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Prepared in cooperation with the
Mississippi Board of Water Commissioners
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WATER RESCOURCES INVESTIGATIONS
SHEET 1 OF 1 OPEN-FILE REPORT 78-131

THE CITRONELLE AQUIFERS IN MISSISSIPPI

INTRODUCTION

This atlas describing the aquifers in the Citronelle Formation is the 11th in a series of aquifer atlases prepared by the U.S. Geological Survey in cooperation with the Mississippi Board of Water Commissioners. The report summarizes records on file for over 5,000 water wells and data from many other borings and geophysical logs.

The Citronelle Formation is the shallowest significant source of ground water in much of southern Mississippi. The formation, highly dissected by streams in its area of outcrop (fig. 1), makes up many discontinuous and hydrologically independent water-bearing units or aquifers. The aquifers contain freshwater--water having less than 1,000 mg/L (milligrams per liter) of dissolved solids--except in small areas along the Gulf Coast where saltwater has intruded from estuarine streams, or from the Mississippi Sound.

Fifty years ago Stephenson, Logan, and Waring (1928) recognized the Citronelle Formation as a major aquifer in Mississippi. At that time it was the principal source for the wells and springs that were used for public water supplies at the following places:

Wells		Springs
Brookhaven	Liberty	Lucedale
Centreville	McComb	Magee
Gallman	Summit	Wesson
Gloster	Wiggins	
Hazlehurst		

The Citronelle Formation would have been used more extensively as a source of water, but many users were located in valleys near or below the base of the aquifer. In some places wells were drilled to deeper aquifers for better quality water and higher yields. In the coastal lowlands, wells were drilled several hundred feet below the Citronelle aquifer for the large natural flows that could be obtained from the Miocene aquifers.

The Citronelle aquifers contain freshwater in an area of about 8,000 square miles. The discontinuous outcrop area covers about 6,000 square miles and about 1,000 square miles is covered by coastal deposits, alluvium, and loess. The rest of the freshwater strata are beneath the coastal deposits that underlie Mississippi Sound and the Gulf of Mexico (fig. 1).

GEOLOGY

The name Citronelle Formation was given by Matson (1916, p. 168) to "sediments of Pliocene age, chiefly nonmarine, that occur near the seaward margin of the Gulf Coastal Plain, extending from a short distance east of the western boundary of Florida westward to Texas." Matson (1916, fig. 15) restricted the Citronelle Formation to the area south of the 32d parallel, thereby eliminating all Citronelle-like terrace deposits in the northern two-thirds of Mississippi. The formation was named for Citronelle, Mobile County, Ala., where exposures were considered to be typical. The Citronelle as used in this report includes the strata designated by Matson; however, several outliers assigned to the formation by Belt and others (1945) lie slightly north of the 32d parallel (fig. 1).

Matson (1916, p. 187) suggests that most of the sediments that compose the Citronelle Formation were deposited in the valleys of streams that were subject to large changes in velocity produced by floods and quiet water. Brown (1967) postulated that the gravel deposits in south-central Mississippi were laid down by a southwestward trend of an ancestral Tennessee River system. A "post Catahoula unit" described by May and Marble (1976, p. 14) includes strata that earlier workers might have included with the Citronelle. The presence or absence of this unit may account for some of the large variations in thickness of the formation.

The Citronelle Formation is composed mostly of quartz sand, chert gravel, and lenses and layers of clay, in proportions that vary from place to place; however, the percentage of gravel decreases southward. The original deposits probably formed a continuous blanket that extended much farther north than the 32d parallel. Erosion during the Pleistocene and Holocene has reduced the areal extent of the formation and has left a southward-thickening wedge of highly dissected and discontinuous ridge-forming strata. Only along the Gulf Coast and in the Louisiana border counties of southwestern Mississippi does the Citronelle Formation have continuity into the subsurface (fig. 2).

The most northern strata assigned to the Citronelle Formation cap some of the highest hills in southern Scott County. The base of the formation in the Morton area, of Scott County, is nearly 600 feet above National Geodetic Vertical Datum of 1929 (NGVD). The southerly dip averages about 6 feet per mile and the base gradually lowers to NGVD a few miles north of the coast. The dip steepens gradually southward. At Gulfport the base is about 100 feet below NGVD and at Ship Island, perhaps 200 feet below NGVD (Brown and others, 1944, pl. 14).

Because the dip of the Citronelle is slightly steeper than the southward topographic slope, the base gradually lowers into the valleys and the average thickness of the unit increases. The base rests unconformably upon middle Eocene to Pliocene (?) strata. Most have been called the Hattiesburg and Pascagoula Formations (fig. 2).

HYDROLOGY

The Citronelle Formation is very permeable and readily receives and transmits water from precipitation. In Mississippi, water infiltrates to the water table and then either moves laterally to valley walls to be discharged by springs and seeps or it continues downward into underlying aquifers. Where the underlying units are permeable sand (fig. 2), a large part of the water may continue downward and where underlying clays predominate, most of the water moves laterally to discharge points. Because of this drainage effect, only a part of the permeable sand and gravel in the Citronelle is saturated. Therefore, water levels are low and drawdown space in wells is small. The saturated zone thickens southward as the unit thickens. In the extreme southern part of the area, many sand beds are completely saturated and, in some places, confined.

Water levels in the Citronelle aquifers change seasonally. The highest levels occur in the spring as a result of the rains and from reduced evapotranspiration during the winter and early spring. Water-level declines that result from pumping are not pronounced because there is little development of the aquifer.

One hydrologically important aspect of the Citronelle Formation is its function as the principal source of the water that sustains the low flow of many streams. The Citronelle absorbs, temporarily stores, and gradually releases rainfall through springs and seeps, thereby sustaining streamflow through dry periods. Low flows greater than 0.5 $(ft^3/s)/mi^2$ are common where the Citronelle is areally extensive. The stored water also recharges the underlying confined aquifers that are hydraulically connected to the basal sand and gravel in the Citronelle. In effect, the Citronelle outcrop area is equivalent to a 6,000-mi^2 surface reservoir that stores water, constantly replenishes underlying aquifers, and sustains streamflow.

Aquifer Characteristics and Well Yields

In Mississippi, the Citronelle Formation ranks second only to the Mississippi River valley alluvial aquifer in hydraulic conductivity. Aquifer thickness varies according to the saturated thickness of the sand and gravel beds in the formation.

Six aquifer tests made using wells screened in the Citronelle (Newcome, 1971) and analyses using methods described by Lohman (1972) are summarized in the following table.

	Saturated thickness (ft)	Transmissivity (ft^2/d)	Specific capacity 1/ (gal/min)/ft
Maximum	103	13,000	46
Median	80	11,000	11
Minimum	20	4,000	6.2

1/ Specific capacity varies with well efficiency

The average saturated thickness in about 5,200 wells is 45 feet. Assuming that the average hydraulic conductivity of the aquifer is about 150 ft/d, the average transmissivity of the aquifer is about 7,000 ft^2/d.

Newcome and Thomson (1970) report specific capacities as large as 66 (gal/min)/ft and indicate that the aquifer is potentially capable of yielding more than 5,000 gal/min to wells in places (1970, table 7). The potential for large yields becomes better toward the south, as the formation thickens and aquifers are more extensive.

Generally the water table (the top of the saturated zone in an unconfined aquifer) has a configuration that is similar to the land surface; that is, the water table is highest beneath the highest part of the hills and it is lowest near the sides of hills. The direction of water movement is from the center of hills and ridges toward discharge points (springs and seeps) along valley walls (fig. 3). Hydraulic gradients in the Citronelle water table are steeper toward discharge points than in the direction of dip; therefore, the downdip movement of water is of little significance except in the southern part of the study area where some Citronelle aquifers are confined.

Wells made in the Citronelle aquifers typically have short screens and deep static water levels. Effective screen length is controlled by the saturated thickness of the aquifer. Low static-water levels leave limited space for drawdown during pumping. Ideally, the screen should be short enough that the top remains submerged while the well is being pumped. Specific capacity (expressed in gallons per minute per foot of drawdown) is directly related to transmissivity, screen length, and well efficiency. Although many wells made in the Citronelle have very high specific capacities, the yields of some wells are low because the static level is only a few feet above the top of the screen or above the blank screen extension (fig. 3, well A). Larger yields are possible in locations away from valley walls where more of the aquifer is saturated (fig. 3, well B). Except in areas where underlying confined aquifers are hydraulically connected to the Citronelle aquifer, the confined aquifer water levels and the Citronelle water levels at the same site are not related (fig. 3, well C).

WATER QUALITY

Water from the Citronelle Formation generally is soft, acidic, and very low in dissolved solids (table 1). Iron is present nearly everywhere and in some areas the water requires treatment for the removal of excessive iron in solution. The highest concentration of fluoride, 1.1 mg/L, was found in water from a domestic well in Jackson County.

Analyses of water from several springs and from selected public and industrial water-supply wells are given in table 1 and locations of analyses are shown on figure 1. The following table summarizes values observed for selected constituents in water from the Citronelle aquifers in Mississippi.

	SiO_2	Fe	Cl	Na	Ca	(HCO_3)	F	D.S.
Maximum	59	14	970	284	34	318	1.1	1,020
Median	9.6	.11	5.1	4.8	3.8	16	.0	62
Minimum	.8	.00	.2	1.4	.0	.0	.0	14
Number of observations	79	105	210	60	92	74	68	76

As the Citronelle everywhere is at shallow depths, the water temperature is at or within 3°C (5.4°F) warmer than the average annual air temperature. The water temperatures can be expected to range from about 18°C (64°F) in very shallow wells in the northern part of the study area to about 23°C (73.4°F) in 300-foot wells on the Gulf Coast where the average annual temperature is 20°C (68°F).

CONTAMINATION

The characteristics that make the Citronelle Formation a productive aquifer also render it highly susceptible to contamination. A number of abandoned sand and gravel pits in the Citronelle have been converted to landfills that may be sources of contamination. The Citronelle aquifers are now contaminated at many places by industrial and oil-field wastes, sewage, land-fill leachate and other liquid contaminants that move into the water-table aquifers. Fortunately, most of the contaminants probably move toward springs and seeps and are dispersed by streams; however, where the Citronelle overlies confined aquifers the contaminants can migrate into the deep subsurface (fig. 4). These contaminants will affect ground-water supplies. Although the practice of using "evaporation" disposal pits is presumed to have ended, it is likely that "slugs" of contaminated water from old evaporation pits and landfills are today moving down the dip in the aquifers.

Other sources of contamination include leaking sewers, sewage lagoons, pipelines, and injection wells.

SALTWATER ENCROACHMENT

In the Gulf Coastal area the Citronelle aquifers are subject to saltwater (sea water) encroachment because of the nearly direct hydraulic connection to the Mississippi Sound and to estuarine streams. Saltwater "wedges" are known to move many miles upstream from the Mississippi Sound in estuarine streams (Harvey and others, 1965; Newcome and others, 1968), especially under conditions of extremely high tides or during periods of low streamflow. Under natural conditions in the coastal area, the water table in the Citronelle aquifers and the hydraulically connected younger surficial deposits is maintained a few feet above sea or stream level by the abundant rainfall, and the water moves toward the estuary or the sea. Ground-water withdrawals, however, may lower the water table so that the hydraulic gradient is reversed and saltwater moves into the aquifers. Any planning for the development of shallow aquifers in the Gulf Coastal area will need to consider the potential for saltwater encroachment.

AQUIFER POTENTIAL

The potential yield of an unconfined aquifer is related to the availability of water for recharge, hydraulic conductivity, and to the saturated thickness. The Citronelle Formation is in an area where precipitation exceeds 50 inches per year. The surface is very permeable and the infiltration rate is believed to be high.

The average saturated thickness of the aquifer is about 45 feet. This physically limits drawdown space and emphasizes efficient well construction. Assuming that the specific yield of the Citronelle is about 25 percent, each 4 feet of water-level decline in the aquifer equals 1 foot of water or 640 acre-feet of water per square mile. Withdrawn over a period of 1 year, the rate would be about 570,000 gal/d mi^2--the equivalent of 12 inches of recharge. The 6,000 mi^2 area of outcrop (or recharge of the Citronelle could, on this basis, yield about 3,400 Mgal/d. The nearly isolated 200-mi^2 body of the Citronelle Formation in the Crystal Springs-Hazlehurst area, of Copiah County (fig. 1), might supply about 115 Mgal/d of water if small wells were ideally distributed over the area.

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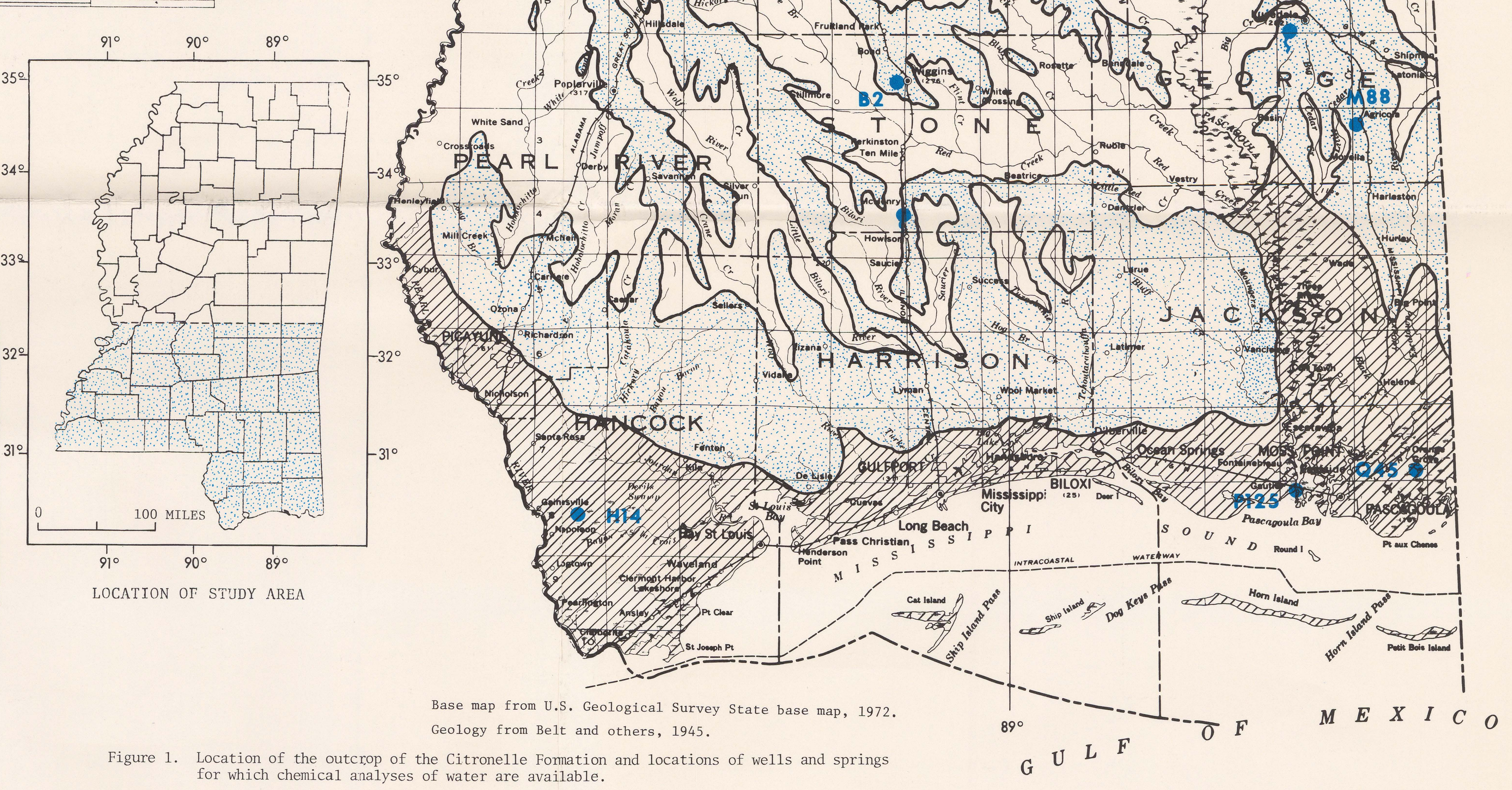

Base map from U.S. Geological Survey State base map, 1972.
Geology from Belt and others, 1945.

Figure 1. Location of the outcrop of the Citronelle Formation and locations of wells and springs for which chemical analyses of water are available.

To convert inch-pound units to International System units

Multiply	by	To obtain
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.044	cubic meter per second (m^3/s)
foot per mile (ft/mi)	0.189	meter per kilometer (m/km)
gallon per minute per foot (gal/min)/ft	0.21	liter per second per meter (L/s)/m
cubic foot per day per square foot $(ft^3/d)ft^2$	0.305	cubic meter per day per square meter $(m^3/d)/m^2$
cubic foot per day per foot $(ft^3/d)/ft$	0.093	cubic meter per day per meter $(m^3/d)/m$

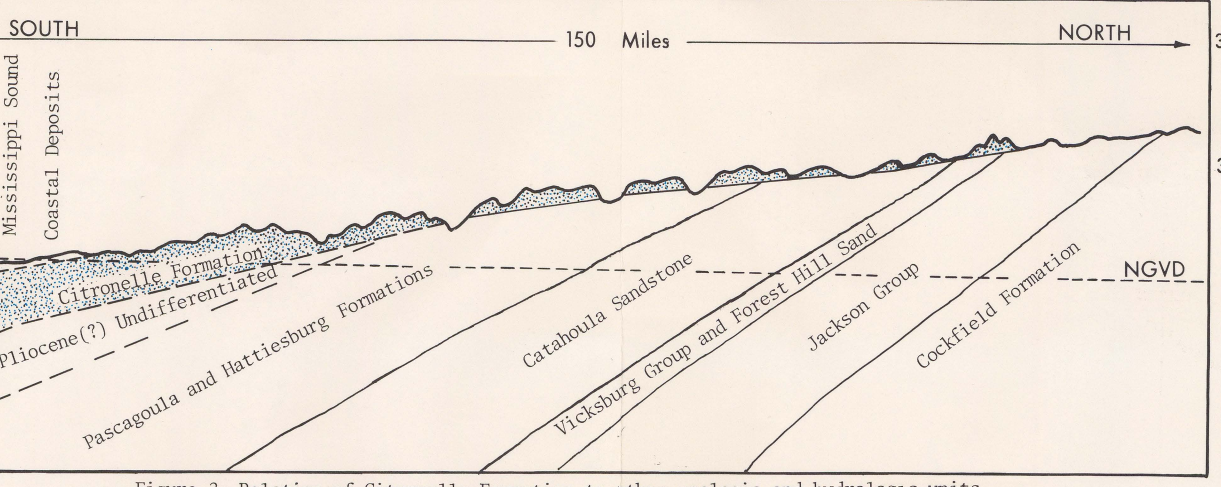

Figure 2. Relation of Citronelle Formation to other geologic and hydrologic units.

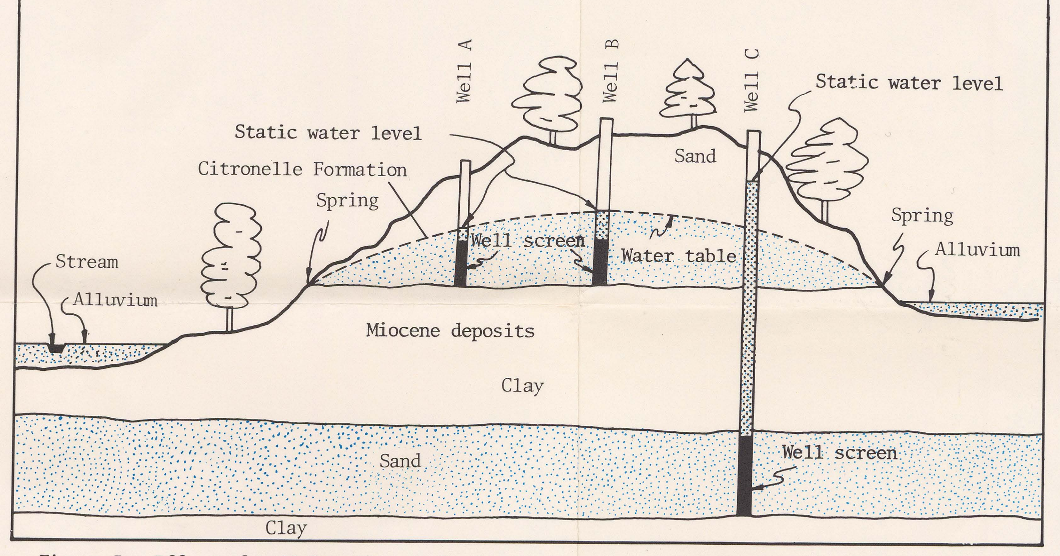

Figure 3.--Effect of well location on depth to water table and water levels in confined and unconfined aquifers.

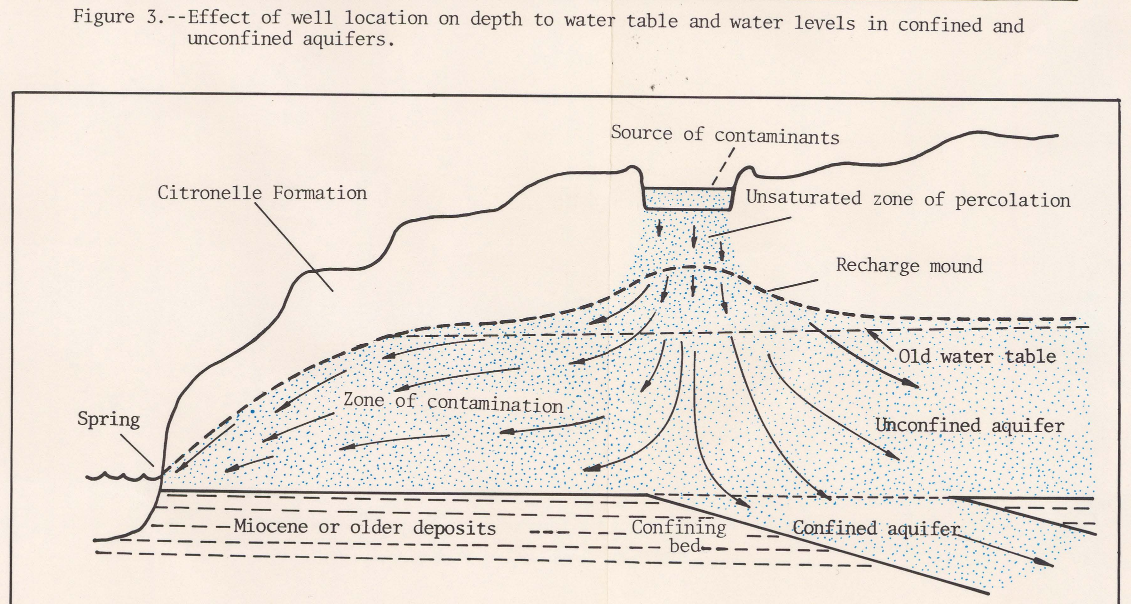

Figure 4.--Diagram showing percolation of contaminants through the unsaturated zone (modified from Deutsch, 1963).

Table 1. Water-supply and water-quality data for aquifers in the Citronelle Formation.

County	Water user WA - Water association	Depth of well (ft)	Pumping rate of well (gal/min)	Daily withdrawal (1,000 gal/d)	Electric log No.	Pumping test	Well No.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids	Hardness as $CaCO_3$	pH
							Chemical analyses of water (Dissolved constituents and hardness given in milligrams per liter)													
Amite	Gloster	80	220	c/	--	X	F20	13	0.11	1.9	0.8	6.8	.3	9	1.2	9.9	.0	41	8	5.6
	Liberty	160	100			X	N3	15	.34	2.2	.7	4.8	1.0	15	.2	4.1	.0	38	8	5.6
Copiah	Crystal Springs	90-110	100-320	617	192	--	D3	14	.03	11	6.0	18	2.9	22	17	30	0.1	135	52	6.0
	Wesson (Spring)	--	--	a/	--	--	--	12	.17	1.0	.6	2.5	.6	9	.2	2.3	.1	24	5	5.8
	Self-supplied industrial	120-140	250-630	--	75	--														
George	Agricola School	80	60	--	--	--	M88	6.8	.01	.9	.9	2.6	.5	2	.1	5.2	.0	24	6	5.0
	Lucedale (Spring)	--	--	a/	--	--	--	13	.05	.6	.6	--	--	17	1.9	4.5	--	58	4	--
Hancock	NSTL	140	510	c/	55	X	H14													
Jackson	U.S. Geological Survey (test well)	140	--	c/	--	--	Q45	5.6	2.8	5.3	2.6	94	3.5	158	.0	70	.0	293	24	7.6
	Self-supplied industrial	180	--	--	--	--	P125	9.5	1.6	17	9.8	90	6.0	188	.0	91	.2	341	83	7.8
Lamar	Baxterville	200	170	10	64	X	J136	10	.18	1.3	.2	2.7	.5	5	.2	3.2	.0	25	39	7.5
	Lakeview WA	46-54	20-50	5	--	--	L69													
	Self-supplied industrial	110-130	20-30	--	--	--														
Lawrence	JT&T WA	210	350		32	--	M39	12	.00	1.6	.5	3.1	1.1	1.0	.4	3.5	.0	30	6	5.4
Lincoln	Brookhaven	160	170-410	b/	95	X	H5	15	.16	2.2	.7	5.1	.6	15	.2	5.5	.0	40	8	5.7
	Self-supplied industrial	160	80-400	--	--	--	H10	7.6	.00	4.3	3.5	11	1.3	21	13	15	.0	67	25	6.7
Pearl River	Self-supplied industrial	80	100	--	--	--														
Pike	McComb	100	300	c/	--	--	D1	11	.10	9.8	4.2	13	1.9	7	31	16	.1	111	42	5.3
	North Pike WA	150-170	180	100	128	--	A155	22	.00	2.2	.8	4.2	1.9	14	1.4	2.5	.0	46	9	5.5
	Percy Quinn State Park	130	70		--	--	D15	11	.01	1.3	.4	2.4	.7	8	.2	2.4	.0	25	5	4.9
	Southwest Junior College	180	100	b/40	--	--	B104	18	.55	3.8	1.0	3.1	1.3	14	.2	2.5	.2	39	14	5.6
	Summit	100	300	30	--	X	A1	10	.68	4.0	1.2	18	.3	8	.2	22	.0	98	15	5.2
	Self-supplied industrial	100-180	20-110	--	--	--														
Simpson	Highway 28 WA	200	220	92	97	--	O7	8.5	.04	1.5	.1	3.2	.4	7	.8	2.9	.1	31	4	5.9
	Magee	100-110	350-500	250-500	129	--	Q15	13	.11	3.9	.3	5.0	.7	15	.8	4.6	.1	48	11	6.5
	Magee (Spring)	--	--	a/			--	11	.05	1.3	.2	2.1	.4	6	.0	3.3	.0	22	4	5.5
	Okatoma WA	200	500	79	157	--	L13	9.6	.01	1.0	0.8	3.5	1.0	5	.4	4.2	.0	38	6	5.4
	Sanitorium	130	100-350		--	--	K5	9.6	.01	1.3	.9	3.1	.8	10	2.0	3.8	.0	36	7	5.2
	Smith Crossing WA	120	180		89	--	K7	8.8	.02	1.4	.6	2.9	.6	8	.0	3.6	.0	32	6	5.7
Stone	Wiggins	200	400	b/100	--	X	B2	2.3	.00	1.4	.6	2.8	.5	4	.8	4.5	.1	--	6	6.3
	McHenry (Spring)	--	--	a/	--	--	--	8.3	.04	2.8	3.1	--	--	24	2.0	11	--	79	20	--
Wilkinson	Centreville	110-130	160-200	--	--	--	O23	16	.01	1.2	1.2	11	1.4	15	3.4	12	.0	74	8	5.6

a/ Spring formerly used for public water supply.
b/ Part of water supply is obtained from other aquifers.
c/ Well unused or destroyed.

THE CITRONELLE AQUIFERS IN MISSISSIPPI

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1979