03

GROUNDWATER RESOURCES OF THE BONITA BAY DEVELOPMENT LEE COUNTY, FLORIDA

VOLUME I. TEXT

Prepared for

DAVID B. SHAKARIAN AND ASSOCIATES, INC.
P. O. Drawer H
Bonita Springs, Florida 33923

October, 1981

MISSIMER AND ASSOCIATES, INC.

Consulting Hydrologists, Geologists, and
Environmental Scientists

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October 12, 1981

Mr. Gary Armstrong, Project Manager
David B. Shakarian & Associates, Inc.
P. O. Drawer H
Bonita Springs, Florida 33923

Subject: Final Report on the "Groundwater Resources of the Bonita Bay Development, Lee County, Florida"

Dear Mr. Armstrong:

Missimer and Associates, Inc. is pleased to submit this final report entitled "Groundwater Resources of the Bonita Bay Development, Lee County, Florida". This report is the result of an intensive 4-month, multi-phased hydrogeologic investigation. The report is presented in two volumes; one text volume and one data volume.

We have developed a plan to utilize the groundwater resources on-site to supply 4.13 MGD of water for irrigation. This plan involves drawing water from four separate sources, which are: the water-table aquifer, Tamaimi Aquifer System-Zone I, Hawthorn Aquifer System-Zone I, and rennovated wastewater. Since the use of potable water is not necessary for irrigation, a mix of the water from these sources will produce a non-potable quality water, which will be excellent for irrigation use and will help conserve the existing potable quality water located to the east of the site.

This invesigation was the most intensive hydrogeologic evaluation ever performed in southwest Florida. The team of investigators from Missimer and Associates, Inc. who performed the study are:

Project Manager: Thomas M. Missimer, Senior Hydrologist
Roland S. Banks, Senior Geologist
Lloyd E. Horvath, Senior Hydrologist
Marycarol Testi, Geologist
David B. Hire, Senior Hydrologic Technician
Ken Harper, Technical Draftsman

We would be pleased to answer any questions concerning this report or the investigation in general.

Sincerely,

MISSIMER AND ASSOCIATES, INC.

Thomas M. Missimer

Thomas M. Missimer, P.G., C.P.G.S.
President

TMM:sm

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VOLUME I. TEXT

I. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

A hydrogeologic investigation was conducted in Sections 20, 21, 28, 29, 32 and 33 of Township 47S, Range 25E for the purpose of evaluating a source of irrigation water supply for the Bonita Bay Development in Lee County. Upon completion of the investigation, the following conclusions were drawn:

1. Ten years into the development at Bonita Bay, 4.13 MGD of water will be required for irrigation use.

2. Exploratory drilling revealed that the site is underlain by 3 aquifers which can potentially be used as sources of water supply. These aquifers are: the water-table aquifer, Tamiami Aquifer System-Zone I, and Hawthorn Aquifer System-Zone I.

3. Aquifer performance tests conducted on the Bonita Bay site with subsequent analyses show that the usable aquifers have the following hydraulic characteristics:

Water-Table Aquifer

Transmissivity	=	65,000 gpd/ft
Specific Yield	=	0.05

Tamiami Aquifer System-Zone I

Transmissivity	=	60,000 gpd/ft
Storage Coefficient	=	1×10^{-4}
Leakance	=	1.3×10^{-3} gpd/ft^3

Hawthorn Aquifer System-Zone I

Transmissivity	=	70,000 gpd/ft
Storage Coefficient	=	5×10^{-5}
Leakance	less than	1×10^{-5} gpd/ft^3

4. Flow through the water-table aquifer moves from east to west; flow through Tamiami Aquifer System-Zone I moves from northeast to southwest; and flow through Hawthorn Aquifer System-Zone I moves from southeast to northwest.

5. The quality of water in the water-table aquifer is good over much of the site except adjacent to tidal waters. Dissolved chloride concentrations range from 10 to 2,200 mg/l. The water is hard and contains a significant concentration of

dissolved iron. The quality of water makes it an excellent source for irrigation supply.

6. Quality of water in Tamiami Aquifer System-Zone I ranges from slightly saline to very saline. The 400 mg/l isochlor passes north and south through the utility site and the 1,000 mg/l isochlor parallels it about 1¼ miles to the west of U.S. 41. Dissolved chloride concentrations range from 320 mg/l to 1,400 mg/l. Most of the water in the aquifer is usable for irrigation.

7. Quality of water in Hawthorn Aquifer System-Zone I is exclusively saline with a dissolved chloride concentration ranging from 1,400 to 1,500 mg/l. It can be used for irrigation only if it is diluted.

8. Pumping of 1.1 MGD (net) of water from the water-table aquifer will not significantly effect any existing water user, will not significantly effect the surface environment, and will not cause significant migration of saline water.

9. Pumping of 1.5 MGD of water from Tamiami Aquifer System-Zone I will not significantly effect any existing water user and will not induce significant migration of saline water. The operation of this wellfield will create an elongated cone of depression, which will permanently inhibit the eastward migration of saline water toward the Bonita Springs Wellfield. The interference between the Bonita Bay Wellfield and the Bonita Springs Wellfield will not cause any significant impacts either to the utility or existing water users.

10. Use of water from Hawthorn Aquifer System-Zone I will not have any adverse impacts on the aquifer system or existing users.

11. The calculated composite dissolved chloride concentration for the mix of the four sources of water at equilibrium is 320 mg/1, which is a quite acceptable quality for irrigation use.

2. Recommendations

1. Of the 4.13 MGD of water required for irrigation at Bonita Bay, 1.1 MGD of the water should be pumped from the water-table aquifer, 1.5 MGD should be pumped from Tamiami Aquifer System-Zone I, 0.13 MGD should be pumped from Hawthorn Aquifer System-Zone I, and 1.4 MGD of rennovated wastewater should be utilized.

2. All groundwater withdrawals should be made from the designated utility site east of U.S. 41, which is the best location to minimize potential impacts.

3. The 1.1 MGD of water to be pumped from the water-table aquifer should be withdrawn from 3 wells located in a north-south orientation. The 1.5 MGD of water to be pumped from Tamiami Aquifer System-Zone I should be withdrawn from 3 wells in a similar alignment. The 0.13 MGD of water to be utilized from Hawthorn Aquifer System-Zone I should be taken from a single well located in the northeast corner of the utility site. Rennovated wastewater should be used directly or should be allowed to percolate into the

water-table aquifer and then be pumped from the aquifer through wells placed around the percolation ponds.

4. All four sources of water should be pumped into a holding basin for mixing before the water is pumped into the central irrigation system.

5. A performance monitoring program should be used to manage the groundwater system of Bonita Bay. Pumping rates, rainfall, water levels, and water quality should be measured on a regular basis. Withdrawal rates should be modified in accordance with the data obtained from the monitoring program.

II. INTRODUCTION

1. Authorization

Missimer and Associates, Inc. was authorized on February 20, 1981, (Phase I) and on May 15, 1981, (Phase II) by David B. Shakarian & Associates to investigate the ground-water hydrology at the proposed site of the Bonita Bay development in southwest Lee County (Figure 2-1). The purpose of the investigation was to locate and test a ground-water source for irrigation use. The area investigated was a 2,375-acre site located west of U.S. 41 and an additional 60-acre site east of U.S. 41 (Figure 2-2). All of the land is located in Sections 20, 21, 28, 29, 32, and 33, Township 47S, Range 25E.

2. Scope of Work

The scope of work included: 1) a compilation and review of all existing hydrogeologic information available from south Lee and north Collier Counties, 2) a well inventory of the surrounding area, 3) an extensive test drilling and observation well construction program to define the geology and to delineate the aquifers underlying the site, 4) the writing of specifications, location, and supervision of construction of three test-production wells,

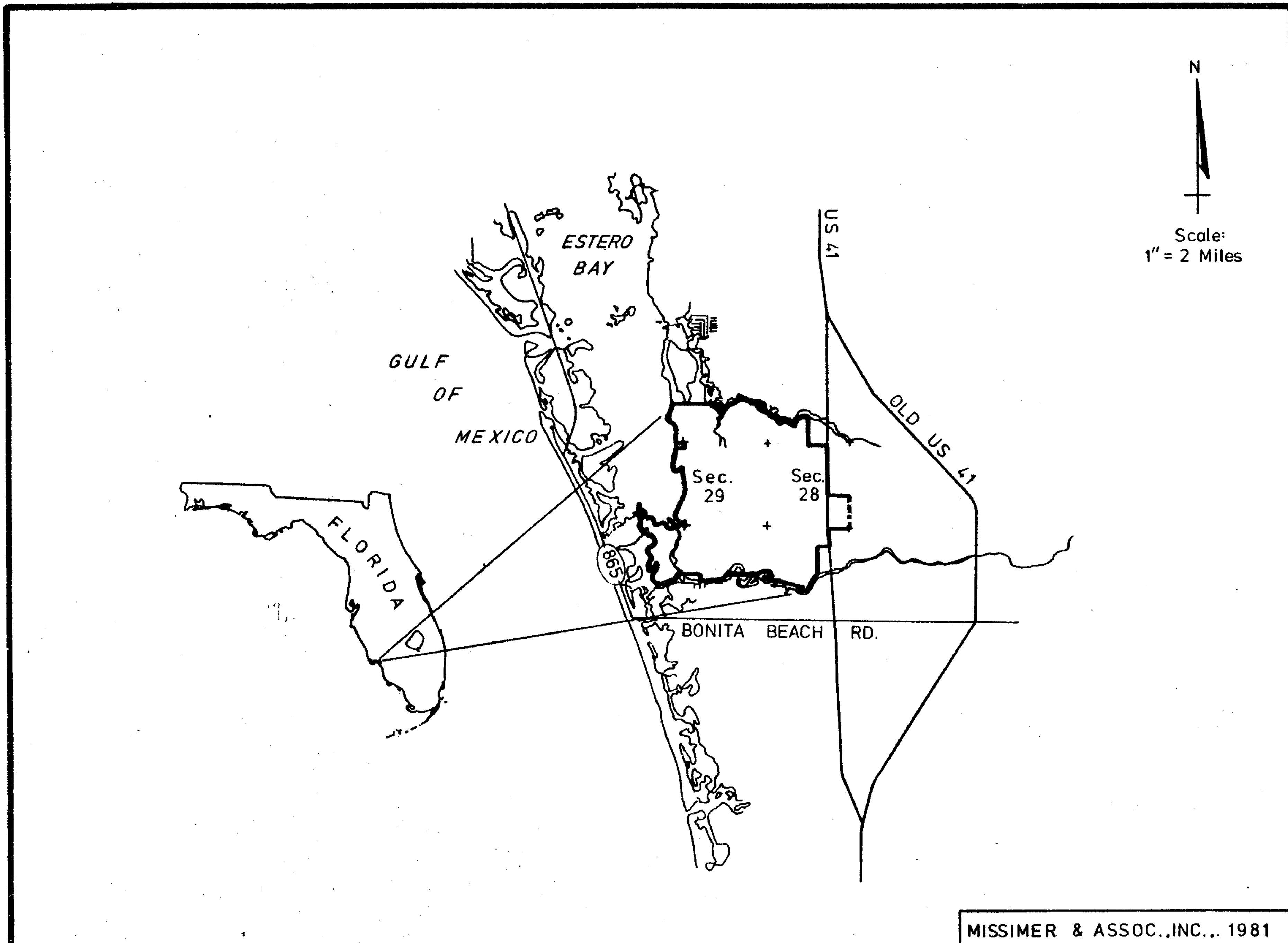

FIGURE 2-1. MAP SHOWING LOCATION OF AREA OF INVESTIGATION.

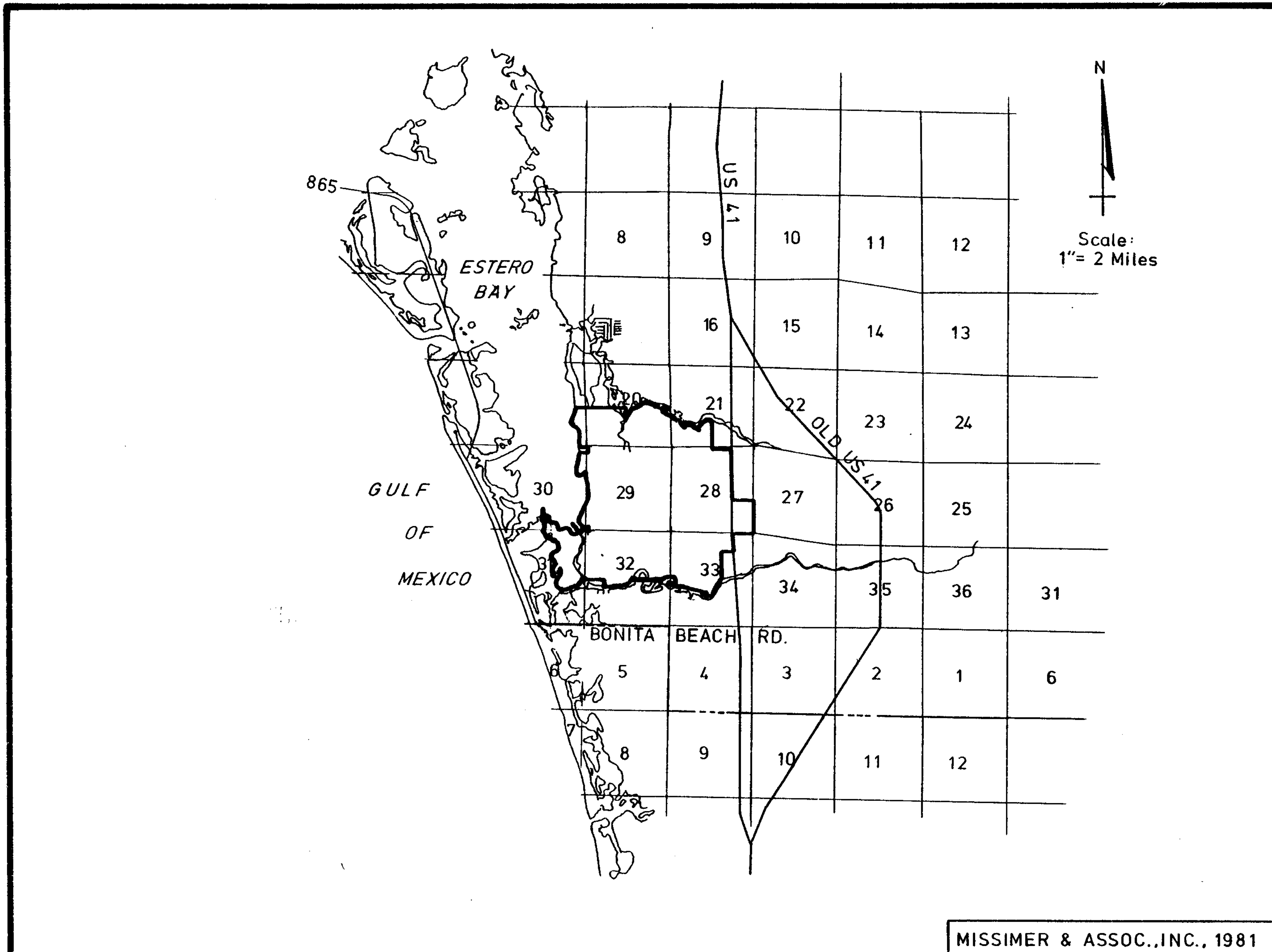

FIGURE 2-2. MAP SHOWING BOUNDARIES OF THE SITE.

5) the collection and analysis of geologic, geophysical, water quality, and water level data from all wells and test holes, 6) the performance and analysis of three aquifer tests, 7) the modeling of potentiometric surface changes and saline-water movement caused by pumping, 8) the production of a technical report with recommendations concerning the availability of water and predicted changes in quality, and 9) coordination with the water management district to obtain a water use permit.

3. Acknowledgments

We wish to thank Mr. Gary Armstrong of David B. Shakarian and Associates, who supervised the progress of the project, Mr. Rick Barber, Mr. Ray Miller, and Mr. Waafa Assad of Wilson, Miller, Barton, Soll & Peek, Inc. for providing information and review of the project in all phases, and Dr. Patrick Gleason and Mr. Rick Bower of the South Florida Water Management District, who reviewed the plan of investigation and provided intermediate reviews of the data.

III. GEOLOGY AND HYDROLOGY OF SOUTHWEST LEE COUNTY

1. Introduction

A series of investigations made over the past 10 years in south Lee and north Collier Counties have revealed the general character of the geology and hydrology of the area. The information contained in this summary originated in reports by the U. S. Geological Survey, in consultant reports to the City of Naples, in reports to various clients by Missimer and Associates, Inc., and in various research papers. All of the bibliographic references used in this summary are given in a list at the end of the report.

2. Geology

Due to the complexity of the shallow geologic section beneath southwest Lee County, there are differing opinions concerning the placement of formational contacts and lateral continuity of various lithic units. The formations penetrated in the upper 700 feet of section are a mixture of carbonate and clastic sediments. The terminology used herein conforms to that given in Missimer and Associates, Inc. (1978a; 1981) and Peck and others (1979) with minor modifications. A generalized geologic column for southwest Lee County is given in Figure 3-1.

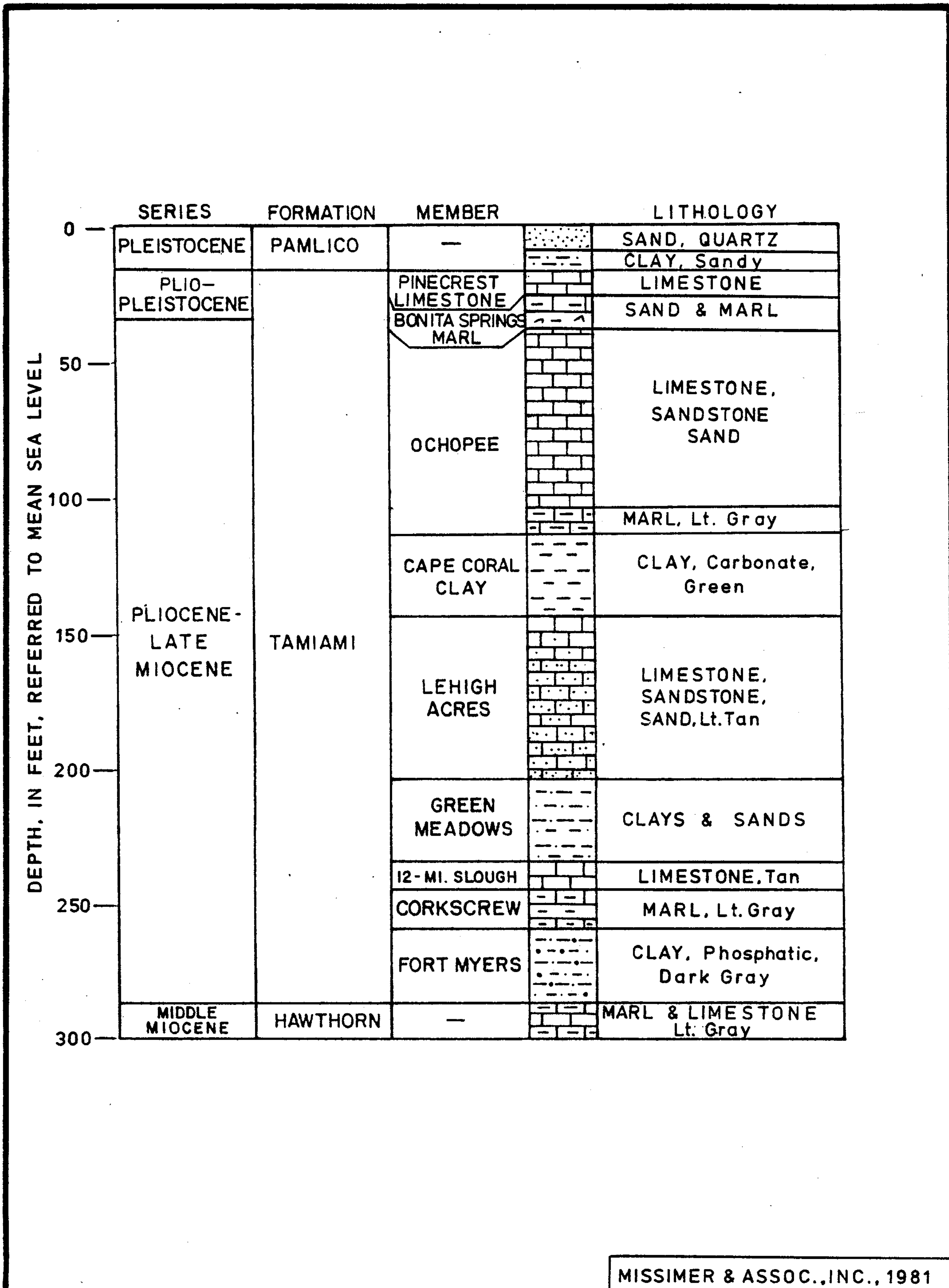

FIGURE 3-1. GENERALIZED GEOLOGY OF SOUTHWEST LEE COUNTY.

Pamlico Sand

The Pamlico Sand is the uppermost and youngest stratigraphic unit encountered. It is a marine terrace deposit of late Pleistocene age. The formation consists predominantly of medium to fine-grain, quartz sand and shell. A crustal, sandy limestone occurs in parts of the Pamlico sequence near land surface. The limestone ranges from 1 to 5 feet in total thickness. The overall thickness of the Pamlico Sand is quite variable, but ranges generally from 5 to 40 feet. Some residual clays and organic detritus are often present in the upper 2 to 5 feet of sand (soil zone).

Tamiami Formation

The Tamiami Formation is a thick sequence of mixed carbonate and clastic sediments which underlies all of south Florida. Based on the present definition, it ranges in age from late Miocene to middle Pliocene (Peck, 1976; Peck and others, 1979). A new definition has been proposed, which will restrict its age to middle and early Pliocene. In most of south Lee County, the Tamiami Formation lies unconformably beneath the Pamlico Sand. Nine or perhaps ten mappable members of the formation have been defined in southwest Lee and Collier County (Figure 3-1). The thickness of the formation ranges from 250 feet to a reported 800 feet in south Lee and north Collier County (Geraghty and

Miller, 1977). Only the upper five members have been sufficiently studied to merit discussion.

The uppermost member of the Tamiami Formation is the Pinecrest Sand or Limestone. This unit was introduced informally by Hunter (1968) to name shelly sands in Monroe, eastern Collier, Glades, and southern Highlands Counties. Meeder (1979) extended the definition to cover time-equivalent Pliocene reefal limestones in Collier and southern Lee Counties.

The Pinecrest lies unconformably beneath the Pamlico Sand. It is characterized by abrupt changes in thickness and lithology. Thickness ranges from 0 to 40 feet in south Lee County. The reefal limestones have a very high permeability, especially where aragonitic shell has been selectively dissolved to form an enhanced secondary porosity.

A sequence of green to gray marl lies beneath the Pinecrest reefs. This unit has been informally termed the Bonita Springs Marl Member by Missimer and Associates, Inc. (1981). The deposit ranges from 0 to 50 feet thick in south Lee County. It consists predominantly of lime mud with various proportions of quartz sand, phosphate, and shell. Vertical permeability of the unit varies with the local geology.

The Ochopee Limestone Member was originally named and described by Mansfield (1939) with modifications by Hunter (1968). It occurs from the base of the Bonita

Springs Marl, where present, to a depth of between 100 and 150 feet below land surface. It has a variable lithology but is predominantly a sandy, light tan limestone. It is often riddled with solution cavities from the microscopic range to several feet in height. The thickness of the Ochopee Limestone ranges from 0 to 70 feet in south Lee County. It thickens and thins because its upper surface has been eroded to a variable degree.

The Cape Coral clay member often underlies the Ochopee Limestone. It is a regional geologic unit, which underlies most of Lee County. The unit tends to pinch out at a location north of Bonita Springs (Missimer and Associates, Inc., 1981). In areas south of the pinch out, the Ochopee Limestone lies directly on the Lehigh Acres Sandstone. The Cape Coral clay is a silica rich clay and lime mud with dolomite rhombs. It has a variable composition with the clastic fraction ranging from 5 to 90 percent. The unit ranges from 0 to 60 feet in thickness in southwest Lee County.

A rather inhomogeneous unit, the Lehigh Acres Sandstone Member, lies beneath the Cape Coral clay. Much confusion has occurred regarding this unit because it often lies directly on the Ochopee Limestone in south Lee County. This unit ranges from 5 to 50 feet in thickness. In parts of south Lee County, it contains three separate units: an upper sandy limestone, an interbedded sequence of shell and quartz sand, and a sequence of thin sandstone and quartz sand beds.

The lower Tamiami Formation members and the upper part of the Hawthorn Formation have been explored to a minor degree at two nearby locations, at the Pelican Bay site to the south and in a U. S. Geological Survey well at Bonita Springs. Since none of these units are believed to contain any usable quality water, they are not considered any further in this summary.

3. Aquifer Descriptions

Water-Table Aquifer

The water-table aquifer is unconfined or open directly to atmospheric pressure (Figure 3-2). It is recharged directly by rainfall and it responds rapidly to any climatic changes or alteration of drainage. A description of the aquifer in south Lee County is given by Missimer and Boggess (1974).

The Pamlico Sand and permeable sediments in the Pinecrest Limestone Member of the Tamiami Formation form the water-table aquifer. Clays or marls within either the Caloosahatchee Marl or the upper part of the Tamiami Formation form the base of the aquifer. The water-table aquifer ranges in thickness from 10 to 40 feet.

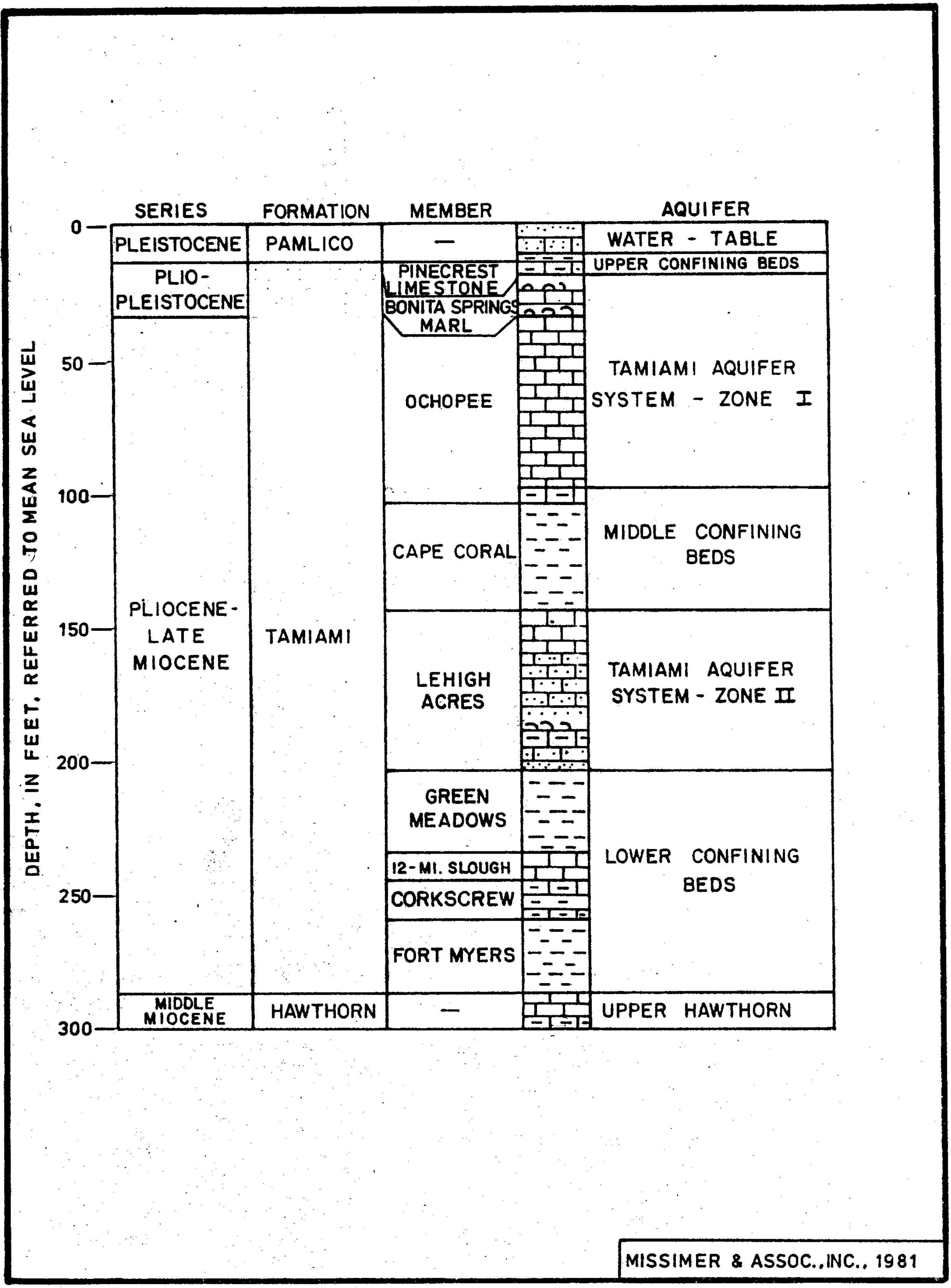

FIGURE 3-2. STRATIGRAPHIC POSITIONS OF THE SHALLOW AQUIFERS BENEATH WESTERN COLLIER COUNTY.

Tamiami Aquifer System-Zone I

The principal water-bearing unit in southwest Lee County is Tamiami Aquifer System-Zone I. There has been considerable confusion with regard to definition of this aquifer. It has been termed the shallow aquifer and has been described as being unconfined by Sherwood and Klein (1961), McCoy (1972), and Klein (1972). It has also been termed the Coastal Ridge Aquifer with the implication that it is limited in areal extent to the Naples area (Black, Crow, and Eidsness, Inc., 1970). These early assumptions and definitions are now known to be conceptually in error.

Zone I is either a semi-unconfined or semi-confined aquifer depending on the degree of confinement provided by clays within the Caloosahatchee Marl or upper Tamiami Formation. The aquifer underlies all of Collier County as well as parts of Lee, Hendry, Monroe, and Dade Counties. It occurs in the Ochopee Limestone Member and the Lehigh Acres Sandstone Member of the Tamiami Formation, which is a regional stratigraphic unit. The clay or marl beds, which overlie the aquifer, vary considerably in thickness in southwest Lee County. Therefore, the degree of confinement provided by these beds varies accordingly. In general, the aquifer is best confined in the Bonita Springs area, and the degree of confinement lessens to the southeast and to the northeast. This is caused by the presence of the Bonita Springs Marl.

The base of Tamiami-Zone I is formed by low permeability clays within the Green Meadows clay unit. These clays form a very effective confining layer between Zone I and Tamiami-Zone III below it. Tamiami-Zone I is roughly 85 feet thick along the coast (Missimer and Associates, 1979c), and thickens to 110 feet about 6 miles to the east (Missimer and Associates, 1978b).

Tamiami Aquifer System-Zone II

Tamiami Aquifer System-Zone II is a minor aquifer in southwest Lee County and is equivalent to the "Sandstone Aquifer". It lies within the Lehigh Acres Sandstone Member of the Tamiami Formation north of the area where the Cape Coral clay pinches out. The aquifer is classified as semi-confined, but is extremely well-confined compared to Zone I. Dense clays and marls lying in the Buckingham Limestone and the Cape Coral clay members of the Tamiami Formation form the top of the aquifer and various beds of lime mud and marl in the lower Tamiami Formation members form the lower confining unit. The aquifer is less than 20 feet thick in most areas and is usually in a sequence of interbedded sandstones and marls. Zone II is recharged only by downward movement of water from overlying aquifers caused by vertical pressure differences. The top of the aquifer lies between 200 and 270 feet below land surface in south Lee County, when present as a unique aquifer.

Where it merges with Zone I, the entire thickness of the aquifer is considered to be Zone I only.

4. Aquifer Hydraulic Properties

Water-Table Aquifer

The hydraulic characteristics of the water-table aquifer vary depending on the thickness of the aquifer and the lithology of the strata within it. Very few pumping tests have been performed on the aquifer. However, the variation in transmissivity can be estimated from both the available test data and from yields of wells tapping the aquifer.

An aquifer performance test was conducted on the aquifer at a location adjacent to the coast in the Pelican Bay development (Missimer and Associates, 1979c). At this location, the aquifer consisted of 30 feet of quartz sand with minor beds of organic material. A transmissivity of 30,000 gpd/ft was calculated at this location. Another aquifer performance test was conducted on a thin surficial limestone unit at Spring Creek Village. This test yielded a transmissivity of only 8,600 gpd/ft.

In many areas of southwest Lee County, the water-table aquifer occurs in quartz sand, shell, and some limestone. Numerous high capacity wells with a total depth of 30 to 40 feet occur throughout the area. Transmissivities of the aquifer have been measured up to 3,000,000 gpd/ft (Missimer and Associates, Inc., 1980).

In summary, the water-table aquifer has an extremely variable transmissivity which ranges from about 5,000 to 3,000,000 gpd/ft. The specific yield of the aquifer has been measured in only a few localities and probably ranges from 0.01 to 0.35.

Tamiami Aquifer System-Zone I

Ten aquifer tests have been performed on Zone I in the south Lee and north Collier Counties. A map showing the locations of the test sites is given in Figure 3-3 and a listing of aquifer coefficients is given in Table 3-1. In all cases, the aquifer behaves as a semi-confined or leaky type in southwest Lee County. However, further to the north in Lee County and in parts of the Naples area to the south, the aquifer shows delayed yield, which causes it to respond as either a semi-unconfined or unconfined system. The response to pumpage at a given locality is strictly a function of the local geology and more specifically the nature of the confining strata.

Based on the aquifer tests performed in the area, the transmissivity of the aquifer increases from 100,000 gpd/ft at the coast to over 600,000 gpd/ft 7 miles east of the coast. The leakance value of the tests range from 3.8 to 1×10^{-3} gpd/ft^3. Storage coefficient values range

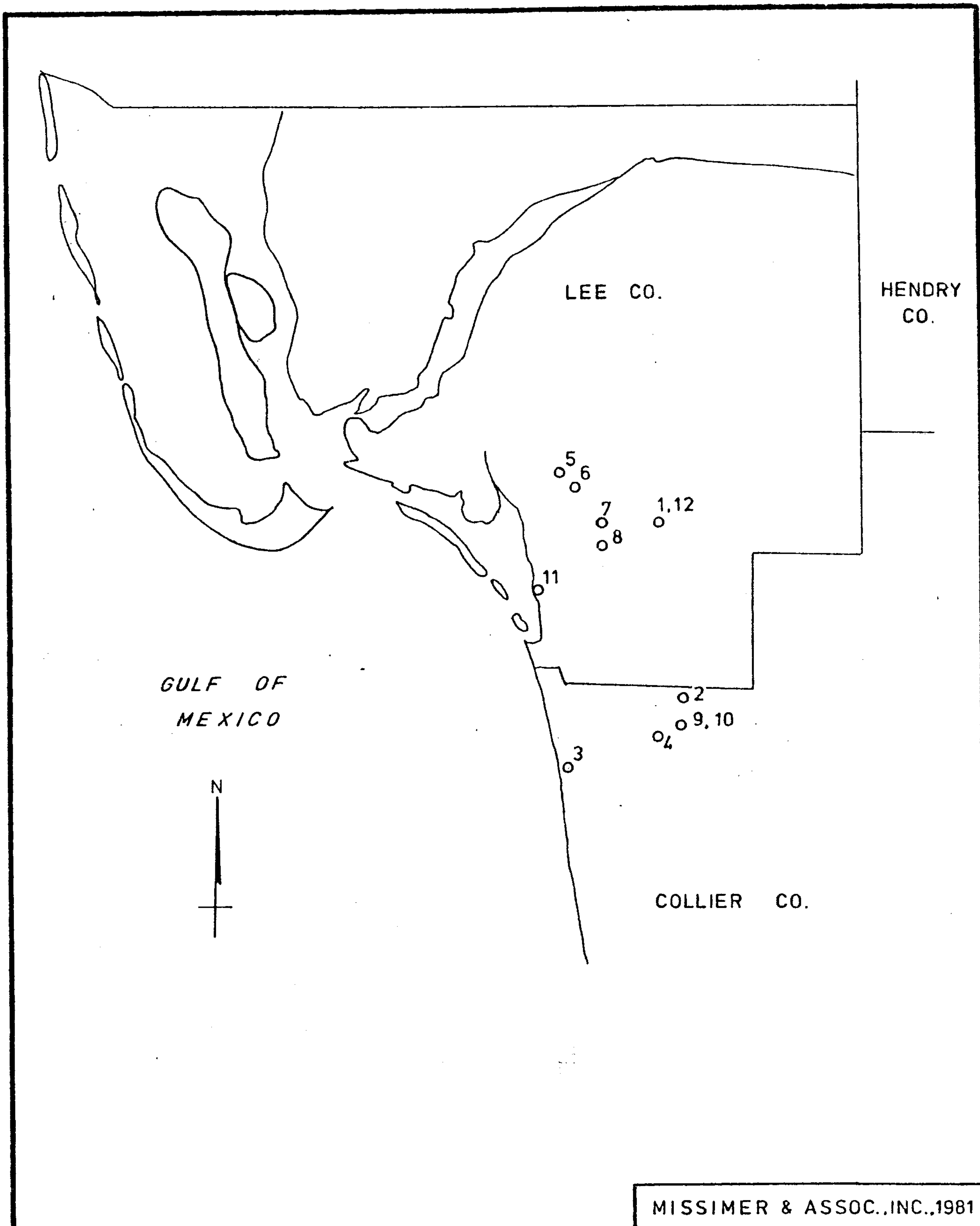

FIGURE 3-3. MAP SHOWING LOCATIONS OF SELECTED AQUIFER TESTS IN LEE AND COLLIER COUNTIES.

TABLE 3-1. CALCULATED AQUIFER COEFFICIENTS AT LOCATIONS IN SOUTH LEE AND NORTH COLLIER COUNTIES.

Aquifer	Test Location	T gpd/ft	S	k'/b' gpd/ft³
Tamiami-Zone I	Lee County Wellfield (1)	200,000	0.17	--
Tamiami-Zone I	Gulf Coast Farms (2)	220,000	2×10^{-4}	1×10^{-3}
Tamiami-Zone I	Pelican Bay Site (3)	100,000	2×10^{-4}	2×10^{-2}
Tamiami-Zone I	Pelican Bay Wellfield (4)	180,000	4×10^{-5}	2×10^{-2}
Tamiami-Zone I	San Carlos Wellfield (5)	175,000	0.23	--
Tamiami-Zone I	San Carlos Wellfield(new) (6)	197,000	0.20	1×10^{-2}
Tamiami-Zone I	San Carlos Wellfield(south) (7)	140,000	--	3.8
Tamiami-Zone I	San Carlos Wellfield(south) (8)	327,000	--	1.2
Tamiami-Zone I	Quail Creek Wellfield (9)	600,000	2×10^{-4}	1×10^{-3}
Water-Table	Quail Creek Wellfield(10)	1,000,000	0.2	--
Water-Table	Spring Creek Wellfield(11)	8,600	7.7×10^{-3}	3.1×10^{-2}
Tamiami-Zone II	Lee County Wellfield(12)	20,000	3×10^{-5}	4.7×10^{-4}

from 0.23 to 4×10^{-5}.

5. Water Levels

Water-Table Aquifer

The water level in an unconfined aquifer is a direct indication of the volume of water in storage within the aquifer. The position of the water table fluctuates in response to recharge and discharge from the aquifer. During the wet season, June to October, rainfall is abundant and the water table is high, but during the dry season, when little rain falls, the water table declines to a position well below land surface.

Under natural conditions, the normal annual range in water table fluctuation would be about 3 feet. Most of the water lost from storage is caused by evapotranspiration. In southwest Lee County, the natural system has been disturbed to some degree by the construction of ditches, canals, and dikes associated with agricultural production and drainage enhancement. The water table adjacent to the deeper canals and streams such as the Imperial River is depressed due to subsurface drainage. The ditches also cause a depressed water table condition, but to a lesser degree.

Normally the altitude of the water table is a reflection of land surface altitude and where the land surface is high, the water table is correspondingly high. Under natural conditions, the water in the aquifer moves westward toward the coast from high to low areas. However, the flow of water through the aquifer in southwest Lee County is toward local discharge points, canals, ditches, sloughs, and streams and is controlled by local topography.

Tamiami Aquifer System-Zone I

Water levels in Tamiami Aquifer System-Zone I correspond to a certain extent to the water table. In nearly all cases, the Zone I potentiometric surface lies at a lower altitude than the water table. This is indicative of a downward directed recharge gradient. Where the water table has been artifically lowered in an extreme manner, the reverse occurs as in the case of the spring in the Cocohatchee Canal in Collier County.

The regional flow direction in the aquifer is from northeast to southwest or sometimes directly east to west. However, local pumping of the aquifer has significantly distorted the potentiometric surface and the flow direction. The potentiometric surface of Zone I in southwest Lee County sometimes drops below mean sea level during the dry season in centers of pumpage. Where pumpage is heavy, flow in the aquifer is radial into the depressed areas.

6. Water Quality

Water-Table Aquifer

The quality of water within the water-table aquifer is known from samples collected by the U. S. Geological Survey from privately owned wells and observation wells. Total dissolved solids concentration in the water ranges from 100 to 1,000 mg/l. Most of the dissolved material in the water is chloride, bicarbonate, calcium, magnesium, and carbon dioxide. The dissolved chloride concentration is generally less than 40 mg/l. In most areas, the water meets potable standards with the exception of color, which is high, and the dissolved iron concentration, which is usually above 1 mg/l.

In areas adjacent to tidal waters, the salinity of the water is significantly increased, based on the balance of heads and the relative density of the mixing waters.

Tamiami Aquifer System-Zone I

More than 30 wells tapping Tamiami Aquifer System-Zone I have been sampled by the U. S. Geological Survey in north Collier County in the vicinity of S.R. 846 (McCoy, 1962) and in the Bonita Springs area (unpublished). Also, about 25 wells have been sampled by Missimer and Associates, Inc. during preliminary assessments of water use in the area (Missimer and Associates, Inc., 1978b).

IV. INVESTIGATION OF THE BONITA BAY DEVELOPMENT SITE

1. Introduction

A study of the existing information in the general geographic locality of Bonita Bay showed that an intensive testing program would be necessary to safely develop a ground-water supply. In order to assess the yield characteristics and water quality of the usable aquifers, it was necessary to construct many observation and test-production wells. Aquifer performance tests were also conducted to analyze the quantity of water available for use. This section of the report provides a description of the program.

2. Test Drilling and Well Construction

A comprehensive test drilling and observation well construction program was conducted on the Bonita Bay site. Twenty-three observation wells were constructed into the three (3) different aquifers located beneath the site. These wells were utilized to obtain geologic, water quality, and water level data. Three test-production wells were constructed, one each into the water-table aquifer, Tamaimi Aquifer System-Zone I, and Hawthorn Aquifer System-Zone I. The locations of the wells are shown in Figure 4-1 and the construction details are given in Table 4-1.

Dissolved chloride concentrations range from 14 to 1000 mg/l depending on well location and depth. Areas adjacent to the Imperial River or the Cocohatchee Canal have significantly higher dissolved chloride concentrations than locations to the north or east. Potable water exists in the aquifer 2 to 3 miles east of U. S. 41. The color of water from the aquifer is clean and the dissolved iron concentration generally ranges from 0.01 to 0.1 mg/l. Dissolved solids concentrations range from 400 to 1200 mg/l in the area.

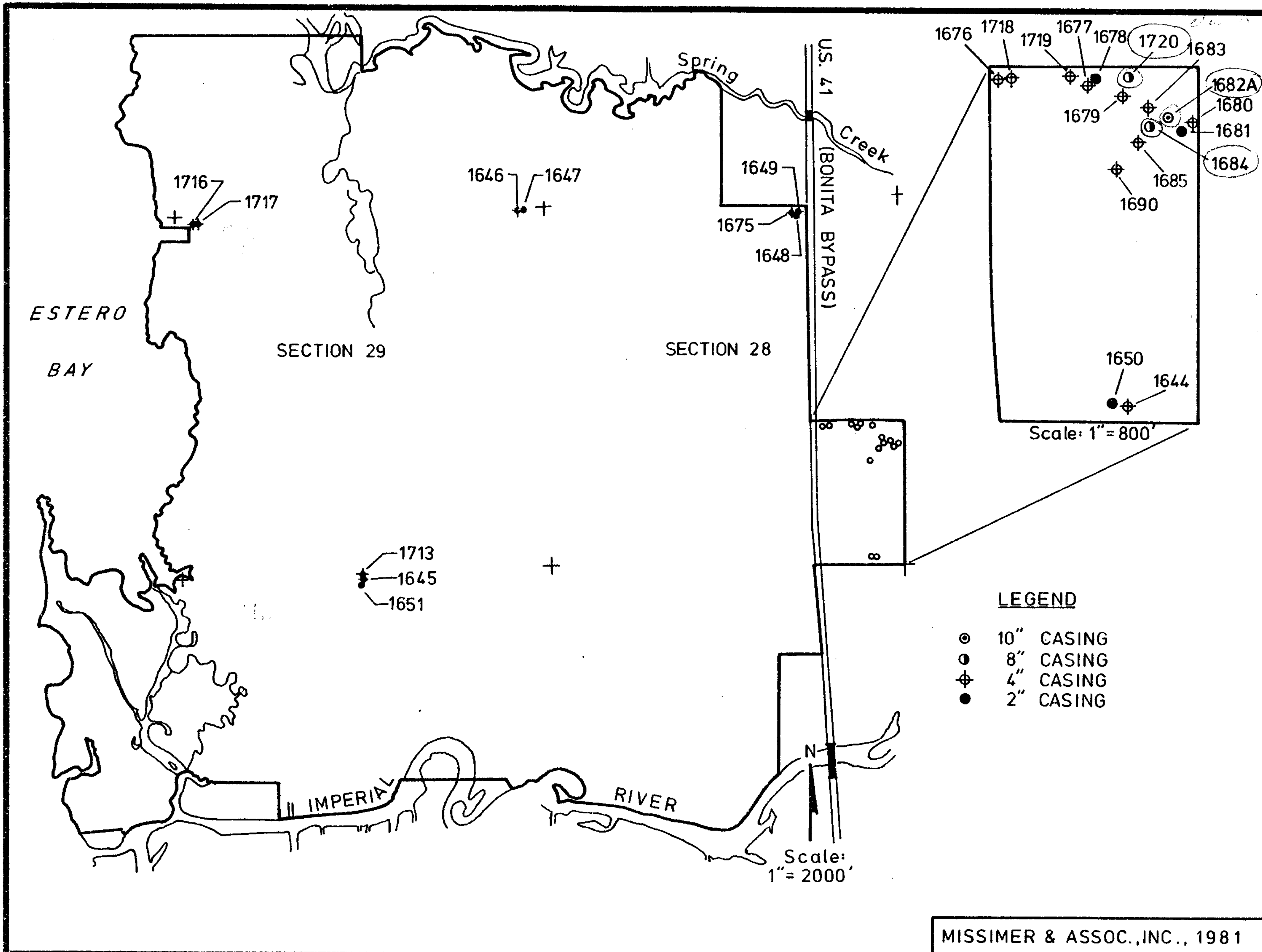

FIGURE 4-1. LOCATIONS OF TEST-PRODUCTION AND OBSERVATION WELLS CONSTRUCTED ON THE BONITA BAY SITE.

TABLE 4-1. LIST OF OBSERVATION AND TEST-PRODUCTION WELLS WITH TOTAL DEPTH, CASING DEPTH AND DIAMETER, SCREENED INTERVAL OR OPEN-HOLE, AND AQUIFER TAPPED

Well No.	Total Depth(ft)	Casing Depth(ft)	Casing Diameter(in)	Screened Interval(ft) or Open-Hole	Aquifer
Observation Wells:					
L-M-1644	86	75	4	Open-Hole	Tamiami-Zone I
L-M-1645	104	97	4	Open-Hole	Tamiami-Zone I
L-M-1646	128	120	4	Open-Hole	Tamiami-Zone I
L-M-1647	23	18	2	18 - 23	Water-Table
L-M-1648	23	18	2	18 - 23	Water-Table
L-M-1649	100	78	4	Open-Hole	Tamiami-Zone I
L-M-1650	25	20	2	20 - 25	Water-Table
L-M-1651	24	19	2	19 - 24	Water-Table
L-M-1675	238	220	4	Open-Hole	Hawthorn-Zone I
L-M-1676	120	67	4	Open-Hole	Tamiami-Zone I
L-M-1677	125	70	4	Open-Hole	Tamiami-Zone I
L-M-1678	23	18	2	18 - 23	Water-Table
L-M-1679	120	70	4	Open-Hole	Tamiami-Zone I
L-M-1680	127	74	4	Open-Hole	Tamiami-Zone I
L-M-1681	27	22	2	22 - 27	Water-Table
L-M-1683	25	21	4	Open-Hole	Water-Table
L-M-1685	30	26	4	Open-Hole	Water-Table
L-M-1690	32	26	4	Open-Hole	Water-Table
L-M-1713	255	230	4	Open-Hole	Hawthorn-Zone I
L-M-1716	215	201	4	Open-Hole	Hawthorn-Zone I
L-M-1717	100	87	4	Open-Hole	Tamiami-Zone I
L-M-1718	238	213	4	Open-Hole	Hawthorn-Zone I
L-M-1719	248	228	4	Open-Hole	Hawthorn-Zone I
Production Wells:					
L-M-1682A	120	74	10	Open-Hole	Tamiami-Zone I
L-M-1684	33	19	8	Open-Hole	Water-Table
L-M-1720	255	235	8	Open-Hole	Hawthorn-Zone I

The water-table aquifer test production well, L-M-1684, was drilled to a total depth of about 33 feet (Figure 4-2). An approximate 12-inch diameter borehole was drilled to a depth of about 21 feet and 20 feet of 8-inch diameter, schedule 40, PVC casing was installed. The casing was presure grouted with neat cement, filling the annulus from the base of the casing to land surface. Care was taken to properly seat the casing into the coralline limestone part of the aquifer. A nominal 8-inch diameter borehole was drilled with compressed air below the casing to a depth of about 33 feet. The borehole remained open during pump testing, but may require screening in the future.

The Tamiami Aquifer System-Zone I test production well, L-M-1682, was drilled to a total depth of about 120 feet below surface (Figure 4-2). A nominal 15-inch borehole was drilled by the hydraulic rotary mud method to a depth of about 75 feet. A 74-foot string of 10-inch diameter, schedule 40, PVC casing was installed in the borehole. Centralizers were attached to the exterior wall of the casing to keep it centered in the borehole. The annulus was pressure-grouted from the base of the casing to land surface with neat cement. A nominal 10-inch diameter borehole was drilled below the casing by the hydraulic rotary-air method to a depth of about 120 feet. The well was then developed with compressed air to remove debris from the borehole.

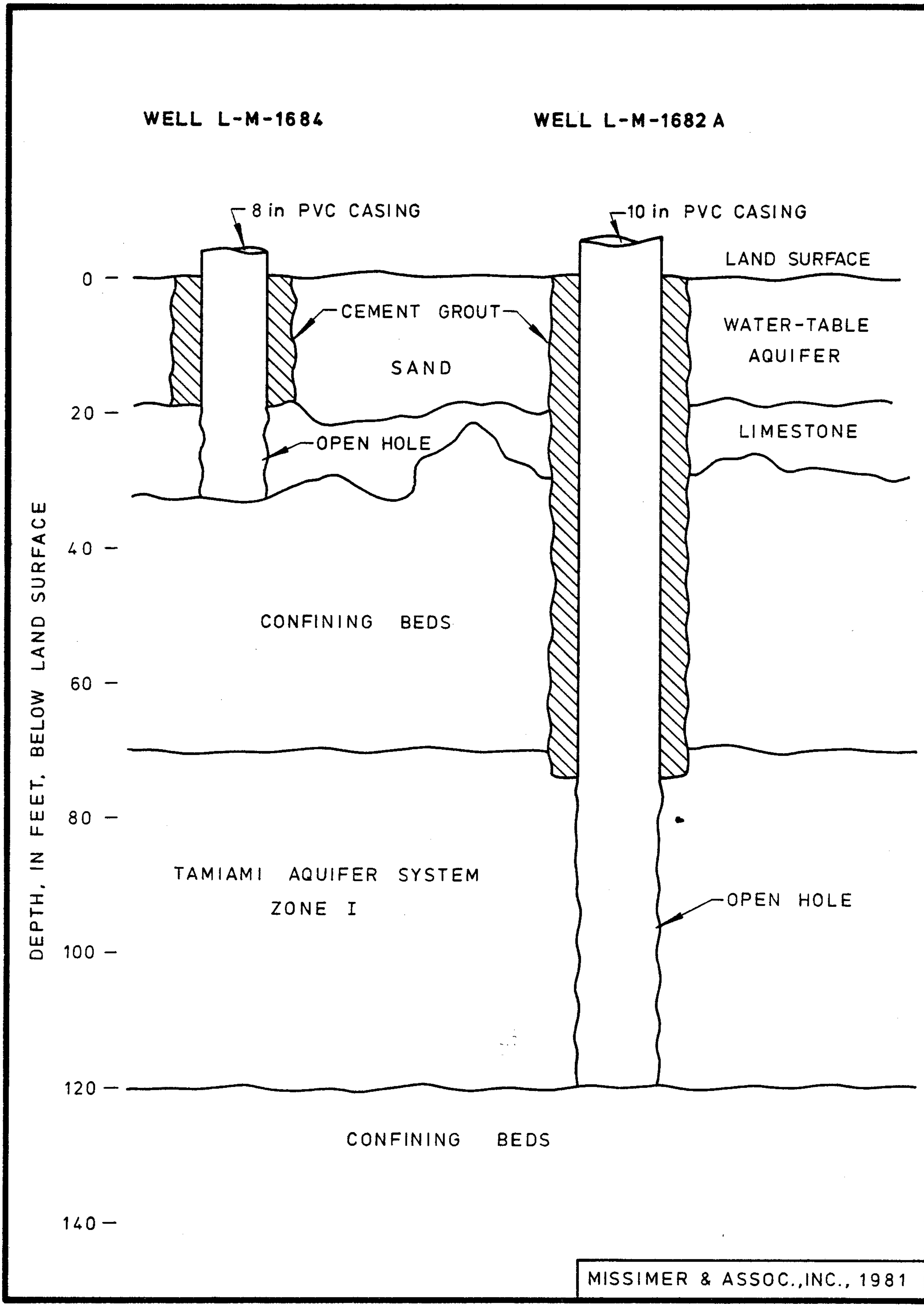

FIGURE 4-2. CONSTRUCTION DETAILS OF WATER-TABLE AQUIFER AND TAMIAMI AQUIFER SYSTEM - ZONE I TEST PRODUCTION WELLS.

The Hawthorn Aquifer System-Zone I test-production well, L-M-1720, was drilled to a total depth of about 255 feet below surface (Figure 4-3). A nominal 12-inch diameter borehole was drilled to a depth of about 236 feet by the hydraulic rotary-mud method. Care was taken to maintain a sufficient mud density in order to prevent flow. A string of 235 feet of 8-inch diameter, schedule 40 PVC casing was installed in the borehole. Centralizers were utilized to keep the casing in the proper position within the borehole. The cement grout dried for a period of 24 hours before drilling proceeded. A nominal 8-inch diameter borehole was drilled below the casing by the air-rotary method to a depth of 255 feet.

Observation wells were constructed at various locations on the site. All of these wells were constructed by the hydraulic rotary-mud method and each well was properly developed with compressed air to clean the borehole of mud and cuttings.

3. Aquifer Tests

Three aquifer tests were performed on the site, one each on the water-table aquifer, Tamiami Aquifer System-Zone I, and Hawthorn Aquifer System-Zone I.

<u>Water-Table Aquifer</u>

A step-drawdown test was performed on well L-M-1684

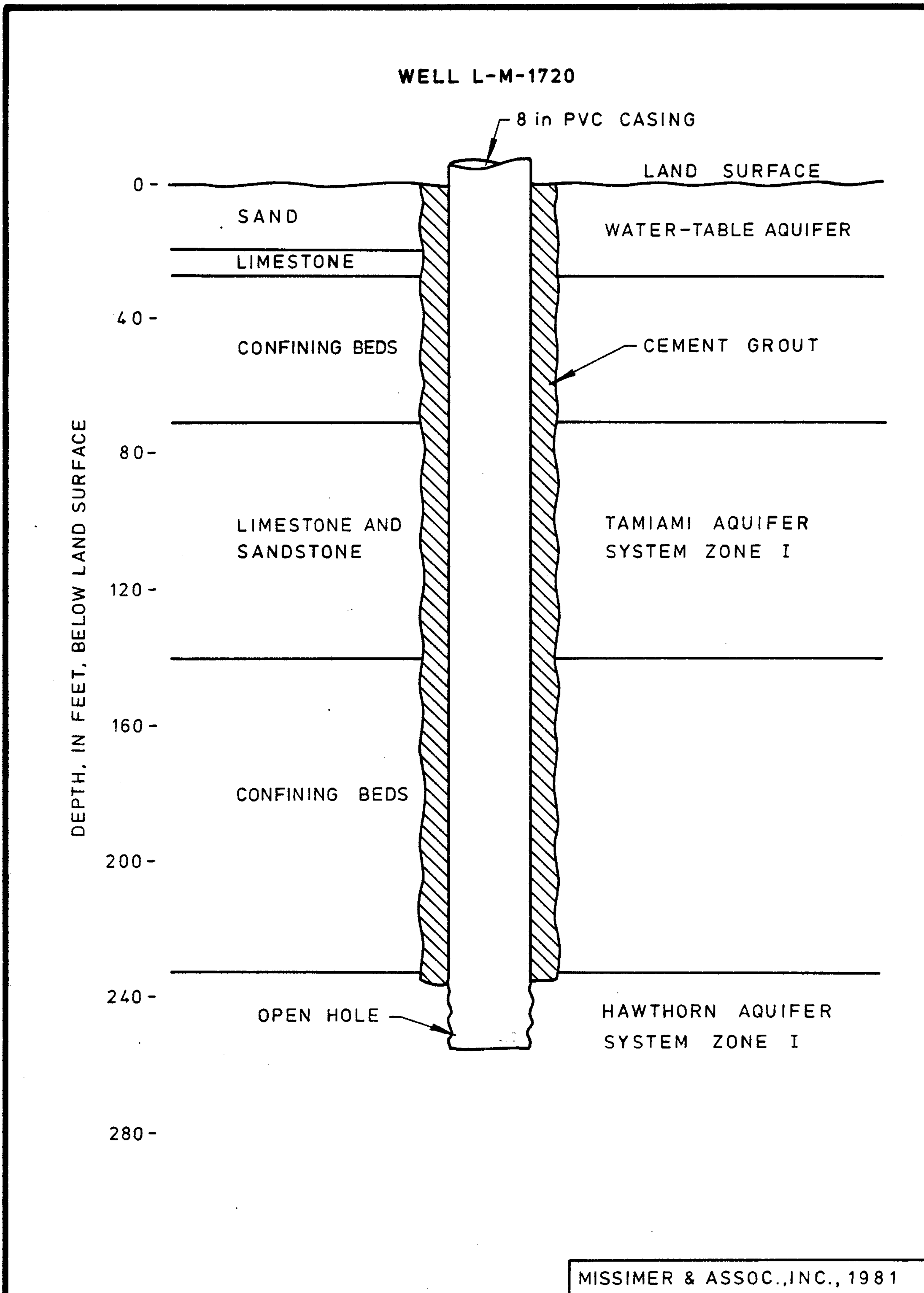

FIGURE 4.-3. CONSTRUCTION DETAILS OF THE HAWTHORN AQUIFER SYSTEM-ZONE I TEST PRODUCTION WELL.

several days prior to beginning the primary aquifer test on the water-table aquifer. A series of five steps were completed at different pumping rates for a period of about 60 minutes each. The progression of pumping rates used were: 150 gpm, 250 gpm, 350 gpm, 450 gpm, and 520 gpm.

The water-table aquifer performance test was conducted on June 23, 1981. Well L-M-1684 was pumped continuously at a rate of 340 gpm for a period of 9 hours, after which a heavy rainfall caused termination of the test. The well was pumped with an extended-shaft, electric, turbine pump powered by a generator. The pump bowls were set at about 18 feet below land surface. Water discharged by the pump was piped 400 feet to the south into a low-lying slough, which conveyed it further south and east. Pump discharge was monitored at the end of the discharge pipe by utilizing a 4-inch orifice plate mounted at the end of a 6-inch diameter pipe with a clear plastic manometer tube extending above the discharge line.

Drawdowns of the water table were measured in the production well, L-M-1684, by electric tape. Drawdowns in four observation wells, L-M-1683, L-M-1681, L-M-1685, and L-M-1690, were continously recorded by use of Steven's Type-F recorders and drawdowns in observation wells L-M-1678, and L-M-1682A were tape-measured. All of the wells described above tap the water-table aquifer with the exception of well L-M-1682A, which taps Tamiami Aquifer System-Zone I.

This aquifer performance test was terminated sooner than planned because of heavy rainfall. The collection of water level recovery data was not possible due to the same reason. We did not repeat the test because sufficient data were collected to perform an accurate analysis of the aquifer.

During the aquifer test, water quality was collected at various intervals. A complete chemical analysis of the water was made from a sample collected at the beginning of the test and the dissolved chloride concentration was measured.

A schematic diagram showing the water-table aquifer test set-up is given in Figure 4-4.

Tamiami Aquifer System-Zone I Test

A step-drawdown test was completed on test-production well L-M-1682A to evaluate well efficiency (see Section 5-3) and to set the final pumping rate for the primary aquifer test. A series of steps were run at pumping rates of 600 gpm, 700 gpm, 800 gpm, and 900 gpm. Each step was conducted to an approximate equilibrium state which occurred between 30 and 55 minutes after a new discharge rate was established. Only 4 steps were completed because the pump was not capable of maintaining a higher discharge rate.

An attempt was made to conduct the Tamiami-Zone I aquifer test on June 9 and 10. After 1200 minutes of continuous pumping at a rate of 440 minutes, pump failure occurred. The aquifer performance test was restarted as of June 15 and ran for the full 72-hour period. The second test was conducted

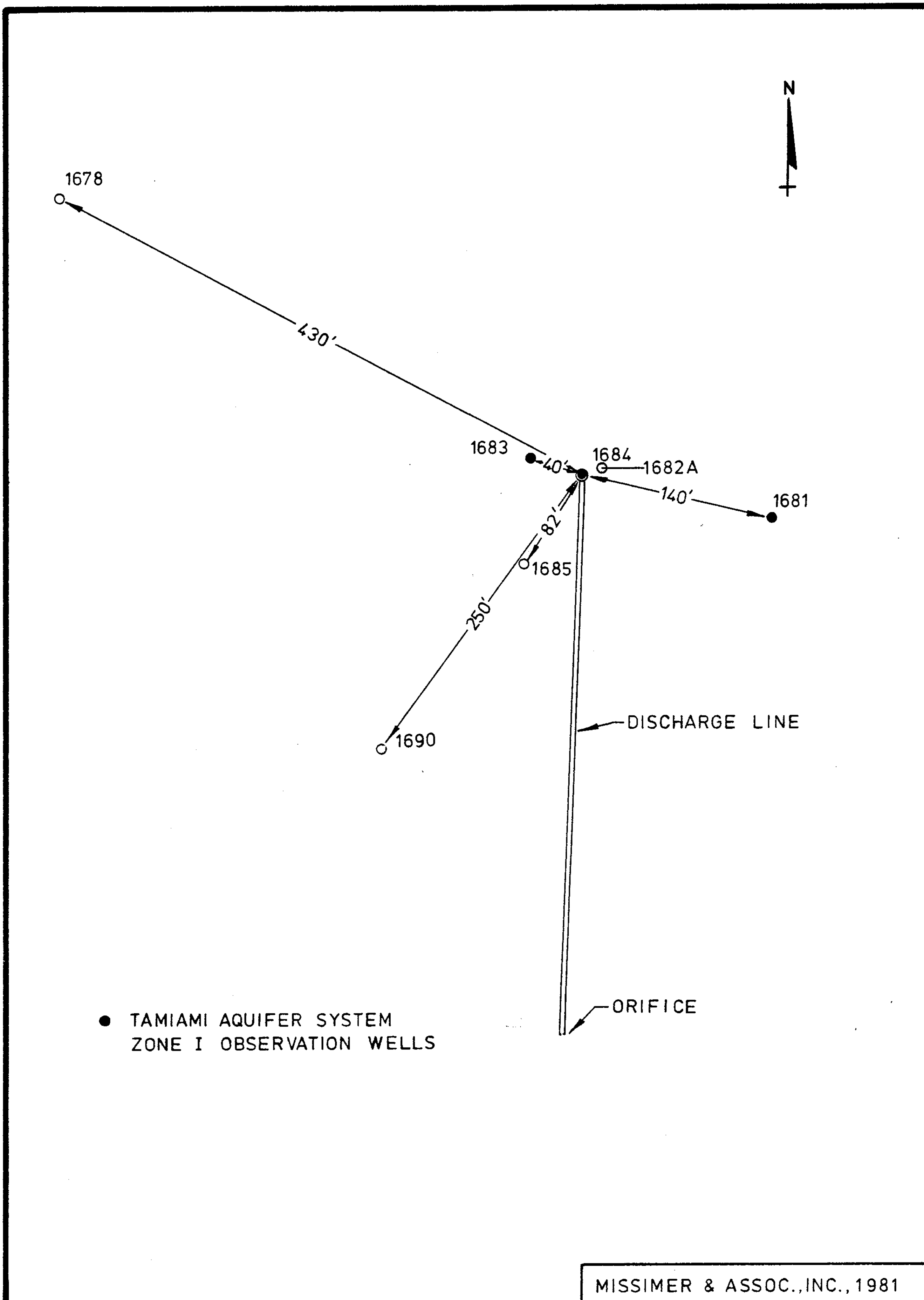

FIGURE 4-4. SCHEMATIC DIAGRAM OF THE WATER-TABLE AQUIFER TEST SET-UP.

with a pumping rate of 576 gpm. An extended shaft, turbine pump was used during the test. The pump bowls were set at approximately 50 feet below surface. Water discharged from the production well was piped 300 feet to the south into a low-lying slough which conveyed it to the east away from the test site. Pump discharge was monitored by use of a 6-inch orifice plate mounted at the end of an 8-inch diameter pipe with a clear plastic manometer tube extending above the discharge line.

Drawdowns of the Tamiami-Zone I potentiometric surface were measured in the production well by electric tape. Water level changes were measured in 6 Zone I observation wells and in 3 water-table aquifer observation wells. Wells L-M-1680, L-M-1679, L-M-1677 and L-M-1676 were monitored by use of Stevens Type-F water level recorders which were manually checked at each significant time interval. Zone I observation wells L-M-1644 and L-M-1649 were tape-measured along with the 3 water-table aquifer observation wells, L-M-1684, L-M-1683, and L-M-1681. Barometric pressure fluctuations were measured by use of a recording micro-barograph.

Upon termination of pumping, recovery data were collected from the test-production well and from observation wells L-M-1680, L-M-1679, and L-M-1677. Data collection was discontinued after 120 minutes.

A schematic diagram of the Tamiami Aquifer System-Zone I aquifer test set-up is given in Figure 4-5.

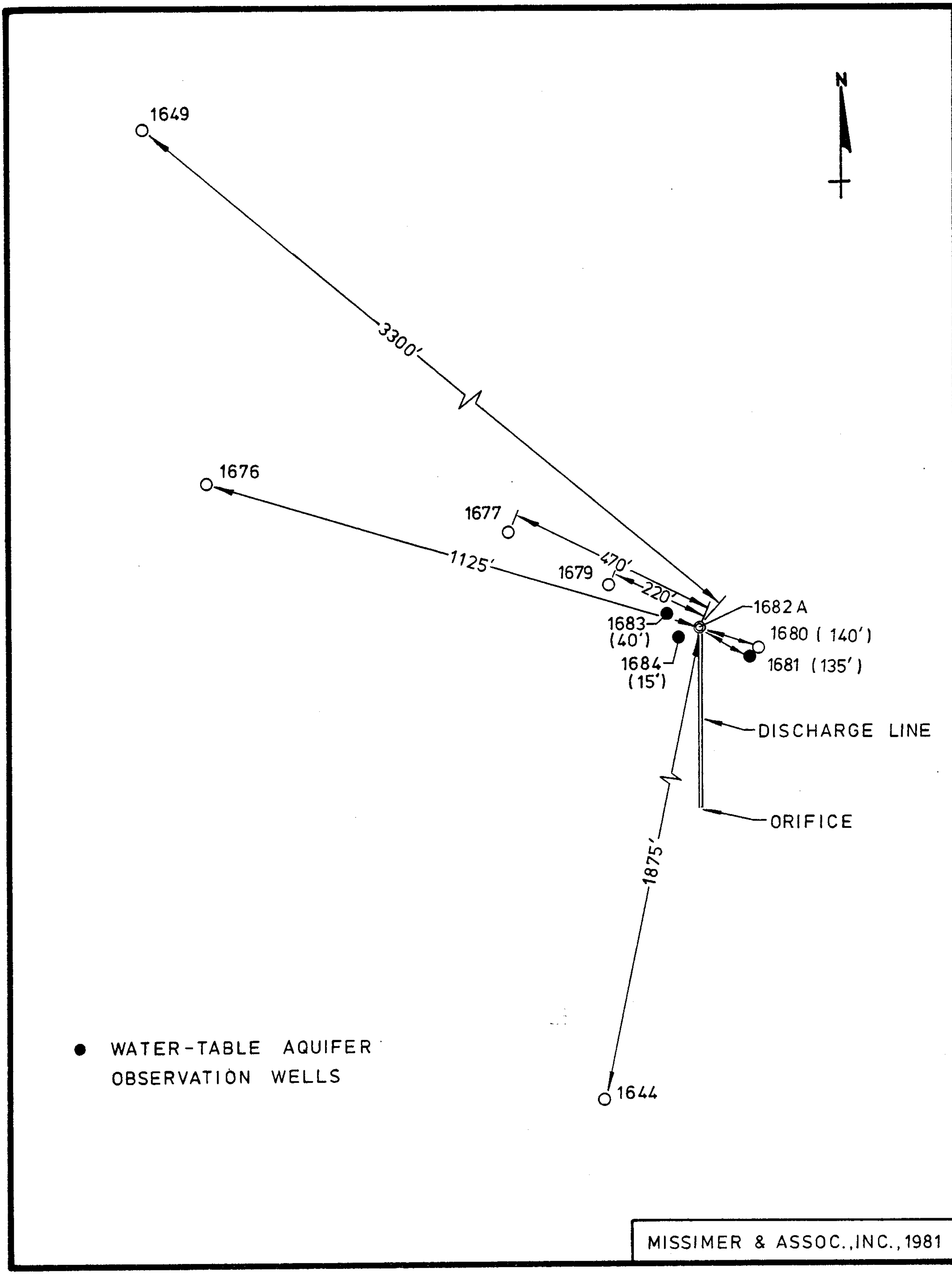

FIGURE 4-5. SCHEMATIC DIAGRAM OF THE TAMIAMI AQUIFER SYSTEM-ZONE I TEST SET-UP.

Hawthorn Aquifer System-Zone I

A step-drawdown test was performed on test-production well L-M-1720 to evaluate well efficiency and to set the final pumping rate for the primary aquifer performance test. The pump discharge was varied progressively through four different rates, 380 gpm, 446 gpm, 508 gpm, and 560 gpm. Each step was conducted to an equilibrium state, which occurred after 45 to 75 minutes of pumping at a unique rate.

The aquifer performance test was conducted from August 13 to 14. Well L-M-1720 was pumped at a rate of 400 gpm for a continuous period of nearly 28 hours. Pumping was terminated due to the departure of drawdown data above the Theis Curve, which is indicative of a subsurface boundary condition. An extended shaft, turbine pump was used during the test. The pump bowls were set at about 20 feet below land surface. Water discharged from the production well was piped 200 feet to the east into a low-lying Melaleuca stand. Pump discharge was monitored at the terminus of the discharge line by use of a 4-inch orifice plate mounted at the end of a 6-inch pipe with a clear plastic manometer tube extending above the discharge line.

Drawdowns of the Hawthorn-Zone I potentiometric surface were measured in the production well by electric tape. Water level changes were measured in 3 Hawthorn-Zone I observation wells by use of Stevens Type-F water level recorders, which were manually checked at each critical time interval. At each observation well, L-M-1719, L-M-1718, and L-M-1675, platforms had to be constructed to a height of roughly 15 feet above land surface because the potentiometric surface occurred at 12 feet above land surface. Barometric pressure fluctuations were measured by use of a recording microbarograph.

Upon termination of pumping, recovery data were collected from the production well and from observation wells L-M-1719 and L-M-1718. Collection of data was discontinued after 90 minutes of recovery.

A schematic diagram showing the Hawthorn Aquifer System-Zone I aquifer test set-up is given in Figure 4-6.

4. Well Inventory and Water Use Assessment

A field inventory of existing wells was conducted in the vicinity of the Bonita Bay Development in order to assess both water quality and water use. Most of the wells located tap Tamiami Aquifer System-Zone I and a lower percentage tap the water-table aquifer. Well construction details were obtained from owners and water samples were collected to measure the water quality. The information collected from the wells is given in Table 4-2 and locations are given in Figure 4-7.

Most of the wells are small diameter and used for lawn irrigation. Although the area is served by the Bonita Springs

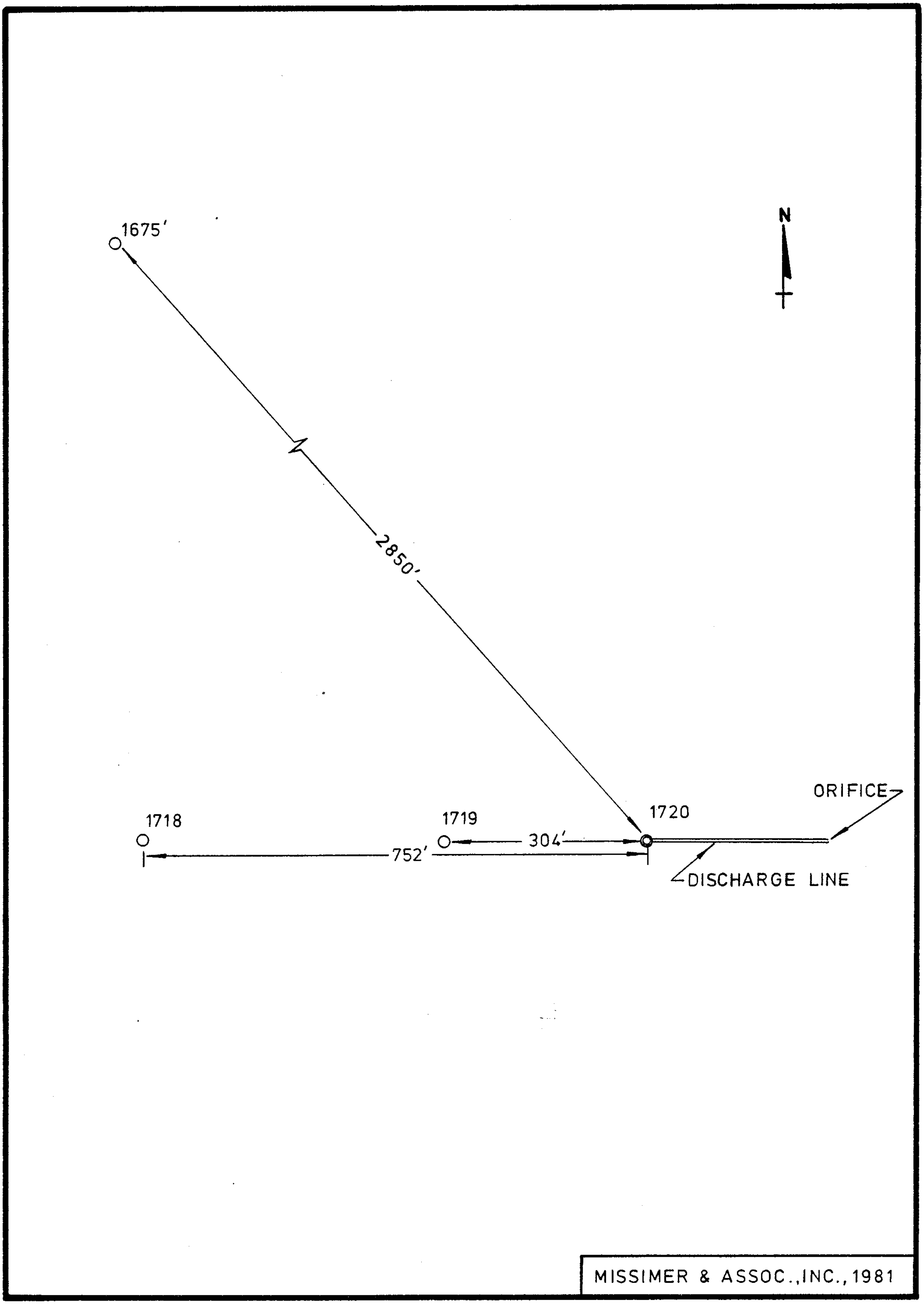

FIGURE 4-6. SCHEMATIC DIAGRAM OF THE HAWTHORN AQUIFER SYSTEM-ZONE I TEST SET-UP.

TABLE 4-2. LIST OF WELLS LOCATED NEAR THE PROJECT SITE WITH CONSTRUCTION DETAILS AND WATER QUALITY.

Well No.	Total Depth(ft)	Casing Depth(ft)	Casing Diameter(in)	Use	Aquifer	Dissolved Chlorides(mg/l)
L-M-469	90	80	2	Irrigation	Tamiami-Zone I	210
L-M-638	345	--	6	Test	--	--
L-M-689	75	--	4	Dom.,Stock,Irr.	Tamiami-Zone I	--
L-M-690	450	--	4	Dom.,Stock	--	--
L-M-691	250	--	4	Stock	Tamiami-Zone I	--
L-M-692	75	--	4	Stock	Tamiami-Zone I	--
L-M-695	54	21.5	3	Dom.	Tamiami-Zone I	--
L-M-897	115	70	4	Irrigation	Tamiami-Zone I	270
L-M-1637	33	28	4	Observation	Water-Table	30
L-M-1638	88	84	4	Observation	Tamiami-Zone II	140
L-M-1639	37	31	4	Observation	Water-Table	34
L-M-1640	35	30	4	Observation	Water-Table	18
L-M-1641	28	23	4	Observation	Water-Table	18
L-M-1642	26	21	4	Observation	Water-Table	18
L-M-1643	38	28	8	Test	Water-Table	18
L-M-1652	112	92	4	Test	Tamiami-Zone II	140
L-M-1653	330	113	6	Irrigation	Hawthorn-Zone I	1,420
L-M-1655	91	--	2	Irrigation	Tamiami-Zone I	1,390
L-M-1656	56	--	2	Irrigation	Tamiami-Zone I	1,340
L-M-1657	20	--	1-1/4	Irrigation	Water-Table	Saline
L-M-1658	35	--	2	Irrigation	Water-Table	120
L-M-1659	35-40	--	2	Irrigation	Water-Table	30
L-M-1660	15-20	--	2	Irrigation	Water-Table	40
L-M-1661	85	--	2	Irrigation	Tamiami-Zone I	Saline
L-M-1662	125	--	2	Irrigation	Tamiami-Zone I	Saline
L-M-1663	--	--	2	Irrigation	Tamiami-Zone I	3,040
L-M-1664	--	--	--	Irrigation	Tamiami-Zone I	1,280
L-M-1665	90(?)	--	2	Irrigation	Water-Table	150
L-M-1666	--	--	8	Irrigation	Tamiami-Zone I	1,220
L-M-1667	650+	300	4	Observation	Hawthorn-Zone II	2,650

TABLE 4-2. LIST OF WELLS LOCATED NEAR THE PROJECT SITE WITH CONSTRUCTION DETAILS AND WATER QUALITY - CONTINUED:

Well No.	Total Depth(ft)	Casing Depth(ft)	Casing Diameter(in)	Use	Aquifer	Dissolved Chlorides(mg/l)
L-M-1687	80	63	4	Observation	Tamiami-Zone I	1,110
L-M-1688	70	53	4	Observation	Tamiami-Zone I	130
L-M-1712	--	--	--	Irrigation	--	840
L-M-1732	--	--	2	Observation	Water-Table	40
L-M-1733	--	--	2	Observation	Tamiami-Zone I	306
L-M-1734	47	--	2	Observation	Tamiami-Zone I	620
L-M-1735	--	--	2	Observation	Tamiami-Zone I	264
L-M-1736	--	--	3	Observation	Tamiami-Zone I	360
L-M-1737	--	--	2	Observation	Tamiami-Zone I	208
L-M-1738	--	--	2	Observation	Tamiami-Zone I	386
L-M-1739	65	--	3	Observation	Tamiami-Zone I	328
L-M-1740	68	--	2	Observation	Tamiami-Zone I	264
L-M-1741	--	--	3	Observation	Tamiami-Zone I	124
L-M-1742	--	--	4	Observation	Tamiami-Zone I	220
L-M-1743	69	--	2	Observation	Tamiami-Zone I	124
L-M-1744	--	--	3	Observation	Water-Table	76
L-M-1745	--	--	2	Observation	Tamiami-Zone I(?)	132
L-M-1746	100	--	2	Domestic	Tamiami-Zone I	260
L-M-1747	65	--	2	Irrigation	Tamiami-Zone I	236
L-M-1748	63	--	2	Irrigation	Tamiami-Zone I	300
L-M-1749	--	--	2	Irrigation	Water-Table	20
L-M-1750	--	--	2	Irrigation	Water-Table	22
L-M-1751	65	--	2	Irrigation	Tamiami-Zone I	666
L-M-1752	--	--	2	Domestic	Tamiami-Zone I(?)	180
L-M-1753	--	--	3	Irrigation	Tamiami-Zone I	1,050
L-M-1754	--	--	2	Irrigation	Tamiami-Zone I	940
L-M-1796	65	--	2	Public Supply	Tamiami-Zone I	280
L-M-1798	65	--	2	Public Supply	Tamiami-Zone I	240
L-M-1799	65	--	2	Public Supply	Tamiami-Zone I	240
L-M-1800	65	--	2	Public Supply	Tamiami-Zone I	280
L-M-1801	21	--	2	Irrigation	Water-Table	49
L-M-1802	--	--	8-10	Irrigation	Tamiami-Zone I	418

TABLE 4-2. LIST OF WELLS LOCATED NEAR THE PROJECT SITE WITH CONSTRUCTION DETAILS AND WATER QUALITY - CONTINUED:

Well No.	Total Depth(ft)	Casing Depth(ft)	Casing Diameter(in)	Use	Aquifer	Dissolved Chlorides(mg/l)
L-M-1803	80	--	2	Irrigation	Tamiami-Zone I	240
L-M-1804	78	--	2	Domestic	Tamiami-Zone I	94
L-M-1805	55	--	4	Domestic	Tamiami-Zone I	114
L-M-1806	50	--	2	Irrigation	Tamiami-Zone I	148
L-M-1807	--	--	2	Irrigation	Water-Table	14
L-M-1808	--	--	2	Irrigation	Tamiami-Zone I	326
L-M-1809	63	--	2	Irrigation	Tamiami-Zone I	196
L-M-1810	60	--	--	Irrigation	Tamiami-Zone I	200
L-M-1811	66	--	2	Irrigation	Tamiami-Zone I	78
L-M-1812	--	--	--	Domestic	Tamiami-Zone I(?)	112
L-M-1813	62	--	2	Domestic	Tamiami-Zone I	188
L-M-1814	20	--	2	Domestic	Water-Table	18
L-M-1815	60-65	--	--	Domestic	Tamiami-Zone I	76
L-M-1816	65	--	2	Domestic	Tamiami-Zone I	80

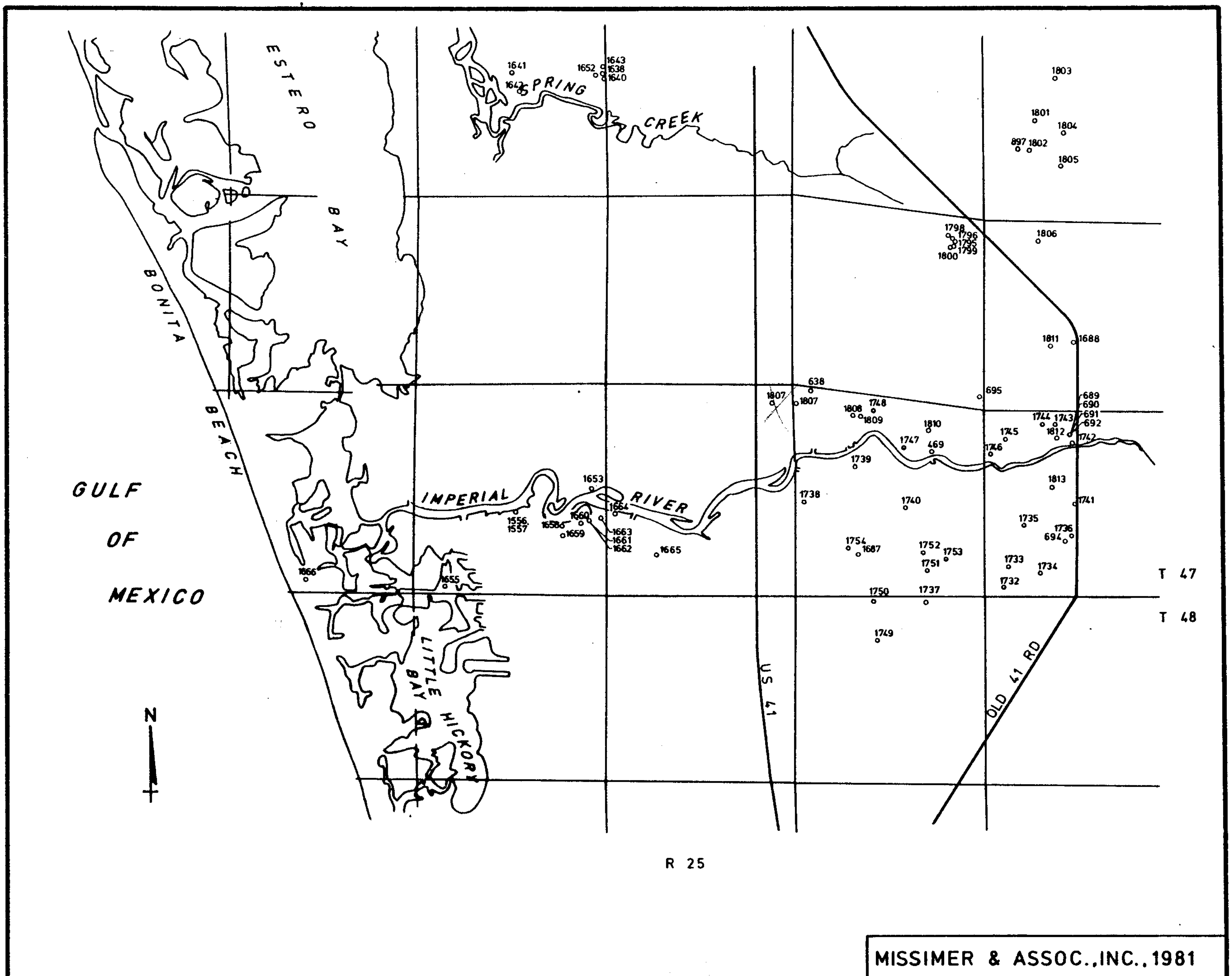

FIGURE 4-7. MAP SHOWING THE LOCATION OF WELLS NEAR THE SITE.

Water Company, numerous residences still use their own wells for domestic supply. Most of these people live near old U.S. 41 or to the east of it.

A large majority of the wells tap Tamiami Aquifer System-Zone I. The capacities range from 20 to about 60 gpm with the exception of a few large diameter wells, which can be pumped at 500 gpm. Dissolved chloride concentrations range from about 80 to 3,000 mg/l.

About 10% of the wells in the area tap the water-table aquifer. These wells range from 15 to 25 feet in depth and yield 10 to 20 gpm. Water quality is generally good with dissolved chloride concentrations below 100 mg/l and dissolved iron at about 0.3 mg/l.

A few old flowing wells exist in the area. These wells tap one of the three zones in the Hawthorn Aquifer System. The wells flow from 100 to 500 gpm with dissolved chloride concentrations ranging from 1,400 to 2,650 mg/l.

A small public supply wellfield is located about 2000 feet to the northeast of the Bonita Bay utility site. This wellfield at Imperial Harbor trailer park taps Tamiami Aquifer System-Zone I to feed a reverse osmosis treatment plant. Water use is relatively small.

There are several hundred existing small diameter wells in the Bonita Springs area. The use of water from these wells is most difficult to estimate, but probably ranges from 100,000 to 300,000 gpd.

5. Environmental Description

The Bonita Bay site along with the utility area exhibits a wide range of environmental communities. The sand ridges are characterized by a rosemary-dwarf oak-lichen xyrophytic community. Most of the high flat areas are occupied by pine flatwoods, which can be subdivided into the acid sand slash pine-saw palmetto-fetter bush community and the slash pine-saw palmetto community. Additional environments observed on the site are: a few bay tree hammocks, some wet prairie, and freshwater marsh. Both black and red mangrove areas occur in tidal waters surrounding the property.

V. GEOLOGY AND HYDROLOGY OF BONITA BAY

1. Geology

The geology of Bonita Bay, including both the area west of U.S. 41 and the utility site, was investigated through an extensive exploratory drilling program. Twenty-six observation wells were drilled, including 10 shallow wells about 25 feet deep, 10 intermediate wells about 100 feet deep, and 6 deep wells over 200 feet in total depth. These wells were located in clusters at 6 sites on the property (see Figure 5-1 for well locations). Each cluster of wells contained at least one shallow, an intermediate, and a deep well.

Detailed lithic descriptions were made of the cuttings collected from each test hole by microscopic examination (see Geologist's Logs in Appendix Tables A-1 to A-17). The cuttings from only two wells, L-M-1678 and L-M-1681, were not included because of their proximity to other wells and their shallow depth. Geophysical logs were run on a large number of the observation wells including all of the deep wells and several of the intermediate wells (see Appendix Figures A-1 to A-23).

The geologic section beneath Bonita Bay was explored to a depth of nearly 240 feet below mean sea level (Figure 5-2). Sediments in three separate formations were penetrated,

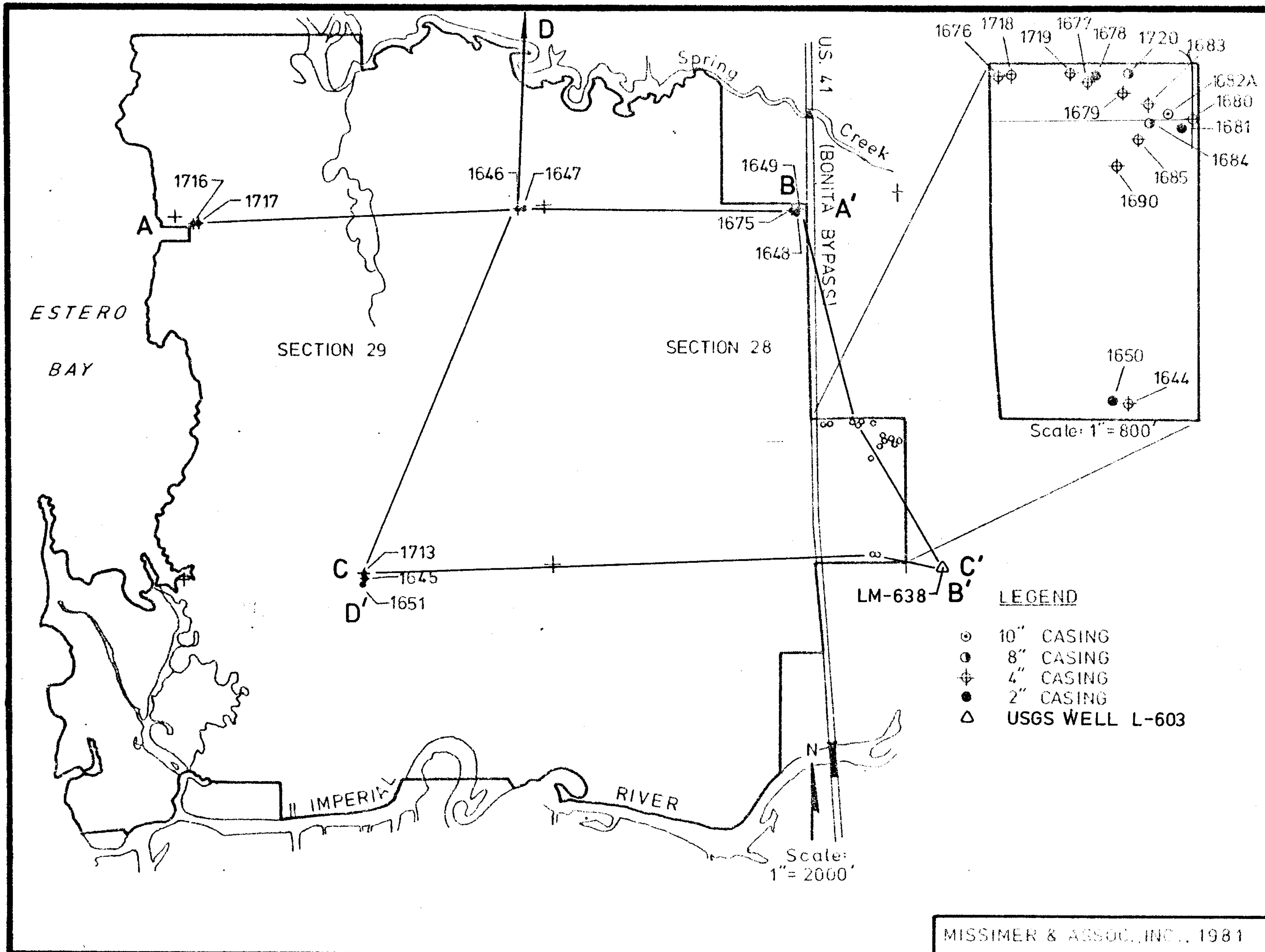

FIGURE 5-1. MAP SHOWING THE LOCATION OF WELLS AND CROSS SECTIONS.

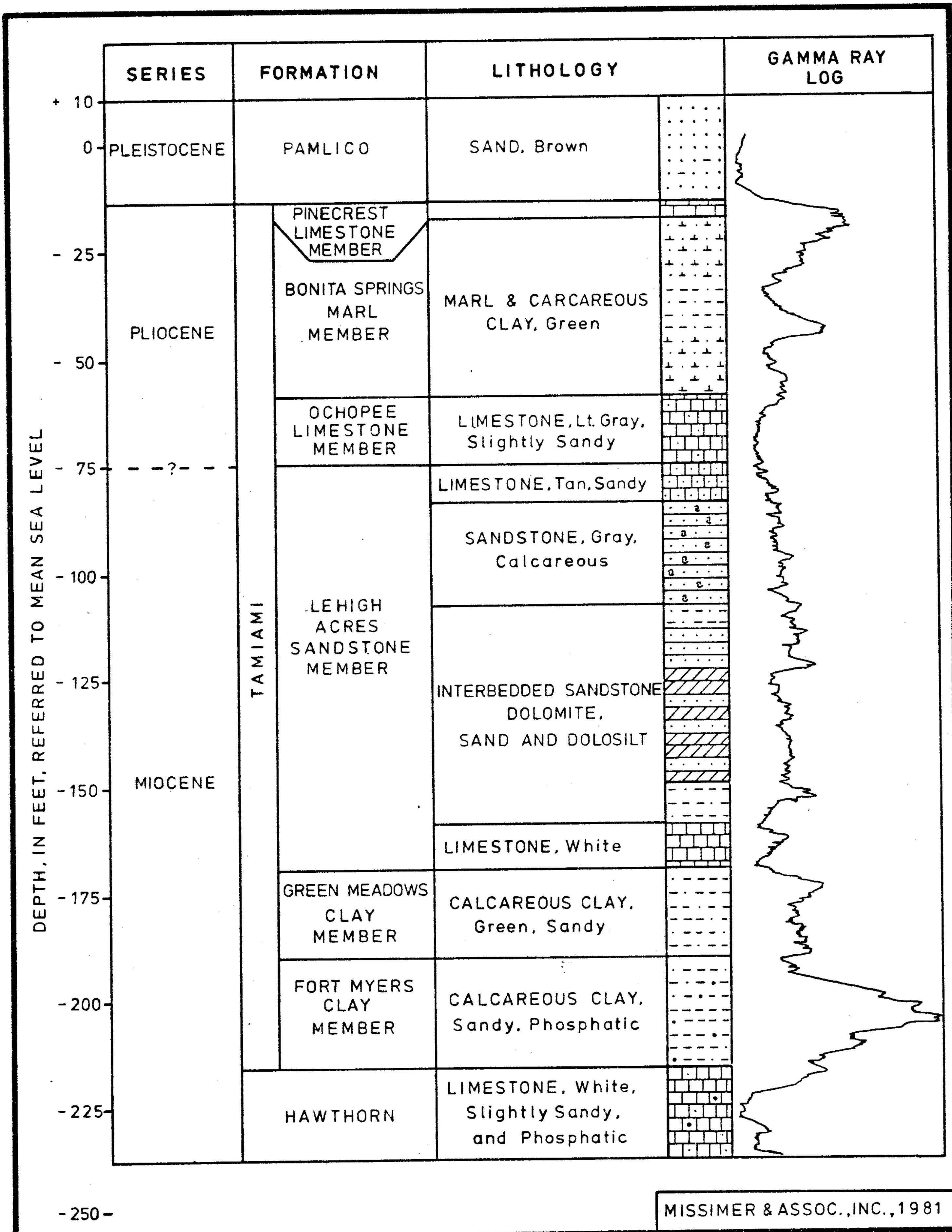

FIGURE 5-2. GEOLOGIC SECTION IN WELL L-M-1719.

including all of the Pamlico Sand, the Tamiami Formation, and the upper part of the Hawthorn Formation. As illustrated in Figure 5-2, the Pamlico Sand lies at the top of the geologic section. Lying below the Pamlico Sand is the lithologically complex Tamiami Formation in which 6 distinct members were recognized. These members are: the Pinecrest Limestone, the Bonita Springs Marl, the Ochopee Limestone, the Lehigh Acres Sandstone, the Green Meadows Clay, and the Fort Myers Clay. To the north of Bonita Bay, the Cape Coral clay member pinches out. The Tamiami Formation is characterized by water bearing limestones and sandstones separated by relatively impermeable calcareous clays and dolosilts (Figure 5-2).

The Hawthorn Formation lies unconformably beneath the Tamaimi Formation. Exploration wells penetrated only the upper 20 feet of the formation.

The stratigraphic relationships of the various lithic units generally described above are shown in cross section view in Figures 5-3, 5-4, 5-5, and 5-6, and tops of the various units are given in Table 5-1.

Pamlico Sand

A Pleistocene-age sand deposit blankets the underlying Pliocene and Miocene sediments. This surficial sand, formerly termed the Pamlico Sand, forms the major part of the site topography. It is predominantly a medium-to fine-grain, quartz sand with minor amounts of organic and pelitic

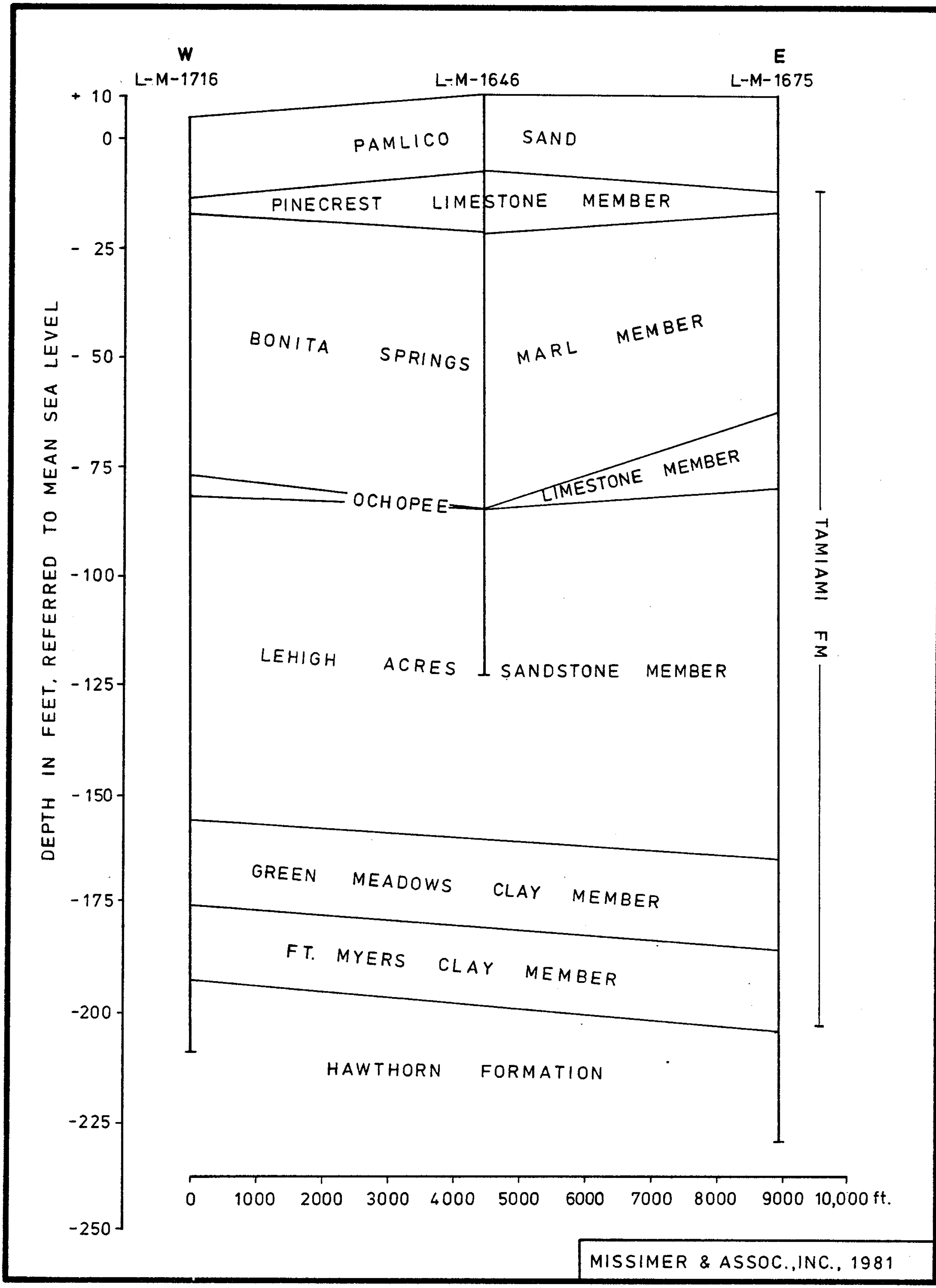

FIGURE 5-3. GEOLOGY OF THE SITE (EAST - WEST CROSS SECTION A-A').

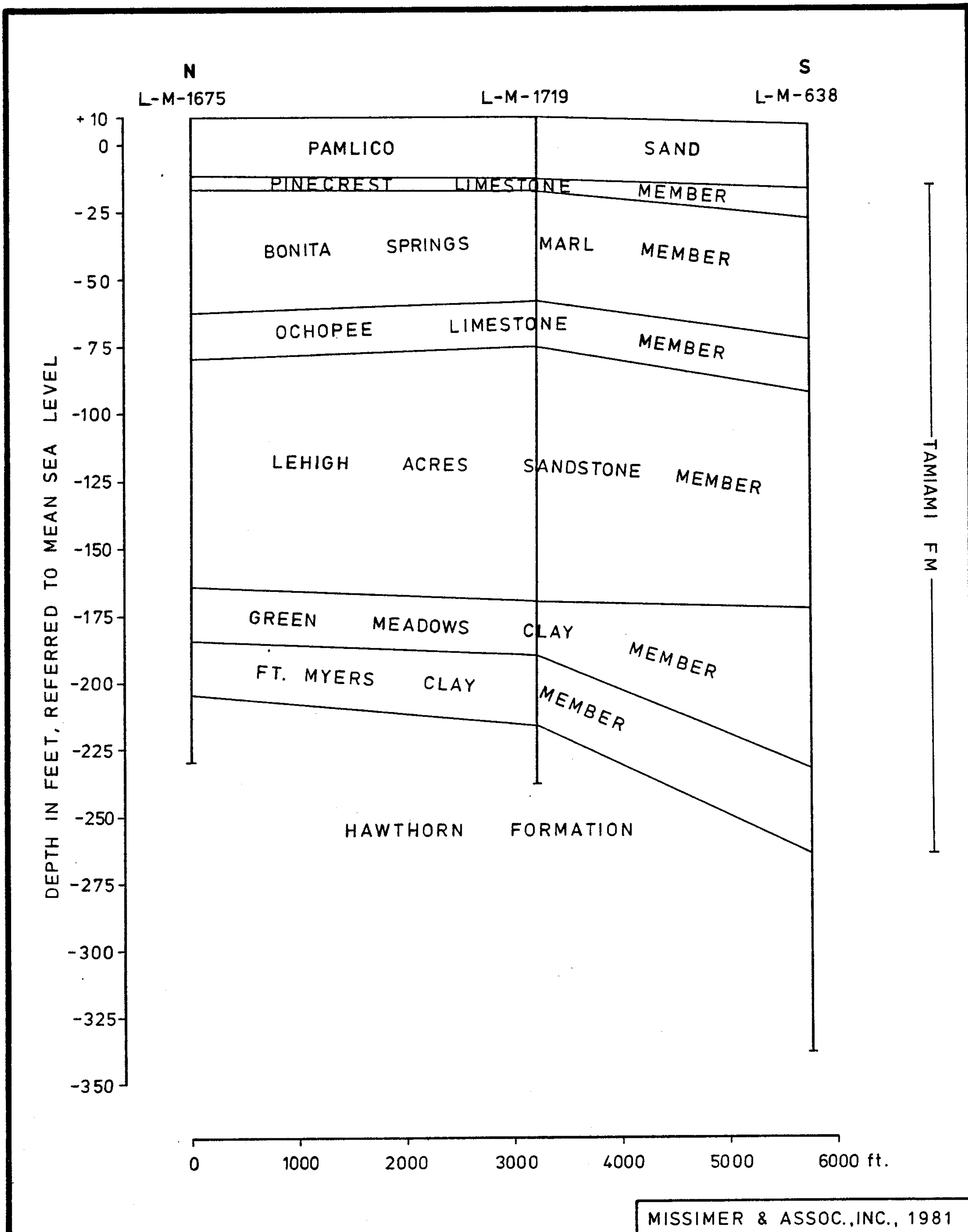

FIGURE 5-4. GEOLOGY OF THE SITE (NORTH-SOUTH CROSS SECTION B-B').

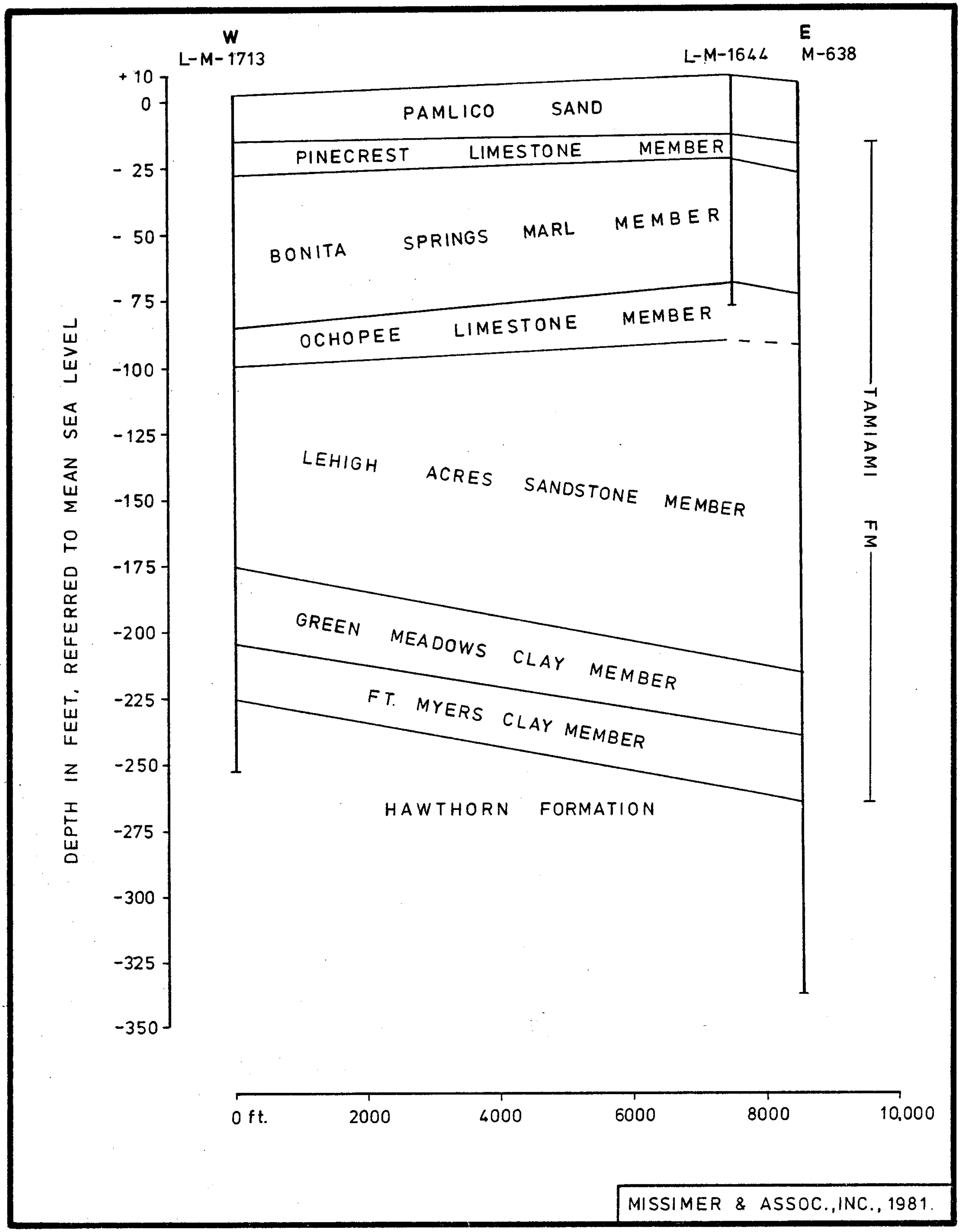

FIGURE 5-5. GEOLOGY OF THE SITE (EAST-WEST CROSS SECTION C-C').

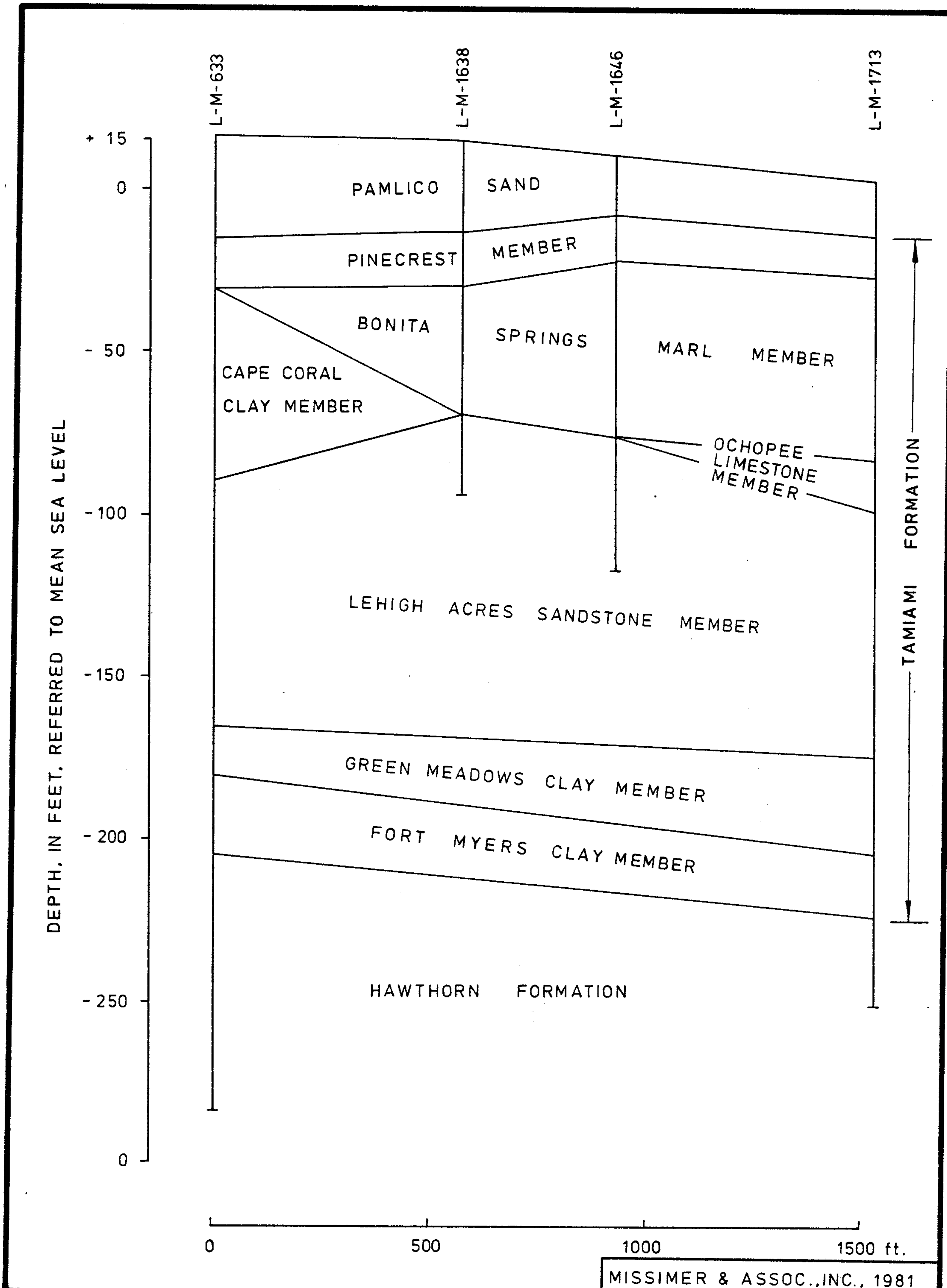

FIGURE 5-6. GEOLOGY OF THE SITE (NORTH-SOUTH CROSS SECTION D-D').

TABLE 5-1. TOP AND THICKNESS DATA FOR FORMATIONS

Well #	Pamlico Top	Pamlico Th	Pinecrest Top	Pinecrest Th	Bonita Sprs Top	Bonita Sprs Th	Ochopee Top	Ochopee Th	Lehigh Acrs Top	Lehigh Acrs Th	Green Mead Top	Green Mead Th	Ft. Myers Top	Ft. Myers Th	Top Hawth.	T.D.
L-M-1716	+ 5	18	-13	4	-17	60	-77	4	-81	74	-155	20	-175	17	-192	215
L-M-1646	+10	18	- 8	14	-22	63	Not Pres.		-85							128
L-M-1675	+10	22	-12	5	-17	46	-63	17	-80	85	-165	20	-185	20	-205	220
L-M-1676	+12	24	-12	3	-15	38	-53	15	-68							120
L-M-1718	+12	22	-10	5	-15	38	-53	15	-68	90	-158	15	-173	27	-200	238
L-M-1719	+10	24	-14	3	-17	42	-59	16	-75	95	-170	20	-190	26	-216	248
L-M-1677	+10	19	- 9	5	-14	45	-59	16	-75							125
L-M-1720	+ 8	19	-11	7	-18	45	-63	19	-82	98	-180	27	-207	23	-230	255
L-M-1679	+ 8	24	-16	6	-22	45	-67	20	-87							120
L-M-1682	+10	17	- 7	15	-22	53	-75	20	-95							120
L-M-1680	+ 8	17	- 9	15	-24	48	-72	20	-92							127
L-M-1644	+10	23	-13	9	-22	47	-69									86
L-M- 638	+ 7	24	-17	9	-26	34	-60	28	-88	128	-216	23	-239	26	-265	345
L-M-1713	+ 3	18	-15	12	-27	57	-84	15	-99	76	-175	30	-205	20	-225	255

Formation tops are referred to mean sea level.

material. A basal sandy clay, about 5 feet thick, occurs over much of the area. The sands were deposited as a segmented barrier island-dune complex, which parallels the present coastline. The barrier island-dune ridge system is visible on aerial photographs, topographic maps, and shows on the isopach map of the Pamlico Sand as thickened areas (Figure 5-7). Test boring data from engineering studies along with test well data were used to construct Figure 5-7. The high ridge areas contain a finer sand than the low-lying areas. A low-lying slough that transects the property through Section 29 is probably a former lagoon area.

Permeability of the Pamlico Sand is high especially in the dune areas. Local variation in permeability is common and is dependent on the percentage of fine-grained material. The basal part of the formation has low permeability because of the high percentage (10 to 20%) of clay matrix.

Tamiami Formation

In this report, we utilize the definition of Parker and others (1955) for the definition of the Tamiami Formation, which includes sediments down to the top of the middle Miocene. The units described are formally defined in Peck and others (1979), Missimer and Associates, Inc. (1978), and Missimer and Associates (1981).

The Tamiami Formation is between 180 and 210 feet

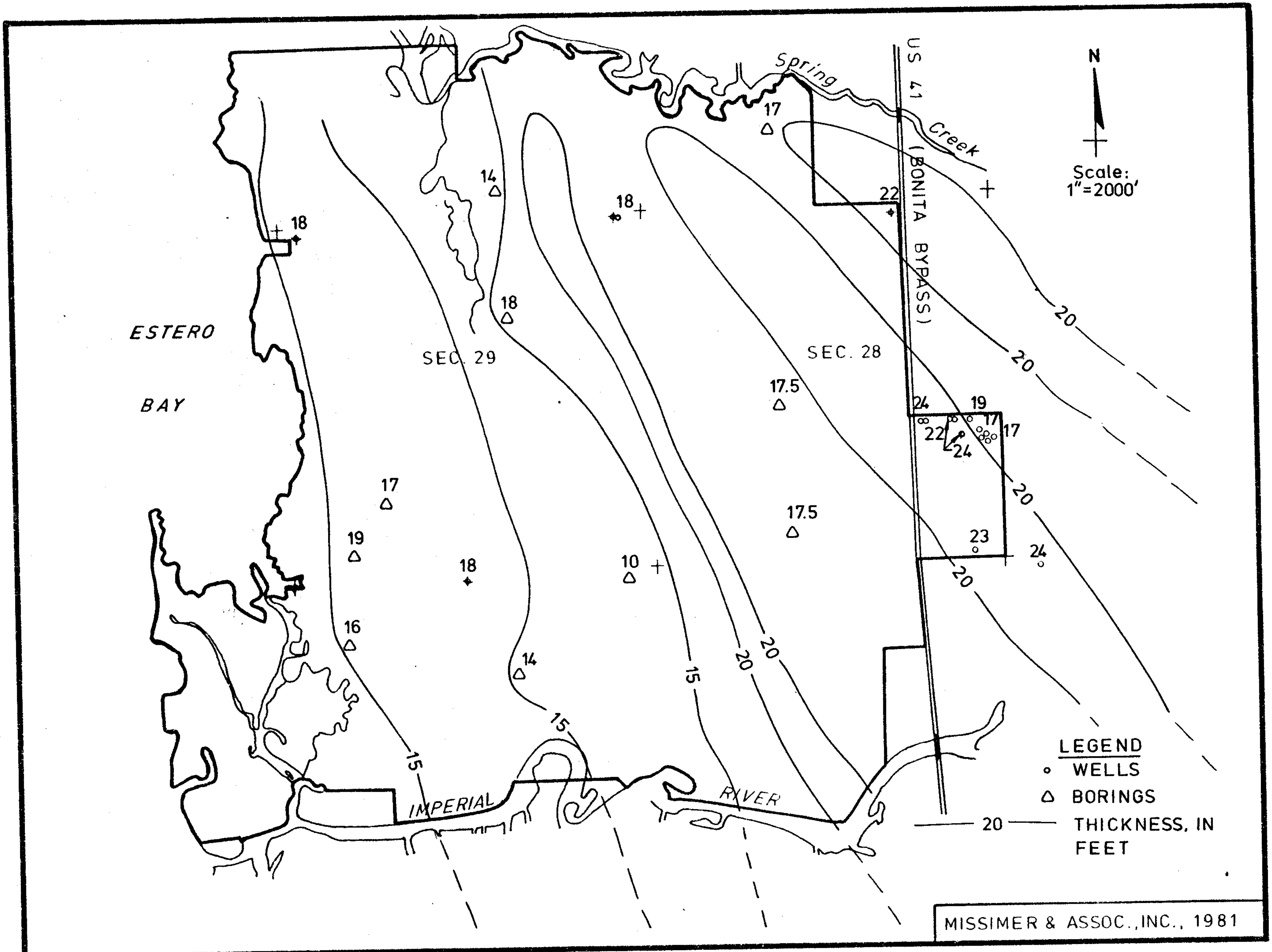

FIGURE 5-7. MAP SHOWING THICKNESS OF THE PAMLICO SAND.

thick beneath Bonita Bay. About 5 miles to the east of Bonita Bay, the formation thickens to over 500 feet. As a result of the general east to west thinning of the formation, several members of the Tamiami have pinched out, such as the Cape Coral clay and parts of the Corkscrew marl. As a result, the Ochopee Limestone Member lies directly on top of the Lehigh Acres Sandstone Member without the immediate separation of the Cape Coral clay and likewise, the Corkscrew marl does not lie between the Green Meadows clay and the Fort Myers Clay Members. The pinch out of the Cape Coral clay to the north of Bonita Bay is shown in Figure 5-6 along with the pinch out of the Ochopee Limestone.

Pinecrest Limestone Member

The uppermost member of the Tamiami Formation, the Pinecrest Limestone, lies unconformably beneath the Pamlico Sand. Commonly, a thin, hard mudstone separates the Pinecrest from the Pamlico. This mudstone is several feet thick in wells L-M-1680, L-M-1683, L-M-1684, and L-M-1646. The Pinecrest is characterized by abrupt changes in thickness and lithology. Across the Bonita Bay study area, it ranges from 3 to 15 feet thick (Figure 5-8). The abrupt thickening of the unit is caused by the occurrence of coralline patch reefs. The areal extent of the reef complexes is exhibited by the pattern of the isopachous lines at the utility site.

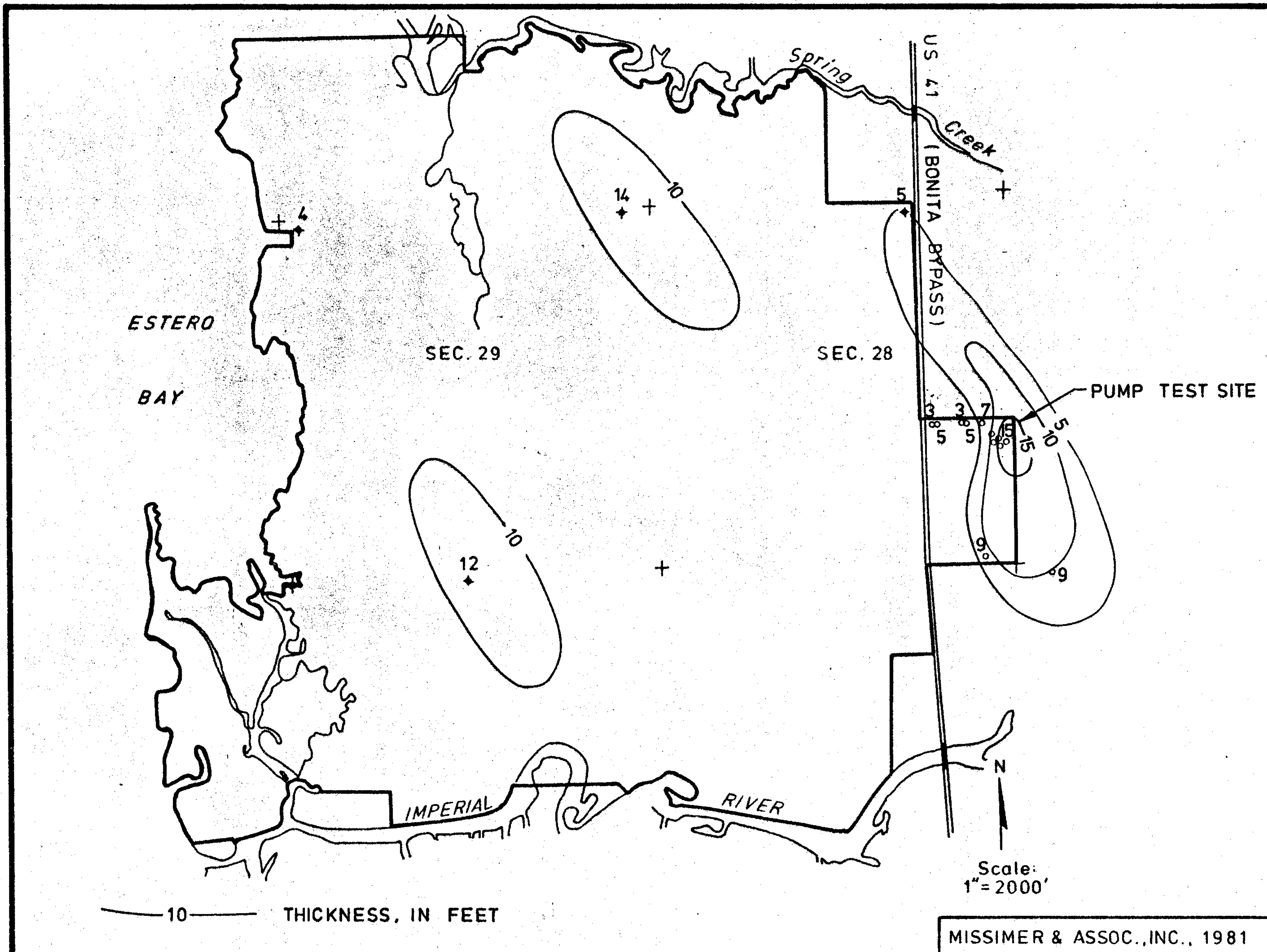

FIGURE 5-8. ISOPACHOUS MAP OF THE PINECREST LIMESTONE MEMBER OF THE TAMIAMI FORMATION.

Lithofacies of the Pinecrest Member include a white, coralline, biomicrudite and a gray, sandy, oyster-rich, molluscan, moldic biomicrudite. The reefal limestones were encountered beneath the eastern test area in wells L-M-1680, L-M-1682, and L-M-1684 and at the southwest test site. It is probable that the reefal limestones also occur at both the north-central and southeast site based on circulation losses in wells L-M-1646 and L-M-1644.

Pinecrest sediments have a generally very high permeability and a high porosity. The coralline biomicrudites are very permeable, especially where corals have been re-crystallized into calcite spar. However, the molluscan-moldic, biomicrudites have a higher porosity and permeability. These porosities are at 30% or more due to the combination of abundant intergranular voids with secondary moldic porosity caused by the dissolution of aragonitic shells. Large crystals of calcite spar often are common in this unit.

Bonita Springs Marl Member

Green marls and calcareous clays lie beneath the Pinecrest limestone. These fine-grain, unlithified, sandy, and shelly lime muds are herein termed the Bonita Springs marl. The Bonita Springs marl contains abundant quartz sand and shell in the upper 10 to 20 feet. A denser calcareous clay with a minor percentage of quartz sand forms the middle part of this unit and a basal 5 to 10 feet of olive green, marly limestone with abundant bivalves and barnacle shells occurs at each drill site except at the northern sites in Section 29.

The upper surface of the Bonita Springs marl dips gently to the south as shown in a structure contour map (Figure 5-9). It is observed that the patch reef and associated circulation loss zones in the Pinecrest occur in structural lows on top of the Bonita Springs marl and not high areas which is the usual case. The apparent reason the corals developed in the lower areas is that water depth was more favorable to the growth of corals. Further, since water depth was apparently deeper to the east and southeast of Bonita Bay, it is probable that reef development was more intense in these areas and consequently, high permeability areas will occur associated with the reefs.

The thickness of the Bonita Springs marl increases from the southeast to the northwest from 40 to 60 feet (Figure 5-10). The thickness of the unit at the north end of the property may be somewhat lower than indicated, because as shown in Figure 5-6, the Cape Coral clay unit lies immediately below the Bonita Springs marl, which has a very similar lithology. Vertical permeability tends to decrease with the overall increase in unit thickness.

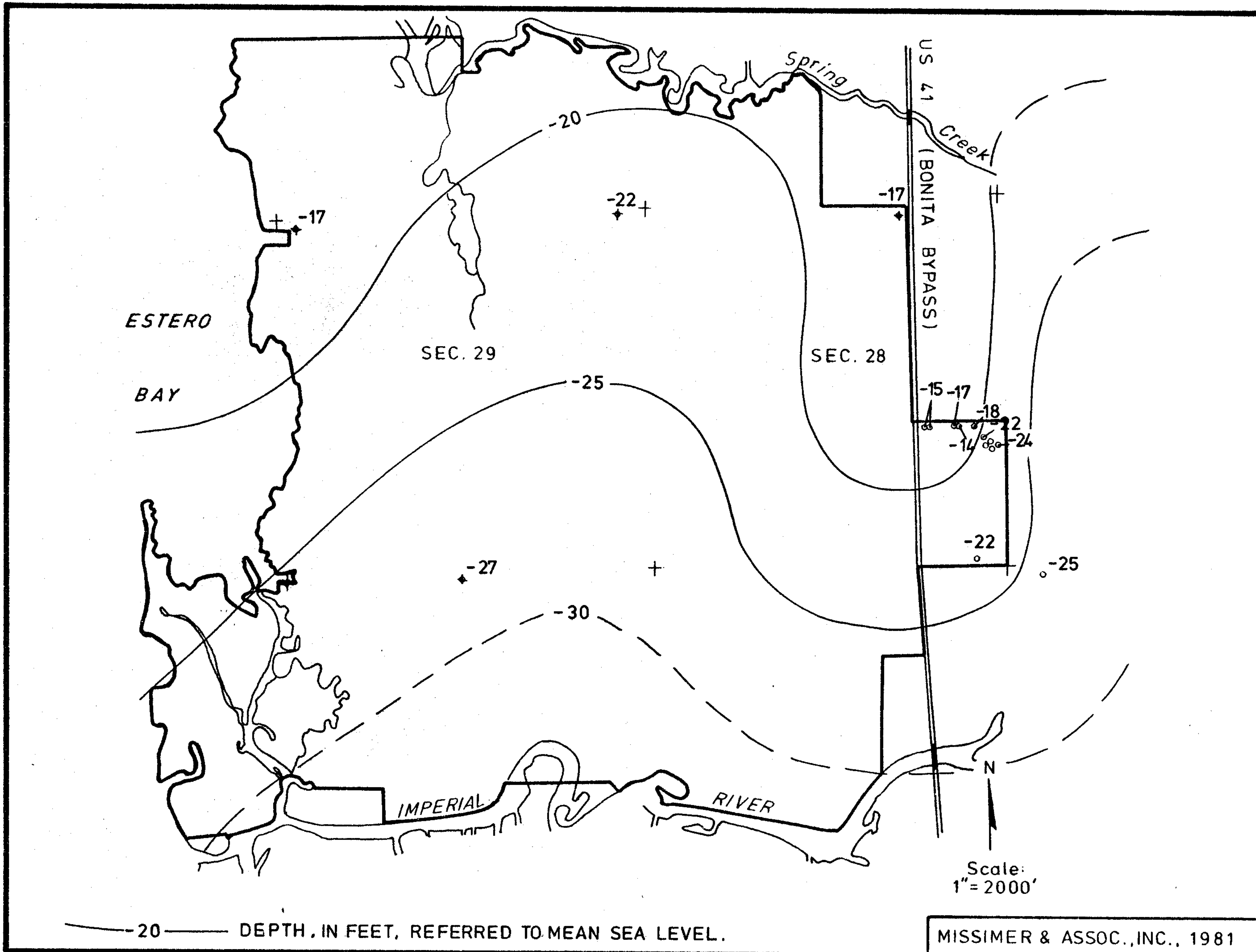

FIGURE 5-9. STRUCTURE CONTOURS ON TOP OF THE BONITA SPRINGS MARL MEMBER OF THE TAMIAMI FORMATION.

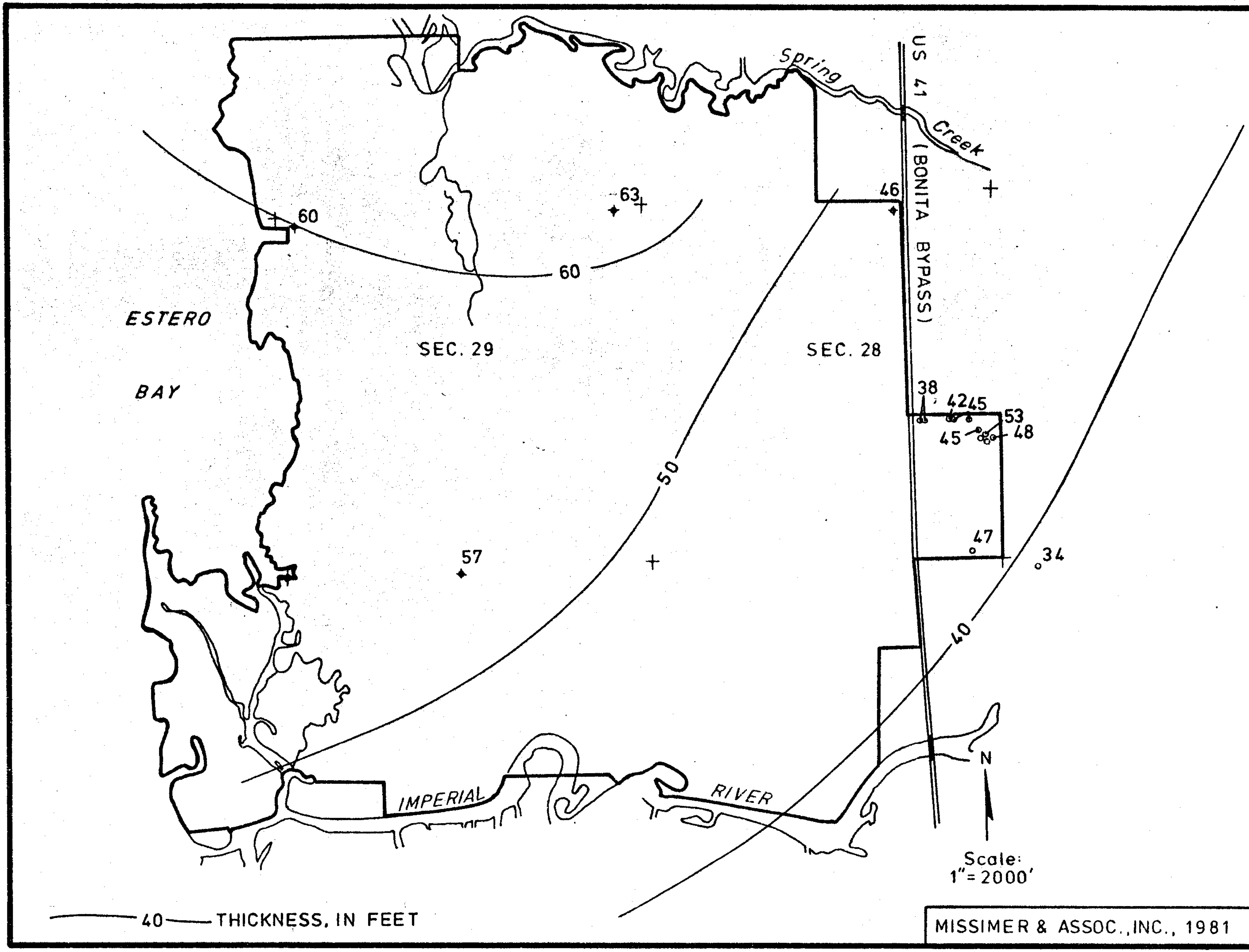

FIGURE 5-10. THICKNESS MAP OF BONITA SPRINGS MARL MEMBER.

Ochopee Limestone Member

The Ochopee Limestone Member of the Tamiami Formation lies unconformably below the Bonita Springs marl member. A structure contour map of the Ochopee shows up to 40 feet of relief across the Bonita Bay site (Figure 5-11). This relief is the probable result of subaerial exposure and erosion during a regression of the sea. Erosion was significant enough to completely remove the Ochopee in the northwest part of the site (Figure 5-12). Thickening of the unit occurs to the southeast with a total maximum thickness of 25 feet occurring on the utility site and along the Imperial River near U.S. 41. The direction of thinning of the unit is exactly opposite to that occurring in the overlying Bonita Springs marl (Figure 5-10).

Lithologically, the Ochopee is a sandy, molluscan, moldic biomicrudite. The dissolution of aragonitic shell material, creating large interconnecting molds and vugs, accounts for the high permeability of this unit. The occurrence of sparry cement is another indication of secondary diagenesis and the high permeability of the limestone. The general tendency of permeability in the unit is to decrease with depth as secondary alteration becomes less significant and as the percentage of quartz silt and sand increases.

The contact between the Ochopee Limestone and the underlying Lehigh Acres Sandstone appears to be gradational from the geologic data collected. However, the absence

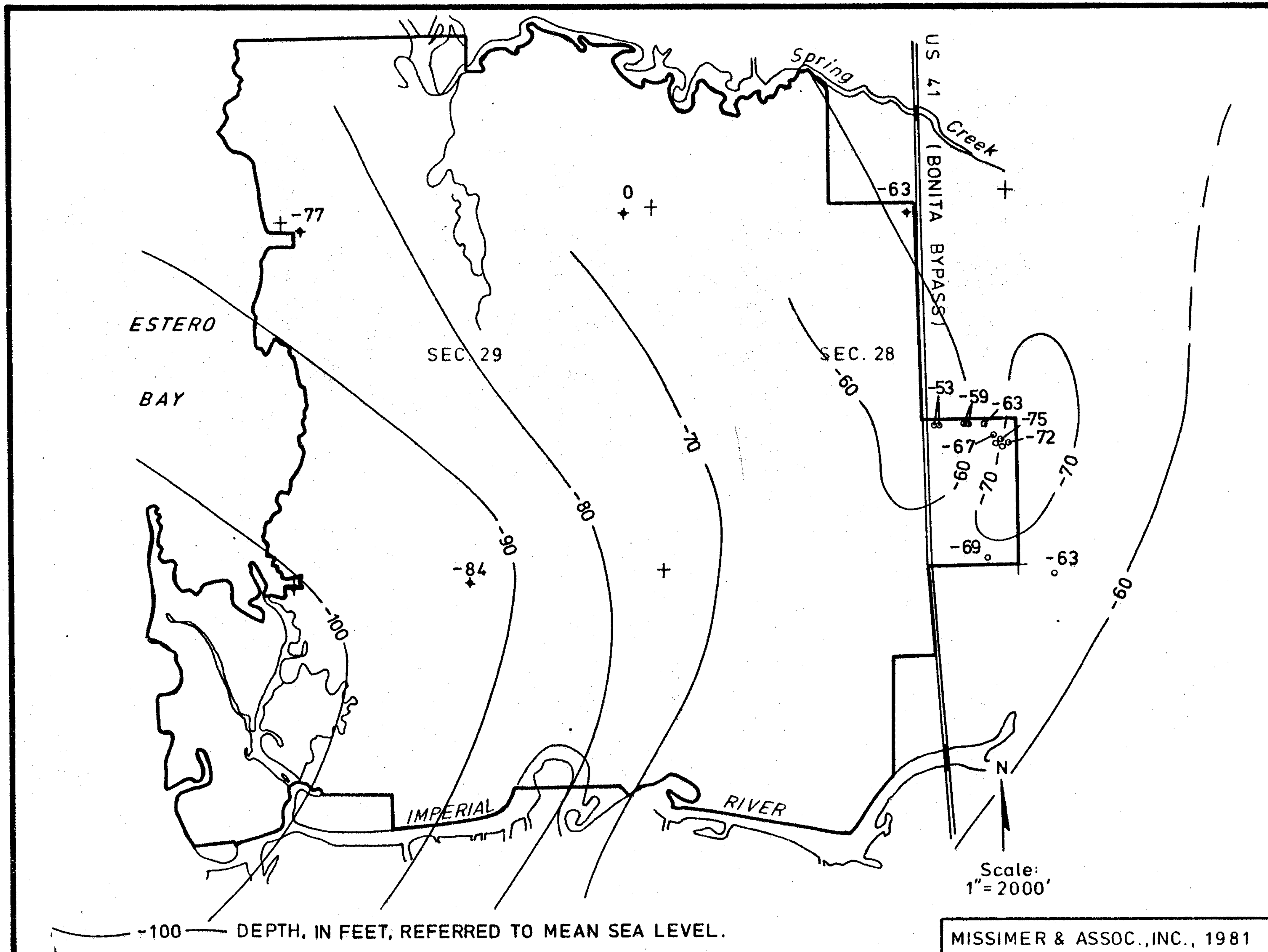

FIGURE 5-11. STRUCTURAL CONTOURS ON TOP OF THE OCHOPEE LIMESTONE MEMBER OF THE TAMIAMI FORMATION.

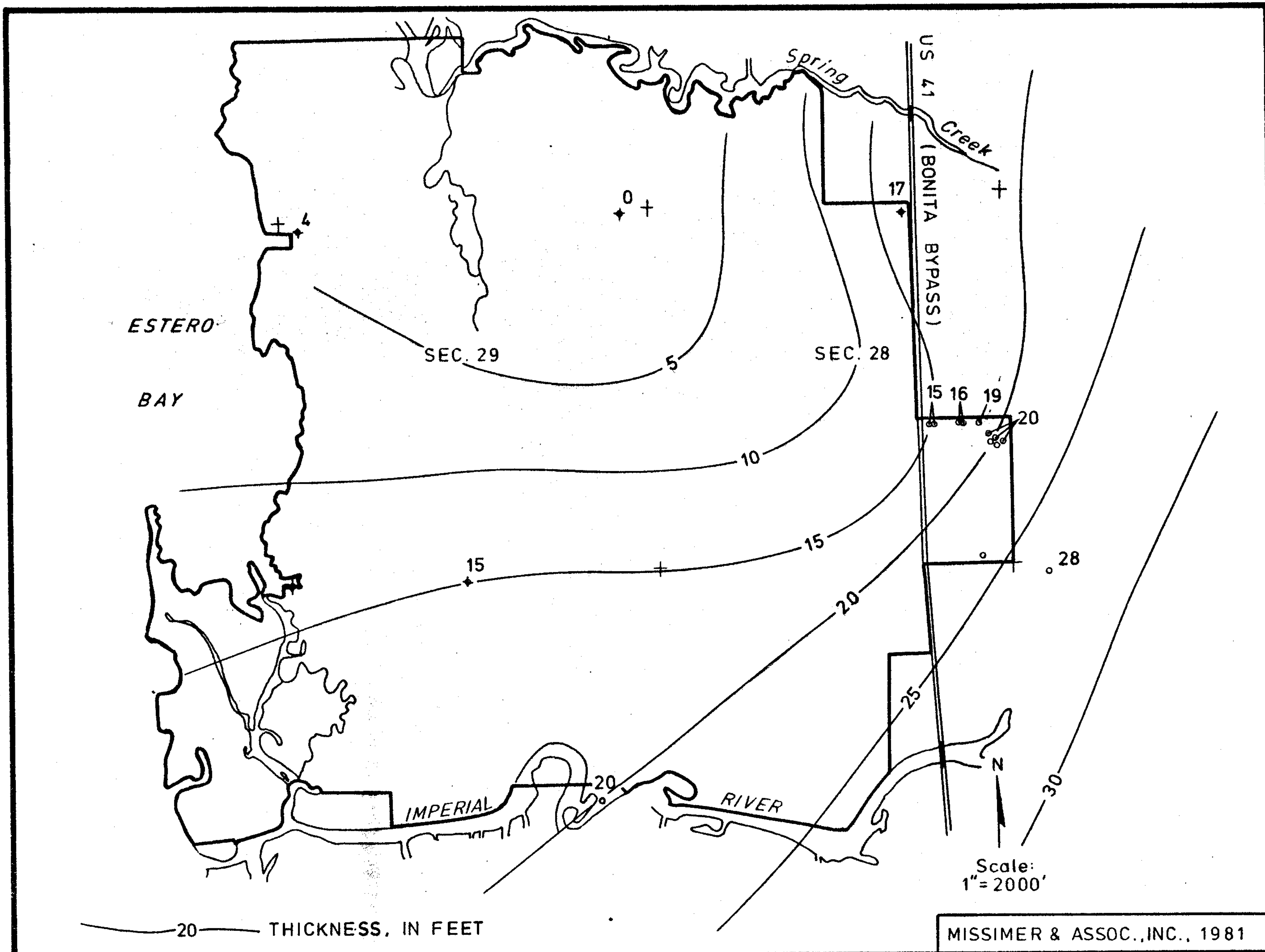

FIGURE 5-12. ISOPACHOUS MAP OF THE OCHOPEE LIMESTONE MEMBER OF THE TAMIAMI FORMATION.

of the Cape Coral clay member from the main part of the study area indicates a gap in the geologic record caused by either erosion or non-deposition.

Cape Coral Clay Member

The Cape Coral clay member lies beneath the Ochopee Limestone in most of Lee County. However, as shown in cross section Figure 5-6, the Cape Coral clay pinches out just to the north of Spring Creek. This occurs with a similar pinch out of the Bonita Springs marl. It should be noted that although these two units pinch out in close proximity, they are not time equivalent and cannot be considered to be a single unit.

Lehigh Acres Sandstone Member

The Lehigh Acres Sandstone is a mixed carbonate-clastic unit beneath Bonita Bay. The top of the unit lies between 70 and 100 feet below mean sea level atop the Ochopee Limestone (Figure 5-13). A local high on the Lehigh Acres occurs in Section 28 and the unit dips to both the south and east. The general structure parallels that described in Missimer and Gardner (1976) and Missimer (1974). The thickness of the unit is uniform beneath the western part of the site at about 80 feet, but it thickens significantly to the southeast to about 130 feet (Figure 5-14).

The Lehigh Acres Sandstone Member includes an upper,

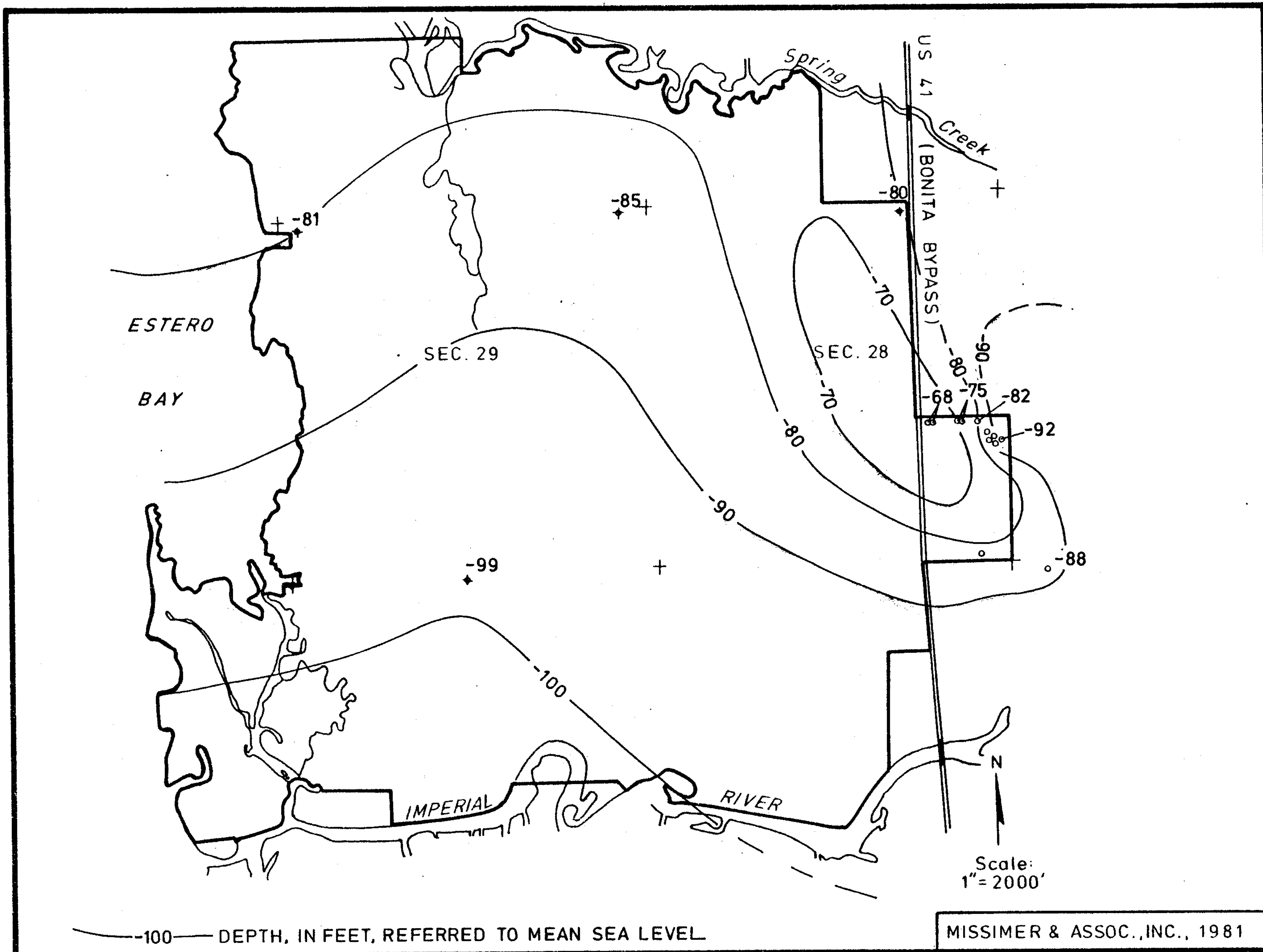

FIGURE 5-13. STRUCTURAL CONTOUR ON TOP OF LEHIGH ACRES SANDSTONE MEMBER.

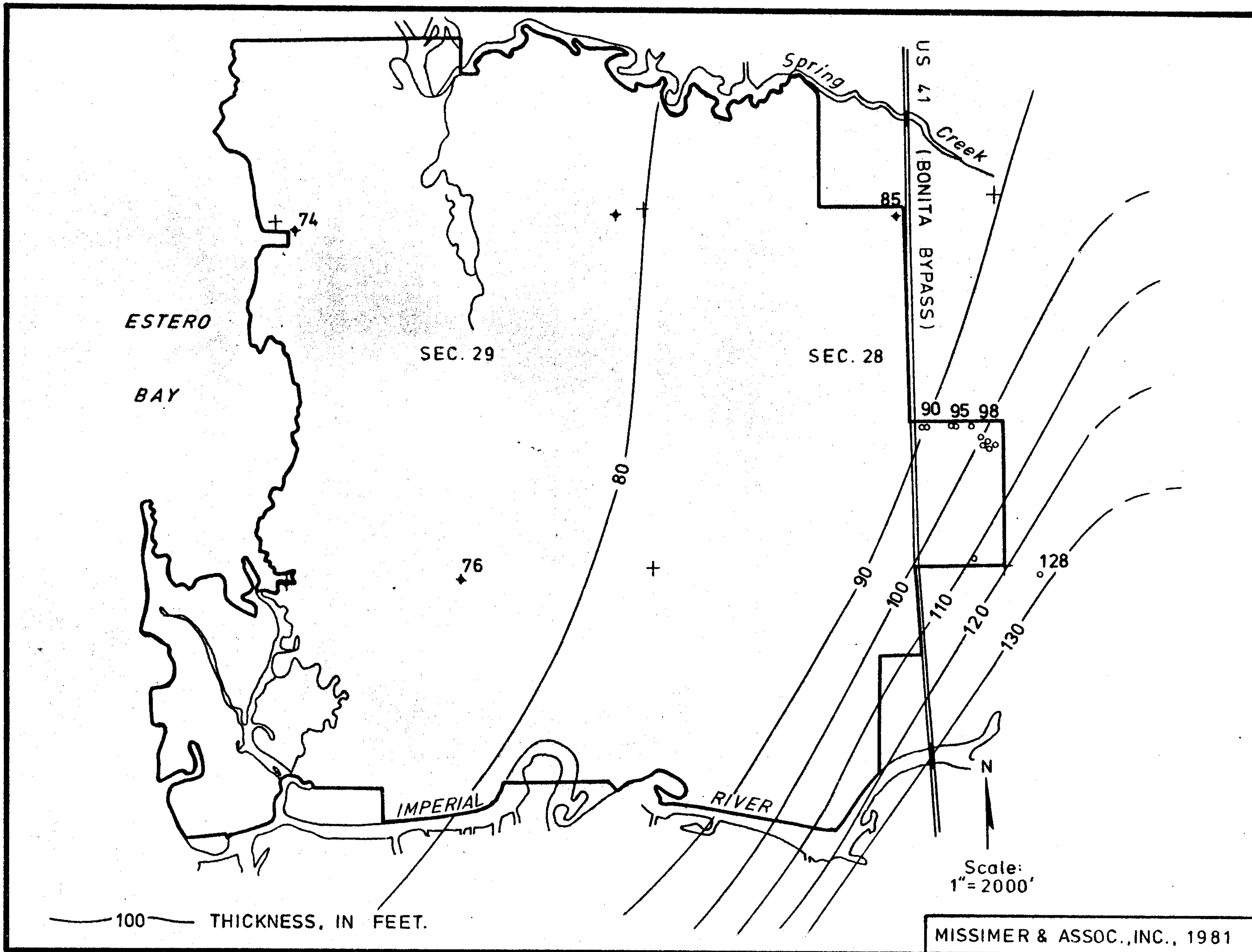

FIGURE 5-14. MAP SHOWING THICKNESS OF LEHIGH ACRES SANDSTONE.

tan, sandy limestone underlain by gray calcareous sandstone, green dolosilts, and minor quartz sands, shell beds, and gray dolomites. A white limestone and marl approximately 10 feet thick lies at the base of the member and above the green calcareous clays of the Green Meadows clay member.

Sediments of the Lehigh Acres Sandstone typically have low to medium permeability. The limestones are friable, micritic calcarenites lacking the secondary porosity so abundant in the overlying Ochopee Limestone. The sandstones are moderatly sorted, fine to coarse-grained, but the intergranular pores are filled with a lime mud matrix. Several thin hard sandstone and dolomite beds have higher permeability, but they are laterally discontinuous and are interbedded with low permeability calcareous clays. Although the Lehigh Acres Sandstone is over 4 times thicker than the Ochopee Limestone, it has an overall much lower permeability.

Green Meadows Clay Member

The Green Meadows clay member lies 160 to 190 feet below the surface at Bonita Bay. This member is rather thin, ranging from 15 to 30 feet thick (Table 5-1). Lithologically, the Green Meadows clay member is a dark green, sandy, unconsolidated, calcareous silt and clay with a minor amount of phosphorite. The percentage of calcite to dolomite is difficult to assess because of the very fine micro-crystalline nature of the sediments. This unit is dense, which causes slow bit penetration during drilling, and has a very low permeability.

Fort Myers Clay Member

The Fort Myers Clay Member lies conformably beneath the Green Meadows clay. It is lithologically similar to the Green Meadows clay being an unlithified, sandy, calcareous silt and clay. However, the Fort Myers Clay is dark greenish-gray in color with up to 30% quartz sand and 10% phosphorite pebbles. The high concentration of phosphorite causes a large increase in emitted gamma ray intensity, which appears as a large marker on gamma ray logs. This gamma ray marker can be traced beneath the entire site and all of Lee County.

Hawthorn Formation sediments lie unconformably beneath the Fort Myers Clay. Much of the clastic sediment in the Fort Myers Clay, especially the quartz sand and phosphorite, was derived from erosion of the Hawthorn Formation in structurally high areas. The erosion-derived "rubble" in the unit consists of quartz sand, phosphorite nodules and pebbles, limestone fragments, and detrital dolomite rhombs. These clastics were deposited in a fine grain matrix of carbonate mud with minor amounts of attapulgite and montmorillonite clays (Missimer, 1978, p. 34). The Fort Myers clay has a low permeability comparable to that of the Green Meadows clay.

Hawthorn Formation

The Hawthorn Formation, as presently defined, is a Miocene deposit of large regional extent. In most of western Charlotte and Lee Counties, the Hawthorn is a marine, white, phosphatic limestone (Missimer, 1978). Beneath Bonita Bay, the Hawthorn Formation lies at between 192 and 230 feet below mean sea level (Figure 5-15). The top of the formation dips to the southeast. The Section 28 high area, present in Tamiami Formation sediments, also exists at the top of the Hawthorn. The thickness of the Hawthorn beneath Bonita Bay is unknown since the test wells penetrated only the upper limestone section to the first calcareous clay or about 20 feet. Well L-M-638, located east of Bonita Bay, penetrated 73 feet of Hawthorn sediments.

Hawthorn Formation sediments are very fossiliferous with abundant mollusks and bryozoans. Impurities within the limestone sections are about 5% phosphorite and quartz sand. These limestone have undergone diagenesis, which has included selective dissolution of aragonitic shells creating moldic porosity. The interconnection of the moldic porosity with the original intergranular porosity account for the overall high permeability of the upper Hawthorn limestone.

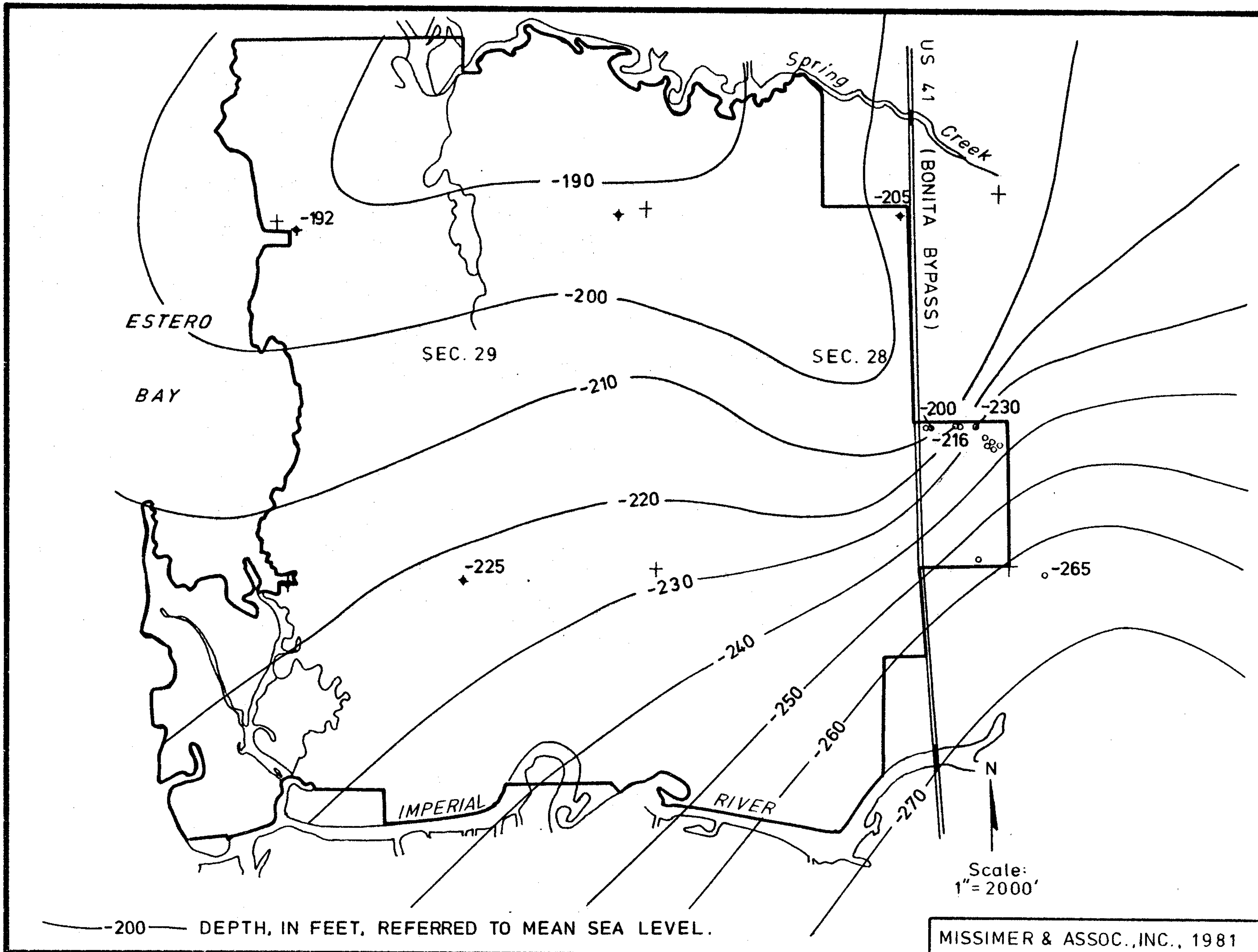

FIGURE 5-15. STRUCTURE CONTOUR ON TOP OF THE HAWTHORN FORMATION.

2. Aquifer and Confining Bed Descriptions

Bonita Bay is underlain by many different wat bearing zones of which only three have been studied because of their significance (Figure 5-16). In order of depth from land surface, the three principal aquifers underlying the site are: the water-table aquifer, Tamiami Aquifer System-Zone I and Hawthorn Aquifer System-Zone I. Each aquifer is separated by low permeability clays, which inhibit the vertical movement of water to variable degrees.

Water-Table Aquifer

Sediments within the Pamlico Sand and the Pinecrest Limestone Member of the Tamiami Formation form the water-table aquifer. The thickness of the aquifer ranges from 22 to 32 feet across the Bonita Bay site (Figure 5-17).

The aquifer does not have uniform permeability because it is a two-layer system with a sand unit overlying a limestone unit. The relative thicknesses of the component layers vary across the site (Figures 5-7 and 5-9) along with the local permeabilities within the units. The upper quartz sand has a significantly lower permeability than the underlying coralline limestones. A large volume of water can be developed from the thicker limestone sections because of the high effective porosity. Porosities in excess of 30% occur in the coralline limestone. The base

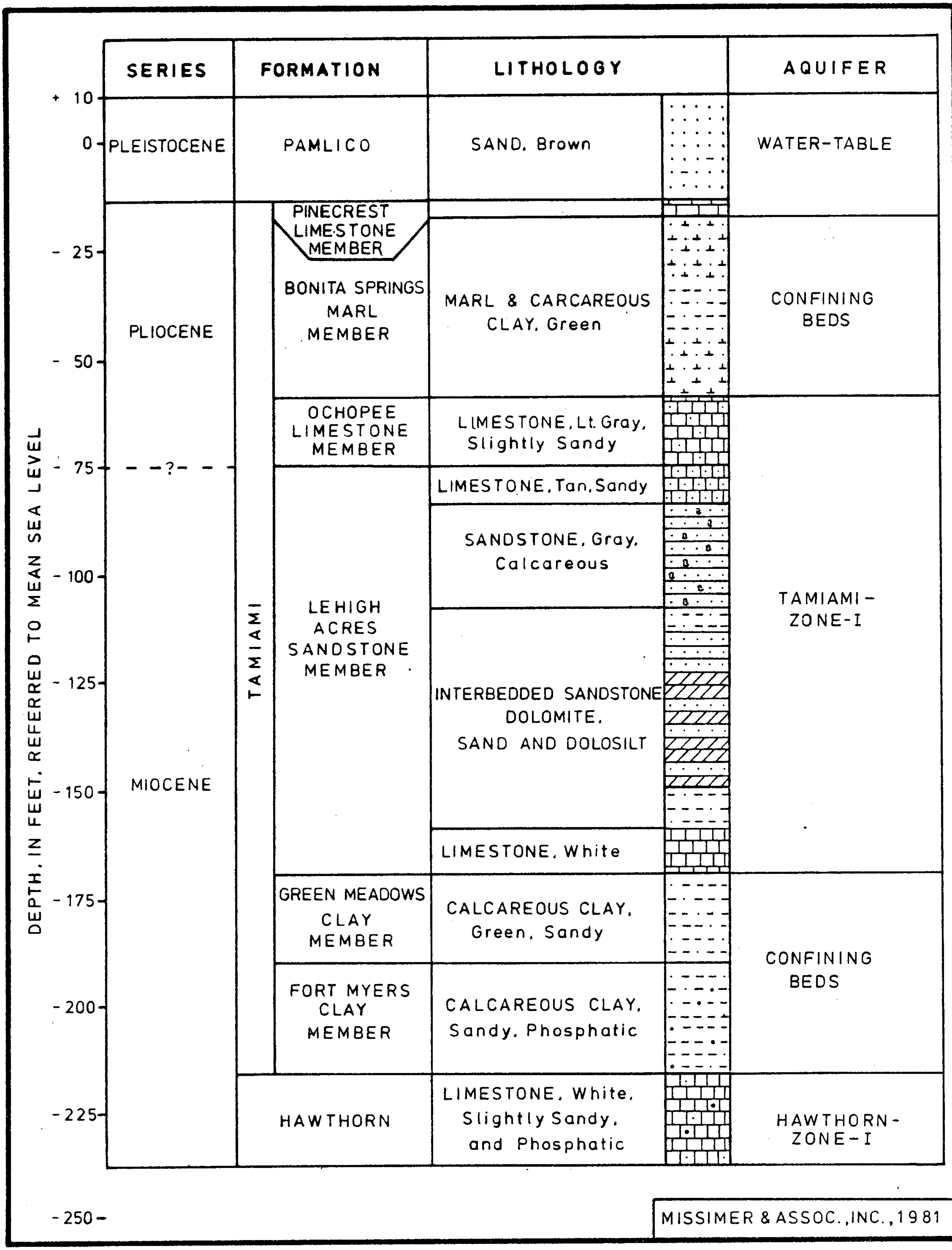

FIGURE 5-16. AQUIFER LOCATIONS IN GEOLOGIC SECTION, WELL L-M-1719.

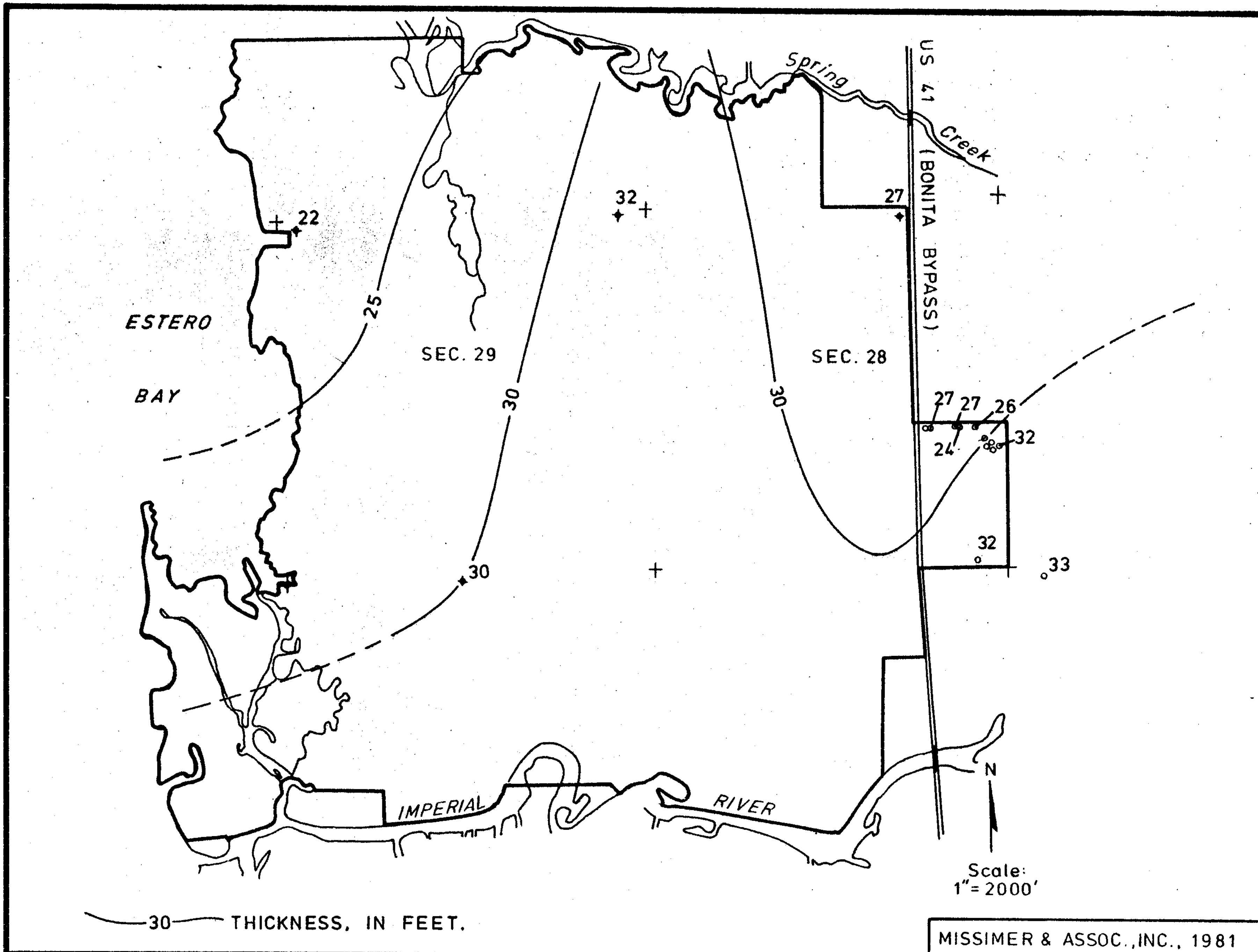

FIGURE 5-17. MAP SHOWING THE THICKNESS OF THE WATER TABLE AQUIFER.

of the aquifer is formed by low permeability clays within the Bonita Springs Marl.

Confining Beds Between the Water-Table Aquifer and Tamiami Aquifer System-Zone I

Low permeability clays and marls within the Bonita Springs Marl Member of the Tamiami Formation form the confining beds between the water-table aquifer and Tamiami Aquifer System-Zone I. The thickness of the confining beds ranges from 40 to 60 feet as shown in Figure 5-10. The carbonate muds, which are the primary component of this unit, have a very low permeability. Therefore, the leakage of water from the water-table aquifer into Tamiami-Zone I will be at a low rate.

Tamiami Aquifer System-Zone I

Permeable sediments within the Ochopee Limestone and Lehigh Acres Sandstone Members of the Tamiami Formation form Tamiami Aquifer System-Zone I. The top of the aquifer begins at depths ranging from -60 to -100 feet below mean sea level (Figure 5-11). Although the aquifer is quite thick, ranging from 80 to 160 feet (Figure 5-18), the major yield of water will come from the upper section. The Ochopee Limestone is very permeable compared to the underlying Lehigh Acres Sandstone. Therefore, the productivity of Tamiami Aquifer System-Zone I is dependent to a great degree on the

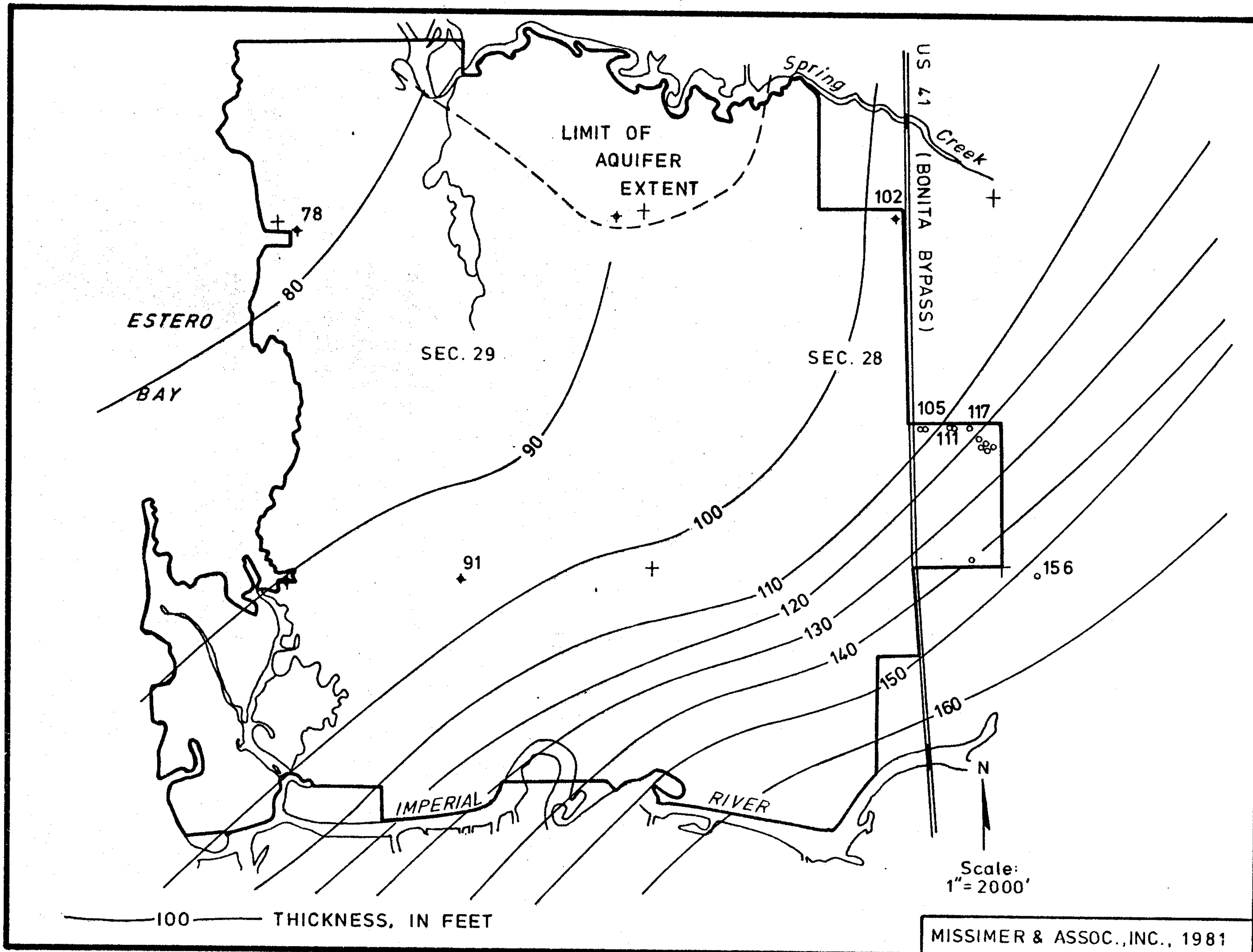

FIGURE 5-18. MAP SHOWING THE THICKNESS OF THE TAMIAMI AQUIFER SYSTEM ZONE I.

thickness of the Ochopee Limestone (see Figure 5-12). An increase in the aquifer transmissivity can be expected from the northwest part of the site to the southeast. Because of the permeability differential between the two members, only about 10 to 15 percent of the aquifer yield may originate below the upper limestone.

To the north of the Bonita Bay site, the Ochopee Limestone is separated from the Lehigh Acres Sandstone by the Cape Coral clay. Where this separation occurs, there are two distinct aquifers termed Tamiami Aquifer System-Zone I (Ochopee) and Tamiami Aquifer System-Zone II (Lehigh Acres) as proposed by Missimer (1978). These aquifers have unique potentiometric surfaces, differing water qualities, and differing hydraulic characteristics. At Bonita Bay, the two aquifers merge into a single aquifer with no significant separation and therefore, the full aquifer is termed Tamiami Aquifer System-Zone I. The base of the aquifer is formed by clays in the basal members of the Tamiami Formation.

Confining Beds Between Tamiami Aquifer System-Zone I and Hawthorn Aquifer System-Zone I

A section of low permeability clays in the Green Meadows clay and Fort Myers Clay Members of the Tamiami Formation form the confining strata between Tamiami-Zone I and the saline-water in Hawthorn-Zone I. The composite thickness of the confining beds ranges from 30 to 50 feet.

The lime muds, particularly in the Green Meadows clay, are quite dense and have a very low permeability in comparison to even the Bonita Springs Marl (Figure 5-19).

Hawthorn Aquifer System-Zone I

Hawthorn Aquifer System-Zone I lies within a permeable limestone in the upper 20 feet of the Hawthorn Formation. It is a relatively thin aquifer, which is confined from underlying zones by a dense dolomitic mud. Little is known about the regional correlation of this particular unit, which could be equivalent to the "upper Hawthorn aquifer" of northwest Lee County.

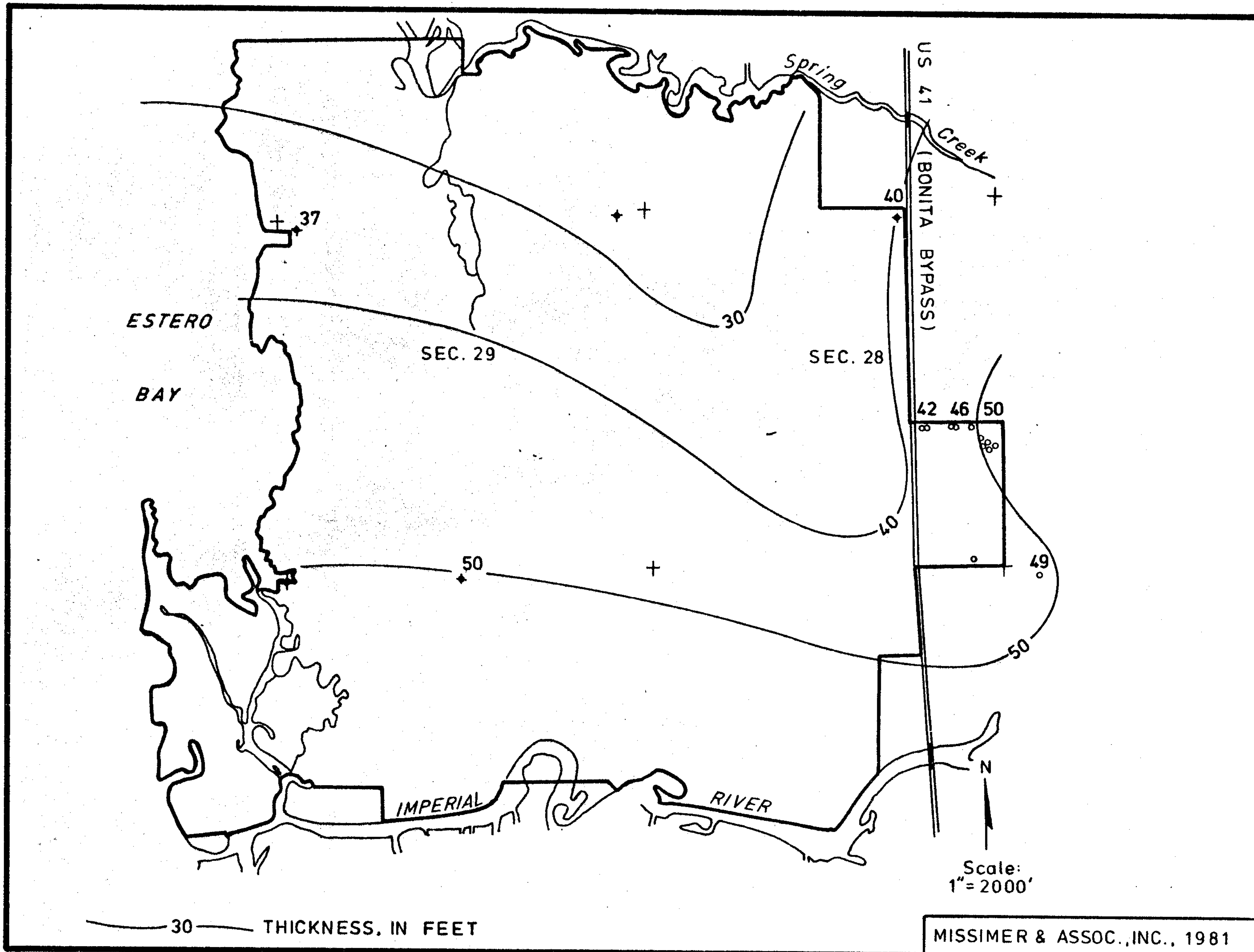

FIGURE 5-19. MAP SHOWING THICKNESS OF CONFINING BEDS BETWEEN TAMIAMI AQUIFER SYSTEM-ZONE I AND HAWTHORN AQUIFER SYSTEM-ZONE I.

3. Aquifer Characteristics

The aquifer system beneath the proposed wellfield site is both geologically and hydraulically complex. Determination of the hydraulic properties of the three usable aquifers underlying the site, therefore, requires the following information: 1) detailed geologic data, 2) aquifer test data, and 3) water level data. The geologic information and aquifer delineation has been presented in Sections 5.1 and 5.2 and the water level data is presented in Section 5.4 of the report.

There are four basic types of aquifers according to the Dutch definitions (Kruseman and DeRidder, 1970). The types are defined on the basis of the degree of confinement and are: 1) unconfined aquifers, 2) semi-unconfined aquifers, 3) semi-confined aquifers, and 4) confined aquifers. Of the three aquifers studied and tested, the water-table aquifer is semi-unconfined, and both Tamiami Aquifer System-Zone I and Hawthorn Aquifer System-Zone I are semi-confined.

Semi-unconfined aquifers occur where there is no significant obstruction to the vertical flow of water from land surface to the aquifer base. When a semi-unconfined aquifer is pumped, water moves vertically into the wellbore, but the aquifer is stratified to a certain degree. The stratification causes the decline of the water table to be delayed as water is moving horizontally from more permeable zones into the wellbore. When the pressure reduction is sufficient to allow the vertical movement, the water table begins to decline as it did initially. In order to properly assess the effects of pumping a semi-unconfined aquifer, it is necessary to determine three hydraulic coefficients: the transmissivity, an early storage coefficient (artesian), and a later storage coefficient known as the specific yield.

Semi-confined aquifers occur where continuous beds of low permeability bound the aquifer both above and below it and confine it from the atmosphere and other aquifers. Although the aquifer is fully confined, water can still move vertically through the confining beds. When a semi-confined aquifer is pumped, water is withdrawn not only from the aquifer, but also from and through the adjacent confining beds. Since pumping reduces the pressure in the aquifer, groundwater in the confining beds moves vertically into the aquifer. In long term pumping of a semi-confined aquifer, an equilibrium between the discharge rate of the pump and the recharge rate through the confining beds will occur. In order to properly assess the effects of pumping a semi-confined aquifer, it is necessary to determine three hydraulic coefficients from aquifer test data. These coefficients are:

Transmissivity (T)	-	The ability of an aquifer to transmit water, reported in gallons/day/foot (gpd/ft)

Storage Coefficient (S) - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head, reported as a dimensionless number.

Leakance (k'/b') - The effective permeability of a confining bed divided by the thickness of the confining bed, reported in gallons/day/cubic foot/ (gpd/ft^3).

Water-Table Aquifer

A preliminary and a primary aquifer test were conducted on the water-table aquifer. An initial step-drawdown test was made on test-production well L-M-1684. Five 60-minute steps were completed with pump discharge rates set at 150 gpm, 250 gpm, 350 gpm, 450 gpm, and 520 gpm (Table A-18). The corresponding specific capacities for each step were: 130 gpm/ft, 119 gpm/ft, 113 gpm/ft, 107 gpm/ft, and 102 gpm/ft. From this initial testing, the discharge rate for the primary aquifer test was set at 340 gpm.

An aquifer performance test was conducted on the water-table aquifer with continuous pumping for a period of 9 hours, after which a heavy rainfall caused termination of the test. A complete description of the test procedure and set-up is given in Section 3.3

Drawdown in test-production well L-M-1684 was still increasing at the time of test termination. After 540 minutes of pumping at 340 gpm, it had a specific capacity of 96.9 gpm/ft. Drawdown data collected from the pumped well were not utilized to calculate aquifer coefficients because of efficiency considerations. Time and drawdown data for well L-M-1684 are given in Table A-19.

Drawdown of the water table was continuously recorded in four observation wells, L-M-1683, L-M-1685, L-M-1681, and L-M-1690, which were located 40 feet, 82 feet, 140 feet, and 250 feet respectively from the production well. Water levels were tape measured in another water-table aquifer well, L-M-1678, and in a Tamiami-Zone I well, L-M-1682A. Time and drawdown data for these 6 wells are given in Tables A-20 to A-25.

Geologic information collected from test holes drilled through the aquifer show that the system is unconfined or semi-unconfined. The aquifer reacted to pumping as a semi-unconfined aquifer, which showed some delayed yield. Analysis of the pumping test data was performed by utilizing the general method of Boulton (1954; 1963) as modified by Prickett (1965). Log plots of time vs. drawdown were made for all four of the primary observation wells and were compared to the appropriate Prickett type curves (see Figures 5-20 to 5-23). It should be noted that the early drawdown data from well L-M-1681, approximately the first 10 minutes, fall below the type curve. This is probably caused by well construction, as this well penetrates only the upper part of the aquifer and the lower vertical permeability of the formation material may have dampened the drawdown rate.

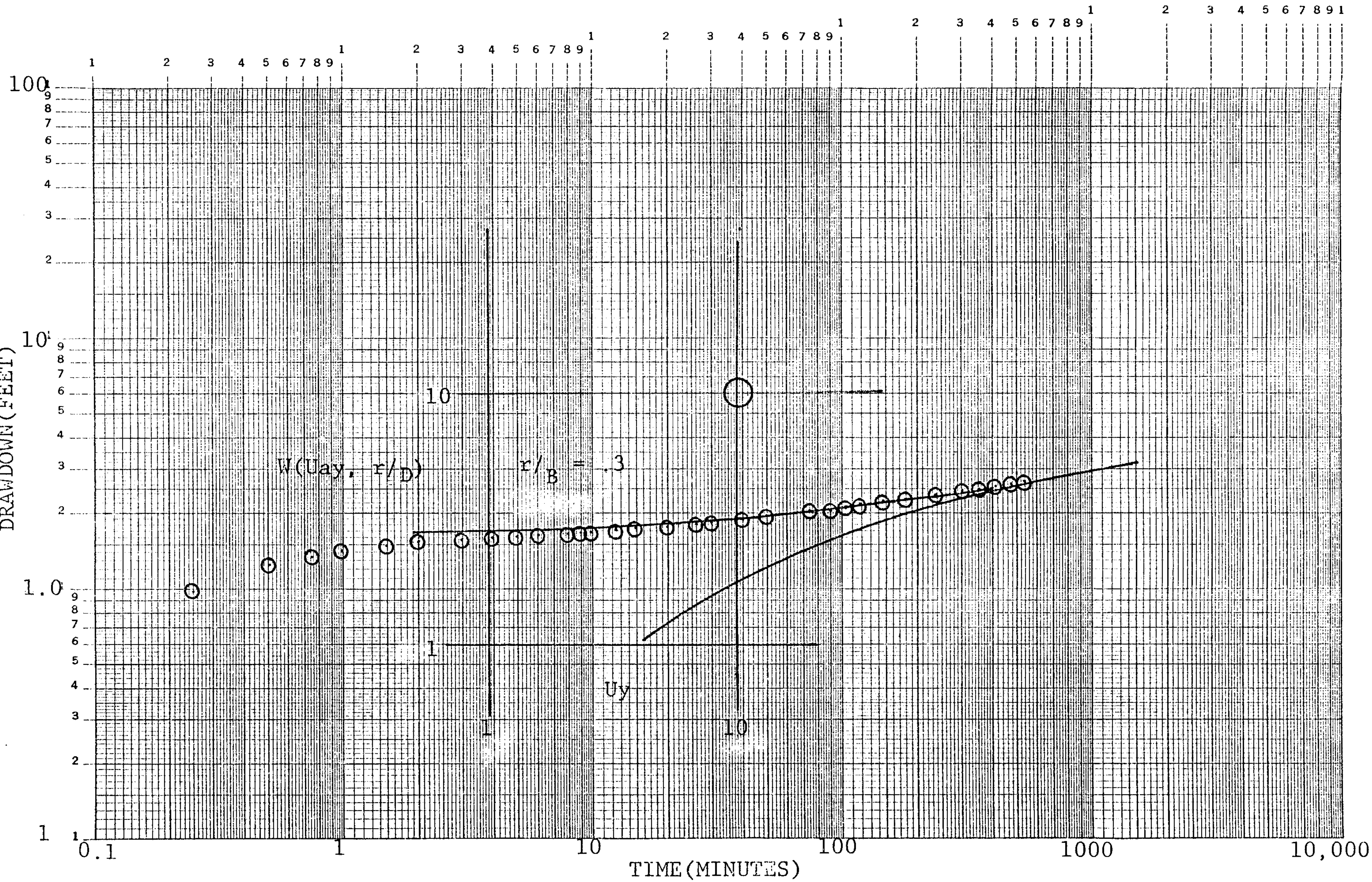

FIGURE 5-20. LOG-LOG PLOT OF DRAWDOWN VS. TIME FOR WELL 1683 AND COMPARISON TO APPROPRIATE BOULTON TYPE CURVE.

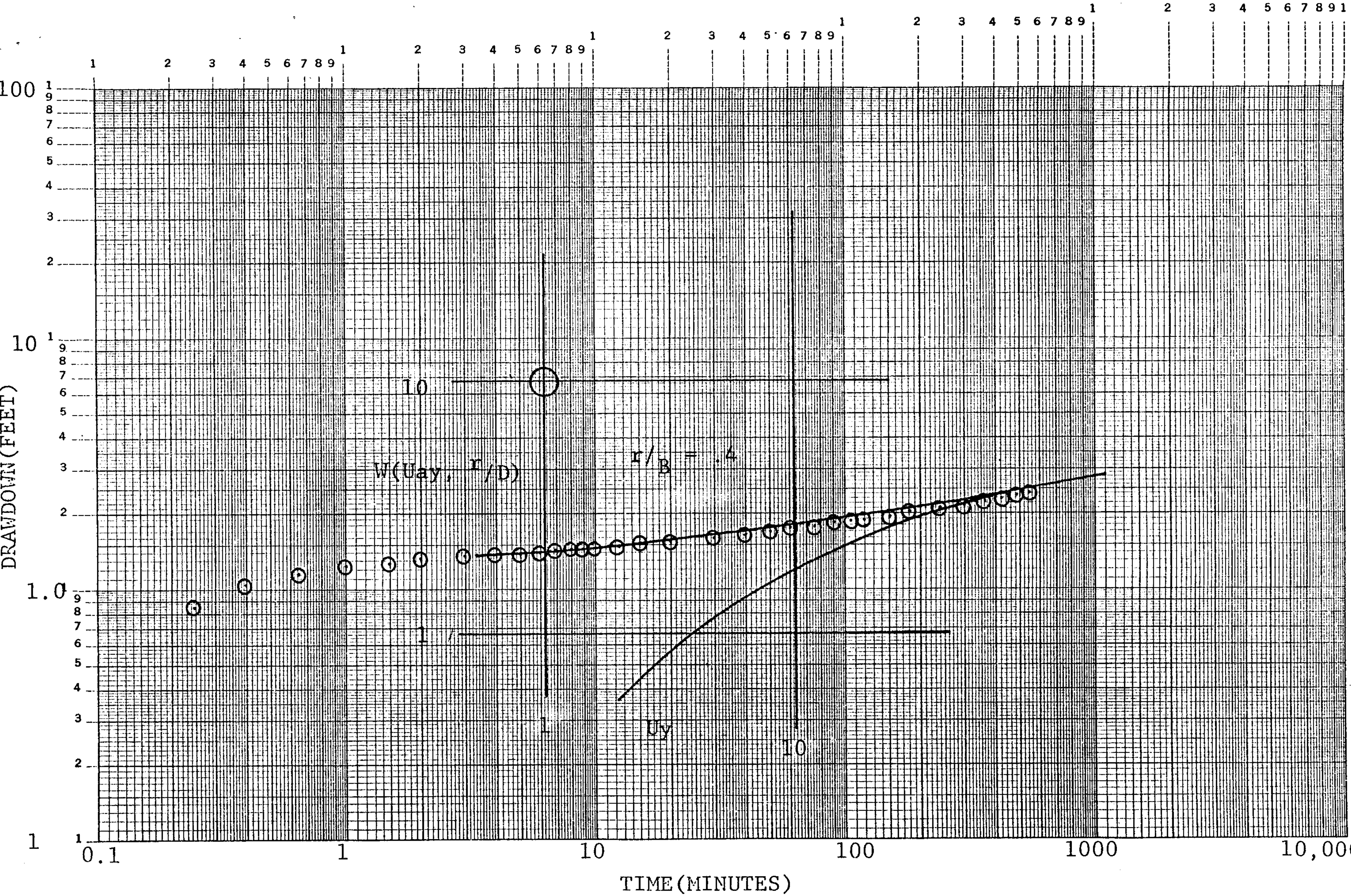

FIGURE 5-21. LOG-LOG PLOT OF DRAWDOWN VS. TIME FOR WELL 1685 AND COMPARISON TO APPROPRIATE BOULTON TYPE CURVE.

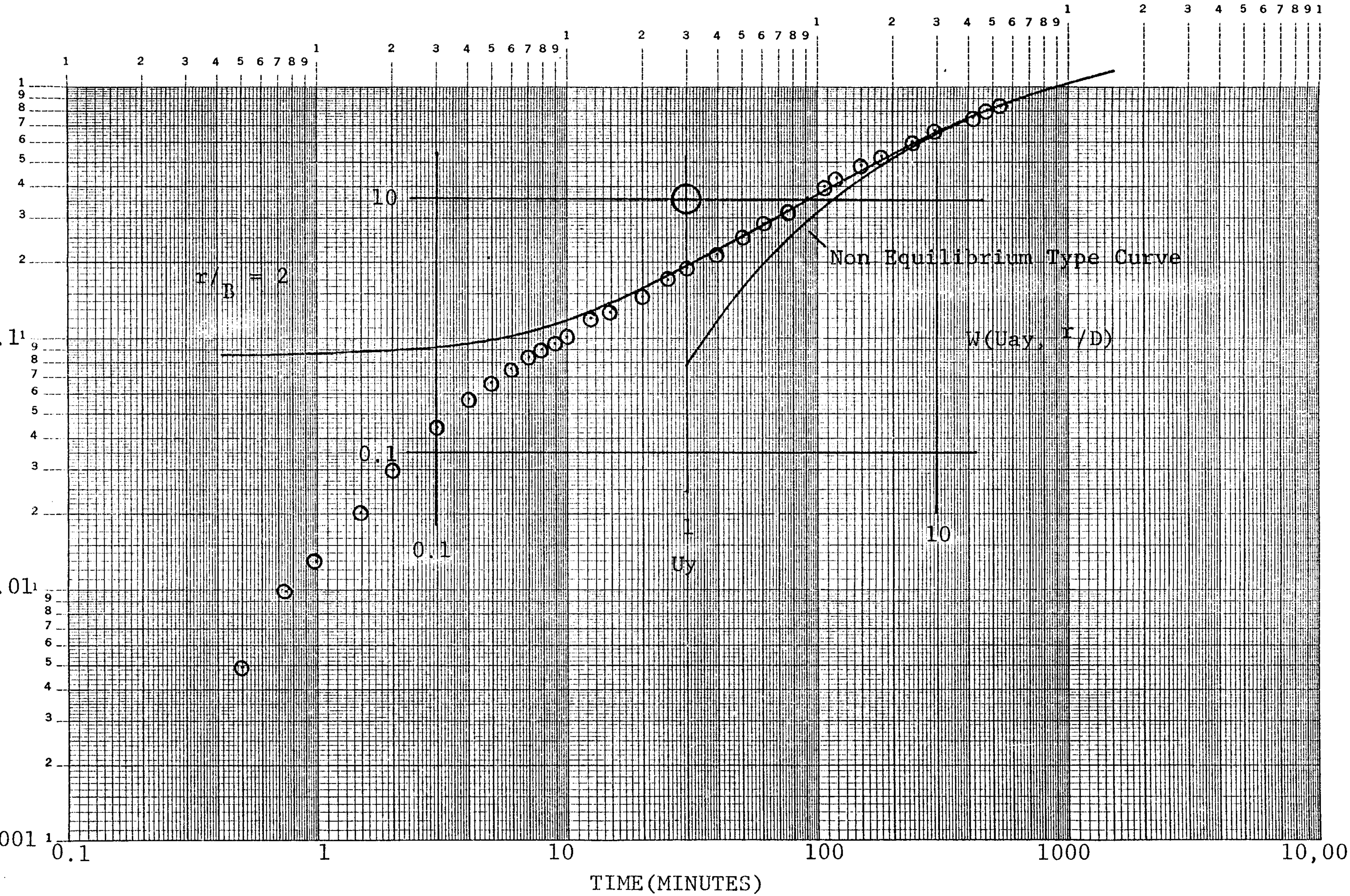

FIGURE 5-22. LOG-LOG PLOT OF DRAWDOWN VS. TIME FOR WELL 1681 AND COMPARISON TO APPROPRIATE BOULTON TYPE CURVE.

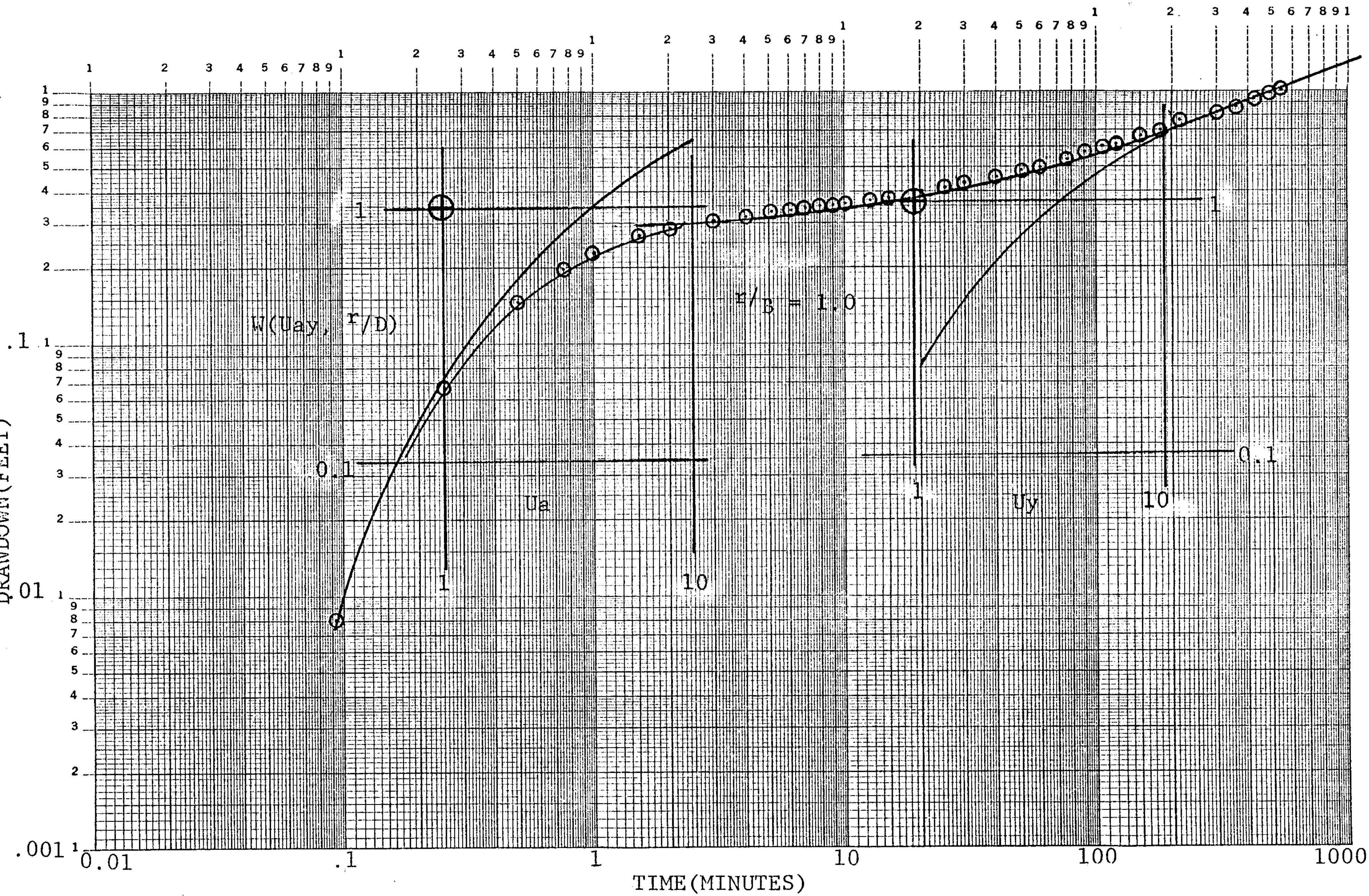

FIGURE 5-23. LOG-LOG PLOT OF DRAWDOWN VS. TIME FOR WELL 1690 AND COMPARISON TO APPROPRIATE BOULTON TYPE CURVE.

The match points between the observed and type curves were substituted into the following equations:

$$T = \frac{114.6\ Q\ W(U_{ay},\ {}^{r}/D)}{s} \qquad (1)$$

$$S_a = \frac{U_a\ Tt}{1.87\ \ r^2} \qquad (2)$$

$$S_y = \frac{U_y\ Tt}{1.87\ \ r^2} \qquad (3)$$

where,

T = transmissivity, in gpd/ft

Q = discharge, in gpm

$W\ (U_{ay}, {}^{r}/D)$ = Prickett curve function

S = drawdown, in feet

S_a = storage coefficient (early)

S_y = storage coefficient (late)

U_a, U_y = Prickett curve function

t = time, in days

r = distance from pumped well, in feet

The resultant aquifer coefficients given in Table 5-2 were calculated by substituting the match point data into equations 1, 2 and 3.

A Jacob distance-drawdown analysis was performed using

TABLE 5-2. AQUIFER COEFFICIENTS CALCULATED FOR THE WATER-TABLE AQUIFER

Boulton Method

Early Data

Well No.	Transmissivity(gpd/ft)	Sa
L-M-1683	65,000	3.6×10^{-4}
L-M-1685	67,000	1.0×10^{-4}
L-M-1681	---	---
L-M-1690	110,000	1.0×10^{-4}

Late Data

Well No.	Transmissivity(gpd/ft)	Sy	Delay Index(min.)	Drainage Factor(gpd/ft^3)
L-M-1683	65,000	.057	22	3.6
L-M-1685	67,000	.023	14	1.5
L-M-1681	108,000	.061	4	2.2
L-M-1690	110,000	.012	10	1.7

Jacob Distance-Drawdown Method

Transmissivity(gpd/ft)	Specific Yield
65,000	0.05

the drawdowns at all four primary observation wells after 540 minutes of pumping. Delayed yield at this point in the test has ceased to effect the drawdown and, therefore, analysis by this method is valid for the existing conditions. The distance-drawdown plots for both the north-south and east-west alignments of observation wells are given in Figure 5-24. The result from the distance drawdown plot is considered to be the most reliable analysis of the site and, therefore, the coefficients to be used for modelling are:

Transmissivity = 65,000 gpd/ft

Specific Yield = 0.05

The coefficients listed above are conservative estimates and could be considered to be higher. Because the production and observation wells tap only the limestone section of the aquifer, the specific yield value of 0.05 may not reflect the character of the full aquifer thickness. A closer number including the sand section is 0.15, which is more typical of unconfined aquifers.

An analysis of well efficiency of the production well was made by utilizing the technique of Jacob (1947) as modified by Rorabough (1953). A plot of drawdown divided by discharge vs. discharge was made to determine both well losses and formation losses. The graphically determined coefficients were substituted into the following equations:

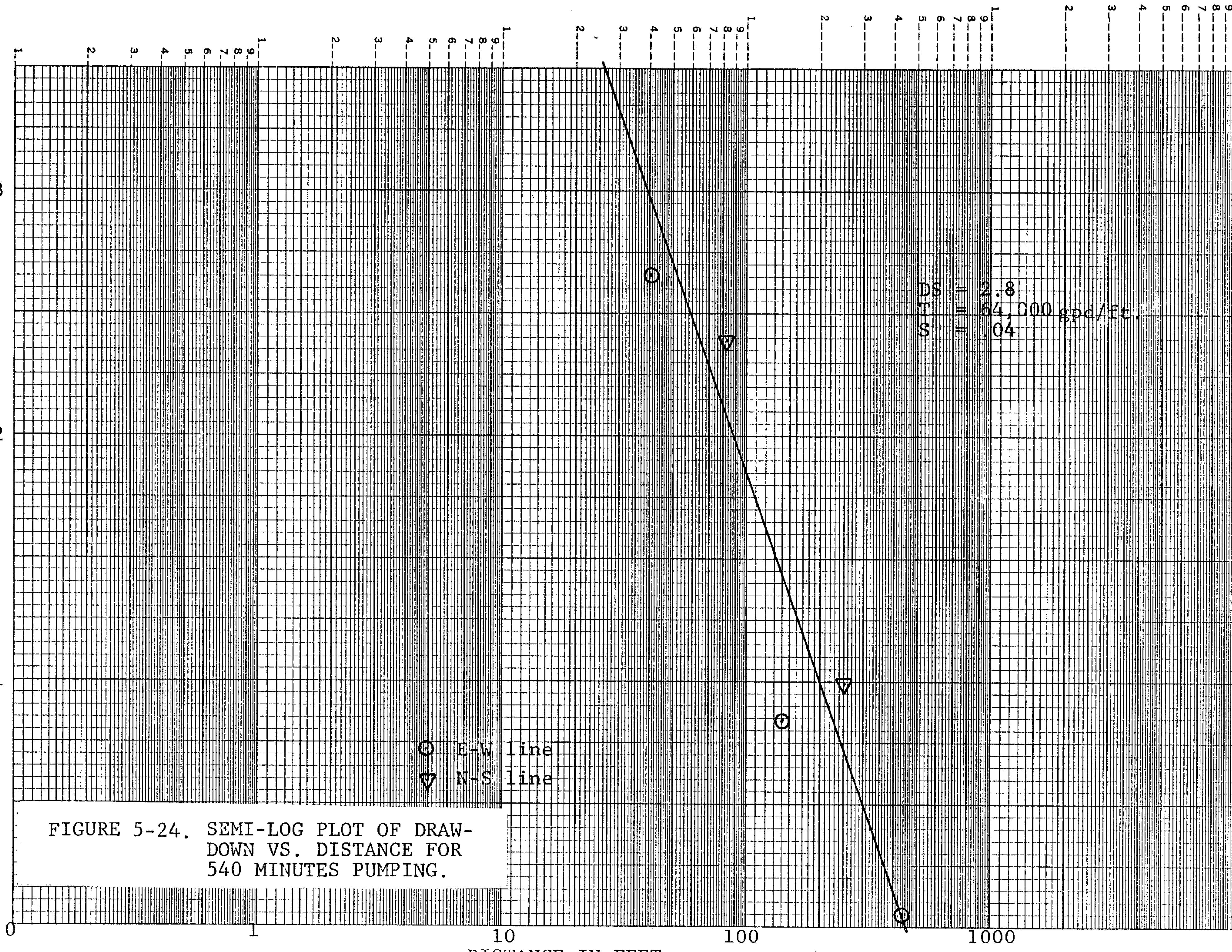

FIGURE 5-24. SEMI-LOG PLOT OF DRAWDOWN VS. DISTANCE FOR 540 MINUTES PUMPING.

$$E = \frac{BQ}{S_w} \times 100\% \qquad (4)$$

$$S = BQ + CQ^2 \qquad (5)$$

where,

E = efficiency as a percent

Q = discharge, in gpm

S_w = drawdown, in feet

BQ = formation losses, in feet

CQ^2 = well losses, in feet

The analysis yielded well efficiences ranging from 90.4% to 70.6% depending on the discharge rate (Table 5-3). When the drawdowns in the pumped well were compared to the theoretical drawdowns calculated from the aquifer coefficients, it was found that the transmissivity in the vicinity of the production well is much higher than the average value. The transmissivity near the production well is probably close to 200,000 gpd/ft, but is not representative of the aquifer as a whole.

Tamiami Aquifer System-Zone I

A preliminary and a primary aquifer test were conducted on Tamiami Aquifer System-Zone I. An initial step-drawdown test was completed on test-production well L-M-1682A during

TABLE 5-3. CALCULATED EFFICIENCIES FOR WELL L-M-1684 BY THE JACOB METHOD.

Q(gpm)	Sw(ft)	Sw/Q	BQ(ft)	CQ^2(ft)	E
150	1.15	0.0077	1.0395	0.1222	90.4%
250	2.10	0.0084	1.7325	0.3394	82.5%
350	3.10	0.00886	2.4255	0.6652	78.2%
450	4.20	0.0933	3.1185	1.0996	74.2%
520	5.10	0.00981	3.6036	1.4683	70.6%

$C = 5.43 \times 10^{-6}$ $B = 0.00693$

which pump discharge rates were set at 600 gpm, 700 gpm, 800 gpm, and 900 gpm (Table A-26) The corresponding specific capacities for each step were: 24 gpm/ft, 23 gpm/ft, 22 gpm/ft, and 21 gpm/ft. A fifth step was not completed due to pump difficulties. From this initial testing, the pump discharge rate for the primary test was set at 400 gpm. This lower rate was used because of the difficulty in managing the discharged water at a higher rate.

An aquifer performance test was conducted on Tamiami Aquifer System-Zone I with continuous pumping for 22 plus hours, at which time the test was terminated because of pump failure. The test was restarted several days later at a higher pump discharge rate of 576 gpm. A complete description of the aquifer test set-up and procedure is given in Section 3.3.

Drawdown in test-production well L-M-1682A was near stability at the termination of the second test at 72 hours. It had a specific capacity of about 22.6 gpm/ft. Drawdown data from the production well were not utilized to calculate aquifer coefficients because of efficiency considerations. Time and drawdown data for well L-M-1682A for both the 440 and 576 gpm pumping rates are given respectively in Tables A-27 and A-28.

Drawdown of the Tamiami-Zone I potentiometric surface was continuously recorded in four observation wells, L-M-1680, L-M-1679, L-M-1677, and L-M-1676, which were located 135.6 feet, 220 feet, 470 feet, and 1125 feet respectively from the production well. Water levels were also tape-measured in two other Tamiami-Zone I observation wells, L-M-1644 and L-M-1649, and 3 water-table aquifer observation wells, L-M-1684, L-M-1683, and L-M-1681. Recovery data were collected from numerous wells upon termination of the 72-hour test at 576 gpm. Time and drawdown data for both tests of Tamiami Aquifer System-Zone I are given in Tables A-29 to A-50.

Preliminary analyses of the time and drawdown data from all of the Tamiami-Zone I observation wells were made by utilizing the straight line method of Jacob (Cooper and Jacob, 1946; Jacob, 1950). Data from the three closest observation wells were given emphasis. Semi-log plots of drawdown vs. time show the departure of the data points from the theoretical Theis Curve. This departure is indicative of leakage of water into the aquifer from and through adjacent confining beds. The data for the first aquifer test, conducted at a pumping rate of 440 gpm, are shown in Figure 5-25. These plots are consistent on the Theis Curve until the data departs from the curve at between 100 and 120 minutes into the test (Figure 5-25). The time and drawdown data for the test at a pumping rate of 576 gpm showed a similar departure from the Theis Curve (Figure 5-26). However, during the later part of the test, distant pumping from the aquifer caused an irregular fluctuation of water levels. A Jacob analysis was performed on each set of data by

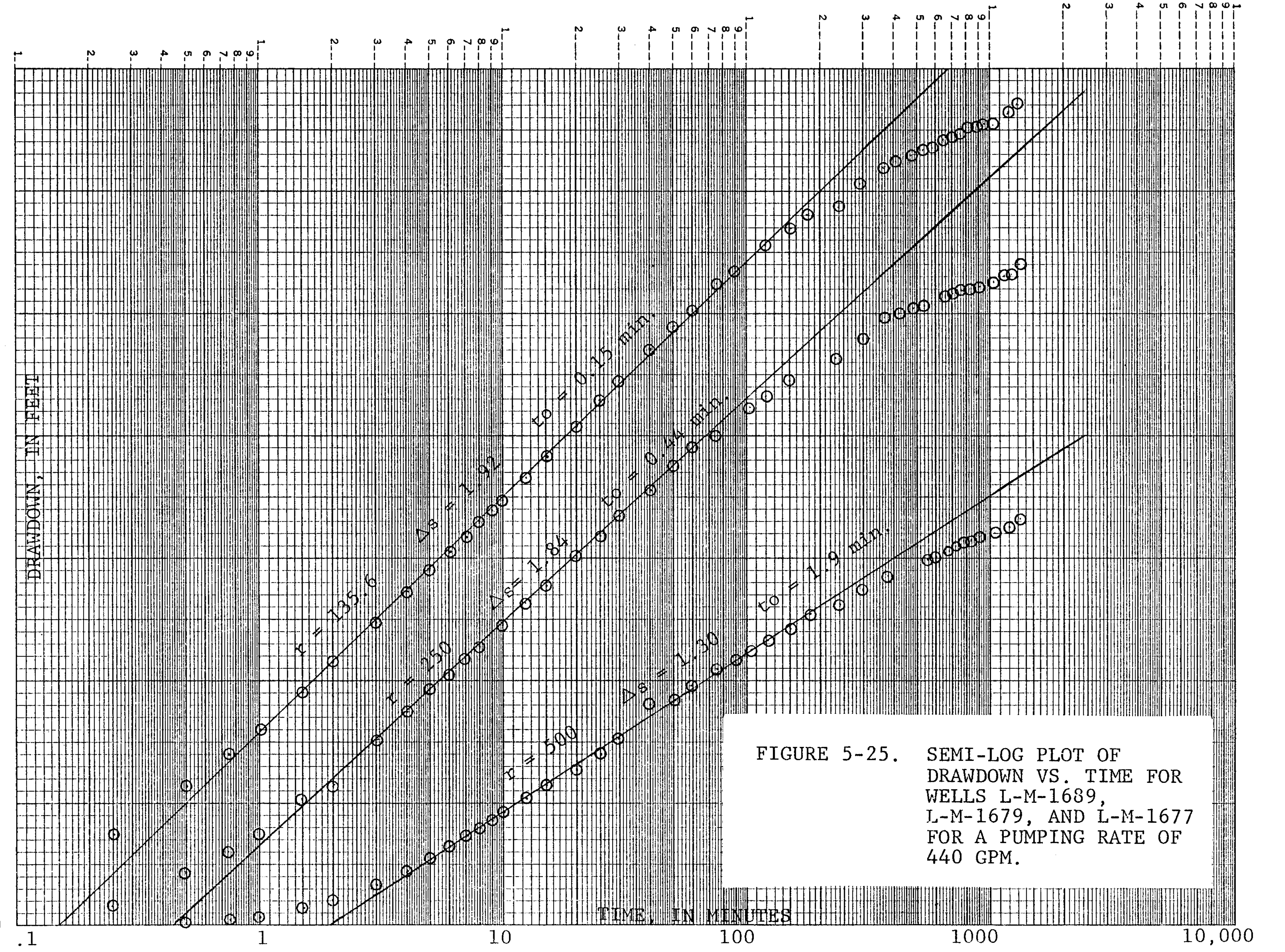

FIGURE 5-25. SEMI-LOG PLOT OF DRAWDOWN VS. TIME FOR WELLS L-M-1689, L-M-1679, AND L-M-1677 FOR A PUMPING RATE OF 440 GPM.

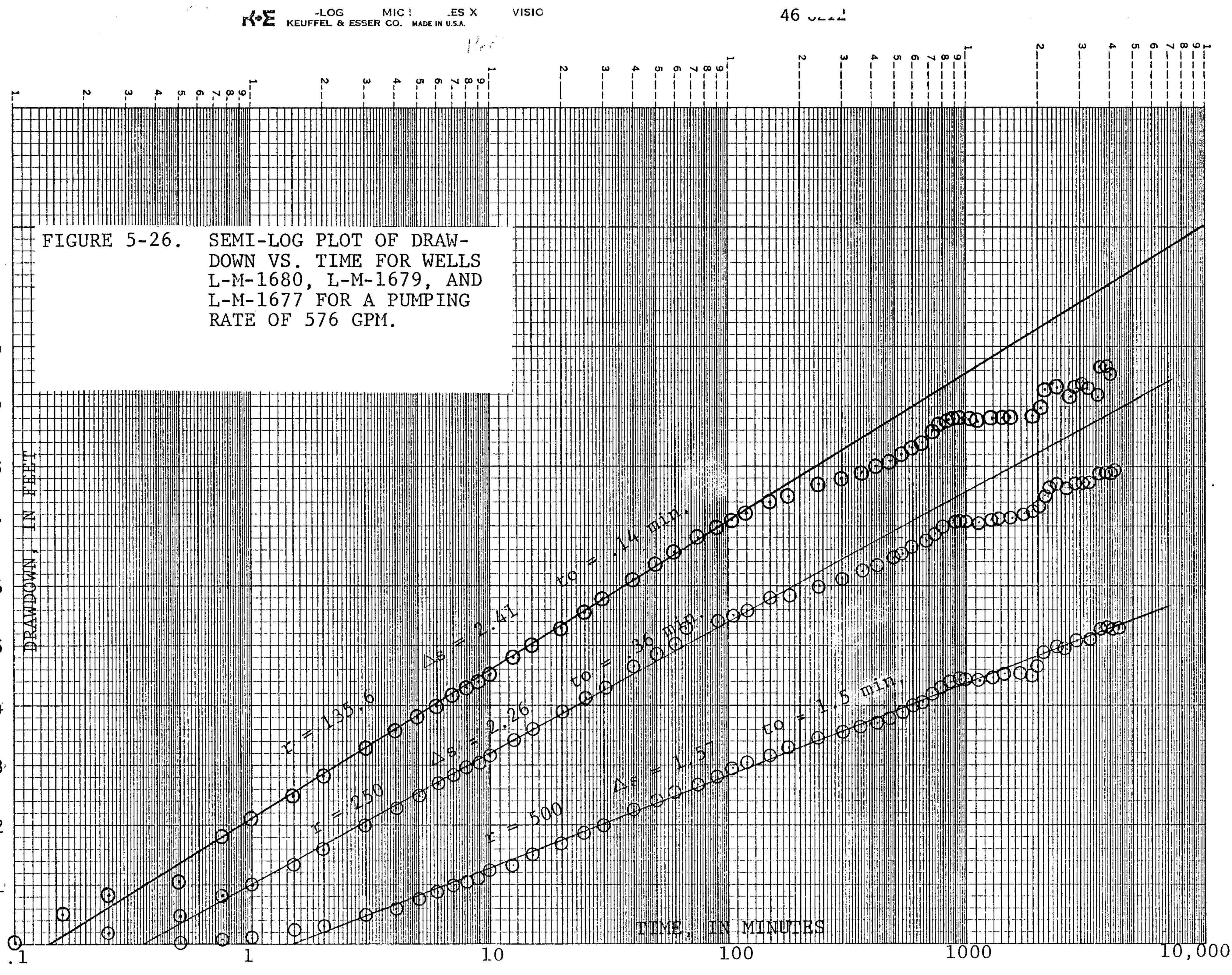

FIGURE 5-26. SEMI-LOG PLOT OF DRAWDOWN VS. TIME FOR WELLS L-M-1680, L-M-1679, AND L-M-1677 FOR A PUMPING RATE OF 576 GPM.

substituting the information obtained from Figures 5-25 and 5-26 into the following equations:

$$T = \frac{264\ Q}{\Delta s} \qquad (6)$$

$$S = \frac{0.3T\ to}{r^2} \qquad (7)$$

where,

T = transmissivity, in gpd/ft

Q = discharge, in gpm

Δs = drawdown between log cycles, in feet

S = storage coefficient, dimensionless

to = intercept time, in days

r = distance from pumped well, in feet

The Jacob analyses yielded a range in transmissivity from 60,500 to 92,000 gpd/ft and storage coefficient values ranged from 8.1×10^{-5} to 1.3×10^{-4}. Jacob analyses on some of the other Zone I observation wells yielded higher values of transmissivity, but these analyses are not considered reliable due to the large distance between the production well and the individual observation wells.

Previous aquifer tests conducted on Tamiami Aquifer System-Zone I in the general vicinity, see Section 3.4, suggest that it reacts to pumpage as a semi-confined aquifer.

The s ls presented previously in this Section confirms this assumption. When log plots of time vs. drawdown were compared to the Hantush-Jacob type-curves for semi-confined aquifers (Jacob, 1950; Hantush, 1956; 1960; Lohman, 1979), very good matches were obtained (see Figures 5-27 to 5-32). Two complete sets of data are presented because of the shortness of the first test at 440 gpm and the pumping interference which occurred during the second test. The match points between each observed curve and the corresponding type curve were substituted into the following equations as presented by Lohman (1979):

$$T = \frac{Q\,L(u,v)}{4\pi s} \qquad (8)$$

$$S = \frac{4T\,t/r^2}{1/u} \qquad (9)$$

$$k'/b' = \frac{4\,T\,v^2}{r^2} \qquad (10)$$

where,

T = transmissivity, in ft^2/day

Q = discharge, in ft^3/day

$L(u,v)$ = Hantush Curve function

s = drawdown, in feet

S = storage coefficient, dimensionless

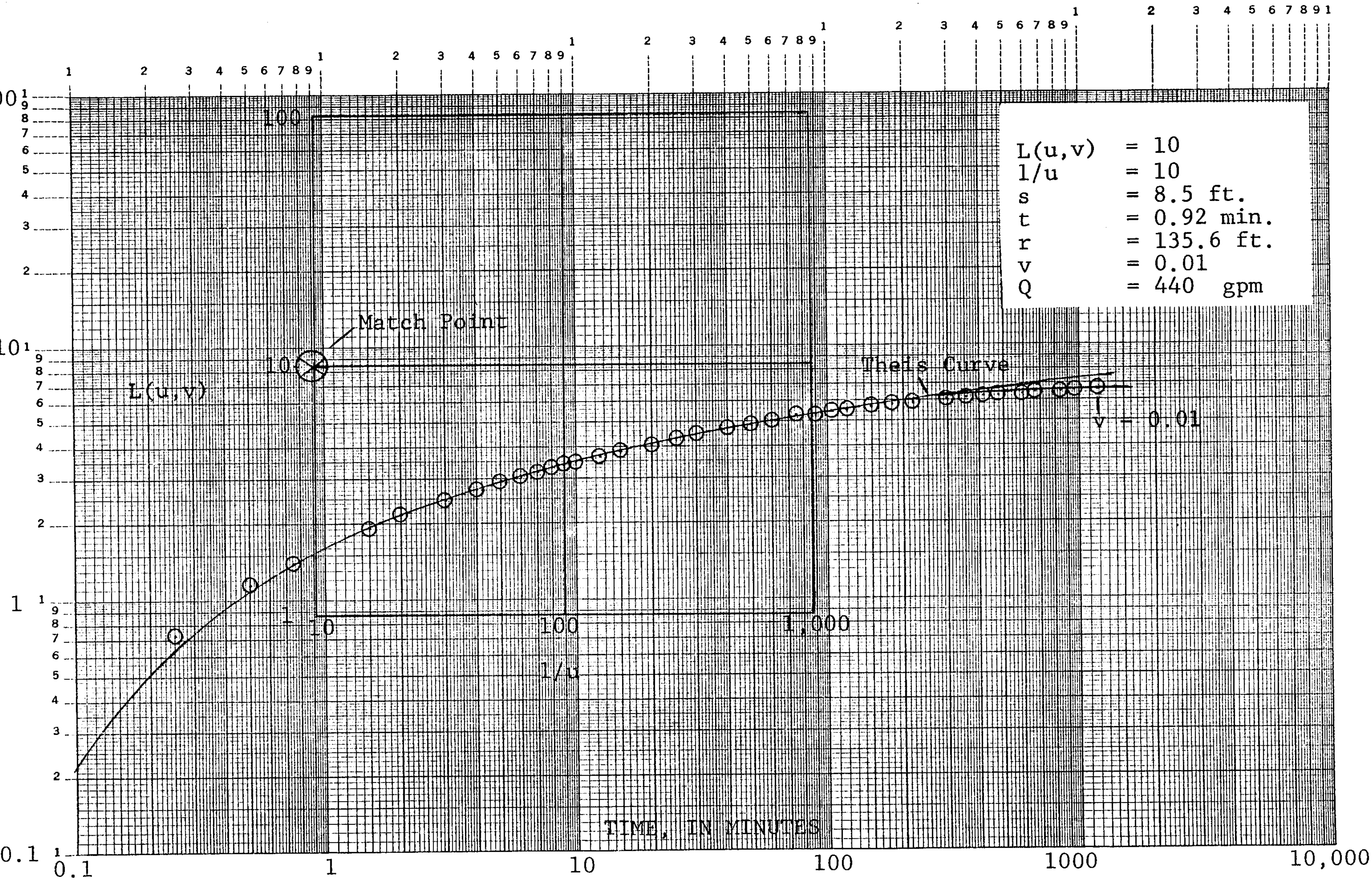

FIGURE 5-27. LOG PLOT OF DRAWDOWN VS. TIME FOR WELL L-M-1680 AND A COMPARISON TO THE APPROPRIATE HANTUSH-JACOB TYPE CURVE (Q = 440 GPM).

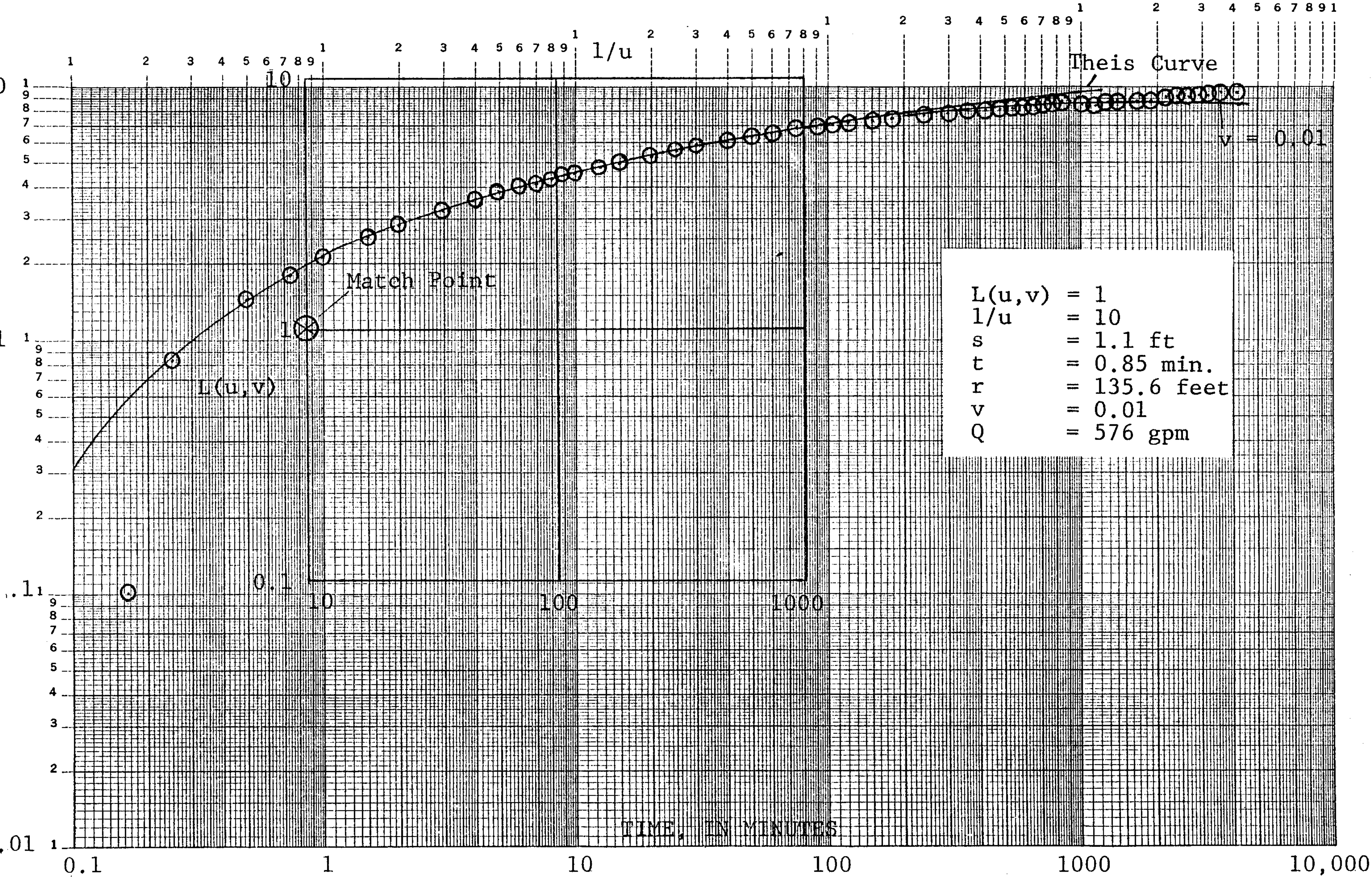

FIGURE 5-28. LOG PLOT OF DRAWDOWN VS. TIME FOR WELL L-M-1680 AND A COMPARISON TO THE APPROPRIATE HANTUSH-JACOB TYPE CURVE (Q = 576 GPM).

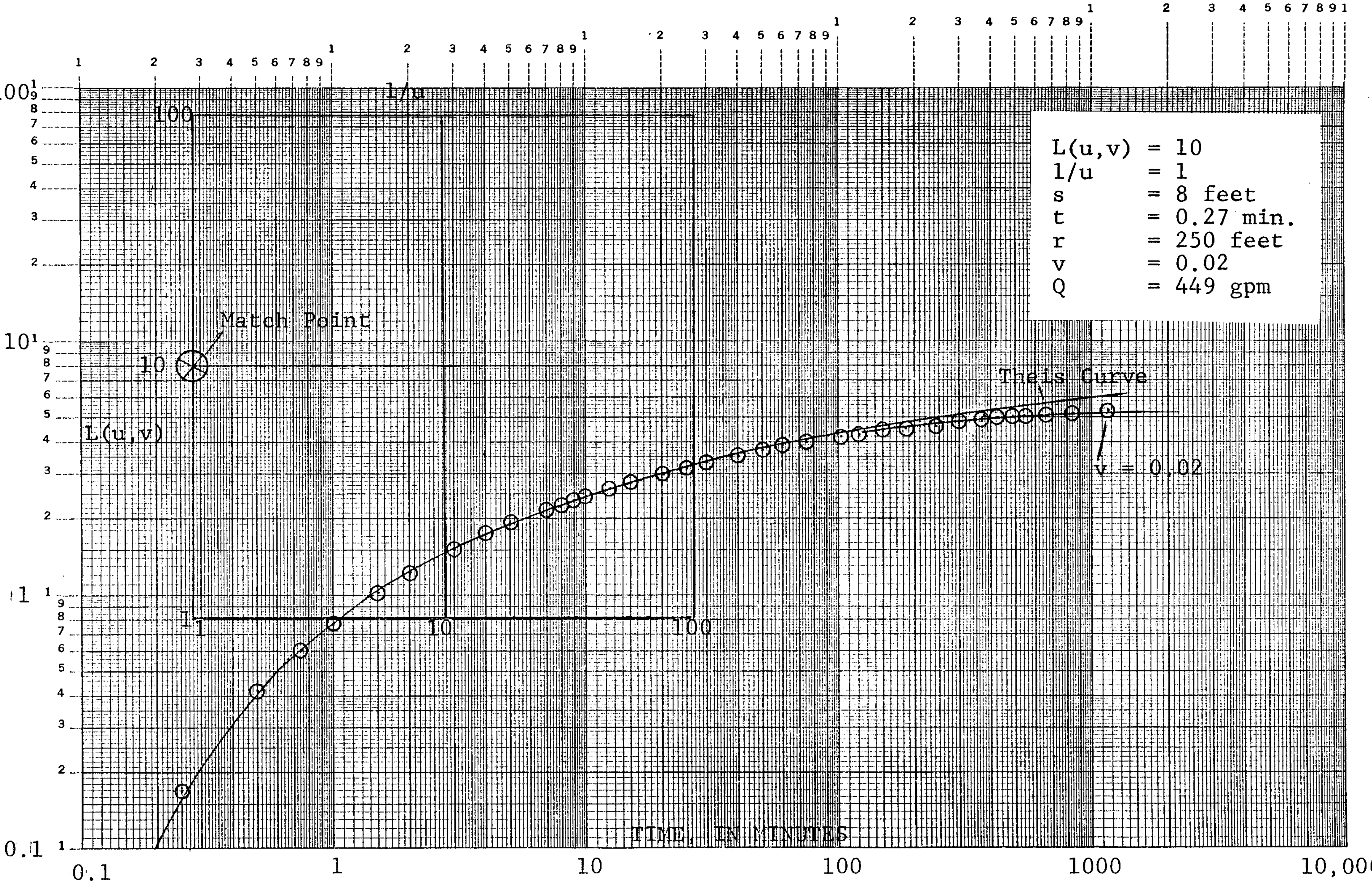

FIGURE 5-29. LOG PLOT OF DRAWDOWN VS. TIME FOR WELL L-M-1679 AND A COMPARISON TO THE APPROPRIATE HANTUSH-JACOB TYPE CURVE (Q = 440 GPM).

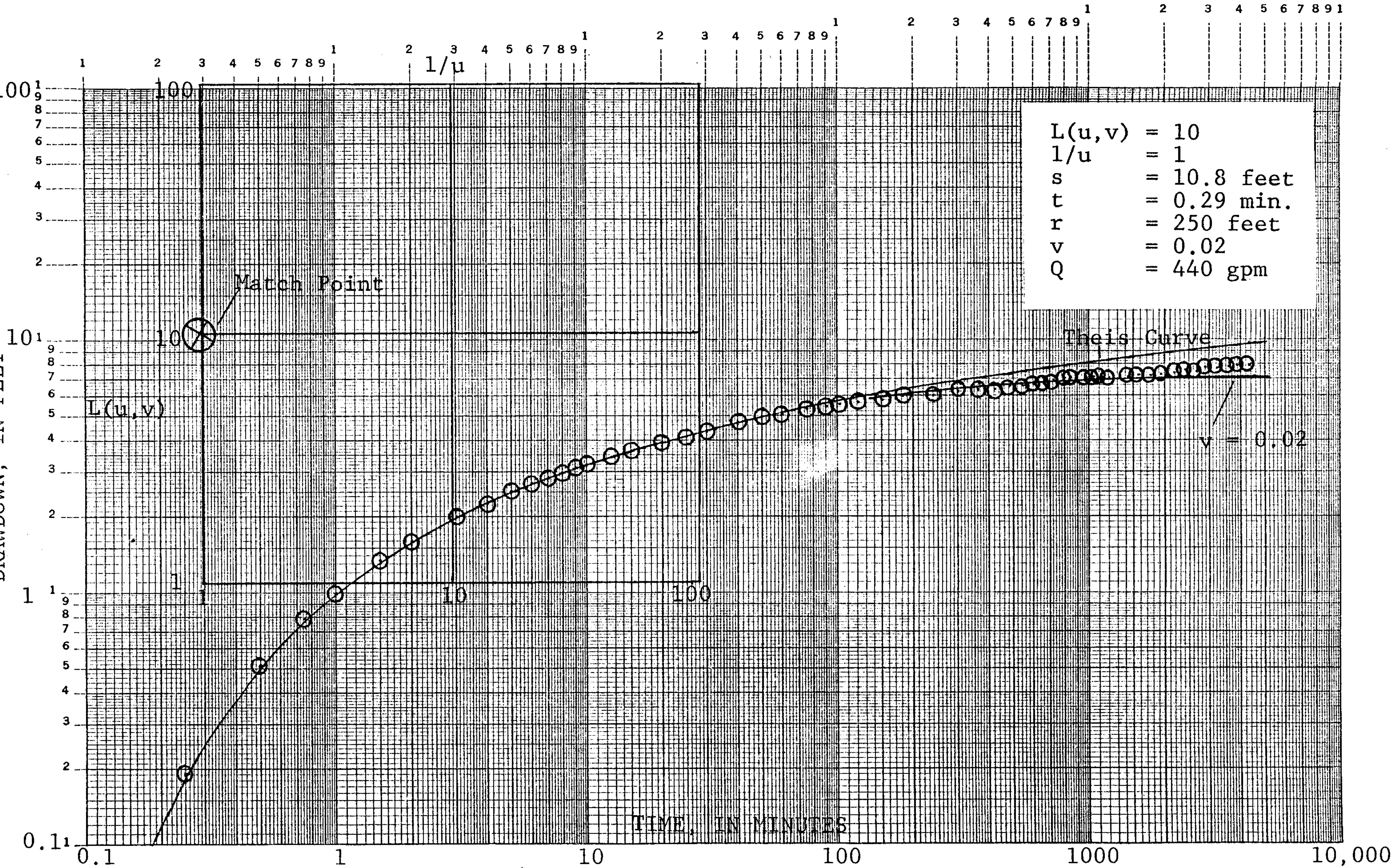

FIGURE 5-30. LOG PLOT OF DRAWDOWN VS. TIME FOR WELL L-M-1679 AND A COMPARISON TO THE APPROPRIATE HANTUSH-JACOB TYPE CURVE (Q = 576 GPM).

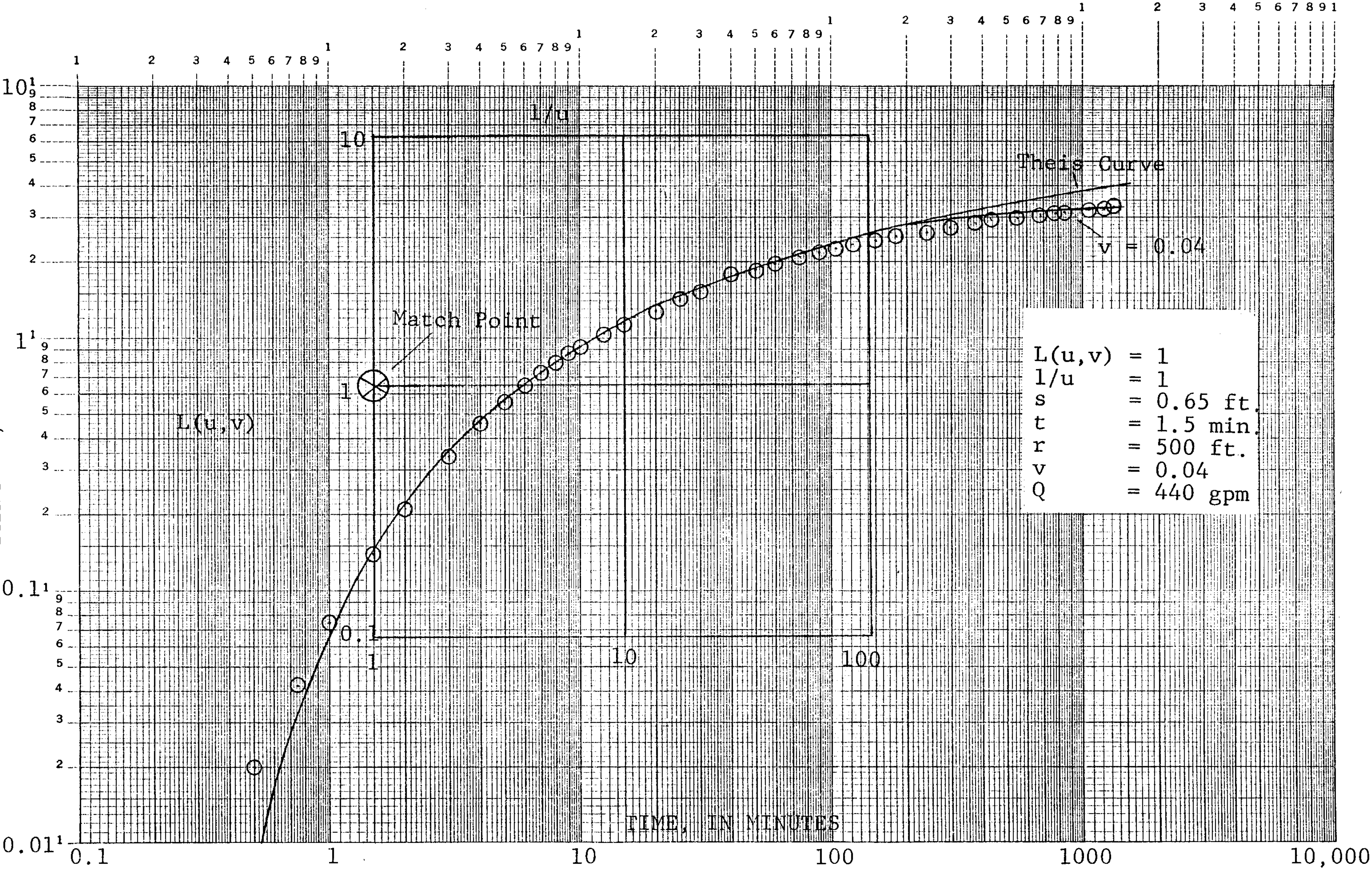

FIGURE 5-31. LOG PLOT OF DRAWDOWN VS. TIME FOR WELL L-M-1677 AND A COMPARISON TO THE APPROPRIATE HANTUSH-JACOB TYPE CURVE (Q - 440 GPM).

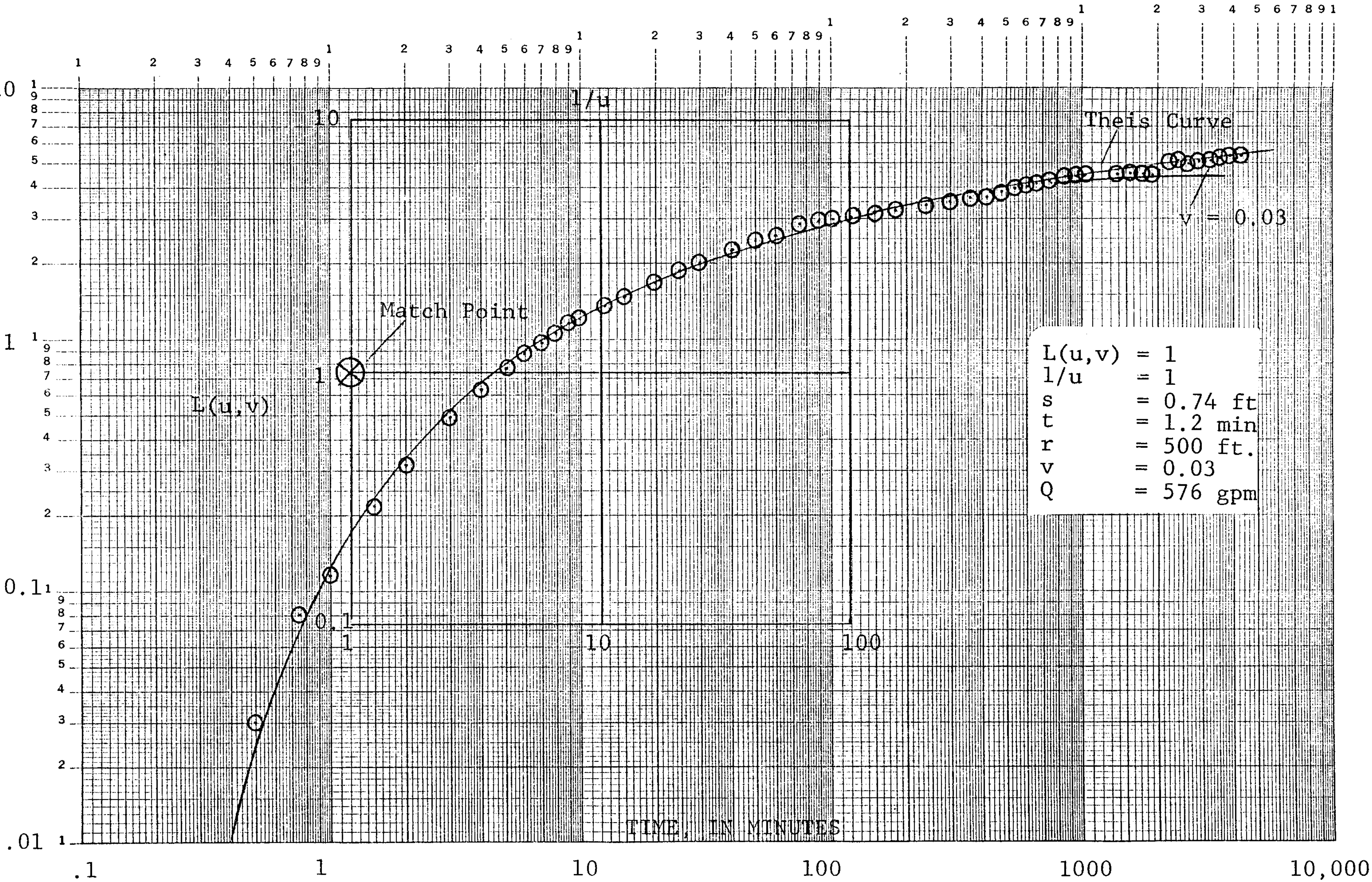

FIGURE 5-32. LOT PLOT OF DRAWDOWN VS. TIME FOR WELL L-M-1677 AND A COMPARISON OF THE APPROPRIATE HANTUSH-JACOB TYPE CURVE (Q = 576 GPM).

u = Hantush curve function

t = time, in days

r = distance from pumped well, in ft.

k' = vertical permeability of confining beds, in ft/day

b' = thickness of confining strata, in ft.

k'/b' = leakance, in 1/days

v = Hantush curve function

unit conversions

$(7.48\ g/ft^3)(ft^2/day) = 1\ gpd/ft$

$(7.48\ g/ft^3)(1/days) = 1\ gpd/ft^3$

A comparison of the aquifer coefficients obtained from the three primary observation wells is given in Table 5-4. Transmissivity values ranged from 59,000 to 89,000 gpd/ft. The differences between values determined for each test on the same well vary between 1.7 and 12% and the range of the difference increases as the distance from the production well becomes greater. The differences in transmissivities calculated for each well by the two different analysis methods were less than 10% in each case.

Several attempts were made to perform a distance-drawdown analysis to determine Tamiami-Zone I hydraulic coefficients. These analyses yielded unrealistic numbers, because the aquifer characteristics change considerably in an east-west direction. As shown in Figure 5-33, the

TABLE 5-4. AQUIFER COEFFICIENTS CALCULATED FOR TAMIAMI AQUIFER SYSTEM-ZONE I USING VARIOUS ANALYSIS METHODS.

Analysis Method	Transmissivity (gpd/ft)	Storage Coefficient	Leakance (gpd/ft^3)
Well L-M-1680 at Q = 440 gpm			
Jacob	60,500	1×10^{-4}	---
Hantush-Jacob	59,000	1×10^{-4}	1.2×10^{-3}
Well L-M-1680 at Q = 576 gpm			
Jacob	60,800	9.6×10^{-5}	--
Hantush-Jacob	60,000	1×10^{-4}	1.3×10^{-3}
Well L-M-1679 at Q = 440 gpm			
Jacob	63,000	9.2×10^{-5}	--
Hantush-Jacob	63,000	1×10^{-4}	1.6×10^{-3}
Well L-M-1679 at Q = 576 gpm			
Jacob	67,000	8.1×10^{-5}	--
Hantush-Jacob	61,000	1×10^{-4}	1.6×10^{-3}
Well L-M-1677 at Q = 440 gpm			
Jacob	84,000	1.3×10^{-4}	--
Hantush-Jacob	78,000	1.7×10^{-4}	2×10^{-3}
Well L-M-1677 at Q = 576 gpm			
Jacob	92,000	1.2×10^{-4}	--
Hantush-Jacob	89,000	1.6×10^{-4}	1.3×10^{-3}

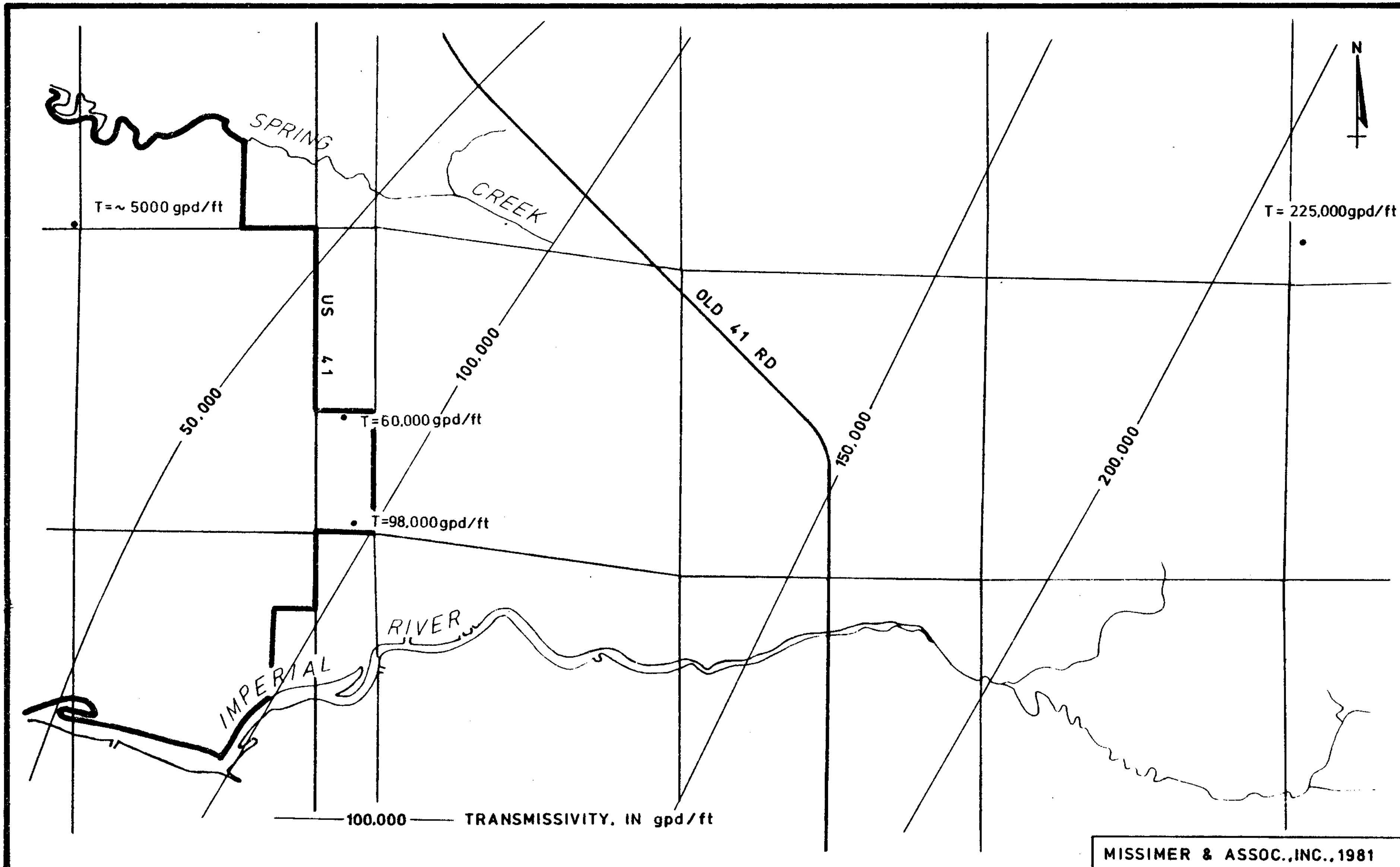

FIGURE 5-33 MAP SHOWING THE TRANSMISSIVITY OF THE TAMIAMI AQUIFER SYSTEM - ZONE I, NEAR BONITA BAY.

transmissivity of Zone I in the northwest part of the site is near 5,000 gpd/ft compared to 60,000 gpd/ft on the north side of the utility site to 225,000 gpd/ft 3 miles east of the project in the Bonita Springs Wellfield.

After careful analysis of the data collected, the most accurate aquifer coefficients determined for Bonita Bay are:

$$T = 60{,}000 \text{ gpd/ft}$$

$$S = 1 \times 10^{-4}$$

$$^{k'}/b' = 1.3 \times 10^{-3} \text{ gpd/ft}^3$$

An analysis of the efficiency of production well L-M-1682A was made by utilizing the technique previously discussed (Jacob, 1947). A plot of drawdown divided by discharge vs. discharge was made to determine both well losses and formation losses. The graphically determined coefficients were substituted into equations 4 and 5. This analysis yielded coefficients ranging from 71.2% to 62.2% depending on the discharge rate (Table 5-5).

Hawthorn Aquifer System-Zone I

Both preliminary and primary aquifer tests were conducted on Hawthorn Aquifer System-Zone I. An initial step-drawdown test was made on test-production well L-M-1720.

TABLE 5-5. CALCULATED EFFICIENCIES FOR WELL L-M-1682A BY THE JACOB METHOD.

Q(gpm)	Sw(ft)	Sw/Q	BQ(ft)	CQ^2(ft)	E
600	25.10	0.04183	17.88	6.84	71.2%
700	30.60	0.04371	20.86	9.31	68.2%
800	36.35	0.04544	23.84	12.16	65.6%
900	43.1	0.04789	26.82	15.39	62.2%

$B = 0.0298$ $C = 1.9 \times 10^{-5}$

Four steps were completed to an approximate steady-state condition with pump discharge rates set at 380 gpm, 446 gpm, 508 gpm, and 560 gpm (Table A-51). The corresponding specific capacities for each step were: 21 gpm/ft, 20 gpm/ft, 18 gpm/ft, and 16.5 gpm/ft. After completing this test, the pump discharge rate was set at 400 gpm.

An aquifer performance test was conducted on Hawthorn Aquifer System-Zone I with continuous pumping for a period of 28 hours. The test was terminated because of the unusual reaction of the aquifer to pumping. A complete description of the test procedure and set-up is given in Section 3.3.

Drawdown in test-production well L-M-1720 had not stabilized at the termination of the test. After 1,655 minutes of pumping, the well had a specific capacity of 18.4 gpm/ft. The drawdown data collected from the pumped well were not further utilized for calculation of aquifer co-efficients because of efficiency considerations. Time and drawdown data for well L-M-1720 are given in Table A-52.

Drawdown of the Hawthorn-Zone I potentiometric surface was continuously recorded in three observation wells, L-M-1718, L-M-1719, and L-M-1675, which were located 304 feet, 752 feet, and 2,850 feet respectively from the production well. Time and drawdown data for these wells are given in Tables A-53 to A-55. Recovery data were also recorded and are given in Tables A-56 to A-58.

A preliminary analysis of the time and drawdown data was made by utilizing the straight line method of Jacob (Cooper and Jacob, 1946; Jacob, 1950). Semi-log plots for the three observation wells showed a close match to the Theis Curve during the first 40 minutes of the test and then the data departed above the curve. This departure is contrary to the normal behavior of semi-confined aquifers and was probably caused by the occurrence of a subsurface boundary. A Jacob analysis was performed on each set of data by substituting the information determined from the plots shown in Figure 5-34 into equations 6 and 7.

The Jacob analysis yielded transmissivities ranging from 88,000 to 123,000 gpd/ft and storage coefficients ranging from 4×10^{-5} to 9.5×10^{-4}. The analysis for well L-M-1675, which yielded the highest values, is questionable because of the long distance from the production well.

Aquifer performance tests conducted on Hawthorn Aquifer System-Zone I in other parts of Lee County suggests that it reacts as a "tight" semi-confined aquifer. When log plots of time vs. drawdown were compared to the Hantush-Jacob type curves for semi-confined aquifers, fair matches were obtained (Figures 5-35 and 5-36). Only plots of wells L-M-1718 and L-M-1719 were used and L-M-1675 was excluded because of the distance problem. The corresponding match points were substituted into equations 7, 8 and 9.

The aquifer coefficients calculated from these curve matches are given in Table 5-6. The transmissivity ranged

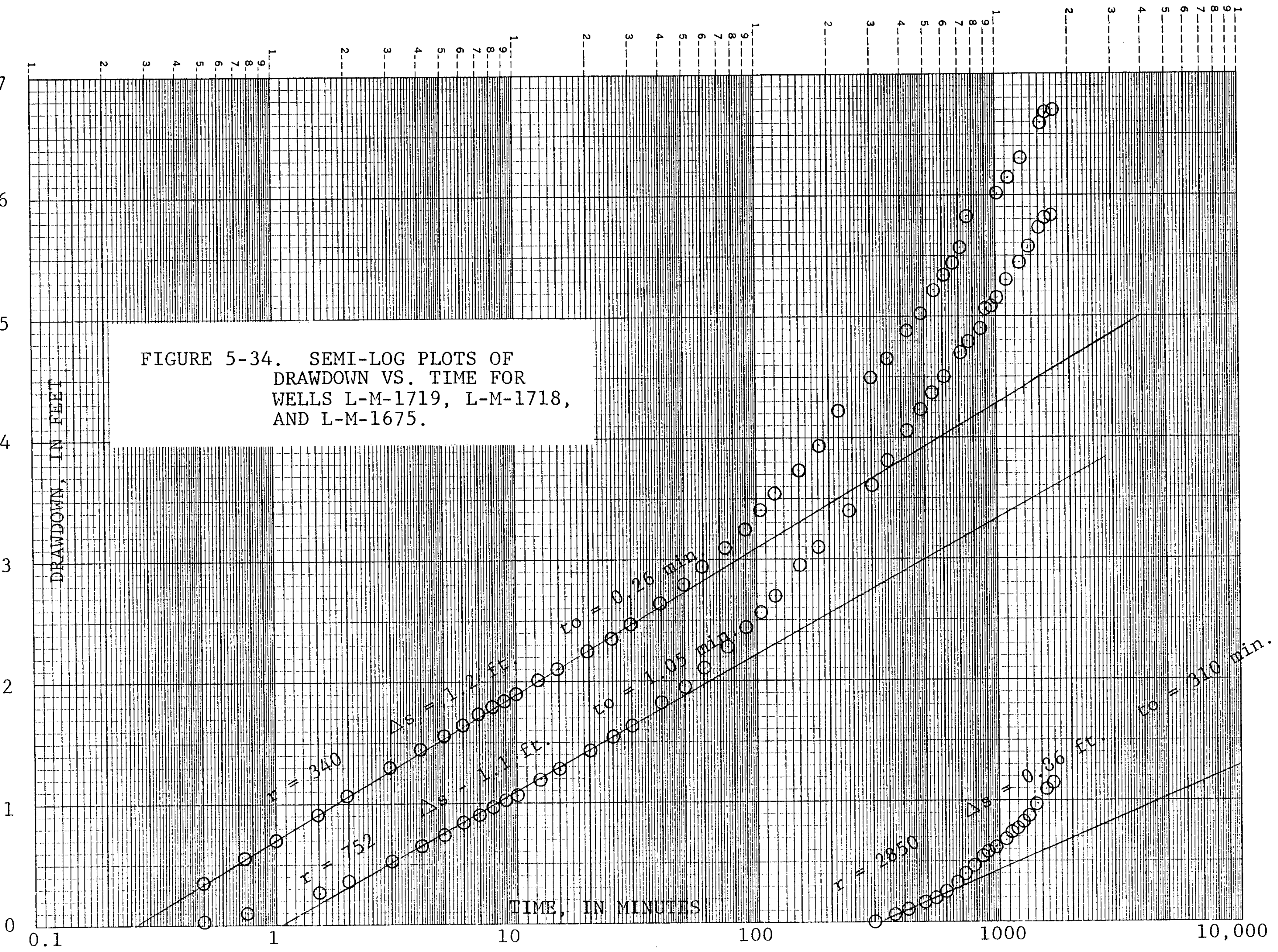

FIGURE 5-34. SEMI-LOG PLOTS OF DRAWDOWN VS. TIME FOR WELLS L-M-1719, L-M-1718, AND L-M-1675.

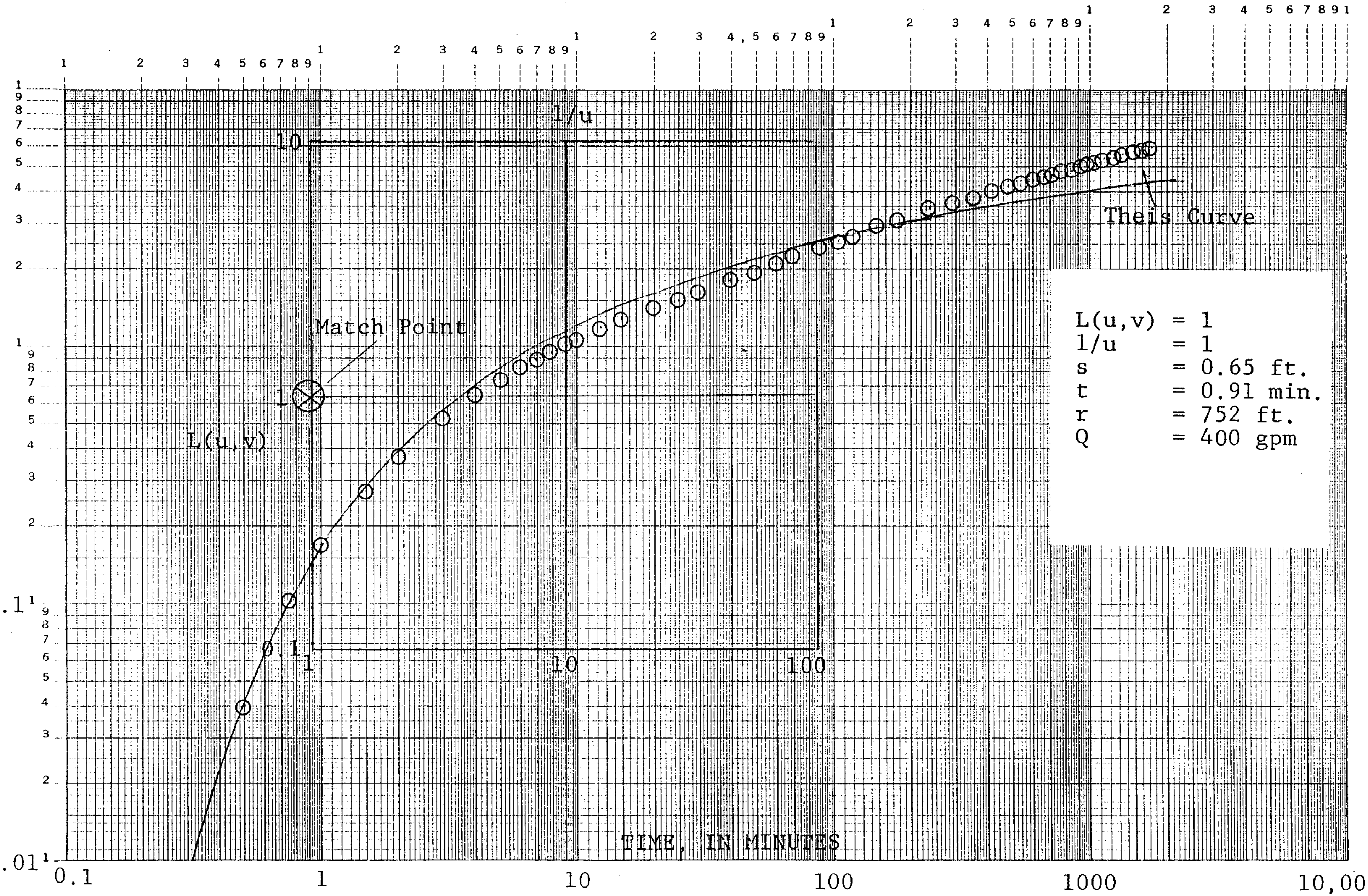

FIGURE 5-35. LOG PLOT OF DRAWDOWN VS. TIME FOR WELL L-M-1718 AND A COMPARISON TO THE APPROPRIATE HANTUSH-JACOB TYPE CURVE.

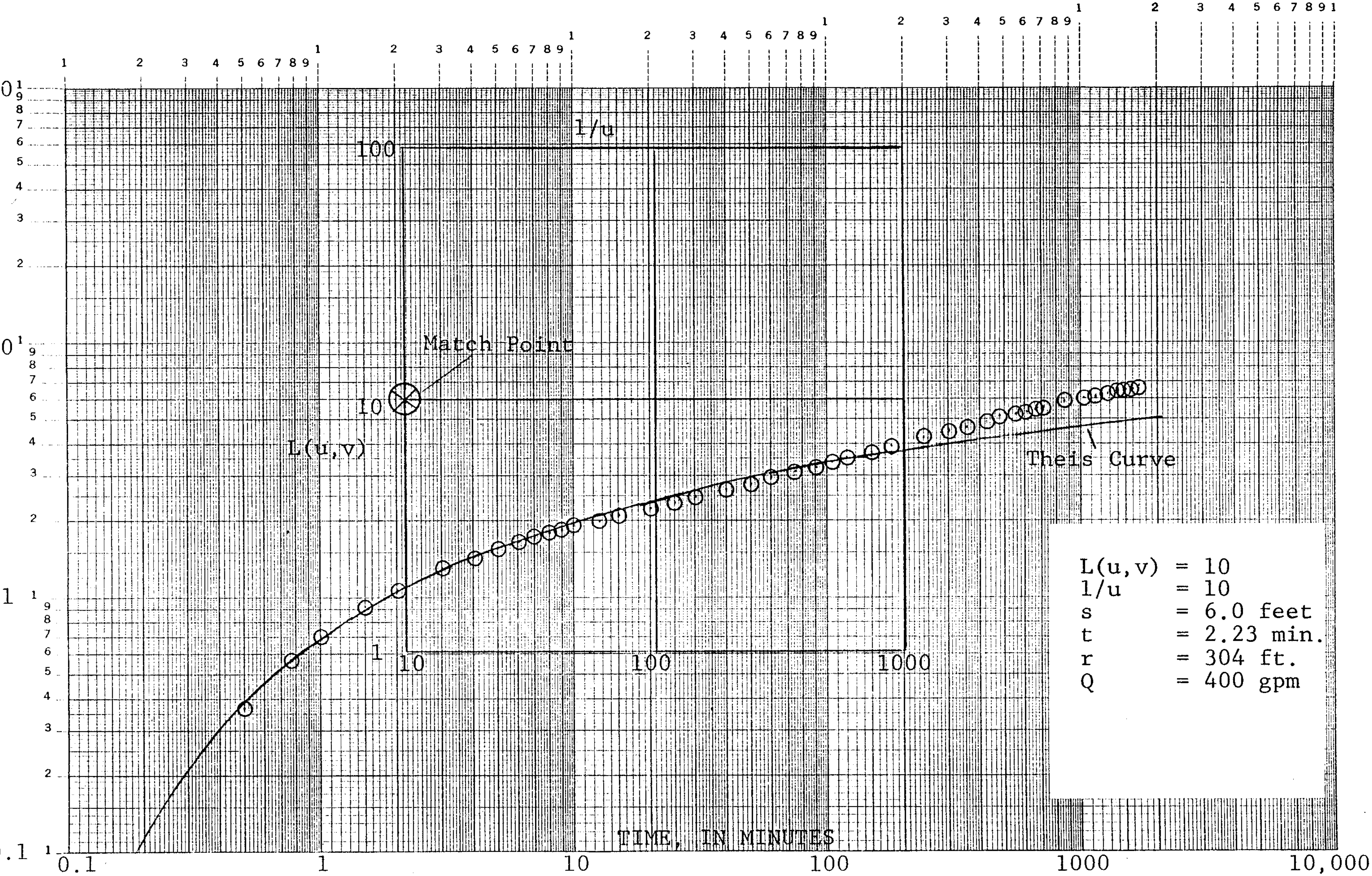

FIGURE 5-36. LOG PLOT OF DRAWDOWN VS. TIME FOR WELL L-M-1719 AND A COMPARISON TO THE APPROPRIATE HANTUSH-JACOB TYPE CURVE.

TABLE 5-6. AQUIFER COEFFICIENTS CALCULATED FOR HAWTHORN AQUIFER SYSTEM-ZONE I USING VARIOUS ANALYSIS METHODS.

Analysis Method	Transmissivity(gpd/ft)	Storage Coefficient	Leakance (gpd/ft^3)
Well L-M-1719			
1. Jacob	88,000	5.2×10^{-5}	
2. Hantush-Jacob	76,000	6.8×10^{-5}	
Well L-M-1718			
1. Jacob	96,000	4×10^{-5}	
2. Hantush-Jacob	70,000	4.2×10^{-5}	
Well L-M-1675			
1. Jacob	123,000	9.5×10^{-4}	

between 70,000 and 76,000 gpd/ft and the storage coefficient between 4.2×10^{-5} and 6.6×10^{-5}. It was not possible to evaluate for a leakance because of the curve match uncertainty caused by the inferred boundary problem. From previous aquifer tests in Lee County, we estimate that the leakance of this unit is 1×10^{-5} gpd/ft^3 or less. For the purpose of assessing the regional impacts of pumping from Hawthorn Aquifer System-Zone I, the following aquifer coefficients will be used:

Transmissivity	=	70,000 gpd/ft
Storage Coefficient	=	5×10^{-5}
Leakance	=	1×10^{-5} gpd/ft^3

An analysis of well efficiency of production well L-M-1720 was made by utilizing the technique of Jacob (1947). A plot of drawdown divided by discharge vs. discharge was made to determine both well losses and formation losses. The graphically determined coefficients were substituted into equations 4 and 5. The analysis yielded well efficiencies ranging from 38.5 to 29.7% depending on the discharge rate (Table 5-7). These values are very low, which is common for this analysis method on wells with a static head above land surface.

TABLE 5-7. CALCULATED EFFICIENCIES FOR WELL L-M-1720 BY THE JACOB METHOD

Q(gpm)	Sw(ft)	Sw/Q	BQ(ft)	CQ^2(ft)	E
380	17.77	0.04676	6.84	10.90	38.5%
446	22.00	0.04933	8.03	15.11	36.5%
508	28.45	0.05600	9.14	19.61	32.1%
560	33.95	0.06062	10.08	23.83	29.7%

$C = 7.6 \times 10^{-5}$ $B = 0.018$

4. Water Levels and Recharge

Water-Table Aquifer

Water levels in an unconfined aquifer fluctuate in direct response to recharge and discharge, which are controlled by climatic conditions, drainage, vegetation type, and pumping from wells. At Bonita Bay, the position of the water table is affected by only natural conditions and little drainage alterations have been made, such as the construction of ditches and canals. The position of the water table on the site is greatly affected by natural discharge from the aquifer to Spring Creek, the Imperial River, the central slough area, and Estero Bay.

A water table map, constructed from data collected on September 11, 1981, shows the effects of the discharge areas on the position of the water table (Figure 5-37). Hydraulic gradients are relatively steep. The water table fluctuates on a seasonal basis on the site between 1 and 5 feet depending on the land surface altitude and proximity to a discharge point. Figure 5-37 shows an approximate seasonal high water table position.

The Bonita Bay site receives recharge to the water-table aquifer both by rainfall and by lateral flow through the aquifer. Flow of water through the aquifer moves essentially from northeast to southwest with the distortions caused by the discharge areas. The volume of lateral recharge

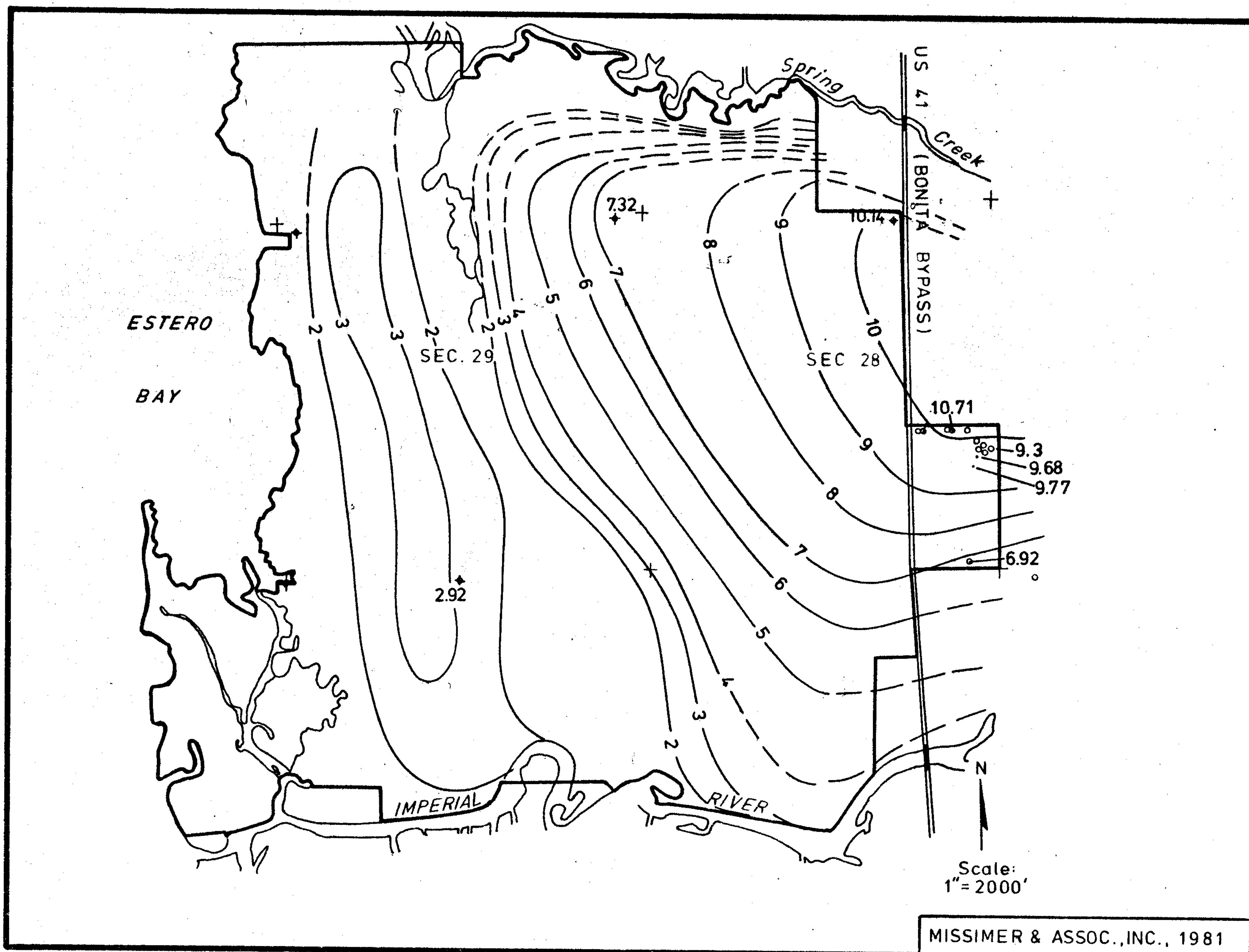

FIGURE 5-37. MAP SHOWING THE POTENTIOMETRIC SURFACE OF THE WATER TABLE AQUIFER ON SEPTEMBER 11, 1981.

was calculated by assuming a transmissivity of 65,000 gpd/ft and a hydraulic gradient of 4 feet/mile (from Figure 5-37). Two corridor widths were evaluated, which include the entire site at 8,000 feet and the east utility site at 2,000 feet. These values were substituted into the Darcy Equation listed below:

$$Q = TIL \qquad (11)$$

where,

Q = recharge, in gpd

T = transmissivity, in gpd/ft

I = hydraulic gradient, in ft/mile

L = length, in miles

On September 11, 1981, the horizontal recharge rate was about 0.39 MGD for the entire site and 0.1 MGD for the utility site.

Tamiami Aquifer System-Zone I

Tamiami Aquifer System-Zone I is confined from the overlying water-table aquifer by low permeability clays. The potentiometric surface of Tamiami-Zone I is a unique surface, which occurs at a different altitude compared to the water table. The Zone I potentiometric surface does respond to changes in position of the water table because of vertical loading. Seasonal fluctuations of the Zone I potentiometric surface range from 3 to 8 feet depending on proximity to centers of pumpage (see the hydrograph of well L-1691 in Missimer, 1976).

Measured altitudes of the Tamiami Aquifer System-Zone I potentiometric surface ranged from 5.3 to 6.74 feet above mean sea level. Flow of water through the aquifer moves from northeast to southwest (Figure 5-38). The volume of flow through the aquifer or recharge was calculated by assuming a transmissivity of 60,000 gpd/ft, a hydraulic gradient of 1 ft/mile, and a corridor width varying from 2,000 to 8,000 feet. These values were substituted into the Darcy equation as presented in equation 11 to obtain approximate lateral recharge numbers. Lateral recharge to Tamiami Aquifer System-Zone I at the Bonita Bay site is about 90,000 gpd and across the utility site is about 22,000 gpd.

Above the 6-foot potentiometric contour, the Zone I surface lies below the water table and vertical leakage is directed downward. In areas below the 6-foot contour and adjacent to Spring Creek and the Imperial River, the Zone I surface lies above the water table and vertical leakage is directed upward. Therefore, the vertical recharge rate in the upland section of the site was calculated by estimating the leakance at 1.3×10^{-3} gpd/ft^3 and the vertical head differential averages about 2 feet. Roughly 1,000 acres

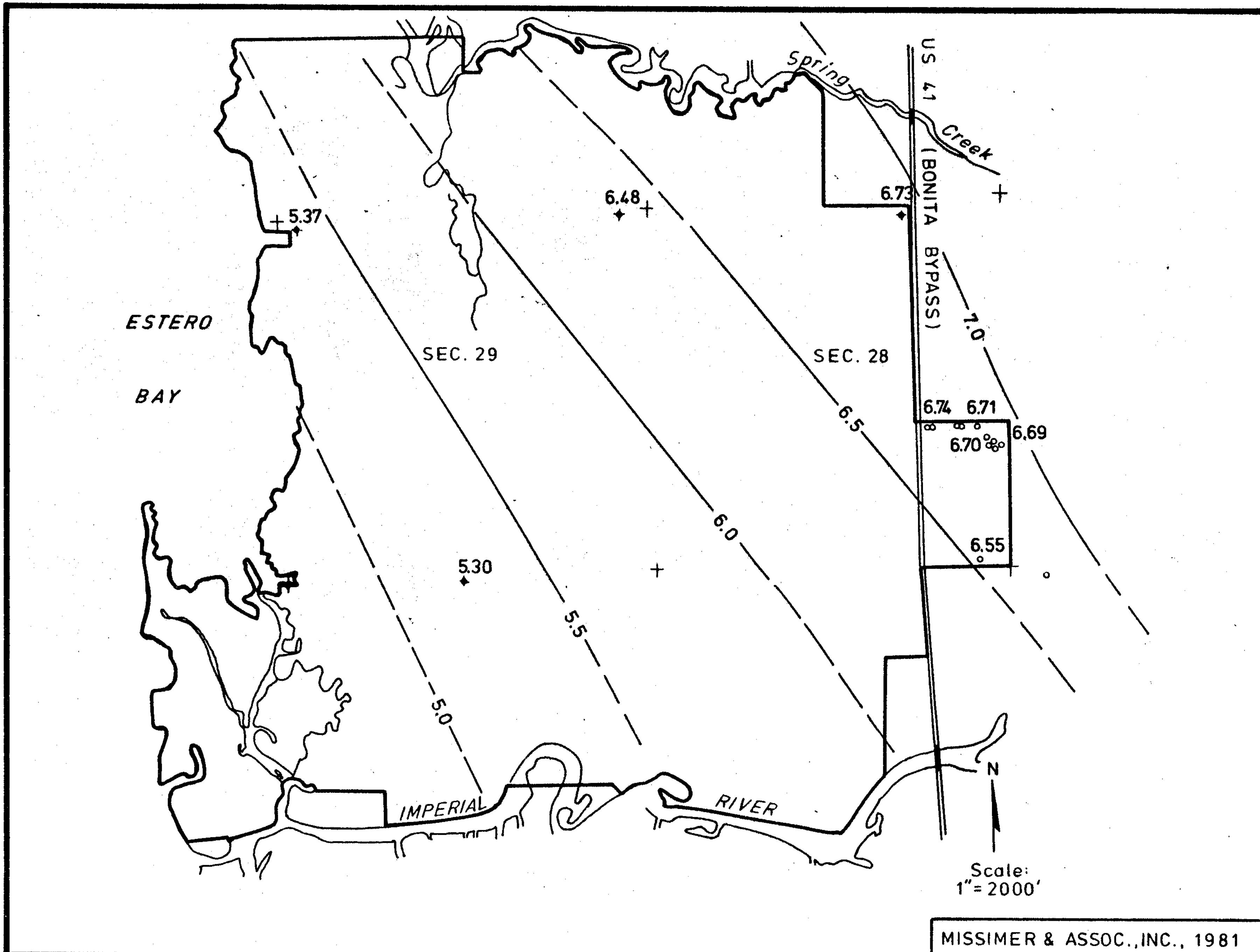

FIGURE 5-38. MAP SHOWING THE POTENTIOMETRIC SURFACE OF THE TAMIAMI AQUIFER SYSTEM—ZONE I ON SEPTEMBER 11, 1981.

occurs in the recharge area. These values were substituted into the following equation:

$$Q = (\Delta H)\ (k'/b')\ A \qquad (12)$$

where,

Q = vertical recharge, in gpd

ΔH = average head differential, in ft.

k'/b' = leakance, in gpd/ft

A = area, in ft^2

The vertical recharge rate on September 11, 1981 was about 125,000 gpd.

Hawthorn Aquifer System-Zone I

The Hawthorn Aquifer System-Zone I potentiometric surface lies at altitudes above land surface over the entire site. Correlation of this specific water-bearing zone to others in north Lee County is problematical because of the altitude of the potentiometric surface, which ranges from 21.29 to 26.54 feet above mean sea level. From the potentiometric surface map, shown in Figure 5-39, flow of water through the aquifer moves from southeast to northwest, which is exactly opposite to the regional flow pattern shown in Boggess (1974) for the "lower Hawthorn aquifer". A rational explanation for this discrepancy is that the confining beds between Hawthorn-Zone I and Hawthorn-Zone II pinches out to the south, which

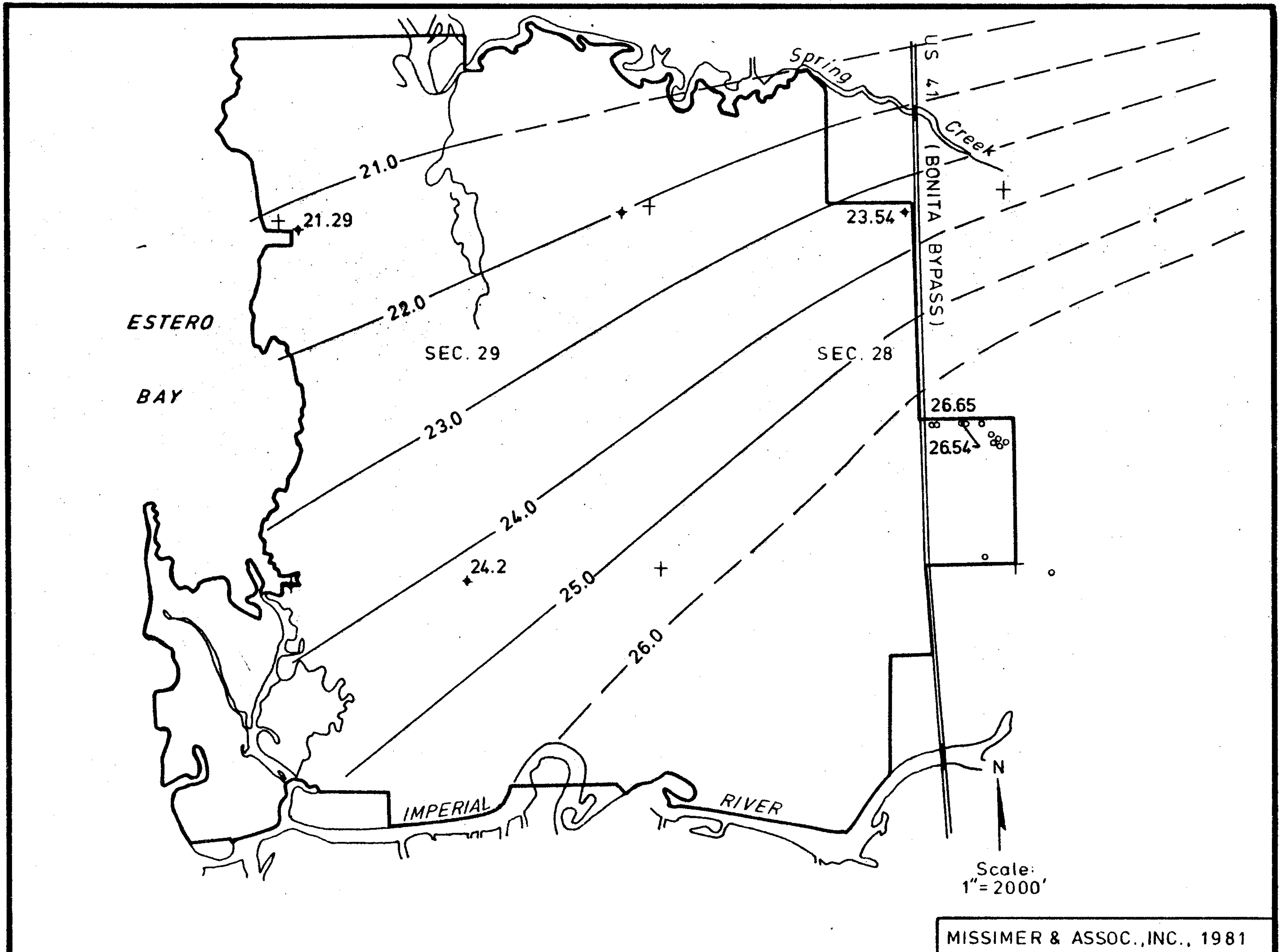

FIGURE 5-39. MAP SHOWING THE POTENTIOMETRIC SURFACE OF THE HAWTHORN AQUIFER SYSTEM - ZONE I, ON SEPTEMBER 11, 1981.

causes a lateral pressure gradient to form in the reverse direction. It is also possible that Hawthorn-Zone I in south Lee County has been completely removed by erosion and the aquifer herein located is a different zone. This problem of flow, recharge, and regional correlation cannot be solved without constructing a three-dimensional geologic model of Lee County.

The lateral recharge to Hawthorn Aquifer System-Zone I was assessed for September 11, 1981. The transmissivity of the aquifer was estimated to be 70,000 gpd/ft, the hydraulic gradient is roughly 4 ft/mile, and the corridor width is about 2 miles. When these values were substituted into equation 11, the resultant lateral recharge rate was 560,000 gpd.

Because it was not possible to accurately determine the leakance coefficient, the horizontal exit of water from the aquifer to overlying aquifers was not calculated.

5. Water Quality

Water-Table Aquifer

The quality of water in the water-table aquifer beneath the Bonita Bay site varies greatly because of the influence of tidal saline water. Sources of high salinity water are Estero Bay on the west, the Imperial River on the south, and Spring Creek on the north. The general pattern of water quality was established from the data base created by the regional well inventory and from sampling of on-site observation wells. The dissolved chloride concentrations in the inventoried wells are given in Table 4-2 and in the observations in Table 5-8. Several wells were sampled to obtain complete chemical analyses of the water (see Appendix Tables A-59 to A-64).

The occurrence of saline-water within the aquifer is limited to areas immediately adjacent to tidal water and most of the area west of the tidal slough, which bisects the Bonita Bay site (see Figure 5-40). High salinity water was found in only two observation wells, L-M-1647 and L-M-1651, which are located adjacent to the slough immediately to the east and west sides respectively. The dissolved chloride concentration in well L-M-1651 was measured several times and it varied from 1,900 to 2,140 mg/l. All other dissolved chloride concentrations in the observation wells were less than 40 mg/l. The pattern of water quality in Figure 5-40 shows that in most cases the saline-freshwater interface is located within a few hundred feet of the tidal water bodies and it is maintained at that distance because of the rather steep hydraulic gradients. A detailed study of the saline-freshwater interface adjacent to tidal water in close proximity to Bonita Bay was conducted by Missimer and Associates, Inc. (1980b) at Spring Creek Village. Discharge of water through the water-table aquifer into a canal system maintained the interface at less than 40 feet upgradient from the canal.

TABLE 5-8. DISSOLVED CHLORIDE CONCENTRATIONS AND CONDUCTIVITY OF WATER FROM OBSERVATION WELLS CONSTRUCTED ON THE SITE (measured by Missimer and Associates, Inc.).

Well No.	Dissolved Chlorides (mg/l)	Conductivity (μmhos)
L-M-1644	480	2,000
L-M-1645	980	3,500
L-M-1646	970	3,750
L-M-1647	950	--
L-M-1648	26	380
L-M-1649	470	2,040
L-M-1650	20	325
L-M-1651	1,900	6,935
L-M-1675	1,300	5,800
L-M-1676	420	2,160
L-M-1677	320	--
L-M-1678	40	510
L-M-1679	320	--
L-M-1680	310	1,600
L-M-1682A	320	--
L-M-1683	28	538
L-M-1684	20	330
L-M-1685	12	335
L-M-1690	12	300
L-M-1713	1,520	5,986
L-M-1716	1,440	4,620
L-M-1717	800	3,100
L-M-1718	1,460	5,500
L-M-1719	1,470	6,100
L-M-1720	1,460	6,000

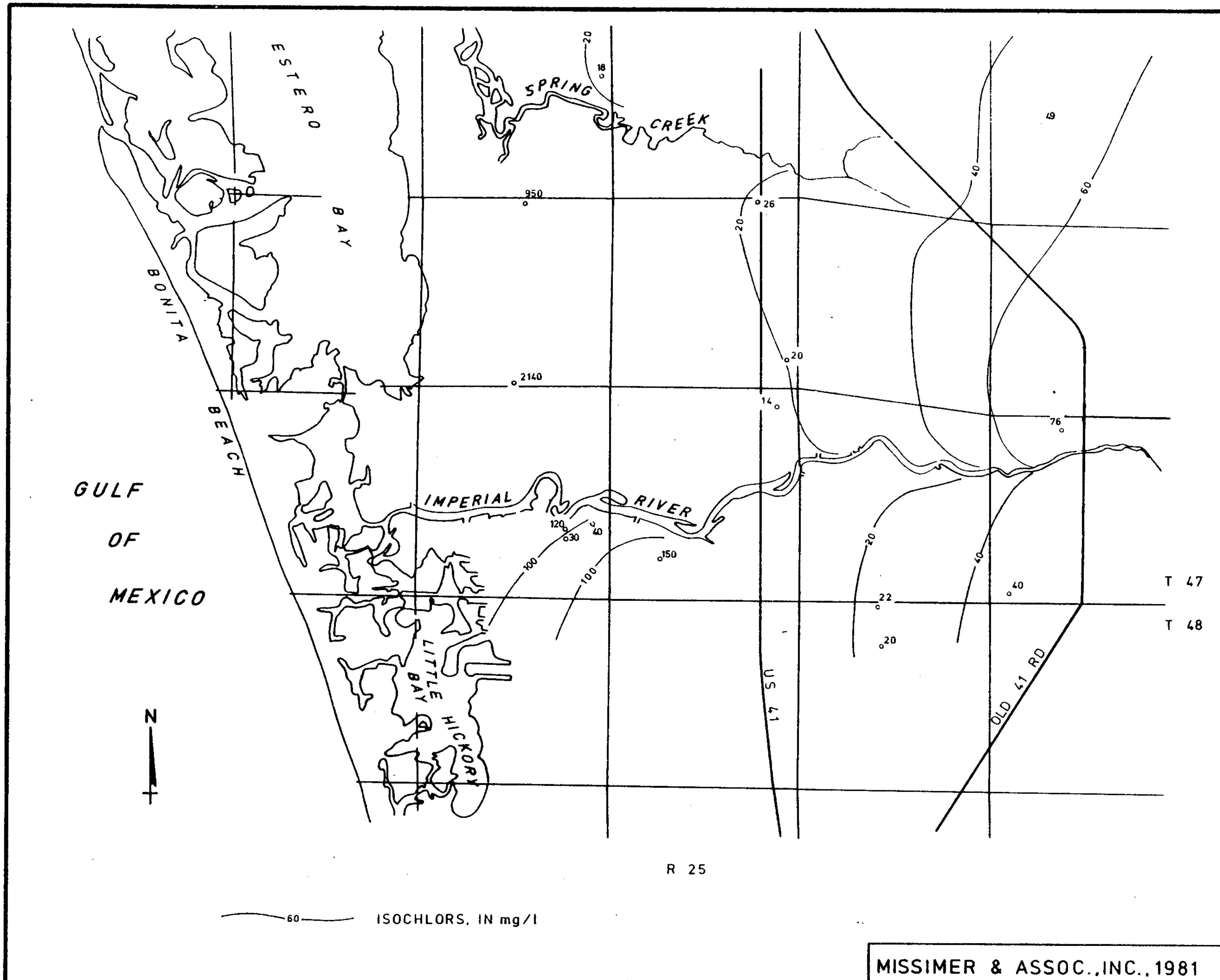

FIGURE 5-40. MAP SHOWING THE DISSOLVED CHLORIDE CONCENTRATIONS IN THE WATER-TABLE AQUIFER.

The overall quality of water in the water-table aquifer is quite good over most of the site. It is a calcium carbonate type water with high levels of alkalinity and hardness (see Table 5-9). In the utility site area, the quality of water meets all potable supply limits set by the U. S. Environmental Protection Agency. The water commonly is colored and has a relatively high concentration of dissolved iron. It is quite suitable as a source for either public supply or irrigation. During pumping of the test production well, water samples were collected and analyzed for dissolved chloride concentration, which stayed constant at near 20 mg/l.

Tamiami Aquifer System-Zone I

Quality of water in Tamiami Aquifer System-Zone I varies widely in south Lee County and particularly in the vicinity of Bonita Bay. The aquifer is not directly affected by surface-water quality, but vertical migration of water and the occurrence of residual saline water influences the pattern of water quality. The general water quality characteristics of the aquifer were again established by conducting a regional well inventory and by measuring the quality of water in on-site observation wells. These data are reported in Tables 4-2 and 5-8 respectively. Several wells, including the test-production and observation wells, were sampled to obtain complete chemical analyses of the water (see Appendix Tables A-65 to A-74).

TABLE 5-9. SUMMARY OF WATER QUALITY WITHIN THE WATER-TABLE AQUIFER.

Constituent	Range in Concentration (mg/1)
Total dissolved solids	200 - 4588
Alkalinity, Total, as $CaCO_3$	164 - 286
Alkalinity, Phenolphthalein, as $CaCO_3$	0 - 8
Alkalinity, Carbonate, as $CaCO_3$	0 - 16
Alkalinity, Bicarbonate, as $CaCO_3$	148 - 274
Alkalinity, Hydroxide, as $CaCO_3$	0
Carbonate, as CO_3	0 - 10
Bicarbonate, as HCO_3	181 - 334
Hardness, Total, as $CaCO_3$	170 - 1140
Hardness, Calcium, as $CaCO_3$	162 - 620
Hardness, Magnesium, as $CaCO_3$	8 - 520
Hardness, Carbonate, as $CaCO_3$	164 - 286
Hardness, Non-Carbonate, as $CaCO_3$	6 - 854
Sulfide, Including hydrogen, as H_2S	$<$0.01 - 0.01
Iron, Total, as Fe	1.44 - 6.1
Calcium, as Ca	66 - 248
Magnesium, as Mg	2 - 244
Chloride, as CL	10 - 2330
Fluoride, as F	$<$0.1
Sulfate, as SO_4	3 - 215
Color, P.C.U.	20 - 300
Turbidity, N.T.U.	0.96 - 125
pH	7.1 - 8.0
pHs	6.6 - 7.4

TABLE 5-9. SUMMARY OF WATER QUALITY WITHIN THE WATER-TABLE AQUIFER - Continued:

Constituent	Range in Concentration(mg/l)
Saturation Index	-0.3 - 1.1
Conductivity	310 - 6000

All dissolved chloride data collected on the aquifer were compiled to develop a regional isochlor map (Figure 5-41). Dissolved chloride concentrations in Tamiami Aquifer System-Zone I range from 280 to 1120 mg/l beneath Bonita Bay. The pattern of water quality is relatively uniform across the site with isochlor lines trending north and south, which is nearly perpendicular to groundwater flow. The positons of the isochlor lines may be dynamic to a certain degree depending on seasonal water level changes, but the lines do not move large distances under natural conditions. It is also probable that in the western part of the site the water in the aquifer is density stratified to a variable degree.

The chemistry of the water is an example of a calcium carbonate type water (Table 5-10). It has high concentrations of calcium, magnesium, and bicarbonate. The aquifer contains much less dissolved iron as compared to the overlying water-table aquifer. Water quality in Tamiami-Zone I does not meet most drinking water standards. However, the water is quite adequate for irrigation purposes. Even if dissolved chloride concentrations would rise to 500 mg/l, the water would still be usable for irrigation.

During the Tamiami-Zone I aquifer performance test, the quality of water in the production well was tested to assess stability. The dissolved chloride concentrations rose only 5 mg/l, from 310 to 315 mg/l (Table 5-11). This rise is within the error range of the measurement and,

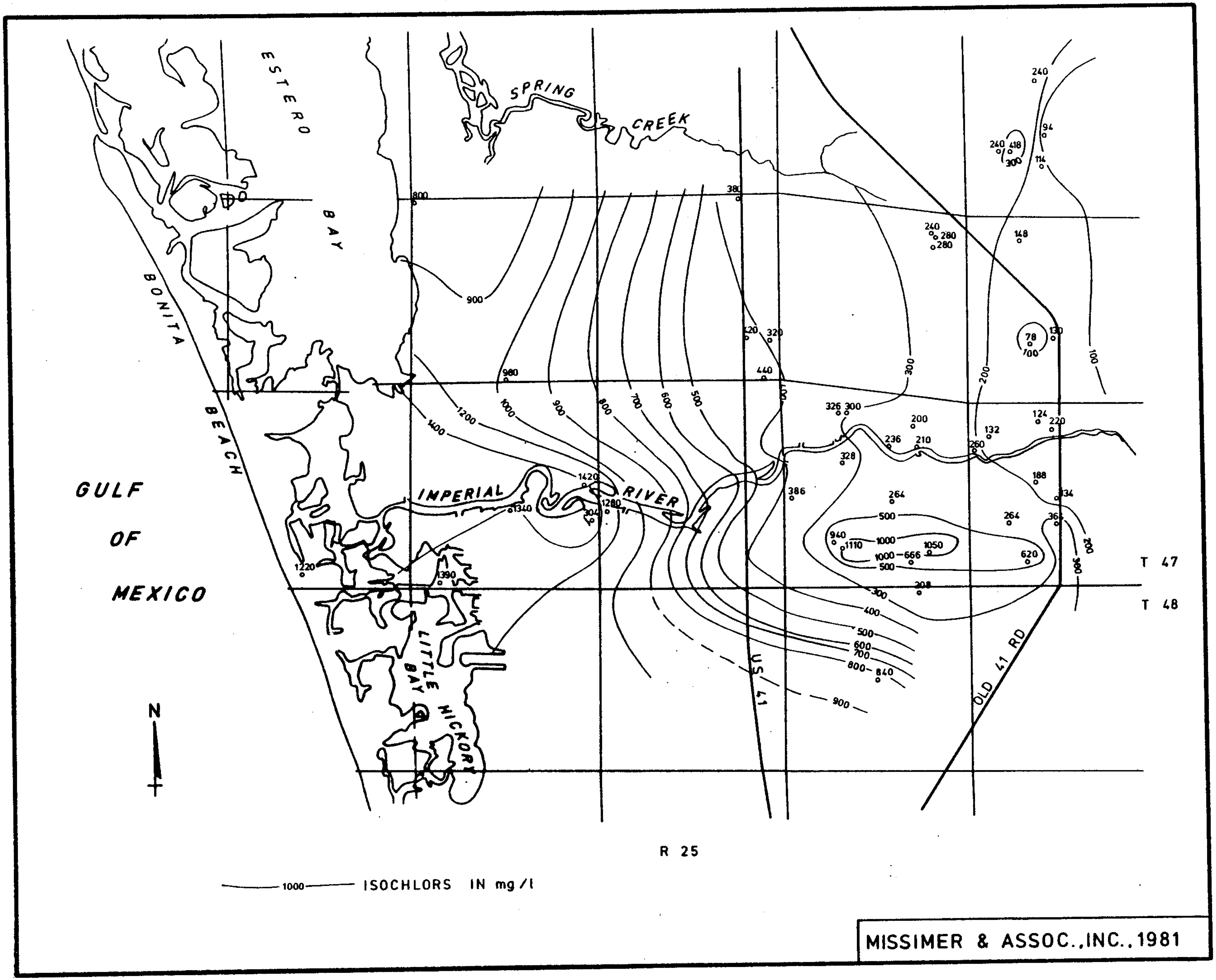

FIGURE 5-41. MAP SHOWING THE DISSOLVED CHLORIDE CONCENTRATIONS IN THE TAMIAMI AQUIFER SYSTEM - ZONE I.

TABLE 5-10. SUMMARY OF WATER QUALITY WITHIN TAMIAMI AQUIFER SYSTEM-ZONE I

Constituent	Range in Concentration (mg/l)
Total dissolved solids	984 - 2510
Alkalinity, Total, as $CaCO_3$	174 - 234
Alkalinity, Phenolphthalein, as $CaCO_3$	0 - 12
Alkalinity, Carbonate, as $CaCO_3$	0 - 24
Alkalinity, Bicarbonate, as $CaCO_3$	154 - 234
Alkalinity, Hydroxide, as $CaCO_3$	0
Carbonate, as CO_3	0 - 14
Bicarbonate, as HCO_3	209 - 285
Hardness, Total, as $CaCO_3$	422 - 820
Hardness, Calcium, as $CaCO_3$	264 - 484
Hardness, Magnesium, as $CaCO_3$	60 - 444
Hardness, Carbonate, as $CaCO_3$	174 - 234
Hardness, Non-Carbonate, as $CaCO_3$	190 - 636
Sulfide, Including hydrogen, as H_2S	$<$0.01 - 0.01
Iron, Total, as Fe	0.02 - 0.17
Calcium, as Ca	112 - 161
Magnesium, as Mg	15 - 108
Chloride, as CL	280 - 1120
Fluoride, as F	0.4 - 0.6
Sulfate, as SO_4	34 - 275
Color, P.C.U.	$<$5 - 19
Turbidity, N.T.U.	0.26 - 6.4
pH	7.1 - 8.0
pHs	6.9 - 7.1

TABLE 5-10. SUMMARY OF WATER QUALITY WITHIN TAMIAMI AQUIFER SYSTEM-ZONE I - Continued:

Constituent	Range in Concentration (mg/l)
Saturation Index	0.2 - 0.9
Conductivity, µmhos	1400 - 3400

TABLE 5-11. DISSOLVED CHLORIDE CONCENTRATION AND CONDUCTIVITY MEASUREMENTS FROM PRODUCTION WELL L-M-1682A DURING THE AQUIFER TEST (Q = 576 GPM).

Time (minutes)	Dissolved Chloride (mg/l)	Conductivity (µmhos)
0	310	1,620
35	310	1,680
120	320	1,700
150	315	1,670
250	310	1,630
380	315	1,500(?)
570	315	1,600
810	315	1,680
1,020	310	1,680
1,320	315	1,580
1,920	315	1,620
1,620	315	1,630
1,740	315	1,650
2,400	315	1,630
3,000	315	1,690
3,330	315	1,690
3,840	315	1,700

therefore, is not considered significant. Long-term pumping will cause some changes in water quality, but will not cause any change outside of the Bonita Bay property.

Hawthorn Aquifer System-Zone I

Water quality in Hawthorn-Zone I was assessed in 5 wells located on the site (Table 5-8). Dissolved chloride measurements were made and water samples were collected for complete chemical analysis (see Appendix Tables A-75 to A-79).

Hawthorn-Zone I is part of the deep, saline-water aquifer system in Lee County. Dissolved chloride concentrations ranged from 1,300 to 1,630 mg/l in the various wells located on the site. Some discrepancies in measurement of the concentration are noted for the various laboratories used, but all measurements agreed within about 10 percent. There is no verifiable pattern of water quality within the aquifer.

The overall chemistry of the water again shows a calcium carbonate type water (Table 5-12). It has a high level of hardness and very low iron concentrations. Sulfate concentrations are also very high. This water is not directly usable for either potable supply or for irrigation purposes. However, it can be blended with water from the two shallower aquifers and used for irrigation.

Water samples collected during the aquifer test showed that water quality remained essentially stable (Table 5-13). The dissolved chloride concentration apparently dropped from

TABLE 5-12. SUMMARY OF WATER QUALITY WITHIN HAWTHORN AQUIFER SYSTEM-ZONE I.

Constituent	Range in Concentration (mg/l)
Total dissolved solids	3152 - 3560
Alkalinity, Total, as $CaCO_3$	134 - 162
Alkalinity, Phenolphthalein, as $CaCO_3$	6 - 8
Alkalinity, Carbonate, as $CaCO_3$	12 - 16
Alkalinity, Bicarbonate, as $CaCO_3$	122 - 150
Alkalinity, Hydroxide, as $CaCO_3$	0
Carbonate, as CO_3	7 - 10
Bicarbonate, as HCO_3	149 - 182
Hardness, Tota, as $CaCO_3$	510 - 990
Hardness, Calcium, as $CaCO_3$	332 - 428
Hardness, Magnesium, as $CaCO_3$	82 - 582
Hardenes, Carbonate, as $CaCO_3$	134 - 162
Hardness, Non-Carbonate, as $CaCO_3$	376 - 788
Sulfide, Including hydrogen, as H_2S	<0.01
Iron, Total, as Fe	0.01 - 0.06
Calcium, as Ca	133 - 171
Magnesium, as Mg	20 - 141
Chloride, as CL	1420 - 1630
Fluoride, as F	0.9 - 1.4
Sulfate, as SO_4	390 - 615
Color, P.C.U.	0 - 15
Turbidity, N.T.U.	0.30 - 0.56
pH	7.5 - 7.8
pHs	7.0 - 7.2

TABLE 5-12. SUMMARY OF WATER QUALITY WITHIN HAWTHORN AQUIFER SYSTEM-ZONE I - Continued:

Constituent	Range in Concentration (mg/l)
Saturation Index	0.5 - 0.7
Conductivity, µmhos	4100 - 4700

TABLE 5-13. DISSOLVED CHLORIDE CONCENTRATIONS AND CONDUCTIVITY MEASUREMENTS FROM PRODUCTION WELL L-M-1720 DURING THE AQUIFER TEST.

Time (minutes)	Dissolved Chloride (mg/l)	Conductivity (μmhos)
0	1,460	6,222
240	1,460	6,000
600	1,420	6,000
1,440	1,400	6,000
1,550	1,420	6,000

1,460 mg/l to 1,420 mg/l, which is nearly insignificant in terms of percentage of change vs. accuracy of measurement.

6. Summary

Bonita Bay is underlain by three principal aquifers, which are the water-table aquifer, Tamiami Aquifer System-Zone I, and Hawthorn Aquifer System-Zone I. A detailed hydrologic investigation was completed on the site to obtain geologic, hydraulic, and water quality data from each of the aquifers.

The water-table aquifer occurs within the sediments of the Pamlico Sand and the Pinecrest Limestone. It ranges from 22 to 32 feet in thickness on the site. The aquifer has a measured transmissivity of 65,000 gpd/ft and a specific yield of 0.05. Water moves through the aquifer essentially from northeast to southwest and it discharges into tidal water. The quality of water is very good in areas east of the slough, which divides the Bonita Bay site. The water meets most potable and all irrigation quality requirements.

Tamiami Aquifer System-Zone I occurs within the Ochopee Limestone and Lehigh Acres Sandstone Members of the Tamiami Formation. The aquifer is quite thick, from 80 to 160 feet, but permeability within the unit decreases with depth. Tamiami-Zone I has a measured transmissivity of

60,000 gpd/ft, a storage coefficient of 1 x 10^{-4} and a leakance of 1.3 x 10^{-3} gpd/ft^3. The transmissivity of the aquifer is less than 5,000 gpd/ft about 1½ miles northwest of the utility site and increases to 225,000 gpd/ft about 3 miles east of the site. Water moves through the aquifer from northeast to southwest. Quality of water varies considerably beneath the site with dissolved chloride concentrations ranging from 280 to near 1,000 mg/l. Isochlors trend generally north and south perpendicular to regional flow.

Hawthorn Aquifer System-Zone I occurs in sediments at near the top of the Hawthorn Formation. The aquifer has a measured transmissivity of 70,000 gpd/ft, a storage coefficient of 5 x 10^{-5}, and a leakance less than 1 x 10^{-5} gpd/ft^3. Flow through the aquifer apparently moves from the southeast to the northwest, which is opposite to that of the regional flow pattern. Water quality is poor with a dissolved chloride concentration of 1,400 to 1,600 mg/l. This water can be used for irrigation only if it is diluted with other water.

VI. WATER USE

1. Public Supply

A total of about 9,240 units is presently planned for construction at Bonita Bay. Potable water will be supplied to the residents of Bonita Bay by either the Bonita Springs Water Company or by the Bonita Bay Improvement District. This document is an analysis of the on-site groundwater resources and there are no present plans to develop an on-site potable water-supply.

A detailed analysis of the potable supply requirements for Bonita Bay is given in the Development of Regional Impact Statement, Section 23. About 3.4 MGD will be required at buildout of the development in 27 years.

2. Irrigation Supply

Water will be required for irrigation of landscaped and turf grass areas in the Bonita Bay Development. All irrigation water will be conveyed through a central system. The dual-system will provide metered connections for both potable and non-potable water.

There are four land use classifications which will require irrigation of acreage. The residential classification is subdivided into R-1 (single family dwellings), R-2 (multi-family low rise), and R-3 (multi-family high rise). Commercial areas will require small quantities of water for irrigation of landscaping. In the recreational use, the golf course (GC) will require the bulk of irrigation water and the park areas (O) will require a minor volume of water to irrigate play fields and other grassed areas. The landscaped areas adjacent to road rights-of-way will also require irrigation.

In order to estimate water use of residential single-family dwellings (R-1), it was assumed that most of the units will be equipped with automatic sprinkler systems. From observations in affluent residential settings, it is estimated that the average sprinkler system will be used 3 days per week during the dry season. A typical sprinkler system is divided into 3 quadrants. Each quadrant is charged for a period varying between 15 and 30 minutes. The sprinklers discharge between 40 and 60 gpm in each quadrant. Therefore, an average discharge is about 2,500 gallons for a complete cycle. Since the system is used 3 times per week, about 7,500 gallons of water is pumped per week or about 1,000 gpd, which is the figure used to estimate R-1 irrigation water use (Table 6-1). The 990 units will require about 0.99 MGD of irrigation water during dry periods.

The use of water for irrigation at multi-family dwellings was estimated based on acreage and a 70% irrigation area (the remaining 30% is not irrigated). The daily rate

TABLE 6-1. IRRIGATION WATER USE

	Total Acreage	Units	Water Use
I. Residential			
R-1	582	990	0.99 MGD
R-2	385.5	3100	2.20 MGD
R-3	367.9	5150	2.10 MGD
	1335.4		5.29 MGD
II. Commercial			
C-1	133.3		
C-2	13.8		
C-3	16.4		
	163.5		0.27 MGD
III. Recreational			
GC	151.4		0.99 MGD
O	31.7		0.05 MGD
	183.1		1.04 MGD
IV. Miscellaneous			
Reserve	490.5		0
Right-of-Way	146.0		0.71 MGD
Misc. Water Mgt.	27		0
	663.5		0.71 MGD
		Total:	7.31 MGD

of application was assumed to be 0.3 inch per day during the dry season. Therefore, the daily rate of irrigation for the R-2 and R-3 areas is calculated by the following equation:

$$Q = 8145.72 \, A \, P \qquad (13)$$

where,

Q = daily irrigation rate, in gallons per day

A = area, in acres

P = percentage of acreage irrigated

Based on the 0.3 inch per day application rate, about 4.3 MGD will be required to irrigate all landscaped areas adjacent to R-2 and R-3 structures.

Only about 20% of the commercial area will be irrigated. Equation 13 was again used to calculate water use based on the 0.3 inch per day application rate.

Irrigation of the golf course and park areas was calculated by Equation 13. Of the 151.4 acres allocated to the golf course, about 80 percent will be irrigated. Only 20 percent of the park areas will be irrigated.

The road right-of-ways and the entrance to the development will be landscaped to a great extent. It is estimated that about 60 percent of the total right-of-way acreage will require some irrigation.

drawdown at 120.0000 days

t= 65000 gpd/ft

s =.05000000000

l = 0.00000000001

grid spacing = 1000 ft

	1	2	3	4	5	6	7	8	9	10	11
1	0.51	0.63	0.75	0.86	0.94	0.97	0.94	0.86	0.75	0.63	0.51
2	0.65	0.82	1.00	1.17	1.30	1.34	1.30	1.17	1.00	0.82	0.65
3	0.80	1.03	1.30	1.57	1.78	1.87	1.78	1.57	1.30	1.03	0.80
4	0.95	1.26	1.64	2.07	2.46	2.64	2.46	2.07	1.64	1.26	0.95
5	1.08	1.47	1.98	2.63	3.40	3.89	3.40	2.63	1.98	1.47	1.08
6	1.17	1.61	2.21	3.09	4.45	7.6[illegible]	4.45	3.09	2.21	1.61	1.17
7	1.18	1.63	2.26	3.18	4.63	7.21	4.63	3.18	2.26	1.63	1.18
8	1.12	1.54	2.09	2.84	3.86	4.91	3.86	2.84	2.09	1.54	1.12
9	1.01	1.35	1.79	2.30	2.83	3.10	2.83	2.30	1.79	1.35	1.01
10	0.87	1.13	1.44	1.77	2.05	2.16	2.05	1.77	1.44	1.13	0.87
11	0.71	0.91	1.12	1.33	1.49	1.55	1.49	1.33	1.12	0.91	0.71
12	0.56	0.71	0.85	0.98	1.08	1.11	1.08	0.98	0.85	0.71	0.56
13	0.44	0.53	0.63	0.72	0.78	0.80	0.78	0.72	0.63	0.53	0.44

U.S. 41

Production Wells

Utility Site

FIGURE 7-3. REGIONAL DRAWDOWN OF THE WATER TABLE FOR A PUMPING RATE OF 1.1 MGD FROM 3 WELLS.

Bonita Bay will require about 7.31 MGD of irrigation water at buildout of the project. It is believed that the figure is somewhat high, but since no individual home wells will be permitted on the site, it will be possible to maintain absolute control over water consumption. An assessment of irrigation water use, by year for the various land uses, is given in Table 6-2. Only 1.3 MGD will be required in the first year and the use will increase slowly to 7.31 MGD over a 27 year period.

TABLE 6-2. IRRIGATION WATER USE BY YEAR

Year	I	II	III	IV	Total	Cum. Total
1	0.2053		0.99	0.1	1.2953	1.2953
2	0.2053	0.03		0.1	0.3353	1.6306
3	0.2053			0.1	0.3053	1.9359
4	0.2053			0.1	0.3053	2.2412
5	0.2053		0.05	0.1	0.3553	2.5965
6	0.2314	0.07		0.1	0.4014	2.9979
7	0.2314			0.11	0.3414	3.3393
8	0.2314				0.2314	3.5707
9	0.2314				0.2314	3.8021
10	0.2314	0.1			0.3314	4.1335
11	0.2754				0.2754	4.4089
12	0.2754				0.2754	4.6843
13	0.2754				0.2754	4.9597
14	0.1954				0.1954	5.1551
15	0.1954				0.1954	5.3505
16	0.2084				0.2084	5.5589
17	0.1824				0.1824	5.7413
18	0.1824				0.1824	5.9237
19	0.1303				0.1303	6.0540
20	0.1303	0.07			0.2003	6.2543
21	0.1564				0.1564	6.4107
22	0.1564				0.1564	6.5671
23	0.1564				0.1564	6.7236
24	0.1564				0.1564	6.8799
25	0.1564				0.1564	7.0363
26	0.1564				0.1564	7.1927
27	0.1173				0.1173	7.31
	5.29	0.27	1.04	0.71	7.31	

VII. IMPACT ASSESSMENTS

1. Impact on the Aquifer System (water levels)

Water-Table Aquifer

The impact of pumping from the water-table aquifer was assessed for withdrawal rates of 1.1 MGD and 2.5 MGD. For the higher withdrawal rate 1.4 MGD of rennovated wastewater is recharged to the system. All major withdrawals would be made on the utility site as shown in Figure 7-1. Two different assessments were made which both have a net pumpage of 1.1 MGD.

The first assessment made involves the pumping of three wells on the site. Well W-1 (L-M-1684) would be pumped at a rate of 350 gpm and wells W-2 and W-3 would be pumped at 200 gpm each. Well W-1 will be pumped at a higher rate because of its very high efficiency and the thickness of limestone as compared to other areas on the site. Local drawdowns of water levels in the aquifer were calculated by utilizing a nonsteady state Theis program. The following assumptions were made: aquifer transmissivity is 65,000 gpd/ft, the specific yield is 0.05, and the aquifer will receive no recharge for a 120-day period. The drawdown pattern for the utility site is given in Figure 7-2 and a more regional view is given in Figure 7-3. The most significant drawdowns are within the boundaries

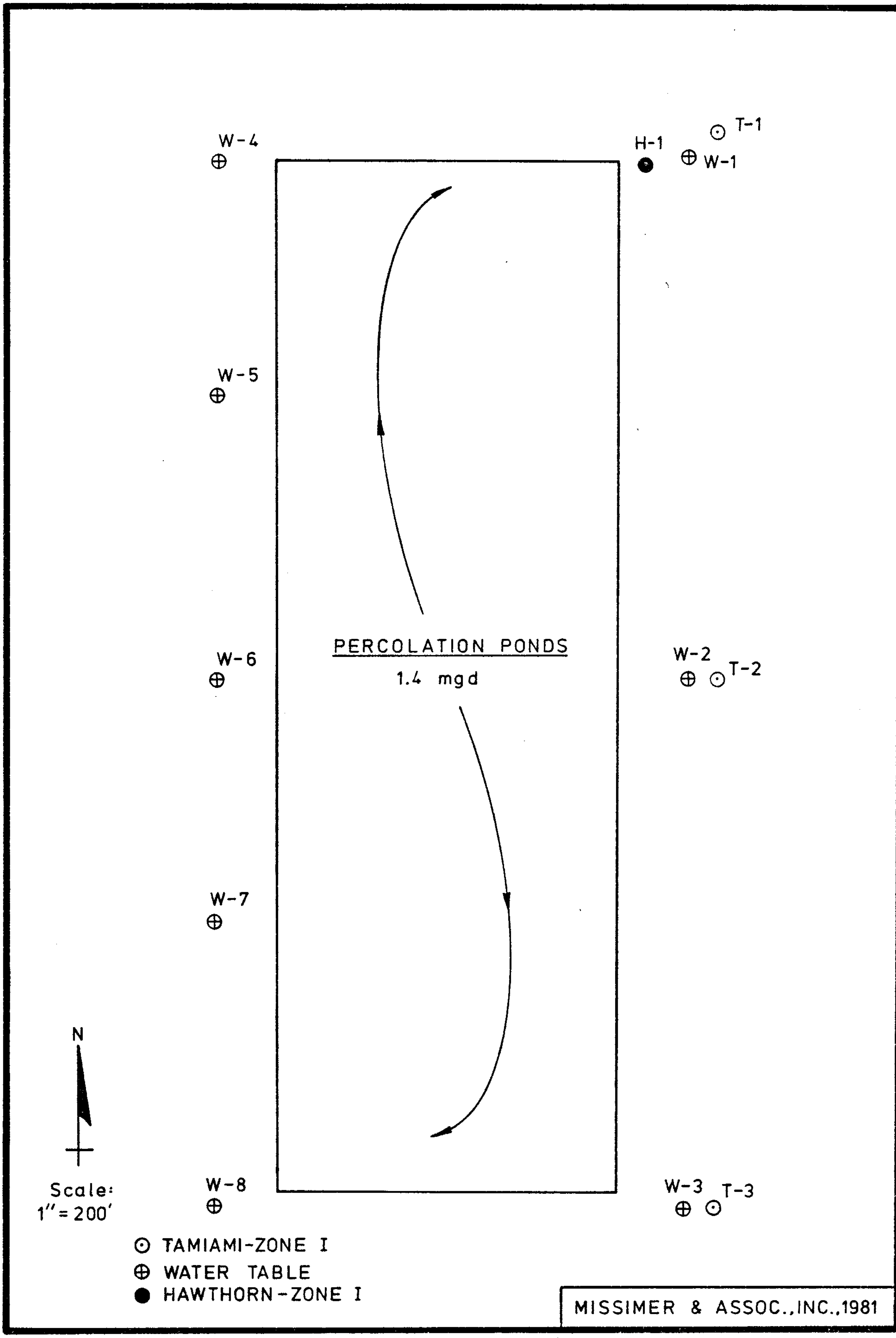

FIGURE 7-1. MAP SHOWING THE LOCATION OF PROPOSED PRODUCTION WELLS ON THE UTILITY SITE.

t= 65000 gpd/ft

s =.05000000000

l = 0.00000000001

grid spacing = 200 ft

	1	2	3	4	5	6	7	8	9	10	11
1	4.08	4.37	4.66	4.96	5.21	5.31	5.21	4.96	4.66	4.37	4.08
2	4.29	4.63	5.01	5.44	5.89	6.13	5.89	5.44	5.01	4.63	4.29
3	4.46	4.85	5.30	5.88	6.70	7.72	6.70	5.88	5.30	4.85	4.46
4	4.59	5.00	5.49	6.11	6.96	8.00	6.96	6.11	5.49	5.00	4.59
5	4.67	5.09	5.58	6.13	6.71	7.01	6.71	6.13	5.58	5.09	4.67
6	4.69	5.11	5.58	6.11	6.64	6.93	6.64	6.11	5.58	5.11	4.69
7	4.67	5.08	5.54	6.06	6.71	7.93	6.71	6.06	5.54	5.08	4.67
8	4.61	5.00	5.43	5.91	6.44	6.83	6.44	5.91	5.43	5.00	4.61
9	4.52	4.88	5.28	5.71	6.10	6.28	6.10	5.71	5.28	4.88	4.52
10	4.39	4.73	5.11	5.52	5.95	6.19	5.95	5.52	5.11	4.73	4.39
11	4.23	4.55	4.90	5.32	5.89	7.07	5.89	5.32	4.90	4.55	4.23
12	4.05	4.33	4.64	4.99	5.42	5.78	5.42	4.99	4.64	4.33	4.05
13	3.85	4.09	4.34	4.60	4.83	4.94	4.83	4.60	4.34	4.09	3.85
14	3.64	3.83	4.03	4.21	4.35	4.40	4.35	4.21	4.03	3.83	3.64
15	3.42	3.58	3.74	3.87	3.96	3.99	3.96	3.87	3.74	3.58	3.42

Production Wells ⊙

—Utility Site

FIGURE 7-2. DRAWDOWNS OF THE WATER TABLE ON THE UTILITY SITE FOR A PUMPING RATE OF 1.1 MGD FROM 3 WELLS.

of the utility site with the 6-foot contour being enclosed mostly within the property boundaries. As shown in Figure 7-3, the drawdowns adjacent to tidal water north and south of the utility site are quite small at about 2 foot. Drawdowns to the west of U.S. 41 are again low and are not significant especially considering that most of the water pumped from the utility site will be dumped on this land. Recharge to the water-table aquifer from irrigation will cause a minor high to develop on the water table. The overall conclusion is that the drawdowns will not significantly affect water levels outside of the utility site.

A second assessment was made to evaluate the pumping of 8 production wells at a gross rate of 2.5 MGD with a large percolation pond recharging the aquifer at a rate of 1.4 MGD. Again, Well W-1 will be pumped at 350 gpm and the remaining 7 wells will be pumped at 200 gpm each. Identical assumptions were made to the first assessment. The drawdown pattern for the utility site is given in Figure 7-4. The magnitude of the drawdowns is very similar to the 1.1 MGD withdrawal rate. It is quite probable that the on-site drawdowns will be higher than shown on the utility site because of variability in the percolation rate from the pond into the aquifer. The regional drawdown assessment shown in Figure 7-5 is quite similar to that shown in Figure 7-3. Again, the overall conclusion is that the drawdowns will not significantly affect water t= 65000 gpd/ft

s =.05000000000

l = 0.00000000100

grid spacing = 200 ft

	1	2	3	4	5	6	7	8	9	10	11
1	4.03	4.28	4.54	4.77	4.94	5.04	5.11	5.12	5.00	4.75	4.44
2	4.24	4.55	4.88	5.22	5.45	5.50	5.60	5.76	5.62	5.18	4.74
3	4.43	4.79	5.21	5.74	6.26	5.87	5.93	6.81	6.53	5.57	4.97
4	4.58	4.98	5.45	6.06	6.71	5.54	5.43	6.67	6.56	5.65	5.06
5	4.68	5.09	5.57	6.14	6.76	4.82	4.48	5.54	5.79	5.47	5.04
6	4.74	5.15	5.60	6.07	6.16	4.81	4.45	5.30	5.58	5.34	4.98
7	4.75	5.16	5.60	6.07	6.58	4.67	4.31	5.74	5.82	5.28	4.91
8	4.73	5.13	5.57	6.02	6.09	4.70	4.30	5.20	5.44	5.14	4.82
9	4.68	5.07	5.51	6.02	6.80	4.59	4.08	4.88	5.15	5.01	4.73
10	4.58	4.97	5.41	5.91	6.09	4.90	4.51	5.16	5.27	4.99	4.66
11	4.44	4.81	5.24	5.82	6.92	5.41	5.31	5.98	5.70	4.99	4.57
12	4.26	4.58	4.96	5.40	5.77	5.49	5.34	5.51	5.30	4.80	4.41
13	4.05	4.32	4.60	4.87	5.03	5.02	4.97	4.92	4.76	4.48	4.19
14	3.83	4.04	4.25	4.43	4.54	4.57	4.55	4.48	4.34	4.15	3.94
15	3.60	3.77	3.93	4.06	4.15	4.18	4.17	4.10	4.00	3.86	3.69

Production Wells

Percolation Ponds

Utility Site

FIGURE 7-4. DRAWDOWNS OF THE WATER TABLE ON THE UTILITY SITE FOR A PUMPING RATE OF 2.5 MGD FROM 8 WELLS WITH PERCOLATION OF 1.4 MGD OF RENNOVATED WASTEWATER.

drawdown at 120.0000 days

t= 65000 gpd/ft

s =.05000000000

l = 0.00000000010

grid spacing = 1000 ft

	1	2	3	4	5	6	7	8	9	10
1	0.71	0.89	1.08	1.25	1.77	1.41	1.34	1.20	1.02	0.83
2	0.88	1.13	1.41	1.69	1.89	1.96	1.84	1.60	1.31	1.04
3	1.05	1.39	1.79	2.24	2.62	2.76	2.52	2.09	1.64	1.26
4	1.20	1.62	2.17	2.88	3.67	4.05	3.46	2.63	1.96	1.45
5	1.29	1.78	2.45	3.43	5.00	6.65	4.41	3.03	2.17	1.57
6	1.31	1.80	2.51	3.55	5.17	4.99	4.32	3.05	2.19	1.58
7	1.24	1.69	2.30	3.13	4.14	4.67	3.70	2.73	2.02	1.49
8	1.11	1.48	1.94	2.48	2.98	3.12	2.77	2.23	1.73	1.31
9	0.95	1.23	1.55	1.88	2.13	2.19	2.03	1.74	1.41	1.10
10	0.77	0.98	1.20	1.40	1.54	1.57	1.49	1.31	1.10	0.89
11	0.61	0.76	0.90	1.03	1.11	1.13	1.08	0.98	0.84	0.69
12	0.47	0.57	0.67	0.75	0.80	0.82	0.78	0.72	0.63	0.53
13	0.35	0.42	0.49	0.54	0.57	0.58	0.56	0.52	0.46	0.39

Percolation Pond

U.S. 41

Utility Site

Wells

FIGURE 7-5. REGIONAL DRAWDOWN OF THE WATER FOR A PUMPING RATE OF 2.5 MGD FROM 8 WELLS WITH PERCOLATION OF 1.4 MGD OF RENNOVATED WASTEWATER.

levels outside of the utility site.

Tamiami Aquifer System-Zone I

The impact of pumping 1.5 MGD of water from Tamiami Aquifer System-Zone I was assessed for the region within 2 miles of the utility site. Withdrawals would be made from 3 production wells located on the utility site about 800 feet apart as shown in Figure 7-1. Each well would be pumped at 350 gpm on a continuous basis.

This impact assessment was not a straight forward problem, because the transmissivity of the aquifer varies from 5,000 to 225,000 gpd/ft over a 4 mile area running east and west (see Figure 5-33). Therefore, in order to assess the drawdown under the natural conditions, it was necessary to model the aquifer using the finite difference model of Prickett and Lonnquist. Transmissivity values used in this effort ranged from 5,000 to 150,000 gpd/ft, which were entered into the grid at node points. A uniform storage coefficient of 1×10^{-4} and a uniform leakance of 1.2×10^{-3} gpd/ft were used at all grid points. The results of the nodal calculations are given in Figure 7-6. It can be observed that the cone of depression caused by pumping on the utility site extends further toward the east, which is the direction of higher transmissivity. The drawdown values are somewhat conservative because the highest transmissivities entered were 150,000 gpd/ft

-0.06	-0.07	-0.09	-0.11	-0.13	-0.15	-0.16	-0.17	-0.17	-0.17	-0.16	-0.15
-0.06	-0.08	-0.10	-0.12	-0.15	-0.17	-0.19	-0.21	-0.21	-0.20	-0.19	-0.17
-0.07	-0.08	-0.10	-0.14	-0.18	-0.21	-0.24	-0.27	-0.27	-0.25	-0.23	-0.20
-0.07	-0.08	-0.10	-0.17	-0.21	-0.28	-0.31	-0.36	-0.37	-0.33	-0.29	-0.25
			17		16 US 41		15		14		
-0.08	-0.07	-0.07	-0.17	-0.23	-0.42	-0.66	-0.61	-0.52	-0.44	-0.37	-0.30
-0.09	-0.07	0.00	-0.50	-1.09	-1.42	-1.20	-0.93	-0.72	-0.58	-0.46	-0.37
			20		21		22		23		
-0.16	-0.40	-0.65	-1.09	-2.41	-2.52	-1.83	-1.29	-0.95	-0.72	-0.55	-0.43
-0.32	-0.83	-1.54	-2.64	-3.90	-4.57	-2.77	-1.71	-1.18	-0.84	-0.62	-0.46
			29		28		27		26		
-0.33	-0.72	-1.33	-2.56	-4.73	-9.27	-3.74	-1.97	-1.29	-0.89	-0.64	-0.48
-0.42	-0.61	-0.90	-1.80	-2.99	-3.95	-2.67	-1.73	-1.20	-0.86	-0.62	-0.46
			32		33		34		35		
-0.40	-0.54	-0.77	-1.20	-1.79	-2.09	-1.74	-1.35	-1.01	-0.75	-0.56	-0.43
-0.35	-0.46	-0.59	-0.84	-1.14	-1.29	-1.19	-1.01	-0.81	-0.63	-0.49	-0.38
			5		4		3		2		
-0.30	-0.38	-0.47	-0.60	-0.73	-0.82	-0.82	-0.74	-0.62	-0.51	-0.41	-0.33
-0.26	-0.31	-0.38	-0.46	-0.53	-0.58	-0.58	-0.54	-0.48	-0.40	-0.33	-0.28
-0.22	-0.26	-0.31	-0.36	-0.40	-0.43	-0.43	-0.41	-0.37	-0.32	-0.27	-0.23
-0.18	-0.21	-0.25	-0.28	-0.31	-0.32	-0.33	-0.31	-0.29	-0.26	-0.22	-0.19

FIGURE 7-6. DRAWDOWNS OF THE TAMIAMI AQUIFER SYSTEM-ZONE I POTENTIOMETRIC SURFACE FOR A PUMPING RATE OF 1.5 MGD FROM THE UTILITY SITE.

instead of the 225,000 gpd/ft measured at the Bonita Springs Wellfield. The pattern of higher drawdowns to the east compounded with the regional flow gradient from that direction (Figure 5-38) indicates that more recharge to the wellfield will come from east of U.S. 41. Based on the ratio of the transmissivity values, approximately two-thirds of the recharge will originate in that direction.

Hawthorn Aquifer System-Zone I

Withdrawals from Hawthorn Aquifer System-Zone I will be quite small, but this pumping was also evaluated for impact. One well on the utility site will be allowed to flow at a rate of 130,000 gpd. The following assumptions were made: aquifer transmissivity is 70,000 gpd/ft, and the leaknce is 1 x 10^{-5} gpd/ft^3. An equilibrium condition was simulated by the Hantush-Jacob, semi-confined aquifer model as modified by Walton (1970). The drawdowns for the utility site and adjacent areas are given in Figure 7-7. Withdrawing 130,000 gpd of water from Hawthorn Aquifer System-Zone I will not have any significant impact on water levels.

2. Impacts on Other Water Users

Water-Table Aquifer

The withdrawal of 1.1 MGD of water from the water-table aquifer will have a minor effect upon only a few drawdown at equilibrium

t= 70000 gpd/ft

l= 0.00001000000

grid spacing = 500 ft

	1	2	3	4	5	6	7	8	9	10
1	0.93	0.96	0.99	1.01	1.02	1.03	1.02	1.01	0.99	0.96
2	0.96	0.99	1.03	1.06	1.08	1.09	1.08	1.06	1.03	0.99
3	0.99	1.03	1.08	1.12	1.16	1.17	1.16	1.12	1.08	1.03
4	1.01	1.06	1.12	1.19	1.26	1.29	1.26	1.19	1.12	1.06
5	1.02	1.08	1.16	1.26	1.39	1.49	1.39	1.26	1.16	1.08
6	1.03	1.09	1.17	1.29	1.49	3.25	1.49	1.29	1.17	1.09
7	1.02	1.08	1.16	1.26	1.39	1.49	1.39	1.26	1.16	1.08
8	1.01	1.06	1.12	1.19	1.26	1.29	1.26	1.19	1.12	1.06
9	0.99	1.03	1.08	1.12	1.16	1.17	1.16	1.12	1.08	1.03
10	0.96	0.99	1.03	1.06	1.08	1.09	1.08	1.06	1.03	0.99
11	0.93	0.96	0.99	1.01	1.02	1.03	1.02	1.01	0.99	0.96
12	0.90	0.93	0.95	0.96	0.97	0.98	0.97	0.96	0.95	0.93

U.S. 41

Production Well

Utility Site

FIGURE 7-7. DRAWDOWNS OF THE HAWTHORN AQUIFER SYSTEM-ZONE I POTENTIOMETRIC SURFACE FOR A PUMPING RATE OF 0.13 MGD FROM THE UTILITY SITE.

private wells located near Bonita Bay. In no case will the pumping at Bonita Bay cause a drawdown in an off-site well to be more than 1.5 feet (Figures 7-2 to 7-4). This will not cause a significant change in well yield.

Tamiami Aquifer System-Zone I

Pumping of 1.5 MGD from Tamiami Aquifer System-Zone I will affect the nearest existing well by about 2.5 feet and the interference with the Bonita Springs Well Company wellfield will be about 0.25-foot (Figure 7-6). The draw-downs caused by pumping at Bonita Bay will not significantly affect any existing water user that is tapping Tamiami-Zone I.

Hawthorn Aquifer System-Zone I

No water is presently being used from Hawthorn-Zone I within a 5-mile radius of Bonita Springs. Therefore, pumping of Hawthorn-Zone I at Bonita Bay will not affect any other water user.

3. Impact on the Surface Environment

Water-Table Aquifer

Pumping of 1.1 MGD from the water-table aquifer on the utility site will affect the surface environment to a minor degree. A "permanent" lowering of the water table will occur beneath most of the utility site. This will affect growth rates of slash pines and will allow conversion of wetland areas into pine-flatwoods. Since there are no significant wetland areas (more than 1 acre isolated) on the utility site, there will be no impact.

Wetland areas located west of U.S. 41 will be recharged to a variable degree by irrigation water pumped from the utility site. Some of the wet-weather ponds near the utility site may show water levels slightly below present dry season conditions during long dry periods coupled with maximum on-site pumpage. If this would become a problem, some of the water from the utility site could be pumped into these wetlands as recharge. The performance monitoring program will identify any potential need for moving water to various on-site areas.

Tamiami Aquifer System-Zone I

Pumping from Tamiami-Zone I does not directly affect surface environmental conditions. Water pumped to the site from this aquifer will help maintain the water table at acceptable levels.

VIII. WATER BUDGETS

1. Introduction

A water budget or balance is a quantitative assessment that accounts for all water entering and leaving a system. The inflow of water into any area is balanced by an equal amount of outflow from it, with consideration for any changes in storage. The basic water budget equation used for analysis of the aquifers beneath Bonita Bay is:

$$R + G_I + S_I = ET = G_o + S_o \pm \Delta S_t \quad (14)$$

where,

R = rainfall

G_I = groundwater inflow

S_I = surface-water inflow

ET = evapotranspiration

G_o = groundwater outflow

S_o = surface-water outflow

ΔS_t = change in storage

A water budget for each of the three usable aquifers underlying Bonita Bay was calculated for an average year.

2. Water-Table Aquifer

Inflow

There are essentially four sources of inflow to the water-table aquifer, which are: rainfall, lateral groundwater inflow, the net horizontal groundwater inflow, and surface-water inflow. Bonita Bay receives an average of about 53 inches of rainfall per year on the 2,435 acres of the site (main site plus utility site). If this rainfall is averaged over a one-year period and converted to flow, it amounts to 9.6 MGD. Horizontal groundwater inflow was calculated by use of the Darcy Equation to be about 0.39 MGD (Section 5) based to the measured hydraulic parameters and the flow-net (Figure 8-1). Vertical inflow of groundwater occurs, because there is an upward directed hydraulic gradient over more of the site than the downward directed gradient found in the eastern part of the site (Figure 8-2). The net inflow calculated for vertical groundwater movement is 0.12 MGD. The inflow of surface water in the site is minor and is considered to be an insignificant quantity on an average daily basis. Therefore, the overall quantity of water entering the water-table aquifer on an average daily basis is 10.11 MGD.

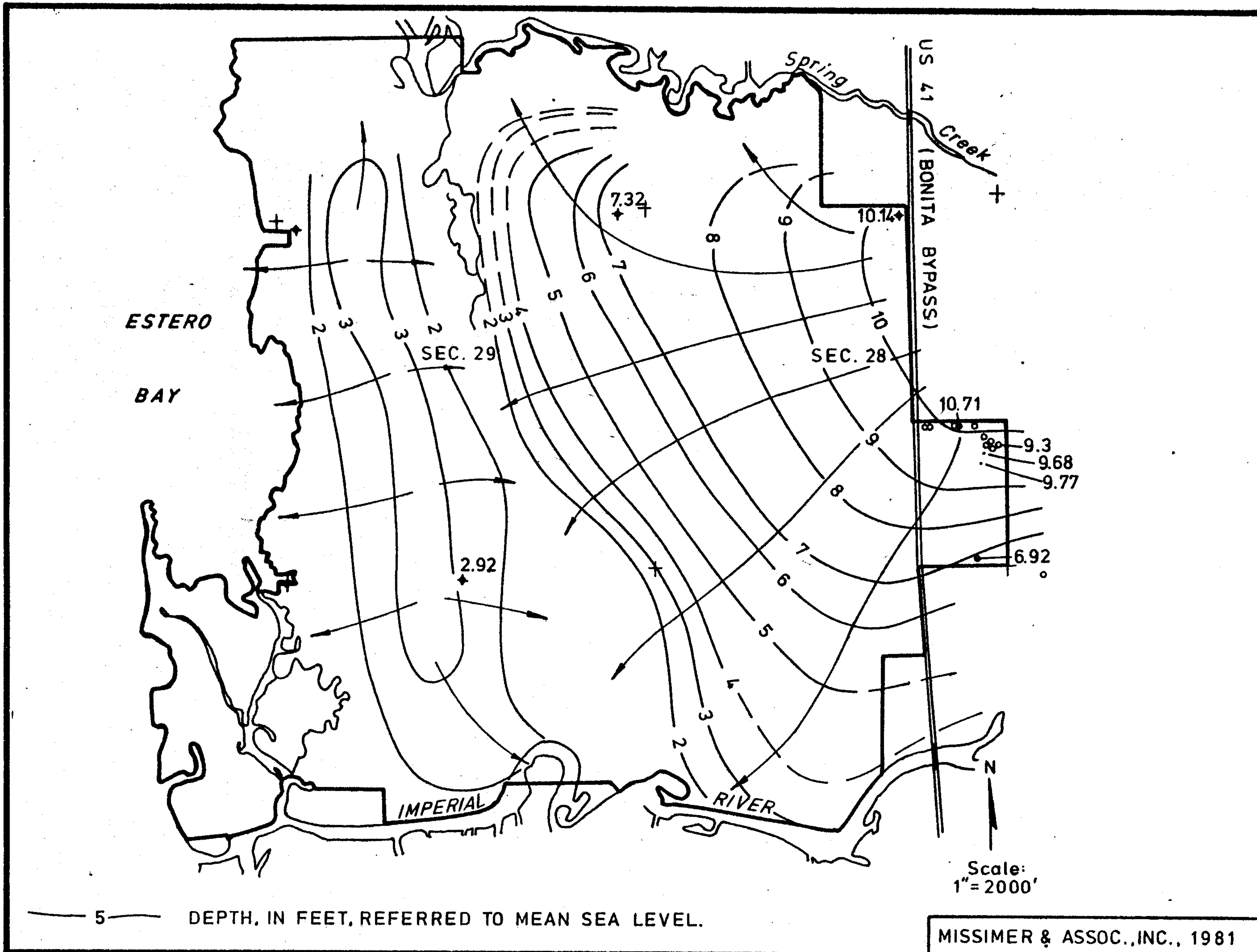

FIGURE 8-1. WATER-TABLE AQUIFER FLOW NET.

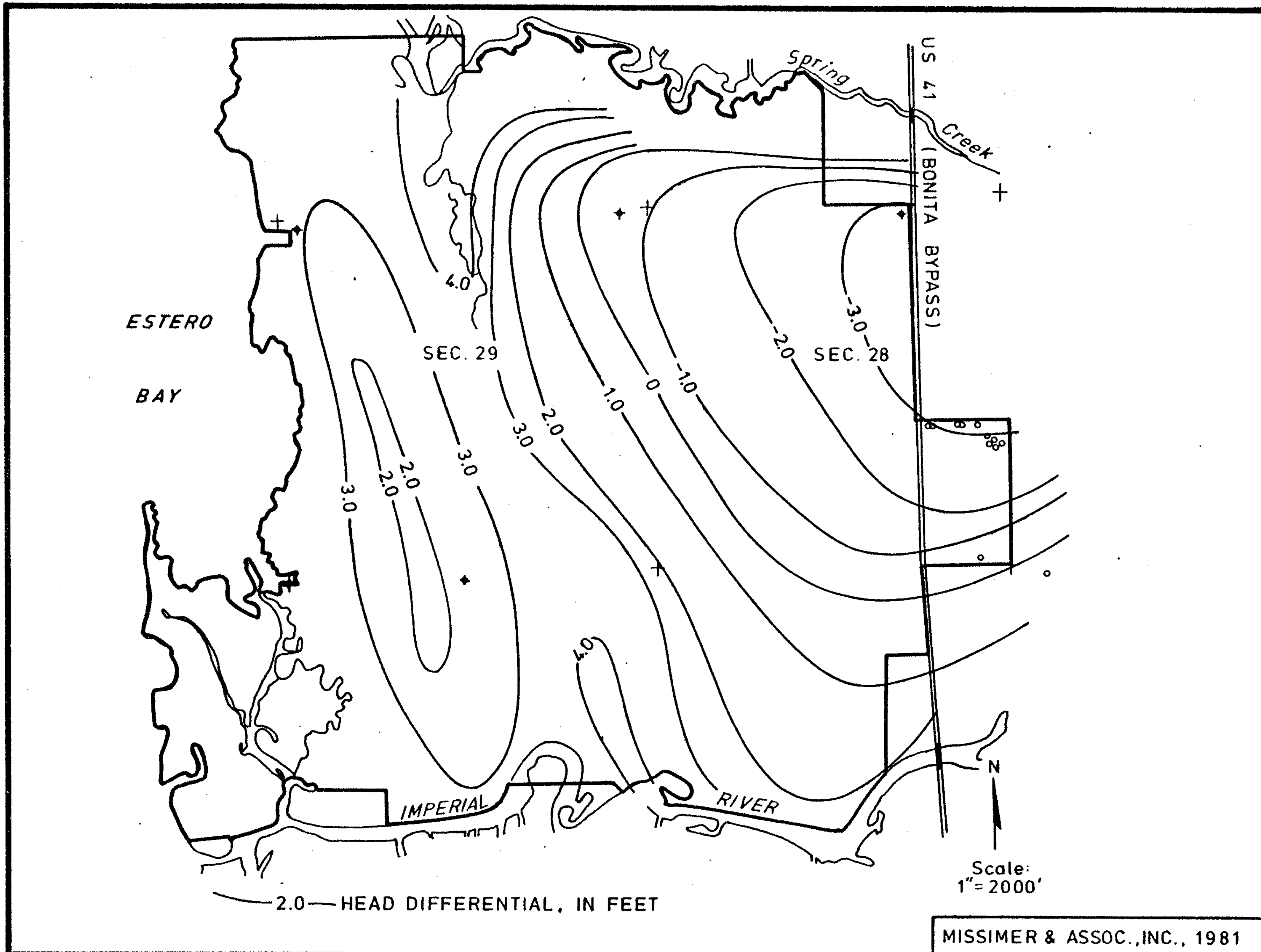

FIGURE 8-2. HEAD DIFFERENTIAL MAP BETWEEN THE WATER-TABLE AQUIFER AND TAMIAMI AQUIFER SYSTEM - ZONE I (APPROXIMATE).

Outflow

Water leaves the water-table aquifer by essentially three routes, which are: evapotranspiration, horizontal groundwater outflow, and through runoff and surface-water discharge. A recent study conducted in the Cocohatchee River Basin to the south found that about 76% of the total annual rainfall is lost to evapotranspiration (Missimer and Associates, Inc., 1981). This percentage applied to Bonita Bay yields an annual loss of 40.28 inches or 7.3 MGD. All horizontal groundwater entering Bonita Bay from the east discharges into either the Imperial River, Spring Creek, or the central slough. Therefore, the exit of groundwater is about 0.39 MGD. Since surface water runoff is the last remaining outflow and it is not easily quantified, we have chosen to calculate it as a residual number, or 2.42 MGD. This is equivalent to about 13.4 inches of runoff for the entire site on an annual basis. If the rainfall total of the period from July 15 to September 15 is summed, this number is close to the annual runoff figure because of the high position of the water table. The rainfall accumulation of this period is near 16 inches, therefore, our estimate is somewhat conservative.

Discussion

The water budget given in Table 8-1 is a reasonable estimate of the annual inflows to and outflows from the water-table aquifer in an average year. The estimates are based on no net change in storage from year to year and are simplified to a large degree. Water shown to be surface runoff may actually discharge as subsurface flow over a short duration, such as during a single storm event.

Pumping of a net 1.1 MGD for use as irrigation will not greatly impact the water budget of the overall site. The water drawdown from the utility site area will be transported to the main site west of U.S. 41 to be used for irrigation. Roughly 50% of the irrigation water pumped will be recycled back into the aquifer west of U.S. 41. With the addition of water pumped from Tamiami-Zone I, Hawthorn-Zone I, and treated wastewater, the water-table aquifer will receive a large quantity of recharge.

3. Tamaimi Aquifer System-Zone I

Inflow

There are only two sources of inflow to Tamiami Aquifer System-Zone I, which are lateral or horizontal groundwater flow and vertical groundwater flow. Lateral flow of water through the aquifer was evaluated as typical Darcy flow controlled by conditions defined in the flow

TABLE 8-1. WATER-TABLE AQUIFER WATER BUDGET

Inflow	Parameters, in MGD
Rainfall	9.60
Horizontal groundwater flow	0.39
Vertical groundwater flow (net)	0.12
Surface water	0
	10.11

Outflow	
Evapotranspiration	7.30
Horizontal groundwater flow	0.39
Surface water (runoff)	2.42
	10.11

net with a transmissivity of 60,000 gpd/ft (see flow net in Figure 8-3). If a corridor width of 10,000 feet is used and a calculated hydraulic of 0.0002 from the flow net, then the average daily flow is about 120,000 gpd. The inflow of water from vertical leakage is limited to roughly 600 acres according to the head differential map (Figure 8-2). If an average vertical gradient of 2 feet is used and a leakance of 1.3×10^{-3} gpd/ft, then the average daily vertical inflow rate is about 79,000 gpd. Therefore, the total inflow to Tamiami Aquifer System-Zone I is about 200,000 gpd (Table 8-2).

Outflow

The only outflows from Tamiami-Zone I are from lateral and vertical groundwater flow. Most of the outflow leaves the aquifer through upward leakage into the water-table aquifer. Analysis of the head differential map shows that upward leakage occurs beneath about 1,835 acres of the site with an average vertical gradient of about 2 feet. About 0.196 MGD is the calculated vertical loss rate. The difference between 0.199 MGD and the vertical loss rate yields the lateral outflow rate or 0.03 MGD. This reduced lateral outflow rate is a reflection of lateral head losses and a reduction in the transmissivity of the aquifer to the west.

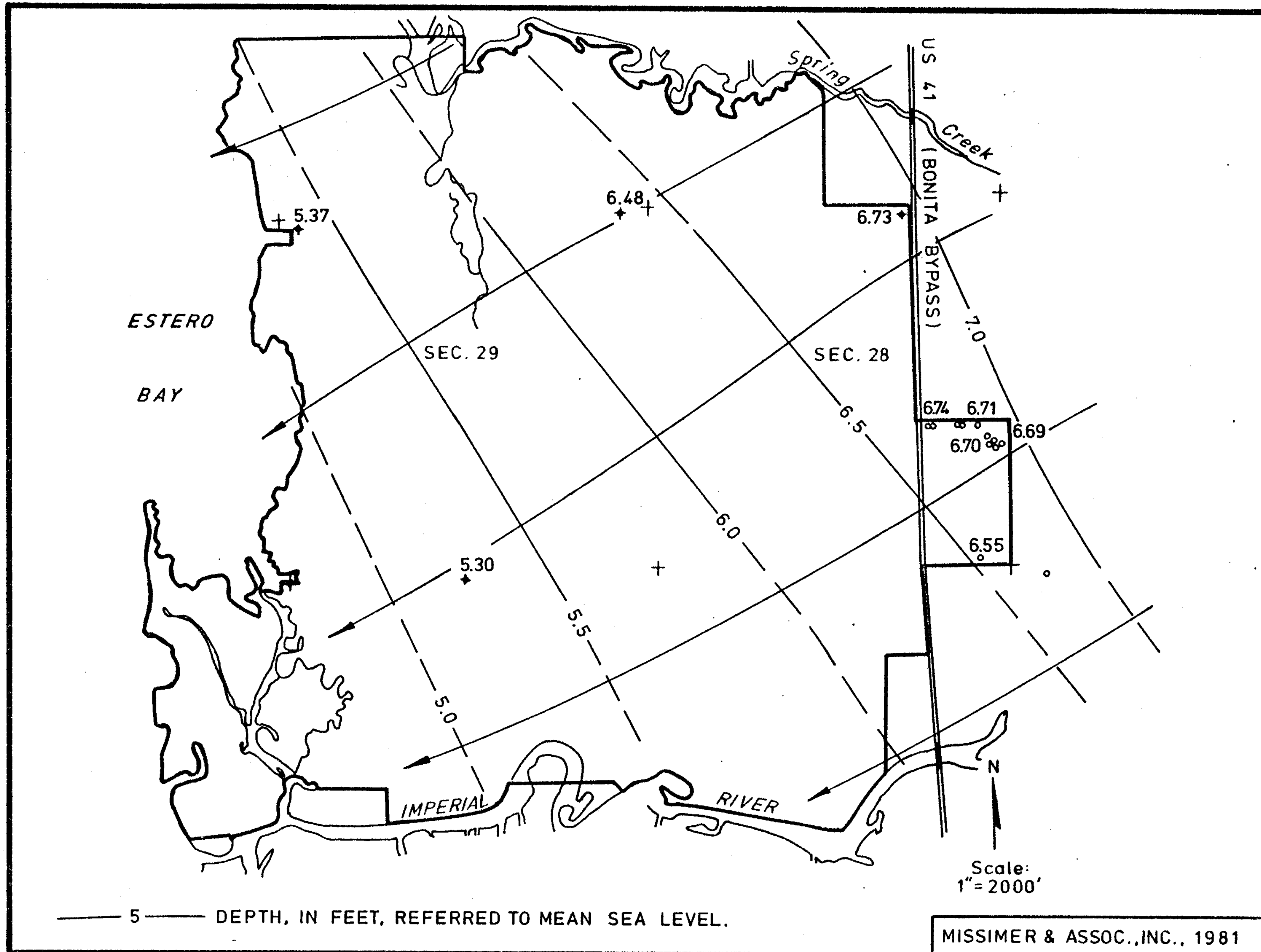

FIGURE 8-3. TAMIAMI AQUIFER SYSTEM - ZONE I FLOW NET.

TABLE 8-2. TAMIAMI AQUIFER SYSTEM-ZONE I WATER BUDGET

Inflow	Parameters, in MGD
Groundwater	
Horizontal	0.120
Vertical	0.079
	0.199

Outflow	
Groundwater	
Horizontal	0.003
Vertical	0.196
	0.199

Discussion

The inflows and outflows from Tamiami-Zone I are quite low because of the relatively small hydraulic gradients, which occur in the system under natural conditions. The water budget given in Table 8-2 was again calculated based on no net change in storage from a given year into the next.

Pumping of 1.5 MGD of water from the utility site will significantly affect both the vertical and horizontal gradinets in the vicinity of the site. As shown in Section 7, the drawdowns caused by the pumping of Zone I will be greatest to the east of the sit. Also, the pumping of Zone I and discharge into the water-table aquifer west of U.S. 41 will cause a slight increase in the Zone I potentiometric head due to vertical loading. The water budget of Tamiami-Zone I will be altered in that a much larger quantity of flow will enter the utility site from the northeast and east.

4. Hawthorn Aquifer System-Zone I

Discussion

Flow of water into and out of Hawthorn-Zone I is essentially limited to lateral flow, because of the very low vertical leakage rates. The Darcy flow across the site amounts to about 560,000 gpd (Figure 8-4).

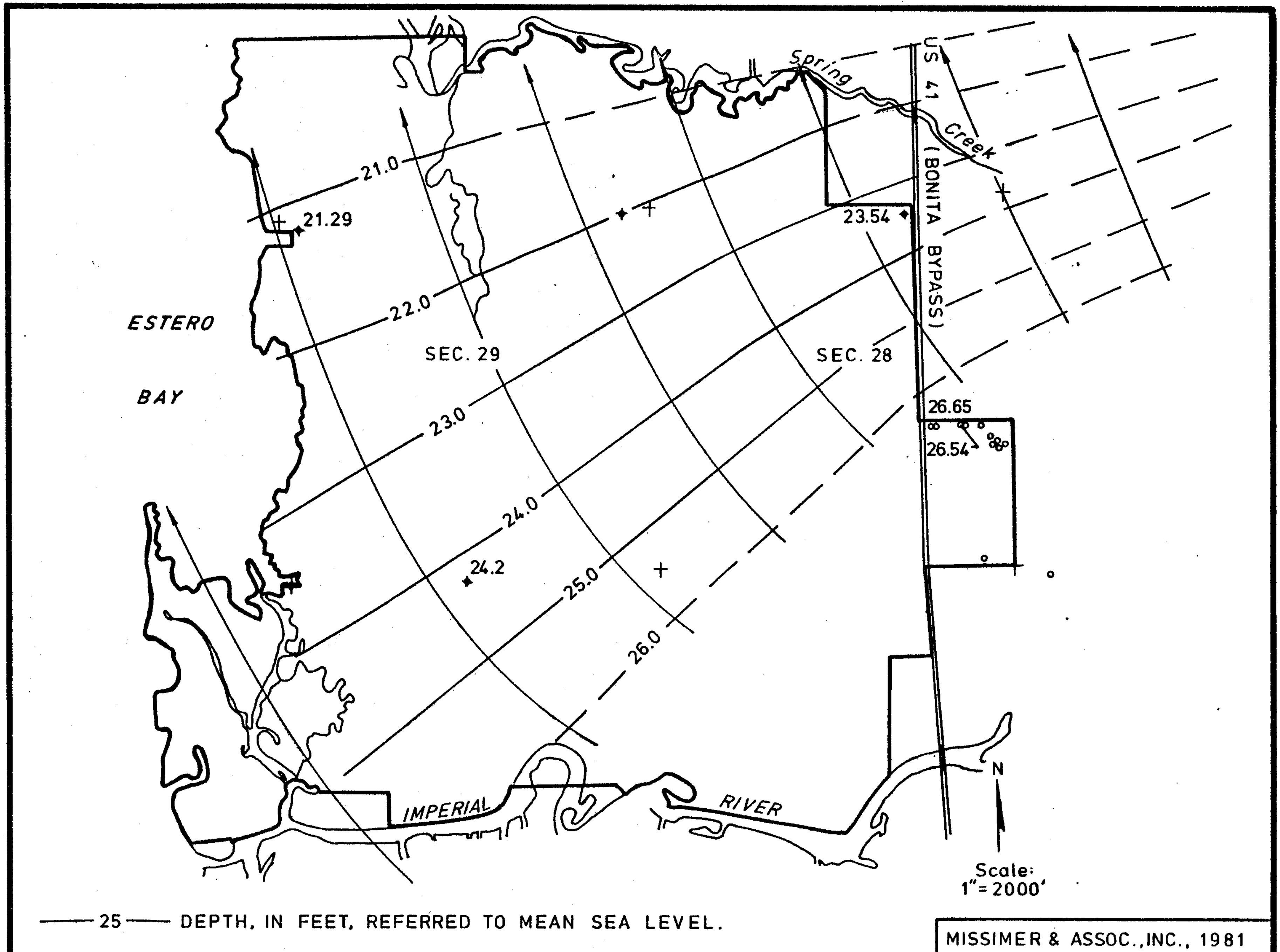

FIGURE 8-4. HAWTHORN AQUIFER SYSTEM - ZONE I FLOW NET.

Since the aquifer is basically a flow-thru system, the outflow is approximately equivalent to the inflow.

Pumping of water from Hawthorn-Zone I will not have any significant effect on the water budget as shown in Section 8.

IX. SALINE-WATER INTRUSION

1. Water-Table Aquifer

Pumping the water-table aquifer at a net rate of 1.1 MGD will cause a cone of depression, which will intersect tidal saline water at two locations. Since lowering of potentiometric head in the vicinity of tidal water tends to increase the potential for lateral intrusion of saline water, we have performed an analysis of the potential magnitude of the intrusion.

Tidal saline water occurs to the south of the utility site in the Imperial River and north of the site in Spring Creek. These water bodies are located 2,700 feet and 3,500 feet respectively from the boundaries of the utility site. Saline water also occurs about 1 mile west of the utility site in the southern part of the central slough. In order to induce saline water intrusion, the slope of the hydraulic gradient must be reversed away from the source of the denser water. To the south of the utility site, the natural hydraulic gradient is about 1.5 feet/1,000 feet during the wet season and probably will level to near 1 foot/1,000 feet during the dry season. The slope induced by pumping in the vicinity of Imperial River is near 0.6 to 0.7 foot/1,000 feet, which is less than the dry season gradient. The lake located immediately south of the utility site will actually reduce the true gradient to less than 0.1 foot/1,000 feet to the south. Therefore, since the gradient will not be reversed and the aquifer thickness is only 30 feet, saline water intrusion will not be induced from the Imperial River into the wellfield. A similar arrangement can be made for saline-water intrusion from the north. In this case, the natural hydraulic gradient near Spring Creek is near 5 feet/ 1,000 feet, whereas the induced hydraulic gradient is less than 0.5 foot/1,000 feet. Therefore, saline-water intrusion will not be induced from the northern direction. The pumping-induced hydraulic gradient within the water-table aquifer will not cause saline-water intrusion from any direction.

2. Tamiami Aquifer System-Zone I

The saline-freshwater interface within Tamiami Aquifer System-Zone I parallels U.S. 41 beneath the Bonita Bay site. The pumping of 1.5 MGD of water from the aquifer on the utility site will create an elongated cone of depression as shown in Figure 7-6. When the cone of depression is superimposed on the isochlor map (Figure 5-41), with consideration of the 1 foot/mile hydraulic gradient inducing flow from the northwest, it is evident that at least two-thirds of the water recharging the aquifer comes from east of U. S. 41. This recharge is essentially good quality water leaking into Zone I from the water-table aquifer and will help stabilize water quality from the production wells. It is our opinion from the dissolved chloride data, that chloride concentrations in the Tamiami-Zone I production wells will increase from 320 mg/l to stability near 450 mg/l based on recharge and flow within the aquifer system.

The Bonita Bay Wellfield will not cause inland migration beyond the point of withdrawal. This pumpage will create a hydraulic barrier to the migration of saline water into the nearby Imperial Harbor wellfield and the Bonita Springs wellfield to the east.

X. EFFECTS OF IRRIGATION ON WATER QUALITY

1. Water-Table Aquifer

Water quality within most of the water-table aquifer west of U.S. 41 is quite good according to the samples collected from observation wells (Section 5.5). Saline water is limited to areas adjacent to tidal water. Since non-potable quality water will be used to irrigate large portions of the development, some questions have been raised concerning water quality of the aquifer over the long term.

At the 10-year threshold in the development of Bonita Bay, about 4.13 MGD of water will be required for irrigation. Since four different sources of water with different qualities will be utilized, it is necessary to evaluate both the composite quality of the mix and the effect of the irrigation water on the overall quality within the aquifer. The sources of water, pumping rates, and the quality of water in each source are given in Table 10-1. An analysis of the mixture of these sources at the proposed pumping rates yields a composite dissolved chloride concentration of 320 mg/l. All water pumped from the various sources will be mixed in a holding pond located either on the utility site or nearby. The mixing operation will be monitored carefully in order to prevent surges of high salinity water

TABLE 10-1. GROSS PUMPAGE AND THE QUALITY OF WATER TO BE USED FOR IRRIGATION

Aquifer	Proposed Pumping Rate	Dissolved Chloride(mg/l)
Water-Table	1.1 MGD	40
Tamiami-Zone I	1.5 MGD	450
Wastewater	1.4 MGD	250
Hawthorn-Zone I	0.13 MGD	1500

Composite weighted quality = 320 mg/l

into the secondary irrigation system. The 320 mg/l dissolved chloride level will not significantly affect the composite quality of water in the aquifer for many years, because of dilution by rainfall and natural flushing caused by the high permeability of the sandy soils.

XI. WELLFIELD MANAGEMENT AND OPERATION

1. Wellfield Management

The irrigation water supply proposed to serve Bonita Bay is unique, because four separate sources of raw water will be used. This system will provide both the volume and quality of water required to maintain the landscape and turf grass in the development. The approximate use rates for the first 10 years from each source are given in Table 11-1. Most of the water used will be pumped from the water-table aquifer, Tamiami Aquifer System-Zone I, and from the rennovated wastewater percolation ponds. Water from Hawthorn Aquifer System-Zone I will be used to make up volume only if necessary and it will never exceed 30% of the total volume pumped from the other sources.

Proposed positions of production wells are given in Figure 7-1. Of the wells shown on Figure 7-1, only the Tamiami-Zone I and Hawthorn-Zone I wells will definitely be positioned at the sites shown. The water-table aquifer wells will vary depending on where the percolation ponds are positioned. If the 60-acre site is used for the rennovated wastewater percolation ponds, then a total of 2.5 MGD will be pumped from the wells. Since the ponds will be recharged at a rate of 1.4 MGD, the net pumpage from the aquifer will be 1.1 MGD. This option of using wells

TABLE 11-1. PUMPING SCHEDULE AT PEAK DEMAND FOR 10 YEARS

Source of Water	Pumping Rate
Water-Table Aquifer	1.1 MGD
Tamiami Aquifer System-Zone I	1.5 MGD
Rennovated Wastewater	1.4 MGD
Hawthorn Aquifer System-Zone I	0.13 MDG (standby)
	4.13 MGD

to induce percolation from the ponds is preferred because it would both recharge the aquifer and provide clean water for irrigation. Even if the site is not used for the percolation ponds, 1.1 MGD of water will be pumped from the water-table aquifer.

2. Proposed Locations and General Specifications for New Wells

Assuming that treated wastewater will be placed in utility site percolation ponds, there will be 12 production wells required to produce 4.13 MGD. Eight of the wells will tap the water-table aquifer; three will tap Tamiami-Zone I, and one will tap Hawthorn-Zone I. If treated wastewater were to be used directly, only three water-table aquifer production wells would be constructed on the utility site. The general construction specifications proposed for the production wells are given in Table 11-2.

3. Pumping Schedule

At the present time, all production wells will be pumped at the rates given in Table 11-2. A holding pond of some type will be utilized as a mixing basin for the different waters pumped from the various sources. Pumping from the wells will be based on need only and excess pumping will not be allowed.

TABLE 11-2. PROPOSED PRODUCTION WELL SPECIFICATIONS

Well No.	Aquifer	Total Depth(ft)	Casing Depth(ft)	Casing Diameter(ft)	Pumping Rate (gpm)
W-1 (L-M-1684)	Water-Table	33	19	8	350
W-2	Water-Table	32	19	10	200
W-3	Water-Table	32	19	10	200
W-4	Water-Table	27	18	10	200
W-5	Water-Table	29	18	10	200
W-6	Water-Table	30	19	10	200
W-7	Water-Table	32	19	10	200
W-8	Water-Table	32	19	10	200
T-1 (L-M-1682A)	Tamiami-Zone I	120	74	10	350
T-2	Tamiami-Zone I	120	75	10	350
T-3	Tamiami-Zone I	120	75	10	350
H-1 (L-M-1720)	Hawthorn-Zone I	255	235	8	350

4. Monitoring

The management of the Bonita Bay irrigation system will be based on performance monitoring. There will be four components to the overall groundwater monitoring system, which will include: 1) keeping accurate records of gross pumpage from each production well, 2) measurement of rainfall accumulation, 3) measurement of groundwater levels, and 4) measurement of groundwater quality.

Measurement of pumpage from each production well will be made by use of time elapse meters, flow meters, or by recorded time with pump discharge. These records will be kept on a daily basis and will be compiled monthly to be evaluated.

Measurement of rainfall will be accomplished on a continuous basis at some point on-site by utilizing a continuous recording gage. One or more plastic standard gages will be used at other site locations. This information will be compiled on a monthly basis. The data will be used to evaluate irrigation needs for the golf course and common landscaped areas.

Monitoring of water levels in the three aquifers to be used is very important in order to prevent overpumpage and saline-water intrustion. A series of 26 observation wells will be used to monitor water levels. Three of these wells will be equipped with continuous water level recorders and the others will be measured on a monthly basis. All information will be compiled and will be reviewed by a hydrologist at the end of each month.

Groundwater quality will be monitored very carefully in order to observe saline-water movement and to observe nutrient migration from the percolation ponds. The dissolved chloride concentration will be measured in key observation and production wells, on a month basis (or daily by the operator if major fluctuations are observed). In certain other wells the dissolved chloride concentration will be measured bi-annually at the end of the wet and dry seasons, or October and May. The dissolved nutrient concentrations in water-table aquifer production wells will be measured quarterly.

The key to proper management of the irrigation system described in this report is the implementation and maintenance of the monitoring system. Major adjustment can be made in pumping rates or the overall management strategy of the system based on what is observed. The frequency of both water level and water quality measurements will be altered in the future based on what is observed. The data collected over the years will serve to support future water use permit modifications. A summary of the monitoring program is given in Table 11-3 and a location map of the wells is given in Figure 11-1.

TABLE 11-3. PROPOSED PERFORMANCE MONITORING PROGRAM

Well No.	Aquifer	Water Levels	Water Quality	Type of Well
L-M-1678	Water-Table	M	--	Observation
F-1	Water-Table	M	--	Observation
B-1	Water-Table	M	--	Observation
C-1	Water-Table	M	--	Observation
A-1	Water-Table	M	--	Observation
E-1	Water-Table	M	--	Observation
D-1	Water-Table	M	M,Cl	Observation
L-M-1648	Water-Table	M	--	Observation
L-M-1647	Water-Table	M	--	Observation
L-M-1650	Water-Table	R	M,Cl	Observation
L-M-1651	Water-Table	M	--	Observation
F	Water-Table	R	M,Cl	Observation
W-1	Water-Table	--	M,Cl Q,N	Production
W-2	Water-Table	--	M,Cl Q,N	Production
W-3	Water-Table	--	M,Cl Q,N	Production
W-4	Water-Table	--	M,Cl Q,N	Production
W-5	Water-Table	--	M,Cl Q,N	Production
W-6	Water-Table	--	M,Cl Q,N	Production
W-7	Water-Table	--	M,Cl Q,N	Production
L-M-1676	Tamiami-Zone I	R	B,Cl	Observation
L-M-1677	Tamiami-Zone I	M	B,Cl	Observation
L-M-1680	Tamiami-Zone I	M	B,Cl	Observation
B-2	Tamiami-Zone I	M	M,Cl	Observation
C-2	Tamiami-Zone I	M	B,Cl	Observation
A-2	Tamiami-Zone I	M	B,Cl	Observation
E-2	Tamiami-Zone I	M	B,Cl	Observation
D-2	Tamiami-Zone I	M	B,Cl	Observation
L-M-1649	Tamiami-Zone I	M	B,Cl	Observation
L-M-1646	Tamiami-Zone I	M	B,Cl	Observation
L-M-1717	Tamiami-Zone I	M	B,Cl	Observation
L-M-1645	Tamiami-Zone I	M	B,Cl	Observation
L-M-1644	Tamiami-Zone I	M	M,Cl	Observation
T-1	Tamiami-Zone I	--	M,Cl	Production
T-2	Tamiami-Zone I	--	M,Cl	Production
T-3	Tamiami-Zone I	--	M,Cl	Production
L-M-1718	Tamiami-Zone I	M	B,Cl	Observation
H-1(L-M-1720)	Tamiami-Zone I	--	B,Cl	Production

Key

M = monthly measurement
R = recorder
Cl = dissolved chloride measurement
Q = quarterly measurement
N = nutrients
B = bi-annual measurement

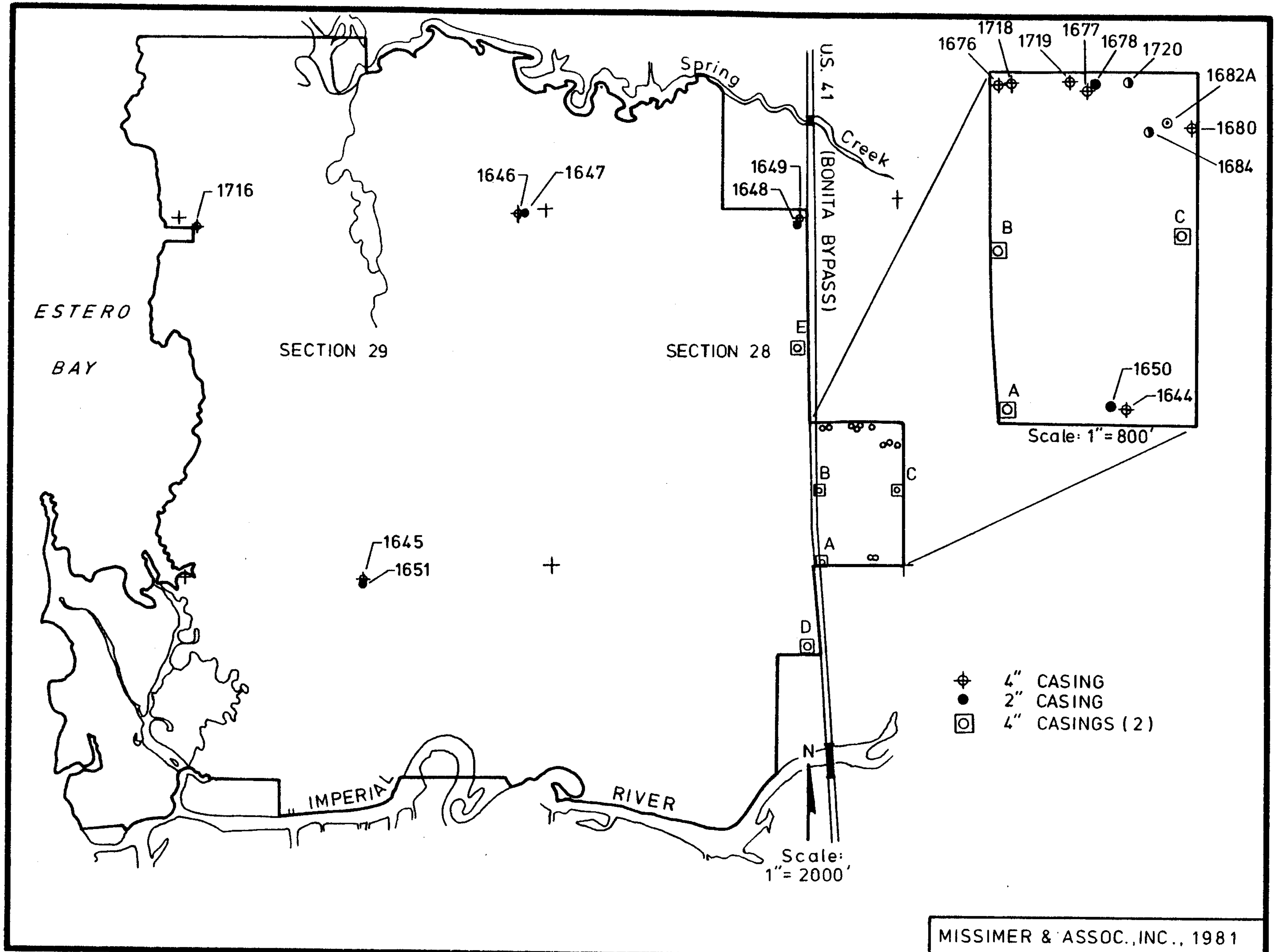

FIGURE 11-1. MAP SHOWING THE LOCATION OF OBSERVATION WELLS TO BE USED FOR MONITORING.

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