Ground-Water Resources of The Pascagoula River Basin Mississippi and Alabama

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1839-K

Prepared in cooperation with the Mobile District, Corps of Engineers, U.S. Army

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

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By ROY NEWCOME, JR.

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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A general description of ground-water availability, quantity, and quality in a major river basin of the Gulf Coast region

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CONTENTS

ILLUSTRATIONS

TABLES

GROUND-WATER RESOURCES OF THE PASCAGOULA RIVER BASIN, MISSISSIPPI AND ALABAMA

By Roy Newcome, Jr.

ABSTRACT

Abundant ground-water resources underlie the Pascagoula River basin. These resources have been developed intensively in only a few places—namely, Hattiesburg, Laurel, Meridian, and Pascagoula. Seepage from the ground water reservoirs sustains the base flows of the Leaf, Chickasawhay, Pascagoula, and Escatawpa Rivers and their tributaries.

The fresh-water-bearing section is 300 to 3,500 feet thick and is composed chiefly of sand and clay of Eocene to Recent age. Major rock units represented are the Wilcox, Claiborne, Jackson, and Vicksburg Groups and formations of Miocene and Pliocene ages.

Aquifers in the Claiborne Group provide water for all purposes in the northern third of the basin. The Claiborne is underlain by the potentially important but virtually untapped Wilcox Group. Miocene aquifers are the main source of water supplies in the southern half of the basin, but Pliocene aquifers furnish most supplies in the Jackson County area at the basin's southern extremity.

Much of the fresh-water section has undergone no water-supply development because of the great depth of many aquifers and the availability, at shallow depths, of supplies adequate for present needs. However, a large part of any substantial increase in ground-water withdrawal will probably come from wells deeper than those commonly drilled in the region.

Ground-water levels are within 50 feet of the surface in most places, and flowing wells are common in the valleys and near the coast. Water-level declines due to pumping have become serious problems only in a few localities of heavy withdrawal. In most of these places redistribution of pumpage would alleviate the problem of excessive drawdown.

Although few wells in the basin yield more than 500 gallons per minute, yields of 2,000 gallons per minute or more could be reasonably expected from efficiently constructed wells almost anywhere in the region.

Total ground-water pumpage is estimated to be about 60 million gallons per day. Potential pumpage is many times that figure. Well fields capable of yielding several million gallons of water per day would be feasible in most places.

The ground water is of good to excellent quality. Most of it is a sodium bicarbonate type of water. It usually is soft and has a low to moderate dissolved-solids content. Excessive iron is a problem in places, particularly where

water supplies are obtained from shallow aquifers, but at least a part of the excess iron comes from corrosion of well and distribution-line fittings by slightly acidic water.

Salt-water encroachment is a potential problem in the coastal area, but little increase in salinity has been observed in monitor wells in the period 1960–65. Saline-water resources are available for development at considerable depth in most of the region.

OBJECTIVE OF REPORT

This report, describing the geology and ground-water resources of the Pascagoula River basin, was prepared at the request of the Corps of Engineers, U.S. Army, as part of a comprehensive program to appraise the resources of selected river basins The ultimate purpose of the program is to present facts that will lead to optimum development of the natural and cultural resources of large areas constituting the river basins. Other basin studies underway in Mississippi are for the Big Black and Pearl Rivers.

In scope this report deals with the major aspects of ground-water occurrence and development and their interrelation with the geology of the selected region. No attempt is made to give detailed descriptions of specific localities or even of counties; that effort is reserved for future investigations.

DESCRIPTION OF AREA

Most of southeastern Mississippi and a small part of southwestern Alabama are included in the Pascagoula River basin (fig. 1). The basin contains all or parts of 22 counties in Mississippi and parts of 3 counties in Alabama; the total area is about 9,700 square miles.

Landforms in the basin consist of low rounded hills, stream flood plains, and coastal flats. Elevations range from sea level to about 700 feet. Local topography is rugged in the northeast corner of the basin, but gently rolling to flat in the remainder of the area.

Major streams, in addition to the Pascagoula River, are the Leaf, Chickashawhay, and Escatawpa Rivers. The subbasins drained by these streams are shown on the location map (fig. 1). Average discharge of the Pascagoula River at Merrill is 9,587 cfs (cubic feet per second). Minimum flow is 696 cfs and maximum is 178,000 cfs. Average flows of the larger tributary streams are Leaf River at Hattiesburg, 2,608 cfs; Chickasawhay River at Leakesville, 3,711 cfs; and Escatawpa River near Wilmer, Ala., 1,003 cfs (U.S. Geological Survey, 1964). Base flows of the streams are sustained by ground-water discharge.

Average annual precipitation in the Pascagoula River basin ranges from 50 to 64 inches, depending on geographic location. Average annual precipitation for the basin is 57 inches.

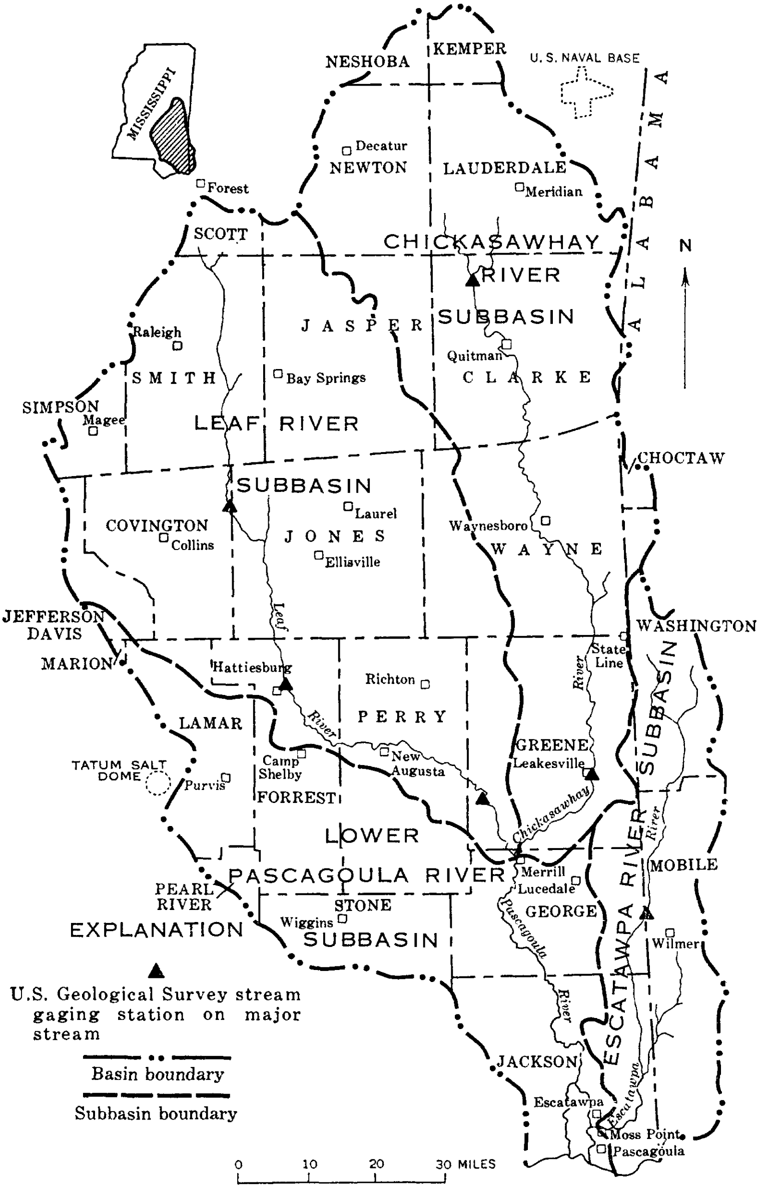

FIGURE 1.—Location and major drainage of the Pascagoula River basin.

The average annual temperature is 66°F, about the same as the temperature of ground water in shallow aquifers. Temperature extremes are +110° and −10°F. The growing season averages 222 days between late March and early November, except in the immediate vicinity of the coast where the time between killing frosts may be as much as 290 days.

PREVIOUS INVESTIGATIONS AND CURRENT ACTIVITY IN THE REGION

The geology and water resources of all or parts of the Pascagoula River basin are described, in varying degree of detail, in the publications listed in the references at the end of the report.

Current water-resources investigations by the U.S. Geological Survey are under way in the Forrest-Perry-Greene-Jones-Wayne Counties area, in Lamar County (special study related to AEC testing at Tatum dome), and in the Jackson-George Counties area.

SUMMARY OF GEOLOGY

The Pascagoula River basin is in the Coastal Plain physiographic province. The basin is a topographic feature only and not a geologic entity. Exposed rock formations are sedimentary in origin and range in age from early Eocene to Recent (table 1). Sand and clay in various proportions constitute most of the formations; a few thin units consist of marl or limestone. Sand beds are irregular in thickness and few can be traced with certainty more than a few miles; however, sandy zones, as differentiated from clayey zones, are readily correlated over substantial areas—some throughout the basin.

The beds dip south-southwestward at 25 to 80 feet per mile. Dip is steepest across the southern half of Jackson County (fig. 2) where the weight of deltaic sediments that accumulated during the late part of the Tertiary Period caused the greatest downwarping. This downwarping becomes even more pronounced farther westward along the Gulf Coast toward the axis of the Mississippi River trough. The dip approaches 100 feet per mile in Hancock County.

The Moodys Branch Formation of late Eocene age is a thin but easily recognized marker bed underlying most of the Pascagoula River basin. A contour map (fig. 3) on this formation illustrates the general attitude of the formations in the region.

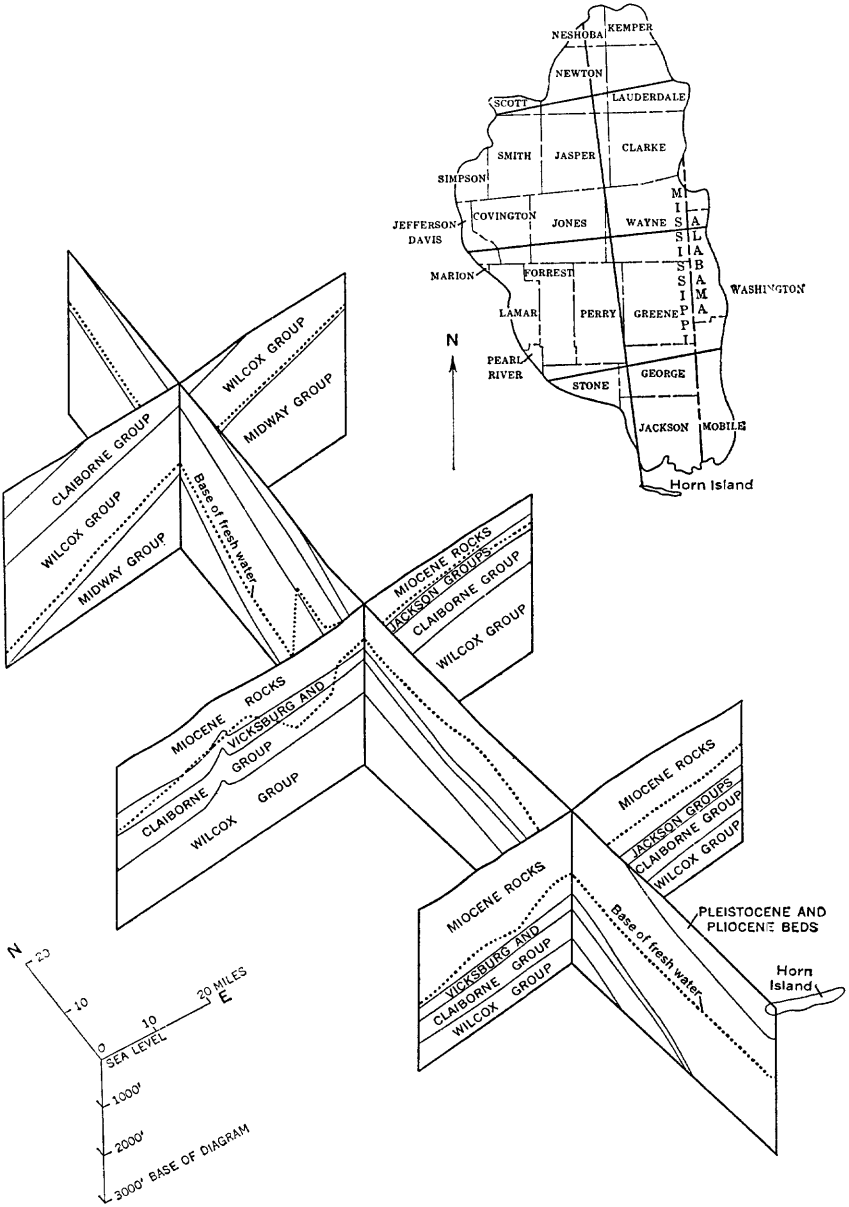

FIGURE 2.—Fence diagram of the Pascagoula River basin, Mississippi and Alabama.

TABLE 1.—*Stratigraphic units in the Pascagoula River basin and their water-bearing character*

System	Series	Stratigraphic unit		Uneroded thickness (feet)	Water resources
Quaternary	Recent		Alluvium	0–100	Not important aquifer. Near coast, where thickness is substantial; the aquifer is intruded by salty water.
	Pleistocene		Terrace deposits	0–100	Large quantities of water available but relatively untapped. Intruded by salty water from tidal estuaries near coast.
	Pliocene		Citronelle Fm	0–150	Supplies shallow domestic wells over much of basin and a few municipal wells.
			Graham Ferry Fm	150	Main source of water supply for municipal and industrial use in the Pascagoula area.
	Miocene		Pascagoula Fm	1, 500–2, 000	Main source of water supply for domestic, industrial, and municipal users in more than half of basin. Difficult to differentiate in subsurface, but all three units contain thick aquifers capable of supplying large quantities of water.
			Hattiesburg Fm		
			Catahoula Sandstone		
	Oligocene	Vicksburg Group	Undifferentiated	250–550	Not generally an aquifer, but limy beds yield water to wells locally.
			Forest Hill Sand		Good source of water supply locally, but sand too fine in many places.

Tertiary	Eocene	Jackson Group	Yazoo Clay		Not an aquifer.
			Moodys Branch Fm		Not an aquifer.
		Claiborne Group	Cockfield Fm	850–1, 100	Contains significant aquifers locally, but not generally a source of large water supplies.
			Cook Mountain Fm		Not an aquifer.
			Sparta Sand		Source of water supply for several municipalities in northern part of basin. Large additional supplies available.
			Zilpha Clay		Not an aquifer.
			Winona Sand		Good aquifer locally.
			Tallahatta Fm		Meridian Sand Member is potentially important but generally untapped source of water supply in northern half of basin.
		Wilcox Group	Undifferentiated	1, 100–2, 000	Large quantities of water available but untapped in northern third of basin. Best aquifers are in basal part of group.

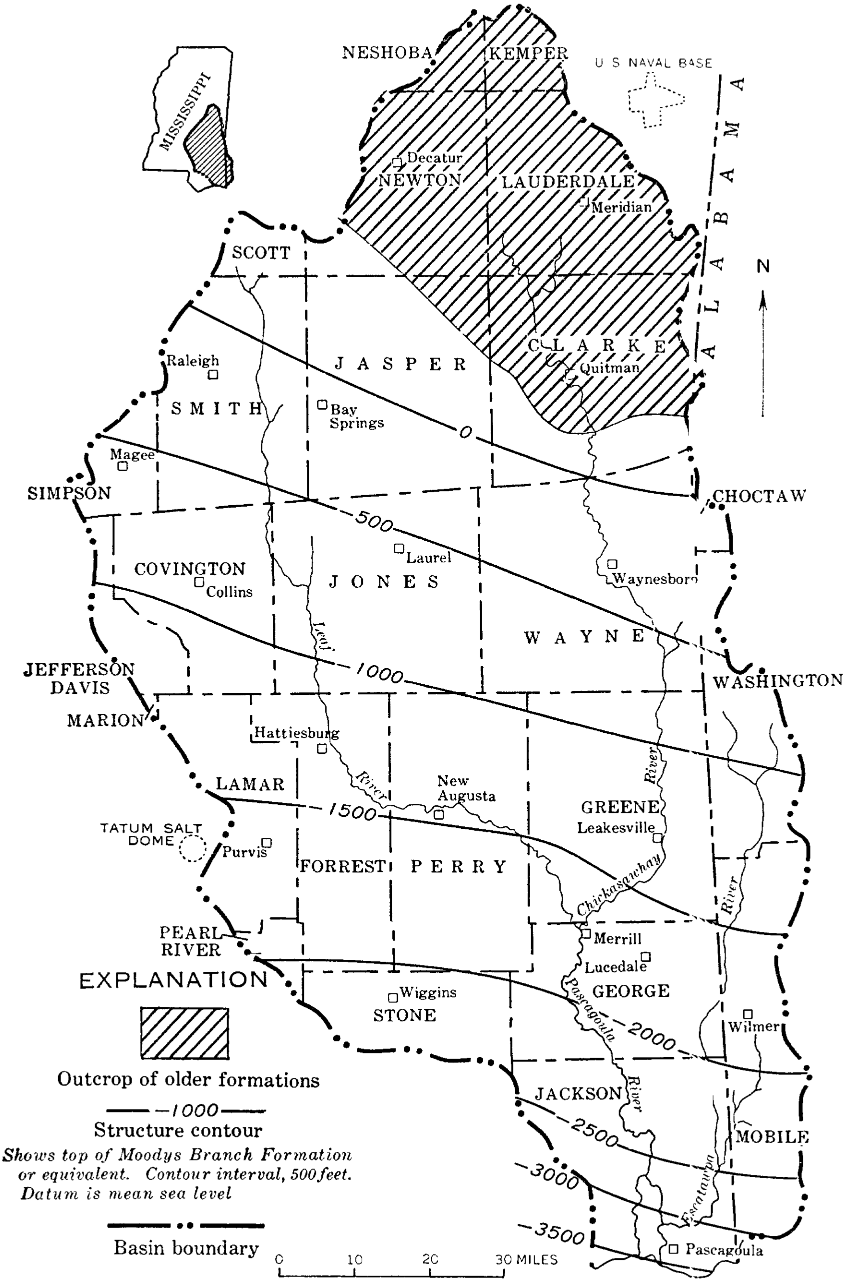

FIGURE 3.—Configuration of the top of the Moodys Branch Formation or equivalent.

AVAILABILITY OF GROUND-WATER SUPPLIES

FRESH-WATER-BEARING SECTION

Fresh ground water[1] is available in the Pascalouga River basin to depths ranging from near sea level elevation on the northeast margin to more than 3,000 feet below sea level in the west-central part (fig. 4). All the exposed formations of the basin are fresh-water bearing. The fresh-water section ranges in thickness from 300 to 3,500 feet. It is thinnest in the northeast and thickens southward into the Smith-Jasper-Wayne Counties area where fresh water extends farthest south in the basal part of the Wilcox Group. From this area southward the fresh-water section ranges between 1,900 and 700 feet in thickness. Greene and Perry Counties and southern Wayne County have a relatively thin fresh-water section restricted to rocks of Miocene age and younger.

LOCATION AND EXTENT OF AQUIFERS

A map of the general distribution of fresh ground water according to geologic units (fig. 5) shows that beds of Miocene age are sources of ground-water supplies throughout the southern two-thirds of the basin and are the only significant sources in about half of the basin.

The Claiborne Group furnishes practically all existing ground-water supplies in the northern third of the region. Although the underlying Wilcox Group occupies about 1,000 feet of the fresh-water section in that area, the Wilcox is virtually untapped for water supplies.

The Miocene and Wilcox beds generally do not contain fresh water in the same locality. Miocene and Claiborne aquifers, however, are both present in a band underlying the northern halves of Covington, Jones, and Wayne Counties. In this area nearly all water supplies are obtained from the shallower Miocene beds.

In Jackson County, Miss., and the southwestern part of Mobile County, Ala., fresh water can be obtained from geologic units of Pleistocene, Pliocene, and Miocene ages. The Pleistocene deposits are comparatively thin; most ground-water-supply development is in the underlying Pliocene beds, although the Miocene aquifers supply some municipal users.

Table 2 contains representative data obtained from electric logs of selected oil tests and water wells (fig. 6). These examples of fresh-water sand intervals at various localities throughout the Pascagoula basin emphasize availability of the untapped ground-water resources. The relation of fresh-water sand zones across the basin is illustrated by electric-log sections *A–A′* and *B–B′* (fig. 7).

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[1] Fresh water is defined as water containing less than 1,000 ppm (parts per million) of dissolved solids.

TABLE 2.—*Fresh-water sand intervals in the Pascagoula River basin*

[Data, in feet, from electric logs of oil test wells]

County	No. shown on fig. 6	Location	Elevation	Top of log	Sand intervals
		Mississippi			
Clarke	20	Quitman, 3 miles east	265	400	590–670 725–745 780–820 860–900 1410–1450 1520–1605 1870–1900
Covington	11	Collins, 3½ miles east	415	441	510–540 560–585 610–695 760–820 895–955 1790–1900
Forrest	15	Hattiesburg, 10 miles south	360	50	350–580 710–910 950–1270 1450–1580
George	4	Lucedale, 6 miles southwest	190	100	670–730 990–1020 1050–1075 1100–1140 1170–1230
Greene	13	Leakesville, 11 miles northwest	290	104	360–380 490–615 665–710 805–830
Greene	27	State Line, 4 miles west	140	100	85–210 275–465
Jackson	1	Vancleave, 9 miles northwest	110	148	540–630 695–790 1110–1155 1470–1600
Jasper	20	Paulding, 5 miles southwest	350	100	240–385 610–750 1115–1175 2515–2650 2680–2780
Jones	71	Laurel, 3 miles southwest	285	89	170–250 365–465 965–990
Kemper	3	DeKalb, 10 miles southwest	555	153	285–345 370–550
Lamar	26	Purvis, 5 miles northwest	385	75	75–275 800–940 1130–1490 1580–1640 1680–1800
Lauderdale	16	Meridian, 4 miles northeast	475	270	415–425 590–620 750–825
Neshoba	8	House, 1 mile southwest	495	261	355–365 740–900 1000–1065
Newton	3	Decatur, 5 miles southwest	485	295	720–880 1745–1855
Perry	32	Richton, 4 miles south	215	94	100–250 410–520 650–750
Perry	64	Janice, 1½ miles southeast	165	422	490–640 905–960
Scott	31	Norris, 3½ miles southeast	550	118	260–425 620–820 1195–1380 1645–1700 2450–2760
Smith	34	Magee, 5 miles east	535	161	161–470 570–620 680–720 1120–1320 1570–1980

TABLE 2.—*Fresh-water sand intervals in the Pascagoula River basin*—Continued

[Data, in feet, from electric logs of oil test wells]

County	No. shown on fig. 6	Location	Elevation	Top of log	Sand intervals
Mississippi—Continued					
Smith	57	Raleigh, 5 miles northeast	435	50	140–160 515–650 845–900 1020–1200 1970–2020 3350–3385 3420–3490
Stone	28	Wiggins, 5 miles southwest	195	56	56–140 180–250 600–640 760–1130 1240–1600 1750–1810 1830–1860
Wayne	27	Strengthford, 5 miles south	285	78	110–170 300–440 540–640
Wayne	127	Matherville, 1½ miles southwest	250	335	490–530 875–975 1460–1490 1810–2120
Alabama					
Mobile	2	Reiking, 6 miles southeast	295	53	53–275 390–450 685–720

DEPTH OF WELLS

Drilled water wells in the Pascagoula basin range in depth from about 50 feet to more than 1,000 feet. At least 60 percent of the wells are less than 300 feet deep; however, the average depth of wells near the coast is greater than in the northern and central parts of the basin. The following table provides a statistical comparison of well depths for three counties representing the northern, central, and southern parts of the basin.

Well depth (ft)	Percentage of wells		
	Lauderdale County	Jones County	Jackson County
Less than 100	7	27	26
100–199	26	26	12
200–299	37	25	15
300–399	18	6	13
400–499	4	7	5
500–599	0	5	6
600–799	5	1	8
800–999	2	0	10
1,000 and more	1	3	5
Number of wells used in computation	271	161	687

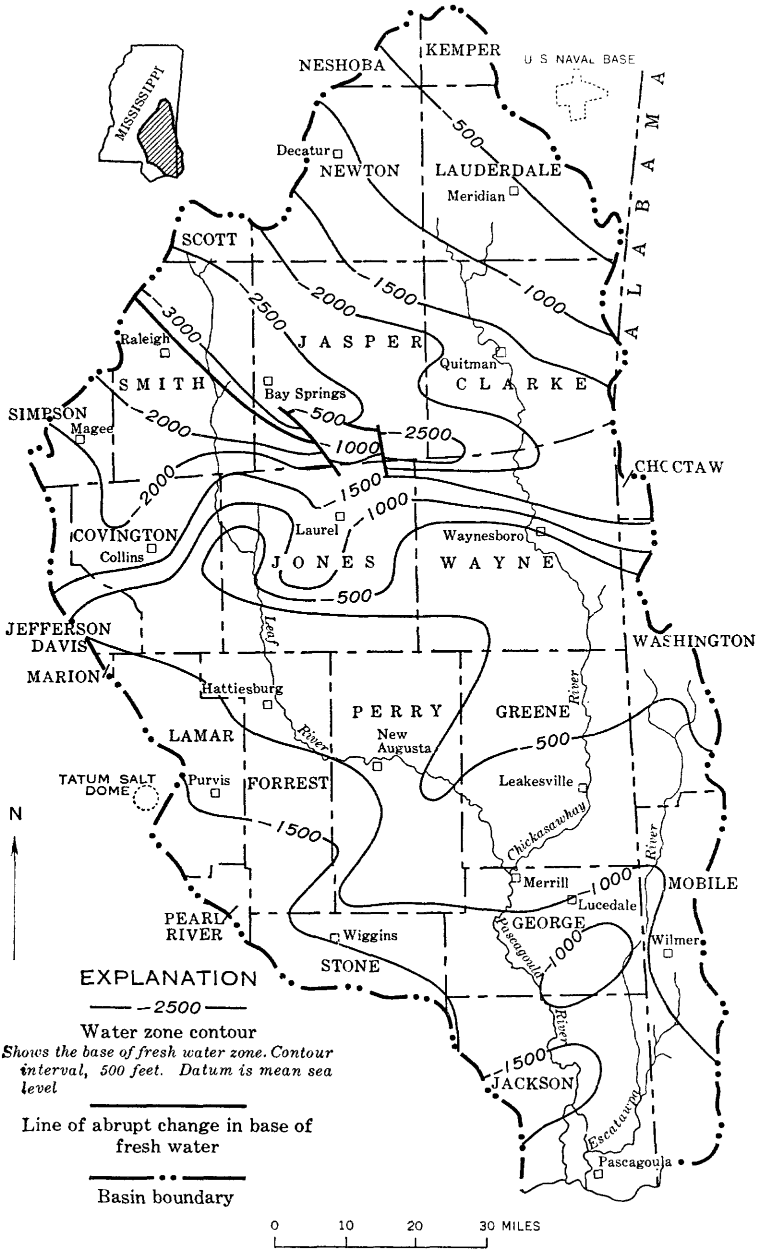


Figure 4.—Configuration of the base of fresh water.

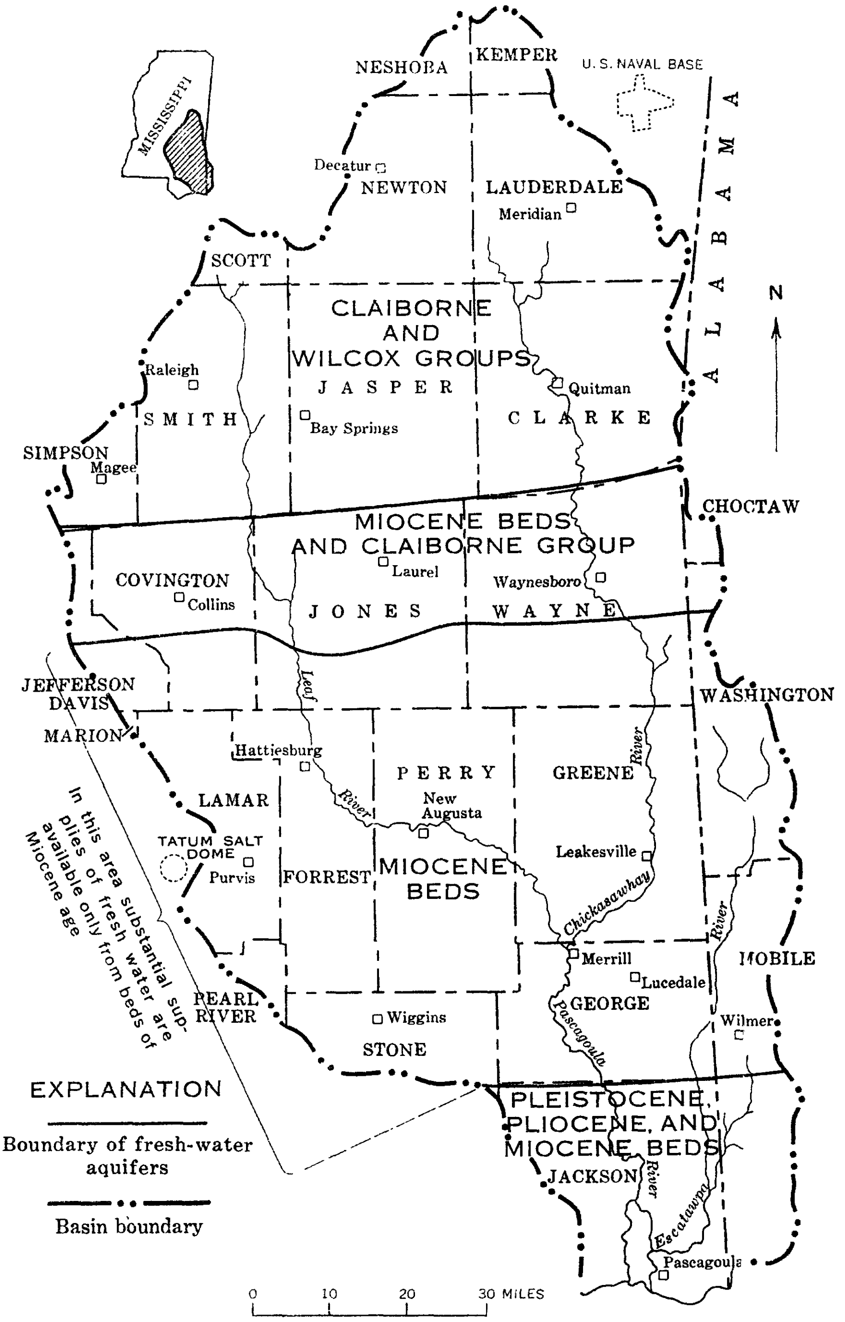


FIGURE 5.—Distribution of fresh-water aquifers.

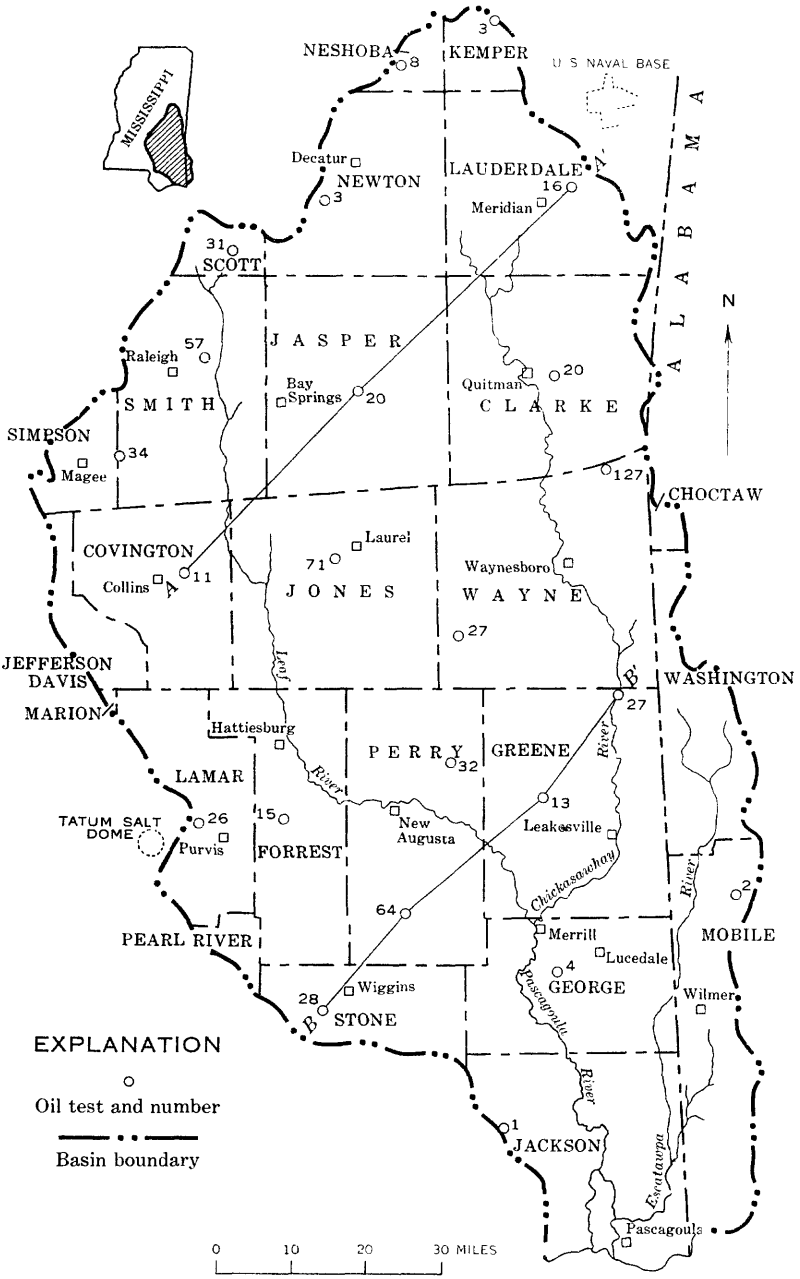


Figure 6.—Location of oil tests used to determine thickness of fresh-water sands and to construct cross sections. See table 2 for thickness of sand intervals. Sections *A–A′* and *B–B′* are shown in figure 7.

There is little doubt that a large part of any substantial increase in ground-water withdrawal will come from wells deeper than those commonly drilled in the region. The great thickness of the fresh-water section and the massiveness of many of the deep-lying beds of sand invite exploration and development of these untapped sources of supply.

WATER LEVELS AND RECHARGE

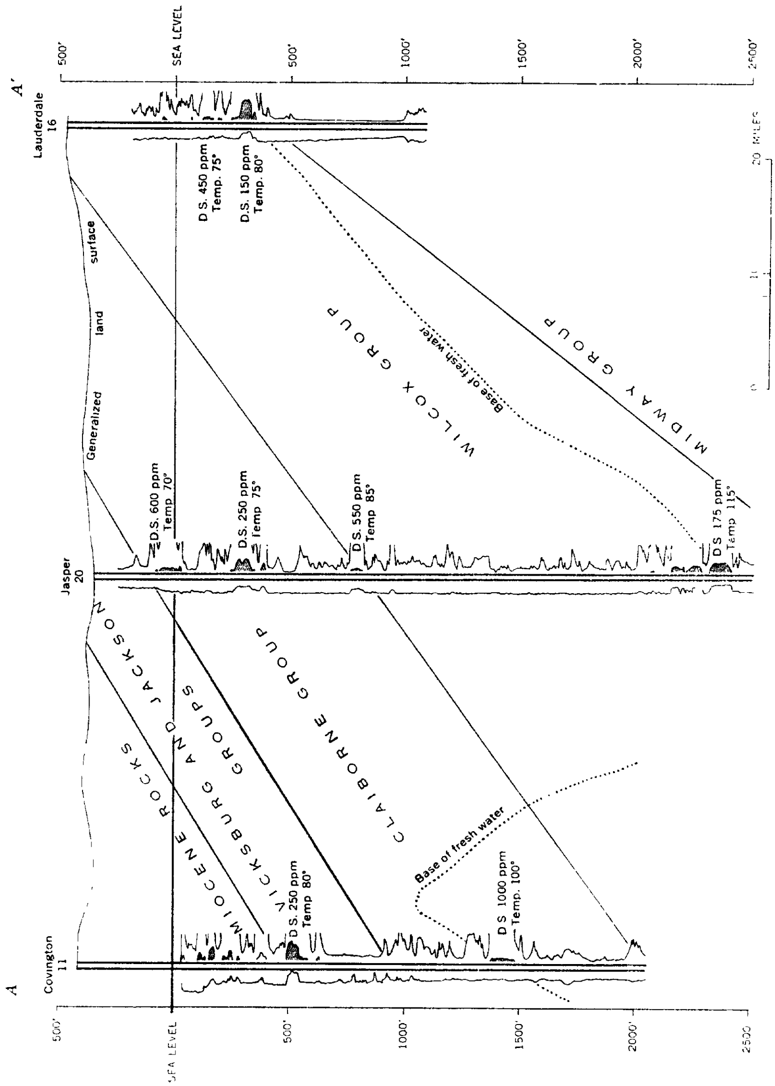
Practically all drilled wells in the basin are artesian—that is, the water is under natural pressure and rises above the top of the aquifer when the aquifer is penetrated by a well. Nonpumping water levels are within 50 feet of the land surface in more than half the wells and within 200 feet of the surface in nearly all of them. A large percentage of the wells flow owing to a combination of hydrostatic pressure and low topographic position. The greater proportion of flowing wells is in the southern counties where the land is low and where the deeper wells tapping aquifers having greater artesian head are more abundant.

The same counties used to illustrate well-depth distribution are analyzed for water-level distribution.

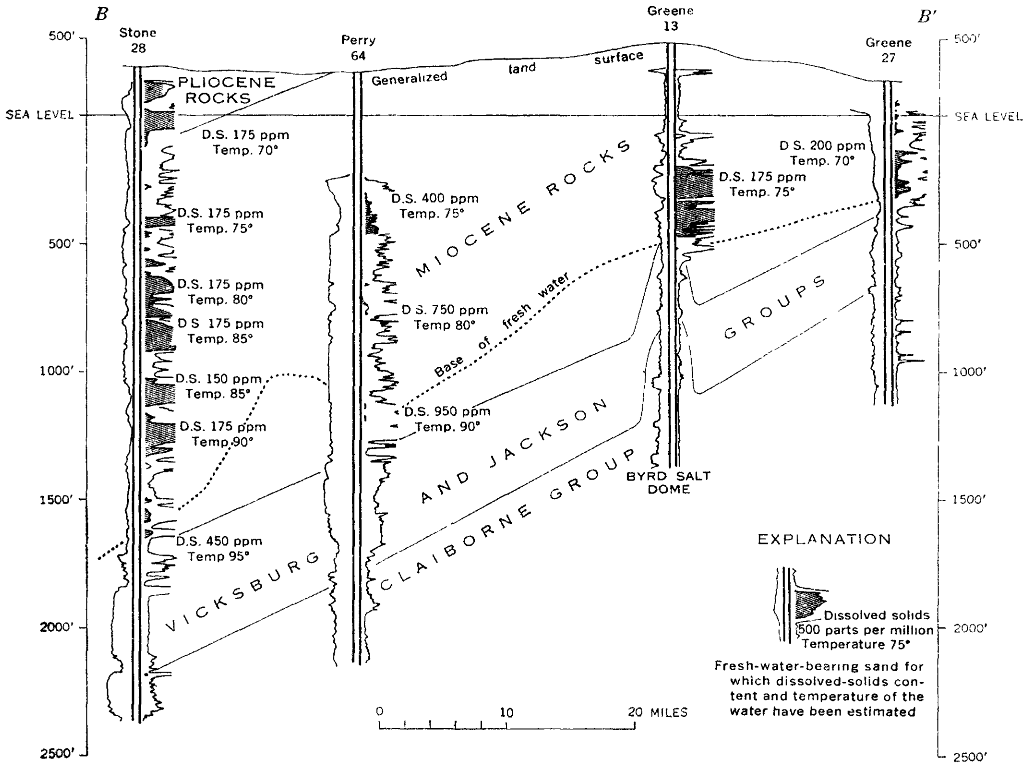
Water level (ft) below land surface	Percentage of wells		
	Lauderdale County	Jones County	Jackson County
Flowing	8	8	33
0–49	41	40	62
50–99	23	29	4
100–199	24	23	1
200–299	3	0	0
300 and more	1	0	0
Number of wells used in computation	224	113	639

Ground-water levels are declining in many places in the basin. Declines take place at a slow rate (usually less than 1 ft per yr) where they result only from land-use changes and low-rainful phases of the climatic cycle but at higher rates in areas of large withdrawal through wells. Hydrographs (fig. 8) show water-level trends and the effect of changes in pumping on water levels.

In a few places, where substantial withdrawals are made, water-supply problems have arisen as a result of lowered water levels. Where feasible, the problems can be alleviated by redistribution of pumpage, either geographically or stratigraphically or a combination of the two.



Section *A'–A'* from near Collins to near Meridian.



Section *B–B′* from near Wiggins to northeastern Greene County.

FIGURE 7.—SECTIONS *A–A′* AND *B–B′* BASED ON ELECTRIC LOGS, PASCAGOULA RIVER BASIN, MISSISSIPPI AND ALABAMA

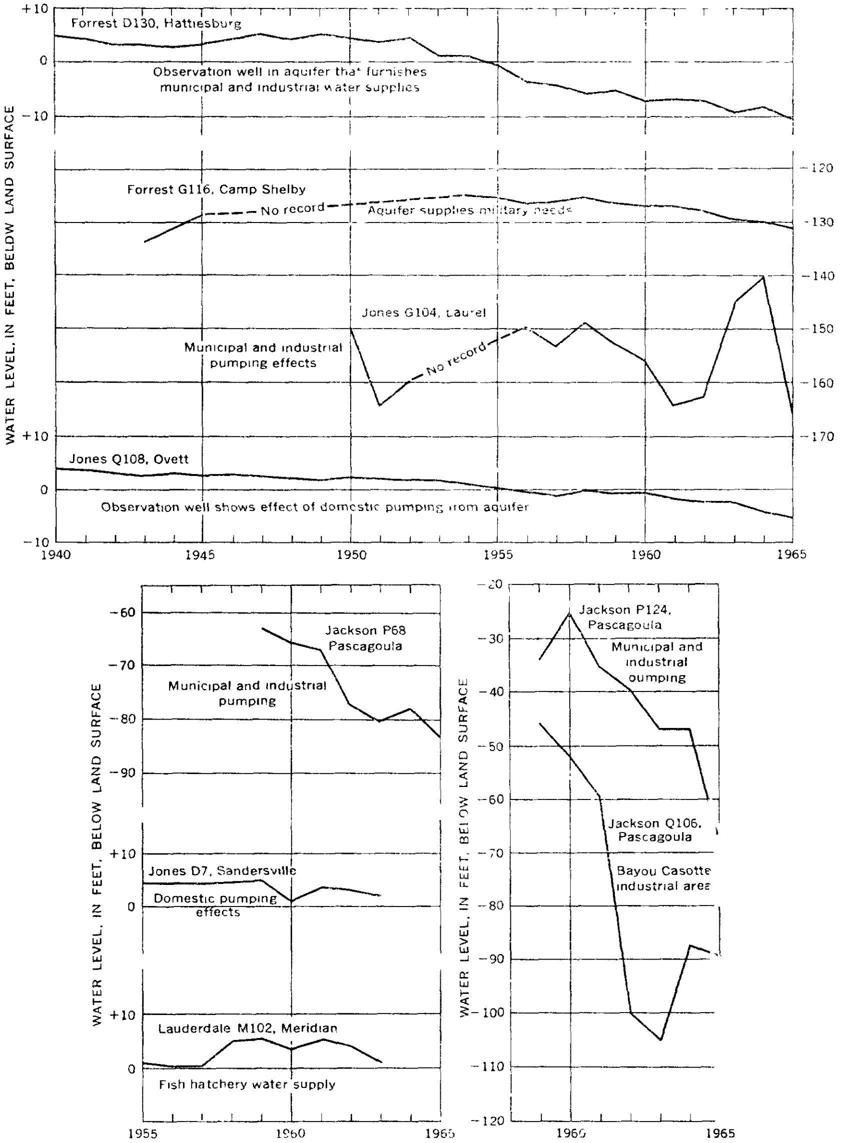


FIGURE 8.—Water-level trends in selected observation wells.

Recharge to the ground-water reservoirs in the basin takes place in upland areas where the aquifers crop out or are covered by a thin mantle of permeable sediments of Pliocene and Pleistocene ages. Although the younger formations crop out in the basin and receive recharge there, most recharge to the basal beds of the Wilcox Group occurs outside the basin in the uplands of Kemper and Neshoba Counties on the north.

Artesian head is imparted to the water as it moves down the gradient in the aquifers and becomes confined between beds of low permeability. Part of the head is lost owing to friction, but that remaining commonly is sufficient to force the water many feet above the land surface where the aquifers are penetrated by wells. This is particularly true of deep aquifers that have undergone little or no development and which contain water under sufficient pressure to cause its rise to 100 feet or more above sea level.

AQUIFER CHARACTERISTICS

The artesian aquifers of the Pascagoula basin differ greatly in their capacity for transmitting water. Coefficients of transmissibility computed from pumping tests range from 2,800 to 200,000 gpd per ft (gallons per day per foot), and coefficients of storage do not vary much from 0.0001 (table 3). Because the coefficient of transmissibility is the product of the two variables—aquifer thickness and coefficient of permeability—it must be obtained either directly by pumping test or indirectly by multiplying the aquifer thickness by a known or assumed coefficient of permeability.

Permeabilities of 110 to 2,250 gpd per sq ft have been determined in the basin; it is probable that these values span the range of permeability for the significant aquifers of the region and most permeability values fall within a range of 300 to 1,000 gpd per sq ft. The limited number of pumping tests available does not permit conclusions on the relative permeability of the water-bearing units. However, the great thickness of many Miocene sand beds implies generally higher transmissibility for that part of the geologic section, and it is transmissibility and available drawdown that determine how much water a well can be expected to yield.

The practical application of measured or assumed aquifer characteristics is in predicting the yields of wells and the effects of ground-water withdrawal. A graph (fig. 9) relating transmissibility to drawdown and well yield is useful in estimating well yields and pump setting. Many of the sand beds listed in table 2 are capable of maintaining well yields in excess of the 2,500-gpm (gallons per minute) limit of the graph; however, not many wells are constructed to supply more than that amount.

TABLE 3.—*Aquifer characteristics determined from pumping tests in and near the Pascagoula River basin*

County	Location of test	Water-bearing unit	Depth (ft)	Thickness (ft)	Coefficient of transmissibility (gpd per ft)	Coefficient of permeability (gpd per sq ft)	Coefficient of storage	Theoretical specific capacity of wells (gpm per ft)
Forrest	Camp Shelby	Hattiesburg	400	70–108	32, 000–133, 000	310–1, 590	0. 0002–. 0005	16–60
Do	Hattiesburg	Catahoula	485	130	140, 000	1, 080		70
Do	do	do	600	80	32, 000	400	. 00005	16
Do	do	do	607	80	48, 000	600	. 0003	23
Do	Hattiesburg Airport.	Hattiesburg	190		124, 000		. 0002	54
Greene	Leakesville	do	125	25	2, 800	110		1
Do	State Line	Catahoula	205	58	27, 000	470		13
Jackson	Bayou Casotte (Pascagoula).	Citronelle	200	80	45, 000	560	. 0006	22
Do	do	Graham Ferry.	360	60	20, 000	330	. 0002	10
Do	do	do	375	50	24, 000	480		12
Do	do	do	350	80	25, 000	310	. 0003	12
Do	Escatawpa	Pascagoula	450		40, 000		. 0003	18
Do	Moss Point	do	950	56	60, 000	1, 100	. 0001	26
Do	do	do	830	80	60, 000	750	. 0007	28
Do	Pascagoula	Graham Ferry.	320	100	54, 000	540	. 0005	25
Jones	Ellisville	Catahoula	550	80	40, 000	500	. 0002	18
Do	Laurel	do	395	100	44, 000	440	. 0003	21
Do	do	do	410	59	17, 000	290		8
Lamar	Tatum Salt Dome	Hattiesburg	680	80	33, 000	400		16
Do	do	Caprock	1, 026		8, 000		. 0001	4
Lauderdale	Meridian, Kroehler Plant.	Wilcox	834	120	90, 000	750		44
Do	Meridian Fish Hatchery.	do	729		26, 000			13

Do	U.S. Naval Base	do	215	100	76, 000	760	. 00002	35
Do	do	do	210	89	200, 000	2, 250	. 0002	90
Perry	Richton	Hattiesburg	564	--------	6, 000	--------	--------	3
Scott	Forest	Cockfield	350	130	64, 000	470	. 0004	30
Stone	Wiggins	Pascagoula	200	100±	82, 000	800±	. 010	44
Do	do	do	400	60	27, 000	450	--------	13
Wayne	Waynesboro	Vicksburg	120	55	25, 000	450	--------	12
Do	Waynesboro Tree Nursery.	Citronelle	190	52	58, 000	1, 025	. 0001	24

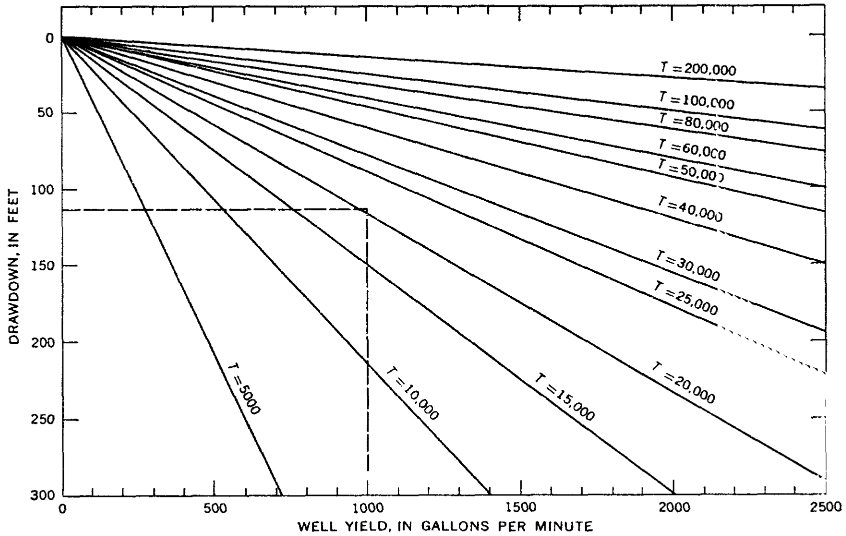


FIGURE 9.—Transmissibility-drawdown-yield relation. Where aquifer transmissibility is known or estimated, the chart will provide the drawdowns caused by various pumping rates or the well yields for various amounts of drawdown. Values are based on artesian conditions and on a 100-percent-efficient 12-inch well; for well efficiencies less than 100 percent, the yield will be decreased or the drawdown increased proportionately. Drawdown computations are based on 1 day of pumping; at 10 days the drawdown would be about 10 percent greater.

An example of the graph's use follows:

An electric log of a test hole showed a 40-ft thickness of sand at a depth of 500 ft. From other wells tapping that aquifer the static water level is known to be 50 ft below land surface. How deep should a pump be set to supply 1,000 gpm from a 12-in. well?

If the permeability of the aquifer is conservatively figured as 500 gpd per sq ft, the transmissibility would be 20,000 gpd per ft (40×500). On the graph the T=20,000 line crosses the 1,000 gpm line at the 115-ft drawdown line. As the static level is 50 ft, a drawdown of 115 ft would place the pumping level at 165 ft. This assumes a well with a 100-percent efficiency—one in which no head is lost in movement of water from the aquifer into the well. A fully efficient well is atypical; 75-percent efficiency is more realistic. Therefore it is likely that a pumping level of nearly 200 ft would be required in this example. Of course, any deviation from the assumed permeability or well efficiency will affect the drawdown value.

The effect that pumping the above well would have on the artesian pressure surface for the aquifer can also be predicted. A second graph (fig. 10) relates transmissibility and drawdown effect at various times and distances for a selected rate of pumping. This graph is useful in guiding decisions on well spacing and withdrawal rates.

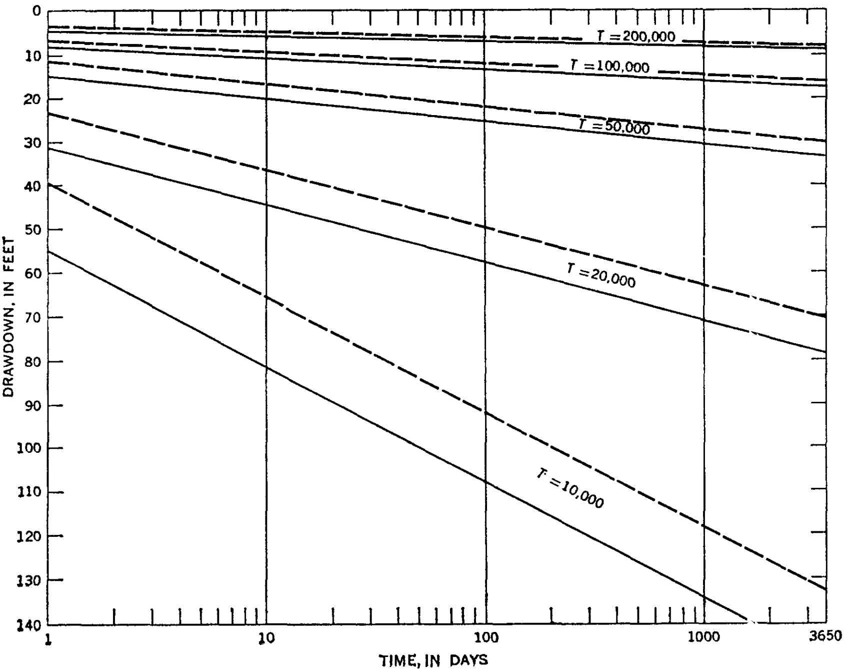


FIGURE 10.—Time-drawdown relations for selected aquifer characteristics. Pumping rate is 1,000 gpm. For other rates the drawdown will be proportional. Solid line represents drawdown at a distance of 500 feet; dashed line, at 1,000 feet from pumped well. *T* is coefficient of transmissibility in gallons per day per foot. Coefficient of storage is assumed to be 0.0001.

YIELDS OF WELLS

Only a few wells in the Pascagoula basin yield more than 500 gpm. However, well-yield measurements are ordinarily of little value in appraising an aquifer's capacity to supply water. Wells usually are constructed to provide only the amount of water needed at the time; seldom is the full potential of an aquifer utilized in the wells.

Nearly all the aquifers shown on the sections (fig. 7) are capable of yielding 2,000 gpm or more from properly constructed and fully developed wells. This holds true for most parts of the basin. Figure 7 shows that any aquifer having a coefficient of transmissibility as great as 25,000 gpd per ft could supply 2,000 gpm to a well in which there is as much as 200 feet of available drawdown. With higher transmissibility, less drawdown is required.

Well yields must be tailored not only to water-use requirements but to potential effect on the source of supply. Distribution of withdrawal, as to both time and space, must be considered, or even the most abundant resource will eventually prove inadequate. Well locations and pumping schedules should be arranged, consistent with economic considerations, so that interference of pumping influence remains at a minimum.

An excellent means of pumpage distribution is available in many places in the Pascagoula basin where more than one aquifer underlies a site. Batteries of wells can be located in a small area and thereby make use of two or more aquifers, provided quality of the water poses no insurmountable problem. In addition, single wells are sometimes screened in two or more separate aquifers; this practice is not always satisfactory, as differences in water level and in aquifer transmissibility favor interchange of water between aquifers to the detriment of well performance.

Using the graphs of figures 9 and 10, one may predict the amount of water that can be obtained in an area of specified size and shape and with a specified maximum drawdown. An example of this prediction is given in the following problem:

Situation: A square plot 1,000 ft on a side (23 acres) is available for installation of a well field needed to supply about 13 mgd (million gallons per day). Maximum pumping depth should be no lower than 300 ft below land surface. An aquifer available at a depth of 500 ft has a coefficient of transmissibility of 50,000 gpd per ft and a coefficient of storage of 0.0001. The static water level is 20 ft below average land surface.

Information desired: How many wells are needed, what should be their pumping rate, and how should they be spaced?

Answer: Eight fully efficient wells pumped at 1,125 gpm each and arranged around a 1,000-ft square on 500-ft centers. The greatest drawdown at the end of 1 year would be 274 ft (294 below land surface). This well field would supply 12.95 mgd. Water levels will be drawn down substantially in the area adjacent to the well field; however, the effects will decrease as distance from the well field increases.

PUMPAGE

PRESENT

Total ground-water pumpage in the Pascagoula River basin is estimated to be 60 mgd in 1965. Centers of heaviest withdrawal are Hattiesburg (8 mgd), Laurel (9 mgd), Meridian (5 mgd), and Pascagoula (11 mgd). Practically all domestic and municipal water supplies and most industrial supplies are obtained from the ground-water reservoir. A notable exception is the water supply of the International Paper Co. at Escatawpa where 45 mgd of water from the Escatawpa River is delivered by a pipeline 13 miles long. The city of Mobile, although outside the Pascagoula River basin, uses about 100 mgd from the Big Creek Reservoir, which is in the Escatawpa River subbasin.

POTENTIAL

It is probable that nowhere in the Pascagoula basin has pumpage reached the point that no further development can be wisely undertaken in the general vicinity. Even in places where substantial drawdown of the water level has occurred, areal redistribution of pumpage or tapping of deeper aquifers offers remedies for local overdevelopment.

On the basis of known aquifer thicknesses and assumed hydraulic characteristics, ground-water supplies as large as 25 mgd can be obtained in 1-square-mile areas at several localities in the region. Of course, recovery of such quantities through wells may not be economically feasible everywhere because of limitations on size and, therefore, discharge of individual wells and pumps.

EFFECTS

The effect of pumpage on water levels has been covered in preceding sections, and the effect of pumpage on quality of the water is explained in the following section. However, one effect of pumpage that receives little attention, possibly because it is of a positive nature, is the diversion—toward the center of withdrawal—of ground water that would normally flow through and around the area of pumping influence. In effect, the deeper the pumping water level is lowered, the farther out the cone of influence that funnels water toward the center of withdrawal is extended. As the cone of influence approaches an area of recharge to the aquifer, surface water that would have been rejected by a full aquifer is received instead, enters the aquifer, and replaces the water pumped out.

Water cannot be pumped without lowering the water level. The ideal situation is one in which the lowering of pumping water levels does not result in excessive pumping costs and is at the same time great enough to induce inflow from an area of substantial size—one which will insure the longevity of the well field.

ARTIFICIAL RECHARGE

Artificial recharging of aquifers for raising water levels, preventing salt-water encroachment, and disposing of waste water is feasible in the Pascagoula basin. In addition, water spreading to flush saline water from coastal terrace aquifers and for storage has received some consideration in recent years. The objectives of most artificial-recharge operations are to maintain or reestablish water levels and to maintain or improve water quality. Therefore, disposal of clean waste water into aquifers and storage of water in one season for use in another season are to be encouraged in most circumstances.

SALINE-WATER RESOURCES

Saline-water aquifers are used only as disposal receptacles for oil-field brine at present. Saline water in the ground should be considered as a resource. Industrial processes that can tolerate saline water are far from unknown. Advances in desalination imply a definite potential for the resource. An obvious question of the inland water planner is: "Why desalt and transport sea water, which contains about 35,000 ppm dissolved solids, when water of lower salinity is available beneath our feet?" In addition, the byproducts that might be made available in desalination of ground water are potentially of value.

The contour map (fig. 11) was constructed to show the approximate elevation of the uppermost significant saline-water aquifers. Comparing this map with figure 4 shows that the saline aquifers are in general 2,000 to 4,000 feet deeper than the base of fresh water. Intervening beds consist chiefly of clay, silt, and consolidated rock. There are sand beds in the interval, but they are mostly thin and not considered to represent substantial sources of water.

Artesian pressure in the saline-water aquifers probably is sufficient to force the water to elevations at least 200 feet above sea level.

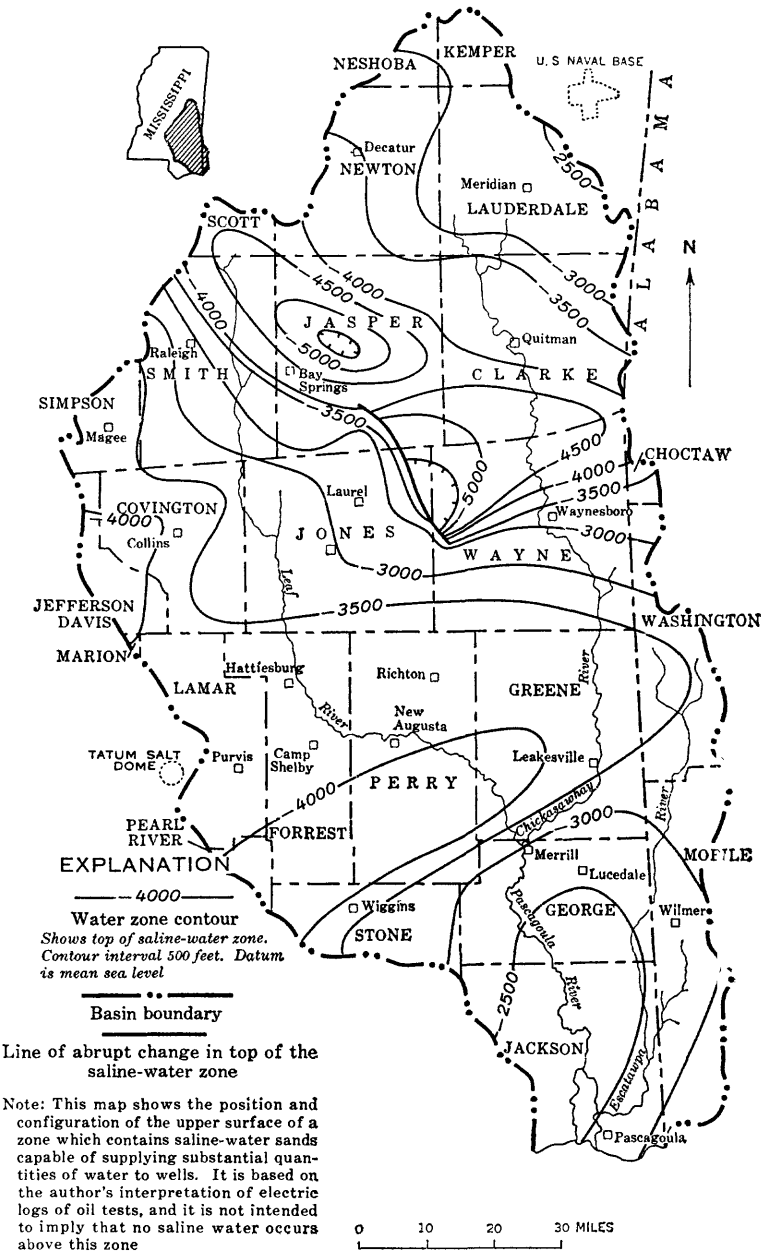
QUALITY OF THE WATER

CHEMICAL CHARACTER

Ground water of good to excellent quality is available throughout the basin. In places the near-surface aquifers contain somewhat corrosive water, which results in excessive concentrations of iron in the water; but deeper zones in the same localities provide satisfactory supplies. The water is chiefly a sodium bicarbonate type. It is generally soft and low to moderate in dissolved-solids concentration. The chemical analyses in table 4 represent ground water from all parts of the Pascagoula basin (fig. 12).

The water is suitable for practically all uses, although water in the deeper aquifers usually has a percent sodium exceeding the desirable limits for irrigation water. Little treatment is applied ordinarily for municipal and industrial uses. Aeration facilities to permit the escape of carbon dioxide, and thus raise the pH, is the treatment most commonly applied. Iron removal often accompanies aeration.

Estimates of the dissolved-solids concentration in water in the deep untapped aquifers can be made where electrical resistivity of the water in the formations is recorded by electric logs. Predicted values obtained from this source are given opposite the aquifer intervals on the sections (fig. 7). The deepest extent of fresh water (fig. 4) is also determined in this manner.



EXPLANATION

——4000——
Water zone contour
Shows top of saline-water zone. Contour interval 500 feet. Datum is mean sea level

—— •• ——
Basin boundary

——
Line of abrupt change in top of the saline-water zone

Note: This map shows the position and configuration of the upper surface of a zone which contains saline-water sands capable of supplying substantial quantities of water to wells. It is based on the author's interpretation of electric logs of oil tests, and it is not intended to imply that no saline water occurs above this zone

FIGURE 11.—Configuration of the top of the saline-water-resource zone.

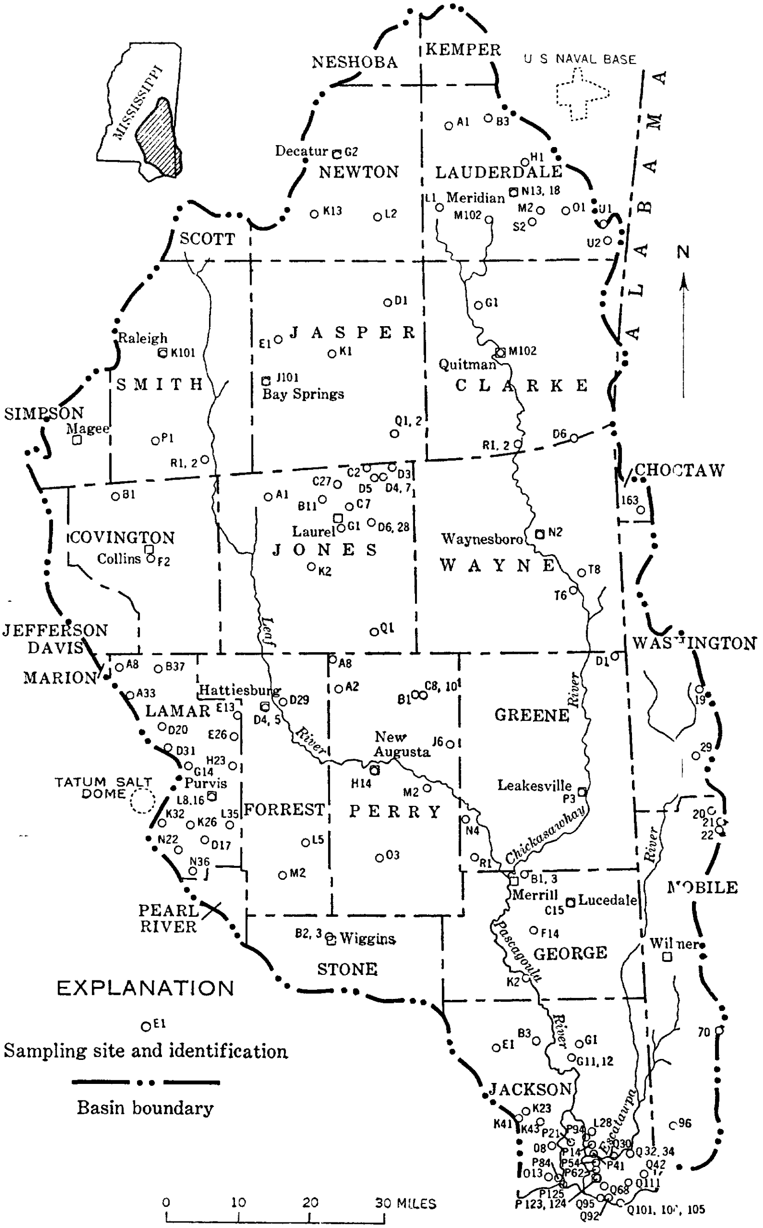


FIGURE 12.—Location of water-sampling sites. Chemical analyses in table 4.

Typically, the ground water of the basin is more highly mineralized than water in the surface streams; however, it is constant in quality and temperature, and turbidity is not a problem. Depending upon the needs of the user, ground water or surface water or a combination of the two would satisfy almost any chemical-quality requirements.

SALT-WATER ENCROACHMENT

All the artesian aquifers contain salty water at depth. Heavy pumping that reduces artesian pressure permits the gradual updip movement of the interface between fresh water and salt water. Similarly, in the tidal area near the coast, heavy pumping from water-table aquifers in the surface deposits would induce inflow of brackish water from the estuarine streams.

Other causes of salt-water contamination of aquifers are disposal of industrial wastes by injection into fresh-water zones and incomplete plugging of wells that enter the salt-water zone and permit the upward flow of salt water from that zone.

Salt-water encroachment has become noticeable in a few places along the Gulf Coast (Lang and Newcome, 1964). The Pascagoula Formation now yields water of marginal quality to some wells in Pascagoula. Chloride concentrations in water from wells screened in the Graham Ferry Formation in the Pascagoula area generally exceed 100 ppm (Newcome and Golden, 1964); but the rate of encroachment is very slow and, in some monitor wells, no increase in chloride content has been observed in the 5 years preceding this report.

WATER TEMPERATURE

Ground water in shallow aquifers (50- to 150-ft depths) in the Pascagoula basin has a temperature of about 66°F. From this, the temperature rises 1°F for every 55- to 60-foot increase in depth. The measured temperature of the discharge from a 1,200-foot well at Gulfport was 86°. Farther west, in Hancock County, the temperature of water from a depth of 1,875 feet was 100°.

Accurate aquifer-temperature measurements are difficult to obtain. It has been found that the temperature of water from deep wells can be measured reliably at the surface only if the flow or pump yield is sufficient to overcome the cooling effect of lower temperatures at shallow depth outside the wells. Discharges of 100 gpm or more are desirable to insure representative aquifer-temperature data.

Ground-water temperature is constant the year around. The resource thus can be used for either cooling or heating, as well as for constant-temperature processes.

TABLE 4.—*Chemical analyses of water from wells in the Pascagoula River basin*

[Analyst: USGS is U.S. Geological Survey; MBH is Mississippi Board of Health. Sodium: Asterisk (*) indicates sodium and potassium reported as sodium. Constituents are in parts per million]

Well no. in fig. 12	Depth (ft)	Date of analysis	Dissolved solids	pH	Silica (SiO_2)	Total iron (Fe)	Hardness as $CaCO_3$	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Analyst
Clarke County														
G1	411	May 1955	232	8.9	4.4	0.16	2	88	187	12	3.0	0.3	0.1	USGS
M102	209	do	224	7.5	23	.18	75	43	185	10	3.0	.2	.8	Do.
R1	550	do	738	8.6	----	.28	10	294	713	3.6	7.2	----	2.2	Do.
R2	200	do	451	8.2	3.6	.24	17	182	436	33	22	1.0	1.5	Do.
Covington County														
B1	210	Jan. 1959	98	7.4	7.3	4.9	59	6.3	76	7.2	3.0	0.2	0.2	USGS
F2	217	Sept. 1959	40	6.8	5.5	.23	8	2.1	12	1.0	2.2	.1	.4	Do.
Forrest County														
D4	485	Feb. 1964	80	6.2	26	0.91	24	9.2	43	8.8	2.5	0.4	0.1	USGS
D5	678	do	121	7.1	12	.42	32	30	108	8.8	1.6	.2	.0	Do.
D29	134	May 1964	19	5.3	20	.07	6	2.1	10	.2	2.3	.0	.1	Do.
L5	525	Sept. 1964	162	7.4	30	.20	1	54	130	9.4	3.4	.4	.0	Do.
M2	700–900	do	127	6.9	38	1.5	12	33	95	.6	3.4	.2	.1	Do.
George County														
B1	525	Apr. 1959	281	8.7	5.1	0.08	4	105	126	6.4	7.0	0.3	1.0	USGS
B3	185	do	221	7.4	7.7	.33	6	66	144	2.2	21	.4	.6	Do.
C15	1,020	Dec. 1958	186	6.9	8.9	.10	2	56	114	8.4	18	.1	.2	Do.
F14	63	Apr. 1959	26	5.4	2.3	.46	4	2.2	5	.8	3.5	.0	.6	Do.
K2	93	do	112	7.6	18	.45	24	16	64	6.2	3.2	.0	.3	Do.

Greene County

D1	205	May 1964	41	5.8	52	11	20	2.5	25	3.2	2.7	0.0	0.1	USGS
N4	164	do	91	8.4	25	1.3	2	38	76	6.4	4.5	.4	.1	Do.
P3	125±	do	111	8.1	26	.02	3	41	97	5.4	3.2	.1	.0	Do.
R1	58	do	20	5.3	11	3.7	6	1.1	4	.0	3.7	.0	.6	Do.

Jackson County

B3	1,128	June 1959	297	8.8	3.8	0.04	6	106	236	6.6	6.2	0.5	2.1	USGS
E1	230	Dec. 1959	158	7.4	17	.18	6	44	118	6.4	2.5	.2	.6	Do.
G1	416	Dec. 1958	442	8.3	4.1	.07	2	169	410	2.6	20	.7	.1	Do.
G11	258	Aug. 1960	380	8.2	6.4	----------	10	132	346	1.4	13	.3	.5	Do.
G12	810	Sept. 1960	400	7.9	2.5	----------	7	146	382	1.6	12	.8	.3	Do.
K23	326	Dec. 1958	347	8.2	4.6	.26	4	131	320	3.6	18	.6	.4	Do.
K41	800	do	500	8.2	6.1	.07	6	180	280	2.6	123	.4	.1	Do.
K43	1,333	Oct. 1961	559	7.7	12	----------	10	212	408	1.4	93	.8	.1	Do.
L28	660	Nov. 1959	684	8.6	7.7	.15	6	259	576	.0	48	1.4	.8	Do.
O8	217	Dec. 1958	226	7.0	19	.20	19	55	144	3.4	16	.2	.2	Do.
O13	964	May 1959	772	8.7	6.9	.26	6	287	462	2.2	150	1.3	.9	Do.
P14	328	Dec. 1958	405	8.2	4.0	.18	4	148	300	2.0	57	.6	.4	Do.
P21	1,220	May 1959	1,120	8.5	5.5	.30	8	421	536	.2	312	1.9	1.2	Do.
P41	207	May 1960	637	7.3	13	.35	42	189	244	.0	190	.6	2.2	Do.
P54	829	Nov. 1958	686	8.2	6.0	.15	8	257	346	.8	200	.7	.2	Do.
P62	326	May 1959	516	8.0	11	.18	10	178	324	1.0	95	1.2	1.5	Do.
P84	600	June 1959	589	8.7	3.1	.00	2	221	344	.4	122	.9	.5	Do.
P94	758	Apr. 1960	588	8.6	22	.07	8	192	296	.0	120	1.1	1.1	Do.
P123	340	May 1959	602	7.9	13	.12	10	211	308	.6	155	.8	1.6	Do.
P124	801	do	867	8.1	9.0	.16	8	306	352	1.4	275	1.1	.4	Do.
P125	179	Apr. 1960	341	7.8	9.5	1.6	83	90	188	.0	91	.2	1.2	Do.
Q30	255	May 1960	614	8.2	8.4	.11	14	213	412	.0	105	1.1	2.8	Do.
Q32	241	Dec. 1958	657	8.2	4.7	.18	9	248	448	1.0	126	1.1	.2	Do.
Q34	1,253	May 1959	1,050	8.4	5.6	.40	7	401	744	1.4	175	2.7	1.5	Do.
Q42	415	do	825	8.6	5.1	.55	6	300	434	1.6	192	1.3	.7	Do.
Q68	654	Dec. 1958	863	8.0	6.8	.15	8	324	360	4.6	285	.9	.4	Do.
Q92	308	May 1959	532	8.0	6.0	.27	29	185	318	1.6	118	1.1	2.5	Do.
Q95	156	Apr. 1960	546	7.3	8.4	1.3	66	173	232	2.6	195	.7	2.8	Do.
Q101	374	Sept. 1958	605	8.1	5.3	.24	10	228	348	.8	155	1.4	.6	Do.
Q104	151	Nov. 1959	524	7.9	8.2	3.6	104	138	200	1.4	185	.1	3.1	Do.
Q105	840	Aug. 1959	834	7.8	7.7	----------	8	305	364	.2	260	1.0	1.6	Do.
Q111	357	Nov. 1958	582	8.1	7.8	.26	16	207	352	.4	128	1.2	.5	Do.

TABLE 4.—*Chemical analyses of water from wells in the Pascagoula River basin*—Continued

Well no. in fig. 12	Depth (ft)	Date of analysis	Dissolved solids	pH	Silica (SiO_2)	Total iron (Fe)	Hardness as $CaCO_3$	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Analyst
Jasper County														
D1	265	Dec. 1962	187	7.0	4.0	1.0	147	*15	184	17	6	0.1		MBH
E1	404	Aug. 1961	528	8.0	14	.1	168	*128	286	102	73	.1		Do.
J101	652	May 1955	420	7.4	12	.26	14	142	230	73	40	.7	0.3	USGS
K1	341	Dec. 1962	366	7.1	4.4	.1	177	*70	238	71	41	.1		MBH
Q1	864	Apr. 1952	355	8.7		0	0	*154	348	8.2	5	.1		Do.
Q2	360	Apr. 1955	418	8.5	11	.08	9	152	287	56	30	.1	1.1	USGS
Jones County														
A1	46	May 1955	50	6.8		1.2	19	2.1	22	0.6	4.0		2.0	USGS
B11	120	July 1955	35	5.9		2.1	12	2.8	12	3.0	2.5		.0	Do.
C2	235	May 1955	112	6.9	17	.67	37	12	62	11	3.2		.4	Do.
C27	78	July 1955	47	6.0		12	18	4.3	17	8.0	3.5		.1	Do.
C7	158	May 1955	46	6.4		2.4	28	2.0	34	1.0	3.0		.3	Do.
D3	640	Apr. 1955	556	8.6		.32	1	218	429	49	28	2.0	2.6	Do.
D4	70	May 1955	134	7.0	27	4.0	15	22	65	10	2.8		1.8	Do.
D5	126	do	236	8.4		.32	43	64	194	12	4.2		.5	Do.
D6	76	Mar. 1955	86	7.9		.41	46	6.2	64	6.2	4.0		.0	Do.
D7	210	do	296	8.5		.17	14	110	250	19	4.2		1.2	Do.
D28	226	do	141	7.0	35	.25	34	18	78	8.2	4.0		.6	Do.
G1	326	Feb. 1964	183	7.7	39	.04	2	59	140	9.6	2.7	.3	.0	Do.
K2	549	do	174	7.6	59	.07	9	46	112	12	2.3	.1	.0	Do.
Q1	190	July 1943	120	7.3	17	.65	57	20	103	9.1	4.4	.0	.0	Do.
Lamar County														
A8	396	Jan. 1962	62	6.2	15	6.0	22	5.5	41	0.8	1.2	0.1	0.0	USGS
A33	255	do	120	6.2	52	5.6	22	8.5	49	.6	1.3	.2	.0	Do.
B37	382	Mar. 1964	47	6.7	27	.05	10	3.0	17	.0	3.2	.1	.1	Do.
D20	400	Jan. 1962	126	6.8	43	8.9	33	9.4	63	.3	3.0	.1	.0	Do.
D31	724	do	98	6.4	28	10	18	14	54	.6	4.1	.2	.0	Do.
E13	500	do	97	6.1	42	4.9	16	8.3	30	6.0	3.9	.1	.0	Do.
E26	420	Dec. 1961	27	6.1	2.0	1.2	5	6.7	12	5.6	2.9	.4	.0	Do.
G14	137	Jan. 1962	47	6.4	20	8.5	5	4.1	12	.0	4.0	.0	.0	Do.
H23	455	do	91	6.9	32	2.8	22	14	64	.0	3.0	.1	.0	Do.

K26	90	Sept. 1961	46	3.3	4.2	1.6	18	2.3	0.00	0.2	1.0	0.4	1.0	USGS
K32	85	May 1961	14	5.5	4.6	.98	4	1.8	6	.0	2.2	.0	.6	Do.
L8	35	Sept. 1961	48	5.7	5.7	.06	13	6.8	5	.6	14	.0	7.1	Do.
L16	978	Feb. 1962	109	6.5	43	----------	5	19	46	4.6	4.1	.2	.0	Do.
L35	250	Jan. 1962	64	6.7	32	.05	6	5.5	20	.8	2.0	.2	.0	Do.
N22	132	do	27	6.2	8.7	.21	7	3.9	14	.4	2.9	.1	.4	Do.
N36	1,005	Sept. 1961	141	7.6	27	.00	0	47	122	1.4	3.0	.2	.6	Do.
O17	640	Jan. 1962	185	7.7	27	1.0	10	63	169	3.8	3.0	.4	.0	Do.
Lauderdale County														
A1	492	Sept. 1961	149	8.3	3.6	0.1	64	*36	154	3.6	4	0.2	----------	MBH
B3	231	do	87	6.3	2.8	7.5+	48	*2.5	50	17	5	.2	----------	Do.
H1	478	do	126	7.2	5.6	4.5	89	*9.5	127	3.3	6	.2	----------	Do.
L1	280	do	229	7.9	10	Trace	134	*26	173	46	5	.2	----------	Do.
M2	300	Oct. 1954	210	8.7	----------	.08	10	78	184	5.8	2.8	----------	0.7	USGS
M102	728	Sept. 1962	198	8.5	15	.02	16	62	170	5.6	4.0	.2	.0	Do.
N13	296	Dec. 1955	142	6.5	----------	15	55	10	78	11	3.5	----------	.1	Do.
N18	745	Oct. 1961	154	7.4	34	.04	90	10	132	5.6	2.2	.0	.0	Do.
O1	260	Sept. 1961	174	7.8	5.2	.2	103	*28	168	11	6	.1	----------	MBH
S2	250	do	62	6.3	6.4	.2	35	*8.0	47	6.2	5	.2	----------	Do.
U1	320	do	226	8.2	4.8	0	112	*30	222	34	6	0	----------	Do.
U2	420	do	277	7.3	29	.3	199	*20	232	36	8	.2	----------	Do.
Newton County														
G2	335	Dec. 1960	102	5.9	8.8	1.0	48	*16	65	19	7	0.2	----------	MBH
K13	312	do	119	6.2	6.0	.5	81	*13	113	6.4	6	.2	----------	Do.
L2	88	do	64	5.2	3.6	.2	21	*13	10	16	18	.2	----------	Do.
Perry County														
A2	294	Sept. 1955	156	8.0	----------	0.17	23	45	134	9.8	3.5	0.2	0.2	USGS
A8	658	Sept. 1964	144	7.2	6.4	.65	48	35	129	11	4.4	.1	.0	Do.
B1	85	Sept. 1955	43	5.8	----------	.04	8	2.6	8	2.4	3.0	.1	.8	Do.
C8	1,192	do	60	5.7	----------	.17	16	5.2	9	2.0	8.5	.2	8.8	Do.
C10	728	do	157	7.4	----------	2.9	4	43	111	1.6	5.0	.2	.0	Do.
H14	786	May 1964	259	8.1	12	.07	2	104	201	.0	42	.4	.1	Do.
J6	483	Oct. 1964	86	6.2	26	.84	22	14	51	6.8	4.0	.2	.0	Do.
M2	460	May 1964	411	7.9	18	.03	7	154	148	14	148	.1	.1	Do.
O3	315	Sept. 1964	160	7.8	6.6	.00	7	62	148	5.0	9.6	.2	.1	Do.

TABLE 4.—*Chemical analyses of water from wells in the Pascagoula River basin*—Continued

Well no. on fig. 12	Depth (ft)	Date of analysis	Dissolved solids	pH	Silica (SiO_2)	Total iron (Fe)	Hardness as $CaCO_3$	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Analyst
Smith County														
K101	1,180	May 1955	220	8.4	6.0	0.12	2	80	198	11	2.0	0.1	0.4	USGS
P1	160	June 1962		6.4		1.5	22		53		2			MBH
R1	357	May 1955	121	6.6	24	1.6	9	21	50	10	2.8	.1	.1	USGS
R2	1,135	do	467	8.5		.21	4	173	362	30	26		2.4	Do.
Stone County														
B2	200	Sept. 1959	29	6.3	2.3	0.00	6	2.8	4	0.8	4.5	0.1	0.9	USGS
B3	425	do	39	6.8	2.8	.12	4	4.6	15	.2	3.8	.2	.4	Do.
Wayne County														
D6	190	Sept. 1964	270	7.9	20	0.36	112	54	256	19	4.2	0.3	0.1	USGS
N2	110	May 1955	198	7.4	9.4	.20	129	21	180	16	6.2	.0	.3	Do.
T6	650	Sept. 1964	806	7.9	7.5	.02	10	310	716	.0	67	2.9	.2	Do.
T8	125	Nov. 1956	40	5.5	3.3	5.0	4	5.5	12	.0	4.0			Curtis Lab.
Choctaw County, Ala.														
163	108	Sept. 1948					13		10	1.0	5.0	0.0	16	USGS
Mobile County, Ala.														
20	61	Aug. 1954	40	5.5			12		4		6			USGS
21	110	do	22	5.8			8		9		5.5			Do.
22	735	do	152	8.1	15	0.11	1	49	125	3.2	11	0.2	0.4	Do.
70	212	do	41	6.2			7		36		3.0			Do.
96	65	Jan. 1947					12		4	3	8		3.2	Do.
Washington County, Ala.														
19	256	Jan. 1947					57		79	6	4		0.1	USGS
29	147	do					12		109	2	8		.1	Do.

CONCLUSIONS

Abundant ground-water resources underlie the Pascagoula River basin. Present water-supply developments tap only a small fraction of the quantity available to wells. Efficient use of the resource requires (1) tapping of thick aquifers deeper than present wells, (2) construction of efficient large-capacity wells, and (3) proper spacing of wells to avoid excessive interference.

With careful programs of exploration and development, it should be possible to obtain water supplies as great as 25 mgd in many localities. Individual well yields of 2,000 gpm could become commonplace, and yields of 5,000 gpm are not unreasonable to expect in some places.

Quality of the ground water is adequate for practically all uses, although suitable supplies for irrigation will not be as readily obtainable as those for other purposes because of the natural predominance of water of a sodium bicarbonate type.

In the interest of optimum development of the ground-water resources, as well as their conservation, it is desirable that the potential effects of engineering works on the ground-water reservoirs be evaluated. The extent of manmade effects ordinarily can be determined only by detailed studies of the hydrologic environment in the localities concerned.

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