GROUND-WATER RESOURCES INVESTIGATION

For the

PELICAN BAY PROJECT

For

CORAL RIDGE ----- COLLIER PROPERTIES, INC.

GEE & JENSON • ENGINEERS-ARCHITECTS-PLANNERS, INC.
West Palm Beach, Florida

in association with

GERAGHTY & MILLER, INC.
CONSULTING GROUND-WATER GEOLOGISTS AND HYDROLOGISTS
Tampa, Florida

April 1977

GEE & JENSON ENGINEERS-ARCHITECTS-PLANNERS, INC.
2019 OKEECHOBEE BOULEVARD, WEST PALM BEACH, FLORIDA . . . 33409 . . . 305-683-3301

FRED A. GREENE, P.E.
FRED TEVERBAUGH
RICHARD M. MILLER, P.E.
WALTER D. STEPHENS, JR., P.E.
WILLIAM G. WALLACE, JR., L.S.
PHILIP A. CRANNELL, JR., A.I.A.
REED B. FULLER, A.I.A.
Director Emeritus
H. C. GEE, P.E.
THEODORE B. JENSON, P.E.

April 12, 1977

Coral Ridge - Collier
Properties, Inc.
Post Office Box 2722
Naples, Florida 33940

Re: Pelican Bay Project
Ground-Water Resources Investigation

Gentlemen:

We present herein the results of our investigation and analysis regarding the use of artesian water as a potable water supply source for the Pelican Bay project.

The major conclusion derived, that the artesian source can be used without adversely impacting other water supplies in the area, will be of great interest to those local and state agencies which have been reviewing the Development of Regional Impact document. It is our opinion that this report adequately addresses all of the concerns raised by the reviewing agencies.

We thank you for this opportunity to be of service to you.

Respectfully submitted,

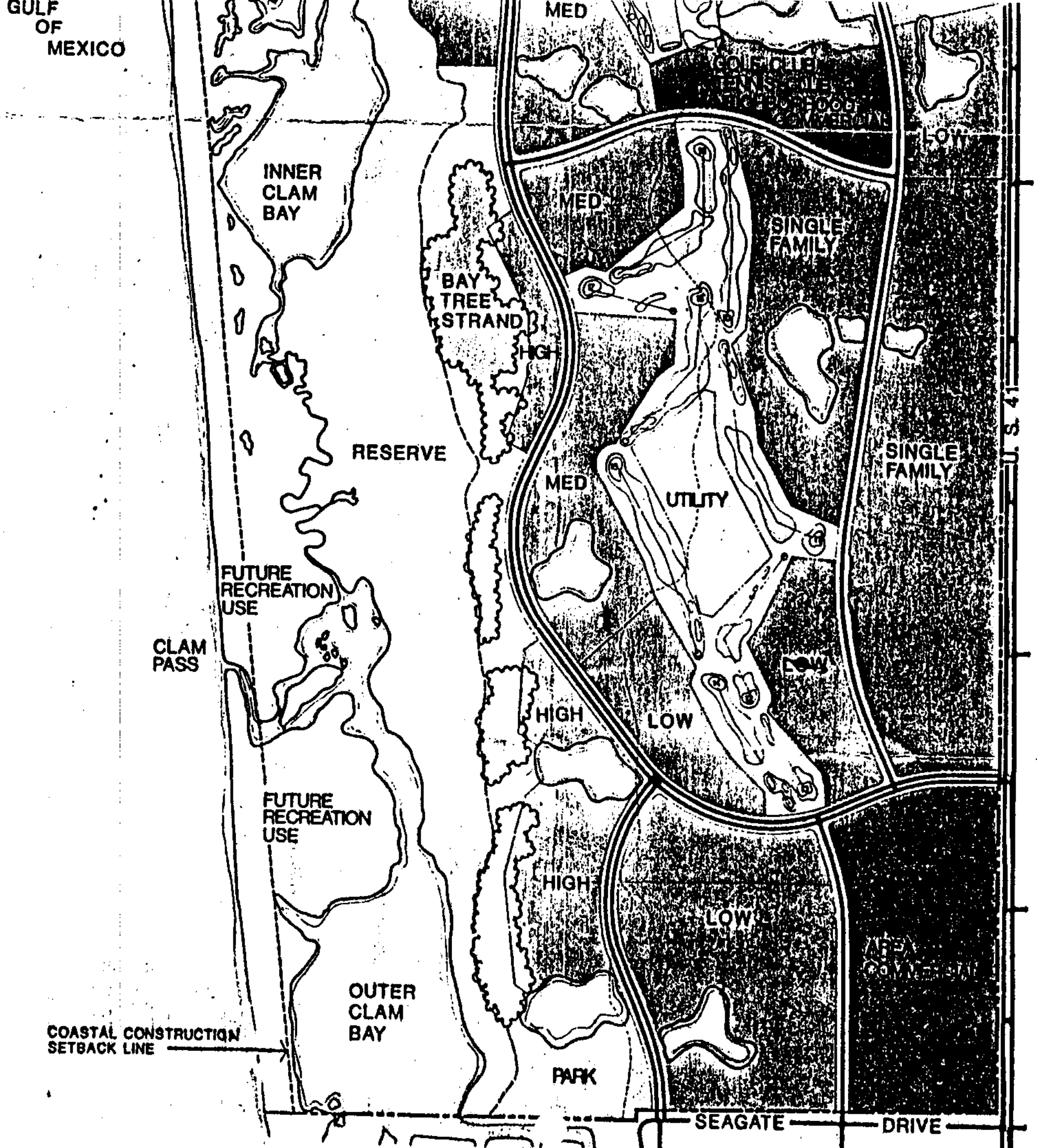
GEE & JENSON
Engineers-Architects-Planners, Inc.

John F. McKune

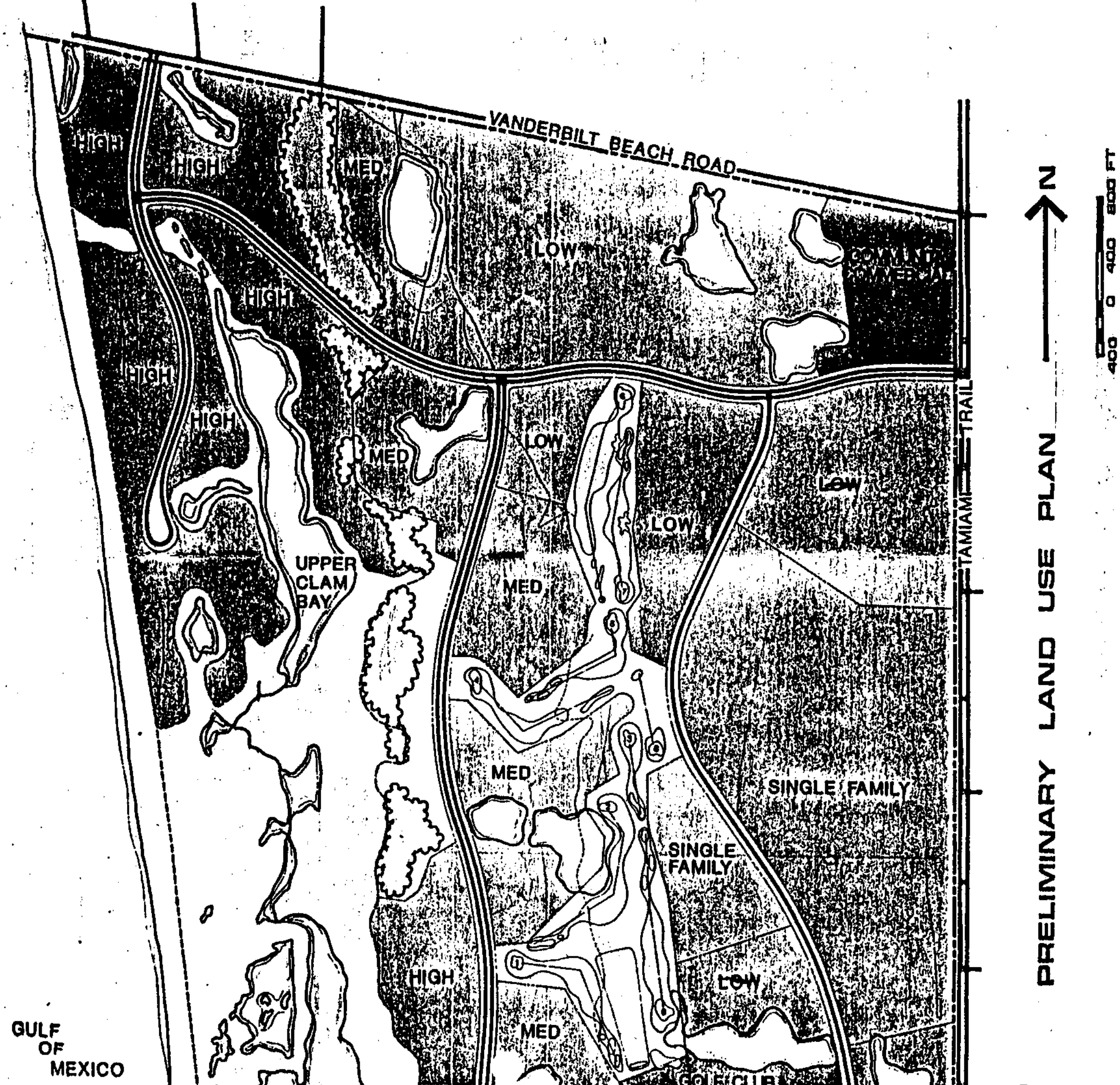
John F. McKune, P.E.
Florida Certificate No. 16208

jfm:cl
73-257A
enc

TABLE OF CONTENTS



PELICAN BAY IMPROVEMENT DISTRICT



PRELIMINARY LAND USE PLAN

GENERAL

The subject of water supply for the proposed development has been under consideration for several years. Prior to the creation of the Pelican Bay Improvement District, the responsibility for providing water and sewer facilities to this site was vested with the Clam Bay Water and Sewer District, which was created by an Act of the State Legislature in 1973.

In March of 1974, a report entitled "Water Supply Study for Clam Bay Water and Sewer District" was prepared by Gee & Jenson. This report represented the first comprehensive engineering study to determine an appropriate potable water supply system to serve the ultimate needs of the proposed site development. Four potential sources of water supply for the project were identified and discussed. These were surface water, the shallow aquifer, the artesian aquifer and water from the Gulf of Mexico. The following summarizes the pertinent information contained in that previous report.

Surface Water

Surface water quality changes more often and fluctuates over a broader range of values than ground-water. Because of these variations, the use of surface water as a source of potable water supply is generally not recommended if an adequate source of ground-water is available. Surface water bodies tend to collect many different types of pollutants from agricultural and urban runoff. During dry periods in the Naples area, canal flows are maintained by ground-water discharge from the upper formations of the shallow aquifer. In many areas of Collier County the water from this aquifer is highly mineralized. The effects of evaporation from surface water bodies also tends to increase the background mineral concentrations. Consequently, the combination of surface runoff, ground-water infiltration and evaporation tends to reduce the overall surface water quality.

The quantity of water which could be made available from surface water bodies would be largely dependent upon the areal extent of the reservoir. Close water quality monitoring of the source would be required, in many areas of Collier County, to prevent over pumping which would result in pulling in more mineralized ground-water than desired.

Shallow Aquifer

The principal source of ground-water in Collier County is the shallow aquifer, which extends to depths of approximately 130 feet. The permeability of the Tamiami Formation, which is the source of water for the Coastal Ridge aquifer, is fairly consistent as it extends into the interior portions of Collier County. However, in certain areas between 5 to 10 miles inland poor flushing of the ground-water in the aquifer has created pockets within the formation containing highly mineralized water. Lack of flushing has, in all probability, been caused by deposits of marl and other impermeable strata predominate in these interior sections. In these regions, ground-water at depths of up to 40 feet is relatively low in chloride concentration. However, at greater depths, the chloride concentration significantly increases, approaching 250 milligrams per liter. Some test well samples have evidenced total dissolved solids at the lower depths approaching 1,000 milligrams per liter.

Based upon the yield of test wells north of State Road 846, a potential ground-water supply capable of yielding the estimated potable water requirements of the proposed project appears to be available from the shallow aquifer. This potential source is located approximately 2 miles to the north of State Road 846 in line with State Road 858. However, the costs of developing the well field and acquiring right-of-way for raw water transmission to the project site did not appear economically feasible.

Artesian Aquifer

Historically, shallow ground-water less than 100 feet in depth has been the principal source of water supplying the municipal, industrial and agricultural needs of the area.

Development of the artesian aquifer has not been required in the past as freshwater supplies from the shallow aquifer have been adequate.

The more highly mineralized water contained in the artesian aquifer requires treatment by reverse osmosis. Even though the necessity of using reverse osmosis treatment would result in a somewhat higher cost of finished product water to the consumer, the general scarcity of water in Collier County allows the artesian aquifer to become a viable water supply source. Quoting from the United States Geological Survey (USGS) Report of Investigation No. 63, entitled "Hydrology of Western Collier County, Florida", "The Floridan aquifer doubtless will become more important when water demands are such that conversion of slightly saline water to freshwater may become feasible".

Although very little data was available, in 1974, regarding the artesian aquifer in the vicinity of the proposed project, the initial Clam Bay Study predicted that water obtained from the artesian zone, at a depth of approximately 800 feet, would have a chloride concentration of approximately 1,000 milligrams per liter and a total dissolved solids concentration approaching 3,000 milligrams per liter. Based upon additional data obtained at that time from the USGS, it was expected that an appreciable quantity of water could be obtained from the Suwannee Formation at a depth of about 800 feet.

Gulf Waters

The use of the waters of the Gulf of Mexico as a potable water supply would require treatment by either evaporative desalinization or the use of recently developed reverse osmosis membranes designed for highly saline waters. Because of the higher cost of treatment involved, the expected difficulty of process reject water disposal and other environmental concerns, the use of Gulf waters was not considered a viable alternative.

Recent Investigations

On November 5, 1974, a Special Act of the Legislature of the State of Florida created the Pelican Bay Improvement District. The District has, among other powers, the authority and responsibility for providing a potable water system within its boundaries.

Largely as a result of the previous water supply study prepared for the Clam Bay Water and Sewer District, the

Pelican Bay Improvement District, in April 1976, elected to construct an 8-inch diameter test/production well within the District's boundaries as the first step in providing the data necessary to adequately describe the geology and water quality of the various aquifers lying beneath the District. A detailed description of this well construction program and its results is contained in the appended report prepared by Geraghty & Miller, Inc. This initial testing program provided valuable data regarding the basic geology of the underlying strata and the quality of water which could be expected to be obtained from the artesian zone.

Several items of concern were developed by the Southwest Florida Regional Planning Council, the South Florida Water Management District (formally the Central and Southern Florida Flood Control District) and the Collier County reviewing agencies during their normal course of review of the Development of Regional Impact (DRI) document prepared for the proposed development. The remainder of this report provides the data necessary to properly address these concerns.

SCOPE AND OBJECTIVES

The initial review of the water supply concept contained within the DRI was provided by the South Florida Water Management District. As stated in their DRI Impact Evaluation, "The insufficiency of data currently available on the feasibility of withdrawing large quantities of water from the Floridan aquifer in this area indicates the need for more detailed study of the capability of the aquifer to supply the Pelican Bay development without adversely impacting, both quantitatively and qualitatively, other water supplies in the area. Therefore, the extent of future development should be contingent upon the results of data produced by detailed hydrogeological studies of the area."

After meeting with representatives of the South Florida Water Management District, a test well program was developed having the following objectives:

1. Obtain additional detailed geologic information.

2. Determine the hydrologic characteristics of the proposed withdrawal zone.

3. Estimate the water quality constancy.

4. Evaluate the impact of artesian zone withdrawal upon the shallow Coastal Ridge aquifer.

CONSTRUCTION PERFORMED

Aquisition of the necessary data required the construction of a deep observation well. After meeting with representatives of the South Florida Water Management District, it was agreed that the depths of construction of the proposed deep observation well should duplicate, as closely as possible, the construction of the existing 8-inch diameter test/production well.

Consequently, at the direction of Coral Ridge - Collier Properties, Inc., Gee & Jenson prepared plans and specifications for the construction of the required observation well. A diagram of this observation well, as constructed, is shown on Figure 5 contained within the appended Geraghty & Miller report. The well was constructed by McGregor Pump Company, Inc., the same drilling company that had constructed the 8-inch diameter test/production well for the Pelican Bay Improvement District. Construction of the deep observation well commenced on February 7, 1977 and was completed on February 14, 1977. Following completion of construction, the following geophysical logs were obtained from the well:

1. Electric.
2. Gamma-ray.
3. Caliper.

Electric logging is the most common method of borehole geophysical logging. It serves to verify and supplement the descriptive logging of the hole which is recorded as drilling proceeds.

An electric log consists of a record of the apparent resistivity of the subsurface formations and spontaneous potentials generated in the borehole, both plotted in terms of depth below the ground surface. These two properties are related indirectly to the character of the subsurface formation and to the quality of water contained in them. They can be measured only in mud filled, uncased boreholes.

When dry, both sand and clay show very high resistivities. Saturating either one with water reduces its resistivity, but to differing degrees in each material. This occurs because water is an electrical conductor, so its presence in the interconnected pores of a formation provides a conductive medium that lowers the overall formation resistivity. The degree to which resistivity is lowered by the addition of water depends primarily upon the degree of mineralization, or level of dissolved minerals, of the formation water.

This follows from the fact that the electrical conductivity of water varies with its content of dissolved minerals. Distilled water is a poor conductor with high resistivity; salt water is a good conductor with low resistivity.

The water of saturation in clay is always highly mineralized because it dissolves minerals from the chemically active surfaces of the millions of clay particles that make up the formation. As the result, clay formations show relatively low resistivity.

In contrast, sand formations saturated with freshwater show relatively high resistivity because the water of saturation picks up only small amounts of minerals from the surfaces of the sand particles.

Sand formations saturated with salt water may show resistivities as low as those shown for clay formations. This makes it almost impossible to distinguish a salt water sand from a clay bed by using only the resistivity curve of the electric log.

An integral part of a complete electric log is the SP curve, a curve showing the change in spontaneous potential, or self-potential, with depth. These down-hole potentials are the results of currents of electro-chemical origin. Such currents occur at the contact of the drilling mud and the water in the permeable strata, and across the clay layers above or below the permeable strata.

The SP curve is most useful in formations composed of both clay and granular aquifers, especially below a few hundred feet. Where formation waters are much more saline than the drilling mud, the SP is generally more negative in granular aquifers than in the clay strata. This permits the use of the curve for formation identification, data correlation and for determining the depth and thickness of various strata.

Gamma-ray logging measures the natural radiation of gamma-rays from certain radioactive elements that occur in varying amounts in subsurface formations. This log is a diagram showing the relative emission of gamma-rays, plotted against depth below the surface.

Changes in radiation are commonly associated with differences between the types of materials making up successive strata. In most cases, clay particles contain higher concentrations of radioactive elements than limestone, sandstone and sand. In many cases, the gamma-ray log is a more distinct indicator of clay formations than the electric log.

Changes in water quality within the borehole have little effect on the gamma-ray log. Consequently, the log is of greater value in identifying the position and thickness of clay formations, especially where alternating sand formations contain highly saline water.

The caliper log measures the actual finished diameter of the borehole with respect to depth below the land surface. Sections of the borehole penetrating a clay layer will tend to remain stable and consequently show little variation in diameter, whereas penetration of a sand layer may be evidenced by a marked increased in borehole diameter. This is normally caused by some of the sand washing out of the formation during the drilling process, leaving a partial cavity. The caliper log, when interpreted in conjunction with the electric and gamma-ray logs, provides a valuable description of the subsurface strata.

TESTING PROCEDURE

To properly determine the hydrologic characteristics of the proposed withdrawal zone, and to measure the impact of withdrawal upon the upper Naples well field, a 72-hour pumping test was performed. Water was withdrawn from the 8-inch diameter Pelican Bay Improvement District test/production well at the constant rate of 500 gallons per minute (gpm) during this 72-hour period. During the pumping test, periodic measurements of the declining water levels were made in both the 8-inch well and the newely completed 4-inch observation well. In addition, water levels were continuously recorded in a 4-inch shallow well which had previously been constructed to a depth representative of the existing City of Naples' wells located along the Coastal Ridge. By monitoring the water level in the Coastal Ridge, any impact of pumping from the artesian zone would be measured by the water level recorded for the upper zone. Water samples were collected periodically from the pumped well and analyzed to evaluate the change of the chemical characteristics of the discharged water as pumping progressed throughout the 72-hour period. A detailed description of this testing procedure is contained within the appended report prepared by Geraghty & Miller.

The disposal of the brackish water being discharged from the pumped well was a prime consideration. As the pumping test was to be conducted during the dry season, it was imperative that the disposal technique be coordinated with and approved by representatives of Collier County.

After conferring with Mr. Irving Berzon, County Engineer, and Mr. Bernie Yokel, representing the Collier County Conservancy, it was agreed that an appropriate point of discharge would be the mangrove fringe area located west of the black rush. Due to the influence of spring tides, it was felt that this discharge point would allow the discharged water to mingle with waters of similar chemical characteristics and preclude the entry of the discharged water into the shallow zone of the Coastal Ridge aquifer.

To accomplish these objectives required the temporary installation of 3,340 feet of 6-inch diameter pipe from the pumped well site to the mangrove fringe.

EVALUATION OF TEST DATA

Geology

For a detailed description of the geology evidenced by analysis of the well cuttings and well logs, refer to Appendix A of the appended report prepared by Geraghty & Miller.

In summary, the geologic analysis revealed:

1. A thin layer of surficial sand and shells extend from the surface to a depth of approximately 30 feet.

2. The zone from 30 feet to approximately 200 feet contained a limestone formation of gray to tan limestone with sand and shell fragments. This zone is representative of the Coastal Ridge aquifer penetrated by the City of Naples' well field.

3. From approximate depths of 200 feet to 330 feet a thick sequence of clays exists. These clay layers represent the upper confining bed of the artesian zone.

4. Below 330 feet a limestone unit is present.

5. It is believed that the aquifer material present between the 330 and 610 foot depth is associated with the secondary artesian aquifer of the Hawthorn Formation.

6. At a depth of 945 feet in Test Hole No. 1 (TH1), the initial hole constructed by the Pelican Bay Improvement District and subsequently abandoned, it is believed the Suwannee Formation of the Floridan aquifer was encountered.

Hydrogeology

For a detailed description of the hydrogeology evidenced by analysis of the pump test data, refer to the appended report prepared by Geraghty & Miller.

In summary, the hydrogeologic analysis revealed:

1. During the pumping test no negative impact was observed within the Coastal Ridge aquifer.

2. The values of the transmissivity and storage coefficient of the pumped artesian aquifer systems are 45,000 gpd/foot and 1.2×10^{-4}, respectively.

3. During the three day pump test, no recharge or discharge boundaries were encountered within a radius of 6 miles from the pumped well.

4. There was no evidence of a nearby connection between the Gulf of Mexico and the pumped artesian aquifer.

Hydrochemistry

For a detailed description of the hydrochemistry evidenced by analyses of water samples obtained during construction of the observation well and performance of the pumping test, refer to the appended report prepared by Geraghty & Miller.

In summary, the hydrochemical analysis revealed:

1. The chemical characteristics of the water which flowed from the observation well during construction remained essentially constant as the depth of the well increased. At a depth of 462 feet the water temperature was 24.5 degrees C., while upon completion of the well to 650 feet the temperature of the flowing water increased slightly to 26.5 degrees C.

2. During the 3 day pumping test, the water quality improved slightly and appeared to be approaching stabilization.

3. At the conclusion of the pumping test, the water being withdrawn from the artesian zone had values of total dissolved solids and chlorides of 4,296 mg/l and 1,675 mg/l, respectively.

Water Availability

The following table indicates the estimated potable water requirements for the proposed development on an annually increasing basis:

TABLE 1

ESTIMATED POTABLE WATER REQUIREMENTS

Year Ending	Average Number of Dwelling Units	Average Number of People	(1) Average Daily Demand (MGD)	(2) Average Daily Aquifer Withdrawal (MGD)
1978	30	90	0.01+	0.02-
1979	140	403	0.06	0.09
1980	410	1,093	0.16	0.25
1981	918	2,320	0.35	0.54
1982	1,425	3,546	0.53	0.82
1983	1,933	4,773	0.72	1.11
1984	2,380	5,820	0.87	1.34
1985	2,885	6,987	1.05	1.62
1986	3,419	8,209	1.23	1.89
1987	3,884	9,259	1.39	2.14
1988	4,334	10,263	1.54	2.37
1989	4,769	11,223	1.68	2.58
1990	5,204	12,182	1.83	2.82
1991	5,639	13,142	1.97	3.03
1992	6,040	14,026	2.10	3.23
1993	6,315	14,634	2.20	3.38

TABLE 1 (Cont'd)

Year Ending	Average Number of Dwelling Units	Average Number of People	(1) Average Daily Demand (MGD)	(2) Average Daily Aquifer Withdrawal (MGD)
1994	6,590	15,241	2.29	3.52
1995	6,865	15,848	2.38	3.66
1996	7,140	16,456	2.47	3.80
1997	7,415	17,064	2.56	3.94
1998	7,690	17,671	2.65	4.08
1999	7,970	18,278	2.74	4.22
2000	8,240	18,887	2.83	4.35
2001	8,515	19,494	2.92	4.49
2002	8,770	20,051	3.01	4.63
2003	8,970	20,471	3.07	4.72
2004	9,100	20,745	3.11	4.78
2005	9,188	20,929	3.14	4.83
2006	9,288	21,113	3.17	4.88
2007	9,363	21,296	3.19	4.91
2008	9,450	21,480	3.22	4.95
2009	9,538	21,663	3.25	5.00
2010	9,600	21,794	3.27	5.03
Commercial (add to above)			0.17	0.26
Total Requirements			3.44	5.29

(1) Based on 150 gallons per day per person

(2) Based on a reverse osmosis treatment plant efficiency of 65 percent (i.e., for every 100 gallons withdrawn from the aquifer, 65 gallons are available to supply potable requirements).

The average daily amount required to be withdrawn from the artesian aquifer slowly increases to the ultimate requirement of 5.29 MGD. Because of the general lack of information concerning the artesian aquifer systems in western Collier County, no one at this time can predict with certainty the performance characteristics of the artesian systems during the next 30 to 40 years. However, artesian water resources have been in use for many years in southwest Florida. Over 2,500 artesian wells and test holes have been constructed in Lee County for purposes of providing potable and agricultural water supplies. In Collier County, the City of Everglades has been obtaining its potable water supply from the artesian zone since 1927.

Based upon the data developed during the testing program, it is our opinion that the proposed water supply program can be efficiently performed and effectively managed.

CONCLUSIONS

The following conclusions are derived from this ground-water resources investigation:

1. The proposed artesian zone of withdrawal is within the Hawthorn Formation.

2. During the pumping test, there was no negative impact on the overlying Coastal Ridge aquifer.

3. The chemical characteristics of the pumped water improved during the first stages of the pumping test and remained constant thereafter.

4. The artesian aquifer tested represents a viable source of potable water for complete development of the Pelican Bay project, as presented to Collier County.

RECOMMENDATIONS

During the development of the water resource it is imperative that the effects of pumping be continuously monitored. As more data becomes available regarding the response of the aquifer to continuous withdrawals, better predictions can be made regarding the long term performance of the resource.

As stated in the appended report by Geraghty & Miller, construction of additional observation wells, as part of the continuous monitoring program, would provide much of the data that is currently not available. The construction of these additional wells should be phased into the overall development of the water resource by the Pelican Bay Improvement District. For example, as the development increases in population, a second production well will be required to provide additional capacity and reliability to the raw water supply system. This second production well could also be utilized as an observation well.

It is our opinion that representatives of the Pelican Bay Improvement District should work closely during the development of this resource with the Collier County Water

Management Advisory Board, the Collier County Environmental Advisory Committee, the Collier County Coastal Area Planning Commission, the Collier County Board of County Commissioners, the Big Cypress Basin Board and the South Florida Water Management District, and, furthermore, the Pelican Bay Improvement District should apply to the South Florida Water Management District for a consumptive use permit utilizing the proposed water resource.

APPENDIX

Evaluation of the Ground-Water Resources of the Pelican Bay Development Project, Naples, Collier County, Florida

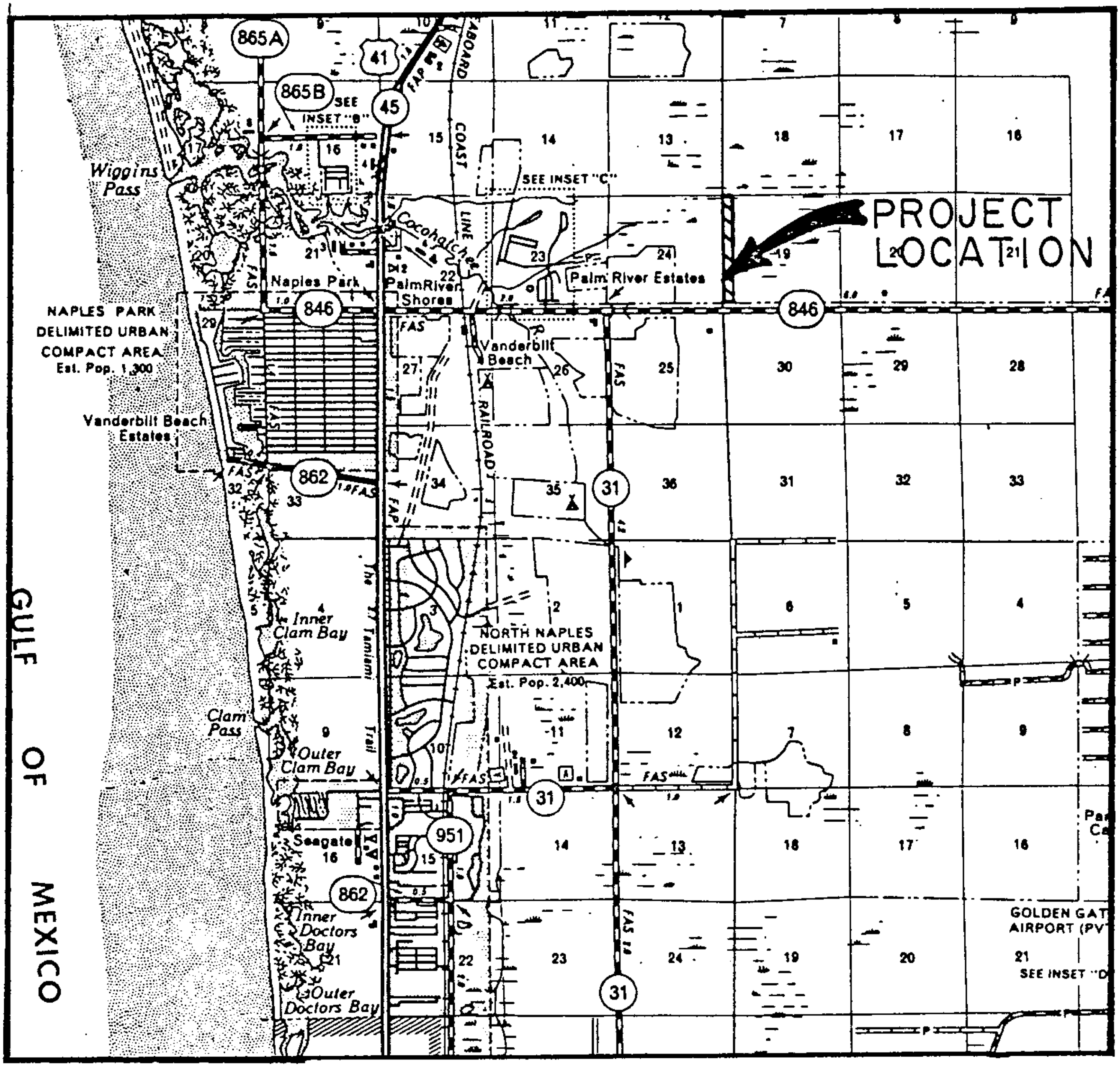
April 1977

Geraghty & Miller, Inc.
Consulting Ground-Water Geologists and Hydrologists
13902 N. Dale Mabry Highway
Tampa, Florida 33618

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES



LOCATION MAP

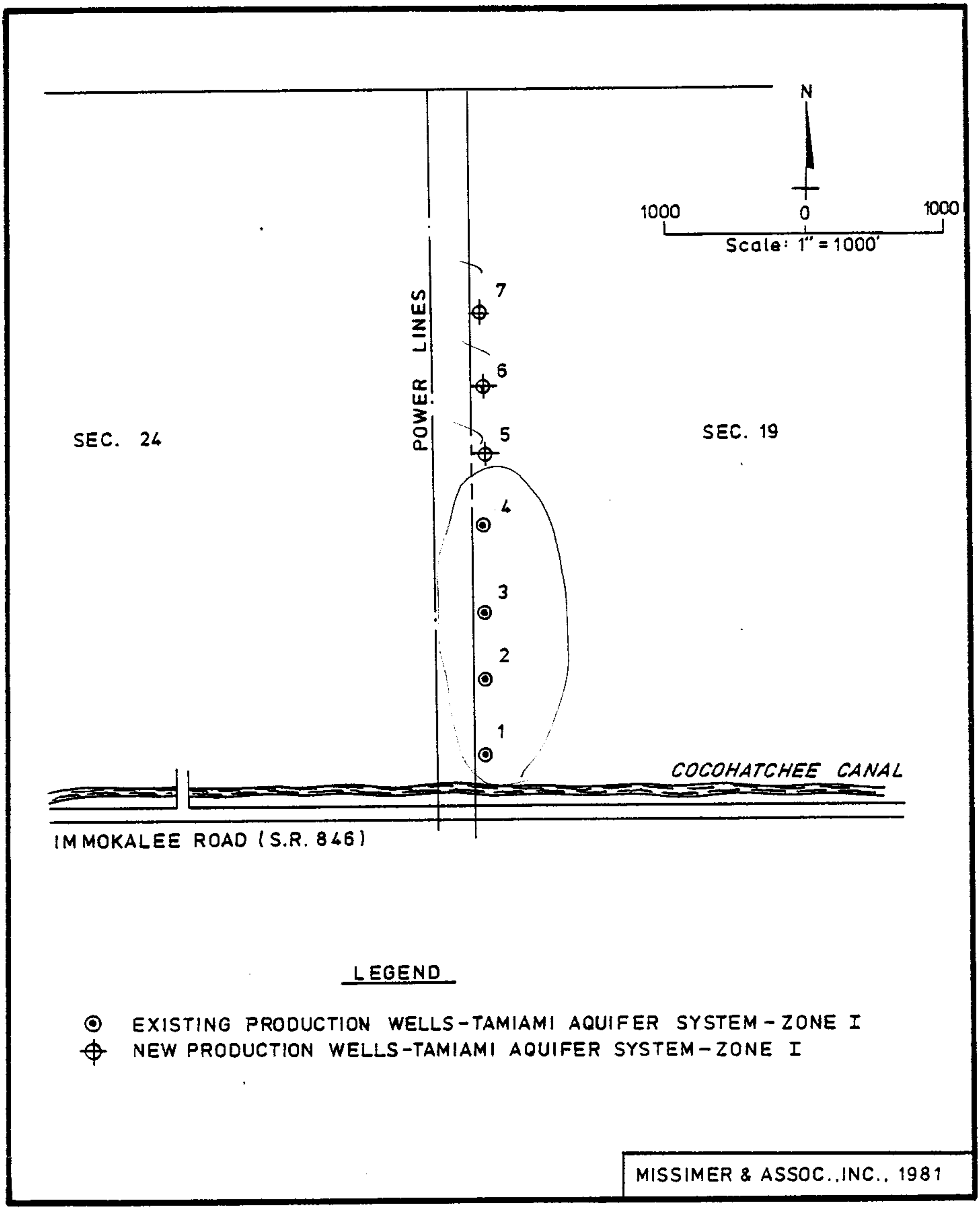


FIGURE 1. MAP SHOWING LOCATION OF OLD AND NEW PRODUCTION WELLS.

INTRODUCTION

Objectives of the Investigation

In December 1976, Gee & Jenson, Inc. (the Client) contacted Geraghty & Miller, Inc. (the Consultant) to assist in the evaluation of the ground-water resources at the Pelican Bay development project near Naples in Collier County, Florida. The location of this site is shown in Figure 1. The principal objective of the investigation was to provide answers to questions posed by the Pelican Bay Improvement District and the South Florida Water Management District concerning the dependability of the potential ground-water supply in terms of meeting the water demands of the project's ultimate population, and also the influence of the proposed well field on the aquifer which is tapped by the City of Naples well field. In addition, possible impacts to the regional water quality and quantity were also to be assessed.

Location of the Site

The property is bordered on the west by the Gulf of Mexico, on the north by Vanderbilt Beach Road, on the east by U. S. Highway 41, and on the south by Seagate Drive. The test-well site lies directly west of U. S. 41 about 5,600 ft east of the Gulf of Mexico (Figure 1). It is located in a

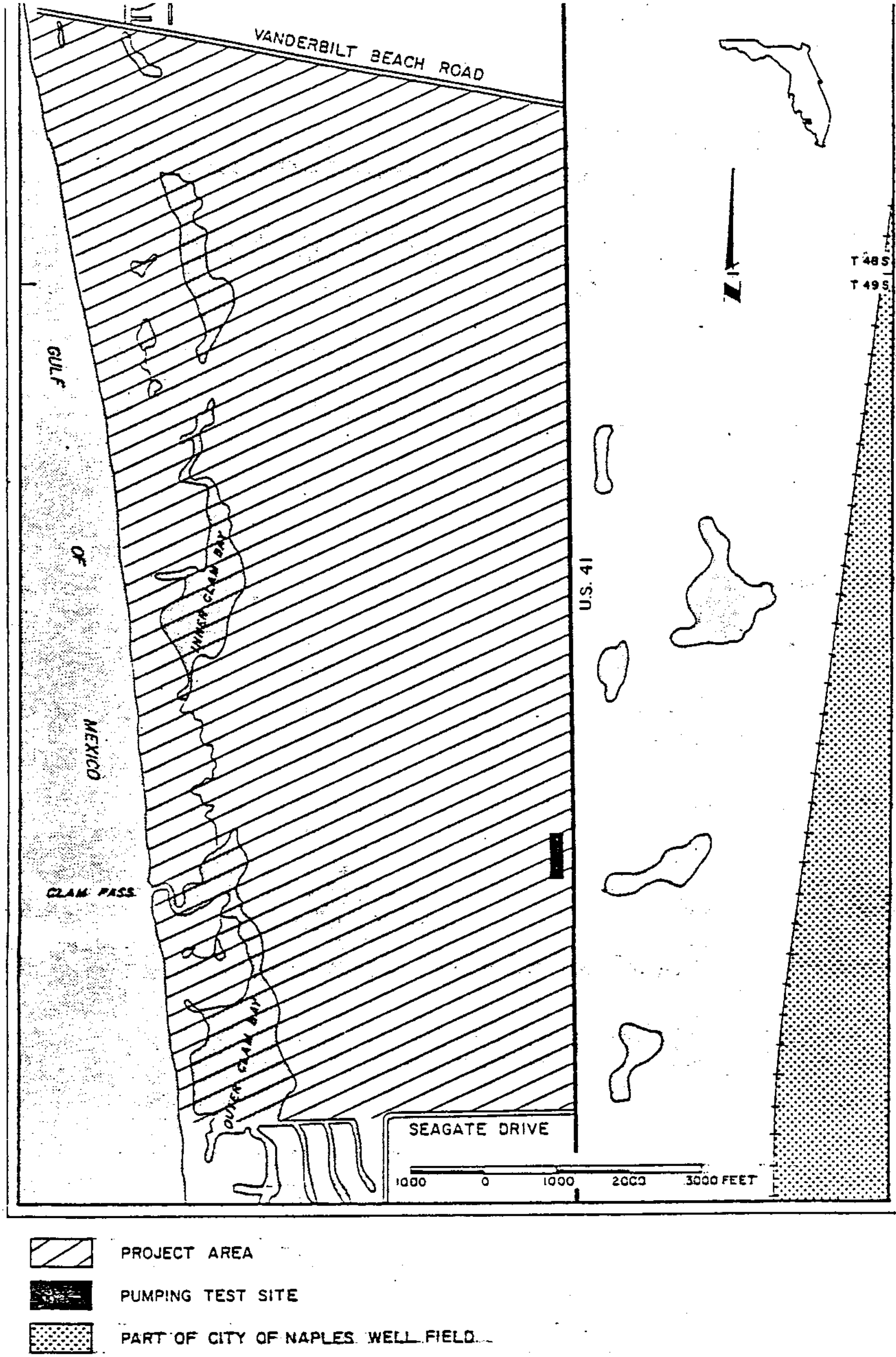


Figure 1 - LOCATION OF PELICAN BAY DEVELOPMENT PROJECT.

region possessing limited fresh-water resources contained in the uppermost unconfined and semi-confined aquifer, which has a maximum thickness of about 200 ft. The semi-confined aquifer is tapped by the City of Naples well field, which is located less than one mile east of the test site. Because of the limited fresh-water resources, the developers intend to utilize brackish ground water as a raw water supply for a reverse osmosis plant that will provide drinking water for the proposed development.

Work Performed

Prior to the Consultant's involvement in the project, a test well, drilled to a depth of 955 ft (TH1), was abandoned after sanding problems required the installation of a liner, thus reducing the well diameter. This reduction in diameter was unacceptable and the well was subsequently abandoned and grouted back to land surface. A new 8-inch diameter test-production well (TPW) was drilled at a distance of 285 ft from the original test well to a depth of 650 ft and cased to 350 ft. In addition, a 4-in diameter shallow observation well (SOW) was drilled to a depth of approximately 60 ft and cased to about 40 ft to monitor the water level fluctuations in the aquifer tapped by the Naples well field.

During the week of February 7, 1977, the Consultant collected drill cuttings and water quality samples and supervised the drilling, construction, development, and geophysical logging of a 4-in diameter deep observation well (DOW). This well was drilled by the mud rotary technique to a depth of 652 ft and cased to 350 ft. The location of the test production well (TPW) and the observation wells is shown in Figure 2.

On February 17, a water level recorder was installed on DOW with the water-level fluctuations recorded on a continuous basis prior to and during part of the pumping test; on February 25 a continuous water-level recorder was installed on SOW; and on March 7 a turbine pump was installed in TPW. The system was designed so that the pumped water was discharged through a 4 x 6-inch diameter orifice and conveyed into an open pit. A second pump pumped the brackish water from the pit westerly through a 3340-ft pipeline into the mangrove area adjacent to Clam Bay.

On March 8 a 72 hour, 500 gpm (gallons per minute) controlled pumping test was initiated. During the 72 hours of pumping and 46 hours of recovery, water levels in TPW, SOW, and DOW were measured and recorded. In addition, a total of six water samples were collected at periodic

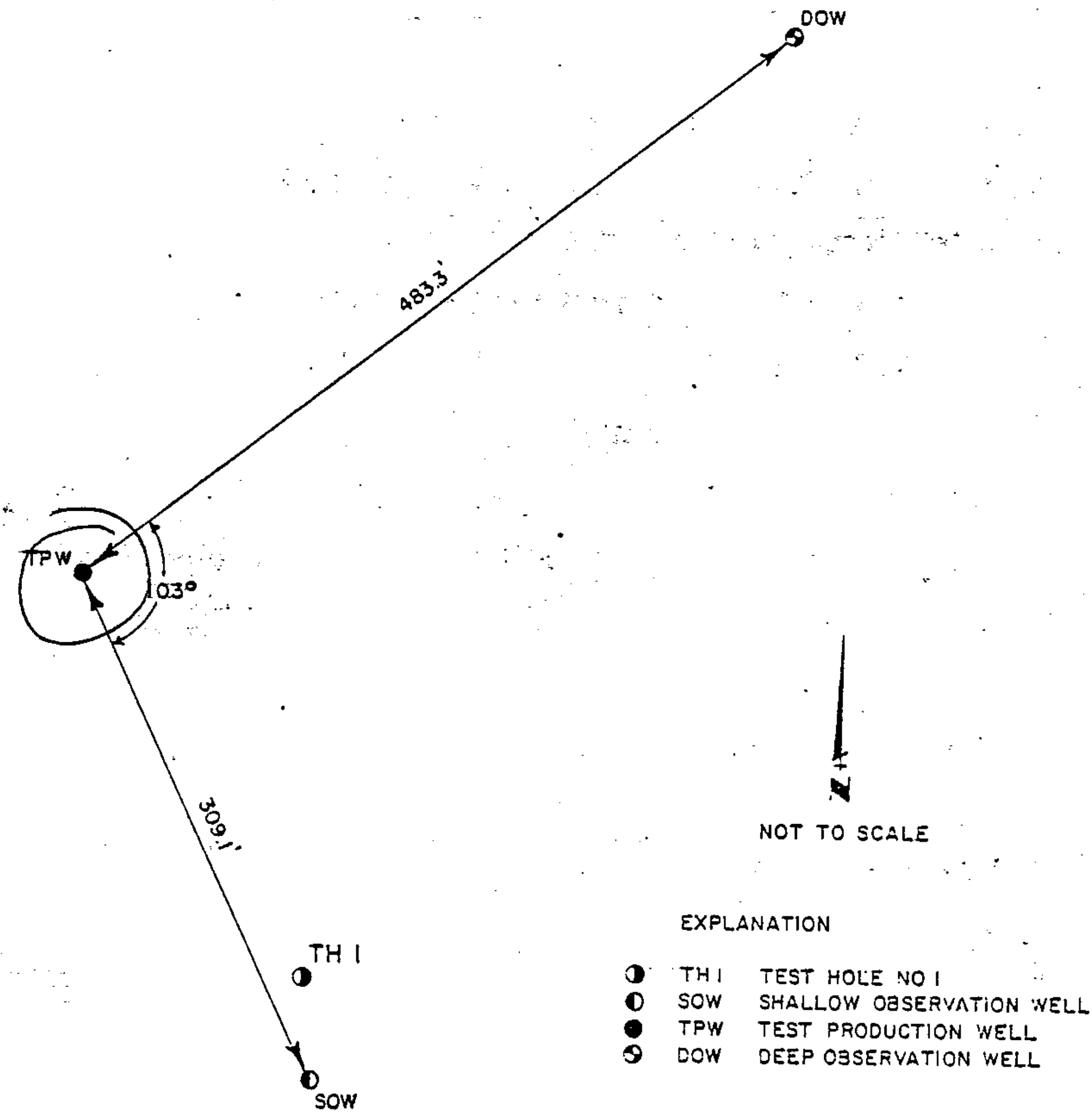


Figure 2 -- LOCATION OF TEST PRODUCTION AND OBSERVATION WELLS.

intervals from TPW during pumping. The results of the pumping test data analyses, in addition to pertinent geohydrologic data collected from the area, form the basis of this report.

EVALUATION OF THE GROUND-WATER RESOURCES

Geology

Analysis of Drill Cuttings

During the drilling of TH1 and TPW, geologic samples were collected by the driller (McGregor Pump Co.) and described by personnel from the Fort Myers branch of the U. S. Geological Survey. The lithologic logs of these wells and the lithologic log of DOW, described by the Consultant, are shown in Appendix A. All three logs generally show a thin layer of surficial sands and shells approximately 30 ft thick overlying a limestone formation. This formation, containing gray to tan limestone with sand and shell fragments, extends to approximately 200 ft in the TPW and the DOW. At that depth, a greenish clay sequence is present which contains quartz and black phosphatic sands and shells. This clay sequence was not observed in the TH1 to a depth of 235 ft. Below 235 ft circulation was reportedly lost for a 200 ft interval and therefore no samples were collected.

Below the 200-ft level the geologic logs of TPW and DOW are generally the same while the log of TH1 differs from the logs of TPW and DOW. The lithologic cross-section shown in Figure 3 was prepared from the logs of TPW and DOW and indicates that from a depth of approximately 200 ft to about

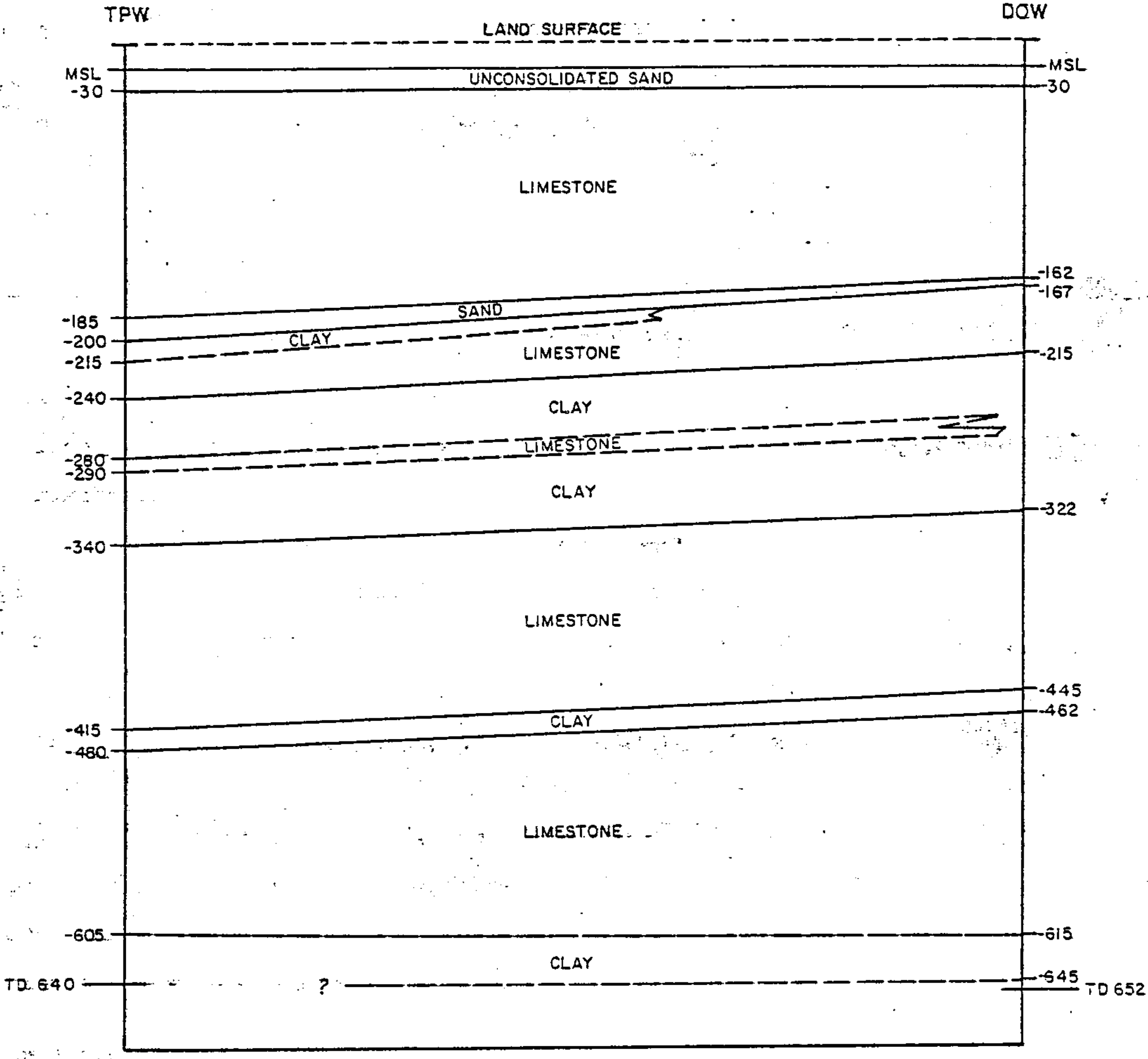


Figure 3 - STRATIGRAPHIC CROSS SECTION AT THE PELICAN BAY DEVELOPMENT PROJECT.

330 ft a fairly thick (100 ft) sequence of clays exist containing occasional stringers of sand, shell, and limestone. Between 330 ft and about 610 ft, a limestone unit is present which contains some phosphatic sand in addition to shell, marl and clay. Below 610 ft in TH1, the limestone sequence grades into a phosphatic and sandy clay unit which persists down to a depth of 945 ft. Circulation was lost below 945 ft during the drilling and no further samples were collected. Because lost circulation usually occurs when cavities are encountered, the 945-ft depth probably represents the base of the confining deposit and the beginning of the water-bearing zone associated with the Floridan Aquifer.

It is believed that the aquifer material present between the 330-and 610-ft depth is associated with the secondary artesian aquifer of the Hawthorn Formation. Although this unit has not been positively identified, the elevation of the potentiometric surface in March, 1977 measured approximately 25 ft above msl (mean sea level), which is too high to be associated with the younger Tamiami Formation. The potentiometric surface of the Tamiami Formation in the Bonita Springs area, 8 to 10 mi north of the test-well site, is reported to be about 13' above msl (oral communication, T.H. O'Donnell, March, 1977). Boggess (1973) reports that the elevation of the potentiometric surface of the lower Hawthorn Formation was 31 ft above msl in 1972 in the Bonita Springs area.

Much uncertainty exists concerning the correct determination of the formation being tapped, because of the general lack of information of the geology below a depth of 250 ft. The U. S. Geological Survey is analyzing the formations encountered during the drilling of TH1 but the results were unknown prior to the time of publication of this report. However, based on the elevation of the potentiometric surface, it is most likely that the zone from 350 to 600 ft represents the secondary artesian aquifer associated with the Hawthorn Formation while the aquifer believed to have been encountered at the 945-ft depth is probably the Floridan Aquifer.

Electric, gamma ray and caliper geophysical logs were run for TPW and DOW by personnel of the U. S. Geological Survey office in Ft. Myers and by the Engineering firm of Black, Crow and Eidsness, respectively.

Hydrogeology

Previous Pump Test

Prior to the pump test of March 8 through March 11, 1977, another test was conducted by McGregor Pump Company under conditions which were not ideal. The turbine pump was installed such that water under artesian pressure flowed freely between the pump base and the well casing. This free flow prior to the test certainly influenced the pump-test results. The Consultant obtained part of the pump-test data from the McGregor Pump Company. The analysis of the data by means of the Cooper-Jacob Modified non-equilibrium (semi-logarithmic straight line) method, indicated a value of transmissivity of approximately 67,000 gpd/ft (gallons per day per foot).

Present Pump Test

The layouts of TPW, DOW, and SOW have been previously shown in Figure 2. The distance between TPW and DOW is 483.3 ft. and the distance between TPW and SOW is 309.1 ft. TPW and DOW were constructed in a similar manner and are open to the geologic formations over the same depth interval. Construction details of TPW and DOW are shown in Figures 4 and 5, respectively.

The reference points (MP) utilized in measuring the water levels in TPW was the top of the concrete slab with an MP elevation of 16.55 ft above msl. The MP of the DOW was the bottom of the nipple, one inch above the top of the metal flange. The elevation of the MP is 18.57 ft above msl. The MP of the SOW was the top of the casing with an elevation of 16.89 ft above msl.

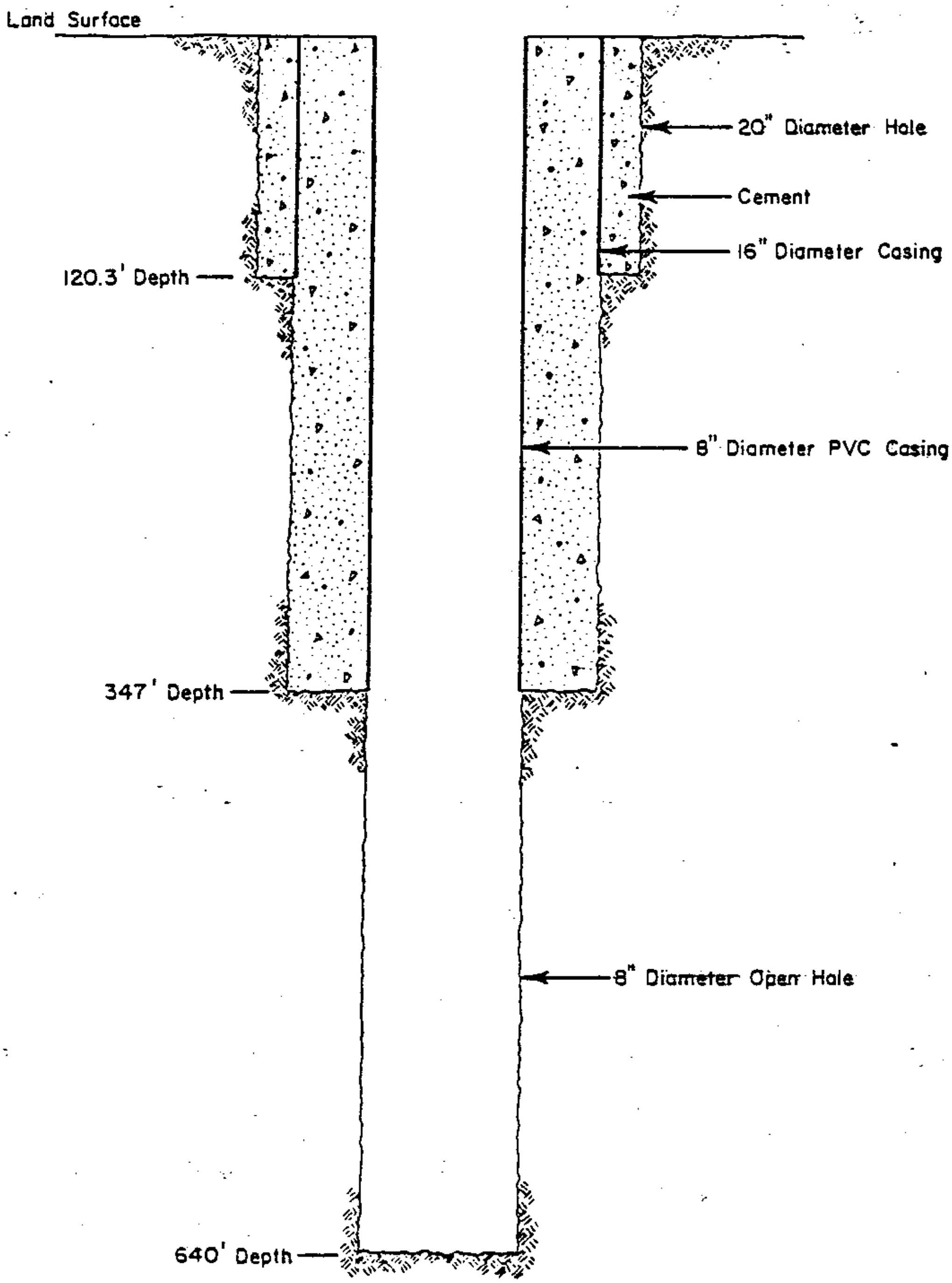


Figure 4 - CONSTRUCTION DIAGRAM OF TPW.

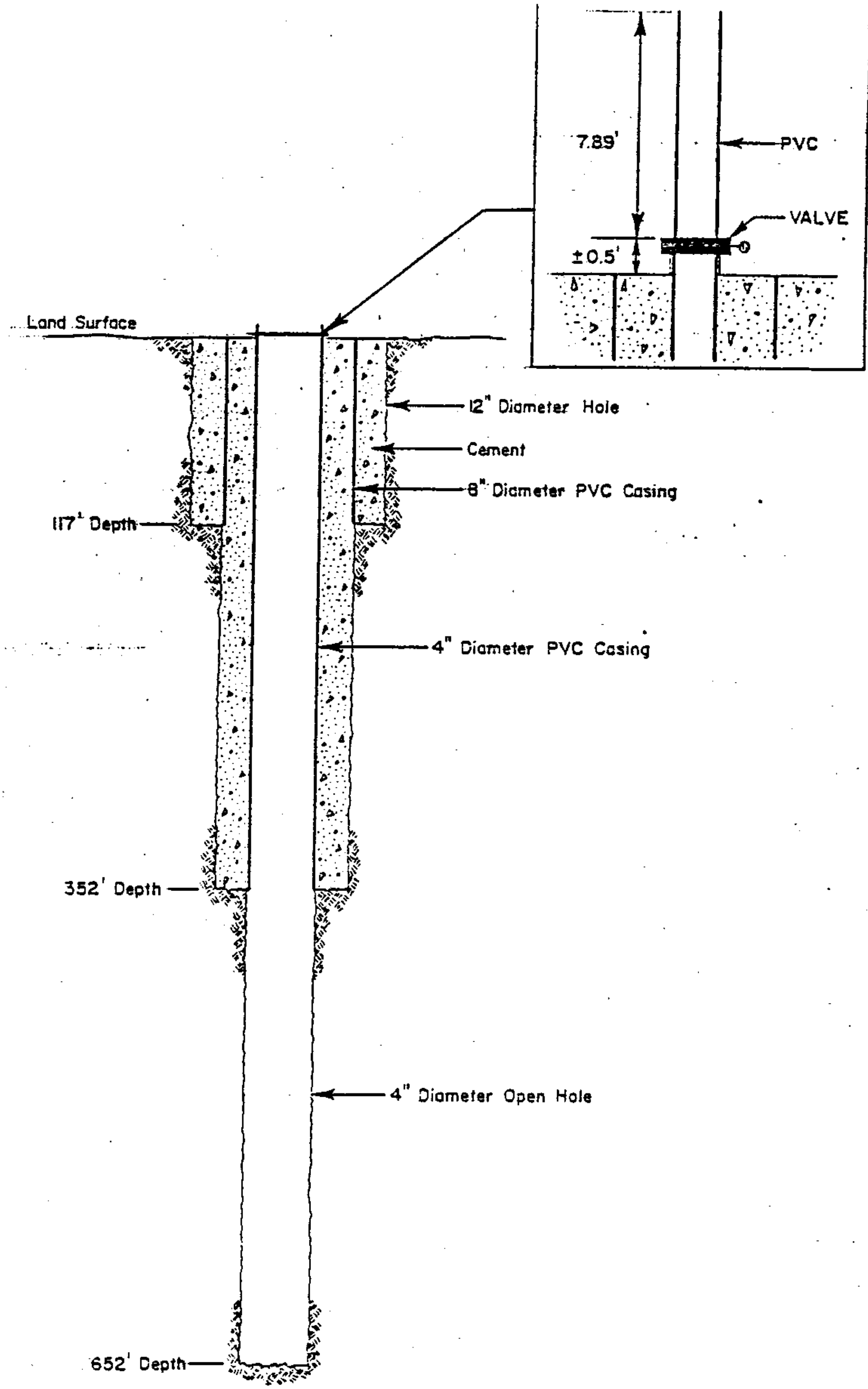


Figure 5 — CONSTRUCTION DIAGRAM OF DOW.

The static water level prior to the pump test in DOW was 24.95 ft above msl and 10.70 ft above msl in SOW. The manner in which the pump was installed on the TPW precluded the measurement of a static water level in the TPW.

The pump test started at 4:21 on March 8, 1977 and proceeded for 72 hours until 4:21 p.m. on March 11. Water level recovery measurements were taken from 4:21 p.m. on March 11 until 2:00 p.m. on March 13. The pumping rate of 500 gpm was controlled and held constant by means of a gate valve in the discharge pipe. The water was discharged into a 50-ft long unlined ditch for conveyance to another pump which transported the water through a 3340-ft pipeline to mangroves near Clam Bay.

Data Collection

Water-level measurements were taken in SOW, DOW and TPW. The measurements in the SOW were recorded on a Stevens water-level recorder. The static water level in the DOW at the start of the test was 6.38 ft above MP. During the beginning of the test, the water levels in DOW were read from a clear plastic manometer tube connected to the standpipe at the MP. When water levels fell below the bottom of the tube they were measured inside the standpipe using a tape.

The water levels in the TPW were measured with an M. scope, an electric measuring device, through a P.V.C. pipe installed in the annulus between the pump column and the casing. The water-level measurements for the three wells, (SOW, DOW, and TPW) during pumping and recovery are shown in Figure 6.

During the pump test no drawdown was observed in SOW. In fact, a small increase of 0.09 ft occurred. This increase could be the result of changes in the pumping rate and schedule in the City of Naples Well Field, or it could be the result of recharge from rainfall prior to the start of the pumping test.

Analysis of Pump-Test Data

The collected data were analyzed using various analytical methods to ascertain the values of transmissivity, storage coefficient and possible leakance. The methods used were the Hantush Modified Method for leaky confined aquifers (Lohman, 1972) and the Cooper-Jacob Modified non-equilibrium (or semi-log straight-line) method.

Both methods were applied to the analyses of the water-level data collected during the pumping and the recovery stages of the test. A log-log plot of the drawdown data from DOW is shown in Figure 7. The recovery data from

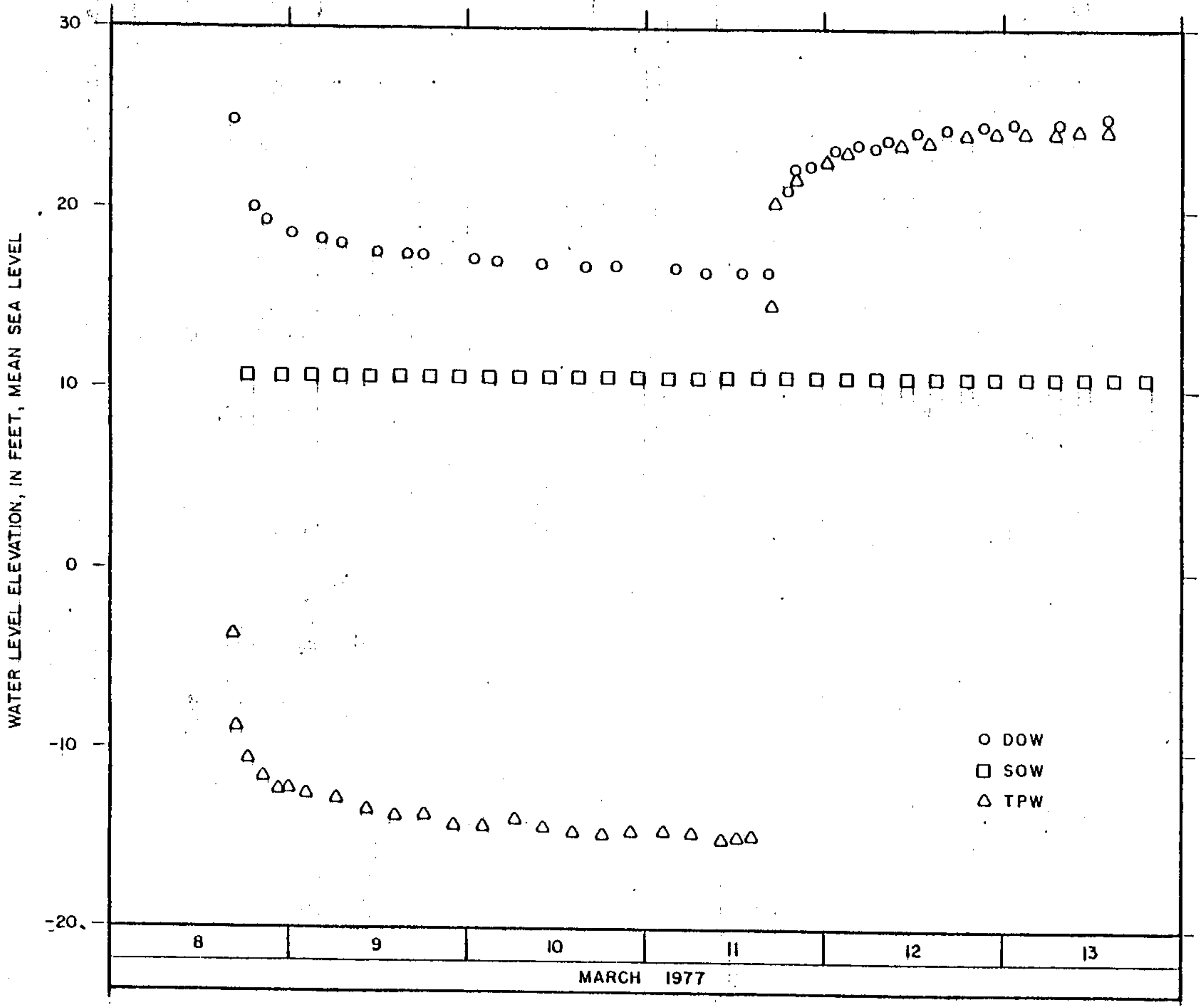


Figure 6 - WATER-LEVEL DRAWDOWN AND RECOVERY DATA FOR DOW, SOW, AND TPW.

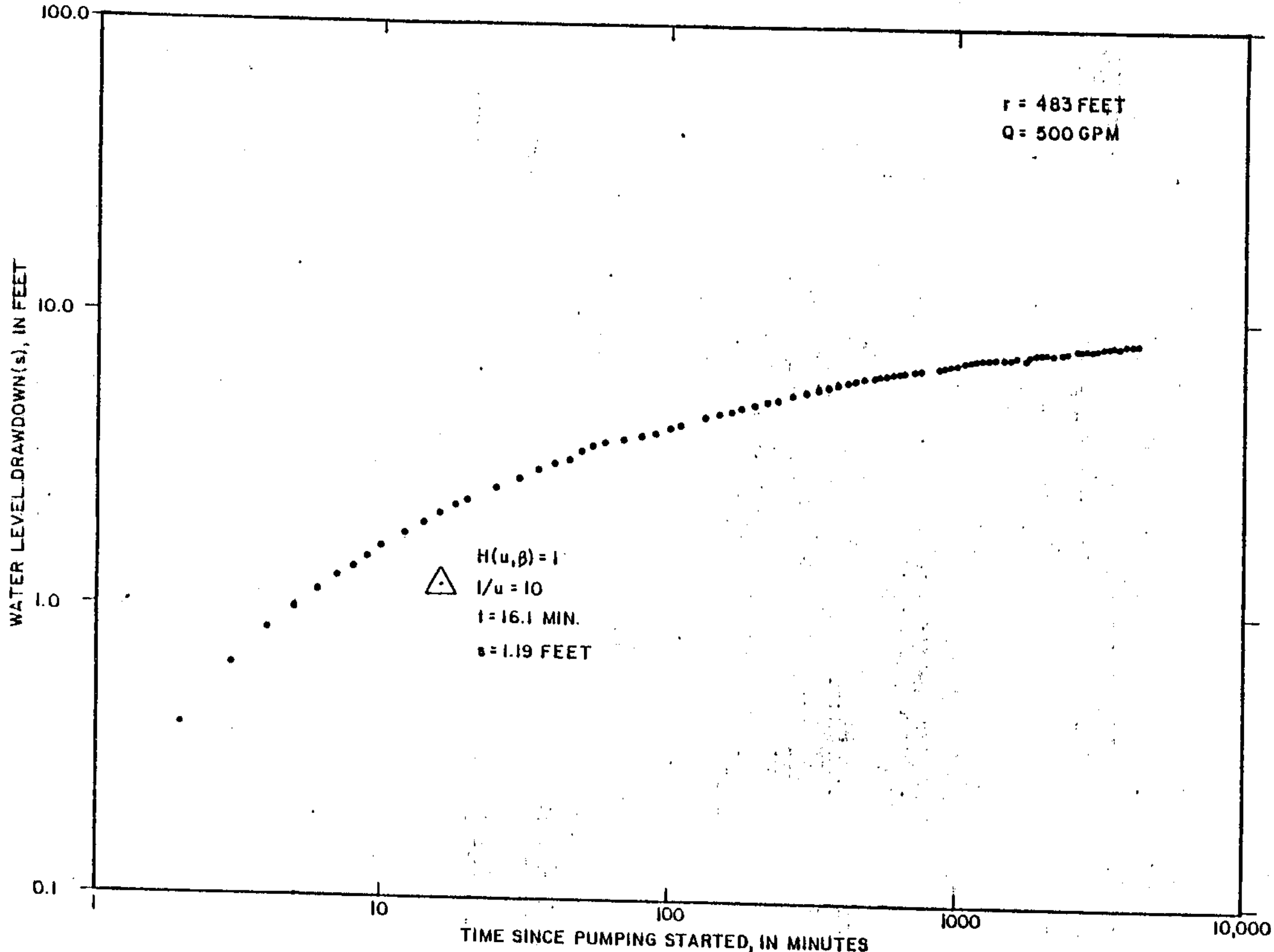


Figure 7 - LOGARITHMIC PLOT OF WATER-LEVEL DRAWDOWN DATA FOR DOW.

DOW were also plotted on log-log paper. These plots were matched to the type curves shown on Plate 4 of Lohman's (1972) paper. The results of the analyses showed that the plotted data completely matched the standard Theis type curve. This fact indicates that the aquifer system, during the testing period, responded as a completely confined non-leaky system.

A similar analysis was performed using the adjusted recovery data. The adjustment of the data comprised the calculation of the residual drawdown data as described in "Ground Water and Wells", Chapter 6. Figure 8 shows a semi-log plot of the calculated recovery data for DOW.

A summary of the results of the various pump-test data analyses are shown in Table 1. The values of transmissivity range from a high of 48,150 gpd/ft to a low of 40,000 gpd/ft. The values of the storage coefficient ranges from 1.1×10^{-4} to 1.4×10^{-4}. The results of the various analyses are in very close agreement with each other. A value of 45,000 gpd/ft and 1.2×10^{-4} are considered as representative for the transmissivity and storage coefficient of the aquifer system.

The results of the analyses indicate that during the three days of pumping, water was derived solely from storage depletion within the aquifer with no water contributed from

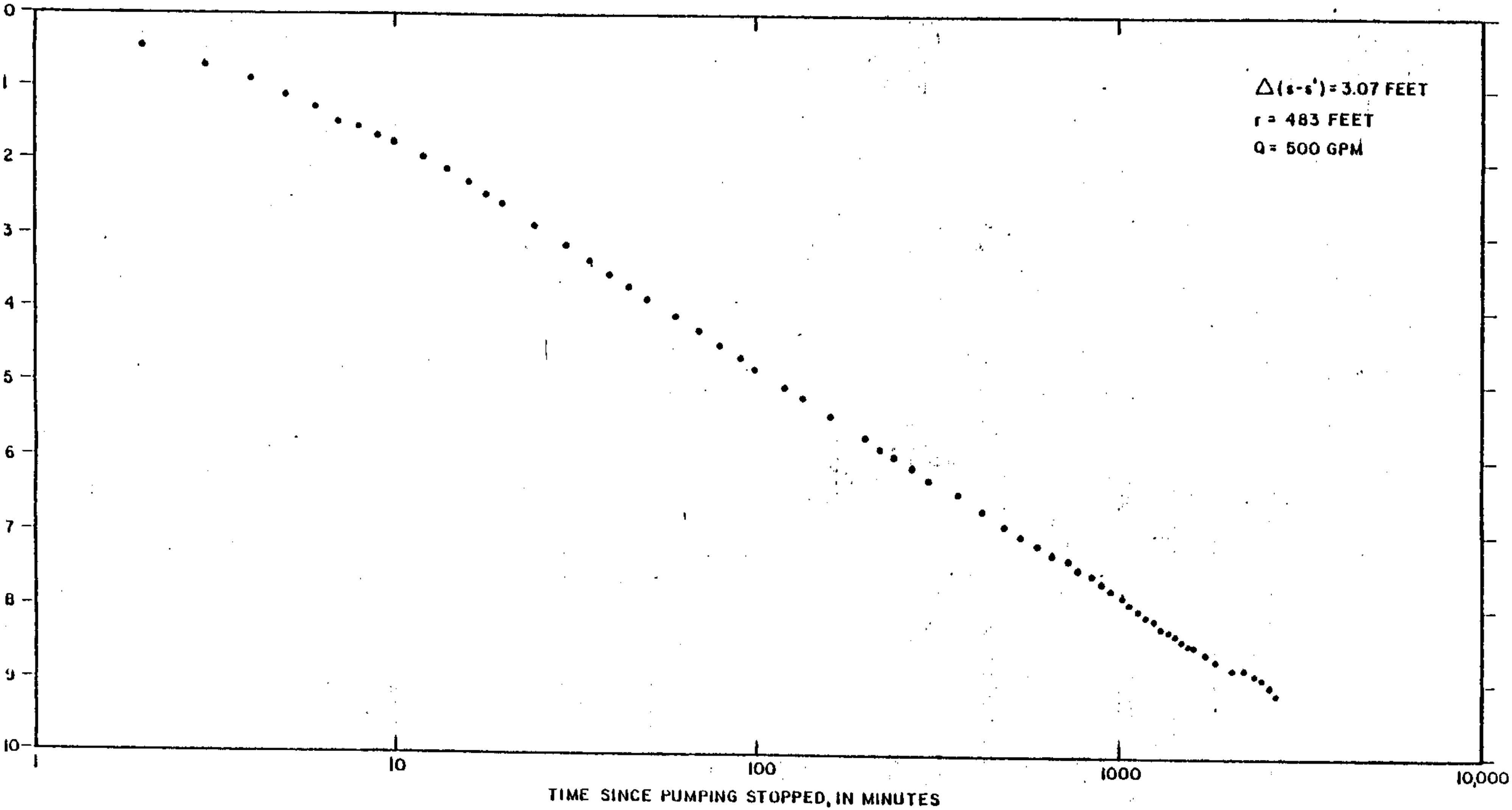


Figure 8 - SEMI-LOGARITHMIC PLOT OF CALCULATED WATER-LEVEL RECOVERY DATA FOR DOW.

Table 1 - SUMMARY OF PUMP-TEST DATA ANALYSES

Well	Type of Data Analyzed	Method of Analysis	Transmissivity (gpd/ft)	Storage Coefficient (diversionless)
DOW	Drawdown	HMM[1]	48,150	1.2×10^{-4}
TPW	Drawdown	CJM[2]	40,120	- - -
DOW	Drawdown	CJM	46,300	1.4×10^{-4}
TPW	Recovery	CJM	44,600	- - -
DOW	Recovery	HMM	44,760	1.1×10^{-4}
DOW	Recovery	CJMRD[3]	43,000	1.1×10^{-4}

[1] HMM = Hantush Modified Method

[2] CJM = Cooper-Jacob Modified Non-Equilibrium Method

[3] CJMRD = Cooper-Jacob Modified Non-Equilibrium Method for Residual Drawdown

leakage through the confining units from the overlying and underlying zones. In other words, the clay and marl confining units that exist above and below the secondary artesian aquifer effectively confine the water within this aquifer and prevents the interchange of water between underlying and overlying aquifers, at least within the cone of depression created by the pumping well. Calculations indicate that the limit of the cone of depression, assumed to be a 0.1-ft drawdown in the potentiometric surface, extended to a radius of approximately 6 mi from the pumping well. No recharge or discharge boundaries were encountered within the cone of depression.

Tidal Influence on Water-Level Fluctuations in DOW

For several weeks prior to the pumping test, water-level fluctuations were recorded. In Figures 9 and 10 the water-level fluctuation in DOW is shown in addition to the predicted gulf tides and the daily barometric readings at Naples. The diurnal fluctuation of the water levels in DOW is primarily the result of cyclic variations in the atmospheric pressure, which is greatest at about 10:00 a.m. and 10:00 p.m. and least at about 4:00 a.m. and 4:00 p.m. As shown in Figures 9 and 10, the diurnal fluctuations are reinforced by earth tides during the phases of the new and full moon, which occurred on February 19, 1977, and March 5, 1977,

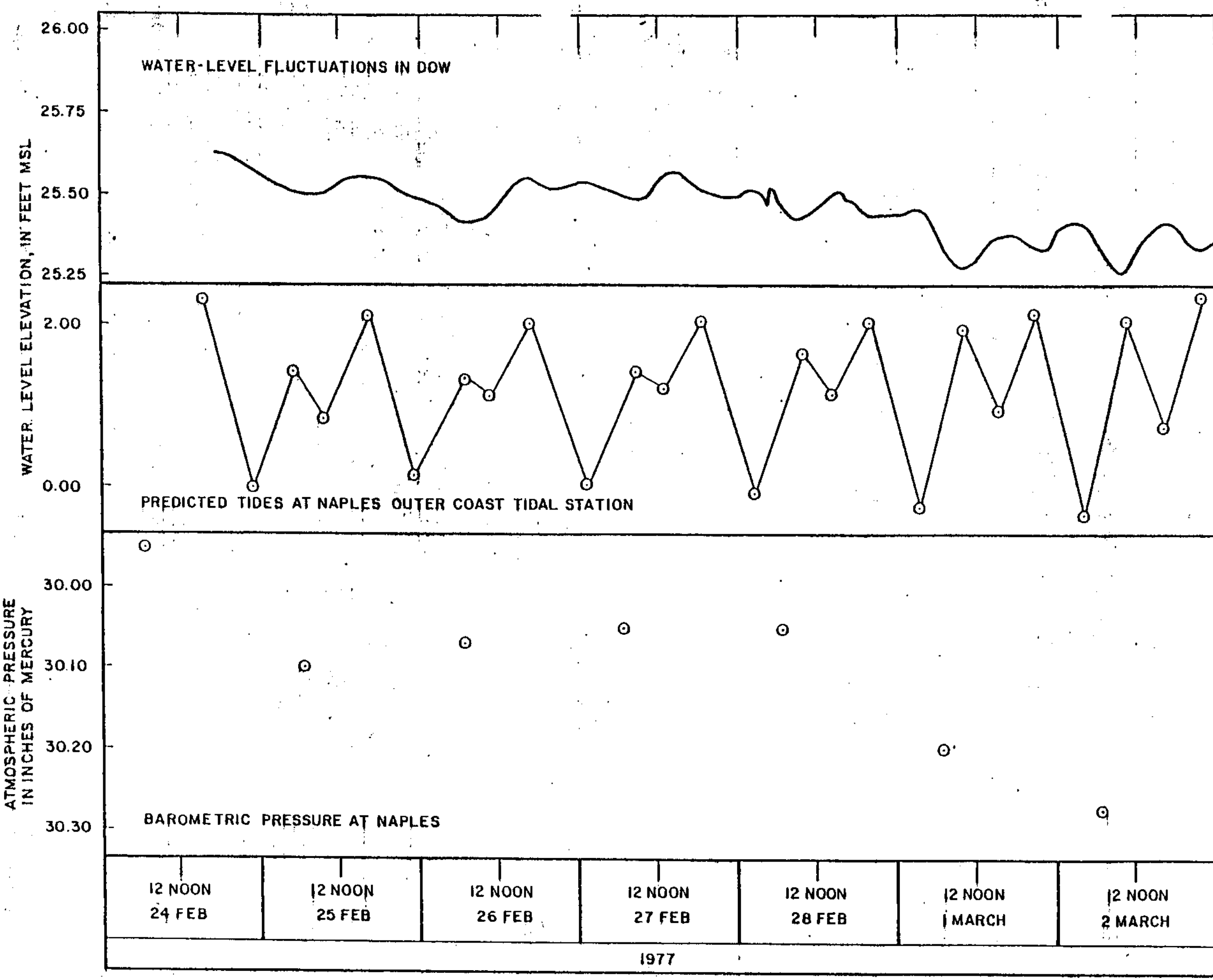


Figure 9 - WATER-LEVEL FLUCTUATIONS IN DOW AND TIDAL AND BAROMETER PRESSURE READINGS IN NAPLES, FEBRUARY 24-MARCH 2, 1977.

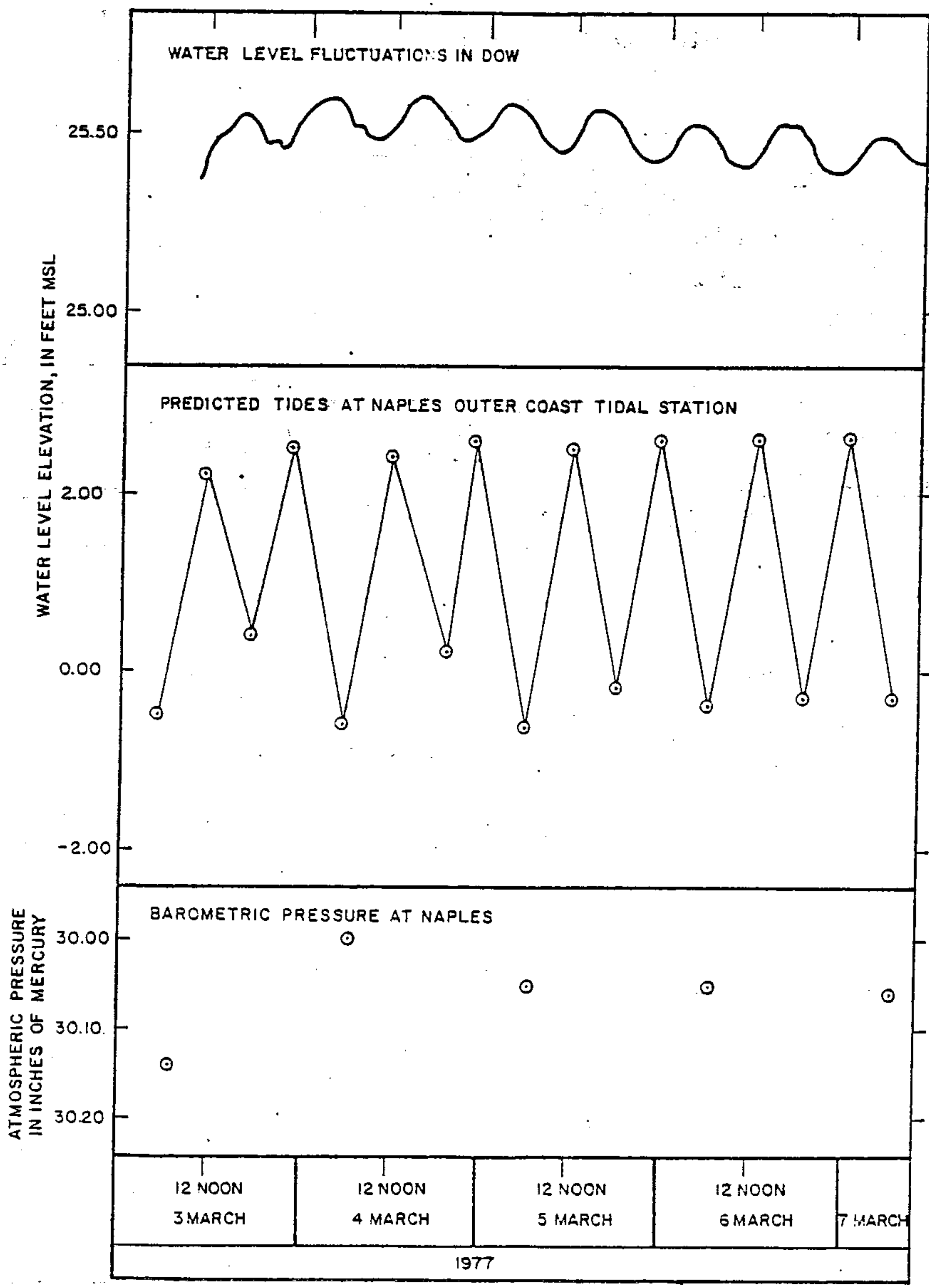


Figure 10 - WATER-LEVEL FLUCTUATIONS IN DOW AND TIDAL BAROMETRIC PRESSURE READINGS IN NAPLES, MARCH 3-MARCH 8, 1977

respectively, and was counteracted by the earth tides during the first and third quarters of the moon's transit, which occurred on February 26, 1977, and March 12, 1977, respectively. It is important to note that no apparent correlation exists between the gulf tides and the water-level fluctuation in DOW. This is clearly evident about the first of March when the Gulf tides are approximately 180° out-of-phase with the water-level fluctuation in DOW. If there were a direct connection between the Gulf of Mexico and the secondary artesian aquifer nearby, the peaks and troughs in the water level in DOW would have consistently lagged the high and low tides in the Gulf by a fixed amount of time. The upward and downward trends in the water-level fluctuations in DOW do not appear to be the result of well interference but merely a response to trends in the atmospheric pressure.

Hydrochemistry

Changes in Water Quality with Depth

During the drilling and development of DOW two water samples were collected. Because the well was drilled by the mud-rotary method, representative water samples could not be collected during the drilling process itself. However, when the well reached a depth of 462 ft drilling was temporarily stopped and during the night the well began to flow. A water sample was collected from the free-flowing well before drilling was resumed the next morning. A similar sample was collected when the well reached its final depth of 650 ft. The chemical analyses of these water samples are shown in Appendix B.

The results indicate that the chemistry of the water changed little as the well was deepened. In fact, the sulfate, chloride and sodium concentrations were the same in each case. There are several possible explanations for the apparent similarities, one of which is the possibility that the water quality is uniform throughout the open bore hole interval of the aquifer. Another plausible explanation is that the upper portion of the aquifer is much more permeable than the lower portion and thus contributes most of the water yielded to the well.

Changes in Water Quality during Pumping

The chemical analyses of the water samples collected from TPW during the pump test are also shown in Appendix B. Chemical analysis of the water indicates that the ground-water from TPW is somewhat more mineralized than that of DOW.

To ascertain the influence that pumping the aquifer could have on the chemical quality of the ground water, six water samples were collected during the pump test. The first and last samples were analyzed for standard constituents, containing the major cations and anions. The four intermediate samples were analyzed for the contents of total dissolved solids, chlorides and sulfates.

Figure 11 shows the chloride, sulfate, and total dissolved-solids concentrations as a result of analysis of each of the six water samples. The chloride concentration decreased 9.4% from 1,875 mg/l (milligrams per liter) to 1,675 mg/l after 2,450 minutes of pumping and appeared to stabilize for the remainder of the pump test. In a similar manner, both the total dissolved-solids and sulfate concentrations decreased 9.6% and 15%, respectively, from their initial concentrations by the end of the test and appeared to be approaching stabilization. No ready explanation can be given for this apparent improvement in the water quality. It is possible, however, that the extending cone of depression intercepted somewhat fresher ground-water resources in the vicinity of the pumping well. Comparison of the chemical analyses of the first and the last water sample also revealed that total hardness as $CaCO_3$ declined, as did the calcium hardness and the calcium, while the silica content

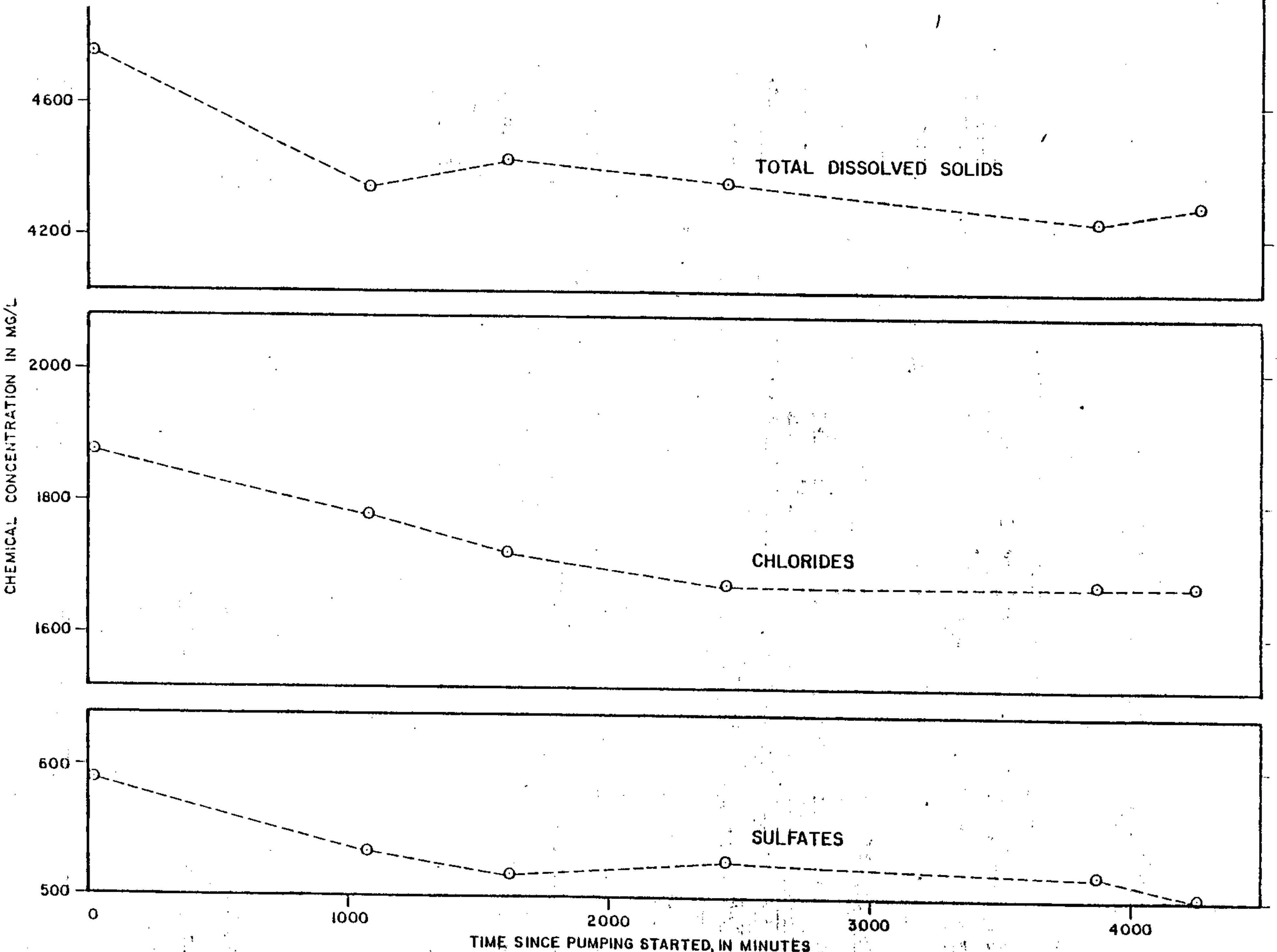


Figure 11. - CHANGES IN CHEMICAL CONCENTRATIONS OF SELECTED CONSTITUENTS DURING PUMPING.

increased somewhat. These changes could possibly indicate that more water from a more sandy formation flowed to the well between the beginning and the end of the pump test.

Effects of Pumping on Long-term Water Quality

The majority of the water withdrawn from ground-water sources in Lee County comes from the uppermost semi-confined aquifer. The secondary artesian aquifer is used in isolated cases for irrigation purposes in eastern Lee County but is virtually untapped in the Naples area.

The results of the pump test indicate that the secondary artesian aquifer is effectively isolated from the underlying and overlying aquifers by thick deposits of clays and marls. The presence of these confining deposits will most likely prevent any significant deterioration in the quality of the ground-water in the secondary artesian aquifer as a result of upconing of more highly mineralized water that may be contained in the underlying Floridan Aquifer.

The problem of assessing the lateral landward intrusion of salt water, as the result of ground-water withdrawals for the Pelican Bay development, is difficult because of the lack of information available for the area. The position of the salt/fresh-water interface within the secondary artesian aquifer is presently unknown. However, because the artesian head is 25 ft above msl, the interface is probably located some distance offshore. During the three day pump test the quality of water withdrawn improved with time and no increase in mineralization of the water was apparent. Had the pumping well been located within the zone of diffusion associated with the salt/fresh interface then a degradation in the water quality would probably have resulted. The phenomenom of a salt/fresh interface being located offshore in confined aquifers is not uncommon. Recent studies in Fort Walton Beach, Florida, which is located on the Gulf of Mexico in northern Florida, have concluded that it would probably be several decades or more before the lateral landward movement of the salt/fresh water interface would begin to adversely affect the city's wells (Geraghty & Miller, 1976), even though the potentiometric surface of the tapped aquifer has been depressed as low as 100 ft below msl.

WATER AVAILABILITY

The availability of a ground-water resource is generally dependent on three factors. The first is the rate at which the resource is recharged when pumped; the second is the limit imposed on the pumping rate to avoid adverse impacts; and the third is the change in chemical quality of the resource.

Recharge

Unfortunately, the information necessary to evaluate possible recharge and discharge areas for the aquifer tapped by TPW is virtually nonexistant. As mentioned previously, it is believed that TPW is open to the upper and lower portions of the Hawthorn Formation. The Hawthorn Formation is quite extensive in the area and it is known to be a source of water in Lee County, north of the site, where it is estimated that between 2500 to 3000 deep artesian wells and test holes have been drilled. A large number of these tap the Hawthorn Formation (Sproul, Boggess and Woodard (1972).) The geologic map prepared by Vernon and Puri (1965) shows that the Hawthorn Formation crops out in West Central Florida. The first outcrop occurs about 60 mi north of the site in De Soto County.

Based on the analyses of the regional geologic information and of the potentiometric surfaces of the various aquifers, it seems reasonable to assume that possible recharge areas lie quite some distance to the north or northeast of the site.

To make a determination as to where ground water would be discharging from the aquifer to saline water bodies is completely speculative because of the complete lack of information.

Impacts from Pumping

The cone of depression that formed in the potentiometric surface of the aquifer as a result of the pumping test did not encounter any recharge or discharge boundaries. This fact is verified by the straightness of the line as shown in Figure 8. If the cone of depression had encountered a recharge boundary, the line would have been deflected upward. If it had encountered a discharge boundary, it would have been deflected downward.

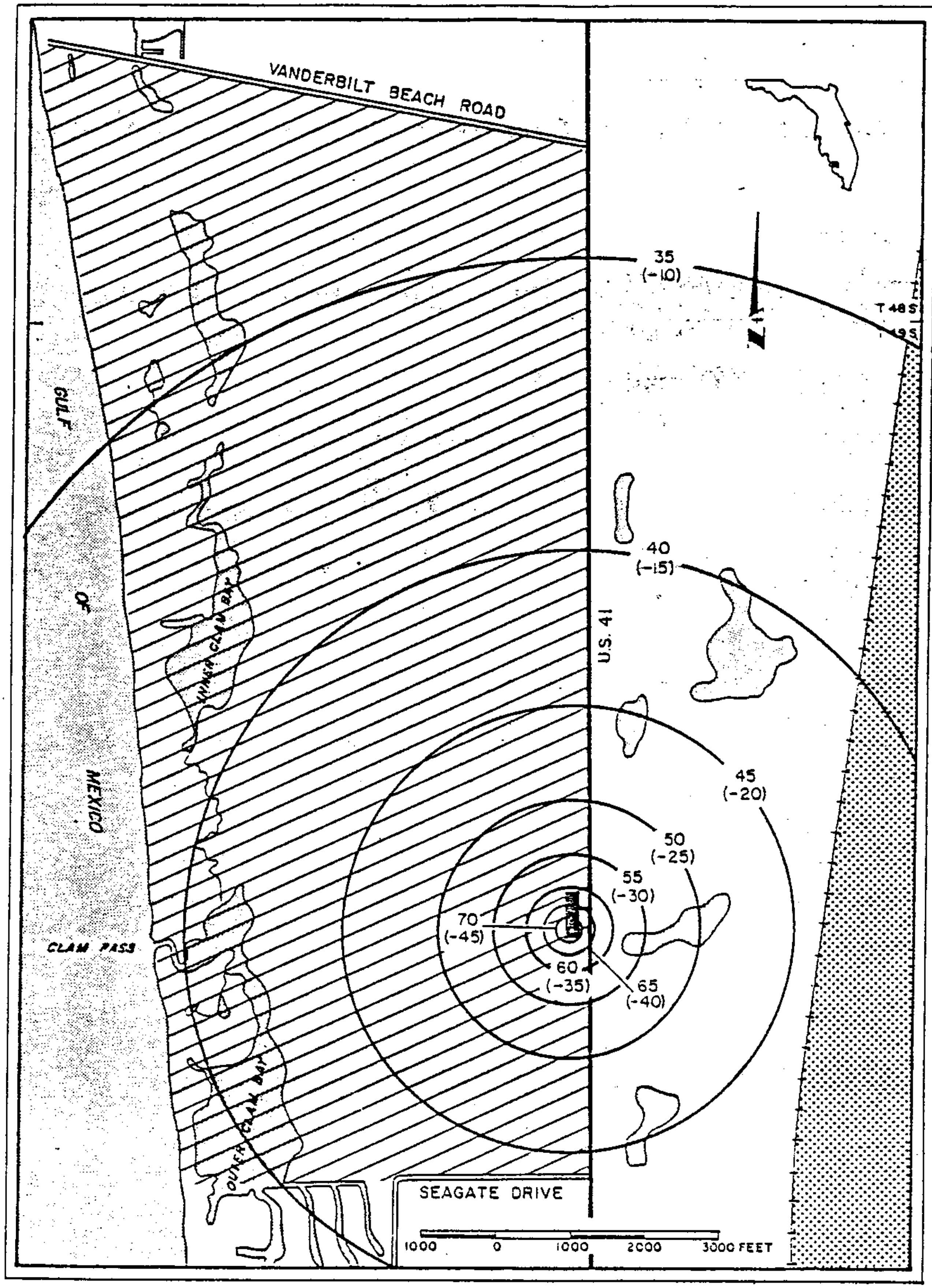
Comparison of the curve in Figure 7 with the standard non-leaky Theis-type curve shows that the aquifer system was completely confined. This means that no water leaked into the aquifer being pumped from the aquifers above or below. The conclusion drawn from this observation is that pumping from the aquifer open to TPW will not affect the overlying semi-artesian aquifer from which the City of Naples draws its water. Thus no adverse impacts from pumping on the overlying water-bearing zones has been observed.

Water Quality

As explained in the previous section on Hydrochemistry, no degradation of water quality (in fact an improvement) was observed during pumping. If the potentiometric surface should continue declining as a result of continued pumping some time in the future, salt water from the tidal water bodies (the Gulf of Mexico) might start to leak into the aquifer some distance away. However, the water quality could also improve because the expanding cone of depression could intercept a recharge boundary. Because of the lack of regional information, both of these scenarios are purely hypothetical.

Long-Term Withdrawals

A water-level drawdown map was prepared to show the effects of pumping on the aquifer system at the end of 1990 (Figure 12). The initial pumping rate was assumed to equal 178 gpm beginning in 1980 and increased by a rate of 178 gpm every year thereafter through 1990. The aquifer was assumed to be homogeneous, isotropic, and not leaky; and that all the water was withdrawn at TPW. This idealized



—50— DRAWDOWN IN POTENTIOMETRIC SURFACE, IN FEET

(-25) ESTIMATED ELEVATION OF THE POTENTIOMETRIC SURFACE, IN FEET, MSL

Figure - 12 - PROJECTED DECLINES IN THE POTENTIOMETRIC SURFACE BY THE END OF 1990.

graph shows that by the end of 1990 the water level in DOW will have declined by approximately 60 ft. The water-level decline in TPW is estimated to be about 120 ft below the present static water level of 25 msl. This translates into a pumping water level of -95 ft msl.

Of course, the assumptions are idealistic. The aquifer is not homogeneous and surely not isotropic. The expanding cone of depression might encounter recharge or discharge boundaries and water quality changes could occur. It appears, therefore, that during the first ten years of development the water-level and water-quality monitoring program should continue to assess more fully the quantitative and qualitative responses of the aquifer system to the proposed long-term withdrawals.

Sufficient amounts of water are available for the first stages of the proposed development. The results of the continuous monitoring program will allow more accurate predictions regarding the ultimate performance of the aquifer systems.

CONCLUSIONS AND RECOMMENDATIONS

The analyses of the collected information has led to the following conclusions:

(1) The test production well TPW taps the aquifers in the Hawthorn Formation.

(2) At the test site, these aquifers are separated from the overlying semi-confined aquifer, from which the City of Naples draws its water, by approximately 100 ft of confining deposits consisting primarily of clays.

(3) During the pumping test no drawdown in the water levels in the overlying aquifer was observed.

(4) Analyses of the pumping test data showed that the ground-water system acted as a completely confined artesian aquifer. No indications were found that leakance of water from aquifers below or above entered the pumped zone.

(5) The expanding cone of depression in the potentiometric surface did not encounter any recharge or discharge boundaries.

(6) The values of transmissivity and storage coefficient are 45,000 gpd/ft and 1.2×10^{-4}, respectively.

(7) The chemical quality of the ground water improved during the first stages of the pumping test and remained constant thereafter. At the end of the pumping test the total dissolved solids content was 4296 mg/l.

The general lack of information concerning the aquifer system, in the area surrounding the test site, is a major difficulty in predicting the long term impacts of the proposed ground-water resources development in relation to the aquifer system itself, to other aquifer systems above (or below), and to the water quality. It is, therefore, recommended that the effects of the pumping during the first stages of development should be closely monitored. Ideally, two additional observation wells in the same zone as the pumping well and a deep observation well in the aquifer below the Hawthorn Formation, will be needed to provide an important amount of additional data necessary to evaluate and answer questions pertaining to geologic structure, to the possible location of recharge and discharge areas, and to water quality. The data to be collected are as follows: (1) continuous discharge measurements; (2) weekly water-level measurements in all observation wells; (3) weekly electrical specific conductance measurements of the water taken from the observation and production wells; and (4) quarterly chemical analyses for major constituents of water samples taken from these wells.

When new wells are installed, it is recommended that they be drilled with the reverse-air rotary technique which will allow for the collection of water samples from the formation during the drilling process. This information will be useful in assessing the vertical profile of the ground-water quality, necessary for the construction of the production wells so that the ground water being pumped will contain the lowest possible total dissolved-solids content.

ACKNOWLEDGEMENTS

The project was directed from the Tampa office of Geraghty & Miller, Inc. The principal investigators were Peter L. Palmer (project manager) and Peter J. Schreuder (project supervisor). Kurt G. Sommers supervised the test drilling and geophysical logging, and collected and analyzed the geologic samples. Other members of the staff who contributed to the study include Mary L. Ritter and Gerald G. Parker. William J. Baldwin drafted the illustrations, Dianne Y. Sutton prepared the manuscript, and Margaret S. Ordey edited and proofread the report. The initial stages of the project were coordinated by Mr. Vincent P. Amy of the West Palm Beach office.

The efficient and timely execution of the test program was largely due to the cooperation and guidance received from Mr. John F. McKune of Gee & Jenson, Engineers, Architects-Planners, Inc.

Mr. T.H. O'Donnell of the U.S. Geological Survey in Ft. Myers provided useful hydrogeologic information concerning the study area. Mr. G. Smith and Mr. D. Fowler of Coral

Ridge-Collier Properties, Inc. provided invaluable assistance prior to and during the pumping test.

Respectfully submitted,

GERAGHTY & MILLER, INC.

Peter J. Schreuder
Project Supervisor

Peter L. Palmer
Project Manager

April 11, 1977

SELECTED BIBLIOGRAPHY

Anonymous, 1972, Ground Water and Wells: Johnson Division, Universal Oil Products Co., St. Paul, Minn.

Geraghty & Miller, Inc., 1976, Status of the Fresh Ground-Water Resources of the Fort Walton Beach Area, Okaloosa County, Florida--With Special Emphasis on the Threat of Salt-Water Encroachment: prepared for City of Fort Walton Beach.

Klein, Howard, 1954, Ground-Water Resources of the Naples Area, Collier County, Florida: U.S. Geol. Survey Rept. Invest. No. 11.

Klein, Howard, 1972, The Shallow Aquifer of Southwest Florida: U.S. Geol. Survey Rept. Map Series No. 53.

Lohman, S.W., 1972, Ground-Water Hydraulics: U.S. Geol. Survey, Prof. Paper 708.

McCoy, Jack, 1972, Hydrology of Western Collier County, Florida: U.S. Geol. Survey Rept. Invest. No. 63.

McCoy, Jack H., 1975, Summary of Hydrologic Conditions in Collier County, Florida, 1974: U.S. Geol. Survey, Open File Report FL-75007

Meyer, Frederick W., 1974, Evaluation of Hydraulic Characteristics of a Deep Artesian Aquifer from Natural Water-Level Fluctuations, Miami, Florida: U.S. Geol. Survey Rept. Invest. No. 75.

Missimer, T.M. and O'Donnell, T.H., 1975, Fluctuations of Ground-Water Levels in Lee County, Florida, in 1974: U.S. Geol. Survey, Open File Report FL-75008.

Sherwood, C.B. and Klein, Howard, 1961, Ground-Water Resources of Northwestern Collier County, Florida: U.S. Geol. Survey, Info. Circ. No. 29

Sproul, C.R., 1972, Saline-Water Intrusion from Deep Artesian Sources in the McGregor Isles Area of Lee County, Florida: U.S. Geol. Survey Rept. Info. Circ. No. 75.

Vernon, R.O. and Puri, H.S., 1965, Geologic Map of Florida: U.S. Geol. Survey, Map Series 18.

APPENDIX A

PELICAN BAY DEEP OBSERVATION WELL

Collier County, Florida

(Samples Described by Geraghty & Miller, Inc.)

Depth (Feet)	Description
0-20	Sand, fine- to medium-grained, light brown.
20-30	Sand, shells.
30-50	Limestone, gray, soft, shells.
50-70	Limestone, grayish cream to cream, shells, gray clay decreasing downward.
70-90	Limestone, grayish-cream, soft, shells, highly fossiliferous decreasing downward.
90-120	Limestone, cream, soft, shells, mixed fossils.
120-162	Limestone, tan, soft, sand and black phosphatic sand grains, shells and fossils increasing downward.
162-167	Sand, medium-grained, quartzose, unconsolidated.
167-190	Limestone, gray, porous, biogenic, shells and fossil fragments, interbedded with tan limestone toward base.
190-215	Limestone, brown to gray, fine-grained, soft to medium-hard, low porosity to pitted and honey-combed, abundant fossils, interbedded with white limestone and with white clay toward base.
215-235	Clay, green to gray, fine-grained quartz sand and black phosphatic sand present.
235-268	Clay, green to gray, very fine- to coarse-grained quartz sand and black phosphatic sand present, shells, some interbedded white clay, creamy limestone stringers and abundant black phosphatic sand grains near base.
268-322	Clay, blue-green to dark green, black phosphatic grains increasing downward, creamy limestone stringers at base.

Depth (Feet)	Description
322-387	Limestone, grayish cream to tan, finely granular to finely crystalline, pitted, shell fragments and fossils.
387-401	Limestone, white to cream, medium hard, highly fossiliferous, abundant shells.
401-402	Shell bed, unconsolidated.
402-420	Limestone, creamy tan to white, granular shell fragments, fossils, unconsolidated shell bed or cavity between 407-409 feet.
420-445	Limestone, cream to tan, soft, some shell fragments, some green clay increasing at base.
445-462	Clay, green to gray, fossils, shell fragments.
462-490	Limestone, creamy gray to tan, soft to medium-hard, peppered with phosphate grains, some shell fragments and fossils.
490-515	Limestone, cream, soft, finely crystalline to granular with fossils and shell fragments in basal 10 feet.
515-520	Limestone, tan, dense with fossils and shell fragments.
520-550	Limestone, cream to light tan, soft, shell fragments and fossils, interbedded with white phosphatic clay.
550-580	Limestone, gray to cream, soft to medium hardness, peppered with phosphate grains, fossils and shell fragments, finely crystalline dense tan limestone interbedded in basal 5 feet.
580-615	Limestone, cream, soft, peppered with black phosphate grains, fossils and shell fragments, interbedded with white clay stringers.
615-645	Clay, blue-gray to gray, soft, interbedded with white to cream limestone stringers.
645-652	Limestone, cream, medium-hard fine-grained, peppered with phosphate grains, high gray clay content.
652 T.D.	

PELICAN BAY TEST/PRODUCTION WELL

Collier County, Florida

(Samples Described by U.S. Geologic Survey)

Depth (Feet)	Description
5-10	Sand, fine, light gray.
10-25	Sand, fine, brown (iron stained).
25-30	Sand, fine, brown; few tan limestone fragments.
30-35	Limestone, tan, marly; few shells.
35-45	Limestone, tan; few shells.
45-55	Limestone, gray tan, hard, slightly sandy.
55-70	Limestone, gray tan, marly, sandy.
70-80	Limestone, gray tan, slightly marly; shell.
80-90	Limestone, gray tan; shell.
90-105	Limestone, gray tan.
105-120	Same with shell.
120-130	Limestone, gray tan, slightly sandy.
130-140	Limestone, tan, sandy.
140-160	Same with few shell.
160-170	Limestone, tan, sandy; shell; some marl.
170-185	Limestone, gray tan, very sandy; shell.
185-195	Sandstone, gray tan, calcareous; shell.
195-200	Sandstone as above and sand; some limestone fragments.
200-205	Clay, green, very sandy, phosphatic; abundant shell.
205-215	Clay, green, sandy, phosphatic; shell.
215-230	Limestone, tan, slightly sandy.
230-235	Limestone, tan, very sandy, some marl.
235-240	Limestone, gray tan, sandy, marly.

Depth (Feet)	Description
240-260	Clay, gray, very sandy.
260-265	Clay, green, tough.
265-270	Clay, green, very sandy, some phosphorite.
270-275	Clay, green, sandy.
275-280	Clay, green and gray, phosphatic, marly; limestone.
280-290	Limestone, marly, phosphatic.
290-300	Clay, gray, phosphatic, sandy.
300-310	Clay, dark gray, slighty sandy, phosphatic.
310-340	Clay, dark gray, very sandy, very phosphatic.
340-355	Limestone, gray, phosphatic.
355-365	Limestone, tan, phosphatic.
365-380	Limestone, gray, phosphatic; shell.
380-400	Limestone, gray; shell.
400-465	Limestone, tan, slightly sandy, slightly phosphatic, trace of clay.
465-480	Marl, gray and green, sandy, phosphatic.
480-525	Limestone, tan, slightly phosphatic.
525-540	Limestone, brown and tan, dolomitic, slightly phosphati
540-560	Limestone, tan, very little phosphate.
560-590	Limestone, gray, very phosphatic and phosphatic marl.
590-605	Limestone, gray, phosphatic.
605-625	Marl, dark and light gray, slightly phosphatic.
625-640	Marl, gray, little phosphate.

PELICAN BAY TEST HOLE NO. 1

Collier County, Florida

(Samples Described by U.S. Geologic Survey)

Depth (Feet)	Description
0-10	Sand, fine, light brown, organic.
10-15	Sand, fine, light brown.
15-20	Sand, fine, dark brown, very organic.
20-30	Limestone, tan, sandy; shells.
30-35	Limestone, tan, sandy; abundant shells.
35-40	Limestone, gray to tan, sandy.
40-45	Limestone, gray; shells.
45-55	Limestone, gray; abundant shells.
55-65	Limestone, gray; tan coral; shells.
65-80	Limestone, tan; abundant shells.
80-105	Limestone, tan, sandy; abundant shells.
105-110	Limestone, gray and tan, slightly sandy; fewer shells.
110-120	Limestone, gray.
120-130	Limestone, tan, marly, slightly sandy.
130-160	Limestone, gray to tan, slightly sandy.
160-170	Limestone, gray to tan, slightly sandy, marly.
170-180	Marl, gray, slightly sandy; limestone fragments; some shell.
180-215	Limestone, gray to tan; shell fragments.
215-235	Limestone, gray to tan.
235-435	Lost circulation, no samples.
435-455	Limestone reported, no sample.
455-465	Limestone and sandstone, gray to tan; shell fragments.
465-475	Sandstone, gray, calcareous; shell.

PELICAN BAY TEST HOLE NO. 1 (Continued)

Depth (Feet)	Description
475-535	Sandstone and limestone, gray.
535-550	Limestone, gray to tan, very sandy.
550-575	Sandstone, calcareous, gray to tan.
575-615	Limestone, very sandy, light gray and tan.
615-625	Limestone, sandy, light gray, marly.
625-635	Sand reported (no sample).
635-675	Sand, fine to medium, dark gray to green, phosphatic; some sandstone and limestone.
675-695	Same except highly phosphatic. Another sample same depth shows sand, medium light brown.
695-715	Sand and clay, phosphatic; dark gray to green.
715-735	Clay and sand, gray; phosphate.
735-755	Clay and sand, dark gray, phosphatic.
755-815	Clay and sand, gray, phosphatic.
815-835	Clay, light gray to white, sandy.
835-875	Clay, gray, very sandy, slightly phosphatic.
875-895	Clay, light gray to white, very sandy.
895-915	Clay, dark gray, sandy, phosphatic.
915-945	Clay, dark gray to green (stiff).
945-955	Lost circulation, no samples.

APPENDIX B

STANDARD WATER ANALYSIS REPORT

Orlando Laboratories, Inc.

P. O. Box 8025A • Orlando, Florida 32806 • 305/843-1661

Report to: Geraghty & Miller

Appearance: Turbid

Date: 16 Feb. 77

Sampled by: Client

Report Number: 12887-2

Identification: Pelican Bay Development 2-9-7 Well Flowing all night Unfiltered. $T^{o}C$=24.5 DOW - Depth = 462'

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 @ 180°C	x	3500	Total Hardness, as $CaCO_3$	x	440
Phenolphthalein Alkalinity, as $CaCO_3$	x	0	Calcium Hardness, as $CaCO_3$	x	180
Total Alkalinity, as $CaCO_3$	x	80	Magnesium Hardness, as $CaCO_3$	x	260
-bonate Alkalinity, as $CaCO_3$	x	0	Calcium, as Ca	x	72
Bicarbonate Alkalinity, as $CaCO_3$	x	80	Magnesium, as Mg	x	63
Carbonates, as CO_3	x	0	Sodium, as Na	x	980
Bicarbonates, as HCO_3	x	98	Iron, as Fe	x	0.2
Hydroxides, as OH	x	0	Manganese, as Mn	x	<0.05
Carbon Dioxide, as CO_2	x	4.1	Copper, as Cu	x	<0.1
Chloride, as Cl	x	1450	Silica, as SiO_2	x	18
Sulfate, as SO_4	x	400	Color, PCU	x	0
Fluoride, as F	x	1.8	Odor Threshold	x	0
Phosphate, as PO_4	x	0.37	Turbidity, NTU	x	6.3
pH (Laboratory)	x	7.6			
pHs	x	7.8			
Stability Index	x	8.0			
Saturation Index	x	-0.2			

Signed: Donna Turbin

Chemist

STANDARD WATER ANALYSIS REPORT

Orlando Laboratories, Inc.

P. O. Box 8025A • Orlando, Florida 32806 • 305/843-1661

eport to: Geraghty & Miller

ate: 16 Feb. 77

eport Number: 12887-1

Appearance: Turbid

Sampled by: Client

Identification: Pelican Bay Development Post Development. Unfiltered Flowing @ 125 gpm for 4 hours $T^{o}C$ = 26.5o DOW - Depth = 650'

METHODS

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

RESULTS

etermination	Date Significance	mg/l	Determination	Date Significance	mg/l
otal Dissolved Solids @ 180°C	x.	3400	Total Hardness, as $CaCO_3$	x.	440
henolphthalein Alkalinity, as $CaCO_3$	x.	0	Calcium Hardness, as $CaCO_3$	x.	220
otal Alkalinity, as $CaCO_3$	x.	70	Magnesium Hardness, as $CaCO_3$	x.	220
rbonate Alkalinity, as $CaCO_3$	x.	0	Calcium, as Ca	x.	88
carbonate Alkalinity, as $CaCO_3$	x.	70	Magnesium, as Mg	x	53
rbonates, as CO_3	x.	0	Sodium, as Na	x.	980
carbonates, as HCO_3	x.	85	Iron, as Fe	x	0.15
ydroxides, as OH	x.	0	Manganese, as Mn	x	<0.05
rbon Dioxide, as CO_2	x.	7.3	Copper, as Cu	x	<0.1
loride, as Cl	x.	1450	Silica, as SiO_2	x.	23
lfate, as SO_4	x.	400	Color, PCU	x.	0
uoride, as F	x.	1.9	Odor Threshold	x.	0
osphate, as PO_4	x	0.47	Turbidity, NTU	x.	8.2
(Laboratory)	x	7.3			
s	x	7.8			
bility Index	x	8.3			
uration Index	x	-0.5			

Signed: Donna Turbish

Chemist

REPORT OF ANALYSIS

Orlando Laboratories, Inc.

OLI
3314 Bay to Bay Blvd. - Tampa, FL - 33609 - (813) 839-8802

TO:

Report # T-0657 C
Date: 3/16/77
Sampled by: Client

GERAGHTY & MILLER
Post Office Box 17174
Tampa, Florida 33682

IDENTIFICATION:

Pelican Bay, Naples, Florida Pump Test Analysis

1 = Pumping Time 1080 mins.
2 = Pumping Time 1609 mins.
3 = Pumping Time 2450 mins.
4 = Pumping Time 3880 mins.

RESULTS OF ANALYSIS:	1	2	3	4
Total Solids, @ 105°C	4348	4428	4360	4256
Chloride, as Cl	1775	1725	1675	1675
Sulfate, as SO_4	535	520	530	520

RESULTS EXPRESSED IN mg/l (ppm) UNLESS OTHERWISE DESIGNATED

Respectfully submitted,

ORLANDO LABORATORIES, INC.

Alan Dillon

Chemist/Biologist/Bacteriologist

METHODS: "Standard Methods for the Examination of Water and Wastewater," Latest Edition, APHA, AWWA and WPCF and/or other EPA approved methods unless otherwise designated.

F.H.A./V.A. WATER ANALYSIS REPORT

Orlando Laboratories, Inc.

3314 Bay to Bay Blvd. — Tampa, FL. 33609 — (813) 839-8802

Report to: GERAGHTY & MILLER, INC.

Date: March 16, 1977

Report Number: T-0657 A

Appearance: Clear

Sampled by: Client

Identification: Pelican Bay, Naples, Fla.
Pump Test Analysis
Pumping Time 20 minutes

METHODS

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

RESULTS

Determination	mg/l	Determination	mg/l
Total Dissolved Solids, @ 105°C.	4764	Total Hardness, as $CaCO_3$	1120
Phenolphthalein Alkalinity, as $CaCO_3$	0	Calcium Hardness, as $CaCO_3$	640
Total Alkalinity, as $CaCO_3$	186	Magnesium Hardness, as $CaCO_3$	480
...onate Alkalinity, as $CaCO_3$	0	Calcium, as Ca	264
Bicarbonate Alkalinity, as $CaCO_3$	186	Magnesium, as Mg	117
Carbonates, as CO_3	0	Iron, as Fe	<0.1
Bicarbonates, as HCO_3	227	Manganese, as Mn	<0.05
Hydroxides, as OH	0	Copper, as Cu	<0.1
Carbon Dioxide, as CO_2	15	Silica, as SiO_2	9.4
Chloride, as Cl	1875	Color, Standard Platinum Cobalt Scale	2
Sulfate, as SO_4	590	Odor Threshold	0
Fluoride, as F	2.25	Turbidity, Jackson Units	0.2
Phosphate, as PO_4	3.53	Hydrogen Sulfide, H_2S (field-fixed)	
pH (Laboratory)	7.4		
pHs	6.9		
Stability Index	6.4		
Saturation Index	0.5		

Signed: alan Dillon
Chemist

NALYSIS OF WATER, WASTEWATER, OIL, GAS & COAL - RADIATION MONITORING

F.H.A./V.A. WATER ANALYSIS REPORT

Orlando Laboratories, Inc.

3314 Bay to Bay Blvd. — Tampa, FL. 33609 — (813) 839-8802

Report to: GERAGHTY & MILLER, INC.

Appearance: Clear

Date: March 16, 1977

Sampled by: Client

Report Number: T-0657 B

Identification: Pelican Bay, Naples, Fla.
Pump Test Analysis
Pumping Time 4255 minutes

METHODS

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

RESULTS

Determination	mg/l	Determination	mg/l
Total Dissolved Solids, @ 105°C.	4296	Total Hardness, as $CaCO_3$	1020
Phenolphthalein Alkalinity, as $CaCO_3$	0	Calcium Hardness, as $CaCO_3$	540
Total Alkalinity, as $CaCO_3$	174	Magnesium Hardness, as $CaCO_3$	480
rbonate Alkalinity, as $CaCO_3$	0	Calcium, as Ca	216
Bicarbonate Alkalinity, as $CaCO_3$	174	Magnesium, as Mg	117
Carbonates, as CO_3	0	Iron, as Fe	< 0.1
Bicarbonates, as HCO_3	212	Manganese, as Mn	< 0.05
Hydroxides, as OH	0	Copper, as Cu	< 0.1
Carbon Dioxide, as CO_2	14	Silica, as SiO_2	11.0
Chloride, as Cl	1675	Color, Standard Platinum Cobalt Scale	2
Sulfate, as SO_4	500	Odor Threshold	0
Fluoride, as F	2.25	Turbidity, Jackson Units	0.1
Phosphate, as PO_4	2.60	Hydrogen Sulfide, H_2S (field-fixed)	
pH (Laboratory)	7.4		
pHs	7.1		
Stability Index	6.8		
Saturation Index	0.3		

Signed: Alan Dillon
Chemist

ANALYSIS OF WATER, WASTEWATER, OIL, GAS & COAL - RADIATION MONITORING