Geraghty & Miller, Inc.

32

GROUND-WATER AVAILABILITY
AT THE
ROSCHMAN ENTERPRISES PROPERTY
STUART, FLORIDA

November 1978

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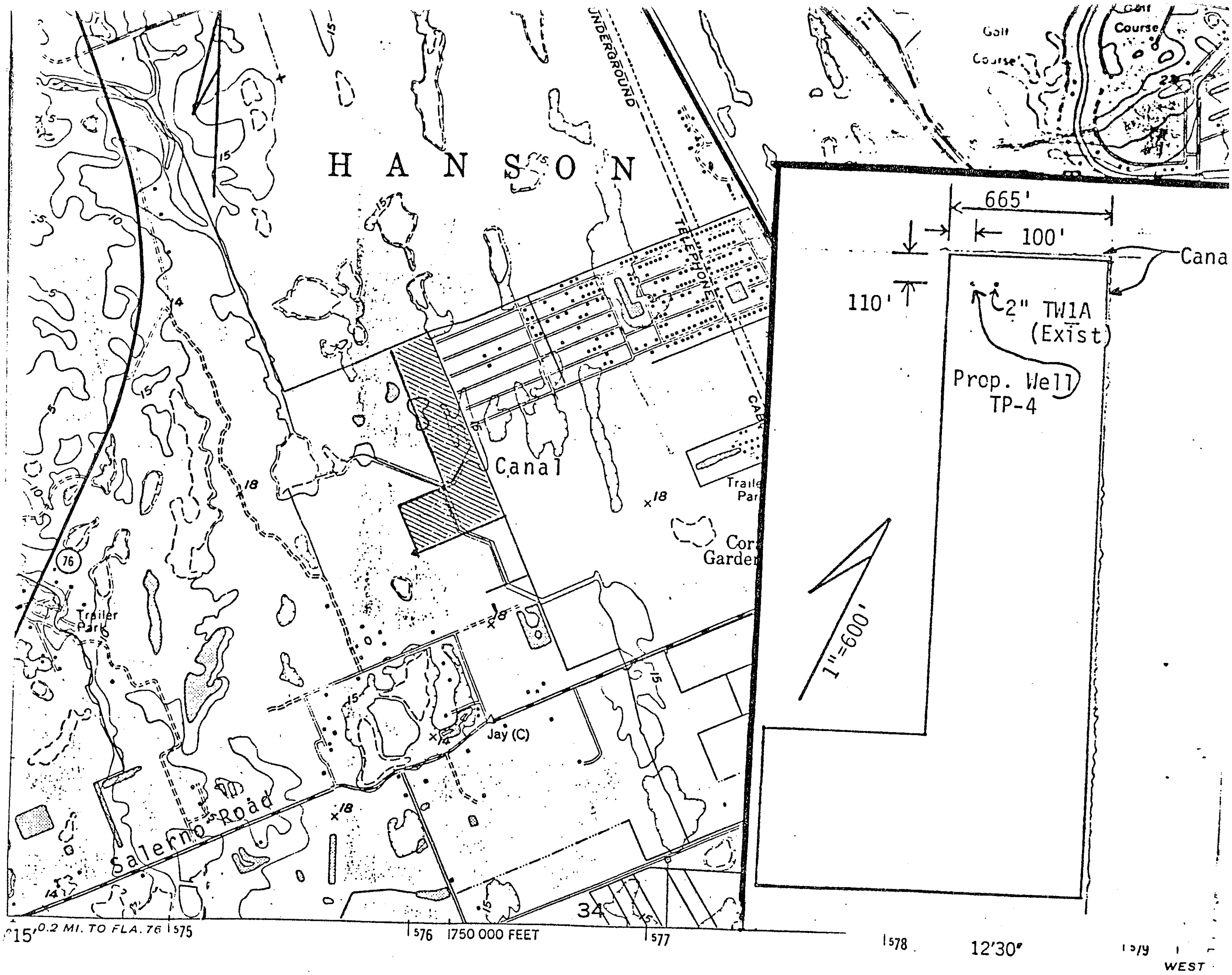

BESSEMER PROPERTIES

TEST/PRODUCTION WELL TP-4

WELL LOCATION MAP
St. Lucie Inlet Quadrangle

MARTIN COUNTY
Florida

82-3029-12
August, 1984

... and 98 of the Plat
of PORT SEWALL (SEWALL'S POINT LAND COMPANY SUBDIVISION) as recorded in Plat Book 3, page 7, public records of Palm Beach (now Martin) County, Florida, and being more particularly described as follows:

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

PLATES

GROUND-WATER AVAILABILITY
AT THE
ROSCHMAN ENTERPRISES PROPERTY
STUART, FLORIDA

INTRODUCTION

In May 1978, Roschman Enterprises authorized Geraghty & Miller, Inc., to investigate ground-water availability at a 600-acre site in Stuart, Florida. The site under study is located between Indian Avenue and Salerno Road, and between SR-76 and US-1. Lee Brock of Stuart, Florida was the project engineer. Drilling contractors were Doug Arnold Well Drilling of Stuart, and Fraser Engineering and Testing of Fort Pierce, Florida.

From existing information about various diversions in the area, and based on the experiences of Doug Arnold, who has installed numerous wells on the Stuart peninsula, it was determined that a highly productive water-bearing zone exists at a depth of 60 to 70 feet below land surface at this site. To evaluate the potential for ground-water withdrawals from this zone, a drilling and testing program was devised by Geraghty & Miller. The drilling program consisted of the installation of an eight-inch-diameter production well and a number of small-diameter observation wells. A 72-hour pumping test was planned.

WELL CONSTRUCTION

Production Well

The installation of the eight-inch-diameter production well was begun and completed in June 1978. Casing was installed to 62 feet below land surface by Doug Arnold Well Drilling using the cable-tool method. Where compacted or consolidated material was encountered, rotary drilling was first used to break up the material. The material inside the casing was then removed using compressed air.

Once the casing had been cleaned out, the formation material from the bottom of the casing to 70 feet below land surface was removed by continuing to drill with the combination of air jetting and rotary drilling. The borehole between 62 and 70 feet remained open and no well screen was needed. Development of the well was completed by surging with compressed air. During development, the driller estimated that discharge rates of more than 1000 gpm (gallons per minute) were achieved.

Observation Wells

To monitor drawdowns, seven observation wells were installed in June 1978 by Doug Arnold Well Drilling (Wells A1 to A4, S1, S2, and D1). These wells are all located within 400 feet of the production well. Their locations are shown on Plate 1. Wells A1 through A4 were installed to the same depth as the production well. These wells were constructed with two-inch-diameter PVC casing and 5-foot-long, 0.040-inch slot PVC screens. The casing lengths of Wells A1, A3, and A4 are 68 feet. To compensate for the slope of the land surface, which slopes westward, 65 feet of casing was installed in Well A2. Thus, these four wells are all open to the aquifer at the same elevation as the production well.

Wells S1, S2, and D1 were installed so that different depths could be monitored. Well S1 is located ten feet northeast of the production well. It is constructed with 12½ feet of two-inch-diameter casing and 2½ feet of 0.025-inch slot PVC screen and taps the upper part of the aquifer. Well D1, at the same location, is constructed with 125 feet of two-inch-diameter PVC casing and 5 feet of 0.030-inch slot PVC screen. Well S2, located adjacent to Well A2, is of similar construction to

Well S1. All of these observation wells installed in June were constructed by a combination of rotary drilling and air jetting. The annular space between the rotary-drilled borehole and the two-inch-diameter casing was filled with clean sand in the screen zone, and then backfilled to provide a seal.

In September 1978, six additional observation wells (Wells B1 through B6) were installed by Fraser Engineering and Testing of Fort Pierce, Florida, to the same approximate depth as the production well. They are located at much greater distances from the production well than were those wells constructed in June. Their locations also are shown on Plate 1.

All these wells were constructed by the rotary method. Formation samples were obtained by split-spoon sampling (eighteen-inch core sample obtained at five-foot intervals). Casings were 1½-inch-diameter PVC with 5-foot-long PVC well screens. Backfilling of the annular space between the borehole and casing was as described for the wells installed in June. Construction details of all wells are shown in Table 1.

PUMPING TEST PROCEDURE

In preparation for the 72-hour pumping test in June 1978, a vertical turbine pump (six-inch-diameter pump and column)

TABLE 1

CONSTRUCTION DETAILS
OF OBSERVATION WELLS
AT
ROSCHMAN ENTERPRISES
STUART, FLORIDA

Well	Casing Length (feet)	Screened Interval (feet below land surface)	Elevation of Casing Top, Measuring Point (feet above MSL)
S1 ✓	12½	11½ - 14	17.16
✓S2 ✓	12½	11½ - 14	13.63
D1 ✓	125	124 - 129	17.58
A1 ✓	68	66 - 71	17.34
✓A2 ✓	65	63 - 68	16.00
A3 ✓	68	67 - 72	16.28
A4 ✓	68	66 - 71	17.02
B1 ✓	66	64 - 69	17.08
B2 ✓	66	64 - 69	18.58
B3 ✓	66	64 - 69	17.52
B4 ✓	66	64 - 69	18.62
B5 ✓	60	58 - 63	15.32
B6 ✓	62	60 - 65	17.95

NOTE: Short lengths of casing were added to Wells S2 and A2 during the testing program. All reported data have been referenced to the final casing top elevation. All casings extend one to two feet above land surface.

capable of producing 500 gpm was installed in the production well. A 200-foot-long, leak-free discharge line was laid to the small pond nearby, adjacent to which Wells S2 and A2 had been installed. At the discharge end of the pipe, a 3-inch by 4-inch orifice and a manometer were installed to measure the discharge rate. A gate valve was installed in the discharge line so that the pumping rate could be controlled.

Prior to the start of testing, an electric recording barometer was installed at Lee Brock's office in nearby Stuart. A staff gauge was erected in the small pond, and a rain gauge was erected in a clearing within 50 feet of the production well. A water-level recorder was installed on Well A1. In addition, the consulting engineers for the City of Stuart were informed that testing at the Roschman property would be conducted during June and that they could observe the water-level recorders 3500 feet away at the City's Indian Avenue test site for possible effects of pumping.

1

A pumping test (Pumping Test I) was begun on June 8, 1978, at a constant discharge rate of 325 gpm, and water-level measurements were recorded in the seven observation wells located within 400 feet of the pumped well ("A" wells, "S" wells, and the "D" well). When the pump motor failed, after 5½ hours, the test was terminated. This short pumping period did not provide sufficient data for proper interpretation of the data. It did, however, provide valuable insights into the aquifer response which might be expected during a longer test.

A second pumping test at constant discharge was begun on

2 June 12, 1978 (Pumping Test II). The electric barometer, staff gauge, rain gauge, and water-level recorder continued to operate during the period between the first and second tests so that adequate pre-test barometric, precipitation, surface-water, and ground-water records were obtained during the interim.

It was planned to run the test at a constant rate of 325 gpm for 72 hours. However, after 26 hours the pump motor began to run erratically, and the pumping rate began to fluctuate. After 29½ hours, it was decided to abort the test. The barometer, rain gauge, and water-level recorder were then removed.

Water-level behavior during this test was such that aquifer coefficients could not be determined with any degree of reliability. For this reason, observation wells B1 through B6 were installed at greater distances from the pumped well in early September 1978. A more detailed explanation of the rationale for the installation of these wells will be found in a succeeding section.

A third test was performed at a constant discharge rate of 300 gpm from September 19 to September 22, 1978 (Pumping Test III). The electric barometer, rain gauge, and water-level recorder were reinstalled four days prior to the test. The water-level recorder was installed on Well A3, rather than on Well A1 as it had been in previous tests. No pump problems were experienced during this test, which was conducted for 71 hours and 55 minutes. Water levels during the test were measured in all available observation wells at the site, in the production well, and in several other wells in the area. After pumping was terminated, recovery measurements were taken in all wells for two hours. The pump was then restarted, and operated briefly at 550 gpm in order to determine if the well could be successfully pumped at a higher rate.

HYDROGEOLOGIC SETTING

Detailed driller's and geologist's logs were compiled for Wells B1 through B6 when they were drilled. The driller's logs are found in Appendix I. These logs indicate that geologic conditions in this area to a depth of 70 feet are fairly consistent in areas southeast, east, and northeast of the production well.

Varicolored, fine-grained sand was encountered in all "B" borings from the land surface down to depths of 25 to 30 feet below land surface. Within this section, a "hardpan" layer of brown, cemented, fine, silty sand was encountered at a depth of 4 to 6 feet below the surface. Some organic material was recovered from this depth zone by split-spoon sampling. Between 6 and 20 feet in several of the borings, the fine sand tended to have a high clay content, but below 20 feet, the sand was without clay to about 30 feet below the surface. Below 30 feet, the fine-grained sand tends to be gray colored and contains traces of shell fragments and limestone nodules. This material was reported to be uncemented to slightly cemented at depths to 45 feet below land surface. Below 45 feet to a depth of about 60 to 65 feet, cementation was much more common, as illustrated by both the reported penetration rates and field descriptions (Appendix I). Below 60 to 65 feet, fine-grained, gray, cemented and silty sand with limestone lenses was reported to the total depth of 70 feet below land surface in all borings.

The production well was completed in the 60- to 70-foot zone of cemented sand and limestone lenses. The production well is uncased beyond 62 feet below land surface. From 62 to 70 feet below land surface, an air compressor was used to create an open cavity. The formation material blown out of the well in this depth interval consisted of fine gray sand and large, porous limestone nodules. These large limestone nodules (some football-sized) apparently comprise a cemented rock unit which provides the wall strength for the borehole. By developing the production zone with compressed air, the fine sand was removed from the cavities in the porous limestone, thus developing the well.

Of the wells constructed at Roschman Enterprises, only one penetrated to a depth greater than 70 feet: Well D1, ten feet away from the production well, was drilled to 130 feet below land surface. The driller reported that zones of lower permeability were encountered between 70 and 130 feet. However, the data indicate that these zones occur in material similar to that found between 30 and 70 feet, differing from that zone primarily in physical hardness, degree of cementation, and dissolution of the limestone.

Comparison of the barometer and water-level records collected prior to Pumping Test II indicates that the aquifer responds very little to barometric fluctuations. In fact, during the pretest period, a decline in barometric pressure equal to 0.14 feet of water occurred. A corresponding rise in the water level in the observation well would have been expected; the reverse occurred, and only a slight decline was observed. Apparently, the barometric efficiency is low or nonexistent, suggesting the aquifer exists under water-table conditions. A significant tidal fluctuation in the water-level record has not been observed in the aquifer at the Roschman Enterprises site.

Because observation wells in the vicinity of the production well were screened at different depths, it was possible to monitor water-level changes at various zones in the shallow aquifer during pumping tests. In this regard, particular attention was paid to comparing water levels in Wells S1 and D1 and in Wells S2 and A2. Figure 1 demonstrates these relationships in a graph of water-level elevation versus logarithmic time during Test II. The relative rise in the water level in the discharge pond adjacent to Wells S2 and A2 also is shown. The only precipitation during this test occurred between 195 and 240 minutes after the start of pumping, when 0.06 inch of rain was recorded.

Wells S1 and D1 are located about ten feet from the production well. Comparison of the graphs of the data from these Wells indicates that the water levels responded in the same manner during the 29½ hours of the pumping test. Water levels declined slowly but steadily at about the same rate in the first

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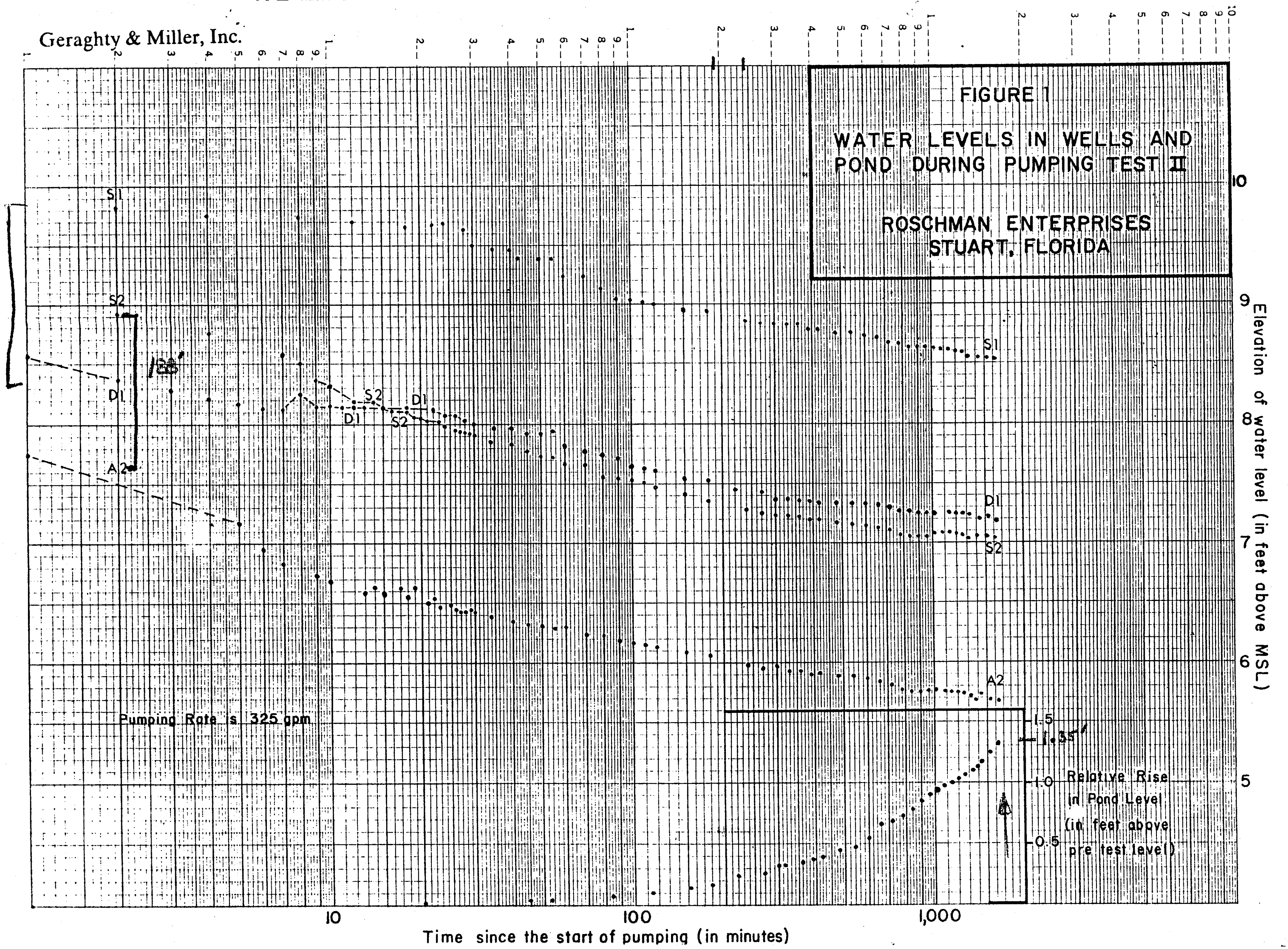

six minutes of pumping. A period followed in which the water levels declined very little, until about 20 minutes into the test. After 20 minutes, water levels again declined at a slow but steady and nearly identical rate. Thus, water levels in both these wells responded to pumping in the same manner, even though they tap shallower and deeper zones than the production well. Examination of Figure 1 shows that about the same amount of drawdown occurred in each well. Such behavior indicates the high degree of interconnection between zones and is evidence that these beds function as a single aquifer.

The same comparison also can be made with the data from Wells A2 and S2. Both of these wells are located 188 feet southwest of the production well at the shoreline of the nearby pond. The plots of the data indicate that the water levels declined steadily and at about the same rate throughout the test. Furthermore, although levels declined more rapidly than in S1 and D1 in the early part of the test, toward the end of the test the rates of decline in all four wells were nearly the same. The total drawdown recorded in Well S2 was only slightly less than that noted in Well A2. Such behavior is additional evidence of the existence of a single aquifer.

The comparisons made here indicate that a direct hydraulic connection exists at this site between the shallow, saturated sands (as represented by water levels in Wells S1 and S2), the production zone (as represented by water levels in Well A2), and the deep zone from which the Stuart production wells withdraw water (as represented by water levels in Well D1).

Comparison of the plots from Wells A2 and S2 indicate another feature--a lack of hydraulic connection between the pond near the production well and the shallow aquifer. As noted previously, the water levels in Wells A2 and S2 declined steadily throughout the test. Meanwhile, the water level in the pond rose steadily as a result of discharge from the well into the pond. In fact, the water level rose so that the land surface around these wells became flooded, and it was necessary to wade to them to collect water-level data. If a significant degree of hydraulic connection existed between the pond and the water table, a rapid stabilization or even a rise in water level in Well S2 would have been expected. Apparently, the pond lies in a closed depression with a bottom or substrata of low permeability due to the accumulation of a layer of fine-grained sediments and organic debris. In effect, the water in the pond is "perched" above the water table. It is unlikely that the bottom of the pond in question is completely sealed so that none of the discharged water was returned to the shallow aquifer. However, the volume of returned water must have been very small, as evidenced by the lack of effect on the water level in Well S2.

PUMPING TEST ANALYSIS

From review of the test data from all three pumping tests, it has been concluded that the aquifer exists under water-table conditions. The test data clearly show that pumping from depths of 62 to 70 feet affects water levels in shallow strata at depths of 15 feet and a deep zone at 130 feet at a location within ten feet of the production well. Also, at a distance of 188 feet from the production well, drawdowns in a well 68 feet deep are similar to those in a well 15 feet deep at the same location. Based on review of these data and from other wells drilled in the area, the water-table aquifer is estimated to extend to 140 feet below land surface beneath the site.

Water-level data from eight of the wells monitored during the third test are graphically presented as linear plots in Figure 2. The similarity in shape of all the graphs lends support to the concept of the existence of a single water-table

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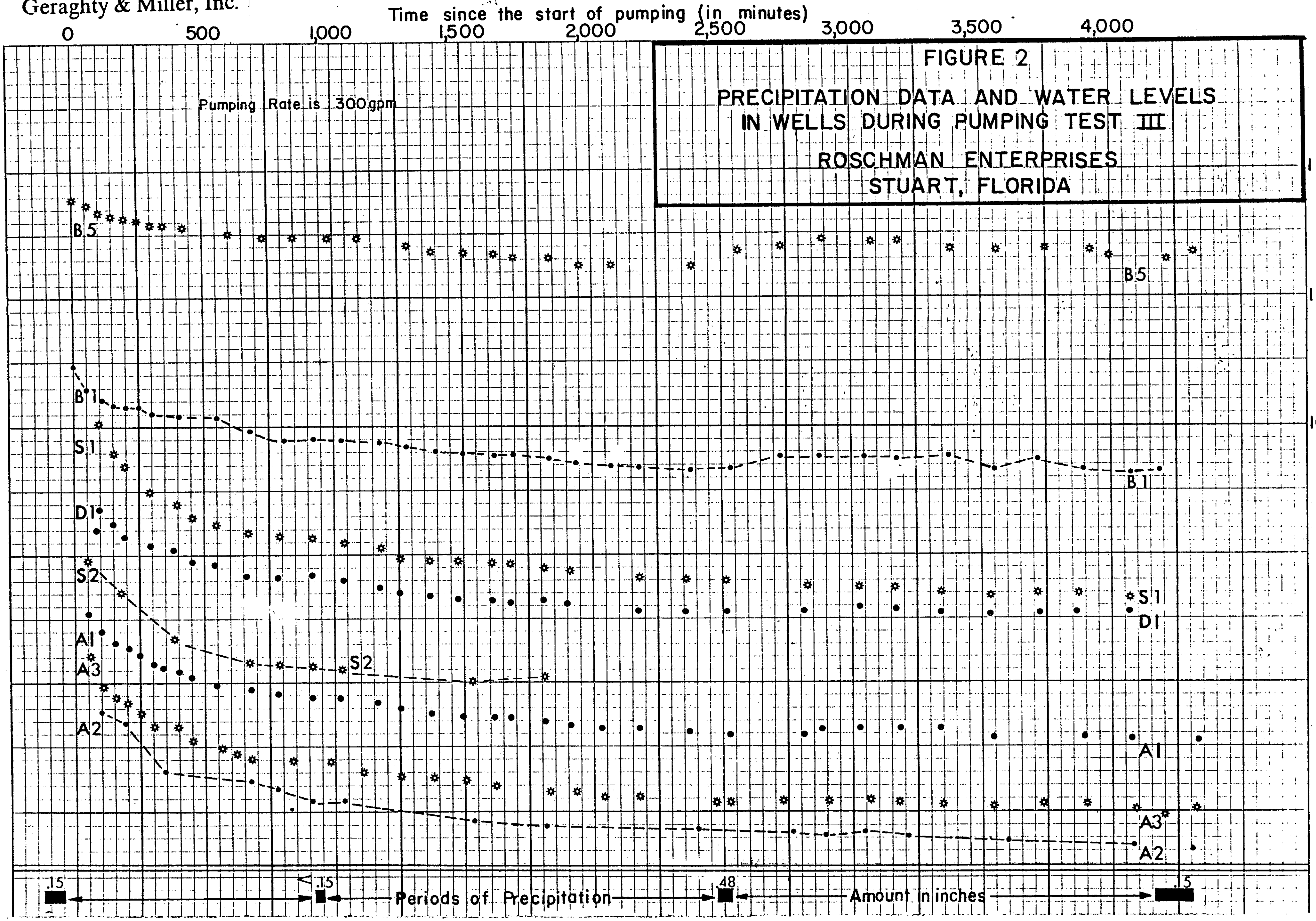

FIGURE 2
PRECIPITATION DATA AND WATER LEVELS IN WELLS DURING PUMPING TEST III
ROSCHMAN ENTERPRISES
STUART, FLORIDA

aquifer to the 140-foot depth at this site. Further, the correspondence in the rise of water levels in observation wells with periods of precipitation shows that the fine sands and the hardpan layer close to land surface do not restrict the infiltration of recharge to the aquifer.

Once it had been determined after the second pumping test that a water-table aquifer extending to 140 feet existed at the site, it was concluded that, considering the construction details of the production well, an insufficient number of observation wells existed at large distances from the production well where partial penetration effects are negligible and do not have to be corrected for in the analysis. It was for this reason that the "B" wells were installed in September 1978. In interpreting pumping test data from these "B" wells, partial penetration and dewatering effects may be neglected, and the uncorrected data can be used in test interpretation.

A methodology for deriving aquifer coefficients from a water-table aquifer was detailed by T. A. Prickett (1965). His method is based upon the concept of delayed yield expressed by N. S. Boulton (1963) wherein, after the commencement of pumping, additional water is released from storage by gravity drainage of unsaturated sediments above the cone of depression. Because the release of this water is not instantaneous with a decline in water levels in the aquifer, the phenomenon is known as delayed yield.

To apply the methodology, drawdown data from Wells B1, B3, and B5, located 1000 feet southeast, east, and northeast, respectively, from the pumped well were plotted versus time since pumping started on logarithmic graph paper. The data from these wells were selected for interpretation because these wells, unlike the "A" designated wells, are far enough away from the production well that partial penetration effects are minimal and do not have to be corrected for.

The plotted data were superimposed on two families of type curves (type "A" and type "Y" curves) for delayed yield responses from data tabulated by Boulton (1963). These type curves were presented by Lohman (1972). As much of the early time-drawdown data as possible was matched to one of the type A curves. A matching point on both grids was selected. The time-drawdown data curve was then shifted horizontally and matched to a type Y curve with the same r/B value. A second matching point was selected. According to Prickett (1965), the remaining time-drawdown data can be matched to a straight line drawn tangential to both curves. The time-drawdown data, constructed match curves, and nonleaky artesian (non-equilibrium or Theis) type curves for Wells B1, B3, and B5 are shown in Figures 3, 4, and 5, respectively.

From the curves and match points selected, the appropriate values may be substituted into the following equations in order to derive the aquifer coefficients:

$$T = \frac{114.6 \quad Q \quad W\left(u_{A,Y}, \frac{r}{B}\right)}{s}$$

$$S_A = \frac{T\ u_A t_A}{2693\ r^2}$$

$$S_Y = \frac{T\ u_Y t_Y}{2693\ r^2}$$

$$\frac{1}{\alpha} = \frac{4t\ u_Y}{(r/B)^2}$$

Where

s = drawdown in observation well, in feet

r = distance from pumped well to observation well, in feet

Q = pumped discharge rate, in gallons per minute

t_A, t_Y = time since pumping started, in minutes at the respective A and Y match points

T = coefficient of transmissivity, in gallons per day per foot

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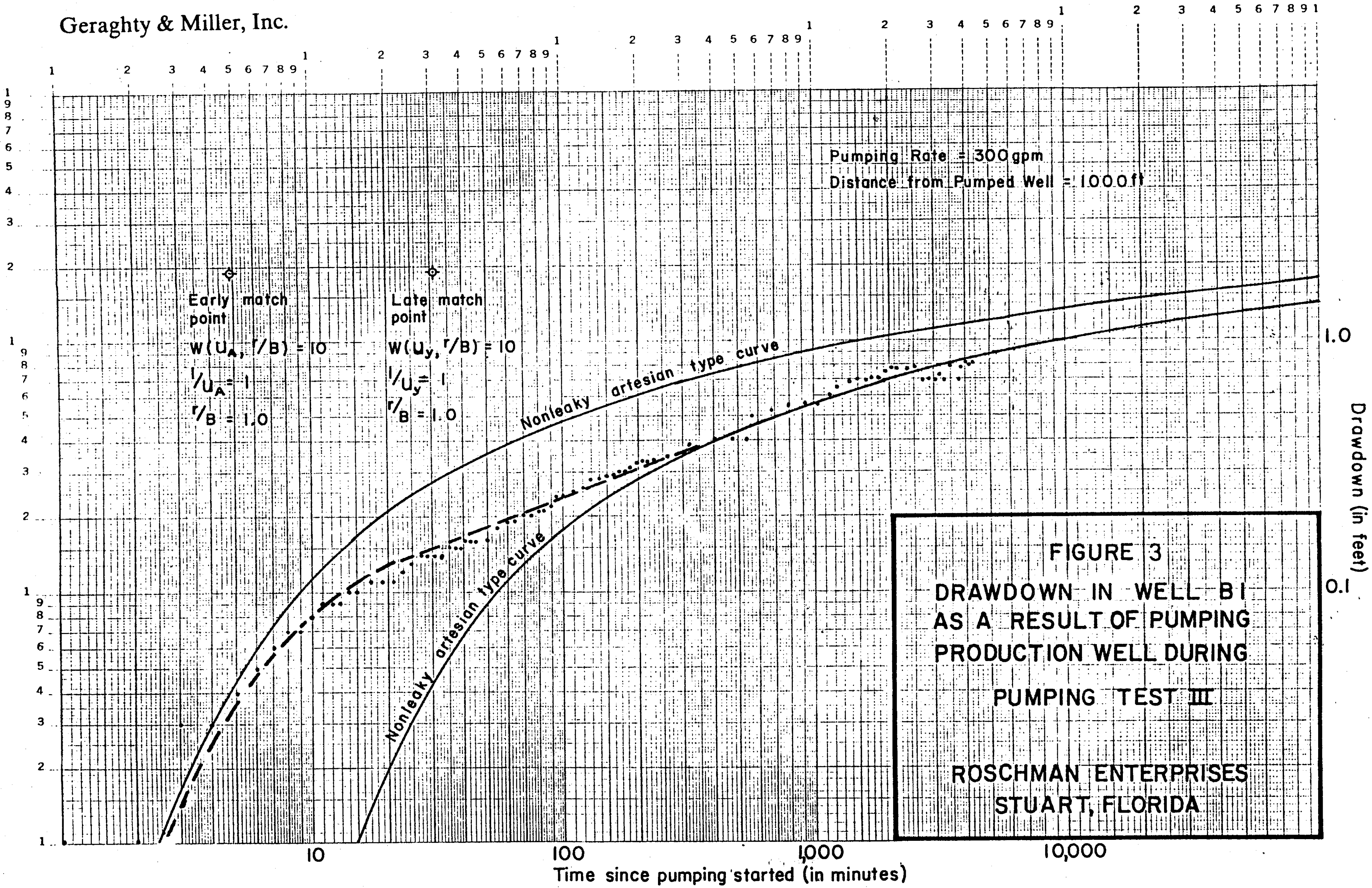

FIGURE 3
DRAWDOWN IN WELL B1 AS A RESULT OF PUMPING PRODUCTION WELL DURING PUMPING TEST III

ROSCHMAN ENTERPRISES
STUART, FLORIDA

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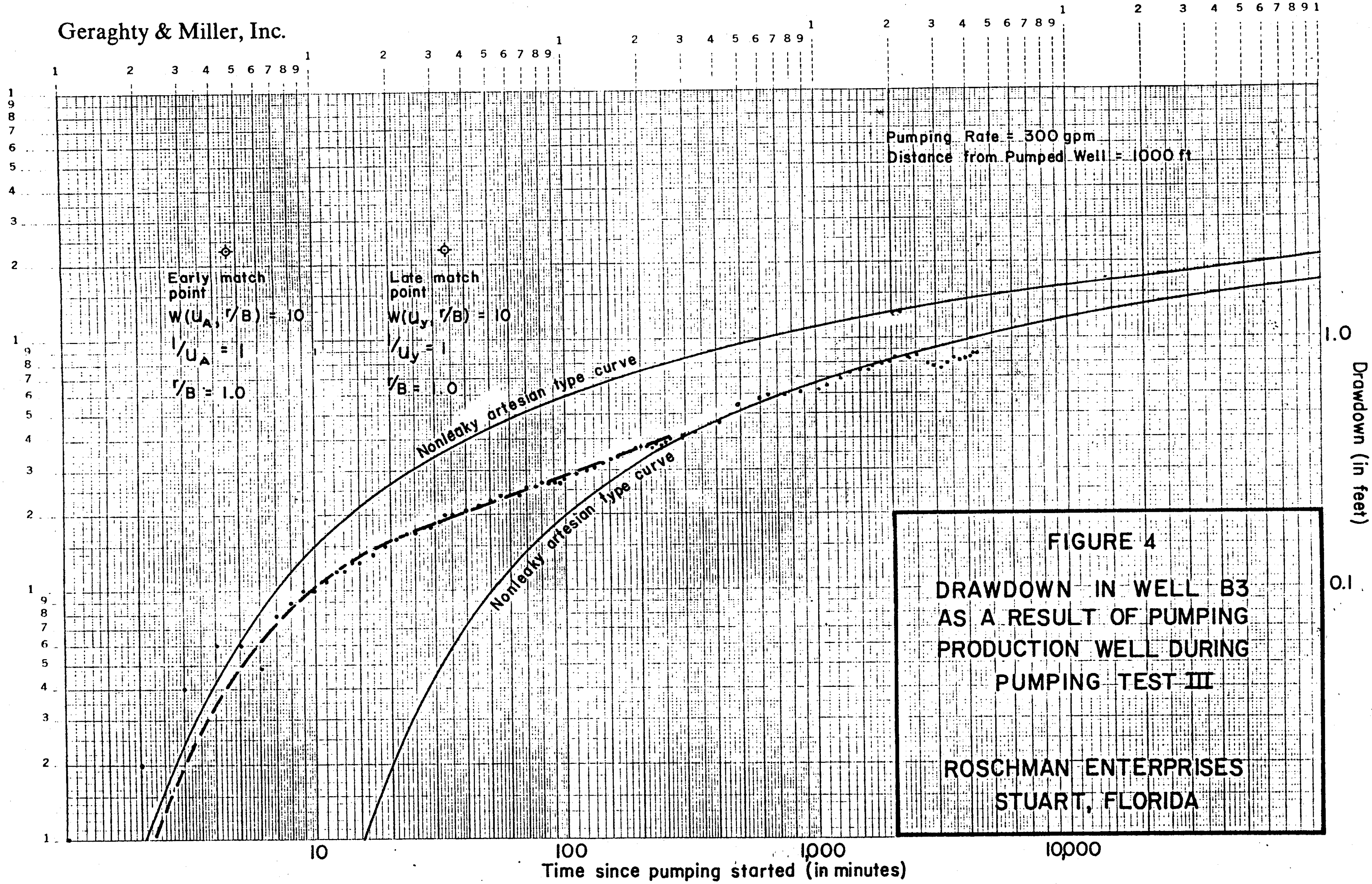

FIGURE 4

DRAWDOWN IN WELL B3 AS A RESULT OF PUMPING PRODUCTION WELL DURING PUMPING TEST III

ROSCHMAN ENTERPRISES
STUART, FLORIDA

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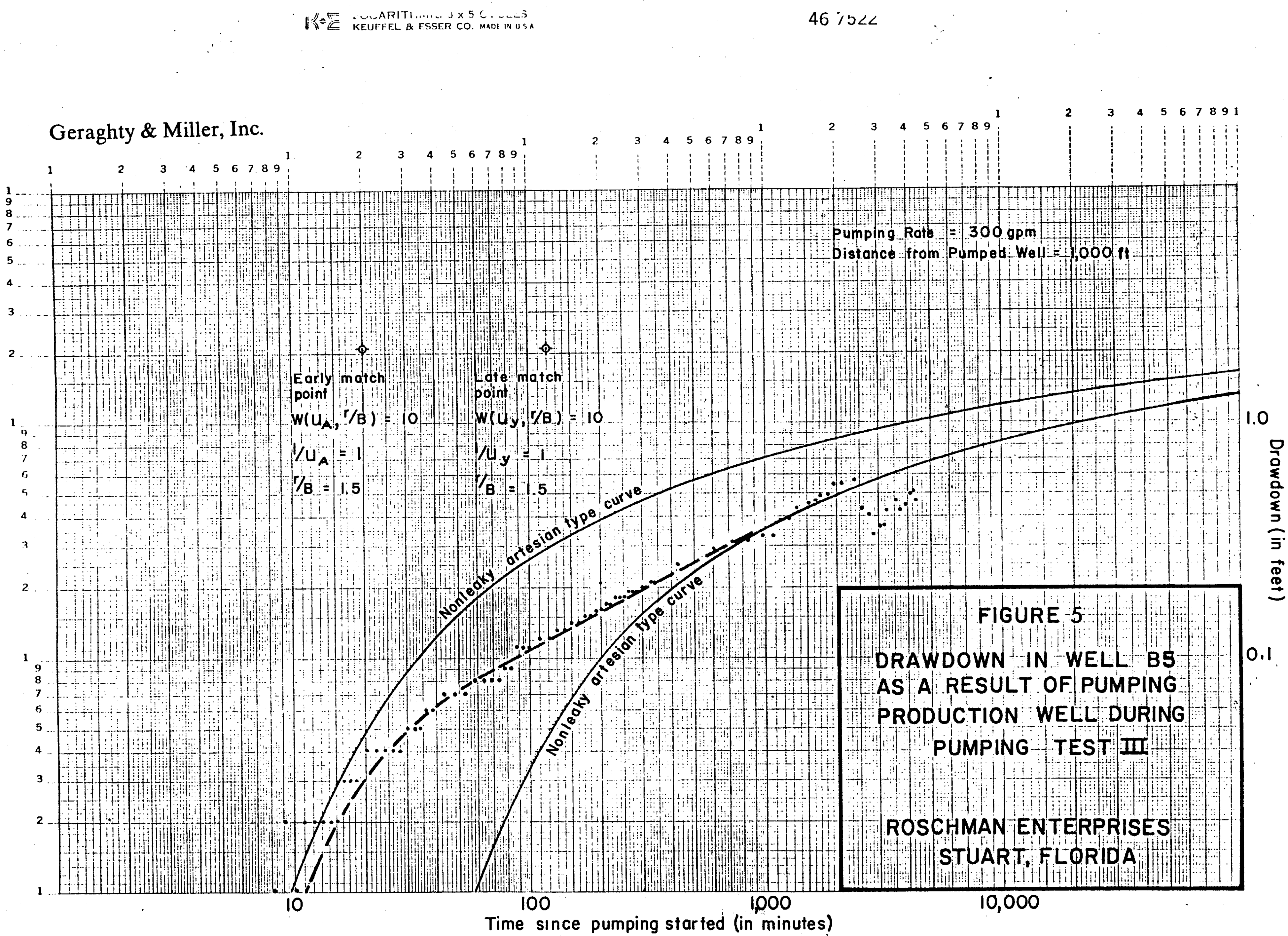

FIGURE 5

DRAWDOWN IN WELL B5 AS A RESULT OF PUMPING PRODUCTION WELL DURING PUMPING TEST III

ROSCHMAN ENTERPRISES
STUART, FLORIDA

S_A = volume of water instantaneously released from storage per unit drawdown per unit horizontal area, or the effective early-time coefficient of storage, dimensionless

S_Y = total volume of delayed yield from storage per unit drawdown per unit horizontal area (commonly referred to as the specific yield), dimensionless

$\frac{1}{\alpha}$ = delay index in minutes

$W\left(u_{A,Y},{}^{r}/_{B}\right)$ = well function for water-table aquifers, dimensionless

Table 2 lists the transmissivity, effective early-time coefficient of storage, apparent specific yield, and delay index in the vicinity of Wells B1, B3, and B5. As may be seen from the data, the aquifer appears to be slightly anisotropic. The degree of anisotropy does not appear significant. Therefore, mean aquifer coefficients have been selected by averaging the derived coefficients.

Data from Wells B2, B4, and B6 were not selected for interpretation because no significant drawdowns were observed in these wells until nearly ten hours into the test. Thus, the data collected in the three-day test was sufficient to establish

TABLE 2

AQUIFER COEFFICIENTS
AS CALCULATED FROM
DATA FROM OBSERVATION WELLS B1, B3, B5
DURING PUMPING TEST III
ROSCHMAN ENTERPRISES
STUART, FLORIDA

Well No.	Transmissivity (gpd/ft)	Effective Early-Time Storage Coefficient	Specific Yield	Delay Index (minutes)
B1	181,000	3.3×10^{-4}	2.1×10^{-3}	124
B3	149,000	2.6×10^{-4}	1.9×10^{-3}	136
B5	164,000	1.2×10^{-3}	7.3×10^{-3}	213
Mean	165,000 gpd/ft	6.0×10^{-4}	3.8×10^{-3}	

only the first or earlier of the two match points. Further, the drawdowns in these wells throughout the test were relatively small. Because these wells were so distant from the pumped well and drawdowns were small, the water levels were affected by external influences like precipitation, and other incidental pumpages in the area. During the test, no evidence of the effects of pumping the Roschman test well were observed in any of the wells monitored outside the property limits.

The transmissivity of the aquifer may be confirmed with data from the pumped well. Although access for water-level measurements in the pumped well was difficult because a six-inch-diameter pump column had been installed in the eight-inch-diameter well, occasional measurements were made during the second and third tests. From these measurements, specific capacities have been calculated. For the second test, the specific capacity is calculated to be 100 gpm/ft for the 29½-hour test at 325 gpm. For the third test, the specific capacity is 63 gpm/ft after 72 hours of pumping at 300 gpm.

W. C. Walton (1970) has provided the following equation for estimating theoretical specific capacity of a well discharging at constant rate in a homogeneous, isotropic, non-leaky artesian aquifer infinite in areal extent.

$$Q/s = \frac{T}{264 \log\left(\frac{Tt}{2693\, r_w^2\, S}\right) - 65.5}$$

Where:

Q/s = specific capacity, in gpm/ft

T = coefficient of transmissivity, in gpd/ft

S = coefficient of storage or specific yield

r_w = nominal radius of well, in feet

t = time since pumping started, in minutes

The equation assumes that the production well is uncased and fully penetrating the aquifer; well loss is negligible; and the effective radius of the production well has not been affected by drilling and development. Although the production well at the Roschman site violates most of the conditions and assumptions of the equation, the equation may be used to confirm the order of magnitude of the calculated transmissivities by trial and error. Using a specific yield value of 0.005, the transmissivities are calculated at 220,000 gpd/ft and 140,000 gpd/ft based on the specific-capacity data from the second and third tests, respectively. These are of the same order of magnitude as the coefficients determined from the analysis of the observation well data.

GROUND-WATER AVAILABILITY AT THE ROSCHMAN ENTERPRISES SITE

Ground-Water Recharge

The availability of ground water on the Stuart peninsula has been a subject of considerable discussion among planners, water managers, and hydrologists. Much of this discussion has centered upon the source and quantity of ground-water recharge in the area.

The last comprehensive mapping of the shape of the water table on the peninsula was presented by W. F. Lichtler (1960). He recorded water levels in selected water-table wells on the peninsula on July 6 and October 5, 1955. The two maps which he produced indicate that ground-water flow occurs generally from the center of the peninsula toward the St. Lucie River on the east, north, and west. A component of inflow occurs from south of Salerno Road toward the peninsula. A ground-water divide is indicated in the center of the peninsula parallel to US-1. East of the divide, ground-water flow is generally east to the St. Lucie River. West of the divide, flow is toward the South Fork of the St. Lucie River. With flow directions thus described, it is apparent that nearly all ground-water recharge to the water-table aquifer is derived locally and that no flow is possible from west of the South Fork of the St. Lucie River into the area. It may also be concluded from studying the maps that shallow ground-water flow at the Roschman site was from east to west in 1955. The static water elevations recorded at the Roschman site in September, 1978, before the third pumping test (Plate 1), indicate that ground-water flow is still from east to west, 23 years after Lichtler's mapping.

Since the flow pattern in the water-table aquifer indicates that aquifer recharge is derived locally, it is necessary to ascertain the source of recharge. Once again, the static water elevations recorded before the third pumping test are useful. Comparisons of the static levels of Wells S1 and D1 or Wells A2 and S2 indicate that a downward vertical component of flow existed in the aquifer under non-pumping conditions at the Roschman site. This phenomenon is not unexpected; it indicates that recharge is derived locally from precipitation. The abrupt response to precipitation indicated by the rise in water levels in the "B" wells during the third pumping test (Figure 2) supports this conclusion.

Because local precipitation is the principal source of ground-water recharge, a comparison of available recharge with present and anticipated pumpage on the peninsula is valuable in predicting the potential availability of ground water at the Roschman property. Nearly all the pumpage on the peninsula is located north of the southern boundary of Hanson Grant. This area has been planimetered from the southern boundary of Hanson Grant between the South Fork and Manatee Creek northward. The area thus defined is 17.9 square miles. This area is available to capture precipitation for recharge to the water-table aquifer. The area east of Manatee Creek (Miles Grant area) has been excluded, as have the various tidal creeks and the mangrove areas along the South Fork.

Based on 20 years of record, the mean annual precipitation in the Stuart area as reported by Lichtler (1960) is 56 inches. Of this quantity, a large portion is returned to the atmosphere by evaporation and transpiration by plants. A much smaller portion is discharged by direct surface runoff from the peninsula. The remainder is available for ground-water recharge.

Evaporation and transpiration losses are often combined under the descriptive term "evapotranspiration" (ET). Direct measurements of evapotranspiration are rare, but empirical methods have been devised to estimate that quantity. Parker, and others (1955), estimated evapotranspiration losses from a coastal ridge area south of Miami, with similar vegetative cover, soil conditions, and depth to water to that in Stuart. Total annual losses were estimated at 35 inches per year.

As reported by Lichtler, and others (1976), several investigators have made water-budget studies of large river basins in central Florida and presented ranges in annual evapotranspiration of 27.5 to 42.6 inches. These basins contain many different types of areas, including lakes and swamps, which are not common on the Stuart peninsula. Annual lake evaporation is very high, and it is likely that annual evapotranspiration from lakes and marshlands is equally high. Presumably, ET losses on sandy uplands like the coastal ridge are lower; 37.5 inches is assumed to be a reasonable annual ET value on central Florida uplands. For the Stuart peninsula, 36 inches may be assumed to be a reasonable average value for annual ET losses. Since rainfall is 56 inches per year, 20 inches per year remains available for use on the peninsula.

Surface-water drainage on the peninsula is slight. Only a few small creeks are found. Although no streamflow records exist for any of these creeks, it may be presumed that direct surface runoff is low--probably about two inches per year. The annual available ground-water recharge may thus be calculated as follows:

Precipitation	+56 inches/year
Evapotranspiration	-36 inches/year
Direct Surface Runoff	- 2 inches/year
Available Ground-Water Recharge	+18 inches/year

4.8×10^{-8} ft/D

As pumpage in the Stuart area increases, approaching the volume of annual ground-water recharge available, direct surface runoff and evapotranspiration may be slightly reduced. The volume of ground-water recharge may be similarly increased, so that slightly more than 18 inches may be ultimately available. However, in keeping with the conservative nature of this analysis, the figure of 16 inches per year of ground-water recharge will be used for calculations. Considering that the area on the peninsula north of the southern boundary of Hanson Grant is 17.9 square miles, available ground-water recharge is conservatively estimated at 4.98 billion gallons per year, or 13.6 mgd (million gallons per day).

Diversions on the Stuart Peninsula

The total diversion by users on the Stuart peninsula has been inventoried, and the major allocated, reported, and estimated diversions are listed in Table 3. Three major permitted diversions have been considered differently in this tabulation.

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TABLE 3

DIVERSIONS ON STUART PENINSULA
NEAR
ROSCHMAN ENTERPRISES

User	Average Allocated, Reported and Estimated Diversions	How Judged
City of Stuart	2,900,000 gal/day	Permitted
Intracoastal Utilities	600,000 9/76 ~~1,500,000 gal/day~~	Permit Pending
Fisherman's Cove	~~10,000 gal/day~~	Estimated
Miles Grant	~~261,000 gal/day~~	Permitted
~~Lakeside Flowers~~	~~16,783 gal/day~~	Reported
Lake St. George Golf	~~133,911 gal/day~~	Permitted
A W McKnight K. M. Wright	143,460 gal/day	Permitted
Florida Cuttings (Cove)	~~5,000 gal/day~~	Reported
location ? Calif-Fla Plant	100,000 gal/day	Estimated
~~Peter Green~~	~~Minimal~~	Estimated
Clifford M. Luce & Son	20,000 gal/day	Estimated
APP 24200 - Dorcas Flower Farm North of Indian	75,600 gal/day	Reported
~~Martin County Commissioners~~	~~Minimal~~	Estimated
Kings Mtn. Condo	30,532 gal/day	Permitted
~~Yacht & Country Club~~	~~147,180 gal/day~~	Permitted
Duane K. Luce	16,739 gal/day	Reported
Duane K. Luce	16,739 gal/day	Estimated

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Table 3
(cont.)

User	Average Allocated, Reported and Estimated Diversions	How Judged
Martin County Golf	101,500 gal/day	Permitted from shallow
Tyson Flower Farm	18,000 gal/day	Estimated
Karl Kruger	14,730 gal/day	Reported
Smith Flower Farms	46,869 gal/day	Reported
? Schramm's Flowers	30,000 gal/day	Estimated
~~Ed Miller & Son~~	~~60,000 gal/day~~	~~Estimated~~
K. F. Flowers	30,000 gal/day	Estimated
Florida Cuttings (Alhambra) 7½ ac	Minimal	Estimated
Florida Cuttings (Glendale) 5 ac	Minimal	Estimated
	4.77×10^6	

Haverty's
[illegible]
Alora
2871718

- Miles Grant, occurring as it does on a ridge east of Manatee Creek is relatively isolated from the main body of the aquifer on the peninsula. It is likely that shallow ground water in the vicinity of Miles Grant discharges naturally to the creek, Manatee Pocket, and Great Pocket. Therefore, consumptive use at Miles Grant is not considered to be part of consumption on the peninsula.

- Likewise, the permitted 133,911 gpd (gallons per day) diversion of Lake St. George Golf Club has also been disregarded. This area is largely undeveloped and rather remote from other centers of pumpage.

- Intracoastal Utilities has a permit pending for an allocation of 1.5 mgd. Although the present diversion is considerably smaller, it is anticipated that the requested 1.5 mgd allocation will be approved, and it was thus tabulated.

  As one of the permit conditions, Intracoastal is expected to be required to restrict their pumpage to 600,000 gpd from the two wells located at the Yacht & Country Club. The additional 900,000 gpd will be withdrawn from wells located one-half mile or more south of the southern boundary of Hanson Grant. The impact of pumpage from these wells under steady-state conditions is not expected to extend north of the boundary. Therefore, only the 600,000 gpd quantity will be considered in evaluating the impact of the diversion from the Roschman property.

The total allocated, reported, and estimated major diversions in this area total 4.4 mgd. An additional 1.0 mgd is estimated for non-permitted ground-water use (600,000 gpd north of Indian Avenue; 300,000 gpd south of Indian Avenue east of US-1; and 100,000 gpd in the remaining area). A total of 5.4 mgd is thus estimated to be used or allocated.

The difference between present and future total use is not great. Most agricultural users are withdrawing their maximum allocations at present. Likewise, the City of Stuart's average-day demand is very close to its allocation. Of the major users, only Intracoastal Utilities is pumping much less than it will be allocated. Intracoastal presently withdraws about 200,000 gpd from the Yacht & Country Club well field.

Total ground-water consumption on the peninsula is not expected to approach 5.4 mgd. Twenty percent of the domestic supplies, or 900,000 gpd, both public and private, may be estimated for lawn and garden irrigation. Assuming an irrigation efficiency of 50 percent, 450,000 gpd is returned to the aquifer by domestic irrigation. Thus, the true consumptive use is probably closer to 5.0 mgd, or 37 percent of the available ground water on the peninsula north of the southern boundary of Hanson Grant. The quantity available is 8.6 mgd.

Steady-State Model

The Roschman property is located in an area of minimal ground-water use at present. In fact, no adjacent ground-water users have diversions sufficient to require consumptive use permits. The nearest diversion of any size is that of the Dorcas Flower Farm, with a reported consumptive use of 75,600 gpd. Therefore, a rather simple model has been developed to determine the volume of water which may be withdrawn from the shallow aquifer at the Roschman site, and to predict the impacts of pumping that volume.

Because the aquifer on the peninsula is recharged by local precipitation and because existing pumpage has not caused salt-water intrusion (insofar as can be determined), a steady-state condition has been presumed to exist about all of the area's diversions with total consumptive use balanced by recharge. Thus, the cones of depression may be assumed to extend only to a distance adequate to intercept a volume of recharge equal to the diversion. The perimeters of these cones of depression have been mapped (see Plate 2). North of Indian Avenue in the City of Stuart, diversions are concentrated west of the airport. Cones of depression for many existing diversions in this area overlap. Consumptive use in this area is estimated at 3.6 mgd, including all allocated, reported, and estimated flower farm diversions, the city's allocation, and unpermitted (600,000 gpd) pumpage. The 3.6 mgd figure takes into account the 50-percent irrigation efficiency of pumpage which is used for lawn and garden irrigation.

A 3.6-mgd diversion will develop a steady-state cone of depression with a radius of 6400 feet. The center of the area of concentrated pumpage has been arbitrarily selected adjacent to the west side of the City well field on US-1 about 3000 feet north of Monterey Avenue. This places the center between the City wells and the large number of flower farm wells. The cone extends to the St. Lucie River on the north and the South Fork on the west, to Indian Avenue on the south and the center of the airport on the east. The cone of depression thus defined expresses the observed conditions in this area where no significant salt-water intrusion has been reported except temporarily in wells along the coast during the dry season. Other diversions which are sufficiently remote from this concentrated area of pumpage to develop their own cones of depression are Karl Kreuger, Martin County Golf, and Dorcas Flower Farm. These are shown on Plate 2.

A similar steady-state cone of depression has been generated for consumptive use in the Port Salerno area. Principal uses in this area are the pending allocation for Intracoastal Utilities from wells located at the Yacht and Country Club (600,000 gpd), the allocations for the Yacht & Country Club of Stuart (147,180 gpd), Ed Miller and Son Farms (60,000 gpd), and other unpermitted uses (300,000 gpd). Calculating ten percent return of pumped water from Intracoastal's wells and unpermitted uses, the consumptive use in this area is estimated at 1,017,180 gpd. A steady-state cone of depression from this diversion is calculated to extend 3400 feet from its center, which has been arbitrarily selected to be at the entrance gate to the Yacht and

Country Club, in the middle of Intracoastal's well field and centered between the Yacht & Country Club wells and those of Ed Miller & Son.

The various diversions in the area are expected to have a small impact on a diversion at the Roschman property. A seven-well field is being considered at the site. However, because the aquifer transmissivity is so high, the effect of pumping individual wells is not apparent away from the immediate vicinity of the wells. Therefore, a single large-capacity well in the middle of the proposed field may be used to represent the total diversion.

Within 7000 feet of such a well at the Roschman site, 4.21 mgd is assumed to be available as recharge. However, under steady-state conditions, the users previously noted require a portion of that recharge as part or all of their diversions. By calculating the overlapping area between a 7000-foot radius cone of depression from the middle of the Roschman well field and the various other cones of depression in the area, it is possible to deduct from the 4.21 mgd the quantity necessary to support the other diversions. For example, the users in Stuart, west of the airport and north of Indian Avenue require 0.26 mgd of this recharge to maintain steady-state conditions in that area. In Port Salerno east of US-1, 0.17 mgd is required from recharge to provide water in that area. Other consumptive uses within a 7000-foot cone of depression are Dorcas Flower Farm (75,600 gpd), Fisherman's Cove (10,000 gpd), Lakeside Flowers (16,783 gpd), and an estimated 10,000 gpd from the 100,000 gpd in unpermitted diversions west of US-1 (consumptive use is small in that area because the area is unsewered). These diversions place an additional demand on the recharge available to the Roschman site. The "water budget" within a 7000-foot radius cone of depression from the Roschman site is shown below:

Recharge within 7000-foot radius	+4.21 mgd
Consumptive use north of Indian Avenue	-0.26 mgd
Consumptive use east of US-1	-0.17 mgd
Additional consumptive uses within the cone of depression	-0.10 mgd
Total recharge available within 7000 feet of center of Roschman well field	+3.68 mgd

A steady-state cone of depression about the large-capacity well can be generated. When applied to a multi-well field, the model will not precisely reflect the drawdowns in the immediate vicinity of pumping wells. However, because of the high aquifer transmissivity, the influence from pumping individual wells will be minimal outside the property limits, and a large-capacity well may be used to represent the pumpage from all wells.

Using the transmissivity calculated from data from the third pumping test, an aquifer thickness of 140 feet, an an effective cone of depression of radius 7000 feet, the Thiem equation has been employed to model drawdowns in the cone of depression for a consumptive use of 3.68 mgd. It is assumed that no portion of the 3.68 mgd is returned to the aquifer, although it is recognized that as the site is developed irrigation return will reduce consumption.

The Thiem equation may be expressed as (UOP-Johnson, 1966):

$$s = m - \sqrt{m^2 - \frac{1055 \text{ mlog } R/r}{T} \quad (Q)}$$

Where

s = drawdown, in feet at radius r from the pumped well

m = aquifer thickness, in feet

r = radius to observation point of interest, in feet

T = aquifer transmissivity, in gpd/ft

R = radius of cone of depression, in feet

Q = pumping rate, in gpm

Assumptions upon which the Thiem equation is based are:

1. The water-bearing materials are of uniform permeability within the cone of depression.

2. The aquifer is not stratified.
3. The aquifer thickness is constant before pumping starts.
4. The pumping well is 100 percent efficient.
5. The well penetrates to the bottom of the aquifer.
6. The water table has no slope; it is a horizontal surface.
7. Laminar flow exists.
8. The cone of depression does attain equilibrium.

Several of these assumptions are contravened within short distances of the pumped well. However, they may be assumed to hold true at greater distances. Thus, this analysis should serve as an adequate approximation of drawdown in the aquifer in areas away from the well field.

Within the cone of depression, a drawdown of three feet will be observed at 3000 feet, and two feet at 4000 feet. The 0.5-foot drawdown contour is predicted at a radius of 6000 feet, as shown in Figure 6.

Nonsteady-State Model

The steady-state cone of depression will adequately represent the effect of a long-term 3.68 mgd diversion from the Roschman Enterprises property. However, it is recognized that for drought periods, the ground-water system may not be

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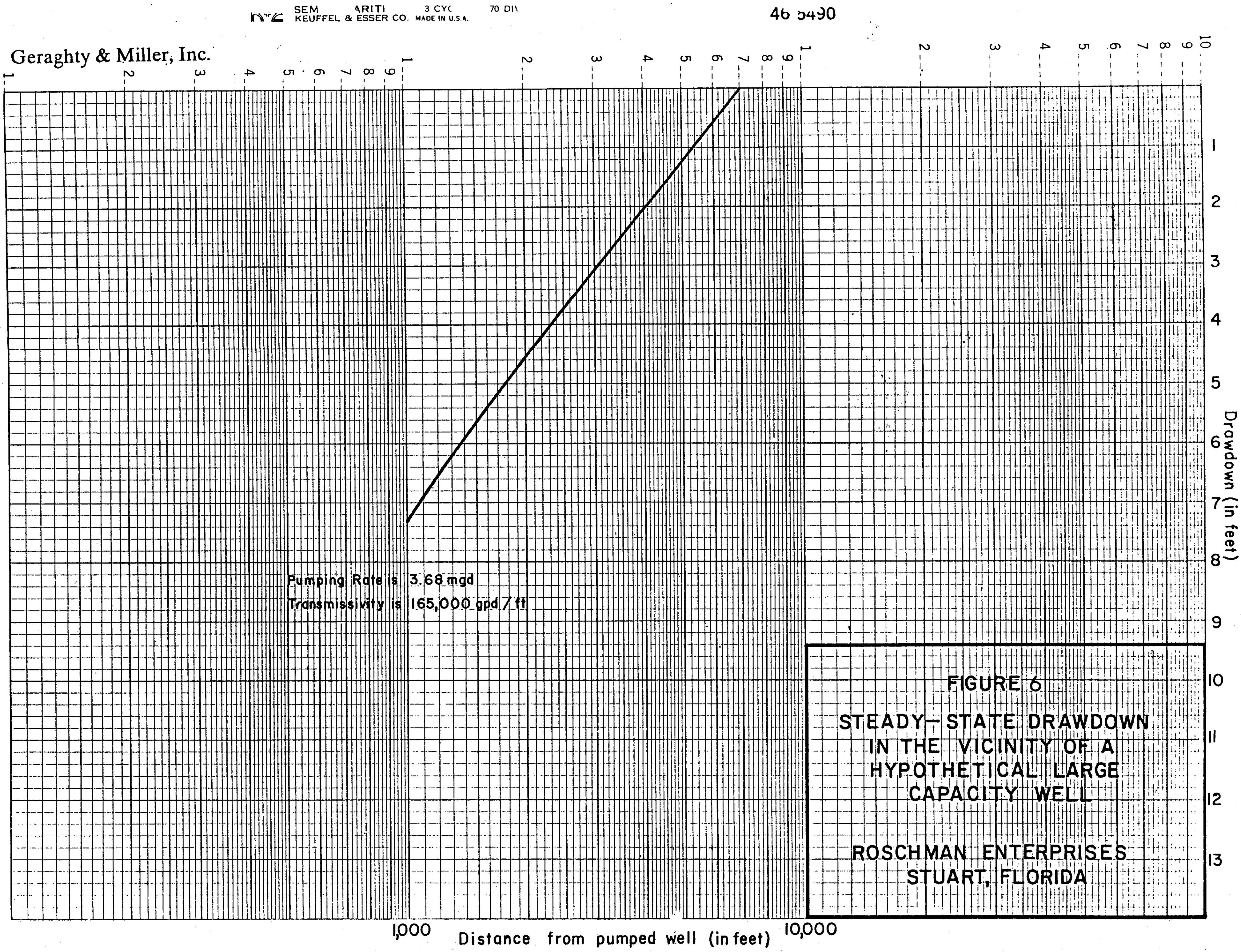

FIGURE 6

STEADY-STATE DRAWDOWN IN THE VICINITY OF A HYPOTHETICAL LARGE CAPACITY WELL

ROSCHMAN ENTERPRISES
STUART, FLORIDA

adequately described by the equilibrium or steady-state condition because recharge from precipitation will be less than the daily pumpage. For this reason, the non-equilibrium well formula of Theis (UOP-Johnson, 1966) has been used in the predictive model. The formula is:

$$s = \frac{114.6\ Q\ W(u)}{T}$$

Where

s = drawdown, in feet, at the observation point in question

Q = pumping rate, in gpm

T = coefficient of transmissivity, in gpd/ft

$W(u)$ = well function of u where W(u) is an exponential integral

In the exponential integral

$$u = 1.87\ r^2\ S/Tt$$

where

r = radius to observation point in question, in feet

S = coefficient of storage, dimensionless

t = time since pumping started, in days

Although this equation was derived as a means of mathematically describing water-level response in a non-leaky artesian aquifer, it serves to approximate drawdowns in a water-table aquifer after the effects of delayed yield have dissipated. Using the aquifer coefficients as derived from the data from the third pumping test (transmissivity equals 165,000 gpd/ft, and the coefficient of storage under water-table conditions--specific yield--equals 0.0038), the non-equilibrium cone of depression has been generated for a 90-day period of no recharge to the aquifer. The 90-day period was selected as being the maximum period for a prolonged drought in the dry season during which no recharge to the aquifer might occur.

For modeling purposes, seven production wells have been used spaced 1000 feet apart in a line trending northwest to southeast, parallel to and 5000 feet from US-1. The northernmost well is at the location of the eight-inch-diameter test well. Each well was pumped at 365 gpm continuously for a total well field demand of 3.68 mgd. The wells were operated for 90 days, and the cone of depression from this pumpage was computed.

The nonsteady-state model confirms the assumption of a circular shape for the outer limit of the cone of depression in the steady-state model. Despite the alignment of the production wells, drawdowns from the nonsteady-state situation will create a slightly elliptical cone of depression at large distances from the well field with the major axis of the ellipse trending through the line of wells. The drawdown from this diversion will extend beneath the peninsula; six feet of drawdown is predicted to occur 6000 to 7000 feet from the center of the well field, and five feet of drawdown will occur 8000 to 9000 feet away. These predicted drawdowns represent a "worst case" condition, which could be anticipated in a severe drought with no recharge to the aquifer. The actual impact is expected to be less because even in severe droughts some precipitation will occur which can recharge the aquifer. Furthermore, as the water table declines in areas where it is close to the land surface, evapotranspiration will be salvaged. As shown in previous calculations, when sufficient recharge is available, the cone of depression from such a diversion will stabilize within a radius of 7000 feet. Furthermore, the nonsteady-state model presumes that none of the pumped water will be returned to the aquifer. However, it may be assumed

7000' assumed at R in Calc.

that about twenty percent of the pumped water will be used for irrigation. With an irrigation efficiency of 50 percent, this use will result in a return of 370,000 gallons per day to the aquifer. Thus, the impacts of pumping even in this "worst case" condition will be less than predicted.

GROUND-WATER QUALITY

Ultimately, all water used in the Stuart area is derived from recharge by local precipitation on the peninsula. For wells tapping the water-table aquifer, recharge migrates downward and eventually reaches the well. Thus, the quality of water from a pumped well will be directly influenced by the quality of recharge.

The quality of water from the eight-inch test well is shown in Appendix II. The sample was obtained on June 13, 1978, on the second day of Pumping Test II. The water appears to be of good quality. Total dissolved solids are about what one might expect for this area. Hardness is high, but typical. The iron concentration, although above recommended public health limits, is not excessive. Hardness and iron concentrations are treatable with present technology, and a potable product can be delivered.

Saline Ground Water

Salt-water intrusion potential at the Roschman site is believed to be low. The South Fork of the St. Lucie River west of the site is the closest body of saline water. This water is reported to have a salinity of 10,000 to 15,000 ppm. Even though the St. Lucie River is salty, there is no guarantee the ground water is. Considering the location of the area on the river encompassed by the steady-state cone of depression, it is possible that the ground water may be fresh. Although no large diversions exist in the area under study, small diversions adjacent to SR-76 and Indian Avenue (Dorcas Flower Farm, Riverbend Trailer Park, and Fisherman's Cove) are much closer to the river but have shown no evidence of salt-water intrusion. This is not surprising. Even if a hydraulic connection does exist between the river and the aquifer, only a small section of the steady-state cone of depression extends to the river from the Roschman site. The brackish water which might be drawn into the aquifer through that section will be considerably diluted by the much greater volume of fresh water derived from recharge by precipitation.

It also should be noted that a 3.68-mgd diversion from the Roschman property will be much less than the total present diversion calculated for the area to the north in the City of Stuart, which is bounded on three sides by salt water.

CONCLUSIONS

1. A highly productive water-bearing zone exists at depths of 60 to 70 feet below land surface.

2. Production wells can be completed without well screens in the 60- to 70-foot zone.

3. To depths of 70 feet below land surface, formation materials consist mainly of fine sand, cemented to varying degrees.

4. Below 70 feet, zones of lower permeability exist. However, no significant confining beds were reported between the water table and the 130-foot depth. Hardpan at 4-5' but no clay.

5. A single aquifer exists under water-table (unconfined) conditions in the area and extends to an estimated depth of 140 feet.

6. The pond into which the discharges from the pumping tests were conducted exists as a perched pond. Little or no

water drains from this pond to the water-table aquifer. The other ponds on the property are probably also perched.

7. Water levels in the water-table aquifer respond rapidly to precipitation but little or not at all to tidal and barometric changes.

8. No effect from the 72-hour pumping test was noted in observation wells at Stuart's Indian Avenue test site. These wells are screened in the zone from which the City withdraws its water.

9. The transmissivity of the water-table aquifer is 165,000 gpd/ft. The specific yield is 0.0038.

10. Ground-water flow directions in the water-table aquifer have changed very little since they were last mapped in 1955.

11. Recharge to the water-table aquifer is derived locally from precipitation. The average annual aquifer recharge is 16 inches.

12. Conservatively estimated, 13.6 million gallons per day of recharge is available to wells on the main body of the Stuart peninsula. Present consumptive use on the peninsula is 5 mgd.

assumed in steady state analysis

13. Within a radius of 7000 feet of the center of a properly designed well field at Roschman Enterprises, 3.68 mgd is available for long-term use from ground-water recharge.

14. During droughts, a drawdown of six feet is possible within 6000 to 7000 feet of a seven-well field at Roschman Enterprises.

15. The quality of water from wells at Roschman Enterprises is generally good, although hard and high in iron. The water is treatable with present technology, and a potable product can be delivered.

16. The salt-water intrusion potential at this site is low, considering the planned diversion. No salt-water intrusion has been reported in wells between the site and the brackish South Fork of the St. Lucie River.

RECOMMENDATIONS

1. Wells could be installed at this site to achieve an average-day demand of 3.68 mgd.

2. Positive surface-water drainage measures should be undertaken to promote aquifer recharge in this area.

Respectfully submitted,
GERAGHTY & MILLER, INC.

Thomas L. Tessier

Thomas L. Tessier

Vincent P. Amy

Vincent P. Amy

November 10, 1978

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APPENDIX I

Description of "B" Borings

Roschman Enterprises
Stuart, Florida

FRASER ENGINEERING AND TESTING

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FORT PIERCE (305) 461-7508
VERO BEACH (305) 567-6167
STUART (305) 283-7711

OCT 0

September 14, 1978

Mr. Lee Brock, P.E.
Post Office Box 259
Stuart, Florida 33494

Gentlemen:

Enclosed are the results of the Soils Investigation and Piezometer Installation in conjunction with the eight (8) inch test well at Roschman Enterprises, Inc., Indian Avenue Site in Martin County, south of Stuart, Florida.

TEST BORINGS AND PIEZOMETER INSTALLATION

Six (6) seventy (70) foot standard penetration test borings were taken at the site. Borings B-1 and B-2 were taken at 1000 foot intervals respectively, from the test well on a line running due South. Borings B-3 and B-4 were at the same intervals running Southeast from the well and Boring B-5 and B-6 were at the same intervals on a line running due East from the well.

The materials encountered and penetration resistances are as described and noted on the individual boring logs.

Drilling procedures, relative density and consistency correlated with standard penetration resistances, and identification of soils are described in Attachment "A".

At the termination of each boring a 1½" pvc pipe with five (5) foot well screen was installed to the bottom of the bored hole. Clean sand was placed around the screen to a depth above the top of the screen. The hole was then backfilled. After backfilling, the piezometers were pumped until the water cleared.

After completion of the work, the soil samples for each of the test borings were given to Geraghty & Miller, Inc. representative.

Respectively submitted,

FRASER ENGINEERING AND TESTING

Alexander H. Fraser, P.E.

AHF:jn

Enclosures

ATTACHMENT A

DRILLING PROCEDURES

Soil sampling and penetration testing performed in accordance with ASTM D 1586-67. For the first 10 feet continuous sampling was performed using a 24 inch split-spoon sampler advanced at 2 foot increments. The standard penetration resistance is the number of blows of a 140 pound hammer falling 30 inches to drive a 2 inch O.D., 1.4 inch I.D., split-spoon sampler 1 foot.

RELATIVE DENSITY AND CONSISTENCY CORRELATED WITH STANDARD PENETRATION RESISTANCE

TYPE OF MATERIAL	NO. OF BLOWS PER FOOT	RELATIVE DENSITY
Granular Soils	0 - 4	Very Loose
	5 - 10	Loose
	11 - 20	Firm
	21 - 30	Very Firm
	31 - 50	Dense
	Over 50	Very Dense

TYPE OF MATERIAL	NO. OF BLOWS PER FOOT	CONSISTENCY
Cohesive Soils	Below 2	Very Soft
	3 - 4	Soft
	5 - 8	Firm
	9 - 15	Stiff
	16 - 30	Very Stiff
	31 - 50	Hard
	Over 50	Very Hard

IDENTIFICATION OF SOILS

Identification of the soils is in accordance with ASTM D 2488-69, "Standard Recommended Practice for Description of Soils".

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
0			Gray fine sand, trace of organic fiber
	3		.5
			Light tan fine sand
	5		
	9		3.5
			4.0 Dark brown, cemented, slightly silty to silty fine sand
	12		
5			Tan brown, slightly silty fine sand
			8.0
			Tan gray fine sand
	9		
10			
	14		
15			
			17.0
			Brown fine sand
	9		
20			(Continued on Sheet 2)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO: B - 1

DATE DRILLED: 8-24-78

JOB NO.: 20916

CLIENT: Brock

BORING LOG

DEPTH	(1)	(2)	DESCRIPTION
20			Brown fine sand (Continued from Sheet 1)
			22.0
			Dark gray fine sand
	9		
25			
	12		29.5
30			Gray fine sand with some shell fragments and weathered limestone (slightly cemented)
	24		
35			35.5
			Olive gray, slightly silty to silty fine sand, trace of some shell fragments with thin seam of cemented shell fragments
	12		
40			(Continued on Sheet 3)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO B - 1

DATE DRILLED 8-24-78

JOB NO.: 20916

CLIENT: Brock

BORING LOG

DEPTH	(1)	(2)	DESCRIPTION
40 – 42.0			Olive gray, slightly silty to silty fine sand, trace of some shell fragments with thin seam of cemented shell fragments (Continued from Sheet 2)
42.0 – 46.5	22		Gray very fine sand, trace of shell fragments
46.5 – 50.0	29		Light gray fine sand with some slightly cemented weathered, slightly sandy limestone nodules
50.0 – 57.5	32		Light gray, cemented fine sand and sandy limestone, trace of shell fragments
57.5 – 60	67		Slightly cemented, gray fine sand, trace of shell fragments
			(Continued on Sheet 4)

Depth scale: 40, 45, 50, 55, 60

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO B - 1

DATE DRILLED 8-24-78

JOB NO.: 20916

CLIENT: Brock

BORING LOG

DEPTH	(1)	(2)	DESCRIPTION
60			Slightly cemented, gray fine sand, trace of shell fragments (Continued from Sheet 3)
			62.0
			Gray fine sand and weathered limestone nodules, trace of some shell fragments
	42		
65			
	40		
70			70.0
			Boring Terminated at 70'

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO B - 1

DATE DRILLED 8-24-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
0	2		Gray fine sand with surface organics
			.5
			White fine sand
	7		
	9		
			4.0
			Dark brown, cemented, silty fine sand
5			5.5
			White fine sand
			8.5
			Tan gray, slightly silty fine sand
	20		
10			
	29		
15			
			18.0
			Brown fine sand
	10		
20			(Continued on Sheet 2)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO. B - 2

DATE DRILLED 8-25-78

JOB NO.: 20916

FRASER ENGINEERING AND TESTING

CLIENT: Brock

BORING LOG

DEPTH	(1)	(2)	DESCRIPTION
20			Brown fine sand (Continued from Sheet 1)
			21.0
			Dark gray fine sand
	5		
25			
			28.0
			Gray fine sand, trace of some shell fragments
	50		
30			30.0
			Gray fine sand with some shell fragments with slightly cemented seams, trace of some limestone nodules
	27		
35			
			36.0
			Olive gray, slightly silty fine sand, trace of shell fragments
	11		
40			(Continued on Sheet 3)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO: B - 2

DATE DRILLED: 8-25-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
40			Olive gray, slightly silty fine sand, trace of shell fragments (Continued from Sheet 2)
41.0			Gray fine sand, trace of shell fragments
	30		
45			
46.0			Light gray fine sand with some weathered cemented sand nodules, trace of shell fragments, trace of weathered limestone nodules
	43		
50			
50.5			Light gray, cemented fine sand, trace of shell fragments
	39		
55			
58.5			Light gray, very fine uniform fine sand, (silty texture) with some limestone nodules and cemented sand nodules
59.5	23		Light gray, cemented fine sand with some weathered limestone nodules
60			

(Continued on Sheet 4)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO B - 2

DATE DRILLED 8-25-78

JOB NO.: 20916

CLIENT: Brock

BORING LOG

DEPTH	(1)	(2)	DESCRIPTION
60			Light gray, cemented fine sand with some weathered limestone nodules (Continued from Sheet 3)
	38		
65			
			66.0
			Light gray green, slightly silty to silty fine sand
70			70.0
			Boring Terminated at 70'

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO B - 2

DATE DRILLED 8-25-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
0	3		Gray fine sand with surface organics
	6		1.0 White fine sand
	13		
	23		4.0 Dark brown, cemented, slightly silty to silty fine sand, trace of organic fibers
5			5.5 Brown, slightly silty fine sand
			8.5 Tan gray fine sand, trace of slightly clayey fine sand
	9		
10			
	8		
15			
			16.0 Tan gray fine sand with seams of slightly clayey to clayey fine sand
	9		
20			(Continued on Sheet 2)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO. B - 3

DATE DRILLED 8-29-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)		DESCRIPTION
20				Tan gray fine sand with seams of slightly clayey to clayey fine sand (Continued from Sheet 1)
			21.0	Brown fine sand
			24.0	Dark gray fine sand
	6			
25				
			27.0	Gray fine sand, trace of shell fragments
	25			
30				
			32.0	Gray fine sand with some shell fragments and some limestone nodules
	44			
35				
	31			
40				(Continued on Sheet 3)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO: B - 3

DATE DRILLED: 8-29-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)		DESCRIPTION
40			41.0	Gray fine sand with some shell fragments and some limestone nodules (Continued from Sheet 2)
	25		44.5	Tan gray fine sand with some shell fragments and limestone nodules (slightly cemented)
45			45.5	Gray, very fine sand
	49			Light gray (cemented fine sand or sandy limestone) with some shell fragments
50				
	47			
55				
	52			
60				(Continued on Sheet 4)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO B - 3

DATE DRILLED 8-29-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
60			Light gray (cemented fine sand or sandy limestone) with some shell fragments (Continued from Sheet 3)
	33		
65			
			67.0
			Light gray green, slightly silty to silty fine sand with some limestone nodules
	5		
70			70.0
			Boring Terminated at 70'

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO B - 3

DATE DRILLED 8-29-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
0			Gray fine sand with surface organics
	2		.5
			White fine sand
	5		4.0
	23		Dark brown, cemented, slightly silty to silty fine sand
5			5.0
			Brown fine sand
			8.0
			Tan gray fine sand
	9		
10			
	7		
15			
			17.5
			Tan gray fine sand, trace of slightly clayey fine sand
	8		
20			20.0 Gray fine sand

(Continued on Sheet 3)

BORING NO: B - 4

DATE DRILLED: 8-30-78

JOB NO.: 20916

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
20			Gray fine sand (Continued from Sheet 1)
	14		
25			
			28.0
			Gray fine sand, trace of shell fragments with seams of gray fine sand with some shell fragments
	37		
30			
	25		
35			
			35.5
			Gray fine sand with some shell fragments
	30		
40			(Continued on Sheet 3)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO: B - 4

DATE DRILLED: 8-30-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
40			Gray fine sand with some shell fragments (Continued from Sheet 2)
41.5			Light gray fine sand with some shell gragments, with seams of fine sand and shell fragments, trace of weathered limestone nodules
	26		
45			
48.0			White, cemented fine sand and shell fragments with trace of soft white lime clay
	75		
50 / 50.0			Light gray fine sand with some weathered limestone nodules
54.0			Light gray, slightly cemented fine sand and (sandy limestone, cemented sand)
	41		
55			
57.0			Light gray, slightly cemented fine sand and cemented fine sand and shell fragment nodules
	44		
60			(Continued on Sheet 4)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO B - 4

DATE DRILLED 8-30-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
60			Light gray, slightly cemented fine sand and cemented fine sand and shell fragment nodules (Continued from Sheet 3)
			62.0
			Light gray fine sand and limestone nodules (cemented in seams)
	20		
65			
	20		
70			70.0
			Boring Terminated at 70'

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO: B - 4

DATE DRILLED: 8-30-78

JOB NO.: 20916

FRASER ENGINEERING AND TESTING

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
0	3		Gray fine sand with surface organics
	10		1.0 White fine sand
			2.0 Brown, slightly silty fine sand
	7		
	11		4.0 Dark brown, slightly cemented, slightly silty to silty fine sand, trace of organic fibers
5			5.5 Brown fine sand
			7.0 Tan to light gray fine sand, trace of slightly clayey fine sand
	6		
10			
	10		
15			16.0 Light tan gray fine sand with seams of slightly clayey to clayey fine sand
	11		
20			(Continued on Sheet 2)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO B - 5

DATE DRILLED 8-21-78

JOB NO.: 20916

FRASER ENGINEERING AND TESTIN

CLIENT: Brock

BORING LOG

DEPTH	(1)	(2)	DESCRIPTION
20			Light tan gray fine sand with seams of slightly clayey to clayey fine sand (Continued from Sheet 1)
			23.0
			Dark gray fine sand
25	1*		
			26.0
			Gray fine sand, trace of shell fragments with seams of gray fine sand with some shell fragments
	30		
30			
	33		
35			
			37.0
			Light gray fine sand and shell fragments (fine to medium), trace of some weathered limestone nodules
	29		
40			(Continued on Sheet 3)

*for 18"

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO B - 5

DATE DRILLED 8-21-78

JOB NO.: 20916

FRASER ENGINEERING AND TESTI

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
40			Light gray fine sand and shell fragments (fine to medium), trace of some weathered limestone nodules
	16		
45			
45.5			Dark gray, slightly silty fine sand
47.0			Light gray to white cemented fine sand, trace of shell fragments
	29		
50			
54.0			Light gray, cemented fine sand, trace of sandy limestone nodules
	21		
55			
56.0			Light gray and white, cemented fine sand with some weathered, sandy limestone nodules, trace of shell fragment
	42		
60			(Continued on Sheet 4)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO B - 5

DATE DRILLED 8-21-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
60			Light gray and white, cemented fine sand with some weathered sandy limestone nodules, trace of shell fragment
			63.0
	8		Gray green, slightly silty to silty fine sand with some limestone nodules
65			
			68.0
	17		Gray and black, cemented fine sand and shell fragments (limestone)
70			70.0
			Boring Terminated at 70'

(1) PENETRATION BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO B - 5

DATE DRILLED 8-21-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
0	2		Gray fine sand with surface organics
	5		1.0 White fine sand
	13		3.5
	10		4.0 Dark brown, cemented, slightly silty to silty fine sand, trace of organic fibers
5			Dark brown fine sand
			6.0 Light gray fine sand
10	6		
15	7		
			17.0 Gray, sandy clay
			18.5 Gray fine sand, trace of slightly clayey to clayey fine sand
20	8		(Continued on Sheet 2)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO: B - 6

DATE DRILLED: 9-1-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
20			Gray fine sand, trace of slightly clayey to clayey fine sand (Continued from Sheet 1)
			23.0
			Brown fine sand
	13		
25			
			27.0
			Dark gray fine sand
			29.0
			Gray fine sand, trace of some shell fragments
	60		
30			
	47		
35			
	30		
40			(Continued on Sheet 3)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE
- UNDISTURBED SAMPLE

BORING NO: B - 6

DATE DRILLED: 9-1-78

JOB NO.: 20916

FRASER ENGINEERING AND TESTIN

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
40			Gray fine sand, trace of some shell fragments (Continued from Sheet 2)
	35		
45			
			46.0
			White and tan, cemented fine sand and shell fragments
	23		
50			
			52.0
			White to light gray, cemented fine sand with some shell fragments
	57		54.5
55			Light gray, cemented fine sand with some sandy limestone nodules
	23		
60			(Continued on Sheet 4)

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

- GROUND WATER
- LOSS OF DRILLING FLUID
- ROCK CORE

BORING NO: B - 6

DATE DRILLED: 9-1-78

JOB NO.: 20916

BORING LOG

CLIENT: Brock

DEPTH	(1)	(2)	DESCRIPTION
60			Light gray, cemented fine sand with some sandy limestone nodules (Continued from Sheet 3)
65	16		65.0
			Light gray green, slightly silty to silty fine sand with some limestone nodules
70	14		70.0
			Boring Terminated at 70'

(1) PENETRATION - BLOWS PER FOOT

(2) DESIGNATIONS

GROUND WATER

LOSS OF DRILLING FLUID

ROCK CORE

BORING NO B - 6

DATE DRILLED 9-1-78

JOB NO.: 20916

APPENDIX II

Water Quality From Production Well During Pumping Test II

RECEIVED JUN 22

STANDARD WATER ANALYSIS REPORT

Orlando Laboratories, Inc.

P. O. Box 8008 • Orlando, Florida 32856 • 305/843-1661

Report to: D. L. Arnold

Date: 20 June 78

Report Number: 15286

Appearance: Clear

Sampled by: Client

Identification: 8'' Test Well S. Indian Street

METHODS

This water was analyzed according to "Standard Methods for the Examination of Water and Wastewater," Latest Edition, APHA, AWWA and WPCF.

RESULTS

Determination	Data Significance	mg/l	Determination	Data Significance	mg/l
Total Dissolved Solids	x.	360	Total Hardness, as $CaCO_3$	x.	228
Phenolphthalein Alkalinity, as $CaCO_3$	x.	0	Calcium Hardness, as $CaCO_3$	x.	222
Total Alkalinity, as $CaCO_3$	x.	216	Magnesium Hardness, as $CaCO_3$	x.	6
Carbonate Alkalinity, as $CaCO_3$	x.	0	Calcium, as Ca	x.	89
Bicarbonate Alkalinity, as $CaCO_3$	x.	216	Magnesium, as Mg	.x	1.5
Carbonates, as CO_3	x.	0	Sodium, as Na	x.	16
Bicarbonates, as HCO_3	x.	264	Iron, as Fe	.x	0.64
Hydroxides, as OH	x.	0	Manganese, as Mn	.x	<0.05
Carbon Dioxide, as CO_2	x.	22	Copper, as Cu	.x	<0.1
Chloride, as Cl	x.	26	Silica, as SiO_2	x.	13
Sulfate, as SO_4	x.	7	Color, PCU	x.	0
Fluoride, as F	.x	0.6	Odor Threshold	x.	0
Phosphate, as PO_4	.x	0.84	Turbidity, NTU	x.	1.5
pH (Laboratory)	.x	7.3	Sulfide, S (Field fixed)		0.02
pHs	.x	7.1			
Stability Index	.x	6.9			
Saturation Index	.x	0.2			

Signed: Gail Blank

Chemist