STATE OF ARKANSAS
Arkansas Geological and Conservation Commission
Norman F. Williams, Geologist-Director

WATER RESOURCES CIRCULAR NO. 8

FRESH-WATER AQUIFERS OF CRITTENDEN COUNTY, ARKANSAS

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U. S. Geological Survey

Prepared by the U. S. Geological Survey in cooperation with the
Arkansas Geological and Conservation Commission

1961

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CONTENTS

	Page
Summary	1
Introduction	3
Acknowledgments	3
Well-numbering system	3
Geography	4
Climate	4
Ground water	4
Occurrence of ground water	4
Permeability of water-bearing materials	5
Recharge, movement, and discharge of ground water	5
Principles of recovery of ground water by wells	5
Chemical quality of ground water	5
Chemical constituents in relation to use	5
Silica	6
Iron	6
Calcium-Magnesium	6
Sodium-Potassium	7
Alkalinity	7
Sulfate	7
Chloride	7
Fluoride	8
Nitrogen	8
Dissolved solids	9
Hardness	9
Specific conductance	10
Hydrogen-ion concentration (pH)	10
Types of water	11
Geology	11
Regional structural relationships	11
Generalized stratigraphy	11
Tertiary system	11
Paleocene series	11
Midway group	11
Eocene series	20
Wilcox group	20
Claiborne group	21
Jackson group	21

CONTENTS—Continued

Page

Quaternary system 21
Faulting 21
Fresh-water aquifers 22
"1,400-foot" sand 22
Areal extent 22
Lithology 22
Thickness 25
Pumpage 25
Water levels 25
Aquifer tests 25
Quality of water 25
Recharge 26
Possibilities for further development 26
Sands of the Claiborne group 26
Areal extent 26
Lithology 26
Pumpage 26
Water levels 27
Aquifer tests 27
Quality of water 27
Possibilities for further development 28
Deposits of Quaternary age 28
Areal extent and lithology 28
Pumpage 28
Water levels 28
Aquifer tests 38
Quality of water 38
Recharge 42
Possibilities for further development 42
Logs of wells 42
Selected references 48

ILLUSTRATIONS

Page

Figure 1. Map of Arkansas showing areas of ground-water investigation 2

2. Sketch illustrating well-location number 3

3. Map showing Crowley's Ridge and the major streams in part of northeastern Arkansas 4

4. Map showing the Mississippi Embayment and the Fall Line . 11

5. Map showing locations of cross sections based on electric logs 12

6. Cross section A-A′ 13

7. Cross section B-B′ 15

8. Cross section C-C′ 17

9. Cross section of DeMange No. 1-Alpe No. 1-Bond No. 1 . . 19

10. Map of Crittenden County showing well locations 23

11. Map showing the thickness of the surficial clay in Crittenden County 28

12. Map of Crittenden County showing depth to water and the water table in Quaternary deposits, December 1957 . . 29

13. Map of Crittenden County showing depth to water and the water table in Quaternary deposits, March 1958 . . . 31

14. Map of Crittenden County showing depth to water and the water table in Quaternary deposits, June 1958 33

15. Map of Crittenden County showing depth to water and the water table in Quaternary deposits, October 1958 . . 35

16. Hydrograph of well 100 in deposits of Quaternary age . . 39

17. Variation of total iron content with well depth in water from deposits of Quaternary age 40

18. Variation of total hardness with well depth in deposits of Quaternary age 40

19. Soils map of Crittenden County 41

TABLES

Table 1. Generalized geologic section of rocks of Cenozoic age in Crittenden County, Ark. 20

2. Record of wells in Crittenden County, Ark. 49

3. Chemical analyses of water from wells 54

4. Water levels in wells tapping Quaternary deposits 56

5. Partial chemical analyses of water from 6 selected wells tapping deposits of Quaternary age 65

FRESH-WATER AQUIFERS OF CRITTENDEN COUNTY, ARKANSAS

By Raymond O. Plebuch

Summary

Ground water is unquestionably the most important natural resource in Crittenden County, Ark. The total pumpage from all aquifers is estimated to be 9.6 billion gallons per year, and almost 90 percent of this amount is used for irrigation.

Ground water is pumped from wells that are screened in the water-bearing materials of various rock units. The three major aquifers are present throughout the entire county: (1) the "1,400-foot" sand of the Wilcox group (early Eocene); (2) the sands of the Claiborne group (middle Eocene); and (3) the deposits of Quaternary age. The Quaternary deposits yield the most water; about 90 percent of all ground water, approximately 8.7 billion gallons per year, is obtained from this aquifer. About 99 percent of this water is used for irrigation purposes during a 5-month period extending from May to September. Rice irrigation alone accounts for about 6.5 billion gallons per year. The "1,400-foot" sand of the Wilcox group is the second most important source of water. All municipal supplies in the county utilize this aquifer, and pumpage totals about 2.5 mgd (million gallons per day). The sands of the Claiborne group, which constitute the third major aquifer, are relatively undeveloped in Crittenden County, and pumpage from this unit is negligible.

Four cross sections show electric logs of oil-test wells with the thickness and depth below land surface of the different rock units.

The rocks of Cenozoic age underlying Crittenden County, in order from older to younger, are the Midway group, the Wilcox group, the Claiborne group, possibly the Jackson group (late Eocene), and the Quaternary deposits. These rocks of Cenozoic age are underlain by rocks of Late Cretaceous age and older. The geology and water-bearing character of these units is summarized in a table.

The "1,400-foot" sand yields soft water of good quality at a temperature of 73 to 77°F. The only undesirable constituents are iron and free carbon dioxide, which can be readily removed by aeration and filtration. Water from the sands of the Claiborne group is more mineralized and has a temperature of about 64°F. Like the "1,400-foot" sand, this aquifer also yields water that is high in iron and free carbon dioxide content. The Quaternary deposits yield highly mineralized water that is generally high in iron content and very hard, although the iron content and hardness may vary considerably at different points, both laterally and vertically, in the aquifer. The average temperature of the water from the Quaternary deposits is about 62°F.

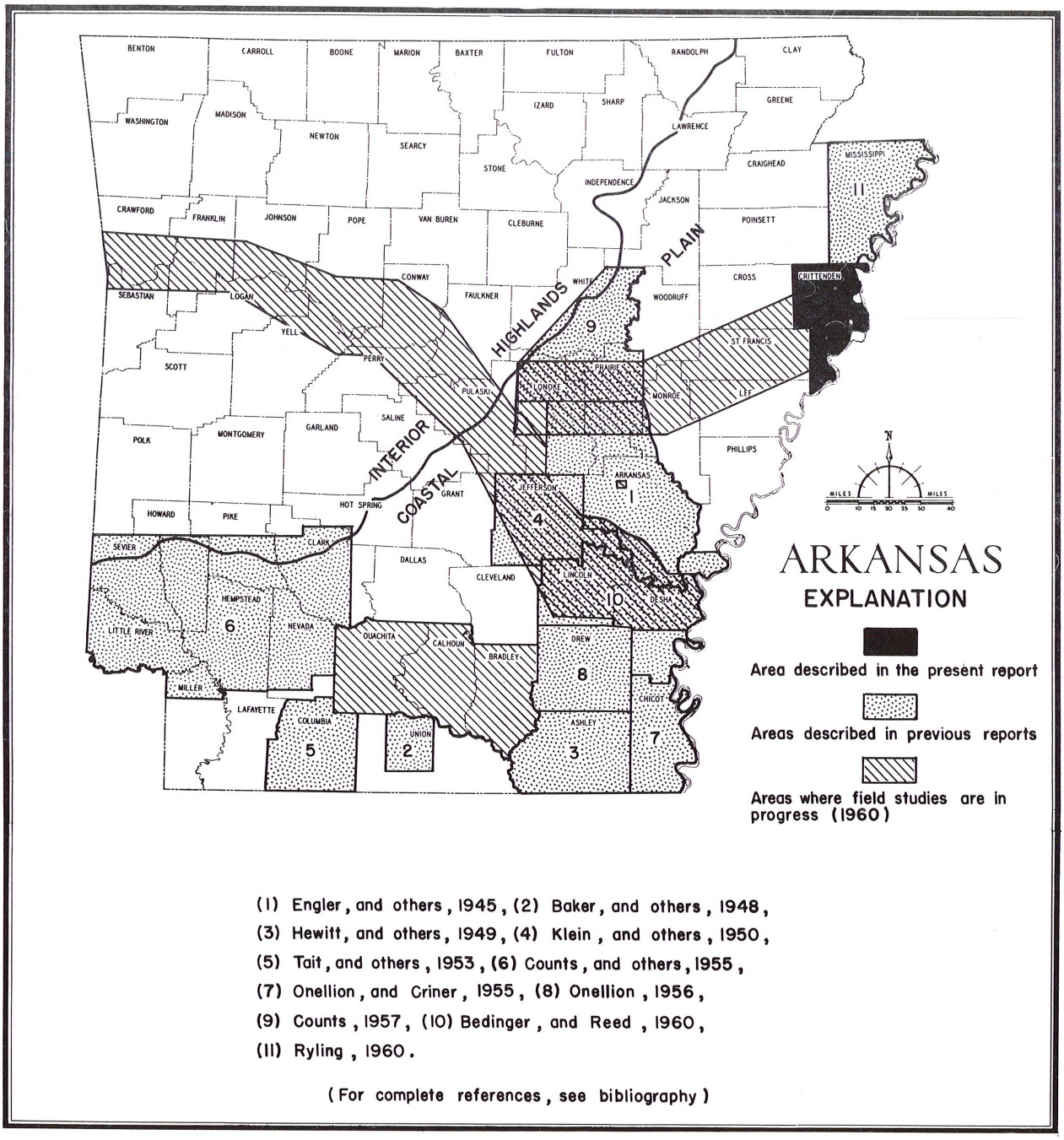
Yields up to 2,000 gpm (gallons per minute) are obtainable from wells screened in the "1,400-foot" sand. The coefficient of transmissibility of the sands of the Claiborne group at nearby Memphis, Tenn., ranges from 100,000 to 420,000 gpd/ft (gallons per day per foot), suggesting that wells with capacities of 1,000 gpm or more can be developed. Well yields in the Quaternary deposits range from a few gpm to a reported 3,200 gpm.

When the "1,400-foot" sand was first penetrated in Crittenden County, wells generally flowed. Water levels now, however, range from 11 to 22 feet below land surface. The greatest decline has occurred in the West Memphis area.

Water levels in wells tapping the sands of the Claiborne group range from about 18 feet below land surface at Turrell to 48 feet below land surface at West Memphis. The static level has declined about 6 feet at Turrell since the early 1900's and about 28 feet at West Memphis since 1934.

Water levels in the Quaternary deposits range from 3 to 26 feet below land surface, and there is no evidence of any general decline of water levels in these deposits in the county. The direction of ground-water movement in the Quaternary deposits is to the south-west under an average hydraulic gradient of 1.7 feet per mile.

The utilization of ground water from the "1,400-foot" sand and the Quaternary deposits can be increased considerably throughout Crittenden County. The sands of the Claiborne group are relatively undeveloped in the county and are an important potential source of additional ground water.



(1) Engler, and others, 1945, (2) Baker, and others, 1948,
(3) Hewitt, and others, 1949, (4) Klein, and others, 1950,
(5) Tait, and others, 1953, (6) Counts, and others, 1955,
(7) Onellion, and Criner, 1955, (8) Onellion, 1956,
(9) Counts, 1957, (10) Bedinger, and Reed, 1960,
(11) Ryling, 1960.

(For complete references, see bibliography)

Figure 1. Map of Arkansas showing areas of ground-water investigation.

INTRODUCTION

This is one of a series of reports on the ground-water resources of Arkansas made under a program of investigations by the U. S. Geological Survey in cooperation with the Arkansas Geological and Conservation Commission. The program has been in progress since 1946.

The areas in Arkansas that have been covered by ground-water studies or where studies are now in progress are shown in Figure 1.

The purpose of this report is to describe the occurrence, availability, movement, recharge, discharge, and chemical quality of the ground water in Crittenden County where there has been a steady increase in the use of ground water for irrigation since the early 1950's. Data in the report can be utilized by municipalities, well drillers, farmers, industries, and others who wish to drill wells to help them predict at any given location, the depth to water, the character of the materials that the drill will penetrate, the chemical quality of the water, and the quantity of water available. In short, its purpose is to present information about the ground-water resources in such a way as to aid the citizens of the area in developing the ground-water reservoirs in the most economical manner.

Earlier reports dealing with ground water in this area were prepared by Veatch (1906) and by Stephenson and Crider (1916).

The investigation on which this report is based was begun in August 1957, and field work continued until the fall of 1959. A complete inventory of irrigation, public supply, industrial, and deep domestic wells was made and samples of water from selected wells were collected for chemical analyses. The chemical analyses were made by the Quality of Water Branch, U. S. Geological Survey, Fayetteville, Ark.

ACKNOWLEDGMENTS

The writer is grateful for the help and cooperation received from many people during the course of this investigation, including well owners, drillers, municipal officials, and representatives of various other government agencies both Federal and State.

Well-numbering system

Each well mentioned in this report has been given a location number which is based on the location of the well as assigned by the Federal land-survey system in Arkansas. The component parts of a location number are the township number, the range number, the section number, and three lower-case letters which indicate respectively, the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section in which the well is located. Suffix numbers may be appended following the three lower-case letters when two or more wells are located in the same quarter-quarter-quarter section.

This system of numbering wells with reference to location is illustrated in figure 2.

Map numbers were also assigned to each well as it was listed in table 2. The regular location number would be hard to read on the maps, especially where there are a large number of wells in a small area. The shorter map number also facilitates cross-referencing between text, maps, and illustrations.

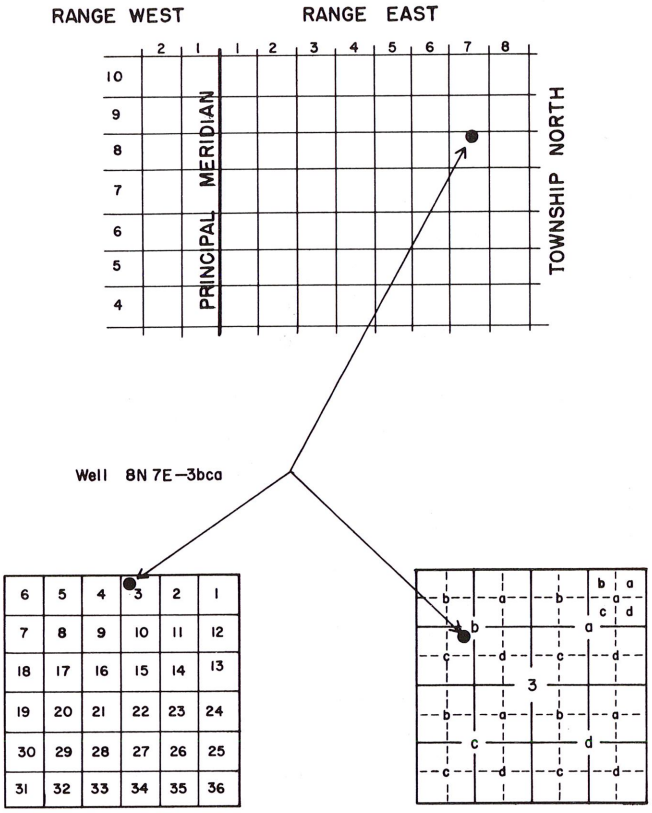


Figure 2. Sketch illustrating well numbering system.

Geography

Crittenden County includes about 648 square miles in northeastern Arkansansas (fig. 1). It is on the alluvial plain of the Mississippi River, and it lies in the north-central part of the Gulf Coastal Plain physiographic province. It is bounded on the east and south by the Mississippi River, on the north by Poinsett and Mississippi Counties, and on the west by Cross, St. Francis, and Lee Counties.

The land surface has a slight general slope to the west and southwest. The highest elevation is about 236 feet above sea level immediately west of the Mississippi River, and the lowest elevation is about 195 feet in the southwestern part of the county.

Flood-plain and old meander-belt topography characterizes the land surface, which is generally flat to slightly undulating with numerous ponds, abandoned stream channels, and bayous. At one time much of the surface was swampy and heavily forested, but most of the swamps have been drained by means of an intricate network of drainage ditches. A considerable amount of timber still remains in some areas, but it is being rapidly cleared.

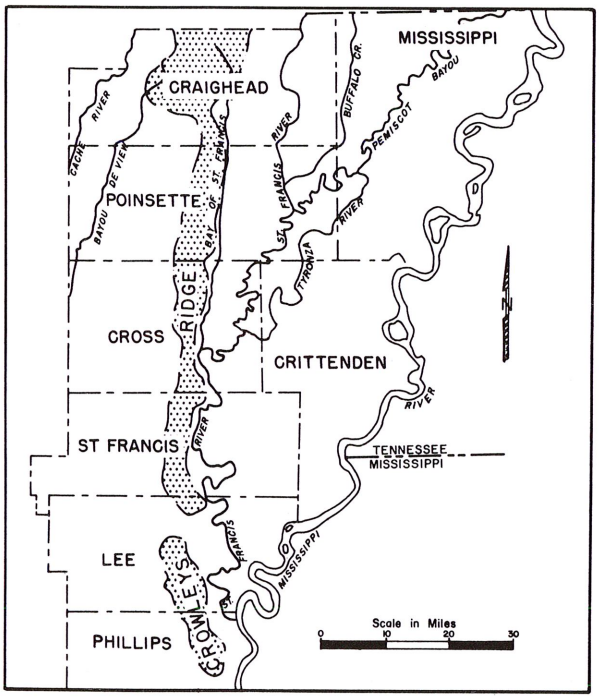


Figure 3. Map showing Crowleys Ridge and the major streams in part of northern Arkansas.

The drainage system of the county (fig. 3), consists of the Mississippi River, which flows along its eastern side; the Tyronza River, which flows roughly south-southwest through the northwestern corner of the county; and numerous bayous flowing in a southwesterly direction. Horseshoe Lake, a prominent oxbow lake, is located in the extreme southern tip of the county.

Climate

The climate in Crittenden County is relatively mild, and rainfall is generally abundant. The average annual temperature is 62°, and rainfall averages 50 to 55 inches per year. Winters are commonly short and mild, but have occasional subfreezing periods of a few day's duration. Summers are long and hot, and temperatures in the high 90's are common during July and August.

Generally, the rainfall is well distributed over the year, but in any given year large deficiencies or excesses may occur.

Ground water

Occurrence of ground water

A brief discussion of the principles of occurrence of ground water is given in this report. The reader is referred to Meinzer (1923, p. 2-102) for a more detailed treatment of the subject.

The crust of the earth is composed of rocks that generally contain numerous voids and interstices. It is in these open spaces that the water below ground surface is stored and from which water is furnished to springs and wells. The porosity, the percentage of the volume of the pore spaces as compared to the total volume of the rock mass, governs the amount of water that can be stored in any rock. Although the porosity of the rock is important, the permeability determines the ability of the strata to yield water to wells and springs. The permeability is determined by the size, shape, and arrangement of the openings in a rock. For example, a bed of silt or clay may have a high porosity or water-holding capacity, but because of the small size of the openings and the adherence of the water to the grains of material, the permeability or water-yielding capacity may be low. Conversely, well-sorted sand or gravel containing relatively large and interconnected openings transmits water freely.

If water-bearing beds are confined between relatively impermeable strata, such as silt or clay, the water within the aquifer may be under artesian pressure, and it will rise in wells above

the level at which the well penetrated the aquifer. If the altitude to which the water will rise in the well is greater than the altitude of the land surface, the well will flow.

The top of the zone of saturation in unconfined deposits (below which all pore spaces are completely filled with water) is called the water table.

Permeability of water-bearing materials

The rate of movement of ground water is determined by the size, shape, quantity, and degree of interconnection of the interstices and by the hydraulic gradient. The capacity of a water-bearing material for transmitting water under hydraulic head is known as its permeability. The field coefficient of permeability is defined by Wenzel (1942, p. 7) as the number of gallons of water a day that moves under prevailing conditions through each mile of water-bearing bed (measured at right angles to the flow) for each foot of thickness of the bed and for each foot per mile of gradient.

Theis (1935) introduced the term "coefficient of transmissibility" (T) which is expressed as the rate of flow of water in gallons per day at the prevailing water temperature through a vertical strip of the aquifer 1 foot wide, extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent (1-foot drop in head in 1 foot of flow distance). It is the field coefficient of permeability multiplied by the saturated thickness of the aquifer.

The coefficient of storage (S) of an aquifer is defined as the volume of water the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Recharge, movement, and discharge of ground water

Ground water is derived from the precipitation that falls on the land surface of the earth. A part of the precipitation runs off into streams, a part is returned to the atmosphere by evaporation and transpiration from vegetation, and a part infiltrates to the zone of saturation after soil moisture has reached field capacity. In the zone of saturation, ground water slowly but steadily moves under the influence of gravity from areas of recharge to areas of discharge. In the more permeable rocks, the water moves with comparative freedom, although the movement is very slow, generally in the magnitude of a few feet per year.

If some part of the water-bearing bed is exposed at the surface or comes in contact with a stream, lake, or another aquifer, the water discharged naturally or through wells can be replenished. If the aquifer is more or less completely enclosed by clay or other relatively impermeable materials, natural recharge will be slow, and the water taken from storage may not be completely replenished, resulting in a decline in water levels and a decrease in yields.

Principles of recovery of ground water by wells

When water is withdrawn from a well, the water level in the vicinity of the well declines and assumes a form similar to an inverted cone. This is called the "cone of depression." As pumping time increases, the decline in water level extends to greater and greater distances away from the pumped well so that water levels may be lowered in wells from several hundred feet to a mile or more from the pumped well. This process continues until an equilibrium is reached between the amount of water being pumped out of the well and the amount of water flowing into the well. It is not uncommon in the Coastal Plain of Arkansas for shallow wells in the vicinity of irrigation wells to "go dry" during periods of prolonged pumping of the irrigation wells. In such cases, the water level is either lowered below the bottom of the well or to such a distance below the surface that suction pumps are incapable of lifting the water to the surface.

Chemical quality of ground water

Chemical constituents in relation to use.— Chemical substances which may be present in natural waters preferably should not occur in excess of certain concentrations if the water is to be used for drinking and culinary purposes. The limits commonly quoted in the United States for drinking water are based on the U. S. Public Health Service standards for drinking and culinary water supplied by interstate carriers. These have been revised several times, and those in current use date from 1946 (U. S. Public Health Service, 1946). According to these standards, the following substances should not be present in excess of the concentrations shown:

	Ppm (parts per million)
Iron and manganese (together)	0.3
Magnesium	125
Chloride	250
Sulfate	250
Fluoride	1.5
Total dissolved solids (good quality)	500
(Where no better water available)	1,000

The list as presented above is not complete but includes only those constituents listed in table 4.

The following general information on the chemical constituents and properties of ground water is taken directly or adapted from U. S. Geological Survey Water-Supply Paper 1454 by Rainwater and Thatcher (1960).

Silica.—Silicon is the most abundant element in igneous rocks and some other types of deposits. Most silica in water is probably derived from the decomposition or metamorphism of silicate minerals rather than from solution of quartz, as quartz is one of the most resistant rock minerals to attack by water. Many waters contain less than 10 ppm of silica; those that drain deposits high in silicate minerals, particularly feldspars, often contain up to 60 ppm; concentrations exceeding 100 ppm are not commonly found. The chemistry of silica in solution is not known with certainty. It is believed that most silica is present in a nonionized form, but ionized silicate(s) is undoubtedly present in some waters.

Silica is not physiologically significant to humans, livestock, or fishes, nor is it of importance in irrigation water.

Most industrial processes tolerate silica in the range normally found, but it is particularly undesirable in boiler feed water. A recommended upper limit for boilers operating at 400 psi or above, is 1 ppm. Silica forms a hard coating on steam-turbine blades, and a limiting concentration of 0.1 ppm in the steam has been recommended.

Iron.—Iron is one of the most abundant minerals in the earth's crust. It occurs in the dark-colored silicate minerals of igneous rocks and as sulfides and oxides. In sandstone, iron oxide and iron hydroxide are often present as cementing materials. Iron is also present as oxides and sulfides in shale. Some of the common humic complexes causing color in water may also be iron bearing.

Because iron is readily precipitated as the hydroxide, it seldom is one of the major constituents in water. The metal occurs in water in both the ferrous and ferric state. Ferrous iron is unstable in solution in the presence of oxygen.

$$2Fe^{+2}+4HCO_3^{-1}+H_2O+\tfrac{1}{2}O_2 \rightarrow 2Fe(OH)_3+4CO_2$$

If the sample is subjected to a strong reducing environment the reaction is reversed, and the solution may contain large quantities of ferrous iron. In the 6-8 pH range the amount of ferric iron in true solution is theoretically limited to the solubility of ferric hydroxide, about $4x10^{-10}$ ppm to $5x10^{-6}$. At lower pH values, the solubility is greatly increased. Most of the ferric iron in apparent solution in alkaline water is believed to be principally in the colloidal form.

Iron in concentrations much greater than 0.20 ppm is objectionable in waters for public supply. The U. S. Public Health Service (1946) recommends that the sum of iron and manganese in drinking and culinary water on carriers subject to Federal quarantine regulations not exceed 0.3 ppm. These limits are not based on toxicity but on esthetic and taste considerations. Iron tends to stain laundry and porcelain, and it also can be tasted in concentrations higher than about 0.5-1.0 ppm. Livestock is sensitive to the taste of iron and may not drink water with a high iron content. Ninety-five percent of the waters that support good fish fauna in the United States have 0.7 ppm or less of iron.

Industries' tolerance for iron varies, but concentrations exceeding 1-2 ppm are generally not satisfactory. It has been established that iron in irrigation water is of no practical significance to plant growth or soil texture.

Calcium.—Calcium is dissolved from practically all rocks but is usually found in greater quantities in waters leaching deposits of limestone, dolomite, gypsum, or gypsiferous shale. Waters associated with granite or silicious sand may contain less than 10 ppm of calcium. Many waters from limestone areas contain 30 to 100 ppm, and waters that traverse gypsiferous shale may contain several hundred ppm.

Calcium imparts the property of hardness to water and when present with alkalinity or sulfate may cause boiler scale. A high ratio of calcium to sodium is desirable in water used for irrigation because calcium flocculates the soil colloids and tends to maintain good soil structure and permeability.

Magnesium.—Magnesium is relatively abundant in the earth's crust. Ferromagnesian minerals in igneous rocks and magnesium carbonate in carbonate rocks are generally considered to be the principal sources of magnesium in natural waters. Carbon dioxide plays an important role in the solution of magnesium from both silicate and carbonate minerals. Water associated with granite and siliceous sand may contain less than 5 ppm of magnesium, but water from dolomite or limestone rich in magnesium may contain 10-50 ppm. Sulfates and chlorides of magnesium are very soluble, and water in contact with such deposits may contain several hundred parts per million. Magnesium is widely used in industry,

and industrial wastes may add appreciable quantities to streams and ground water.

Salts of magnesium act as cathartics and diuretics; the U. S. Public Health Service (1946) recommends that magnesium should not exceed 125 ppm in drinking and culinary water on carriers subject to Federal quarantine regulations.

Magnesium imparts the property of hardness to water and is therefore of concern to industrial users of water. Magnesium acts similarly to calcium in that it flocculates soil colloids and tends to maintain good soil structure and permeability, hence it compliments calcium in consideration of sodium ratios in irrigation water.

Sodium.—Sodium salts are very soluble, and most sodium leached from the soil or rocks tends to remain in solution. The use of sodium salts is common in industry, and industrial waste may contain large quantities of the element.

Sodium is not particularly significant in drinking and culinary water except for those persons having an abnormal sodium metabolism; the water supply in some areas contains sufficient sodium to be a factor in the planning of sodium-free diets. It has been established that more than 50 ppm of sodium plus potassium in boiler water causes foaming. For high-pressure boiler feed water a limiting concentration of 2-3 ppm has been recommended. Water with a high ratio of sodium to calcium plus magnesium is deleterious to soil structure. Sodium tends to disperse the soil colloids with the resultant loss of good tilth and permeability.

Potassium.—Although potassium is relatively abundant in the earth's crust, the potassium content in natural waters is usually small. Potassium occurs in rocks in a form that is not easily brought into solution. Also, several geochemical processes tend to remove potassium selectively and return it to the solid phase. Most waters contain less than 20 ppm potassium, although several hundred parts per million are occasionally found.

Potassium is essential to animal nutrition, but a concentration of 1,000 to 2,000 ppm in drinking water is regarded as the extreme limit. Potassium in water causes foaming, as does sodium, but apparently it is not otherwise significant in industrial water supplies. Potassium stimulates plankton growth and is reported to be somewhat more toxic to fish and shellfish than is calcium, magnesium, or sodium.

Alkalinity.—Alkalinity is the capacity of a water containing a compound or compounds, with or without hydrolisis, for neutralizing strong acid to pH 4.5. The determination of alkalinity is a measure of the excess basic constituents over the amount necessary to balance the strong acid constituents. Alkalinity in water is caused primarily by the presence of bicarbonates, carbonates, and hydroxides. The relative concentrations of hydroxide, carbonate, and bicarbonate are a function of the temperature, pH, and concentration of other dissolved solids.

Because the alkalinity of many waters is primarily a function of the carbonate, bicarbonate, and(or) hydroxide content, the alkalinity determination is sometimes taken as an indication of the concentration of these constituents. Such values are maximums and include titratable weak acid radicals.

Carbonates and bicarbonates are common to most waters because of the abundance of carbonate minerals in nature and because carbon dioxide, which helps dissolve them and other minerals, is readily available. Direct contribution to alkalinity by hydroxides is rare in nature, and the presence of hydroxides can usually be attributed to water treatment or to contamination.

The alkalinity, in equivalents per million (epm), in excess of the alkaline earths has a bearing on the suitability of a water for irrigation. If this excess alkalinity, termed "residual sodium carbonate," exceeds 2.5 epm the water is generally not suitable for irrigation; water containing 1.25 to 2.5 epm is marginal, and that containing less than 1.25 epm is probably safe.

Sulfate.—Sulfate is dissolved from most sedimentary rocks. Large quantities may be derived from beds of gypsum, sodium sulfate deposits, and some types of shale. Water from mines may be high in sulfate as a result of oxidation of pyrite. Organic material containing sulfur adds sulfate to the water as a phase of the sulfur cycle. Sulfate is discharged in many industrial waste products. In natural waters, concentrations range from a few parts per million to several thousand parts per million.

The U. S. Public Health Service (1946) recommends that the sulfate concentration not exceed 250 ppm in drinking and culinary water on carriers subject to Federal quarantine regulations.

The sulfate content of water is not very critical in many industrial processes. The significance is also somewhat dependent on the character of the cations (positive ions). It is less toxic than chloride to crops.

Chloride.—Most naturally occurring chlorides are very soluble. Chloride concentration in natural waters ranges widely from less than 1 ppm

in some waters to many thousand ppm in some brine. Chloride is the major anion (negative ion) in most brines of the United States. The discharge of some industrial wastes into streams or ground-water reservoirs may considerably increase their chloride content. Human and animal excreta are high in chloride and nitrogenous material. In water supplies, the presence of abnormal concentrations of the two together is indicative of possible pollution by human or animal wastes.

A high concentration of chloride imparts a salty taste to the water but the threshold of detection varies with individuals. Although for drinking purposes, water with a chloride content of 1,000 ppm may be physiologically safe, the U. S. Public Health Service (1946) recommends that the concentration not exceed 250 ppm in water on carriers subject to Federal quarantine regulations.

Chlorides may cause and accelerate corrosion in pipes, boilers, and other fixtures. Magnesium chloride when heated releases hydrochloric acid which is highly corrosive. Many crops may be injured by waters containing excessive quantities of chloride. Chloride is generally about twice as toxic to crops as sulfate.

Fluoride.—Unlike chlorides, fluorides are only sparingly soluble and are present in most natural waters in only small amounts. Calcium fluoride (fluorite) is the principal source of fluoride, but there are some other complex fluoride-bearing minerals. The element is often characteristic of waters from deep strata and is frequently found in salt water from oil wells and in water from areas that have been subjected to recent vulcanism. Fluorides are used as insecticides, disinfectants, preservatives, and for a few other purposes in industry. They are seldom found in large quantities in industrial wastes, except as the result of spillage.

Pathological changes in man attributable to fluoride absorption are in the nature of ostosis. Large quantities of fluoride are toxic. It has been reported that daily intakes of about 15-20 mg of fluoride over a period of several years are required to induce chronic fluorosis in an adult man. Excessive quantities in drinking water during calcification may cause discoloration in the teeth of children; adults are not affected. Available evidence indicates that water containing less than 1.0-0.9 ppm of fluoride seldom causes mottling of children's teeth, and the literature describing the beneficial effect of 0.88-1.5 ppm in drinking water as an aid in the reduction of tooth decay in children is abundant. The U. S. Public Health Service (1946) states that the concentration of fluoride shall not exceed 1.5 ppm in drinking and culinary water on carriers subject to Federal quarantine regulations.

Manufacturers of products for internal consumption generally limit the fluoride content of water to about 1.0 ppm. In normal concentrations it is not significant in irrigation; it is generally concluded that the fluoride content of irrigation water has no consistent influence on the fluoride content of plants. The effect of fluoride on livestock is similar to that on humans.

Nitrogen.—Nitrogen makes up about 78 percent by volume of normal air at 20°C, and therefore water in equilibrium with air will contain about 15.6 ppm of dissolved nitrogen gas. Gaseous nitrogen is inert and not important in water chemistry, but the combined forms of nitrogen are. Although ammonia, nitrite, and nitrate are highly soluble, natural waters contain only small quantities, usually less than 10 ppm. Legumes take nitrogen from the atmosphere and fix it in the soil as nitrate. Most plant, animal, and bacterial life require nitrogen, and this nitrogen is constantly being converted from one form to another by tissue synthesis, metabolism, and decomposition. Bacteria are very important in converting the forms of nitrogen because some obtain their energy for life from these chemical reactions.

Both organic and inorganic nitrogen in water may result from the leaching of soils and rocks, from fertilizers, normal decomposition of plants and animals, sewage, industrial effluents, and living organisms.

Ammonia nitrogen includes nitrogen in the form of NH_3 and NH_4^{+1}. As a component of the nitrogen cycle, it is often present in water from natural causes, but usually only in small amounts. Ammonia is used in some water-treatment processes. More than 0.1 ppm usually indicates organic pollution.

There is no evidence that ammonia nitrogen in water is physiologically significant to man or livestock. Fish, however, cannot tolerate large quantities. The toxicity to fish is directly related to the amount of dissociated ammonia in solution; hence the toxicity is dependent on the pH of the water. Ammonia decreases the ability of hemoglobin to combine with oxygen, and the fish suffocate. Although the tolerances of fish differ, 2.5 ppm of ammonia nitrogen is considered harmful in the 7.4-8.5 pH range.

The low concentrations of ammonia in natural waters are of little industrial significance, except

that ammonium salts are destructive to concrete made from Portland cement.

Nitrate is usually the most prevalent form of nitrogen in water because it is the end product of the aerobic decomposition of organic nitrogen. Nitrate from natural sources is attributed to the oxidation of nitrogen of the air by bacteria and to the decomposition of organic material in the soil. Fertilizers may add nitrate directly to water resources. Nitrate concentrations range from a few tenths to several hundred parts per million, but in unpolluted water seldom exceed 10 ppm. Nitrate and chloride are major components of human and animal wastes, and the occurrence of abnormally high concentrations of both constituents suggests possible pollution of the water resources.

Cyanosis due to methemoglobinemia may occur in infants whose drinking or formula water contains a high concentration of nitrates. The nitrates, when ingested, are converted to nitrites in the digestive system of some infants. The nitrite ion oxidizes hemoglobin to methemoglobin and hereby causes cyanosis. It is widely recommended that water containing more than 10-20 ppm of nitrate, expressed as nitrogen, should not be used in infant feeding.

Nitrates in large amounts are injurious to the dyeing of wool and silk and are undesirable in fermentation processes. At least 2 ppm of nitrate prevents intercrystalline cracking of steel in steam boilers.

Dissolved solids.—Theoretically, dissolved solids are the anhydrous residues of the dissolved substances in water. Note that dissolved solid is not a measure of the total weight of dissolved materials as they occur in solution. Neither are dissolved gases of volatile liquids a part of the dissolved solids. In reality, the term "dissolved solids" is defined by the method used in the determination.

All salts in solution affect the chemical and physical properties of the water and exert osmotic pressure. Water with several thousand parts per million of dissolved solids is generally not palatable, although those accustomed to highly mineralized water may complain that less concentrated water tastes flat. A change in the source of drinking water more often may cause gastric disturbances than the concentration of dissolved solids in the water itself. The U.S. Public Health Service (1946) recommends that the maximum concentration of dissolved solids not exceed 500 ppm in drinking and culinary water on carriers subject to Federal quarantine regulations but permits 1,000 ppm if no better water is available. Reports of livestock tolerances are extremely variable and range from 3,000 to 15,000 ppm.

Industrial tolerances for dissolved solids differ widely, but few industrial processes will permit more than 1,000 ppm. Salinity hazard is an important consideration for irrigation water. The water-uptake relations of plants are controlled by the osmotic-pressure differential between soil solution and the plant solution. A plant cannot draw as much water from a concentrated soil solution as from a dilute soil solution. For most waters that could be considered for irrigation, the following general relation is applicable:

Specific conductance X 0.65 ± 0.1 = dissolved solids. The U. S. Salinity Laboratory staff classifies the salinity hazard of irrigation waters, in terms of specific conductance, as follows: Less than 250 micromhos, low; 250-750 micromhos, medium; 750-2,250 micromhos, high; and greater than 2,250 micromhos, very high. However, the satisfactory use of a particular water for irrigation depends on many factors other than water quality, such as soil characteristics, drainage, irrigation practices, and crops grown.

Hardness.—Hardness of water is the property attributable to the presence of alkaline earths. Calcium and magnesium are the principal alkaline earths in natural waters, whereas strontium and barium are usually present only in small quantities.

Hardness of water results from the solution of alkaline-earth minerals from the soil and rocks, or the minerals may enter from direct pollution by wastes. Calcium and magnesium carbonates (limestone and dolomite) are prevalent in the earth's crust but are only sparingly soluble in pure water. Water that contains carbon dioxide or other acidic constituents readily dissolves carbonate minerals; in the presence of carbon dioxide the carbonates are converted to the more soluble bicarbonates. Many waters with a hardness of less than 200-300 ppm may derive practically all of their alkaline earths from carbonate rocks. Gypsiferous shale and evaporites often contain large quantities of more soluble sulfates and chlorides of calcium and magnesium, and waters that traverse these deposits may have a hardness of several hundred parts per million or more.

Hard water is not generally believed to have harmful effects on man, although the relation to urinary concretions is controversial. Hard water decreases the sensitivity of fish to toxic metals,

but experiments with calves and chicks have indicated that those supplied with hard water develop somewhat better than those supplied with distilled water.

Hardness in conjunction with other chemical properties is an indication of the soap-consuming power of the water. Soap will not cleanse or lather until these constituents have either been neutralized or precipitated as insoluble salts of the fatty acids. Hard water is recognized by the curd formed with soap. Carbonates and some sulfates of the alkaline earths are sparingly soluble and tend to precipitate on evaporation; heating converts bicarbonate to carbonate, which precipitates calcium and magnesium carbonate in boilers, pipes, cooking vessels, etc. Calcium sulfate is also relatively insoluble and in addition to silica may comprise a portion of many incrustations found in the home or in industry.

Hardness limitations for water used in steam generation are very exacting and only 2 ppm or less is generally considered permissible in feed water for boilers operating at 400 psi or more. The tolerances of process water differ from one industry to another and range from less than 10 ppm to several hundred. Hard water is usually superior to soft water in irrigation, and it is often stated that hard water makes soft soil and soft water makes hard soil.

Generally, in Arkansas, ranges of hardness are classed as follows:

Concentration (ppm)	**Hardness**
0-60	soft
60-120	moderately hard
120-200	hard
over 200	very hard

Water with hardness greater than 200 ppm requires softening for most uses, although it is commonly used without treatment for rural domestic purposes.

Specific conductance.—The specific conductance of an electrolyte is the reciprocal of specific resistance and is expressed in mhos. Specific resistance is the resistance, in ohms, of a column of solution 1 centimeter long and 1 square centimeter in cross section. In most waters, the conductance is so low that it is more convenient to use micromho as the unit of expression. The specific conductance is a measure of the ability of the water to carry an electric current and is therefore an indication, within rather wide limits, of the ionic strength of the solution.

Many natural waters in contact only with granite, siliceous sand, well-leached soil or other difficulty soluble materials have a conductance of less than 50 micromhos. Specific conductance of most waters in the Eastern United States is less than 1,000 micromhos, but in the arid western parts of the country, a specific conductance of more than 1,000 micromhos is common. Some saline lakes and brines may even reach several hundred thousand micromhos.

Hydrogen-ion concentration (pH).—The pH of a solution is a measure of the effective hydrogen-ion concentration, or more specifically, the hydrogen-ion activity. In water solutions, deviations in pH from 7 are primarily the result of the hydrolysis of salts of strong bases and weak acids, or vice versa. Dissolved gases such as carbon dioxide, hydrogen sulfide, and ammonia also affect the pH appreciably. The effect of dissolved salts of strong acids and strong bases is slight.

Because carbonates are prevalent in nature, most natural waters of the United States are slightly basic. The overall normal pH range is between 6.0 and 8.0. Industrial wastes on the other hand may be strongly acidic or basic, and the effect on the pH of water resources is largely dependent on the normal buffering capacity of the water.

Water with a pH of less than about 4 usually has a sour taste. The U. S. Public Health Service (1946) states that the maximum pH of treated drinking and culinary water on carriers subject to Federal quarantine regulations should be about 10.6. Optimum pH for fish is between 7.8 and 8.5 while acid water with pH below 4.4 and strong basic waters with pH greater than 8.8 generally causes gill irritation and death. pH in conjunction with other factors affects the corrosion potential of water on metals. Low pH also increases the corrosive action of water on concrete. Extremes in pH cannot usually be tolerated by industry. The optimum pH for irrigation water depends on the type of crops to be grown and on the physical and chemical properties of the soil. Acid soils will tolerate the more alkaline water and some alkaline soils will tolerate the more acid water.

All chemical analyses of water listed in this report, with the exception of that by the Arkansas State Board of Health, were made according to methods regularly used by the U. S. Geological Survey. These methods are described in U. S. Geological Survey Water-Supply Paper 1454 by Rainwater and Thatcher (1960).

Types of water

In this report, terms describing the chemical character of a water are used as follows: (1) "calcium bicarbonate" designates a water in which calcium amounts to 50 percent or more of the bases and bicarbonate to 50 percent or more of the acids, in chemical equivalents; (2) "sodium bicarbonate" designates a water in which sodium amounts to 50 percent or more of the bases and bicarbonate to 50 percent or more of the acids, in chemical equivalents.

Geology

Regional structural relationships

Northeastern Arkansas lies within the upper Mississippi embayment, a structural depression whose narrow northern tip extends to Cairo, Ill., (fig. 4). The embayment opens to the south into the Gulf Coastal Plain and dips toward the Gulf of Mexico. The edge of the upper embayment can be traced on the surface through eastern Arkansas, southeastern Missouri, southern Illinois, western Kentucky, western Tennessee, northeastern Mississippi, and northern Alabama by following the Fall Line in these States (Caplan, 1954, p. 4).

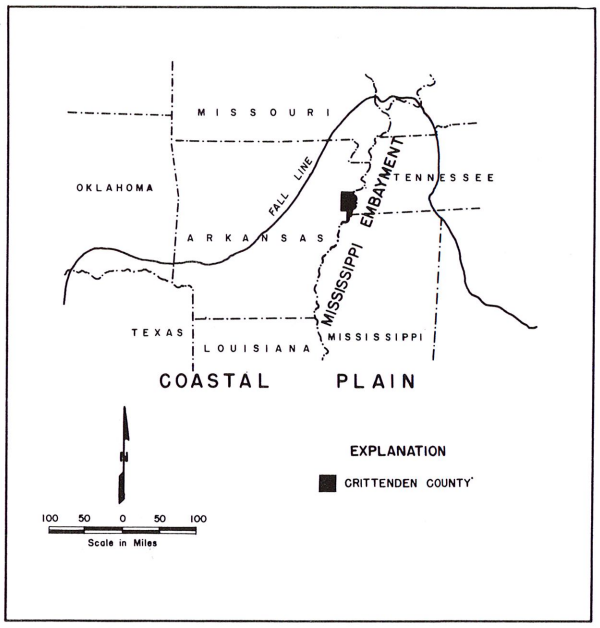


Figure 4. Map showing the Mississippi Embayment and the Fall Line.

The formation of the embayment is believed to have begun at some time during the Cretaceous period, prior to the deposition of the earliest Late Cretaceous sediments. The first stage of development was probably the southward downwarping of the entire embayment area. This was followed by westward downwarping east of the present course of the Mississippi River. Subsequent eastward downwarping in northeastern Arkansas resulted in the present configuration of the upper Mississippi embayment (Caplan, 1954, p. 5).

The structural axis of the embayment passes through eastern Crittenden County following approximately the course of the Mississippi River. Initially, the axis was some distance to the east, but it has reached its present position through progressive westward movement of depositional centers.

This structural depression was invaded by the sea several times during Cretaceous and Tertiary time. Several thousand feet of sediments, both continental and marine, were deposited in the embayment. The formations in the northern part of the embayment dip 10 to 35 feet per mile toward the axis and at a lesser slope toward the south.

Crittenden County is situated near the center of the upper embayment. Because the structural axis of the embayment passes through the eastern part of the county, the strata underlying the county dip in either an easterly or westerly direction depending upon their location with respect to the axis.

Table 1 summarizes the geology and water-bearing character of Paleocene and younger rocks underlying Crittenden County and adjacent areas. A series of cross sections based on electric logs of oil-test wells is presented in figures 6, 7, 8, and 9. The locations of the cross sections are shown in figure 5.

Generalized stratigraphy
Tertiary system
Paleocene series

Midway group

Rocks of the Midway group are found throughout the subsurface of the Mississippi embayment in northeastern Arkansas. They rest unconformably upon rocks of Late Cretaceous age and are overlain by rocks of the Wilcox group of early Eocene age (table 1).

The Midway group is made up of two members. The upper unit, known as the Porters Creek clay consists of blue-gray to dark-gray fissle shale, containing concretionary sideritic layers. It is correlated with the Porters Creek clay of north-

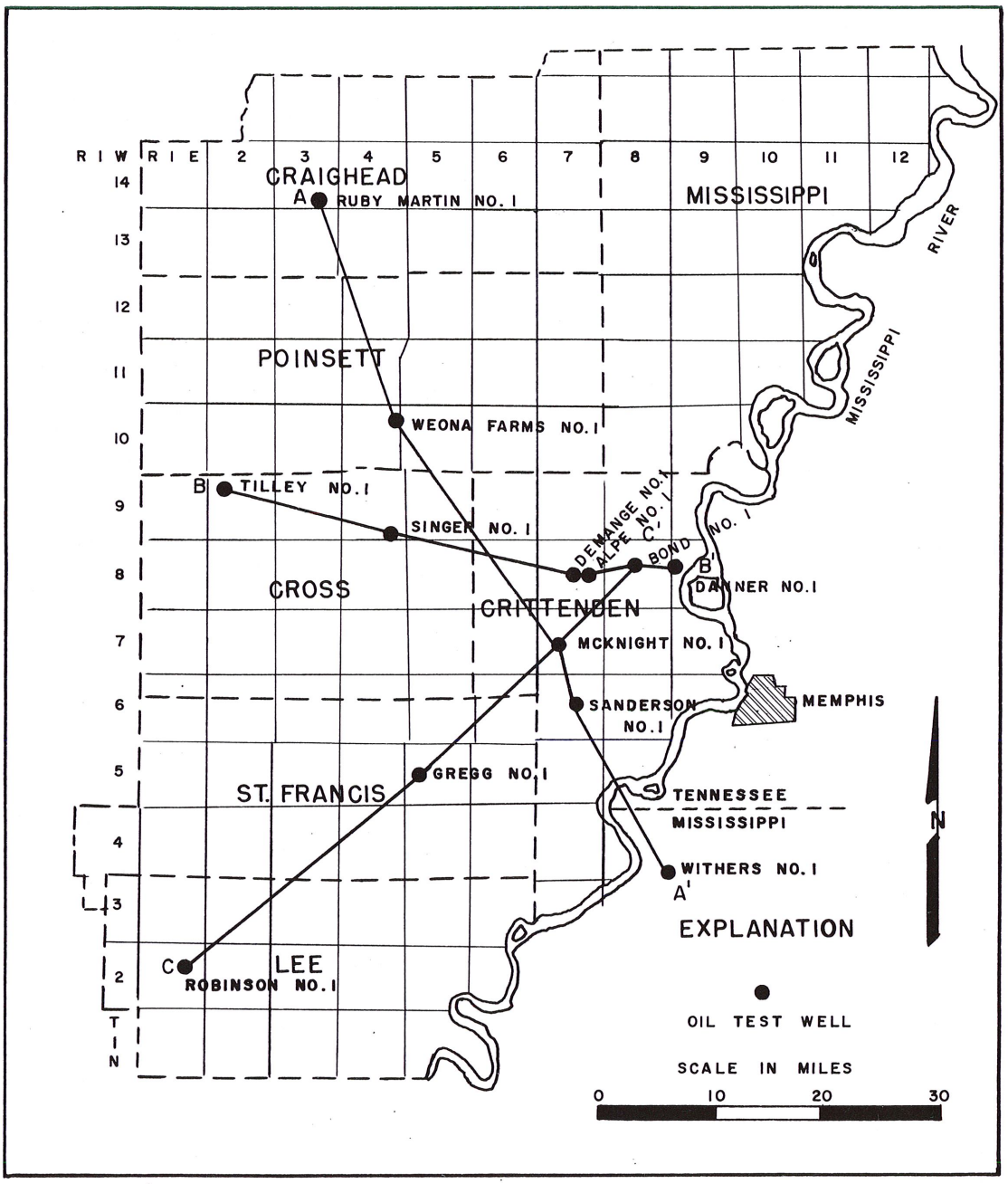


Figure 5. Map showing locations of cross sections based on electric logs.

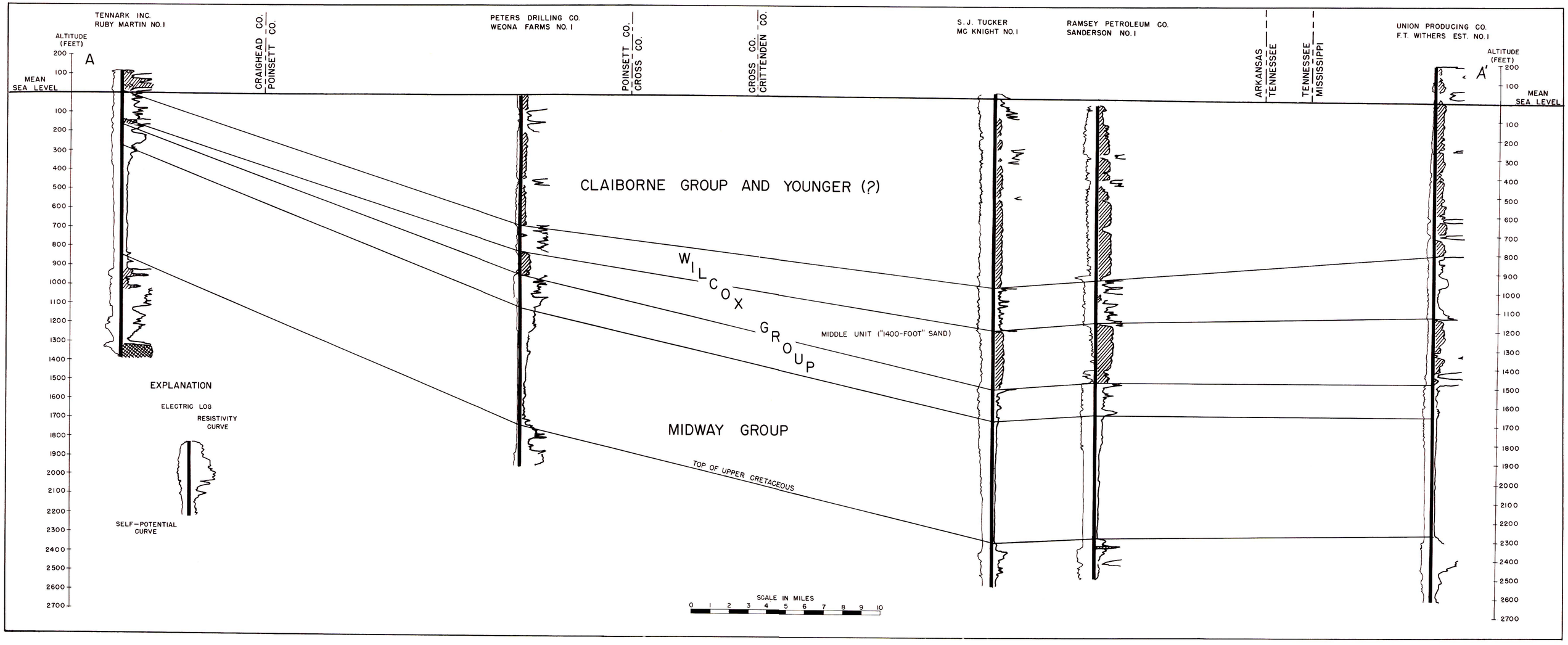


FIGURE 6.- CROSS SECTION A-A'

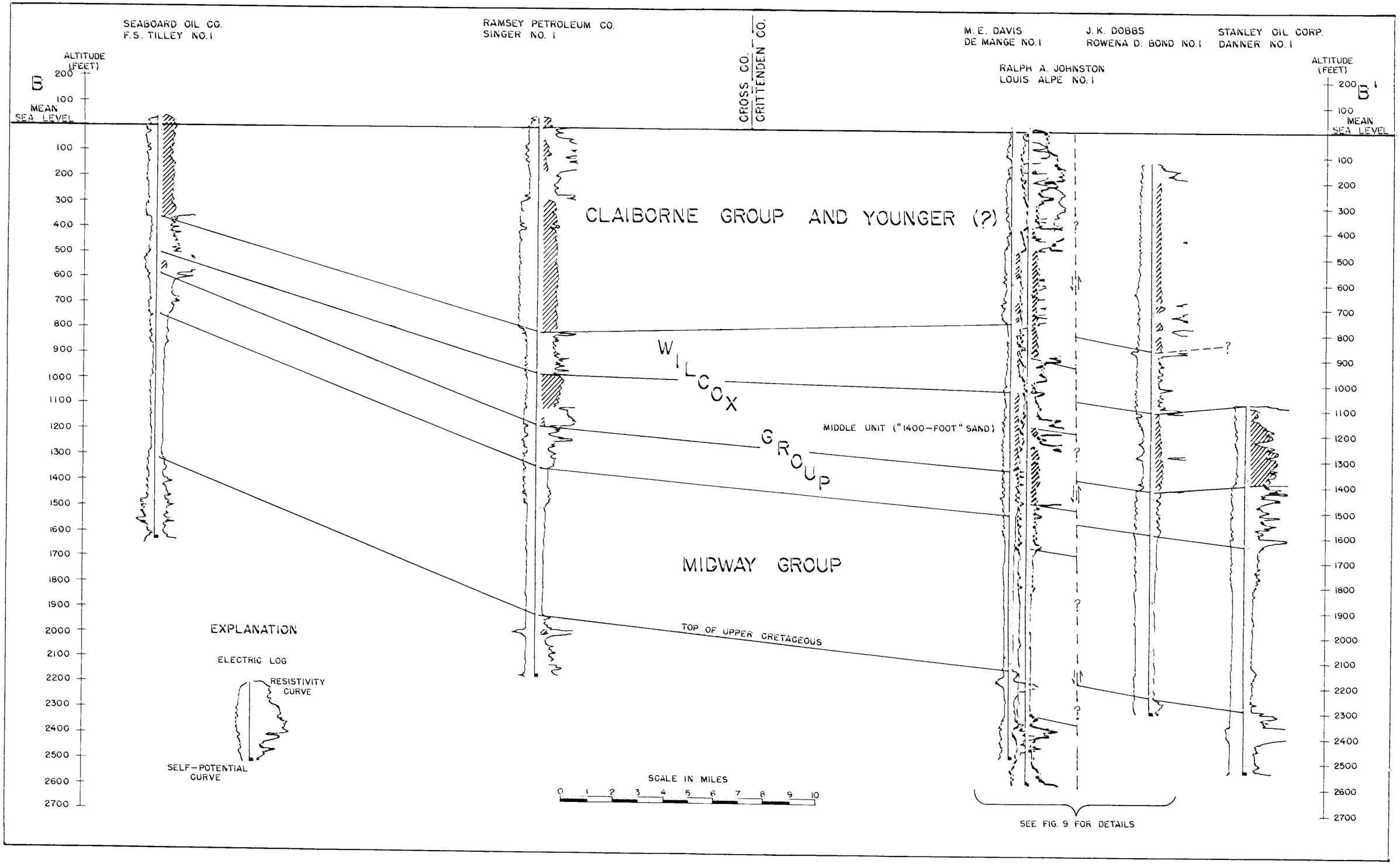


FIGURE 7.—CROSS SECTION B-B'

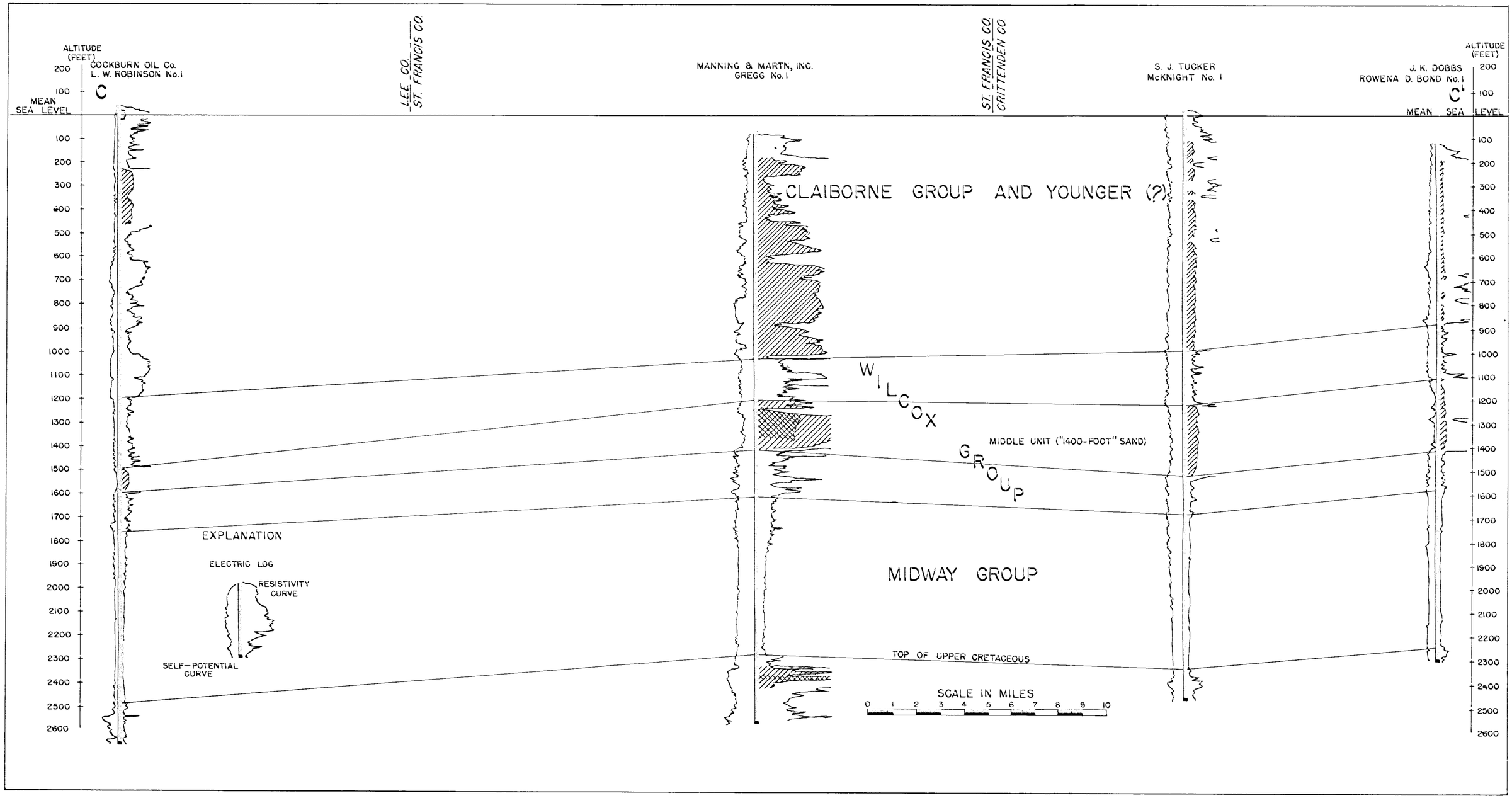


FIGURE 8.—CROSS SECTION C-C'

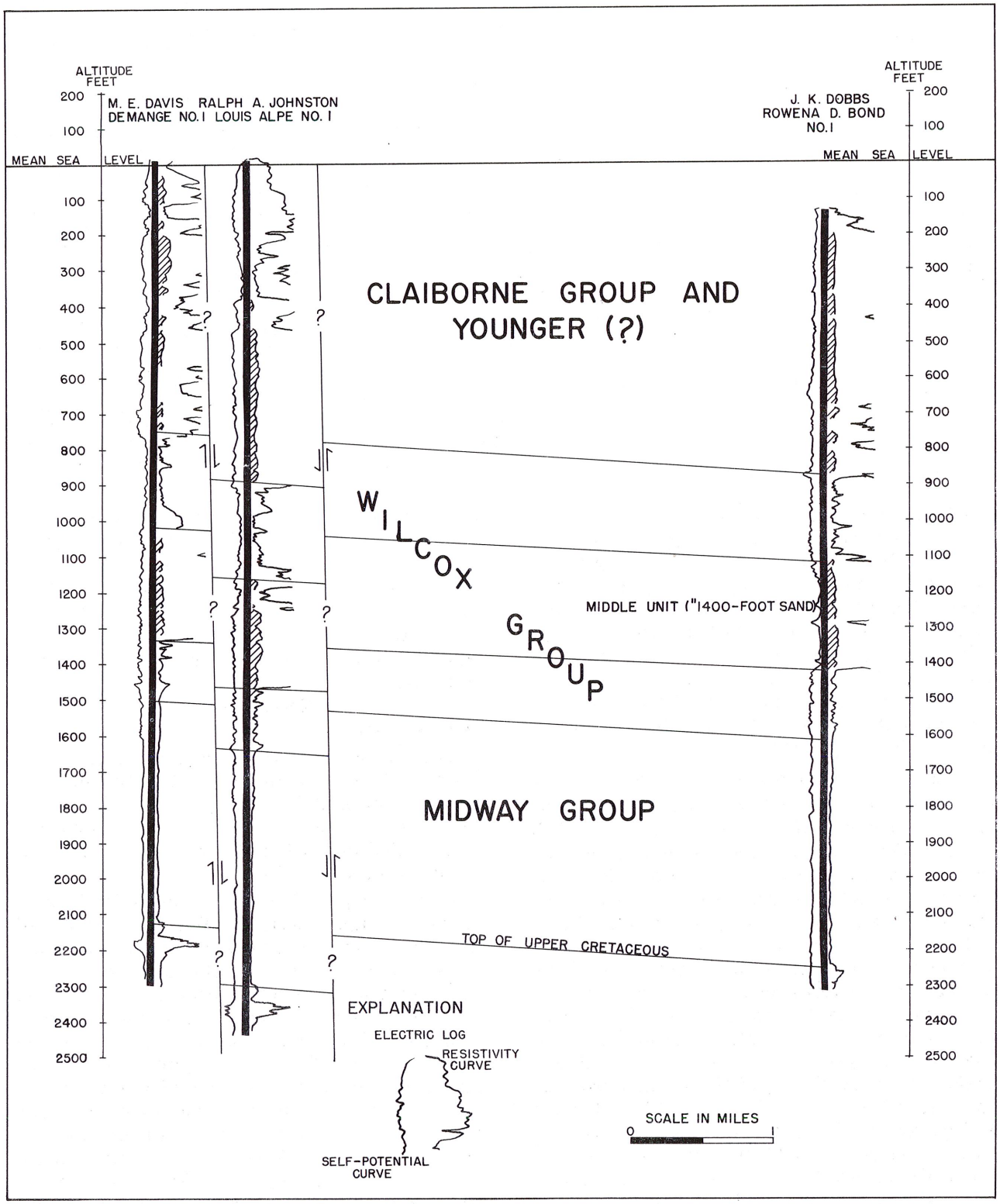


Figure 9. Cross section Demange No. 1—Alpe No. 1—Bond No. 1.

Table 1.—Generalized geologic section of rocks of Cenozoic age in Crittenden County, Ark.

Era	System	Series	Group	Subdivision	Thickness (feet)	Physical and water-bearing character
CENOZOIC	Quaternary			Alluvium	90-200	Clay, silt, sand, and gravel. Water is generally hard and may contain excessive amounts of iron. Yields large quantities of water.
	Tertiary	Eocene	[1]Jackson	?	?	?
			Claiborne	?	900-1,000	Sand and clay, lignitic. Sand beds may attain thicknesses of more than 400 feet. Potentially an important aquifer.
			Wilcox	Upper unit	230-260	Clay, green and silt, glauconitic; contains thin lignite beds.
				Middle unit ("1,400-foot" sand)	305-340	Sand, fine to medium. Yields large quantities of excellent quality water.
				Lower unit	140-240	Clay, gray to greenish-gray, silty, some brown clay; contains thin beds of sand and lignite.
		Paleocene	Midway	Porters Creek clay	650-670	Shale, blue-gray to dark-gray, fissile; contains sideritic, concretionary layers. Does not yield water to wells.
				Clayton formation		Shale, gray, calcareous, fossiliferous; contains scattered lenses of white limestone near the base. Does not yield water to wells.

[1] May be present in the southern part of the county.

ern Mississippi and Tennessee. The lower unit, which is correlated in its entirety by some geologists with the Clayton formation of western Tennessee, consists of gray, calcareous, fossiliferous shale containing scattered lenses of white limestone near the base. Other geologists consider only the limestone lenses as representing the Clayton formation in northeastern Arkansas. In certain areas, a glauconitic, phosphatic layer separates the lower unit from the underlying rocks of Cretaceous age.

There is some controversy as to the location of the top of the Porters Creek clay and the base of the overlying Wilcox group. Renfroe (1949, p. 12) believes that the formational contact occurs at a point where there is a marked lithologic change from silty sandstone to a dark-gray or blue silty shale. Other geologists (Caplan, 1954, p. 95), as a matter of convenience in working with electric logs, select an arbitrary top of the Midway at the base of the last marked resistivity deflection in the Wilcox section. This places about 165 to 180 feet of silty and sandy shale in the Midway group. Sterns and Armstrong (1955, p. 4) place the top of the Midway group at the base of the so-called "1,400-foot" sand of the Wilcox group. They consider the interval between the base of the "1,400-foot" sand and the top of the typical Porters Creek clay as being a regressive sandy zone grading laterally into the Porters Creek clay. In this report, the top of the Midway group is placed, for convenience, at the base of the before-mentioned lowermost well-developed resistivity deflection in the Wilcox (figs. 6-9). This gives the Midway group a thickness of 650 to 670 feet in the Crittenden County area.

The Midway group is not considered a potential source of ground water in northeastern Arkansas.

Eocene series

Wilcox group

The Wilcox group (lower Eocene) overlies the Porters Creek clay and is overlain by the Claiborne group (middle Eocene) as shown in table 1. Rocks of this group are found only in the subsurface in Crittenden County where they attain a thickness of about 700 feet.

In the Memphis, Tenn., area, about 5 miles east of West Memphis, Ark., the Wilcox is subdivided into three units (Criner and Armstrong, 1958, p. 3). The lower unit consists mainly of gray to greenish-gray silty clay, brown carbonaceous clay, and interbedded gray silt, grading upward into gray silt containing thin lenses of clay and very fine sand. Thin beds of lignite are common. Muscovite is commonly associated with the sandy lenses in the upper part of the lower unit. The lower unit of the Wilcox group varies in thickness from 190 to 250 feet in the Memphis area. In Crittenden County, the thickness varies from 140 to 240 feet, as shown by electric logs of 6 oil-test wells (figs. 6-9). Figure 5 shows the locations of the wells.

A prominent bed of fine to medium sand forms the middle unit of the Wilcox group in the Memphis area. This sand, known locally as the "1,400-foot" sand, is an important artesian aquifier at Memphis and is the most important artesian aquifer in Crittenden County and adjacent areas of Arkansas. At Memphis it ranges in thickness from 175 to 210 feet, and in Crittenden County it attains a maximum thickness of about 340 feet.

The upper unit of the Wilcox group includes the clay and silt that lie above the "1,400-foot" sand. The depositional environment appears to have been complex as the green-colored clays and glauconite suggest marine conditions, while the lignite beds and fresh-water plant spores and seeds suggest swamp deposition (Criner and Armstrong, 1958, p. 7). Brown (1947, pl. 4) shows that this upper unit is overlain by the Meridian sand member of the Tallahatta formation (basal Claiborne) in northwestern Mississippi. In Tennessee the upper unit is overlain by the so-called "500-foot" sand. The contact between this sand and the upper unit of the Wilcox group is used in this report as the dividing line between the Wilcox and Claiborne groups. In the Memphis area the upper unit ranges in thickness from 200 to 395 feet. In Crittenden County electric logs show this unit as being rather uniform in thickness, varying from 230 to 260 feet.

Claiborne group

Rocks of the Claiborne group (middle Eocene) are present in the subsurface in Crittenden County and have a total thickness of about 900 to 1,000 feet. They rest unconformably upon the Wilcox group and are in turn overlain by the Jackson group or by deposits of Quaternary age where the Jackson is absent (table 1).

In southwestern Arkansas, where the Claiborne group consists of an alternating sequence of sand and clay, the group is differentiated into the Cane River formation, the Sparta sand, the Cook Mountain formation, and the Cockfield formation. In northeastern Arkansas, the Claiborne group becomes considerably more sandy, and the various formations are unidentifiable.

In the Memphis area, the Claiborne group has been subdivided into upper and lower units (Criner and Armstrong, 1958, p. 7). The lower unit, which attains a thickness of 560 feet, is made up of fine sand containing thin clay and lignite lenses. Coarse channel sands are present locally at the base. The upper unit ranges in thickness from 190 to 400 feet and consists of fine to coarse sand, greenish-gray and tan clay and silt, and minor amounts of lignite. Locally, the two units are collectively known as the "500-foot" sand. The upper unit is the source from which most of the water in the Memphis area is obtained.

Information available at present is insufficient to project this separation beyond the Memphis area. Therefore, in this report the term "sands of the Claiborne group" will be used to designate the water-yielding portions of the group.

Jackson group

According to Fisk (1944, fig. 7), rocks of the Jackson group (upper Eocene) overlie the Claiborne group in part of Crittenden County. He shows it as being present throughout the county except in the northwestern corner and also in a belt extending southwestward through the central part of the county. The Jackson group crops out along Crowleys Ridge (fig. 3) in St. Francis County to about the latitude of Memphis. In Memphis a unit classified as Jackson(?) overlies the "500-foot" sand. According to Criner and Armstrong (1958, p. 8), the Jackson(?) consists predominantly of hard dark-blue to greenish-gray clay and lignite. Near the bottom it is generally more sandy and grades into the underlying "500-foot" sand. No fossils that would identify this unit have been found beneath Memphis, and no continuous body of clay has been traced into the Memphis area from clays known to belong to the Jackson group. Wilbert (1953, p. 103) reports that a test hole drilled near the common corner of Arkansas, Mississippi, and Tennessee encountered strata that contained upper Jacksonian fossils. Thus it appears possible that the Jackson group is present at least in the southern part of the county. However, available drillers' logs of wells in Crittenden County are not sufficiently detailed to corroborate this.

The Jackson group is not considered a potential source of ground water in this area.

Quaternary system

Crittenden County is covered by alluvium of Quaternary age to a maximum depth of about 200 feet. Part of this alluvium may be of Pleistocene age, but owing to the difficulty in differentiating the sediments of Pleistocene age from those of Recent age, they are considered as a single unit.

The alluvium consists of a sequence of sediments that Fisk (1944, p. 17) divided into a basal graveliferous unit and an upper nongraveliferous unit. The lower unit is the principal source of water for irrigation throughout the area.

Faulting

According to Caplan (1954, p. 37), the generally unconsolidated character of the post-

Paleozoic sediments in northeastern Arkansas makes faulting difficult to distinguish because it may be obscured by slumping.

Faulting, slumping, and general evidence of crustal displacement may be expected in those portions of the embayment affected by the New Madrid earthquake of 1811 and the associated shocks of 1812. According to Fuller (1912), the epicenter of this earth movement was in northeastern Arkansas and southeastern Missouri, between Crowleys Ridge and the Mississippi River. Evidence examined by Fuller indicated the existence of a fault or fault system trending northeast-southwest across the general area affected, but actual placement of the fault or fault system could not be made. The maximum expression of faulting and related adjustments attributable to the New Madrid earthquake in Arkansas is likely to be found in the region between Crowleys Ridge and the Mississippi River, from the general vicinity west of Memphis to the Missouri State line.

In Crittenden County, Caplan (1954, p. 33) found evidence of faulting that involved Paleozoic strata in the Davis, DeMange No. 1 well, sec. 22, T. 8 N., R. 7 E. A rubble zone at 4,730 feet suggests that the well passed through a fault trace at this depth. Because no repetition of section was found in the well, he postulated a normal fault striking northeast.

The present investigation revealed displacement of sediments at least as young as Eocene between the DeMange No. 1 well and the Louis Alpe No. 1 well (figs. 7 and 9), suggesting normal faulting with the downthrown block to the east or southeast. In the Alpe well the Upper Cretaceous series appears to be displaced about 160 feet, the Midway group (Paleocene) about 125 feet, and the Wilcox group (early Eocene) about 125 feet with respect to these units as encountered in the DeMange well. In figures 7 and 9, the lines of displacement shown are not intended to establish the actual location of the fault or faults, but to emphasize the discrepancy between the units in the wells. It is entirely possible that the discrepancies are due to slumping of the unconsolidated materials resulting from deep-seated adjustments along previously existing zones of weakness in Paleozoic or older rocks. Renewed activity may have taken place during the New Madrid earthquake along the previously postulated fault through which the DeMange well apparently passed.

Fresh-water aquifers

"1,400-foot" sand

Areal extent.—The "1,400-foot" sand comprises the middle unit of the Wilcox group (lower Eocene) in Crittenden County and surrounding areas of Arkansas, Mississippi, and Tennessee. Its total areal extent has not been determined as yet, but Brown (1947) believed that this sand could be recognized in the subsurface 80 miles south of Memphis. According to Criner and Armstrong (1958, p. 3), the sand is recognizable in the subsurface 15 miles east and 35 miles northeast of Memphis. Also, it has been tentatively recognized in wells about 95 miles north of Memphis. Electric logs of wells in eastern Arkansas indicate that the "1,400-foot" sand should persist as a recognizable unit to about the western boundary of Cross County, or about 55 miles west of Memphis, if the rate of thinning as shown in figure 7 is maintained. It is about 25 feet thick 60 miles northwest of Memphis in west-central Craighead County where it is recognizable in the Tennark, Inc., Ruby Martin No. 1 well (fig. 6). In the Cockburn Oil Corp., L. W. Robinson No. 1 well in Lee County, about 55 miles southwest of Memphis, it has a thickness of about 100 feet (fig. 8).

The area of outcrop of the "1,400-foot" sand has not been determined. The sand dips westward at about 25 feet per mile at Memphis. If it can be projected updip at this rate to the east, it should crop out about 60 miles due east of Memphis. According to Criner and Armstrong (1958, p. 3), there is an exposure of sand in that area that may represent the "1,400-foot" sand. They state, however, that a cross section by Schneider and Blankenship (1950) indicates that in that area the Wilcox group may be overlapped by the Claiborne group.

Lithology.—Most of the detail regarding the lithology of the "1,400-foot" sand derives from the study of the water supply of Memphis. This is supplemented by the interpretation of electric logs of oil-test wells. Criner and Armstrong (1958, p. 7) describe this sand in the Memphis area as consisting predominantly of unconsolidated, well-sorted, fine-to-medium grained, subangular to angular, micaceous quartz. Some logs show that scattered beds of argillaceous sand and sandy clay are interbedded with the sand. These appear to be discontinuous and probably are lenses of no great extent. In eastern Arkansas, little is known of the detailed lithology, because few samples of drill cuttings are available. Most drillers simply refer to the unit

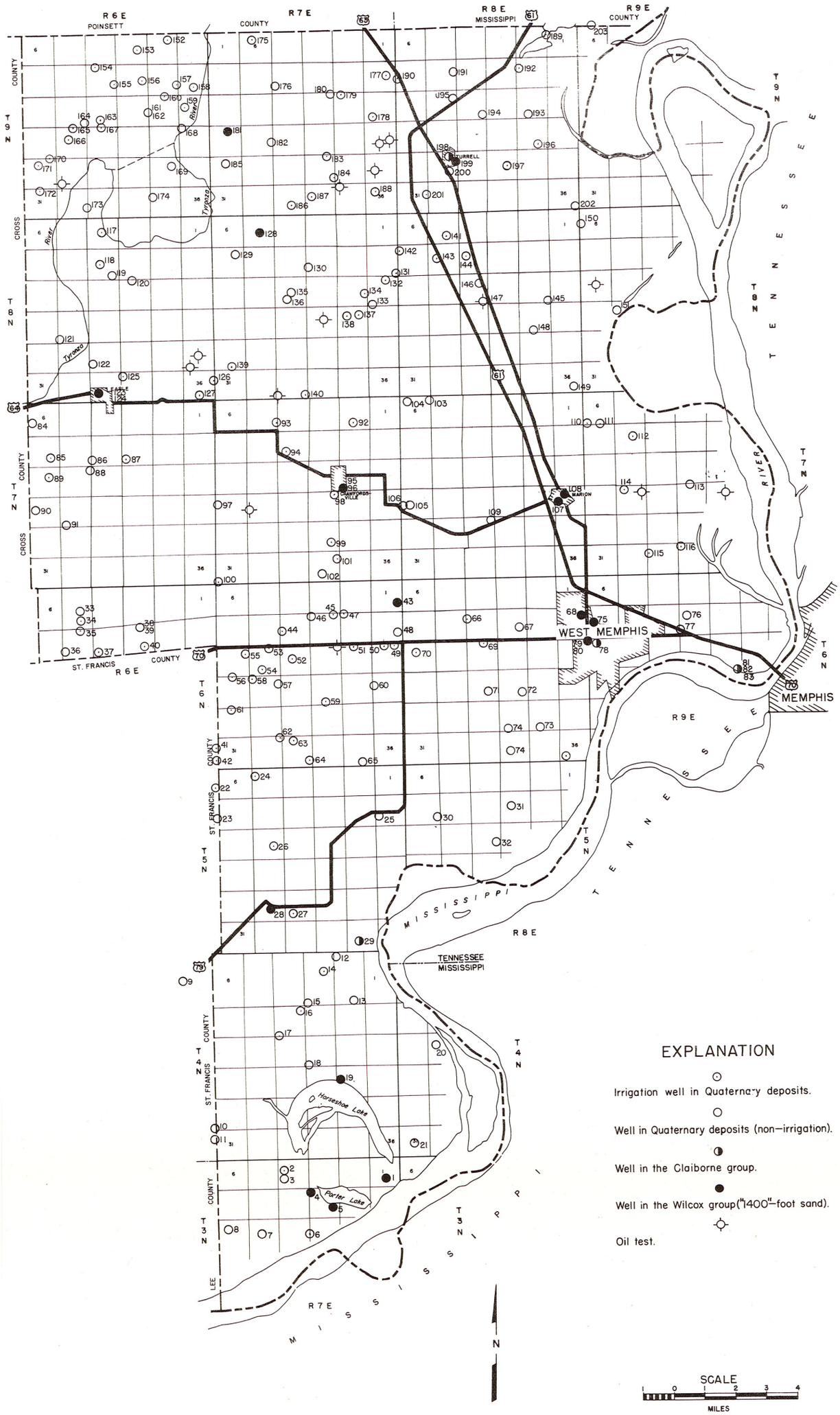


FIGURE 10. MAP OF CRITTENDEN COUNTY SHOWING WELL LOCATIONS

as "sand," "artesian sand," "good sand," or "water-bearing sand."

Thickness.—Drillers' logs and electric logs indicate that in some areas the "1,400-foot" sand varies considerably in thickness in short distances. According to Criner and Armstrong (1958, p. 7), the thickness in the Memphis well fields ranges from 175 to 203 feet. The sand thickens toward the axis of the embayment and reaches a thickness of 300 to 315 feet in 6 oil-test wells in Crittenden County (figs. 6, 7, 8, and 9). The electric log of the Union Producing Co., F. T. Withers Est. No. 1 well in DeSoto County, Mississippi, indicates a thickness of about 350 feet (fig. 6).

Pumpage.—In 1959, 20 wells in Crittenden County were known to be screened in the "1,400-foot" sand (fig. 10). Ten of these wells are for municipal supplies, one is an industrial public-supply well, and the remainder are small-diameter domestic wells, most of which are located on plantations. The distribution of the municipal wells is as follows: Crawfordsville, 1; Earle, 2; Marion, 2; Turrell, 1; and West Memphis, 4. Records of the wells are given in table 2.

The total estimated pumpage from the "1,400-foot" sand in Crittenden County in 1959 did not exceed 2.5 mgd. About 95 per cent of this amount was obtained from the municipal wells.

The only large withdrawals of water from the "1,400-foot" sand in this general area occur in the vicinity of Memphis in Shelby County, Tenn. According to Criner and Armstrong (1958, p. 11), about 13.4 mgd was pumped from this sand in the Memphis area during 1955.

Water levels.—Flowing wells generally were obtained when the "1,400-foot" sand was first tapped in Crittenden County. Since then the static water level has declined as much as 22 feet below land surface. The following table presents the available information on past and present water levels in wells tapping this aquifer.

Well no	Owner	Depth (feet)	Date of measurement	Water level [1] (feet)
28	B. C. Pouncey, Jr.	1,700	1920	+41(?)
79	West Memphis	1,546	1929	+17
Do	do	do	1942	+3
68	do	1,532	1951	−12.75
108	Marion	1,500	1931	Flowed
Do	do	do	1958	−22.4
123	Earle	1,529	1927	Flowed
124	do	1,530	1958	−11.30
199	Turrell	1,510	1958	−15.1

[1] Datum: Land surface

In the West Memphis area, the water level in the "1,400-foot" sand declined from 17 feet above land surface in 1929 to slightly less than 13 feet below land surface in 1951. This indicates a total decline of almost 30 feet in a period of 22 years. Between 1929 and 1942, the average rate of decline was about 1.1 feet per year; between 1942 and 1951, the average rate was 1.8 feet per year. Criner and Armstrong (1958, fig. 6), report a decline in water level of about 27.5 feet in a well in north Memphis between 1945 and 1955. This indicates an average rate of decline of 2.75 feet per year. It is evident that the aquifer is artesian, as water levels in wells tapping the middle unit stand at approximately 1,500 feet above the base of the upper confining unit in Crittenden County.

Aquifer tests.—No aquifer tests were made of the "1,400-foot" sand in Crittenden County. However, a series of tests were made of the sand in the well fields at Memphis (Criner and Armstrong, 1958, p. 11). The average coefficient of transmissibility of the "1,400-foot" sand was about 115,000 gpd per foot; the average coefficient of storage was about 0.0003. A test conducted in 1950 at the Blytheville Air Force Base in Mississippi County, Arkansas, gave a coefficient of transmissibility of 165,000 gpd per foot and a coefficient of storage of 0.0002.

Quality of water.—Water from the "1,400-foot" sand is generally of good quality and ranges in temperature from 73° to 77°F in Crittenden County. The water is of the sodium bicarbonate type and is very soft; the maximum hardness (as $CaCO_3$) recorded in 14 analyses being about 10 ppm and the minimum 1 ppm.

Two undesirable constituents present in water from the "1,400-foot" sand in this area are iron and free carbon dioxide (CO_2). The iron content in the samples ranges from 0.07 to 1.5 ppm. The U. S. Public Health Service recommends 0.3 ppm as the maximum limit for iron plus manganese in drinking water for interstate carriers. Eight of the 14 samples exceed this limit.

Free carbon dioxide was not determined in the 14 samples. However, Criner and Armstrong (1958, p. 14) state that water from the "1,400-foot sand" at Memphis contains about 15 ppm of free carbon dioxide.

The pH determinations shown in table 3 probably are not reliable as they were made several weeks after the water samples were collected. Free carbon dioxide begins to escape immediately upon exposure to the atmosphere or to pressure decrease, resulting in a rise in pH.

Table 3 contains chemical analyses of the 14 water samples collected from the "1,400-foot" sand. The water from this aquifer apparently remains relatively uniform in chemical quality, because analyses made of samples taken at Memphis in 1927 and again in 1947, show relatively little variation (Criner and Armstrong, 1958, p. 14).

Wilcox (1948) rates water for irrigation with respect to the specific conductance and per cent sodium, assuming "average conditions as related to soil, permeability, drainage, quantity of water used, climate, and crops." Water sampled from the "1,400-foot" sand in Crittenden County, when classified by the method described by Wilcox, rates permissible to doubtful because of the high sodium content (88 to 96 per cent). It is doubtful, however, if this water will be used for irrigation in the near future because of the large quantities of water available at shallower depths.

Recharge.—Because the outcrop area of the "1,400-foot" sand has not been determined, little is known regarding recharge to the aquifer. There is a possibility that recharge may occur about 60 miles east of Memphis, if the outcrop of sand reported by Criner and Armstrong, (1958, p. 3) represents that unit. They also report that the sand may crop out 100 to 125 miles north of Memphis. Much additional data are needed before any definite conclusions can be drawn.

Possibilities for further development. — Although water from the "1,400-foot" sand is utilized to some extent in Crittenden County, the quantities thus far developed are small compared to the amounts available. Yields as high as 2,000 gpm are obtainable from properly constructed wells.

Soft water from this aquifer appears to be available everywhere within the county at minimum depths ranging from 1,300 to 1,500 feet below the surface. The only undesirable constituents of this water are iron and free carbon dioxide, and these can be readily removed by aeration and filtration.

Sands of the Claiborne group

Areal extent.—Sands of the Claiborne group are present in the subsurface throughout Crittenden County and much of eastern and northeastern Arkansas and adjoining portions of Tennessee and Mississippi. In this area, the proportion of sand to clay is much greater than in southwestern Arkansas.

In northeastern Arkansas the Claiborne group crops out on Crowleys Ridge in Cross and Poinsett Counties. Throughout the remainder of this area, it is generally overlain by younger materials. According to Criner and Armstrong (1958, p. 8), the outcrop area of the "500-foot" sand (Claiborne group) in Tennessee should extend from about 20 miles east of Memphis to about 60 miles east of Memphis.

Lithology.—Throughout northeastern Arkansas and adjoining portions of Tennessee and Mississippi, the Claiborne group consists of interbedded clay, sand, and lignite. Little is known about the detailed lithology in northeast Arkansas, because few samples of drill cuttings are available and most drillers' logs are too generalized to be useful.

The sands of the Claiborne group extend throughout Crittenden County between average depths of 300 and 1,125 feet below the surface. Drillers' logs and electric logs of oil-test wells indicate that these beds of sand may range in thickness from a few feet to as much as 475 feet. The thicker beds generally occur in the lower part of the group. There appears to be considerable lateral variation in lithology over short distances, as some logs show a greater proportion of clay interbedded with the sand than others. This clay appears to be in the form of discontinuous stringers or lenses.

Pumpage.—A few wells in the West Memphis area of Crittenden County utilize water from the sands of the Claiborne group. Wells 81, 82, and 83 (fig. 10), which are 352 feet, 370 feet, and 335 feet deep, respectively, are owned by the U. S. Army Corps of Engineers. Only wells 81 and 83 are in use at the present time, and they yield 110 and 125 gpm, respectively. Well 78, owned by the Federal Compress and Warehouse Co., reportedly is screened in sand of Claiborne age, but this cannot be verified. However, a chemical analysis of water from this well indicates that it is similar to water from other wells that are known to be screened in the sands of the Claiborne group.

The only other well definitely known to be screened in sands of the Claiborne group is well 198 at Turrell which was originally owned by the Baker Lumber Co. This well is 864 feet deep and apparently reaches the lower part of the unit. The well has not been in use since 1937. The well was tested in August 1959, and was found to be at least partially plugged.

Well 29 is reported by the owner to be about 800 feet deep, which would place the screen in the Claiborne group. The depth could not be verified, however, because no records are available and a check valve prevents measurement.

The heaviest withdrawals from the sands of the Claiborne group are at Memphis, Tenn., where pumpage averaged 120 mgd in 1955. The total pumpage in the area may have reached 180 mgd during periods of maximum demand in that year (Criner and Armstrong, 1958, p. 16). The pumpage from this aquifer is increasing as a result of municipal and industrial growth in the area.

Water levels.—Available information regarding past and present water levels in wells tapping the sands of the Claiborne group is presented in the following table. The well at Earle has not been assigned a number, because it no longer exists.

Well no.	Owner	Depth (feet)	Date of measurement	Water level [1] (feet)
—	City of Earle	474	1916(?)	−14.5
198	Baker Lumber Co., now E. R. Upshaw	864	1916(?)	−12
Do	do	do	1959	−18
81	Corps of Engineers	352	1934	−20
83	do	335	1958	−48

[1] Datum: Land surface

The earliest information on water levels in wells tapping these sands in Crittenden County was recorded by Stephenson and Crider (1916, p. 178). At that time, the static water level at Earle was about 14.5 feet below land surface, and the level at Turrell was 12 feet below land surface. No information is available on the present water level in wells tapping the Claiborne in the vicinity of Earle, but in August of 1959 the level in the old Baker Lumber Co. well (198) at Turrell was about 18 feet below land surface indicating a decline in static water level of about 6 feet since 1916.

In the West Memphis area the static water level in well 81 was reported as being 20 feet below land surface in July 1934. In March 1958, the static level in well 83, located in the same area, was 48 feet below land surface indicating a decline of 28 feet in 24 years.

Criner and Armstrong (1958, p. 13) show the lowest annual water levels in selected observation wells in the Memphis area for the period from 1927 to 1955. One well shows a decline of about 40.5 feet in 28 years and another a decline of 42.5 feet in 27 years.

Criner and Armstrong (1958, p. 17) state that pumping in the Memphis area has been distributed over a larger area by the addition of a new pumping station to the Memphis system in 1952. Since that time, the water-level decline in Memphis has not been as great, except in the vicinity of the new station. The sands of the Claiborne group are still artesian; water levels in wells tapping these sands stand well above the points where the sands were penetrated by the wells.

Aquifer tests.—No aquifer tests have been made of the sands of the Claiborne group in the area discussed in this report. The only available information is from the study of the Memphis water supply. According to Criner and Armstrong (1958, p. 17), tests made in municipal wells yielded values of the coefficient of transmissibility ranging from 100,000 to 420,000 gpd/ft, and values of the coefficient of storage from 0.0024 to 0.0027.

Criner and Armstrong (1958, p. 17) state that these sands produce a greater amount of water at a given drawdown than the computed coefficients of transmissibility and storage indicate that it should. This discrepancy is attributed to the assumption in the computations that the aquifer receives no additional recharge as a result of the pumping. Part of the discrepancy may also be due to the fact that the aquifer is not homogeneous and isotropic and that none of the wells completely penetrate the aquifer.

Quality of water.—Water from the sands of the Claiborne group is of good quality and has a temperature of about 64°F. It is a calcium bicarbonate type of water and its degree of mineralization is between that of water from the "1,400-foot" sand and water from the alluvium of Quaternary age. The total hardness (as $CaCO_3$) in two samples (wells 78 and 81, table 3) was 82 and 91 ppm, which indicates that the water is moderately hard. At Memphis, however, the hardness ranges between 10 and 60 ppm (Criner and Armstrong, 1958, p. 17), and the water is soft.

Two undesirable constituents of the water are iron and free carbon dioxide. The total iron content in the two samples was 0.74 and 3.3 ppm, which exceeds the suggested maximum concentration of 0.3 ppm. At Memphis where a greater number of samples were obtained, the average iron content was about 0.8 ppm, ranging from a minimum of 0.05 to a maximum of 1.7 ppm.

The water from the sands of the Claiborne group is generally acid and contains as much as 100 ppm free carbon dioxide. The field pH of the water at Memphis is generally 5.9 to 6.3, although it may be as low as 5.3 and as high as 7.3 (Criner and Armstrong, 1958, p. 17).

Table 3 contains chemical analyses of water from wells 78 and 81. The pH values in the table are probably too high, because of the time lapse

between the collection and analysis of the samples.

The two samples of water from the sands of the Claiborne group, when classified by the method devised by Wilcox, rate excellent to good for irrigation.

Possibilities for further development.—The sands of the Claiborne group are an important potential source of additional water throughout Crittenden County and much of northeastern Arkansas. Only two of the four wells in the county that are known to be screened in these sands were in use in 1959, and their total pumpage is negligible.

Deposits of Quaternary age

Areal extent and lithology.—Deposits of Quaternary age blanket the entire surface of Crittenden County and comprise a sequence of sediments grading irregularly upward from coarse sand and gravel at the base into progressively finer deposits of sand, silt, and clay. According to Fisk (1944, p. 17), this general upward decrease in grain size makes it possible to divide the section into a basal graveliferous unit and an upper nongraveliferous unit.

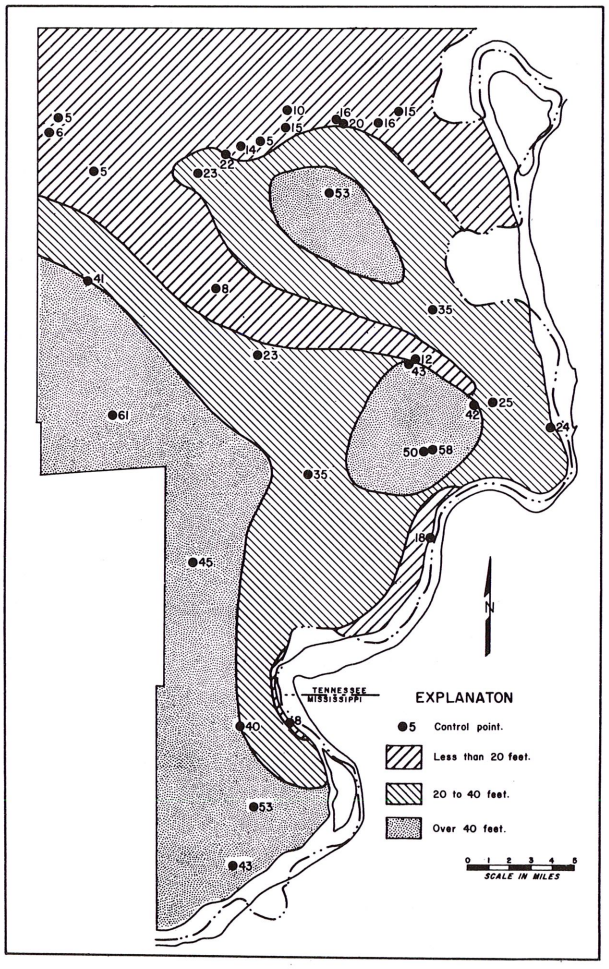


Figure 11. Map showing the thickness of the surficial clay in Crittenden County.

The Quaternary deposits unconformably overlie deposits of Tertiary age. The average thickness of the deposits is about 135 feet, although they range from 90 to 200 feet thick. These deposits consist primarily of gray, bluish-gray and brown silt, clay, sand, and gravel. The basal sand and gravel beds average 78 percent of the total thickness of the deposits. The basal graveliferous unit is generally capped by silty or sandy clay which ranges in thickness from 5 to 61 feet (fig. 11). Fig. 11—Map showing thickness of the surficial clay in Crittenden County. This silt and clay acts as an upper confining layer and, as a consequence, conditions in the aquifer may vary from water-table to semiartesian or artesian.

The sands and gravels of Quaternary age are the most productive water-bearing deposits in Crittenden County as well as in much of northeastern Arkansas.

Pumpage.—The largest withdrawals of ground water in Crittenden County are from the alluvium of Quaternary age. About 90 percent of all ground water used, approximately 8.7 billion gallons per year, is obtained from this aquifer. Approximately 99 percent of this water is pumped for irrigation during a 5-month period from May to September. Rice irrigation alone accounts for about 6.5 billion gallons per year.

In 1959, there were 101 irrigation wells screened in deposits of Quaternary age in Crittenden County. Records of these wells are presented in table 2. During the course of this investigation, approximately 18 percent of these wells were not in use.

Irrigation-well yields of 1,500 to 2,000 gpm are common in the county. Several wells yield more than 2,000 gpm; the largest measured yield, 2,600 gpm, is from well 179. Well 14 is reported to have yielded 3,200 gpm when tested by the driller in 1953.

Only about 1 percent of the water obtained from the Quaternary alluvium is used for rural domestic purposes. At first glance, this appears low considering that most of the rural domestic supplies are obtained from the alluvium. The majority of these wells, however, are shallow-driven wells equipped with pitcher pumps. Few of these wells exceed 50 feet in depth and most are less than 30 feet.

Water levels.—The water level in a well tapping an aquifer is not stationary, but rises and

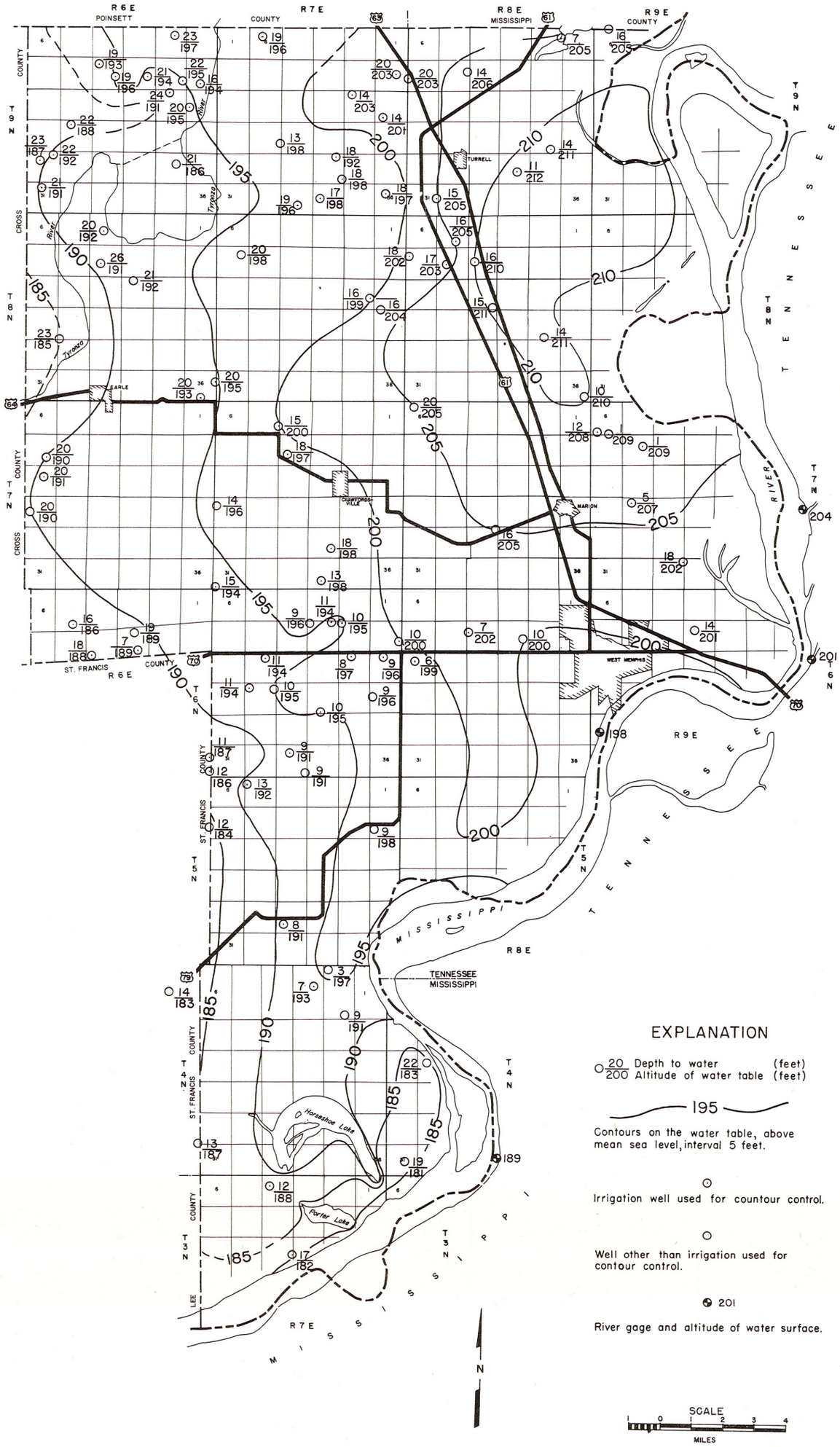


FIGURE 12. MAP OF CRITTENDEN COUNTY SHOWING DEPTH TO WATER AND THE WATER TABLE IN QUATERNARY DEPOSITS, DECEMBER 1957.

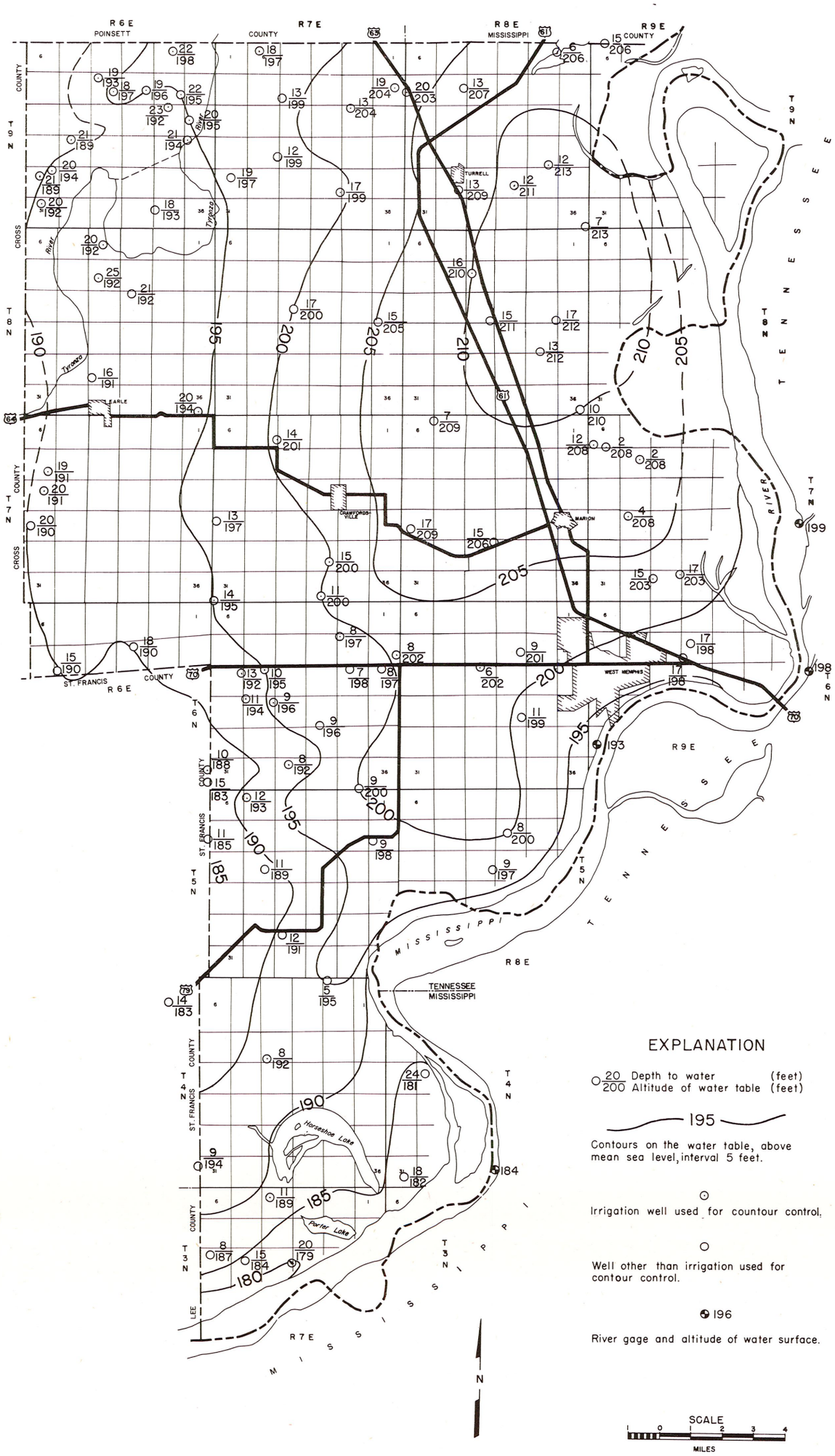


FIGURE 13. MAP OF CRITTENDEN COUNTY SHOWING DEPTH TO WATER AND THE WATER TABLE IN QUATERNARY DEPOSITS, MARCH 1958.

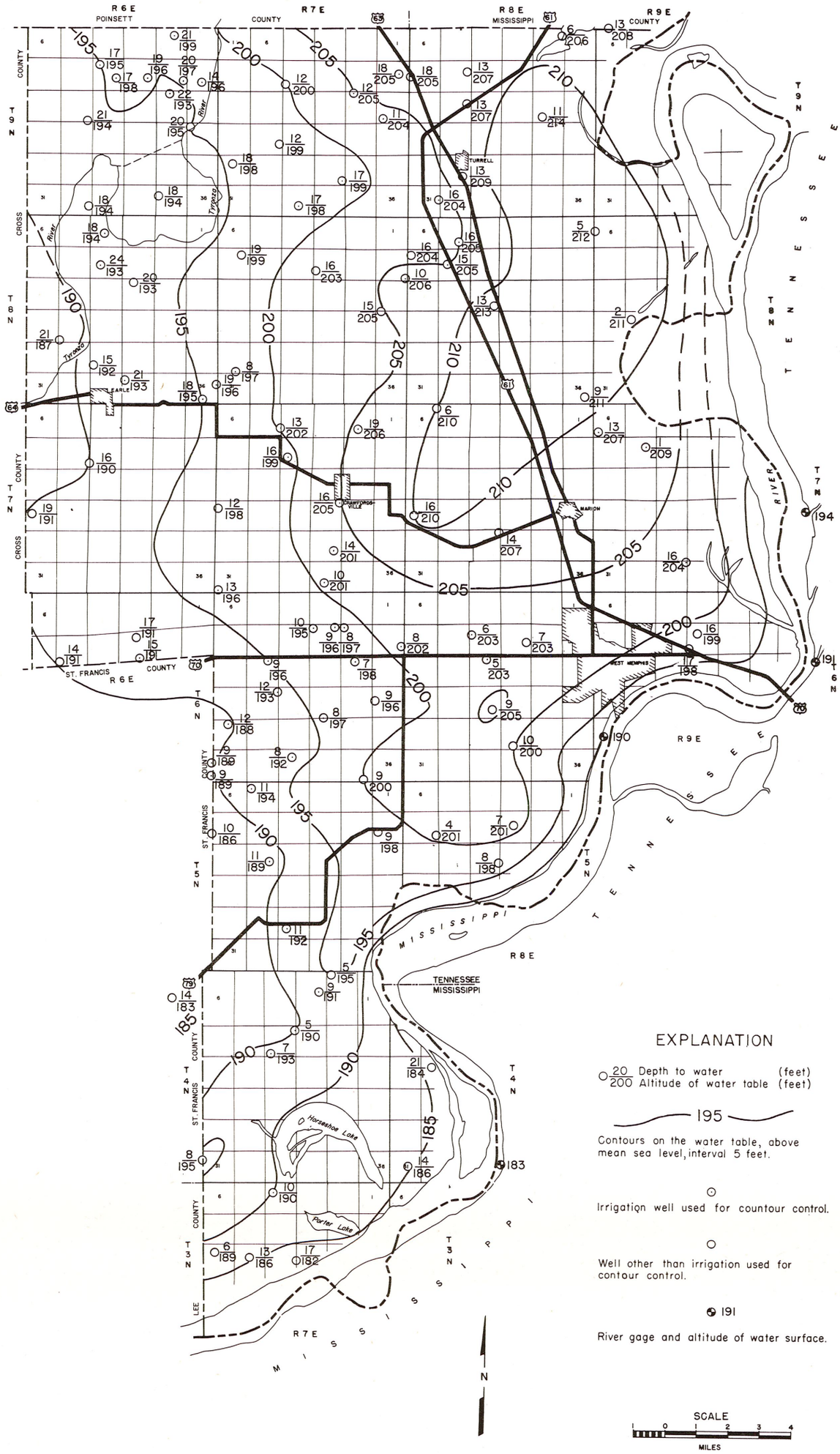


FIGURE 14. MAP OF CRITTENDEN COUNTY SHOWING DEPTH TO WATER AND THE WATER TABLE IN QUATERNARY DEPOSITS, JUNE 1958.

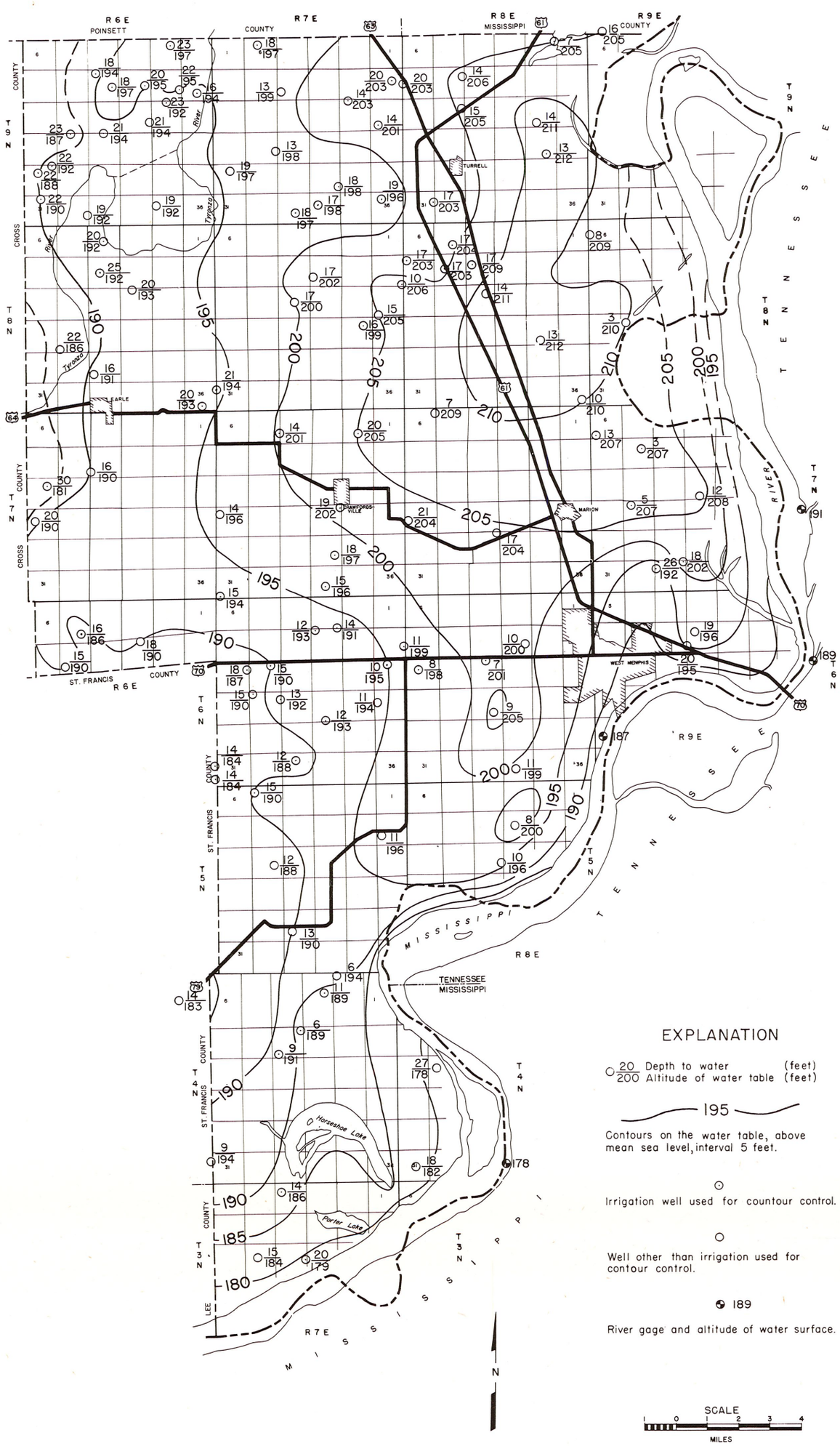


FIGURE 15. MAP OF CRITTENDEN COUNTY SHOWING DEPTH TO WATER AND THE WATER TABLE IN QUATERNARY DEPOSITS, OCTOBER 1958.

falls in a manner comparable to the fluctuations of the water level of a lake. In general, the water level rises when recharge exceeds discharge and falls when discharge exceeds recharge. Thus, the fluctuation of water level indicates to what extent the ground-water reservoir is being replenished or depleted.

Recharge to the deposits of Quaternary age in Crittenden County is from rainfall that penetrates the soil and reaches the water-bearing strata, from water added by influent streams, and from water that enters the county as underflow from adjoining areas.

Discharge is by pumping from wells, by plant transpiration, by evaporation, by seepage into streams, and by subsurface outflow to other areas.

Water levels in the deposits of Quaternary age were measured periodically from December 1957 to October 1958. The measurements were made in irrigation wells and in shallow domestic wells. Most of the domestic wells measured had been abandoned or were in use only part of the year. Water-level measurements are listed in table 4.

Figures 12-15 show the configuration of the water table and depth to water in the deposits of Quaternary age in December 1957, March 1958, June 1958, and October 1958. Each contour line on the maps has been drawn through points on the water table that have the same altitude. The altitudes of the points from which the measurements were made were interpolated from topographic maps. These water-table contour maps may be used to determine the direction of ground-water flow, because ground water moves at right angles to the contours in the direction of maximum slope.

Figure 12 shows the configuration of the water table in December 1957. The contours indicate that the regional movement of the ground water was generally to the southwest toward the St. Francis River (fig. 3) under an average hydraulic gradient of about 1.7 feet per mile. In the northeastern part of the county, however, some ground water was discharging into the Mississippi River along a narrow belt bordering the river. In the east-central portion of the county, the ground-water level and the river level were about equal. East and southeast of Horseshoe Lake, in the extreme southeastern part of the county, the bending of the contours downstream indicates that the river level was higher than the ground-water level and that some movement of water from the river into the Quaternary deposits probably was taking place. It is doubtful, however, if this was of importance in more than a narrow strip bordering the river. Sufficiently steep hydraulic gradients could not have been built up to move appreciable amounts of water more than a short distance inland. Most of the water probably was held in bank storage and was released to the river again when the river stage declined in mid-January 1958.

Figure 13 shows the configuration of the water table early in March 1958. The Mississippi River was beginning to rise at the time the water-level measurements were made. It was still effluent (receiving ground water) along much of the county's border, but was becoming influent (contributing water to the aquifer) in the southeastern part of the county. The bending of the 180- and 185-foot contours downstream indicates that a recharge ridge was again beginning to develop south and east of Horseshoe Lake. The river probably was influent along much of the eastern boundary of the county for several months, as the high river stage lasted until about the end of May 1958.

Figure 14 shows the configuration of the water table at the beginning of the irrigation season in June 1958. Generally, the regional movement of ground water was still southwest, but some ground water was being discharged into the Mississippi River from a narrow belt bordering the river.

Figure 15 shows the configuration of the water table after the close of the irrigation season in October 1958. The Mississippi River was at a relatively low stage and the bending of the contours upstream shows that the river was effluent along the entire eastern border of the county.

A comparison of these four water-table maps shows that the regional slope of the water table generally is to the southwest toward the St. Francis River. The Mississippi River acts as a drain most of the year, but during periods of high water the river may contribute to ground water. This generally is noticeable first in the extreme southeastern part of the county. During these high-water periods, the river probably does not contribute significant quantities of water to the aquifer, because most of the water is held in bank storage and is released back to the river during low-water stage.

Figure 16, a hydrograph of well 100, an unused irrigation well equipped with an automatic water-level recorder, shows fluctuations of the water table from December 1957 to October 1959. Much of the variation shown is due to the effects of pumping during the irrigation season. Generally, the water level in this well begins to

decline early in May with the beginning of the rice-irrigation season. The water level reaches a low in September, and with the close of the irrigation season, it begins a steady rise until the following spring.

Aquifer tests.—Only one aquifer test has been made of the deposits of Quaternary age in Crittenden County. Well 144 at the University of Arkansas Delta Substation, about 3 miles south of Turrell, was pumped for approximately 1 day at a rate of 1,450 gpm. Water-level fluctuations were measured in an observation well 511 feet from the pumped well. An average coefficient of transmissibility of 138,000 gpd/ft was computed. The average value for the coefficient of storage was computed to be 0.00046. Four aquifer tests made of similar materials in Mississippi County to the north yielded coefficients of transmissibility ranging from 116,000 to 290,000 gpd/ft and coefficients of storage ranging from 0.0005 to 0.0009 (Ryling, U. S. Geological Survey, oral communication). Thus, it is evident that, because of the rapid lateral variation in the lithology of the deposits of Quaternary age, the values of the coefficient of transmissibility vary widely from place to place.

Quality of Water.—The deposits of Quaternary age in Crittenden County yield calcium bicarbonate water. Chemical analyses of water from 56 wells screened in these deposits are shown in table 3, and records of the wells are given in table 2. Seventeen of the samples were taken from shallow domestic wells, one sample is from the 100-foot municipal well at Crawfordsville (well 96), and the remainder are from irrigation wells scattered throughout the county.

Water from the deposits of Quaternary age is considerably more mineralized than water from the two deeper aquifers, particularly in its content of iron, calcium, magnesium, sulfate, bicarbonate, and dissolved solids.

Water from the deposits of Quaternary age generally is neutral or slightly alkaline, but individual samples may be slightly acid. The pH of the samples determined in the laboratory ranged from 6.4 to 8.7. These were determined several weeks to several months after the samples were collected. Comparison of the laboratory pH values with pH values taken in the field at the time of sampling indicates that the samples generally become more alkaline with time. This is perhaps best illustrated by table 5 which lists partial chemical analyses of water from six selected shallow wells screened in deposits of Quaternary age. These wells were resampled at intervals over a period extending from October 1, 1958, to June 3, 1959. Water from 5 of the wells had a field pH of 6.8 to 7.2, while water from well 162 had a field pH of 6.0. When checked in the laboratory, the pH values of the samples from the previously mentioned 5 wells were found to range from 7.2 to 8.7. The samples from well 162 had a pH of 6.4 to 8.4.

Because the pH value represents the overall balance of a series of equilibria existing in solution, any disturbance of these equilibria may result in a change in pH (Hem, 1959, p. 46). Water from the deposits of Quaternary age in this area contains dissolved carbon dioxide gas and calcium bicarbonate. Such a water contains a weak acid (H_2CO_3) and its salt and is, therefore, a buffered solution. Most natural waters contain this combination as the principal control of their pH. This carbon dioxide-bicarbonate equilibrium and buffer system is easily disturbed by loss of carbon dioxide. When such a water is brought to the surface, as in a well, carbon dioxide will be lost from solution until the amount equals that which will remain under the partial pressure of the gas in the atmosphere and a new equilibrium will be established. Loss of carbon dioxide is accompanied by a gradual increase in pH, precipitation of iron and sometimes calcium carbonate, and a lowering of total hardness, alkalinity, total solids, and specific conductance.

Ryling (oral communication) determined the change of pH with time in a water sample from the Quaternary deposits of Mississippi County which borders Crittenden County on the north. The pH of the sample was 6.5 at the time the sample was taken. After 41 hours the pH had risen to 7.1, and when rechecked 7 days after sampling, it was still 7.1. After 20 days the pH was 7.2, and a final determination was made 33 days after sampling at which time the pH had risen to 8.6. It may be seen that the laboratory analyses presented in tables 3 and 5 are not necessarily representative of the water as it exists in the aquifer, particularly when the laboratory pH has a value in the neighborhood of 8 or higher. The results are not necessarily invalid, however, because they may be more representative of the water when it is used, particularly when storage is involved prior to use.

Figure 17 shows total iron content in ppm plotted against well depth. There appears to be a tendency toward higher iron content in the water from the deeper portion of the aquifer. Unfortunately, no data are available for the depths between 60 and 100 feet. Only 3 of the 56 analyses presented in table 3 were below the 0.3 ppm limit

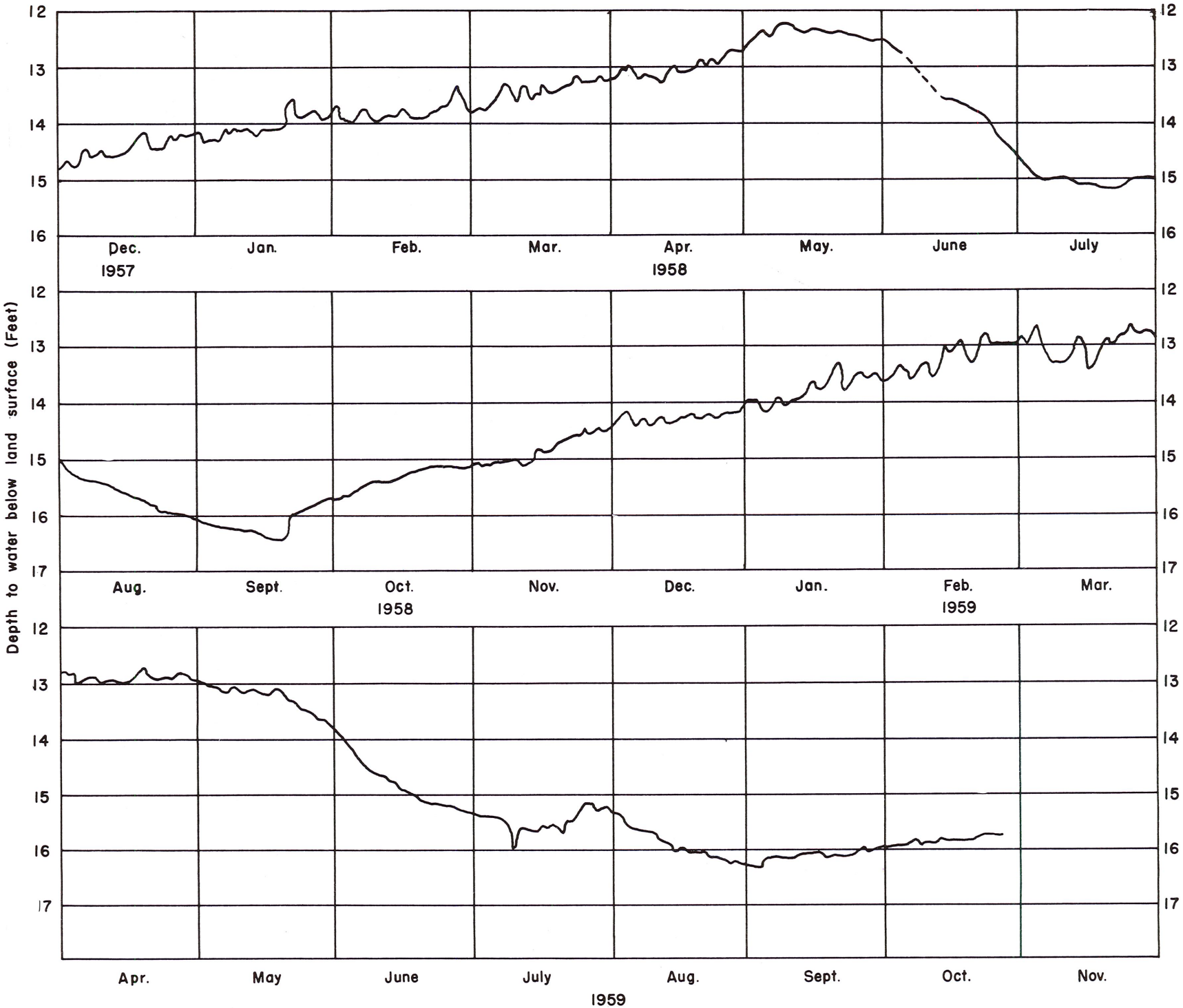


Figure 16. Hydrograph of well 100 in deposits of Quaternary age.

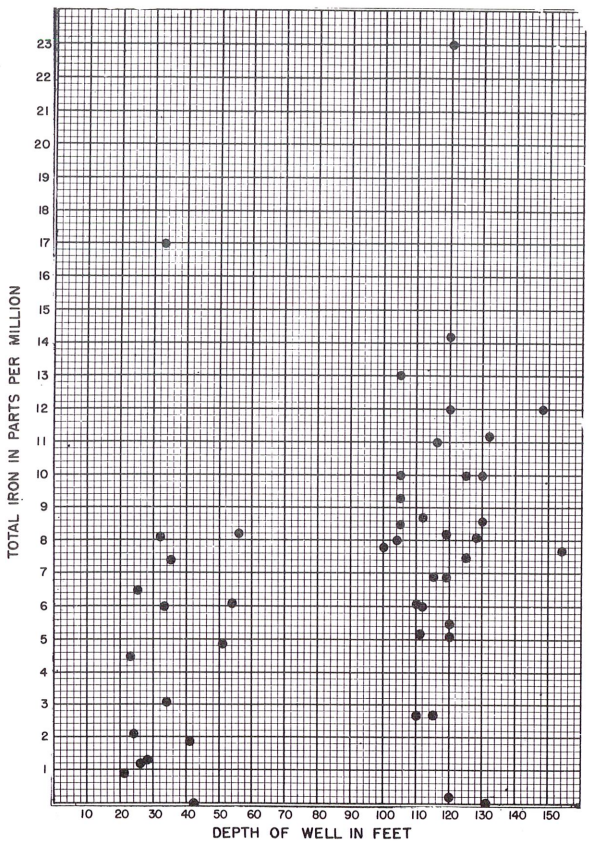


Figure 17. Variation of total iron content with well depth in water from deposits of uaternary age.

for iron plus manganese suggested by the U. S. Public Health Service.

The total iron content of water from individual wells in the Quaternary deposits may fluctuate considerably from time to time as shown in table 5. The greatest fluctuation occurred in water from well 136. The total iron content varied from 2.1 ppm on November 25, 1958, to 14 ppm on March 10, 1959. The greatest single change of 10.9 ppm occurred in a period of 12 days between November 13-25, 1958. Water from all 6 wells showed a decrease in total iron content from November 1958 to February 1959. No explanation is possible at this time as to why this decrease occurred. Sufficient water was pumped in all cases to insure that the sample did not contain water that had remained in contact with the casing since the pump was last used. The samples were clear and colorless at the time of the collection, but within several hours they began to turn yellow as ferric hydroxide began to precipitate.

The high iron content of many of the samples appears impossible in water of neutral or slightly alkaline nature. Because the county is characterized by old flood plain and meander-belt topography with numerous ponds, bayous, and abandoned stream channels, it is likely that the alluvium in many places contains a high content of organic matter, thus producing a reducing environment. Such an environment would be conductive to the retention of iron in the soluble ferrous state even though the water is alkaline.

Water from the deposits of Quaternary age generally is moderately hard to very hard and requires treatment for many uses, although it is commonly used without treatment for rural domestic and irrigation purposes.

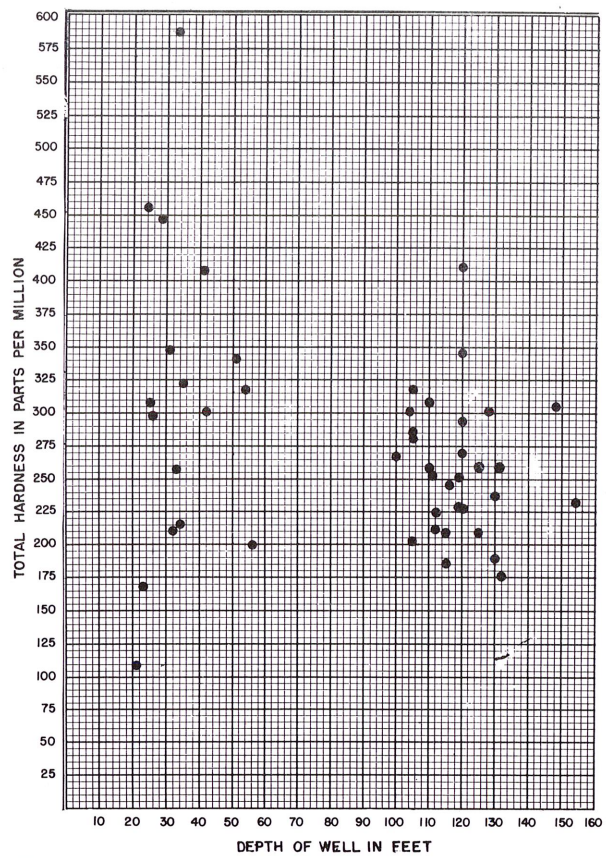


Figure 18. Variation of total hardness with well depth in water from deposits of Quaternary age.

Figure 18 shows total hardness plotted against well depth. The data suggest that hardness is somewhat more uniform at depth, with the majority of samples from wells over 100 feet in depth varying from 175 to 320 ppm of hardness. The shallow wells (less than 60 feet) yield water with a much wider range in hardness.

Silica (SiO_2) is an important chemical constituent of natural waters that was omitted from table 3, because only two analyses listed this component. Water from well 144 had a silica content of 35 ppm, and water from well 154

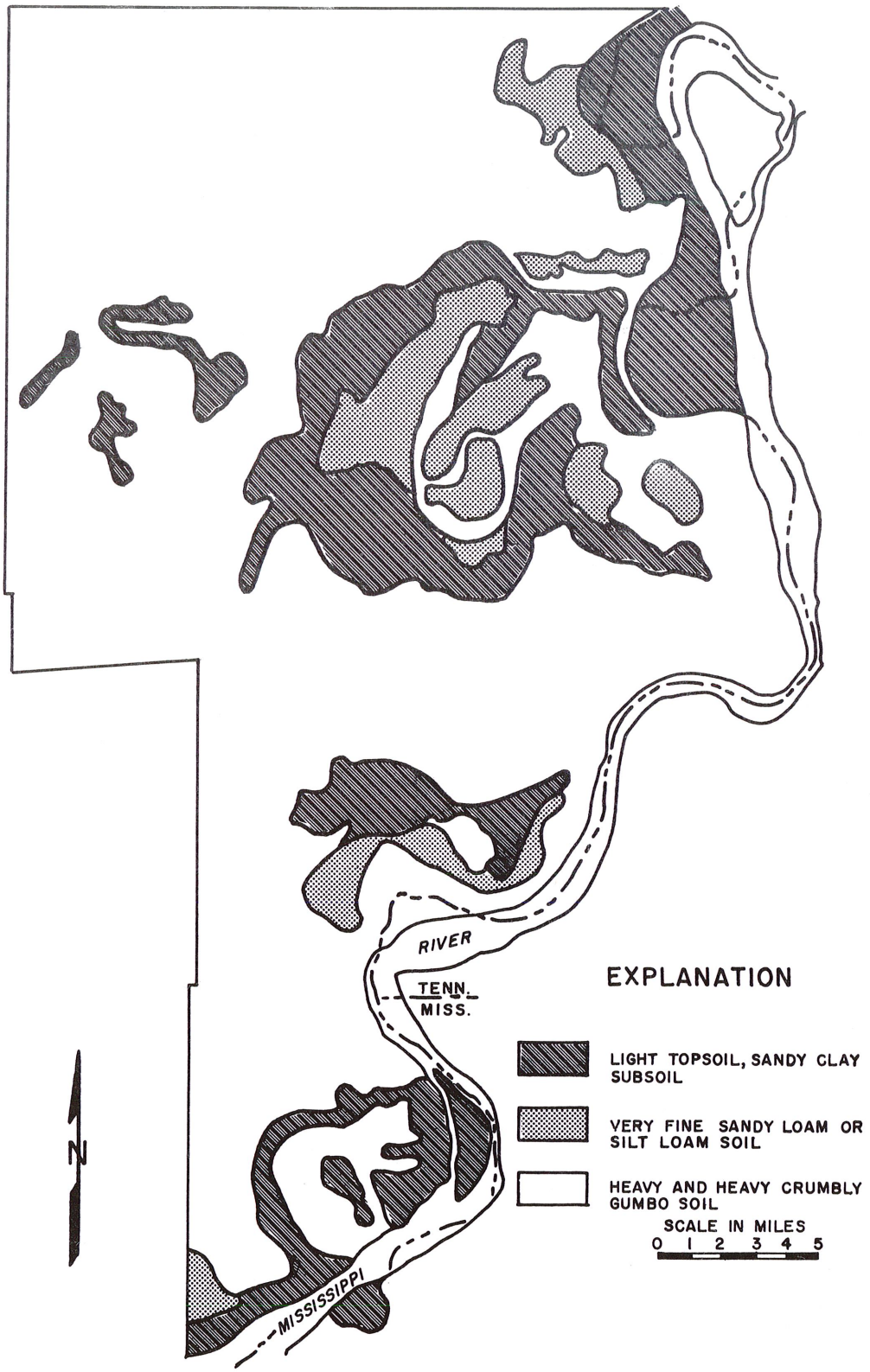


Figure 19. Soils map of Crittenden County (after Soil Conservation Service, U. S. Dept. of Agriculture).

had a silica content of 12 ppm. These two analyses, together with five analyses of water from wells in the alluvium of Mississippi County to the north, indicate that the silica content varies greatly in water from deposits of this type. The analyses from the wells in Mississippi County show a range in silica content from 3.8 to 26 ppm.

When classified by Wilcox's method, 53 of the 56 water samples from the Quaternary deposits rate excellent to good for irrigation. The other 3 samples rate good to permissible.

Recharge.—In general, the clay and silt in the upper part of the deposits of Quaternary age slows the downward percolation of rainfall and surface water into the more permeable lower part of the deposits. At some places, however, the upper part of the deposits is sufficiently permeable to allow an appreciable amount of recharge but the location and extent of these recharge areas is not known at present. Some general information is available, however, which may offer clues as to where recharge could most easily take place.

Figure 11 is a very generalized map showing the thickness of the surface clays. These clays are commonly silty and may contain appreciable amounts of sand. Recharge may more easily occur where this clay cap is thin. This map must be used with caution, as closer control probably would radically alter the configuration of the various zones.

Figure 19 is adapted from a soils map of the county prepared by the Soil Conservation Service of the U. S. Department of Agriculture. The least favorable areas for recharge should be those shown as containing heavy gumbo soil.

Some recharge from the Mississippi River into the Quaternary deposits occurs at times. This, however, can be of importance only in a zone a few miles wide bordering the river, because sufficiently steep hydraulic gradients cannot be established and maintained to move appreciable quantities of water farther inland from the river.

Possibilities for further development.—The utilization of ground water from the deposits of Quaternary age can be increased substantially in Crittenden County. The estimated pumpage in 1959 was about 8.7 billion gallons a year. No permanently enclosed depressions had been developed on the water table at that time, indicating that the Quaternary deposits were not being overdeveloped.

Logs of wells

Listed in the following pages are logs of wells in Crittenden County. All the logs are as reported by the drillers, except that formational boundaries have been added where possible by the author. Altitudes were approximated from topographic maps and are given in feet above mean sea level. The locations of the wells are shown in figure 10, and data concerning the wells are listed in table 2.

WELL 5

Owner: H. M. Brinkley
Location: NW¼NE¼SE¼ sec. 10, T. 3 N., R. 7 E.
Altitude: 200 feet
Driller: C. M. Journey

	Thickness (feet)	Depth (feet)
Quaternary:		
Clay, sandy	22.2	22.2
Sand	69.2	91.4
Gravel	16.9	108.3
Sand	10	118.3
Gravel	16.7	135
Tertiary:		
Eocene:		
Clay, hard	16.4	151.4
Clay	43.7	195.1
Gumbo	5	200.1
Sand	16.2	216.3
Clay	21.3	237.6
Shale gumbo	5	242.6
Sand	10	252.6
Gumbo	6.8	259.4
Sand	21.5	280.9
Shale, sandy	21.4	302.3
Shale	2	304.3
Sand	3	307.3
Gumbo	2	309.3
Sand, hard	5	314.3
Clay	5	319.3
Sand, loose	4.9	324.2
Clay, crumbly	26.4	350.6
Rock, soft	.3	350.9
Shale, hard	5	355.9
Rock, hard	.8	356.7
Sand	5	361.7
Rock, hard	.7	362.4
Gumbo	16.6	379
Rock, soft	.8	379.8
Gumbo	40.5	420.3
Shale	7	427.3
Sand	4.5	431.8
Sand, hard	79.3	511.1
Clay	5.7	516.8
Gumbo	36.9	553.7
Rock	.7	554.4
Shale	6	560.4
Gumbo	13	573.4
Rock, hard	8.8	582.2
Rock	.5	582.7
Gumbo	1.5	584.2
Clay, crumbly	21.7	605.9
Clay, hard	21.8	627.7
Clay	3	630.7
Sand, coarse	17	647.7
Sand	18	665.7
Gumbo	3.8	669.5
Sand	75.5	745
Clay	11.9	756.9
Sand	3	759.9
Shale	3	762.9

	Thickness (feet)	Depth (feet)
Gumbo	2	764.9
Sand	13.8	778.7
Shale	3	781.7
Rock, soft	1.2	782.9
Shale, sandy	17.6	799.5
Shale, hard	21.8	821.3
Shale, sandy	10	831.3
Gumbo, white	12	843.3
Shale, very hard	22.4	865.7
Sand, hard	43.8	909.5
Shale, hard	10	919.5
Shale, sandy	12	931.5
Sand, hard and streaks of shale	22.1	953.6
Shale, hard	10	963.6
Sand, hard	33.8	997.4
Shale, hard	10	1,007.4
Gumbo	2	1,009.4
Clay	3	1,012.4
Gumbo	2	1,014.4
Shale, hard	29.2	1,043.6
Sand	5	1,048.6
Shale	5	1,053.6
Clay, crumbly	8	1,061.6
Sand, hard	44.3	1,105.9
Sand, soft	71	1,176.9
Shale, hard	5	1,181.9
Gumbo, hard	10.7	1,192.6
Unreported	14.4	1,207
Shale, hard	15	1,222
Rock, hard	1.1	1,223.1
Gumbo	4.4	1,227.5
Rock, hard	.9	1,228.4
Clay, shale	2	1,230.4
Rock, medium	1.5	1,231.9
Shale	4	1,235.9
Shale, gumbo	12.7	1,248.6
Clay	22.2	1,270.8
Gumbo	10	1,280.8
Shale, hard	11.2	1,292
Gumbo shale, hard	83.5	1,375.5
Gumbo shale	20.3	1,395.8
Gumbo shale, hard	61.9	1,457.7
Clay	2	1,459.7
Sand, hard	17	1,476.7
Shale	2.2	1,478.9
Sand	42.8	1,521.7
Sand, good	26.2	1,547.9
Clay	15.8	1,563.7
Shale	20.9	1,584.6
Sand	67.7	1,652.3
Clay	15.2	1,667.5

WELL 68

Owner: City of West Memphis
Location: NW¼SE¼NE¼ sec. 12, T. 6 N., R. 8 E.
Altitude: 210 feet
Driller: Layne-Arkansas Co.

	Thickness (feet)	Depth (feet)
Clay	18	18
Soft clay	32	50
Sand	40	90
Sand and gravel	30	120
Boulders	2	122
Sand	14	136
Clay	9	145
Sandy shale	25	170
Shale	22	192
Soft shale	38	230
Sand	54	284
Shale	13	297
Boulders	1	298
Sand	82	380
Clay	6	386
Sand	123	509
Boulder at 509		
Shale	9	518
Shale and boulders	6	524
Shale	14	538
Sandy shale	34	572
Hard shale	8	580
Boulder	1	581
Shale	11	592
Sand	18	610
Shale	20	630
Hard shale	22	652
Shale	18	670
Sandy shale	24	694
Sand and shale	22	716
Sandy shale	132	848
Sand	22	870
Shale	22	892
Sand	150	1,042
Sand with shale streaks	59	1,101
Rock	1	1,102
Shale	5	1,107
Rock	1	1,108
Gumbo	40	1,148
Shale	193	1,341
Hard shale	19	1,360
Shale	44	1,404
Gumbo	28	1,432
Sand	5	1,437
Hard shale	8	1,445
Fine sand	45	1,490
Medium sand	91	1,581
Stopped in sand		

WELL 75

Owner: City of West Memphis
Location: SW¼NW¼ sec. 7, T. 6 N., R. 9 E.
Altitude: ——
Driller: Layne-Arkansas Co.

	Thickness (feet)	Depth (feet)
Gumbo and clay	58	58
Sandy clay	25	83
Loose sand	50	133
Sand	153	286
Shale	16	302
Coarse sand	68	370
Sluffy shale	86	456
Sand	71	527
Sandy shale	304	831
Sand	68	899
Shale, streaks of sand	225	1,124
Hard rock	1	1,125
Hard shale	35	1,160
Sluffy shale	114	1,274
Hard shale	27	1,301
Hard rock	1	1,302
Hard shale and gumbo	39	1,341
Sandy shale	48	1,389
Sand	15	1,404
Sandy shale	37	1,441
Medium water-bearing sand	87	1,528
Broken shale	12	1,540

WELL 80

Owner: City of West Memphis
Location: NW¼NW¼NW¼ sec. 18, T. 6 N., R. 9 E.
Altitude: 210 feet
Driller: Carloss Well Supply Co.

	Thickness (feet)	Depth (feet)
Gumbo	12	12
Quick sand	28	40
Yellow sandy clay	40	80
Tough clay and gravel	28	108
Gumbo (clay)	111	219
Coarse water-bearing sand	22	241
Fine water-bearing sand	77	318
Hard yellow clay	7	325
Very fine sand	169	494
Lignite (solid)	1.5	495.5
Coarse water-bearing sand	54.5	550
Lignite	2	552
Coarse water-bearing sand	51	603
Yellow clay	10	613
Very fine sand	7	620
Hard coarse sand with lignite	80	700
Sandy shale (clay)	25	725
Shale	20	745
Hard fine water-bearing sand	185	930
Sandrock (hard) ?	10	940
Hard sandy shale	50	990
Hard fine sand	20	1,010
Hard yellow clay	5	1,015
Hard fine sand	45	1,060
Tough gumbo (clay)	118	1,178
Hard shale	17	1,195
Hard fine sand	10	1,205
Sandrock	5	1,210
Hard fine sand	30	1,240
Hard tough gumbo (clay) with 3 to 4 ft. of sand	86	1,326
Water-bearing sand	189	1,515

WELL 81

Owner: U. S. Army Corps of Engineers
Location: NE¼NE¼NE¼ sec. 23, T. 6 N., R. 9 E
Altitude: 205 feet
Driller: C. M. Journey

	Thickness (feet)	Depth (feet)
Made land-sand	15	15
Clay loam	26	41
River sand	42	83
Sand and gravel	22	105
Hard clay	20	125
White sand	8	133
White clay	115	248
Fine sand	44	292
Soft white clay	4	296
Water-bearing sand	60	356
Sandy clay	29	385

WELL 82

Owner: U. S. Army Corps of Engineers
Location: NE¼NE¼NE¼ sec. 23, T. 6 N., R. 9 E.
Altitude: 205 feet
Driller: Unknown

	Thickness (feet)	Depth (feet)
Loam and clay	77.4	77.4
River sand	12.6	90
Clay	3	93
Fine sand and clay	10	103
White sand	41	144
White clay	9	153
White sand	2	155
Tough white clay	95	250
Fine white artesian sand	66	316
Coarse white sand, water-bearing	27.09	333.09

WELL 95

Owner: Town of Crawfordsville
Location: SW¼SW¼SW¼ sec. 14, T. 7 N., R. 7 E.
Altitude: 223 feet
Driller: Carloss Well Supply Co.

	Thickness (feet)	Depth (feet)
Quaternary:		
Surface loam	23	23
Sand and gravel	172	195
Tertiary:		
Eocene:		
Claiborne group and younger(?):		
Gumbo	34	229
Soft rock	1	230
Gumbo	25	255
Sand	92	347
Clay	2	349
Sand	5	354
Clay	6	360
Sand	268	628
Sandy clay	44	672
Coarse sand	65	737
Sand rock	1	738
Sand	10	748
Hard gumbo and shale	51	799
Soft clay	31	830
Sandy clay	32	862
Hard sand	44	906
Hard shale and sand	38	944
Rock	1	945
Hard shale and sand	23	968
Gumbo	4	972
Lime rock	10	982
Gumbo	2	984
Lime rock	6	990
Gumbo	3	993
Lime rock	1	994
Gumbo	10	1,004
Hard shale and gumbo	42	1,046
Rock	1	1,047
Gumbo	72	1,119
Soft brown clay and shale	44	1,163
Gumbo	53	1,216
Water sand	10	1,226
Wilcox group:		
Gumbo mixed with sand	10	1,236
Rock	2	1,238
Gumbo	13	1,251
Sandy gumbo and shale	57	1,308
Rock	1	1,309
Gumbo	12	1,321
Lignite	3	1,324
Gumbo	42	1,366
Rotten shale	4	1,370
Hard shale	29	1,399
Sand mixed with clay	11	1,410
Gas rock showing gas	4	1,414
Sand mixed with clay	35	1,449
Hard shale	26	1,475
Clean sand	15	1,490
Sand	8	1,498
Gumbo	24	1,522
Water sand	62	1,584

WELL 102

Owner: Bloodworth Bros.
Location: NE¼SE¼SW¼ sec. 34, T. 7 N., R. 7 E.
Altitude: 211 feet
Driller: Wixson Bros.

	Thickness (feet)	Depth (feet)
Quaternary:		
No information	16	16
Gumbo	45	61
Gravel formation	57.75	118.75

WELL 107

Owner: City of Marion
Location: NE¼SW¼NW¼ sec. 24, T. 7 N., R. 8 E.
Altitude: 220 feet
Driller: Layne-Arkansas Co.

	Thickness (feet)	Depth (feet)
Quaternary:		
Clay	43	43
Coarse sand	66	109
Tertiary:		
Eocene:		
Clay	231	340
Sand	145	485
Shale	5	490
Fine sand	114	604
Shale	113	717
Fine sand	68	785
Shale	31	816
Sandy shale	104	920
Shale	40	960
Sand	26	986
Shale	128	1,114
Rock	1	1,115
Shale	28	1,143
Rock	2	1,145
Hard shale	126	1,271
Rock	1	1,272
Gumbo	50	1,322
Rock	1	1,323
Gumbo	25	1,348
Fine sand	20	1,368
Gumbo	18	1,386
Fine hard sand	43	1,429
Medium sand	71	1,500
Stopped in sand		

WELL 108

Owner: City of Marion
Location: NW¼SE¼NW¼ sec. 24, T. 7 N., R. 8 E.
Altitude: 222 feet
Driller: Layne-Arkansas Co.

	Thickness (feet)	Depth (feet)
Quaternary:		
Gumbo	12	12
Sand	100	112
Tertiary:		
Eocene:		
Claiborne group and younger(?):		
Gumbo	15	127
Thin rock		
Gumbo	150	277
Sand	1	278
Shale	18	296
Sand	202	498
Gumbo	25	523
Boulder		
Gumbo	22	545
Sand	80	625
Gumbo	36	661
Sand	31	692
Gumbo	3	695
Shale	6	701
Hard packed sand	87	788
Gumbo	25	813
Sand	61	874
Shale	16	890
Hard packed sand	196	1,086
Wilcox group:		
Gumbo	36	1,122
Rock	2	1,124
Gumbo	18	1,142
Boulder		
Gumbo	27	1,169
9 inches of rock		
Shale	7	1,176
Gumbo	73	1,249
Shale	15	1,255
Gumbo	16	1,264
Shale	7	1,271
Gumbo	5	1,287
Shale	12	1,299
Sandy shale	6	1,305
Fine sand	53	1,358
Hard packed artesian sand	162	1,520
Gumbo		

WELL 110

Owner: C. E. McMinn
Location: SE¼SW¼SW¼ sec. 6, T. 7 N., R. 9 E.
Altitude: 112 feet
Driller: Wixson Bros.

	Thickness (feet)	Depth (feet)
Quaternary:		
Gumbo	15	15
Blue mud	20	35
Good formation	77	112

WELL 115

Owner: Mound City Planting Co.
Location: SE¼NW¼NW¼ sec. 33, T. 7 N., R. 9 E.
Altitude: 215 feet
Driller: Carloss Well Supply Co.

	Thickness (feet)	Depth (feet)
Clay and top soil	8	8
Blue sand and soft blue clay	7	15
Hard blue clay	27	42
Coarse water-bearing sand and gravel	50	92
Blue clay	12	104

WELL 116

Owner: Mound City Planting Co.
Location: NW¼NW¼NW¼ sec. 34, T. 7 N., R. 9 E.
Altitude: 222 feet
Driller: Carloss Well Supply Co.

	Thickness (feet)	Depth (feet)
Topsoil and clay	5	5
Blue clay	20	25
Very fine brown water sand	10	35
Fine bluish water sand	35	70
Coarse brown water sand and small gravel (18-20 slot)	24	94
Logs and wood	3	97
Coarse water sand and large gravel	11	108
Clay	3	111

WELL 117

Owner: John Twist
Location: NE¼NE¼SW¼ sec. 4, T, 8 N., R. 6 E.
Altitude: 215 feet
Driller: Luhr Bros.

	Thickness (feet)	Depth (feet)
Quaternary:		
Clay	5	5
Fine sand	35	40
Coarse sand	30	70
Coarse sand and gravel	30	100
Heavy gravel	18.75	118.75

WELL 123

Owner: City of Earle
Location: SW¼NE¼SW¼ sec. 33, T. 8 N., R. 6 E.
Altitude: 210 feet
Driller: Layne-Arkansas Co.

	Thickness (feet)	Depth (feet)
Sandy clay	6	6
Clay	35	41
Fine sand	20	61
Gumbo	8	69
Sand	15	84
Sand and gravel	114	198
Gumbo	36	234
Boulder at 234		
Gumbo	74	308
Boulders at 308		
Gumbo	23	331
Hard sand	59	390
Gumbo	10	400
Hard sand	118	518
Gumbo	12	530
Packed sand	25	555
Gumbo	10	565
Sand and gravel	21	586
Sand	40	626
Gumbo	15	641
Sand	22	663
Gumbo	41	704
Rock at 704		
Gumbo	46	750
Boulders at 750		
Shale	30	780
Rock at 780		
Gumbo	3	783
Rock at 783		
Sand	15	798
Gumbo	10	808
Rock at 808		
Gumbo, streaks of boulders	37	845
Hard sand	34	879
Gumbo	6	885
Hard sand	55	940
Shale	30	970
Sand	59	1,029
Gumbo	4	1,033
Water sand	87	1,120
Gumbo	74	1,194
Rock at 1194		
Gumbo	114	1,308
Shale	55	1,363
Gumbo	75	1,438
Fine sand	10	1,448
Water sand	81	1,529

WELL 124

Owner: City of Earle
Location: SW¼NE¼SW¼ sec. 33, T. 8 N., R. 6 E.
Altitude: 210 feet
Driller: Layne-Arkansas Co.

	Thickness (feet)	Depth (feet)
Sandy clay	20	20
Clay and gravel	10	30
Fine sand	20	50
Clay	15	65
Sand and gravel	8	73
Coarse sand	45	118
Sand	21	139
Boulders	2	141
Sand	27	168
Rock	1	169
Sandy shale	31	200
Clay	29	229
Rock	1	230
Clay	16	246
Shale and clay	95	341
Sand	54	395
Sandy shale	16	411
Lignite	6	417
Hard sand	63	480
Sandy shale	20	500
Sand	7	507
Rock	1	508
Shale and lignite	10	518
Sand and shale	28	546
Sand	67	613
Shale	32	645
Sand and lignite	68	713
Hard sand and lignite	27	740
Hard sand	20	760
Hard shale	40	800
Sandy shale	44	844
Hard shale and lignite	66	910
Hard sand	52	962
Sandy shale	78	1,040
Hard shale	40	1,080
Sand and shale	30	1,110
Hard shale	25	1,135
Gumbo	10	1,145
Hard shale	71	1,216
Rock	1	1,217
Gumbo	15	1,232
Hard shale	68	1,300
Gumbo	30	1,330
Hard shale	12	1,342
Rock	1	1,343
Gumbo	12	1,355
Gumbo	23	1,378
Rock	1	1,379
Hard shale	11	1,390
Gumbo	16	1,406
Hard shale	15	1,421
Fine hard sand	4	1,425
Fine sand	19	1,444
Sand	86	1,530

WELL 128

Owner: Leo Linn (formerly J. P. Cobb)
Location: NE¼NE¼SW¼ sec. 5, T. 8 N., R. 7 E.
Altitude: 215 feet
Driller: C. M. Journey

	Thickness (feet)	Depth (feet)
Gumbo	23	23
Sand	45	68
Sand and gravel	22	90
Gravel	66	156
Sand	45	201
Shale	65	266
Gumbo	162	428
Sand	50	478
Shale	134	612
Sand	119	731
Shale	45	776
Sand	290	1,066
Gumbo	67	1,133
Gumbo and rock	45	1,178
Gumbo	64	1,242
Gumbo and rock	21	1,263
Gumbo	64	1,327
Shale	21	1,348
Sand	65	1,413
Shale	42	1,455
Shale and rock	21	1,476
Sand	172	1,648

WELL 167

Owner: Fred Wasmer
Location: NE¼NE¼NW¼ sec. 21, T. 9 N., R. 6 E.
Altitude: 215 feet
Driller: J. H. Abel and Son

	Thickness (feet)	Depth (feet)
Quaternary:		
Clay	30	30
Fine sand	10	40
Medium sand	10	50
Gravel and sand	50	100
Coarse sand	10	110
Gravel	18	128

WELL 170

Owner: John Twist
Location: NW¼NE¼NE¼ sec. 30, T. 9 N., R. 6 E.
Altitude: 210 feet
Driller: Luhr Bros.

	Thickness (feet)	Depth (feet)
Quaternary:		
Clay	5	5
Clay and sand	10	15
Sand and gumbo	10	25
Sand and gumbo	10	35
Fine sand	10	45
Coarse sand	25	70
Coarse sand and gravel	49.7	119.7

WELL 171

Owner: John Twist
Location: NE¼SE¼SW¼ sec. 30, T. 9 N., R. 6 E.
Altitude: 210 feet
Driller: Luhr Bros.

	Thickness (feet)	Depth (feet)
Quaternary:		
Clay	6	6
Fine sand	10	16
Coarse sand	19	35
Coarse sand and gravel	65	100
Coarse sand	4.17	104.17

WELL 184

Owner: Elbert Smith, Jr.
Location: NE¼SE¼SE¼ sec. 27, T. 9 N., R. 7 E.
Altitude: 215 feet
Driller: Wixson Bros.

	Thickness (feet)	Depth (feet)
Quaternary:		
No information	17	17
Sand and mud	33	50
Fine sand	19	69
Good gravel formation	48.25	117.25

WELL 196

Owner: Pacific Place Farms
Location: NE¼SW¼SE¼ sec. 23, T. 9 N., R. 8 E.
Altitude: 225 feet
Driller: Carloss Well Supply Co.

	Thickness (feet)	Depth (feet)
Quaternary:		
Surface clay	15	15
Fine blue sand	45	60
Coarse sand and gravel	55	115

WELL 197

Owner: Pacific Place Farms
Location: SE¼SW¼NE¼ sec. 27, T. 9 N., R. 8 E.
Altitude: 223 feet
Driller: Carloss Well Supply Co.

	Thickness (feet)	Depth (feet)
Quaternary:		
Loam	16	16
Fine to coarse sand	44	60
Coarse sand and gravel	50	110

WELL 198

Owner: E. R. Upshaw (formerly Baker Lumber Co.)
Location: SE¼NW¼NE¼ sec. 29, T. 9 N., R. 8 E.
Altitude: 236 feet
Driller: Johnson and Fleming

	Thickness (feet)	Depth (feet)
Quaternary:		
"Buckshot" grading downward into sand	16	16
Sand and gravel with thin clay partings	166	182
Tertiary:		
Eocene:		
Blue clay with enough fine sand to make sinking by hydraulic process easy	658	840
Gray sand like that at Memphis, containing lignite in large quantities	24	864

WELL 199

Owner: Town of Turrell
Location: SE cor. NE¼ sec. 29, T. 9 N., R. 8 E.
Altitude: 222 feet
Driller: Layne-Arkansas Co.

	Thickness (feet)	Depth (feet)
Quaternary:		
Gumbo	20	20
Fine sand	90	110
Coarse sand	21	131
Clay	1	132
Coarse sand	16	148
Gravel	3	151
Tertiary:		
Eocene:		
Claiborne group and younger(?):		
Clay	68	219
Sandy shale	41	260
Fine loose sand	90	350
Clay	44	394
Sand	10	404
Clay	10	414
Sand	76	490
Clay	23	513
Hard sand	11	524
Shale	14	538
7 inches of rock		
Clay	12	550
10 inches of rock		
Sandy shale	10	560
4 inches of rock		
Sandy shale	7	567
Hard sand	467	1,034
Gumbo	8	1,042
Hard sand	10	1,052

	(feet)	(feet)
Wilcox group(?):		
Gumbo	156	1,208
10 inches of rock		
Gumbo and boulders	6	1,214
Gumbo	97	1,311
Shale	22	1,333
Fine sand	12	1,345
Hard packed sand	79	1,424
Shale and lignite	1	1,425
Hard packed sand	84	1,509
Still in some sand	58	1,567

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TABLE 2

Record of wells in Crittenden County, Ark.

Well number: Well number in parentheses indicates that the chemical analysis of water is given in table 3.
Altitude: Altitudes are of the land surface at the well sites.

Stratigraphic unit: Qt, Quaternary deposits; Claiborne, Claiborne group; Wilcox, Wilcox group.
Use: Irr, irrigation; Dom, domestic; N, none; PS, public supply; I, industrial; stk, stock.

Well No.	LOCATION	OWNER OR TENANT	DRILLER	Altitude above sea level (feet)	Date of well completion	Type of well	Depth of well (feet)	Diameter of well (inches)	Stratigraphic unit	Depth to water below land surface (feet)	Date of water-level measurement	Type of pump	Well yield (gpm)	Use	REMARKS
	T.3N., R.7E.														
(1)	1dbc	Blair Lowrance	C. M. Journey	204	1940	Drilled	1624	4.5–3	Wilcox	--------	--------	Suction	--------	Dom	
2	4bca	H. M. Brinkley	Lewis Diesel Engine Co.	200	1957	do	--------	--------	Qt	9.78	6–12–58	Turbine	--------	Irr	
(3)	4cab	do	--------	200	--------	Driven	28.4	1.25	Qt	10.08	9– 4–58	Pitcher	--------	Dom	
(4)	10bbb	do	--------	200	--------	Drilled	1650±	--------	Wilcox	--------	--------	--------	--------	PS	
5	10dac	do	C. M. Journey	200	1934	do	1650	5–3	Wilcox	--------	--------	--------	--------	PS	See log
6	15bcc	do	Lewis Diesel Engine Co.	199	1957	do	--------	14	Qt	17.23	6–12–58	Turbine	--------	Irr	
7	17bdd	--------	--------	199	--------	Driven	--------	1.25	Qt	12.77	6–12–58	None	--------	N	
8	18bda	--------	--------	195	--------	do	51	1.25	Qt	5.78	6–12–58	Pitcher	--------	N	
	T.4N., R.6E.														
9	1bcc	--------	--------	197	--------	do	30	1.25	Qt	13.52	6–11–58	do	--------	N	St. Francis Co.
10	25ddd	Joe Beck	--------	200	--------	do	37	1.25	Qt	12.63	12–10–57	do	--------	N	St. Francis Co.
11	36dda	do	--------	203	--------	do	29	1.25	Qt	7.97	6–12–58	do	--------	N	St. Francis Co.
	T.4N., R.7E.														
12	2bbb	--------	--------	200	--------	do	24	1.25	Qt	4.56	6–11–58	do	--------	N	
13	2dca	--------	--------	200	--------	do	31	1.25	Qt	8.66	12–10–57	do	--------	N	
14	3aca	Ragland Plantation	Cart Well Co.	200	1953	Drilled	150	16	Qt	8.76	6–12–58	Turbine	3200	Irr	
(15)	3cc	Ragland Plantation	--------	196	--------	Driven	25	1.25	Qt	8.46	9– 9–58	Pitcher	--------	PS	
16	9aaa	do	Cart Well Co.	195	1956	Drilled	144	10	Qt	4.74	6–12–58	Turbine	1400	Irr	
17	9ccd	Nicky Eason Plantations	Wixson Bros.	200	1957	do	110	12	Qt	7.23	6–12–58	do	--------	Irr	
18	15ccd	--------	--------	203	--------	Driven	--------	1.25	Qt	6.98	12–10–57	Pitcher	--------	N	
(19)	23bcd	R. B. Snowden	T. O. Gibbs	200	1950	Drilled	1645	6–3	Wilcox	--------	--------	Turbine	--------	PS	
	T.4N., R.8E.														
(20)	17bdb	--------	--------	205	--------	Driven	33	1.25	Qt	21.48	6–12–58	Pitcher	--------	Dom	
21	31dbb	--------	--------	200	--------	do	--------	1.25	Qt	13.93	6–11–58	do	--------	N	
	T.5N., R.6E.														
22	1daa	Mallory Farms	--------	197	--------	Drilled	--------	--------	Qt	--------	--------	Turbine	--------	Irr	St. Francis Co.
23	12daa	--------	--------	196	--------	Driven	39	1.25	Qt	9.86	5–28–58	do	--------	N	St. Francis Co.
	T.5N., R.7E.														
24	5bcb	E. C. and J. I. Gillespie	Cart Well Co.	205	--------	Drilled	110	12	Qt	10.57	5–28–58	do	2000	Irr	
25	12cba	Barton Planting Co.	--------	207	--------	Driven	24	1.25	Qt	8.62	6–11–58	Pitcher	--------	Dom	
26	17bda	J. E. Neal, Jr.	Lewis Diesel Engine Co.	200	1957	Drilled	125	14	Qt	10.98	6–13–58	Turbine	--------	Irr	
(27)	28cb	B. C. Pouncey, Jr.	do	203	1955	do	--------	12	Qt	11.68	6–11–58	do	--------	Irr	
(28)	29cbb	do	W. G. Lanham	200	1920	do	1700	4	Wilcox	--------	--------	--------	--------	Dom-I	
29	34caa	Carlson Bros.	--------	--------	--------	do	800?	3	?	--------	--------	None	--------	N	
	T.5N., R.8E.														
30	7dad	Mt. Olive Church	--------	205	--------	Driven	19	1.25	Qt	3.51	6–12–58	Pitcher	--------	PS	
31	10bdd	--------	--------	208	--------	do	29	1.25	Qt	6.81	6–12–58	do	--------	N	
32	16daa	Waverly Plantation	--------	206	--------	do	28	1.25	Qt	7.62	6–12–58	do	--------	Dom	
(32a)	22bbb	R. C. Baumann	--------	--------	--------	Drilled	1500	4	Wilcox	--------	--------	--------	--------	Dom	

TABLE 2.—Record of wells—Continued

Well No.	LOCATION	OWNER OR TENANT	DRILLER	Altitude above sea level (feet)	Date of well completion	Type of well	Depth of well (feet)	Diameter of well (inches)	Stratigraphic unit	Depth to water below land surface (feet)	Date of water-level measurement	Type of pump	Well yield (gpm)	Use	REMARKS
	T.6N., R.6E.														
(33)	5dbc	-------	-------	203	-------	Driven	-------	1.25	Qt	14.89	6– 2–58	Pitcher	-------	Dom	
(34)	5dca	R. C. Taylor	Craddock	205	1956	Drilled	110	16	Qt	18.55	3– 5–58	Turbine	1950	Irr	
35	8abb	C. M. Clark	Newman and Williams	206	1954	do	110	10	Qt	-------	-------	do	925	Irr	
36	8ccb	-------	-------	205	-------	Driven	30	1.25	Qt	14.07	6– 2–58	Pitcher	-------	N	
37	9cca	W. B. Hall	J. Bartlett	206	1954	Drilled	160	16	Qt	21.81	3– 5–58	Turbine	1300	Irr	
38	10abb	-------	-------	208	-------	Driven	34	1.25	Qt	16.92	6– 3–58	Pitcher	-------	N	
39	10acb	-------	-------	205	-------	do	24	1.25	Qt	17.38	8–27–57	do	-------	N	
40	10dca	Edmundson	Newman and Williams	206	1954	Drilled	130	16	Qt	14.85	6– 3–58	Turbine	2200	Irr	
(41)	36ada	W. H. Cason	R. Nash	198	1951 or 1952	do	-------	18	Qt	8.68	5–28–58	do	1600	Irr	St. Francis Co.
42	36dad	R. H. White	R. Nash	198	1954 or 1955	do	-------	-------	Qt	9.23	5–28–58	do	-------	Irr	St. Francis Co.
	T.6N., R.7E.														
(43)	1dad	Carlson Bros.	T. O. Gibbs	210	1952	do	1530	4–3	Wilcox	-------	-------	Rod	-------	Dom	
44	9cbb	White Estate	Newman and Williams	205	-------	do	130	12	Qt	-------	-------	Turbine	1550	Irr	
45	10aab	George Perkins	R. Nash	205	1955	do	112	14	Qt	8.55	5–28–58	do	2000	Irr	
(46)	10bbb	J. McKnight	R. Nash	205	1955	Drilled	110–120	14	Qt	9.78	6– 9–58	Turbine	1275	Irr	
47	11bbb	Mrs. E. Barcroft	Lewis Diesel Engine Co.	205	1957	do	127	12	Qt	7.53	5–28–58	do	1725	Irr	
48	12daa	J. M. Leach	R. Nash	210	1953	do	117	12	Qt	8.21	5–28–58	do	-------	Irr	
(49)	13aab	J. McKnight	-------	-------	1953	do	-------	-------	Qt	-------	-------	do	1800	Irr	
(50)	13baa	J. M. Leach	Cart Well Co.	205	1956	do	130	12	Qt	7.35	5–28–58	do	1440	Irr	
51	14baa	L. J. Reynolds	-------	205	1952	do	115±	-------	Qt	7.35	3–11–58	do	-------	Irr	
52	16caa	Perkins and McKnight	-------	205	1950	do	-------	-------	Qt	-------	-------	do	-------	Irr	
(53)	17aba	J. E. Neal, Jr.	-------	205	1953	do	125	14	Qt	9.10	5–28–58	do	1550	Irr	
54	17cda	Robert Craft	-------	205	-------	do	-------	-------	Qt	15.02	6–10–58	do	-------	Irr	
(55)	18aad	White Estate	Newman and Williams	205	-------	do	130	12	Qt	16.10	6– 9–58	do	1400	Irr	
56	18cdd	P. M. Baker	-------	204	1951 or 1952	do	115–120	-------	Qt	-------	-------	do	1350	Irr	
57	20aad	L. J. Reynolds	R. Nash	205	-------	do	118	14	Qt	12.17	6–13–58	do	1670	Irr	
(58)	20bbb	Robert Craft	-------	205	-------	do	-------	-------	Qt	10.61	3– 4–58	do	1675	Irr	
59	22cdd	Perkins and McKnight	-------	205	-------	do	-------	-------	Qt	8.28	5–28–58	do	-------	Irr	
60	24bcc	-------	-------	205	-------	Driven	-------	1.25	Qt	8.55	5–28–58	Pitcher	-------	N	
61	30baa	Robert Craft	-------	200	-------	Drilled	-------	-------	Qt	11.95	6–10–58	Turbine	-------	Irr	
62	32aaa	J. E. Brady and Sons	-------	200	1953	do	120	12	Qt	-------	-------	do	1750	Irr	
(63)	33bad	do	-------	200	1954	do	120	12	Qt	7.62	5–28–58	do	2050	Irr	
64	33dda	-------	-------	200	-------	do	-------	-------	Qt	9.38	12–11–57	do	-------	Irr	
(65)	35dcd	-------	-------	209	-------	Driven	23	1.25	Qt	8.62	6–11–58	None	-------	N	
	T.6N., R.8E.														
66	9bcb	Mrs. R. T. Kuhn	Yoder?	209	-------	Drilled	110–120	16	Qt	5.77	5–28–58	Turbine	-------	Irr	
67	10dab	-------	-------	209	-------	Driven	47	1.25	Qt	7.29	5–28–58	Pitcher	-------	N	
68	12adb	City of West Memphis	Layne-Arkansas	210	1951	Drilled	1532	24–16	Wilcox	-------	-------	Turbine	1500	PS	See log
69	16abb	Mrs. R. T. Kuhn	-------	208	-------	do	-------	-------	Qt	4.97	5–28–58	do	-------	Irr	
(70)	18bda	J. M. Leach	Cart Well Co.	205	1955	do	153	12	Qt	9.38	10– 7–58	do	1200	Irr	
71	21dbd	-------	-------	214	-------	Driven	28	1.25	Qt	9.05	6–12–58	Pitcher	-------	Dom	
72	22dad	-------	-------	210	-------	do	47	1.25	Qt	10.83	3– 4–58	do	-------	Dom	
73	26cd	-------	-------	215	-------	do	38	1.25	Qt	13.54	9–30–57	do	-------	N	
74	27cda	-------	-------	210	-------	do	43	1.25	Qt	10.24	6–12–58	do	-------	Dom	
(74a)	34caa	Lake Grove Church	-------	210	-------	do	23	1.25	Qt	10.45	8–27–58	do	-------	PS	

TABLE 2.—Record of wells—Continued

Well No.	LOCATION	OWNER OR TENANT	DRILLER	Altitude above sea level (feet)	Date of well completion	Type of well	Depth of well (feet)	Diameter of well (inches)	Stratigraphic unit	Depth to water below land surface (feet)	Date of water-level measurement	Type of pump	Well yield (gpm)	Use	REMARKS
	T.6N., R.9E.														
75	7bcd	City of West Memphis	Layne-Arkansas	------	1955	Drilled	1538	16	Wilcox	------	------	Turbine	2000	PS	See log
76	10bdb	------	------	215	------	Driven	36	1.25	Qt	15.62	6–10–58	Pitcher	------	N	
77	10cbc	------	------	215	------	do	55	1.25	Qt	16.77	6–10–58	None	------	N	
(78)	18bac	Federal Compress and Warehouse Co.	------	210	1922	Drilled	600?	6	Claiborne?	------	------	Turbine	1000	I	
79	18bbb$_1$	City of West Memphis	Layne-Central	210	1929	do	1509	10–6	Wilcox	------	------	do	300	PS	
(80)	18bbb$_2$	do	Carloss Well Supply	210	1946	do	1509	10	Wilcox	------	------	do	800	PS	See log
(81)	23aaa$_1$	Corps of Engineers	C. M. Journey	226	1934	Drilled	352	8–6	Claiborne	------	------	Turbine	110±	PS-I	See log
82	23aaa$_2$	do	------	227	1915	do	370	6–4	Claiborne	------	------	Air Lift	------	N	See log
83	23aaa$_3$	do	R. E. Ratliff	227	1958	do	335	6–4	Claiborne	------	------	Turbine	125	PS-I	
	T.7N., R.6E.														
84	6ccb	------	------	210	------	Driven	42	1.25	Qt	24.14	10–21–57	Jet	------	Dom	
(85)	7acb	B. P. Magness Estate	------	210	------	Drilled	------	12	Qt	19.49	3– 5–58	Turbine	1880	Irr	
86	8dda	------	------	206	------	Driven	22	1.25	Qt	15.70	6– 2–58	Pitcher	------	N	
87	10ccb	B. C. Dickey, Jr.	------	210	------	Drilled	------	------	Qt	------	------	Turbine	------	Irr	
88	17aaa	------	------	206	------	Driven	26	1.25	Qt	16.32	12– 2–57	Pitcher	------	N	
(89)	18acb	Alvin Thompson	R. Nash	210	1953	Drilled	------	12	Qt	19.67	3– 5–58	Turbine	1400	Irr	
90	19bcd	------	------	210	------	Driven	42	1.25	Qt	19.21	6– 2–58	Pitcher	------	N	
91	20ccd	------	------	204	------	do	36	1.25	Qt	16.22	9– 5–57	do	------	N	
	T.7N., R.7E.														
92	2cad	Alpe Bros.	Newman and Williams	225	1957	Drilled	110–120	12	Qt	19.27	6–17–58	Turbine	------	Irr	
(93)	5dad	J. M. Leach	Wixson Bros.	215	------	do	132	14	Qt	13.04	5–28–58	do	------	Irr	
94	9cac	D. and J. Marotti	Lewis Diesel Engine Co.	215	1957	do	110	12	Qt	15.91	5–28–58	do	------	Irr	
(95)	14ccc$_1$	Town of Crawfordsville	Carloss Well Supply	223	1936	do	1584	8–4	Wilcox	------	------	do	275	PS	See log
(96)	14ccc$_2$	do	do	223	1957	do	100±	6	Qt	------	------	do	------	PS	
97	19bcb	------	------	210	------	Driven	40	1.25	Qt	12.41	5–28–58	None	------	N	
	T.7N., R.7E.														
98	22aaa	------	------	221	------	Drilled	------	16	Qt	15.74	5–28–58	Turbine	------	Irr	
99	27dac	I. D. Nodini	Lewis Diesel Engine Co.	215	1957	do	140	12	Qt	14.09	5–28–58	do	------	Irr	
100	31ccc	J. McKnight	------	209	1951 or 1952	do	99	16	Qt	15.47	10– 7–58	None	------	N	
101	34aad	Bloodworth Bros.	Wixson Bros.	216	1950	do	112	12	Qt	12.82	12– 5–57	Turbine	1775	Irr	
(102)	34cda	do	do	211	1955	do	119	16	Qt	10.44	5–28–58	do	1475	Irr	See log
	T.7N., R.8E.														
103	5bbb	------	------	216	------	Driven	25	1.25	Qt	6.39	6–11–58	Pitcher	------	N	
104	6bab	------	------	225	------	do	38	1.25	Qt	19.88	12– 4–57	do	------	Dom	
105	19cab	------	------	226	------	do	------	1.25	Qt	15.86	6– 3–58	do	------	N	
106	19cbb	------	------	225	------	do	49	1.25	Qt	20.57	10– 7–58	do	------	N	
(107)	24bca	Town of Marion	Layne-Arkansas	220	1954	Drilled	1500	6–4	Wilcox	20.95	8–14–58	Turbine	------	PS	See log
(108)	24bdb	do	do	222	1931	do	1500	10–6	Wilcox	23.63	8–14–58	do	300-400	PS	See log
(109)	28aad	------	------	221	------	Driven	56	1.25	Qt	13.62	6– 3–58	Pitcher	------	N	
	T.7N., R.9E.														
(110)	6ccd	C. E. McMinn	Wixson Bros.	214	1953	Drilled	112	12	Qt	12.54	6–10–58	Turbine	2000+	Irr	See log
111	6dcc	------	------	210	------	do	------	------	Qt	1.58	3– 5–58	do	2125	Irr	
112	8acb	Hersperger	------	210	1953	do	115?	12	Qt	1.40	6–10–58	None	------	N	
(113)	15dcc	Banks School	------	220	------	Driven	35	1.25	Qt	10.04	6–10–58	Pitcher	------	PS	
(114)	20bab	Herman McMinn	Wixson Bros.	212	1953	Drilled	------	------	Qt	4.46	3– 5–58	Turbine	1675	Irr	
115	33bbd	Mound City Planting Co.	Carloss Well Supply	215	1953	Drilled	104	------	Qt	15.48	3– 5–58	Turbine	2200	Irr	See log
(116)	34bbb	do	do	222	1954	do	111	12	Qt	15.91	6–10–58	do	1800	Irr	See log

TABLE 2.—Record of wells—Continued

Well No.	LOCATION	OWNER OR TENANT	DRILLER	Altitude above sea level (feet)	Date of well completion	Type of well	Depth of well (feet)	Diameter of well (inches)	Stratigraphic unit	Depth to water below land surface (feet)	Date of water-level measurement	Type of pump	Well yield (gpm)	Use	REMARKS
	T.8N., R.6E.														
117	4caa	J. Twist	Luhr Bros.	212	1955	do	119	16	Qt	18.30	5–27–58	do	600+	Irr	See log
118	9caa	J. Jenkins	Lewis Diesel Engine Co.	217	1957	do	120	12	Qt	23.69	5–27–58	do	--------	Irr	
(119)	9ddc	do	M. Watson	210	1958	Driven	32	1.25	Qt	--------	--------	Pitcher	--------	Dom	
120	15bab	--------	--------	213	--------	do	25	1.25	Qt	19.78	6– 3–58	do	--------	N	
121	19ddd	--------	--------	208	--------	do	42	1.25	Qt	20.91	6–11–58	do	--------	N	
122	28cbc	--------	--------	210	--------	do	38	1.25	Qt	14.60	6– 3–58	do	--------	N	
123	33cac$_1$	Town of Earle	Layne-Arkansas	210	1927	Drilled	1529	10–8	Wilcox	--------	--------	Turbine	200	PS	See log
(124)	33cac$_2$	do	do	210	1951	do	1530	10–8	Wilcox	11.30	8–14–58	do	--------	PS	See log
125	34bbc	B. P. Magness Estate	Newman and Williams	214	--------	do	--------	12	Qt	20.78	6–17–58	do	--------	Irr	
126	36ada	E. H. Burrows	Lewis Diesel Engine Co.	215	1957	do	117	12	Qt	19.15	5–28–58	do	--------	Irr	
(127)	36cda	do	do	210	1957	do	105	16	Qt	18.35	5–28–58	do	1825	Irr	
	T.8N., R.7E.														
(128)	5caa	Leo Linn	C. M. Journey	215	1933	do	1648	3–2	Wilcox	--------	--------	Suction	--------	Dom	See log
129	7aca	--------	--------	218	--------	Driven	34	1.25	Qt	18.55	6– 3–58	Pitcher	--------	N	
130	10cbc	--------	--------	219	--------	do	28	1.25	Qt	16.15	6– 3–58	do	--------	Dom	
131	12ddd	Jarrott	R. Nash	216	1952	Drilled	125±	14	Qt	14.70	6–17–58	Turbine	--------	Irr	
	T.8N., R.7E.														
132	13abb	Jarrott	R. Nash	215	1952	Drilled	125±	12	Qt	--------	--------	Turbine	--------	Irr	
133	13ccc	--------	--------	220	--------	Driven	23	1.25	Qt	14.62	6– 3–58	Pitcher	--------	N	
(134)	14daa	Alpe Bros.	--------	215	1957	Drilled	116	16	Qt	16.16	12– 4–57	Turbine	950+	Irr	
135	16caa	--------	--------	217	--------	Driven	47	1.25	Qt	16.77	3–12–58	Pitcher	--------	N	
(136)	16cad	Negro School	--------	218	--------	do	42	1.25	Qt	16.82	9–17–58	do	--------	PS	
137	23aca	Alpe Bros.	Newman and Williams	215	1957	Drilled	110–120	12	Qt	16.00	6–17–58	Turbine	--------	Irr	
138	23bdb	do	--------	215	1957	do	110–120	12	Qt	--------	--------	do	--------	Irr	
139	30dcc	J. M. Leach	--------	205	--------	do	--------	18	Qt	7.86	6–17–58	do	--------	Irr	
140	33ddd	Alpe Bros.	Craddock	215	1954	do	108	8	Qt	13.49	10–21–57	do	--------	Pond	
	T.8N., R.8E.														
141	5dbc	D. B. Wollard Estate	Cart Well Co.	221	1951	do	--------	--------	Qt	16.36	6–10–58	do	2000	Irr	
142	7bbc	Lewis and Rooker	Yoder?	220	--------	do	110–120	18–12	Qt	15.95	6– 3–58	do	--------	Irr	
(143)	8bdc	D. B. Wollard Estate	Cart Well Co.	220	1952	do	148	12	Qt	15.21	6– 3–58	do	2240	Irr	
(144)	9bca	U. of Arkansas	--------	226	1950	do	131	20–12	Qt	16.35	3–12–58	do	1500	Irr	
145	13ccb	--------	--------	229	--------	Driven	95	1.25	Qt	16.52	3– 5–58	Pitcher	--------	Dom	
(146)	16adb	Clarkedale Farms	--------	225	--------	do	34	1.25	Qt	14.45	9– 3–58	do	--------	Dom	
147	16ddb	--------	--------	226	--------	do	27	1.25	Qt	13.25	6– 3–58	do	--------	N	
148	23cda	--------	--------	225	--------	do	45	1.25	Qt	11.73	3–10–58	do	--------	Dom	
149	36dbd	--------	--------	220	--------	do	56	1.25	Qt	9.42	6–10–58	do	--------	N	
	T.8N., R.9E.														
(150)	6bcc	--------	--------	217	--------	Driven	54	1.25	Qt	4.79	5–27–58	Pitcher	--------	Dom	
(151)	20bbd	--------	--------	213	--------	do	--------	1.25	Qt	2.49	6–10–58	do	--------	Dom	
	T.9N., R.6E.														
152	2aca	J. H. Johnson	Lewis Diesel Engine Co.	220	1957	Drilled	120	16	Qt	20.50	5–27–58	Turbine	1800	Irr	
153	3bda	J. Emrich	do	216	1957	do	110	12	Qt	20.57	9–11–57	do	2000	Irr	
(154)	9bac	do	do	212	1954 or 1955	do	110	16	Qt	16.87	6– 3–58	do	3000	Irr	
155	9dad	Pearson	--------	215	--------	do	105	8	Qt	16.80	6– 3–58	do	--------	Irr	
156	10dab	Wes Pearson	Newman and Williams	215	1954	do	105	12	Qt	18.50	6– 3–58	do	1375	Irr	

TABLE 2.—Record of wells—Continued

Well No.	LOCATION	OWNER OR TENANT	DRILLER	Altitude above sea level (feet)	Date of well completion	Type of well	Depth of well (feet)	Diameter of well (inches)	Stratigraphic unit	Depth to water below land surface (feet)	Date of water-level measurement	Type of pump	Well yield (gpm)	Use	REMARKS
	T.9N., R.6E.														
157	11dad	Bert Dickey, Jr.	Lewis Diesel Engine Co.	215	1957	do	111	12	Qt	20.35	5–27–58	do	375+	Irr	
158	12cda	do	Newman and Williams	210	1956	do	--------	12	Qt	14.07	5–27–58	do	--------	Irr	
159	13bcc	do	Lewis Diesel Engine Co.	216	1957	do	112	12	Qt	20.38	3– 5–58	do	--------	Irr	
160	14baa	do	--------	215	1953	do	--------	16	Qt	21.81	5–27–58	do	--------	Irr	
(161)	15dad$_1$	Carl West	Carl West	215	--------	Driven	25.8	1.25	Qt	19.45	9–10–58	None	--------	N	
(162)	15dad$_2$	do	do	215	1934	do	21	1.25	Qt	--------	--------	Jet	--------	Dom	
163	16cda	Bert Dickey, Jr.	Lewis Diesel Engine Co.	216	1958	Drilled	115	12	Qt	--------	--------	Turbine	2000	Irr	
164	17ddc	--------	--------	215	--------	Driven	45	1.25	Qt	20.71	6– 3–58	Pitcher	--------	Dom	
(165)	20ba	J. Twist	Newman and Williams	210	1953	Drilled	105	12	Qt	20.91	3– 6–58	Turbine	1650	Irr	
(166)	20bd	do	Wixson Bros.	210	1953	do	105	12	Qt	--------	--------	do	1950+	Irr	
(167)	21baa	Fred Wasmer	J. H. Abel and Son	215	1958	do	128	12	Qt	16.00	5–27–58	do	2340	Irr	See log
168	23aaa	--------	--------	215	--------	Driven	22	1.25	Qt	19.53	6– 3–58	Pitcher	--------	N	
169	26aca	--------	--------	207	--------	do	28	1.50	Qt	18.91	6– 3–58	None	--------	N	
(170)	30aab	J. Twist	Luhr Bros.	214	1955	Drilled	120	16	Qt	20.48	3– 6–58	Turbine	2300	Irr	See log
(171)	30cda	do	do	210	1955	do	104	16	Qt	20.73	3– 6–58	do	730+	Irr	See log
(172)	31baa	do	Lewis Diesel Engine Co.	212	1957	do	105–120	12	Qt	19.94	3– 6–58	do	1700	Irr	
173	32dad	--------	--------	211	--------	Driven	29	1.25	Qt	16.70	6– 3–58	Pitcher	--------	Dom	
174	35bcc	--------	--------	211	--------	do	31	1.25	Qt	17.23	6– 3–58	do	--------	Dom	
	T.9N., R.7E.														
(175)	5bdb	Pearson	--------	215	1954	Drilled	105	10	Qt	18.00	3– 6–58	Turbine	850+	Irr	
176	9cbc	--------	--------	212	--------	Driven	36	1.25	Qt	12.19	6– 3–58	None	--------	N	
177	12aca	E. B. David	Lewis Diesel Engine Co.	223	1956	Drilled	110	14	Qt	18.40	5–27–58	Turbine	925+	Irr	
(178)	13cca	L. W. Duncan	J. Cooper	215	1954	do	120	22	Qt	10.73	5–27–58	do	3500	Irr	
(179)	14bab	Wallace East	Cart Well Co.	217	--------	do	120	16	Qt	12.47	5–27–58	do	2600	Irr	
(180)	15aaa	--------	--------	215	--------	Driven	51	1.25	Qt	15.56	9–10–58	Pitcher	--------	Dom	
(181)	19acb	W. H. Carrier	T. O. Gibbs	215	1947	Drilled	1647	4	Wilcox	--------	--------	--------	--------	Dom-Stk	
182	20da	--------	--------	211	--------	Driven	--------	1.25	Qt	12.30	6– 3–58	Pitcher	--------	Dom	
(183)	27aba	Elbert Smith, Jr.	Wixson Bros.	210	1954	Drilled	119	16	Qt	--------	--------	Turbine	1750	Irr	
184	27dda	do	do	215	1955	do	117	16	Qt	17.01	5–27–58	do	1250	Irr	See log
185	30bda	--------	--------	219	--------	Driven	62	1.25	Qt	17.92	6– 3–58	None	--------	N	
186	33dbc	William Flippo	Cart Well Co.	215	1957	Drilled	113	16	Qt	17.25	5–27–58	Turbine	1800	Irr	
187	34bcd	do	do	215	1957	do	117	12	Qt	16.80	10– 9–58	do	1200	Irr	
(188)	36bdb	Gilliland Farms, Inc.	do	215	1954?	do	125	16	Qt	19.10	10– 9–58	do	3000	Irr	
	T.9N., R.8E.														
189	2aad	Mrs. R. T. Kuhn	--------	212	--------	do	--------	14	Qt	5.76	6–10–58	do	3360	Irr	
190	7ccb	E. B. David	Lewis Diesel Engine Co.	223	1956	do	130	14	Qt	18.49	5–27–58	do	490+	Irr	
191	8ada	--------	--------	220	--------	Driven	51	1.25	Qt	12.79	6– 3–58	Pitcher	--------	N	
(192)	11bcb	Mrs. R. T. Kuhn	--------		1945?	Drilled	--------	16	Qt	--------	--------	Turbine	450+	Irr	
193	14cac	--------	--------	225	--------	Driven	83	1.25	Qt	10.75	6–10–58	Pitcher	--------	N	
194	16ddb	--------	--------	226	--------	do	45	1.25	Qt	4.18	6–10–58	do	--------	N	
195	17ada	--------	--------	220	--------	do	28	1.25	Qt	13.30	6–10–58	do	--------	Dom	
(196)	23dca	Pacific Place Farms	Carloss Well Supply	225	1956	Drilled	120	16	Qt	12.42	3– 4–58	Turbine	1090	Irr	See log
(197)	27acd	do	do	223	1957	do	120	16	Qt	11.5	3– 5–58	do	1630	Irr	See log
198	29abd	E. R. Upshaw	Johnson and Fleming	236	1901	do	864	4	Claiborne	18.07	8–13–59	None	--------	N	See log
(199)	29add	Town of Turrell	Layne-Arkansas	222	1937	do	1510	8–6	Wilcox	15.10	8–14–58	Turbine	250	PS	See log
200	29dbd	--------	--------	222	--------	Driven	22	1.25	Qt	12.69	6– 3–58	Pitcher	--------	N	
(201)	31ada	D. B. Wollard Estate	Cart Well Co.	220	--------	Drilled	112	10	Qt	15.50	6– 3–58	Turbine	1275	Irr	
202	36ddd	--------	--------	220	--------	Driven	33	1.25	Qt	4.55	2– 6–58	Pitcher	--------	N	
	T.10N., R.9E.														
(203)	31cdd	--------	--------	221	--------	do	41	1.25	Qt	12.59	6–10–58	do	--------	Dom	Mississippi Co.

TABLE 3

Chemical analyses of water from wells
(chemical constituents in ppm)

Well number	Date of Collection	Temperature (°F)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total dissolved solids	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH Field	pH Laboratory
								DEPOSITS OF QUATERNARY AGE											
3	9- 4-58	62	1.3	117	38	19	3.2	424	0	122	11	1.0	594	448	101	8	804	----	7.4
15	9- 9-58	62	6.5	71	32	10	1.3	354	0	29	3.2	.2	360	308	18	7	559	----	7.3
20	6-12-58	63	6	65	43	12	7.7	698	0	26	8	2.5	652	588	16	4	980	----	7.1
27	8-18-55	62	3.2	89	24	7.2	------	392	0	1.8	4.2	.1	356	320	0	5	573	----	7.0
33	8-27-58	62	17	74	18	23	4.4	358	0	4.6	4.8	3.4	359	258	0	16	539	----	7.5
34	6- 2-58	62	6.1	66	23	16	4.3	344	0	3.2	8	.2	319	259	0	12	529	----	7.5
41	8- 4-58	62	7.8	64	20	11	4	322	0	2	3	.3	294	242	0	9	450	----	7.2
46	8-29-58	61	6.9	56	17	8.1	2.2	274	0	1	2.5	.2	271	210	0	8	404	----	7.6
49	8-18-55	62	2.7	50	15	7.4	------	240	0	1.2	2.5	0	227	186	0	8	364	----	7.8
50	6- 9-58	62	8.6	48	17	8.5	2.7	238	4	1.6	4	.3	237	190	0	9	371	7.2	8.3
53	6- 9-58	62	7.5	53	19	10	3.7	268	6	2.4	5.5	.2	260	210	0	9	417	7.4	8.4
55	8-18-55	63	10	66	18	9.2	------	304	0	.8	2.2	0	287	238	0	8	462	----	7.0
58	6-10-58	62	8.5	39	20	12	4.3	242	0	1.8	6	.4	304	180	0	12	478	----	8.2
63	6-17-58	63	.21	74	21	9.6	3.4	351	0	.4	2.5	.9	308	271	0	7	470	----	6.9
65	9- 4-58	62	2.1	133	30	5.8	4.5	484	0	35	22	1	557	456	59	3	797	----	7.6
70	5-28-58	63	7.7	54	24	12	3.3	304	0	1.6	6	.2	283	233	0	10	464	----	7.3
74a	8-27-58	62	4.5	43	15	12	1	204	0	21	4.2	.2	233	169	2	13	356	----	7.4
85	6- 2-58	63	15	69	22	15	4.3	340	0	5.2	9	.3	325	262	0	11	531	7.3	7.1
89	6- 2-58	62	20	75	26	14	3.7	370	0	5.6	12	.2	360	294	0	9	578	7.2	6.8
93	8-18-55	64	11.2	36	21	11	------	235	0	10	6.2	.8	245	176	0	19	390	----	8.2
[1]96	10- -57		7.8	71.4	16.9	------	------	------	--	0	5.5	------	366	268	4	----	------	----	7.1
102	8-27-58	63	6.9	61	19	7.2	2.8	296	0	1.6	2.8	.2	279	230	0	6	441	7.2	7.7
109	9- 3-58	64	8.2	52	17	11	2.1	262	0	.2	2.5	4.4	261	200	0	11	405	----	7.5
110	8-18-55	63	8.7	62	17	9.8	------	288	0	2.4	3.2	0	272	225	0	9	440	----	7.0
113	8-28-58	63	7.4	85	27	13	6.2	394	0	23	3.2	3.3	411	323	0	8	598	----	7.4
114	8-13-58	63	6	54	19	7.5	2.4	266	0	6.8	3.5	.2	251	212	0	7	398	----	8.0
116	8-13-58	63	5.2	62	24	9.9	2.6	320	0	7.2	3	.2	276	253	0	8	454	----	7.2
119	9-11-58	62	8.1	55	18	9	3.2	254	0	16	4.5	.2	280	211	3	8	417	7.2	7.5
127	8-11-58	62	13	77	22	15	3.4	330	0	31	8.5	.5	380	282	12	10	542	----	6.9
134	6- 3-58	62	11	59	24	11	4.7	308	0	4.8	10	.3	303	246	0	9	494	----	7.0
136	9-17-58	63	0	78	26	18	4.5	410	0	1.6	7.2	.3	378	302	0	11	574	7.2	7.4
143	8-18-55	63	12	85	23	10	------	392	0	1.4	3.8	.5	336	306	0	7	583	----	7.6
144	5-22-50	----	.06	58	28	17	6.9	368	0	2.6	3	2.9	342	260	0	12	566	----	7.8
146	9- 3-58	62	3.1	52	21	4.1	1.1	258	0	10	2.2	.5	262	216	4	4	400	7.5	7.6
150	9-17-58	63	6.1	78	30	10	4	420	0	.8	3.8	.2	369	318	0	6	603	7.2	7.7
151	8-28-58	63	31	92	29	10	4	436	0	1.8	3	.6	439	348	0	6	674	----	7.3
154	6-18-58	61	2.7	91	20	10	2.1	386	0	6.4	3	.2	351	309	0	6	564	----	7.2
161	9-10-58	61	1.2	85	21	18	2.3	360	0	28	5.5	3.4	390	298	4	11	575	----	7.4
162	9-10-58	63	.92	29	9.3	14	1.8	136	0	18	5.8	8.4	218	110	0	21	272	----	6.4
165	8-15-55	62	9.3	45	22	13	------	242	0	22	5.8	1.3	250	203	4	12	412	----	8.1
166	5-27-58	62	8.5	83	27	13	3.2	388	0	22	6	.1	387	318	0	8	585	----	7.2
167	8-13-58	62	8.1	83	23	14	3.9	382	0	13	4	.6	352	302	0	10	547	----	7.0
170	6- 3-58	62	5.5	75	26	19	4	366	0	24	7	2	369	294	0	12	587	----	7.3
171	6- 3-58	62	8	75	28	18	3.5	368	0	29	7	2.1	366	302	0	11	583	----	7.3
172	5-27-58	62	7.5	80	25	18	3.2	356	0	34	8	2.4	369	302	11	11	576	----	7.1
175	6- 3-58	62	10	67	29	13	4.6	340	0	22	9	.5	348	286	8	9	561	----	7.2
178	8-13-58	61	5.1	84	25	13	3.5	396	0	8	7.5	.3	380	312	0	8	527	----	7.0
179	8-18-55	62	14.2	62	18	14	------	300	0	4.6	4.5	0	271	228	0	12	456	7.2	8.0
180	9-10-58	63	4.9	91	28	33	4.2	466	0	24	9.5	.4	484	342	0	17	688	----	7.7
183	5-27-58	61	8.2	60	25	12	3.9	324	0	3.2	6	2.4	297	252	0	9	478	----	7.3
188	5-27-58	62	10	65	24	14	4.5	338	0	6.8	7	.2	322	260	0	10	525	7.4	7.2
192	6-10-58	62	16	83	29	8	3.8	408	0	3.2	4	.3	369	326	0	5	609	----	7.0
196	5-27-58	61	12	83	34	7	3.1	412	0	15	4	1	380	347	10	4	621	----	7.0
197	5-27-58	61	23	102	38	9	3.8	484	0	23	6	.2	461	411	14	4	738	----	7.0
201	9-16-58	63	7.4	72	20	7.2	4	334	0	1.4	3.8	.2	307	262	0	5	496	7.3	7.4
203	8-28-58	63	1.9	106	35	4.5	2.1	472	0	23	2.5	.2	442	408	22	----	687	----	7.6
								CLAIBORNE GROUP											
78	11- 5-57	64	3.3	20	7.8	7.5	3.3	110	0	9.2	3.2	.3	110	82	0	16	195	----	6.6
81	11- 5-57	----	.74	25	6.9	8.4	1.6	87	0	4	26	.4	136	91	20	17	317	----	6.5

[1] Arkansas State Board of Health analysis.

TABLE 3—Continued

WILCOX GROUP ("1400-foot" sand)

Well number	Date of Collection	Temperature (°F)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total dissolved solids	Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25°C)	pH	
														Total	Noncarbonate			Field	Laboratory
1	2- 4-58	----	.10	.6	.3	42	2.2	115	0	1.8	2.2	.3	105	2	0	94	198	----	7.9
4	2- 4-58	74	.07	.3	.1	44	2	116	0	2.8	2.2	0	114	1	0	96	181	----	8.2
19	2- 6-58	73	.29	1.1	.1	44	2	115	0	2.8	3	0	110	3	0	95	179	----	7.8
28	1-17-58	----	.74	1	.5	48	2.2	130	0	3.4	3	.2	128	4	0	93	199	----	7.8
32a	4-24-47	----	.45	1.1	.5	55	.5	147	0	1.8	2.2	.2	148	5	----	----	234	----	8.0
43	1-16-58	----	1.5	2.4	.1	36	2.2	100	0	1.8	3.5	.3	111	6	0	89	166	----	7.4
80	3- 8-50	76	.16	2.6	.9	45	1.3	122	0	5.5	3.0	.7	123	10	0	89	236	----	7.4
95	1-16-58	----	.59	1.4	.3	39	2.2	104	0	1.4	3.5	.2	110	4	0	92	177	----	7.4
107	3- 7-58	75	1.11	1.6	0	45	1.2	112	0	10	1	.8	126	4	0	95	185	----	7.4
108	5-15-46	----	.37	1.4	.8	50	1.4	134	0	2.8	2.8	.2	135	7	----	----	213	----	7.7
124	11- 6-57	75	.15	1.6	.1	39	2.3	105	0	1.8	2.5	.3	109	4	0	92	169	----	7.4
128	5-14-58	----	.66	2.5	.5	39	2.6	112	0	.2	4	.8	134	8	0	88	165	----	7.9
181	5-13-58		.13	.3	.5	45	2.1	116	0	.8	5	.5	140	2	0	95	167	----	7.7
199	3- 7-58	77	.52	1.2	.1	38	1	96	0	7.6	0	1.1	108	3	0	95	153	----	7.6

Table 4.—*Water levels in wells tapping Quaternary deposits*

(Feet below land-surface datum)

Well 2 (3N7E-4bca)

Date	Water level
Dec. 10, 1957	12.09
Mar. 4, 1958	11.24
June 12, 1958	9.78
Sept. 29, 1958	11.59

Well 6 (3N7E-15bcc)

Dec. 10, 1957	17.38
Mar. 4, 1958	19.71
June 12, 1958	17.23
Sept. 29, 1958	20.11

Well 7 (3N7E-17bdd)

Mar. 4, 1958	14.59
June 12, 1958	12.77
Sept. 29, 1958	14.95

Well 8 (3N7E-18bda)

Mar. 4, 1958	7.58
June 12, 1958	5.78

Well 9 (4N6E-1bcc)

Dec. 11, 1957	13.61
Mar. 11, 1958	13.61
June 11, 1958	13.52
Oct. 6, 1958	14.05

Well 10 (4N6E-25ddd)

Dec. 10. 1957	12.63

Well 11 (4N6E-36dda)

Mar. 4, 1958	9.18
June 12, 1958	7.97
Sept. 29, 1958	8.82

Well 12 (4N7E-2bbb)

Dec. 10, 1957	3.44
Mar. 4, 1958	5.30
June 11, 1958	4.56
Oct. 6, 1958	6.32

Well 13 (4N7E-2dca)

Dec. 10, 1957	8.66

Well 14 (4N7E-3aca)

Oct. 2, 1957	12.66
Dec. 10, 1957	7.05
June 12, 1958	8.76
Oct. 6, 1958	14.04

Well 15 (4N7E-3ccc)

Date	Water level
Sept. 9, 1958	8.46

Well 16 (4N7E-9aaa)

Oct. 2, 1957	8.25
June 12, 1958	4.74
Oct. 6, 1958	6.15

Well 17 (4N7E-9ccd)

Oct. 2, 1957	10.29
Mar. 4, 1958	8.01
June 12, 1958	7.23
Oct. 6, 1958	8.51

Well 18 (4N7E-15ccd)

Oct. 8, 1957	10.34
Dec. 10, 1957	6.98

Well 20 (4N8E-17bdb)

Nov. 21, 1957	27.71
Dec. 10, 1957	21.87
Mar. 4, 1958	23.77
June 12, 1958	21.48
Sept. 29, 1958	23.93
Oct. 29, 1958	27.10
Nov. 13, 1958	27.86
Nov. 25, 1958	28.01
Mar. 10, 1959	18.41
April 29, 1959	17.24

Well 21 (4N8E-31dbb)

Oct. 7, 1957	22.95
Dec. 10, 1957	19.30
Mar. 4, 1958	17.54
June 11, 1958	13.93
Sept. 29, 1958	17.87

Well 23 (5N6E-12daa)

Dec. 10, 1957	12.43
Mar. 11, 1958	11.19
May 28, 1958	9.86

Well 24 (5N7E-5bcb)

Sept. 4, 1957	23.11
Dec. 9, 1957	12.61
Mar. 11, 1958	11.85
May 28, 1958	10.57
Oct. 6, 1958	15.37

Well 25 (5N7E-12cba)

Nov. 21, 1957	8.14
Dec. 10, 1957	8.74
Mar. 4, 1958	9.17
June 11, 1958	8.01
Oct. 6, 1958	10.00

Table 4.—*Water levels in wells tapping Quaternary deposits (continued)*

(Feet below land-surface datum)

Well 26 (5N7E-17dba)

Date	Water level
Sept. 30, 1957	14.18
Mar. 4, 1958	10.54
June 13, 1958	10.98
Oct. 6, 1958	12.50

Well 27 (5N7E-28cb)

Sept. 4, 1957	14.46
Dec. 10, 1957	11.95
Mar. 4, 1958	11.73
June 11, 1958	11.18
Oct. 6, 1958	12.56

Well 30 (5N8E-7dad)

June 12, 1958	3.51

Well 31 (5N8E-10bdd)

Feb. 3, 1958	7.19
Mar. 4, 1958	8.30
June 12, 1958	6.81
Oct. 6, 1958	8.30

Well 32 (5N8E-16daa)

Feb. 3, 1958	6.11
Mar. 4, 1958	8.79
June 12, 1958	7.62
Oct. 6, 1958	9.75

Well 33 (6N6E-5dbc)

June 2, 1958	14.89

Well 34 (6N6E-5dca)

Aug. 21, 1957	20.58
Oct. 21, 1957	20.38
Dec. 2, 1957	19.26
Mar. 5, 1958	18.55
Oct. 8, 1958	18.84

Well 36 (6N6E-8ccb)

Feb. 25, 1958	14.59
Mar. 5, 1958	14.64
June 2, 1958	14.07
Oct. 8, 1958	14.70

Well 37 (6N6E-9cca)

Aug. 21, 1957	20.25
Oct. 21, 1957	19.41
Dec. 2, 1957	18.38
Mar. 5, 1958	21.81

Well 38 (6N6E-10abb)

Date	Water level
Dec. 2, 1957	18.59
Mar. 11, 1958	17.58
June 3, 1958	16.92
Oct. 7, 1958	18.19

Well 39 (6N6E-10acb)

Aug. 27, 1957	17.38

Well 40 (6N6E-10dca)

Aug. 27, 1957	18.36
Dec. 2, 1957	17.13
June 3, 1958	14.85

Well 41 (6N6E-36ada)

Oct. 2, 1957	16.45
Dec. 9, 1957	10.97
Mar. 11, 1958	9.80
May 28, 1958	8.68
Oct. 6, 1958	13.63

Well 42 (6N6E-36dad)

Oct. 2, 1957	16.65
Dec. 9, 1957	11.85
Mar. 11, 1958	15.38
May 28, 1958	9.23
Oct. 6, 1958	14.44

Well 45 (6N7E-10aab)

Aug. 28, 1957	18.96
Oct. 21, 1957	12.36
Dec. 6, 1957	10.54
May 28, 1958	8.55
Oct. 7, 1958	14.42

Well 46 (6N7E-10bbb)

Sept. 4, 1957	16.62
Dec. 6, 1957	9.43
June 9, 1958	9.78
Oct. 7, 1958	11.83

Well 47 (6N7E-11bbb)

Oct. 21, 1957	11.34
Dec. 6, 1957	9.54
Mar. 11, 1958	8.43
May 28, 1958	7.53

Well 48 (6N7E-12daa)

Oct. 22, 1957	11.05
Dec. 6, 1957	9.65
May 28, 1958	8,21
Oct. 7, 1958	11.16

Well 50 (6N7E-13baa)

Dec. 6, 1957	8.62
Mar. 11. 1958	7.68
May 28, 1958	7.35
Oct. 6, 1958	10.41

Table 4.—*Water levels in wells tapping Quaternary deposits (continued)*

(Feet below land-surface datum)

Well 51 (6N7E-14baa)

Date	Water level
Sept. 3, 1957	14.89
Oct. 22, 1957	9.93
Dec. 6, 1957	8.28
Mar. 11, 1958	7.35

Well 53 (6N7E-17aba)

Oct. 22, 1957	13.74
Dec. 6, 1957	11.24
Mar. 11, 1958	10.18
May 28, 1958	9.10
Oct. 6, 1958	14.89

Well 54 (6N7E-17cda)

June 10, 1958	15.02

Well 55 (6N7E-18aad)

Aug. 28, 1957	20.66
Mar. 11, 1958	13.37
June 9, 1958	16.10
Oct. 6, 1958	17.73

Well 57 (6N7E-20aad)

Sept. 3, 1957	17.63
Dec. 6, 1957	9.58
Mar. 11, 1958	8.66
June 13, 1958	12.17
Oct. 6, 1958	12.55

Well 58 (6N7E-20bbb)

Aug. 28, 1957	18.83
Dec. 10, 1957	11.25
Mar. 4, 1958	10.61
Oct. 6, 1958	14.77

Well 59 (6N7E-22cdd)

Sept. 3, 1957	15.74
Nov. 1, 1957	10.72
Dec. 6, 1957	9.74
Mar. 11, 1958	8.87
May 28, 1958	8.28
Oct. 6, 1958	12.20

Well 60 (6N7E-24bcc)

Sept. 4, 1957	14.07
Nov. 1, 1957	10.07
Dec. 10, 1957	8.59
May 28, 1958	8.55
Oct. 6, 1958	11.05

Well 61 (6N7E-30baa)

Aug. 28, 1957	16.07
Oct. 10, 1958	11.95

Well 63 (6N7E-33bad)

Date	Water level
Sept. 3, 1957	17.38
Dec. 11, 1957	9.02
Mar. 11, 1958	8.49
May 28, 1958	7.62
Oct. 6, 1958	11.99

Well 64 (6N7E-33dda)

Dec. 11, 1957	9.38

Well 65 (6N7E-35dcd)

Mar. 11, 1958	8.90
June 11, 1958	8.62

Well 66 (6N8E-9bcb)

Sept. 5, 1957	14.57
Oct. 31, 1957	9.73
Dec. 5, 1957	7.44
May 28, 1958	5.77

Well 67 (6N8E-10dab)

Oct. 8, 1957	11.68
Dec. 5, 1957	9.71
Mar. 11, 1958	8.60
May 28, 1958	7.29
Oct. 7, 1958	9.94

Well 69 (6N8E-16abb)

Mar. 11, 1958	5.98
May 28, 1958	4.97
Oct. 7, 1958	7.47

Well 70 (6N8E-18bda)

Sept. 9, 1957	10.49
Oct. 31, 1957	6.58
Dec. 6, 1957	5.69
Oct. 7, 1958	7.09

Well 71 (6N8E-21dbd)

Oct. 8, 1957	11.50
June 12, 1958	9.05
Oct. 6, 1958	8.90

Well 72 (6N8E-22dad)

Mar. 4, 1958	10.83

Well 73 (6N8E-26cd)

Sept. 30, 1957	13.54

Well 74 (6N8E-27cda)

June 12, 1958	10.24

Well 74a (6N8E-34caa)

Aug., 27 1958	10.45
Oct. 6, 1958	11.29

Table 4.—*Water levels in wells tapping Quaternary deposits (continued)*

(Feet below land-surface datum)

Well 76 (6N9E-10bdb)

Date	Water level
Oct. 9, 1957	22.50
Dec. 5, 1957	14.14
Mar. 5, 1958	17.09
June 10, 1958	15.62
Oct. 7, 1958	18.96

Well 77 (6N9E-10cbc)

Feb. 26, 1958	18.46
Mar. 5, 1958	17.49
June 10, 1958	16.77
Oct. 7, 1958	19.98

Well 84 (7N6E-6cbb)

Aug. 26, 1957	24.10
Oct. 21, 1957	24.14

Well 85 (7N6E-7acb)

Oct. 21, 1957	20.86
Dec. 2, 1957	20.27
Mar. 5, 1958	19.49

Well 86 (7N6E-8dda)

Mar. 5, 1958	16.43
June 2, 1958	15.70
Oct. 8, 1958	16.32

Well 88 (7N6E-17aaa)

Aug. 26, 1957	16.70
Oct. 21, 1957	16.74
Mar. 5, 1958	16.32

Well 89 (7N6E-18acb)

Oct. 21, 1957	20.91
Dec. 2, 1957	20.41
Mar. 5, 1958	19.67
Oct. 8, 1958	19.97

Well 90 (7N6E-19bcd)

Dec. 2, 1957	20.37
Mar. 5, 1958	19.72
June 2, 1958	19.21
Oct. 8, 1958	19.79

Well 91 (7N6E-20ccd)

Sept. 5, 1957	16.22

Well 92 (7N7E-2cad)

June 17, 1958	19.27
Oct. 9, 1958	20.35

Well 93 (7N7E-5dad)

Date	Water level
Sept. 5, 1957	15.02
Oct. 21, 1957	15.16
Dec. 4, 1957	14.62
Mar. 5, 1958	13.98
May 28, 1958	13.04
Oct. 9, 1958	14.02

Well 94 (7N7E-9cac)

Nov. 6, 1957	18.33
Dec. 4, 1957	17.97
May 28, 1958	15.91

Well 97 (7N7E-19bcb)

Sept. 5, 1957	14.99
Oct. 22, 1957	14.79
Mar. 12, 1958	14.13
May 28, 1958	12.41
Oct. 7, 1958	13.65

Well 98 (7N7E-22aaa)

May 28, 1958	15.74
Aug. 14, 1958	18.27
Oct. 7, 1958	18.89

Well 99 (7N7E-27dac)

Nov. 6, 1957	18.01
Dec. 5, 1957	16.97
Mar. 13, 1958	15.28
May 28, 1958	14.09
Oct. 7, 1958	18.09

Well 101 (7N7E-34aad)

Oct. 21, 1957	14.56
Dec. 5, 1957	12.82

Well 102 (7N7E-34cda)

Oct. 22, 1957	14.55
Dec. 5, 1957	12.79
Mar. 13, 1958	11.33
May 28, 1958	10.44
Oct. 7, 1958	14.70

Well 103 (7N8E-5bbb)

Mar. 13, 1958	7.15
June 11, 1958	6.39
Oct. 9, 1958	6.91

Well 104 (7N8E-6bab)

Oct. 1, 1957	20.36
Oct. 21, 1957	20.34
Dec. 4, 1957	19.88

Table 4.—*Water levels in wells tapping Quaternary deposits (continued)*

(Feet below land-surface datum)

Well 105 (7N8E-19cab)

Date	Water level
Mar. 13, 1958	17.49

Well 106 (7N8E-19cbb)

Oct. 10, 1957	22.17
Oct. 21, 1957	21.77
Oct. 7, 1958	20.57

Well 109 (7N8E-28aad)

Nov. 20, 1957	15.94
Dec. 5, 1957	15.70
Mar. 12, 1958	14.52
June 3, 1958	13.62
Oct. 7, 1958	16.52

Well 110 (7N9E-6ccd)

Sept. 26, 1957	14.69
Dec. 5, 1957	11.87
Mar. 5, 1958	11.92
June 10, 1958	12.54
Oct. 7, 1958	12.91

Well 111 (7N9E-6dcc)

Sept. 26, 1957	4.37
Dec. 5, 1957	1.40
Mar. 5, 1958	1.58

Well 112 (7N9E-8acb)

Oct. 9, 1957	4.77
Dec. 5, 1957	1.38
Mar. 5, 1958	1.60
June 10, 1958	1.40
Oct. 7, 1958	2.66

Well 113 (7N9E-15dcc)

June 10, 1958	10.04
Oct. 1, 1958	12.37
Oct. 29, 1958	13.72
Nov. 13, 1958	14.40
Nov. 25, 1958	14.58
Dec. 23, 1958	15.00
Feb. 5, 1959	14.78
Feb. 18, 1959	12.85
Mar. 10, 1959	11.29
April 29, 1959	10.88
June 3, 1959	11.70

Well 114 (7N9E-20bab)

Sept. 26, 1957	6.48
Dec. 5, 1957	5.46
Mar. 5, 1958	3.46
Oct. 7, 1958	5.32

Well 115 (7N9E-33bbd)

Date	Water level
Mar. 5, 1958	15.48
Oct. 7, 1958	16.36

Well 116 (7N9E-34bbb)

Oct. 9, 1957	21.20
Dec. 5, 1957	17.95
Mar. 5, 1958	17.48
June 10, 1958	15.91
Oct. 7, 1958	18.40

Well 117 (8N6E-4caa)

Oct. 29, 1957	21.50
Dec. 3, 1957	20.44
Mar. 6, 1958	19.68
May 27, 1958	18.30
Oct. 8, 1958	20.40

Well 118 (8N6E-9caa)

Sept. 9, 1957	25.98
Oct. 29, 1957	26.13
Dec. 3, 1957	25.94
Mar. 6, 1958	24.76
May 27, 1958	23.69
Oct. 8, 1958	23.63

Well 120 (8N6E-15bab)

Oct. 1, 1957	21.66
Oct. 29, 1957	21.75
Dec. 3, 1957	21.38
Mar. 6, 1958	20.60
June 3, 1958	19.78
Oct. 1, 1958	20.20
Oct. 15, 1958	20.25
Oct. 29, 1958	20.32
Nov. 13, 1958	20.39
Nov. 25, 1958	20.38
Dec. 10, 1958	20.40
Dec. 23, 1958	20.37
Feb. 5, 1959	20.29
Feb. 18, 1959	20.22
Mar. 10, 1959	19.97
April 29, 1959	19.89
June 3, 1959	20.13

Well 121 (8N6E-19ddd)

Oct. 10, 1957	23.75
Dec. 4, 1957	22.65
June 11, 1958	20.91
Oct. 8, 1958	22.01

Well 122 (8N6E-28cbc)

Mar. 6, 1958	15.58
June 3, 1958	14.60
Oct. 8, 1958	15.95

Well 125 (8N6E-34bbc)

June 17, 1958	20.78

Table 4.—*Water levels in wells tapping Quaternary deposits (continued)*

(Feet below land-surface datum)

Well 126 (8N6E-36ada)

Date	Water level
Sept. 5, 1957	22.45
Oct. 21, 1957	21.82
Dec. 4, 1957	20.22
May 28, 1958	19.15
Oct. 9, 1958	21.08

Well 127 (8N6E-36cda)

Aug. 27, 1957	20.43
Oct. 21, 1957	20.61
Dec. 2, 1957	19.81
Mar. 5, 1958	19.13
May 28, 1958	18.35
Oct. 9, 1958	19.53

Well 129 (8N7E-7aca)

Nov. 20, 1957	20.00
Dec. 4, 1957	19.88
June 3, 1958	18.55
Oct. 9, 1958	19.90

Well 130 (8N7E-10cbc)

Oct. 1, 1957	17.98
June 3, 1958	16.15
Oct. 9, 1958	17.17

Well 131 (8N7E-12ddd)

June 17, 1958	14.70
Oct. 9, 1958	15.40

Well 133 (8N7E-13ccc)

Oct. 10, 1957	16.31
Dec. 4, 1957	15.58
Mar. 12, 1958	14.85
June 3, 1958	14.62
Oct. 9, 1958	15.48

Well 134 (8N7E-14daa)

Sept. 23, 1957	17.19
Oct. 31, 1957	16.54
Dec. 4, 1957	16.16

Well 135 (8N7E-16caa)

Feb. 25, 1958	16.73
Mar. 12, 1958	16.67
Oct. 1, 1958	17.39
Oct. 15, 1958	17.46
Oct. 29, 1958	17.43
Nov. 13, 1958	17.39
Nov. 25, 1958	17.08
Mar. 10, 1959	16.25
April 29, 1959	16.07
June 3, 1959	16.60

Well 136 ((8N7E-16cad)

Date	Water level
Sept. 17, 1958	16.82

Well 137 (8N7E-23aca)

June 17, 1958	16.00
Oct. 9, 1958	16.17

Well 139 (8N7E-30dcc)

June 17, 1958	7.86

Well 140 (8N7E-33ddd)

Oct. 21, 1957	13.49

Well 141 (8N8E-5dbc)

Sept. 24, 1957	18.76
Dec. 4, 1957	16.04
June 10, 1958	16.36
Oct. 9, 1958	17.18

Well 142 (8N8E-7bbc)

Sept. 24, 1957	18.70
Oct. 31, 1957	18.14
Dec. 4, 1957	17.54
June 3, 1958	15.95
Oct. 9, 1958	17.48

Well 143 (8N8E-8bdc)

Oct. 31, 1957	17.86
Dec. 4, 1957	16.75
June 3, 1958	15.21
Oct. 9, 1958	16.92

Well 144 (8N8E-9bca)

May 21, 1950	11.26
Sept. 24, 1957	18.37
Oct. 31, 1957	17.80
Dec. 4, 1957	15.57
Mar. 12, 1958	16.35
Oct. 9, 1958	16.98

Well 145 (8N8E-13ccb)

Feb. 6, 1958	16.38
Mar. 5, 1958	16.52

Well 146 (8N8E-16adb)

Sept. 3, 1958	14.45
Oct. 1, 1958	14.09
Oct. 15, 1958	14.33
Oct. 29, 1958	14.59
Nov. 13, 1958	14.20
Nov. 25, 1958	14.15
Dec. 23, 1958	14.27
Feb. 5, 1959	13.85
Feb. 18, 1959	13.66
Mar. 10, 1959	13.42
April 29, 1959	12.54
June 3, 1959	13.53

Table 4.—*Water levels in wells tapping Quaternary deposits (continued)*

(Feet below land-surface datum)

Well 147 (8N8E-16ddb)

Date	Water level
Dec. 5, 1957	15.41
Mar. 5, 1958	14.62
June 3, 1958	13.25

Well 148 (8N8E-23cda)

Oct. 31, 1957	14.50
Dec. 5, 1957	13.68
Mar. 5, 1958	12.88
June 10, 1958	11.73
Oct. 7, 1958	12.67

Well 149 (8N8E-36dbd)

Oct. 9, 1957	12.45
Dec. 5, 1957	9.63
Mar. 5, 1958	9.75
June 10, 1958	9.42
Aug. 13, 1958	9.34
Oct. 7, 1958	10.26

Well 150 (8N9E-6bcc)

May 27, 1958	4.79
Oct. 7, 1958	8.02

Well 151 (8N9E-20bbd)

June 10, 1958	2.49
Aug. 28, 1958	2.11
Oct. 7, 1958	3.40

Well 152 (9N6E-2aca)

Oct. 29, 1957	23.91
Dec. 3, 1957	22.54
Mar. 6, 1958	22.26
May 27, 1958	20.50
Oct. 8, 1958	23.04

Well 153 (9N6E-3dba)

Sept. 11, 1957	20.57

Well 154 (9N6E-9bac)

Sept. 10, 1957	19.83
Oct. 29, 1957	19.27
Dec. 3, 1957	18.99
Mar. 5, 1958	17.90
June 3, 1958	16.87
Oct. 8, 1958	18.42

Well 155 (9N6E-9dad)

Sept. 10, 1957	19.49
Dec. 3, 1957	19.33
Mar. 6, 1958	17.73
June 3, 1958	16.80
Oct. 8, 1958	18.06

Well 156 (9N6E-10dab)

Date	Water level
Oct. 29, 1957	20.93
Dec. 3, 1957	20.56
Mar. 5, 1958	19.42
June 3, 1958	18.50
Oct. 8, 1958	19.54

Well 157 (9N6E-11dad)

Sept. 11, 1957	23.34
Oct. 29, 1957	23.06
Dec. 3, 1957	22.12
Mar. 6, 1958	21.58
May 27, 1958	20.35
Oct. 8, 1958	21.88

Well 158 (9N6E-12cda)

Sept. 11, 1957	16.99
Oct. 29, 1957	16.75
Dec. 3, 1957	15.61
May 27, 1958	14.07
Oct. 8, 1958	15.71

Well 159 (9N6E-13bcc)

Sept. 11, 1957	22.05
Dec. 3, 1957	20.40
Mar. 5, 1958	20.38

Well 160 (9N6E-14baa)

Sept. 11, 1957	24.64
Dec. 3, 1957	23.69
Mar. 6, 1958	22.92
May 27, 1958	21.81
Oct. 8, 1958	23.24

Well 161 (9N6E-15dad1)

Sept. 10, 1958	19.45
Oct. 1, 1958	20.63
Oct. 15, 1958	19.59
Oct. 29, 1958	19.70
Nov. 13, 1958	19.77
Nov. 25, 1958	19.50
Dec. 23, 1958	19.65
Feb. 5, 1959	19.39
Feb. 18, 1959	19.25
Mar. 10, 1959	18.83
April 29, 1959	19.07
June 3, 1959	19.60

Well 164 (9N6E-17ddc)

June 3, 1958	20.71

Well 165 (9N6E-20ba)

Sept. 10, 1957	23.73
Oct. 29, 1957	23.03
Dec. 3, 1957	22.28
Mar. 6, 1958	20.91
Oct. 8, 1958	22.54

Table 4.—*Water levels in wells tapping Quaternary deposits (continued)*

(Feet below land-surface datum)

Well 167 (9N6E-21baa)

Date	Water level
May 28, 1958	9.86
Oct. 8, 1958	20.88

Well 168 (9N6E-23aaa)

Feb. 5, 1958	20.07
Mar. 6, 1958	20.69
June 3, 1958	19.53

Well 169 (9N6E-26aca)

Sept. 12, 1957	21.61
Oct. 29, 1957	21.90
Dec. 3, 1957	20.83
Mar. 6, 1958	20.16
June 3, 1958	18.91

Well 170 (9N6E-30aab)

Sept. 11, 1957	23.84
Oct. 29, 1957	22.90
Dec. 3, 1957	22.04
Mar. 6, 1958	20.48
Oct. 8, 1958	22.10

Well 171 (9N6E-30cda)

Sept. 10, 1957	24.27
Dec. 3, 1957	22.54
Mar. 6, 1958	20.73
Oct. 8, 1958	22.31

Well 172 (9N6E-31baa)

Dec. 3, 1957	21.29
Mar. 6, 1958	19.94
Oct. 8, 1958	21.73

Well 173 (9N6E-32dad)

June 3, 1958	16.70
Oct. 8, 1958	19.45

Well 174 (9N6E-35bcc)

Feb. 5, 1958	18.30
Mar. 6, 1958	18.34
June 3, 1958	17.23
Oct. 8, 1958	18.98

Well 175 (9N7E-5bdb)

Sept. 11, 1957	19.88
Oct. 29, 1957	19.74
Dec. 3, 1957	18.80
Mar. 6, 1958	17.98
Oct. 8, 1958	18.45

Well 176 (9N7E-9cbc)

Date	Water level
Feb. 5, 1958	12.79
Mar. 6, 1958	12.68
June 3, 1958	12.19
Oct. 8, 1958	12.96

Well 177 (9N7E-12aca)

Sept. 12, 1957	20.59
Oct. 29, 1957	20.80
Dec. 3, 1957	19.90
Mar. 6, 1958	19.33
May 27, 1958	18.40
Oct. 8, 1958	19.99

Well 178 (9N7E-13cca)

Oct. 29, 1957	15.11
Dec. 3, 1957	13.77
Mar. 5, 1958	12.48
May 27, 1958	10.73
Oct. 9, 1958	14.17

Well 179 (9N7E-14bab)

Sept. 12, 1957	15.59
Oct. 29, 1957	13.88
Dec. 3, 1957	13.91
Mar. 6, 1958	13.18
May 27, 1958	12.47
Oct. 8, 1958	13.90

Well 180 (9N7E-15aaa)

Sept. 10, 1958	15.56

Well 182 (9N7E-20da)

Sept. 12, 1957	14.53
Oct. 29, 1957	14.00
Dec. 3, 1957	13.30
Mar. 6, 1958	12.48
June 3, 1958	12.30
Oct. 8, 1958	12.78

Well 183 (9N7E-27aba)

Dec. 4, 1957	17.60

Well 184 (9N7E-27dda)

Sept. 12, 1957	19.91
Oct. 29, 1957	19.04
Dec. 4, 1957	18.36
Mar. 12, 1958	17.17
May 27, 1958	17.01
Oct. 9, 1958	18.21

Well 185 (9N7E-30bda)

Feb. 5, 1958	18.79
Mar. 6, 1958	18.79
June 3, 1958	17.92
Oct. 8, 1958	19.03

Table 4.—*Water levels in wells tapping Quaternary deposits (continued)*

(Feet below land-surface datum)

Well 186 (9N7E-33dbc)

Date	Water level
Sept. 23, 1957	19.31
Dec. 4, 1957	18.63
May 27, 1958	17.25
Oct. 9, 1958	17.98

Well 187 (9N7E-34bcd)

Sept. 23, 1957	18.11
Dec. 4, 1957	17.37
Oct. 9, 1958	16.80

Well 188 (9N7E-36bdb)

Oct. 29, 1957	19.20
Dec. 4, 1957	18.28
Oct. 9, 1958	19.10

Well 189 (9N8E-2aad)

Dec. 5, 1957	7.04
Mar. 5, 1958	6.31
June 10, 1958	5.76
Oct. 7, 1958	7.03

Well 190 (9N8E-7cbb)

Sept. 12, 1957	21.40
Dec. 3, 1957	19.90
Mar. 6, 1958	19.42
May 27, 1958	18.49
Oct. 8, 1958	20.14

Well 191 (9N8E-8ada)

Sept. 25, 1957	14.96
Oct. 31, 1957	14.62
Dec. 5, 1957	13.94
Mar. 12, 1958	13.22
June 3, 1958	12.79
Oct. 8, 1958	14.20

Well 193 (9N8E-14cac)

June 10, 1958	10.75
Oct. 7, 1958	13.60

Well 194 (9N8E-16ddb)

Date	Water level
Dec. 5, 1957	3.68
Mar. 5, 1958	2.66
July 10, 1958	4.18

Well 195 (9N8E-17ada)

Sept. 25, 1957	15.22
June 10, 1958	13.30
Oct. 8, 1958	14.69

Well 196 (9N8E-23dca)

Sept. 26, 1957	14.52
Oct. 31, 1957	15.18
Dec. 5, 1957	13.65
Mar. 4, 1958	12.42
Oct. 6, 1958	12.86

Well 197 (9N8E-27acd)

Sept. 25, 1957	13.51
Oct. 31, 1957	13.34
Dec. 5, 1957	11.17
Mar. 5, 1958	11.56

Well 200 (9N8E-29dbd)

Mar. 12, 1958	12.14
June 3, 1958	12.69

Well 201 (9N8E-31ada)

Sept. 24, 1957	17.80
Oct. 31, 1957	16.90
Dec. 4, 1957	15.08
June 3, 1958	15.50
Oct. 9, 1958	16.95

Well 202 (9N8E-36ddd)

Feb. 6, 1958	4.55

Well 203 (10N9E-31cdd)

Sept. 25, 1957	17.42
Oct. 31, 1957	18.21
Dec. 5, 1957	15.61
Mar. 5, 1958	14.79
June 10, 1958	12.59
Oct. 7, 1958	15.67

TABLE 5

Partial chemical analyses of water from 6 selected wells screened in deposits of Quaternary age (chemical constituents in ppm)

Well number	Location	Date of collection	Depth to water below land surface (feet)	Total iron (Fe)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness as ($CaCO_3$) Total	Hardness as ($CaCO_3$) Noncarbonate	Specific conductance (micromhos at 25°C)	pH Field	pH Laboratory
20	4N8E–17bdb	10-29-58	27.10	5.6	544	0	23	9.8	.9	466	20	780	6.8	8.0
Do	do	11-13-58	27.86	5.7	610	0	22	6.5	.2	498	0	841	6.8	8.1
Do	do	11-25-58	28.01	4.3	232	12	10	6.5	1.2	214	0	383	7.0	8.5
Do	do	3-10-59	18.41	9.5	252	4	5	7	2.2	216	3	389	6.8	8.3
Do	do	4-29-59	17.24	9.5	654	0	6	8.2	2.1	535	0	860	----	8.0
113	7N9E–15dcc	10- 1-58	12.37	7.4	189	0	4	----	.8	172	17	376	----	8.2
Do	do	10-29-58	13.72	7.7	374	0	7	3.8	1.9	302	0	545	7.0	8.2
Do	do	11-13-58	14.40	7.3	392	0	1	3	.4	302	0	534	7.0	7.2
Do	do	11-25-58	14.58	5.5	192	6	5	3	2	152	0	317	7.0	8.4
Do	do	12-23-58	15.00	3.6	224	4	5	3	1.1	180	0	353	----	8.3
Do	do	2- 5-59	14.78	2.5	384	0	5	2.5	0	297	0	556	7.0	7.4
Do	do	2-18-59	12.85	5.5	362	0	12	3.0	.2	292	0	524	----	7.8
Do	do	3-10-59	11.29	6.8	312	0	15	3.2	3.2	249	0	471	6.9	8.1
Do	do	4-29-59	10.88	7.5	340	6	18	3.2	3.1	284	0	527	----	8.3
Do	do	6- 3-59	11.70	6.3	344	6	4	3	3.4	283	0	498	6.9	8.3
119	8N6E–9ddc	10- 1-58	20.20	9.9	267	0	24	4.5	.5	214	0	406	----	7.3
Do	do	10-15-58	20.25	9.8	198	0	24	4.8	.5	159	0	321	7.0	8.0
Do	do	10-29-58	20.32	11	240	0	22	4	.4	197	0	364	6.9	8.1
Do	do	11-13-58	20.39	10	258	0	21	4.8	0	214	2	407	6.9	8.1
Do	do	11-25-58	20.38	5.2	152	4	7	4.5	0	134	3	275	7.0	8.3
Do	do	12-23-58	20.38	3.1	166	0	12	4.5	0	136	0	278	----	8.0
Do	do	1-21-59	--------	6.8	258	0	12	3.5	0	216	4	394	----	7.4
Do	do	2- 5-59	20.29	2.5	258	0	11	4.5	0	211	0	407	6.8	8.0
Do	do	2-18-59	20.22	5.5	362	0	12	3	.2	292	0	524	----	7.8
Do	do	3-10-59	19.97	12	188	0	12	5.2	.4	149	0	281	6.9	8.2
Do	do	4-29-59	19.89	11	256	0	20	6	.2	215	5	407	----	8.2
Do	do	6- 3-59	20.13	10	186	0	8	4.8	.4	157	4	309	6.8	8.2
136	8N7E–16cad	10- 1-58	17.39	12	156	0	1	----	4.2	153	26	380	----	8.2
Do	do	10-15-58	17.46	13	302	0	1	7.2	4.1	226	0	420	6.8	8.0
Do	do	10-29-58	17.43	13	350	0	1	7.8	3.8	272	0	519	6.9	8.2
Do	do	11-13-58	17.39	13	406	0	1	7	.2	298	0	556	6.8	8.2
Do	do	11-25-58	17.08	2.1	214	0	1	8	4.6	151	0	344	6.8	8.2
Do	do	12-23-58	--------	5.1	276	4	1	6.5	5.2	205	0	424	----	8.3
Do	do	2- 5-59	--------	5.3	408	0	1	7.0	0	294	0	579	----	8.0
Do	do	2-18-59	--------	11	410	0	1	7.5	.2	298	0	583	----	7.0
Do	do	3-10-59	16.25	14	222	2	1	7.8	9.2	160	0	350	6.8	8.4
Do	do	4-29-59	16.07	13	410	0	1	8.8	.2	304	0	595	----	7.4
Do	do	6- 3-59	16.60	12	326	0	1	7.5	9.8	242	0	477	6.9	8.2
146	8N8E–16adb	10- 1-58	14.09	3.4	246	10	4	3.5	.4	213	0	354	----	8.4
Do	do	10-15-58	14.33	3	242	8	1	2	.5	216	4	361	7.2	8.4
Do	do	10-29-58	14.59	4.3	258	0	1	2.2	.4	218	6	370	7.2	8.1
Do	do	11-13-58	14.20	3.7	262	0	1	8.5	.4	224	9	396	7.2	8.0
Do	do	11-25-58	14.15	1.8	252	6	3	2	0	224	8	378	7.2	8.5
Do	do	12-23-58	14.27	.8	236	12	3	2	0	217	4	370	----	8.7
Do	do	2- 5-59	13.85	1.4	264	0	3	2.5	0	217	1	370	7.1	7.1
Do	do	2-18-59	13.60	3.1	268	0	4	2	.2	226	6	394	----	7.7
Do	do	3-10-59	13.42	4.2	266	8	6	3	.5	223	0	379	7.1	8.4
Do	do	4-29-59	12.54	3.5	262	0	4	2.5	.8	218	3	407	----	7.8
Do	do	6- 3-59	13.53	3.5	232	14	5	2.5	.6	218	5	375	7.2	8.6
162	9N6E–15dad$_2$	10- 1-58	20.63	3.7	140	0	2	6.5	5	113	0	286	----	8.0
Do	do	10-15-58	19.59	2.4	137	0	2	5	3.1	114	2	269	6.0	7.4
Do	do	10-29-58	19.70	3.5	136	0	1	5	2.1	111	0	268	6.0	7.9
Do	do	11-13-58	19.77	4.4	136	0	1	4.5	3	115	3	267	6.2	7.4
Do	do	11-25-58	19.50	2.5	138	0	6	5	5.2	114	1	260	6.0	8.2
Do	do	12-23-58	19.65	2.4	136	0	5	4.5	5.8	110	0	263	----	8.2
Do	do	1-21-59	--------	1.8	140	0	5	4.5	2.8	112	0	264	----	7.6
Do	do	2- 5-59	19.39	2	136	0	7	5	7.1	112	0	263	6.0	6.4
Do	do	2-18-59	19.25	4.8	136	0	20	4.5	4.2	118	6	267	----	7.5
Do	do	3-10-59	18.83	3.2	140	0	21	5.5	7.2	113	0	267	6.0	8.2
Do	do	4-29-59	19.07	1.6	136	0	24	4.8	8.1	110	0	258	----	6.8
Do	do	6- 3-59	19.60	2.5	124	6	23	5.2	8.4	109	0	257	6.0	8.4