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Interim Report, June 1971

AVAILABILITY OF GROUND WATER FOR PUBLIC-WATER SUPPLY IN THE PENSACOLA AREA, FLORIDA

By

Henry Trapp, Jr.

OPEN-FILE REPORT

72002

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
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STATEMENT OF THE PROBLEM

Earlier hydrologic studies show that ample quantities of soft water of low dissolved solids content are obtainable from the sand-and-gravel aquifer in the Pensacola area. Some wells drilled for the city of Pensacola have yielded water with unacceptably high amounts of iron and carbon dioxide, and wells have had disappointingly low yields. The city, therefore, is seeking hydrologic information, including water-quality data, in an effort to avoid the high cost of well abandonment and to plan for future expansion of the water-supply system.

OBJECTIVES AND APPROACH

This study is intended to provide information on the quality and quantity of water available from the sand-and-gravel aquifer, the only fresh-water aquifer in the Pensacola area, and to delineate those areas favorable for public-supply well sites.

The project area is southern Escambia County, from Pensacola to S.R. (State Road) 196 north of Quintette (fig. 1). During the first year, effort was concentrated in the southern half of the area, generally south of 30°30', which approximately coincides with Interstate Highway 10 in southeastern Escambia County.

Fig. 1 near here

The investigation included the collection of well data, chemical analyses of water samples, test drilling, radioactivity logging of test holes and other wells, and water-level measurements.

Figure 1.--Map showing area of investigation and locations of test holes and wells referred to in text. (Figure is in pocket at end of report.)

GENERAL DESCRIPTION OF THE AQUIFER

The sediments making up the sand-and-gravel aquifer are exposed at the surface throughout Escambia County and extend as much as 1,000 feet below the surface. A thick clay underlies the aquifer in the southern part of the county. The aquifer-flow system is bounded by Perdido River and Perdido Bay to the west, Escambia River and Escambia Bay to the east, and Pensacola Bay and the Gulf of Mexico to the south. These bodies of water act as partially penetrating drains.

The aquifer consists primarily of quartz sand, ranging in size from very fine (1/16-1/8 mm (millimeter)) to very coarse (1-2 mm), and commonly with disseminated small quartz pebbles. The sand is locally cemented by iron minerals into thin layers of hardpan. Layers and lenses of gravel, silt, and clay also occur within the aquifer. Most of these layers and lenses probably extend for only short distances. The variations in porosity and hydraulic conductivity resulting from variations in rock type are important in partly isolating parts of the aquifer from each other and in contributing to variations in hydraulic head with depth.

Most wells and test holes in the Pensacola area penetrate less than 300 feet of the aquifer, and, consequently, most of the data available apply to this upper section. The upper part of the aquifer is noncalcareous and contains few fossils, mostly fresh-appearing woody and carbonized plant remains; the lower part of the aquifer contains abundant fossil shells.

WATER LEVELS

Water Table, Head, and Potentiometric Surface

The rock (including unconsolidated sediments) forming the upper part of the earth's crust contains numerous small pores. In clay or silt these pores are abundant but extremely small. Sand and gravel have fewer but larger openings. The many pores in the rock serve as the storage space for water and also the paths by which it moves. That part of the upper earth's crust in which pores are filled with water is known as the zone of saturation. If an uncased hole is excavated into permeable material below the top of the zone of saturation, water will flow freely into it. The level at which water stands in the hole represents the water table at this point. It is free to rise and fall with changes in the amount of water entering and leaving the saturated zone (recharge and discharge). The water table is not a flat surface but generally reflects, in a subdued way, the irregularities of topography. It intersects the land surface at springs, streams, and lakes.

The level at which water stands in a well cased substantially below the water table is generally not identical to the water table. This is because the water in the ground is usually in motion, moving from points of higher head (potential energy level) to lower head. If there is a downward component to the ground-water movement, the head must be lower at depth than just below the water table. If beds of low permeability intervene, such as clay or silt, the difference in head can be substantial. Thus, to map the configuration of the water table accurately would require a network of observation wells drilled to points just below the water table. Water levels would have to be measured at nearly the same time, and the resulting map would apply only to the time of measurement.

The water levels, or heads, in wells constructed in the same water-bearing zone establish a "potentiometric surface." This would be the water table in wells screened at the water table. Other potentiometric surfaces would be defined by levels in wells screened at various horizons below the water table. In flowing wells, the potentiometric surface is above ground.

Owing to a lack of sufficient data points for a meaningful water-table map or potentiometric map, neither has been prepared for this report.

Changes in Water Levels Due to Pumping

Discharge from a well, by flow or by pumping, produces a cone of depression in the potentiometric surface. Where the producing zone is separated from the water table by material of low permeability, the cone of depression may involve only a lowering of the head around the well without actually draining the aquifer. As pumping continues, the cone will continue to expand until enough water is induced to flow into the cone to replace that removed by pumping.

Where wells are closely spaced the cone of depression of one well will lower the water level of the other to a position below the level produced by its own pumping. This interference between wells results in reduced yields, increased pumping costs, or both.

Transmissivity represents the ability of an aquifer to transmit water and is defined as the flow of water in cubic feet per day through a vertical strip of the aquifer 1-foot wide extending the full saturated thickness of the aquifer under a unit hydraulic gradient.

The storage coefficient is the volume of water the aquifer releases or takes into storage per unit surface area of the aquifer per unit change in head. Storage coefficients of artesian aquifers may range from about 1×10^{-5} to 1×10^{-3} (Ferris and others, 1962, p. 76). The small value for the aquifer at Pensacola indicates that the aquifer is confined by overlying layers of low hydraulic conductivity.

Jacob and Cooper (1940, p. 33-44, table 4), ran pumping tests on nine large-capacity wells in Pensacola and obtained the following values for the aquifer characteristics, converted to current U.S. Geological Survey units:

Transmissivity (T): 7,800 to 13,000 $ft^2\ day^{-1}$, average about 10,000 $ft^2\ day^{-1}$

Storage coefficient (S) = 5.5×10^{-4}

Recovery tests, run on four wells (Jacob and Cooper, 1940, table 5), gave somewhat lower transmissivity values, considered less reliable by the authors. Their transmissivity determinations were affected by partial penetration of the aquifer by the pumped wells, and may be lower than the actual value.

Transmissivity and the storage coefficient can be used to predict the drawdown (s, in feet) in a well pumped at a given rate (Q, in cubic feet per day) for a given time (t, in days) by means of the Theis equation:

$$s = \frac{Q}{4\pi T} W(u)$$

where $u = \frac{r^2 S}{4Tt}$

W(u) (or well function of u) has been computed for various values of u and is available in tabular and graphic form (Ferris, J. G., and others, 1962, p. 91-100, table 2). Application of the equation is based on certain assumed conditions concerning aquifer characteristics and boundaries that are never completely met, but, nevertheless, it has been applied successfully to many ground-water problems.

If it is assumed that the radius of the discharging well can be taken as r in the Theis equation, then the equation can be used to solve for the drawdown in the discharging well at a given time t. Drawdowns calculated for the same set of T, S, r, and Q values, when plotted against a logarithmic time base, will fall along a straight line for all but small values of t. In figure 2, the upper line shows the calculated drawdown in a 24-inch well of 100-percent efficiency after pumping 1,000 gpm (gallons per minute) (approximately 192,500 cubic feet per day) for 1 to 1,000 days, with T = 10,000 ft^2 day^{-1} and S = 5.5 x 10^{-4}. The lower line shows the drawdown produced by pumping 2,000 gpm under the same conditions. The drawdowns are twice as great at twice the pumping rate: 26.8 and 35.9 feet after pumping 1,000 gpm for 1 day and 1 year, respectively, as against 53.7 and 71.8 feet after pumping 2,000 gpm for 1 day and 1 year.

Fig. 2 near here

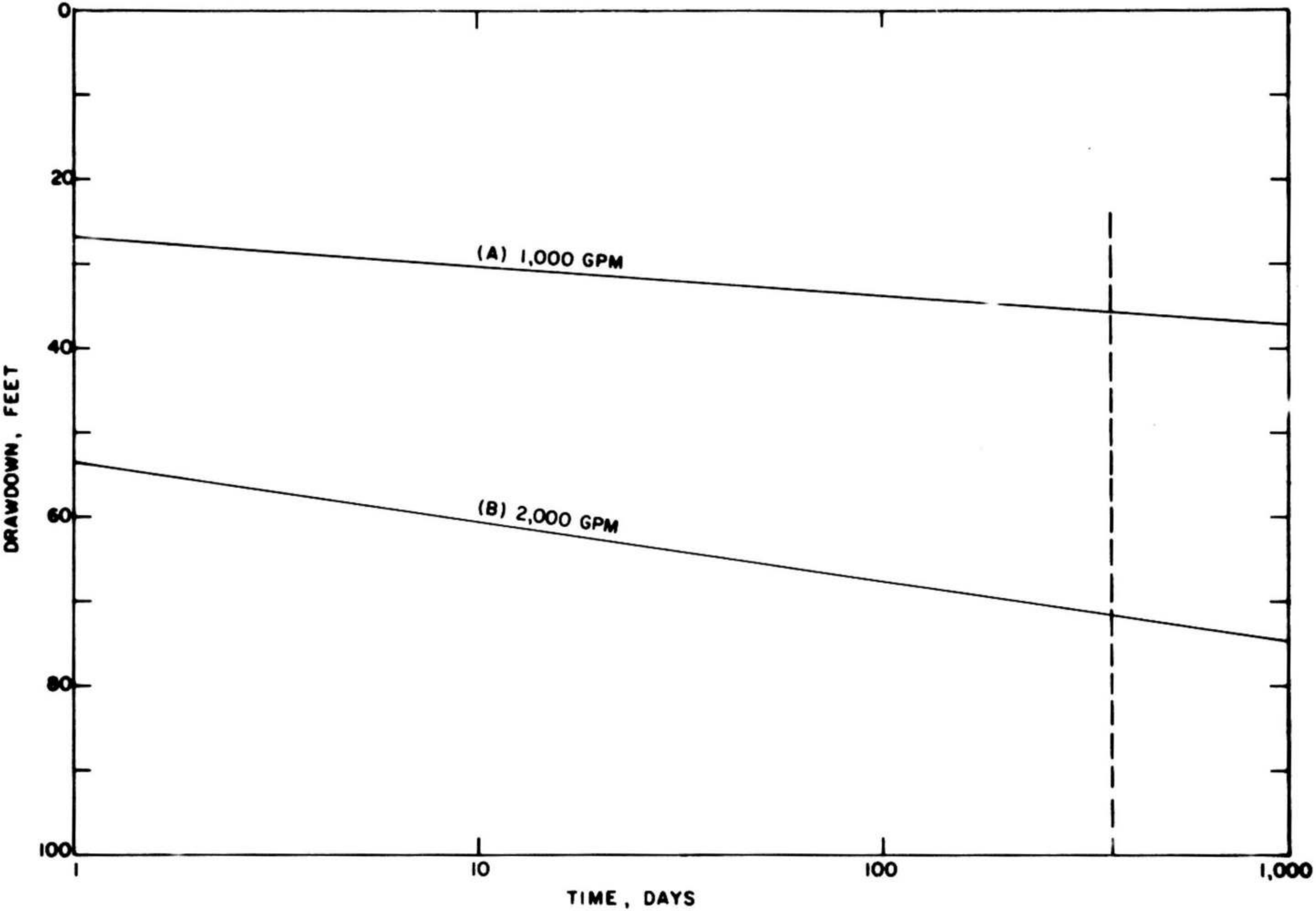

Figure 2.--Graph showing calculated drawdowns in a 100-percent efficient well after continuous pumping from 1 day to 1,000 days at rates of 1,000 and 2,000 gpm.

The line representing each pumping rate intercepts the same increment of drawdown (ΔS) for each log cycle of time. This means that in going from 1 day to 10 days of pumping, the additional drawdown is 3.53 feet at 1,000 gpm and 7.06 feet at 2,000 gpm. If further extrapolation is assumed valid the graphs can be extended through periods of 100 or even 1,000 days. The same increment of drawdown is added for each log cycle of time (10 to 100 days, 100 to 1,000 days). Extrapolating to the left of the region covered by the figure, the drawdown at the end of one-tenth of a day (2.4 hours) could be derived by subtracting ΔS from the drawdown for 1 day. Thus, after pumping for 2.4 hours the drawdown would be 23.3 feet at 1,000 gpm and 46.6 feet at 2,000 gpm.

The drawdowns calculated for 0.1 day and 1 day may be compared with drawdowns reported from some of the city of Pensacola wells given in table 1. (Locations of wells are shown in fig. 1.)

Table 1 near here

The pumping period was specified for only one well, the Lillian well, which was pumped for 8 hours. The reported drawdowns for wells pumping about 2,000 gpm ranged from 27.7 to 77 feet, and averaged 43 feet. For pumping periods of 0.1 to 1 day, the range and average of reported drawdowns is comparable to 46.6 feet at 0.1 day and 53.7 feet at 1 day based on drawdowns shown for the hypothetical well in figure 2.

Table 1.--Reported drawdowns in Pensacola municipal wells.

Table 1. Reported Drawdowns in Pensacola Municipal Wells

City Name or Number	Location Number (Latitude-Longitude)	Pumping Rate (gpm)	Drawdown (feet)
6	302523N0871256.1	2,000	50
8	302535N0871257.1	2,000	50
9	302602N0871307.1	2,000	60
East	302555N0871227.2	2,000	42
West	302514N0871403.1	2,000	54
West Pensacola	302534N0871603.1	2,000	58
12th Avenue	302646N0871227.1	2,000	77
F & Scott	302615N0871344.1	2,090	64
W & Avery	302553N0871457.1	2,000	43
9th Avenue	302901N0871208.1	2,000	28
McAllister	302930N0871128.1	2,000	28
Lillian	302512N0871904.1	800	30

Drawdowns calculated for the same set of T, S, r, and Q values will fall along a straight line when plotted against a logarithmic distance base r, for all but large values of r. In figure 3, the upper line shows drawdowns calculated for distances of from 10 to 10,000 feet for a well pumping 1,000 gpm for 1 year, for values of T = 10,000 ft^2 day^{-1} and S = 5.5 x 10^{-4}. The lower line shows the drawdown produced by pumping 2,000 gpm under the same conditions.

Fig. 3 near here

Figure 3 can be used to predict interference effects, or the amount of drawdown produced in one well by the pumping of another well. Using the assumed T and S values, the head in the aquifer would be lowered 9.5 feet at a distance of 1 mile from a well pumping 1,000 gpm after 1 year, or 19 feet at 2,000 gpm. If a second producing well should be at a distance of 1 mile from the first well, this lowering of head, or drawdown, is added to the drawdown produced by its own pumping.

Because most of the city of Pensacola wells distributed throughout the metropolitan area are more than a mile apart, and are not pumped continuously, interference effects should be somewhat less than those calculated for a 1-mile spacing.

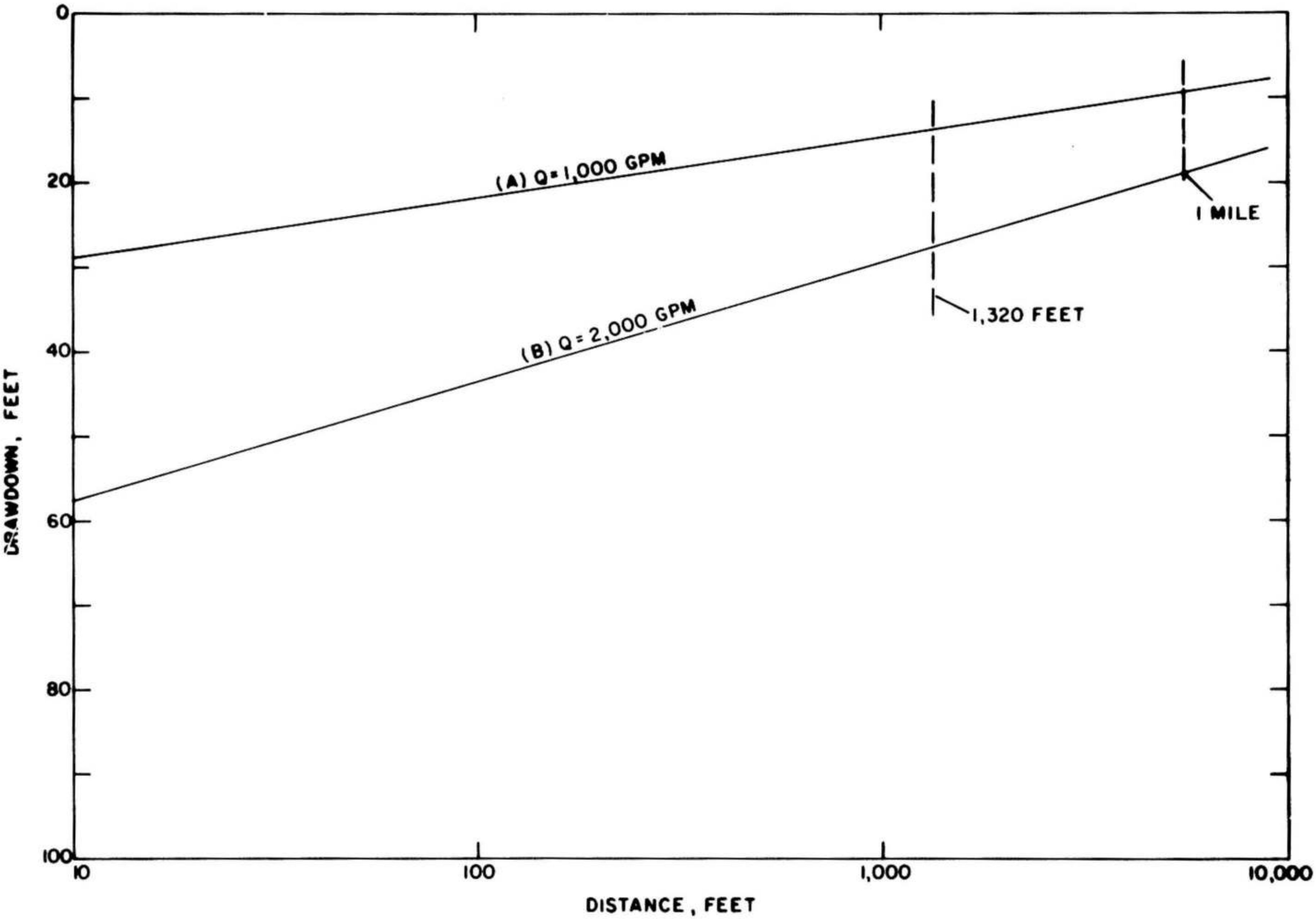

Figure 3.--Graph showing calculated drawdowns at distances of 10 to 10,000 feet from a well pumped continuously for 1 year at rates of 1,000 and 2,000 gpm.

The drawdowns shown in figures 2 and 3 are based on the assumption of no recharge. Any recharge would tend to lessen drawdown and would limit the distance at which drawdown effects could be detected. The longer the time and distance over which drawdown is to be determined, the greater the chance that recharge will substantially affect the results. In the parts of the sand-and-gravel aquifer tapped by the city of Pensacola's wells, recharge is most likely to occur as leakage from shallower parts of the aquifer through a confining bed of lower hydraulic conductivity. Assuming the T and S used in the calculations are reasonably close to actual values, the drawdowns shown in figure 2 for large values of t, and in figure 3 for large values of r, should be regarded as maximum limits rather than as accurate estimates.

In addition to the local effects of interference between wells, the question may arise as to whether there has been a general, continuing lowering of water levels. In other words, is water being mined, or withdrawn faster than it is being replenished by nature?

Long-Term Records of Observation Wells

Long-term records of observation wells show no evidence of an overall decline in water levels in the sand-and-gravel aquifer in the Pensacola area that cannot be attributed to variations in precipitation.

Under the continuing program of cooperation of the city of Pensacola and Escambia County with the U.S. Geological Survey, water levels in observation wells in the Pensacola area have been monitored for more than 30 years. The hydrographs of two representative wells, observation well 026-713-5 (State W-4991) on Alcaniz Street at Borden's Dairy and well 46 (State W-562) on the Frisco Railway right of way at Detroit Road in Ensley are shown in figure 4, together with a graph of annual precipitation at Pensacola. Well 026-713-5, constructed in 1959, is in the southeastern part of the project area, and is within a mile and a half of two operating city wells. Although the average water level in the well declined about 5 feet from 1959 to the present (1971), the beginning of the record was in a period of above-average precipitation (1958-1961). However, the period 1962-1970 had 5 years of below-average precipitation, 3 years above average, and 1 year about average (slightly above).

Fig. 4 near here

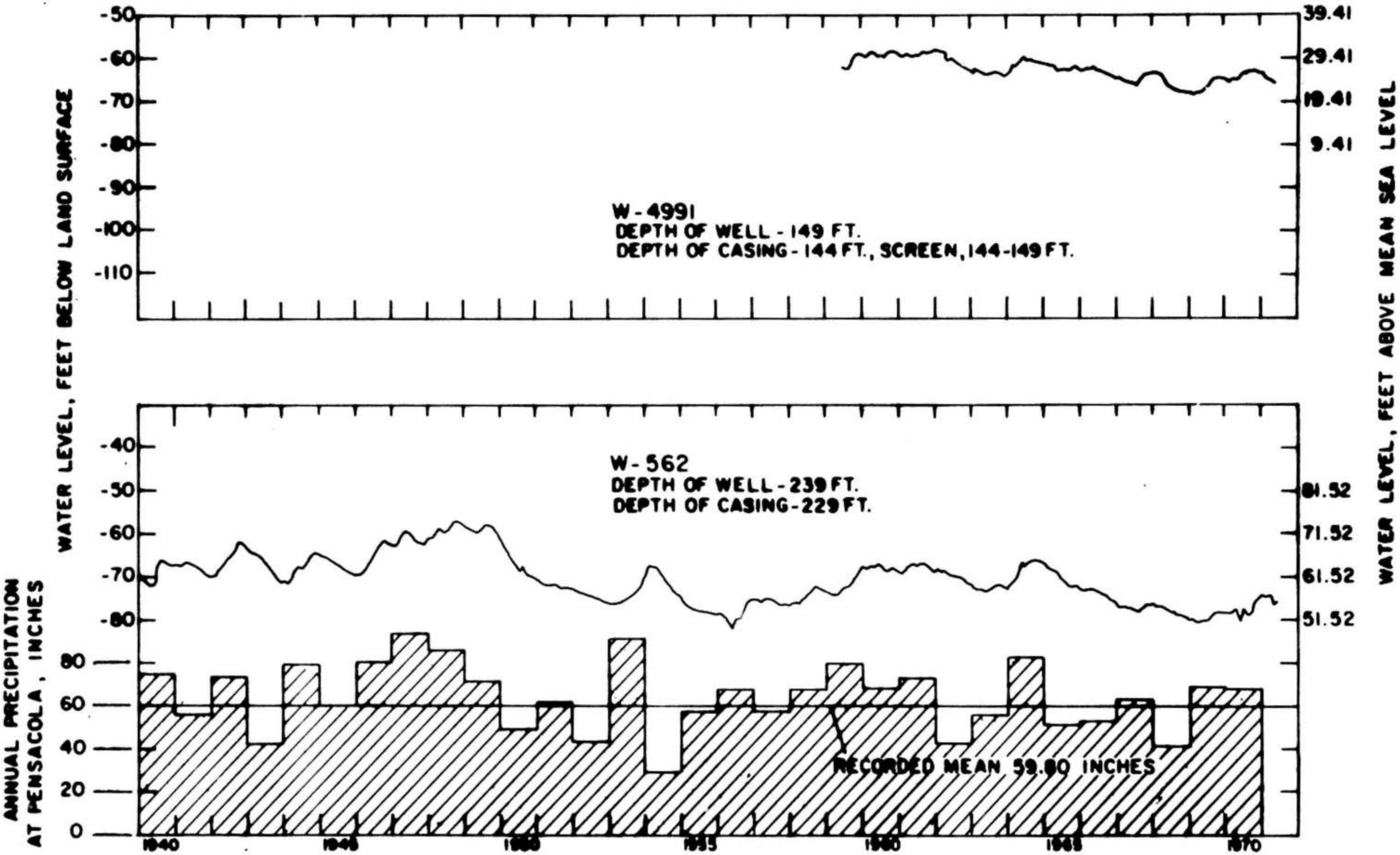

Figure 4.--Hydrographs of observation wells 026-713-5 (W-4991) and 46 (W-562).

Fig. 4

Well 46 has a continuous record from 1940 to the present (1971). The first 10 years of record had higher average water levels, but 7 of these 10 years had above-average precipitation. Although some of the decline since 1949 may be attributed to increased pumping at the St. Regis Paper Company, at Cantonment (6 miles to the north), as well as increased withdrawals for the Pensacola public supply, the effect of reduced precipitation seems adequate to explain all the decline. Since 1950, the water levels seem to have stabilized, although the Monsanto (formerly Chemstrand) plant, 3 miles to the northeast, began pumping in 1953, and the city of Pensacola, Ensley, and Broad Street wells, each less than a mile away, were drilled after 1950.

Miscellaneous Measurements

In a consulting engineering report for the city of Pensacola, John L. Snow (1958, p. 4) wrote that static levels in the Pensacola area had not generally declined in the 21 years previous to 1958. Water-level data (in feet below land surface) from a table in his report (p. 6) are compared with recent data (1970-71) in table 2.

Table 2 near here

The East Plant and 12th Avenue wells had pumps removed and had not been used for some time prior to the recent measurement. The recent static level in the 12th Avenue well is actually the top of a layer of oil on the water. If the oil is sufficiently thick, the apparent static level may be appreciably higher than the true water level in the well, since oil is lighter than water and will rise higher at a given head.

Intermittent measurements of water levels in the three city wells since 1947 and 1953 thus do now show a decline that is inconsistent with that observed in well 46.

Table 2.--Static water levels in three Pensacola municipal wells, 1947-71.

Table 2. Static Water Levels in Three Pensacola Municipal Wells, 1947-71.

City Name	Year Constructed	Static Level 1/ 2/	Nov. 1958 Static Level 2/	Recent Static Level	Date of Measurement
East Plant	1947	61	63	67.9	04-14-71
West Plant	1947	29	31	36.7	12-15-70
12th Ave.	1953	66	68	65.7	04-17-71

1/ From Layne, when constructed (?).

2/ From Snow (1958, p. 6).

Water Levels in Paired Observation Wells

During test drilling for the current project, nine shallow observation wells were constructed alongside deeper observation wells to provide information on variations in head with respect to well depth. Water levels in the nine pairs of wells are measured monthly. The water levels in all but one of the shallow wells have been consistently higher than those in the adjoining deeper wells. The exception is Test Hole 4A (84 feet deep), east of Pine Forest Road (S.R. 297), which had a water level of 31.2 feet below land-surface datum when first measured on February 10, 1971, compared with 25.9 feet in adjoining Test Hole 4 (180 feet deep). In subsequent measurements, water levels in Test Hole 4A were above those in Test Hole 4.

The greatest difference in water levels observed between adjoining wells was on Hurst Hammock Road, where the water level in Test Hole 8A (42 feet deep) was about 18 feet below land surface, contrasted with 79 feet in adjoining Test Hole 8 (198 feet deep). About 110 feet of poorly permeable silt and clay separates the shallow and deep water-bearing zones at this drill site. The shallow zone evidently discharges through springs downslope from the drill site, such as those that fill the ditches along Hurst Hammock Road. The deeper zone probably discharges into Perdido River and Perdido Bay.

A pair of observation wells (USGS Observation wells 60 and 60A) was installed in 1940 at the foot of "H" Street in Pensacola, about 90 feet north of the water's edge on Pensacola Bay. The site of these wells, together with other low lying areas along the coast, would ordinarily be discharge areas, with head increasing with depth, under natural conditions. However, the shallow well (18 feet deep) consistently had water levels higher than those in the deeper (178 feet) well. This difference in water levels probably is due to heavy pumping from the aquifer for industrial use (particularly at Newport Division of Tenneco) within a mile radius. According to Jacob and Cooper (1940, p. 63-64) Newport Industries had been pumping sufficiently to induce salt-water encroachment sometime between 1928 and 1937, as indicated by an increase in chloride content in the water pumped from their wells. The cone of depression from this pumping has expanded into parts of the aquifer underlying Bayou Chico and Pensacola Bay that may have contained saline water originally, or the cone has induced salt water to enter the aquifer by downward flow from the bays. It is likely that the cone of depression has lowered water levels in the two observation wells at the foot of "H" Street, particularly in the deeper well, which has approximately the same depth as industrial wells and likely is hydraulically connected to them.

In those areas where water levels in shallow wells are above the water levels in adjacent deeper wells, the vertical component of ground-water flow is downward, and at least that part of the ground-water body tapped by the deeper wells is receiving recharge. Thus, all this project's paired observation wells were drilled in areas of recharge. Most of the Pensacola area probably is a recharge area.

Flowing Wells

Test Hole 10, on U.S. Alternate 90 about a mile west of Elevenmile Creek, was plugged with concrete after it began flowing from a sand zone between 25 and 32 feet below land surface. The sand is both overlain and underlain by silty clay. The hydraulic head in the sand zone was about 13 feet above land surface at the drill site, indicating a local discharge area in the shallow water-bearing sand. Natural discharge outlets occur as springs in the former Scout camping area southeast of the drill site. The springs are about 60 feet above the level of Elevenmile Creek. The recharge area for this local flow system is in the area of the hilltop northwest of the drill site. If the drilling crew had been able to cement casing through the shallow water-bearing sand and drill deeper, they probably would have penetrated other sand zones in which the water levels would have been below land surface. Water levels in deeper sand zones would probably be a little above the level of Elevenmile Creek, which is about 25 feet above mean sea level. Observation well 032-724-1 (170 feet deep), about 2½ miles west of Test Hole 10, has a water level about 33 feet above mean sea level.

Wells flowing from the sand-and-gravel aquifer have been noted, in the course of well inventories for this and preceding investigations, within a mile of both Perdido and Escambia Bays. The bays and some adjoining land are discharge areas for the aquifer, where the head increases with depth. Wells drilled deep enough in these areas are likely to penetrate a zone in which the head is higher than the land surface, and the well will flow.

Other major areas of ground-water discharge in which wells drilled into the sand-and-gravel aquifer might flow include the valley bottoms of perennial streams, swamps, the edges of bayous, and parts of the shore of Pensacola Bay remote from centers of heavy pumping.

Local areas of discharge depend on the distribution of beds of varying permeability and topography. Their presence is often indicated by springs, but they cannot otherwise be predicted without detailed subsurface information.

QUALITY OF WATER

General

Natural water contains dissolved gases and dissolved and suspended mineral matter. Water in contact with soils or rocks will dissolve some mineral matter. The quantity of dissolved mineral matter in water depends primarily on the length of time and type of rocks or soil with which the water has been in contact. Ground water commonly is more highly mineralized than surface water because it remains in contact with rocks and soil for much longer periods.

As ground water percolates through the upper part of the sand-and-gravel aquifer, it encounters relatively little soluble material and remains soft and relatively unmineralized. The aquifer is composed largely of quartz sand (silica), which is not very soluble. The abundant precipitation in the Pensacola area and the high permeability of the aquifer are other factors tending to keep the ground water moving and from remaining in contact with soluble materials.

However, water in the upper sand-and-gravel aquifer contains dissolved carbon dioxide. Some of this gas may come from the atmosphere and be carried by rain into the aquifer, but most of it originates in the decay of vegetation in the soil. Carbon dioxide, when dissolved in water, forms carbonic acid (H_2CO_3). This is a weak acid, but its presence can be sufficient to make water corrosive to metals. When carbonate ($CO_3^{=}$) or bicarbonate (HCO_3^{-}) ions are present in a solution with carbon dioxide and carbonic acid, they tend to buffer the solution, or reduce the acid effect. In water from the sand-and-gravel aquifer, which is low in dissolved mineral matter including bicarbonate and carbonate, buffering is minimized, and corrosive effects are strong. Corrosion is further enhanced by the generally low iron content of the water.

Hydrogen sulfide is locally present in trace amounts in water from the sand-and-gravel aquifer. The probable source of the gas is the decomposition of organic material buried in the aquifer. Hydrogen sulfide has not been determined in chemical analyses, but its presence can be detected by its characteristic "rotten eggs" odor. As little as 1 mg/l (milligrams per liter) of water would produce a strong odor; but only faint odors have been noted in this investigation. In the concentrations encountered, the only probable adverse effect would be the odor associated with the water. In stronger concentrations it would have a corrosive effect.

Hydrogen-ion concentration is expressed in terms of pH units. The degree of acidity or alkalinity of water, expressed as pH, affects the corrosive powers of water and partly determines the proper treatment that may be necessary in water-treatment plants. A pH of 7.0 indicates that the water is neither acid nor alkaline. Readings progressively lower than 7.0 denote increasing acidity and those progressively higher than 7.0 denote increasing alkalinity. The pH of most ground water in the United States ranges from 6.0 to 8.5. The pH of water from the upper part of the sand-and-gravel aquifer is at the lower end of this range or, commonly, even lower (more acid).

The U.S. Public Health Service established standards for drinking water furnished by interstate carriers. The standards are generally used to evaluate the suitability of public-water supplies in the United States (U.S. Public Health Service, 1962). Concentrations of dissolved mineral constituents in water from the sand-and-gravel aquifer generally fall well below the maximum limits recommended by the Public Health Service except for iron, which locally exceeds the recommended limit of 300 μg/l (micrograms per liter), and fluoride, which locally (near an industrial source) exceeds the recommended limit. Nitrate is an indication of possible pollution by sewage or animal wastes, and excessive concentrations are hazardous to the health of both man and animals. The U.S. Public Health Service recommended (1962, p. 7-8) 45 mg/l as the upper limit for drinking water. No samples analyzed in the course of this investigation exceeded that limit, but concentrations approaching it were detected.

In this report, emphasis will be placed on those chemical constituents in water from the sand-and-gravel aquifer that presently cause problems or are most likely to do so in the future.

Samples were collected from the test holes drilled for this project by the following procedure: The well was first pumped with an air compressor (air lift) from the shallowest practical depth to redevelop the well and draw in fresh water. Most of the wells were then sampled by lowering a corked copper tube on a line to the approximate depth of the screen. The tube was opened by sharply jerking the line and was promptly pulled up. Wells that had water levels within the range of vacuum lift were pumped with a pitcher pump after redevelopment with the air compressor. In the wells sampled with the copper tube, it was thought that the composition of the water near the bottom of the well would be unaffected by the earlier aeration of the upper water by the compressor. The other wells were hand-pumped long enough to draw out the water standing in the casing and draw in fresh water from the aquifer.

Carbon Dioxide

Figure 5 shows the distribution of dissolved carbon dioxide in water from the sand-and-gravel aquifer in the Pensacola area, as determined from water samples taken during the current investigation. The most striking feature of the map is the generally high concentrations of carbon dioxide in the southwestern part of the area--especially south and west from the junction of Lillian Highway (S.R. 298) and Fairfield Drive (S.R. 289A). Concentrations are as high as 100 mg/l. Elsewhere in the area, concentrations are generally less than 30 mg/l.

Fig. 5 near here

A poorly defined area of comparatively low carbon dioxide concentration (less than 10 mg/l) lies north of downtown Pensacola, from Ninth Avenue (S.R. 289) northwest through the Brent area to the area west of Pensacola Boulevard (U.S. 29). Another area of low carbon dioxide lies north of the junction of Interstate 10 and Interstate 110.

Figure 5.--Map showing dissolved carbon dioxide in water from wells in the sand-and-gravel aquifer. (Figure is in pocket at end of report.)

The carbon dioxide content of the samples collected from test holes drilled for this project may have been affected by the method of sampling. Samples from Test Hole 4 (east of Pine Forest Road, S.R. 297), Test Hole 5 (on Eightmile Creek Road north of Mobile Highway, U.S. 90), and Test Hole 7 (Mobile Highway west of Elevenmile Creek) had lower carbon dioxide concentrations than water from wells in the surrounding areas. Samples from some of the other test holes also had low carbon dioxide, but there were not enough other nearby points of control to show that the low carbon dioxide concentrations in the test-hole samples were anomalous. All the test holes were redeveloped with an air compressor before sampling. This would aerate the water, remove carbon dioxide, raise the pH, and precipitate iron. On all but the two wells that could be sampled with a vacuum pump, a sampling tube was lowered to the bottom before being opened in order to avoid the aerated zone. However, it was not known how deep the aeration may have extended. The alternatives to this method were (1) to use the same type of sampler without the air compressor, which would have meant collecting a stagnant sample that had given up much of its carbon dioxide; or (2) to install a pump temporarily in each well for sampling purposes, the cost of which would have exceeded the remaining available project funds.

Differences in the carbon dioxide content of the water probably occur with increasing depth in the sand-and-gravel aquifer, but sufficient control is not available to show this difference. Preliminary carbon dioxide concentration maps were prepared, one for water from wells less than 100 feet deep, the other for water from deeper wells to determine whether a difference existed. They showed the same general pattern of carbon dioxide concentration. However, in the urban area most of the wells available for sampling are deep, large-capacity wells, and in many suburban and rural areas all the wells are shallow, so that shallow and deep points of control generally are not available in the same areas.

Nitrate

Nitrate has been found in samples of water from the sand-and-gravel aquifer as far back as 1924.

The nitrate probably originated from pollution of the ground water by human, animal, and industrial wastes. Figure 6 shows that in 1970-71, nitrate was generally absent in rural areas, except locally in those areas having fairly closely spaced houses with individual septic tanks or livestock operations. **Fig. 6 near here**

The map shows nitrate concentrations for shallow and deep wells in the sand-and-gravel aquifer. The concentrations may change with depth, but data are not available to construct additional maps of the area.

The largest area enclosed by the 1 mg/l line of equal nitrate concentration is V-shaped, extending northeast from Warrington through downtown Pensacola to the area around Ellyson Field, and northwest from Warrington along Mobile Highway (U.S. 90) to the area between Eightmile and Elevenmile Creeks along Detroit Road. Other areas containing more than 1 mg/l nitrate include a site on Dogtrack Road (S.R. 297) north of Pleasant Grove, at a shallow well (302223N0872050.1) on a pig farm (10 mg/l), and the city of Pensacola Sweeney well between U.S. 29 and S.R. 95A, about a mile north of U.S. 90A (1.9 mg/l). No other wells have been sampled for nitrate near the Sweeney well.

Figure 6.--Map showing nitrate in water from wells in the sand-and-gravel aquifer. (Figure is in pocket at end of report.)

Water with the highest nitrate concentration (44 mg/l) was obtained from a shallow private well (303108N0871901.1) on Detroit Road, just west of Pine Forest Road (S.R. 297). Possible sources of pollution include residential septic tanks and a cemetery.

A letter report (June 4, 1968) to J. A. Pounds, then Superintendent of the Pensacola Water Division, from D. A. Goolsby, U.S. Geological Survey, pointed out that wells yielding water with relatively high nitrate concentrations seemed to be centered around the downtown Pensacola area, that concentrations appeared to be increasing, and that in several city wells nitrate accounted for about 30 percent of the dissolved solids. He suggested more detailed sampling as a possible means of locating the source of the nitrate.

The nitrate analyses listed by Goolsby for water from selected wells are given in table 3, together with those from the present investigation.

Table 3 near here

Goolsby showed that nitrate concentrations in water from these city wells had increased over the years and that the concentrations were higher in 1968 than in any previous year. Analyses of water from the wells sampled by Goolsby and sampled again for the present investigation showed a continued increase in nitrate from 1968 to 1970.

Table 3.--Nitrate concentrations in water from selected municipal wells, 1957-1970.

Table 3. Nitrate Concentrations in Water from Selected Municipal Wells, 1957-1970.

Pensacola Wells	Location Number (Latitude-Longitude)	Feb. 1957 mg/l	May 1968 mg/l	1970 Present Study mg/l
"F" & Scott	302615N0871342.1	4.8	7.8	8.6
McAllister	302930N0871128.1		0.8	1.5
Burgess	302918N0871324.1		1.7	3.1
Ninth Ave.	302901N0871208.1		3.0	4.0
West	302514N0871403.1		9.9	12
"W" & Avery	302555N0871457.1		12	14
No. 9	302602N0871307.1		8.3	17

The pattern shown by the nitrate lines in figure 6 does not indicate any single source of nitrate. The nitrate concentrations roughly correspond to the concentration of population. A possible explanation for the occurrence of nitrate, in addition to septic tanks and industrial pollution, is leakage from sewer lines.

Although the nitrate lines were drawn so as to agree in general with nitrate values reported by Goolsby for water from wells not resampled in the present investigation, the control is not shown on the map because the concentrations have been changing with time. It was assumed that nitrate concentrations at these points now are at least as great as the amounts Goolsby reported.

In the southern half of the project area, more wells could be sampled for nitrate in the Warrington area, between Warrington and west Pensacola, and in the area north of Michigan Avenue (S.R. 297), west of Palafox (S.R. 95A), and east of Pine Forest Road (S.R. 297).

Iron

Concentrations of dissolved iron in water from the sand-and-gravel aquifer in the Pensacola area locally exceed the limit of 300 μg/l recommended by the U.S. Public Health Service (1962, p. 7-8) for drinking water.

Figure 7 shows the occurrence of various concentrations of iron in the sand-and-gravel aquifer by means of symbols. Although some of the iron occurs naturally in the ground water, much iron in water originates in the corrosion of the casing and other metallic well parts. Differences in iron concentrations in water samples may be caused by differences in well construction, age of the well, corrosiveness of the water, and length of pumping before sampling, as well as by differences in the natural iron concentration in the ground water.

Fig. 7 near here

Figure 7.--Map showing dissolved iron in water from wells in the sand-and-gravel aquifer. (Figure is in pocket at end of report.)

Whatever the origin of iron in water, the concentrations can vary substantially in water from wells within a short distance of each other, or from different depths at the same location. Therefore, it was not considered practical to show the iron values on figure 7 by means of lines of equal concentration. Instead, symbols were superimposed over each well symbol, showing the approximate concentration. The symbols representing the two lowest concentration ranges indicate water meeting U.S. Public Health Service's drinking water standards.

Although the iron content in a sample from an isolated well may not be representative of the iron concentration in the ground water of the surrounding area, samples from several wells in the same area, all yielding water low in iron, would give a good indication of low iron concentration in the ground water. High iron concentrations in water from recently drilled wells or from wells with plastic casing should be a reliable indication of a large amount of iron in the ground water. In figure 7, areas have been outlined in which all the wells sampled yielded water containing 300 μg/l or less of iron. These areas include downtown Pensacola and northwest along Mobile Highway (U.S. 90) and three smaller areas north of downtown Pensacola.

TEST DRILLING PROGRAM

Ten test holes were drilled for this investigation to depths of 170 to 200 feet and cased as observation wells with 2-inch pipe and a 3- to 4-foot screen. Adjoining these were nine shallower (30- to 85-foot) observation wells cased with 1½-inch flexible plastic tubing, with 2- to 3-foot screens. One test hole was drilled to 32 feet and plugged because of a flow of water that was unanticipated and possibly would have proved difficult to control. Most of the test holes were drilled near potential future municipal well sites; others were drilled in areas where additional data were most needed concerning the hydraulic characteristics of the aquifer and quality of the ground water.

Methods Used

A hollow-stem auger was used initially, with split-spoon drive cores taken at frequent intervals, but it was necessary to shift to NX size wire-line equipment, with about three drive cores taken per hole. Holes drilled in the sand-and-gravel aquifer would not stay open, and it was not practical to keep an electric logger on the job for each hole. Therefore, the holes were cased, and radioactivity logs were obtained at a later date. Radioactivity logging, unlike electrical logging, can be done through a well casing. The holes were developed as observation wells by backwashing with the mud pump on the drill rig and later pumping with an air compressor.

Radioactivity Logging

The two types of radioactivity logs obtained during the Pensacola project were the gamma-ray and neutron logs. The gamma-ray log shows the natural gamma radiation of the material penetrated and is plotted on a scale with radioactivity increasing to the right. In general, clay and shale are more radioactive than clean sand and gravel; and so the log can be used to interpret the types and thicknesses of material penetrated (Schlumberger Ltd., 1969, p. 53-55).

The neutron log provides a measure of the hydrogen content of the formation. Hydrogen content is a function of the amount of water present in water-saturated material, and this, in turn, depends on the porosity of the material and the amount of water absorbed or bound up chemically in it. The neutron probe utilizes a radioactive source and a detector. The source bombards the formation opposite the device with neutrons. When the hydrogen concentration of the material surrounding the neutron source is large, most of the neutrons are slowed down or captured within a short distance of the source. The neutron count at the detector increases for decreased hydrogen concentration (therefore, decreased water) and decreases as the hydrogen concentration increases.

Increased water content is shown by deflection to the left on the neutron log. Clay beds have a high water content and, therefore, are represented by deflections to the extreme left on the neutron log. Dense materials with very low porosity are depicted by deflections to the right. In the sand-and-gravel aquifer, these dense materials might be hard-pan layers. Sand falls between these extremes. Sand with either a high-effective porosity or high-clay content causes deflections to the left on the log. Thus, the neutron log must be interpreted in conjunction with a gamma-ray log showing the degree of "cleanness" of sand beds (Schlumberger Ltd., 1969, p. 47-51).

A qualitative interpretation method, adapted from one originally developed by the Lane-Wells Company (McGaha, Mellies, and Terry) for oil-bearing limestone, has been applied to the project's gamma-ray and neutron logs. A vertical line is drawn on the gamma-ray log 20 percent of the distance between the minimum and maximum radioactivities recorded on the log (Appendix, Test Hole 1). This is labeled "20% Gamma Reference Lane," and the parts of the curve to the left of the line represent the cleanest sand zones. Similarly, a line is drawn on the neutron log half way between the maximum and minimum values below the top of the water-saturated zone (approximately the water table), where the neutron curve is deflected sharply to the right. This is the "50% Neutron Reference Line." The parts of the neutron curve representing the highest water saturation are to the left of this line. These parts of the curve represent clay, clayey silt, and clayey sand as well as sand with high effective porosity. However, those zones that are represented both on the gamma-ray log by deflections to the left of the 20% Gamma Reference Line and on the neutron log to the left of the 50% Neutron Reference Line are potentially the most productive sand zones in the well. In the descriptions of the logged wells in the Appendix, the location and net thickness of the potentially most productive sand is cited for each where possible. Quantitative values of porosity cannot be assigned to these zones from the logs, but when core analysis data are available, quantitative estimates can be made by comparing curve deflections to measured porosities.

If the maximum and minimum values on the gamma-ray and neutron logs for each of the logged holes are assumed to represent the same values of natural radioactivity and hydrogen concentration, respectively, the number of feet of potentially most productive sand in each hole could be considered a direct indication of the potential yield of a well constructed at each site. The relative potential yields to wells at the sites of the logged holes are tentatively compared in the Appendix, although such an assumption is probably not strictly justified.

SUMMARY AND CONCLUSIONS

1. Nonpumping water levels in wells in the Pensacola area are often substantially lower than the water table. Drawdown values recorded during short pumping tests of city wells are broadly consistent with computed values based on average aquifer characteristics derived from long pumping tests.

2. Long-term records of water levels in wells show little evidence of change that cannot be attributed to variations in precipitation.

3. The highest concentrations of dissolved carbon dioxide in water from the sand-and-gravel aquifer appear to be localized in the south-western part of the project area--south and west of the intersection of Fairfield Drive (S.R. 289A) and Lillian Highway (S.R. 298). Elsewhere, trends of carbon dioxide concentration are poorly defined, but areas of low concentration appear to be centered north of downtown Pensacola and north of the junction of Interstate Highway 10 and Interstate 110.

4. The concentration of nitrate in water from the sand-and-gravel aquifer can be approximately correlated with the concentration of population. Available data do not indicate a single source of nitrate pollution. Concentrations of nitrate have increased over the years. Leakage from sewers may be a source as well as septic tanks and industrial pollutants.

5. The lowest concentrations of dissolved iron in ground water are found in wells in downtown Pensacola, three small areas north of downtown, and northwest of Pensacola along the Mobile Highway (U.S. 90).

6. Radioactivity logs, cuttings, and water analyses show the following test hole sites to be favorable for construction of large-capacity wells: Test Hole 2 (Hollywood Avenue north of Fairfield), Test Hole 5 (Dunaway Lane at Eightmile Creek Road), Test Hole 6 (David Street at Barranger Street), and Test Hole 7 (Mobile Highway opposite James Road).

Test Hole 1 (Gonzalez Street at 17th Avenue) would be considered a favorable site except for the possibility of salt-water encroachment. The site of Test Hole 9 (east of Dogtrack Road (S.R. 297) at Ferguson Flying Service) probably would be adequate as to quantity, but the quality of water from the test hole is poorer than in other wells tested. Test Hole 3 (72nd Avenue south of Jackson Road (S.R. 298A)) and Test Hole 11 (Dogtrack Road) are considered marginal sites because the test holes penetrated less clean sand or gravel than in Test Holes 1, 2, 5, 6, and 7.

Test Hole 4 (east of Pine Forest Road (S.R. 297), Kersey Street at Reeders Lane) and Test Hole 8 (Hurst Hammock Road) are unfavorable sites for large-capacity wells because of insufficient thickness of clean sand or gravel below the probable level of pumping.

The site of a test hole drilled for a previous study, well 032-724-1 (east of the intersection of Mobile Highway and U.S. Alternate 90), appears favorable for a large-capacity well.

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APPENDIX

Records and Logs of Test Holes and Wells

Interim Report, June 1971

AVAILABILITY OF GROUND WATER FOR PUBLIC-WATER SUPPLY IN THE PENSACOLA AREA, FLORIDA

By

Henry Trapp, Jr.

OPEN-FILE REPORT

72002

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
CITY OF PENSACOLA
through
BUREAU OF GEOLOGY
FLORIDA DEPARTMENT OF NATURAL RESOURCES

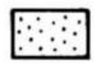
Tallahassee, Florida

1972

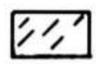
APPENDIX

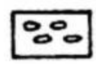
Records and Logs of Test Holes and Wells

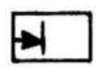
The accompanying logs are graphic representations of the materials and conditions encountered in drilling, sampling, and geophysical testing of the test holes and wells discussed. The following symbols are used throughout this Appendix.

Sand: 

Clay or Shale: 

Silt: 

Gravel or scattered pebbles: 

Core sampling points: 

Test Hole 1 (302541N0871145.1)

Test Hole 1 was drilled at a park at the northeast corner of Gonzalez and 17th Streets using a hollow-stem power auger (fig. 1). The logs indicate that the site is favorable for a large-capacity well; however, there is a strong possibility of eventual salt-water encroachment in the aquifer.

Split-spoon samples were taken at 5-foot intervals initially, but increasing difficulties in sampling and "making hole" resulted in fewer samples being taken at depth, with none below 140 feet. Predominately medium- to coarse-grained sand extends from land surface to 75 feet, fine to medium sand, somewhat more silty and clayey, from 75 to 114 feet, and medium-grained, clean sand below 114 feet. Twenty-four feet of potentially most productive sand were delineated by the combination of gamma-ray and neutron logs at depths between 143 and 193 feet (unfortunately no split-spoon samples were taken in this range). The logged-aquifer section compares favorably to that delineated by the logs of the other holes, and the drill was still in sand at the bottom. It appears that a large-capacity well could be located near this site.

The test hole site is about a quarter of a mile from salt water in the Bayou Texar and the static-water level in the well is about 4 feet above sea level. Heavy pumping in this area could induce salt-water intrusion.

Assuming that $T = 10{,}000\ ft^2\ day^{-1}$, $S = 5.5 \times 10^{-4}$, and $r = 1$, the drawdown in a 100-percent efficient well after 1 year of continuous pumping would be about 35.9 feet at 1,000 gpm and 71.8 feet at 2,000 gpm (fig. 1). At these rates, the pumping level for a well at the site of Test Hole 1 would be about 31.9 and 67.8 feet below sea level, respectively.

From figure 3, the calculated drawdown at 1,320 feet from a pumped well (or one quarter of a mile, which would equal the distance from Test Hole 1 to the edge of Bayou Texar) would be 13.9 feet after pumping 1,000 gpm for 1 year or 27.8 feet for 2,000 gpm. Thus, a hydraulic gradient would be established from the bayou toward the well, and salt water would tend to move toward the well. The degree of salt-water encroachment would depend on the permeability of the material underlying the bayou; if the permeability is low, the flow of salt water into the aquifer would be proportionately low.

A water sample taken on April 15, 1971, from the test hole had a pH of 7.4, unusual for the sand-and-gravel aquifer in being slightly alkaline. The carbon dioxide content was 6.0 mg/1, lower than average. Provided that the composition of the sample was not affected by prior pumping with the air compressor, the water from this site should be substantially less corrosive than most of the water sampled from the sand-and-gravel aquifer. The iron content was zero.

Well name: U.S.G.S. TH 1

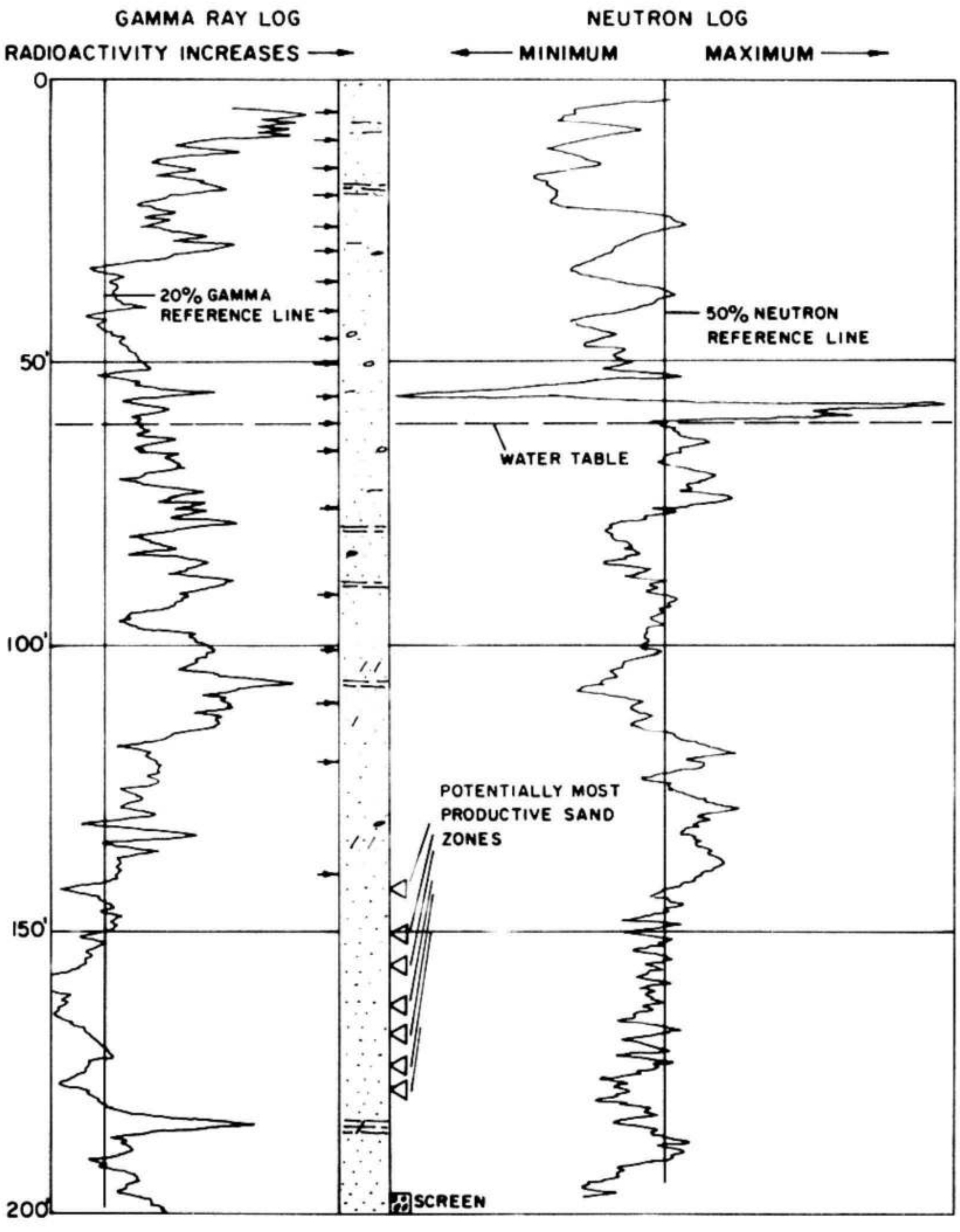
Location Number: 302541N0871145.1

Location Description: Gonzalez at 17th Ave.

Alt. LSD: 62 feet Diam.: 2 inches

Depth: 202 feet Depth to top of screen: 199 feet

Water level: 58.36 feet below LSD Date meas.: 4/16 1971



Test Hole 2 (302643N0871536.1)

Test Hole 2 was drilled on the east edge of Hollywood Avenue, 0.37 mile north of Fairfield Drive (S.R. 289A) at a drive into a sandpit (fig. 1). The first hole at this site was drilled with hollow-stem auger tools, but it was abandoned when the tools became stuck. The drillers changed to NX tools, which were used for the rest of the drilling, and the lithologic log is a composite from several holes drilled within a few feet of each other. The site appears favorable for a large-capacity well.

Medium- to coarse-grained sand extends from the surface to 51 feet, including 15 feet of potentially most productive sand which, however, is too close to the water table to be screened in a heavily-pumped well. The next clean sand extends from 104 feet to about 185 feet, below which, according to the drillers, the material is silty or clayey. A sample at 200 feet consists of very fine-grained, weakly consolidated sandstone, with a clayey silty matrix. The zone from 104 feet to the bottom of the radioactivity logged section at 170 feet contains 20 feet of potentially most productive sand.

The water sample taken April 8, 1971, had a pH of 6.3 and contained 7.5 mg/l dissolved carbon dioxide, which would indicate a somewhat lower corrosiveness than most waters tested from the sand-and-gravel aquifer. The iron content was 200 μg/l.

Well Name: U.S.G.S. TH 2

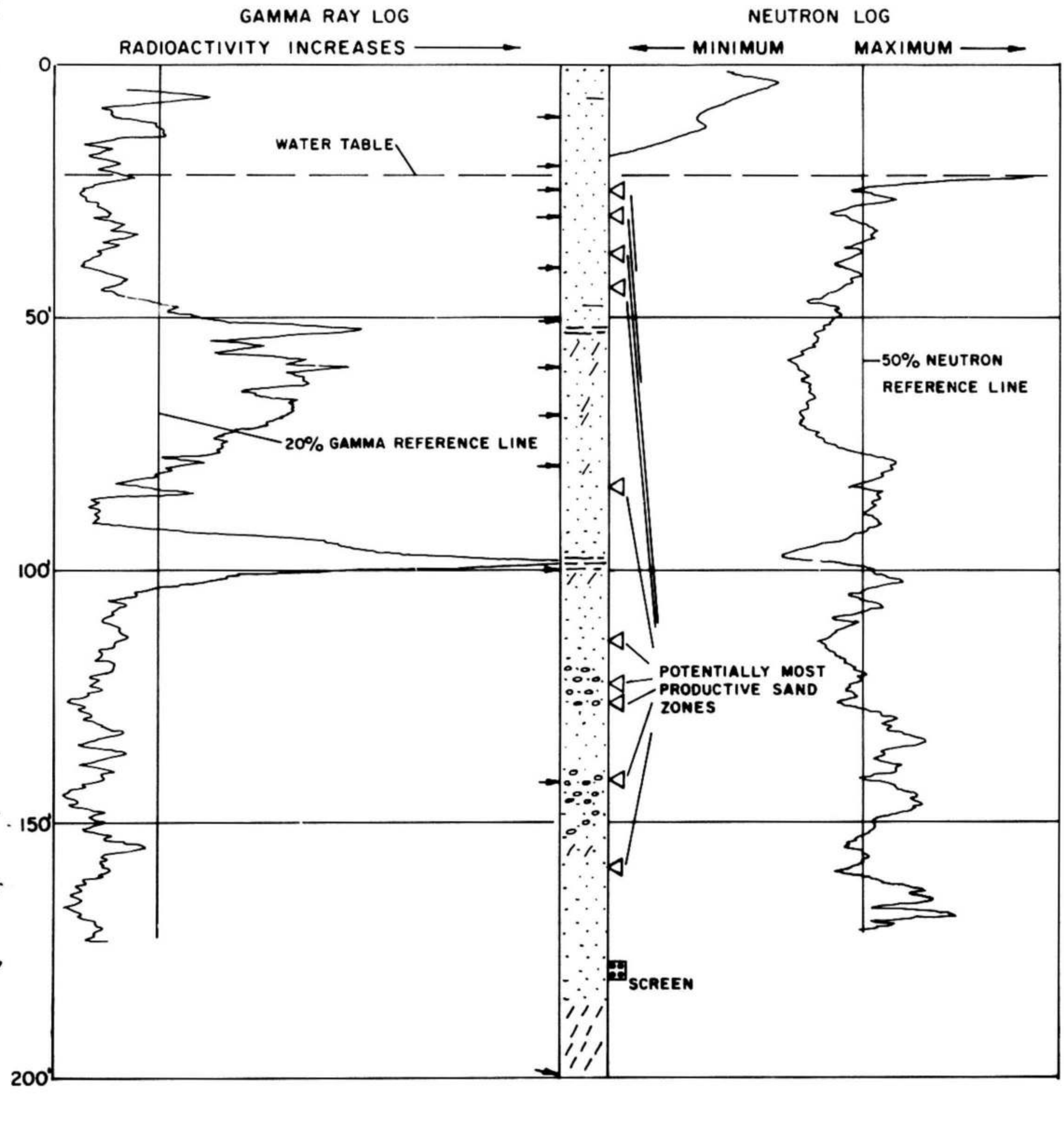
Location Number: 302643N0871536.1

Location Description: Hollywood Ave., 0.37 mi. N. of Fairfield

Alt. LSD: 62 feet Diam.: 2 inches

Depth: 179 feet Depth to top of screen: 176 feet

Water level: 23.97 feet below LSD Date meas.: 4/16 1971



Test Hole 3 (302432N0871826.1)

Test Hole 3 was drilled on the east side of 72nd Avenue, 0.58 mile south of Jackson Street (S.R. 289A, fig. 1). The site appears marginal for location of a large-capacity well.

Three split-spoon samples were taken. These, together with the driller's, gamma-ray, and neutron logs indicate predominately medium-grained sand from the surface to about 70 feet, fine sand from 70 to 102 feet, a silty zone from 70 to 125 feet, medium-grained sand from 125 to 164 feet, and fine sand to bottom at 200 feet. Although the cuttings and drilling rates gave the impression, at the time the hole was drilled, that the site was a favorable location for a high-capacity well, only 6 feet of sand were delineated by the radioactivity logs as being potentially most productive sand zones, including 2 feet just below the static-water level. The neutron curve indicates relatively low-water content opposite the cleaner sand zones delineated by the gamma-ray log. The logged section appears similar to that in the Montclair No. 1 well, (4.5 miles to the northeast) although Test Hole 3 appears to be slightly more favorable.

The water sample taken April 8, 1971, had a pH of 5.9 and a dissolved carbon dioxide content of 8.0 mg/l so that the water is slightly less corrosive than average for waters from the sand-and-gravel aquifer. The iron content was 390 µg/l.

Well Name: U.S.G.S. TH 3

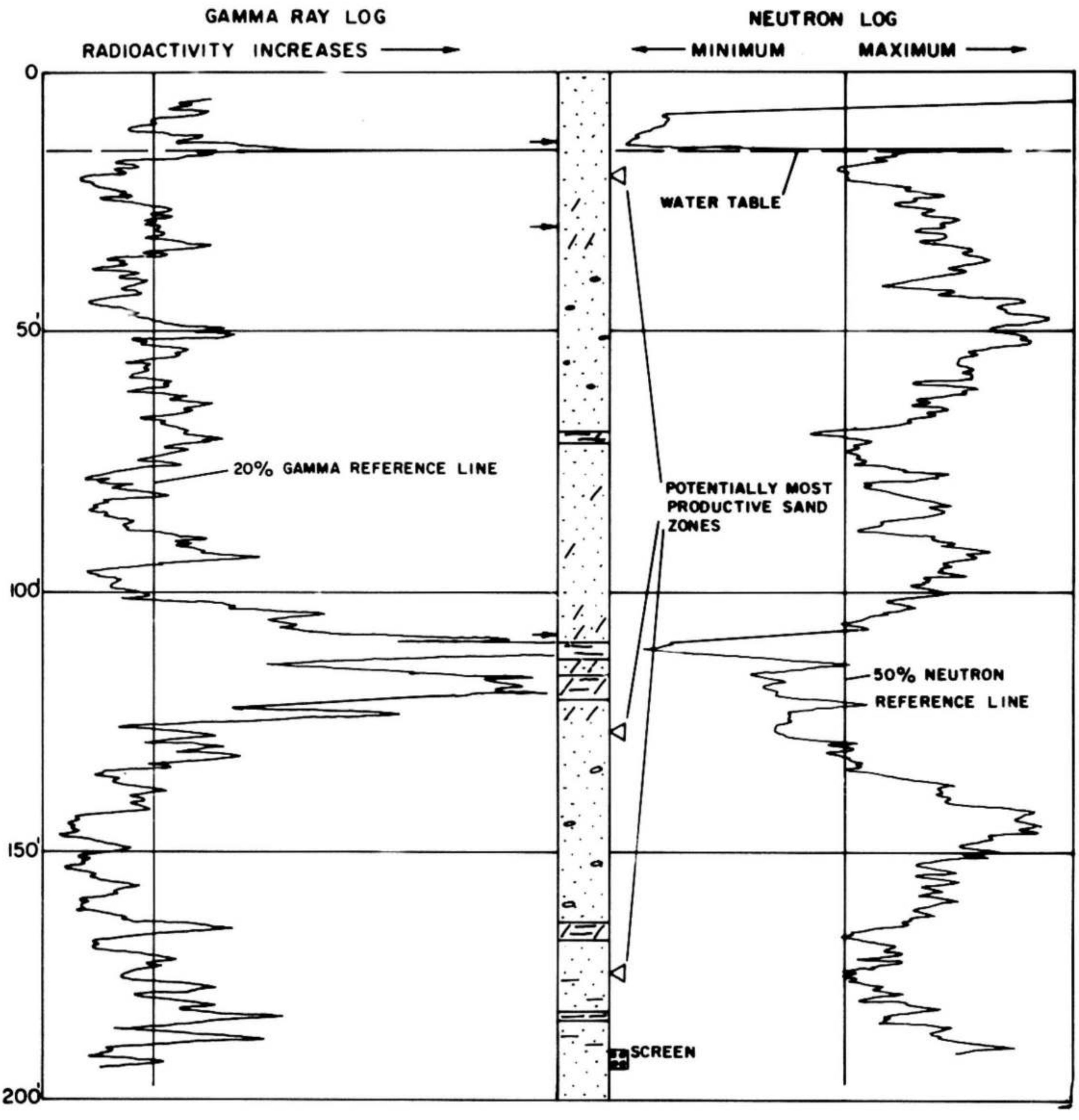
Location Number: 302432N0871826.1

Location Description: 72nd Ave. W., 0.58 mi. S of Jackson

Alt. LSD: 31 feet Diam.: 2 inches

Depth: 195 feet Depth to top of screen: 191 feet

Water level: 14.12 feet below LSD Date meas.: 4/15 1971



Test Hole 4 (303043N0871822.1)

Test Hole 4 was drilled 0.22 mile east of Pine Forest Road (S.R. 297), at the corner of Kersey Street and Reeders Lane (fig. 1). The site appears unfavorable as a location for a large-capacity well.

Six split-spoon samples were taken. The hole penetrated medium-grained sand with interbedded clay from the surface to 22 feet, then fine sand with some silt to 44 feet, of which 15 feet were indicated as being potentially most productive sand by the radioactivity logs, very fine sand, clay, and silt to 55 feet, fine sand to 101 feet, of which 15 feet were potentially most productive, a clayey zone 101 to 112 feet, then predominately fine- to medium-grained sand to the maximum depth reached of 200 feet. In the lower sand, only 3 feet were indicated as being potentially most productive.

The radioactivity logs of this well give a more favorable picture of the site than that obtained by split-spoon samples, cuttings, and drilling behavior. However, most of the potentially most productive sand is not far below the static-water level, where it would not be practical to screen a large-capacity well.

The water sample collected April 14, 1971, had a pH of 7.1 (higher than average) and contained 8.8 mg/l (lower than average) of dissolved carbon dioxide. The iron content was zero.

Well Name: U.S.G.S. TH 4

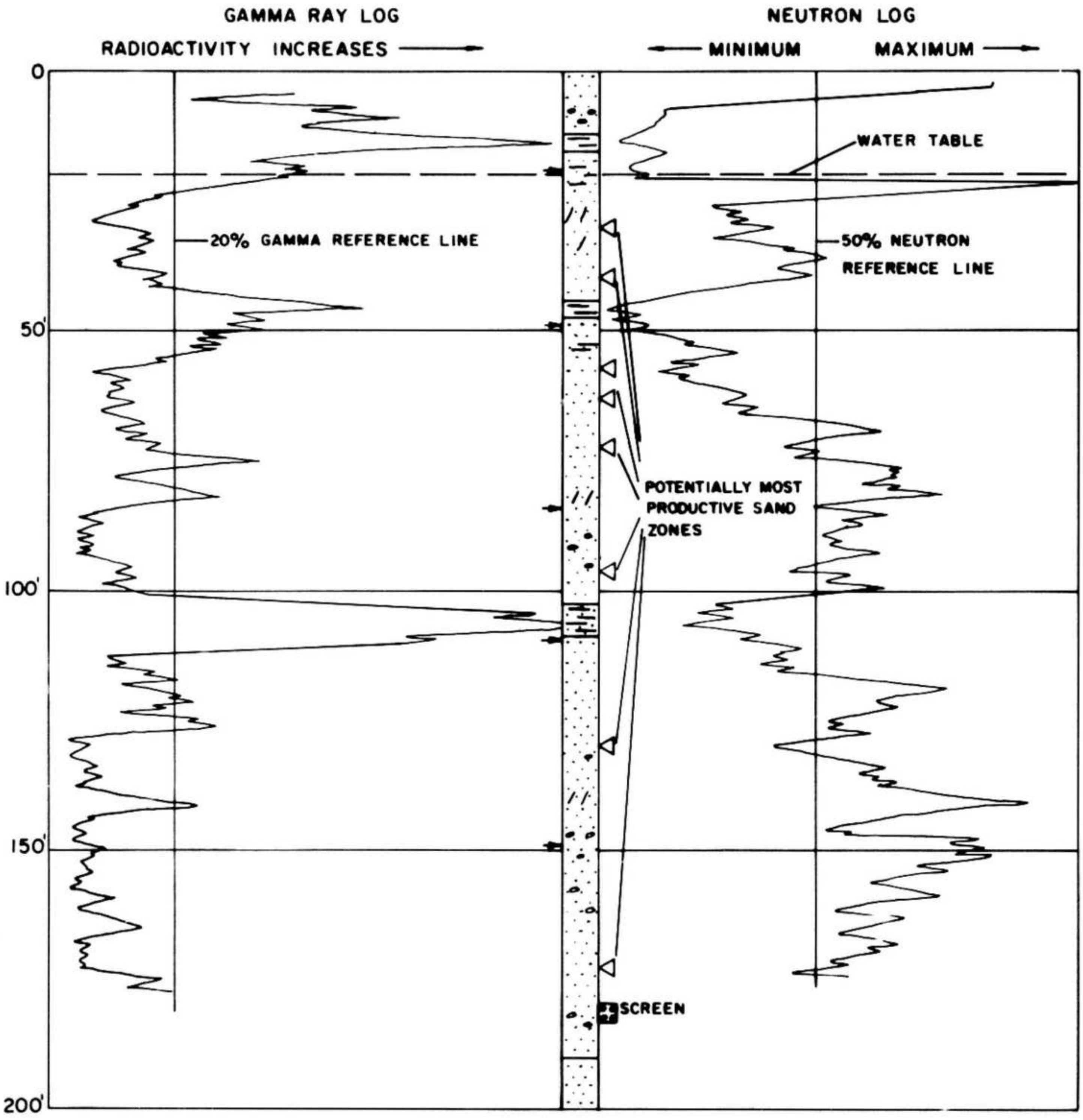
Location Number: 303043N0871822.1

Location Description: Kersey St. at Reeders Lane, 0.22 mi. E. of Pine Forest Road

Alt. LSD: 74 feet Diam.: 2 inches

Depth: 180 feet Depth to top of screen: 176 feet

Water level: 25.85 feet below LSD Date meas.: 4/13 1971



Test Hole 5 (303018N0871922.1)

Test Hole 5 was drilled at the intersection of Eightmile Creek Road and Dunaway Lane, north of Mobile Highway (U.S. 90, fig. 1). From the radioactivity logs as well as the driller's log, this site appeared to be one of the most favorable for a large-capacity well.

Three split-spoon samples were taken. Fine sand interbedded with clay extends to 28 feet, underlain by fine- to medium-grained sand, with a 6-foot clay break at 65 feet. Below this is sand and gravel (except for clay and silt, 120-130 feet) to the total depth of 180 feet. Drilling, still in sand and gravel, was discontinued because the drilling fluid was leaking into the porous aquifer as fast as additional water could be hauled to the site.

There are 87 feet of potentially most productive sand; of which 33 feet are more than 72 feet (estimated drawdown) below the static-water level. The logs were run to only 171 feet, and the chances are that additional productive sand lies below the bottom of the hole.

A water sample collected April 14, 1971, had a pH of 7.2 (unusually high), carbon dioxide content of 5.0 mg/l (unusually low), and an iron content of 20 μg/l. Samples from shallower wells in the area have had CO_2 values in the range 16-32 mg/l, and pH values of 4.9-5.2. A sample from Test Hole 5A, a 59-foot well adjoining Test Hole 5, had a pH of 6.6 and CO_2 of 8.3 mg/l.

Well Name: U.S.G.S. TH 5

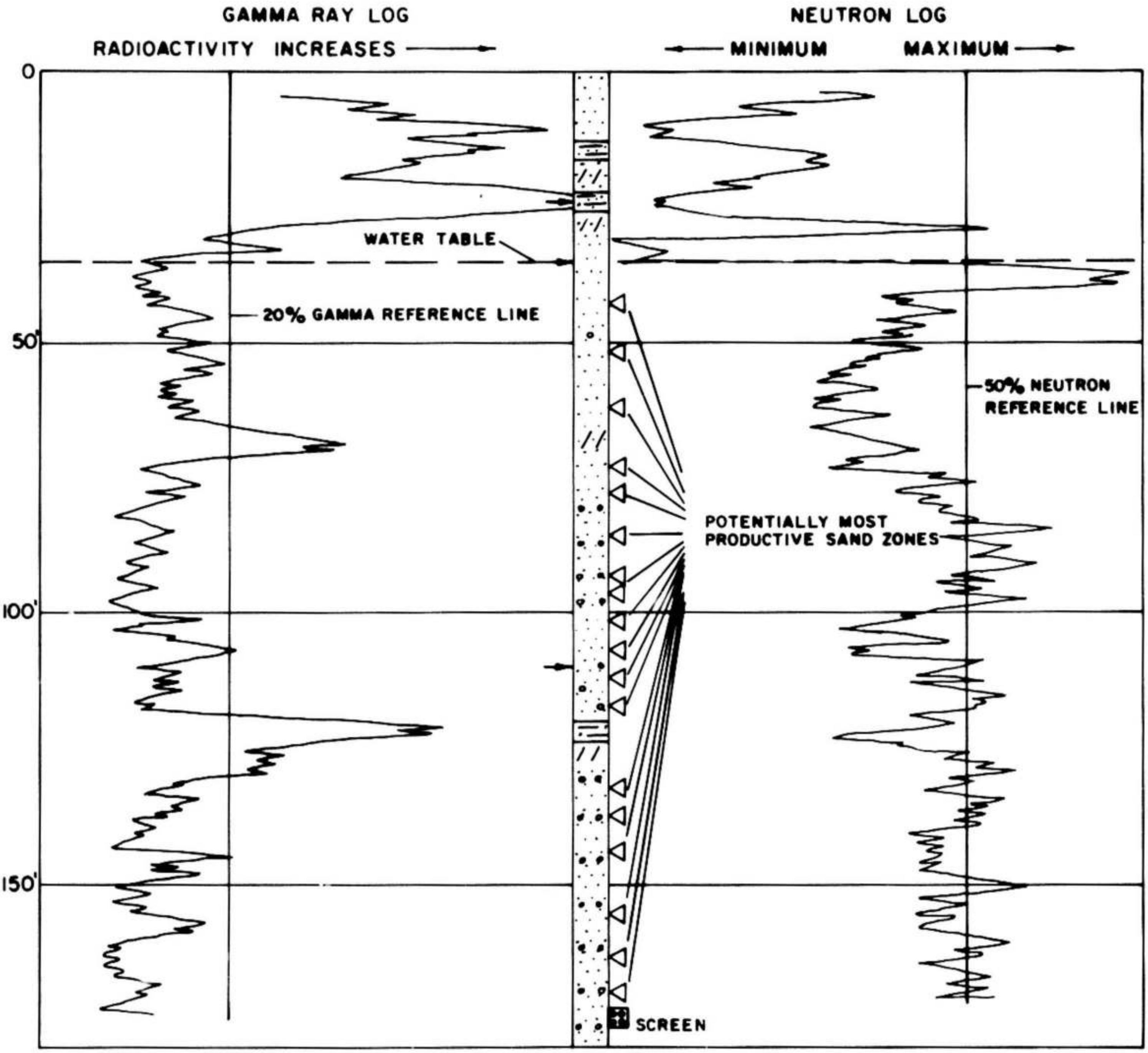
Location Number: 303018N0871922.1

Location Description: Dunaway Lane at Eight-Mile Creek Road

Alt. LSD: 77 feet Diam.: 2 inches

Depth: 177 feet Depth to top of screen: 173 feet

Water level: 40.19 feet below LSD Date meas.: 4/13 1971



Test Hole 6 (303208N0871327.1)

Test Hole 6 was drilled at the corner of Barranger Lane and David Street north of U.S. Alt. 90 and east of Scenic Hills Country Club (fig. 1). The site appears to be favorable for a large-capacity well.

Three split-spoon samples were taken. The test hole penetrated fine- to medium-grained sand from land surface to 46 feet, then clay to 51 feet. Fine- to medium-grained sand extends from 51 to 125 feet, except for a silty zone 90-94 feet. Another silty zone extends from 125 to 135 feet, then fine to coarse sand and gravel to the bottom at 170 feet. The test hole was stopped at this point because of a mud-pump breakdown on the rig. The hole was bottomed in a productive part of the aquifer; additional productive material undoubtedly lies below 170 feet.

Thirty-seven feet of potentially most productive sand are indicated by radioactivity logs down to 158 feet, the maximum depth logged. Of these, 14 feet are more than 72 feet (estimated drawdown) below the static-water level.

In a water sample collected April 14, 1971, the pH was 8.2 (much higher than average for the aquifer), the carbon dioxide concentration was zero, and the dissolved iron concentration was 70 μg/l. Water from the adjoining 44-foot Test Hole 6A, had a pH of 7.0 and 11 mg/l of carbon dioxide. It appeared rusty, but contained no dissolved iron. In contrast to the above, water from the Scenic Hills Country Club well (Florida State Board of Health, April 3, 1968) had a pH of 5.0 and carbon dioxide content of 80 mg/l. Water from other wells south and east of Test Hole 6 had CO_2 concentrations of 9 to 19 mg/l, and pH ranging from 4.9 to 6.4.

Well Name: U.S.G.S. TH 6

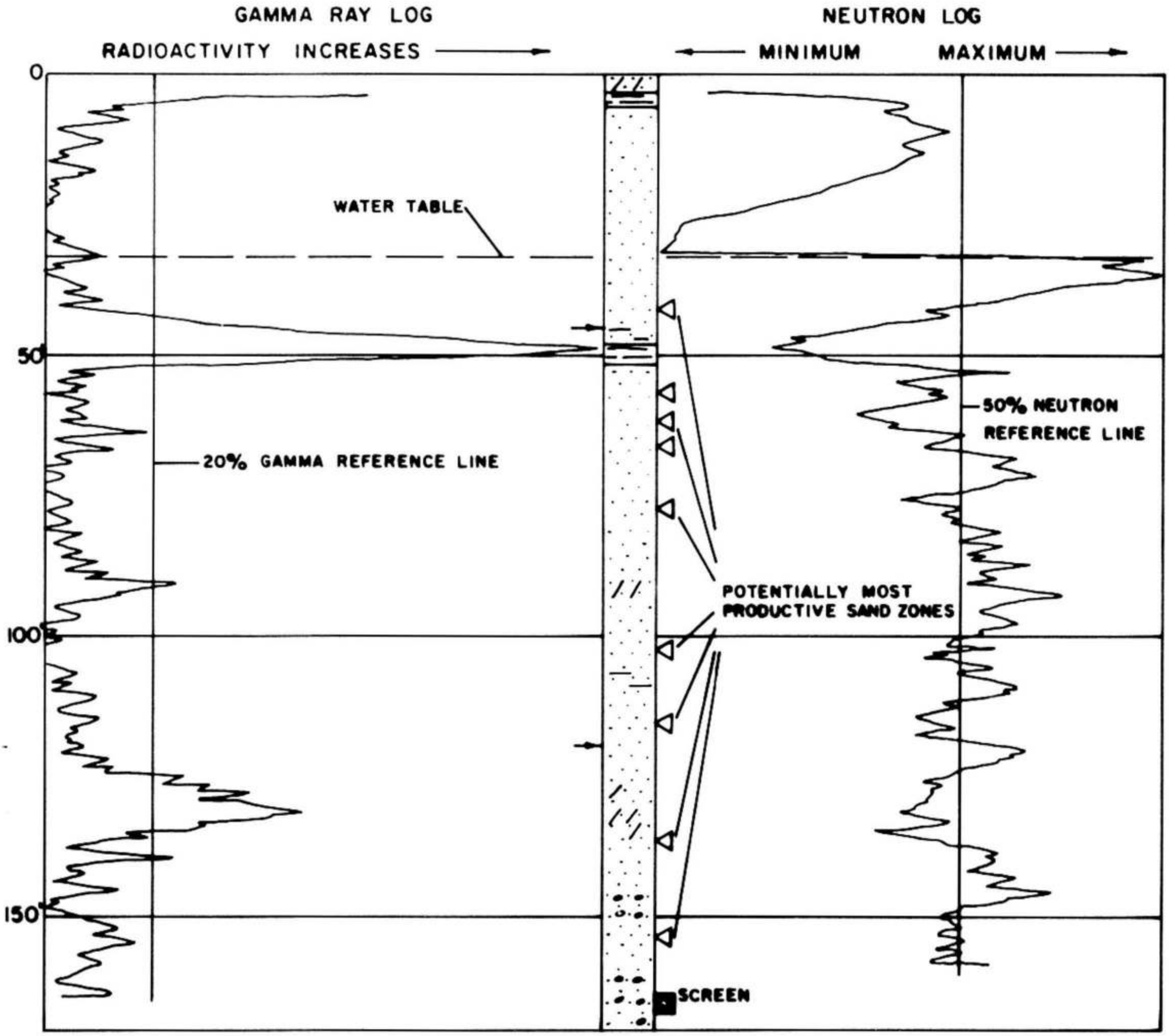
Location Number: 303208N0871327.1

Location Description: David St. at Barranger St.

Alt. LSD: 41 feet Diam.: 2 inches

Depth: 166 feet Depth to top of screen: 162 feet

Water level: 32.69 feet below LSD Date meas.: 4/16 1971



Test Hole 7 (303006N0872052.1)

Test Hole 7 was drilled south of Mobile Highway (U.S. 90), just east of the intersection of James Road (fig. 1). The site appears to be favorable for a large-capacity well, although not quite as favorable as Test Hole 5, in the same general area.

Four split-spoon samples were taken. The test hole penetrates fine- to medium-grained sand, interbedded with silt and clay, from land surface to 76 feet. From 76 to 141 feet is very fine to coarse sand, with some gravel. Silt extends from 142 to 153 feet, and is underlain by fine- to medium-grained sand with local streaks of red clay and silt. The radioactivity logs indicate 43 feet of potentially most productive sand of which 22 feet are more than 72 feet (estimated drawdown) below the static-water level.

A water sample collected April 14, 1971, had a pH of 6.5 and contained 6.3 mg/l of dissolved carbon dioxide. There was no dissolved iron. Water from other wells in the area had 12 to 28 mg/l dissolved carbon dioxide, and a pH range of 5.2 to 6.3.

Well Name: U.S.G.S. TH 7

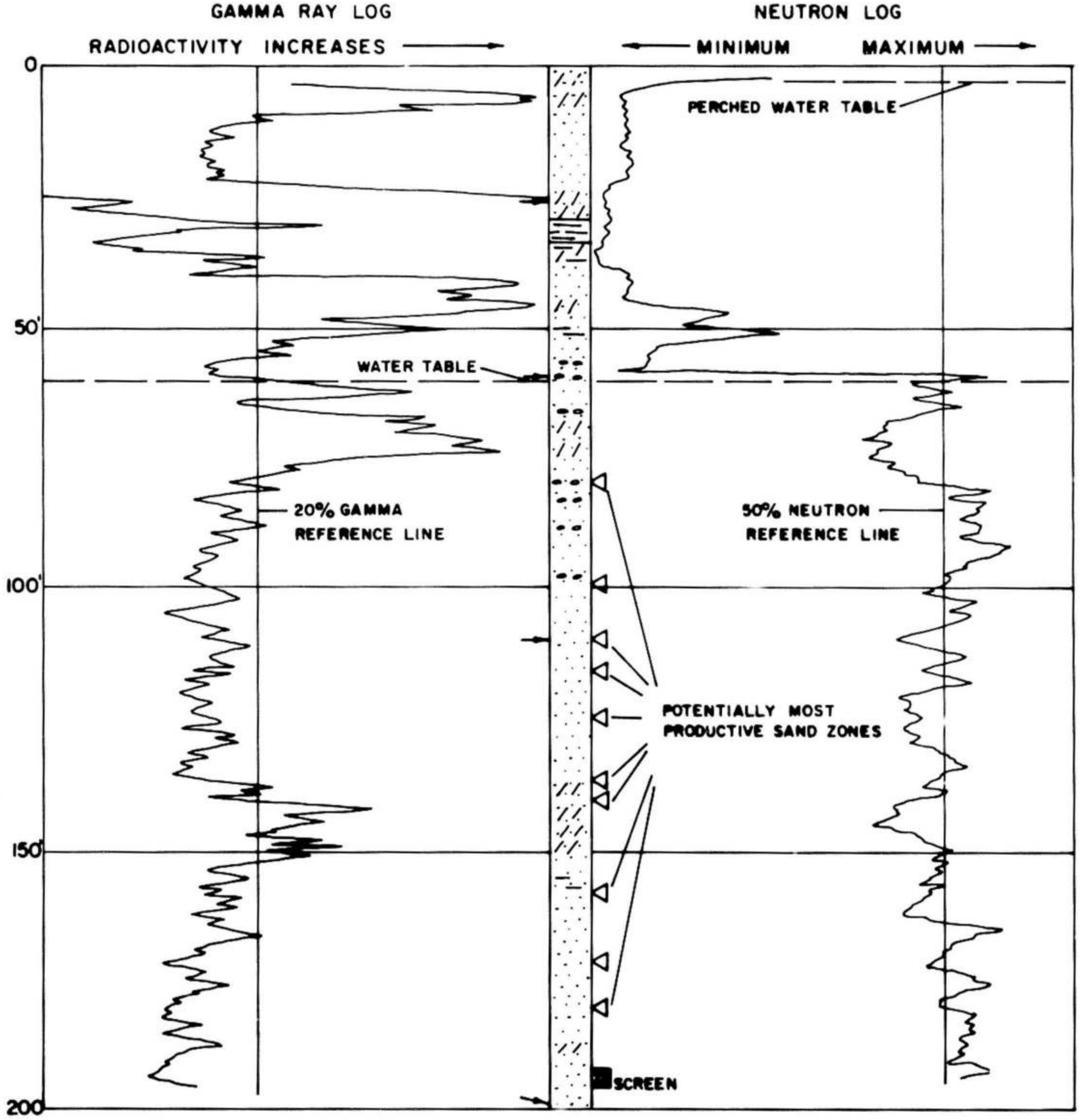
Location Number: 303006N0872052.1

Location Description: S. of Mobile Hwy., 156' E. of James Rd.

Alt. LSD: 89 feet Diam.: 2 inches

Depth: 196 feet Depth to top of screen: 192 feet

Water level: 59.64 feet below LSD Date meas.: 4/13 1971



Test Hole 8 (302958N0872300.1)

Test Hole 8 was drilled on Hurst Hammock Road, 1.4 miles south of Mobile Highway (U.S. 90, fig. 1). The section penetrated is relatively unfavorable for a large-capacity well.

Four split-spoon samples were taken. The test hole penetrates fine- to medium-grained sand from land surface to 32 feet, interbedded silt, clay, and silty sand to 167 feet, and medium-grained sand with thin clayey streaks to bottom at 200 feet. Because of time limitations and the known unfavorable section, no neutron survey was run. From the gamma-ray log, it is estimated that the potentially most productive sand thickness could be no more than 15 feet, although the sand could extend substantially below the 200-foot depth.

A water sample taken April 9, 1971, had a pH of 6.6 and dissolved carbon dioxide content of 15 mg/l. The dissolved iron concentration was 700 μg/l.

Well Name: U.S.G.S. TH 8

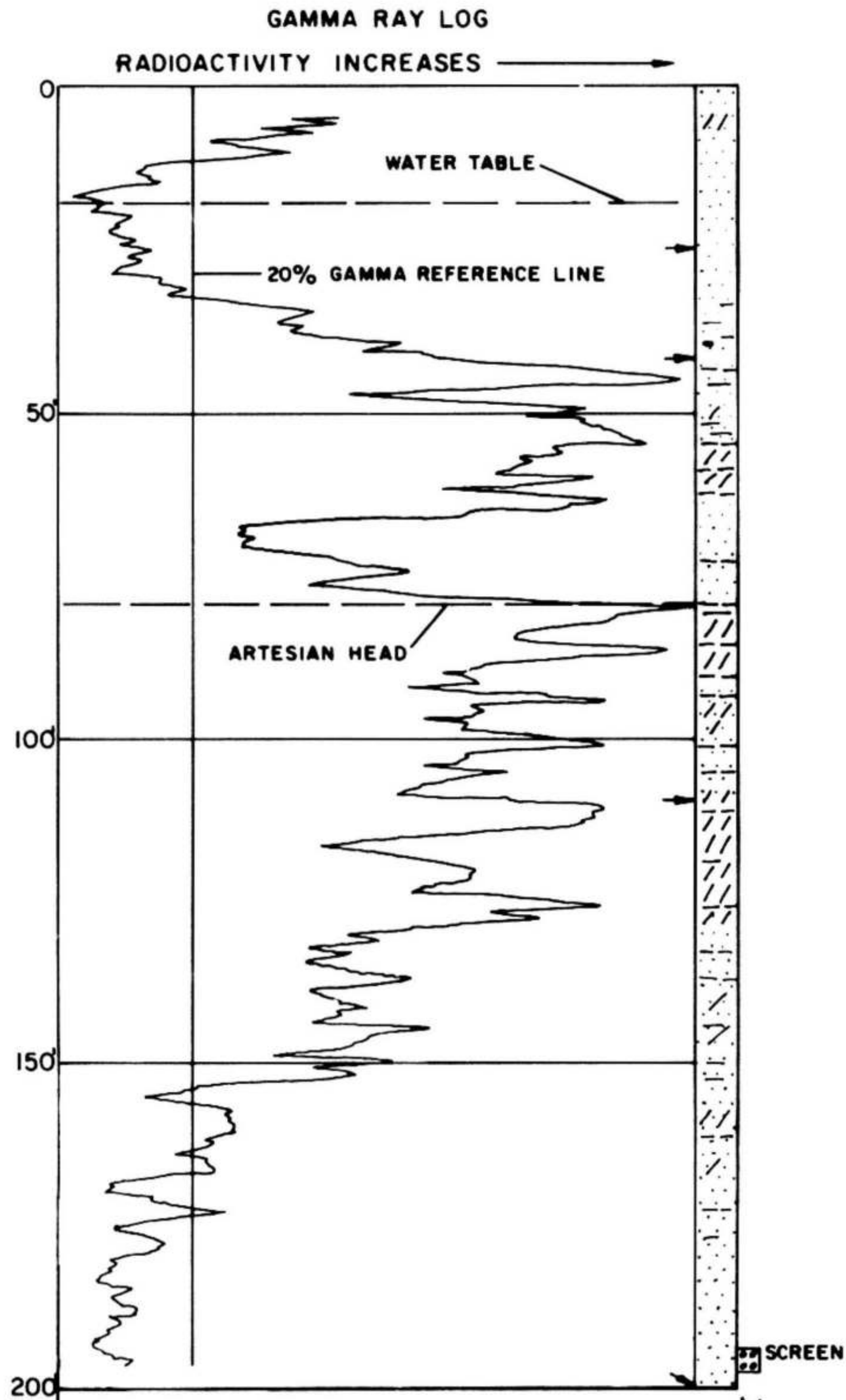
Location Number: 302958N0872300.1

Location Description: Hurst Hammock Road, 1.4 mi. S. of Mobile Highway

Alt. LSD: 103 feet Diam.: 2 inches

Depth: 198 feet Depth to top of screen: 194 feet

Water level: 79.13 feet below LSD Date meas.: 4/19 1971



Test Hole 9 (302354N0872105.1)

Test Hole 9 was drilled west of the entrance to Ferguson Flying Service air strip, south of Temporary U.S. 98, and east of Dogtrack Road (S.R. 297, fig. 1). The site appears unfavorable for a public-supply well because of high dissolved carbon dioxide and iron in the water, and also a trace of hydrogen sulfide gas. If the quality is acceptable, the site would be rated favorable.

Of several split-spoon samples, only one is available for study. The test hole penetrates sand from land surface to 27 feet, and clay to 37 feet. From 37 to 85 feet is silty sand interbedded with clay and gravel. Sand predominates to 167 feet, with occasional interbeds of silty sand, gravel, and clay. The radioactivity logs indicate 34 feet of potentially most productive sand, all of which is more than 72 feet (estimated drawdown) below the static-water level.

The water sample taken April 7, 1971, had a pH of 5.2, a dissolved carbon dioxide content of 81 mg/l, and 1,000 µg/l of dissolved iron. When the well was being developed with the air compressor, a faint "rotten eggs" smell indicated a trace of hydrogen sulfide. The sample was taken by the same method used for most of the other test holes, that is, a corked copper tube was lowered on a line to the bottom of the well. The well had previously been pumped with air from a shallow depth. If aeration affected the composition of the sample, the true carbon dioxide and iron concentrations should be even higher, and the pH should be lower.

Well Name: U.S.G.S. TH 9

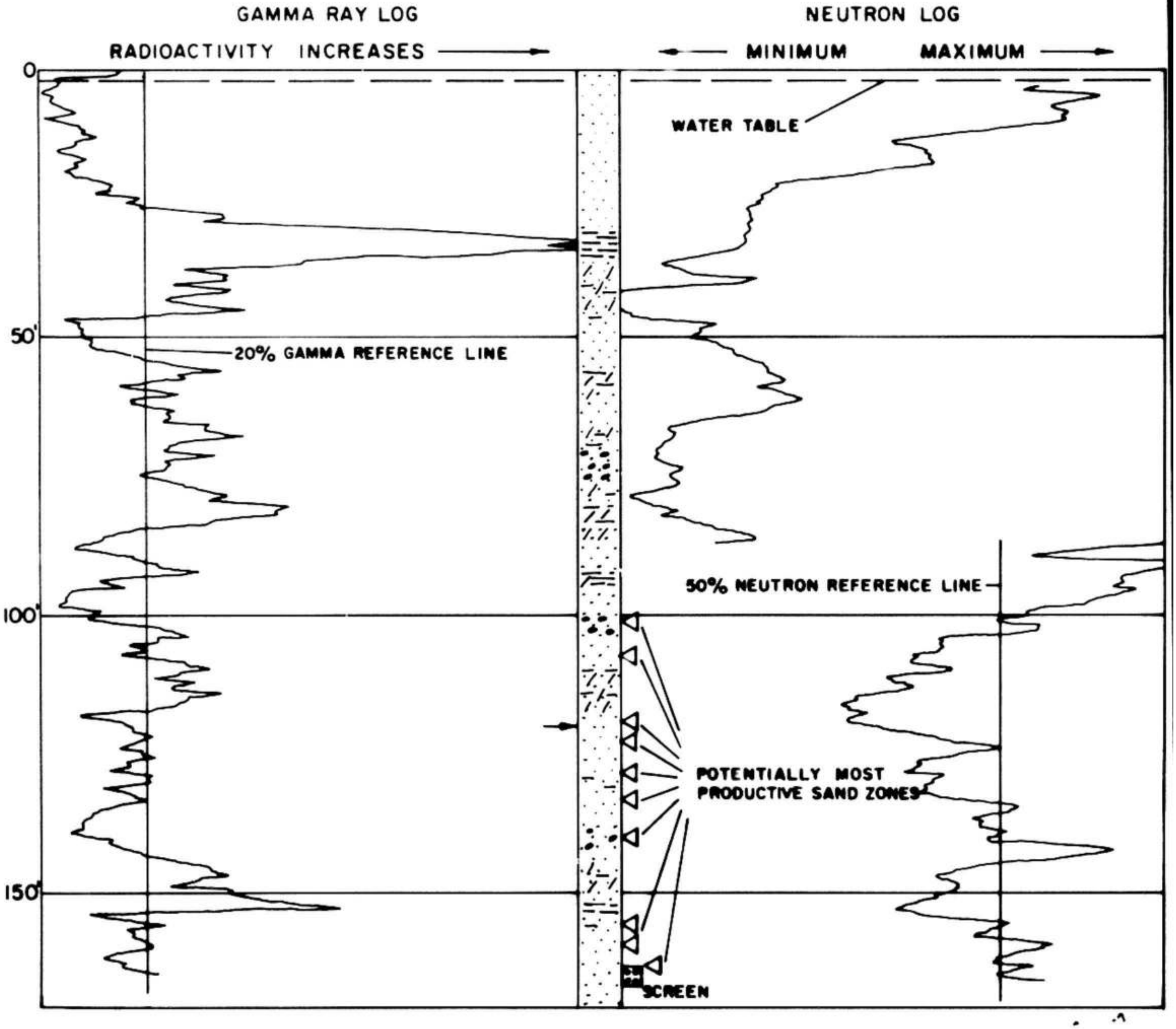
Location Number: 302354N0872105.1

Location Description: At drive into Ferguson Flying Service

Alt. LSD: 26 feet Diam.: 2 inches

Depth: 168 feet Depth to top of screen: 164 feet

Water level: 16.87 feet below LSD Date meas.: 4/15 1971



Test Hole 10 (303204N0872137.1)

Test Hole 10 was drilled on U.S. Alt. 90 about 1 mile west of Elevenmile Creek (fig. 1). It was plugged at 32 feet because of an unanticipated flow of water, and is described further under "Flowing Wells" in this report.

No estimate will now be made of the potential at this site for a large-capacity well.

Test Hole 11 (302220N0872050.1)

Test Hole 11 was drilled west of Dogtrack Road (S.R. 297), one-half mile northwest of Gulf Beach Highway (S.R. 292, fig. 1). The site appears to be marginal for a large-capacity well. The quality of water available could not be determined because of plugging of the well screen.

Two split-spoon samples were taken. The test hole penetrates clean sand from land surface to 43 feet and silty material to 98 feet. Fine sand extends from 98 to 124 feet, underlain by clay and silt to 140 feet. From 140 to 155 feet is clean sand, underlain by silty sand and silt to the maximum depth logged of 187 feet. The radioactivity logs indicate 23 feet of potentially most productive sand, of which 18 feet are more than 72 feet (estimated drawdown) below the static-water level.

The screen appeared to be largely plugged; at any rate, the well could not be pumped out thoroughly.

Although field tests were run on a water sample taken April 15, 1971, the determinations were not considered reliable because they disagreed with the analyses from nearby wells and because the sample was taken without adequate development of the well.

Well Name: U.S.G.S. TH 11

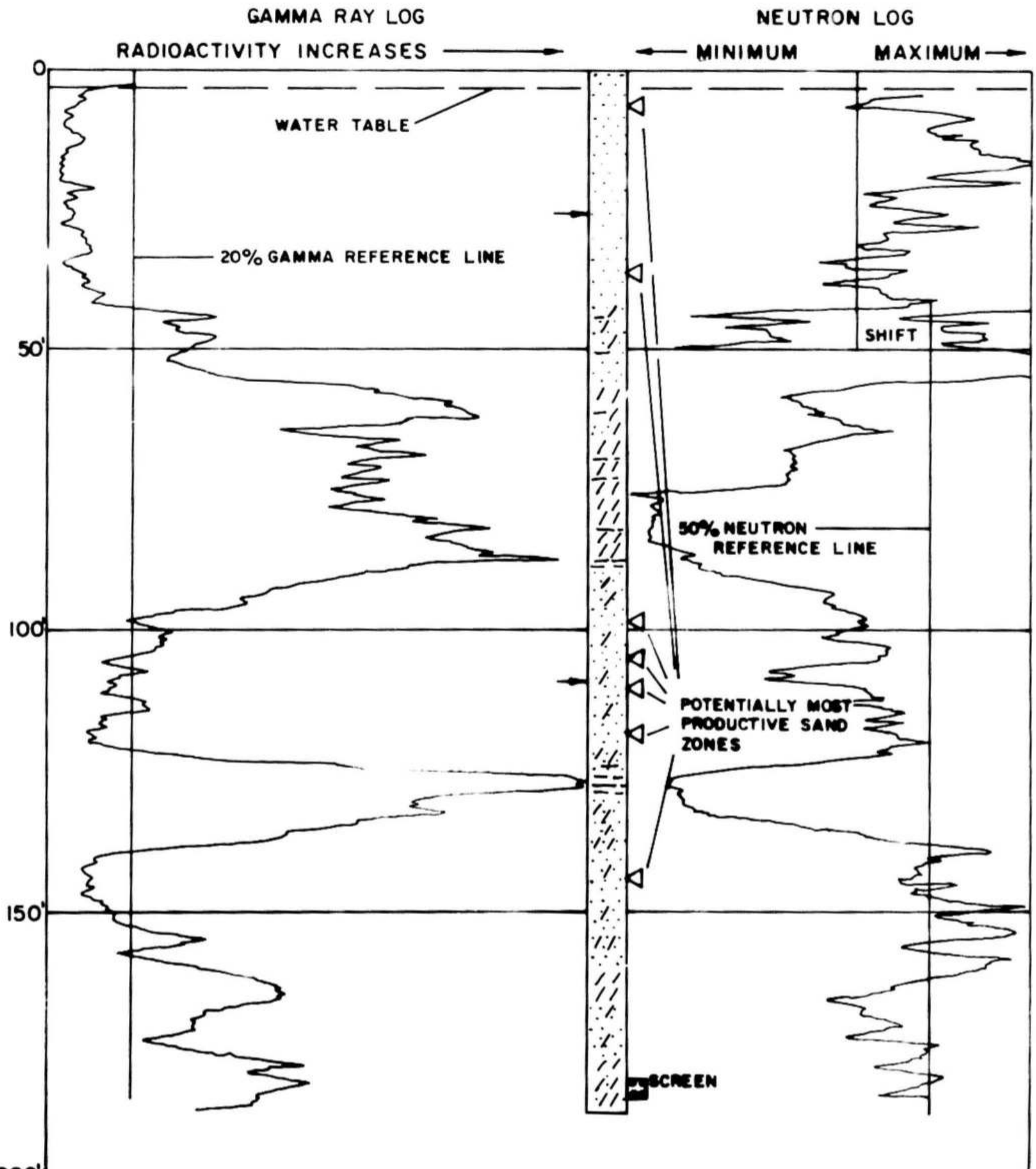
Location Number: 302220N0872050.1

Location Description: Off Dog Track Road, 0.5 mi. NW of Gulf Beach Highway

Alt. LSD: 22 feet Diam.: 2 inches

Depth: 185 feet Depth to top of screen: 182 feet

Water level: 12.87 feet below LSD Date meas.: 5/27 1971



USGS Observation Well 46 (303108N0871623.1)

USGS Observation Well 46 (State W-562) is located east of the Frisco Railway tracks north of Detroit Road, at Ensley (fig. 1). It was drilled in 1939 to 457 feet, and cased with the bottom of the screen at 229 feet. On April 14, 1971, a gamma-ray survey was run to 225 feet. This, combined with the lithologic log, suggests that the site would be favorable for a large-capacity well.

The lithologic log shows that the well was still in the sand-and-gravel aquifer at 457 feet. The upper part of the lithologic log has been modified to conform to the gamma-ray log.

Except for silty and clayey zones from 3-16, 46-81, 135-138, and 164-169 feet, the gamma-ray logged section consists largely of coarse sand.

Well Name: U.S.G.S. Obs. Well 46

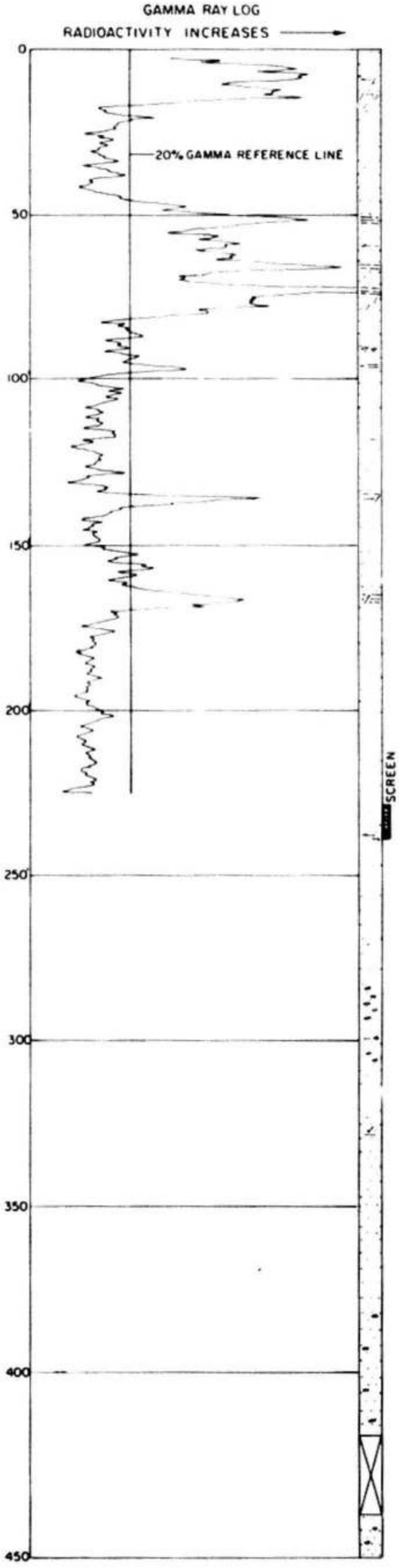
Location Number: 303108N0871623.1

Location Description: Frisco Rwy right-of-way and Detroit Rd., Ensley

Alt. LSD: 132 feet Diam.: 4 inches

Depth: 239 feet Depth to top of screen: 229 feet

Water level: 76.06 feet below LSD Date meas.: 4/14 1971



USGS Observation Well 60 (302402N0871405.1)

USGS Observation Well 60 is at the foot of "H" Street in Pensacola (fig. 1). It was drilled in 1940, and cased to 178 feet. On April 17, 1971, radioactivity surveys were run to 149 feet. The probes did not go deep enough to evaluate the site fully, but the site appears unsuitable for a large-capacity well because of probable salt-water encroachment.

The lithologic log shows that the well was still in the sand-and-gravel aquifer at 300 feet, having entered the lower part of the aquifer at 295 feet, as indicated by the abundance of fossil shells at that depth.

Except for clayey and silty zones from 18-22, 47-60, and 125-137 feet, the radioactivity logged section consists of medium- to coarse-grained sand with gravel. The neutron curve, however, indicates comparatively low porosities for the sand and gravel, as shown by the position of the neutron curve with respect to the 50% Neutron Reference Line. It may be that the position of the 50% Neutron Reference Line is misleading because the logged section did not include a sufficiently dense zone to determine its proper position.

Well Name: U.S.G.S. Obs. Well 60

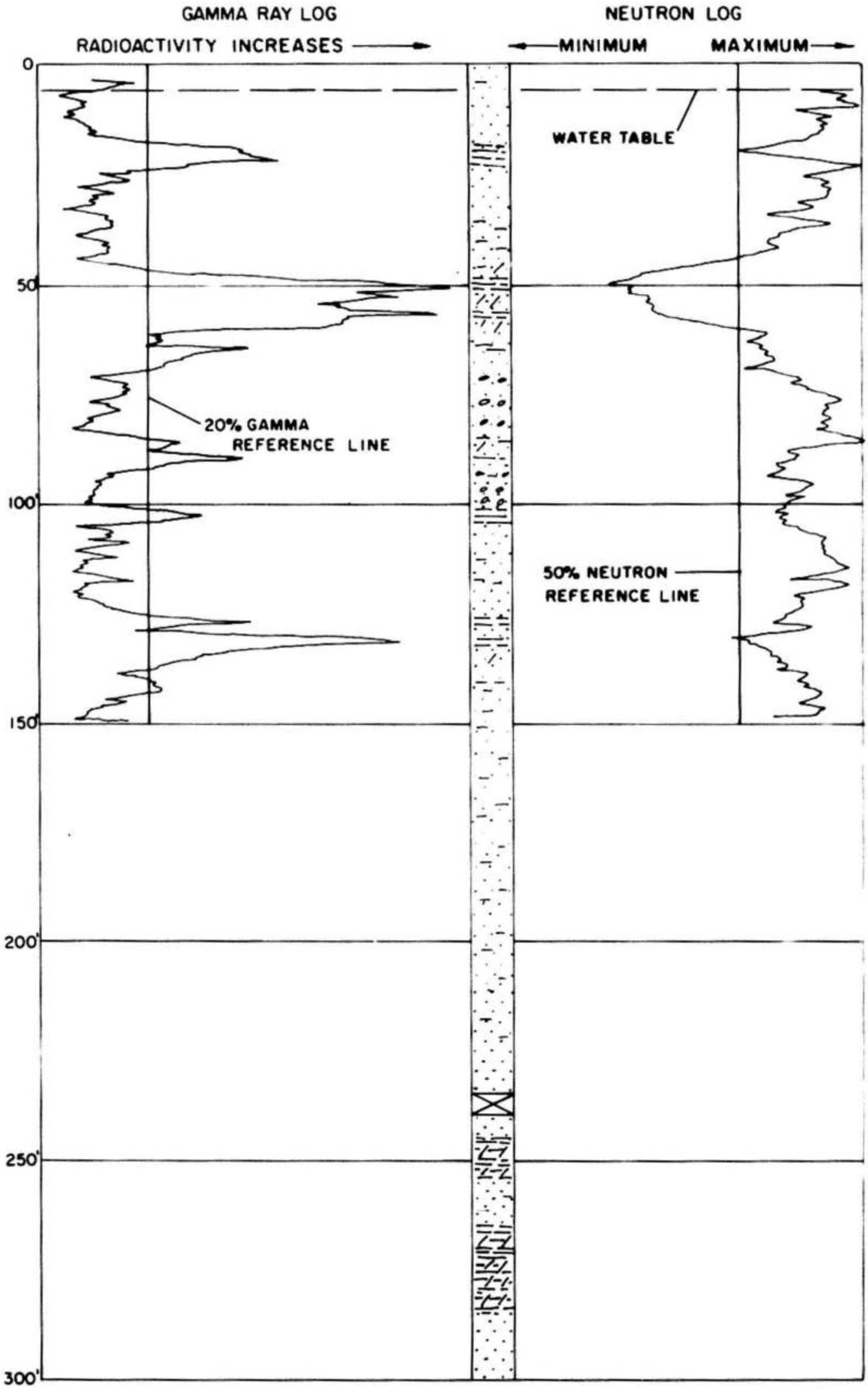
Location Number: 302402 N0871405.1

Location Description: Foot of H Street, 90' N. of water's edge

Alt. LSD: 7 feet Diam.: 4 inches

Depth: cased to 178 feet Depth to top of screen: None feet

Water level: 10.6 feet below LSD Date meas.: July 1940



USGS Observation Well 62 (302432N0871517.1)

USGS Observation Well 62 is 1,140 feet east of the Frisco Railway bridge over Bayou Chico (fig. 1). It was drilled in 1940 to a depth of 142 feet, and cased to bottom. The logging probes reached 114 feet, which was not deep enough to evaluate the site with respect to its potential for a large-capacity well.

The combination of lithologic and radioactivity logs indicates predominately medium- to coarse-grained sand from 4 to 46 feet, predominately very fine sand from 46 to 98 feet, gravel from 98 to 101 feet, and sandy clay from 98 to 108 feet. The lithologic log shows fine to coarse sand extends from 108 feet to the bottom of the hole.

Well Name: U.S.G.S. Obs. Well 62

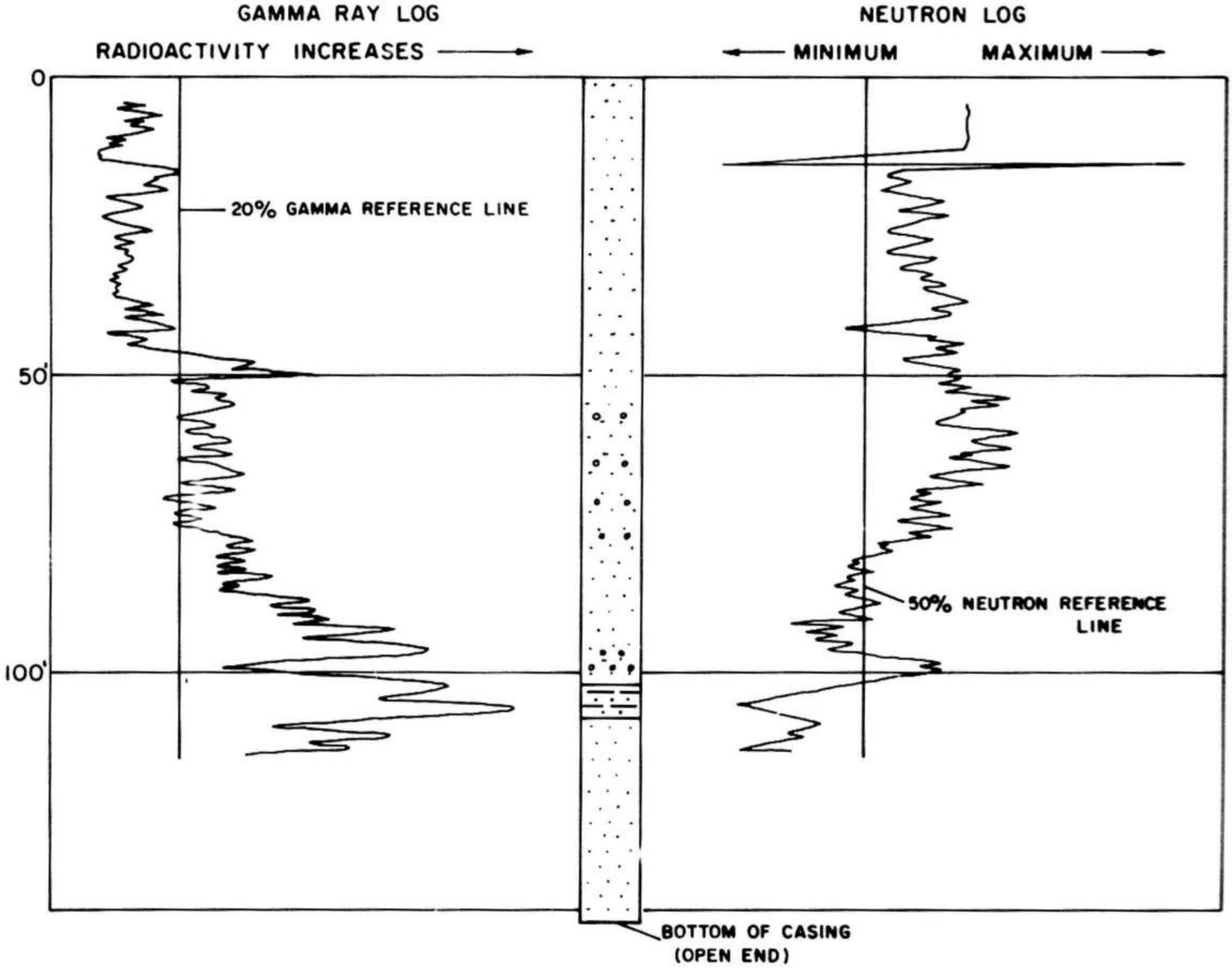
Location Number: 302432N0871517.1

Location Description: Myrick St., 1100 ft. E. of Frisco Rwy. bridge over Bayou Chico

Alt. LSD: 14 feet Diam.: 6 inches

Depth: 142 feet Depth to top of screen: -- feet

Water level: 16.55 feet below LSD Date meas.: 6/4 1940



USGS Observation Well 026-713-5 (302658N0871303.1)

USGS Observation Well 026-713-5 (State W-4991) is on Alcaniz Street near Borden's Dairy (fig. 1). It was drilled in 1959 to a depth of 400 feet, with the bottom of the screen at 150 feet. The radioactive-logging probes reached 146 feet. The radioactivity logged interval does not appear favorable for a large-capacity well and the lithologic log, below 146 feet, is too generalized to serve as a basis for a yield estimate.

The lithologic log shows fossil shells indicating that the lower part of the sand-and-gravel aquifer was reached at 360 feet. The well penetrates medium- to coarse-grained sand from land surface to 11 feet and, according to the neutron log, there may be a perched water table at 2 feet. The surficial sand is underlain by interbedded clay and sand to 22 feet, from 22 to 82 feet is a sand with a few thin clay layers, the upper part is fine to very coarse, and the lower part is medium grained to very coarse grained, of which 18 feet are potentially most productive sand according to the radioactivity logs. However, this is close to the static-water level and therefore subject to dewatering under heavy pumping. From 82 to 139 feet is predominately very coarse sand, according to the lithologic log, but the radioactivity logs show it to be less clean (more clayey or silty) than the 18-foot stratum above. From 139 feet to the bottom of the logged section is clean, very fine to coarse sand.

Well Name: U.S.G.S. Obs. Well 026-713-5

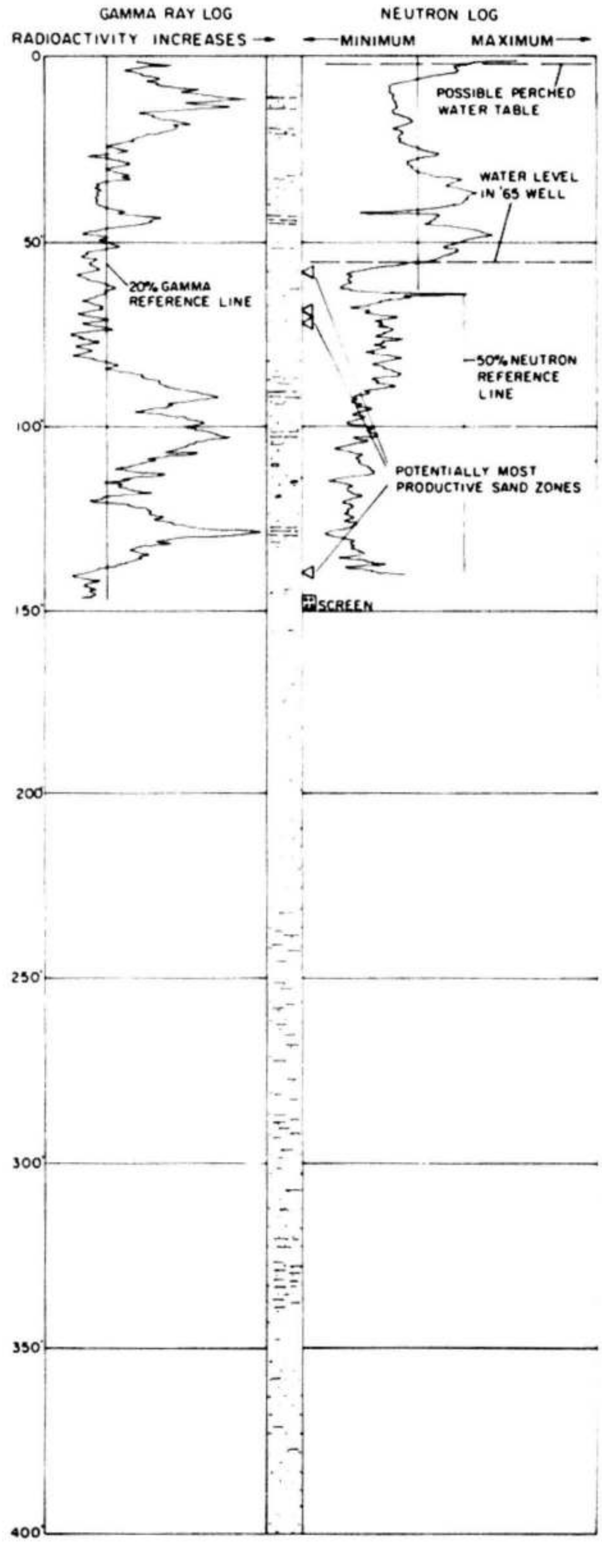
Location Number: 302658N0871303.1

Location Description: Alcaniz St. at Borden's Dairy

Alt. LSD: 89 feet Diam.: 4 inches

Depth: 149.5 feet Depth to top of screen: 144.5 feet

Water level: 64.71 feet below LSD Date meas.: 7/27 1959



USGS Observation Well 032-724-1 (303210N0872424.1)

USGS Observation Well 032-724-1 was drilled adjacent to U.S. Alt. 90 east of its junction with Mobile Highway (U.S. 90, fig. 1) to a depth of 730 feet. On completion of the drilling in 1959, an electric survey was run to 648 feet, the well was cased, and the bottom of the screen was set at 170 feet. Radioactivity surveys were run in April 1971 to 170 feet. The combination of lithologic, electric, and radioactivity logs suggests that the site would be favorable for a large-capacity well.

The lithologic log shows that the well reaches the lower part of the sand-and-gravel aquifer at about 410 feet, as shown by fossil shells, and that the well is still in the aquifer at its total depth of 730 feet. The SP (spontaneous-potential) log seems to be reversed for most of the sand layers in the upper part of the section, where it can be compared to the gamma-ray log. This is common in electric logging where the formation water is fresher than the water in the drilling fluid.

From land surface to 40 feet is very fine to very coarse sand, with gravel in the center. The neutron log suggests a perched water table at 3 feet and the gamma-ray log of the sand-and-gravel body includes 16 feet of potentially most productive sand. From the base of the sand to 52 feet is a clay bed. Predominately medium- to coarse-grained sand, with clay interbeds and hardpan streaks, extends from 52 to 88 feet. Clean, medium- to very coarse-grained sand, of which 10 feet are potentially most productive, extends from 88 to 103 feet. From 103 to 150 feet is very fine to very coarse sand with clay layers. From 150 feet to the base of the radioactivity logs at 170 feet is clean fine sand, of which 11 feet are potentially most productive. Medium-grained sand, which the electric log indicates should be at least as productive as the overlying sand, extends to 205 feet.

Well Name: U.S.G.S. Obs. Well 032-724-1

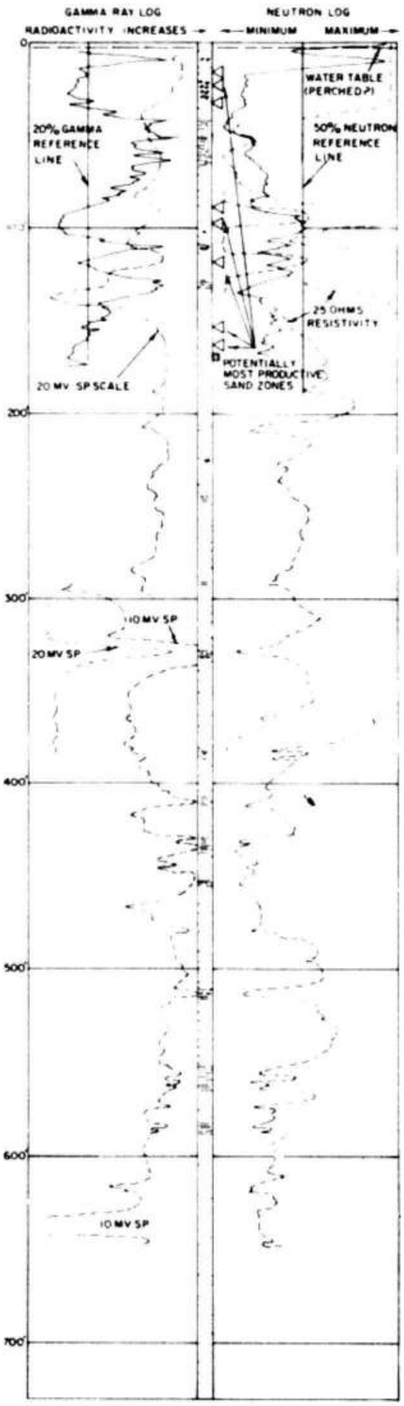
Location Number: 303210N0872424.1

Location Description: U.S. Alt. 90 0.3 mi. E. of Mobile Hwy.

Alt. LSD: 123 feet Diam.: 4 inches

Depth: 170 feet Depth to top of screen: 165 feet

Water level: 90.5 feet below LSD Date meas.: 7/8 1959



City of Pensacola East Plant Well (302555N0871227.2)

A gamma-ray survey was run on the unused City of Pensacola East Plant Well, located at 10th Avenue and Avery Street (fig. 1). The accompanying log shows that from the surface to 20 feet the material is clayey or silty. From 20 to 69 feet, the log indicates sand with silty or clayey interbeds. At 69 feet, which corresponds to the static-water level, the gamma-ray curve is shifted to the left. This may be the effect of the water in the 20-inch casing. From 69 to 120 feet, the section appears to be predominately sand with clayey or silty interbeds. From 120 to 170 feet, the sand beds are thinner than those above, and the clay content increases. From 170 to 257 feet, the maximum depth reached, the section is predominately sand with thin clay streaks.

Well Name: City of Pensacola East Plant Well

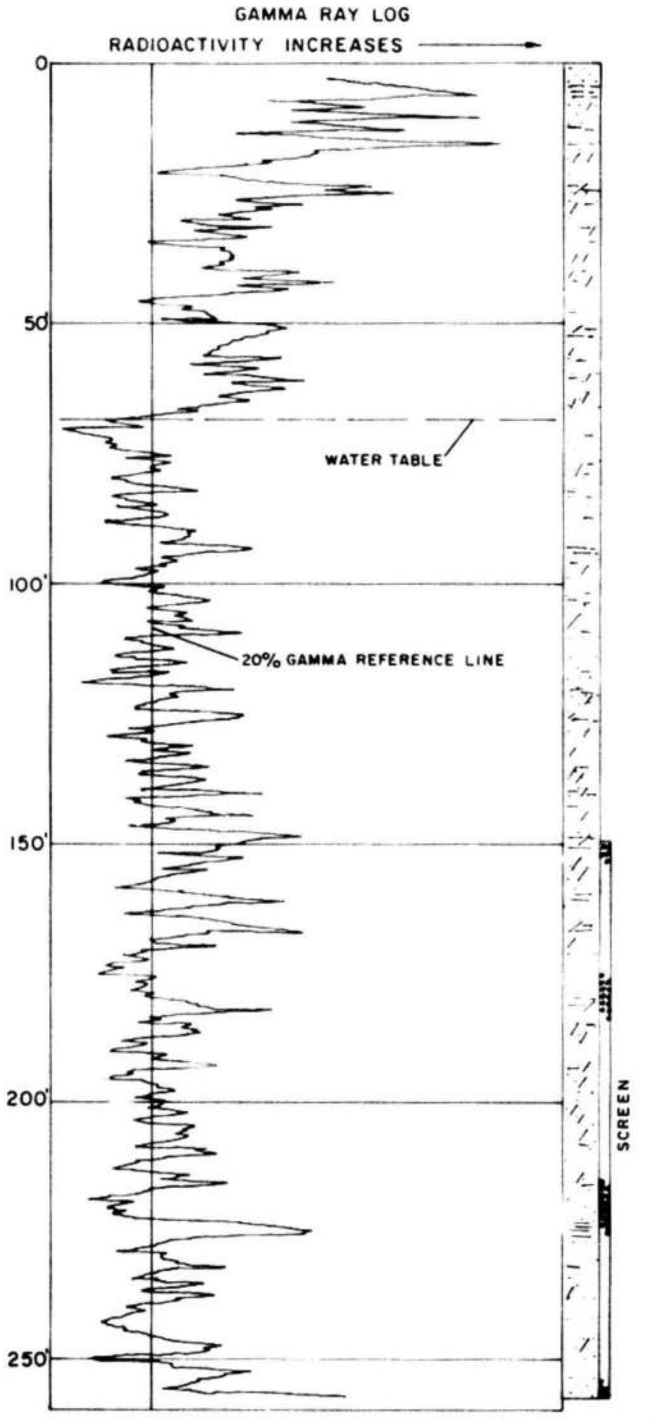
Location Number: 302555N0871227.2

Location Description: 10th and Mallory Streets

Alt. LSD: 79 feet Diam.: 18 inches

Depth: 257 feet Depth to top of screen: 150 feet

Water level: 67.87 feet below LSD Date meas.: 4/14 1971



F

City of Pensacola 12th Avenue Well (302646N0871227.1)

A gamma-ray survey was run on the unused 12th Avenue Well (fig. 1). The neutron log was not run because the 12-inch radius of the well was approximately equal to the maximum radius of investigation of the neutron logging equipment. The gamma-ray log shows that the section, at least below the static-water level of 66 feet, consists mostly of clean sand.

The log indicates a surficial sand layer to 6 feet, underlain by clayey and silty material to 26 feet, and thin sand layers with silt interbedded to 65 feet. From 65 to 144 feet, sand predominates, with occasional thin silty layers. Sand predominates from 144 to 180 feet, but there are clay layers from 144 to 147 feet and from 159 to 161 feet. Clay and silt range from 181 to 200 feet. Clean sand predominates below 200 feet, with occasional silty streaks.

Well Name: City of Pensacola 12th Ave. Well

Location Number: 302646N0871227.1

Location Description: 12th Ave. at Hayes

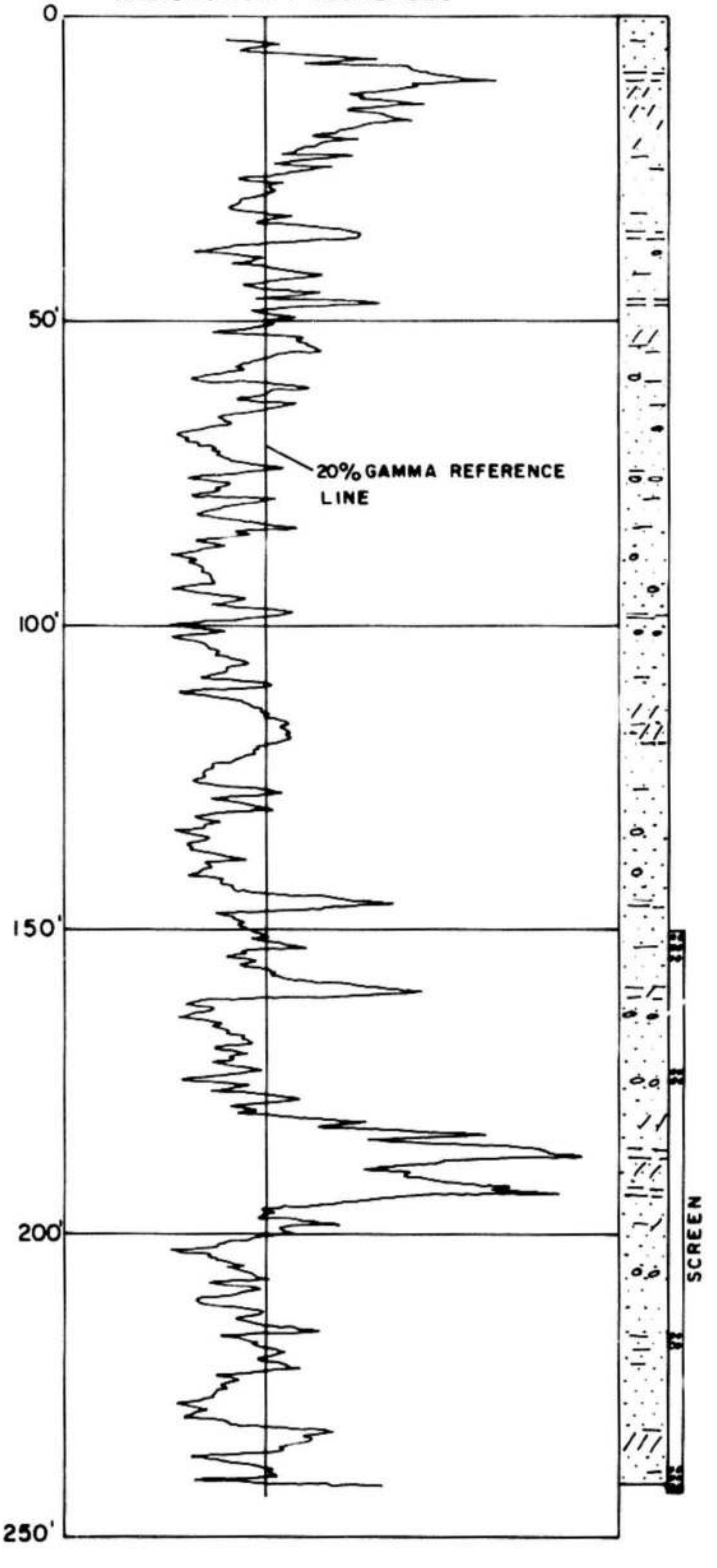
Alt. LSD: 81 feet Diam.: 24 inches

Depth: 242 feet Depth to top of screen: 150 feet

Water level: 65.67 feet below LSD Date meas.: 4/17 1971

GAMMA RAY LOG

RADIOACTIVITY INCREASES →



City of Pensacola Montclair No. 1 Well (302726N0871527.1)

Both gamma-ray and neutron surveys were run on the Montclair No. 1 Well (fig. 1), which had its pump pulled for repairs at the time the logging was done. The section of the aquifer logged at this site has less porosity than the sections logged in some of the other holes, and therefore it is less favorable for a high-capacity well.

From the surface to 37 feet, the gamma-ray log indicates thin beds of sand with silty and clayey interbeds. Sand predominates from 37 to 134 feet, but its expression on the gamma-ray curve is mostly to the right of the 20% Gamma Reference Line, indicating that the sand has a substantial clay content. The gamma-ray curve is shifted to the left at about 46 feet, which is close to the water table as indicated by the neutron log, and close to the static-water level as measured at 47.6 feet.

Clean sand predominates from 134 to 183 feet, which is the section in which the screen in set. However, the neutron values are all to the right of the 50% Neutron Line indicating comparatively low porosity. A scant 5 feet of the entire section penetrated can be classed as potentially most productive sand and this is in separate thin streaks above the screen.

Well Name: City of Pensacola Montclair No. 1 Well

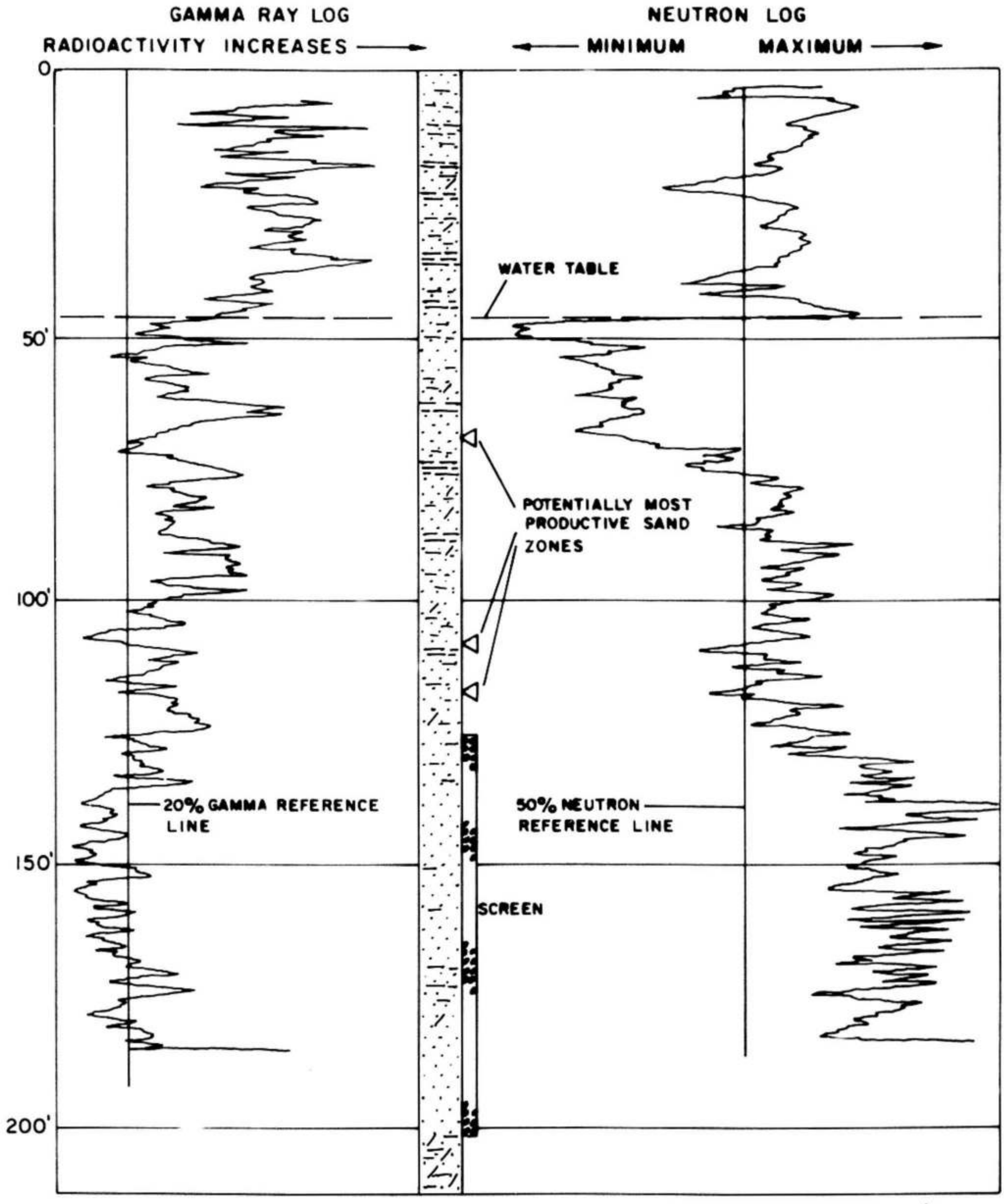
Location Number: 302726N0871527.1

Location Description: Gulf Power right-of-way N. of Bellaire

Alt. LSD: 90 feet Diam.: 18 inches

Depth: 201 feet Depth to top of screen: 125 feet

Water level: 47.60 feet below LSD Date meas.: 4/14 1971



Crystal Ice Company Well (302427N0871406.1)

A gamma-ray survey was run on an unused well at the Crystal Ice Company, at Government and "I" Streets, Pensacola (fig. 1). The well was reported to be 160 feet deep, but the logging probe only reached 110 feet because of the poor condition of the casing or because of an obstruction. A neutron survey was not run because of the risk of losing the probe. The gamma-ray log does not include the chief productive sand zone in the aquifer--131 to 182 feet.

The log shows that clean sand predominates from 9 feet to 74 feet, with silty interbeds. From 74 to 110 feet, silt and clay predominate, with clay increasing from 99 to 110 feet. A driller's log of a well at the old Spearman Brewery (on Barrancas Avenue, within a few hundred feet of the Crystal Ice Company Well), shows "muddy sand" from 90 to 110 feet, clay from 110 to 130 feet, and the productive sand from 131 to 182 feet.

Well Name: Crystal Ice Co.

Location Number: 302427N0871406.1

Location Description: Government St. at I Street

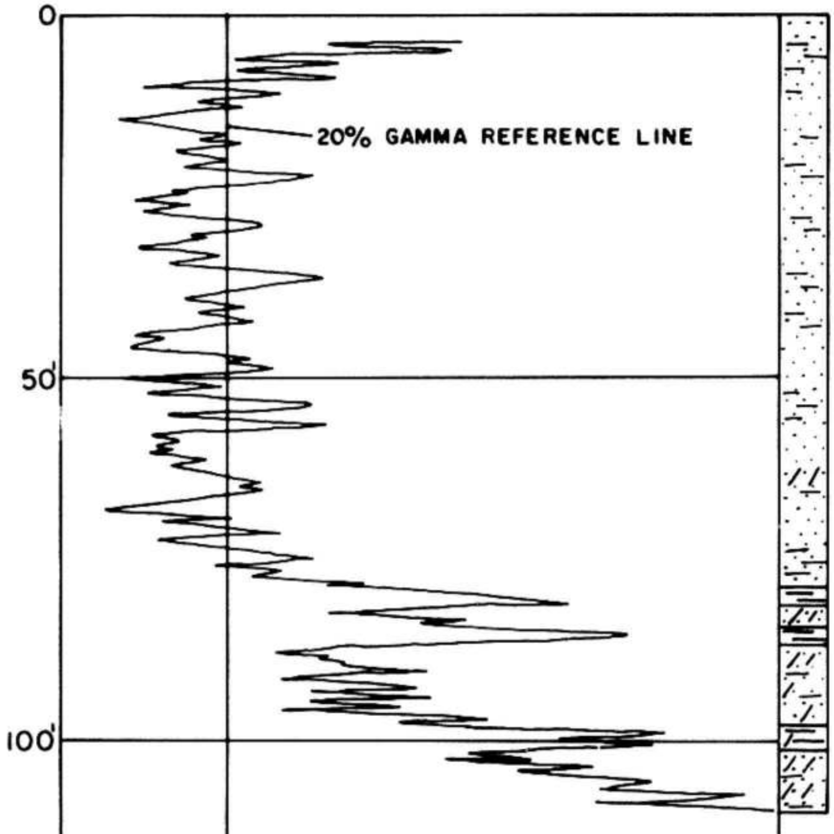
Alt. LSD: 13 feet Diam.: 9 inches

Depth: was 160 feet Depth to top of screen: -- feet

Water level: 18.81 feet below LSD Date meas.: 12/15 1970

GAMMA RAY LOG

RADIOACTIVITY INCREASES ⟶



Haven of Our Lady of Peace Well (302352N0872435.1)

A gamma-ray survey was run on an unused 4-inch well at the former site of the Haven of Our Lady of Peace sanitarium on Lillian Highway (fig. 1). Because of the poor condition of the hole, no neutron survey was attempted.

The gamma-ray log shows clean sand layers from 11 to 17 feet, 38 to 46 feet, 75 to 101 feet, and from 137 feet to the maximum depth logged of 144 feet. These are separated by silty or clayey zones. The driller's log for a nearby well shows sand from 110 to 204 feet.

Well Name: Haven of Our Lady of Peace (Ab'd.)

Location Number: 302352N0872435.1

Location Description: N. Side Lillian Hwy, 0.4 mi. W. of SR 293

Alt. LSD: 20 feet Diam.: 4 inches

Depth: 147 feet Depth to top of screen: -- feet

Water level: 20.9 feet below LSD Date meas.: 10/15 1970