UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

THE SURFICIAL AQUIFER AT THE U.S. NAVAL STATION NEAR MAYPORT, FLORIDA

OPEN-FILE REPORT 80-765

Prepared in cooperation with the
DEPARTMENT OF THE NAVY, SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
Charleston, South Carolina

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GEOLOGICAL SURVEY

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Factors for converting inch-pound units to International System (SI) units and abbreviations of units.

Multiply inch-pound unit	By	To obtain metric unit
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot squared per day (ft^2/d)	0.0929	meters squared per day (m^2/d)

* *

Mean sea level (m.s.l.)	---	National Geodetic Vertical Datum of 1929 (NGVD of 1929).

THE SURFICIAL AQUIFER AT THE

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ABSTRACT

The surficial aquifer at the U.S. Naval Station near Mayport, Florida, consists of about 70 feet of unconsolidated sand, shell, and clay. The principal water-bearing zone is a shell bed 35 to 55 feet below land surface. The aquifer is unconfined, and the water table was about 4 feet below land surface during the investigation (spring 1979). Aquifer tests indicate a transmissivity for the aquifer of approximately 2,400 feet squared per day. Water in the upper 40 feet of the aquifer is fresh, but becomes increasingly brackish with depth. Use of water from the surficial aquifer is limited because of low yields and poor water quality. Feasibility of injection of return cooling water into the surficial aquifer is limited by the shallow water table.

INTRODUCTION

Purpose and Scope

The purpose of this investigation was to determine the hydraulic and chemical characteristics of the surficial aquifer at the U.S. Naval Station near Mayport, Fla., as a cooperative investigation with the Department of the Navy, Southern Division. The information obtained will be used to evaluate the potential of the surficial aquifer as a water-supply source, and to evaluate whether the surficial aquifer may be utilized to receive water from cooling condensers.

The report provides an estimate of transmissivity of the surficial aquifer at the Naval Station, as well as lithologic and water-quality data for the aquifer. Drawdowns in the aquifer as a result of several different pumping rates are calculated.

Location

The area of this investigation is in northeast Florida, in Duval County, at the U.S. Naval Station near Mayport, Fla. The study area is in the extreme northeast section of the naval station, northwest of the intersection of Bailey Avenue and Baltimore Street, adjacent to the existing recreation area (fig. 1).

Previous Investigations

Fairchild (1972) and Causey and Phelps (1978) describe the general characteristics of the shallow aquifer system in Duval County. G. W. Leve and M. I. Backer (written commun., 1976) discuss the geohydrology of a part of eastern Duval County. Law Engineering Testing Co. (written commun., 1975) completed a subsurface investigation in the study area.

Acknowledgments

The author expresses appreciation to James Frazee, hydrologist, and Richard Johnson, geologist, both of the Saint Johns River Water Management District, for making available data from several test wells drilled and logged by their agency in the study area; to John Spandermann, engineer, U.S. Naval Station, for arranging access to detailed topographic maps of the project area; and to James Horton, Law Engineering Testing Co., for supplying geologic (borehole) information near the study site.

SURFICIAL AQUIFER

The surficial aquifer extends from the surface to about 70 feet below ground level and consists of unconsolidated sand, clay, and shell (Causey and Phelps, 1978). Over most of Duval County, the surficial aquifer consists of an upper zone and a lower zone, separated by beds of lower permeability. The upper zone typically extends from land surface to a depth of about 25 to 50 feet, and yields 10 gal/min or less to 2-inch diameter wells. At Kathryn Abbey Hanna Park, about 2 miles south of the location of this study, the upper zone consists primarily of a shell bed and is unusually productive, yielding 40 gal/min of freshwater from a 2-inch well

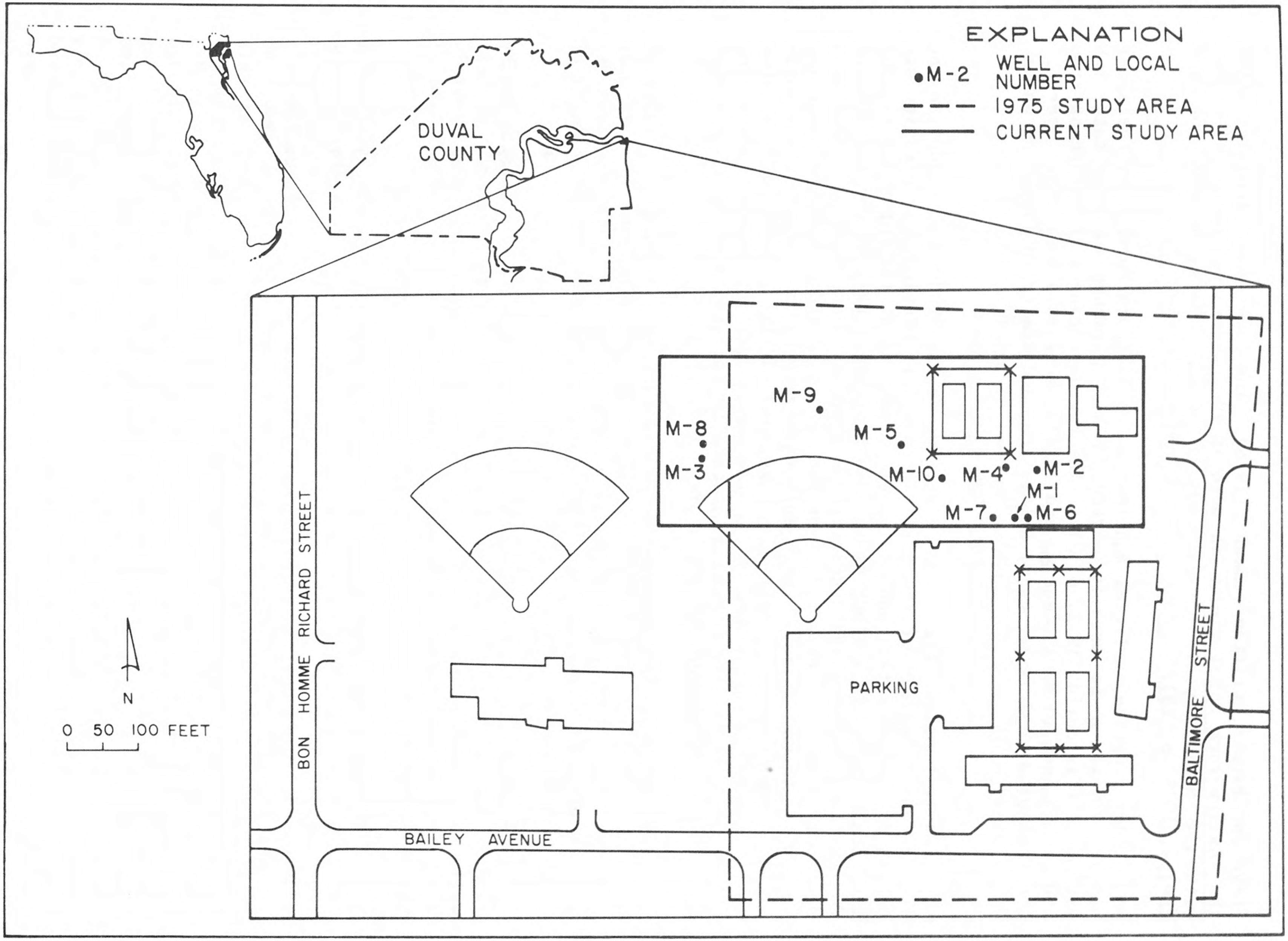

Figure 1.--Location of test wells in study area.

(Leve and Backer, written commun., 1976). The lower zone (locally called the shallow-rock zone) yields as much as 200 gal/min to individual wells, with the maximum yield usually between 30 and 100 gal/min (Causey and Phelps, 1978, p. 23).

Underlying the surficial aquifer is the Hawthorn Formation, the upper surface of which is usually marked by the presence of phosphate-rich sediments (Fairchild, 1972, p. 21). The Hawthorn ranges in thickness from 250 to 500 feet in Duval County, and locally acts as a confining layer; it consists of a mixture of clay, silt, sand, and scattered limestone units.

Geohydrology

Ten test holes (fig. 1) were drilled in the study area to define the geology and hydrology of the surficial aquifer. Geologic information was obtained from all sites; and wells were completed at five of the sites for hydrologic data. In a study of an adjoining area, Law Engineering Testing Co. (written commun., 1975) described a uniform, dense fine gray sand to a depth of 30 feet, interrupted at depths between 3 and 7 feet by a thin (up to 2 feet thick) layer of very soft dark-gray silty clay. This stratigraphic sequence was verified by the test drilling performed in this investigation. Other results of the test drilling indicate that the entire stratigraphic sequence is laterally uniform, although vertically anisotropic, throughout the study area (fig. 2).

The test drilling indicated no persistent semiconfining clay layer at 25 to 50 feet below land surface separating an upper zone from a lower zone, as in other parts of Duval County. Thus, the local surficial aquifer acts as a single unconfined (water-table) aquifer to a depth of about 70 feet below land surface.

The area of investigation at the Naval Station is surrounded by water. The Atlantic Ocean is about 1,600 feet to the east of the test wells and 2,400 feet to the north. Mayport Basin is approximately 2,400 feet to the west. A freshwater lake is about 2,000 feet south of the test well site.

Water-level measurements were made to define the seasonal variations in thickness of the unsaturated zone. The only previous data available on fluctuations in depth to the water table in Duval County are in general studies by Causey (1975) and Fairchild (1972) and water-level measurements in shallow wells during a 6 month interval in 1973 (G. W. Leve and M. I. Backer, written commun., 1976). Because of the brevity of this investigation, it was not possible to monitor the water table over all seasonal extremes. However, a digital recorder was maintained on well M-3 for over 2 months, from mid-February through April 1979, which included the aquifer-test periods. Water levels in wells gradually declined during this time from about 3 feet to slightly more than 4 feet below land surface. Daily tidal fluctuations of about 0.05 feet were observed. A heavy rainstorm (2 inches in 12 hours) near the end of April resulted in a temporary rise in water level of about 0.8 feet. Based on these data and unpublished hydrographs of shallow wells in Duval County, the annual range in water-table altitude is probably less than 2 feet. In the area of investigation this corresponds to a water table range in depth of about 2.5 to about 4.5 feet below land surface.

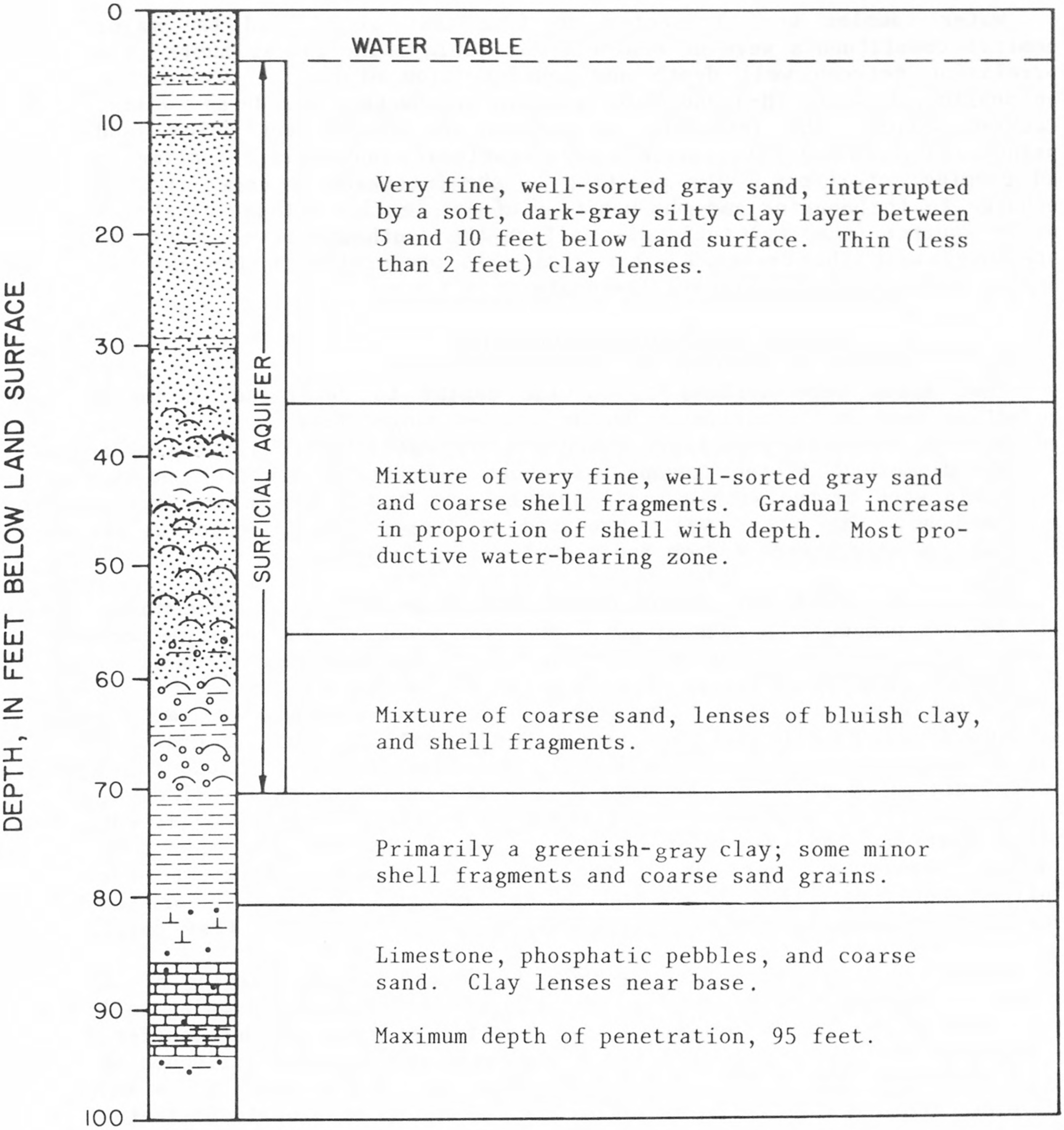

Figure 2.--Generalized lithologic column showing sediments penetrated by test wells.

Water Quality

Water samples were collected at five test sites, and the major chemical constituents were determined. As table 1 indicates, there is a correlation between well depth and concentration of most constituents. The shallowest wells (M-3 and M-10) contain freshwater; the deeper wells, brackish water. The interface is between 35 and 44 feet below land surface and is expected to remain nearly stationary under present climatic and pumping conditions. The position of the interface is controlled by recharge to the aquifer and the position of sea level. Artificial stress on the aquifer (pumping) could also affect the depth and position of the interface, with the brackish water rising in proportion to the rate of pumping and replacing overlying freshwater.

Aquifer Properties

Test holes were drilled to varying depths to determine the most productive zone in the aquifer. Depths drilled ranged from 20 to 95 feet, and five of the test holes were cased and screened (table 2). Well M-5 (3-inch diameter, 47 feet deep) was most productive yielding up to 30 gal/min when tested with a small suction pump and a 1.5-inch-diameter suction hose. The other wells produced at lesser rates, depending on where they were screened and on individual well efficiency.

An aquifer test was conducted to determine hydraulic properties. Well M-5 was pumped at a rate of 20 gal/min for 5 hours. Drawdown in each of the other four wells was measured, and the data analyzed. From plots of drawdown against log time for each of the wells, transmissivity of 2,400 ft^2/d was calculated using the Cooper-Jacob straight-line method (Lohman, 1972, p. 19). From a composite logarithmic plot of drawdown against time from observation well data, a transmissivity of 3,000 ft^2/d was calculated by matching the data to the Stallman type-curves (Lohman, 1972, plate 7E). Both methods of analysis yielded storage coefficient values that were on the order of 10^{-3}--a value that is generally considered to be the upper end of the range of storage coefficients for confined aquifers. The following is offered as explanation for the seemingly erroneous storage coefficient calculated from the test data.

First, according to Boulton (1954) and Neuman (1975), pumping of an unconfined aquifer results in drawdown in the vicinity of the pumping well that initially reflects primarily the specific storage of the aquifer, rather than the specific yield. With continued pumping, the influence of water produced from storage due to the lowering of the water table and attendant draining of the pores becomes apparent and eventually dominates the flow system. The time for the transition from primarily confined-type response to primarily unconfined-type response is generally measured in hours or days rather than in minutes. The aquifer test in this study lasted only 5 hours.

Second, a thin but laterally persistent clay layer occurs near the top of the aquifer a few feet below the water table. This clay layer would tend to retard the drainage of pores at the water table and thus prolong the duration of the artesian-type response.

Table 1.--Water-quality data from selected test wells
[Values in milligrams per liter, except as noted.
Samples collected on April 9, 1979]

Parameter	Local well number				
	M-3	M-10	M-7	M-5	M-8
Depth of well (ft)	11	35	44	47	55
Chloride (Cl)	46	100	4,100	5,000	5,200
Bicarbonate (HCO_3)	268	720	976	1,020	812
Sulfate (SO_4)	26	30	530	480	720
Calcium (Ca)	81	55	130	120	110
Magnesium (Mg)	9.7	60	280	310	310
Sodium (Na)	24	160	2,600	3,000	3,200
Potassium (K)	7.1	49	120	140	150
Strontium (Sr)	.52	.60	2	1.06	2
Iron (Fe)	.07	.11	.08	.06	.08
Specific conductance (μmho/cm at 25°C)	630	1,350	12,800	14,400	15,500
Total hardness, as $CaCO_3$ (calculated)	240	620	1,480	1,580	1,550
Temperature (°C)	22	23	23	23	23

Table 2.--Well construction characteristics.

Characteristic	Local well number				
	M-3	M-5	M-7	M-8	M-10
Depth drilled (ft)	32	77	44	55	35
Depth completed (ft)	11	47	44	55	35
Length screen (ft)	5	10	10	10	10
Well diameter (in)	2	3	4	4	3
Water level (ft below land surface) (04-11-79)	4.15	4.50	4.40	4.78	4.00
Land surface (altitude)	8.36	8.17	8.36	8.62	8.00

The calculation from the test data of an artesian-type storage coefficient is simply an indication of this severe retardation in the delayed-yield phenomenon. The calculated storage coefficient of 10^{-3} yields a specific storage of about 10^{-5}, considering the 70-foot thickness of the aquifer. Neuman (1975, p. 340) suggests that recent, unconsolidated sediments are more compressible than deeper rock aquifers and therefore may exhibit somewhat higher values for specific storage. Measurements of the bulk modulus of compression of various earth materials as given in Walton (1970, p. 627) support this contention. Specific storage determined by Neuman (1975) for an analogous surficial aquifer is similar to that determined from this test. Therefore, the methods of analysis used herein are believed to yield reliable estimates of transmissivity and specific storage. However, because of the short duration of the test, anisotropy of the aquifer, and partial penetration of the wells, the values calculated from this test are considered estimates only. Also, the short duration of the test did not permit determination of the specific yield of the aquifer.

Although the actual transmissivity of the aquifer may be greater than the lower value of 2,400 ft^2/d calculated from the test data, such a value appears reasonable on the basis of lithology of the aquifer. Moreover, using 2,400 ft^2/d in calculations made later will give conservative estimates of the amount of water that can be pumped for specific drawdown. In making these later calculations, the storage coefficient used is not the artesian-type value calculated from the test but rather an estimated specific yield of 0.1. The actual specific yield may be closer to 0.2, but use of the lower value again yields conservative estimates of the amount of water that can be pumped for specific drawdown. For purposes of estimating the effects of prolonged pumping, the aquifer should be regarded as unconfined; thus use of an unconfined storage coefficient is justified.

DISCUSSION

From hydraulic and water quality data, it is possible to determine the potential of the surficial aquifer as a water supply source or as a site suitable for cooling water injection. In the following discussion and calculations, three assumptions were made: (1) Specific yield equals 0.1, based on an estimated value for fine-grained sand, for that portion of the aquifer potentially involved in storage changes; (2) the water quality and temperature of the injection water is the same as the aquifer water; and (3) physical boundary effects are negligible. Additionally, since the aquifer is anisotropic and heterogeneous, drawdowns will vary locally from the predicted values. In order to minimize delayed yield effects, which may be present even after 7 days of pumping, a pumping period of 30 days is used in these calculations. Changes in water quality parameters (especially temperature) might result in changes in the hydraulic conductivity, which could in turn affect the hydraulic characteristics of the aquifer. Such changes are assumed to be minimal. Because the lateral extent of the calculated drawdowns is less than 0.2 foot even at the closest boundary at a pumping rate of 100 gal/min, the effects of boundary interference are assumed negligible.

As an example of the use of the hydraulic data, if a well is pumped at a rate of 30 gal/min for 30 days, the calculated change in head (drawdown) 40 feet away from the pumping well is about 1 foot. This result is a direct application of the Theis equation, $s = (Q/4\pi T) (W(u))$, (Lohman, 1972). Alternatively, injection of 30 gal/min for 30 days should increase water levels at the same point by the same amount. Either increasing pumping rate or decreasing estimated transmissivity would increase estimates of drawdown.

A single well pumping at a rate of 100 gal/min will cause estimated drawdowns of about 4, 3, and 2 feet at distances, respectively, of 60, 120, and 200 feet from the center of pumping (fig. 3). Other distance-drawdown relations for this pumping rate can be determined from figure 3. By choosing different pumping rates and different well spacings, an optimal well field design can be planned to minimize drawdown. Maximum reasonable drawdown is dependent both on properties of the well and of the aquifer--water level must be kept above the top of the pumping zone (screened portion of the aquifer) and drawdown must not exceed capabilities of the pumping equipment. Considering all of these variables, maximum withdrawal should result in a total drawdown of not more than 20 feet.

At distances close in to the pumping well, estimated drawdowns as calculated in the above examples are subject to error because of anisotropy of the aquifer, dewatering effects, and partial penetration. This results in divergence from the Theis equation, which assumes a homogeneous, isotropic aquifer of constant thickness, and a fully penetrating well. Since the error increases close to a pumping well, and since optimal well-field design would separate pumping wells by a distance at least equivalent to the thickness of the aquifer, figure 3 indicates drawdowns only for distances greater than 40 feet from the pumping well.

Although the water above a depth of 40 feet is fresh and initially could be used in a water supply system, after a short pumping interval brackish water from the lower zone would rise in response to a reduction in head, contaminating the upper freshwater zone. For example, even at low pumping rates (20 gal/min), water from well M-10 was observed to be gradually increasing in specific conductance after pumping for about 30 minutes.

Factors that limit the maximum reasonable volumes of water that can be injected into the surficial aquifer are the hydraulic properties of the aquifer and the method of injection (through wells or by a water spreading technique). In order to avoid saturation of the area of injection and consequent flooding, the water level must not be allowed to rise to more than about 1.5 feet below the land surface. As discussed previously, the water-table elevation in the study area is estimated to fluctuate seasonally almost 2 feet, with a minimum depth of about 2.5 feet below land surface. Particularly in the wet seasons (early summer and late fall),

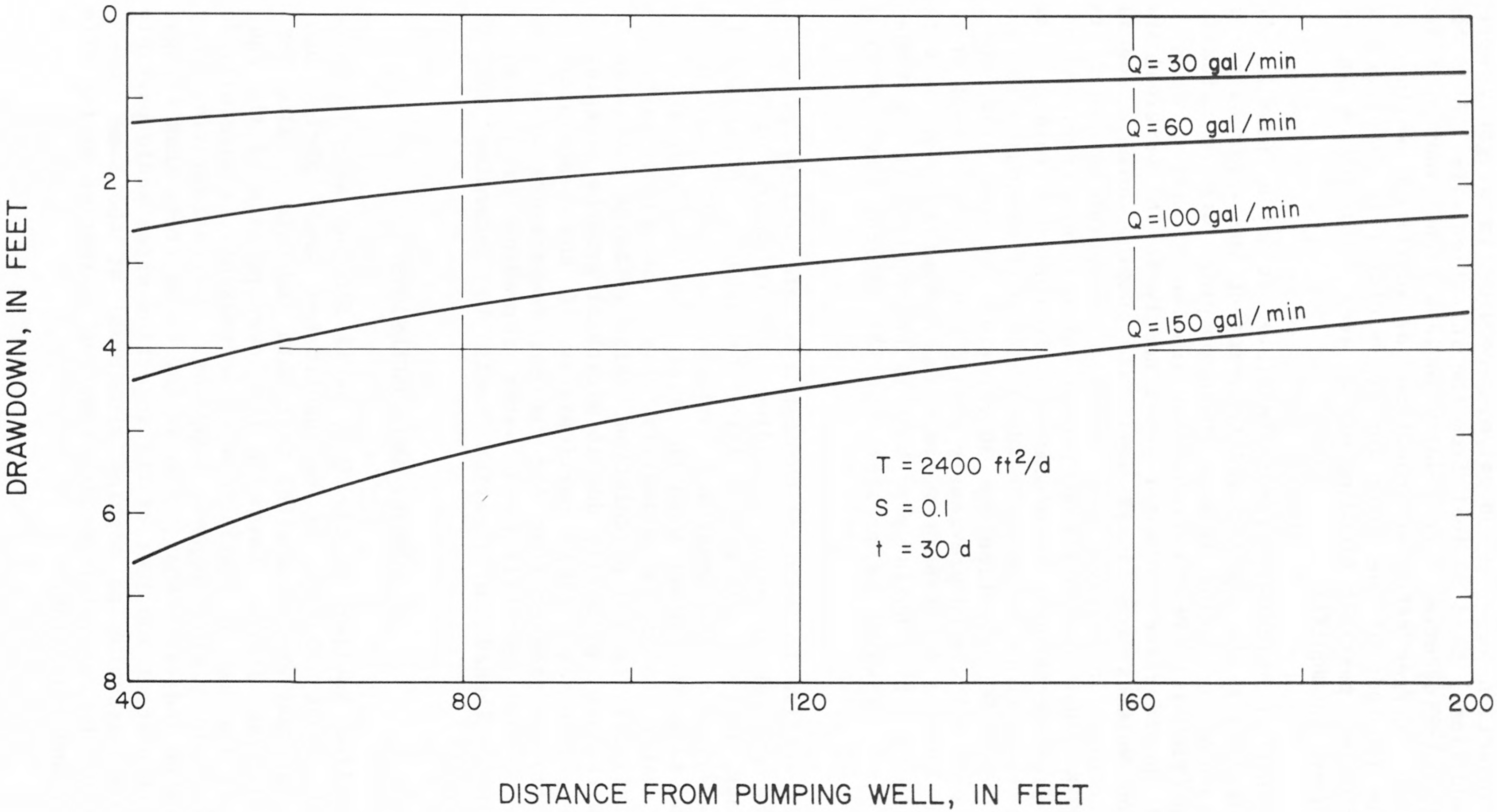

Figure 3.--Distance-drawdown curves for the surficial aquifer for selected pumping rates.

artificial recharge therefore is limited to about 1 foot of change in head. An injection rate of 30 gal/min results in slightly more than 1 foot of additional head 80 feet from the injection site. At a distance of 160 feet, this injection rate results in less than 1 foot of additional head (fig. 3). Larger rates of injection, or additional wells, can only increase the altitude of the water table, resulting in saturation of the surficial sand and possible flooding of the area. This assumes no ongoing withdrawal from the aquifer.

If the use of brackish water is feasible, it may be possible both to withdraw water from the aquifer and to reinject the water back into the system. Drawdown resulting from a known pumping rate is calculated as discussed previously. Reinjection of a similar volume of water into a nearby well should raise the water level nearly to the original surface. If injection volumes are always less than pumping volumes (because of various factors including loss through evaporation, and usage), water-level declines should always exceed water-level rises, and possible saturation problems should be minimized. Further, if injection volumes are similar to pumping volumes, drawdown should be minimal. For example, if pumping exceeds injection by 30 gal/min, the net drawdown at the pumping well as calculated previously should equal about 1 foot at a point between and 40 feet from both wells. One potential problem with this system is the potential build up of heat in the aquifer if the temperature of the reinjection water is greater than the ambient temperature in the aquifer.

One alternative to recharge through a single well or group of wells involves the concept of water spreading, the releasing of water over a large surface area to infiltrate into the ground. According to Todd (1959, p. 252), the most important factors, quantitatively, are area of recharge and time of contact with the soil. In the study area, the soil above the water table is primarily very fine sand, material which restricts infiltration and percolation. Also recharge rates can decrease gradually with time, primarily due to microbial growths clogging the soil pores (Todd, 1959, p. 256), particularly if the temperature of the recharge water is greater than the ambient temperature of the water in the aquifer. The feasibility of water spreading in the study area would require planned infiltration tests to determine soil-drainage characteristics.

SUMMARY AND CONCLUSIONS

The shallow aquifer at the U.S. Naval Station near Mayport, Fla., consists of about 70 feet of unconsolidated sand, shell, and clay. Lithologic information and aquifer test data indicate a value for transmissivity of 2,400 ft^2/d. Water in the lower portion of the aquifer is brackish. If the use of brackish water is feasible, a carefully designed well field could yield adequate supplies. A consideration of various injection rates indicates that, even at low rates (less than 100 gal/min), the area within about 200 feet of the injection sites would possibly incur some flooding, assuming no ongoing withdrawal at the same time. Local development of the surficial aquifer requires evaluation of the effects of both pumping and injection.

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