Development of Ground-Water Supplies at Mississippi Test Facility Hancock County Mississippi

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GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1839-H

Prepared in cooperation with the National Aeronautics and Space Administration

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By ROY NEWCOME JR.

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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A description of ground-water exploration, testing, and development at a NASA rocket-test installation

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DEVELOPMENT OF GROUND-WATER SUPPLIES AT MISSISSIPPI TEST FACILITY, HANCOCK COUNTY MISSISSIPPI

By Roy Newcome, Jr.

ABSTRACT

Potable and industrial water supplies at the National Aeronautics and Space Administration's Mississippi Test Facility in Hancock County, Miss., are obtained from large-capacity wells that tap southward-dipping water-bearing sands of Miocene and Pliocene age. The fresh-water-bearing section is 2,000–3,000 feet thick in the area, and individual aquifers are as thick as 450 feet. Aquifer thickness is not constant over large areas, however; and 100 feet is a more common thickness.

Three wells installed for potable water supply are 1,434–1,524 feet deep and have produced 1,100–2,500 gpm (gallons per minute) by natural flow. Artesian pressure is sufficient to provide a static head as high as 90 feet above land surface. Planned use rate for two of the wells is about 600 gpm each and for the third, 1,250 gpm.

Water for cooling Saturn rocket test-stand deflectors is obtained from three wells 1,873, 1,695, and 672 feet deep. The production rates of these wells are 3,100, 4,500, and 5,000 gpm, respectively; the wells are capable of supplying 7.5 million gallons in a 10-hour period (18 million gallons per day). Artesian head for the aquifers tapped by these wells ranges from 104 feet above land surface for the deepest aquifer to 15 feet for the shallowest.

Aquifer transmissibilities determined in pumping tests range from 81,000 to 200,000 gallons per day per foot. Specific capacities of the wells range from 15 to 47 gpm per foot of drawdown.

Water from the supply wells is soft and of good quality. Dissolved solids range from 236 to 315 parts per million. The water is a sodium bicarbonate type with high pH. The concentration of iron is less than 0.3 part per million. Water temperatures range from 79°F in the shallowest supply well to 100°F in the deepest.

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

The study of the ground-water resources of the Mississippi Test Facility and the surrounding buffer zone was made to (1) insure that the large amount of water required during short periods of time for deflector cooling is available, (2) provide information on well construction and spacing so that water can be obtained with optimum efficiency and with minimum deleterious effect on the resource both inside and outside the area of the test facility, and (3) provide a document that can be used by the National Aeronautics and Space Administration (NASA) and other interested parties in the future planning of large water-supply installations in part of the gulf coastal area.

LOCATION AND DESCRIPTION OF THE AREA

Mississippi Test Facility (MTF) is a 13,550-acre U.S. Government-owned area in the southwestern part of Hancock County (fig. 1). A small part of the facility's boundary is formed by the Pearl River. The community of Gainesville was moved from the area to make way for the extensive construction required for static testing of rocket engines and because of the noise factor inherent in running the engines. A buffer zone about 6 miles wide and comprising 125,000 acres surrounds the test facility. This land is under easement to the U.S. Government and is unavailable for habitation but may be used for farming and grazing. Most of the buffer zone is in Hancock County, Miss., but parts are in Pearl River County, Miss., and St. Tammany Parish, La. The community of Logtown, in Hancock County, was moved from the buffer zone.

The region has a subtropical climate. Rainfall averages 64 inches per year, with July usually being the wettest month and October the driest. Temperature extremes are 5°–105°F. and the mean annual temperature is 67°F. Vegetation consists of coastal meadow grasses, pine trees, and lowland hardwoods. Small-scale farming was carried on by the former residents, many of whom commuted to jobs in neighboring cities.

Land-surface elevations range from 10 to 80 feet above sea level and local relief is negligible. The southern half of the area is swampy. The Pearl River drains the region. River stage is modified by the tide, and salt water from Mississippi Sound moves upriver with the tide. Chloride concentrations as high as 1,000 ppm (parts per million) have been reported for the Pearl near Gainesville. Estimated mean daily discharge is about 1,500 cubic feet per second. Water from the river is pumped into the 7½-mile canal system that serves the barge transportation needs of the test facility. This pumpage maintains the canal level, and a lock on the canal provides the lift required to move barge traffic into the testing area.

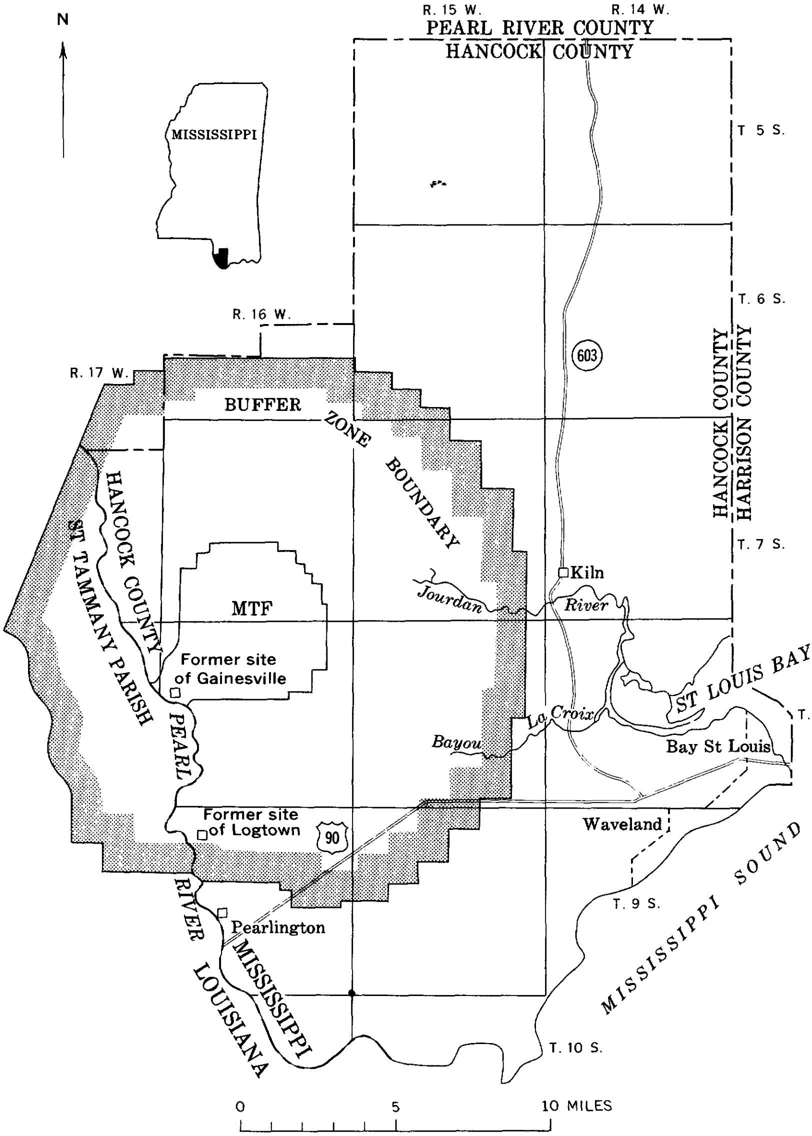

FIGURE 1.—Location of Hancock County and area described in this report.

HISTORY OF THE PROJECT

The U.S. Geological Survey was requested by NASA in April 1964 to make a study of the ground-water resources of the test facility and adjacent area. In requesting the investigation, NASA was interested not only in obtaining an adequate and long-lasting supply of water for its Saturn rocket testing mission but also in determining the effect of its water use on the aquifers tapped by MTF wells and hence on the water resources of neighboring areas in Hancock and Pearl River Counties and in the adjoining part of Louisiana. At the time the Geological Survey study began, a test hole and four supply wells had already been installed. The wells were Potable-Water Wells 1 and 2 in the administrative area and Saturn V Potable-Water Well and Industrial Well 1 in the test area.

Early activity in the ground-water investigation included the testing of Industrial Well 1 to determine well and aquifer characteristics, the inventory and pressure measurement of many unused wells in the MTF area and surrounding region (table 1), and the detailed study of subsurface conditions as recorded on electric logs of three MTF wells and several oil test wells.

Following the initial stages of the investigation, Saturn V Potable-Water Well, Industrial Well 2, and Industrial Well 3 were tested, the two industrial wells having been completed in aquifers recommended in the Geological Survey study. Periodic measurements of artesian pressure and collection of water samples for chemical analysis provided records on several observation wells in and around MTF. Recommendations were made concerning artesian flow from abandoned wells, aquifer selection, well construction, well-pumping schedules between rocket tests, and future ground-water studies.

ACKNOWLEDGMENTS

Permission by NASA to make this report available for public use is gratefully acknowledged. Individuals who have cooperated fully with the writer in the work of the ground-water project are Messrs. J. B. Leslie and O. E. Batson of NASA and Messrs. P. J. Carmichael, W. E. Ruland, and Percy Brewington of the Corps of Engineers, U.S. Army, Mobile District. In addition, Messrs. Leslie Carloss, Jr., and William Turner of Carloss Well Supply Co., Memphis, Tenn., extended their courtesy and help on several occasions. Most of the field data in the project have been collected by P. E. Grantham of the U.S. Geological Survey.

GEOHYDROLOGY

Exposed rocks in the region are of Pliocene, Pleistocene, and Recent age. Subsurface formations in the fresh-water-bearing section are of Miocene, Pliocene, and Pleistocene age. Strike of the beds is approximately northwestward and dip is southwestward at about 50 feet per mile in Hancock County; however, small structural features or faults exist, and apparent local dip is as much as 90 feet per mile.

Fresh ground water can be obtained at depths as great as 3,000 feet in the area controlled by NASA (fig. 2). Electric logs of oil

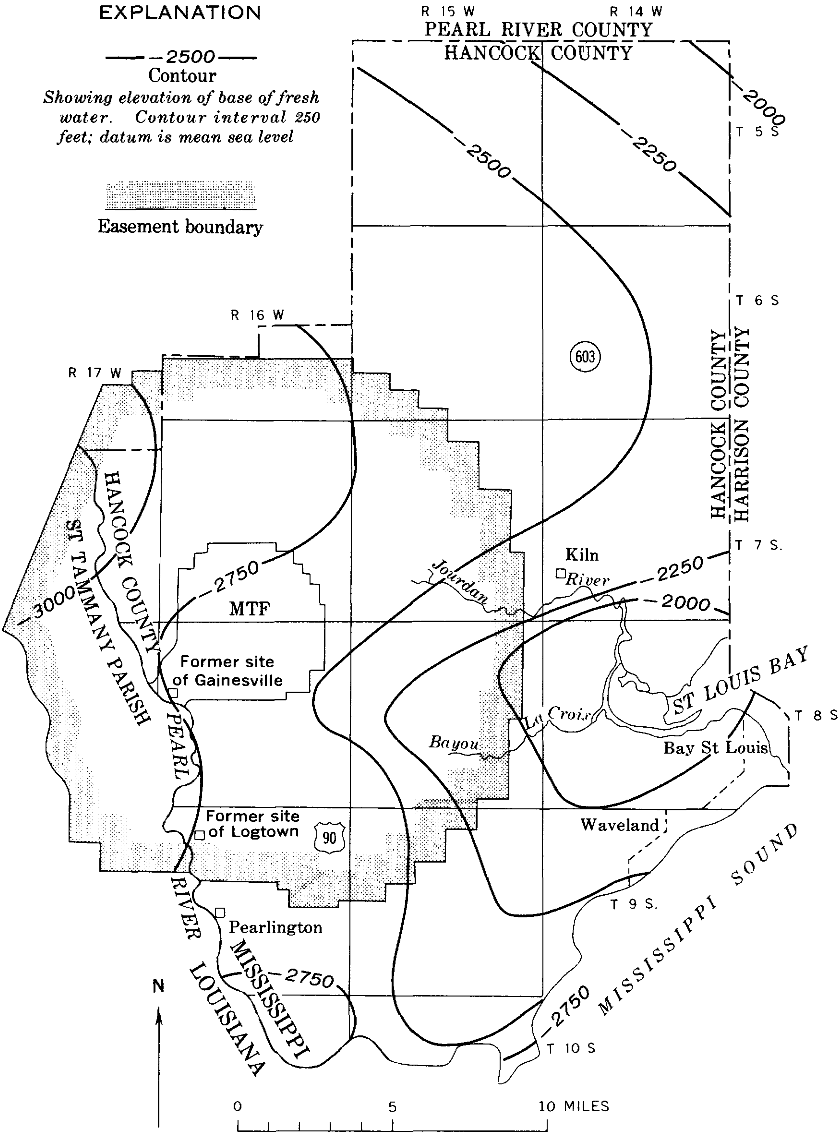

Figure 2.—Contour map of base of fresh water in Hancock County, Miss.

test wells and water wells in Hancock County indicate the fresh-water sand intervals shown on the geohydrologic sections (pl. 1). The sections also show the probable areal correlation of sand beds defined on the electric logs. Water wells near the lines of section are included on the illustrations to show the sources of their production.

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TABLE 1.—*Records of selected wells in and near Mississippi Test Facility*

Well	Owner or tenant	Location			Year drilled	Elevation (ft)	Depth (ft)	Diameter (in.)	Water level		Flow rate (gpm)	Temperature [1] (°F)	Chemical quality		Remarks
		Section	Township south	Range west					Above (+) or below (−) land surface	Date of measurement			Specific conductance [2] (micromhos at 25°C)	Chloride (ppm)	
E1	Dave McQueen	NW¼ 13	7	17		30	[3] 400	2	+21.1	7- 8-65		73	477	3.3	Observation well.
E2	Prentiss Kennedy	Irregular 7	7	17		30	[3] 750	2	+46.1	7- 8-65		80			Do.
E3	John Wheat	NW¼ 27	6	16		80	600	2½	+2.0	6- 5-64		76			
E4	Curtis Wheat	Irregular 11	7	17	1959	37	980	2	+41.3	7- 8-65		80	294	2.5	Do.
E5	Asa McQueen	SE¼ 12	7	17	1939	41	640	2	+7.0	7- 8-65		77	364	3.1	Do.
E6	Hubert Stevenson	Irregular 7	7	17	1950	36	728	2	+17.3	7-18-65					Do.
E7	Mrs. E. M. Frierson	NE¼ 24	7	17		35	840	2	+51.0	7- 8-65		82	304	2.6	Do.
E8	Allen Craft	NW¼ 13	7	17	1924	45	506	3	−5.8	7-22-64				5	Do.
E9	Weston Lumber Co.	NE¼ 24	7	17	1928	36	767	4	+20.2	7- 8-65		78	441	5.8	Do.
E11	C. P. Slay	SW¼ 2	7	16		60	975	2	+47.0	12- 9-64		80	413	6.9	Do.
E12	W. E. Thompson	SW¼ 3	7	16		57	[3] 800	2				81	497	4.5	
E13	Bill Adams	SE¼ 4	7	16	1964	56	1,250	2	+44.5	7-19-64		85	363	16	Do.
E14	Verne Kirby	NW¼ 15	7	16		40		2	−7.08	7- 9-65					
E15	Gertrude Todt	NW¼ 22	7	16		30	1,000	4	+2.0	6-12-64					
E18	— — Robertson	Irregular 30	7	16		30	980	2	+58.0	7- 8-65		83	403	16	Do.
E19	NASA	SW¼ 28	7	16		30	930	2	+56.5	7- 8-65		82	394	24	Do.
E20	Flattop School	NE¼ 33	6	16		70	1,000	2	+27.0	7-24-64		81			
E22	NASA	SE¼ 12	7	17		45	[3] 950	2	+42.2	7- 8-65	46	82			Do.
F1	L. C. Taylor	NE¼ 34	7	15	1949	20	670	4	+20	6- 4-64		80			
F3	L. L. Fletcher	NW¼ 32	7	15	1955	26	523	12				75	401	4.6	
F4	Abraham Solomon	SW¼ 3	7	15	1908	40	[3] 500	6				74	359	4.0	
F5	NASA (formerly Wm. Bosworth).	SE¼ 35	7	15	1950	15	644	6	+36.5	4-20-65	300	79			
F6	Rufus Moran	NW¼ 22	7	15		52	1,030?	2	+60	7- 9-65		90			Do.
F9	Louis Craddock	NE¼ 23	7	15		38	700	2	+8	7-19-65		76			Do.
F22	Loyd B. Griffith	NE¼ 34	7	15	1938	17	582	3	+34	6- 4-65					
G5		NE¼ 26	7	14		40	[3] 500	2	+15.7	6-17-64		75	257	2.7	
G6	J. P. Moran	SW¼ 9	7	14	1928	67	543	3	+7.0	4-17-64		74			
G10	Konewn (spelling?)	SW¼ 20	7	14	1935	30	421	2	+18.2	5-17-64		75	318	4.1	
G25	Mrs. A. J. McLeod	SW¼ 31	7	14		5	540	4	+32	7-22-64		76			
G26	L. P. LeBourgeous	NE¼ 31	7	14	1936		700		+29.5	6-17-65		76	373	8.8	
H10	NASA	NW¼ 10	8	16	1964	25	140	10				69			See dewatering well on table 3.
H31	D. F. Stephens	SE¼ 34	8	16		21	766	2	+4.7	7- 8-65		79	682	37	Observation well.
H32	NASA	NE¼ 28	8	16		16	[3] 420	4	+4.8	7- 8-65		74	601	24	Do.
H34	L. W. Brooks	SE¼ 35	8	16		26	1,323		+56.0	7- 8-65		87	432	20	Do.
H35	NASA	Irregular 30	8	16		22		3	−0.7	7- 8-65					Do.

H36	do	Irregular 30	8	16	1964	25	954	2	+55.0	7-8-65		76	335	2	Do.
H38	State of Mississippi	SW¼ 16	8	16		20	900	2	+56.5	7-8-65		75	411	23	Do.
H39	NASA	Irregular 30	8	16		22	[3] 800	2	+34.5	1-12-65		80			Do.
H40	do	SE¼ 8	8	16	1963	26	361	2	−2						Reported water level.
J1	B. Wailer	Center 25	8	15	1951	6	785	2	+41.6	6-21-51	50	78	492	32	
J2	NASA	SE¼ 33	8	15		16	[3] 500	2	+14.0	4-19-65		76	467	27	Observation well.
J3	— — Cole	NW¼ 1	8	15		20	1,000?	4	+27.0	7-22-64		78	409	24	
J4	T. Zingarling	SE¼ 28	8	15	1917	11	330	2	+3.7	6-18-64		72			
J5	do	NE¼ 28	8	15		16	640	2				78			
J7	Aqua Plantation	SE¼ 27	8	15		5	1,300	4	+30.6	7-8-65		78	560	41	Do.
J8	L. E. Nicholson	SW¼ 33	8	15	1954	18	860	2	+14.2	7-8-65		74	489	32	Do.
J9	NASA	SE¼ 22	8	15		9	900	2	+28.5	7-21-64		78			
J45	J. B. Fasterlinger, Jr.	NE¼ 27	8	15	1928	6	739	3	+35.1	7-21-64		80	470	27	
J49	A. J. Moran	SE¼ 36	8	15	1929	10	839	3	+29.7	6-18-64		80	476	29	
K1	City of Bay St. Louis.	SW¼ 30	8	13	1910	16	1,300	4	+23.5	2-3-65		80	699	36	Do.
K2	Town of Waveland	NE¼ 10	9	14	1963	10	1,000	12¾	+14		500				Reported water level.
K4	City of Bay St. Louis.	SW¼ 30	8	13	1959	16	1,210	6	+22.7	6-25-64	500	85			St. Charles Street well.
K5	do	Irregular 44	8	14	1961	20	1,197	10	+13.0	6-25-64		86			Central Street well.
K6	do	Irregular 19	8	13		11		8	+16.0	6-25-64					Leonard Avenue well.
K7	do	Irregular 29	8	13	1963	22	914	10	+1	6-25-64					Esterbrook Street well.
K8	Holiday Nursery	SE¼ 36	8	14	1958	15	980	4	+22	6-24-64		84	668	34	
K9	L. J. Schwall	SE¼ 34	8	14	1957	19	1,142	2	+44		45	82			Reported water level.
K10	Ronald Storey	SW¼ 38	8	14	1958	8	881	3	+41		90				Do.
K12	George Shubert	SW¼ 18	8	14	1965	7	734	2	+30.8	7-8-65					
K31		SW¼ 31	8	14				4				86	512	27	
K55	George Talbert, Jr.	SE¼ 35	8	14	1936	22	657	3	+4.7	6-24-64		78	295	5.3	
K56	T. J. Chapin	NW¼ 36	8	14	1925	17	1,093	3	+29.4	6-25-64		84	653	36	
K61	Merchants Bank	SW¼ 30	8	13	1917	11	840	3	+15.3	6-24-64		81	542	31	
K78	Dr. Tudery	NW¼ 17	9	14	1924	8	624	3	+9.4	6-18-64		78	416	15	
L69	Oak Harbor Subdivision.	Irregular 20	9	16	1965	8	1,990	8	+104	2-9-65	900	95			
L73	State of Mississippi	SW¼ 12	9	16	1938	20	675	3	+3.7	7-8-65		78			Observation well.
L74	Manuel Borges	SW¼ 9	9	16		12	[3] 500	2	+3	7-21-64	3	75	548	28	
L75	J. A. Sacredode	SE¼ 6	9	16		20	[3] 650	2	+3.5	7-21-64	4	78	659	26	
L76	C. E. Wright	NE¼ 6	9	16	1955	20	720	2	+3.6	7-21-64					
L77	Jerome W. Whipple	NE¼ 9	9	16		15		2	+10.8	7-8-65			606	23	Do.
L78	Charles W. McCarty.	Irregular 15	9	16	1952	10	809	2	+19.9	7-23-64		78	768	60	
L79	Mrs. R. S. Boardman.	SE¼ 17	9	16	1911		411	2½				76			

[1] Measured at land surface. May be lower than temperature in aquifer.
[2] Multiply by 0.65 to obtain approximate dissolved-solids concentration.
[3] Depth calculated using thermal gradient. Well is at least this deep and may be deeper.

Although some of the fresh-water sands (aquifers) are discontinuous, several can be traced throughout a large part of Hancock County. Several of the aquifers that are missing from the sections illustrated are present a short distance from the lines of section.

EXPLORATION AND TESTING

AQUIFER IDENTIFICATION

The first exploratory drilling at the test facility resulted in a 2,500-foot test hole in the southwestern, or administrative, part of the facility. No electric log was made in the test hole, but water samples were collected and measurements of temperature and artesian pressure were made for several aquifers recorded by the driller's log. The data obtained are given in the following table.

Depth interval (ft)	*Dissolved solids (ppm)*	*Shut-in pressure at land surface*		*Temperature (°F)*
		psi	*ft*	
1,038–1,151	272	26	60	80
1,460–1,524	245	39	90	89
1,714–1,810	239	40	92	91
2,335–2,463	--------	44	102	94

NOTE.—On later tests somewhat different values were obtained for some of the above temperatures and pressures.

Although only one test hole was drilled, each production well that was installed provided information on aquifer availability and extent, water quality and temperature, artesian pressure, and aquifer hydraulics. Electric logs, made for all wells except Potable-Water Well 1, provided the data most useful in selecting depths for setting screen.

AQUIFER HYDRAULICS AND WELL PRODUCTION

The amount of water available from a well is directly related to the transmissibility of the aquifer, the available drawdown, and the well efficiency. Transmissibility is the number of gallons per day that can pass through a section of the aquifer 1 foot wide at unit hydraulic gradient. It can be determined by a pumping test and is equivalent to the permeability multiplied by the aquifer thickness. Determination of transmissibility commonly involves the use of the Theis nonequilibrium formula or its modified form (Theis, 1935).

Theis nonequilibrium formula

$$s=\frac{114.6Q}{T}\int_{1.87r^2S/Tt}^{\infty}\frac{e^{-u}}{u}\,du \qquad (1)$$

Usually applied form:

$$T=\frac{114.6QW(u)}{s};\ S=\frac{uTt}{1.87r^2} \tag{2}$$

in which T=transmissibility, in gallons per day per foot;
Q=discharge, in gallons per minute;
s=drawdown or recovery, in feet;
S=coefficient of storage, a decimal fraction;
t=time, in days, since pumping started or stopped;
r=distance, in feet, between pumped well and observation well;
$u=1.87r^2S/T$; and
$W(u)$=well function of u, or the exponential integral of formula 1.

Modified nonequilibrium formula

$$T=\frac{264Q}{\Delta s}; \tag{3}$$

$$S=\frac{0.3Tt_0}{r^2}, \tag{4}$$

in which T, S, Q, and r are as defined above;
t_0 is the time intercept, in days, where the plotted straight line intersects the zero drawdown axis; and
Δs is the change, in feet, in water level over one log cycle of time.

The Theis nonequilibrium formula was derived from the analogy between hydrologic conditions in an aquifer and thermal conditions in an equivalent thermal system. The formula is based on the following assumptions: (1) Aquifer is homogeneous and isotropic, (2) aquifer has infinite areal extent, (3) well penetrates and receives water from the entire thickness of the aquifer, (4) transmissibility is constant at all times and at all places, (5) well has an infinitesimal diameter, and (6) water removed from storage is discharged instantaneously with decline in head. Despite the restrictive assumptions on which it is based, the nonequilibrium formula has been applied successfully to many problems of ground-water flow. Because of its applicability to one-well systems, equation 3 was employed by the Geological Survey in determination of transmissibility from pumping-test data collected at MTF.

The amount of drawdown available limits the rate at which water can be withdrawn from a well. The limit may be set by depth of aquifer, economics of pumping, design of the installation, effects on or of other wells, or combinations of the foregoing. The high static water levels and deep screen settings in the test facility wells permit large drawdowns.

Well efficiency is calculated by the Geological Survey by comparing observed specific capacity (production in gallons per minute per foot of water-level drawdown) with the theoretical specific capacity of a 100-percent-efficient well (a well in which the water level during pumping is the same as the water level, or pressure surface, in the aquifer just outside the well) of the same size and in the same aquifer. The calculation is accomplished by substituting in the nonequilibrium formula the value determined earlier for transmissibility, a storage coefficient determined from pumping tests or assumed on the basis of information available for the area and the aquifer involved, and selected values for time and drawdown. The time and drawdown selected ordinarily are 1 day and 1 foot, respectively, to correlate with a standard 1-day period for reporting of observed specific capacity. The result is the number of gallons per minute that a fully efficient well would produce for each foot of water-level drawdown. The ratio, times 100, of the observed value to the calculated value is the well's efficiency.

The practical importance of well efficiency lies in the economics of pumping costs. Pump design and power usage are affected directly by the depth from which water must be raised.

POTABLE-WATER WELL 1

The first production well, Potable-Water Well 1, was installed 1,350 feet southwest of the test hole. This well produced 2,487 gpm (gallons per minute) by natural flow, which encouraged the belief that the deep-lying aquifers contain sufficient artesian head to provide large supplies of water without the use of well pumps. Descriptions of Potable-Water Well 1 and other wells constructed for the test facility are given in table 2.

POTABLE-WATER WELL 2

Potable-Water Well 2 was drilled 3,350 feet northwest of the test hole and was the first well for which an electric log was made. On the basis of the electric log and the large production of Potable-Water Well 1, Potable-Water Well 2 was screened in the same aquifer. The flow of this well was 1,089 gpm. Pumping tests to determine aquifer transmissibility were not made for either of the potable-water wells in the administrative area.

INDUSTRIAL WELL 1

The first industrial well, Industrial Well 1, was installed 2 miles east-southeast of the test hole. The well was drilled to a depth of 1,799 feet, and an electric log was made. The well was then deepened to

TABLE 2.—*Records of Mississippi Test Facility water wells*

[Potable-water well and industrial well are PWW and IW wells, respectively, of pl. 1]

Well	USGS No.	Driller	Date completed	Depth (ft)	Casing diameter (in.)	Screen: Diameter (in.)	Screen: Interval (ft)	Screen: Opening (in.)	Screen: Gravel packed
Administration area:									
Potable-Water Well 1.	H3	Layne-Central.	Mar. 1963	1,524	12, 8	8	1,464–1,524	0.030	Yes
2	H5	Carloss	Apr. 1964	1,481	12, 8	8	1,418–1,481	.030	Yes
Test area:									
Industrial Well 1.	H4	Layne-Central.	Nov. 1963	1,873	18, 12¾	12¾	1,803–1,873	.030	Yes
Saturn V Potable-Water Well.	H7	Carloss	June 1964	1,434	12, 8	8	1,371–1,434	.030	Yes
Industrial Well 2.	H6	do	July 1964	1,695	18, 10	10	1,585–1,695	.030	Yes
3	H8	do	Mar. 1965	672	24, 12	12	458–494, 532–580, 616–672	.050	Yes

Well	Static water level (ft above land surface)	Specific capacity (gpm per ft of drawdown)	Well efficiency[1] (percent)	Production on test (gpm)	Temperature (°F)	Electric log	Acquifer characteristics: Coefficient of transmissibility (gpd per ft)	Acquifer characteristics: Coefficient of permeability (gpd per sq ft)
Administration area:								
Potable-Water Well 1.	90	[2] 28		2,487	89	No		
2	86	[2] 14		1,089		Yes		
Test area:								
Industrial Well 1	104	12	45	3,550	100	Part	100,000	550
Saturn V Potable-Water Well.	81+	15	60–80	1,218	91	Yes	81,000	930
Industrial Well 2	90	26	30	5,000	96	Yes	200,000	1,670
3	15	47	95	5,865	79	Yes	116,000	685

[1] Calculated by comparing observed specific capacity with theoretical specific capacity for a fully efficient well.
[2] Based on short period; value would be less for standard 24-hr test period.

1,879 feet and screened in the interval 1,798–1,868 feet. No electric log was made for the drilled interval below 1,799 feet. Flow from the well was 1,300 gpm. In a pumping test made several months after the well was completed, a production rate of 3,500 gpm was attained with an accompanying water-level drawdown of 292 feet (fig. 3). The specific capacity was 12 gpm per ft of drawdown.

Aquifer transmissibility determined in the pumping test is 100,000 gpd (gallons per day) per foot. The aquifer in which the well is screened is indicated to be more than 180 feet thick by an electric log of the pilot hole for Industrial Well 2, 1,500 feet to the west. If the thickness of the aquifer is the same at the two locations, less than 40 percent of the aquifer thickness is screened. Allowance was made for incomplete aquifer penetration in calculating the theoretical specific capacity and, consequently, the well efficiency (table 2).

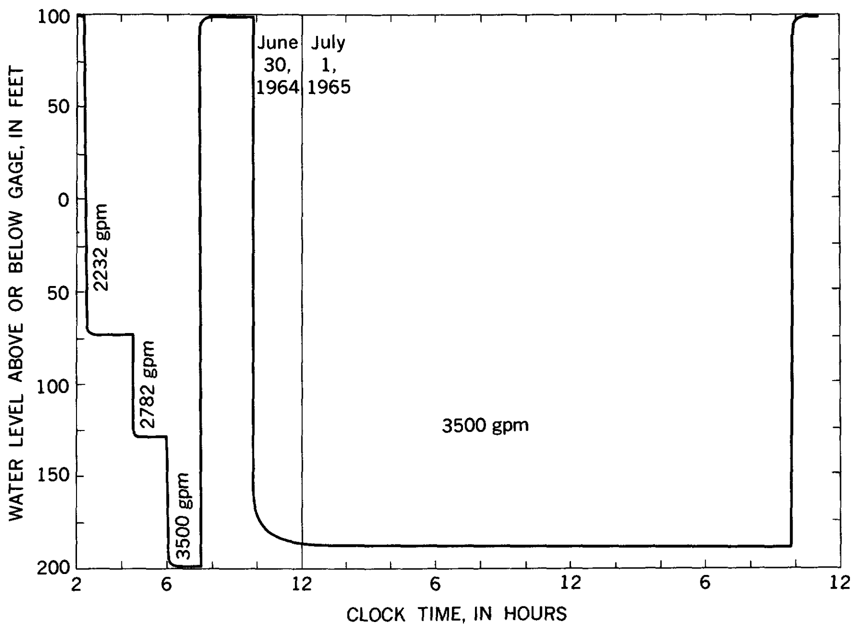

FIGURE 3.—Water level during pumping test of Industrial Well 1.

SATURN V POTABLE-WATER WELL

The only potable-water well installed in the test-stand area, Saturn V Potable-Water Well, is 2,650 feet northwest of Industrial Well 1. It is screened in the same aquifer that yields water to the two potable-water wells in the administrative area. Maximum flow of this well upon completion was 1,160 gpm. An initial flow test at various rates of flow revealed a marked decline in specific capacity with increase in flow rate, an indication of incomplete well development.

An attempt to improve well development several months after completion of the well was made by alternately shutting in and releasing flow during a 10-hour period. The maximum flow was increased to nearly 1,250 gpm, but the well continued to exhibit a decline in specific capacity with increase in flow rate during a step-drawdown test (fig. 4). A 30-hour constant-rate flow test at 1,018 gpm and the recovery following indicated an aquifer transmissibility of 81,000 gpd per ft and a specific capacity of 15 gpm per ft of drawdown (table 2).

INDUSTRIAL WELL 2

The second industrial well was installed 1,500 feet west of the first one. A pilot hole was drilled and electrically logged to a depth of 2,015 feet. In addition to providing data needed for construction

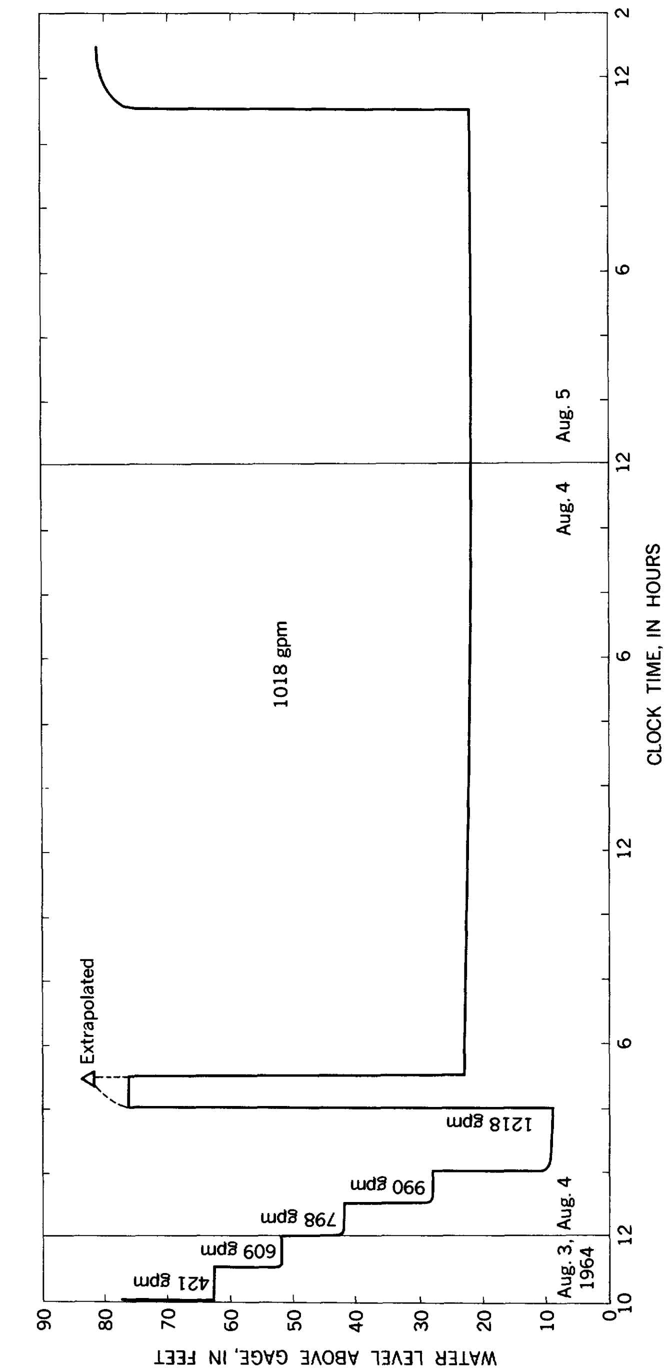

FIGURE 4.—Water-level during flow test of Saturn V Potable-Water Well.

of the well, the pilot hole permitted sampling and electric logging of the deeper aquifer used for Industrial Well 1.

An aquifer from 1,580 to 1,700 feet was selected for Industrial Well 2 because the unit occurs throughout the area and no other MTF wells produce from it. A high proportion of screen length to aquifer thickness was designed to obtain as much water as possible from the aquifer. Natural flow from the well was more than 3,000 gpm, and in a pumping test the well produced 5,000 gpm with 190 feet of drawdown (fig. 5). The transmissibility and the specific capacity determined in the test are 200,000 gpd per ft and 26 gpm per ft of drawdown, respectively. The theoretical specific capacity of a fully efficient well of this size in an aquifer having these characteristics is about 80 gpm per ft of drawdown as calculated using standard Geological Survey procedures.

The aquifer tapped by Industrial Well 2 has higher transmissibility and permeability than the aquifers supplying Industrial Well 1, Industrial Well 3, and Saturn V Potable-Water Well. At the time of the pumping test described above, this well probably had the greatest production capacity of any well in Mississippi.

INDUSTRIAL WELL 3

Industrial Well 3 differs from the other MTF wells in that the concept of obtaining the desired production by natural flow was not followed. The well was designed to tap shallower aquifers and thereby reduce construction costs, although pumping would be necessary. Electric logs of wells throughout the area indicate a persistent sandy zone between depths of 500 and 700 feet. Industrial Well 3 was constructed to tap two sand beds in this interval and one bed just above 500 feet. The three aquifers are separate throughout the area of the test facility, so far as can be determined from available data.

In an effort to achieve greater efficiency than that indicated by tests of the previous wells, a coarser more rounded gravel for the artificial pack and a larger well-screen opening were used in this well than in the other wells. Reduced head loss due to friction at and near the well face was obtained at the expense of pumping some sand. The well flowed at the rate of 280 gpm with a head loss of 7.4 feet upon completion. A pumping test produced 5,865 gpm with a drawdown of 119 feet (fig. 6), which was the capacity of the test pump, not of the well. Industrial Well 3 easily superseded Industrial Well 2 as Mississippi's highest production water well. Although the aquifer transmissibility was not obtained separately for each of the three sands screened, a composite recovery curve indicates a transmissibility of 116,000 gpd per ft. The specific capacity of 47 gpm per ft of drawdown reflects a well efficiency of 95 percent (table 2).

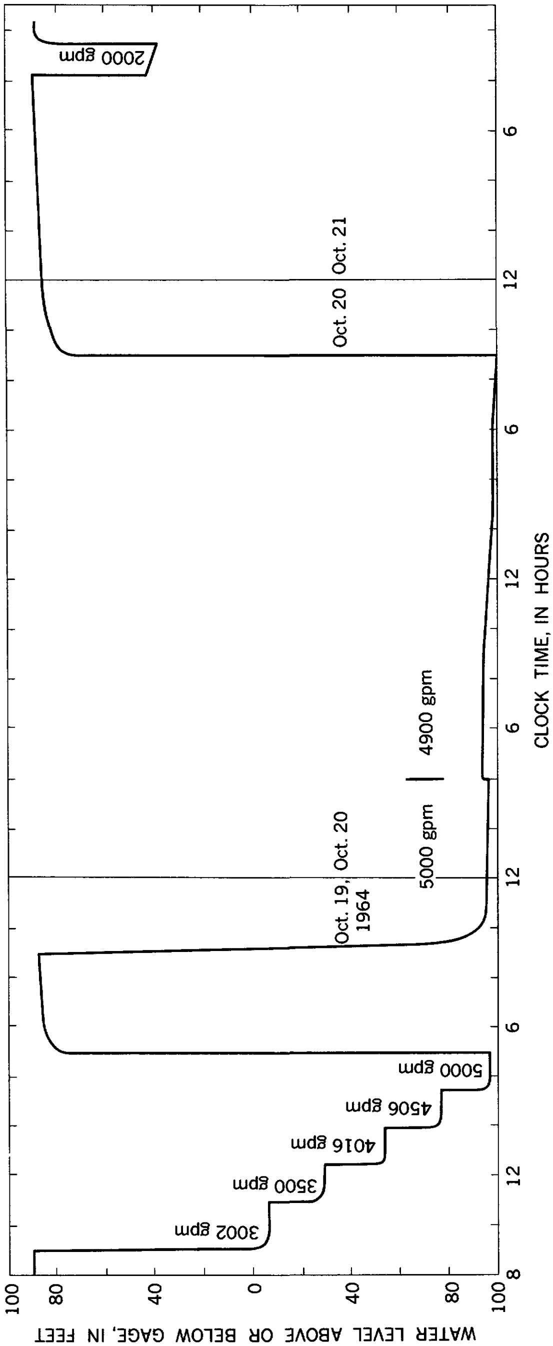

FIGURE 5.—Water level during pumping test of Industrial Well 2.

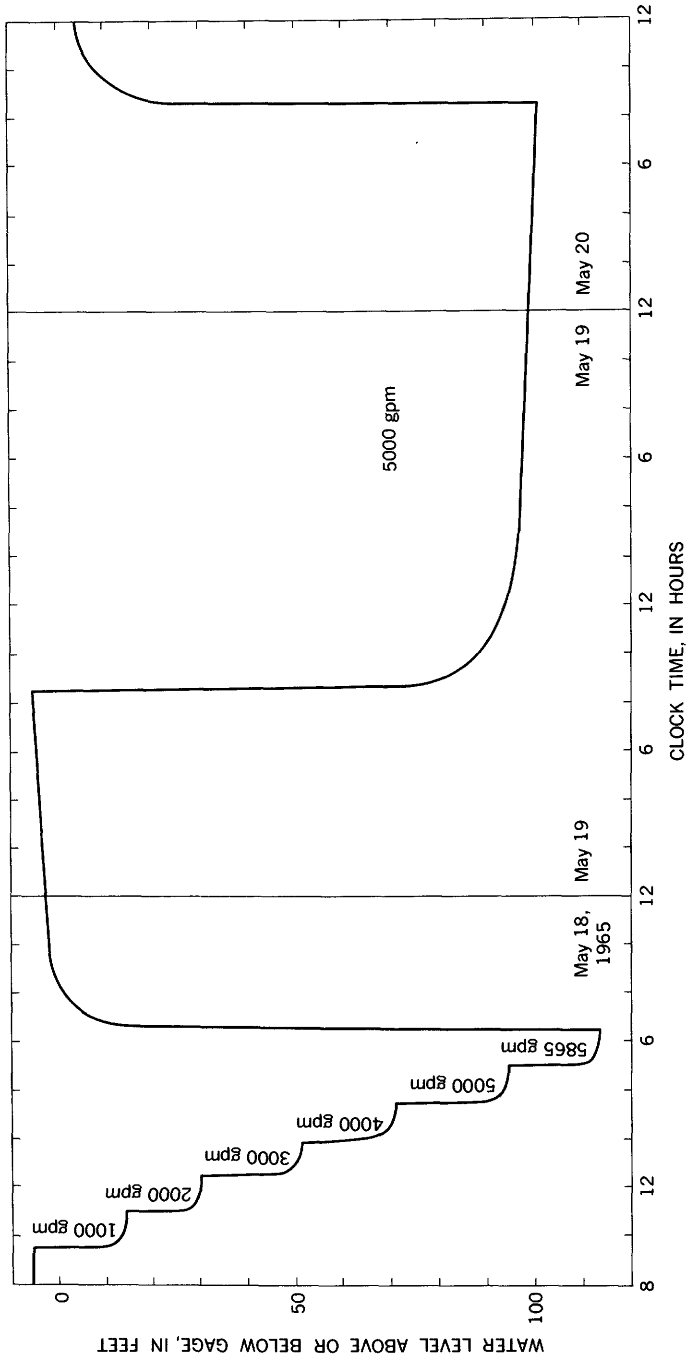

FIGURE 6.—Water level during pumping test of Industrial Well 3.

Sieve analyses of gravel pack material used at Mississippi Test Facility

Sieve opening (in.)	Cumulative percent retained on sieve		
	Industrial Well 1	Industrial Well 2, Potable-Water Well 2, and Saturn V Potable-Water Well	Industrial Well 3
0.187	0		22.9
.094	22.8	15.9	86.9
.047	86.9	83.6	95.0
.023	97.6	98.8	97.5
.012	99.0	99.5	99.0
.006	99.4	99.8	99.8
Pan	100.0	100.0	100.0

The value of using carefully selected gravel for the artificial pack and matching the screen openings to the gravel size was demonstrated by this well. This experience will help in developing design criteria for construction of future wells having high efficiency without the pumping of objectionable amounts of sand. A comparison of the gravels used in packing the industrial wells is given in the above table of sieve analyses.

WELL TEST IN BUFFER ZONE

A pumping test of an unused water system in the buffer zone provided data to supplement those obtained in tests of MTF wells. The test, involving two wells screened in the same aquifer, permitted a calculation of the storage coefficient, an aquifer characteristic not obtainable from a one-well test. The storage coefficient calculated is 0.0001, typical of that determined for aquifers of similar age and composition elsewhere along the Mississippi Gulf Coast. The value indicates definite artesian conditions, and it can be used in calculations of predicted pumping effects.

ARTESIAN PRESSURE

DEPTH-PRESSURE RELATION

The artesian pressure (measured as shut-in pressure at land surface) increases with well depth at most places in the coastal area, as in most other regions. In the MTF area the measurement of shut-in pressures for wells ranging in depth from 110 to 1,873 feet shows an increase of 1.9 pounds per square inch (4.4 ft) for each 100-foot increase in depth (fig. 7). Anomalous measurements may be attributed to decline of pressure in some aquifers as a result of long-term withdrawals.

RECENT TRENDS

Artesian pressures in some aquifers of southwestern Hancock County declined 10 pounds per square inch (23 ft) in the period 1939–64. Most of the decline has been caused by withdrawal of water through continuously flowing wells. A large proportion of the water produced was wasted and, in the process, artesian pressure was reduced. Following the leasing and buying of private land for construction of the test facility, many wells either were left flowing intentionally to prevent well failure from shutting them in or, when the owners moved away, were vandalized and the fittings removed.

Periodic measurement of pressure and depth to water at about 25 wells was begun in mid-1964. Hydrographs of water levels in six aquifers tapped by these observation wells (fig. 8) indicate a general decline in pressure during the period June 1964 to January 1966. The downward trend prevailed in 1965 in four of the aquifers, but measurements in the other two indicate leveling off or rising pressure trends in late 1965. In addition, measurements in two observation wells

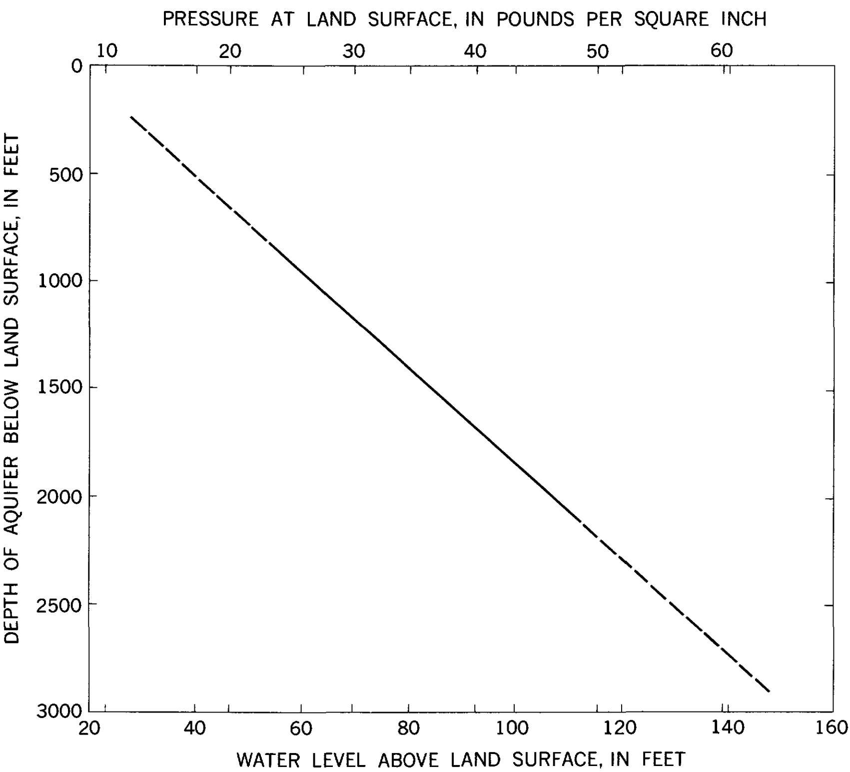

FIGURE 7.—Relation of aquifer depth to artesian pressure. Dashed line is extrapolation.

over a longer period of record (fig. 9) show some pressure recovery between July 1964 and January 1966.

A mosquito-control program by NASA has led to the shutting in of all flowing wells in the MTF area and of many in the buffer zone. This program should reverse or at least reduce the rate of pressure decline in several of the aquifers. An act of the Mississippi Legislature (First Extraordinary Session 1965) empowers the Hancock County Board of Supervisors to take necessary action to stop the flow of water from abandoned wells in the buffer zone. If action is taken in accordance with the new law, a substantial amount of water now flowing to waste will be conserved and artesian pressures will be increased throughout the area.

CHEMICAL QUALITY AND TEMPERATURE OF THE WATER

Water from all the wells at MTF is fresh and of good quality. It is soft, and the dissolved-solids content does not exceed 315 ppm. Table 3 contains chemical analyses of water samples from the potable-water wells, from industrial wells, and from a well screened in a shallow aquifer not tapped by any of the facility's supply wells.

As shown by figure 2 the base of fresh water is nearly 3,000 feet below sea level at MTF; more than 1,000 feet deeper than the deepest well. The concentration of chloride in all samples analyzed was low

TABLE 3.—*Chemical analysis of water from wells at Mississippi Test Facility*

[Analyses by U.S. Geol. Survey. Constituents are in parts per million]

Well	Water-bearing interval (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
Potable-Water Well 1	1,460-1,524	Oct. 1965	20	0.04	1.9	0.1	86	1.1	186
2	1,405-1,480	do	20	.09	2.0	.0	85	1.3	178
Saturn V Potable-Water Well	1,345-1,435	do	20	.02	.8	.7	97	1.2	221
Industrial Well 1	1,800-2,000	do	33	.05	2.5	.2	115	2.0	268
2	1,580-1,730	do	21	.12	2.0	.0	97	1.0	211
3	455-675	do	8.1	.23	.7	.5	106	.8	248
Dewatering Well (H10)	110-140	Feb. 1965	22	.09	1.5	.5	83	.9	198

Well	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	pH at well	Color [1]
Potable-Water Well 1	7	11	16	0.2	0.2	236	5	8.95	10
2	7	13	19	.2	.2	236	5	8.95	10
Saturn V Potable-Water Well	0	11	13	.3	.0	253	5	8.95	5
Industrial Well 1	0	7.6	22	.4	.2	315	7	8.75	5
2	0	11	26	.3	.0	262	5	8.45	10
3	0	4.6	20	.3	.0	263	4	9.1	10
Dewatering Well (H10)	0	4.6	14	.5	.3	232	6	[2] 6.9	30

[1] Expressed in terms of Hazen Pt-Co scale.
[2] Determined in laboratory at time analysis.

(60 ppm or less). Although all the aquifers contain saline water downdip, it is unlikely that pumping at MTF will induce the encroachment of saline water into the area.

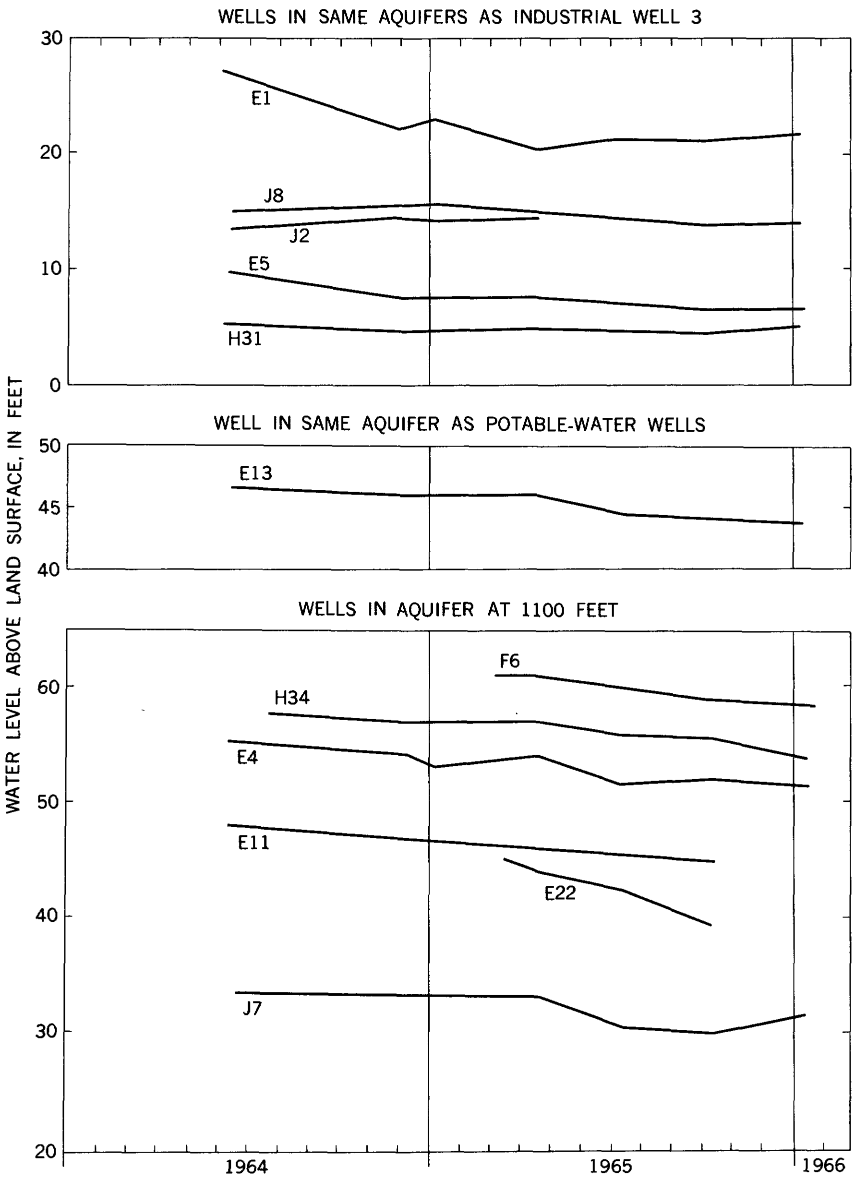

FIGURE 8.—Hydrographs of observation wells and correlation of aquifers.

Water temperatures measured in the wells drilled to date show that the thermal gradient is 1°F for every 55 feet of increase in depth (fig. 10). Water in near-surface aquifers has a temperature of about

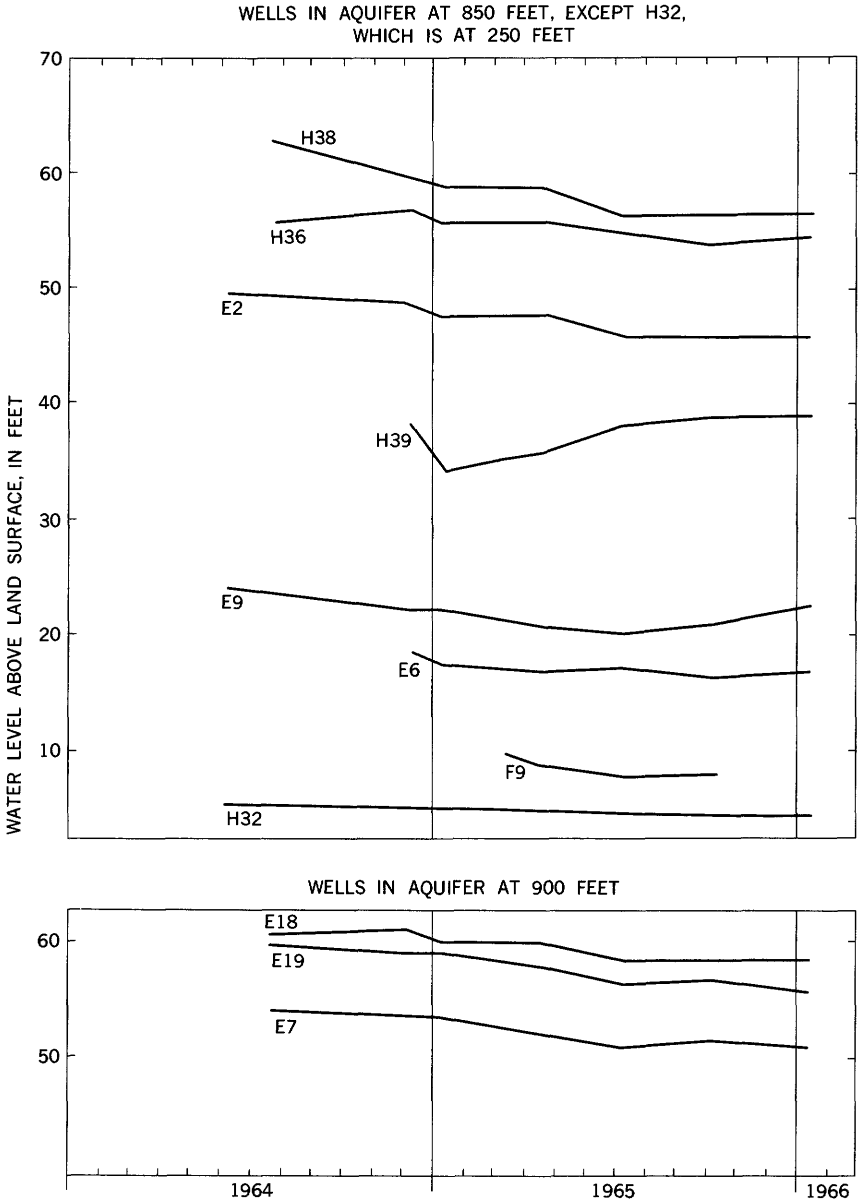

FIGURE 8.—Continued

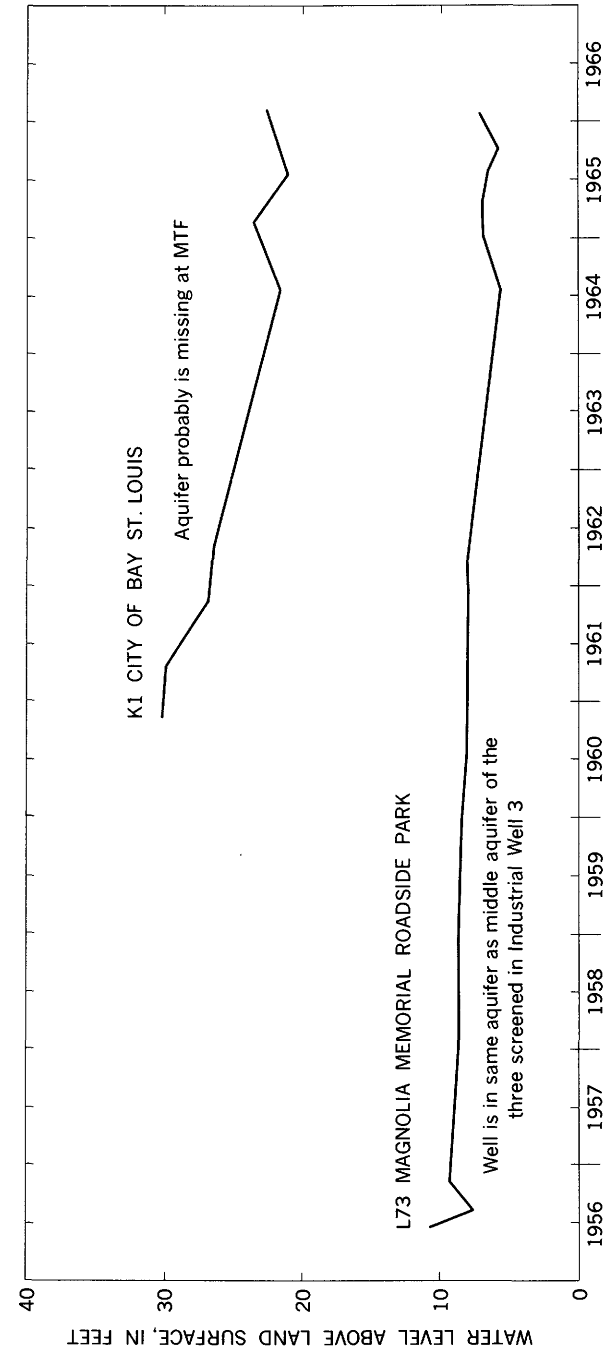

FIGURE 9.—Long-term hydrographs of wells in Hancock County.

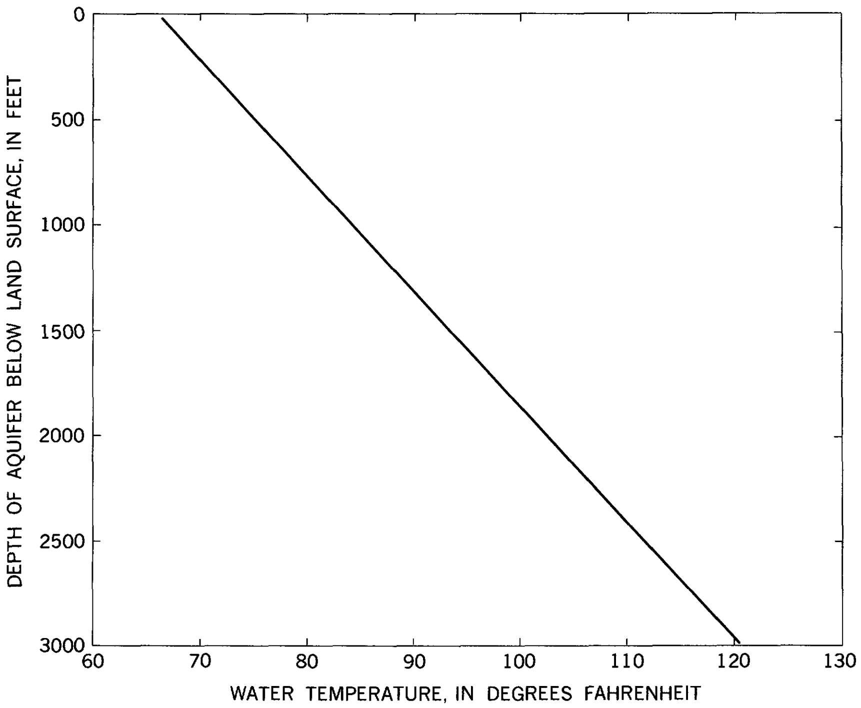

FIGURE 10.—Relation of depth to temperature.

67°F, the same as the mean annual air temperature. Discharge from the deepest well (1,868 ft) has a temperature of 100°F. Ground-water temperatures are practically constant. No variation in temperature is expected for water from the deep wells at MTF.

WATER SUPPLY

POTABLE-WATER WELLS

Only a fraction of the water available from the potable-water wells is being used. Potable-Water Wells 1 and 2 flow into horizontal centrifugal pumps having a capacity of 600 gpm each. The water is used in fire mains and for domestic and other nonindustrial purposes in the administrative area. The two wells may be considered as alternates for one another. Two 300,000-gallon elevated tanks store the water.

The Saturn V Potable-Water Well serves the test-stand area in the same manner that the other potable-water wells serve the administrative area. Two centrifugal pumps capable of delivering a total of 1,250 gpm are installed to provide line pressure in the system; thus no storage tank is used.

INDUSTRIAL WELLS

The three industrial wells supply water directly to a 60-million-gallon ground-storage reservoir. Industrial Well 1 is pumped at 3,100 gpm, Well 2 at 4,500 gpm, and Well 3 at 5,000 gpm. The wells are capable of supplying 7,500,000 gallons in a 10-hour period (18 million gallons per day). The wells generally will be in use only 5 or 6 days per month; and under a full test schedule, pumpage will average 2½ million gallons per day.

Water from the reservoir is pumped to the primary test stand through a pipe 8 feet in diameter at the rate of 300,000 gpm and under a head of 495 feet. Flow to the smaller stands is through 6-foot pipe. Water is sprayed onto the inside of the rocket-exhaust deflectors for the periods of test firing.

Only a small fraction of the 60-million-gallon reservoir's capacity is for active use; the remainder of the water is in dead storage that serves the function of supporting the water to be pumped to the test stands. Elevated tanks would not be feasible in this area of severe vibration and potential catastrophic explosion.

EFFECTS OF DEVELOPMENT

Pumping or natural flow from a well always causes a drawdown of water level (or decline of artesian pressure) in the aquifer tapped by the well. For this reason water-supply wells should be distributed areally or stratigraphically in a manner that minimizes pumping interference between wells.

The test facility is fortunately located in that it is underlain by several extensive aquifers. Although all the potable-water wells at MTF are screened in the same aquifer—that also supplies municipal wells at Picayune (pl. 1)—little interference is likely, even within the area of MTF, because of the planned low rate of withdrawal and adequate spacing of wells. The industrial wells are screened in aquifers separate from one another and from that of the potable-water wells; therefore, no pumping interference should be anticipated.

Pumping effects may be predicted where aquifer characteristics are known or can be reasonably estimated. Pumping tests have been made and aquifer transmissibility calculated for each of the aquifers tapped by MTF wells. Although the only potable-water well at which aquifer transmissibility was determined by pumping test is the Saturn V Potable-Water Well, the value obtained in the test can be used in predicting pumping effects for all the potable-water wells in the administrative area. The aquifer appears almost identical on electric logs made at the two places.

The graphs in figure 11 show predicted drawdown effects, at various times and distances, caused by pumping the MTF wells at their planned rates. Each graph predicts only the water-level effect on the aquifer screened in the well specified.

Automatic water-pressure recorders are installed on the industrial wells and two of the potable-water wells at MTF. These instruments provide a record of artesian-pressure fluctuations between periods of pumping. Pressure recorders are also installed on several observation wells outside the test-stand area. An effort was made to locate the recorders at the nearest wells supplying water from the same aquifers screened in the MTF industrial and potable-water wells. A few wells producing from aquifers not screened at MTF are also being monitored. About 25 observation wells are measured periodically to provide records of water level (pressure) trends.

WELL MAINTENANCE

The use schedule planned for the industrial wells consists of very short periods of withdrawal interspersed with prolonged periods of inactivity. While this schedule promotes aquifer recovery and minimizes the effects of pumping on the area outside MTF, it is not conducive to long life and trouble-free operation of the wells themselves. Long periods of idleness encourage settling and bridging of fine sand in the highly developed region around the well screen.

Difficulty in disposing of excess water, and other factors, make it impracticable to pump the industrial wells continuously or for even a large proportion of the time. Each well, however, should be pumped or allowed to flow once a week for a period of at least 6 hours. The water from the wells can be allowed to overflow the ground-storage reservoir and drain into the barge canal.

If after a time any well indicates, by a decline in specific capacity that aquifer plugging is occurring, it will be necessary to redevelop the well and institute a stricter schedule of between-test pumping or flowing. The decline of specific capacity—not decline of artesian pressure—indicates well deterioration.

FUTURE DEVELOPMENT

STANDBY WELL

A fourth industrial water well has been considered for MTF. In view of the present capability of Industrial Wells 1, 2, and 3 to supply testing needs in the foreseeable future, a fourth well would have standby status. If a fourth industrial well is installed it should be placed near Industrial Well 3 and screened in the aquifer supplying Industrial Well 2. The aquifer, at depths between 1,600 and 1,700 feet, is capable of yielding about twice as much water as any of the aquifers

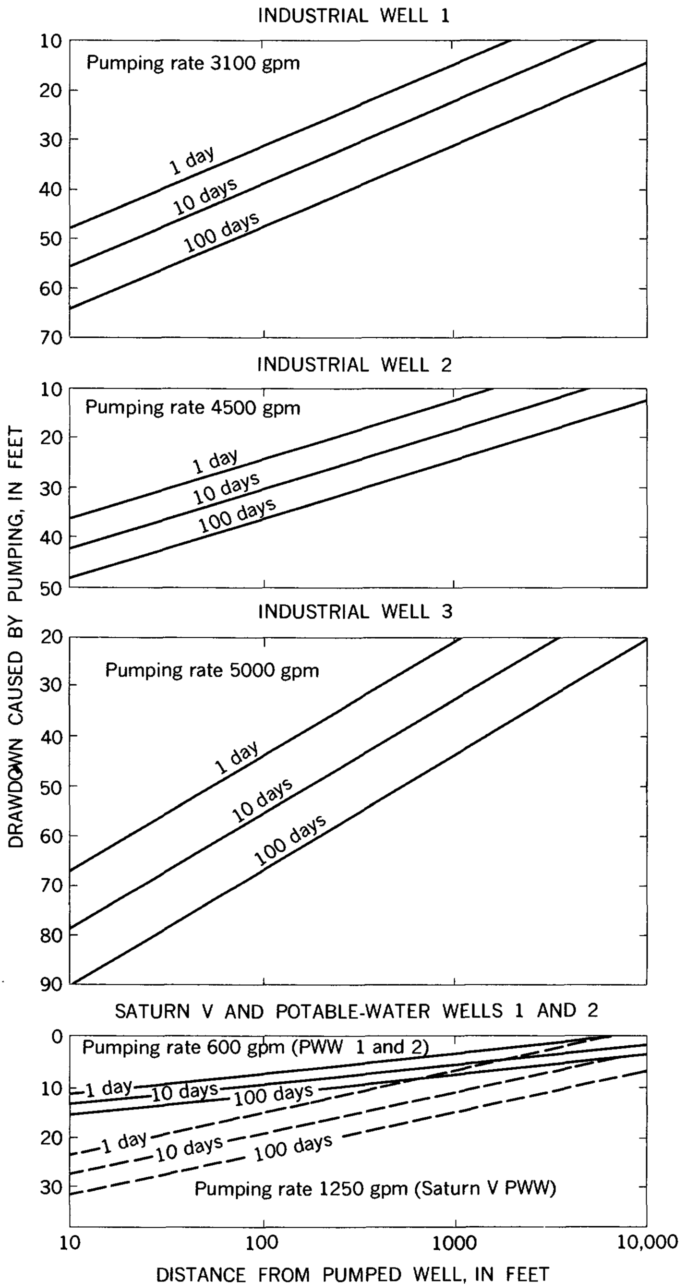

FIGURE 11.—Predicted effects of continuous pumping.

supplying the other MTF wells. A fully efficient large-diameter well in this aquifer should flow about 8,000 gpm at land surface and could reasonably be expected to flow 5,000 gpm at the elevation of the reservoir inlet. This large natural flow obviates the need for a pump.

A well at the location recommended would be 1,500 feet distant from the other well in the same aquifer and 1,000 feet deeper than the nearest well. Consideration should be given to making the proposed well a standby well for the potable-water supply in the test area. Inasmuch as the potable-water supply systems of the testing and administrative areas are separate and as the testing area depends on only one well, it would be desirable to make the standby well available to either system.

PROJECTION

Projection into the future indicates an expansion of rocket-engine testing. It would be logical to locate additional wells near the test stands to be cooled. Inasmuch as the stands are likely to be constructed in the northeastern part of the MTF area, it is important that aquifer conditions be evaluated as early as practicable. Therefore, a test hole should be drilled about 2 miles north of the present industrial area to a depth of 3,000 feet and an electric log should be made. The selection of sand intervals to be tested for water quality and pressure head would be based on study of the electric log and drill cuttings.

Although a test hole was drilled in the warehouse area and four aquifers underlie the present industrial area, the distance between these sites and a potential test-stand complex—2 miles or more—justifies the test hole recommended. In addition, a study of electric logs of oil test wells in the vicinity indicates thick sections of fresh-water-bearing sand at depths below the interval penetrated by MTF's previous test hole and wells. These sands appear, from the electric logs, to be capable of supplying thousands of gallons per minute of good-quality water. The water in the aquifers between 2,500 and 2,800 feet probably is under sufficient artesian pressure to lift it to a height between 130 and 140 feet above land surface. The water temperature should be about 115°F.

To take full advantage of the recommended test hole following deep-aquifer testing, an inexpensively constructed well for quantitative-test purposes should be installed in the shallow sand whose base lies at a depth of about 150 feet. This sand is the aquifer from which large quantities of water were pumped during foundation dewatering operations incidental to test-stand construction. It may be an important supplemental source of water which could some day save the cost of constructing a deep well. Such a test well could be installed in the test hole and might consist of 6- or 8-inch casing, the lower 40 or 50 feet slotted to form a screen. High well efficiency would not be an objective, and gravel packing would not be necessary. Three small-diameter observation wells should be installed at distances of 150 to 500 feet and in different directions from the test well. A 48-hour or longer pumping test at about 500 gpm then would be made to provide the aquifer coefficients of transmissibility and storage and to illustrate directly the effects of pumping from the aquifer.

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