Clay loam	25	25
Fine yellow sand	125	150
Coarse white water sand	10	160

A quarter of a mile east of Stanton a well drilled for Mrs. M. W. Welch has the following log:

Log of Welch well near Stanton

[Authority, R. L. Baxter]

	Thickness (feet)	Depth (feet)
Clay loam	25	25
Yellow sand	6	31
Blue "pipe" clay	105	136
Sand	4	140
Fine sand	160	300
Medium grained white sand	25	325

Water from the shallow wells (analysis 36a) contains 35 parts per million of hardness, whereas water from the deep wells (analysis 36b) contains only 13 parts per million. The iron content of water from both the shallow and the deep wells is high, being 8.86 and 8.34 parts per million respectively.

At and near Wellwood bored wells range from 25 to 80 feet in depth. Drilled wells are as deep as 126 feet.

Woodville is underlain by a bed of lignite 2 to 3 feet thick, at a depth of 30 to 50 feet. Below the lignite is a coarse sand containing some pebbles. Wells end in this sand and are from 35 to 65 feet deep.

Records of wells in Haywood County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement	Method of lift	Use of water
1	3 miles south of Bells on Bells-Union road.	C. H. Nelson	Hillside	380	Bored	103	6	Sand	Alluvium	103	95	Aug. 17, 1928	Bucket	Domestic.
2	10 miles north of Brownsville.	C. A. Jernigan	Upland		do	50	6	do	Grenada	50	45	Aug. 31, 1929	do	Do.
3	9.5 miles north-northeast of Brownsville.	W. B. Eason	Valley bottom.		Dug	10	36	do	Alluvium	10	5	do	Force pump.	Do.
4	4.5 miles east-southeast of Woodville.	J. T. English	Upland		Bored	35	6	do	Grenada	35	33	Sept. 9, 1929	Bucket	Do.
5a	Forked Deer, 3 miles east-northeast of Woodville.	C. T. Humphreys	Hilltop		do	60	6	do	do	60			do	Do.
5b	Forked Deer	J. W. Warren	Hillside		Drilled	483	2	do	Holly Springs	483			Lift pump	Do.
6	Woodville	T. H. Chapman	Upland		Bored	42	6	do	Grenada	42	30	Sept. 9, 1929	Bucket	Do.
7	2.3 miles south-southeast of Woodville.	Hathcock Bros.	Hillside		Drilled	250	2	do	do	250			Lift pump	Do.
8a	Nut Bush, 5 miles south-southeast of Woodville.	Nut Bush Gin Co.	Upland		do	108	2	do	do	108			do	Industrial.
8b	Nut Bush	Nut Bush School	do		Bored	65	6	do	do	65			Bucket	Domestic.
9	6.5 miles southeast of Woodville.	C. S. Hopkins	do		do	42	6	do	do	42	30		do	Do.
10	6.5 miles north of Brownsville.	G. Penal	Lowland		Drilled	195	2	do	do	180			Lift pump	Industrial.
11a	Jones, 200 feet north of railroad and road crossing.	B. C. Booths	Valley bottom.	310	Bored	25	6	do	Alluvium	25	10	Aug. 17, 1928	Hand pump	Domestic.
11b	Jones, 200 feet northeast along railroad track.	J. Cain	Hillside	325	Drilled	80	1½	do	Grenada	80			do	Do.
11c	Jones, 1,000 feet east of railroad.	J. H. Pikin	Hilltop		do	138	2	do	do	138	5	Rept	do	Do.
12	Holly Grove Church	T. J. Castallow	do	360	Bored	80	6	do	do	80	70	Aug. 17, 1928	Bucket	Do.
13a	5.5 miles north of Union Church on Bell road.	J. D. Marbury	Valley bottom.		do	25	6	do	Alluvium	25			do	Do.
13b	6 miles north of Union Church on Bell road.	do	Hilltop		do	62	6	do	Grenada	62			do	Do.
14	Jones, 2.5 miles southeast on Wellwood road.	F. P. Hess	do		Drilled	126	2	do	do	126	80	Rept	Windmill	Do.
15	5.3 miles north-northeast of Brownsville.	R. Hagerty	Upland		do	250	2	do	do	250			Lift pump	Industrial.
16	5.6 miles west of Brownsville on Ripley road.	Lynn Binford	do		do	150	2	do	do	150			Gas motor	Domestic.

Records of wells in Haywood County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement	Method of lift	Use of water
17a	4.7 miles west of Brownsville on Ripley road.	T. J. Mann	Hillside		Bored	40	6	Sand	Grenada	40	37	Aug. 18, 1928	Bucket	Domestic.
17b	do	do	do		Drilled	300	3	do	do	300			Gas motor	Industrial.
18a	Allen	R. J. Bancroft	Upland	364	do	100	2	do	do	100			do	Domestic.
18b	Allen, 0.2 mile west of railroad station, 50 feet north of road.	W. S. Baxter	do	364	do	70	2	do	do	70	49	Rept.	do	Do.
19	3 miles north of Union Church on Bells road.	C. H. Nelson	Hillside	380	Bored	103	6	do	do	103	95	Aug. 17, 1928	Bucket	Do.
20	Wellwood	J. L. Edwards	Valley bottom.		do	62	6	do	do	62	55	Aug. 28, 1928	do	Do.
21	Halfway	J. T. Barden	Highland		Drilled	95	2	do	Holly Springs	85	80	Aug. 16, 1928	do	Do.
22	1 mile north of Union Church on Bells road.	E. B. Drake	Second bottom.		Bored	67	6	do	Grenada	67	42	Rept.	Windmill	Do.
23a	0.8 mile south of Union Church.	H. L. Davis	Upland		do	121	6	do	Holly Springs	121	107	Aug. 15, 1928	Bucket	Do.
23b	Union Church, 300 feet south of road.	I. M. Thomas	do		Drilled	110	2	do	do	110			Gas motor	Do.
24	2.4 miles northeast of Brownsville on Jones road.	P. H. Bell	Hillside		do	152	2	do	Grenada	152	60	Rept.	do	Domestic and stock.
25a	Brownsville	Brownsville Waterworks.	Valley bottom.	344	do	250	8	do	Holly Springs	250	50	do	Electric [a]	Public supply
25b	do	do	do	344	do	142	6	do	Grenada	142	50	do	do [a]	Do.
25c	do	Louisville & Nashville R. R.	do	344	do	310	8	do	Holly Springs	310	50	do	Air lift [b]	Railroad.
25d	do	West Tennessee Power & Light Co.	do	344	do	288	6	do	do	228	51	do	do [c]	Industrial.
26a	3.8 miles west of Brownsville.	B. C. Brummett	Upland	360	do	297	2	do	Grenada	60	55	Aug. 18, 1928	Gas motor	Domestic.
26b	3.7 miles west of Brownsville on Covington road.	John Bishop	do	370	Bored	63	6	do	do	63	43	Aug. 28, 1928	Bucket	Do.
26c	3.4 miles west of Brownsville on Covington road.	C. R. White	Hilltop	395	do	90	6	do	do	90	84	Aug. 18, 1928	do	Do.
27a	7.1 miles west of Brownsville on Covington road.	R. T. Joyner	Valley bottom.	340	do	50	6	do	do	50	38	do	do	Do.
27b	7.3 miles west of Brownsville on Covington road.	do	Hilltop	370	Drilled	325	3	do	do	325			Gas engine	Domestic and industrial.
28	7.8 miles west of Brownsville on Covington road.	C. T. King	Upland		Bored	60	6	do	do	60	55	Aug. 18, 1928	Bucket	Do.

29	2.6 miles south of Brownsville on Dancyville road.	Sidney Ricurrie	Hilltop	370	do	85	6	do	do	85	80	Aug. 16, 1928	do	Domestic.
30	1.5 miles south of Union Church.	R. T. Keeton	Upland		do	146	8	do	Holly Springs	146			Gas motor	Do.
31	2.3 miles south of Hanley	L. A. Bond	do		do	65	6	do	do	65	55	Aug. 15, 1928	Bucket	Do.
32	7 miles southeast of Brownsville.	J. B. Warren	do		Drilled	140	2	do	do	140	110	Rept	Gas motor	Do.
33	4.1 miles south of Brownsville on Dancyville road.	D. B. Mann & Sons.	Hilltop	400	do	170	2	do	Grenada	170	110	do	do	Industrial.
34	4.7 miles south of Brownsville on Dancyville road.	H. E. Powell	Valley bottom.	330	Driven	50	1¼	do	do	50	20	do	Hand pump	Domestic.
35a	180 feet northeast of Shepards along track.	G. A. Hinsley	do	330	do	32	1¼	do	Alluvium	32	20	do	do	Do.
35b	Shepards	Louisville & Nashville Railroad.	do	330	Drilled	172	12	do	Grenada	172	9	do	Steam [d]	Railroad.
36a	1,000 feet north of intersection of Stanton road and highway 1.	Howard Powell	Hillside	355	do	190	3	do	do	190			Gas engine	Domestic.
36b	Intersection of Stanton road and highway 1.	P. W. Welch	Hilltop	355	do	325	3	do	Holly Springs	325	40	Rept	do [e]	Do.
36c	600 feet east of Stanton	D. Ford	Valley bottom.	315	do	70	3	do	Grenada	70			Steam	Industrial.
36d	0.25 mile east of Stanton on Dancyville road.	Mrs. M. W. Welch	Hillside	287	do	287	2½	do	Holly Springs	287	60		Gas engine	Domestic.
36e	0.5 mile southwest of Stanton, 200 feet east of railroad track.	R. L. Baxter	Second bottom.	315	do	160	2	do	Grenada	160	40		do	Do.
37	2.9 miles east of Stanton	G. R. Ford	Hilltop	370	Bored	113	6	do	do	113	107		Bucket	Do.
38	5 miles east of Stanton on Dancyville road.	W. B. Douglas	do	360	Drilled	325	3	do	Holly Springs	325			Gas motor	Domestic and stock.
39	Dancyville	K. M. Dancy	do		Bored	130	6	do	Grenada	130	110	Aug. 16, 1928	Bucket	Domestic.
40	4 miles east of Dancyville	P. E. Stuart	do	450	do	102	10	do	Holly Springs	102	96	Aug. 23, 1928	do	Do.
41	2.5 miles southwest of Hillville.	R. E. Moore	Hillside	400	do	40	6	do	Grenada	40	35	do	do	Do.
42a	Hillville	H. D. Jeter	Hilltop		do	82	6	do	Holly Springs	82	76	do	do	Do.
42b	do	do	do		Drilled	150	2	do	do	150			Gas engine	Do.

[a] Pumpage, 105,000 gallons a day.
[b] Pumpage, 75,000 gallons a day. Capacity of pump, 175 gallons a minute.
[c] Capacity of pump, 300 gallons a minute.
[d] Capacity of pump, 400 gallons a minute.
[e] Pumpage, 1,000 gallons a day.

Analyses of waters from Haywood County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analysis 25a by D. F. Farrar; the rest by Margaret D. Foster]

	8a	11a	18b	25a	27b
Silica (SiO_2)	28	37	22	3	12
Iron (Fe)	3.2	5.1	.78	.6	6.9
Calcium (Ca)	6.0	17	4.4	8	7.4
Magnesium (Mg)	2.4	10	1.7	2	2.9
Sodium (Na)	9.5	66	13	3	9.5
Potassium (K)	1.2	2.7	.8		1.5
Bicarbonate (HCO_3)	45	150	30	30	56
Sulphate (SO_4)	6.0	45	2.3	1	4.8
Chloride (Cl)	4.0	42	12	6	2.9
Nitrate (NO_3)	.05	.71	3.4	.2	.0
Total dissolved solids	74	294	80	36	71
Total hardness as $CaCO_3$ (calculated)	25	84	18	28	30
Date of collection	Sept. 24, 1929	Aug. 17, 1928	Aug. 17, 1928	Aug. 14, 1928	Aug. 18, 1928

	35a	36b	36c	39
Silica (SiO_2)	24	13	17	18
Iron (Fe)	.65	8.3	8.9	.18
Calcium (Ca)	3.8	3.4	8.2	3.6
Magnesium (Mg)	1.5	1.2	3.5	1.4
Sodium (Na)	10	4.5	18	5.4
Potassium (K)	.7	.3	1.5	.5
Bicarbonate (HCO_3)	19	24	39	21
Sulphate (SO_4)	5.8	2.5	23	3.8
Chloride (Cl)	11	1.9	13	3.4
Nitrate (NO_3)	.77	.05	1.5	.74
Total dissolved solids	72	39	106	45
Total hardness as $CaCO_3$ (calculated)	16	13	35	15
Date of collection, 1928	Aug. 16	Aug. 17	Aug. 16	Aug. 16

HENDERSON COUNTY

[Area 536 square miles. Population 17,655]

GEOGRAPHY

Henderson County, in the northeastern part of the area described, is roughly quadrangular and comprises 536 square miles. All of the county lies in the area designated the western plateau by Safford. However, the high land dividing the eastward-flowing and westward-flowing streams crosses the western part of the county. The Beech River, which drains the largest part of the county, flows into the Tennessee River; the headwaters of the North Fork and Middle Fork of the Forked Deer River, which drain the western part of the county, belong to Mississippi River system. All of the county is very hilly. The highest points probably attain an altitude of 600 feet, and the average altitude is 500 feet. Much of the area is forested, and the county is but thinly populated.

GEOLOGY

Six geologic formations crop out in this county—the Eutaw, Selma, Ripley, Porters Creek, Holly Springs, and Pliocene gravel. The Eutaw crops out along the eastern border of the county, forming a strip 4 miles wide. It is a sand formation with much interbedded clay. In places the formation is composed of interlaminated sand in layers half an inch to an inch thick and clay in layers a sixteenth to an eighth of an inch thick. In other places the formation may be mostly carbonaceous clay in beds several feet thick. In still other places the formation is a clean sand. The maximum thickness of the formation is about 175 feet. In the valley bottoms, however, the depth to the underlying Paleozoic rocks can not be very great, for they crop out just east of the county line.

In the description of the Selma clay on page 75 it is shown that this formation thins out in southern Henderson County and that what to the north has formerly been mapped as Selma should be included in the Coon Creek tongue of the Ripley formation. Where both the Selma and Coon Creek are present it is impossible to differentiate the two in the well logs available. As the beds are lithologically similar, are not water bearing, and serve as a confining stratum to the water in the Eutaw formation, they are treated as a unit in this county. They have a maximum combined thickness of about 230 feet in the southern part of the county but thin to about 120 feet in the north.

The Ripley formation, which crops out as a band from 13 to 15 miles in width through the central part of the county, consists largely of sand which ranges in texture from very fine to coarse. This formation erodes easily, and its area of outcrop is unusually hilly. The formation attains a thickness of 500 feet.

The Porters Creek clay crops out in a belt 3 miles wide, which strikes east of north along the western edge of the county. This formation dips 20 to 30 feet to the mile toward the west. Its thickness in Henderson County has not been determined but probably does not exceed 250 feet.

The Holly Springs formation is found in the northwest corner of the county. It is composed of sand and ranges in thickness from 150 feet to a feather edge.

Pliocene gravel occurs on the highland in the eastern part of the county. In places it is 60 feet deep. Toward the west the gravel is missing, but the uplands are covered by a thin mantle of residuum.

WATER RESOURCES

Henderson County is well watered, perennial streams and springs being abundant. Though the Eutaw formation will yield water in the sandy parts the interlaminated carbonaceous clay may impart an unpleasant taste to the water. The Selma clay is not a source of water. Where the Selma is overlain by a fair thickness of gravel or residuum water can be obtained from those beds; otherwise it is necessary to drill through the Selma into the underlying Eutaw formation. The Ripley formation is an excellent source of water. On high ground the water table may be as much as 125 feet deep, but water is plentiful and of excellent quality. As the Porters Creek clay does not yield water, it is necessary in the outcrop area of the Porters Creek to drill into the underlying Ripley, but the Porters Creek is only 116 to 250 feet thick. The Holly Springs sand yields plentiful supplies of good water. The Pliocene gravel, where of sufficient thickness, is an important source of water in the area where the Selma crops out.

LOCAL SUPPLIES

In the hilly region around Bargeton the water table stands from 70 to 90 feet from the surface. Bored wells are used and are in sand throughout.

Darden (altitude 400 feet) is in the valley of the Beech River. Shallow wells 20 feet deep obtain a plentiful supply of water from the alluvium. On the surrounding hills drilled wells obtaining water from Eutaw sands range in depth from 100 to 160 feet.

Hinson Springs (altitude 400 feet), in the area of Ripley sands, is in the valley of the Beech River. Several springs are found in the lowlands. Some of these are chalybeate, and formerly this was a watering resort. The two main springs flow 7 gallons a minute each.

At Huron (altitude 414 feet) bored wells 15 to 60 feet deep are used, the depth depending on topographic position. The wells are lined with tile or wood. The gin, which is in a lowland, obtains abundant water from a well 40 feet deep.

Juno is on the eastern edge of the Porters Creek clay outcrop. Wells from 40 to 50 feet deep pass through the Porters Creek into the underlying Ripley sands.

Law is in the Holly Springs sand area. Wells furnish soft water from sand under pipe clay at an average depth of 50 to 60 feet, the range being from 20 to 85 feet.

Lexington (altitude 484 feet) has a municipal water supply owned by the city. This system consists of three wells. Well 1, a 6-inch well 610 feet deep (analysis 8b) is pumped by an electrically driven reciprocal pump yielding 80 gallons a minute. Well 2 is a 6-inch well 110 feet deep, and well 3 is an 8-inch well 100 feet deep. Both are equipped with electrically driven reciprocating pumps yielding 20 gallons a minute. The water is pumped into a 75,000-gallon elevated tank, from which it is distributed by gravity. This tank is supplemented by a 150,000-gallon reservoir. No figure on daily consumption could be obtained. Wells 2 and 3 derive their water from the Ripley sands, which crop out in this vicinity. The water level stands 40 feet below the surface. Well 1 passes through the Selma clay and obtains its water from the underlying Eutaw sands, in which the water is under artesian pressure, rising within 60 feet of the surface. The log of this well is given below.

Log of well 1 of Lexington waterworks

[Authority, Eli Jones (from memory)]

	Thickness (feet)	Depth (feet)
Ripley formation:		
Red clay and water-bearing sand	110	110
Indurated marl	30	140
Black clay	160	300
Selma clay: Fossiliferous clay	200	500
Eutaw formation: Dark-gray water sand	10	510

The Nashville, Chattanooga & St. Louis Railway finished in 1903 a well 700 feet deep that was not a success. The driller gave the following log from memory:

Log of well of Nashville, Chattanooga & St. Louis Railway, Lexington

	Thickness (feet)	Depth (feet)
Sand with shells of soft sand ironstone 6 to 8 inches thick scattered through it, and a little clay; water in all below 50 or 60 feet (Pliocene and Ripley)	200	200
Clay, blue, with a little water-bearing sand and gravel at the bottom (Selma and Eutaw)	300	500
Limestone, pure; no chert (penetrated)	200	700

Both of these logs are given from memory, and though they give the succession and relative thickness of the formations, the figures should not be taken for exact measurements.

Another well at Lexington is the well of the City Ice & Fuel Co., a 6-inch well 114 feet deep, equipped with a reciprocating pump yielding 35 gallons a minute. This well draws water from the Ripley formation.

Life (altitude 495 feet) is in a high sandy region in the area of Ripley outcrop. The water table stands 40 to 110 feet below the surface. Bored wells are used exclusively and range in depth from 60 to 120 feet.

At Luray (altitude 393 feet) there is a local artesian basin formed by an extensive clay lens in the Ripley formation, which crops out in the high ground to the east of Luray and dips down under the town. This clay bed entraps the water under sufficient pressure to cause wells in Luray to flow. The basin is of small extent and should not be drawn upon by needless wells, for it has only a small capacity, and many wells would reduce the head. The well of Harris Bros. is 2½ inches in diameter and 145 feet deep and flows 14 gallons a minute. (See analysis 56.) This well has a larger flow than any other well at Luray. No log of these wells could be obtained.

At Regan, in high hilly country, it is difficult to obtain adequate supplies of water above the Selma, so wells are drilled through the Selma into the underlying Eutaw formation.

Log of well of A. M. Powers, Regan

[Authority, Eli Jones, driller (from memory)]

	Thickness (feet)	Depth (feet)
Residuum and Ripley formation: Clay and sand, some water	130	130
Selma clay: Blue clay, fossiliferous	177	307
Eutaw formation: Black sand, water-bearing	8	315

Sardis is in the outcrop area of the Selma clay, but there is a covering of Pliocene sand and gravel 40 feet thick. Most of the wells obtain water from the Pliocene. Some wells pass through the Selma clay, which at this point is only from 30 to 40 feet thick, and obtain water from the underlying Eutaw.

Scotts Hill is underlain by the Eutaw formation, which is composed largely of carbonaceous clay. This clay will yield only a little water, which has a strong odor and is not potable. Shallow wells from 25 to 30 feet deep obtain water of fair quality sufficient for domestic use. One well 300 feet deep was drilled for W. E. Kelly, and the log is given below.

Log of well of W. E. Kelly, Scotts Hill

[Authority, Eli Jones, driller (from memory)]

	Thickness (feet)	Depth (feet)
Clay	20	20
Red sand	6	26
Black carbonaceous clay	212	238
Limestone (rock)	19	257
Water-bearing sand	2	259
White fossiliferous clay	41	300

It is difficult to analyze this log. If the bed called limestone is conceded to be the top of the Paleozoic basement, the overlying Eutaw has a thickness comparable to the measurements made of the Eutaw in other places. However, the sand and clay beds underlying this limestone can not be correlated with any formations in the Paleozoic. The driller may have mistaken the drillings derived from a shale formation for clay. On this assumption the limestone is probably Devonian calcareous chert, and the fossiliferous clay could be assumed to be the Birdsong shale, a highly fossiliferous shale of Devonian age.

Shady Hill is underlain by the Selma clay, which is covered by a mantle of residuum 15 feet thick. Some shallow wells obtain a poor and intermittent supply of water from wells in the residuum, but cisterns are largely used. North of Shady Hill some wells have been drilled that pass through the Selma clay into Eutaw sand, which yields a plentiful supply of water. In this vicinity the Selma ranges from 116 to 155 feet in thickness.

Log of well of M. Youngerman, north of Shady Hill

[Authority, Eli Jones, driller (from memory)]

	Thickness (feet)	Depth (feet)
Residuum: Yellow clay	18	18
Selma clay: Gray clay	132	150
Eutaw formation: Fine sand	49	199

Wildersville (altitude 468 feet) is in the valley of the Big Sandy River. A plentiful supply of good water is obtained from bored wells 25 to 30 feet deep.

Records of wells in Henderson County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement	Method of lift	Use of water
1a	Wildersville	L. S. Douglas	Valley bottom.	465	Bored	30	6	Sand	Ripley	30	24	Aug. 1, 1928	Bucket	Domestic.
1b	do	Wilson & Bolen	do	468	do	25	6	do	do	25	20	do	do	Do.
2	8 miles north of Lexington on Wildersville road.	Elijah Jones			Drilled	170	2	do	do	170		do	Lift pump	Do.
3	Bargeton	J. N. Douglas	Upland		Bored	80	8	do	do	80	75	Aug. 2, 1928	Bucket	Do.
4	Juno	W. N. Jordan		530	do	45	8	do	do	45	38	do	do	Do.
5a	0.1 mile north of Luray, 0.1 mile east of railroad station.	H. W. Harris	Hillside	395	Drilled	155	2	do	do	60	(a)	do		Do.
5b	150 feet south of station at Luray.	Harris Bros.	Valley bottom.	385	do	145	2½	do	do	60	(b)	do		Domestic and stock.
5c	200 feet south of Luray, 0.1 mile west of railroad station.	G. W. Priddy	Valley	380	do	151	2	do	do	60	(c)	do		Domestic.
6a	Life, 500 feet south of railroad station.	Chas. D. Bell	Upland	495	Bored	100	8	do	do	100	92	do	Bucket	Do.
6b	Life, 1,000 feet south of railroad station.	A. Mullins	Hillside	500	do	120	8	do	do	120	110	do	do	Do.
6c	Life, 300 feet north of railroad station.	J. C. Cowtton	do	430	do	60	6	do	do	60	40	do	do	Do.
7	Hinson Spring	R. L. McCelley	Valley bottom.	440	Spring				do		(d)	Aug. 3, 1928		Stock.
8a	20 feet north of railroad track, 75 feet east of road to station at Lexington	City Ice & Fuel Co.	do	484	Drilled	114	6	Sand	do	114	40		Oil engine[e]	Industrial.
8b	Lexington, well 1	City of Lexington	do	484	do	510	6	do	Eutaw	510	60		Lift pump, electric[f]	Public supply.
8c	Lexington, well 2	do	do	484	do	110	6	do	Ripley	110	40		do.[g]	Do.
8d	Lexington, well 3	do	do	484	do	110	6	do	do	110	40		do.[g]	Do.
9	Oak Grove Church	County of Lexington			do	305	4	do	Eutaw	103	105		Lift pump	School.
10	Warrens Bluff	W. T. Buck			do	260	2½	do	do		6		do	

[a] Flowing 8,640 gallons a day.
[b] Flowing 20,160 gallons a day.
[c] Flowing 288 gallons a day.
[d] Flowing 10,080 gallons a day.
[e] Pumpage, 50,400 gallons a day. Capacity of pump, 35 gallons a minute.
[f] Capacity of pump 80 gallons a minute.
[g] Capacity of pump 20 gallons a minute.

Records of wells in Henderson County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement	Method of lift	Use of water
11a	250 feet west of railroad station 250 feet south of Darden.	W. O. Hill	Valley bottom.	385	Driven	103	3	Sand	Eutaw	103	75	July, 1928	Lift pump	Domestic.
11b	Darden	E. E. Wilson	Valley	400	Bored	20	8	do	do	20	3	do	do	Do.
12	5.3 miles west of Middleburg.	Ernest L. Dyer	Hilltop	480	do	175	8	do	do		30	do	Bucket	Do.
13	Half a mile east of New Hope Church.	G. H. Davidson	Hill	480	do	154	8	do	do		70	do	do	Do.
14	do	M. Youngerman	do	480	Drilled	199	2	do	do	199	75	do	Lift pump, gas motor.	Do.
15	Middleburg	J. B. Jones	Hilltop	500	Bored	50	6	do	do	50	40	do	Bucket	Do.
16	Shady Hill	F. Smith	Hill		Dug	15	36	do	Ripley		12	do	do	Do.
17	Piney Church, at mill	Floyd Petty	Hilltop	535	Drilled	324	3	do	Eutaw	102	164		Lift pump	Do.
18	Reagan	J. R. Stewart	do		Dug	48	36	do	Ripley	48	47	Sept., 1929	do	Do.
18a	do	A. M. Powers	Hill	575	Drilled	315	3	do	Eutaw	60	140	August, 1929	do	Do.
19a	Scotts Hill, north side of road.	M. M. Brash	Hilltop	490	Dug	25	36	do	do		21	July, 1928	Bucket	Do.
19b	Scotts Hill	W. E. Kelly	do	490	Drilled	300	2	do	do					
19c	do	E. L. Kennedy	do	490	Dug	30	36	do	do	30	27	July, 1928	Bucket	Do.
20	Cedar Grove	H. W. Creasy	Upland	465	do	30	36	do	do		25	do	do	Do.
21a	Sardis, west side of road	J. S. Johnson	Hillside	500	Bored	45	8	Gravel	Pliocene	45	32	do	do	Do.
21b	Sardis	W. A. Johnson	do	500	Punched	40	8	do	do	40	32	do	do	Do.
21c	do	J. W. Wilie	Hilltop	450	Bored	72	8	Sand	Eutaw	72	60	do	do	Do.

Analyses of waters from Henderson County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyzed by D. F. Farrar]

	1b	5b	8a	11a	14	21a
Silica (SiO_2)	8	4	6	9	6.3	14
Iron (Fe)	1.9	.7	1.6	.7	.4	.8
Calcium (Ca)	24	7	16	31	88	8
Magnesium (Mg)	3	1	3	3	9	1
Sodium (Na)	15	2	20	7	3	26
Potassium (K)	4		4			3
Carbonate radicle (CO_3)	0	0	0	0	0	0
Bicarbonate radicle (HCO_3)	12	17	27	100	225	18
Sulphate radicle (SO_4)	58	9	26	5	61	3
Chloride radicle (Cl)	26	.8	36	11	7	45
Nitrate radicle (NO_3)	3	1.2	.3	.2	.8	.4
Total dissolved solids	156	39	130	120	290	112
Total hardness as $CaCO_3$ (calculated)	72	22	52	90	257	24
Date of collection, 1928	Aug. 1	Aug. 2	Aug. 3	July 30	July 30	July 31

HENRY COUNTY

[Area 626 square miles. Population 26,432]

GEOGRAPHY

Henry County, which lies in the northeast corner of western Tennessee, is primarily an agricultural area. The main crops are corn, tobacco, sweetpotatoes, clover, and cotton. In addition dairying is carried on to a considerable extent. Henry County is the center of clay mining in western Tennessee and furnishes almost all of the ball clay produced in this region. The production for 1928 was 45,594 tons.[94] Henry County is served by two railroads, the Louisville & Nashville and the Nashville, Chattanooga & St. Louis. The Louisville & Nashville Railroad has shops at Paris, the county seat and largest city. The eastern boundary of Henry County is formed chiefly by the Tennessee and Big Sandy Rivers.

GEOLOGY

The oldest rocks in Henry County are Devonian rocks found in small outcrops along the west side of the Big Sandy Valley. These rocks dip to the west at about 30 feet to the mile and are encountered a short distance west of their outcrops in shallow wells. Most of the Devonian outcrops are chert, though the Birdsong shale is present. The Fort Payne chert is the formation at the surface along the Tennessee River. It forms rubble slopes of angular fragments of chert. The St. Louis limestone crops out in a small area between the Big Sandy and Tennessee Rivers. The weathered phase of the St. Louis limestone consists of a cherty rubble resembling the Fort Payne. The Eutaw formation, which is not more than 20 to 30 feet thick in Henry County, is very argillaceous and a poor source of water. The Coon Creek tongue of the Ripley formation is a glauconitic, micaceous gray sand containing considerable clay. It does not exceed 50 feet

[94] U. S. Bur. Mines Mineral Resources, 1928, pt. 2, p. 192, 1930.

in thickness. The Eutaw and Coon Creek together form a narrow band not more than half a mile wide which directly overlies the Paleozoic rocks in the eastern part of the county.

A belt of Ripley formation 7 to 8 miles wide crosses the eastern half of the county from south to north. Though the formation is predominantly sand, it contains clay layers and lenses. Its maximum thickness is 350 feet.

The Porters Creek clay crops out in a narrow belt that runs a little north of east through the center of the county. Its outcrop area does not exceed a mile in width, and its thickness at Paris is 140 feet. At the bottom of the Porters Creek is a black carbonaceous clay which may belong to the Ripley formation. The Porters Creek clay dips from 20 to 30 feet to the mile toward the west. It does not yield water.

Throughout the western part of Henry County the Wilcox group occurs at the surface. The Holly Springs sand covers most of the area. It ranges from coarse to fine sand and contains lenses of clay, which may attain a thickness of 50 feet and an extent of 6 acres. The Grenada formation crops out in the northwest corner of Henry County. This formation is predominantly sandy, and at Cottage Grove, where it is excellently exposed, the sand is very fine grained.

In the northeastern part of Henry County there are extensive deposits of Pliocene and Pleistocene gravel as much as 30 feet thick in places. The gravel contains some sand but is made up mostly of chert pebbles.

WATER RESOURCES

Henry County is well watered by perennial streams, and these serve for watering stock. Springs occur at the foot of the hills and are used for domestic purposes. In the outcrop area of the Ripley and Wilcox formations water is easily obtained, although on the hills and ridges the water table may be as much as 100 feet below the surface. In the outcrop area of the Porters Creek clay or just to the west, wells must pass through this formation to the underlying Ripley formation, but the clay is not more than 140 feet thick. The Coon Creek and Eutaw are very poor water bearers, and they rest on the Paleozoic rocks, which are not a favorable source of water. Cisterns are used where these formations occur at or near the surface. Cisterns are also largely used in the areas of Pliocene gravel and where the Fort Payne crops out, because of the difficulties of sinking deep wells in these materials. The Paleozoic rocks may furnish water at depths less than 300 feet, but the water is high in hydrogen sulphide and contains considerable dissolved mineral matter. An example of this type of water is the water from well 46, an analysis of which is given in the table.

LOCAL SUPPLIES

Cottage Grove is on the eastern edge of the Grenada formation. The town is supplied by a public water system owned by C. H. Roberts. (See analysis 38.) It consists of a 3-inch and a 6-inch well, each 150 feet deep. The water is pumped by electrically driven lift pumps into a pressure tank. A log of one of the wells is as follows:

Log of well of C. H. Roberts, Cottage Grove

[Authority, C. H. Roberts]

	Thickness (feet)	Depth (feet)
Red clay and sand (residuum); water at 25 feet	25	25
Black carbonaceous clay (Grenada)	35	60
Medium-grained red sand (Holly Springs)	65	125
Fine white sand (Holly Springs)	25	150

At Buchanan dug and drilled wells from 30 to 100 feet deep are used. East of Buchanan cisterns are largely employed.

Hazel is on the boundary between Kentucky and Tennessee. The public water supply, which is owned by the Farmers Bank, obtains water from a 4-inch well 318 feet deep. Water is pumped by a lift pump and delivered to a pressure tank. The water has a high iron content (see analysis 7) and should be treated.

The public water supply owned by the city of Henry has two 3-inch wells 154 and 165 feet deep. (See analysis 75.) The wells are pumped by lift pumps, and the water is delivered to a pressure tank. The daily consumption averages 10,000 gallons.

Bored and drilled wells are used in and around Manleyville. The bored wells are from 50 to 75 feet deep; the drilled wells from 20 to 120 feet deep. At the foot of the hills springs are common and wherever convenient are used for domestic supply.

Wells in Mansfield range from 30 to 100 feet in depth and average about 60 feet. The deeper wells are drilled and go deeper for a good sand for finishing. The Porters Creek clay crops out to the west of Mansfield, and to obtain good water there wells must be drilled to the underlying Ripley formation. Such wells may be as much as 250 feet deep.

Paris was the fourth largest city in western Tennessee according to the census of 1930, which gives the population as 8,164. The Porters Creek clay crops out in the lowland just east of the city. In order to obtain water wells must pass through the Porters Creek to the underlying Ripley sands. The thickness of the Porters Creek at Paris is 140 feet. Logs of two wells of the Louisville & Nashville Railroad are as follows:

Log of well 2, Louisville & Nashville Railroad, Paris

[Authority, chief engineer]

	Thickness (feet)	Depth (feet)
Surface clay	6	6
Surface clay and sand	8	14
Holly Springs sand:		
Sand and clay	6	20
Sand	39	59
Rock	2	61
Porters Creek clay:		
Hard impervious clay	140	201
Rock	3	204
Ripley formation:		
Sand	27	231
Sand and clay	20	251
Hard impervious clay	16	267
Sand and clay	13	280
Coarse sand	52	332

Log of well 4, Louisville & Nashville Railroad, Paris

[Authority, Layne Central Co. Altitude of collar, 489 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Holly Springs sand:			Ripley formation—Continued.		
Sandy soil	59.5	59.5	Clay	22	280.5
Sandrock	4	63.5	Red sand	17	303.5
Porters Creek clay:			White sand interspersed with clay	22	325.5
Clay	126.5	190	White sand and clay; less clay than in preceding 22 feet	30	355.5
Shale and clay	20.5	210.5	Black plastic clay	10	365.5
Ripley formation:			White sand and clay	48	413.5
Fine white sand	20	230.5	Black stiff clay	4	417.5
Clay (gumbo)	10	240.5			
Sand	18	258.5			

A deep well drilled for the city is reported to have hit rock at 750 feet. It is probable that this was the top of the Paleozoic, but the statement was very indefinite, and too much reliance can not be placed on this figure.

Paris has a public water supply, obtained from four 8-inch wells 375 feet deep, which end in the Ripley formation. The depth to water is 90 feet. The wells are pumped by compressed air, and the water is discharged into a settling basin, where it flows over and under a series of baffles, and a little lime is added to accelerate the precipitation of the iron. The water flows by gravity into a 75,000-gallon reservoir, from which an electric centrifugal pumps it into a 75,000-gallon elevated tank. The average daily consumption of water is about 700,000 gallons.

The Louisville & Nashville Railroad has three wells ranging in depth from 326 to 419 feet from which it pumps an average of 400,000 gallons a day. Additional data for these wells can be found in the table. The Peoples Coal & Ice Co. has an 8-inch well from which it pumps an average of 360,000 gallons a day.

Puryear is in the Holly Springs sand area. The depth of the water table is from 65 to 90 feet, depending on topographic position. Puryear has a public supply owned by W. C. Littleton. Two 3-inch wells 80 feet deep obtain sufficient water. These wells are equipped with lift pumps, which deliver the water to a pressure tank.

Springville is in the lowland in the valley of West Sandy Creek. Here the Paleozoic floor lies as little as 30 feet below the surface. Water from the Paleozoic rocks would probably resemble the water at Sulphur Well, which is not suited for domestic use. Shallow wells, either dug or bored, obtain small supplies of water from Eutaw sand. The users report that the water has an unpleasant taste. The one analysis available (No. 64) shows considerable contamination with decomposed nitrogenous matter, and the sample can not be considered representative.

Records of wells in Henry County

No.	Location	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geological horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Use of water
1	4.6 miles north of Dulac	J. B. Snow	Foot of hill	Dug	20	36	Gravel	Pliocene	0	14	July 8	Bucket	Domestic.
2	Freeland	J. J. Freeland	Hillside	do	51	36	Sand	Ripley	Tile.	48	do	do	Do.
3	1 mile south of Freeland	N. Martin	do	Bored	54	6	do	do	Concrete.	50	do	do	Do.
4	6 miles southeast of Hazel	A. B. Milam	do	Dug	20	36	Gravel	Pliocene	do	19	do	do	Do.
5	4 miles east of Hazel	T. E. Adair	do	do	30	36	do	do	do	25	do	do	Do.
6	1.8 miles east of Hazel	J. M. Hooper	do	Bored	65	6			Tile.				
7	Hazel	Farmers Bank	Upland	Drilled	318	4	Sand	Ripley	318	152	Rept	Lift pump	Public supply.
8	Crossland	J. I. Pascal	do	do	236	2½	do	Holly Springs	236	80	do	do	Domestic.
9	7.4 miles north of Cottage Grove.	A. S. Hazelwood	Lowland	do	72	2	do	do	72			do	Do.
10	5 miles north of Cottage Grove on highway 69.	W. J. Brice	Upland	Bored	56	2	do	do	56			do	Do.
11	5.5 miles west of Puryear	Irlin Pascal	Foot of hill	Dug	35	36	do	do	35	30	July 13	Bucket	Do.
12	3.8 miles west of Puryear	John Coats	Upland	do	47	36	do	do	47	44	do	do	Do.
13	2.5 miles northwest of Puryear.	H. R. Jones		do	29	36	do	do	29	27	do	do	Do.
14	Coynesville	F. K. Page	Upland	do	60	36	do	do	60	56	July 8	do	Do.
15a	Buchanan	Buchanan School	Foot of hill	do	36	36	do	Ripley	36	28	July 9	do	Do.
15b	do	A. G. McGehee	Hilltop	Bored	90	2	do	do	90	60	Rept	Lift pump	Do.
16	3 miles east of Buchanan	H. L. Moody	Bottom	Spring			do	do		(a)	July 9		Do.
17	Dulac	A. H. Presswell	Hilltop	Dug	38	36	do		38	33	July 9	Bucket	Do.
18	0.8 mile east of Dulac	C. J. Williams	Foot of hill	do	18	36	do	Alluvium	18	14	do	do	Do.
19	3 miles southeast of Dulac	J. H. Wallace	do	do	19	36	Chert	Mississippian	0	5	do	do	Do.
20	1.9 mile south of Buchanan	L. C. King	Hilltop	Drilled	60	2	Sand	Ripley	60	50	Rept	Lift pump	Do.
21	1 mile south of Coynesville	J. F. Smith	do	Bored	80	6	do	Holly Springs	80			do	Do.
22a	Puryear	W. C. Littleton	Upland	Drilled	80	3	do	do	80	65	Rept	do	Public Supply.
22b	do	White & West	do	do	90	3	do	do	90			do	Industrial.
22c	do	Dixie Brick & Tile Co.	do	do	112	3	do	do	112	85	Rept		Do.
23	3 miles north of Cottage Grove on highway 69.	L. C. Ridgeway	do	do	120	2	do	do	120	65	do	Lift pump	Domestic.
24	3.8 miles northeast of Cottage Grove.	B. F. Wade	do	Bored	30	6	do	do	30	25	July 12	Bucket	Do.
25	2.4 miles southwest of Puryear.	H. C. Spink Clay Co.	Hilltop	Drilled	198	2	do	do	198			Lift pump	Do.
26	2.9 miles southwest of Buchanan.	W. H. Patterson	do	do	60	2	do	Ripley	60			do	Do.

[a] Flowing 1 gallon a minute.

Records of wells in Henry County—Continued

No.	Location	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geological horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Use of water
27	3.8 miles southwest of Dulac	A. Meadows	Hillside	Spring			Gravel	Pliocene					Domestic.
28a	4.5 miles south of Dulac	Max Lashlee	Foot of hill	do			Chert	Fort Payne		(b)	July 9		Do.
28b	do	F. E. Brown	Hillside	Dug	14	36	do	do	0			Bucket	Do.
29	4.4 miles southwest of Dulac	W. Thompson	do	do	20	36	do	do	20	11	July 6	do	Do.
30	Mount Vista	T. C. Wells	do	Bored	78	6	Sand	Ripley	78	60	do	do	Do.
31	5.6 miles northeast of Whitlock.	E. D. Nanney	do	do	25	6	do	do	25	20	July 9	do	Do.
32	3.6 miles east of Whitlock	B. A. Pillow	Hilltop	do	71	6	do	Holly Springs	71	67	July 8	do	Do.
33	Whitlock	H. C. Compton	Upland	Drilled	110	2	do	do	110	60	Rept	Lift pump	Do.
34	4.8 miles east of Cottage Grove.	D. H. Littleton	Hilltop	do	70	2½	do	do	70			do	Domestic.
35	3.9 miles east of Cottage Grove.	Kentucky-Tennessee Clay Co.	Upland	do	100	3½	do	do	100	58		do	Industrial.
36	3.5 miles east of Cottage Grove on highway 69.	H. W. Callicott		Bored	98	6	do	do	98			Bucket	Domestic.
37	1.6 miles east of Cottage Grove on highway 69.	P. A. Wade	Hilltop	do	60	6	do	do	60	43	July 12	do	Do.
38a	Cottage Grove	C. H. Roberts	Upland	Drilled	150	3	do	do	150	125	Rept	Lift pump	Public supply.
38b	do	do	do	do	150	6	do	do	150	125	do	do	Do.
39	2.3 miles north of Como	E. W. Reynolds	do	Dug	28	36	do	Grenada	28	24	July 16	Bucket	Domestic.
40	3.8 miles southeast of Cottage Grove.	D. M. Highfill	do	Drilled	98	2	do	Holly Springs	98	78	Rept	Lift pump	Do.
41	4.5 miles northwest of Paris on highway 69.	Ed. Bomar	Hilltop	Bored	115	6	do	do	115	105	July 12	Bucket	Do.
42	2.5 miles northwest of Paris on highway 69.	Cooper Miller	do	Dug	36	24	do	do	36	18	do	do	Do.
43	3 miles north of Paris	W. M. Jobe	do	Bored	45	6	do	Ripley	45	40	July 8	do	Do.
44	4 miles northeast of Paris	G. Griffin	Upland	Dug	45½	36	do	do	45½	42	do	do	Do.
45	7 miles northeast of Paris	L. Burton	Hilltop	Bored	65	6	do	do	65	55	July 6	do	Do.
46	2.6 miles east of Elkhorn	E. B. McGehee	Bottom	Drilled	360	6		Paleozoic rocks	20	(c)	do		Do.
47	Elkhorn	T. B. Burton	Hillside	Dug	36	36	Sand	Ripley	36	30	do	Bucket	Do.
48	3 miles east of Paris	R. Dunlap	Hilltop	Bored	34	6	do	do	34	29	do	do	Do.
49a	Paris	Peoples Coal & Ice Co.	do	Drilled	377	8	do	do	377	51	Rept	Air lift [d]	Industrial.
49b	do	City of Paris	Upland	do	375		do	do	375			do [e]	
49c	do	do	do	do	375		do	do	375			do	
49d	do	do	do	do	375		do	do	375			do	
49e	do	do	do	do	375		do	do	375			do	

49f	Paris, well 2	Louisville & Nashville R. R.	do	do	326	14[f] 10[g]	do	do	326	93	Rept.	do[h]	
49g	Paris, well 4	do	do	do	419	18[f] 12[g]	do	do	419			Centrifugal[i]	
50	3 miles west of Paris	W. H. Tompkins	Hilltop	Bored	94	6	do	Holly Springs	94	92	July 16	Bucket	Domestic.
51	6.5 miles west of Paris	Mrs. Wm. Young	do	Drilled	100	2	do	do	100			Lift pump	Do.
52a	2.5 miles east of Como	Midway School	do	Bored	85	6	do	do	85	72	July 16	Bucket	Do.
52b	do	J. E. Mathmay	Hillside	do	52	6	do	do	52	44	do	do	Do.
53	Como	Davis & Mans	do	Drilled	80	2	do	do	80			Lift pump	Do.
54	2.5 miles south of Como	W. H. Lawrence	do	Bored	30	6	do	do	30	17	July 27	Bucket	Do.
55	3.8 miles southeast of Como	J. F. Lawrence	Lowland	do	32	6	do	do	32	21	do	do	Do.
56	2.8 miles south of Paris	Lee Taylor	Hilltop	do	90	6	do	do	90	85	July 16	do	Do.
57	3.3 miles southeast of Paris	E. H. VanDyke		Dug	20	36	do	Residuum	20	14	July 11	do	Do.
58	2.7 miles southeast of Paris	Mrs. J. H. Harris	Hillside	Bored	32	6	do	do	32	26	do	do	Do.
59	1.6 miles southeast of Paris on highway 69.	W. D. Russell	Lowland	Drilled	187	2	do	Ripley	187			Lift pump	Do.
60	3 miles southeast of Paris on highway 69.	P. R. Boothe	Hilltop	Dug	45	36	do	do	45	40	July 10	Bucket	Do.
61	5.4 miles southeast of Paris on highway 69.	Holland and Medlock.	do	Bored	105	6	do	do	105	100	do	do	Do.
62	6.4 miles east of Paris	A. P. Norton	Hillside	do	75	6	do	do	75	71	do	do	Do.
63	7.2 miles east of Paris	E. W. Dunlap	do	Dug	45	36	do	do	45	38	do	do	Do.
64	Springville	Etta Moody	do	Bored	35	6	do	do	35	15	do	do	Do.
65	1.4 miles east of Springville	J. W. Hicks	Upland	do	35	6	do	Eutaw	35	28	do	do	Do.
66	2.4 miles east of Springville	C. A. Love	Hilltop	Dug	34	36	Chert	Devonian	34	31	do	do	Do.
67	1.8 miles south of Springville	J. W. Baucman	do	Bored	64	6	Sand	Ripley	64	55	do	do	Do.
68a	Manleyville	Manleyville School.	Ridgetop	Drilled	80	2	do	do	80	40	do	Lift pump	Do.
68b	0.5 mile northeast of Manleyville.	A. A. Doty	Hilltop	Bored	62	6	do	do	62	57	do	Bucket	Do.
69	6.5 miles southeast of Paris	I. D. Quillen	do	do	50	6	do	do	50	38	July 11	do	Do.
70	3 miles northeast of Henry on Louisville & Nashville R. R.	Q. E. Routon	Upland	do	65	6	do	Holly Springs	65			do	Do.
71	1.5 miles north of Henry	H. B. Allen	Hilltop	Drilled	100	2½	do	do	100	54	Rept.	Lift pump	Do.
72	3 miles northwest of Henry	Carl Wallace	do	Bored	118	6	do	do	118	106	July 27	Bucket	Do.
73	5.4 miles south of Como	C. E. Verdell	Hillside	do	65	6	do	do	65	61	do	do	Do.
74	6.2 miles south of Como	Success School	do	Dug	31	36	do	do	31	28	do	do	Do.
75a	Henry	City of Henry	Upland	Drilled	154	3	do	do	154	50	Rept.	Lift pump	Public supply.
75b	do	do	do	do	165	3	do	do	165	50	do	do	Do.
76	8.2 miles southeast of Paris	R. B. Travik	Hilltop	Bored	90	6	do	do	90	79	July 11	Bucket	Domestic.
77a	10.4 miles southeast of Paris	L. C. Stagnar	Valley	Dug	15	36	do	do	15	6	July 19	do	Do.
77b	do	J. R. Walters	Foot of hill	Bored	20	6	do	do	20	16	July 11	do	Do.
78	4.5 miles east of Mansfield	Wilfred Smith	Hillside	do	30	6	do	Ripley	30	15	do	do	Do.
79	Mansfield	W. R. Cate	do	Drilled	84	2	do	do	84	24	Rept.	Lift pump	Do.
80	3.7 miles west of Mansfield	C. Mathis	do	Bored	38	6	do	Holly Springs	38	31	July 11	Bucket	Do.
81	6.2 miles west of Mansfield	H. C. Barham	Hilltop	do	60	6	do	do	60	40	do	do	Do.
82	3 miles southwest of Henry	J. E. Brown	Upland	do	100	6	do	do	100	85	July 27	do	Do.

[b] Flowing 20 gallons a minute.
[c] Flowing 120 gallons a minute.
[d] Capacity of pump, 275 gallons a minute.
[e] Pumpage, 700,000 gallons a day.
[f] Top.
[g] Bottom.
[h] Capacity of pump, 200 gallons a minute.
[i] Capacity of pump, 600 gallons a minute.

Analyses of waters from Henry County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyses 28, 46, and 75 by D. F. Farrar; the rest by Margaret D. Foster]

	7	15a	22a	28a	33	38b
Silica (SiO_2)	26	17	17	3.5	13	13
Iron (Fe)	6.7	.78	.08	.4	1.2	1.3
Calcium (Ca)	5.6	19	4.4	15	4.5	3.4
Magnesium (Mg)	4.2	3.1	2.0	4	1.7	1.6
Sodium (Na)	2.5	4.0	8.0	3	2.7	3.7
Potassium (K)	1.1	2.4	1.0		1.3	1.3
Bicarbonate (HCO_3)	32	64	15	20	20	12
Sulphate (SO_4)	9.1	14	3.7	35	2.6	4.9
Chloride (Cl)	2.4	3.8	12	5	2.2	4.8
Nitrate (NO_3)	.05	.33	6.0	.3	4.2	3.8
Total dissolved solids	70	97	68	76	56	44
Total hardness as $CaCO_3$ (calculated)	31	60	19	54	18	15
Date of collection, 1929	July 13	July 9	July 12	July 9	July 13	July 16

	46[a]	49a	64	68a	75a	79
Silica (SiO_2)	16	8.4	32	11	3.3	13
Iron (Fe)	.4	2.1	.11	.46	.6	3.6
Calcium (Ca)	52	6.2	19	2.7	6	2.4
Magnesium (Mg)	14	3.1	14	1.1	2	1.2
Sodium (Na)	105	3.0	55	2.3	1	1.5
Potassium (K)	9	1.4	5.9	1.1		.6
Bicarbonate (HCO_3)	196	27	16	25	15	12
Sulphate (SO_4)	47	9.3	44	4.6	9	2.8
Chloride (Cl)	154	2.8	66	2.2	2	1.8
Nitrate (NO_3)	1.2	.08	98	5.3	.2	.33
Total dissolved solids	500	49	355	52	34	30
Total hardness as $CaCO_3$ (calculated)	187	28	105	31	23	11
Date of collection	Oct. 13, 1928.	July 15, 1929.	Sept. 12, 1929.	Oct. 12, 1929.	July 28, 1929.	July 11, 1929.

[a] Hydrogen sulphide (H_2S), 22.0 parts per million.

LAKE COUNTY

[Area 122 square miles. Population 10,486]

GEOGRAPHY

Lake County lies in the northwest corner of Tennessee and is bounded on the west by the Mississippi River. Agriculture is the only activity, and cotton is the principal crop, though some corn and hay are grown.

The whole of Lake County is situated on the alluvial plain of the Mississippi River, and its general altitude is about 290 feet above mean sea level. The surface shows slight irregularities, and in the eastern part there is a well-defined ridge of higher ground. Reelfoot Lake, in the northeastern part of the county, is supposed to have been formed during the New Madrid earthquake of 1811, and it is probable that most of the surface features of the alluvial plain in this section were produced by that earthquake. The lower ground in Lake County is flooded during very high water of the Mississippi River.

GEOLOGY

The surface formation everywhere in Lake County is alluvium, which has a thickness of 100 to 150 feet. This material was laid down by the Mississippi River in its wanderings across the flood plain. It changes rapidly in composition both vertically and horizontally. Lenses and bars of gravel, sand, silt, and clay alternate in an unpredictable manner. As the alluvium contains considerable organic matter and marcasite, the water from it is likely to contain considerable iron, be hard, and have an unpleasant taste. The Jackson formation underlies the alluvium, which in turn is underlain by the Grenada, Holly Springs, and Ackerman formations of the Wilcox group. These formations can not be differentiated in well logs, all consisting of sand intercalated with beds and lenses of clay. Layers of coarse sand in which good wells can be developed are found in the Wilcox group, the total thickness of which is about 1,700 feet. The Porters Creek clay, a hard, tight clay 250 feet thick, underlies the Wilcox and is in turn underlain by the Ripley formation. The Ripley consists of sand and clay and includes at some horizons coarse water-yielding sand. The following log gives a complete section to the underlying Paleozoic rocks:

Log of well of Reelfoot Dome Oil Co., northwest side of Reelfoot Lake at Proctor City

[Authority, De Armand, driller]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Wilcox group—Continued.		
Soil	10	10	Sand, hard, coarse	60	1,080
Sand and gravel	135	145	Gumbo	60	1,140
Jackson formation:			Sand, brown, coarse	125	1,265
Clay, blue-gray, sticky	20	210	Midway group:		
Wilcox group:			Gumbo, sandy	210	1,475
No sample	55	190	Shale, black	25	1,500
Sand and clay, like buttermilk with wood; some reddish	15	225	Gumbo, sandy	80	1,580
Quicksand	75	300	Shale, black	20	1,600
Sand, blue, little clay	80	380	Shale, hard, yellow, fine shells	20	1,620
Sand, gray	103	483	Cretaceous:		
Sand	45	528	Gumbo, sandy	30	1,650
Gumbo	37	565	Shale, black with blue shells and white flint	70	1,720
Sand, hard	20	585	Shale, blue with hard shells of flint and pyrite	230	1,950
Sand, brown, coarse	200	785	Shells and hard sandstone	24	1,974
Sand, hard, and gravel	115	900	Paleozoic:		
Sandrock	50	950	Limestone	101	2,075
Shale, black	70	1,020			

The correlations in the above log are supplied by the writer and differ from those given by Jillson.[95]

WATER RESOURCES

There are no rivers in Lake County. Ponds for watering stock are readily dug. Driven wells are used throughout the county; these average 40 feet in depth. The water is of the usual poor alluvial type.

LOCAL SUPPLIES

At Cornersville wells are from 15 to 30 feet and from 80 to 100 feet deep. The shallow wells go dry during the late summer.

Phillippy has driven wells 15 to 30 feet and drilled wells 70 to 100 feet deep.

[95] Jillson, W. R., Oil-field stratigraphy of Kentucky: Kentucky Geol. Survey, ser. 6, p. 175, 1922.

Ridgely has a public water supply owned by the Southern Utilities Co. Water is derived from the Wilcox group by means of a 6-inch well 668 feet deep, pumped by a vertical centrifugal pump. The water passes through two rapid sand filters and then into a 75,000-gallon elevated tank. The average daily consumption is 100,000 gallons. Analyses of the water before and after treatment are given in the table on page 210 (Nos. 11a, 11).

Log of well of Southern Utilities Co., Ridgely

[Authority, Carloss Well Supply Co.]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Wilcox group—Continued.		
Gumbo	15	15	Clay and sand	58	422
Fine sand	11	26	Fine sand	31	453
Coarse sand and gravel	83	109	Hard clay	9	462
Wilcox group:			Soft clay	13	475
Hard clay	30	139	Hard clay	83	568
Coarse sand	26	165	Medium sand	10	578
Clay and boulders	64	229	Hard clay	43	621
Clay and sand	62	291	Coarse water-bearing sand	47	668
Fine sand	73	364	Hard clay.		

Tiptonville obtains its water from Reelfoot Lake.

Records of wells in Lake County

No.	Location	Owner	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement	Method of lift	Use of water
1	Phillippy, 8.5 miles northeast of Tiptonville on Illinois Central R. R.	J. L. Phillippy	Bottom	Driven	31	1½	Sand	Alluvium	31			Suction pump	Domestic.
2	Bessie	E. F. Wadley	do	do	34	1½	do	do	34			do	Do.
3	Cronanville	Mrs. J. M. Jones	do	Drilled	80	1½	do	do	80			Lift pump	Do.
4	Markham, 6 miles northeast of Tiptonville.	J. T. Yarboro	do	Driven	23	1½	do	do	23			Suction pump	Do.
5	Wynnburg	O. F. Haynes	do	do	35	1½	do	do	35			do	Do.
6	2½ miles east of Wynnburg	T. J. Rogers	do	do	30	1½	do	do	30			do	Do.
7	1 mile south and 1.8 miles east from Wynnburg.	C. Morse	do	do	32	1½	do	do	32			do	Do.
8	2.5 miles west-southwest of Wynnburg.	Mooring School	do	do	40	1½	do	do	40			do	Do.
9	Madie, 1.8 miles north-northeast of Ridgely.	D. Burton	do	do	36	1½	do	do	36			do	Do.
10	3 miles east and 1.2 miles north from Ridgely.	W. L. Willingham	do	do	33	1½	do	do	33			do	Do.
11	Ridgely	Southern Utilities Co.	do	Drilled	670	6	do	Holly Springs	670	18	Rept.	Centrifugal [a]	Public supply.
12	3½ miles west-southwest of Ridgely.	A. C. Taylor	do	Driven	65	1½	do	Alluvium	65			Suction pump	Domestic.
13	3½ miles southwest of Ridgely	H. T. Haines	do	Drilled	110	2	do	Grenada	110			Lift pump	Do.
14	1½ miles south of Ridgely	W. B. Marshall	do	Driven	42	1½	do	Alluvium	42			Suction pump	Do.

[a] Capacity of pump, 250 gallons a minute; pumpage 100,000 gallons a day.

Analyses of waters from Lake County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyzed by D. F. Farrar]

	(a)	5	11a	11b
Silica (SiO_2)	4.5	8	9	4
Iron (Fe)	.3	1.4	1.6	1
Calcium (Ca)	48	88	44	42
Magnesium (Mg)	5	10	3	3
Sodium (Na), Potassium (K)	2	5	1	3
Bicarbonate (HCO_3)	154	296	145	136
Sulphate (SO_4)	12	15	3	9
Chloride (Cl)	3	8	1.5	2
Nitrate (NO_3)	1.3	.7	.1	.1
Total dissolved solids	164	291	140	135
Total hardness as $CaCO_3$ (calculated)	140	261	122	117
Date of collection, 1929	Sept. 17	Sept. 16	Sept. 16	Sept. 16

[a] Public water supply of the city of Tiptonville obtained from Reelfoot Lake.
[b] Treated water.

LAUDERDALE COUNTY

[Area 456 square miles. Population 23,406]

GEOGRAPHY

Lauderdale County is bounded on the west by the Mississippi River and lies midway between the northern and southern boundaries of Tennessee. Lumbering and farming are the only activities. Cotton is the principal crop, with corn second. Strawberries and tomatoes are raised for northern markets, and dairying is becoming of increased importance. Lumbering is carried on in the Mississippi bottoms, cypress and gum being cut. The bottoms are swampy, subject to flooding at periods of high water, and therefore but sparsely settled and in large part still uncleared.

The Mississippi River washes the foot of the bluffs at Fulton, in the southern part of the county, but the alluvial plain attains a width of about 5 miles in the north. The surface of the plain is slightly irregular, both lakes and sloughs being found on it. At the bluffs the land rises abruptly to the upland surface, in many places 150 feet or more higher. Adjacent to the bluffs the upland or plateau surface is deeply incised, and owing to the ability of the surface formation to stand in vertical faces the valleys are very narrow and steep-sided. The remainder of the plateau has a rolling surface, and the land along the South Fork of the Forked Deer River and the Hatchie River is level.

GEOLOGY

The surface formation of the flood plain of the Mississippi River is alluvium, which consists of clay, sand, and gravel laid down in irregular bodies. The alluvium is characterized by abrupt changes both horizontally and vertically from one material to another. This is illustrated by the following log of a test boring made by the Mississippi River Commission at Ashport.[96]

[96] United States Mississippi River Comm. Progress Rept., p. 196, 1881.

Log of boring No. 1, Ashport

	Thick-ness (feet)	Depth (feet)	Diameter of grains (inches)	
			Aver-age	Great-est
1. Sandy loam	0.3	0.3	0.127	0.254
2. Sandy loam	8.1	8.4	.036	.10
3. Sandy yellow clay, finer; pasty on bringing to surface	1.4	9.8	.025	.051
4. Bluish clay. From 8.4 to 9.8 feet, coarse bluish sand; 9.8 to 11.8 feet, blue clay; 11.8 to 14.5 feet, gradually coarser in texture; 14.5 to 15 feet tenacious clay; pasty to 16 feet; 16 to 16.4 feet, stiff; 16.4 to 19.8 feet, pasty. All these were pronounced clay. 19.8 to 20 feet, stiff clay. All specimens mentioned as stiff or tenacious less than 0.008 millimeter	10.2	20.0	.013	.051
5. Mud, 50 per cent	1.3	21.3	.025	.051
Coarse sand, 50 per cent			.51	1.27
The usual fine sand succeeding clay corresponding in color, growing coarser. No marked division between Nos. 5, 6, 7, and 8, though one that could not be located was suspected in the specimen marked 5 between sand and mud.				
6. Sand	4.7	26.0	.62	1.27
7. Sand, 50 per cent	1.4	27.4	.62	1.27
Gravel, 50 per cent			2.54	4.23
8. Sand, 50 per cent	2.3	29.7	.726	1.27
Gravel, 50 per cent			4.23	[a] 3.81
9. Blue clay	.9	30.6	.0127	.062
10. Blue sand; a small amount of lignite at 41 feet	13.4	44.0	.51	1.27
11. Blue clay	.2	44.2	.0127	.051
12. Sand	9.8	54.0	.85	1.27
13. Sand, 75 per cent	3.5	57.5	.85	1.27
Gravel, 25 per cent			12.7	[a] 5.08
14. Lignite of different ages	1.8	59.3	------	------
15. Sand, 25 per cent	1.8	61.1	.85	1.27
Gravel, 75 per cent			5.1	1.27
16. Sand, 55 per cent	13.7	74.8	1.0	1.27
Gravel, 45 per cent			2.1	[a] 5.71
Ball of sand, gravel, and lignite from depth of 62 feet.				
17. Sand, 67 per cent	10.4	85.2	.85	1.27
Gravel, 33 per cent			3.2	[a] 4.45
18. Lignite, 10 per cent	4.8	90.0	------	------
Sand, 45 per cent			3.2	1.27
Gravel, 45 per cent			8.5	[a] 5.08
19. Sand, 67 per cent	4.0	94.0	.51	1.27
Gravel, 33 per cent			6.2	[a] 4.45
20. Sand, 80 per cent	2.7	96.7	.51	1.27
Gravel, 20 per cent			2.1	6.4
21. Sand, 33 per cent	9.3	106.0	.85	1.27
Gravel, 67 per cent			12.7	[a] 75.08
22. Sand	4.3	110.3	.51	1.27
23. Mud, 10 per cent	4.7	115.0	.025	------
Sand, 23 per cent			.51	1.27
Gravel, 67 per cent			4.2	[a] 1.88
24. Sand, fine	5.0	120.0	.17	.51

[a] Centimeters.

As the alluvium contains considerable organic matter and marcasite (a sulphide of iron), the waters derived from it are variable in composition. The alluvium is about 100 feet thick. From the bluffs eastward the surface of Lauderdale County is covered with a mantle of loess. The loess has a maximum thickness of 90 feet at the bluffs, where it is excellently exposed and can be readily studied, but thins to not more than 10 feet at the eastern boundary of the county. Pliocene sand and gravel underlie the loess in the high areas west of State highway 3, but east of this highway the gravel is missing. The thickness of the gravel is variable. The maximum exposed thickness in the bluffs is 20 feet, but William Kimmerling reports that two layers of gravel encountered in a well at Dry Hill had a combined thickness of 60 feet. This thickness is exceptional. The gravel is not uniform either in thickness or in distribution. It probably underwent some erosion before the loess was deposited. The Pliocene gravel is an excellent source of water.

Below the alluvium and the Pliocene sand and gravel, deposits of Eocene age are found throughout the county. From younger to older these are the Jackson formation, the Grenada, Holly Springs, and Ackerman formations of the Wilcox group, and the Porters Creek clay of the Midway group. It is impossible to differentiate the Jackson and Grenada formations from each other. The Jackson consists of beds of fine sand and interstratified clay, with rather characteristic layers of lignite. Some small layers or lenses of coarse sand occur, but they are irregular in distribution and not common. What has been said of the Jackson is true of the upper part of the Grenada, which is characteristically fine grained; layers of fine sand alternate with layers of clay, and lignite is also present. In general the Jackson and top part of the Grenada are poor sources of water, for it is difficult to find a sufficient thickness of sand coarse enough to be checked by a strainer to finish a well in. The lower part of the Grenada is coarser grained and contains thicker layers of sand. The Holly Springs formation consists of medium to coarse grained sand with intercalated lenses of clay. This is a good water bearer, and it is from this formation that large supplies of water are developed. In Lauderdale County no well has been drilled to the Ackerman formation, but a deep well at Blytheville, Ark., probably penetrates this formation and shows that the Ackerman contains beds of water-bearing sand as much as 60 feet in thickness. The water is under artesian pressure and rises above the level of the river bottoms. The Porters Creek is a clay formation and does not yield water. The total thickness of the Eocene beds is from 1,100 to 1,600 feet, divided between the Jackson, 70–120 feet; Grenada, 350–425 feet; Holly Springs, 350–425 feet; Ackerman, 100–330 feet; and Porters Creek, 250–300 feet. The Eocene deposits are underlain by the Ripley formation, which contains layers of coarse, water-yielding sand.

Log of well at Blytheville, Ark.

[Authority, W. P. Maingault]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Wilcox group—Continued.		
Top soil	20	20	Clay	3	879
Fine dirty sand	15	35	Sand	166	1,045
Coarse brown sand	35	70	Hard brown clay	5	1,050
Gravel	10	80	Soft clay	6	1,056
Coarse brown sand	55	135	Sand	9	1,065
Jackson formation:			Clay	8	1,073
Hard brown clay	5	140	Rock	1	1,074
Blue clay; bottom of 14-inch pipe at 141.50 feet	41	181	Clay	73	1,147
			Rock	1	1,148
Streaks of sand and clay	32	213	Clay	27	1,175
Wilcox group:			Rock	3	1,178
Clean sand	182	395	Clay	1	1,179
Clay	5	400	Rock	2	1,181
Sand	32	432	Clay	25	1,206
Clay	51	483	Sand	26	1,232
Sand	19	502	Clay	8	1,240
Clay	8	510	Sand	20	1,260
Sand	35	545	Rock	3	1,263
Clay	25	570	Clay	5	1,268
Sand	121½	691½	Sand	4	1,272
Clay	15½	707	Rock	2	1,274
Sand	39	746	Shale	2	1,276
Appears to be clay; do not know	21	767	Sand and lignite	6	1,282
			Clean sand	68	1,350
No record taken by Mr. Lanham	19	786	Sand and lignite	23	1,373
Sand	19	805	From 1,373 on down to below 1,450 feet was sand except one small streak of clay between 3 and 5 feet thick.		
Clay	9	814			
Streaks of sand and clay	57	871			
Rock	5	876			

WATER RESOURCES

Though streams are abundant in Lauderdale County the practice of watering stock, especially cows, from wells is becoming more prevalent. Springs are abundant along the foot of the bluffs and are used. In the bottoms driven wells are employed. Some of them supply a fair water, but generally it is desirable to go deeper to the Grenada. The fact that water from the Pliocene gravel is hard and the ease of making cisterns makes cistern water supplies popular, especially where it is necessary to go very deep for wells. Of the 53 wells listed in the table, 9 are bored and average 52 feet in depth, whereas 42 are drilled and average 202 feet in depth.

LOCAL SUPPLIES

At Arp and in the surrounding country drilled wells are from 175 to 300 feet deep. The differences in depth are determined by the need of finding a sand sufficiently coarse to be checked by a strainer. There is a spring at the bottom of the hill at Arp.

Ashport is on the Mississippi River. Driven wells 20 to 25 feet deep obtain sufficient water for domestic needs. If the water is palatable such wells are used; otherwise wells about 100 feet deep are drilled.

At Curve cisterns are largely used, though there are some pipe wells 120 to 150 feet deep. The log of the abandoned well of the Illinois Central Railroad is as follows:

Log of abandoned well of Illinois Central Railroad, Curve

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Brown soil and alluvial deposit	14	14	Dark-gray clay	10	210
Red sand	13	27	Clay and lignite	20	230
White sand	43	70	Lignite	10	240
Yellow sand; streaks of clay	30	100	Dirty sand and clay	87	327
Fine gray sand	25	125	Dirty quicksand	38	365
Gray sand and lignite	5	130	Hard blue clay	25	390
White sand	30	160	Dark-blue lignitic clay	60	450
Fine cherty gray sand	20	180	Coarse water-bearing sand	36	496
Dark-gray clay, also lignite and decayed vegetation	20	200			

In the vicinity of Double Bridges the loess is about 35 feet deep. This is underlain by fine white sand. Both bored and drilled wells are used; the bored wells are from 30 to 80 feet deep and the drilled wells 60 to 125 feet.

At Dry Hill the loess is 80 feet deep and this is underlain by 60 feet of sand and gravel, which is in turn underlain by sand. This lower sand is coarse enough to be checked by a strainer, and wells from 180 to 200 feet deep derive water from it. Cisterns are still largely used in this neighborhood.

At and near Durhamville bored wells are largely used. Deep wells must go as much as 400 feet.

Log of well of E. R. Anthony & Co., Durhamville

[Authority, William Kimmerling, driller]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Brown surface clay	20	20	Gray medium-grained sand	25	425
Fine brown sand interstratified with clay	50	70	Hard blue clay (soapstone)	75	500
Hard blue and plastic clay	90	160	Medium coarse sand	25	525
Medium hard clay	180	340	Very hard clay; cuts like sand but washing shows only clay	81	606
Fine silty sand	50	390	Very coarse sand.		
Plastic clay	10	400			

At Edith cisterns are still generally used. Wells range from 158 to 196 feet in depth.

Log of deep well at Edith

[Authority, William Kimmerling, driller]

	Thickness (feet)	Depth (feet)
Loess	80	80
Alternating layers of sand and gravel	60	140
Pipe clay	50	190
Sand	6	196

On top of the bluffs at Fulton cisterns are used almost exclusively. Wells obtain water at 100 to 110 feet. On the second bottom wells 30 to 40 feet are in use, and on the first bottom driven wells 17 to 30 feet deep obtain enough water for household needs.

At Gates bored wells obtain small supplies of water from 30 to 80 feet. Larger supplies are derived from drilled wells 100 to 350 feet deep.

In some places in Glimp a thin layer of sand is found at 60 to 80 feet. If this is not encountered it is necessary to go from 200 to 331 feet to obtain a sand sufficiently coarse to finish a well in.

Log of gin well at Glimp

[Authority, William Kimmerling, driller]

	Thickness (feet)	Depth (feet)
Brown clay	40	40
Stiff blue clay	20	60
Variegated red and yellow clay, sand in various colors, and intermixed gravel	15	75
Blue clay and pipe clay	75	150
Lignite	5	155
Plastic pipe clay	12	167
Fine silty sand; layer of lignite about 200 feet	33	200
Very tough blue-gray clay	100	300
Sand growing progressively coarser with depth	31	331

Halls has a public water supply owned by the West Tennessee Power & Light Co. Water is obtained from three 8-inch wells 180 feet deep. The wells are pumped by plunger pumps each having a capacity of 100 gallons a minute. The water flows to a sedimentation tank, from which it is pumped to a 50,000-gallon head tank. In addition there is a 100,000-gallon reservoir. The average daily consumption is 96,000 gallons. The water is moderately hard, containing 160 parts per million of total hardness. (See analysis 6.)

The public water supply at Henning, which is owned by the Henning Ice & Coal Co., derives water from one 3-inch well 50 feet deep, one 4-inch well 420 feet deep, and one 4-inch well 440 feet deep. The first two wells are pumped by electrically driven force pumps, the third by a Cook steam head. Water is pumped directly into the system, but there is a 40,000-gallon overhead tank. The average daily consumption is 40,000 gallons. Water from the shallow well is moderately hard; water from the deep wells is much softer but has a very high iron content. (See analyses 38a, 38b.)

Log of well of A. V. Johnson, 2.5 miles west of Henning

[Authority, William Kimmerling, driller]

	Thickness (feet)	Depth (feet)
Brown clay (loess)	20	20
Blue mud	15	35
Blue clay	5	40
Heavy brown clay	87	127
Very fine silty gray sand	18	145
Pipe clay	10	155
Fine gray sand	20	175
Hard gray clay; a streak of lignite in it	50	225
Gray sand, a little coarser than 155 to 175 feet	13	238
Hard dark-colored pipe clay	37	275
Interstratified very hard clay and medium-grained sand in layers from 6 inches to 2 feet thick	21	296
Sand which grows progressively coarser; sand at bottom was coarser than 0.25 millimeter	22	318

At Mack drilled wells 90 to 100 feet deep obtain water but in the Hatchie River bottom driven wells 20 to 40 feet deep are used. A deep well drilled on the north side of the road a mile west of Mack has the following log:

Log of well 1 mile west of Mack

[Authority, William Kimmerling, driller]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Silty sand	60	60	Medium coarse sand	30	490
Gravel	2	62	Hard clay	135	625
Gray sand and clay (looks like ashes)	138	400	Very coarse sand.		
Fine sand	60	460			

At Orysa bored wells from 30 to 60 feet in depth are used, but there is one well 398 feet deep.

Log of well of E. E. Foust, Orysa

[Authority, William Kimmerling, driller]

	Thickness (feet)	Depth (feet)
Soil	4	4
White sandy clay	31	35
Brown and yellow sand and yellow interstratified clay; the sand is very fine	10	45
Gray water sand, fine	15	60
Clay	40	100
Hard blue-gray clay (soapstone)	75	175
Fine sand	8	183
Hard blue-gray clay (soapstone)	48	231
Rock, 14 inches thick	1	232
Hard blue-gray clay (soapstone)	108	340
Very fine gray sand which grows coarser	45	385
Very coarse sand	13	398

The public water supply at Ripley, owned by the West Tennessee Power & Light Co., has an 8-inch well 694 feet deep and a 10-inch well 695 feet deep. The wells are 100 feet apart. Both are pumped by air lift, and the water flows into a sedimentation tank, where half a grain of alum per gallon is added. From the sedimentation tank the water flows by gravity to three gravity filters, thence into a 150,000-gallon reservoir. From the reservoir the water is pumped by three centrifugal pumps, each yielding 350 gallons a minute, into a 100,000-gallon elevated tank. The average daily consumption is 140,000 gallons. Alum is added to the water to flocculate the iron hydroxide and accelerates its precipitation in the sedimentation tank. The iron hydroxide could be removed by the filter without using the alum, but the filters would become dirty more quickly and need washing more often, and the cost of the additional washing of the filters would be greater than the cost of the alum. The chemical composition of the water before and after treatment is shown by analyses 21 and 21a.

Records of wells in Lauderdale County

No.	Location [a]	Owner	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement	Method of lift	Use of water
1	3.4 miles north of Halls on highway 3.	A. Mathias	Lowland	Bored	20	6	Sand	Alluvium	20	16	Aug. 31, 1929	Bucket	Domestic.
2	5.7 miles northwest of Halls	G. C. Meadows	Upland	Drilled	80	2	do	Jackson	80			Lift pump	Do.
3	6.5 miles northwest of Halls	W. D. Dodson	Second bottom.	Spring						([b])	Sept. 2, 1929		Do.
4	Double Bridges, 3.8 miles west-northwest of Halls.	W. M. Kenley	Upland	Bored	32	6	Sand	Jackson	32	26	do	Bucket	Do.
5	1.9 miles west-northwest of Halls.	C. B. Sloan	do	Drilled	107	2	do	do	107			Lift pump	Do.
6a	Halls	West Tennessee Power & Light Co.	Lowland	do	181	8	do	Grenada				Lift pump, electric.[c]	
6b	do	do	do	do	178	8	do	do				do [c]	
6c	do	do	do	do	178	8	do	do				Lift pump steam.[c]	
7a	Nankipoo, 4.8 miles west-southwest of Halls.	J. E. Wright	Upland	Drilled	47	2	Sand	Jackson	47	20	Rept.	Lift pump	Domestic.
7b	do	L. E. Olds	do	do	310	2	do	Grenada	310			do	Do.
7c	do	do	do	do	190	2	do	do	190	60	Rept.	do	Do.
8	7.4 miles west of Halls	W. E. Crews	Ridge	do	128	2	do	Jackson	128			do	Do.
9	Edith, 6.8 miles west of Gates	Mrs. James Hunt	Upland	do	196	2	do	Grenada	196			do	Do.
10	3.8 miles west of Gates	Dry Hill School	Hilltop		200	2	do	do	200			do	Do.
11	1.7 miles west-southwest of Gates.	Halley Pinington	Upland	Bored	63	6	do	Jackson	63	58	Sept. 5, 1929	Bucket	Do.
12a	Gates	Gates Gin Co	Lowland	Drilled	328	2	do	Grenada	328			Lift pump	Industrial.
12b	do	M. A. Whitaker	do	do	100	2	do	Jackson	100			do	Domestic.
13	1.2 miles east-northeast of Curve.	Mrs. J. F. Rasberry.	Upland	do	125	2	do	do	125			do	Do.
14	2 miles northwest of Curve	M. J. Boyd	do	do	124	2	do	do	124			do	Do.
15	3.3 miles west of Curve	Bexar School	do	do	125	2	do	do	125			do	Do.
16	4.8 miles west-southwest of Curve.	Central School	do	do	140	2	do	do	140			do	Do.
17	4 miles northwest of Ripley	F. A. Halfacre	do	do	150	2	do	do	150			do	Do.
18a	2.5 miles north-northwest of Ripley.	G. Caldwell	Hilltop	do	237	2	do	Grenada	237			do	Do.
18b	do	I. C. Greer	Foot of hill	do	90	2	do	Jackson	90			do	Do.

[a] Distances scaled from county health map.
[b] Flowing 1 gallon a minute.
[c] Capacity of pump, 70 gallons a minute.

Records of wells in Lauderdale County—Continued

No.	Location [a]	Owner	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement	Method of lift	Use of water
19	3.5 miles northeast of Ripley on highway 3.	A. J. Shand	Lowland	Bored	50	6	Sand	Jackson	50		Sept. 5, 1929	Bucket	Domestic.
20	2.8 miles northeast of Ripley	Whitefield School	Hilltop	Drilled	165	2	do	do	165			Lift pump	Do.
21	Ripley	West Tennessee Power & Light Co.	Hillside	do	695		do	Holly Springs	154		July, 1928	Air lift [d]	Public supply.
22	3 miles west of Ripley on highway 19.	E. L. Grammer	do	do	225	2	do	Grenada	225			Lift pump	Domestic.
23	4.6 miles west of Ripley on highway 19.	J. D. Morris	Hilltop	do	250	2	do	do	250			do	Do.
24	7.6 miles west of Ripley on highway 19.	B. Chatman	Second bottom.	Driven	25	2	do	Alluvium	25			Suction pump	Do.
25	12.2 miles west of Ripley on highway 19.	Ashport School	Bottom	do	23	1½	do	do	23			do	Do.
26	Ashport	E. C. Connor	do	Drilled	100	1½	do	do	100			do	Do.
27a	Lightfoot, 7.5 miles west-southwest of Ripley.	A. N. Crowder	Upland	do	87	2	do	Jackson	87			Lift pump	Do.
27b	do	W. F. Roberson	do	do	350	2	do	Grenada	350			do	Do.
28	4 miles west-southwest of Ripley.	J. W. McMahan	Hillside	Bored	45	6	do	Jackson	45	37	Sept. 6, 1929	Bucket	Do.
29	1.6 miles southeast of Ripley	Clyde Johnson	Hilltop	Drilled	165	2½	do	do	165			Lift pump	Do.
30	3.7 miles southeast of Ripley on highway 19.	A. D. Johnson	do	do	205	4	do	Grenada	200			do	Do.
31	3.2 miles south-southeast of Ripley.	H. Arnold	Upland	do	260	2¼	do	do	260			do	Do.
32	3.8 miles south-southwest of Ripley on highway 3.	J. Turner	do	Bored	36	6	do	Pliocene	36	30	Sept. 8, 1929	Bucket	Do.
33	6.7 miles southwest of Ripley	E. A. Best	Hilltop	do	82	6	do	do	82			Lift pump	Do.
34	0.5 miles south of well 33	D. Conrad	do	do	53	6	do	do	53	36	Sept. 6, 1929	Bucket	Do.
35	Lockett, 7 miles west-northwest of Henning.	Luckett School	Upland	Drilled	90	2	do	Jackson	90			Lift pump	Do.
36a	Glimp, 4.6 miles west of Henning.	T. N. Hopper	do	do	256	2	do	Grenada	256			do	Do.
36b	do	Glimp School	do	Bored	67	6	do	Pliocene	67	42	Sept. 6, 1929	Bucket	Do.
37a	2.4 miles west of Henning	W. T. Mitchell	Hillside	do	50	6	do	do	50	35	do	do	Do.
37b	do	A. V. Johnson	do	Drilled	318	2	do	Grenada	318			Lift pump	Do.
38a	Henning	C. S. O. Rice	Lowland	do	275	3	do	do	275	40	Rept.	do	Do.
38b	do	Henning Ice & Coal Co.	do	do	50	4	do	do	50			do	Public supply.

38c	do	do	do	do	440	4	do	do	440			do	Do.
39	3.5 miles east of Henning	W. J. Rose	Upland	Bored	35	6	do	Pliocene	35	30	Sept. 6, 1929	Bucket	Domestic.
40a	Durhamville	E. R. Anthony & Co.	do	Drilled	425	2½	do	Grenada	425		do	Lift pump	Do.
40b	do	do	Lowland	do	75	3	do	Jackson	75	1	do	do	Do.
41a	Orysa, 3.2 miles south of Durhamville.	E. E. Foust	Upland	do	398	3	do	Grenada	398			do	Do.
41b	do	M. E. Rice	do	Bored	50	6	do	Pliocene	50	30	Sept. 6, 1929	Bucket	Do.
42	2 miles south-southwest of Henning.	J. R. Crutcher	do	Drilled	480	2	do	Grenada	480			Lift pump	Do.
43	6 miles west-southwest of Henning.	J. D. Jenning	do	do	180	2	do	Jackson	180			do	Do.
44	Cherry	W. P. Winn	do	do	85	2	do	do	85			do	Do.
45	Mack, 3.8 miles west of Cherry.	McKenney Hutchison.	Ridgetop	do	97	3	do	do				do	Do.
46	Fulton	Wallace and Andrews.	Upland	do	107	1½	do	do	107	100	Rept.	do	Do.

[d] Capacity of pump, 250 gallons a minute; pumpage, 140,000 gallons a day.

Analyses of waters from Lauderdale County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyzed by Margaret D. Foster]

	6	9	12b	21	([a])	25	38b	38c
Silica (SiO_2)	22	17	14	14	11	26	41	12
Iron (Fe)	1.7	1.8	41	6.1	.04	1.7	.02	5.6
Calcium (Ca)	33	68	15	18	18	97	38	17
Magnesium (Mg)	19	41	9.4	10	10	34	24	8.7
Sodium (Na)	5.7	7.6	5.1	6.1	5.7	2.0	5.9	6.9
Potassium (K)	1.1	.9	1.8	1.6	1.6	1.5	1.2	1.6
Bicarbonate (HCO_3)	196	410	102	113	111	434	185	105
Sulphate (SO_4))	7.1	4.5	4.1	6.6	7.2	16	8.0	6.3
Chloride (Cl)	1.8	2.4	1.7	2.0	2.0	6.8	14	2.1
Nitrate (NO_3)	.10	13	.05	.15	.10	2.6	29	.05
Total dissolved solids	176	349	94	107	103	373	236	101
Total hardness as $CaCO_3$ (calculated)	160	338	76	86	86	382	193	78
Date of collection, 1929	Sept. 7	Sept. 9	Sept. 7	Sept. 7	Sept. 7	Sept. 9	Sept. 6	Sept. 6

[a] Treated water from well 21.

MADISON COUNTY

[Area 552 square miles. Population 51,059]

GEOGRAPHY

Madison County is almost in the center of western Tennessee. Jackson, the county seat, is the second largest city in the area, having a population of 22,172. The city is a railroad center, being served by the Illinois Central, the Nashville, Chattanooga & St. Louis, and the Gulf, Mobile & Northern Railroads, and is a distributing point for the surrounding country. There is a cotton mill at Bemis, near by. Agriculture is the principal activity, and though some spring vegetables are raised, cotton is the main crop.

The South Fork of the Forked Deer River flows across the middle of the county in a northwesterly direction. Its flood plain is from 1 to 3 miles wide. With the exception of the valley of the Middle Fork of the Forked Deer, in the northern part of the county, the remainder of the county is very hilly. Though no determinations of altitude in the hilly section are available, it can be safely said that the high land in the southeastern part of the county attains an altitude of 550 feet above sea level.

GEOLOGY

A narrow band of the Ripley formation, not exceeding a mile in width, crops out along the southeastern boundary of Madison County. The thickness of this formation is not definitely known, for the partial log of the Baum oil test well, the only well in the county to pass through the Ripley, is too fragmentary to give any precise information. It is probably about 500 feet thick, and as it dips to the west at 20 to 30 feet to the mile it is found at progressively greater depths toward the west. The Ripley formation is a good source of water. The static level of the water ranges from about 400 feet above sea level at Pinson to about 350 feet at the western boundary of the county.

Log of Baum well, about 5 miles southeast of Jackson

	Thickness (feet)	Depth (feet)
Ripley formation:		
Sand and gumbo	174	734
Gumbo	51	785
Coon Creek tongue of Ripley formation or Selma clay:		
Gumbo and 3 feet of hard shale	19	804
Shale	22	826
Gumbo	61	887
Gumbo and 1 foot of shale	20	907
Eutaw formation:		
Gumbo	136	1,043
Soft sandstone	8	1,051
Gumbo	49	1,110
Paleozoic: Hard brown carboniferous sandstone	51	1,115

Overlying the Ripley is the Clayton formation. Its outcrop area is small, and its thickness does not exceed 30 feet. The Clayton is a glauconitic sand and, though it yields water, the water is of poor quality.

The outcrop of the overlying Porters Creek clay crosses Madison County in a direction a little east of north as a band about 5 miles wide. The Porters Creek, which is about 250 to 275 feet thick, consists of plastic gray clay with a characteristic hackly structure. It does not yield water but serves as a confining bed for the water in the underlying Ripley formation.

The Holly Springs sand of the Wilcox group crops out over most of the county. It consists predominantly of sand, though it contains large lenses of clay. It is an excellent source of water wherever it occurs. It ranges in thickness from a featheredge at its contact with the Porters Creek formation to about 400 feet at the western boundary of the county. In the western part of the county the Ackerman formation may occur in depth between the overlying Holly Springs sand and the underlying Porters Creek clay.

WATER RESOURCES

The many streams in Madison County are used for watering stock, and where streams are not available ponds are dug. Though springs are found at the foot of the hills they are no longer much used. There are very few dug wells in the county. In the outcrop area of the Holly Springs and Ripley formations bored wells from 35 to 160 feet in depth are most commonly used for domestic water supplies, although there are some drilled wells. In the upland areas the water table may be as much as 150 feet below the surface. In the outcrop area of the Porters Creek and for a distance of 1 or 2 miles west of the outcrop it is necessary to drill to the Ripley formation to obtain water. These wells are from 225 to 600 feet deep. The static level of the water in the Ripley formation ranges from 400 feet at Pinson to 350 feet at the western edge of the county, and in land of lower elevation wells drilled through the Porters Creek clay will flow. Such flowing wells are found in the valley of the South Fork at Pinson and Jackson and could be obtained elsewhere in the valley. The depth of such wells would be progressively greater toward the west. Needless waste of the artesian water from the Ripley formation should be stopped, for increased yield is obtained only by decreasing the head. As more and more wells are drilled the water level will drop, and, though this is unavoidable, needless wells lower the head to no purpose.

LOCAL SUPPLIES

At Beech Bluffs, in the valley of the South Fork, springs are numerous and are used for domestic supplies. Wells about 30 feet deep obtain water from Ripley sand, and wells about 150 feet deep pass through a clay lens that forms a local artesian basin, so that these wells flow.

Bemis, in the valley of the South Fork, is supplied with water by the Bemis Brothers Bag Co., which has three wells—one well 174 feet deep, one 24-inch well 166 feet deep, and one 2-inch well 430 feet deep. The 174 foot and 166-foot wells, both of which obtain water from the Holly Springs sand, are pumped by centrifugal pumps and yield 370 and 400 gallons a minute, respectively. The 166-foot well has a drawdown of 62 feet. The water is pumped to a 110,000-gallon aeration pool, and thence into a 50,000-gallon elevated tank. The 430-foot well penetrates the Ripley formation and flows at the rate of 38 gallons a minute.

Log of 430-foot well of Bemis Bros. Bag Co., Bemis

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Holly Springs sands:			Porters Creek clay—Continued.		
Red and white clay	21	21	Blue clay	13	294
Sand and clay	20	41	Sandstone	1	295
Water-bearing sand	29	70	Blue clay	75	370
Blue clay	75	145	Clayton formation: Black water-bearing sand (flowing 3½ gallons a minute)	15	385
Sand	10	155	Ripley formation. Alternate thin layers of sandstone, clay, and sand	55	430
Sandstone	2	157			
Porters Creek clay:					
White clay	38	195			
Hard blue clay	95	280			
Sandstone	1	281			

Log of 166-foot well of Bemis Bros. Bag Co., Bemis

[Authority, Kelly Well Co.]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Filled in	8	8	Yellow sandy clay	35	130
Sandy clay	16	24	Yellow sand	4	134
Streaks of red clay, white clay, and sand	31	55	Hard sandy clay	21	155
Quicksandy clay	20	75	Blue sand	9	164
Blue sandy clay	20	95	Blue clay.		

Carroll is in the valley of Deer Creek, a tributary of the Middle Fork of the Forked Deer River. The water table stands 5 feet below the surface, and shallow wells 20 feet deep obtain an abundance of water.

At Claybrook bored wells from 40 to 90 feet deep obtain water from the Holly Springs sand.

At Denmark dug wells obtain water in the alluvium, and drilled wells obtain water from the Holly Springs sand at about 100 feet.

Five Point is on the eastern edge of the Porters Creek outcrop. Here the formation is about 18 feet thick. Shallow wells 25 to 50 feet deep obtain water in the underlying Ripley formation. West of Five Point wells must pass through greater and greater thicknesses of Porters Creek to penetrate the Ripley formation.

Huntersville is underlain by 20 feet of sandy clay, followed by 50 feet of yellow sand. Below this sand is about 20 feet of clay which is underlain by coarse yellow sand. Either dug wells about 50 feet deep or drilled wells 100 to 120 feet deep are used.

The city of Jackson has a public water supply. (See analyses 15a and 15c.) Water is obtained from four wells 32 inches in diameter and from 140 to 152 feet in depth. These wells are gravel-wall wells and have a specific yield of 11 to 18 gallons per foot of drawdown. A log of one of the wells is as follows:

Log of well 3, Jackson well department

[Authority, Kelly Well Co.]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Blue and yellow clay	7	7	Yellow sand and clay balls	13	85
Blue clay and quicksand	7	14	Red sand and clay	7	92
Yellow sand	4	18	White sand and red clay	12	104
Yellow sand and clay balls	47	65	Hard packed sand, clay balls	41	145
Fine sand and clay	3	68	Sand and clay	7	152
Fine sand and stone	4	72			

The wells are pumped by turbine centrifugal pumps, which deliver the water to a steam triple-expansion direct-action pump of the fly-wheel type, having a capacity of 6,000,000 gallons a day. The water goes to the mains under direct pressure. The average daily consumption is 3,400,000 gallons. The city also has a 12-inch well 130 feet deep and a 12-inch well 480 feet deep. The deep well obtains water from the Ripley formation and flows 300 gallons a minute. This water is not used in the city system, owing to its high iron content. The well was formerly 525 feet deep. The following log is given by Glenn:[97]

Log of city well, Jackson

	Thickness (feet)	Depth (feet)
Holly Springs sand:		
Clay, sandy, red	12	
Clay, tough, blue	16	28
Sand, coarse, white	12	40
Clay, snow-white, very tough	6	46
Sand, nearly pure white; some small gravel and thin ironstone crusts; water bearing at base	60	106
Clay at top, light colored; lower part variegated, red, yellow, etc	43	149
Sandstone, dark, brick-red, soft	11	160
Porters Creek clay: Clay, fine, leaden-colored	170	330
Clayton formation: Rock, hard, dark	5	335
Ripley formation:		
Sand, white, with water	13	348
Quicksand, white, very micaceous	28	376
Shales, dark leaden-colored, with hard streaks of micaceous sandy material, lignite fragments, and iron pyrite (at about 418 feet shark teeth)	72	448
Sand, white, water bearing	77	525

[97] Glenn, L. C., op. cit., p. 98.

The water from the Ripley formation (see analysis 15c) is quite similar to the water from the Holly Springs sand (see analysis 15a). It contains a little more iron, but the iron content of the Holly Springs water is also sufficiently high to make treatment desirable. Aeration followed by filtration or sedimentation would effectively remove the iron from either of these waters. The industries that consume much water have their own wells which are listed in the well tables. They obtain water from either the Holly Springs or the Ripley formation. At present almost 4,000,000 gallons a day is pumped from the Holly Springs sand and about 1,300,000 gallons a day from the Ripley formation. The original static level of water in the Holly Springs formation is not known; the present level is about 326 feet mean sea level.

At Malesus bored wells about 65 feet deep are universally used.

The depth to water at Medon is about 60 feet. Either drilled or bored wells from 75 to 80 feet deep are in use.

Mercer is in the valley of Black Creek. Many springs are found at the foot of the hills, but these are no longer used, being supplanted by dug wells about 30 feet deep. On the upland drilled wells about 150 feet deep are widely used.

Log of well of Ernest Elston, Mercer

	Thickness (feet)	Depth (feet)
Mostly pipe clay	85	85
Sand, water	5	90
Pipe clay	2	92
Sand	64	156

At Neelys a good water sand is found at depths of 100 to 175 feet. The lower part of the sand is coarse. Bored wells about 120 feet deep or drilled wells about 160 feet deep are used.

Pinson is in the valley of the South Fork, in the outcrop area of the Porters Creek clay. To obtain water it is necessary to drill through the Porters Creek to the underlying Ripley formation. The Porters Creek is about 220 feet thick in Pinson but is slightly thinner to the east and thicker to the west. As the altitude of Pinson is 388 feet above mean sea level the wells flow.

At Spring Creek there are bored and drilled wells from 50 to 100 feet deep.

The water table at Uptonville is 140 feet or more deep. Bored and drilled wells 150 to 200 feet deep obtain abundant water.

Records of wells in Madison County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
1a	0.5 mile west of Spring Creek.	R. W. Pierce	Hillside	450	Bored	50	6	Sand	Holly Springs	50	45	Aug. 8	Bucket	Domestic.
1b	Spring Creek, east of highway.	Y. Y. Utley	Hilltop	500	do	60	6	do	do	60	45	do	do	Do.
1c	Spring Creek, west of highway.	D. W. Ward	do	500	do	68	6	do	do	68	60	do	Lift pump, gas motor.	Do.
2	Claybrook	D. H. Pearson	do		do	90	6	do	do	90	80	Aug. 7	Bucket	Do.
3	Crawford Springs	Madison Fox Club Association.	Upland		Drilled	300	6	do	do	300			Lift pump, gas motor.	Do.
4	Oakfield, 150 feet east of railroad station.	C. H. Pierce	Valley bottom.		Bored	69	12	do	do	69	54	August	Bucket	Do.
5	Carroll, 50 feet east of railroad station.	Section house, Louisville & Nashville R. R.	do		do	18	6	do	do	18	5	do	do	Do.
6a	Noales store	J. F. and H. I. Doleach.	do	400	Drilled	85	3	do	do	85	70	Rept	Lift pump, gas motor.	Industrial.
6b	do	Pope County Hill School.	do	400	do	85	2	do	do			do	Lift pump	School.
7	5 miles northwest of Jackson on Humbolt road.	W. M. Moore	Upland	430	do	86	2	do	do	86	76	August	do	Domestic.
8	6.5 miles northwest of Jackson on Bells highway.	J. S. Matthass	do	425	do	160	2	do	do	160	120	Rept	Lift pump, gas motor.	Do.
9	4 miles northwest of Jackson on Bells highway.	Belle Meade Dairy.	Valley bottom.	372	do	700	2	do	Ripley		(a)	Aug. 13		Stock.
10	1 mile west of White Fern	R. W. Mattock			Bored	22	6	do	Holly Springs	22	14	Aug. 2	Bucket	Domestic.
11	500 feet east of railroad station, 100 feet south of Beech Bluff.	W. T. Diamond	Valley bottom.	395	do	30	6	do	Ripley	30	10	Aug. 7	do	Do.
12	7.8 miles east of Jackson on Beech Bluff road.	E. D. Alexander	do	400	Drilled	228	3	do	do	90	(b)			Do.
13	3.7 miles east of Jackson on Beech Bluff road.	E. J. Rushing	Hillside	415	Bored	90	6	do	Holly Springs	90	82	Aug. 7	Bucket	Do.
14	2.5 miles east of Jackson on Beech Bluff road.	S. S. Bond	do	420	Drilled	126	3	do	do		55	Rept	Lift pump, electric.	Domestic and stock.
15a	Jackson, 25 feet west of South Royal Street, 75 feet south of pumping station.	Jackson city waterworks.	Valley	360	do	152	32	do	do	152	18	do	Turbine centrifugal.[c]	Public supply.

[a] Flowing 25,920 gallons a day. [b] Flowing 10,800 gallons a day. [c] Capacity of pump, 1,000 gallons a minute.

Records of wells in Madison County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed		Depth to which well is cased (feet)	Water level		Method of lift	Use of water
								Character of material	Geologic horizon		Below surface (feet)	Date of measurement (1928)		
15b	Jackson, 200 feet east of South Royal Street.	Jackson city waterworks.	Valley	370	Drilled	140	32	Sand	Holly Springs	140	27	Rept.	Turbine centrifugal.[d]	Public supply.
15c	Jackson, Jackson Street pumping station.	do	do	370	do	480	12	do	Ripley	480	(e)	Est.		General.
15d	Jackson, Hopkins and Shannon Streets.	Beare Ice Co.	Valley bottom.	350	do	120	6	do	Holly Springs	120	−209	Rept.	Steam plunger pump.[f]	Industrial.
15e	Jackson, plant 2, Lee and Extension Streets.	do	Hill slope	350	do	149	8	do	do	149				Do.
15f	do	do	do	350	do	165	8	do	do	165				Do.
15g	Jackson, Mobile & Ohio R. R. new shops.	do	Valley bottom.	340	do	432	8	do	Ripley		(g)	Rept.		Do.
15h	do	do	do	340	do	438	6	do	do		(g)	do		Do.
15i	Jackson, Beasley and Lancaster Streets.	Morgan Hitchcock Co.	do	350	do	65	6	do	Holly Springs	65	20	do	Steam plunger pump.[h]	Do.
15j	Jackson, Chester Levee road	Jackson Railway & Light Co.	River bottom.	340	do	486	8	do	Ripley	486	(i)	do		Do.
15k		West Tennessee Experiment Station.	Valley bottom.	350	do	104	4	do	Holly Springs	104			Lift pump, gas motor.	Do.
16	3 miles west of Jackson on highway 1.	B. F. Wood, sr.	do	340	do	640	4	do	Ripley		(j)			Domestic.
17	5 miles northwest of Jackson.	T. C. Long	do	360	do	691	2	do	do	500	(k)			Stock.
18	5 miles west of Jackson on highway 1.	S. T. McLemor	Upland	400	do	200	2	do	Holly Springs	200			Lift pump, gas motor.	Domestic and stock.
19a	Huntersville	E. C. Cole	do	440	Dug	55	48	do	do	55	52	Aug. 15.	Bucket	Domestic.
19b	do	H. T. Crittenden	Hilltop	430	Driven	108	2	do	do	108			Lift pump	Do.
19c	do	Huntersville School.	Upland	450	do	112	2	do	do	112			do	School.
20a	Denmark	D. M. Hardee	Hilltop		Dug	35	36	do	do	35	30	August	Bucket	Domestic
20b	do	L. M. Wilson	Upland	420	Drilled	103	3	do	do	103			Steam plunger pump.	Industrial.
21a	Gin, 200 feet north of railroad	J. N. Hart	Ridgetop	480	do	160	2	do	do	160			Plunger pump, gas motor.	Do.
21b	300 feet west and 100 feet north from railroad station at Nealy.	J. F. Williamson	do	430	Bored	121	6	do	do	121	116	August	Bucket	Domestic.
22a	Bemis, A and Tennessee Streets.	Bemis Bros. Bag Co.	Valley bottom.	400	Drilled	174		do	do	174			Lift pump, electric.[l]	Industrial.

22b	Same (south well)	do	do	400	do	166	24	do	do	166	14	Rept.	do [m]	Do.
22c	Bemis, in street south of coal-storage shed at mill.	do	do	400	do	443	2	do	Ripley	170	([n])	Aug. 7.		None.
23	1 mile south of Bemis, 1,000 feet west of railroad track.	C. D. Caldwell	Hill slope	450	do	100	2½	do	Holly Springs	100	60	August	([o])	Domestic and stock.
24	500 feet south and 300 feet east from railroad station, Malesus.	H. R. Feutrell	Hillside		Bored	65	8	do	do	65	55	do	Bucket	Domestic.
25	8 miles southeast of Jackson	County school	Hill slope		Drilled	225	3	do	Ripley	30	([p])	do	Lift pump, windmill.	Do.
26	4 miles north of Pinson, 0.3 mile south of road, 0.2 mile west of road.	C. E. Grimes			do	180	3	do	do	50	([p])	do		Stock.
27	4 miles north of Pinson, 0.3 mile north of road, 0.3 mile east of road.	W. E. Smith			do	240	2½	do	do	60	([q])	do		Do.
28	1 mile northwest of Five Points.	Lee Allen	Hill slope		do	300	3	do	do	225	15	do	Lift pump	Domestic.
29a	Five Points	Five Points Gin Co.	Hillside		do		3	do	do					
29b	do	T. A. Hayes	do		Bored	33	6	do	Pliocene	33	25	do	Bucket	Do.
30	2.2 miles west of Pinson	S. H. Hailey	Valley bottom.		Drilled		2	do	Ripley	100	([p])	do		Do.
31	1.2 miles west of Pinson	Mount Pleasant Church.	Hillside	390	do	325	3	do	do	250	([r])	do		Do.
32a	Pinson	M. H. Houston	Valley bottom.	375	do	220	2	do	do	100	([k])	do		Do.
32b	do	T. B. Mays	do	385	do	165	2½	do	do	160	([k])	do		Do.
32c	do	R. H. Ray	do	375	do	225	2¾	do	do		([k])	do		Do.
33	Half a mile east of Pinson, 500 feet south of railroad.	H. Hayes	do	385	do	240	2½	do	do	60	([s])	do		Do.
34a	Medon	R. V. Arnold	Hilltop		do	75	6	do	Holly Springs	75	70	do	Bucket	Do.
34b	do	McDonald Bros.	do		do	75	2	do	do	75	60	Rept.	Lift pump	Do.
35a	Uptonville	County school	Upland	460	do	175	2	do	do	175	150	do	do	Do.
35b	do	T. L. Tamobon	do	460	Bored	150	2	do	do	150	140	August	Bucket	Do.
36a	0.1 mile east of railroad station at Mercer.	Ernest Elston	Hilltop	420	Drilled	156	2	do	do	156	125	Rept.	Lift pump, gas motor.	Do.
36b	250 feet east of railroad station at Mercer.	Town	Valley bottom.	340	Bored	30	8	do	do	30	20	August	Bucket	Do.
37	1.25 miles northwest of Mercer.	O. R. Pentercost	Second bottom.	370	do	54	6	do	do	54	47	do	do	Do.

[d] Capacity of pump, 800 gallons a minute.
[e] Flowing 432,000 gallons a day.
[f] Capacity of pump, 200 gallons a minute; reported pumpage, 250,000 gallons a day.
[g] Flowing 144,000 gallons a day.
[h] Capacity of pump, 20 gallons a minute.
[i] Flowing 504,000 gallons a day.
[j] Flowing 504,000 gallons a day.
[k] Flowing 2,160 gallons a day.
[l] Capacity of pump, 370 gallons a minute.
[m] Capacity of pump, 600 gallons a minute.
[n] Flowing 54,700 gallons a day.
[o] Reported pumpage, 3,000 gallons a day.
[p] Flowing 17,280 gallons a day.
[q] Flowing 8,640 gallons a day.
[r] Flowing 14,400 gallons a day.
[s] Flowing 4,520 gallons a day.

Analyses of waters from Madison County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers preceding table. Analyzed by D. F. Farrar]

	1c	2	15a	15c	17
Silica (SiO_2)	3.8	4	3.4	6	7
Iron (Fe)	.8	.8	.7	1.3	1.4
Calcium (Ca)	4	4	20	28	38
Magnesium (Mg)	1	1	5	3	6
Sodium (Na) } Potassium (K) }	3	3	1	2	3
Carbonate (CO_3)	0	0	0	0	16
Bicarbonate (HCO_3)	17	11	35	83	100
Sulphate (SO_4)	.5	2	38	14	13
Chloride (Cl)	4	5.5	2	2.5	3
Nitrate (NO_3)	.2	1.3	.3	.1	.2
Total dissolved solids	26	26	90	104	148
Total hardness as $CaCO_3$ (calculated)	14	14	70	82	119
Date of collection, 1928	Aug. 9	Aug. 7	Aug. 11	Aug. 11	Aug. 14

	19b	21b	31	34b	36a
Silica (SiO_2)	4	12	6	4	4
Iron (Fe)	1.1	2.2	1	1	.3
Calcium (Ca)	9	24	17	5	8
Magnesium (Mg)	1	6	4	1	1
Sodium (Na)	5	12	2	2	1
Potassium (K)		1			
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO^3)	30	19	49	18	25
Sulphate (SO_4)	.2	.3	16	.3	.4
Chloride (Cl)	8	11	3.5	3.5	2
Nitrate (NO_3)	.2	98	.3	.2	.3
Total dissolved solids	44	183	80	26	30
Total hardness as $CaCO_3$ (calculated)	27	85	59	17	24
Date of collection, 1928	Aug. 15	Aug. 10	Aug. —	Aug. 10	Aug. 10

McNAIRY COUNTY

GEOGRAPHY

[Area 588 square miles. Population 19,901]

McNairy County is in the southeastern part of the area. The ridge that forms the divide between the Mississippi and Tennessee drainage basins crosses the eastern part of the county and is the highest region in southwestern Tennessee. The exact altitude of this region is not known, but the highest points probably exceed 600 feet. The lowest point in the county is at about 345 or 350 feet, where Rose Creek crosses its western boundary. The western part of the county is hilly and broken. The eastern parts are more nearly level, although there are no large areas of flat country. This region is but sparsely populated, and much of it is still forested. The Mobile & Ohio Railroad crosses the county from north to south and the Southern Railway crosses its southwestern edge. Agriculture is the main occupation, and cotton and corn are the principal crops. There are no large towns in the county.

GEOLOGY

The Eutaw formation crops out as a narrow band along the eastern edge of the county, but as it dips to the west it underlies the whole county. Though composed largely of sand it contains much clay, which occurs either as large lenses or as thin interlaminated layers.

The Selma clay has a greater development in thickness and areal extent in this county than elsewhere in Tennessee. Its thickness ranges from 210 feet in the southern part of the county to about 100 feet at the northern boundary. Its width decreases from 8 miles in the south to 4 miles in the north. This formation gives rise to what are locally called "bald hills" or "bald places," areas on which the only vegetation consists of scattered clumps of grass and a few bushes. The gray-white soil, over which are strewn large oysterlike fossils, is very conspicuous and characteristic. This formation dips 20 to 30 feet to the mile toward the west.

The Ripley formation is found at the surface over the western half of the county. This formation has been divided into the Coon Creek tongue at the base, the McNairy sand member in the middle, and the Owl Creek tongue at the top. In this report, however, these subdivisions are not differentiated. The Coon Creek is a black fossiliferous marl which can not be distinguished from the Selma in most well logs and thus is often included with the Selma. The Ripley formation is about 600 feet thick in the southern part of the county but is slightly thinner toward the north. The formation is predominantly sand but includes intercalated lenses of clay.

Pliocene gravel covers the upland surface in the eastern part of the county and along Cypress Creek and its tributaries. It locally attains a thickness as great as 40 feet but is usually less. The upland surface over the remainder of the county is covered with the usual mantle of residuum.

WATER RESOURCES

McNairy County is well watered. Permanent springs are plentiful and furnish water to the numerous streams throughout the year. These springs are used for domestic supply, for sawmills, and for watering stock. In the valleys dug or driven wells furnish abundant water. The Eutaw formation is a fair water bearer, and water can be easily obtained from this formation where it occurs at the surface. The Selma clay will not yield water, and where this formation is found at the surface it is necessary to drill through the Selma to the underlying Eutaw formation. The depth to the Eutaw varies, but nowhere in the area of Selma outcrop will it exceed 300 feet.

Under the Selma clay the water in the Eutaw formation has a static head of 400 feet above sea level. Hence in wells that penetrate the Eutaw the water stands at this level, and such wells in places where the altitude is less than 400 feet will flow. Flowing wells are found at Chewalla and Guys. Much of the higher ground in the Selma outcrop area is covered by Pliocene gravel, and where this gravel is of sufficient thickness, small supplies of water can be obtained from it.

In the area where the Ripley formation comes to the surface an ample supply of water can be obtained from it. On the higher hills the water table stands 30 to 100 feet below the surface, and wells must exceed these depths to obtain a permanent supply.

LOCAL SUPPLIES

Adamsville is in the area of Eutaw outcrop. Dug wells averaging 30 feet in depth furnish sufficient water for domestic use. Just west of the town the Selma clay crops out and wells range in depth from 100 to 200 feet.

Bethel Springs (altitude 468 feet) is in a valley. Springs are numerous and are used for domestic supply. Shallow dug wells supply water to the families that do not have springs. Bethel Springs belongs to the Mobile & Ohio Railroad and is used for watering locomotives. The water is of excellent quality. (See analysis 10.)

Chambers is just west of the eastern contact of the Selma clay, which is therefore thin here. Wells from 30 to 60 feet deep obtain ample water from the underlying Eutaw formation.

Chewalla is in the valley of Indian Creek at an altitude of 410 feet. As the Selma clay occurs at the surface it is necessary to obtain water from the underlying Eutaw. The thickness of the Selma at Chewalla is 300 feet. Drilled wells from 300 to 340 feet in depth are used. The static head of water in the Eutaw is 400 feet, therefore the wells in the valley bottom at a lower level flow. Luther Cope has a flowing well in the valley of Cypress Creek, 2½ miles west of Chewalla. The collar of this well is at an altitude of 390 feet, and the well, which is 3 inches in diameter, yields 8 gallons a minute. Anywhere in the lowland along Indian Creek or the Tuscumbia River west of Chewalla flowing wells could be obtained by drilling through the Selma clay.

At Finger (altitude 430 feet) springs are plentiful. These springs furnish sufficient water for domestic use and for watering stock throughout the year.

The high ground around Gravel Hill is covered with Pliocene terrace gravel from 20 to 40 feet thick. Sufficient water for domestic use is obtained from shallow wells in this gravel. For larger supplies of water it would be necessary to drill through the Selma clay to the underlying Eutaw formation, which would be reached at depths of 250 to 300 feet.

Guys (altitude 442 feet) is in the outcrop area of Selma clay, and wells must penetrate to the Eutaw, which is reached at depths of 200 to 280 feet. Water rises within 50 feet of the surface. Some shallow wells that obtain water from the valley alluvium are also in use.

Leapwood is in hilly ground in the Selma clay outcrop area. Drilled wells from 300 to 340 feet deep obtain water from the Eutaw formation. This water has a high content of iron and carbon dioxide and is hard and of very poor quality. (See analysis 23.) West of Leapwood there are two sulphur springs.

McNairy (altitude 455 feet) is in a valley bottom. Driven wells from 10 to 20 feet deep are used. The water in these wells stands within a few inches of the surface, and some of the wells flow. In the higher ground east of the town wells attain depths of 100 feet.

At Mitchie, which is on a hill, shallow wells 30 feet deep obtain ample water for domestic use from the Pliocene gravel. In the neighboring lowland the gravel is absent, so it is necessary to drill though the Selma clay to the Eutaw formation. Such wells obtain water within 100 feet.

Milledgeville is in the valley of White Oak Creek. Dug and bored wells from 20 to 30 feet deep obtain water from the Eutaw sands.

At Purdy, on the Mississippi-Tennessee divide, which is here a narrow plateau, many springs flow from the base of hills on each side. In the town the wells in the base of the Pliocene gravel average about 30 feet deep, and those that enter the Selma clay go 200 feet or more before reaching the Eutaw formation.

At Ramer (altitude 412 feet) drilled wells 300 feet deep obtain water from the underlying Eutaw formation. This water has a static head at 400 feet, hence flowing wells are obtained in low ground.

Selmer (altitude 441 feet) is in the area where the Ripley formation comes to the surface, and here the Ripley has a thickness of 80 feet. The water-bearing capacity of the bottom 30 feet, however, is very low. Below the Ripley is the Selma clay, 300 feet thick, which in turn is underlain by the Eutaw formation, a fair source of water. Most of the wells in Selmer are from 20 to 30 feet deep, and these wells furnish plenty of water. The Selmer Ice Co. obtains water from a 400-foot well, and four other deep wells in town obtain water from the Eutaw formation at about the same depth. Further developments would procure water from wells in the Ripley or from deep wells that tap the Eutaw. The analysis of a sample of water from the Eutaw formation (11b) is given in the table on page 233.

Log of well of Selmer Ice Co., Selmer

[Authority, owner (from memory)]

	Thickness (feet)	Depth (feet)
Soil	10	10
Ripley formation:		
Sand, water bearing	50	60
Sandy clay	30	90
Selma clay: Clay containing shells	300	390
Eutaw formation: Sand, water bearing	10	400

In 1905 a wildcat oil test hole was drilled 1 mile north of Selmer, in the valley of Cypress Creek. The test was abandoned at 510 feet when still in sand. The log, as given by the driller, with formation names added by the writer, is as follows:

Log of well of Acacia Development Co., Selmer

[Authority, W. H. Anderson, driller]

	Thickness (feet)	Depth (feet)
Ripley formation: Sand and good drinking water	40	40
Selma clay (including Coon Creek tongue of Ripley formation): Blue tough gumbo	275	315
Eutaw formation: Sand, mud, gravel, plenty of wood; nothing uniform. Water rose in well to 40 feet of the top (altitude 400 feet)	195	510

This well did not reach the Paleozoic basement, though Paleozoic rocks probably do not lie much deeper. The statement as to the presence of gravel is very general. If it was at the bottom of the well, it is probably the Tuscaloosa formation.

At Stantonville the Pliocene gravel is 35 to 40 feet thick and has at the base several feet of rounded chert gravel in which water is abundant. Beneath it is the Eutaw formation, but this is quicksand here and tends to fill up a well. A mile or less to the west the Selma clay is struck, and wells are bored 80 to 250 feet through it into the Eutaw sands below.

Records of wells in McNairy County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
1	Milledgeville	J. O. Lott	Valley bottom.	410	Bored	20	8	Sand	Alluvium	20	12	June 29	Bucket	Domestic.
2	5.9 miles south of Henderson on Selmer Highway.	W. L. McCeskill	Valley		Spring			do	Ripley		(a)	June 30		Do.
3	Leapwood	W. E. Sewell	Upland	520	Drilled	330	2	do	Eutaw	330	140	June 28	Lift pump, gas motor.	Do.
4	3 miles south of Leapwood on Adamsville road.	J. Curby	do		do	300	2	do	do	300			Lift pump	Do.
5	Adamsville	J. M. Littlefield			Dug	25	36	do	do		19	June 28	Bucket	Do.
6	Cyclone	J. L. Gilchrist	Hillside	500	Spring			Gravel	Pliocene		(b)	June 24		Domestic and stock.
7	9.1 miles east of Selmer on highway 15.	A. H. Gilchrist	Hilltop		Drilled	185	2¾	Sand	Eutaw	184			Lift pump	Domestic.
8	6.7 miles east of Selmer on highway 15, 100 feet north of highway.	E. Wagoner	Hillside	500	Dug	16	36	do	Ripley		13	Sept. 24	Bucket	Do.
9	2.1 miles east of Selmer, on highway 15,100 feet north of highway.	E. H. Kirkpatrick	Foot of hill	450	do	15	36	do	Alluvium		12	do	do	Do.
10	Bethel Springs	Mobile & Ohio R. R.	Valley	460	Spring									Railroad.
11a	Selmer	Louis Adams	Bottom	411	Drilled	390	3½	Sand	Eutaw	90	45	Rept.	Lift pump	Domestic.
11b	do	Selmer Ice Co.	do	411	do	400	6	do	do	200	30	do	Lift pump, oil motor.	Industrial.
12	Ramer	J. A. Houston	do	420	do	300	3	do	do	30	(c)	June 27		Domestic and stock.
13	2 miles northeast of Chewalla	Luther Coke	do	390	do	316	3	do	do	18	(d)			Stock.
14	Chewalla	E. Blakenship	do	415	do	310	2	do	do		10	Rept.	Lift pump	Domestic.
15	Guys	R. M. Houston	do	442	do	215	4	do	do	23	35	do	do	Do.
16	Michie	W. T. Gooch	Hilltop		Dug	30	30	Gravel	Pliocene	30	22	June 28	Bucket	Do.
17a	Chambers	T. S. Thomas	Valley		do	30	36	Sand	Eutaw	30	26	do	do	Do.
17b	do	do	do		do	30	36	do	do	30	26	do	do	Do.

[a] Flowing 7,000 gallons a day.
[b] Flowing 38,000 gallons a day.
[c] Flowing 5,760 gallons a day.
[d] Flowing 11,520 gallons a day.

Analyses of waters from McNairy County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyzed by Margaret D. Foster]

	1	3	5	10	11b
Silica (SiO_2)	12	24	18	12	19
Iron (Fe)	.16	9.1	.20	.07	.27
Calcium (Ca)	3.0	125	80	2.0	52
Magnesium (Mg)	1.1	61	20	.9	20
Sodium (Na)	.8	30	165	1.5	7.7
Potassium (K)	1.0	9.0	37	.5	5.1
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	4.0	155	148	4.0	208
Sulphate (SO_4)	2.1	486	43	7.1	55
Chloride (Cl)	1.8	5.9	232	1.4	2.8
Nitrate (NO_3)	6.6	.0	250	.77	1.0
Total dissolved solids	38	875	972	29	260
Total hardness as $CaCO_3$ (calculated)	12	563	282	8.7	212
Date of collection, 1928	June 29	June 29	June 28	June 29	June—

	12	14	16	17
Silica (SiO_2)	25	21	16	15
Iron (Fe)	.59	.31	.17	.08
Calcium (Ca)	56	41	11	.1.8
Magnesium (Mg)	18	13	3.5	.8
Sodium (Na)	5.5	5.7	10	2.1
Potassium (K)	1.6	3.9	1.9	.7
Carbonate (CO_3)	0	0	0	0
Bicarbonate (HCO_3)	218	184	22	7.0
Sulphate (SO_4)	37	19	2.5	1.8
Chloride (Cl)	3.7	2.5	18	1.5
Nitrate (NO_3)	.0	.56	21	4.6
Total dissolved solids	256	193	108	37
Total hardness as $CaCO_3$ (calculated)	214	156	42	7.8
Date of collection, 1928	June 27	July 7	June 28	June 28

OBION COUNTY

[Area 552 square miles. Population 29,086]

GEOGRAPHY

Obion County is in the northwestern part of western Tennessee. The county falls into two parts having distinct physiographic features; the northwestern part is hilly and but slightly settled; the southern and western part of the county is well developed. Three railroads cross the western section. Agriculture is the major occupation; the principal crop, measured by acres planted, is corn; cotton follows, and hay is a close third. Some tobacco is grown, and there is considerable dairying. Union City, the county seat, is at the junction of the Nashville, Chattanooga & St. Louis and the Mobile & Ohio Railroads, and the Illinois Central Railroad passes 2 miles to the east. Union City is the fifth largest city in western Tennessee, having a population of 5,865.

The Obion River flows through the southeastern part of the county in a direction a little north of southwest. The land surface slopes gently down to the river in the southwestern part of the county but rises again to the high land in the northwest. This northwest section is very hilly and has a maximum altitude of 483 feet above mean sea level. From the bluffs that mark the edge of the hilly country the surface drops abruptly to the flood plain of the Mississippi River. Obion County included within its boundary a narrow strip of the Mississippi lowlands 1 to 2 miles wide. This area has a general altitude of 300 feet. The broad first and second bottoms of the Obion River are but little higher, and the altitude of the eastern section of the county must average above 325 feet.

GEOLOGY

With the exception of the eastern edge and the river bottoms Obion County is covered with a surface mantle of loess, a fine-grained structureless deposit that has a characteristic property of standing with vertical faces. It is well exposed in the bluffs. The loess has a thickness of 75 feet in the western part of the county but thins out in the eastern part. It does not yield water.

Underlying the loess in the western part of the county is a deposit of Pliocene sand and gravel. This consists of chert pebbles of varying size, the maximum being about 5 inches. The sand ranges from coarse to fine but is predominantly coarse. The Pliocene sand and gravel have a maximum thickness of 30 feet but thin out toward the east. This formation is well exposed in the bluffs. The gravel is an excellent source of water, though the water from it is hard. Most of the wells in the western part of the county derive water from this formation.

Underlying the gravel is the Jackson formation, which consists of fine, uniform sand, clay, and lignite. Unlike the clay in the Wilcox group, the Jackson clays occur in beds of considerable horizontal extent. In places they contain a fair amount of sand and are gritty to the feel. The lignite occurs in layers several feet thick but is not persistent, though characteristic of the Jackson sediments. The Jackson formation is a poor source of water. The sands are so fine that it is difficult to check them with the finest strainers, and the lignite imparts an unpleasant taste to the water near by.

The Wilcox group underlies the Jackson formation, and it is in the sands of this group that all wells more than 300 feet deep obtain water. The thickness of the Wilcox ranges from about 800 feet in the northeast corner to 1,500 feet in the west. In Obion County the Wilcox group contains considerable clay and streaks of lignite. The clay is in many places mixed with fine sand, the material grading from fine sand to clay and back again. If a coarse sand is not found between 100 and 200 feet, it may be necessary to drill to 600 or 700 feet to reach a good coarse sand. The character of the Wilcox group is clearly shown in the following log:

Log of S. J. Bradshaw oil test well No. 1, Cashtown

[Descriptions by B. W. Blanpied, 85–2, 070 feet; by G. I. Whitelotch, 2, 070–2, 610 feet]

	Depth from which sample came (feet)
Wilcox:	
Pale-green, tan, light-gray, and dark-brown lignitic mudstone. No foraminifers. Bit sample (?)	85
Lignite. Tan, pale-green, and medium-brown sandy mudstone. Bit sample (?)	220–280
Lignitic. Light-brown and cream-colored argillaceous sand. Cuttings	440–468
Light-brown and light grayish-brown sand and sandy mudstone. Bit sample	480–500
Light-brown fine to coarse grained sand. Cuttings	500–520
Same as above. Cuttings	520–560
Cream-colored and tan mudstone, with a streak of sandy material. Bit sample	560–575
Cream-colored kaolin (?). Bit sample (?)	565–650
Same as above. Bit sample	660–680
Same with medium-red and tan mudstone. Fine to coarse grained sand and siderite concretions. No fossils. Bit sample	680–700
Light-gray fine to medium grained sand and argillaceous sand. No fossils. Core	730–740
Coarse-grained friable sandstone. No fossils. (Labeled "core," probably cuttings.)	815
Coarse-grained sand (rice sand). Sandy mudstone and lignite. No fossils. Cuttings	850
Light-gray medium-grained sand. Lignite. No foraminifers. Core	880
Same as material from 850 feet	900
Light-brown, fairly coarse grained friable sandstone. No fossils. Core	930
Fragments of kaolin, sandy mudstone, lignite, and fine to coarse grained sand. No foraminifers. Cuttings	950
Fine to very coarse grained sand. Traces of lignite. Cuttings	975
Fine and coarse grained sand with thin streaks of dark-brown lignitic material. No fossils. Core	1, 000
Medium-brown noncalcareous sandy lignitic finely micaceous mudstone. No foraminifers. Core	1, 035
Light-brown noncalcareous, very fine grained, slightly micaceous sand and sandy mudstone. Core	1, 040
Light-brown sand and sandy mudstone. No fossils. Core	1, 047–1, 053
Very coarse grained sand. Core	1, 068–1, 075
Light to dark brown noncalcareous silty lignitic mudstone. No foraminifers. Core	1, 080–1, 087
Dark-brown noncalcareous lignitic, slightly micaceous mudstone. No fossils. Core	1, 095–1, 103
Fine to medium grained lignitic sand. Core	1, 140–1, 148
Fine to coarse grained micaceous sand. Core	1, 155–1, 163
Light and medium brown fine to medium grained argillaceous friable sandstone streaked with lignite. No foraminifers. Core	1, 167–1, 175
Light-gray micaceous noncalcareous banded silty mudstone. Few reworked Cretaceous foraminifers and *Inoceramus* prisms. Core	1, 168–1, 170

Wilcox—Continued.	Depth from which sample came (feet)
Light grayish-brown noncalcareous waxy mudstone and pearl-gray kaolin. Fine-grained sand. No fossils. Core	1, 180–1, 185
Cream-colored fine-grained noncalcareous silty lignitic micaceous friable sandstone. No foraminifers. Core	1, 185–1, 193
Light-gray fine-grained argillaceous lignitic micaceous friable sandstone. Same as above. Core	1, 193–1, 200
Light-gray fine-grained silty micaceous friable sandstone and lignite. Core	1, 200–1, 208
Light-brown silty lignitic micaceous noncalcareous mudstone. Core	1, 220–1, 228
Light greenish-yellow sandy micaceous mudstone and light and medium brown mottled waxy mudstone. Core	1, 228–1, 235
Medium-brown silty lignitic micaceous mudstone with thin light-brown fine-grained sand lenses. Core	1, 236–1, 243
Medium and light gray silty lignitic finely micaceous noncalcareous mudstone. Core	1, 243–1, 248
Pale yellowish-green noncalcareous lignitic mudstone. Core	1, 248–1, 260
Light-gray, medium-brown, and light-green noncalcareous, slightly micaceous lignitic waxy mudstone. Core	1, 260–1, 268
Light-gray and tan lignitic micaceous waxy mudstone and hard, very fine grained sandstone. Core	1, 268–1, 278
Light brownish-gray sandy micaceous lignitic mudstone. Core	1, 278–1, 283
Light and medium brown noncalcareous lignitic waxy mudstone. Core	1, 285–1, 293
Pale greenish-yellow micaceous, slightly lignitic silty mudstone and light-brown siltstone. Core	1, 293–1, 300
Lignite. Core	1, 300–1, 307
Light and dark brown lignitic mudstone. Core	1, 303–1, 312
Light-gray banded, slightly lignitic micaceous sandy mudstone and very fine grained sand. No fossils. Core	1, 312–1, 319
Light grayish-brown, slightly lignitic micaceous mudstone. Core	1, 319–1, 326
Same. Core	1, 326–1, 335
Light-brown fine to medium grained sand. Core	1, 355–1, 363
Same. Core	1, 380–1, 388
Same. Core	1, 400–1, 410
Same. Core	1, 470–1, 482
Same. Core	1, 580–1, 590
Fine to coarse grained sand with a few fragments of light-brown mudstone and lignite. No foraminifers. Cuttings	1, 640–1, 660
Same. Cuttings	1, 660–1, 675
Light-gray fine-grained micaceous sand with thin streaks of dark-gray and brown lignitic mudstone. No foraminifers. Core	1, 675–1, 685
Light-brown fine to medium grained argillaceous friable sandstone. Core	1, 695–1, 700
White, light-gray, and brown banded sandy mudstone and sandstone. Bit sample	1, 700–1, 710
Dark-brown fine-grained glauconitic (rotten) argillaceous sandstone. No fossils. Core	1, 725–1, 727
Same. Core	1, 727–1, 734
Same. Core	1, 734–1, 738

	Depth from which sample came (feet)
Wilcox—Continued.	
Dark-gray noncalcareous waxy mudstone. No fossils. Core	1, 738–1, 758
Light-gray, very fine grained micaceous, argillaceous friable sandstone. Core	1, 740–1, 748
Light-gray, highly micaceous silty mudstone. Core	1, 748–1, 753
Light-gray, highly micaceous silty mudstone with streaks of very fine grained sand. Core	1, 753–1, 770
Same as material at 1,748–1,753 feet. Core	1, 770–1, 775
Same. Core	1, 775–1, 780
Midway:	
Medium-gray, highly micaceous noncalcareous silty mudstone. Core	1, 780–1, 784
Dark-gray, finely micaceous noncalcareous waxy mudstone. Fine-grained glauconite and a few pyritized foraminifers. Core	1, 785–1, 792
Medium-gray noncalcareous waxy mudstone with thin light-gray silty partings. Few pyritized diatoms. Core	1, 792–1, 798
Dark-gray noncalcareous waxy mudstone. *Globigerina* sp., *Cristellaria* cf. *C. midwayensis* (small), gastropods, pelecypods, and ostracodes. Core	1, 798–1, 818
Light-gray medium-grained glauconitic micaceous sand. Shell fragments. No foraminifers. Core	1, 840–1, 855
Same. No fossils. Core	1, 855–1, 864
Light and medium-gray sandy mudstone. Few shell fragments. No foraminifers. Bit sample	1, 864
Dark-gray slightly calcareous sandy mudstone. Shell fragments. Bit sample	1, 875–1, 890
Medium-gray very slightly calcareous waxy mudstone. *Cristellaria* sp. (small), *Anomalina* sp., and few shell fragments. Core	1, 900–1, 910
Medium-gray calcareous micaceous mudstone. *Globigerina* sp., *Anomalina* sp., *Gyroidina soldanii.* Few arenaceous foraminifers. Core	1, 925–1, 935
Same, with *Textularia* sp., *Discorbis* sp., and *Bolivina* sp. Core	1, 960-1, 975
Medium-gray calcareous mudstone and light-gray fine-grained, highly micaceous friable sandstone. *Cristellaria* sp. (small), *Anomalina* 2 sp., *Gyroidina soldanii, Globigerina* sp. Core	2, 000–2, 015
Medium-gray calcareous micaceous silty mudstone. *Lagena sulcata, Textularia* sp., *Anomalina* sp., *Gyroidina soldanii, Cristellaria* sp., *Cristellaria midwayensis,* arenaceous foraminifers. Core	2, 015–2, 030
Dark-gray calcareous waxy mudstone. *Globigerina.* Core	2, 040–2, 050
Medium and dark gray calcareous mudstone and light-gray fine-grained, closely cemented pyritic sandstone. *Cristalleria midwayensis, Anomalina* sp., *Gyroidina soldanii, Polymorphina cushmani, Cristellaria* cf. *C. pseudo-mamilligera.* Core (?)	2, 050–2, 055
Medium-gray, slightly calcareous, finely micaceous waxy mudstone. *Cristellaria* sp. (small), *Anomalina* sp., *Globigerina* sp., *Ammobaculites* sp., *Cristellaria midwayensis* (fragment). Core	2, 060–2, 065
Highly micaceous gray coarse siltstone. Core	2, 070–2, 080
Gray shaly siltstone. Core	2, 080–2, 094

	Depth from which sample came (feet)
Cretaceous:	
Coarsely crystalline light-tan, highly fossiliferous limestone. Core	2, 100–2, 101
Calcareous fossiliferous dark greenish-gray siltstone. Core	2, 101–2, 105
Highly calcareous reddish-tan coarse-grained sandstone (?) Core	2, 105, 2, 108
Tan to brown sandy clay containing fragments of chalk. Core	2, 108–2, 112
Medium tan-brown fossiliferous coarse sandstone. (1 large fossil in sack, "gastropod.") Piece is calcareous to acid. Core	2, 112–2, 115
Soft dark-gray micaceous silty clay. Core	2, 125–2, 135
Light-gray, highly micaceous fine-grained argillaceous limestone. Core	2, 140–2, 141
Dark-gray shaly siltstone. Core	2, 141–2, 145
Dark-gray shaly micaceous soft siltstone. Core	2, 150–2, 160
Same	2, 165–2, 170
Light-gray micaceous fine loose sandy silt. Core	2, 176–2, 180
Dark-gray micaceous shaly siltstone. Core	2, 185–2, 190
Dark-gray shaly siltstone. Core	2, 190–2, 196
Dark-gray micaceous fine loose sand. Core	2, 215–2, 216
Very coarse green to brown sandstone	2, 220–2, 224
Dark-gray micaceous siltstone. Core	2, 224–2, 228
Friable clay-bound gray fine-grained sandstone. Core	2, 235–2, 238
Dark-gray sandy shale. Core	2, 242–2, 247
Same	2, 255–2, 259
Same	2, 280–2, 285
Loose gray clay and medium-grained sand	2, 312–2, 314
Light-gray argillaceous sandstone. Core	2, 355–2, 360
Contact of a soft, friable, very light gray fine-grained sandstone and a hard dark-gray fine-grained sandstone. Core	2, 408–2, 410
Piece of marcasite and dark-gray fine-grained sandstone. Core	2, 610

The Wilcox group is underlain by the Porters Creek clay, which has a thickness of 250 feet. This is underlain in turn by the Cretaceous formations, which are about 500 feet thick and contain some thick layers of coarse sand.

In the Mississippi lowland the top formation is alluvium, deposited by the Mississippi River as it moves back and forth across its flood plain. The alluvium is 100 feet thick and varies rapidly both vertically and horizontally, lenses and bars of coarse sand giving place abruptly to clay. The alluvium contains much organic matter and considerable iron. Hence the water from it is often charged with iron and is unpalatable. Owing to the great variability of the alluvium it is impossible to predict at what depth wells in it can obtain water.

WATER RESOURCES

With the exception of the Obion River most of the streams in Obion County go dry in the summer, and stock is generally watered from stock ponds made in low places, though it is becoming more common to water stock from wells. Springs are numerous and large along the foot of the bluffs, where the water comes out from the base of the Pliocene sand and gravel. In the rest of the county springs are rare. In the northwestern part of the county wells are from 90 to 120 feet in depth and obtain water from the Pliocene sands and gravel. The water is hard, and therefore cisterns are largely used for wash water and in places for drinking water. On the second bottom water can not be struck in the first 50 feet, and below that the alluvium is too fine, so that wells are from 200 to 300 feet deep. In the first bottom wells 25 feet deep obtain ample water. In the eastern part of the county bored wells are most common, though dug wells are still used.

LOCAL SUPPLIES

At Elbridge (400 feet above sea level) bored wells 60 to 80 feet obtain water from the Pliocene sand and gravel. A coarse sand is found in the Wilcox at a depth of 300 feet.

Fulton, Ky., just across the Obion County line, has a public water supply owned by the city. Water is pumped by air lift from a 10-inch well 628 feet deep. The water level in the well stands 22 feet below the surface, and the drawdown is 46 feet when the well is pumped at 1,188 gallons a minute. The water flows into a 300,000-gallon reservoir, from which it is pumped into the mains by two steam pumps. The average daily consumption is 800,000 gallons. The water is of excellent quality. (See analysis 1.)

At Glass dug wells are still used; these end in blue clay and go dry in the late summer. Drilled wells range from 165 to 210 feet in depth and obtain good water. At a depth of 250 feet lignite is encountered.

Kenton is in the valley of the Rutherford Fork of the Obion River. The municipal water supply comes from a 10-inch well 580 feet deep. The water (analysis 57) is pumped by air lift into a 250,000-gallon reservoir and thence into a 45,000-gallon elevated tank. The average daily consumption is 360,000 gallons. The depth to water is 20 feet.

At Hornbeak (480 feet above sea level) drilled wells 90 to 125 feet deep obtain water from the Pliocene sand and gravel.

Obion is on the second bottom. The city has a municipally owned water supply, obtained from three 6-inch wells 70 feet deep. The wells are pumped by force pumps, which deliver the water to a 75,000-gallon reservoir, from which it is pumped by a centrifugal pump to a 75,000-gallon elevated tank. The average daily consumption is 75,000 gallons.

Log of well 1 of the city of Obion

[Authority, J. B. Saunders]

	Thickness (feet)	Depth (feet)
Soil	4	4
Red clay	12	16
Blue clay	20	36
Medium coarse sand	34	70

The water is moderately hard and contains enough iron to make its removal desirable. (See analysis 53.)

Rives is in the valley of the North Fork of the Obion. Shallow driven wells 30 to 40 feet deep obtain ample water for domestic use, but the water is hard. Water can be obtained from wells 100 feet deep. Glenn [98] gives the following log:

Log of Illinois Central Railroad well at Rives

	Thickness (feet)	Depth (feet)
Soil and clay, dark, loamy	40	40
Sand, water-bearing	20	60
Clay, blue "gumbo"	82	142
Sand, coarse, water-bearing	18	160
Silty or bastard sand, very fine grained, with sticky blue clay in places	540	760

Troy has a municipally owned public supply (see analysis 38), obtained from a 12-inch well 200 feet deep, pumped by a turbine centrifugal pump that delivers the water to a 50,000-gallon elevated tank. This well ends in good coarse sand. Many people in Troy still use their own wells, which range in depth from 30 to 65 feet.

The municipal water supply at Union City is derived from two 8-inch wells 560 feet deep. (See analyses 19a, and 19b.) The wells are pumped by an air lift that delivers the water to a 255,000-gallon reservoir, from which it is pumped by two centrifugal pumps and discharged under direct pressure into the mains. The average daily consumption is 600,000 gallons. The Citizens Coal & Ice Co. obtains water from an 8-inch well 120 feet deep. This furnishes abundant water but it is hard.

Log of well of Union City waterworks

[Authority, C. B. Allen]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	90	90	Yellow sand	1	326
White sand	60	150	White clay (some fine sand)	164	490
Clay and blue "soapstone"	175	325	White sand	70	560

[98] Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U. S. Geol. Survey Water-Supply Paper 164, p. 103, 1906.

Records of wells in Obion County

No.	Location	Owner	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Use of water
1	Fulton, Ky.	City of Fulton	Upland	Drilled	628	10	Sand	Holly Springs	628	22	Rept.	Air lift [a]	Public supply.
2	6 miles west of Fulton on State line.	W. W. Ethridge	do	do	120	2	do	Jackson	120			Lift pump	Domestic.
3	4.7 miles north of Union City	C. D. McDaniel	do	do	110	2	do	do	110			do	Do.
4	Woodland	Woodland Gin Co.	do	do	165	2	do	do	165			do	Do.
5	4 miles west-northwest of Woodland.	Thedron Wheeler	do	do	188	2	do	do	188			do	Do.
6	3½ miles south of State line at foot of Bluffs.	E. P. Powell	Second bottom.	Dug	35	36	do	Alluvium	35			Bucket	Do.
7	Crystal, 4.5 miles southeast of Woodland.	Crystal School	Hilltop	Drilled	308	2	do	Grenada	308			Lift pump	Do.
8	3.5 miles southwest of Woodland on road to Crystal.	J. E. Isbell	Upland	do	180	1½	do	Jackson	180			do	Do.
9	3.3 miles northwest of Union City on road to Woodland.	Mrs. Al Brevard	do	do	115	2	do	do	115			do	Do.
10	2 miles north of Union City	W. H. Neely	Hilltop	Dug	30	36	do	Pliocene	30	15	Sept. 13	Bucket	Do.
11	6 miles northeast of Union City on highway 3.	T. S. Humphrey	do	Drilled	120	2	do	Jackson	120			Lift pump	Do.
12	Pierce, 2 miles southwest of Fulton.	C. E. Lowe	Lowland	Bored	45	6	do	do	45	15	Sept. 11	Bucket	Do.
13	1.8 miles south of Fulton on highway 43.	G. L. Swiggart	Upland	do	90	6	do	do	90	86	do	do	Do.
14a	McConnell	W. O. Cooks	Lowland	do	34	6	do	do	34	25	do	do	Do.
14b	4.4 miles south of Fulton on highway 43.	J. T. Caldwell	do	do	30	10	do	do	30	25	do	do	Do.
15	3 miles west of Harris	W. B. Robey	Upland	do	82	6	do	do	82	75	Sept. 10	do	Do.
16	Harris	L. D. Allen	do	do	45	6	do	do	45	36	do	Lift pump	Do.
17a	Gibbs, intersection of Illinois Central R. R. and Nashville, Chattanooga & St. Louis Ry.	J. D. Blackwell	Second bottom.	do	35	6	do	do	35	30	Sept. 11	Bucket	Do.
17b	do	C. D. Hall	do	Drilled	165	3	do	do	165			Lift pump	Do.
18	2.5 miles northeast of Union City on highway 3.	F. W. Morse		do	116	2	do	do	116			do	Do.
19a	Union City just east of Mobile & Ohio R. R. and south of highway 3.	Union City	Lowland	do	550	8	do	Holly Springs	550	41	Rept.	Air lift [b]	Public supply.
19b	do	do	do	do	560	8	do	do	560	41	do	do	Do.

[a] Capacity of pump, 1,188 gallons a minute; reported pumpage, 80,000 gallons a day.
[b] Capacity of pump, 650 gallons a minute; reported pumpage, 600,000 gallons a day.

Records of wells in Obion County—Continued

No.	Location	Owner	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Use of water
19c	Union City, 100 feet south of Second Street.	Citizens Coal & Ice Co.	Lowland	Drilled	120	8	Sand	Jackson	120	28	Rept.	Centrifugal [c]	Industrial.
20	2.3 miles west of Union City on Lake road.	Mrs. J. Caldwell	do	do	85	2	do	do	85			Lift pump	Domestic.
21	4.3 miles west of Union City on Lake road.	A. M. Logan		do	156	2	do	do	156			do	Do.
22	6.7 miles west of Union City on Lake road.	J. N. Caldwell	Upland	do	90	2	do	do	90			do	Do.
23a	8.5 miles west of Union City on Lake road.	Elton Caugle	do	do	60	2	do	do	60			do	Do.
23b	do	Park Bros.	do	do	240	2	do	Grenada	240			do	Do.
24a	Clayton, 10 miles west of Union City on Lake road.	J. S. Ratcliff	do	Bored	42	6	do	Jackson	42			Bucket	Do.
24b	do	A. E. Caldwell	do	do	265	2	do	Grenada	265	100	Rept.	Lift pump	Do.
25	4 miles north of Samburg	Denborn estate	Foot of bluffs	Spring			Gravel	Pliocene					Do.
26	Samburg	Charles Gleason	do	do			do	do		([d])	Sept. 17		Do.
27	11.5 miles west of Union City	Protemus School	Hilltop	Bored	30	6	do	do	30	21	do	Bucket	Do.
28	Old Maupin, 6.5 miles west of Union City.	I. Glover	Upland	Drilled	102	3	Sand	Jackson				Lift pump	Do.
29	4 miles southwest of Union City on highway 3, 2 miles west of highway.	A. D. Osborne	do	do	60	2	do	do	60			do	Do.
30	2.2 miles southwest of Union City on highway 3.	Wade Wiley	Lowland	do	135	3	do	do				do	Do.
31a	Rives	W. L. Clemens and others.	Bottom	do	100	3	do	Grenada				do	Do.
31b	do	Phebus & Shore Hardware Co.	do	Driven	40	1½	do	Alluvium				Suction pump	Do.
32	6.7 miles southwest of Union City on highway 3.	L. M. Shore	Hillside	Dug	30	36	do	Pliocene	30	15	Sept. 12	Bucket	Do.
33	4.5 miles west of Hornbeak on highway 21.	C. W. Lester	Foot of bluff	Drilled	228	2	do	Grenada	229			Lift pump	Do.
34	2 miles west of Hornbeak on highway 21.	G. W. Davis	Upland	do	97	2	Gravel	Pliocene	97			do	Do.
35	Hornbeak	Hornbeak Gin Co.	Hilltop	do	105	3	do	do	105			do	Industrial.
36	4.8 miles west of Troy on highway 21.	J. W. Thompson	Upland	do	84	2	Sand	Jackson	84			do	Domestic.
37	2.2 miles west of Troy on highway 21.	J. King	Second bottom.	Bored	30	14	do	Alluvium	30	15	Sept. 14	Bucket	Do.

38	Troy, 500 feet east of highway 3	City of Troy	Lowland	Drilled	200	12	do	Grenada				Centrifugal	Do.
39	2 miles east of Troy	W. B. Anderson	do	do	186	2	do	do				Lift pump	Do.
40	2.5 miles southeast of Reeves on road to Kenton.	W. W. Hamilton	Hilltop	do	150	1½	do	do				do	Do.
41a	5 miles southeast of Reeves on road to Kenton.	G. T. Philips	Upland	do	80	1½	do	do				do	Do.
41b	do	do	Lowland	Bored	40	6	do	do	40	25	Sept 11	Bucket	Do.
42a	Polk, 6 miles southwest of Reeves on Illinois Central R. R.	Polk School	Hillside	Drilled	110	2	do	do	110			Lift pump	Do.
42b	do	K. H. Polk	Second bottom.	Dug	50	36	do	Alluvium	50	46	Sept. 12	Bucket	Do.
43	2.2 miles southeast of Troy on highway 5.	Paul Irwin	Hilltop	Drilled	210	2	do	Grenada	210			Lift pump	Do.
44	2.2 miles south of Troy on highway 3.	T. C. Wilson	Hillside	do	109	2	do	do	109			do	Do.
45	2.7 miles north of Glass	Mount Moriah School.	Upland	do	69	2	Gravel	Pliocene	69			do	Do.
46	3.1 miles south of Hornbeak on road to Glass.	J. B. Faust	do	Dug	50	36	do	do	50			Bucket	Do.
47	5.3 miles north of Gratio	John Webb	Foot of bluffs.	Spring			do	do		(e)	Sept. 14		Do.
48	2.7 miles north of Gratio	H. Kendal	do	do			do	do		(e)	do		Do.
49	Gratio	County	do	do			do	do		(f)	do		Do.
50	3 miles east of Eldridge	Minnich School	Upland	Drilled	103	2	do	do	103			Lift pump	Do.
51a	Eldridge	Town of Eldridge	Hilltop	Bored	60	10	do	do	60	56	Sept. 12	do	Do.
51b	Half a mile south of Eldridge	L. E. Maloney	do	Drilled	325	2	Sand	Grenada	325			do	Do.
52a	Glass	Glass School	Second bottom.	do	204	2	do	do	204			do	Do.
52b	do	J. T. Foster	do	Dug	35	36	do	Alluvium	35	18	Sept. 12	Bucket	Do.
53a	Obion	City of Obion	Lowland	Drilled	70	6	do	do	70	35	Rept	Force pump	Public supply.
53b	do	do	do	do	70	6	do	do	70	35	do	do	Do.
53c	do	do	do	do	70	6	do	do	70	35	do	do	Do.
54	4.7 miles southeast of Troy on highway.	M. A. Hall	Second bottom.	Driven	50	1½	do	Alluvium				Suction pump	Domestic.
55	7.2 miles southeast of Reeves	T. J. Jackson	do	do	66	1½	do	Grenada				Lift pump	Do.
56	1½ miles northeast of Kenton	Macedonia School	Hillside	Drilled	134	1½	do	do				do	Do.
57	Kenton	City of Kenton	Lowland	do	580	10	do	Holly Springs	580	20	Rept	Air lift	Public supply.
58	2.1 miles west of Kenton on highway.	B. McClough	Hilltop	do	100	1½	do	Grenada	100			Lift pump	Domestic.
59	3 miles northwest of Kenton	S. A. Lancaster	Upland	Bored	55	6	do	do				do	Do.
60	Mason Hall, 35 miles west of Kenton.	Mason Hall School	do	Drilled	100	1½	do	do				do	Do.
61	1.9 miles northwest of Mason Hall	T. H. Erwin	Hilltop	do	110	1½	do	do				do	Do.
62a	2.4 miles south of Glass	Guy Revell	Second bottom.	Driven	87	2	do	do				do	Do.
62b	2.2 miles south of Glass	Mrs. L. Lucker	do	Dug	40	36	do	Alluvium				Bucket	Do.
63	1½ miles south of Eldridge	Consolidated School.	Bottom	Drilled	275	2	do	Grenada	275			Lift pump	Do.
64	2.7 miles southwest of Eldridge	R. B. Galloway	Second bottom.	Dug	50	36	do	Alluvium	50			Bucket	Do.
65	2.4 miles south of Gratio	C. P. Sanford	do	Drilled	286	2	do	Grenada	286			Lift pump	Do.

[c] Capacity of pump, 150 gallons a minute. [d] Flowing 2 gallons a minute. [e] Flowing 1 gallon a minute. [f] Flowing 3 gallons a minute.

Analyses of waters from Obion County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyses 1, 17b, 19b, and 57 by Margaret D. Foster; the rest by D. F. Farrar]

	1	17b	19c	19b	24b
Silica (SiO_2)	11	22	7	13	8
Iron (Fe)	.03	15	.4	.79	1.1
Calcium (Ca)	3.7	7.2	65	16	132
Magnesium (Mg)	2.0	3.4	7	8.1	11
Sodium (Na)	4.2	7.0	8	7.4	6
Potassium (K)	1.0	1.0		1.6	
Bicarbonate (HCO_3)	22	44	227	98	452
Sulphate (SO_4)	6.7	6.3	3	7.5	2
Chloride (Cl)	2.1	3.5	12	2.1	10
Nitrate (NO_3)	.10	.15	.3	.05	.4
Total dissolved solids	35	69	218	99	408
Total hardness as $CaCO_3$ (calculated)	17	32	191	73	375
Date of collection, 1929	Sept. 27	Sept. 12	Sept. 13	Sept. 13	Sept. 17
	33	**35**	**38**	**53**	**57**
Silica (SiO_2)	7	1.8	6	6	8.2
Iron (Fe)	1.3	.8	2.1	.9	3.5
Calcium (Ca)	74	113	63	58	13
Magnesium (Mg)	4	16	6	8	6.3
Sodium (Na)	1	4	2	9	3.2
Potassium (K)					1.4
Bicarbonate (HCO_3)	244	407	219	205	71
Sulphate (SO_4)	2	12	1	8	3.1
Chloride (Cl)	.5	6	4	15	2.5
Nitrate (NO_3)	.1	.4	.2	.2	.0
Total dissolved solids	218	365	198	213	69
Total hardness as $CaCO_3$ (calculated)	201	348	182	178	58
Date of collection, 1929	Sept. 17	Sept. 14	Sept. 12	Sept. 12	Aug. 12

SHELBY COUNTY

[Area 801 square miles. Population 306,482]

GEOGRAPHY

Shelby County, in the southwest corner of Tennessee, is bounded on the west by the Mississippi River and on the south by the State of Mississippi. It consists largely of gently rolling uplands, which slope slightly toward the northwest and end abruptly at a line of bluffs that mark the edge of the Mississippi alluvial plain. The uplands have been dissected by three large streams, the Loosahatchie and Wolf Rivers and Nonconnah Creek, and their tributaries. All these streams have wide flood plains or "bottoms," as well as old flood plains or "second bottoms." The alluvial plain of the Mississippi River is not very wide in this county, the maximum being 6 or 7 miles at the Mississippi line; at Memphis the river washes the foot of the bluffs. The average altitude of the county is 300 feet. The highest part is at the southeastern edge of the county, where an altitude of 400 feet is probably attained. Memphis is about 270 feet above sea level.

Shelby County is the most thickly settled part of western Tennessee. Cotton growing, dairying, and trucking are actively carried on. Many towns are scattered over the area, and Memphis, the largest city in Tennessee and an industrial and railroad center, is situated in the western part of the county.

GEOLOGY

Alluvium, loess, Pliocene gravel, and Jackson and Grenada formations crop out in Shelby County, and these are underlain by the formations of Eocene and Cretaceous age that crop out to the east. Of these older formations the Grenada and Ackerman are important as sources of water and will be discussed here.

The alluvium is found in the river bottoms, being the reworked material from the older formations which has been brought down by the streams. It is of variable composition, consisting of clay, sand of different sizes, and gravel.

The loess covers most of the county. It is well exposed in the west, where it forms the top layer of the bluffs. Here it has a maximum thickness of 100 feet, but it thins to a feather edge toward the east and disappears before reaching the eastern boundary of the county. Its fine texture, lack of structure, and property of standing in vertical faces are very characteristic.

The loess is underlain by Pliocene gravel, but the gravel was locally removed by erosion before the deposition of the loess and is not everywhere present. It includes some sand, but the gravel phase has wider distribution. In some places it is from 30 to 50 feet thick and consists of coarse gravel, boulders over 6 inches in diameter being reported. The Pliocene gravel is underlain by sediments of Jackson age, consisting of clay, fine sand, and lignite. This formation has a maximum thickness of 200 feet. It is exposed in the bluffs but has not been seen to the east, though it probably underlies much of the county.

The Wilcox group of this area includes the Grenada, Holly Springs, and Ackerman formations. The Grenada and the upper part of the Holly Springs consist throughout of sands of different age with intercalated lenses of clay. The Holly Springs, however, becomes more argillaceous in depth and contains in its lower part beds that are dominantly clay. The Ackerman formation is chiefly lignitic clay but contains some beds of sand. Though it is impossible to differentiate these formations in well records, for reasons given on page 283, it seems reasonable to assume that the sand below 1,300 feet belongs to the Ackerman formation, and it is so classified in this report. The Wilcox group dips about 25 feet to the mile toward the west and attains a thickness of about 1,900 feet in western Shelby County.

The Ripley formation is separated from the Holly Springs sand by about 300 feet of the Porters Creek clay and Clayton formation. These formations all dip about 25 feet to the mile toward the west. Very little is known about the Ripley formation in Shelby County. The log of the 2,600-foot well of the Memphis Artesian Water Department (p. 284) gives a general idea of the character of the first few hundred feet. The character of the Ripley formation as found in the outcrop is fully described on pages 76–86.

WATER RESOURCES

There are but few springs in Shelby County, and these yield hard water. Shallow wells in the alluvium furnish abundant water. Both dug and driven wells are used. The water-bearing capacity of the loess is very low and the water is hard, and in areas where it is thick deep wells or cisterns are used.

The Pliocene gravel will furnish small supplies of water for domestic use. In places where the thicker reefs of gravel are found large supplies of water can be developed from it. The Jackson formation is a poor source of water, for it is difficult to exclude the fine sand from the wells, the specific yield of the sands is not high, and the proximity of the lignitic beds gives an unpleasant taste to the water, thus rendering it unpotable. The Wilcox group contains lenses of coarse sand which are excellent sources of water. These lenses are as much as 150 feet thick. They may extend over several square miles and within smaller areas may seem to be continuous beds. This is not the case, however; they are discontinuous large lenses occurring at the same general horizon. Hence, the exact depth at which they are to be found is variable, and some wells will not encounter them at all. One such lens is the 400-foot sand (150 feet below sea level) at Memphis, which at Collierville, at the eastern edge of the county, is found at a depth of 230 feet (154 feet above sea level). The static head of the water in this lens at Memphis is 235 feet above sea level. At Memphis the Ripley formation is separated from the Wilcox group by about 400 feet of Porters Creek clay and Clayton formation. This places the top of the Ripley at a depth of about 1,950 feet (1,700 feet below sea level). From 2,371 to 2,634 feet the Ripley contains a good water-bearing sand. This sand has not been penetrated elsewhere in the county but would be reached at about 1,100 feet below sea level at the eastern edge of the county and progressively lower toward the west, with 1,700 feet below sea level at Memphis as a limiting figure. The static head of the water in the Ripley formation is 265 feet above sea level. At Memphis the water from the Ripley formation has a high mineral content and is not fit for domestic or industrial use.

Impervious clay lenses of small extent may, if properly situated, form local artesian basins. (See p. 42.) Such basins have a small capacity and should not be drawn upon by many wells. Such a basin occurs at Brunswick.

Though dug and bored wells are still used in some places in Shelby County, they are being replaced by drilled wells throughout the county. All the larger farms have drilled wells. Some of the drilled wells may go as deep as 600 feet in search of a coarse sand, but the average depth of the wells listed is 243 feet.

LOCAL SUPPLIES

At Arlington, in the valley of the Loosahatchie River, shallow dug or driven wells obtain sufficient water from the valley alluvium. The town has a public water supply derived from one 4-inch well 291 feet deep. (See analysis 8a.) This is equipped with an electrically driven centrifugal pump which delivers the water directly into the mains. Inasmuch as there are no facilities for storage and the cost of pumping continuously is too great, water from the public supply is available for only a few hours a day. Therefore, most of the homes still use their private wells.

Log of town well, Arlington

[Authority, Dean Leak, driller (from memory)]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Mud	65	65	White clay	5	260
Good sand	25	90	White sand	31	291
Blue quicksand	165	255			

The Louisville & Nashville Railroad obtains water from a 10-inch well 221 feet deep. This well is equipped with a duplex steam pump which delivers 250 gallons a minute. The water level is 8 feet below the ground.

An oil test hole drilled for the Arlington Oil & Gas Co. on the Garrett farm showed the following section:

Log of well No. 1 of Arlington Oil & Gas Co., Garrett farm, Arlington

[Authority, V. E. Hines, driller]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Wilcox group:			Wilcox group—Continued.		
Brown clay	20	20	Hard white sand	35	535
Sandrock	2	22	White sand	160	695
Water sand	12	24	Clay	15	710
White chalk (clay)	31	65	Red clay	28	738
Pipe clay	35	100	Lignite	2	740
Brown shale	20	120	Blue clay	40	780
White clay	10	130	Sandrock	1	781
Gumbo	19	149	Blue clay	119	900
Lava rock	1	150	Lava rock	1	901
Sandy shale	20	170	Gas sand	3	904
Pipe clay	10	180	Blue shale	6	910
Water sand	25	205	Brown and blue shale	13	923
White sand	295	500	Gas sand	2	925

At Bartlett (altitude 263 feet) water is obtained from the Pliocene gravel at depths of 50 to 100 feet or else from the Grenada formation, which has a coarse lens at 275 to 340 feet. The Pliocene gravel in this locality is confined to a reef a few hundred feet in width. Outside of this area it is necessary to put in deep wells for good supplies of water.

Log of well of A. R. Appling, Bartlett

[Authority, Mr. Martin, driller (from memory)]

	Thickness (feet)	Depth (feet)
Soil	25	25
Blue clay	100	125
Blue quicksand; little water	150	275
Coarse white sand, water bearing	65	340

In Capleville (altitude 307 feet) shallow and deep wells are in use. The shallow wells obtain water at 20 to 40 feet; the deep wells obtain water from the Grenada at 200 to 345 feet.

Log of well of J. T. Tuggle, Capleville

[Authority, Dean Leak, driller (from memory)]

	Thickness (feet)	Depth (feet)
Alluvium	15	15
Gravel	15	30
Sand and clay	100	130
Sand growing coarser with depth	95	225

In the high land west of Capleville small supplies of water can be obtained just below the loess from a bed of sand 10 to 20 feet thick, found at a depth of 60 to 80 feet. Larger supplies of water can be obtained from a coarse sand lens in the Grenada at a depth of 350 to 450 feet.

Collierville (altitude 387 feet) has a public water supply which obtains water from two 6-inch wells 270 feet deep, spaced 10 feet apart. (See analysis 24a.) These wells are equipped with double-action lift pumps, electrically driven. The water is pumped into a 25,000-gallon elevated tank, from which it is distributed by gravity.

Good springs are found at the foot of the ridge on each side of the town, and wells in the lowlands of either the Wolf River or the Coldwater River average about 20 feet in depth.

Log of well of H. W. Mann Ice Co., Collierville

[Authority, Dean Leak, driller (from memory)]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Yellow clay	30	30	Fine sand	25	225
Pink sand	60	90	White clay	5	230
Fine white sand	50	140	Good coarse sand	14	244
Interlaminated sand and "pipeclay"	60	200			

At Cordova (altitude 365 feet) water is obtained from the Pliocene gravel at depths of 10 to 55 feet, also from a thin lens of sand at 95 to 106 feet, and from a deeper sand at 300 feet.

Log of well of C. A. Chaffee, Cordova

(Authority, Mr. Chaffee (from memory)]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	24	24	Blue clay	90	150
Gravel	11	35	Interbedded fine sand and clay	150	300
Very fine sand	25	60	Coarse white sand	15	315

Eads is in hilly country in the eastern part of the county. In this area the loess is absent. Shallow dug or bored wells obtain water at depths of 35 to 65 feet, and a coarse white sand is found at 175 feet.

Log of well of Charles Richmond, Eads

[Authority, Dean Leak, driller (from memory)]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface clay	35	35	White clay	15	175
Red water-bearing sand	30	65	Coarse white sand	33	209
Blue clay and some lignite	95	160			

At Forest Hills (altitude 369 feet) the first good water sand is found at a depth of 160 feet and another sand at 275 feet. On the high ground east of Forest Hills the Pliocene gravel has a thickness of 40 feet and is tapped by shallow wells.

Germantown (altitude 379 feet) has a public water system (analysis 21) obtaining water from two wells—one 6 inches in diameter, the other 8 inches. These wells are equipped with reciprocal pumps driven by electric motors. The water is pumped into a 25,000-gallon elevated tank, from which it is distributed by gravity. The average daily consumption is 15,000 gallons.

Log of town well, Germantown

[Authority, H. S. Williams]

	Thickness (feet)	Depth (feet)
Clay	25	25
Sand	38	63
Blue clay	68	131
Coarse sand	150	281

At Kerrville (altitude 335 feet) dug wells obtaining water from the Pliocene sand and gravel supply domestic needs. These wells are from 30 to 50 feet deep, according to topographic position.

Log of well of DeSoto Oil Co., Kerrville

[Authority, J. Sullivan, driller]

	Thickness (feet)	Depth (feet)
Clay soil	10	10
Gravel	4	14
Blue clay	386	400
Sandy clay	100	500
White medium sand	35	535

Locke is in the northwest corner of Shelby County. The loess is rather thick in this vicinity, in some places as thick as 100 feet. Water is obtained from the Pliocene gravel, which underlies the loess, but as this water is hard many people prefer to use cisterns. Deep wells would obtain water from the underlying Grenada formation at about 500 feet.

The conditions at Memphis are described in detail on pages 267–311.

Millington (altitude 272 feet) has a public water system (analysis 6a) consisting of two 6-inch wells 250 feet deep spaced 10 feet apart. These wells are pumped by electrically driven reciprocating pumps, which deliver the water into a small reservoir. Thence it is pumped by a centrifugal pump into a 50,000-gallon elevated tank and distributed by gravity. The average daily consumption is 40,000 gallons.

In the vicinity of Mullins small supplies of water can be obtained from wells about 90 feet deep.

At Oakville the well of the Oakville Memorial Sanatorium found water at two good horizons—one in the Pliocene from 85 to 105 feet, and the other in the Grenada formation from 200 to 339 feet. The lower sand probably corresponds to the 400-foot sand at Memphis. At present most of the wells in Oakville are obtaining water from the shallow bed.

Log of well of Oakville Memorial Sanatorium, Oakville

[Authority, Layne Central Co.]

	Thickness		Depth			Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*	Jackson formation—Continued.	*Ft.*	*in.*	*Ft.*	*in.*
Loess: yellow clay	30	0	30	0	Shale	9	0	199	10
Pliocene:					Clay	65	10	265	8
Sand	35	0	65	0	Wilcox group:				
Sand and clay	20	5	85	5	Sand	12	3	277	11
Sand and gravel	15	3	100	8	Gravel	26	3	298	2
Boulders	4		104	8	Sand	40	9	338	11
Jackson formation:					Clay and shale	39	8	378	8
Blue clay	13	0	117	8	Hard clay	21	3	399	11
Hard clay	24	3	141	11	Sand and clay	19	7	419	6
Sand and clay	13	0	154	11	Hard clay	64	5	483	11
Hard clay	5	6	160	5	Sand and clay	17	10	501	9
Sand and clay	30	5	190	10					

In the region around Raines (altitude 290 feet) drilled wells from 38 to 90 feet deep obtain sufficient water from the Pliocene gravel.

At Ridgeway (altitude 325 feet) small supplies of water are obtained from wells 15 to 118 feet deep, which end in Pliocene gravel. Larger supplies are derived from the Grenada formation at about 350 feet.

Log of well of Clarence Saunders, Ridgeway

[Authority, Layne Central Co.]

	Thickness (feet)	Depth (feet)
Clay	15	15
Sand and gravel; pebbles one-fourth inch in diameter; some heavy boulders	103	118
White clay	172	290
Gravel and clay	10	300
Interstratified sand and clay	40	340
White sand	45	385

At Rosemark dug wells range in depth from 30 to 50 feet, drilled wells from 100 to 125 feet and from 500 to 530 feet.

Woodstock (altitude 246 feet) is in the valley of the Loosahatchie. A good water sand is found at a depth of 40 feet.

Records of wells in Shelby County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
1a	Rosemark	S. B. Moffatt	Valley		Dug	44	36	Gravel	Pliocene	44	24	July 29	Plunger pump, electric.	Domestic.
1b	do	School	do		Drilled	125	3	Sand	Grenada	125	30	Rept.	do	Do.
1c	do	Mrs. A. Thompson.	do		do	528	3	do	Holly Springs	528	40	do	do	Do.
2a	Kerrville, 200 feet west of railroad station.	DeSoto Oil Co.	Hillside	340	do	535	2½	do	Grenada	535	65	do	do	Industrial.
2b	Kerrville, 2,000 feet east of railroad station.	B. H. Jones	Hilltop	370	Dug	45	36	Gravel	Pliocene	45	33	July 30	Lift pump	Domestic.
3	3 miles west of Sloanville	M. Jefferson	do		Washed	96	2	do	do	96			do	Do.
4	Locke	County School	do		Drilled	75	2	do	do	75	15	July 29	Plunger pump, gas motor.	Do.
5	Sloanville	C. T. McClellan	Upland		Driven	69	2	do	do	69	44	Rept.	Lift pump	Do.
6a	Millington	City of Millington	Valley		Drilled	250	6	Sand	Grenada	250	40	do	Plunger pump, electric.[a]	Public supply.
6b	Intersection of highway 3 and crossroads to Millington.	Oliver Brank	Hillside		do	90	4	do	do	90			Plunger pump, gas motor.	Industrial.
7	Hanson Hurst	C. C. Hanson	Valley		do	400	4	do	do	400	50	July 29	Air lift	Domestic.
8a	Arlington	City of Arlington	Valley bottom.		do	291	4	do	do	291	6	Rept.	Plunger pump, electric.[b]	Public supply.
8b	do	Louisville & Nashville R. R.	do		do	221	10	do	do	221	8	do	Plunger pump, steam.[c]	Railroad.
9	Woodstock	Chas. N. Smith	do	260	Driven	50	1¼	Gravel	Pliocene	50	15	do	Lift pump	Domestic.
10	4.5 miles south of Woodstock on highway 3.	J. W. Alexander	do	220	do	90	2	Sand	Grenada	90			do	Do.
11	0.6 mile north of Ridgeway	Shelby County Post House.	Hilltop	310	Drilled	537	3	do	do	537	80	Rept.	Electric lift	Do.
12	Memphis, Rayleigh road	National Cemetery.			do	388	4	do	do	381	30	do	do	Do.
13a	Bartlett, 250 feet west of railroad track on highway.	A. R. Appling	Valley bottom.	263	do	340	4	do	do	340	65	do	Lift pump	Do.
13b	Bartlett	John M. Jenkins	do	260	do	50	4	Gravel	Pliocene	50			Lift pump, electric.	Do.
13c	do	Chas. H. Schwan	Hill slope	280	do	100	2½	do	do	100			do	Do.

[a] Pumpage, 40,000 gallons a day. [b] Capacity of pump, 600 gallons a minute. [c] Capacity of pump, 250 gallons a minute.

Records of wells in Shelby County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
14	0.5 mile south of Eads	Chas. Richmond	Upland	365	Drilled	208	2	Sand	Grenada	208	100	Rept	Lift pump, gas motor.	Domestic.
15a	Cordova, 600 feet east of railroad station.	C. A. Chaffee	do	365	do	315	3	do	do	315	60	do	Lift pump, electric.	Do.
15b	Cordova, 600 feet east and 2,000 feet south from railroad station.	J. E. Humphreys	do	365	Bored	106	2½	do	do	106	15	do	Lift pump, gas motor.	Do.
16		County work-house.						do	do					
17	0.8 mile north of Mullins	W. L. Brackett	Hilltop		Drilled	350	3	do	do	350	140	Rept	Lift pump, gas motor.	Domestic.
18	East of Whites	Colonial Country Club.	Upland	385	do	385	4	do	do	385			Electric lift.[d]	Do.
19	1,000 feet east of railroad station at Ridgeway.	Lew Tisdale		320	do	220	2½	do	do	220	50	Rept	Lift pump	Do.
20a	0.7 mile west of railroad station at Ridgeway.	Ridgeway Country Club.		310	do	425	6	do	do	425	100	do	Lift pump, electric.	Do.
20b	1.0 mile south of Brookfield	Clarence Saunders		300	do	386	8	do	do	386	55	do		Do.
21	Germantown	City of Germantown.		379	do	281	6	do	do	281	65	do	Lift pump, electric.	Public supply.
22a	200 feet east of railroad station at Forest Hills.	J. W. Skinner		364	do	180	2½	do	do	180	70	do	Lift pump, gas motor.	Industrial.
22b	0.25 mile west of railroad station at Forest Hills.	W. G. Keller		364	do	308	6	do	do	308			Lift pump, electric.	Domestic.
23	Bailey	Davis & Co	Ridgetop	400	do	225	3	do	do	225	60	Rept	do	Do.
24a	Collierville	City of Collierville.	Hillside	390	do	270	6	do	do	270	90	do	do	Public supply
24b	1,700 feet west and 600 feet south from railroad station at Collierville.	H. W. Mann Ice Co.	do	375	do	244	4½	do	do	244	70	do	do	Industrial.
25a	North side Pigeon Roost road, Oakville.	J. J. Arnold		300	Bored	65	2	do	do	65	55	do	Lift pump, gas motor.	Do.
25b	Oakville	Oakville Memorial Sanatorium.			do	501	8	do	do	501			Rotary electric.[e]	Domestic.
26	Nonconnah, Peebles Avenue.	Railway Ice Co.	Valley	230	Drilled	360	15¼	do	do	210	32	Rept	Steam, double plunger.	Industrial
27	3 miles south of Nanconnah on highway 14.	W. E. McLardy	Upland		do	60	1½	Gravel	Pliocene	60	45	do	Lift pump, gas motor.	Domestic.

28	2 miles west of Raines	B. B. Perry			do	38	2	do	do	38	20	do	Lift pump	Do.
29a	0.4 mile east of Raines	G. T. Banks			do	90	3	do	do	90	65	do	Lift pump, gas motor.	Stock.
29b	Raines, 1,500 feet south of railroad station, 500 feet west of tracks.	L. Banks	Hillside	320	do	64	3	do	do	64	39	do	Lift pump, electric.[f]	Do.
30	Whitehaven	J. W. Hale		330	do	72	2½	do	do	72			Lift pump, gas motor.	Domestic.
31	3 miles east of Whitehaven	H. Farris	Hilltop	350	do	355	2½	Sand	Grenada	355	70	Rept	do	Do.
32a	4 miles east of Whiteville, on Mississippi-Tennessee line.	F. V. Holmes	Upland	460	do	90	2	Gravel	Pliocene	90	80	do	Lift pump	Do.
32b	do	do	do	401	do	401	2½	Sand	Grenada		150	do	Lift pump, gas motor.	Do.
33a	1.7 miles west of Capleville	F. Dyer	do	370	do	440	2½	do	do	440			Lift pump, electric.	Do.
33b	2.0 miles west of Capleville	R. R. Hall	do	360	do	40	2	Gravel	Pliocene	40	30	Rept	Lift pump	Do.
34a	1,000 feet west of railroad station at Capleville.	M. A. Stephenson	Valley	300	do	248	2½	Sand	Grenada	248			Lift pump, gas motor.	Do.
34b	500 feet east of railroad station at Capleville.	J. T. Tuggle	do	300	do	225	2½	do	do	225	60	Rept	do	Do.

[d] Capacity of pump, 20 gallons a minute. [e] Capacity of pump, 350 gallons a minute. [f] Pumpage, 1,000 gallons a day.

Analyses of waters from Shelby County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analysis 8a by D. F. Farrar; the rest by Margaret D. Foster]

	6a	8a	21	24a	28
Silica (SiO_2)	19	9	13	15	20
Iron (Fe)	.05	.8	2.6	.41	.48
Calcium (Ca)	65	29	5.4	2.8	65
Magnesium (Mg)	35	4	2.1	1.0	37
Sodium (Na)	15	23	5.6	3.3	13
Potassium (K)	1.0	3	.6	.8	1.1
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	387	76	34	18	402
Sulphate (SO_4)	8.6	16	3.2	2.6	3.5
Chloride (Cl)	5.0	40	2.9	1.8	5.6
Nitrate (NO_3)	.74	1	0	.10	3.0
Total dissolved solids	333	177	49	35	340
Total hardness as $CaCO_3$ (calculated)	306	89	22	11	314
Date of collection, 1928	July 25	July 28	July 23	July 24	July 23

TIPTON COUNTY

[Area 442 square miles. Population 27,498]

GEOGRAPHY

Tipton County abuts upon the Mississippi River, the western boundary of Tennessee. Most of the county consists of a gently rolling or level upland surface with an average altitude of 325 feet which rises slightly toward the west until it attains about 375 feet (Randolph 378 feet) at the Chickasaw Bluffs, where the surface drops abruptly to the Mississippi lowland. From Randolph to Richardsons Landing the Mississippi River washes the foot of the bluffs, and at no place in this county does the alluvial plain attain an appreciable width. The Hatchie River, which forms the northern boundary of the county, has a broad flood plain. Above this lies the terrace of the second bottom.

Agriculture is almost the only occupation of this region. Some timber is cut in the swampy bottoms of the Hatchie.

GEOLOGY

The geology of Tipton County is very similar to that of Shelby County, to the south. The loess forms a covering for the whole county, and the sunken roads that develop in this formation are a striking feature of the area. The Pliocene is a sandy and gravelly formation that in general underlies the loess but has locally been removed by erosion. The Jackson is exposed in the bluffs, but though it undoubtedly underlies much of the county it does not crop out elsewhere. The Grenada and Holly Springs underlie the Jackson and can be penetrated by drilling.

WATER RESOURCES

Stock ponds supplement the streams for watering stock. In the lowlands along the rivers shallow driven wells obtain abundant water.

As the loess does not yield water, it is sought in the underlying Pliocene gravel. As the gravel is in places very thin, dug wells are more satisfactory, for they have a larger capacity and thus allow a certain amount of storage in the well. For this reason dug wells are still largely used.

The water from the Pliocene gravel is hard, owing to the fact that water seeping through the overlying loess dissolves considerable calcium carbonate. For this reason many people prefer to use cistern water, and many cisterns are found throughout the county. In the eastern part of the county the Jackson and the top of the Grenada formation consist of very fine sand, locally called quicksand. Though this sand contains water it offers unusual difficulties to well drillers, who find it almost impossible to finish a well so as to check the sand. For this reason bored and drilled wells are not common. Although coarser sand can be found at greater depths the cost of a well 300 or 400 feet deep is too much for many farmers.

LOCAL SUPPLIES

At Atoka (altitude 424 feet) dug wells obtaining water from the Pliocene gravel are used. The depth to the gravel ranges from 35 to 80 feet.

At Brighton shallow dug or bored wells are most common. These obtain sufficient water at about 30 feet. A few wells about 100 feet deep have been drilled.

The country around Charleston is high. Bored wells from 50 to 110 feet deep obtain water from the Pliocene or the Jackson formation. These wells are not permanent, running dry during the summer, so cisterns are used to a great extent. In this region drilled wells about 300 feet deep would obtain large quantities of water.

At Covington (altitude 393 feet) water is obtained at two horizons, one at a depth of 60 to 90 feet, another at 500 to 600 feet. The shallow water-bearing bed consists of fine sand, and only relatively small quantities of water can be developed from it. Thus a well (analysis 9a) owned by the city of Covington, 22 inches in diameter and 98 feet deep, with 60 feet of strainer and gravel-wall finish, has a drawdown of 35 feet when pumped at 150 gallons a minute. The 500-foot sand is an excellent source of water. The city of Covington's 12-inch well, 587 feet deep (analysis 9b) develops 800 gallons a minute with only an 8-foot drawdown. The static head is 33 feet below the surface. The city wells are equipped with turbine centrifugal pumps driven by electric motors. The water is pumped into a tank and thence into the mains under direct pressure. Storage is provided by an 85,000-gallon reservoir and an 85,000-gallon tank. The daily water consumption is 400,000 gallons. To the southeast and west of Covington cisterns are largely used. The farms that do not use cisterns have dug wells from 30 to 60 feet deep, which obtain water from the Pliocene gravel.

In the region around Detroit water is obtained from the Pliocene gravel at depths of 60 to 80 feet.

At Drummond the loess is as much as 100 feet thick. To reach the underlying Pliocene wells must exceed this depth.

In the region around Gainesville dug wells averaging 40 feet in depth are used. Two miles north of Gainesville a well was drilled to a depth of 242 feet but encountered nothing but fine sand and so was abandoned. The gin at Gainsville, owned by John D. McCallahan, obtains water from a 3-inch well 425 feet deep. (See analysis 44.) The water rises within 40 feet of the surface. Throughout this section drilled wells from 400 to 600 feet deep would obtain ample supplies of good water.

At Giltedge dug wells averaging 40 feet in depth obtain water from the Pliocene gravel. Along the creek water is obtained from the alluvium.

At Leigh Chapel dug wells obtain water at 60 feet and drilled wells at 100 to 150 feet.

At Mason water is obtained from dug or bored wells averaging 30 feet in depth. Drilled wells from 160 to 230 feet in depth obtain water from the Grenada formation.

Log of well of Mason Ginning Co., Mason

[Authority, J. H. McCraw, driller (from memory)]

	Thickness (feet)	Depth (feet)
White clay	30	30
Sand and clay	15	45
Pipe clay	50	95
Fine sand growing coarser and ending in coarse sand	135	230

At Munford and in the surrounding country the depth to the bottom of the Pliocene gravel ranges from 46 to 75 feet. Dug wells end in this formation.

At Quito most wells are about 60 feet deep. Two miles to the west, along the bluffs overlooking the Mississippi alluvial plain, springs are abundant.

Randolph is on the bluffs overlooking the Mississippi River. Dug wells averaging 40 feet in depth are used. In the lowland along the bluffs springs are common.

Rialto is in the valley of the Hatchie River. Shallow driven wells furnish ample water.

At Tabernacle dug wells 30 to 40 feet deep are used. Glenn [99] reports a 4-inch bored well sunk to a depth of 225 feet. The water was abundant and soft and rose within 106 feet of the surface. The section down to 184 feet, where the water rose 78 feet in the pipe, was chiefly alternating sand and clay. This was followed by a thin sand-ironstone layer, then 21 feet of thin clay, and beneath it another sand, which was entered to a depth of 225 feet from the surface. The water in this sand rose within 164 feet of the surface only, and so the casing was pulled back and the well made at 184 feet. This well is no longer in operation.

At Tipton (altitude 342 feet) dug wells from 30 to 50 feet in depth furnish hard water. Bored or drilled wells go to a depth of 130 feet.

[99] Glenn, L. C., op. cit., p. 117.

Records of wells in Tipton County

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
1	250 feet east of railroad station at Rialto.	Lewis Munford	Valley bottom.	274	Driven	20	1	Sand	Alluvium	20	9	Rept.	Lift pump	Domestic.
2	1.7 miles west of highway 3 on road to Leigh Chapel.	George Wartham	do	270	Dug	34	36	do	do	34	18	Sept. 7	Bucket	Do.
3a	Leigh Chapel, 50 feet east of road.	C. A. Beat	Hilltop	310	do	60	36	do	Grenada	60	46	do	do	Do.
3b	Leigh Chapel	Elmer Linsey	do	310	Driven	117	2	do	do	117			Lift pump	Do.
4	2.4 miles northeast of Covington on highway 3.	A. L. Hensley	Upland	400	Dug	31	36	Gravel	Pliocene	31	23	Sept. 7	Bucket	Do.
5	7.6 miles east of Covington.	T. T. Kinman	Valley bottom.		Driven	35	1½	Sand	Alluvium	35	25	Rept.	Lift pump	Do.
6	Gift, 500 feet west of crossroads.	H. V. Winford	Hillside	400	Dug	50	36	do	Grenada	50	46	Aug. 28	Bucket	Do.
7	3.5 miles east of Covington.	S. M. Bell	Hilltop		do	50	36	do	do	50	47	do	do	Do.
8	1.8 miles east of Covington on Gift road.	W. S. Hunt	Upland	365	do	40	36	Gravel	Pliocene	30	10	do	do	Do.
9a	Covington between College Street and highway 3.	City of Covington	Hillside		Drilled	98	22	Sand	Grenada	98	38	Sept. 8	Lift pump, electric.[a]	Public supply.
9b	do	do	do		do	587	12	do	Holly Springs	587	33	do	do.[b]	Do.
9c	Covington, 0.5 mile north of railroad station.	National Cottonseed Products Co.	Valley bottom.		do	68	4	do	Grenada	68	30	Rept.	Steam plunger [c]	Industrial.
10	2.3 miles west of Covington on Randolph road.	J. S. Ralph	Hilltop	380	Dug	56	36	Gravel	Pliocene	38–56	40	Aug. 28	Bucket	Domestic.
11	10.7 miles west of Covington on Randolph road.	W. H. Murphy	Valley		do	25	36	Sand	Grenada	25	19	do	do	Do.
12	2 miles east of Detroit on Covington road.	H. G. Howard	Hilltop		do	76	36	Gravel	Pliocene		70	Aug. 29	do	Do.
13	Detroit	J. C. Vaughan	Hillside		Driven	65	2	Sand	Grenada		65		Lift pump	Do.

[a] Capacity of pump, 410 gallons a minute.
[b] Capacity of pump, 800 gallons a minute; pumpage, 400,000 gallons a day.
[c] Pumpage, 15,000 gallons a day.

Records of wells in Tipton County—Continued

No.	Location	Owner	Topographic position	Altitude (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1928)	Method of lift	Use of water
14	2.5 miles south of Detroit on Randolph road.	J. C. Petty	Hilltop		Dug	30	36	Gravel	Pliocene	30	24	Aug. 29	Bucket	Domestic.
15a	Giltedge	W. H. Barton	Hillside	310	Drilled	78	2½	Sand	Grenada	78	38	Rept.	Oil engine	Industrial.
15b	14.2 miles west of Covington on Randolph road.	do	do	340	Dug	40	36	Gravel	Pliocene	40	20	Aug. 29	Bucket	Domestic.
16	1 mile west of Holly Grove.	A. C. Barron	Hilltop	390	do	56	36	do	do	56	50	Sept. 7	do	Do.
17	Holly Grove	H. A. Baskin	do	380	Bored	45	6	do	do	45	30	do	do	Do.
18	Liberty	Schoolhouse	do		Dug	50	36	do	do	50	32	do	do	Do.
19	1.8 miles southwest of highway.	County Poor House.	Hillside	350	Drilled	172	4	Sand	Grenada	172	25	Rept.	Lift pump	Stock.
20	3 miles south of Covington on Mount Carmel road.	Green Watkins	Hilltop	410	Dug	42	36	Gravel	Pliocene	42	33	Sept. 8	Bucket	Domestic.
21	3.4 miles southeast of Covington on Mason road.	Wm. Barrett	Upland	430	do	36	36	do	do	36	30	Aug. 27	do	Do.
22	Tabernacle	B. G. Adams	do	380	Bored	36	6	do	do	35	25	Aug. 28	do	Do.
23a	0.2 mile west of Charleston.	E. P. Cole	do		Drilled	110	2	Sand	Grenada		102	Aug. 27	Lift pump, gas motor.	Do.
23b	0.6 mile west and 0.7 mile north from Charleston.	C. H. Davis	do		Bored	94	6	do	do	94	70	Aug. 28	do	Do
24a	5.2 miles southeast of Covington on Mason Road.	R. L. Bryan	do		Drilled	165	2	do	do	165	10	Rept.	do	Do.
24b	5 miles southeast of Covington on Mason road.	Mrs. W. L. Hastin	do		Bored	48	6	Gravel	Pliocene	48	45	Aug. 27	Bucket	Do.
25	Randolph	O. C. Graves	Valley	340	Dug	45	36	do	do	45	25	Aug. 29	do	Do.
26	Beaver	L. G. Beaver	do	315	do	48	36	Sand	Grenada	48	5	Sept. 7	do	Do.
27	3.4 miles west of Holly Grove.	Bishop	Second bottom.	320	Bored	26	6	do	Alluvium	25	18	do	do	Do.
28a	Brighton	R. L. Smith	Hillside	340	Dug	30	36	Gravel	Pliocene	30	15	Aug. 30	do	Do.
28b	do	School	River bottom.	320	Drilled	100	2	Sand	Grenada	100			Lift pump	Do.

29	6.5 miles south of Covington on Mount Carmel road.	Thomas Morris	Upland	410	do	175	2	do	do	175			do	Do.
30	8.2 miles southeast of Covington on Mason road.	S. S. Dennis	do	450	Dug	40	36	do	do	40	37	Aug. 27	Bucket	Do.
31	1.6 miles north of Gainesville.	J. W. Stevens	do	390	do	48	36	do	do	48	45	Aug. 28	do	Do.
32a	Atoka, 100 feet west of railroad station.	J. J. Fleming	Hillside	475	do	70	36	do	do	70	40	Sept. 6	do	Do.
32b	Atoka, 0.3 mile west of railroad station.	L. D. Templeton	Hilltop	440	do	38	36	do	do	38	31	do	do	Do.
33a	500 feet east of schoolhouse, Munford.	J. C. Harris	Upland	450	Bored	63	6	Gravel	Pliocene	63	42	do	do	Do.
33b	Munford	County school	do	450	Drilled	75	2½	do	do	75			Lift pump	Do.
34	2.2 miles southeast of Simonton on Giltedge road.	J. S. Wilkins	Hilltop	430	Dug	46	36	do	do	46	36	Sept. 7	Bucket	Do.
35	2 miles west of Munford on Drummond road.	J. W. Fizer	Hillside		do	52	36	do	do		45	Sept. 6	do	Do.
36	Simonton	J. W. Turnage	Hilltop	420	do	70	24	do	do	70	55	Sept. 7	do	Do.
37a	Drummond	Schoolhouse	Upland	460	Drilled	111	2	Sand	Grenada	111			Lift pump	Do.
37b	do	W. H. Baxter	do	460	do	86	2	do	do	86			Steam plunger	Industrial.
38	2.1 miles south of Drummond.	W. S. Hornsby	do	460	Driven	96	2	do	do	96			Lift pump	Domestic.
39	Quito	J. H. Pouncey	Hilltop	440	Dug	60	36	Gravel	Pliocene	60	55	Sept. 8	Bucket	Do.
40	1.2 miles west of Wilkinsville.	Kerrville Bank	do	370	do	65	36	Sand	Grenada	65	32	do	do	Do.
41	Wilkinsville	T. M. Mathews	Valley	340	Drilled	56	2½	do	do	56			Lift pump	Do.
42	Tipton	Illinois Central R. R.	Hilltop	360	Bored	65	6	Gravel	Pliocene	65	29	Sept. 6	Bucket	Do.
43	Wright	Thos. Anderson	do	380	do	45	6	Sand	Grenada	45	31	Sept. 8	do	Do.
44	Gainesville	J. D. McCallahan	Hillside	380	Drilled	425	3	do	do	425	40	Rept.	Steam plunger	Industrial.
45a	Mason	J. R. Exum	do	330	Bored	30	6	Gravel	Pliocene	30	15	Aug. 27	Bucket	Domestic.
45b	do	Mason Ginning Co.	Valley bottom.	307	Drilled	160	4	Sand	Grenada	160	40	Rept.	Steam plunger	Industrial.

Analyses of waters from Tipton County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyzed by D. F. Farrar]

	6	9a	9b	23b	25
Silica (SiO_2)	6	3	7.5	5	11
Iron (Fe)	.7	.1	.3	.2	1.3
Calcium (Ca)	17	25	20	16	138
Magnesium (Mg)	3	3	4	2	18
Sodium (Na)	3	7	2	2	20
Potassium (K)					2
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	60	86	74	52	466
Sulphate (SO_4)	5	2	5	4	29
Chloride (Cl)	5	12	3	2.5	34
Nitrate (NO_3)	.6	.2	.2	.2	1
Total dissolved solids	72	94	81	61	494
Total hardness as $CaCO_3$ (calculated)	55	75	66	48	418
Date of collection, 1928	Aug. 28	Sept. 8	Sept. 8	Aug. 28	Aug. 29

	33	39	44	45a
Silica (SiO_2)	9	9	12	8
Iron (Fe)	1.1	1.3	.8	.5
Calcium (Ca)	56	132	17	38
Magnesium (Mg)	7	5	3	5
Sodium (Na)	3	11	3	29
Potassium (K)		2		3
Carbonate (CO_3)	0	0	0	0
Bicarbonate (HCO_3)	198	416	60	37
Sulphate (SO_4)	5	3	4	77
Chloride (Cl)	3.5	21	5	51
Nitrate (NO_3)	.6	.6	.3	.4
Total dissolved solids	187	398	79	248
Total hardness as $CaCO_3$ (calculated)	168	350	55	115
Date of collection, 1928	Sept. 7	Sept. 8	Sept. 8	Aug. 27

WEAKLEY COUNTY

[Area 580 square miles. Population 29,262]

GEOGRAPHY

Weakley County is in the middle of the northern part of western Tennessee. Farming is the only activity. Though cotton is the main crop, the growing of early vegetables is actively carried on, with Greenfield and Sharon as the shipping points. There is considerable dairying.

Weakley County is drained by the North, Middle, and South Forks of the Obion River and their tributaries. These streams all flow to the west. The region is gently rolling with the exception of a high area in the eastern part of the county north of Dresden. The highest altitude precisely known in Weakley County is 415 feet above mean sea level at Martin; the lowest is 320 feet at a point 3.6 miles north of Greenfield, on the Middle Fork of the Obion River. The hills north of Dresden may attain an altitude of 500 feet. The average altitude throughout the county is between 400 and 450 feet.

GEOLOGY

The Wilcox crops out over the whole of Weakley County. Except in a small area in the southeastern part of the county, where the Holly

Springs sand is found at the surface, the Grenada formation of the Wilcox group occurs everywhere. The Grenada is composed of sand of variable size and color, with intercalated lenses and layers of clay.

WATER RESOURCES

Cattle in Weakley County are watered from streams or where these are not convenient from stock ponds. During dry periods recourse is had to wells. Water in sufficient quantities for domestic or industrial use can be obtained from the Grenada formation at any place. Clay lenses may be encountered, but these nowhere exceed 100 feet in thickness and by passing through them water will be obtained. In some places in the formation fine sand may be encountered but deeper drilling will reach coarser sands below. The average depth of the 65 bored wells listed in the table is 61 feet. The drilled wells average 241 feet. This difference is due to the fact that drilled wells are used when large supplies are needed; also a drilled well may go deep in search of a coarse sand. The average depth to the water table is 56 feet, but on the high hills it is as much as 140 feet.

LOCAL SUPPLIES

Dresden, the county seat of Weakley County, has a public water supply owned by the city. Water is obtained from two 6-inch wells, one 275 feet and the other 460 feet deep. (See analyses 41a and 41b.) The wells are pumped by air lift and the water is delivered to a 85,000-gallon reservoir, from which it is lifted to a 50,000-gallon elevated tank by means of a centrifugal pump yielding 100 gallons a minute. The city consumes on the average 75,000 gallons a day. There is no need for drilling deeper than 275 feet at Dresden, as the well of that depth is quite satisfactory. Wells of the same depth properly spaced would supply all needs.

A layer of clay underlies Dukedom, and to obtain permanent water wells must be drilled through this clay. Wells 175 to 200 feet deep will penetrate to sand. In the lowland shallow wells 40 feet deep furnish sufficient water for domestic needs.

Gardner is situated in low land, and very shallow wells 20 to 30 feet deep obtain abundant water. On the high land to the north of the town drilled wells are used and are as much as 150 feet deep.

At Greenfield (altitude 433 feet) the city water supply (analysis 70) has two wells, a 6-inch well 286 feet deep and an 8-inch well 436 feet deep. Both wells are pumped by an air lift to a 100,000-gallon reservoir, from which it is lifted to a 50,000-gallon overhead tank by a centrifugal pump having a capacity of 400 gallons a minute. The average consumption is 150,000 gallons a day. Underlying Greenfield and to the east there is a layer of lignite. This lignite at Greenfield is found at a depth of about 90 feet, and water obtained from sand just below it has a high iron content. A fine sand is found at 145 to 200 feet, but below this there is a coarse sand. It is needless to go deeper than 300 feet at Greenfield. Abundant good water can be obtained 200 to 300 feet below the surface.

Martin, at the junction of the Illinois Central and the Nashville, Chattanooga & St. Louis Railroads, is the largest city in Weakley County. The public water supply is owned by the city. (See analysis 37.) Water is obtained from three wells—a 3-inch well 320 feet deep, a 6-inch well 550 feet deep, and a 10-inch well

537 feet deep. The first two wells are pumped by air lift and the third by a centrifugal pump. The water goes into a reservoir, from which it is pumped to an elevated tank. The city uses about 600,000 gallons a day. Good water-bearing sand is found at 100 to 125 feet, but water from this horizon attacks boilers vigorously. Another layer of good sand is found between 300 and 400 feet, and a third from 480 to 555 feet. The depth of water at Martin is 75 feet.

At Palmersville the depth to water is about 70 feet. Bored wells 80 to 100 feet deep and drilled wells as much as 110 feet deep obtain sufficient water. Owing to the considerable depth to water in the area a few miles south of Palmersville cisterns are exclusively used, but wells from 100 to 200 feet deep should obtain plenty of water.

The public water supply of the city of Sharon (analysis 58) is equipped with two wells, both 6 inches in diameter; one is 267 feet deep and the other is 496 feet deep. The wells are pumped by force pumps, and the water is delivered to a 50,000-gallon elevated tank.

Records of wells in Weakley County

No.	Location [a]	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Use of water
1	4 miles east of Dukedom	J. C. Glass	Hilltop	Bored	81	6	Sand	Grenada	81	76	July 20	Bucket	Domestic.
2	3.5 miles east of Dukedom	C. Fields	Bottom	do	26	6	do	do	26	6	do	do	Do.
3	2.2 miles east of Dukedom	J. L. Foy	Upland	Drilled	100	2	do	do	100	50	Rept	Force pump	Do.
4a	Dukedom	E. H. McClain	Hillside	do	190	2	do	do	190			do	Do.
4b	do	Mrs. A. Rose	Upland	do	176	2	do	do	176	115	Rept	do	Do.
5	4.3 miles southwest of Dukedom.	W. B. McConell	do	Bored	42	6	do	do	42	39	July 20	Bucket	Do.
6	5 miles southwest of Dukedom	J. B. Nannay	do	Drilled	135	2	do	do	135	109	Rept	Force pump	Do.
7	5.7 miles southeast of Dukedom.	E. H. McClain	Hillside	Bored	40	6	do	do	40	32	July 20	Bucket	Do.
8	7 miles southeast of Dukedom	R. C. Austin	Lowland	do	48	6	do	do	48	40	do	do	Do.
9	9.3 miles east of Dukedom	C. S. Brooks	Upland	do	60	6	do	do	60	57	do	do	Do.
10	3.2 miles northeast of Palmersville.	W. J. McClure	Second bottom.	do	38	6	do	do	38	32	do	do	Do.
11	5.2 miles northeast of Lantham.[b]	L. B. Norman	Hilltop	do	65	6	do	do	65			do	Do.
12	2.5 miles northeast of Lantham.[b]	J. A. Brundige	Lowland	do	32	6	do	do	32	24	July 24	do	Do.
13	6 miles north of Martin	W. S. Winstead	Upland	do	60	6	do	do	60	50	July 20	do	Do.
14	4 miles northeast of Martin	K. M. Counce	Hillside	do	40	8	do	do	40	36	do	do	Do.
15	Latham	W. H. Legans	Lowland	do	30	6	do	Alluvium	30	20	July 24	do	Do.
16	4 miles west of Palmersville	O. E. Grooms	Upland	do	86	6	do	Grenada	86	80	do	do	Do.
17a	Palmersville	Cooperative cheese factory.	do	Drilled	110	2	do	do	110			Force pump	Industrial.
17b	do	J. J. Tyson	do	Bored	82	8	do	do	82	70	July 26	Bucket	Domestic.
18	2 miles east of Palmersville on Cottage Grove road.	D. A. Puryear	Hillside	Drilled	100	2	do	do	100			Lift pump	Do.
19	2.7 miles east of Palmersville on Cottage Grove road.[b]	H. Roberts	Lowland	Bored	30	6	do	do	30	18	July 26	Bucket	Do.
20	7.2 miles north of Dresden	N. Hawks	Upland	do	75	6	do	do	75	68	July 24	do	Do.
21	3 miles northeast of Martin	W. M. Pierce	do	do	82	6	do	do	82	73	July 20	do	Do.
22	1.5 miles northeast of Terrell	J. C. Gray	do	Drilled	156	2½	do	do	156			Lift pump	Do.
23a	Terrell	T. A. Futrell	Lowland	Bored	32	6	do	do	32	26	July 23	Bucket	Do.
23b	do	C. C. Talleson	do	do	32	6	do	do	32	26	do	do	Do.
24	Gardner	J. Bryan	do	do	26	6	do	do	26	22	do	do	Do.

[a] Distances scaled from State map except as otherwise noted.

[b] Distances as given by speedometer.

Records of wells in Weakley County—Continued

No.	Location	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed		Depth to which well is cased (feet)	Water level		Method of lift	Use of water
							Character of material	Geologic horizon		Below surface (feet)	Date of measurement (1929)		
25	1.6 miles northeast of Martin	J. Johnson	Upland	Bored	81	6	Sand	Grenada	81	74	July 20	Bucket	Domestic.
26	5 miles east of Martin	A. N. Babb	do	Drilled	120	2½	do	do	120	99	July 24	Lift pump	Do.
27	6.5 miles east of Martin	J. J. Bynum	Hillside	Bored	70	6	do	do	70	65	do	Bucket	Do.
28	6 miles north of Dresden on Lanham road.[b]	W. H. Harris	do	do	45	6	do	do	45	40	do	do	Do.
29	5.9 miles northeast of Dresden on road to Palmersville.[b]	T. R. Prince	do	do	90	6	do	do	90	79	July 26	do	Do.
30	3.8 miles southwest of Henry County line on Cottage Grove-Dresden road.[b]	W. H. Killebrew	do	do	70	6	do	do	70	68	do	do	Do.
31	4.4 miles east of Palmersville on road to Cottage Grove.[b]	G. W. Parish	do	do	35	6	do	do	35	29	do	do	Do.
32	12 miles east of Dresden	J. S. Tuck	Hilltop	do	68	6	do	do	68	63	do	do	Do.
33	9.7 miles southwest of Henry County line on Cottage Grove-Dresden road.[b]	Hillcrest School	Hillside	Drilled	180	2	do	do	180			Lift pump	Do.
34	3.8 miles northwest of Dresden on road to Palmersville.[b]	G. T. Blacknall	do	Bored	90	6	do	do	90	84	July 26	Bucket	Do.
35	3 miles north of Dresden on Lanham road.[b]	B. Smith	Hilltop	do	65	6	do	do	65	63	July 24	do	Do.
36	Ralston	R. E. Little	do	do	180	6	do	do	180	140	Rept.	do	Do.
37a	Martin, just east of railroad station.	City of Martin	Upland	Drilled	550	6	do	Holly Springs	550	97.5	July 25	Air lift	Public supply.
35b	do	do	do	do	557	10	do	do	557			Vertical centrifugal.[c]	Do.
37c	do	do	do	do	320	3	do	do	320			Air lift	Do.
37d	Martin, 137 Church Street	Martin Coal & Ice Co.	do	do	450	6	do	do	450	75	Rept.	do [d]	Industrial.
38	2.4 miles south of highway 22; 0.3 mile east of Obion County line.[b]	Sam Fugua	Hillside	Bored	33	6	do	Grenada	33	6	July 22	Bucket	Domestic.
39	5.5 miles south of Terrell	J. C. Wagster	Upland	do	90	6	do	do	90			do	Do.
40	2.8 miles east of Ralston on highway 22[b]	W. C. Adams	Hillside	do	86	86	do	do	86	80	July 25	do	Do.
41a	Dresden, 75 feet south of railroad station.	Town of Dresden	Upland	Drilled	460	6	do	Holly Springs	460	40	Rept.	Air lift [e]	Public supply.
41b	do	do	do	do	275	6	do	do	275	30	do	do [f]	Do.

42	2.6 miles east of Dresden on Paris road. [b]	W. T. Milton	Hilltop	Bored	108	6	do	Grenada	108	90	July 27	Bucket	Domestic.
43	5.6 miles east of Dresden on Paris road. [b]	J. F. Taylor	Upland	do	75	6	do	do	75	69	do	do	Do.
44	7.9 miles east of Dresden on Paris road. [b]	J. H. Moore	Hillside	do	30	6	do	do	30	25	do	do	Do.
45	9.9 miles east of Dresden on Paris road. [b]	A. Redford	do	do	36	6	do	do	36	31	do	do	Do.
46	2.8 miles south of Ore Springs on road to Gleason. [b]	R. A. Tatum	Lowland	do	38	6	do	do	38	27	do	do	Do.
47	6.4 miles northwest of Gleason on highway 22. [b]	R. T. Overton	Hilltop	Drilled	85	2½	do	do	85	67	July 26	Lift pump	Do.
48	On highway 43, 3 miles north of Sharon. [b]	J. H. Ellis	do	Bored	93	6	do	do	93	79	July 22	Bucket	Do.
49	8.5 miles south of Terrell on Obion County line. [b]	C. T. Brooks	Lowland	do	44	6	do	do	44	33	do	do	Do.
50	Sidonia	H. H. Hawkins	Upland	Drilled	100	2½	do	do	100			Lift pump	Do.
51	2 miles east of Illinois Central R. R. at Hillside. [b]	A. D. Anderson	do	Bored	80	6	do	do	80	72	July 24	Bucket	Do.
52	3.8 miles southeast of Sharon	L. L. Brewer	Hillside	Drilled	180	2½	do	do	180			Lift pump	Do.
53	6.3 miles southeast of Sharon	M. Levy	Lowland	Bored	23	6	do	do	23	12	July 24	Bucket	Do.
54	2 miles southeast of Dresden	M. E. Chandler	do	Dug	30	2½	do	do	30	22	July 23	do	Do.
55	2.8 miles northwest of Gleason on highway 22. [b]	Monroe Corcoran	do	Bored	30	6	do	do	30	22	July 26	do	Do.
56a	Gleason, east side of railroad track.	City of Gleason	Upland	Drilled	110	6	do	do	110	40	Rept.	Force pump	Public supply.
56b	do	do	do	do	110	6	do	do	110	40	do	do	Do.
57	5.6 miles south of Dresden	G. B. Oliver	Hillside	Bored	16	6	do	do	16	12	July 23	Bucket	Domestic.
58a	Sharon	City of Sharon	Upland	Drilled	276	6	do	do	267	60	Rept.	Force pump [g]	Public supply.
58b	do	do	do	do	493	6	do	Holly Springs	493	96	do	do. [h]	Do.
59	3 miles west of Sharon	W. C. Royster	do	Drilled	85	6	do	Grenada	85	72	July 22	Bucket	Domestic
60	8.2 miles northwest of Greenfield.	Wm. Hillis	Hillside	do	40	6	do	do				do	Do.
61	2.5 miles southwest of Sharon	Dew Bros.	Upland	do	55	6	do	do	55	49	July 22	do	Do.
62	3 miles southeast of Sharon [b]	J. J. Higgs	Hilltop	do	96	2½	do	do	96	65	Rept.	Lift pump	Do.
63	2.5 miles west of Gleason	W. L. Finch	Hillside	do	35	6	do	do	35	30	July 25	Bucket	Do.
64	4.4 miles northwest of Carroll County on highway 22. [b]	E. L. Greene	Upland	do	60	6	do	do	60	51	July 27	do	Do.
65	4 miles southwest of Gleason	J. C. Phillips	Hillside	do	120	6	do	do	120	115	July 25	do	Do.
66	2.5 miles east of Greenfield on Dresden road.	Wm. Baker	Upland	do	40	2½	do	do	40			Lift pump	Do.
67	3 miles southwest of Gibson County line on road between Greenfield and Forks of the River.	L. D. Holder	do	Drilled	100	2½	do	do	100			do	Do.
68	2 miles west of Greenfield [b]	L. E. Daniel	do	Bored	75	6	do	do	75	73	July 22	Bucket	Do.

[b] Distances as given by speedometer.
[c] Pumpage, 575,000 gallons a day.
[d] Pumpage, 75,000 gallons a day.
[e] Capacity of pump, 270 gallons a minute.
[f] Capacity of pump, 270 gallons a minute; pumpage, 75,000 gallons a day.
[g] Capacity of pump, 50 gallons a minute.
[h] Capacity of pump, 700 gallons a minute; pumpage, 50,000 gallons a day.

Records of wells in Weakley County—Continued

No.	Location	Owner or name	Topographic position	Type of well	Depth of well (feet)	Diameter of well (inches)	Water-bearing bed: Character of material	Water-bearing bed: Geologic horizon	Depth to which well is cased (feet)	Water level: Below surface (feet)	Water level: Date of measurement (1929)	Method of lift	Use of water
69	2 miles southwest of Greenfield on Trenton road.[b]	E. W. Jeter	Upland	Dug	40	36	Sand	Grenada	40	37	July 22	Bucket	Domestic.
70a	Greenfield, 200 feet north of railroad station.	City of Greenfield	do	Drilled	286	6	do	Holly Springs	286	122	Rept.	Air lift [i]	Public supply.
70b	do	do	do	do	436	8	do	do	436	122	do	do. [j]	Do.
70c	Greenfield, 900 feet south of railroad station.	do	do	do	222	6	do	do	222			do. [k]	Industrial.
71a	Rinda, 3.5 miles east of Greenfield.	O. Galloway	Hillside	Bored	25	6	do	Grenada	25	17	July 23	Bucket	Domestic.
71b	do	Z. W. Grooms	Upland	Dug	36	24	do	do	36	32	July 25	do	Do.
72	8.3 miles west of McKenzie on Greenfield road.[b]	J. J. Featherstone	Lowland	Bored	21	6	do	do	21	15	do	do	Do.
73	5.4 miles west of McKenzie on Greenfield road.[b]	R. E. Williams	Upland	do	115	6	do	Holly Springs	115	108	do	do	Do.
74	2.9 miles west of McKenzie on Greenfield road.[b]	J. W. Adams	Hilltop	do	130	6	do	do	130			do	Do.
75	2 miles northwest of Carroll County line on highway 22.[b]	Mrs. D. Witworth	Upland	do	58	6	do	do	58	47	July 27	do	Do.
76	7.7 miles southeast of Greenfield.	J. B. Hall	do	do	45	6	do	Grenada	45	40	July 25	do	Do.
77	7 miles southeast of Greenfield	R. Featherstone	Hilltop	do	87	6	do	do	87	82	do	do	Do.
78	4.5 miles southeast of Greenfield.	Ray Wicker	Hillside	do	62	6	do	do	62			do	Do.
79	2 miles southeast of Greenfield on Trezevant road.	W. W. Brooks	Upland	Drilled	150	2½	do	do	150			Lift pump	Do.
80	0.6 mile north of Gibson County line on highway 43.[b]	E. Coats	Bottom	Bored	33	6	do	Alluvium	33	30	July 22	do	Do.
81	4.0 miles southeast of Greenfield on Trezevant road.[b]	T. Z. Ellinder	Hilltop	do	90	6	do	Grenada	90	80	July 23	Bucket	Do.
82	7.5 miles southeast of Greenfield on Trezevant road.	T. Galey	do	do	40	6	do	Holly Springs	40	34	do	do	Do.
83a	10.2 miles southwest of Greenfield on Trezevant road.	R. W. Cunningham	do	do	48	6	do	do	48	46	do	do	Do.
83b	do	do	do	Drilled	80	2½	do	do	80			Lift pump	Do.

[b] Distances as given by speedometer.
[i] Capacity of pump, 100 gallons a minute.
[j] Capacity of pump, 100 gallons a minute; pumpage, 150,000 gallons a day.
[k] Pumpage, 50,000 gallons a day.

Analyses of waters from Weakley County

[Parts per million. Numbers at heads of columns refer to corresponding well numbers in preceding table. Analyses 17a and 41b by D. F. Farrar; the rest by Margaret D. Foster]

	4a	17a	23b	24	36
Silica (SiO_2)	12	3.2	21	36	16
Iron (Fe)	3.6	.4	.50	.12	.93
Calcium (Ca)	4.2	11	33	28	6.2
Magnesium (Mg)	2.4	3	18	13	2.7
Sodium (Na)	6.1	3	76	93	10
Potassium (K)	1.3		2.0	5.8	2.9
Bicarbonate (HCO_3)	74	27	290	114	27
Sulphate (SO_4)	5.5	16	20	15	3.6
Chloride (Cl)	2.2	5	35	108	11
Nitrate (NO_3)	0	.3	18	83	12
Total dissolved solids	[a] 79	58	368	454	83
Total hardness as $CaCO_3$ (calculated)	[b] 46	40	156	123	27
Date of collection, 1929	July 20	July 26	July 23	July 23	July 23

	37	41a	56	58a	70b
Silica (SiO_2)	12	13	3.4	12	14
Iron (Fe)	.02	.02	.5	.08	.06
Calcium (Ca)	2.8	2.2	12	3.1	2.8
Magnesium (Mg)	2.1	1.8	1	2.1	2.6
Sodium (Na)	4.5	2.5	10	2.6	2.7
Potassium (K)	1.1	2.2		.8	1.3
Bicarbonate (HCO_3)	26	17	25	20	20
Sulphate (SO_4)	4.1	4.1	7	4.6	5.2
Chloride (Cl)	1.6	1.4	19	1.0	1.6
Nitrate (NO_3)	.10	.10	.4	.05	.10
Total dissolved solids	36	32	58	34	36
Total hardness as $CaCO_3$ (calculated)	16	13	34	16	18
Date of collection, 1929	July 25	July 23	July 26	July 24	July 22

[a] Includes 24 parts per million of zinc (Zn); may be from we llcasing.
[b] 46 parts per million due to zinc (Zn).

MEMPHIS

Memphis is in the southwest corner of western Tennessee, on the east bank of the Mississippi River. At this point the Mississippi washes the foot of the bluffs. The Wolf River lies on the northern edge and Nonconnah Creek on the southern edge of the city. With the exception of the lowland along those two streams, the city is situated above high flood-water level of the Mississippi River.

The area of the city in 1930 was 50.7 square miles and the population 253,143. Ten trunk-line railroads serve Memphis. The city is a large cotton market, 186 firms being engaged in the cotton business. Next to cotton comes lumber, especially hardwood. Thirty hardwood sawmills and 60 additional offices of firms dealing in hardwood are located in Memphis.

The city water supply and the private water systems of industrial plants in Memphis constitute the largest ground-water development in western Tennessee. Among the cities of the United States that use ground water listed in 1928,[1] Memphis ranked third in gallons of water pumped, and it is to be classed among the ground-water developments in this country which have a very large pumpage per unit area. The average daily pumpage of the Memphis Artesian Water Department for 1928 was 17,600,000 gallons, and that of the

[1] Water-supply statistics of American municipalities, reprinted from American Municipal Index, 1929.

private plants about 21,000,000 gallons. Ground-water conditions at Memphis are of primary interest not only locally but also throughout western Tennessee, for the area affords both the most complete data on ground-water conditions and an opportunity to study the behavior of the water-bearing beds under heavy pumping. Hence considerable time has been given to the accumulation of data in this city and to the study of the problems that were encountered.

Through the cooperation of the Memphis Artesian Water Department it was possible to install two automatic water-stage recorders over representative observation wells, which give continuous records of the depth to the water level in these wells and thus show with much precision the relation between the withdrawal of the artesian water and the subterranean inflow of new supplies to recharge the artesian reservoir that underlies the city of Memphis. It becomes continuously more apparent that any quantitative study of the ground-water supply in an area must be made from data accumulated over a considerable period of time, and that the longer the record the more accurate are the resulting conclusions. Any deductions as to quantity of water made from measurements taken during a brief period are likely to be premature and may lead to erroneous conclusions. For this reason it is planned to continue observations at Memphis for a period of years.

Though the field work for this report was done largely in the summer of 1928 and terminated in the fall of 1929, it has seemed advisable to bring the record of pumping, well draft, and river stage up to April 1, 1931, for the purpose of ascertaining if the prolonged low stages of the Mississippi River during the last two months of 1930 and the first three months of 1931 would more clearly reveal the relationship between these factors. Furthermore, there have been incorporated in this report the results of partial chemical analyses made on samples from wells scattered throughout the city which were collected in August, 1930, and January, 1931, for the purpose of detecting any change in the chemical character of the waters in the Wilcox group of formations due to inflow of water from the Mississippi River. It has been impossible, however, to bring all the data up to 1931, and for this reason some of the discussion will relate to the date 1929.

HISTORY OF ARTESIAN WATER DEVELOPMENT

The early history of the development of the municipal water supply at Memphis is given by Lundie[1] as follows:

Prior to 1870 Memphis relied wholly for its water supply on cisterns and shallow wells. In 1867–68 an investigation as to a general system of water supply was made by Charles Hermany, C. E., a report on which was presented to the board of commissioners of the city July 15, 1868. In this report Mr. Hermany recom-

[1] Lundie, John, Report on the waterworks system of Memphis, Tenn., Memphis, 1898.

mended that a supply be taken from Wolf River near its mouth. This led to the formation of the Memphis Water Co., which in 1870 secured a charter from the State legislature to supply water to the city. The company erected a pumping plant on the south bank of the Wolf River about 2 miles from the center of the city and laid 17 miles of pipe through which the city was supplied with water pumped from the river. The enterprise was a financial failure, and the plant was sold under foreclosure proceedings in the United States circuit court in December, 1879, to the reorganized Memphis Water Co. for $200,000, the company's statement of cost being $472,278.

The yellow-fever scourge in 1878–79 aroused the citizens of Memphis to a thorough sense of the crying demand for improved sanitary conditions, which resulted in the adoption of a sewerage system, the first sections of which were built in 1879–80, under the direction of George E. Waring, jr., C. E. These sewers called for an extension of the water pipes to supply the flushing tanks which are an integral part of the system.

The Memphis Water Co. in May, 1882, concluded a contract with the taxing district of Shelby County (now the city of Memphis) for public water supply; the contract to remain in force for a period of 20 years from May 1, 1882. Rapid extension of the piping system followed this contract.

In 1885 a citizens' movement was instituted with a view toward securing a better water supply, the principal objection to the supply, urged at that time, being its turbidity. A committee was appointed by the legislative council of the taxing district to investigate and report on the question. Gen. Colton Greene made a preliminary report to this committee in February, 1886, and in December, 1886, the committee presented its report to the council.

The committee considered three principal sources of supply which seemed available—viz, the Mississippi River, South Horn Lake, and Wolf River at a point near the Louisville & Nashville Railroad crossing about 8 miles east of the city. All projects involved methods of filtration.

Prospective supply from wells had been brought to the attention of the committee, but evidence at that time seemed to cast doubt on the practicability of such a system of water supply for city purposes, after the failure of several experimental wells was reported, which had been sunk at the instance of the Memphis Water Co. * * *

While the report of this committee was in preparation, the late Mr. R. C. Graves, then superintendent of the Bohlen-Huse Ice Co., had a well sunk on the company's property on Court Street near the bayou, primarily for the object of obtaining water for condensing purposes, to a depth of 354 feet. After having passed through a stratum of clay 150 feet thick, water-bearing sand—the source of the present supply—was reached, and a flowing well was the result, the water from which rose several feet above the surface of the ground.

A company was organized for the purpose of supplying the city with water from this source, which, after some further experimentation, entered into a contract with the taxing district on July 30, 1887, under the name of the Artesian Water Co., covering terms of public and private supply and anticipating a consolidation of the interests of this company with those of the Memphis Water Co., then under contract for public supply.

Both water companies then proceeded to sink wells, but consolidation of their interests was consummated in April, 1889, shortly after which the Wolf River plant was abandoned and dismantled, a temporary station having been erected near the present station (the Auction Avenue station), connecting with such wells as were then operative.

In 1903 the interest of the Memphis Water Co. was purchased by the city, the Memphis Artesian Water Department was organized, and a board of water commissioners was formed for its supervision.

Forty-two wells were drilled during 1888 to 1889, and the Auction Avenue pumping station was put in operation in 1890. The Auction Avenue plant consisted of a tunnel 5 feet in diameter and smaller branching tunnels situated 75 to 80 feet below the surface. Wells discharged directly into these tunnels, and the water flowed by gravity to a central well at the pumping station. Three vertical compound condensing high-duty pumping engines pumped the water from the central well and delivered it under pressure directly to the service mains.

New wells were drilled from time to time as old wells failed and as additional supplies of water were required, but no change was made in the system until 1907. By this time the Auction Avenue plant had become inadequate, and a new pumping station was built at Central Avenue during 1907 and 1908. The Central Avenue plant consisted of six wells pumped by compressed air and had a capacity of about 5,000,000 gallons in 24 hours.

Prior to 1907 the Artesian Water Department had done some experimenting with segregated pumps. By 1910 the feasibility of these pumps had been demonstrated and several installations were made at different points around the city. Ultimately 14 such installations were available for use. They served to handle peak loads and heavy local drafts.

Realizing that the existing plant was becoming inadequate and that the system was liable to pollution by seepage of sewage into the tunnels the water commissioners contracted with the firm of Chester & Fleming, hydraulic engineers, in 1919, to make a thorough study of the water-supply system and to submit recommendations for future development. Chester & Fleming submitted their report in April, 1920. A further study was made by the firm of Fuller & McClintock, hydraulic engineers, who submitted a report to the commissioners in March, 1922. This report considered the various methods of developing a larger water supply and recommended a new plant that would obtain water from wells pumped by compressed air. The recommendations were approved by the water commissioners, and Fuller & McClintock undertook the construction of the new plant, which was put into operation in 1925.

The supply in 1928 was obtained from 23 wells 375 to 575 feet deep and 9 wells about 1,400 feet deep. The 375 to 575 foot wells are located at intervals of 500 feet along North Parkway (see pl. 11, wells marked C–6 to C–24); the 1,400-foot wells are at the same well houses as wells C–1, C–2, C–3, C–4, C–5, C–20, C–21, C–22, C–23, and C–24.

The wells are pumped by compressed air under a pressure of 90 pounds to the square inch at the pumping station and 60 to 70 pounds at the wells. The air is delivered to the well houses by three 10-inch lines, which drop to two 10-inch lines, and the last few wells are supplied by one 6-inch line. The water discharges into surge tanks, from which it flows by gravity through a duplicate system of mains to a 1,000,000-gallon raw-water reservoir at the pumping station at North Parkway and Dunlap Streets. The raw water is pumped from the reservoir to the aerator by four secondary centrifugal pumps, three having a capacity of 9,000,000 gallons a day and one of 15,000,000 gallons a day, driven by hydroturbines, which in turn are propelled by the water as it passes from the pumps to the city mains. The water is aerated by flowing over coke, and from the aerator it flows by gravity through the rapid sand filters and into a 9,000,000-gallon reservoir. The water is pumped from the reservoir into the city mains by two compound reciprocating pumps and two centrifugal pumps driven by turbines. Each of the four pumps has a capacity of 15,000,000 gallons a day.

Work on a new plant to duplicate the present Parkway unit, several miles to the east, on a tract of land just east of the Western State Normal School (see pl. 11), is now under way.

Records of wells of the Memphis Artesian Water Department

[Except as noted measurements of depth to water were made on Mar. 15, 1929]

No.	Altitude above mean sea level (feet)	Depth of well (feet)	Diameter of well (inches)		Geologic horizon	Depth to water (feet)	Yield with air lift (gallons a day)
			Top	Bottom			
C-1		425	12	10	Grenada formation		1,440,000
C-2		453	12	10	do		1,440,000
C-3		409	12	10	do		1,440,000
C-4		519	12	10	do		1,440,000
C-5	359.4	1,400	10	8	Ackerman formation	23.6	
C-6		504	12	10	Grenada formation		1,440,000
C-7		522	12	10	do		1,440,000
C-8					do		
C-9		544	12	10	do		1,440,000
C-10		495	12	10	do		1,440,000
C-11		525	12	10	do		1,440,000
C-12		518	12	10	do		1,440,000
C-13		510	12	10	do		1,440,000
C-14		479	12	10	do		1,440,000
C-15	355.8	495	12	10	do		1,440,000
C-16	356.0	527	12	10	do		1,440,000
C-17	356.5	522	12	10	do		1,440,000
C-18	356.6	527	12	10	do		1,440,000
C-19	357.1	371	12	10	do		1,440,000
C-20	356.6	371	12	10	do		1,440,000
C-21	358.3	345	12	10	do		1,440,000
C-22	358.7	357	12	10	do		1,440,000
C-23	358.4	393	12	10	do		1,440,000
C-24	358.1	369	12	10	do		1,440,000
C-25		2,656	10	8	Ripley formation	22.3	
C-26	360.5	1,400	10	8	Ackerman formation	24.9	
C-27	363.9	1,400	10	8	do	16.6	
C-28	355.7	1,400	10	8	do	11.4	
C-29	350.6	1,400	10	8	do	8.3	
C-30	357.5	1,400	10	8	do	9.2	
C-31	358.6	1,400	10	8	do	8.3	
C-32		1,400	10	8	do	6.4	
C-33		1,400	10	8	do		
C-50	290.3	513	10	10	Grenada formation	[a] 51.7	
C-51	287.0	1,370	10	8	Ackerman formation	[a] 54	

[a] Date of measurement Mar. 11, 1931.

PRIVATE WELL SUPPLIES

The first deep well in Memphis was drilled for the Bohler Huse Ice Co. in 1886, but no interest was aroused in the artesian water supply until another well drilled for the same company in 1887 on Court Street proved to be a flowing well. Immediately wells were drilled for other industrial plants in Memphis, and Safford [2] reported 57 wells exceeding 185 feet in depth in the city in May, 1889. Of these wells, 32 were city wells and 25 private wells.

Although no records exist of the number of wells drilled or the quantity of water pumped by private concerns during subsequent years, information gathered from old drillers in the region indicates that practically every plant requiring a supply of water of more than 10,000 gallons a day was equipped with its own well. Chester and Fleming, in their report made in 1920, listed 58 private plants with large yields. The writer, in 1928, listed 86 private plants. The location of these wells is shown in Plate 11, and data in regard to them are given in the accompanying table. From the first well drilled in Memphis until the present time pumpage from private wells has equaled or exceeded the pumpage of the Memphis Artesian Water Department.

Most of the private wells are pumped by compressed air, because pumping by air lift serves to aerate the water, thereby precipitating the iron that is in the solution and also liberating the free carbon dioxide. The installation of an air lift is simple; there are no wearing parts, and overhauling is easy. Some of the more recent pumping installations are equipped with turbine centrifugal pumps. These pumps give a very compact installation, and the cost of pumping is slightly less than with an air lift. Most of the sawmills use reciprocating pumps. These mills do not consume much water—about 25,000 gallons a day—and as the iron content of the water is immaterial and the power consumption is of no importance to them, reciprocating pumps give satisfaction.

[2] Safford, J. M., The water supply of Memphis: Tennessee State Board of Health Bull., vol. 5, p. 102, 1890.

Records of drilled wells in Memphis, Tenn.

Section in Plate 11	No.	Owner	Location	Altitude above mean sea level (feet) [a]	Depth of well (feet)	Diameter of well (inches)		Depth to which well is cased (feet)	Water level		Method of lift	Capacity of pump (gallons a minute)	Drawdown (feet) [c]	Daily pumpage (gallons)	Source of data [b]	Quality of water	
						Top	Bottom		Depth below surface (feet)	Date of measurement (1928) [b]						Date sampled (1928)	Content of dissolved iron (parts per million)
I	1	Fisher Lumber Co.	North Second St., well 1	220	422	12	12	422	33	Rept.	Centrifugal	300	13				
I	2	do	North Second St., well 2	220	414	16	16	414	43	do	do	850	19	450,000	Rept.		
I	3	James C. Clark	100 feet north of Plum Ave., 150 feet west of Illinois Central R. R.		445	6	6		35	Oct. 12	Air lift	80		125,000		Oct. 12	0.94
I	4	James E. Stark Co.	150 feet north of intersection of North Seventh St. and Illinois Central R. R., 20 feet west of track.	225	450	4	4	450			do						
I	5	Turner, Faber & Lovel Co.	100 feet north of Seventh St., 75 feet east of Illinois Central R. R.	225	480	6	6	480			Reciprocating	70		30,000	Est.	Oct. 11	1.4
I	6	Anderson Tully Co.	200 feet north of intersection of Illinois Central R. R. and North Second St.	230	450	4½	4½	450			Air lift	200		100,000	do	do	.64
I	7	American Snuff Co.	Front and Keele Sts.	235	388	10	6	388	33	Rept.	Reciprocating with steam head.			30,000	do	do	2.0
I	8a	Bannon Ice & Coal Co.	190 feet west of Seventh St., 125 feet south of Auction Ave.	240	408	8	8	408	45	do	Air lift					do	.24
I	8b	do	200 feet west of Seventh St., 75 feet south of Auction Ave.	240	396	10	10	396	45	do	do	600	10	860,000	Est.		
I	9	James E. Stark Co.	75 feet north of Plum Ave., 75 feet west of Illinois Central R. R.	230	445	6	6	445	28	do	do	350	9	125,000	do		

[a] Altitudes were determined from positions on the U. S. Geological Survey topographic map, which has a 10-foot contour interval.
[b] Rept., information given by engineer in charge of the plant. Est., estimated; for water level and drawdown the figures given were determined from the shut-in pressure of the air lift; for daily pumpage the figures given were computed from ice production or pounds of steam used.
[c] Drawdown when pumping at capacity of pump unless otherwise noted.

Records of drilled wells in Memphis, Tenn.—Continued

Section in Plate 11	No.	Owner	Location	Altitude above mean sea level (feet)	Depth of well (feet)	Diameter of well (inches)		Depth to which well is cased (feet)	Water level		Method of lift	Capacity of pump (gallons a minute)	Drawdown (feet)	Daily pumpage (gallons)	Source of data	Quality of water	
						Top	Bottom		Depth below surface (feet)	Date of measurement (1928)						Date sampled (1928)	Content of dissolved iron (parts per million)
I	10	Kelsey Wheel Co.	725 feet north of Plum Ave., 25 feet west of Illinois Central R. R.	230	480	8	8	480			Air lift	500		700,000	Est.	Oct. 11	1.3
I	11	Memphis Hardwood Flooring.	1,225 feet north of Plum Ave., 375 feet west of Thomas St.	230	412	4	4	412	34	Rept.	do.	150		200,000		do.	1.4
I	12	Green River Lumber Co.	725 feet north of Plum Ave., 25 feet east of Belt Line track.	230	425	4	4	425			Reciprocating with steam head.			250,000		do.	1.2
I	13	E. L. Bruce Flooring Co.	400 feet east of Thomas St.	230	385	8	6	385			Air lift	350		200,000			
II	14	Virginia Bridge Co.	550 feet west of Morehead Ave., 65 feet south of White St.	240	440	8	8				Reciprocating electric.	80		40,000	Rept.	Oct. 11	4.4
II	15	Golf Shaft & Block Co.	200 feet east of Morehead Ave., 10 feet south of White St.	230	430	6	6	430			Air lift	50		15,000	do.		
II	16	Electric Ice Co.	80 feet east of Waldran St., 200 feet from east-west alley.	250	492	16	10	430	90	Rept.	Centrifugal electric.	750		720,000	Est.	Oct. 9	1.1
II	17	Valrath Outdoor Enterprise.	Nedra Ave.		267	3	3	267	100	do.	Reciprocating						
III	18	King Haase Furniture Co.	500 feet south of Chelsea Ave.	240	55	4	4	55	10	do.	do.			50,000	Est.		
III	19	Urania Petroleum Co.	100 feet east of Hollywood St., 75 feet north of Union R. R.		530	6	6	530	30.5	Oct. 12	Air lift	340	41.5	500,000	do.		
III	20	Hollywood Ice Co.	West of Hollywood St., 60 feet from Louisville & Nashville R. R.		377	8	6	377	35	Rept.	Turbine	325	15	470,000	Est.	Oct. 12	.94
III	21	Alabama Fertilizer Co.	900 feet east of Hollywood St., 50 feet south of Louisville & Nashville R. R. siding.			6	6				Air lift	400		600,000		do.	.20

III	22	Hartwell Bros.	25 feet west of Fairfax St.		395	6	6	395	19	Oct. 12	do.	200	49	40,000			
	23	Forest Products Chemical Co.	Speed Ave.		565	10	10	565	23	Oct. 13	do.	600	12	500,000	Est.	Oct. 11	.45
	24	Dixie Cotton Oil Co.	775 feet west of Illinois Central R. R., 600 feet north of Speed Ave.		500	8	8	500	40	Rept.	Centrifugal	1,170					
	25	Cudahy Packing Co.	500 feet north of Speed Ave.		438	8	8	438	20	do.	do.	550	45	400,000	Rept.	Oct. 11	.96
	26	Wood Lumber Co.	300 feet south of Speed Ave.		[d] 40			40			Reciprocating with steam head.	10		15,000	do.		
	27	Louisville & Nashville R. R.	500 feet east of Leewood St., 125 feet north of main track.		435	16½	12	435	25	Rept.	Centrifugal	400		500,000	Est.		
	28[a]	Buckeye Cotton Oil Co.	Raleigh Road, 50 feet east of Louisville & Nashville R. R.		377	24	24	377			do.	1,500					
	28[b]	do.	do.		426	24	24	426			do.	900					
	28[c]	do.	do.		290	24	24	290			do.	1,800		2,500,000	Rept.		
	29	Chickasaw Cooperage Co.	Scott St. near Phillips Ave.								Air lift	120		150,000	do.	Oct. 12	.35
	30	Memphis Ice Co.	Summer Ave. and Union R. R.			4	4				do.	250		360,000	do.		
IV	31	Shelby County Workhouse.	Old Raleigh Road		520	8	6	520	36	Rept.	Double-acting reciprocating.	150					
	32	National Cemetery	Old Raleigh Road at intersection with Louisville & Nashville R. R.		388	4	2	388	30	do.	Reciprocating						
V	33	Memphis Cold Storage Co.	99 South Front St.	270	510	8	8	510	60.5	do.	Air lift	300	16	250,000	Rept.		
	34	Swift & Co.	31-39 Union Ave.	270	468			468	52	do.	do.			45,000			
	35	Gayoso Hotel	75 feet east of Front St., 100 feet north of McCall St.	260	420	8	8	420	90	do.	do.	120	12	200,000	Rept.		
	36	Oliver Finnie Co.	Vance Ave., under south sidewalk at west end.		500	8	8	500	60	do.	do.	110		60,000	do.	Oct. 8	.71
	37	Tennessee Brewing Co.	Tennessee St.	280	520	10	10	520	70	do.	do.	400	20	450,000	Est.	Oct. 13	2.5
	38	Grand Central Station.	200 feet north of West Georgia Ave., west of South Main St.	275	498	12	12		80	do.	Centrifugal	569		500,000	Rept.		
	39	Chisca Hotel	Mulberry St., under east sidewalk, 75 feet south of Linden St.	255	490	6	6	490	70	do.	Air lift	200		185,000	do.	Oct. 8	.17
	40	Orpheum Theater	McCall Ave., under south sidewalk, 50 feet north of Main St.	260	475	10	8	475	65	do.	Turbine	400					
	41	Hotel Peabody	Union Ave.	250	448	10	10	448	50	do.	Air lift	500	46	500,000	Est.		
	42	Bank of Commerce & Trust Building.	Madison Ave. and Main St.	260	500			500	62	do.	do.		12	60,000	Rept.	Oct. 9	.65

[a] Altitudes were determined from positions on the U. S. Geological Survey topographic map, which has a 10-foot contour interval.

[b] Rept., information given by engineer in charge of the plant. Est., estimated; for water level and drawdown the figures given were determined from the shut-in pressure of the air lift; for daily pumpage the figures given were computed from ice production or pounds of steam used.

[c] Drawdown when pumping at capacity of pump unless otherwise noted

[d] Pumping 100 gallons a minute.

Records of drilled wells in Memphis, Tenn.—Continued

Section in Plate 11	No.	Owner	Location	Altitude above mean sea level (feet)	Depth of well (feet)	Diameter of well (inches)		Depth to which well is cased (feet)	Water level		Method of lift	Capacity of pump (gallons a minute)	Drawdown (feet)	Daily pumpage (gallons)	Source of data	Quality of water	
						Top	Bottom		Depth below surface (feet)	Date of measurement (1928)						Date sampled (1928)	Content of dissolved iron (parts per million)
	43	Loeb Steam Laundry.	282–290 Madison Ave.	255	416	6	6	416	38	Oct. 9	Air lift	200	12	100,000	Rept.	Oct. 10	.42
	44	Southern United Ice Co.	308 Court St.	250	480	10	10	480	35	Rept.	do.	700	53	1,000,000	do.	Oct. 12	.0
	45	Coca Cola Bottling Co.	50 feet west of Fourth St., 100 feet north of Washington Ave.	245	450	8	6	450	45	do.	Double-acting reciprocating.	53		25,000	do.	Oct. 9	.88
	46	Memphis Union Station Co.	1,000 feet south of Calhoun Ave., 50 feet west of South Third St.	260	558	8	8	558	70	do.	Centrifugal	400		250,000	do.	Oct. 12	1.1
	47[a]	Memphis Power & Light Co.	South Fourth St.	270	527	12	12	527	80.5	Oct. 15	Air lift					do.	4.4
	47[b]	do.	do.	270	485	10	10	485	76.9	do.	do.						
	47[c]	do.	do.	270	503	16	16	503	75.7	do.	do.						
	7[d]	do.	do.	270	501	16	16	501			do.			860,000	Rept.		
V	48	Broadway Ice Co.	100 feet west of Lauderdale St., 50 feet south of railroad.	280	500	8	8	500	70	Rept.	do.	600	20	860,000	do.	Oct. 18	1.7
	49	Consumers Coal & Ice Co.	75 feet north of Beale Ave., 100 feet west of its intersection with Southern Ry.	255	395	10	10	395	59	do.	do.	500	20	720,000	do.	Oct. 10	.60
	50	Lily Ice Cream Co.	658 Madison Ave.	260	453	8	8	453	89	do.	do.	300	11	400,000	do.		
	51	Kraus Cleaners Co.	726 Madison Ave.	255	473	6	6							30,000	do.		
	52[a]	Clover Farm Dairy	Beale Ave. and Manassas St.	260	524	6	6	524	81.5	Oct. 19	Air lift	303	50			Oct. 10	2.3
	52[b]	do.	do.	260	597	6	6	597	81.5	do.	do.	344	50	360,000	Rept.		
	53	do.	Union Ave. and Walnut St.	270	596	8	6	596	74	Rept.	do.	345	41				
	54	Southern United Ice Co. (formerly Valley Ice & Coal Co.).	100 feet north of Alston Ave., 200 feet east of Porter St.									600		800,000	Rept.		

VI	55	Crescent Laundry Co.	Dunlap St. near Beale Ave.	275	390	6	6	390			Air lift	200		115,000	do	Oct. 10	.36
	56	Baptist Hospital	Madison Ave	265	490	6	6	490	77	Oct. 10	do	300	33	200,000	do	do	.80
	57	Memphis Steam Laundry.	Jefferson Ave	240	463	6	6	463	60.6	do	do	450	11.6	190,000	do	Oct. 18	.48
	58	Success Steam Laundry.	Jefferson Ave. and Pauline St.	255	460	6	6	460	20	Est	do	132	12	79,000	do	Oct. 10	.41
	59	Memphis Furniture Manufacturing Co.	Dudley St	300	417	4	4	417	35	Rept	do	35	15	21,000	do	Oct. 17	.93
	60	DeSoto Hardwood Flooring Co.	Sledge St	305	[e]90	5½	5½	90			Reciprocating			20,000	do	Oct. 18	.05
	61	Model Bluff City Laundry.	Linden Ave. and Camilla St.	260		6	6				Air lift			80,000	do	Oct. 23	.94
	62	Lamar Steam Laundry.	Lemar Ave. opposite Redcliffe Pl.	270	487	6	4	487			do	125		75,000	do	do	2.4
	63	Southern Cotton Oil Co.	Williams Ave	315	498	16	8	498	100	Rept	do	450	25	180,000	do	do	2.1
	64	Blumenfeld Ice & Coal Co.	Lamar Ave. and Haywood St.	305	495	10	8	495	76	do	Centrifugal	450		650,000	do	do	1.1
VII	65	East End Ice & Coal Co.	Central Ave. and Cooper St.	295	400	8	8	400			Air lift	400		500,000	do		
	66	Virginia Carolina Chemical Corp.	Poplar Ave		449	6	6				do	60	2	30,000	do	Oct. 12	0
VIII	67	Clarence Saunders	Goodwyn St. and Lafayette Ave.		361	14	5	361	47	Rept							
	68	Chickasaw Golf Club.	Galloway Ave		100	8	8	100			Double-acting reciprocating.	80		50,000	Rept		
	69[a]	West Tennessee State Normal School.		300	515			515	74	Oct. 28	Air lift						
	69[b]	do		300	461	8	8	451	74	do	do			175,000	Rept		
IX	70	American Fork & Hoe Co.	Arkansas St. and Wisconsin Ave.		420	6	4	420	80	Rept	do	120	20	40,000	do	Oct. 18	1.5
	71	Weis & Lesh Plant Motorwheel Corp.	Wisconsin Ave. and Pennsylvania St.	285	580	6	6	580			do	355		118,000	do	Oct. 11	4.4
	72	DeSoto Oil Co	998 Kansas Ave	285	548	6	6	548	60	Rept	Reciprocating	300	20	72,000	do		
	73	Memphis Power & Light Co.	McLemore Ave., 1,000 feet west of Florida St.	270	485	8	8	485	73	Est	Air lift	408	25	600,000	do	Oct. 18	.48
	74	Liquid Carbonic Corp.	Florida St., 200 feet north of McLemore Ave.	295	435	8	6	435	90	do	do	200		150,000	do		
	75	Wabash Screen Door Co.	Florida St. and Triggs Ave.	285	400	3½	3½	400	91	do	do	100	9	30,000	do	Oct. 18	1.3
	76	Ford Hardwood Lumber Co.	McGeher Ave. and Florida St.	285	[e]85	6	6	85			Reciprocating.	30		40,000	do	do	0
	77	Gayoso Lumber Co	Florida St. and Fay Ave	260	460	4	4	460	60?	Rept	Air lift			125,000	do	do	.43
	78	Pioneer Pole & Shaft Co.	1197 South Third St., 200 feet west of street.	280	545	6	6	545	72	do	do	500			do	do	.02

[a] Altitudes were determined from positions on the U. S. Geological Survey topographic map, which was a 10-foot contour interval.

[b] Rept., information given by engineer in charge of the plant. Est., estimated; for waterlevel and drawdown the figures given were determined from the shut-in pressure of the air lift; for daily pumpage the figures given were computed from ice production or pounds of steam used.

[c] Drawdown when pumping at capacity of pump unless otherwise noted.

[d] Pumping 100 gallons a minute.

[e] Well ends in Pliocene gravel.

Records of drilled wells in Memphis, Tenn.—Continued

Section in Plate 11	No.	Owner	Location	Altitude above mean sea level (feet)	Depth of well (feet)	Diameter of well (inches)		Depth to which well is cased (feet)	Water level		Method of lift	Capacity of pump (gallons a minute)	Drawdown (feet)	Daily pumpage (gallons)	Source of data	Quality of water	
						Top	Bottom		Depth below surface (feet)	Date of measurement (1928)						Date sampled (1928)	Content of dissolved iron (parts per million)
X	79	Apex Steam Laundry.	Lamar Ave. and Kyle St.	285	[a] 90	6	6	90	60	Rept.	Reciprocating	95		35,000	Rept.		
XI	80	Swift Co. Oil Mill		300	443	10	10	443	73	do	Air lift	300	15	75,000	do	Oct. 23	2.4
	81	Southern Ry., Forrest Yards.	Southern Ave.	305	554	10	10	554			do	500		200,000	do	do	.05
	82	St. Louis-San Francisco Ry., Yale Yards.	Well 2		390	8	8	390	50	Rept.	Centrifugal	568					
	83	do	Well 1		386	8	8	386	56	do	do	533					
XII	84	Memphis Country Club.	Southern Ave.		392	8	6	392			Reciprocating			20,000			
XIII	85	Railway Ice Co.	Peebles Ave.	230	360	15	12	360	32	Rept.	do	300	12	430,000	Rept.	July 19	1.19
	86	Illinois Central R. R., Nonconnah Yards.	1,500 feet west of Horn Lake Road.	235	361	10	10	361	51	do	do	400		548,000	do		

[a] Altitudes were determined from positions on the U. S. Geological Survey topographic map, which has a 10-foot contour interval.

GEOLOGIC FORMATIONS

The geologic setting of Memphis is given in the description of Shelby County (p. 245). The formations encountered from the surface down are loess, Pliocene gravel, Eocene deposits (the Jackson formation, Wilcox group (including the Grenada, Holly Springs, and Ackerman formations), Porters Creek clay, and possibly the Clayton formation), Cretaceous deposits (Ripley, Selma, Eutaw, and Tuscaloosa formations), and consolidated Paleozoic rocks. Figure 11 gives a section at Memphis.

The loess has a maximum thickness at Memphis of about 70 feet but thins out in the lowland. The base of the loess is about 230 feet above mean sea level. The loess does not yield water.

The Pliocene gravel has a maximum thickness of about 55 feet, but commonly it is from 25 to 40 feet thick or even less. The coarseness of the gravel and the amount of admixed sand vary considerably from place to place. The gravel is found from about 185 feet to 230 feet above mean sea level. Where it is thickest the Pliocene gravel is used for supplies of water as great as 10,000 gallons a day.

Beneath the gravel occurs the Jackson formation, the nature of which is best determined from the well logs of the Memphis Artesian Water Department. It is dominantly a hard blue clay, though in places it contains interlaminated beds of fine gray or white sand, brown clay, and lignite. That it is practically a continuous clay formation is shown by the logs of 200 wells drilled by the Memphis Artesian Water Department. These logs show that the formation contains about 10 per cent of sand. Although the sand is irregularly distributed, as shown in Plate 12, continuous passageways of sand through the clay may exist. Such passageways, however, must be few and very tortuous. The Jackson formation is from 150 to 200 feet thick and is encountered from about sea level to 200 feet above sea level. It is not a source of water, the sand layers being too thin and the sand too fine grained to yield water to wells, but it forms a confining bed for the water in the Wilcox group formations.

Below the Jackson formation occurs the Wilcox group, which consists of sand of various sizes and clay. The log of well 109 of the Memphis Water Department gives a detailed and representative section of the Wilcox. As the well was drilled with clear water the descriptions are good.

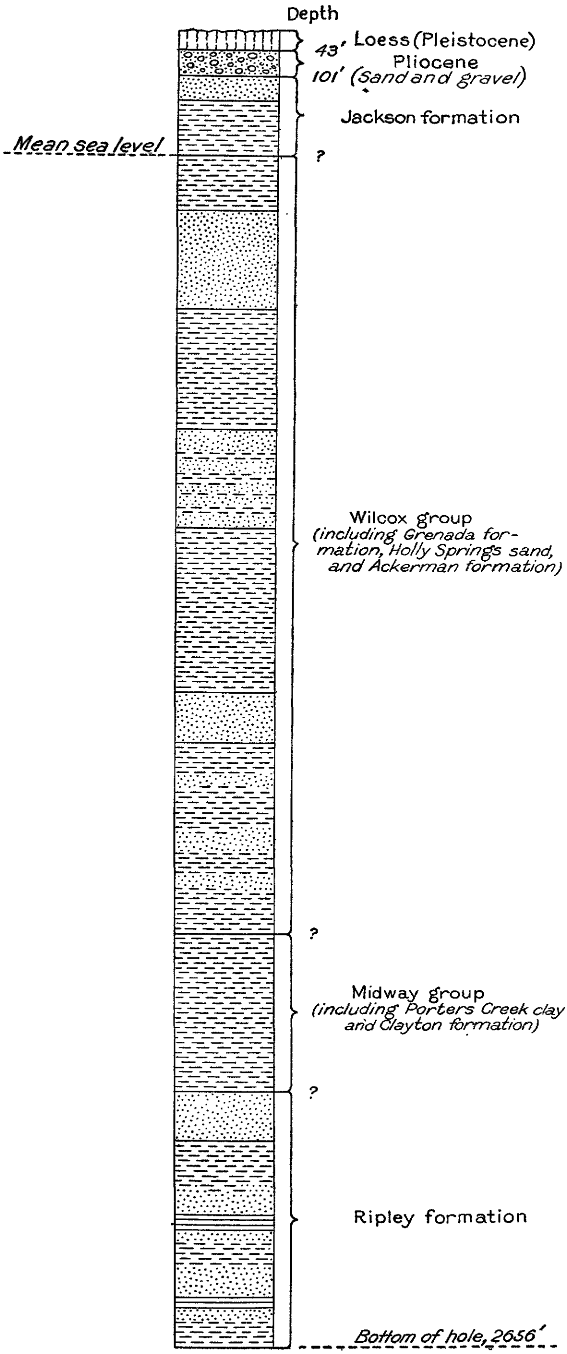
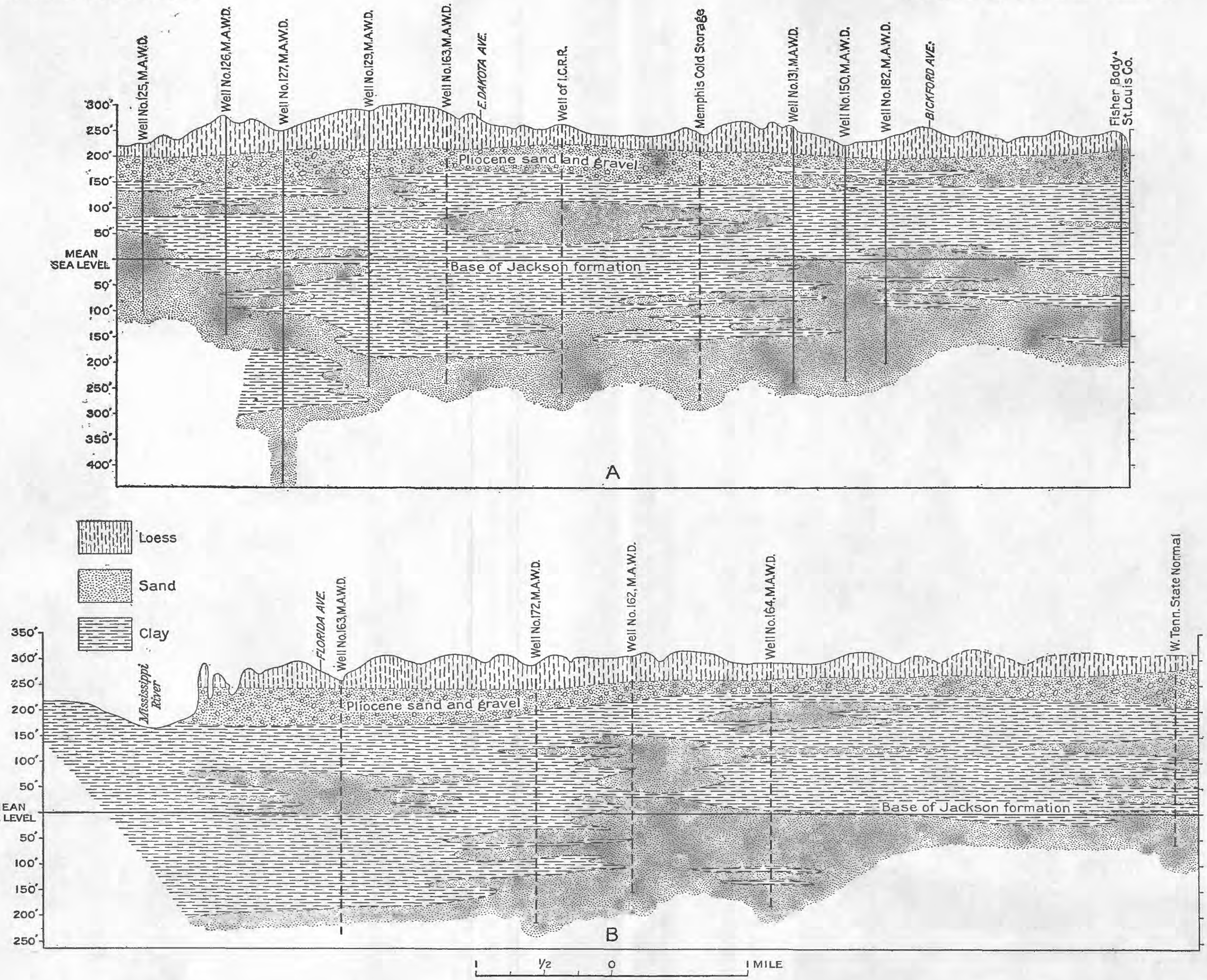


FIGURE 11.—Log of well C-25 of Memphis Artesian Water Department. Depth 2,656 feet



SECTIONS THROUGH MEMPHIS

A, South to north; *B*, west to east.

Log of well 109, Memphis Water Department

	Feet
Loess:	
Yellow clay	0– 27
Hard brown clay	27– 37
Slightly soft brown clay	37– 45
Pliocene: Gravel and sand	45– 49
Jackson formation:	
Soft brown clay and shale	49– 63
Slightly harder brown clay	63– 76
Stiff blue clay	76– 79
Soft blue clay	79– 83
Stiff blue clay	83– 86
Soft brown clay	86– 89
Very hard brown clay	87– 89
Hard reddish clay	89– 90
Hard blue clay	90– 106
Soft blue clay	106– 121
Stiff blue clay	121– 122
Soft brown clay	122– 126
Slightly hard brown clay	126– 127
Hard brown clay	127– 196
Hard blue clay	196– 223
Sandy blue clay	223– 276
Wilcox group:	
Fine sand and clay	276– 303
Fine sand	303– 338
Fine sand and lumps of clay	338– 370
Coarse sand and lumps of clay	370– 390
Soft blue clay	390– 407
Sandy blue clay	407– 417
Fine sand and clay	417– 432
Sandy blue clay	432– 445
Fine sand and clay	445– 452
Sandy blue clay	452– 474
Fine sand	474– 476
Sandy blue clay	476– 483
Fine sand	483– 484
Coarse sand and clay	484– 490
Soft blue clay	490– 492
Fine sand and clay	492– 510
Very fine sand	510– 535
Very fine sand and clay	535– 575
Very fine sand	575– 590
Very coarse sand	590– 598
Lignite and iron pyrite	598– 600
Fine sand and lignite	600– 630
Very fine sand	630– 795
Soft white clay	795– 812
Very fine sand	812– 865
Hard brown clay	865– 896
Hard white sand	896– 926
Hard brown clay	926– 950
Fine sand	950–1,000

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Wilcox group—Continued.	Feet
Stiff brown clay	1,000 -1,025
Very hard substance	1,025 -1,026
Very stiff blue clay	1,026 -1,058
Blue clay, slightly sandy	1,058 -1,160
Shale	1,160 -1,160½
Sandy clay	1,160½-1,164
Gravel	1,164 -1,170
Blue clay and sand	1,170 -1,196
Sand and rock	1,196 -1,203
Sand and blue clay	1,203 -1,209
Sand and clay and rock	1,209 -1,232
Fine sand and clay	1,232 -1,240
Blue clay and sand	1,240 -1,286
Sand and clay	1,286 -1,365
Fine sand	1,365 -1,400
White sand (water flowed to surface)	1,400 -1,404
White sand	1,404 -1,442
Blue clay	1,442 -1,537
Good sand	1,537 -1,557
Black sand	1,557 -1,563
Blue clay and sand	1,563 -1,566
Clay	1,566 -1,582
Fine gray sand	1,582 -1,583

W. C. Spooner,[2a] who has compiled and correlated logs of wells in Arkansas, places the base of the Grenada at Memphis at a depth of 1,172 feet, the bottom of the Wilcox at about 2,000 feet, and the bottom of the Eocene at 2,450 feet.

The log of the Spring Creek Development Co.'s well (see p. 76) shows a thickness for the Cretaceous of 1,080 feet. Allowing for thickening of the Cretaceous from Hardeman County to Memphis, as is suggested by data to the south, in Mississippi, would make the total thickness of Eocene and Cretaceous more than 3,500 feet.

The 1,400-foot wells at Memphis show that a continuous bed of tough blue clay about 300 feet thick persists over many square miles. Evidence of the continuity of this clay layer is given by the fact that the static level of water below the clay is quite different from the static level of water above the clay. Water from the sand overlying the clay bed differs markedly in chemical character from water from the sand below the clay bed. The water below the clay is a sodium bicarbonate water (see analysis 9), whereas the water from the sand overlying this clay layer is a normal calcium bicarbonate water. The water below the clay is similar in character to water from a well at Louisville, Miss., which derives water from the Ackerman.[3] These facts would indicate that this clay bed represents the transition from the dominantly sandy Holly Springs formation to the dominantly

[2a] Personal communication.

[3] Stephenson, L. W., Logan, W. N., and Waring, G. A., The ground-water resources of Mississippi: U. S. Geol. Survey Water-Supply Paper 576, p. 492, 1928.

clayey Ackerman formation. Although no definite correlation can be made, the differences in lithology and in static level and chemical composition of the contained water make it advisable to regard the material below 1,300 feet as Ackerman formation.

A more detailed description of the physical character of the Grenada and Holly Springs formations is given on pages 91–106. They are about 1,300 feet thick at Memphis and are found at depths from sea level to 1,300 feet below sea level. These formations are the principal water-bearing formations at Memphis, and from them is derived all the water consumed, with the exception of a few million gallons a day pumped by the Memphis Artesian Water Department from the Ackerman formation.

The Ackerman formation has a thickness of about 600 feet and is encountered from 1,050 to 1,700 feet below sea level. It is predominantly clay, though it contains in its upper part about 200 feet of medium-grained sand which yields water freely, and it is from this sand that the 1,400-foot wells of the Memphis Artesian Water Department obtain water.

Very little is known about the Midway group at Memphis. The wells that penetrate it furnish only meager and indefinite information about the lithology. It is probably a calcareous or arenaceous mudstone containing some fossils and probably exceeds 350 feet in thickness. It is impervious to water and forms a confining bed for water in the Ripley formation below.

Cretaceous.—The thickness and nature of the Cretaceous formations at Memphis is not definitely known. Well 25 of the Memphis Artesian Water Department attained a depth of 2,656 feet and was still in unconsolidated material. From the generalized log of this well, which follows, it seems as if the Cretaceous is dominantly clay, though some sand is present. Wells drilled in Crittenden County, Ark. (see pp. 27–29), corroborate this conclusion.

Log of well 25 of Memphis Artesian Water Department

[Authority, W. G. Lanham, about September, 1927]

	Thickness (feet)	Depth (feet)
Loess:		
Yellow clay	43	43
Sand and gravel	68	101
Wilcox group:		
Rock	2	103
Sand and gravel	18	121
Clay	24	145
Sand	15	160
Clay	198	358
Sand	72	430
Good water-bearing sand	117	547
Clay	5	552
Sand	8	560
Clay	240	800
Sand	31	831
Clay	20	851
Rock	2	853
Clay	87	940
Sand	45	995
Clay	6	1,001
Rock	1	1,002
Clay	10	1,012
Rock	2	1,014
Clay	6	1,020
Rock	4	1,024
Clay	1	1,125
Rock	3	1,128
Clay	31	1,159
Rock	6	1,165
Clay	48	1,213
Rock; may be very hard shale	16	1,229
Clay	20	1,249
Rock	2	1,251
Clay	77	1,328
Probably sand	16	1,344
Water-bearing sand	90	1,434
Clay	256	1,700
Probably rock	5	1,705
Clay (muck)	39	1,744
Rock	2	1,746
Clay	38	1,784
Rock	4	1,788
Clay	36	1,824
Rock	2	1,826
Clay	4	1,830
Wilcox group—Continued.		
Rock	6	1,836
Clay	11	1,847
Rock; may be hard shale	12	1,859
Clay	11	1,870
Rock	2	1,872
Clay	13	1,885
Rock	5	1,890
Clay	6	1,906
Rock	2	1,908
Clay	102	2,010
Midway group:		
Rock	2	2,012
Clay	42	2,054
Rock	1	2,055
Clay	38	2,093
Rock	1	2,094
Clay	26	2,120
Soft as if sand; no returns	15	2,135
Clay	4	2,149
Probably sand; no returns	20	2,169
Water-bearing sand [a]	51	2,220
Probably sand; seems to be boulder ahead of drill	22	2,242
Black shale or lignitic clay. All cuttings below 2,200 feet seemed to be more of a black shale than clay	100	2,340
Cuts like rock; may be hard shale	15	2,355
Shale	16	2,371
Ripley formation:		
Cuts like sand; no returns	24	2,395
Rock	4	2,399
Clay	6	2,405
Rock; may be very hard shale	24	2,429
Sand	27	2,456
Clay	13	2,569
Rock	2	2,571
Clay	7	2,578
Sand	41	2,619
Rock	3	2,622
Sand	12	2,634
Rock	2	2,636
Shale	20	2,656

[a] Before setting a strainer at 2,169–2,220 feet about 40 gallons of sand flowed out. When strainer was set found nothing but black clay or shale.

Well 25 of the Memphis Artesian Water Department encountered sandy water-yielding material at 2,371 to 2,395 feet, 2,429 to 2,456 feet, and 2,578 to 2,634 feet. Strainers were set in these sandy beds, and the water rose to an altitude of 360 feet. The water has a high mineral content and is not suitable for domestic or industrial use. (See analysis 10.)

Nothing is known of the Eutaw and Tuscaloosa formations at Memphis. If they would yield water to wells the water would probably have a very high mineral content and be unsuitable for domestic or industrial use.

QUALITY OF WATER

The chemical quality of the water pumped from the Grenada and Holly Springs formations at Memphis is not essentially different from that of the average water derived from them throughout western Tennessee, as can be seen by comparing the analysis of a representative water from the Wilcox group given in the following table with the analysis of a sample from a well in Memphis. The total dissolved solids in the water from Memphis are about 20 parts per million greater than in the representative sample from the Wilcox group. This increase is distributed in small amounts throughout the mineral constituents.

In order to determine whether there was any relation between the chemical character of the water from different wells in Memphis and their location with reference to the Mississippi River 51 samples were taken from wells throughout the city and were examined for iron and sulphate. No such relation was found. In addition 21 of these wells were selected for further study; samples were collected August 22, 1930, and examined for iron, calcium, bicarbonate, sulphate, chloride, and hardness. The calcium ranged between 16 and 6 parts per million, the bicarbonate between 126 and 60 parts, and the hardness between 106 and 40 parts. For comparison with these a sample was collected from the Mississippi River just above the Harriman Bridge and was found to contain 36 parts per million of calcium, 128 of bicarbonate, and 144 of hardness. A comparison of these analyses with the analysis of an average water from the Wilcox group (see analysis 2) shows that the water from many of the wells deviates widely from the normal water from the Wilcox and approaches in chemical character the water from the Mississippi River. It can not be said, however, that there is a definite relation between the location of a well with reference to the river and the chemical character of the water, for though all the wells within 1½ miles of the river show more than 90 parts per million of bicarbonate and those at a greater distance usually show less than 70 parts, yet certain distant wells show a very high bicarbonate, for example, wells 59 and C–82, which show 92 and 107 parts per million, respectively. Such high bicarbonate might be due to leakage of water from a higher bed into the lower sand, either at the well itself or from other near-by abandoned wells. Furthermore, it may be that the bicarbonate is due to the inflow of water from the Pliocene gravel, which (see p. 109) has a high content of calcium bicarbonate. To determine whether the mineral content of the water changes to any marked degree 6 of the wells showing high bicarbonate were sampled on January 22, 1931, and partial analyses of the samples were made. (See table, p. 286.) Such variations as appear fall within the limits of error of the analyses.

Approximate partial analyses of waters from Memphis and vicinity

[Parts per million. Numbers in first column refer to corresponding numbers in table of well records on p. 251. Analyzed by Margaret D. Foster]

Well No.	Date of collection	Iron (Fe)	Calcium (Ca), by turbidity	Bicarbonate (HCO_3)	Sulphate (SO_4), by turbidity	Chloride (Cl), by turbidity	Total hardness as $CaCO_3$
M-1	Aug. 23, 1930	1.8	11	103	3	3.5	93
1	Jan. 22, 1931		20	102	7	3.0	80
C-3	Aug. 23, 1930	.59	13	80	2	1.5	52
7	do	1.1	16	126	3	2	106
7	Jan. 22, 1931		14	128	1	2.5	90
8b	Aug. 23, 1930	1.0	14	92	3	2	66
C-16	do	.39	12	71	3	1.2	46
23	do	1.4	14	77	2	2	64
C-24	do	.63	10	68	3	1.5	40
32	do	.75	13	104	3	1.7	76
36	Aug. 22	.86	13	94	3	1	63
36	Jan. 22, 1931		16	97	2	1.6	68
39	Aug. 22, 1930	.83	14	94	3	2.7	63
39	Jan. 22, 1931		12	90	5	1.8	62
47b	Aug. 22, 1930	.86	15	86	3	1	60
52a	do	.25	15	66	3	2.7	57
56	do	1.3	14	89	3	2	60
59	do	.45	14	92	2	.8	52
64	do	2.4	6	60	5	1.7	63
69a	do	.18	10	61	4	2.7	32
71	do	.66	13	90	3	.7	63
77	do	.49	14	92	3	2.2	60
77	Jan. 22, 1931		12	88	3	1.8	60
82b	Aug. 22, 1930	.68	14	107	7	2.3	64
82b	Jan. 22, 1931		14	79	4	3	64
84	Aug. 22, 1930	1.4	12	61	2.5	10	56
A	do	.45	15	84	3	1.5	60
B	do		36	[a] 158	60	3.5	144
C	Aug. 23		6	27	3	1.8	20

[a] Includes equivalent of 15 parts per million of carbonate (CO_3).

A similar study of the alkalinity of water samples from several wells made by Chester & Fleming shows a relation between the chemical character of the water and the location of the well with reference to the Mississippi River. The relation is well brought out in Plate 13, on which are drawn lines bounding areas of equal alkalinity. The alkalinity ranged between 54 and 126 parts per million. The minimum is equal to the alkalinity of the average water from the Wilcox group. For water of this type the alkalinity may be taken as practically a direct measure of the hardness.

The water at Memphis is soft enough for most uses and gives no trouble with boilers, but laundries and industries using large amounts of soap find it necessary to soften the water.

The iron content of the 51 samples taken throughout Memphis by the writer ranges from 0.4 to 2.5 parts per million. This is considerably more iron than is desirable in a water supply for general use, but the excess is easily removed by aeration followed by filtration or sedimentation. The water is pumped from many wells by air lift, which accomplishes the necessary aeration while raising the water. Separation of iron may take place to some extent in the wells by deposition on the casing. A sample from such a well will show less iron than is present in the water in the ground. Analyses 3 and 4 in the following table indicate the improvement as regards iron resulting in aeration followed by rapid filtration of water for the public supply of Memphis. The reduction from 0.61 to 0.08 part per million of iron much improves the appearance of the water on standing and its suitability for laundry use.

Analyses of ground waters from Memphis and other places in western Tennessee and Mississippi

[Parts per million]

	1	2	3	4	5	6
Silica (SiO_2)	19	13	21	16	5.5	13
Iron (Fe)	.05	1.6	.61	.08	1.2	1.2
Calcium (Ca)	65	8.9	11	8.6	20	15
Magnesium (Mg)	35	3.9	5.5	4.2	4.0	6.8
Sodium (Na)	15	5.0	6.5	15	3.0 (Na + K)	6.8
Potassium (K)	1.0	1.6	1.6	1.2		1.6
Bicarbonate (HCO_3)	387	50	74	80	68	89
Sulphate (SO_4)	8.6	5.2	3.7	4.4	9.0	4.0
Chloride (Cl)	5.0	2.8	1.8	1.8	4.5	3.6
Nitrate (NO_3)	.74	0	0	.07	.2	0
Total dissolved solids	333	65	83	87	85	91
Total hardness as $CaCO_3$ (calculated)	306	38	50	39	66	65
Date of collection	July 25, 1928.	Aug. 8, 1929.	July 26, 1928.	July 26, 1928.	June 1, 1929.	July 19, 1928.
Analyst [a]	M. D. F.	M.D.F.	M. D. F.	M. D. F.	D. F. F.	M. D. F.

	7	8	9	10	11
Silica (SiO_2)	27	4.0	20	16	6.9
Iron (Fe)	.35	.7	1.6	.4	17
Calcium (Ca)	40	7.0	3.0	3.2	1,101
Magnesium (Mg)	12	1.0	1.0	1.0	166
Sodium (Na)	6.6	2.0 (Na + K)	35	432 (Na + K)	8,070
Potassium (K)	4.9		2.7		16
Bicarbonate (HCO_3)	137	17	104	[b] 1,068	119
Sulphate (SO_4)	54	9.0	5.5	1.8	14
Chloride (Cl)	2.7	.8	1.0	16	14,990
Nitrate (NO_3)	.0	1.2	.55	.02	----------
Total dissolved solids	217	39	124	1,026	24,750
Total hardness as $CaCO_3$ (calculated)	149	22	12	12	3,430
Date of collection	June 22, 1928	Aug. 1, 1929	July 26, 1928	Sept. 26, 1927	June, 1930
Analyst [a]	M. D. F.	D. F. F.	M. D. F.	F. A. M.	S. K. L.

[a] M. D. F., Margaret D. Foster; S. K. L., S. K. Love, U. S. Geological Survey; D. F. F., D. F. Farrar, Tennessee Geological Survey; F. A. M., F. A. Mantel, Memphis Artesian Water Department.
[b] Includes equivalent of 71 parts of carbonate (CO_3).

1. 250-foot well owned by town of Millington.
2. 296-foot well owned by city of Dyer.
3. 475-foot well at southwest corner of pumping station, owned by city of Memphis.
4. Treated water from wells comprising public supply for city of Memphis.
5. West Tennessee State Teachers' College well, 515 feet deep, Memphis.
6. 350-foot well owned by Railroad Ice Co., Nonconnah, Memphis.
7. 230-foot well owned by Hugh Carter, Bolivar.
8. 145-foot well owned by Harris Bros., Luray.
9. 1,400-foot well, No. 27, at southeast corner of pumping station, owned by city of Memphis.
10. 2,656-foot well of Memphis Artesian Water Department, Memphis.
11. 3,434-foot well in NE. ¼ sec. 21, T. 7 N., R. 16 E., Lauderdale County, Miss., owned by Lauderdale Oil & Gas Co., water from 3,300-foot level.

Samples 1 to 6 are from the Grenada and Holly Springs formations; 7 to 9 from the Ackerman formation; 10 from the Ripley formation; 11 from the Tuscaloosa formation.

Water from the Ripley formation at Memphis differs markedly from the water from the Ripley in its outcrop area. The water at Memphis is a sodium bicarbonate water; it has a very high mineral content and is unfit for domestic or industrial use.

Though the water from the Eutaw formation in its outcrop area is fairly soft and has a moderately low content of dissolved solids, the water from deep wells in Mississippi contains sufficient dissolved solids to be noticeable to the taste and is unsuitable for domestic and industrial use.

There is no definite information concerning the chemical character of the water from the Tuscaloosa formation at Memphis, owing to the fact that no well penetrates the formation, but it seems probable that the water would have a high mineral content. Analyses of water from the Tuscaloosa formation in Mississippi show increasing mineral content with increasing depth. The only available analysis of water from the Tuscaloosa formation at a depth comparable to the depth of the Tuscaloosa at Memphis represents water from Lackey well 1, an oil test in the NE. ¼ sec. 21, T. 7 N., R. 16 E. Choctaw meridian, Lauderdale County, Miss., at a depth of 3,300 feet (correlation by E. N. Lowe). This water is a sodium chloride water (see analysis in preceding table) high in calcium and containing 17 parts per million of iron and 24,750 of total dissolved solids. Such a water is unfit for any use.

Care should be used in sealing off wells in order to prevent flow of water from the overlying Pliocene gravel into the Wilcox group. In water from Pliocene gravel overlain by loess (see p. 109) the total hardness ranges from 110 to over 400 parts per million. Such water needs treatment before it can be used for most industrial purposes, and it is only by preventing pollution through leaky wells that the present low mineral content of the water from the Wilcox group can be maintained.

HEAD OF GROUND WATER

SEASONAL FLUCTUATION OF HEAD IN WELLS

A continuous record of the position of the water level in any well will show fluctuations resulting from many causes. In order to determine the nature and magnitude of the fluctuations of the pressure head at Memphis and to deduce their causes, two continuous water-level recorders have been installed—one in the Auction Avenue "wet well" and the other in the Central Avenue well. The level of the water in the "wet well" represents the static level in about 100 wells scattered over a rectangular area of 5,000 by 3,000 feet. These wells flow into tunnels that lead to the "wet well." An examination of Plate 11 will show that this well gang is within 400 feet of the Wolf River at the nearest point and that it is near the center of all pumpage that derives water from the upper Wilcox. A record of the water level in the Auction Avenue "wet well" taken at 8.30 a. m. has been kept since April, 1927, and a continuous recorder has been operating in the well since October, 1928. (See pl. 14.) The well at Wills Park, on Central Avenue, is 4 miles from the Mississippi River and 2 miles from the nearest pumping well of the Memphis Artesian Water Department and is in a section where there is but little private pumping.

Since the completion of well C-50, in March, 1930, a measurement of the static level in this well has been made every other day. The well is at the eastern boundary of the city, about 8¼ miles east of the Mississippi River and 3½ miles east of the Artesian Water Department's well gang. There is practically no pumping near this well, and it is far enough from both the main city pumpage and the Mississippi River not to be directly affected by either.

The data obtained from the continuous recorder, and the measurement of well C-50 are graphically shown in Plate 14. Prior to 1928 the point given is the daily reading; after this date the level given is the lowest reading of the 24 hours, midnight to midnight, on the continuous recorders.

For comparison, curves of the altitude of the Mississippi River of the daily pumpage of the Memphis Artesian Water Department from the upper Wilcox, and of the rainfall at Bolivar have been plotted in Plate 15.

The pumpage of the Memphis Artesian Water Department from the upper Wilcox is derived by subtracting from the total daily pumpage the amount pumped from the Ackerman formation. The curve is plotted in reverse sense, a larger pumpage being lower on the graph than a small pumpage, in order that the water level and pumpage can be readily compared. It should be borne in mind that the pumpage of the Memphis Artesian Water Department represents only 38 per cent of the total pumpage from the upper Wilcox, the remainder being pumped by industrial plants. However, as the factors that necessitate an increase or decrease in the pumpage of the Memphis Artesian Water Department have somewhat similar effects on the industrial pumping, the total roughly parallels the pumpage for the city waterworks, with the following exceptions. Industrial pumping is cut by at least 3,440,000 gallons on Sundays. This figure represents the cut of laundries, sawmills, and such plants as stop completely on Sundays. Other plants may run at lower capacity on Sundays, so that the total Sunday cut of industrial pumping is probably more than 3,440,000 gallons. The pumpage of the Memphis Artesian Water Department on Sunday shows no such cut but increases or decreases according to the weather. It is possible for the city to meet increase or decrease in the demand for water by increasing or decreasing the amount taken from the Ackerman formation. This is illustrated by the increased pumpage from the Grenada formation during February and March in both 1928 and 1929, which was due to cessation of pumping from the Ackerman formation and does not indicate an increase in total pumpage. Any sudden peak in pumpage such as that for January 16, 1928, can be accounted for in this way. Thus changes in pumpage may not show in the graph of the pumpage from the upper Wilcox, but as a rule the ratio of the pumpage from the Ackerman formation to the pumpage from the upper Wilcox remains about the same, and it can be assumed that the graph of the pumpage from the upper Wilcox represents in a general way the variations of the total pumpage in all Memphis.

The stages of the Mississippi River at Memphis given by the Memphis River Commission have been used in plotting the altitude of the river.

The rainfall at Bolivar, Tenn., which lies almost due east of Memphis in the outcrop area of the Wilcox group, has been plotted. Except for local summer rains precipitation usually occurs over the whole of the outcrop area of the Wilcox group during the same days, so that when it rains at Bolivar rainy weather can be assumed throughout the area.

An examination of the graph of the water level in the Auction Avenue "wet well" shows that the water level usually attains its highest point in the early summer, either May or June. It drops off rapidly during the summer, reaching the lowest point in August or September, after which it starts to rise. The rise is continuous during the fall and early winter but the water level may fall a little in February and March before rising to its spring high point. The maximum variation from May 1, 1927, to April 1, 1931, is 13.6 feet; the yearly variation is 8.3 feet May 1, 1927, to May 1, 1928; 7.6 feet May 1, 1928, to May 1, 1929; 12.6 feet May 1, 1929, to May 1, 1930; and 10.8 feet May 1, 1930, to April 1, 1931. The average yearly variation for the period of nearly four years is 9.8 feet.

The record at Central Avenue is incomplete and covers only two years. The graph parallels in a general way the Auction Avenue curve, showing a high point in May which drops off rapidly to a low point in August or September and October. Likewise the water level rises rapidly in the fall and early winter, but unlike that in the Auction Avenue well it reaches its highest point in January. The maximum yearly variation as determined from the fragmentary record was 9.5 feet, during the year October 1, 1929, to October 1, 1930, but the variation was only 5 feet during the preceding year, October 1, 1928, to October 1, 1929.

The record for well C–50 covers only one year, March, 1930, to March, 1931, and unfortunately that was a year of exceptional drought. The graph shows that the water stood at an almost constant high level during March, 1930. Beginning in April it fell slowly but almost uninterruptedly until September and remained at this low point until March, when it rose slightly. The total greatest difference in level was 3 feet.

In accordance with the variation in water level the graph of pumpage shows that the period of lowest water level (August) usually corresponds to the time of maximum pumping. Pumpage diminishes rapidly from September to December and remains small from January to April, the minimum occurring some time within this period. Pumpage increases again in May and June and reaches a maximum in August. Thus the greatest pumpage and lowest water level in the Auction Avenue "wet well" coincide, but the least pumpage and highest water level do not, as can be clearly seen by comparing the pumpage and water level in November, 1928, with the pumpage and water level in May, 1929. An explanation of this difference can be found by comparing the water level in the Auction Avenue "wet well" with the altitude of the Mississippi River. The river is at high stages from March until the end of June, the maxima usually occurring in April and May, although they may occur any time during these four months. The river falls rapidly in July and remains low until October, when it begins to rise. This curve roughly parallels the water-level curve, and the maxima and minima of the two curves are coincident. Further proof of the influence of the river on the water level is given in Figure 12. In this graph the water level in the Auction Avenue "wet well" continues to rise as the river rises and the pumpage increases. Because there was no rain, the rise of nearly 2 feet in the water level in spite of the increased pumpage can only be attributed to the influence of the rise in the river level. This is further shown by studying the following table, which gives the average daily pumpage, the average river level, and the average water level in the Auction Avenue "wet well" for June and August, 1927, and June, 1928. Though the pumpage is nearly the same there is a difference of 4.2 feet in static level.

	Pumpage (gallons a day)	Altitude (feet above sea level)	
		Water level at Auction Avenue well	River
June, 1927	12,350,000	204.5	220.0
August, 1927	12,280,000	200.3	200.1
June, 1928	12,270,000	203.8	212.8

The lack of synchronism between the drawdown and pumpage might be attributed to the effect of lag. It has been observed in other artesian areas that the water levels in wells do not respond immediately to the starting and stopping of pumpage in adjacent wells, but there is a time interval, or lag, before adjustment takes place. The curves given by Lundie[4] (see fig. 13) show that when

[4] Lundie, John, op. cit., p. 19

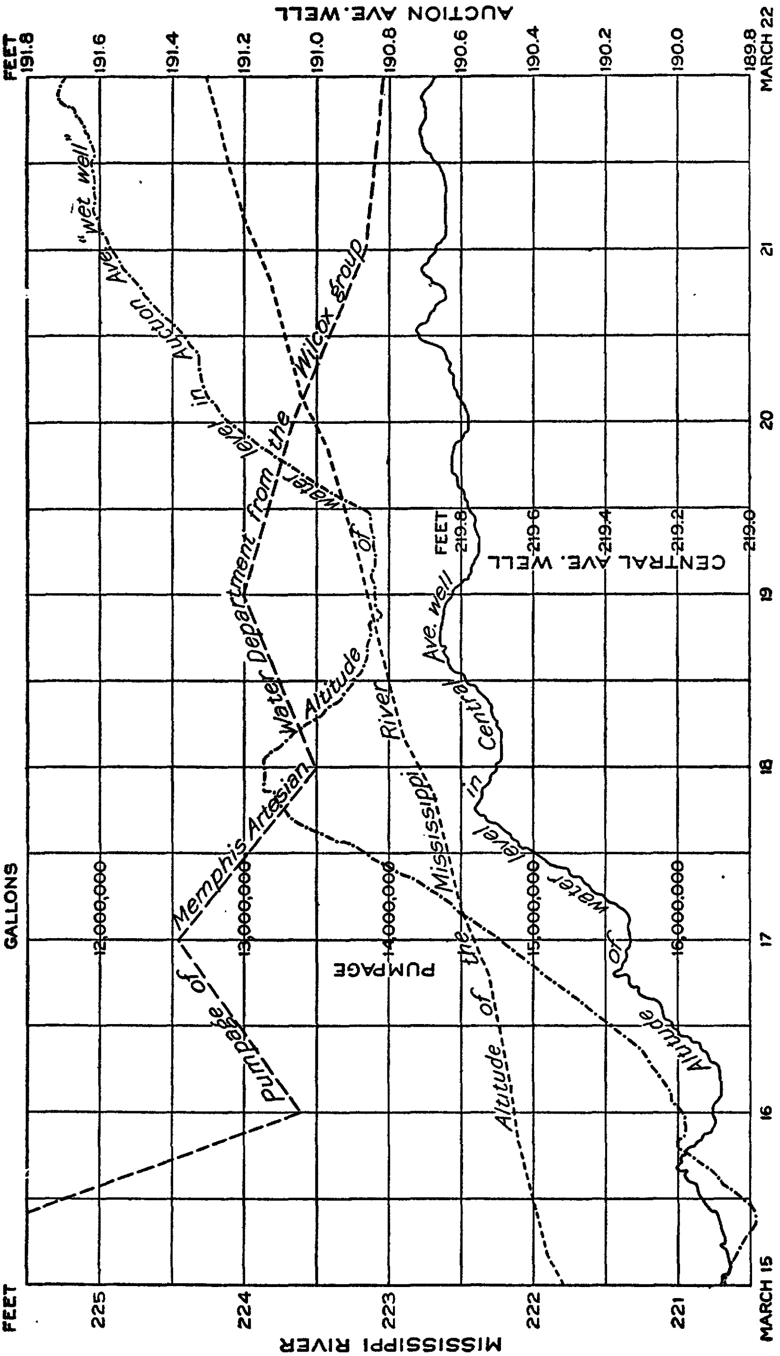

FIGURE 12.—Rise of water level in Auction Avenue "wet well" with rise in the Mississippi River and increase in pumping from the upper Wilcox

pumpage was stopped at the Auction Avenue plant the recovery of head was very rapid—for example, in the first hour after the shutdown on October 25, 1891, the head recovered 30 feet. Chester & Fleming state that the water level at the Central Avenue pumping station returned to normal 35 minutes after the cessation of pumping. Further proof of the rapid recovery of wells after the cessation of pumping is given in Plate 16, in which is graphically shown the rate of rise of water level in several wells of the Memphis Artesian Water Department on cessation of pumping from the upper Wilcox for a period of 13½ hours, from 4.30 p. m. March 7 to 6 a. m. March 8,

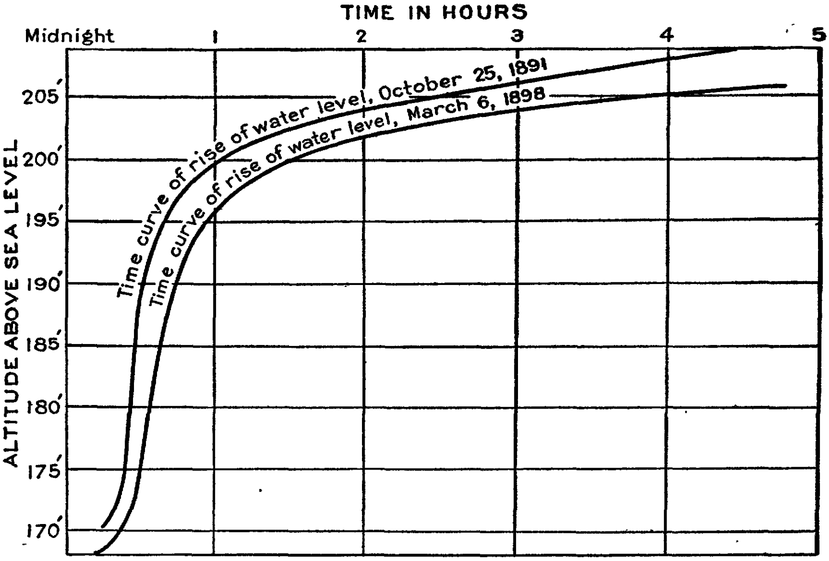

FIGURE 13.—Rate of rise of water level after shutting down pumps at Auction Avenue station October 25, 1891, and March 6, 1898

1931. The wells showed different amounts of rise, from 8.2 to 19 feet, but all responded within 12 hours.

These facts would indicate that the head responds very rapidly to changes in pumpage and that the failure of the water level to respond in the cases given can not be explained on the basis of lag.

From March 1 to April 10, 1930, the pumpage of the Memphis Artesian Water Department from the upper Wilcox remained about constant, showing a maximum variation of only 1,000,000 gallons a day, and when averaged over 5-day periods varying by only 100,000 gallons. The Mississippi River rose about 6 feet and fell about 12 feet during this period; the water level in the Auction Avenue "wet well" remained about constant during the rise of the river but fell about 2 feet when the river fell, and the water level in the Central Avenue well remained constant during the rise of the river and fell about 1 foot when the river fell. If, in order to exclude minor fluctuations, 5-day averages are taken, it is found that the river fell 10.1 feet during this period, the water level in the Auction Avenue wet well fell 1.7 feet, and the water level in the Central Avenue well fell 0.5 foot. Well C–50 was unaffected. Thus it is clearly seen that the Mississippi River influences the static level of water in the upper Wilcox and that the influence is greatest next to the river, the water level in the Auction Avenue wet well varying about 1 foot for every 6-foot change in the river, and the variation diminishing away from the river until at well C–50 it is negligible. Furthermore, the water level in the upper Wilcox does not respond immediately to changes in river level but lags by several days.

Another factor that may influence the water level is the rainfall over the outcrop area of the Wilcox group. A large part of the yearly precipitation occurs from January to June, and the period from July to October is relatively dry. During the growing season most of the precipitation is taken up by the vegetation, and therefore very little of the rainfall reaches the zone of saturation. Hence the period of principal recharge is from November to March, and it may be assumed that in the outcrop area the water level reaches its highest level in the early spring and its lowest in the late summer and early fall. These variations in water level at the outcrop represent variations of load on the confined portion of the water-bearing beds and should cause changes in the artesian head. Data are not available to prove this assumption, and the variations are so small that they are possibly concealed by the more prominent factors. The record of well C–50 (see pl. 13) is too short to give conclusive evidence as to the fluctuations in water level at a distance from the Mississippi River and from heavy pumpage. Unfortunately the period of the record has been one of unusual drought. This is shown in the almost continuous decline of the water level, but the rise in March, 1931, indicates that in normal years the water level in the well would rise during the wet period of winter and spring.

It has been shown that the water level varies with pumpage, river level, and possibly rainfall. The records thus far obtained are so short that it is impossible to evaluate definitely the several factors, but figures which are believed to be fair approximations have been obtained. From these it is found that pumping is the major factor, producing 1 foot of drawdown in the Auction Avenue "wet well" for every 1,000,000 gallons of pumping (see p. 300), and the Mississippi River is the second large factor, producing about 1 foot of variation at the Auction Avenue "wet well" for every change in stages of 6 feet. In any consideration of drawdown or of specific yield these two factors must be borne in mind.

ORIGINAL STATIC LEVEL

Glenn[5] gives the original static level at Memphis as 225 feet above mean sea level. Safford[6] was the source for Glenn's figures, but Safford does not state definitely when this measurement was made, and it is probable that this figure is not the original static level but the level at the time Safford made his investigation, which was after several wells had been drilled. The altitude of the collar of the first successful well is not definitely known. This well was drilled for the Bohlen-Huse Ice Co. in the bayou at Court Street and had a large flow. The bayou is now 230 to 240 feet above sea level, and there is no evidence of filling.

Chester & Fleming state that in 1908, when the first well at Central Avenue was drilled, the water level from March to May averaged 232.7 feet above mean sea level. The average water level in well C–50 (see pl. 14) from March 15 to March 31, 1930, was 241 feet above sea level. Though the level fell to 238 feet during the summer of 1930, this was probably due to the exceptionally dry weather, so 240 feet can be taken as the average static level at this well. As the well is 6.6 miles east of the original well on Court Street, its static head would have been higher than the original static head at the Court Street well. If a hydraulic gradient of 1.5 feet to the mile (see p. 308) is used it would give 230 feet as the original static level at Court Street. All these facts indicate that the original static level in the vicinity of the Auction Avenue wells was more than 225 feet, probably about 230 feet.

QUANTITY OF WATER

PUMPAGE

The daily pumpage of the Memphis Artesian Water Department during 1930 showed a maximum of 28,859,000 gallons, a minimum of 15,926,000 gallons, and an average of 19,750,000 gallons. These figures include the pumpage from the 1,400-foot stratum, which amounted in 1930 to a maximum of 8,947,000 gallons a day and an average of 6,145,000 gallons a day. The average daily pumpage during 1930 was 4,858,000 gallons more than the average for 1920. The population of Memphis in 1930 was 253,143; in 1920, 162,351. On the basis of these figures the average daily per capita consumption in 1930 was 78 gallons; in 1920, 91.7 gallons. This decrease in per capita consumption of 13.7 gallons is contrary to what would be expected and is probably due to the extension of the corporate limits of Memphis in 1929, thereby including within the city several thousand people who do not yet receive city water. Otherwise the per capita consumption has probably remained about constant.

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[5] Glenn, L. C., op. cit., p. 110.

[6] Safford, J. M., op. cit., p. 102.

The pumpage of the water department represents only a part of the pumpage from the upper Wilcox formation in Memphis. Soon after the drilling of the first deep well in Memphis many of the local industrial plants developed private water supplies from deep wells. Owing to the ease of obtaining a good well and the cheapness of operation, private plants, even those with small water consumption, found it most economical to have their own wells. Another factor that favored private wells was the fact that air-lift pumping reduced the iron and carbon dioxide content of the water considerably, and the water so pumped was therefore superior to city water from the Auction Avenue plant. For these reasons virtually all the industrial plants and large buildings had private supplies.

As there are no records of the amount of water pumped by individual concerns in Memphis prior to 1920, it is impossible to determine whether this pumpage has steadily increased, whether it has reached a high point and remained constant, or whether it has reached a maximum and declined. The normal growth of the city could lead to an increase in the private pumpage, which might be assumed to parallel the increase in city pumpage. The following factors, however, would tend to decrease the private pumpage:

1. Effective treatment of the water furnished by the city waterworks since 1925 has greatly improved its quality and made it better than the water that is pumped privately by air lifts.

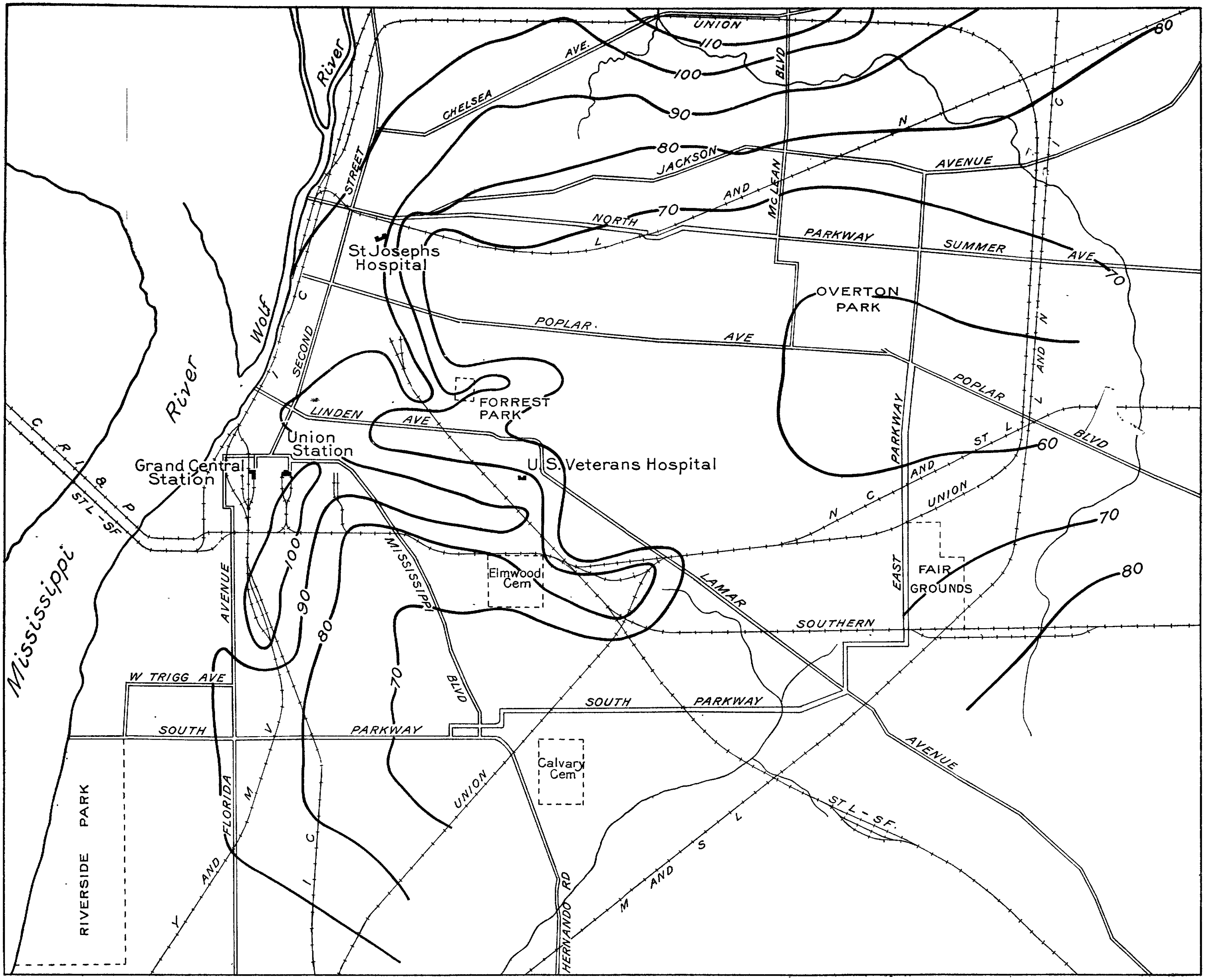
2. The necessity of renewing wells and pumping machinery has induced many small water consumers to use city water.

3. The need of having a city connection for fire protection involves a minimum fixed charge, and if the amount of water consumed is only slightly greater than that covered by the minimum charge it is not economical to have a private supply.

4. In many small power plants one engineer had charge of both the plant and the pumping machinery, and the replacement of such a plant by electrical power has displaced the engineer, as it is not profitable to employ one simply to supervise the pumps. Centrifugal pumps could be operated by electric motors without much supervision, but owing to the iron content of the water air lifts are preferred to centrifugal pumps.

5. Formerly, Memphis manufactured large quantities of ice for shipment to outlying points, but the development of small, simple machines for producing ice has resulted in the establishment of local ice plants at these points, and at present Memphis ships very little ice. The consumption of water in Memphis ice plants has therefore decreased.

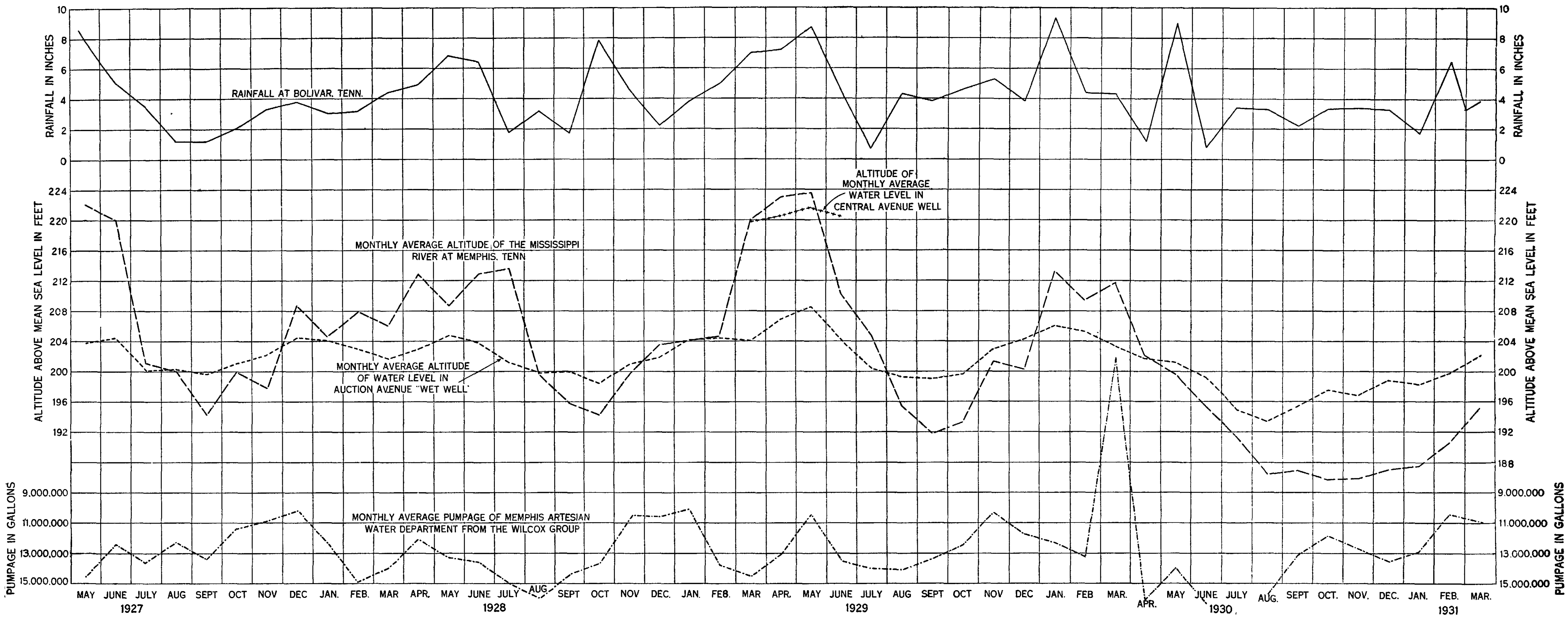
6. The use of spray ponds for cooling condenser water has diminished the amount of condenser water used. The quantity of water used for condensing by the Memphis Power & Light Co. (Memphis



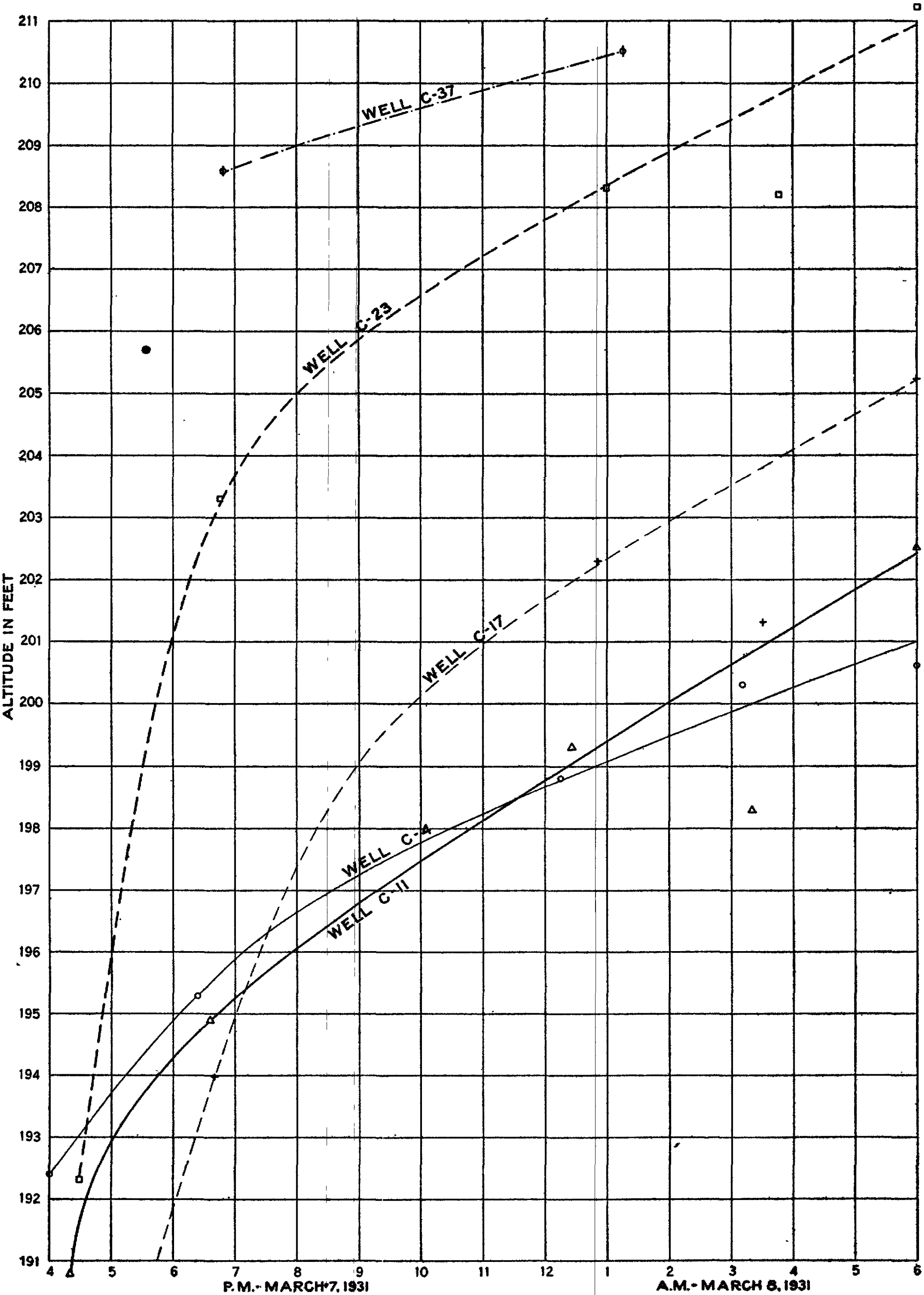
MAP SHOWING AREAS OF EQUAL ALKALINITY IN MEMPHIS

In parts per million. After Chester & Fleming.

ALTITUDE OF WATER LEVEL IN AUCTION AVENUE "WET WELL," CENTRAL AVENUE WELL, AND WELL C-50; PUMPAGE OF MEMPHIS ARTESIAN WATER DEPARTMENT FROM WILCOX GROUP; AND RAINFALL AT BOLIVAR, TENN.



MONTHLY AVERAGE ALTITUDE OF WATER LEVEL IN AUCTION AVENUE "WET WELL" AND CENTRAL AVENUE WELL, MONTHLY AVERAGE OF DAILY PUMPAGE OF MEMPHIS ARTESIAN WATER DEPARTMENT FROM WILCOX GROUP, AVERAGE ALTITUDE OF MISSISSIPPI RIVER, AND TOTAL MONTHLY RAINFALL AT BOLIVAR, TENN., MAY, 1927, TO MARCH, 1931



RATE OF RISE OF WATER LEVEL IN WELLS C-4, C-11, C-17, C-23, AND C-37 ON CESSATION OF PUMPING FROM WILCOX GROUP BY MEMPHIS ARTESIAN WATER DEPARTMENT, MARCH 7-8, 1931

Electric Co. and Memphis Street Car Co.) has decreased about 10,000,000 gallons per 24 hours since 1920.

It is impossible to evaluate these factors; factors 2, 3, and 4 involve small supplies, and the total amount was probably not large; the amount represented by factor 5 may be considerable. The combined influence of factors 1 to 5 probably did not compensate for the normal increase in consumption due to increase of population but only served to lessen the total increase. Factor 6 represents a considerable decrease.

Chester & Fleming, in their report of 1920, list 58 private plants of large consumption with an aggregate estimated average daily pumpage of 21,740,000 gallons. This list was not complete, and the pumpage given is an estimate, which is, however, sufficiently accurate for the present purpose.

The pumpage as here used is the estimated average daily pumpage for periods during which a plant was running continuously at full capacity. Therefore, the average given is probably considerably in excess of a daily average determined by dividing the total pumpage throughout the year by 365. Inasmuch as the figures for private pumpage are estimates derived by various methods, they are not exact, and any attempt to arrive at an average daily pumpage that would be a true daily average of the pumpage throughout the year would be attempting a precision that the data do not justify.

In 1928 the writer listed 86 private plants with an aggregate estimated average daily pumpage of 21,000,000 gallons. Although this list did not include every pumped well in greater Memphis, it is believed to have included every plant with a pumpage of 50,000 gallons or more in 24 hours. Many of the figures of pumpage are estimated. Of the wells listed by Chester & Fleming, eight, with a combined production of 290,000 gallons a day, are no longer in operation. Of the wells listed in 1928, six, with a present combined production of 1,255,000 gallons a day, were in operation in 1920 but were not listed by Chester & Fleming. A study of 37 plants listed both by Chester & Fleming and the writer shows increase in pumpage of 32 per cent since 1920. As these plants are distributed among the various industries the increase in pumpage from their wells can be considered representative of the general trend of private pumping, other than the pumping which has been decreased for reasons previously given. On the assumption that there has been an increase of 32 per cent in private pumping since 1920, the total pumpage of the six wells not listed by Chester & Fleming in 1920 was 853,000 gallons a day at that time. This brings the estimated total daily pumpage by private plants in 1920 to 22,593,000 gallons.

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The average daily pumpage of the city water supply from the Grenada formation in 1920 was 14,982,000 gallons a day, which added to the private pumpage of 22,593,000 gallons made the total pumpage from the upper Wilcox 37,575,000 gallons a day. In 1928 the estimated pumpage from private wells, all derived from the upper Wilcox, was 21,000,000 gallons a day, and the city pumpage from the upper Wilcox was 12,984,000 gallons a day, making a total of

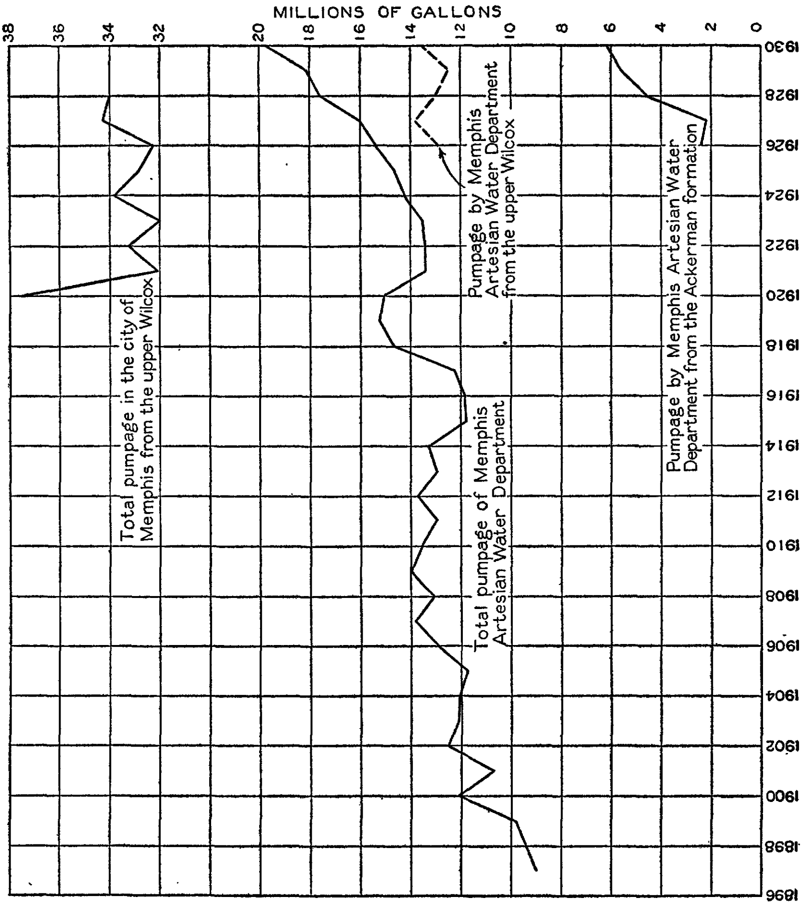

FIGURE 14.—Average daily pumpage in Memphis, 1897–1930

33,984,000 gallons a day, or 3,591,000 gallons less than in 1920. This decrease was due to two factors—the development of wells in the sand of the Ackerman formation by the Memphis Artesian Water Department and a cut of 10,000,000 gallons a day by the Memphis Power & Light Co. during the years 1920 to 1926. In 1928 the Memphis Artesian Water Department pumped an average of 4,616,000 gallons a day from the Ackerman formation. The cut made by the Memphis Power & Light Co. was effected as follows: In 1921 the introduction of a spray point cut off 5,000,000 gallons a day; there was a gradual cut of 2,500,000 gallons a day in 1924; the shutdown of the Beach Street plant in January, 1926, involved an immediate cut of 1,500,000 gallons a day and a gradual cut of 1,000,000 gallons more. It is estimated that from 1920 to 1928 the other plants in the city increased their consumption 32 per cent, and in addition about 5,000,000 gallons a day was developed by new plants. These two factors nearly compensated for the cut of the Memphis Power & Light Co.

The total average daily pumpage, the average daily pumpage from the upper Wilcox, and the average daily pumpage from the Ackerman formation by the Memphis Artesian Water Department are shown graphically in Figure 14. As the Memphis Artesian Water Department obtained all of its water from the upper Wilcox prior to 1925, the curve for its total pumpage and the curve for its pumpage from the upper Wilcox coincide for the period 1897 to 1925. In 1925 a small amount of water was pumped from the Ackerman formation by the Memphis Artesian Water Department, and in succeeding years this pumpage has increased. This is shown by the bifurcation of the curve beyond 1925.

Figure 14 also gives a graph of the total average daily pumpage from the upper Wilcox in the city of Memphis from 1920 to 1928. Only two points on this curve are definitely known—1920 and 1928; the intermediate points were determined by deducting the known cuts in pumpage and distributing the normal increase and new pumpage over the eight years. This curve is therefore not accurate, but it shows the general trend of the fluctuations in the total pumpage. An examination of these curves shows that the pumpage of the Memphis Artesian Water Department reached a maximum in about 1920 and has never reached this point again; also that the total pumpage from the Wilcox group reached in 1920 a maximum which it did not exceed between 1920 and 1928 and probably has not exceeded since 1928. This is due to two facts—that private pumpage, all of which is derived from the upper Wilcox, was greater in 1920 than in 1928, and whereas the total pumpage of the Memphis Artesian Water Department was greater in 1928 than in 1920 the amount pumped from the upper Wilcox was less because an average of 4,616,000 gallons a day was obtained from the Ackerman formation. These two facts should be borne in mind in any studies of the influence of pumping in lowering the water level.

RELATION OF PUMPAGE TO REGIONAL DRAWDOWN

The average altitude of the water level at the Auction Avenue plant for the year 1928 was 202 feet above mean sea level. This is 28 feet lower than the assumed original altitude, 230 feet. Taking 34,000,000 gallons for the average daily pumpage from the upper Wilcox in 1928 makes the yield of the group about 1,200,000 gallons a day for each foot of drawdown as measured at the Auction Avenue well. Another figure for drawdown at the Auction Avenue "wet well" for each million gallons of pumpage by the Memphis Artesian Water Department can be obtained by comparing the drawdown and the pumpage when influencing factors other than pumpage are either not operative or constant. Such a condition existed from August 15 to September 15, 1930. During this interval the river showed a maximum variation of only 1 foot. There were two heavy rains, one at the beginning and one at the end of the period, but inasmuch as these rains caused only very slight changes in water level in well C–50 it is probable that their influence at the Auction Avenue well was negligible. It is found that for this period the static level in the Auction Avenue "wet well" showed a drawdown of 1 foot for each increase of pumpage of a million gallons by the Memphis Artesian Water Department.

In succeeding pages it is shown that the drawdown is not everywhere the same, so it is desirable to determine the drawdown and the yield per foot of drawdown at a point within the present well gang of the Memphis Artesian Water Department. A continuous record of the static level in well C–11 during 1930 is available. The average altitude of the water level in this well during 1930 was 194 feet above sea level. The average daily pumpage by the Memphis Artesian Water Department from the upper Wilcox was 13,605,000 gallons. On the assumption that the average private pumpage was 23,400,000 gallons a day, the yield of the upper Wilcox per foot of drawdown in well C–11 was about 1,000,000 gallons a day. This compares closely with the drawdown in the Auction Avenue well, and inasmuch as well C–11 is practically in the center of the heaviest pumping it probably represents the maximum drawdown in Memphis. These figures for yield must be accepted as only approximate, because the original static level is not known exactly, because the water level has a considerable seasonal variation, and because the figure for total pumpage is an estimate and may be somewhat in error.

If a well in an artesian water-bearing bed is pumped at a given rate, the pressure-indicating surface, as determined by measuring the depth to water at the pumped well and in other wells located in various directions and at various distances from the pumped well, will be found to conform in shape to the surface of a solid of revolution determined by an exponential curve, the vertex of which is at the pumped well. Such a surface is called a cone of depression. A group of closely spaced wells distributed approximately uniformly throughout a circular area and having about the same pumpage can be likened to one well with a pumpage equal to the combined pumpage of the individual wells, and the pressure-indicating surface for such a group of wells is similar in a general way to the cone of depression of a single isolated well. Under most conditions the drawdown, or lowering of the pressure-indicating surface, at a pumped well is directly proportional to the rate of pumping—for instance, if the rate of pumping is doubled the drawdown is doubled. This is also true of the lowering of the pressure-indicating surface at any well in a group of wells, such as the group described above, so long as the distribution of the wells remains the same and the rates of pumpage from each remain in the same ratio. If, however, new wells situated at a distance are pumped or if the ratio of pumpage of the wells relative to each other is changed, the drawdown in any well is not proportional to the total pumpage. Without changing the total pumpage, it is possible to change the drawdown in any well in a group by changing the location of pumpage relative to the well. Also total pumpage can be changed without changing the drawdown in any well by changing the location of pumpage relative to the well.

Prior to 1907 most of the pumping in Memphis was concentrated in the downtown section of the city and the pressure-indicating surface was a conelike depression, with its apex at the Auction Avenue "wet well." The slope of the cone was steep in the downtown section but was almost flat a short distance away. Increases in pumpage were all in the same area and the drawdown at the Auction Avenue "wet well" was in general proportional to pumpage. This can be seen by comparing profiles of the water surface in 1898 and 1902 as given by Lundie and Hider.[7] (See fig. 15.)

In 1907 pumping for the city waterworks was started in the Central Avenue plant, and in 1910 pumping from segregated wells was started. Private pumping showed a similar scattering. The influence of scattering of pumpage on the water level in the Auction Avenue "wet well" can be seen by comparing the figures of pumpage and water level in the following table:

Year	Average static level in Auction Avenue "wet well" (feet above mean sea level)	Average daily pumpage of Memphis Artesian Water Department from upper Wilcox (gallons)	
		At Auction Avenue	Total
1898	175.5	9,400,000	9,400,000
1923	175.7	5,697,000	13,510,000
1928	202.0	None.	13,000,000

Thus, though the pumpage has increased, the water level in the Auction Avenue "wet well" has risen, owing to a change in the location of the pumped wells. There has been a lowering of the pressure-indicating surface, however, over the rest of the city, as is clearly shown in Figures 16 and 17.

[7] Hider, Arthur, Omberg, J. S., jr., and Bell, S. T., Engineers' report on the waterworks system of Memphis, Tenn., Memphis, 1904.

Further evidence is given in well 172, in which the water level had an altitude of 208.5 feet on September 13, 1916, and 204.9 feet on October 30, 1928. Chester & Fleming state that the wells drilled at

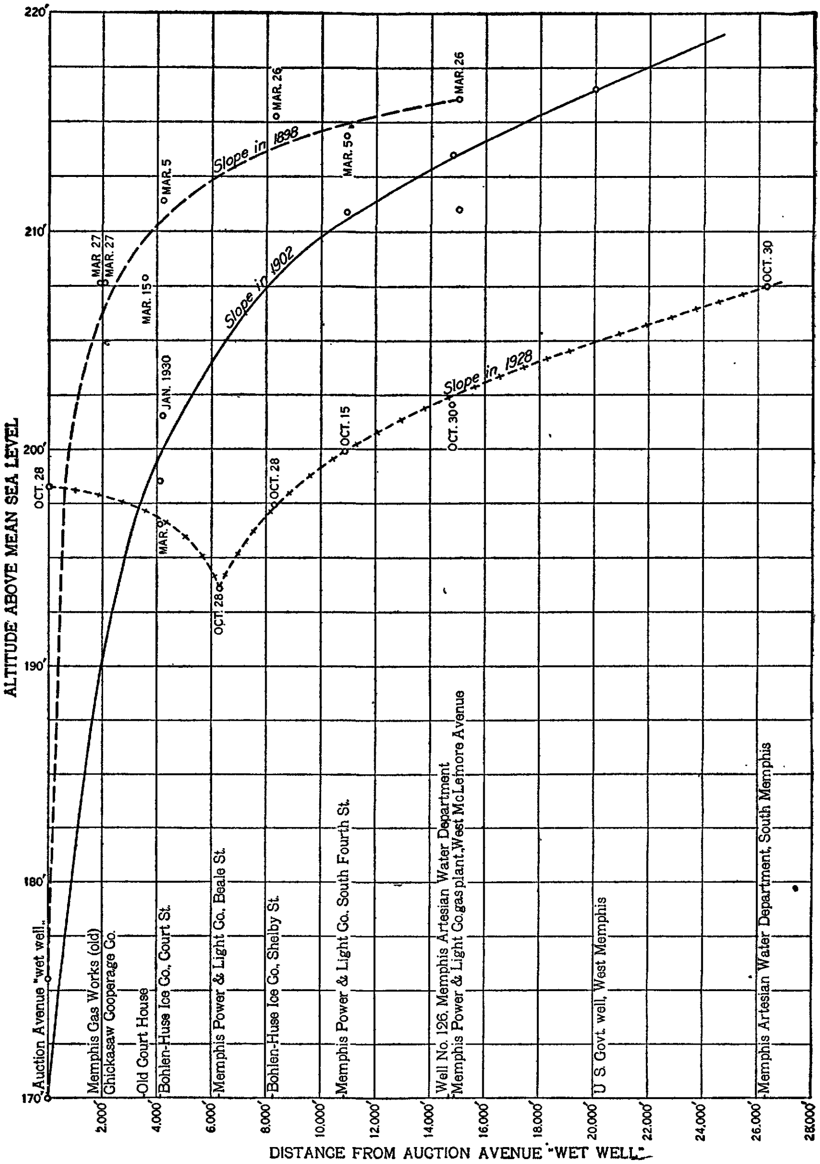

FIGURE 15.—Profiles of pressure-indicating surface along line A–A in Plate 11, 1898, 1902, and 1928. Levels of wells in 1898 from Lundie, in 1902 from Hider, both correlated to present datum. Distances are scaled from plat of Memphis and do not agree with distances given by Lundie and Hider

Central Avenue in 1908 had water levels at an average altitude of 232.3 feet from March to May, inclusive. The water level in well 157, in the same location, had an altitude of 226.2 feet on April 10, 1916, and 225.4 feet on June 18, 1916. From March to May, 1929, its average was 220.6 feet.

In considering any figure for drawdown in Memphis, such as that given above, or in estimating what effect increased pumpage will have on lowering the water level it should be borne in mind that the lowering of the water level is very largely dependent on the location of pumpage. By distributing pumping over a very large area the quantity pumped can be greatly increased with only slight lowering of the water level over the whole area.

The pressure-indicating surface has been considerably lowered over a large area, and its lowest point has moved slightly east from its

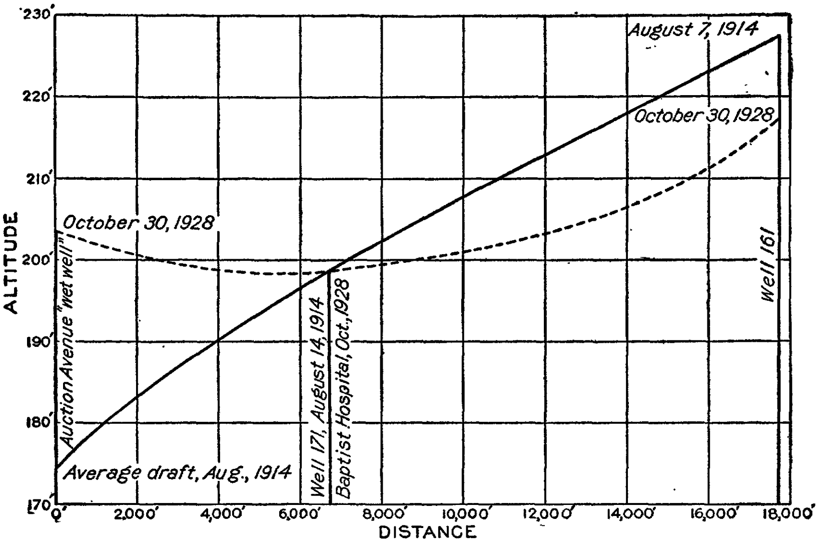

FIGURE 16.—Profiles of pressure-indicating surface along line B–B in Plate 11, 1914 and 1928

former position at the Auction Avenue "wet well," but the maximum drawdown has not increased. The present pressure-indicating surface roughly resembles a trough, the sides and ends of which are determined by parabolas and the bottom of which is a level line. The long axis of the trough parallels the river. The drawdown has increased only slightly since about 1900. The farther north, south, or east a well is from this axis the higher is the static level in the well and the less is the pumping lift. This fact shows that a wider distribution of pumping will allow increased pumpage without increasing the pumping lift.

The above discussion of the lowering of the pressure-indicating surface demonstrates that the present pumpage in the city of Memphis can be considerably increased in the outlying areas without materially increasing the drawdown in the downtown area. Also, in view of the large amount of pumping in the city, the drawdown at the Auction

Avenue "wet well" is not great, and it is believed that additional supplies can be developed in the downtown part of the area. If more

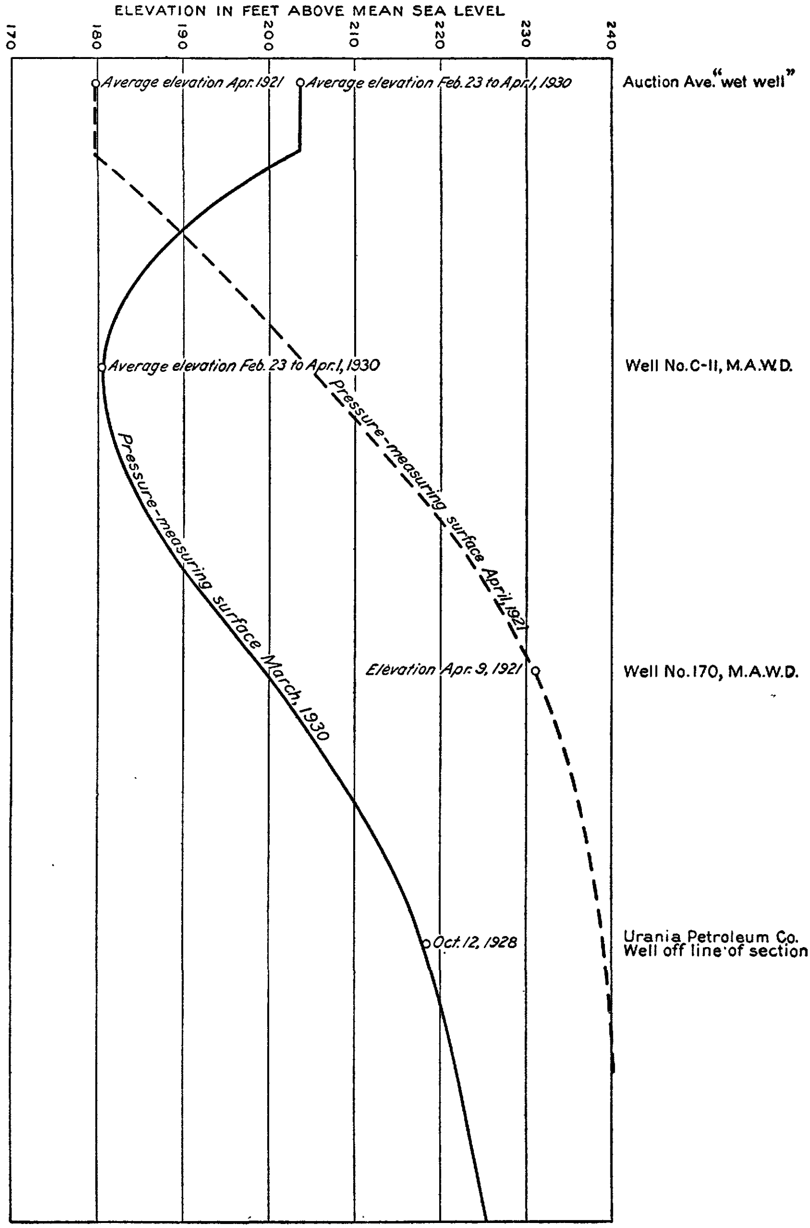

FIGURE 17.—Profiles of pressure-indicating surface along an east-west line through Auction Avenue "wet well" and well 170 of Memphis Artesian Water Department, April, 1921, and March, 1930

water is pumped, the head will doubtless decline, but for any increase anticipated in the immediate future the decline will not be excessive.

FACTORS THAT DETERMINE THE QUANTITY OF GROUND WATER AVAILABLE

The factors that determine the quantity of ground water which can be derived from a water-bearing formation are primarily the areal extent of the formation and the rainfall over the outcrop area. The outcrop area of the Wilcox group in Tennessee is roughly 5,000 square miles. The outcrop area in Kentucky, Missouri, and Arkansas is negligible. The rainfall over this area averages about 48 inches a year. Even if only a small fraction of the rainfall reaches the zone of saturation the amount of recharge must be very large. The other factors in the problem are the cross-sectional area of the formation, the permeability of the formation, and the hydraulic gradient.

Thickness and character of the upper and middle Wilcox.—The thickness of the upper and middle Wilcox at Memphis has been given as 1,300 feet. Only a part of this, however, is sand. There are five wells of the Memphis Artesian Water Department which pass completely through the upper and middle Wilcox and for which logs are available. Some of these logs list sand, sandy clay, and clay; others simply sand and clay. The three wells listing sand and clay have 34 per cent sand and 66 per cent clay. Of the other two wells one has 34 per cent sand, 30 per cent sandy clay, and 44 per cent clay; one has 50 per cent sand, 24 per cent sandy clay, and 20 per cent clay. The log of the third well, No. 109 of the Memphis Artesian Water Department, is given on page 281. This log is more detailed than those of the other wells and represents more truly the material encountered. It can not be assumed, however, that the materials in the other wells are identical. If it is assumed that the material classed as sandy clay is interstratified sand and clay, as seems probable from a study of the outcrop, and further, if it is assumed that half of the "sandy clay" is sand, the sand makes up 50 per cent of the upper and middle Wilcox, which gives a thickness of sand of 375 feet.

Permeability.—The coefficient of permeability may be expressed as the quantity of water, in gallons a day, at 60° F., that is conducted laterally through each mile of the water-bearing bed under consideration (measured at right angles to the direction of flow) for each foot of thickness of the bed and for each foot per mile of hydraulic gradient.[8] The coefficient of permeability was determined in the laboratory on 48 samples collected throughout the outcrop area of the Wilcox group (see p. 100), and the average of these determinations was 514. The samples of sand probably included fine material containing clay which would not be classed by a driller as sand. As in any computation of quantity of water at Memphis the thickness of the water-yielding sand is involved and as such figures of thickness are derived from drillers'

[8] Stearns, N. D., Laboratory tests on physical properties of water-bearing materials: U. S. Geol. Survey Water-Supply Paper 596, p. 148, 1928.

logs, it is probable that the average figure for the coefficient of permeability given above is too low, for in it are included determinations of the coefficient of permeability of materials which would not be classed as sand by a driller and which have low coefficients. A better figure can be obtained by averaging the coefficients of samples obtained from wells 51 and 50 of the Memphis Artesian Water Department. Well 51 passes through the upper and middle Wilcox, and the method of sampling is described in connection with the physical properties of the upper and middle Wilcox (p. 105). The average coefficient of permeability of 3 samples from well 50 at depths between 285 and 343 feet and 12 samples from well 51 at depths below 390 feet is 875.

A field method for determining permeability is given by Thiem.[9] If the drawdown in two wells within the cone of influence of a pumping well and at different distances from the pumping well, the quantity of water being pumped, and the thickness of the formation are known, it is possible to determine the coefficient of permeability by the following formula:

$$P=\frac{g(\log_e a_1-\log_e a)}{2\pi m(s-s_1)}$$

in which

P = coefficient of permeability as defined by Meinzer,
g = quantity of water pumped, in gallons per 24 hours,
a = distance of near well from pumping well, in feet,
a_1 = distance of far well from pumping well, in feet,
s = drawdown in near well, in feet,
s_1 = drawdown in far well, in feet.

This method was applied in Memphis to wells 22, 23, and 24 of the Memphis Artesian Water Department. First, well 24 was pumped and the drawdown in wells 22 and 23 was measured; then well 22 was pumped and the drawdown in wells 23 and 24 was measured. The nearest pumping well was well 16 of the Memphis Artesian Water Department, 2,850 feet west of well 22. With an assumed thickness of 375 feet for the sand in the upper and middle Wilcox, the coefficient of permeability was determined as 148 when well 24 was pumped and 230 when well 22 was pumped.

The difference between the two results and the fact that both are in error due to drawdown caused by general city pumping can best be explained by considering a diagram of the conditions found in these wells during the tests. In Figure 18 AA' is the original pressure-measuring surface, but owing to general city pumpage this surface is lowered to some surface such as BB'. When well 24 was pumped this surface was further lowered to CC'. The correct drawdowns for use in Thiem's method, s and s_1 of the formula, were aa'' and bb''.

[9] Thiem, G., Hydrologische Methoden, pp. 6–12, Leipzig, 1906.

The values for s and s_1 actually determined were a' a'' and b' b'' less than the true values by the amounts aa' and bb', respectively.

The difference $s-s'$ was therefore too large, for it can be readily seen that the value b' b'' was different from the correct value bb' by a

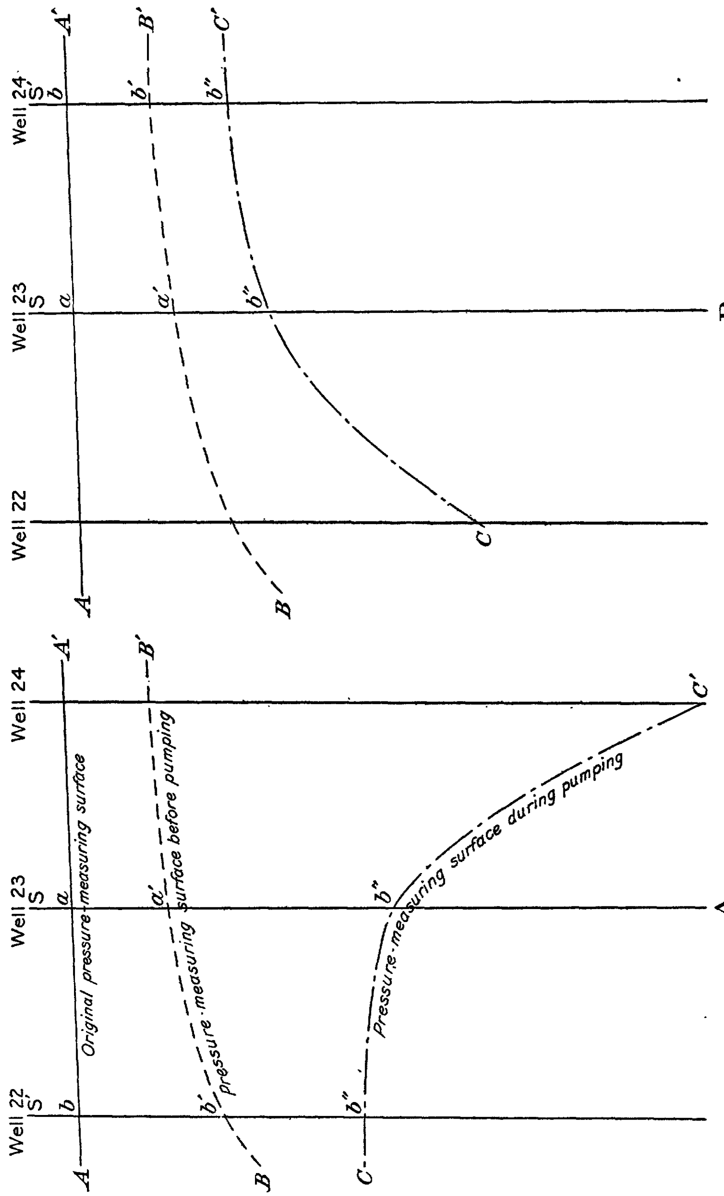

FIGURE 18.—Pressure-measuring surface in wells C-22, C-23, and C-24 (A) when well 24 was pumped; (B) when well 22 was pumped

greater amount than the value a' a'' was different from the correct value aa''. As the difference $s-s'$ is too large and as it goes into the denominator of the equation, the resulting value for the coefficient of permeability (*P*) was too small. Likewise, when well 22 was pumped the difference between the true drawdown and the measured drawdown *aa'* was greater than the difference between the true drawdown and the measured drawdown *bb'*; hence the value of $s-s'$ was too large and the values for *P* too small. This diffierence was not as great as when well 24 was pumped, however, for well 24 was less affected by. city pumping than well 22; consequently the error was not so large. This fact indicates that the city pumping introduced errors into the results, and as they are not in accord with all other evidence they may be rejected.

To summarize, the average coefficient of permeability as determined on 48 samples from the outcrop was 514; on 15 samples from wells passing through the upper and middle Wilcox at Memphis, 875. The writer is of the opinion that the result obtained from the well samples more nearly represents the actual coefficient of permeability of the upper and middle Wilcox at Memphis, but it should be used with caution, for it is always uncertain whether samples from a well are true samples free from contamination. The figure 514 is certainly a safe minimum for the coefficient of permeability, but it probably is much too low. If the total thickness of sand of the upper and middle Wilcox is used the quantity of water that will flow through each mile of cross section for each foot of head is 328,000 gallons a day.

Hydraulic gradient.—The small number of precise level lines in western Tennessee and the difficulty of obtaining access to wells has limited the determinations of the altitude of the water level. Unfortunately where such levels were most desired it was quite impossible to obtain them. The original water level at Memphis is not definitely known, and as it has been shown that the water level varies with the stages of the Mississippi River, it is impossible to arrive at any accurate determination of the original hydraulic gradient in Memphis. It was possible to determine the altitude of the static level at the deep well of Clarence Saunders (p. 252), near Brookfield, 4 miles east-southeast of well C–50, and at a deep well of the Louisville & Nashville Railroad at Arlington (p. 251), 19 miles northeast of well C–50. The water level in Mr. Saunders's well was 255.6 feet above sea level and that in the railroad well 270.8 feet above sea level. If 241 feet above sea level is taken as the altitude of the water level in well C–50, the hydraulic gradient is 3.9 feet to the mile toward the east and 1.6 feet to the mile toward the northeast. If 230 feet is taken as an average altitude for the static level at Court Street prior to the drilling of the first well and if 241 feet is the average altitude of the water level at well C–50 the hydraulic gradient between these points is 1.6 feet to the mile.

ACKERMAN FORMATION

The Memphis Artesian Water Department obtains part of its water from the Ackerman formation. Since 1925, when water was first pumped from the Ackerman, the total daily pumpage has increased from a few thousand gallons to an average of 6,145,000 gallons in 1930, and undoubtedly increasing quantities of water will be derived from this formation in the future. Unfortunately the original static level in the formation is not definitely known. After a complete cessation of pumping from February 14 to March 15, 1929, the static level at the Parkway station was 239 feet above mean sea level. After a shutdown of 44 days in the spring of 1930 the water level in well C–51 was 240.6 feet, and it had remained at this altitude for 6 days. It would seem that 239 feet is probably very close to the original static head in the Ackerman at the Parkway station.

For the 15 days just before February 14, 1929, 6,765,000 gallons a day was pumped from the Ackerman formation, and this average rate of pumping had been maintained for several months. The drawdown in well 27 was 27.4 feet. This gives a figure of 247,000 gallons for each foot of drawdown in well 27 with the present distribution of wells.

The average coefficient of permeability of six samples from the Ackerman formation (p. 91) is 802. Theim's method was applied on wells 5, 29, and 27 of the Memphis Artesian Water Department and gave a coefficient of permeability of 1,050. These two results are of the same general order of magnitude and are probably a close approximation to the true condition.

Very few data exist on which to base any estimates of the thickness of sand in the Ackerman formation. Well 25 of the Memphis Artesian Water Department, which passes through the Ackerman formation, shows 106 feet of sand; well 109, which stops in the Ackerman, shows 182 feet; and the well on the Overton lease, which probably traverses the complete thickness of the Ackerman, shows 268 feet. The average of these three is 164 feet. Many of the 1,400-foot wells of the Memphis Artesian Water Department show more than 100 feet of sand in the Ackerman, and as the sand occurs mostly in the top of the formation the average figure 164 feet is probably correct.

If the average thickness of sand in the Ackerman is taken as 164 feet and the coefficient or permeability as 800, 131,000 gallons of water a day flows through each mile of formation for each foot of head.

It has been shown that about 328,000 gallons of water flows through each mile of the upper and middle Wilcox for each foot of head. This is two and a half times the rate of flow through the Ackerman formation. The permeability of the upper and middle Wilcox and the Ackerman are about the same, 875 and 802, respectively, but the sand in the Wilcox is about three times as thick as the sand in the

Ackerman. The yield per foot of drawdown in well 11 of the Memphis Artesian Water Department, which ends in the upper and middle Wilcox, is 1,000,000 gallons a day, whereas the yield per foot of drawdown in well 27 of the Memphis Artesian Water Department, which draws water from the Ackerman, is 247,000 gallons a day. It is interesting to compare these yields with a similar result obtained at Atlantic City, N. J.,[9a] where the thickness of the water-bearing bed is 80 feet and the coefficient of permeability is practically 2,800. The yield per mile for each foot of drawdown is 224,000 gallons a day.

RELATION OF MISSISSIPPI RIVER TO WATER IN WILCOX GROUP

The fact that a relation exists between the stages of the Mississippi River and the static level in the Auction Avenue "wet well" was recognized many years ago. This relation has been discussed in the section on seasonal fluctuation of head in wells. There are two possible explanations of the relation: either the water in the Mississippi River has access to the Wilcox deposits and is in hydrostatic equilibrium with it, or else the increased weight of the river water at high stages compresses the underlying formations and thereby increases the water levels in the wells.[10] The nature of the Jackson formation, which consists predominantly of a tough clay (see pp. 106–107), and the fact that the original static level of the water in the upper Wilcox stood many feet above the level of the river seems to preclude the first explanation.

Though a study of the relation between river level, water level, and pumping does not yield conclusive evidence, a longer record may eventually do so. The drop in the static level in the Auction Avenue "wet well" often lags behind the drop in the river level. An example of this is seen on Plate 14. On December 27, 1927, the river started to fall, but the water level in the Auction Avenue "wet well" continued to rise until January 1, 1928, even though the pumpage was increasing. This may be explained as due to the fact that the flow from the river into the upper Wilcox continued after the river began to fall; or it may be explained as a lag in the elastic recovery of the Wilcox formations. The fact that at times the river level is much higher or much lower than the static level in the Auction Avenue "wet well" indicates that any connection that may exist must be very tortuous and of low permeability and small capacity.

Chester & Fleming found a relation between the distribution of the concentrations of alkalinity of water from the upper Wilcox and the Mississippi River. Their map of areas of equal alkalinity (pl. 13) shows that these areas have a relation to the Wolf River and Nonconnah Creek as well as to the Mississippi River. The minimum

[9a] Thompson, D. G., Ground-water supplies of the Atlantic City region: New Jersey Dept. Conservation and Development Bull. 30, p. 93, 1928.

[10] Meinzer, O. E., Compressibility and elasticity of artesian aquifers: Econ. Geology, vol. 22, pp. 263–291, 1928.

alkalinity corresponds to the average of 60 parts per million for the waters of the upper Wilcox. The maximum is 110 parts per million. The average alkalinity of the Mississippi River water is 129 parts per million, and the alkalinity for the late winter and spring, when the river is high, is 100 parts per million.

In order to verify the conclusions of Chester & Fleming samples for partial analyses were collected from wells throughout Memphis in the summer of 1918 and again in August, 1930. A discussion of the results is given on page 285. The conclusion was reached that though water of high bicarbonate content had gained access to the Wilcox formations it could not be definitely proved that such flow had not taken place through old leaky wells. The consistent higher bicarbonate content of water from all wells adjacent to the river indicated, however, that a small quantity of water from the Mississippi River had entered the upper Wilcox.

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