GEOHYDROLOGY AND DEVELOPMENT OF GROUND WATER AT FORT POLK, LOUISIANA

By Harry C. McWreath, III, and Charles W. Smoot

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/year)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
square foot (ft^2)	0.09294	square meter (m^2)
square foot per day (ft^2/d)	0.0929	square meter per day (m^2/d)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per minute per foot [(gal/min)/ft]	0.207	liter per second per meter [(L/s)/m]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: °F = 1.8 X °C + 32.

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

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ABSTRACT

An investigation of the geohydrologic characteristics of the Williamson Creek and Carnahan Bayou aquifers, their development, and the effects of pumpage on water levels in those aquifers was conducted at Fort Polk, Louisiana, from 1985 to 1987. Confining units hydrologically separate these aquifers from each other and from overlying and underlying aquifers. Predevelopment ground-water flow patterns followed the dip of the geohydrologic units, from areas of recharge northwest of Fort Polk, to areas of discharge to the southeast. Cones of depression at Fort Polk and at a paper mill near De Ridder in Beauregard Parish, 15 miles southwest of Fort Polk, have modified the flow pattern in the Williamson Creek aquifer. Cones of depression around Fort Polk and Leesville, Louisiana, 6 miles northwest of North Fort Polk, and around the Kisatchie well field in Rapides Parish, 31 miles east of North Fort Polk, have modified the flow pattern in the Carnahan Bayou aquifer.

The B sand of the Williamson Creek aquifer is the principal source of water to wells at (south) Fort Polk. The average transmissivity of the B sand is 4,600 ft^2/d (feet squared per day) and the average storage coefficient is 0.0002. Interference among wells completed in the B sand accounts for 40 to 54 percent of the drawdown. Doubling the spacing between the wells would reduce total pumping lift by less than 4 percent. Some wells at Fort Polk have specific capacities that are less than would be expected, primarily caused by screen encrustation, intrusion of fine material into the gravel pack, or partial filling of the screen openings with sand. Historical data indicate a long-term decline in water level of 2.0 ft/yr (feet per year) in the Williamson Creek aquifer, attributed to the pumpage at Fort Polk. Data collected during this investigation indicate a rate of water-level decline of 10.2 ft/yr from March 1985 to July 1987. Pumpage from the B sand has been increasing at an average rate of 0.35 Mgal/d (million gallons per day) per year since 1983. Pumpage at (south) Fort Polk in 1986 was 3.6 Mgal/d.

The principal source of water to wells at North Fort Polk is the C sand of the Carnahan Bayou aquifer. The transmissivity of the C sand is 12,000 ft^2/d and the storage coefficient is 0.0002. Pumpage at North Fort Polk in 1986 was 0.4 Mgal/d. Water-level declines of 1.2 ft/yr in the Carnahan Bayou aquifer at North Fort Polk are attributed primarily to pumpage at Leesville. Water-level trends in several wells in Vernon Parish outside the study area indicate regional declines in the Carnahan Bayou aquifer that can be attributed to cumulative effects of pumping at Leesville, Fort Polk, and the Kisatchie well field.

INTRODUCTION

Since the construction of Fort Polk in 1941, ground water has adequately met the needs of the U.S. Army installation, nearby Leesville, and the smaller communities in Vernon Parish. An investigation of the water resources in Vernon Parish by Rogers and Calandro (1965) showed that the parish had plentiful supplies of good quality ground and surface water. However, the effects of increased development of the ground water over the past 20-25 years have not been evaluated. The concerns of the U.S. Army are the effect of ground-water development at Fort Polk on water levels in the aquifers, and the capability of the water-supply system to deliver the water to users now and in the future. In 1985, the U.S. Army entered into a cooperative study with the U.S. Geological Survey to investigate these concerns.

Fort Polk is the largest water user in Vernon Parish, La., with an average withdrawal rate of 4.0 Mgal/d (million gallons per day) in 1986, supplying drinking water to a population of about 27,000. Since the early 1940's, pumpage of ground water has ranged from about 2.0 to 4.0 Mgal/d during active periods and less than 1.0 Mgal/d during the years Fort Polk was closed. In the event of military mobilization, the population could reach more than 40,000 and the demand could exceed 6.2 Mgal/d.

Only the nearby town of Leesville's water use of 2.0 Mgal/d in 1986 approaches the magnitude of water use at Fort Polk. Six other small-town public-supply systems in Vernon Parish used from 0.05 to 0.5 Mgal/d in 1986. The only other types of water use in Vernon Parish are for domestic and livestock. Although the parish has two large reservoirs, Lake Vernon and Anacoco Lake, ground water is the source for all public supply and domestic water use.

Purpose and Scope

This report describes the results of an investigation from March 1985 to July 1987 of ground-water development of the aquifers in the Fort Polk area, Vernon Parish, La. Specifically, this report addresses three basic objectives: (1) Describe the geohydrology and evaluate the hydraulic characteristics of the aquifer system, (2) describe the development of ground water at Fort Polk, and (3) evaluate the effects of pumpage on water levels of the aquifers at Fort Polk.

As part of the cooperative study, the U.S. Geological Survey contracted with a private engineering firm to evaluate the capability of the Fort Polk water-distribution system to meet present and future water demands. The contractor has prepared a separate technical report (Planning, Design and Research Engineers, Inc.,[1] written commun., 1987) to address this concern.

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[1] Use of the brand or firm names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey or the U.S. Army.

The scope of work consisted of making water-level measurements in accessible wells, conducting multiple-well and single-well aquifer tests and specific-capacity tests, evaluating the hydraulic characteristics of the aquifers using selected analytical techniques, and reviewing and evaluating well and pumpage records and geophysical logs. Transmissivities, hydraulic conductivities, and storage coefficients were determined applying appropriate analytical techniques to aquifer-test data. The history of development of the aquifers at Fort Polk was determined from well and pumpage records. The effects of pumpage on water levels in the aquifers were evaluated by comparison of pumpage histograms with well hydrographs at Fort Polk and by preparation of maps of the potentiometric surfaces of the Williamson Creek and Carnahan Bayou aquifers in Vernon Parish, using 1986 water-level data. The data presented in this report are from the field work and records described above, which are on file at the Louisiana District Office of the U.S. Geological Survey or are cited in the Selected References section.

Location of Study Area and Geographic Features

Fort Polk is situated near the center of Vernon Parish, in west-central Louisiana. Six mi (miles) to the northwest is Leesville (population 9,000), the parish seat and largest town in the parish. Locations of six other towns and villages (each with less than 1,000 people) that have public-supply systems are shown in figure 1. Vernon Parish is predominantly rural with large tracts of land designated for use as a national forest, wildlife management areas, and a state park. Land cover is predominantly open fields or pasture and conifer woodlands. Most of the Fort Polk Military Reservation (fig. 1) is used for tank and artillery impact areas and training areas. The study area for this report includes the two cantonments of Fort Polk and North Fort Polk and the surrounding local area at the extreme western end of the reservation as shown in figure 1. In this report, when it is necessary to distinguish these two cantonments from the collective Fort Polk study area they will be referred to as (south) Fort Polk and North Fort Polk.

The topography at Fort Polk, and generally throughout Vernon Parish, is gently rolling with altitudes ranging from 250 to 400 ft (feet) above sea level. Fort Polk is situated on a local topographic high; thus, surface drainage patterns generally radiate outward from Fort Polk. Principal streams in Vernon Parish include the Calcasieu River, Bayou Anacoco, and Bayou Castor. Two reservoirs, Lake Vernon (6.6 mi^2, square miles) and Anacoco Lake (4.06 mi^2) are located in the Bayou Anacoco drainage basin to the west and northwest of Fort Polk. The Sabine River forms the western boundary of the parish as part of the Louisiana-Texas State line.

The climate in the area is generally mild. The January mean minimum temperature is 3°C and the July mean maximum temperature is 34°C. The average annual precipitation is 56 in. (inches) (Muller and others, 1984).

Previous Investigations

The geology and geohydrology of northern Louisiana, which includes Vernon Parish, were first described by Veatch (1906). The geology of Vernon Parish

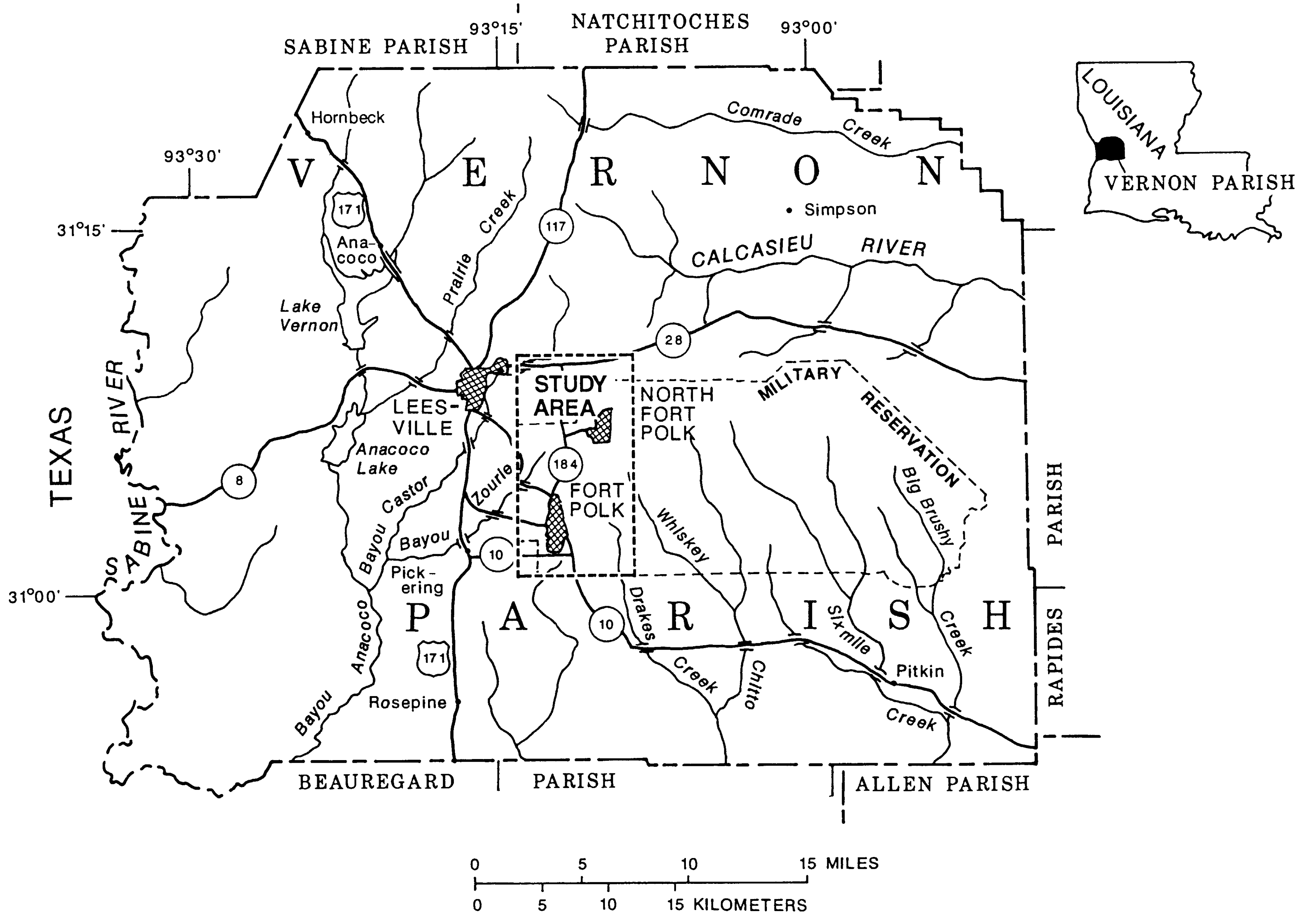

Figure 1.--Location of study area at Fort Polk, Vernon Parish, Louisiana.

was investigated by Welch (1942). An areal investigation of the water resources of Vernon Parish was reported by Rogers and Calandro (1965). Maher and others (1943) prepared an unpublished report on ground-water conditions at Fort Polk and published a condensed version (1945). Klug (1956) prepared a report based on a reconnaissance study of the geologic and hydrologic characteristics of the Catahoula Formation of Miocene age in the Leesville area.

GEOHYDROLOGY

Unconsolidated sedimentary deposits ranging in age from Pleistocene to Eocene are sources of ground water in Vernon Parish (Rogers and Calandro, 1965). These deposits correspond to the geohydrologic units shown in table 1.

Table 1.--Geologic and geohydrologic units of Fort Polk, Louisiana, and adjacent areas

Geologic Age		Geologic unit		Geohydrologic unit	
Period	Epoch				
Quaternary	Pleistocene	Alluvial deposits		Alluvial aquifers	
		Terrace deposits		Terrace aquifers	
Tertiary	Pliocene	Fleming Formation	Blounts Creek Member	Evangeline aquifer	
	? Miocene		Castor Creek Member	Castor Creek confining unit	
			Williamson Creek Member	Jasper Aquifer system	Williamson Creek aquifer
			Dough Hills Member		Dough Hills confining unit
			Carnahan Bayou Member		Carnahan Bayou aquifer
			Lena Member		Lena confining unit
		Catahoula Formation		Catahoula aquifer	
	? Oligocene	Vicksburg and Jackson Groups		Vicksburg-Jackson confining unit	
	Eocene				
		Cockfield Formation		Cockfield aquifer	

Alluvium of Pleistocene age fills the stream valleys, and deposits of Pleistocene age form local stream terraces throughout Vernon Parish and blanket the surface of the southern part of the parish (fig. 2). These deposits make up the alluvial and terrace aquifers, respectively. The alluvial aquifers are shallow and thin and have little water-supply potential. The terrace aquifers only have water-supply potential where they blanket the southern part of the parish (Rogers and Calandro, 1965). The village of Rosepine (fig. 1) in the south-central part of the parish uses the terrace aquifer as its source of public supply.

Six geohydrologic units, in descending order, are in the Blounts Creek, Castor Creek, Williamson Creek, Dough Hills, Carnahan Bayou, and Lena Members of the Fleming Formation of Miocene and Pliocene (?) age. The Evangeline aquifer is the source of ground water to the public-supply wells for the town of Pitkin and to domestic wells in the southern part of the parish. The Williamson Creek aquifer is a source of water to public-supply wells at Fort Polk, the Ward 4 Water District at Pickering and to domestic wells north and west of Fort Polk (fig. 1). The Carnahan Bayou aquifer is a source of water to public-supply wells at Fort Polk, in the towns of Leesville and Simpson, and to domestic wells north and west of Fort Polk (fig. 1). The Catahoula and Cockfield aquifers in the Miocene Catahoula Formation and the Eocene Cockfield Formation, respectively, are the sources of water to public-supply wells in the towns of Anacoco and Hornbeck, respectively, and the Catahoula aquifer is the source of water to domestic wells in the parish north of Leesville (fig. 1).

All geohydrologic units of Miocene age and younger are exposed at land surface in Vernon Parish, except the Catahoula aquifer, which is exposed in Sabine and Natchitoches Parishes to the north. These surface exposures represent the updip limits of the aquifers and confining units, and constitute the recharge areas for the aquifers (fig. 2). The contacts between the units show the general strike. The dip of these units is to the southeast at a rate of 50 to 70 ft/mi (feet per mile) near the updip limit, increasing to greater than 100 ft/mi near the southern boundary of Vernon Parish. The units thicken in the downdip direction. The total thickness of the sediments of Miocene age increase from 3,000 ft in southern Vernon Parish to at least 12,000 ft southward toward the Gulf of Mexico (Welch, 1942, p. 37).

The geohydrologic characteristics that differentiate aquifers from confining units in unconsolidated sediments are primarily determined by the depositional history and lithology. The alluvial and terrace aquifers are of fluviatile origin and consist of gravel, sand, silt, and clay. The Evangeline, Williamson Creek, Carnahan Bayou, and Catahoula aquifers also are of fluviatile origin but consist of sandstone, siltstone, sand, silt, and clay. The Castor Creek, Dough Hills, and Lena confining units are sediments of brackish water origin and consist of lenticular deposits of calcareous clay and silt (Welch, 1942).

Previous investigators have noted the complexity of the sequence of these geohydrologic units. Welch (1942, p. 49) stated that these units should not be thought of as distinct and clear-cut units with uniform thickness and lithology, but rather as phases of sedimentation that vary in character in any direction. Rogers and Calandro (1965, p. 8) noted that sand commonly grades laterally and vertically into silt or clay, making correlation of individual sand units very difficult. Plate 1 is a fence diagram of the geohydrologic units in the Fort Polk and Leesville area.

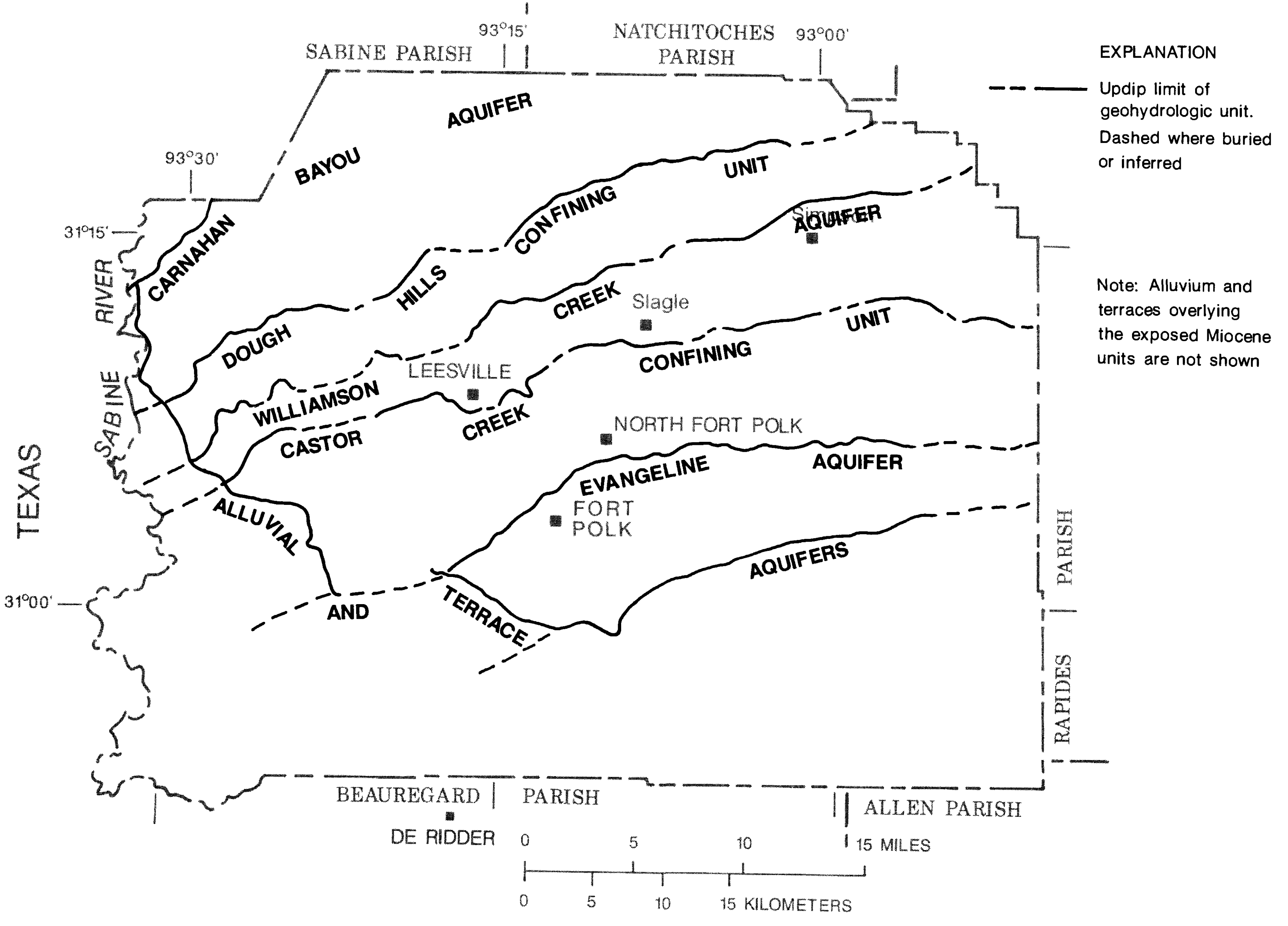

Figure 2.--Updip limits of geohydrologic units of Miocene age and younger in Vernon Parish, Louisiana.

In the study area, the geohydrologic system defined for this report consists of the Williamson Creek and Carnahan Bayou aquifers; and the Castor Creek, Dough Hills, and Lena confining units (pl. 1). Only the Williamson Creek and Carnahan Bayou aquifers are included in this investigation because they are the only aquifers developed for water supply within the study area. The three confining units hydrologically separate these two aquifers from each other and from other overlying and underlying aquifers. The Castor Creek confining unit is 200 to 400 ft thick in the study area, overlying the Williamson Creek aquifer. Between the two aquifers is the Dough Hills confining unit, 300 to 400 ft thick. The Lena confining unit, which underlies the Carnahan Bayou aquifer, is 300 to 400 ft thick in the study area.

Ground-Water Flow System

Water enters the aquifers by infiltration and downward percolation of rainwater in the recharge areas (fig. 2) and by vertical leakage from adjacent units. The recharge area for the Williamson Creek aquifer is a 2- to 6-mi wide zone about 7 mi northwest of Fort Polk. The recharge area for the Carnahan Bayou aquifer is a zone 8 to 11 mi wide about 15 mi northwest of Fort Polk. The direction and rate of flow of water in aquifers are determined by the hydraulic gradient from areas of high hydraulic head (recharge areas) to areas of low hydraulic head (discharge areas). In the recharge areas of the Carnahan Bayou and Williamson Creek aquifers, water levels generally reflect the topographic surface. Water levels are highest where the land surface altitude is the greatest. Ground-water levels in most stream valleys are lower than in adjacent upland areas; thus, some ground water in the recharge areas discharges locally to streams.

The natural hydraulic gradients in the confined parts of the Carnahan Bayou and Williamson Creek aquifers generally conform with the strike and dip of the geohydrologic units, except near the Sabine River. Water-level measurements from both the Carnahan Bayou and Williamson Creek aquifers near the Sabine River indicate that the river serves as a discharge boundary to both aquifers. In southeastern Vernon Parish and further downdip, to the south and east of parish boundary, the ground water becomes salty and increases in density. The hydraulic gradient is upward through the geohydrologic units to the surface, where the water eventually discharges to streams.

The potentiometric surface of the Williamson Creek aquifer in 1986 is shown in figure 3. Two cones of depression are evident, one around (south) Fort Polk and the other around a paper mill near the town of De Ridder in Beauregard Parish, 15 mi southwest of Fort Polk. These cones define the altered flow pattern in the Williamson Creek aquifer. Flow of water is normal to the lines of equal hydraulic head (potentiometric contour).

The potentiometric contours in figure 3 shows a relatively steep hydraulic gradient of about 20 ft/mi between Leesville and Fort Polk. In contrast, the gradient from the recharge area to the center of the cone of depression near De Ridder is about 11 ft/mi. Throughout eastern and

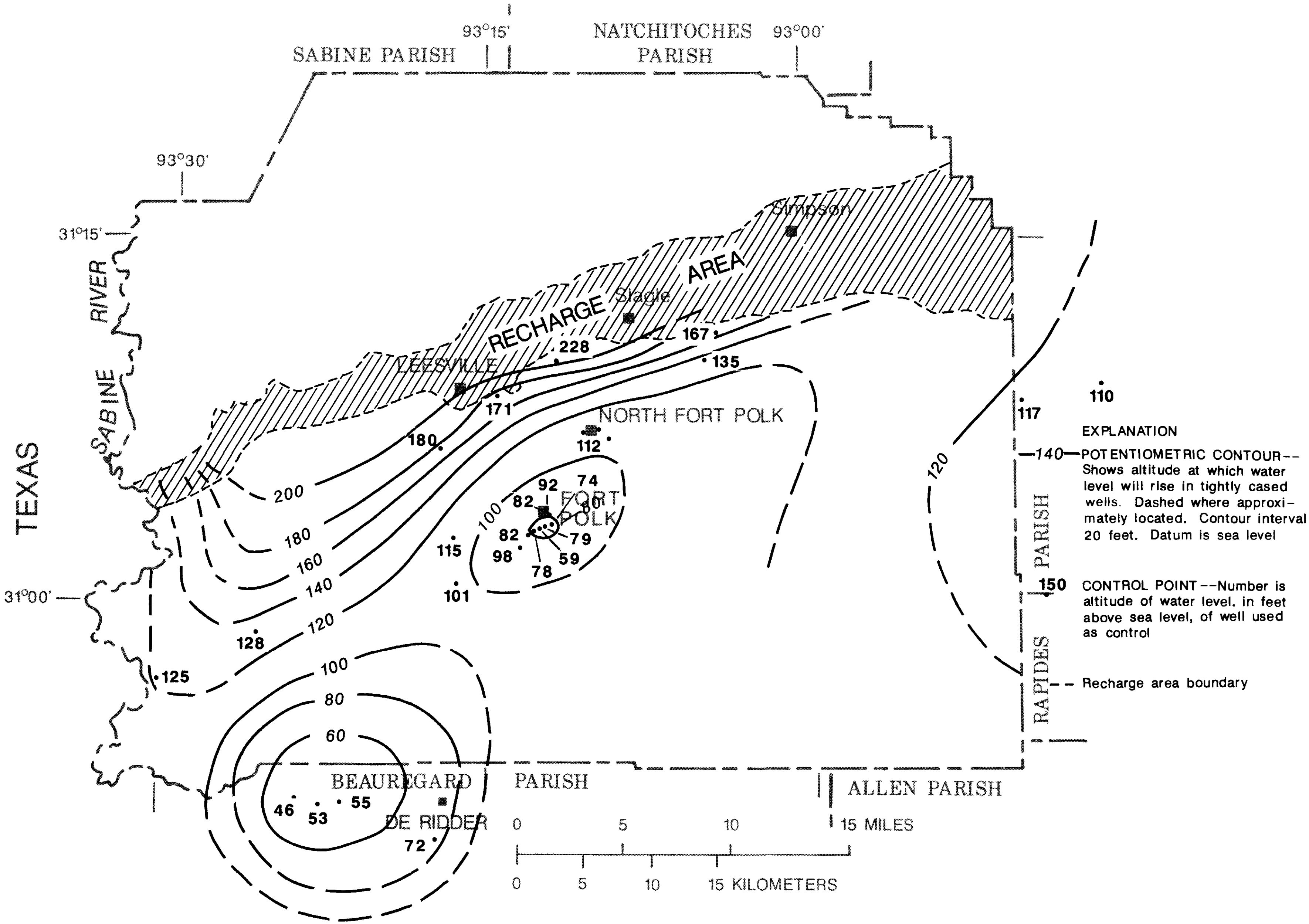

Figure 3.--Potentiometric surface of the Williamson Creek aquifer, 1986.

southeastern Vernon Parish, the potentiometric surface becomes relatively flat, although few water-level measurements are available to adequately define the surface.

The potentiometric surface of the Carnahan Bayou aquifer in 1986 is shown in figure 4. A cone of depression, defined by a 160-ft contour line, is present around Fort Polk and Leesville. Between Leesville and the recharge area of the Carnahan Bayou the hydraulic gradient is about 12 ft/mi. Water levels between Leesville, North Fort Polk, and (south) Fort Polk were about 150 to 160 ft above sea level in 1986. The hydraulic gradient within this cone of depression and to the west, south, east, and northeast of the cone is probably less than 2 ft/mi, although few water-level measurements are available to adequately define the potentiometric surface in Vernon Parish south of Fort Polk. A second, much larger cone of depression is defined by the lines of equal hydraulic head in eastern Vernon Parish and extending into Rapides Parish. The flow of water in the Carnahan Bayou aquifer in eastern Vernon Parish is toward the center of this cone, the Kisatchie well field (not shown in fig. 4), 31 mi east of North Fort Polk.

Between the recharge areas and Leesville, water levels in the Williamson Creek aquifer are higher than water levels in the Carnahan Bayou aquifer (figs. 3 and 4). Some vertical flow of water from the Williamson Creek aquifer to the Carnahan Bayou aquifer occurs because of the difference in heads (water levels). At Leesville, for example, the water level in the Williamson Creek aquifer was about 200 ft above sea level (fig. 3) and the water level in the Carnahan Bayou aquifer was about 160 ft above sea level in 1986. An approximate amount of water leaking through the Dough Hills confining unit can be calculated by applying Darcy's law, $Q = KA\ (dh/dL)$ (Lohman, 1972). Assuming a vertical hydraulic conductivity, K, of 10^{-4} ft/d and a thickness, dL, of 400 ft for the Dough Hills confining unit; and where $dh = 40$ ft, $A = 1\ ft^2$, then $Q = 10^{-5}\ ft^3/d$ (cubic feet per day).

About 2 mi to the southeast of Leesville, water levels in both aquifers are approximately equal. Proceeding toward (south) Fort Polk, water levels in the Williamson Creek aquifer dropped to an average of 80 ft above sea level (fig. 3), but water levels in the Carnahan Bayou aquifer dropped to only about 150 ft above sea level (fig. 4) in 1986. Thus, at Fort Polk, some water flows vertically upward from the Carnahan Bayou aquifer to the Williamson Creek aquifer. Again, an approximate flow can be calculated. Using the above water levels and the same values for K and dL as in the previous example, the flow of water leaking from the Carnahan Bayou aquifer through the Dough Hills confining unit to the Williamson Creek aquifer at (south) Fort Polk is about $1.75 \times 10^{-3}\ ft^3/d$ (across a unit area of $1\ ft^2$).

Hydraulic Characteristics

Three hydraulic characteristics of confined aquifers were determined from aquifer tests conducted at Fort Polk. Transmissivity is the rate at which water of the prevailing kinematic viscosity is transmitted across an area of the entire saturated thickness of the aquifer times unit width under a unit

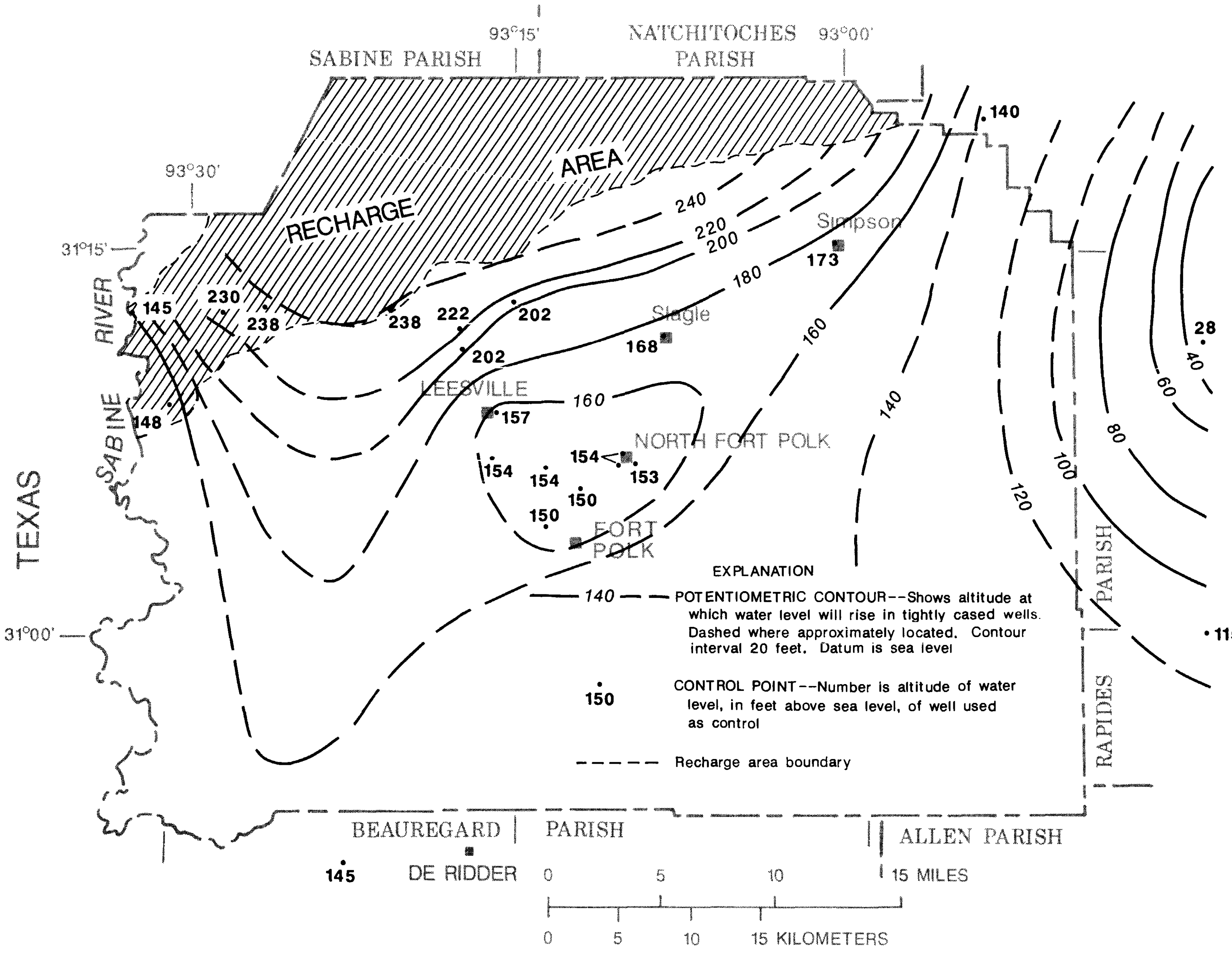

Figure 4.--Potentiometric surface of the Carnahan Bayou aquifer, 1986.

hydraulic gradient. It is equal to an average hydraulic conductivity multiplied by the saturated thickness of the aquifer (Heath, 1983; Lohman and others, 1972). The units of measurement (in this report) are feet squared per day. The storage coefficient, a dimensionless unit, is the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (Heath, 1983; Lohman and others, 1972). Hydraulic conductivity is the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient across a unit area (Heath, 1983; Lohman and others, 1972). The units of measurement (in this report) are in feet per day.

The hydraulic characteristics of the aquifers in the study area were determined from selected aquifer tests. The data are presented in table 2 by well site. Where the results from more than one aquifer test are presented for a well site, the values of transmissivity, storage coefficient, sand thickness, and hydraulic conductivity were averaged. Transmissivity and storage coefficient were determined by the test-analysis method listed. Hydraulic conductivity was calculated by dividing the transmissivity by the sand thickness of the screened interval of the observed well.

In evaluating the aquifer test results it is important to consider the assumptions underlying the test-analysis method. For the three methods listed in table 2 the following assumptions apply (Kruseman and DeRidder, 1970).

Theis nonequilibrium method and Theis recovery method:

- The aquifer is confined and has unlimited extent.

- The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the pumping test.

- Prior to pumping, the potentiometric surface is nearly horizontal over the area influenced by the pumping test.

- The aquifer is pumped at a constant rate.

- The pumped well penetrates the entire aquifer and thus receives water from the entire thickness of the aquifer by horizontal flow.

- The flow to the well is in unsteady state.

- The water from storage is discharged instantaneously with decline in head.

- The diameter of the pumped well is very small, such that storage in the well can be neglected.

Jacob nonequilibrium method:

- Same assumptions as the Theis method.

- The values of u are small (<0.01), where u is a function of the ratio of the distance between the pumping well and the well from which the data were collected to the time since pumping started.

Table 2.--Hydraulic characteristics determined from selected aquifer tests at (south) Fort Polk and North Fort Polk, Louisiana

[gal/min, gallon per minute; min, minute; ft, feet; ft^2/d, feet squared per day; ft/d, feet per day. Test analysis method: J, Jacob modified nonequilibrium method; R, Theis recovery method; T, Theis nonequilibrium (graphical) method]

Observed well[1]	Pumped well[1]	Pumping rate (gal/min)	Pumping duration (min)	Trans-missivity (ft^2/d)	Storage coeffi-cient	Observed well sand thickness (ft)	Hydraulic conduc-tivity[2] (ft/d)	Date of test	Source of test data	Test analysis method	Remarks
				A sand of the Williamson Creek aquifer at (south) Fort Polk							
Well site 6											
6B (V-446)	6B (V-446)	503	360	2,300	-------	45	50	5- 8-80	Driller	J	
Well site 9											
9 (V-109)	9 (V-109)	-----	5,700	1,000	-------	63	15	3- 7-43	(3)	TR	Well 9 screened in 2 sand intervals.
				B sand of the Williamson Creek aquifer at (south) Fort Polk							
Well site 8											
8B (V-420)	5A (V-420)	510	1,440	4,800	0.00025	85	55	10-16-85	(4)	T	
8A (V-108A)	8A (V-108A)	-----	2,880	5,000	-------	89	55	3-16-43	(3)	TR	
8A (V-108A)	6A (V-106A)	-----	2,880	4,400	.00016	89	50	3-23-43	(3)	T	Early data used (80-900 min).
Site average------------------------				4,700	.0002	88	55				
Well site 7											
7A (V-510)	5A (V-448)	510	1,440	4,300	.00029	69	60	10-16-85	(4)	T	Well 7A screened in 2 sand intervals.
7A (V-510)	7A (V-510)	495	210	3,600	-------	69	50	3-21-83	Driller	J	Well 7A screened in 2 sand intervals.
7A (V-510)	7A (V-510)	-----	770	4,900	-------	69	70	12- 6-74	Driller	J	Well 7A screened in 2 sand intervals.
Site average------------------------				4,300	.0003	69	60				

See footnotes at end of the table.

Table 2.--Hydraulic characteristics determined from selected aquifer tests at (south) Fort Polk and North Fort Polk, Louisiana--Continued

Observed well[1]	Pumped well[1]	Pumping rate (gal/min)	Pumping duration (min)	Trans-missivity (ft^2/d)	Storage coeffi-cient	Observed well sand thickness (ft)	Hydraulic conduc-tivity[2] (ft/d)	Date of test	Source of test data	Test analysis method	Remarks
B sand of the Williamson Creek aquifer at (south) Fort Polk--Continued											
Well site 6											
6C (V-479)	11A (V-518)	736	1,440	4,800	0.00028	69	70	1-21-86	(4)	T	Well 6C screened in 3 sand intervals.
6C (V-479)	5A (V-448)	510	1,440	3,900	.00027	57	70	10-16-85	(4)	T	Well 6C screened in 3 sand intervals.
6C (V-479)	6C (V-479)	503	350	4,300	-------	57	75	8- 5-81	Driller	J	Well 6C screened in 3 sand intervals.
6 (V-106)	6A (V-106A)	-----	2,880	3,700	.00018	55	65	3-23-43	(3)	T	
6A (V-106A)	6A (V-106A)	445	2,880	3,600	-------	79	45	3-23-43	(3)	TR	
Site average-----------------------				4,100	.0002	63	65				
Well site 5											
5A (V-448)	11A (V-518)	736	1,440	3,400	.00010	45	75	1-21-86	(4)	TR	
5A (V-448)	5A (V-448)	503	360	3,300	-------	45	75	10-11-79	Driller	J	
Site average-----------------------				3,400	.0001	45	75				
Well site 9											
9A (V-497)	11A (V-518)	736	1,440	3,700	.00011	45	80	1-21-86	(4)	T	
Well site 11											
11A (V-518)	11A (V-518)	736	1,440	4,800	-------	69	70	1-21-86	(4)	J	
11A (V-518)	11A (V-518)	752	120	4,900	-------	69	70	1-21-86	(4)	J	
11 (V-111)	11 (V-111)	-----	4,920	4,800	-------	69	70	3-13-43	(3)	TR	
Site average-----------------------				4,800		69	70				

Well site 12										
12 (V-112)	12 (V-112)	503	350	5,300	-------	67	80	9-30-80	Driller	J
12 (V-112)	12 (V-112)	-----	2,880	4,700	-------	67	70	3- 7-43	(3)	TR
Site average------------------------				5,000		67	75			
				B sand of the Williamson Creek aquifer at North Fort Polk						
Well site 8										
8-PS (V-127)	6-PS (V-124)	-----	3,000	5,800	0.00010	55	105	3-23-43	(3)	T
8-PS (V-127)	8-PS (V-127)	-----	120	6,000	-------	55	110	3-18-43	(3)	TR
Site average------------------------				5,900	.0001	55	105			
Well site 6										
6-T (V-118)	2-PS (V-121)	-----	3,300	4,700	.00027	86	55	3-13-43	(3)	T
6-T (V-118)	4-PS (V-123)	-----	2,880	5,300	.00022	86	60	3-20-43	(3)	T
6-PS (V-124)	4-PS (V-123)	-----	2,880	5,100	.00028	64	80	3-20-43	(3)	T
Site average------------------------				5,000	.0003	79	65			
Well site 4										
4-TS (V-116)	4-PS (V-123)	-----	2,880	5,700	.00022	73	80	3-20-43	(3)	T
4-TS (V-116)	6-PS (V-124)	-----	3,000	4,900	.00033	73	65	3-23-43	(3)	T
4-PS (V-123)	6-PS (V-124)	-----	3,000	4,600	.00023	64	70	3-23-43	(3)	T
4-TS (V-116)	4-TS (V-116)	-----	3,000	5,700	-------	73	80	3- 6-43	(3)	TR
Site average------------------------				5,200	.0003	71	75			

See footnotes at end of the table.

Table 2.--Hydraulic characteristics determined from selected aquifer tests at (south) Fort Polk and North Fort Polk, Louisiana--Continued

Observed well[1]	Pumped well[1]	Pumping rate (gal/min)	Pumping duration (min)	Trans-missivity (ft^2/d)	Storage coeffi-cient	Observed well sand thickness (ft)	Hydraulic conduc-tivity[2] (ft/d)	Date of test	Source of test data	Test analysis method	Remarks
				B sand of the Williamson Creek aquifer at North Fort Polk--Continued							
Well site 2											
2A-PS (V-522)	6-PS (V-124)	330	80	4,400	-------	71	60	9-10-85	(4)	T	Pump broke suction at 80 min.
2-PS (V-121)	4-PS (V-123)	-----	2,880	6,100	0.00026	67	90	3-20-43	(3)	T	
2-PS (V-121)	6-PS (V-124)	-----	3,000	4,400	.00023	67	65	3-23-43	(3)	T	
Site average------------------------				5,000	.0002	68	75				
				Unnamed sand in the Carnahan Bayou aquifer at North Polk							
Well site 4											
4A-PS (V-503)	4A-PS (V-503)	800	350	4,300	-------	50	85	4- 9-86	(4)	J	Multiple discharge boundaries at 50, 130, and 200 min. Pump broke suction after 350 min.
				C sand of the Carnahan Bayou aquifer							
Well site 14D											
14D (V-496)	14D (V-496)	1,200	185	17,100	-------	65	265	10-22-86	(4)	J	
14D (V-496)	14D (V-496)	1,200	1,450	18,400	-------	65	285	1-19-82	Driller	J	
Site average------------------------				17,800		65	275				
Well site Hunt 2											
Hunt 2 (V-515)	Hunt 2 (V-515)	1,200	1,440	13,200	-------	68	195	8- 1-85	Driller	J	
Well site Hunt 1											
Hunt 1 (V-514)	Hunt 2 (V-515)	1,200	1,440	12,700	.00019	76	165	8- 1-85	(4)	T	

Hunt 1 (V-514)	Hunt 1 (V-514)	1,200	1,440	5,800	-------	76	70	6-11-85	Driller	J	Calculated from 1-38 min.
				8,800							Calculated 38-1440 min. Recharge boundary at 38 min.
Well site 6											
6A-PD (V-504)	6A-PD (V-504)	585	1,440	2,800	-------	78	35	6- 3-85	(4)	J	Well 6A-PD screened in 3 sand intervals.
6A-PD (V-504)	6A-PD (V-504)	503	1,440	3,600	-------	78	45	12-19-83	Driller	J	Screen may not be open to all.
Site average				3,200		78	40				
Well site 7											
7-PD (V-126)	2-PD (V-122)	-----	1,680	9,900	0.00016	100	100	3- 8-43	(3)	T	
7-PD (V-126)	2-PD (V-122)	-----	1,620	8,800	.00016	100	90	3-24-43	(3)	T	
7-PD (V-126)	7-PD (V-126)	-----	180	10,900	-------	100	110	3-17-43	(3)	TR	
Site average				9,900	.0002	100	100				
Well site 2											
2-PD (V-122)	2-PD (V-122)	-----	2,280	12,200	-------	58	210	3-24-43	(3)	TR	
					D sand of the Carnahan Bayou aquifer						
Well site 8											
8-PD (V-128)	8-PD (V-128)	-----	2,280	7,200	-------	49	145	3-14-43	(3)	TR	

1 Top number is the Fort Polk well number; bottom number in parentheses is the U.S. Geological Survey local well number.
2 Determined by dividing transmissivity by sand thickness of observed well.
3 Maher and others, 1943.
4 Collected during this study.

For the aquifer tests listed in table 2 the above assumptions were generally met. The assumption of infinite areal extent is seldom met in reality, but an apparent infinite extent usually can be approximated within the period of the aquifer test. Departures from the above assumptions are most likely to occur with the assumptions that the aquifers are homogeneous, isotropic, and of constant thickness. In the following sections, some of the aquifer tests are evaluated for their departures from these assumptions.

Another assumption that may not be fully met is the assumption that the aquifers are confined. Strictly speaking, a confined aquifer has impervious upper and lower confining units. This does not occur in unconsolidated sediments such as those found in the study area. The Williamson Creek and Carnahan Bayou aquifers are separated from each other and from overlying and underlying aquifers by confining units of clay and silt hundreds of feet thick (as previously described). A pumping well in one of these aquifers can create a hydraulic head difference between the aquifer and its confining units. Consequently, some water leaks vertically from the confining units into the aquifer. Because the methods used to analyze the aquifer tests assume no leakage, the values of the hydraulic characteristics presented in table 2 may be different from the actual values. The degree to which the confining units leak water to the Williamson Creek and Carnahan Bayou aquifers under the pumping stresses occurring at Fort Polk is not known and cannot be determined from these aquifer tests. However, the authors believe that the differences between the calculated values and the actual values are reasonably small. A practical method to evaluate and quantify leakage would be through the development of a ground-water flow model.

Williamson Creek Aquifer

At Fort Polk, two principal sand units in the Williamson Creek aquifer can be identified by interpretation of electric logs. These are known locally as the A sand and the B sand. The A sand, averaging 60 ft in thickness, lies between 605 and 689 ft below land surface at (south) Fort Polk (fig. 5). At North Fort Polk, the sand is too thin and fine grained to be considered as a source of water and is not easily identifiable on electric logs.

The B sand at (south) Fort Polk lies between 806 and 930 ft below land surface (figs. 5 and 6) and at North Fort Polk lies between 517 and 624 ft below land surface. The minimum thickness is 18 ft; the maximum is 89 ft; and the average is 62 ft. The thickness of the B sand penetrated by currently operating wells ranges from 45 to 71 ft. Sandy clay and shale separate thin lenses of sand. Sieve analyses of sand samples indicate medium and fine grain sizes (Maher and others, 1943, p. 8).

A transmissivity of 1,000 ft^2/d (feet squared per day) was determined for the A sand using the Theis recovery method of analysis of a single-well aquifer test performed in 1943 (Maher and others, 1943, p. 21). Analysis of a driller's well-acceptance test (a pumping test of the developed well with the permanent pump at the design pumping rate prior to acceptance of the well for operation) at a different well site, using the Jacob modified nonequilibrium method, indicated a transmissivity of 2,300 ft^2/d. From these tests the hydraulic conductivity of the A sand is calculated to be between 15 and 50 ft/d

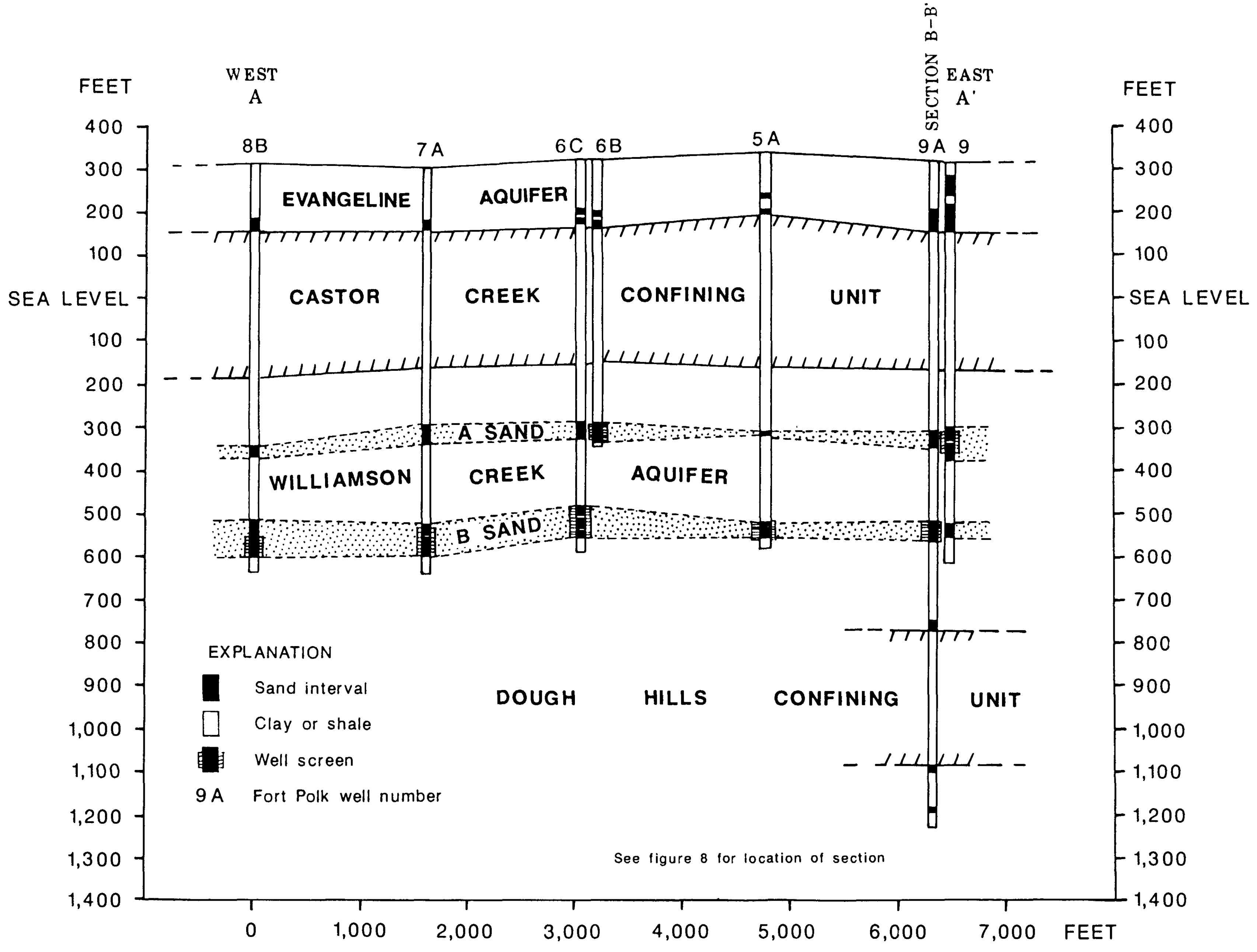

Figure 5.--Generalized section A-A' at (south) Fort Polk, Louisiana.

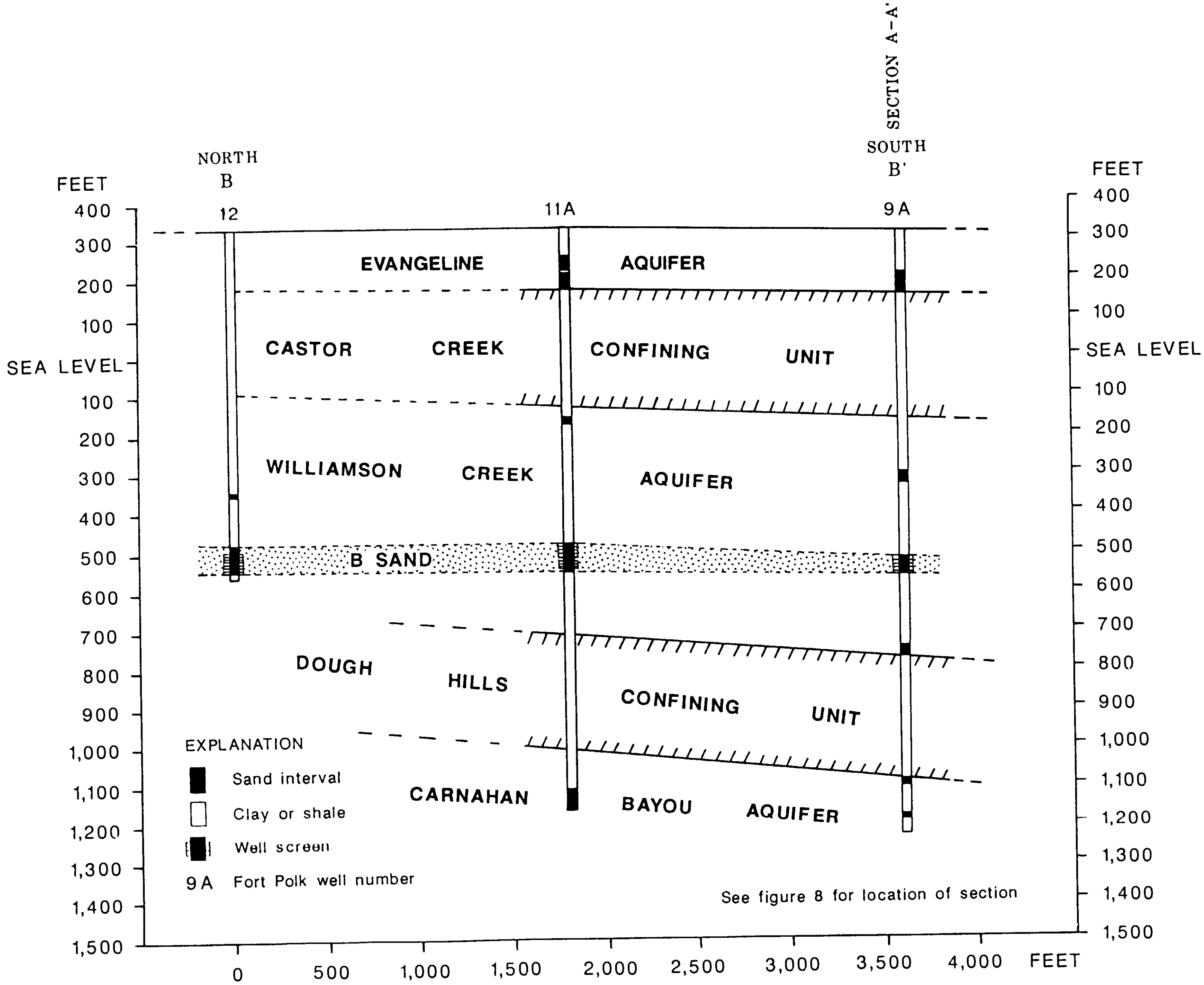

Figure 6.--Generalized section B-B' at (south) Fort Polk, Louisiana.

(table 2). Sieve analyses of sand samples indicate that the sand grains of the A sand are poorly sorted and rather fine grained (Maher and others, 1943, p. 7), typical of sands with conductivities in this range; thus, the calculated conductivities appear reasonable. Of the sands at Fort Polk that have been tested, the A sand has the lowest transmissivity and hydraulic conductivity. From the results of these aquifer tests and sand sample analyses, and by interpretation of driller's and electric logs, the A sand is not considered to be a satisfactory primary source of water for future development. However, as supported by analyses of geophysical logs and aquifer tests, locations may be found where the A sand has sufficient thickness and suitable hydraulic characteristics for the development of a well to supplement the development of a well or wells in the B sand or the C sand.

Only single-well tests have been performed in the A sand. Storage coefficients cannot be determined from single-well tests because the effective radius of the pumped well is not known and the total drawdown in the pumped well is affected by well loss.

Transmissivities of the B sand determined from aquifer tests range from 3,400 to 5,000 ft^2/d (well-site averages, table 2). The average transmissivity for all well sites at (south) Fort Polk is 4,300 ft^2/d. At North Fort Polk, transmissivities are higher, ranging from 5,000 to 5,900 ft^2/d (well-site averages, table 2) with an average of 5,300 ft^2/d for all well sites. The overall transmissivity for the B sand is about 4,600 ft^2/d, average of all well sites at (south) Fort Polk and North Fort Polk.

Storage coefficients for the B sand range from 0.00010 to 0.00033, with an average of 0.0002. Calculated hydraulic conductivities are about 70 ft/d at (south) Fort Polk and 80 ft/d at North Fort Polk (average of well-site averages, table 2).

Carnahan Bayou Aquifer

The Carnahan Bayou aquifer contains a sand unit that has been developed at all well sites in North Fort Polk and at one well site in (south) Fort Polk. This sand unit is known locally as the C sand (fig. 7). A deeper sand unit in the Carnahan Bayou aquifer, known locally as the D sand, had been developed at one site in North Fort Polk, although no wells presently are active in this unit.

The C sand is about 1,200 ft below land surface at North Fort Polk and 1,400 to 1,600 ft below land surface at (south) Fort Polk. Its thickness ranges from 58 to 110 ft, averaging 81 ft. At locations of presently operating wells, the thickness ranges from 61 to 85 ft. Interpretations of electric logs indicate numerous clay or shale partings within the sand interval. Sieve analyses indicate that sand grain sizes range from very fine to very coarse. Grain sizes in the medium to fine range predominate, although some samples contain more than 20 percent coarse sand (Rogers and Calandro, 1965, p. 21; Maher and others, 1943, p. 9).

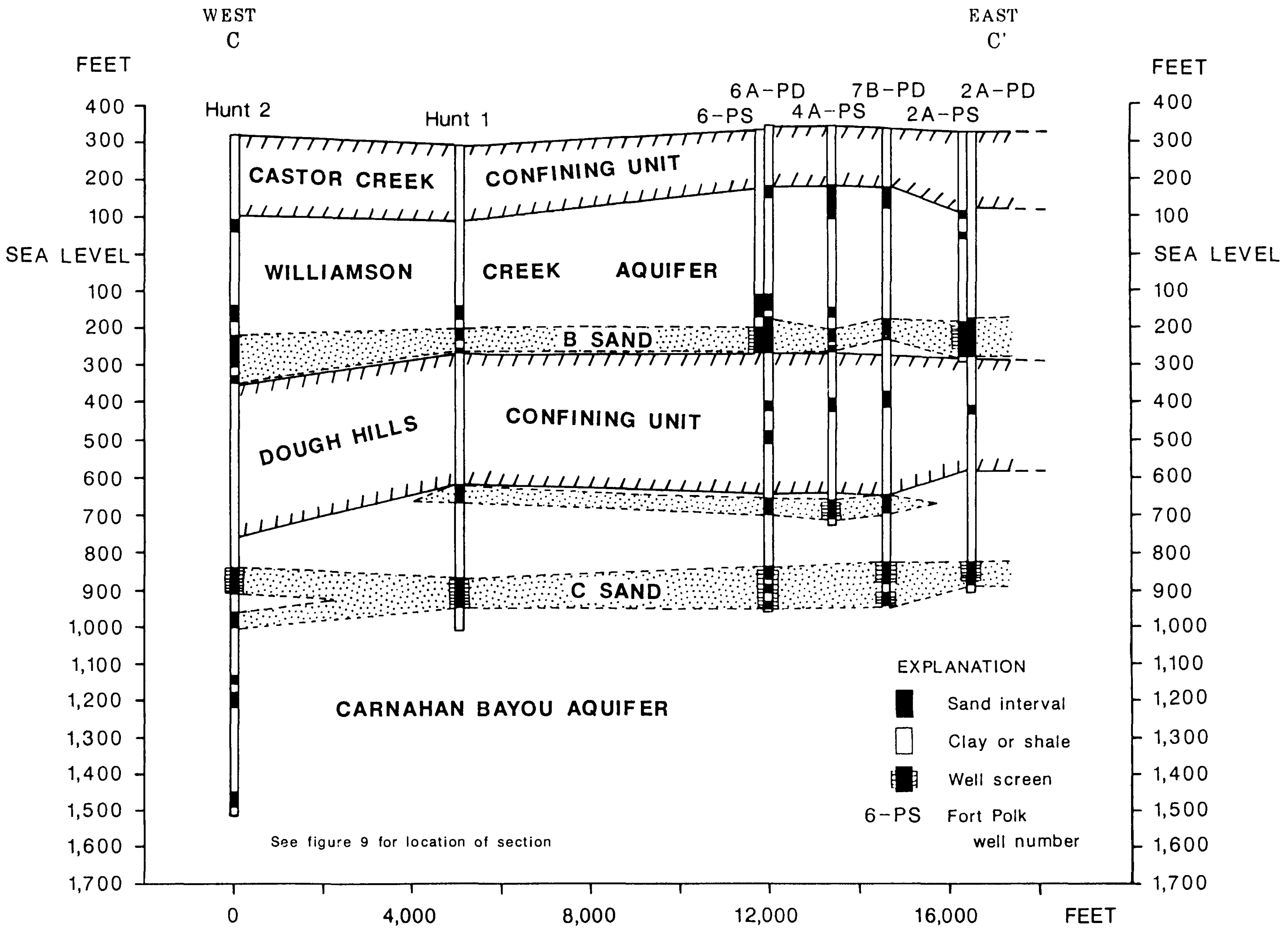

Figure 7.--Generalized section C-C' at North Fort Polk, Louisiana.

Transmissivity of the C sand is the highest of the four sands, but values determined from aquifer tests vary greatly and range from 2,800 to 18,400 ft^2/d. The storage coefficient averages 0.0002. Hydraulic conductivities (calculated from the transmissivities) similarly have a wide range of values from 35 to 285 ft/d. (See table 2 for data of hydraulic characteristics.)

Determining average or most representative hydraulic characteristics for the C sand is difficult. Correlation of well logs, sieve analyses, and analyses of aquifer tests indicate that the C sand is variable in thickness and lithology. This information supports the findings of previous investigators (Welch, 1942; Rogers and Calandro, 1965) on the complexity of the geohydrologic units. The following discussion evaluates the results of aquifer tests with extreme values of transmissivity.

A multiple-well aquifer test was conducted in August 1985 with well Hunt 2 (V-515)[2] pumping 1,200 gal/min for 24 hr (hours) and well Hunt 1 (V-514), at a distance of about 5,100 ft, serving as the observation well (table 2). Water-level measurements were taken at both wells during the drawdown and recovery periods. Transmissivity at the pumping well, Hunt 2, was determined to be 13,200 ft^2/d, and at the observation well, Hunt 1, 12,700 ft^2/d. These values are in relatively close agreement. Sieve analyses of sand samples from the two wells indicate medium to coarse sand from well Hunt 2 and mostly coarse to very coarse sand from well Hunt 1. The hydraulic conductivity for the sand at well Hunt 2 was calculated to be 165 ft/d, which may be slightly higher than would be expected based on the sieve analysis. The hydraulic conductivity for the sand at well Hunt 1 was calculated to be 195 ft/d, which is reasonable based on the sieve analysis.

In a well-acceptance test performed by the driller on well Hunt 1 in June 1985 (table 2), the transmissivity was determined to be 5,800 ft^2/d, using measurements for the first 38 min of pumping. After 38 min a recharge boundary was encountered by the expanding cone of depression (the rate of drawdown decreased). This recharge boundary was interpreted to represent a significant thickening of the sand. Using data after 38 min of pumping, the transmissivity was determined to be 8,800 ft^2/d. Analysis of electric-log data indicates that the screened interval of 76 ft at well Hunt 1, which is updip from well Hunt 2, does not correlate with the screened interval of 68 ft at well Hunt 2 but correlates with another sand interval of 41 ft in thickness 52 ft below the screened interval of well Hunt 2. These two sand intervals probably merge between wells Hunt 1 and Hunt 2; thus, accounting for the hydraulic connection between the two wells and the variability in transmissivities determined from the two aquifer tests. The conclusion is that assumption of uniform aquifer thickness has not been met. The transmissivity values from this aquifer test, determined from the Jacob method, may not be valid.

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[2] In this report the first well number (or name) is the well owner's (Fort Polk) identification of the well. The second number is the local number assigned by the U.S. Geological Survey. In Louisiana, the U.S. Geological Survey assigns local numbers to all registered water wells. A letter prefix represents the parish in which the well is located and the numeral is its order in the well inventory.

In another aquifer test conducted in June 1985 at the North Fort Polk well 6A-PD (table 2), transmissivity of the C sand was determined to be 2,800 ft^2/d. This result is in relatively close agreement with the transmissivity of 3,600 ft^2/d determined from data obtained from the driller's well-acceptance test in December 1983. Well 6A-PD is screened in three sand intervals totalling 78 ft in thickness; sand intervals are separated by two clay layers, 13 and 20 ft in thickness. Sieve analysis of sand samples indicate fine sand. The calculated hydraulic conductivities from the two tests are 35 to 45 ft/d. The conclusion is that, although sufficient water from the C sand at well site 6 can be and has been withdrawn, the hydraulic characteristics at that location do not follow the assumption of homogeneity of the aquifer, as required by Theis and Jacob modified nonequilibrium methods to derive transmissivity. Thus, the calculated transmissivities at well site 6 may not be valid.

At the high end of the range of transmissivity values for the C sand, two aquifer tests conducted at well 14D in the family housing area of (south) Fort Polk (table 2) yielded transmissivity values in close agreement with each other. However, the calculated hydraulic conductivity averaged 275 ft/d, which is much higher than calculated hydraulic conductivities from other tests (table 2). Sieve analyses of sand samples show sizes from the screened interval to be in the fine to medium range, which should yield a hydraulic conductivity in the same range of 50 to 80 ft/d as hydraulic conductivities from other aquifer tests. Therefore, the high transmissivity and hydraulic conductivity values may indicate that the sand thickness interpreted from the electric log of well 14D is not representative of the effective sand thickness in the vicinity of the well; the C sand probably thickens considerably near well 14D. The assumption of uniform aquifer thickness, as required by the Theis and Jacob methods, may not be true. Therefore, the hydraulic characteristics determined from the aquifer tests may not be valid.

Except for the results of the aquifer tests discussed above, the remainder of the aquifer tests of the C sand are in relatively close agreement with transmissivities between 8,800 and 13,200 ft^2/d. Based on the preponderance of results in this range, the conclusion is that a representative transmissivity for the C sand of the Carnahan Bayou aquifer is about 12,000 ft^2/d and a representative hydraulic conductivity is 130 ft/d. The storage coefficient for the C sand, determined from three aquifer tests (table 2), is 0.0002.

The D sand is 1,400 ft below the surface at North Fort Polk and is about 49 ft in thickness as determined from two driller's logs and interpretation of natural gamma logs from wells 8-T and 8-PD. Test wells were drilled to sands deeper than the C sand at only one other site at North Fort Polk and one site at (south) Fort Polk. Because no wells have been completed in these deeper sands, it is not possible to determine if these sands are in hydraulic connection with the identified D sand at North Fort Polk. Correlation of well logs (stratigraphic position) is not conclusive because sand commonly grades laterally to silt or clay. Samples of sand from the well site at North Fort Polk show the grains to be very coarse in texture (Maher and others, 1943, p. 9), but no samples are available on which to base judgment of the lithologic character at other locations.

A single-well aquifer test of the D sand was conducted in March 1943. Transmissivity was determined to be 7,200 ft^2/d (Maher and others, 1943, p. 22), which is higher than that of the B sand but not as high as for the C sand. Because a single well was used for the test, no storage coefficient could be determined using the Theis recovery method.

No wells presently withdraw ground water from any sand deeper than the C sand. Well-log information for wells that have penetrated the D sand or sands deeper than the C sand indicates that these sands are thinner than both the B sand and the C sand. Thus, it may be expected that well yields from the D sand would be lower than well yields from the B sand or the C sand. However, sands below the C sand in the Carnahan Bayou aquifer may have good potential for additional water supply at some localities. Therefore, test wells for future supply wells should be drilled at least to the base of the aquifer to explore this potential.

DEVELOPMENT OF THE GROUND WATER

In 1941, nine water wells were completed at seven sites to supply ground water to (south) Fort Polk. Currently, nine wells are active at eight sites to supply about 3.6 Mgal/d to approximately 25,000 people living and working at (south) Fort Polk. Figure 8 shows the location of all wells drilled for water supply at (south) Fort Polk since 1941. Table 3 describes basic information about each active well. Wells 5A, 6B, 6C, 7A, 8B, 9A, 11A, and 12 are screened in the A sand and B sand of the Williamson Creek aquifer (figs. 5 and 6). Well 14D is screened in the C sand of the Carnahan Bayou aquifer.

Nine wells were completed at five sites in 1942-43 to supply water to North Fort Polk. Currently, six wells at four sites are active, pumping about 0.4 Mgal/d. In addition, two wells at other sites were completed in 1985 to supply water to a new family housing area about 1 mi southwest of the North Fort Polk well system. Figure 9 shows the locations of all wells drilled for water supply at North Fort Polk since 1942. Table 4 describes basic information about each active well. Wells 2A-PS and 6-PS are screened in the B sand of the Williamson Creek aquifer; and wells 2A-PD, 6A-PD, Hunt 1, and Hunt 2 are screened in the C sand of the Carnahan Bayou aquifer (fig. 7).

A description of the inactive water-supply wells at (south) Fort Polk and North Fort Polk are described in table 5. This well information is from the period January 1941 to March 1943 and one well in March 1966. Other wells in the Fort Polk area are described in table 6.

Well 4A-PS is screened in a sand in the Carnahan Bayou aquifer between the B sand and the C sand (fig. 7). Although this sand is relatively thick (50 ft), it is probably of limited areal extent because it can only be correlated on logs of some nearby wells. In addition, a single-well aquifer test conducted in 1986 by the U.S. Geological Survey revealed numerous discharge boundaries after 50 min of pumping. These discharge boundaries are interpreted to be the limits of the areal extent of the sand (where the lithology changes from sand to silt and clay). After 6 hr of pumping, the drawdown

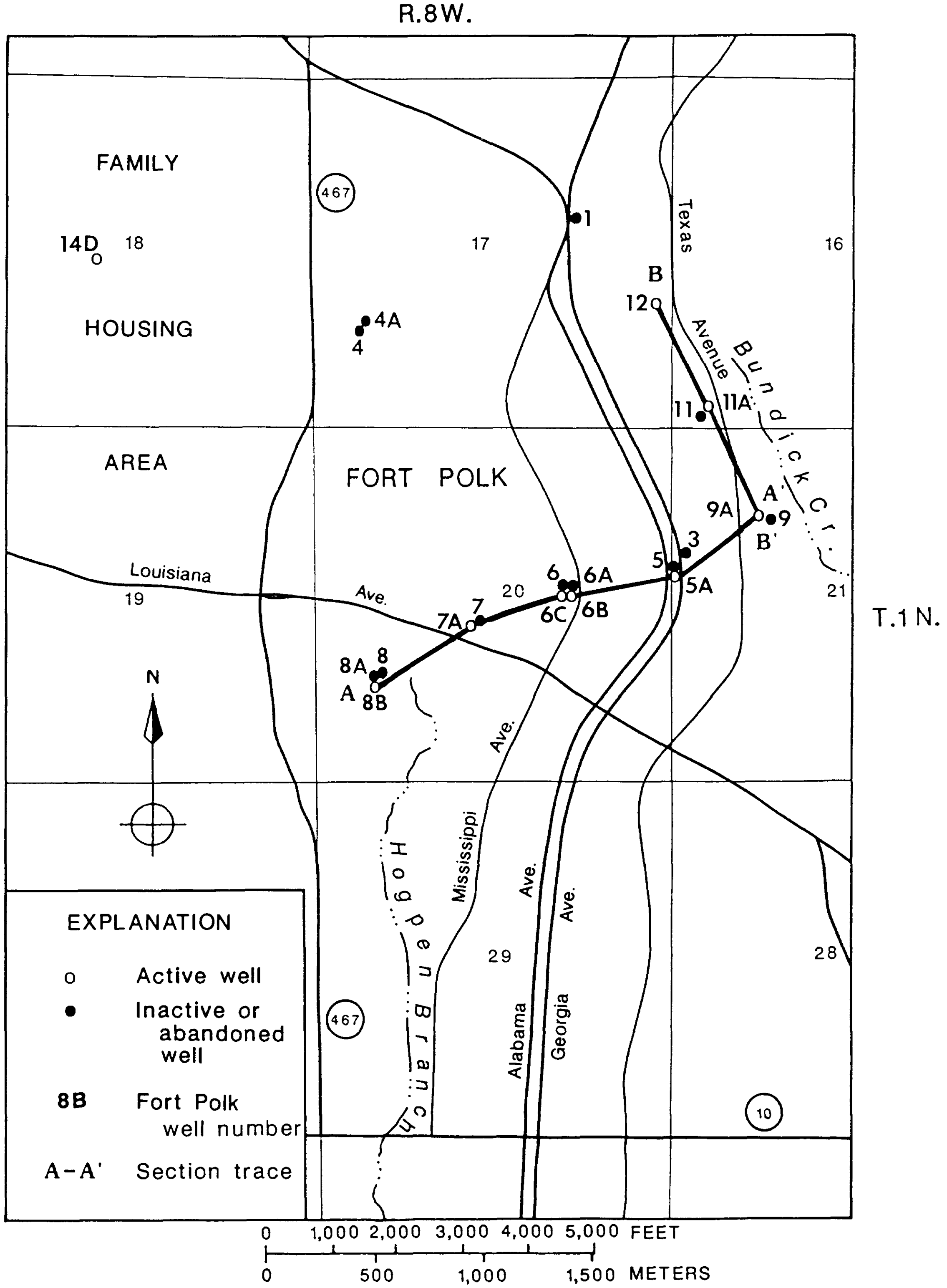

Figure 8.--Location of wells at (south) Fort Polk, Louisiana.

Table 3.--Well information for active water-supply wells at (south) Fort Polk, Louisiana

[D, driller's; E, electrical]

Well number[1]	Altitude (feet)	Date completed	Test hole depth (feet)	Well depth (feet)	Casing diameter (inches)	Screen setting (feet below land surface)	Screen opening[2] (inches)	Sand unit screened	Sand unit interval (feet below land surface)	Logs available
5A (V-448)	340	4- -70	922	910	12-6	858-910	0.014	B sand	860-872 879-895	D,E
6B (V-446)	325	9-28-71	670	660	14-10	620-660	.020	A sand	615-660	D,E
6C (V-479)	325	1- -75	920	886	12-8	820-880	.030	B sand	806-828 838-857 865-881	E
7A (V-510)	305	1- -75	954	900	12-8	840-900	.030	B sand	830-853 860-906	E
8B (V-420)	315	12- 1-64	958	920	14-8	863-914	.030	B sand	829-914	D,E
9 (V-109)	315	5-19-41	930	671	18-10	621-671	-----	A sand	614-642 654-689	D
9A (V-497)	320	10- -82	1,562	885	16-10	838-878	.020	B sand	838-883	D,E
11A (V-518)	335	7-29-86	1,500	885	16-10	819-854 859-879	.035	B sand	814-883	D,E
12 (V-112)	333	5-23-41	895	877	18-10	827-877	.080	B sand	810-877	D
14D (V-496)	284	4-29-82	2,127	1,415	16-10	1,339-1,409	-----	C sand	1,344-1,409	D,E

[1] Top number is the Fort Polk well number; bottom number in parentheses is the U.S. Geological Survey local well number.
[2] All wells are finished with a gravel pack.

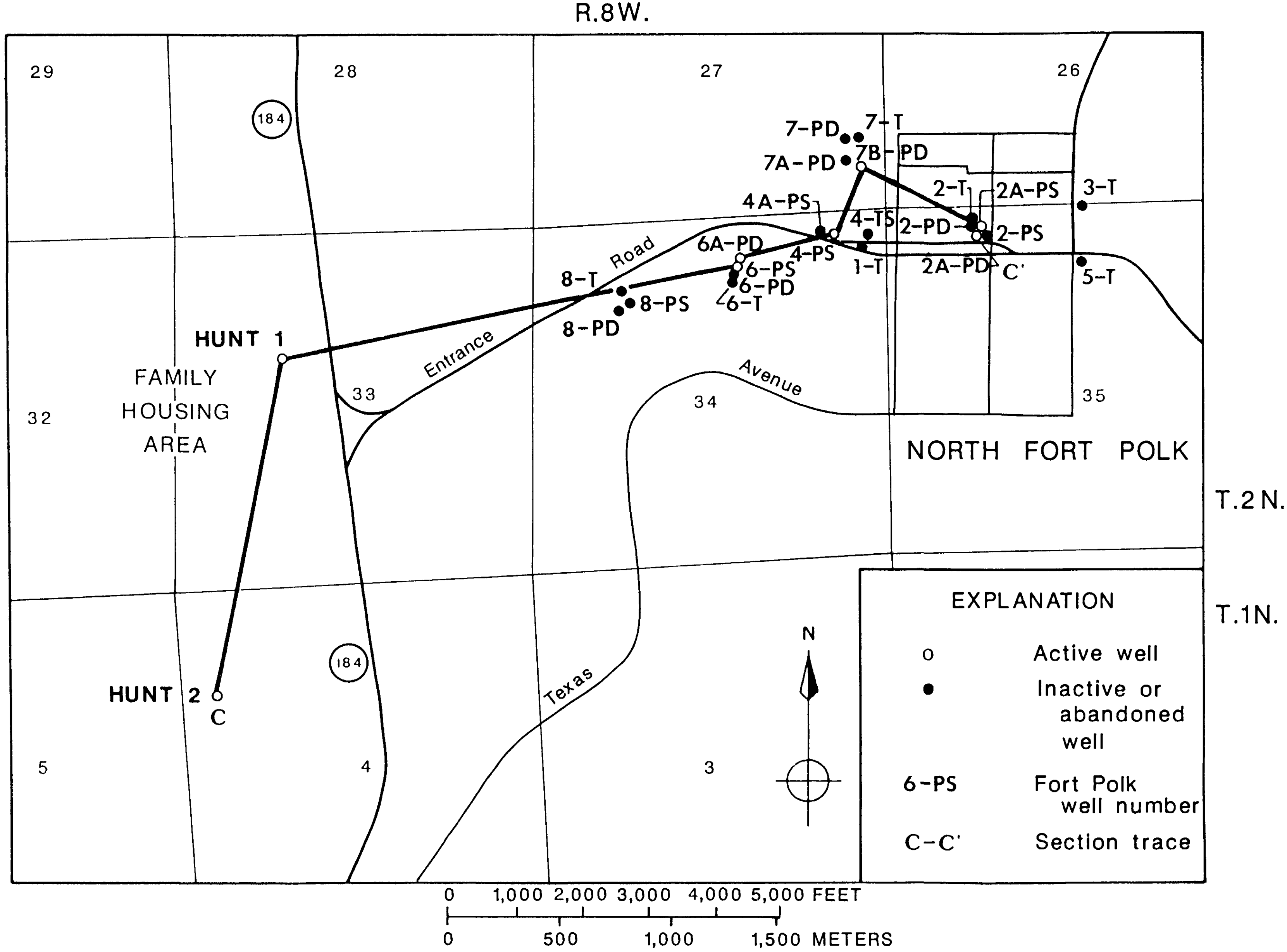

Figure 9.--Location of wells at North Fort Polk, Louisiana.

Table 4.--Well information for active water-supply wells at North Fort Polk, Louisiana

[D, driller's; E, electrical; T, temperature; N, neutron; G, gamma; GG, gamma-gamma; C, caliper]

Well number[1]	Altitude (feet)	Date completed	Test hole depth (feet)	Well depth (feet)	Casing diameter (inches)	Screen setting (feet below land surface)	Screen opening[2] (inches)	Sand unit screened	Sand unit interval (feet below land surface)	Logs available
2A-PS (V-522)	325	7-22-66	623	588	16-10	528-588	-----	B sand	517-588	D,E
2A-PD (V-447)	325	9-22-72	1,235	1,211	12-8	1,163-1,211	0.020	C sand	1,150-1,211	D,E
4A-PS (V-503)	340	8-12-83	1,072	1,055	16-10	1,008-1,055	-----	Isolated sand	1,004-1,054	D,E
6-PS (V-124)	328	12-14-42	600	598	12-8	532-598	.020 .022	B sand	536-600	D
6A-PD (V-504)	340	12- 1-83	1,305	1,288	24-16-10	1,190-1,288	-----	C sand	1,180-1,216 1,229-1,253 1,273-1,291	D,E
7B-PD (V-513)	335	10-12-82	1,282	1,280	16-10	1,167-1,217 1,245-1,275	.025	C sand	1,165-1,219 1,245-1,276	E
Hunt 1 (V-514)	290	5- 8-85	1,314	1,238	24-16-10	1,164-1,235	.035	C sand	1,159-1,235	D,E
Hunt 2 (V-515)	320	7-10-85	1,837	1,233	24-16-10	1,160-1,228	-----	C sand	1,160-1,228	D,E,T,N, G,GG,C

1 Top number is the Fort Polk well number; bottom number in parentheses is the U.S. Geological Survey local well number.
2 All wells are finished with a gravel pack.

Table 5.--Well information for inactive water-supply wells at (south) Fort Polk and North Fort Polk, Louisiana

[D, driller's; E, electrical; G, gamma]

Well number[1]	Altitude (feet)	Date completed	Test hole depth (feet)	Well depth (feet)	Casing diameter (inches)	Screen setting (feet below land surface)	Screen opening (inches)	Sand unit screened	Sand unit interval (feet below land surface)	Logs available	Status
1 (V-101)	367	1-16-41	901	893	4.5	849-891	0.020	B sand	818-896	D,E	Abandoned
3 (V-103)	337	1-15-41	904	902	4.5	858-900	.016	B sand	833-899	D,E	Abandoned
4 (V-104)	345	1-31-41	908	856	8.0	836-856	.020	B sand	836-854	D,E	Abandoned
4A (V-104A)	347	2- 5-41	856	852	4.5	830-850	.016	B sand	833-856	D,E	Abandoned
5 (V-105)	341	2-23-41	912	907	18-10	847-907	.080	B sand	839-907	D	Abandoned
6 (V-106)	333	3- 5-41	892	877	8-6	837-877	.020	B sand	822-877	D,E,G	Abandoned
6A (V-106A)	333	4-14-41	899	892	18-10	842-892	-----	B sand	818-897	D	Abandoned
7 (V-107)	304	4-24-41	925	903	18-10	853-903	.080	B sand	841-922	D	Abandoned
8 (V-108)	306	2-17-41	678	675	8-6	640-675	.020	A sand	605-676	D,E,G	Observation well
8A (V-108A)	319	4- 8-41	940	920	18-10	870-920	.080	B sand	841-930	D	Abandoned
9 (V-109)	315	5-19-41	930	671	18-10	621-671	-----	A sand	614-642 654-689	D	Inoperative
11 (V-111)	334	5- 2-41	915	885	18-10	835-885	-----	B sand	819-888	D	Abandoned
1-T (V-113)	349	5- 5-42	600	587	4	572-587	-----	B sand	562-600	D	Abandoned
2-T (V-114)	324	5- 5-42	800	800	4	582-597	-----	B sand	554-619	D	Abandoned
3-T (V-115)	349	5-18-42	801	672	4	553-619	-----	B sand	567-580 596-605	D	Abandoned

4-TS (V-116)	345	5-18-42	800	624	8	552-618	-----	B sand	551-624	D	Abandoned
5-T (V-117)	339	5-25-42	1,000	487	4	470-485	-----	B sand	455-487	D	Abandoned
6-T (V-118)	328	5-18-42	610	577	4	562-577	-----	B sand	520-606	D	Abandoned
7-T (V-119)	342	6- 8-42	1,275	1,234	4	1,213-1,234	-----	C sand	1,171-1,270	D	Abandoned
8-T (V-120)	338	6-18-42	1,500	1,435	4	1,420-1,435	-----	D sand	1,407-1,452	D	Abandoned
2-PS (V-121)	325	11-10-42	617	602	12-8	543-601	0.022 .020	B sand	545-612	D	Abandoned
2-PD (V-122)	323	11-13-42	1,233	1,228	12	1,170-1,228	.020 .018	C sand	1,174-1,232	D	Abandoned
4-PS (V-123)	337	10-28-42	613	606	12-8	539-605	.022 .020	B sand	542-606	D	Abandoned
6-PD (V-125)	328	10-24-42	1,307	1,280	12-10	1,171-1,211 1,240-1,280	.022 .020	C sand	1,160-1,168 1,184-1,218 1,225-1,280	D	Abandoned
7-PD (V-126)	338	11-16-42	1,279	1,278	12	1,192-1,278	.018 .020	C sand	1,173-1,273	D	Abandoned
8-PS (V-127)	339	10-25-42	604	602	12-8	552-602	.020	B sand	543-598	D	Abandoned
8-PD (V-128)	338	3- 1-43	1,456	1,450	12-8	1,407-1,450	-----	D sand	1,407-1,456	D,G	
7A-PD (V-418)	339	3- -66	1,304	1,276	16-10	1,236-1,276	.015	C sand	1,154-1,214 1,224-1,274	E	Abandoned

[1] Top number is the Fort Polk well number; bottom number in parentheses is the U.S. Geological Survey local well number.

Table 6.--Well information for other water wells in the Fort Polk, Louisiana, study area

[D, drillers; E, electrical]

Well number[1]	Altitude (feet)	Date completed	Test hole depth (feet)	Well depth (feet)	Casing diameter (inches)	Screen setting (feet below land surface)	Screen opening (inches)	Sand unit screened	Sand unit interval (feet below land surface)	Logs available	Status
Capehart 1 (V-204)	305	8-19-57	1,219	1,099	18-10	1,011-1,099	0.025	C sand	1011-1099	D,E	Observation
Capehart 2 (V-205)	295	9-17-57	1,226							E	Test hole
Capehart 3 (V-206)	245	10-14-57	620	602	8-4	569-602		B sand		E	Observation
(V-467)	320	12-01-75	726	560	8-4	500-560	.012		486-622	D,E	Northwestern State University at Fort Polk water well
(V-492)	285	6-15-81	1,636	608	10-6	568-608			565-610	D,E	South tank wash well 1
(V-494)	350[2]	6-15-81	687	675	10-6	591-641 657-675			590-640 658-678	D,E	North tank wash well 1

1 Top number is the Fort Polk well number; bottom number in parentheses is the U.S. Geological Survey local well number.
2 Estimated.

exceeded the pump bowl setting and the pump broke suction. Figure 10 shows the results of this test. If the sand were extensive (beyond the distance from the well that the drawdown cone would reach within the pumping period) the data points in figure 10 should define a straight line; that is, a constant rate of drawdown with time. Because of the limited areal extent of this sand, well 4A-PS can only be used on a standby basis and for very short pumping periods.

Well Interference

Interference due to pumping between the seven wells screened in the B sand of the Williamson Creek aquifer in (south) Fort Polk was analyzed using "NWELLS," a Theis-condition well-field program for the Hewlett-Packard HP-41C, hand-held calculator (van der Heijde, 1983). The purpose of this analysis was to determine what part of the total drawdown in each well is attributable to interference from the other pumping wells and whether or not enlarging the well field could substantially reduce well interference.

For the analysis the following assumptions were made:

1. Conditions in the aquifer satisfy the assumptions stated by Theis (1935).

2. All wells were pumping simultaneously for the duration of each test.

3. Transmissivity was 4,300 ft^2/d and storage coefficient was 0.0002.

4. Total drawdown does not include drawdown due to well efficiency loss.

Two well interference tests were conducted, one using the existing well field and one using a hypothetical well field. Distances between wells in the existing well field range from about 1,450 to 1,850 ft (fig. 8). By selecting some of the wells from the existing well field (wells 8B, 6C, and 11A) and adding additional wells at selected hypothetical sites (wells X, Y, and Z), a hypothetical well field was designed with distances between wells approximately twice those in the existing well field. Figure 11 shows the locations of the wells in the hypothetical well field at (south) Fort Polk. Well 5A served as an observation well.

Both tests were conducted at a total pumping rate of 3.5 Mgal/d for 365 days. The duration was deemed to be sufficient to attain a steady-state condition. The pumping rate of each existing well was determined based on its measured pumping rate (table 7). Pumping rates of the hypothetical wells (X, Y, and Z), were selected to bring the total pumping rate to 3.5 Mgal/d.

Tables 8 through 10 show the data and results of the interference tests. For the existing well field, 40 to 54 percent of the drawdown[3] is attributable

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[3] Drawdown is theoretical; it is an average based on continuous pumping at the stated discharge for a period of 365 days. Actual drawdowns would depend on how the well pumps are operated on a daily basis.

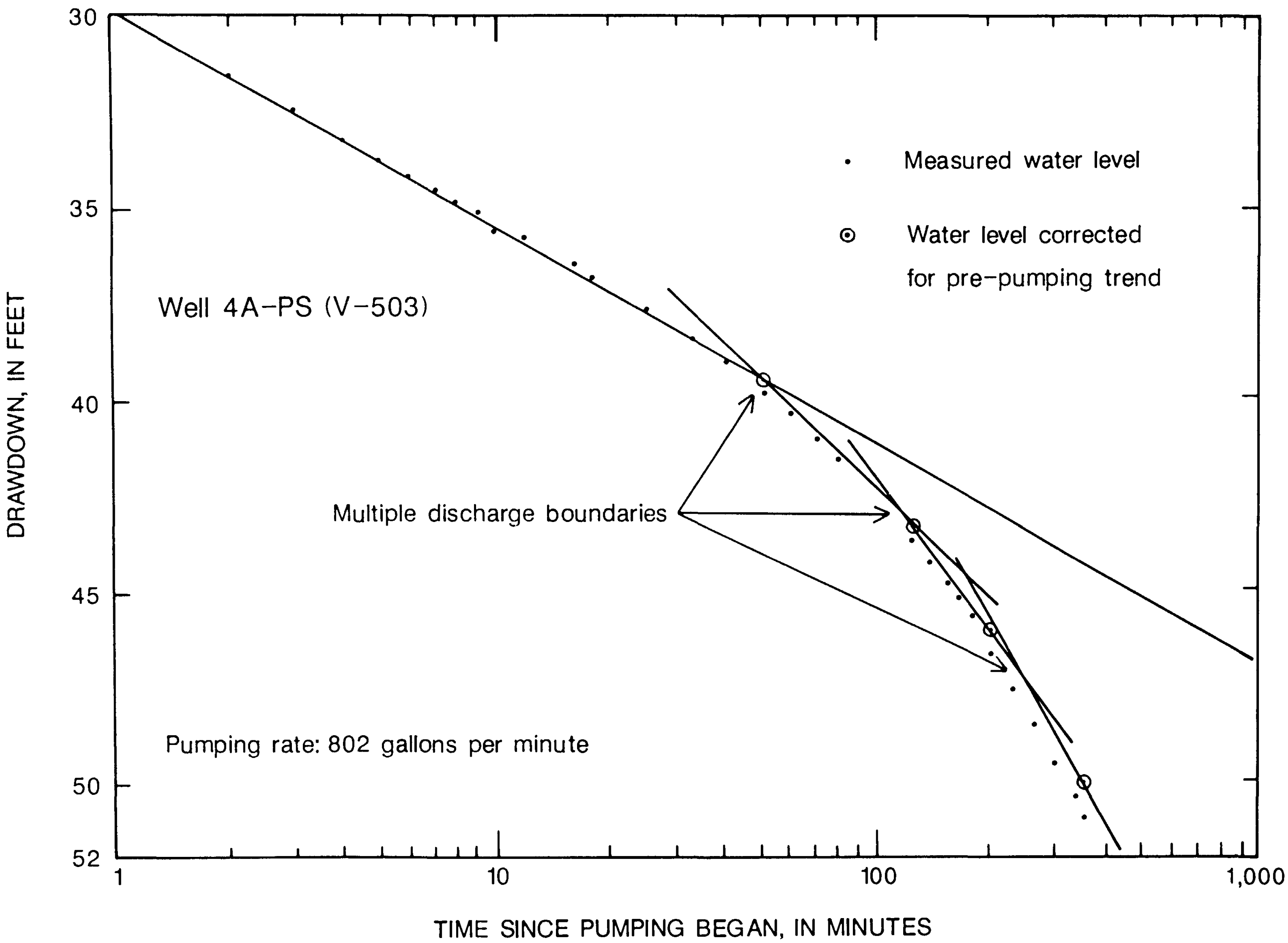

Figure 10.--Aquifer-test data at well 4A-PS, North Fort Polk, Louisiana, April 9, 1986.

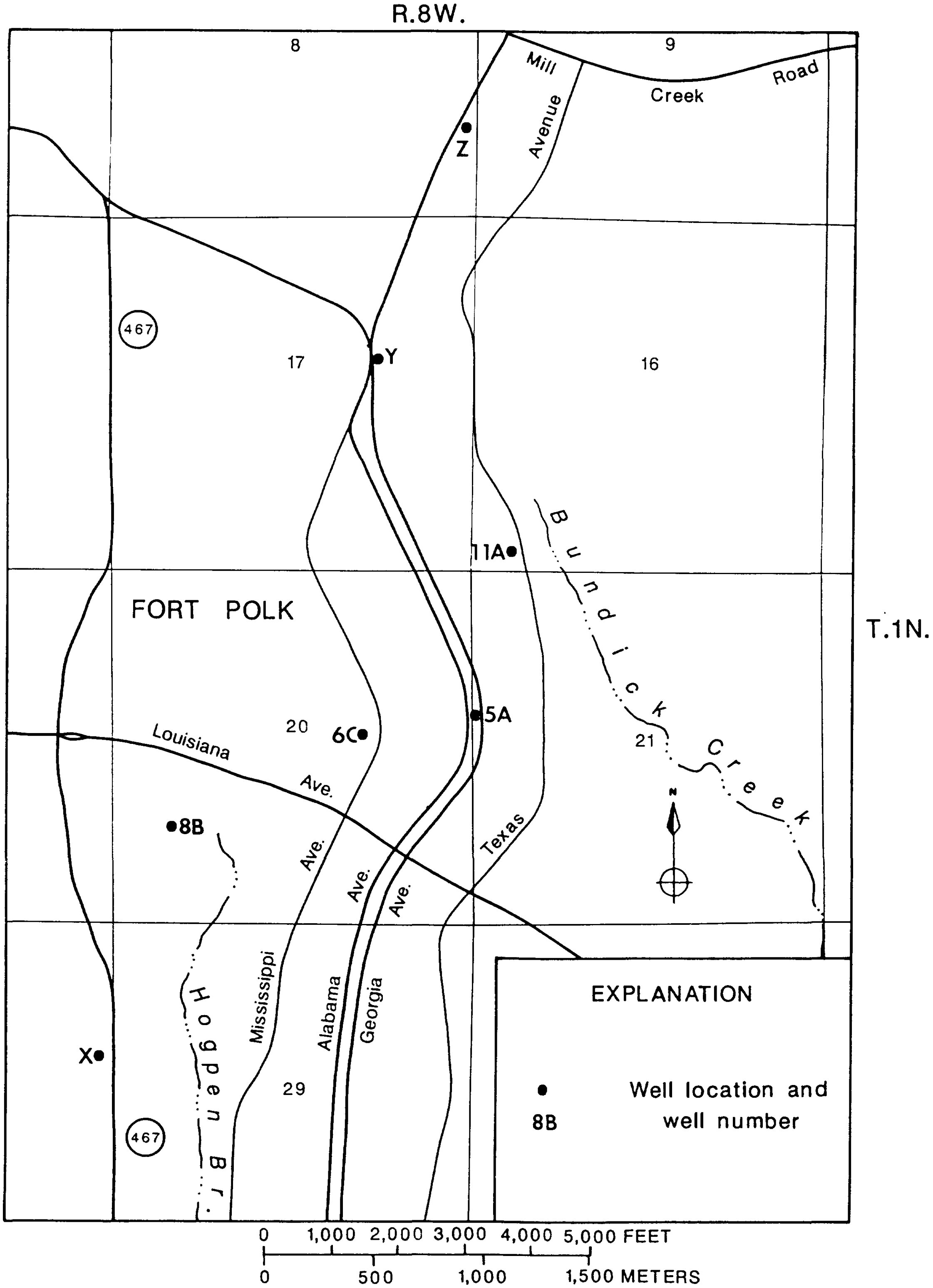

Figure 11.--Location of wells in hypothetical well field at (south) Fort Polk, Louisiana.

Table 7.--Specific capacity and water-level data for water-supply wells at (south) Fort Polk and North Fort Polk, Louisiana

[gal/min, gallon per minute; gal/min-ft, gallons per minute per foot; hr, hour; static water levels are in parentheses]

Well number[1]	Specific capacity (gal/min-ft)[2]	Pumping rate (gal/min)[3]	Date of pumping	Pumping water level[4]	Initial water level[5]	Static water levels (feet below land surface) Date of measurement						
5A	5.2	503	10-11-79	331		(239.75)	(243.20)	(247.38)	(249.50)	(258.00)	(262.74)	(260.35)
(V-448)	6.1	510	10-17-85	333.1		3-18-85	5-22-85	7- 9-85	10-18-85	3-25-86	7- 1-86	10-22-86
						(266.10)	(284.95)	(260.30)				
						12- 9-86	4-29-87	7-30-87				
6B	7.2	560	9-28-71	293	215	(233.80)	(225.36)	(228.05)	(232.50)	(224.62)		
(V-446)	5.8	503	3-10-80	294	9-28-71	3-19-85	7-12-85	11- 6-85	3-12-86	10-22-86		
	6.5	459	7-11-85	295.7								
6C	5.1	503 (15 hr)	8-22-74	306	208	(223.22)	(221.35)	(239.08)	(228.5)	(239.70)	(243.60)	(231.20)
(V-479)	11.2	503 (6 hr)	8- 5-81	291	8-22-74	3-18-85	5-22-85	7-11-85	10-18-85	11- 6-85	3-12-86	6-16-86
						(231.26)						
						1-13-87						
7A	12.8	503	12- 6-74	230.55	191.7	(214.09)	(210.5)	(227.1)	(225.70)	(224.20)	(231.90)	(229.25)
(V-510)	11.4	495	3-21-79	246.52	12- -74	7-10-85	10-18-85	4-10-86	6-16-86	6-24-86	8-12-86	12-30-86
	7.5	752	10-21-83	298								
	8.8	700	7-11-85	294.0								
8B	11.8	662 (4.5 hr)	12- 1-64	240.0	184	(219.52)	(229.58)	(223.0)	(237.5)	(227.85)	(219.35)	(235.80)
(V-420)	12.9	503 (6 hr)	9-19-74	255	12- 1-64	5-22-85	7- 9-85	10-18-85	3-12-86	6-24-86	9-16-86	12- 9-86
	16.0	517	7-10-85	261.9		(257.43)	(239.21)					
						4-29-87	7-30-87					
9	3.4	387	6-27-41	255.0	153.8	(220.83)	(223.02)	(227.83)	(234.60)	(223.00)	(232.43)	(237.60)
(V-109)					6- 2-41	3-18-85	5-22-85	7-11-85	11-15-85	3-13-86	6-16-86	9-16-86
						(224.80)	(237.08)					
						12- 9-86	4-29-87					

9A	5.6	500 (6 hr)	10-22-82	321.6	231.67	(236.17)	(244.2)	(245.65)	(256.10)		
(V-497)	3.8	459	3-13-86	363.6	10-22-82	10-18-85	3-12-86	6-16-86	12-30-86		
11	10.8	540 (48 hr)	6-27-41		177.60	(231.76)	(235.52)	(242.2)	(242.10)		
(V-111)	14.9	500 (6 hr)	5-30-80	259.2	6-25-41	3-18-85	6-10-85	7-11-85	10-18-85		
11A	7.8	736	1-22-86	331.4	242.35	(248.25)	(254.35)	(248.69)			
(V-518)					1-22-86	6-16-86	12-18-86	7-30-87			
12	13.5	370	1941		169.5	(209.9)	(233.85)	(238.22)	(241.68)	(252.95)	
(V-112)	15.3	503 (6 hr)	9-30-80	273	6-27-41	3-19-85	7-11-85	11-06-85	3-25-86	9-16-86	
	13.8	580	7-10-85	275.8							
14D	23.1	1200	1-19-82	172.8	120.8	(134.72)					
(V-496)	21.2	1200	10-16-86	187.8	1-18-82	10-22-86					
2A-PS	15.5	305 (8 hr)	7-22-66	206.35	188	(207.00)	(205.47)	(209.87)	(211.82)	(216.23)	(212.97)	(217.98)
(V-522)					6-23-66	9-10-85	11- 6-85	3-12-86	6-24-86	9-10-86	12- 9-86	4-29-87
						(214.20)						
						7-30-87						
2A-PD	9.4	500	10- 5-72		154	(160.0)	(162.02)	(162.90)	(159.92)	(160.66)	(162.08)	(160.29)
(V-447)					9- -72	3-19-85	5-22-85	7-10-85	11- 6-85	2-12-86	6-16-86	9-10-86
4A-PS	9.1	802	9- 1-83		185	(182.16)	(174.34)	(191.15)	(257.23)	(297.91)	(224.20)	(279.64)
(V-503)	(6)	800 (6 hr)	4- 9-86		8-12-83	3-19-85	5-22-85	7-11-85	11- 6-85	4- 9-86	6-16-86	9-10-86
						(265.23)	(201.03)					
						12-30-86	4-29-87					
6-PS	15.6	339	8-20-42		174	(210.06)	(210.02)	(201.40)	(213.10)	(214.06)	(218.50)	(220.45)
(V-124)	18.7	600 (12 hr)	1951		8-20-42	3-19-85	5-22-85	7-11-85	9-10-85	11-06-85	6- 6-86	9-10-86
	10.7	625	1961			(218.30)	(223.20)					
	3.9	400 (6 hr)	4-14-83	310.7		12-30-86	4-29-87					
	(6)	330 (1.5 hr)	9-10-85	213.0								

See footnotes at end of the table.

Table 7.--Specific capacity and water-level data for water-supply wells at (south) Fort Polk and North Fort Polk, Louisiana--Continued

Well number[1]	Specific capacity (gal/min-ft)[2]	Pumping rate (gal/min)[3]	Date of pumping	Pumping water level[4]	Initial water level[5]	Static water levels (feet below land surface) Date of measurement						
6A-PD	7.5	503	12-20-83	240.00	173.30	(173.68)	(174.96)	(175.37)	(174.35)	(173.67)	(175.80)	(176.90)
(V-504)	10.7	585	6- 4-86	230.56	12-19-83	3-19-85	5-22-85	7-11-85	11- 6-85	3-12-86	6- 3-86	10-21-86
						(176.05)						
						12-30-86						
7B-PD	8.8	503 (6 hr)	10-12-82		193.0	(180.37)	(180.28)	(179.20)	(181.11)	(182.80)	(180.75)	(181.05)
(V-513)	9.1	550	7-10-85	240.58	10-12-82	3-19-85	7- 9-85	3-12-86	6- 3-86	9-10-86	12-31-86	4-29-87
						(182.55)						
						7-30-87						
Hunt-1	19.3	1200	6-11-85	191.0	134.10	(136.50)	(135.22)					
(V-514)					6-10-85	8- 1-85	9-10-86					
Hunt-2	27.9	1200	8- 2-85	210.4	164.70	(166.80)	(170.05)	(169.20)	(169.22)			
(V-515)					8- 1-85	3- 6-86	9-16-86	12- 9-86	4-29-87			

1 Top number is the Fort Polk well number; bottom number in parentheses is the U.S. Geological Survey local well number.
2 Specific capacity measured at or projected to 24 hours pumping unless otherwise noted under pumping rate.
3 Pumping rate against line pressure.
4 Pumping water level in feet below land surface.
5 Initial water level (in feet below land surface) and date of first measurement taken after completion of well.
6 Pump broke suction (water level was drawn down to pump bowl) during the test.

Table 8.--Data and results of well-interference test of existing well field

[gal/min, gallons per minute; Mgal/d, million gallons per day; ft^3/d, feet cubed per day; ft, feet]

Well	Pump capacity (gal/min)	Pump capacity (Percent of total)	Discharge (Mgal/d)	Discharge (ft^3/d)	Drawdown[1] Total (ft)	Drawdown[1] Interference (ft)	Drawdown[1] Interference (Percent of total)
8B	517	13	0.455	60,834	109.4	51.7	47
7A	700	18	.630	84,231	132.7	52.9	40
6C	503	13	.455	60,834	116.7	59.0	51
5A	510	13	.455	60,834	115.9	58.2	50
9A	459	11	.385	51,474	106.8	58.0	54
11A	736	18	.635	84,231	132.8	53.0	40
12	580	14	.490	65,512	114.6	52.5	46
Y[2]	---	--	-----	------	58.2	58.2	100
Total	4,005	100	3.500	467,950			

1 Drawdown is theoretical; it is an average based on continuous pumping at the stated discharge for a period of 365 days. Actual drawdowns would depend on how the well pumps are operated on a daily basis.

2 Well Y is a hypothetical well located at well site 1 (fig. 8).

Table 9.--Data and results of well-interference test of hypothetical well field

[Wells X, Y, and Z are hypothetical wells. Gal/min, gallons per minute; Mgal/d, million gallons per day; ft^3/d, feet cubed per day; ft, feet]

Well	Pump capacity (gal/min)	Pump capacity (Percent of total)	Discharge (Mgal/d)	Discharge (ft^3/d)	Drawdown[1] Total (ft)	Drawdown[1] Interference (ft)	Drawdown[1] Interference (Percent of total)
X	750	19	0.665	88,910	122.3	38.0	31
8B	517	13	.455	60,834	104.3	46.6	45
6C	503	12	.420	56,155	102.3	49.1	48
5A[2]	---	--	-----	------	57.7	57.7	100
11A	736	18	.630	84,231	124.8	45.0	36
Y	750	19	.665	88,910	128.6	44.3	34
Z	750	19	.665	88,910	123.8	39.5	32
Total	4,004	100	3.500	467,950			

1 Drawdown is theoretical; it is an average based on continuous pumping at the stated discharge for a period of 365 days. Actual drawdowns would depend on how the well pumps are operated on a daily basis.

2 Well 5A served as observation well.

Table 10.--Reduction in interference drawdown and total pumping lift of hypothetical well field versus existing well field

Well no.	Pumping water level (feet below land surface)	Reduction in Interference drawdown[1] (feet)	Reduction in Pumping lift (percent)
8B	261.9	5.1	1.9
6C	291	9.9	3.4
5A	333.1	0.5	.2
11A	333.4	8.0	2.4
Y[2]	-----	13.9	---

1 Drawdown is theoretical; it is an average based on continuous pumping at the stated discharge for a period of 365 days. Actual drawdowns would depend on how the well pumps are operated on a daily basis.

2 Well Y is a hypothetical well located at well site 1 (fig. 8).

to interference among the pumping wells (table 8). For the hypothetical well field, 31 to 48 percent of the drawdown is attributable to interference (table 9). Interference drawdown at the approximate center of the well fields, well 5A, is virtually the same for the two well field configurations. The greatest difference in interference drawdown between the two well field configurations is at well Y[4], 13.9 ft (table 10). Although this represents a 24 percent reduction in interference drawdown, it represents an improvement of only about 10 percent in total drawdown (from static water level to pumping water level). Presently, measured pumping water levels (table 7) in the B sand at south Fort Polk range from about 262 to 364 ft below land surface. Of the four existing wells (8B, 6C, 5A, and 11A) common to the two well fields presented in this interference analysis, the difference in total pumping lift between the existing well field and the hypothetical well field is less than 4 percent (table 10). Thus, expanding the size of the existing well field may not result in significantly reducing total pumping lift.

Specific Capacity

Specific capacity tests were performed for most wells at Fort Polk in 1985 and 1986. Records were searched for specific-capacity data from driller's well-acceptance tests and from previous specific-capacity tests. The data for each well are presented in table 7. The specific capacity of a

4 Well Y is a hypothetical well located at well site 1 (fig. 8).

well decreases with time as drawdown increases with time. For wells in confined aquifers, the specific capacity is usually determined for a 24-hour pumping period. For pumping periods less than 24 hours the specific capacity can be projected to 24 hours assuming a constant rate of drawdown. In table 7 the specific capacities of each well are given for a 24-hour pumping period, unless otherwise noted.

Specific-capacity data are used in the selection of the size and setting of the permanent pump for a new well. Usually, after drilling and completing a new well, the driller will conduct a specific-capacity test with a temporary pump. Given the hydraulic characteristics of an aquifer, or sand unit within an aquifer that the well is screened in, a specific capacity can be estimated. This estimate is generally higher than the actual specific capacity that a test will indicate because the estimated specific capacity assumes that the aquifer is homogeneous and isotropic, the entire sand interval is screened, and the well is 100 percent efficient. Estimated specific capacities range from 13 to 18 (gal/min)/ft (gallons per minute per foot) for the B sand at (south) Fort Polk, from 18 to 21 (gal/min)/ft for the B sand at North Fort Polk, and from 12 to 42 (gal/min)/ft for the C sand. Specific-capacity tests on new wells that result in values much less than 50 percent of the estimated specific capacity may indicate that the well is not properly developed or that the pump was oversized.

The specific capacity of a well may change over time. Some variations in specific capacity may result from test to test, but a significant drop in the measured specific capacity of a well over time indicates that the well is becoming less efficient. A decline in specific capacity can be caused by encrustation of the screen, intrusion of fine material into the gravel pack, or partial filling of the screen with sand.

The wells at Fort Polk have a history of screen encrustation and intrusion of fine material (Russell Bruce, U.S. Army, Fort Polk, La., oral commun., 1986). Many of the well pumps are water lubricated, with a water-lube line feeding directly from the wellhead water main to the pump shaft. These water-lube lines have been observed to be on at all times, even when the pump is off or shut down for maintenance or repair. This may be a mechanism for the introduction of iron bacteria into the well. The iron bacteria could grow on the well screen, eventually clogging the screen. Previous investigators (Rogers and Calandro, 1965; Maher and others, 1943) have noted objectionable amounts of iron in some wells at Fort Polk. Data from these reports show concentrations of total iron as high as 6.2 mg/L (milligrams per liter) in water samples from the Williamson Creek aquifer and 3.0 mg/L in samples from the Carnahan Bayou aquifer. The U.S. Environmental Protection Agency's (1978, p. 78) secondary standard for drinking water is a maximum of 0.3 mg/L. The data also show water from these aquifers to be slightly acidic, which may account, in part, for the high iron concentrations. Sampling and analysis of well water for iron bacteria or other quality of water characteristics was not within the scope of this project. Such sampling and analysis conducted for all existing wells at Fort Polk would allow for a proper evaluation of the screen encrustation problem. The water-lube lines controlled by automatic valves that open and close with the operation of the well pump could reduce the potential for iron bacteria contamination. Some wells have failed as a result of fine sand intrusion. Careful attention to development of the well, proper grain size selection of the gravel pack, and selection of the screen size should reduce the potential for fine sand intrusion.

Review of the specific-capacity data (table 7) indicates that four wells may be operating at a low efficiency. At North Fort Polk, well 4A-PS (V-503) is pumping from a sand with limited areal extent. Drawdown during pumping exceeds the pump setting after about 6 hours at 800 gal/min. The excessive drawdown is probably a consequence of the limitation of the sand unit to supply water to the well, not an inefficiency of the well.

Well 6-PS (V-124) has excessive drawdown during pumping. The well broke suction (drawdown exceeded the pump setting) after about 80 min pumping at 330 gal/min (September 10, 1985). The condition of screen encrustation or fine material intrusion probably exists for this well.

At (south) Fort Polk, well 9A (V-497) had an encrusted screen problem when aquifer and specific-capacity tests were conducted in 1985 and 1986. The screen was cleaned in late 1986 (Russell Bruce, U.S. Army, Fort Polk, La., oral commun., 1986). Well 7A (V-510), at (south) Fort Polk, may be another well affected by screen encrustation or fine material intrusion into the gravel pack.

Effects of Pumpage on Water Levels in the Williamson Creek Aquifer

The B sand of the Williamson Creek aquifer is the most developed and most heavily pumped sand at Fort Polk. Thus, the history of water levels in the B sand best represents the pumpage history at Fort Polk. This relation is shown in figure 12. The histogram shows annual pumpage since 1941 from wells in (south) Fort Polk. Years with no pumpage reflect missing data rather than no pumpage. The hydrograph shows water levels measured from two wells screened in the B sand of the Williamson Creek aquifer. At well 4 (V-104), the data include an original nonpumping water-level measurement in 1941 and continuous recorder measurements from 1951 to 1977; and at well 8B (V-420), the data include periodic measurements for 1985 and 1986. Where pumpage data are missing, the values can be estimated from the hydrograph.

The hydrograph in figure 12 indicates three patterns of water levels in the Williamson Creek aquifer. Annual fluctuations indicate the pattern of seasonal pumpage at Fort Polk. Fluctuations that span several years indicate significant short-term changes in pumpage. During the periods (1954-55 and 1959-61) when water levels were recovering, Fort Polk was closed and pumpage was minimal. The period (1970-72) of increased water-level declines indicates that pumpage significantly increased. In 1968, a paper mill began operations about 15 mi southwest of Fort Polk, near De Ridder in Beauregard Parish, pumping approximately 15 Mgal/d. The increased water-level decline in the B sand at Fort Polk may reflect this additional stress to the Williamson Creek aquifer. During 1973, however, water levels in the B sand recovered somewhat while pumpage at the paper mill continued at the same or higher rate. Although pumpage data from Fort Polk are missing from 1970 to 1975, it can be assumed that pumpage increased at Fort Polk in response to an increase of military personnel, then declined after 1972.

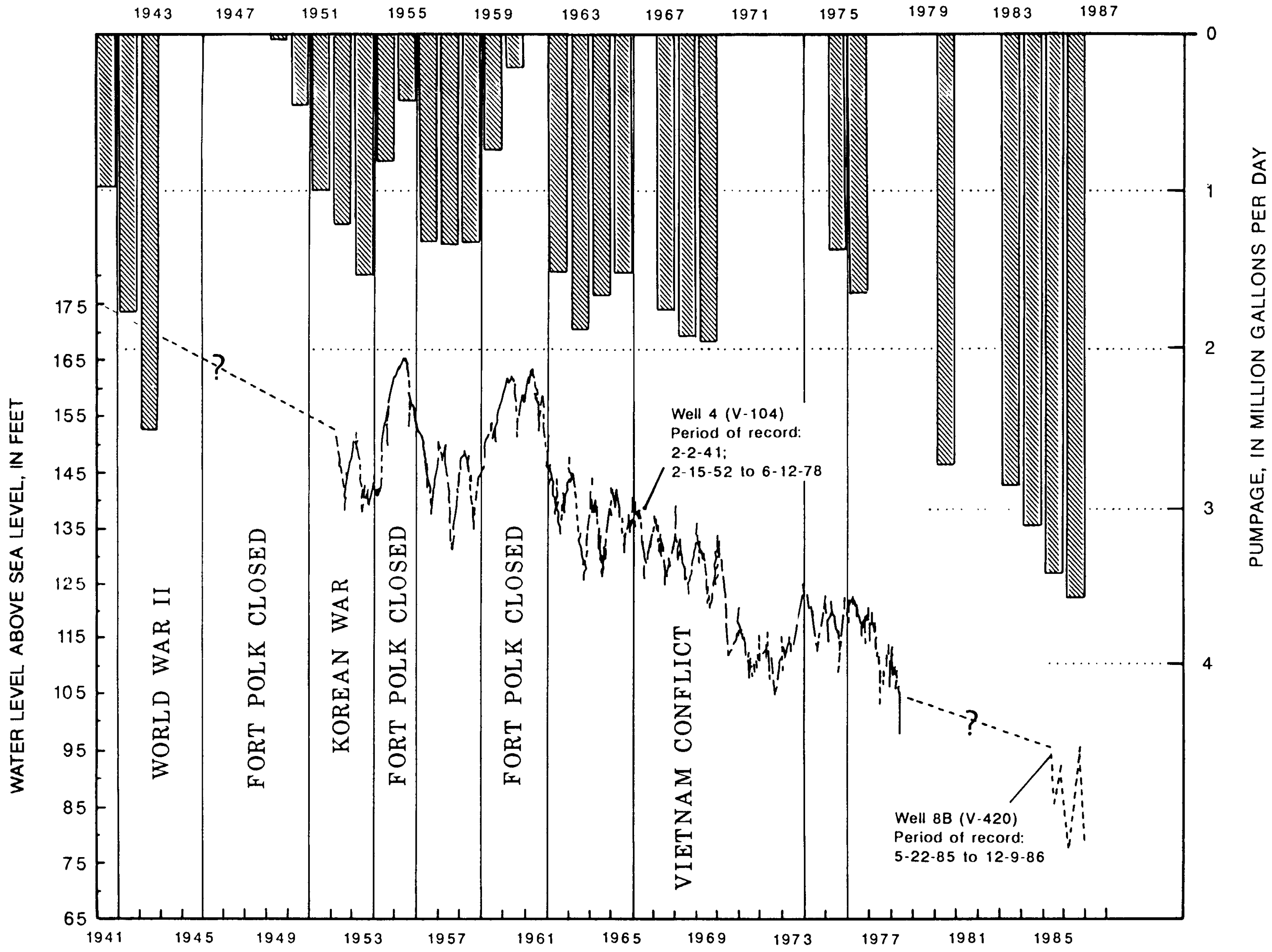

Figure 12.--Pumpage at (south) Fort Polk, Louisiana, and water levels in the B sand of the Williamson Creek aquifer, 1941-86.

The third pattern of water levels is the long-term trend from the original water level in 1941 in well 4 (V-104) at about 170 ft below land surface to the present day water level in well 8B (V-420) at about 255 ft below land surface (adjusted to land surface at well 4). This pattern reflects the combined effect of the long-term increase in pumpage at Fort Polk and a lowering of water levels as a result of development of ground water in the Williamson Creek aquifer outside the study area.

At the center of the cone of depression at the paper mill (fig. 3) water levels in the Williamson Creek aquifer have declined about 100 ft since 1968. Water-level data are insufficient to indicate the long-term trend; however, pumpage at the paper mill has decreased somewhat in recent years and water levels at the center of pumping appear to have stabilized.

At the center of the cone of depression around (south) Fort Polk (fig. 3) water levels in the Williamson Creek aquifer, as represented by the B sand, have declined about 90 ft since 1941. The long-term decline in water level is approximately 2.0 ft/yr (feet per year), as determined by taking the difference of the average water levels in 1941 and 1986 and dividing by the interval.

In recent years (1985-87), the decline in water levels in the B sand at Fort Polk has accelerated. Water-level data collected during the period of this investigation, 1985-87, indicate an average rate of decline of 10.2 ft/yr, as determined by a best-fit linear regression of water levels in well 8B (fig. 13). This recent rate of decline is about five times greater than the long-term decline (fig. 13). Since 1983, pumpage from wells in the B sand at (south) Fort Polk (wells 5A, 6C, 7A, 8B, 9A, 11, and 12) has been increasing at an annual rate of 0.35 Mgal/d, as determined by a best-fit linear regression (fig. 14). This recent trend fits into the pattern of short-term changes noted previously; however, total pumpage at Fort Polk is not expected to decrease in the future. Therefore, declines in water levels in the Williamson Creek aquifer can be expected to continue at the same rate.

The conclusion of this analysis is that water levels in the Williamson Creek aquifer at Fort Polk have continuously declined since 1941 as a result of long-term increases in pumpage from the B sand of the Williamson Creek aquifer from wells at Fort Polk. It is not believed that pumpage from the wells at the paper mill is appreciably affecting water levels at Fort Polk because the cones of depression around the two pumping centers have not coalesced to an appreciable degree and the cone around the paper mill appears to have stabilized.

Effects of Pumpage on Water Levels in the Carnahan Bayou Aquifer

The relation between water levels (hydrograph) in and pumpage (histogram) from the C sand of the Carnahan Bayou aquifer since 1966 is shown in figure 15. Years with no pumpage reflect missing data rather than no pumpage. Pumpage data prior to 1983 are from all wells at North Fort Polk, which include some pumpage from the B sand of the Williamson Creek aquifer. Records for this period did not separate pumpage by aquifer. However, based on the number of pumps and their rated capacities, it can be estimated that about one-third of the pumpage from North Fort Polk during this period was from the

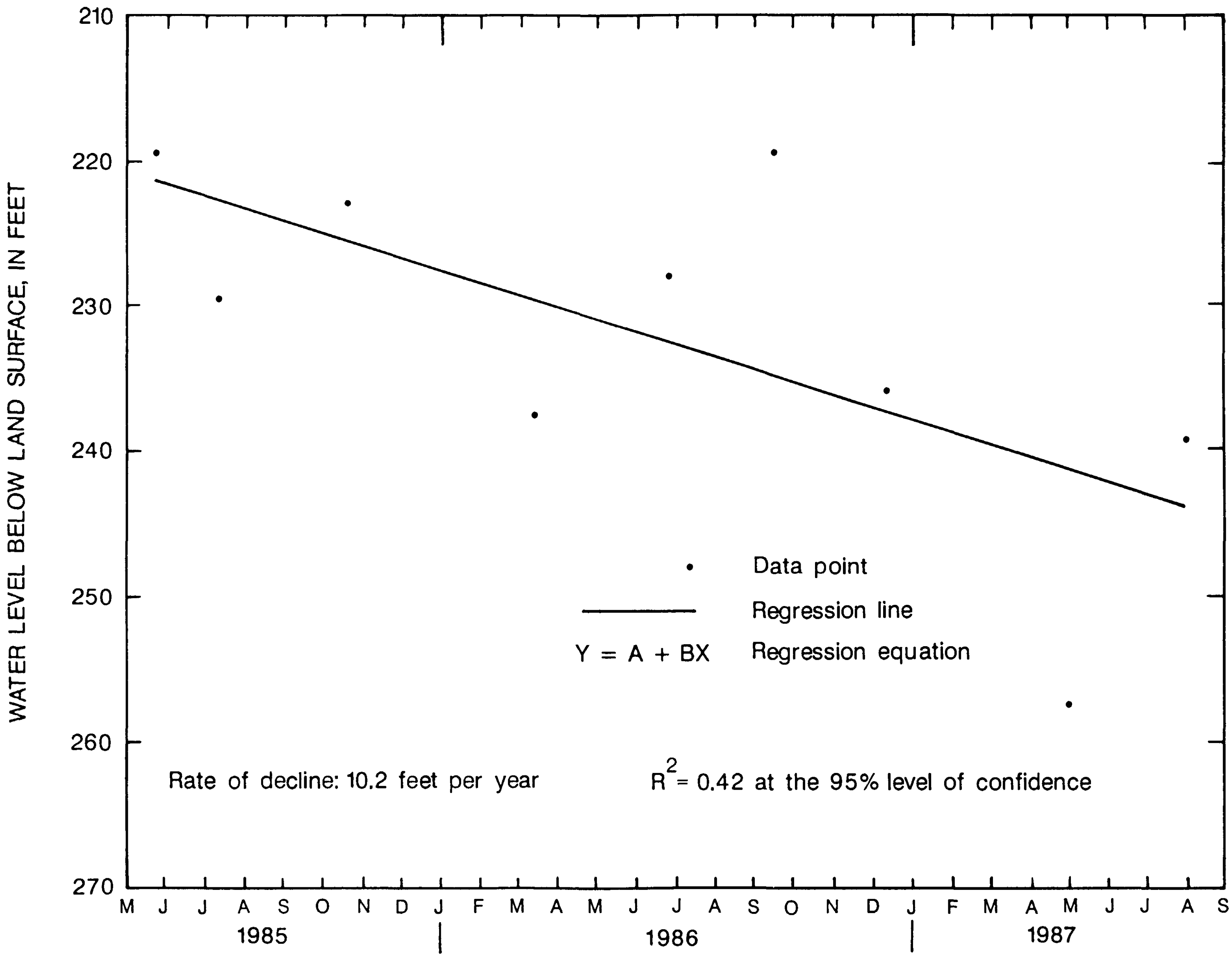

Figure 13.--Water level in well 8B, May 1985 to July 1987.

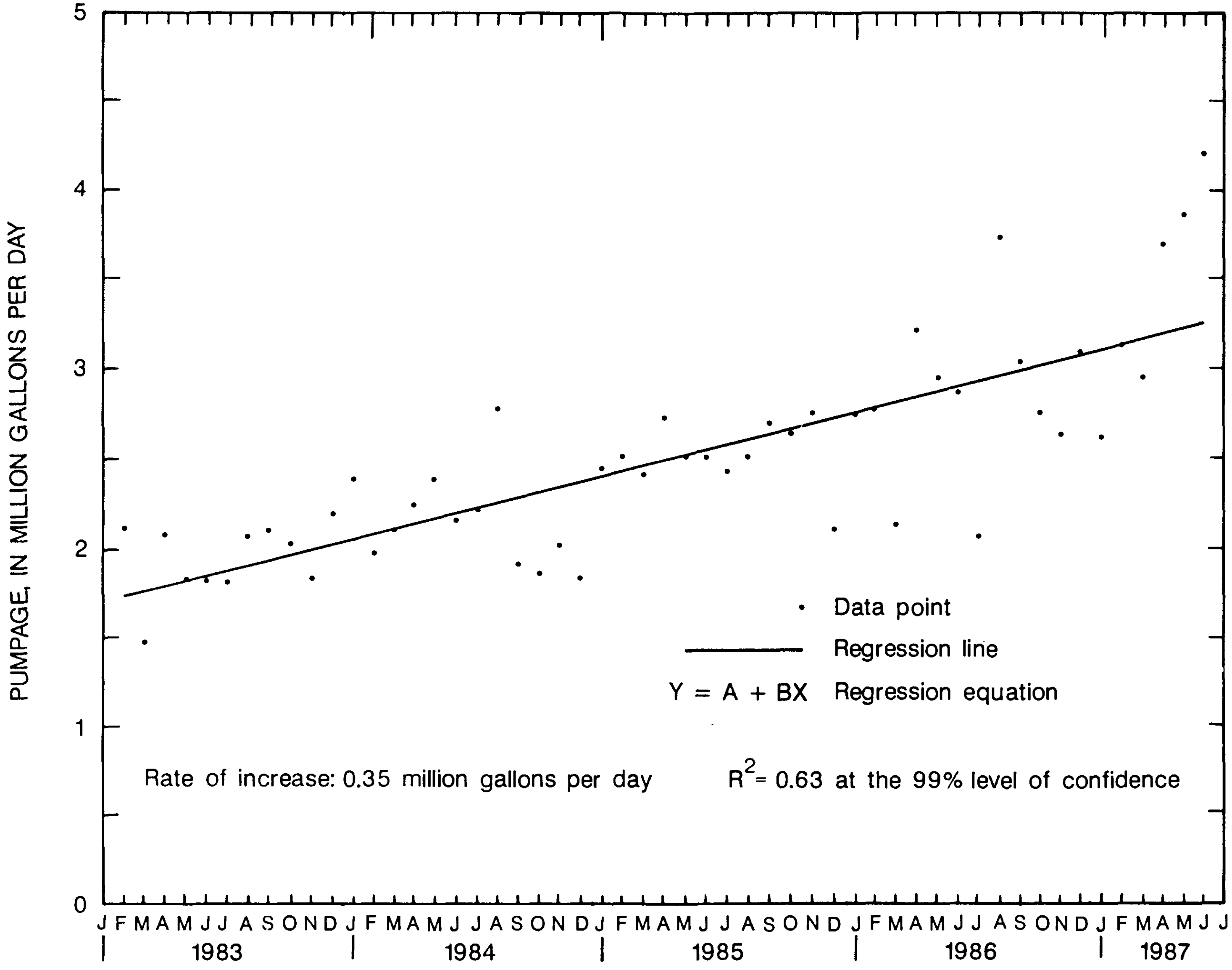

Figure 14.--Ground-water withdrawal from the B sand of the Williamson Creek aquifer at (south) Fort Polk, 1983-87.

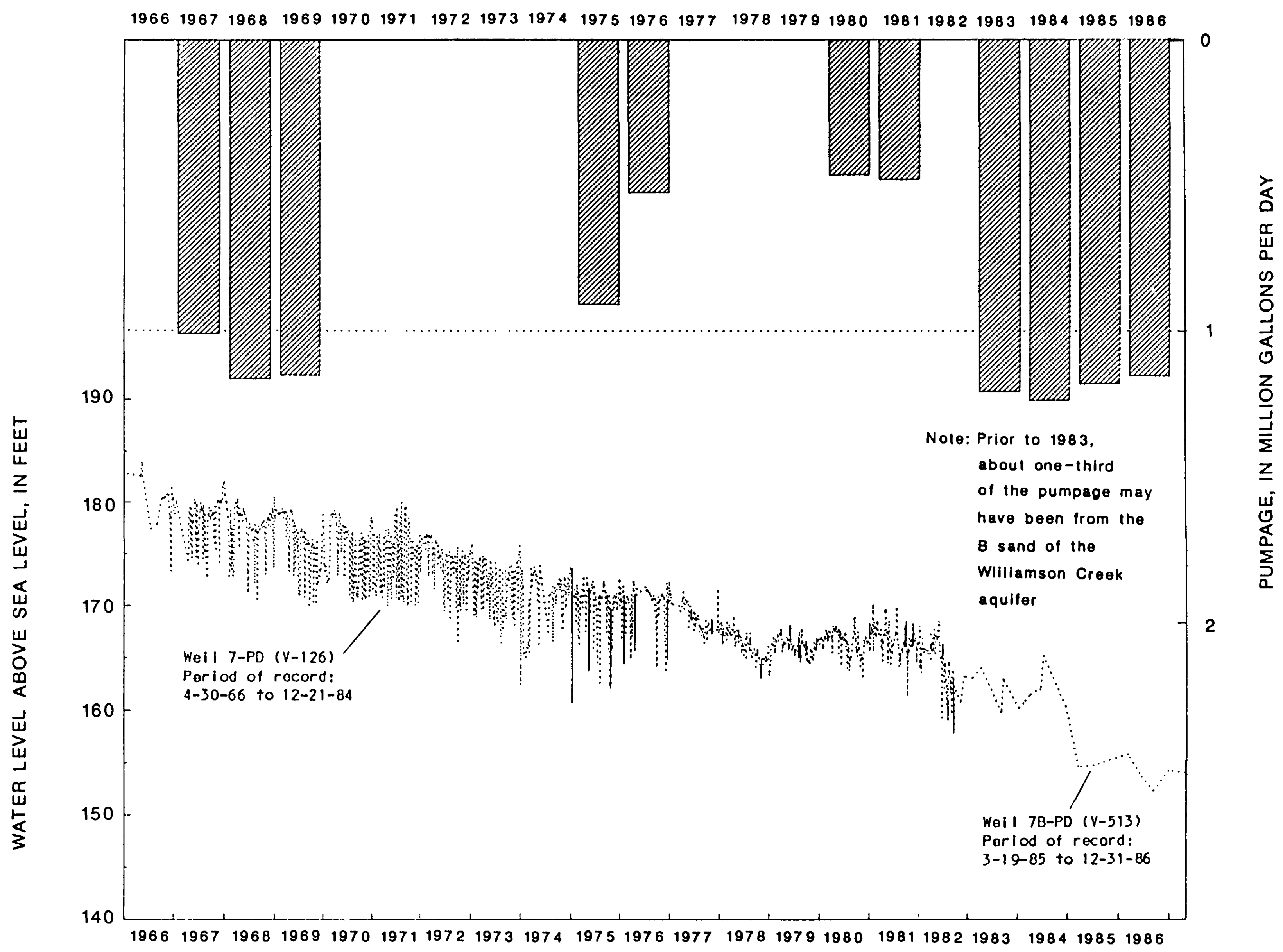

Figure 15.--Pumpage from and water levels in the C sand of the Carnahan Bayou aquifer, 1966-86.

B Sand. Pumpage data from 1983 to 1986 are from the C sand, except a small percentage contributed by well 4A-PS, which pumps from another sand in the Carnahan Bayou aquifer above the C sand. During this period one-third of the total pumpage from the C sand was from wells in North Fort Polk. Two-thirds of the pumpage from the C sand was from well 14D in (south) Fort Polk.

The water-level data are from recorder values taken at well 7-PD (V-126) during the period 1966-82, periodic measurements taken manually in 1983 and 1984, and quarterly measurements taken manually at well 7B-PD (V-513) in 1985 and 1986. The original water level in well 7-PD (not shown in fig. 15) was 201 ft above sea level in January 1943, but no data exist for the period 1943-66.

In figure 15, the dominant pattern in the hydrograph is a relatively constant rate of declining water levels from 1966 to 1986 at an average rate of 1.25 ft/yr. However, there appears to be a significant drop in the water level in early 1985. The average water level in 1984 was 161.7 ft above sea level, and in 1985 the average water level was 154.7 ft above sea level, a drop of 7 ft. This drop may be an actual decline in the water level or an error in matching the data from well 7B-PD (1985-86) to the data from well 7-PD (1966-84).

To check if the 7 ft drop in water level from 1984 to 1985 was a real drop or a data match error, rates of decline were determined for several intervals within the total period of record from 1943 to 1986. Water levels were averaged within each calendar year. The difference between the average water levels in the beginning year and ending year of an interval was divided by the number of years in the interval. The rates of decline in water level for the C sand, as measured from well 7-PD, were 0.88 ft/yr from 1943 to 1966, 0.91 ft/yr from 1966 to 1982, 0.80 ft/yr from 1983 to 1984; and as measured from well 7B-PD, 0.7 ft/yr from 1985 to 1986. These rates are very consistent with each other. In addition, pumpage decreased slightly from 1984 to 1985. Therefore, the 7 ft difference between the average water levels from well 7-PD in 1984 and from well 7B-PD in 1985 is probably a data match error between the two wells. The source of this error may be the locations of the two wells relative to each other in the gradient of the potentiometric surface. Therefore, the conclusion is that the actual rate of decline of water levels in the C sand of the Carnahan Bayou aquifer is about 1 ft/yr; a rate that has been relatively constant since 1943.

Prior to 1966, data indicate that pumpage at North Fort Polk fluctuated in a similar pattern to pumpage at (south) Fort Polk (fig. 12), coincident with the periods when the military installation was open and closed. During the period shown in figure 15 pumpage fluctuated from 1.2 Mgal/d in 1968 and 1969 (0.8 Mgal/d from the Carnahan Bayou aquifer) to 0.5 Mgal/d in 1980 (0.17 Mgal/d from the Carnahan Bayou aquifer), then to 1.2 Mgal/d (from the Carnahan Bayou aquifer) from 1983 to 1986. The hydrograph shows only the slightest of response to the changes in pumpage. In contrast, pumpage from the Carnahan Bayou aquifer for public supply at Leesville has steadily increased from 0.6 Mgal/d in 1960 to about 2.0 Mgal/d in 1986. Since 1943, water levels at North Fort Polk have declined 47 ft; and since 1956, water levels at Leesville have declined about 58 ft. This information indicates that water levels in the C sand of the Carnahan Bayou aquifer at Fort Polk are predominantly affected by long-term pumping stresses from beyond the Fort Polk study area. Increases in pumpage at Leesville are a likely source for these long-term stresses.

A cone of depression in the potentiometric surface of the Carnahan Bayou aquifer is defined by the lines of equal hydraulic head in eastern Vernon Parish and extending into Rapides Parish (fig. 4). A large cone of depression (fig. 4) has developed from pumpage at the Kisatchie well field (not shown on fig. 4) in Rapides Parish, 31 mi east of North Fort Polk. The Kisatchie well field began operation in 1968 to provide most of the public water supply to the city of Alexandria (not shown on fig. 4), 17 mi northeast of the well field (Rogers, 1981, p. 6). Pumpage at the Kisatchie well field has increased from about 1.8 Mgal/d in 1968 (Rogers, 1981) to over 25 Mgal/d in 1986. The Kisatchie wells pump from several aquifers at depths ranging from about 200 to 2,100 ft below land surface. Most of this pumpage is from the deeper aquifers, which include the Williamson Creek and Carnahan Bayou (Rogers, 1981). As indicated by the potentiometric surfaces in figures 3 and 4, it is the Carnahan Bayou aquifer that is the most heavily pumped aquifer at the Kisatchie well field.

Water-level trends in the Carnahan Bayou aquifer between the cones of depression around Leesville and Fort Polk and the Kisatchie well field indicate constant rates of decline. At Slagle, water levels are declining at a rate of 1.2 ft/yr (1967-86); at Simpson, the rate of decline is 0.9 ft/yr (1967-86) (fig. 4). The declines in water levels at these two sites are probably influenced to varying degrees by both pumping centers.

The conclusion from this analysis is that water levels in the Carnahan Bayou aquifer in the Fort Polk study area are primarily affected by pumpage at Leesville in Vernon Parish and possibly by pumpage at the Kisatchie well field in Rapides Parish. Present pumpage from the aquifer at Fort Polk has only a slight effect on water levels. Analysis of hydrographs from wells at Fort Polk and at other locations in Vernon Parish indicates long-term regional water-level declines.

FURTHER INVESTIGATIONS

Continued data collection on pumpage and water levels from wells in and around Fort Polk would be useful. These data can be used in refining estimates of water-level trends in the Williamson Creek and Carnahan Bayou aquifers and for input to a ground-water flow model. Regular periodic measurements of well yields and pumping levels may be instituted to insure timely evaluation of well efficiency.

Development of a regional ground-water flow model could provide quantitative analysis and prediction of the effects of pumpage at several regional pumping centers on water levels in aquifers at Fort Polk and throughout Vernon Parish. Additionally, such a model could improve definition of the ground-water flow system by quantitatively determining the leakage characteristics between aquifers and confining units, and could quantitatively assess the potential for further development of the Williamson Creek and Carnahan Bayou aquifers at Fort Polk.

Collection of water-quality data and evaluation for water-quality trends could be beneficial. Little is known about changes in ground-water quality in and around the Fort Polk area since the reconnaissance study by Rogers and Calandro (1965). Review of historical water-quality data indicate high iron concentrations in the aquifers, and observations and discussions with Fort Polk personnel indicate a potential for iron bacteria contamination of the wells.

SUMMARY AND CONCLUSIONS

Ground water is the source of supply for Fort Polk and all public-supply systems in Vernon Parish, La. An investigation of the water resources in Vernon Parish in 1965 showed that the parish had adequate supplies of ground water. However the effects of increased development of the ground water at Fort Polk since then had not been determined prior to this investigation.

In Vernon Parish unconsolidated deposits of Pleistocene age to Eocene age are sources of ground water. Within the study area the Miocene Williamson Creek and Carnahan Bayou aquifers in the Williamson Creek and Carnahan Bayou Members of the Fleming Formation are the sources of water to public supply wells. Confining units, 200 to 400 ft in thickness, hydrologically separate these aquifers from each other and from overlying and underlying aquifers.

Predevelopment ground-water flow patterns in the Williamson Creek and Carnahan Bayou aquifers within the study area followed the dip of the units. Water entered the study area from the recharge areas 7 to 15 mi northwest of Fort Polk and flowed southeast, eventually discharging to streams east and south of Vernon Parish. During the past 20-35 years cones of depression have formed in the potentiometric surface of the Williamson Creek aquifer around Fort Polk and around a paper mill near De Ridder in Beauregard Parish, 15 mi southwest of Fort Polk. In the Carnahan Bayou aquifer, cones of depression have formed around Leesville, 6 mi northwest of North Fort Polk, and Fort Polk, and around the Kisatchie well field in Rapides Parish, 31 mi east of North Fort Polk.

In the Williamson Creek aquifer at Fort Polk two principal sands, the A sand and the B sand, have been identified. The A sand, averaging 60 ft in thickness, lies between 605 and 689 ft below the land surface at (south) Fort Polk. Transmissivity of the A sand ranges from 1,000 to 2,300 ft^2/d. The B sand, averaging 62 ft in thickness, lies between 517 and 624 ft below land surface at North Fort Polk and between 806 and 930 ft below land surface at (south) Fort Polk. The average transmissivity of the B sand is 4,600 ft^2/d, the average storage coefficient is 0.0002, and the average hydraulic conductivity is 70 and 80 ft/d at (south) Fort Polk and North Fort Polk, respectively.

The Carnahan Bayou aquifer has one sand unit, the C sand, that has been developed at North Fort Polk and at one well site in (south) Fort Polk. The C sand is about 1,200 ft below land surface at North Fort Polk and 1,400 to 1,600 ft below land surface at (south) Fort Polk. Transmissivity of the C sand is difficult to determine. Interpretation of electric logs indicates variable sand thickness and numerous clay or shale partings within the sand interval. A representative transmissivity, determined from analysis of numerous aquifer tests, is about 12,000 ft^2/d and a representative hydraulic conductivity is 130 ft/d. The storage coefficient is 0.0002.

Several other deeper sands occur in the Carnahan Bayou aquifer. One of these deeper sands had been developed at one well site in North Fort Polk and was designated the D sand at that site. From only one aquifer test, the transmissivity of the D sand, which lies about 1,400 ft below land surface at North Fort Polk, was determined to be 7,200 ft^2/d. Because the D sand may have good hydraulic characteristics and is not presently being used as a source of water at Fort Polk, future test holes for new supply wells that penetrate through the D sand could provide the information to determine its water-supply potential.

Presently, nine wells at eight sites are operating at (south) Fort Polk; most are completed in the B sand of the Williamson Creek aquifer. At North Fort Polk eight wells at six sites are operating; most wells are completed in the C sand of the Carnahan Bayou aquifer.

The B sand of the Williamson Creek aquifer is the most heavily pumped sand at Fort Polk. Wells are spaced about 1,450 to 1,850 ft apart. Interference among the wells accounts for 40 to 54 percent of the drawdown; however, increasing the spacing of the wells by factor of two would reduce total pumping lift by less than 4 percent.

Some wells at Fort Polk have specific capacities that are lower than would be expected. Two wells, 4A-PS (V-503) and 6-PS (V-124), have drawdowns during pumping that exceed the pump setting and cause the pump to break suction. Well 4A-PS is completed in a sand with limited recharge and well 6-PS may have an encrusted screen or sand intrusion. Two wells, 9A (V-497) and 7A (V-510), now have significantly lower specific capacities than when they were developed, indicating possible screen encrustation or sand intrusion into the gravel pack.

Water-level data collected since 1941 indicate a long-term rate of decline of 2.0 ft/yr in the B sand of the Williamson Creek aquifer at (south) Fort Polk. Water-level data collected during this project period (1985-87) indicate an accelerated decline of 10.2 ft/yr. Pumpage from the B sand has been increasing at an average rate of 0.35 Mgal/d per year. These trends appear to relate closely with available pumpage data at (south) Fort Polk.

Pumpage at North Fort Polk is primarily from the C sand of the Carnahan Bayou aquifer. Water-level data indicate a constant rate of decline of about 1.25 ft/yr from 1966 to 1986. This decline is not closely related to pumpage at North Fort Polk, which has fluctuated since 1968, but is largely attributed to increases in pumpage at Leesville, about 6 mi northwest of North Fort Polk. Water-level trends in several wells in Vernon Parish outside the study area indicate regional declines in the Carnahan Bayou aquifer that can be attributed to additive effects of pumping at Leesville, Fort Polk, and the Kisatchie well field in Rapides Parish.

Collection of water-level data and pumping records would be beneficial. Development of a regional ground-water flow model would be useful for quantitative analysis and prediction of the effects of pumpage on water levels and to quantitatively define flow characteristics in aquifers at Fort Polk and throughout Vernon Parish. Collection of water-quality data and evaluation for water-quality trends would be useful because these data are lacking.

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