UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DEEP ARTESIAN AQUIFERS OF SANIBEL AND CAPTIVA ISLANDS, LEE COUNTY, FLORIDA

OPEN-FILE REPORT 82-253

Prepared in cooperation with the

CITY OF SANIBEL and the
BOARD OF COMMISSIONERS OF LEE COUNTY, FLORIDA

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CONVERSION FACTORS

For those readers who prefer to use metric (SI) units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric (SI) units
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785×10^{-3}	cubic meter (m^3)
gallon per minute (gal/min)	0.0631	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
million gallons (Mgal)	3.785×10^3	cubic meters (m^3)

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National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

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Tallahassee, Florida

1982

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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LEE COUNTY, FLORIDA

By D. H. Boggess and T. H. O'Donnell

ABSTRACT

Sanibel and Captiva Islands, two of the barrier islands off the lower west coast of Florida, have a resident population of about 6,000 and an additional 6,000 visitors during the peak of the tourist season. Rapid growth and extensive development in recent years have imposed progressively greater stress on the water resources of the islands.

Sanibel and Captiva Islands are underlain by a series of geologic formations containing some zones of relatively freshwater and other zones of more mineralized, or even very saline water. Two aquifers are the principal sources of water supply on the islands. The upper aquifer is in the upper part of the Hawthorn Formation. The lower aquifer is in the lower part of the Hawthorn Formation and the underlying upper part of the Tampa Limestone. Both aquifers are under sufficient artesian pressure to permit wells to flow at land surface. The potentiometric surface of the lower Hawthorn-upper Tampa aquifer has been lowered in the central part of Sanibel Island where the Island Water Association operates about 10 wells that tap the lower aquifer.

In 1977, the average pumpage from these 10 wells was 1.4 million gallons per day. The water is processed through a desalination plant before distribution. In 1977, the total volume of water withdrawn from both the lower and upper aquifers for all purposes was 690 million gallons, an average of about 1.9 million gallons per day.

Water from the upper Hawthorn aquifer during the period 1975-77 contained dissolved solids concentrations ranging from 721 to 2,390 milligrams per liter. Water from the lower Hawthorn-upper Tampa aquifer during the same period contained concentrations ranging from 1,700 to 4,130 milligrams per liter. Water from both aquifers is hard and contains relatively high concentrations of sodium, sulfate, and chloride.

INTRODUCTION

Sanibel and Captiva Islands form part of the barrier island chain off the lower west coast of Lee County, Florida (fig. 1). Both islands are resort areas and have a resident population of 6,000 and an additional 6,000 people during the peak of the tourist season (Sanibel Planning Council, 1977, written commun.). Rapid growth and extensive development in recent years have imposed progressively greater stress on the land and water resources of the islands.

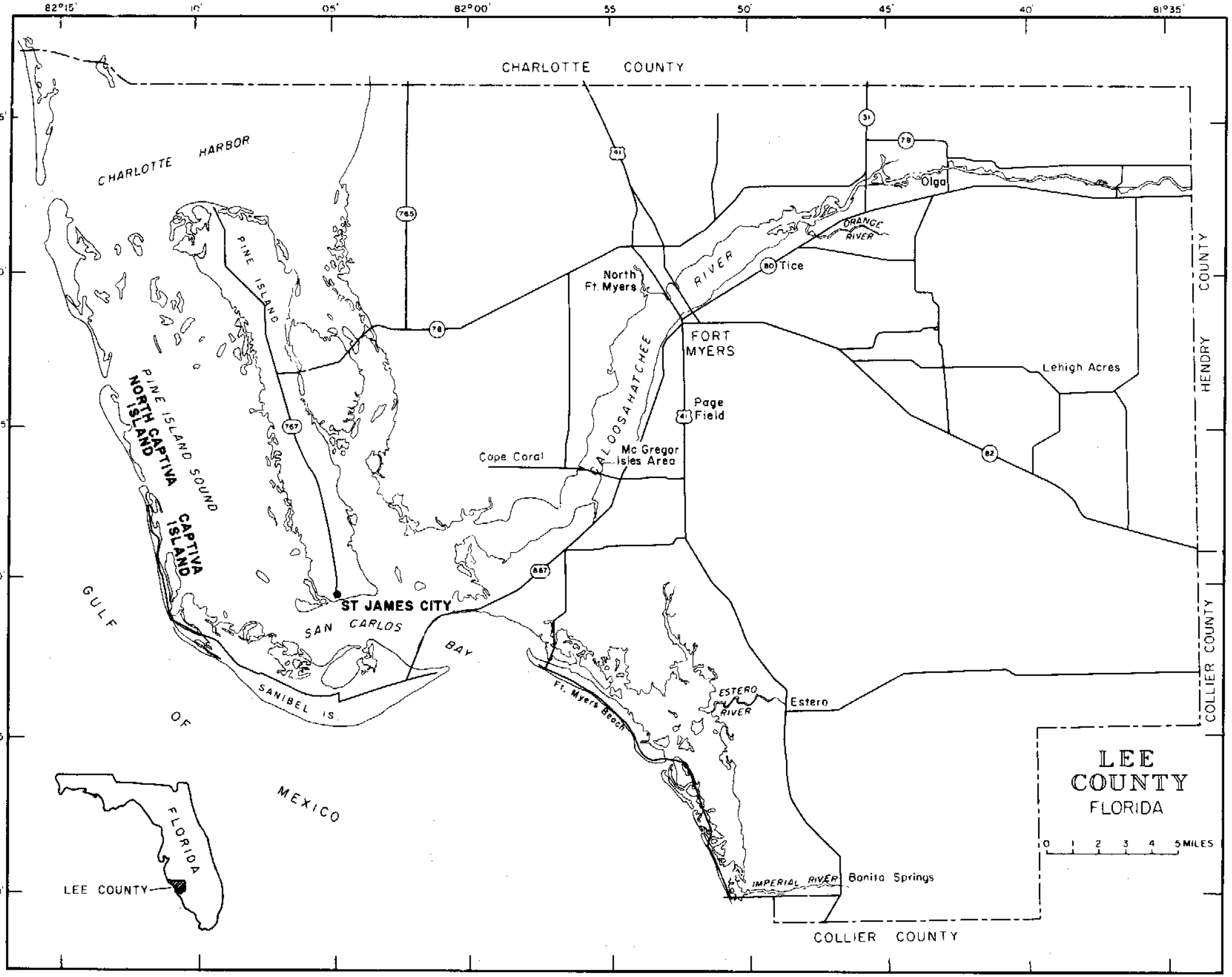

Figure 1.--Location of Sanibel and Captiva Islands.

Historically, fresh ground water on Sanibel and Captiva Islands has been obtained from shallow wells, generally less than 15 feet deep. These wells provide only small supplies and frequently yield brackish or saline water during the dry season.

A pipeline was constructed in 1966 which transports water purchased from the Greater Pine Island Water Association well field and treatment plant on the mainland to provide a dependable water supply to the islands. This pipeline extends beneath San Carlos Bay from St. James City to the northern end of Sanibel Island. The water-supply system on Sanibel and Captiva Islands at that time (1966) consisted of pumping stations and water distribution lines. Beginning in 1973, a number of deep (about 300 to 900 feet) artesian wells were drilled for public supply. The saline water from these wells (Boggess, 1974a, fig. 4) is processed by electrodialysis for domestic use. The pipeline and the desalination plant provided sufficient water for most needs, but recent increased demand has resulted in increased importation of water from the mainland.

Purpose and Scope

During the time that the desalination plant has been in operation, questions have been raised by water-management agencies concerning the ability of the deep artesian aquifers underlying Sanibel and Captiva Islands to continue supplying the water needed to meet the increasing demand with a salinity low enough for the desalination plant to operate effectively. The purpose of this investigation was to evaluate the water-supply potential of the deeper aquifers.

During the 24-month investigation, October 1975-77, an important objective was to locate and inventory all existing wells that tapped the deep artesian aquifers. Except for a few, all known wells were found. Water levels and water samples were obtained at the wells. No test wells were drilled as part of this investigation, although one observation well was drilled on Sanibel Island as part of a countywide monitoring network. The data included in this report will provide a better understanding of the water quality of the deep aquifers underlying these offshore islands for the effective development of the water resources.

Acknowledgments

The authors gratefully acknowledge the cooperation and assistance of the residents of Sanibel and Captiva Islands in providing data included in this report. All well owners, including the Island Water Association of Sanibel, freely permitted access to their wells so that water-level data and water samples could be obtained. The cooperation and support of officials of the city of Sanibel and the Board of County Commissioners are also gratefully acknowledged.

Well-Numbering System

All wells listed in this report or for which data are cited are numbered as part of a countywide system. The wells were numbered in sequence as each well or test hole was inventoried. The locations of wells and test holes on which information was obtained during the investigation are shown in figure 2.

GEOLOGY

The surficial deposits on Sanibel and Captiva Islands are Holocene and Pleistocene in age and include sand, shells, clay, and limestone generally less than 120 feet thick. Below these deposits is the Tamiami Formation of Pliocene age which consists chiefly of gray and green clay and sandy clay. Thin beds of sandstone, sand, or limestone occur locally in the Tamiami, and phosphorite is a common accessory mineral. Thickness of the Tamiami ranges from about 200 feet beneath central Sanibel Island to less than 100 feet beneath other parts of the islands.

The Hawthorn Formation and Tampa Limestone of Miocene age successively underlie the Tamiami Formation and range in thickness from about 300 feet beneath central Sanibel Island to about 400 feet beneath other parts of the islands. Both formations consist predominantly of gray and gray-white phosphatic limestone with interbedded marl or calcareous clay. Phosphorite is abundant with major concentrations in the lower part of the Hawthorn Formation.

Below the Tampa Limestone, the Suwannee Limestone is usually penetrated 600 to 700 feet below land surface. This formation consists predominantly of tan limestone. The Suwannee Limstone may extend to 1,100 feet or more beneath Sanibel Island.

The sequence of geologic units and water-bearing units are shown in figure 3 with lithologic and gamma-ray logs of well 2524 on the southwest shore of Sanibel. The gamma-ray activity of the phosphorite is high because it contains a minute quantity of uranium (Altschuler and others, 1958). The gamma-ray peaks in the lower part of the Hawthorn have been assigned numbers (4E, 5C, and 5D) and are used as markers for correlation purposes. They have been identified in nearly all the test holes and wells on Sanibel and Captiva Islands for which gamma-ray logs have been obtained. On the basis of gamma-ray correlation, the lithology is fairly consistent (fig. 4). The geologic section (fig. 4) is constructed from data of four test wells along an east-trending line across Sanibel Island (fig. 2).

Comparable beds penetrated at greater depth in well 1704 than in well 2401 may indicate that some vertical displacement has occurred (fig. 4). For example, the gray-white, phosphatic limestone (which marks the top of the Hawthorn Formation) occurs at a depth of about 200 feet in well 2401, and at a depth of 350 feet in well 1704. These wells are 1.7 miles apart, so that the intevening slope of the top of the phosphatic limestone is about 90 ft/mi. Although the top of the limestone is an erosional surface, the beds lying at greater depths have similar slopes. Displacement of beds by folding is possible in this general area. Missimer and Gardner (1976)

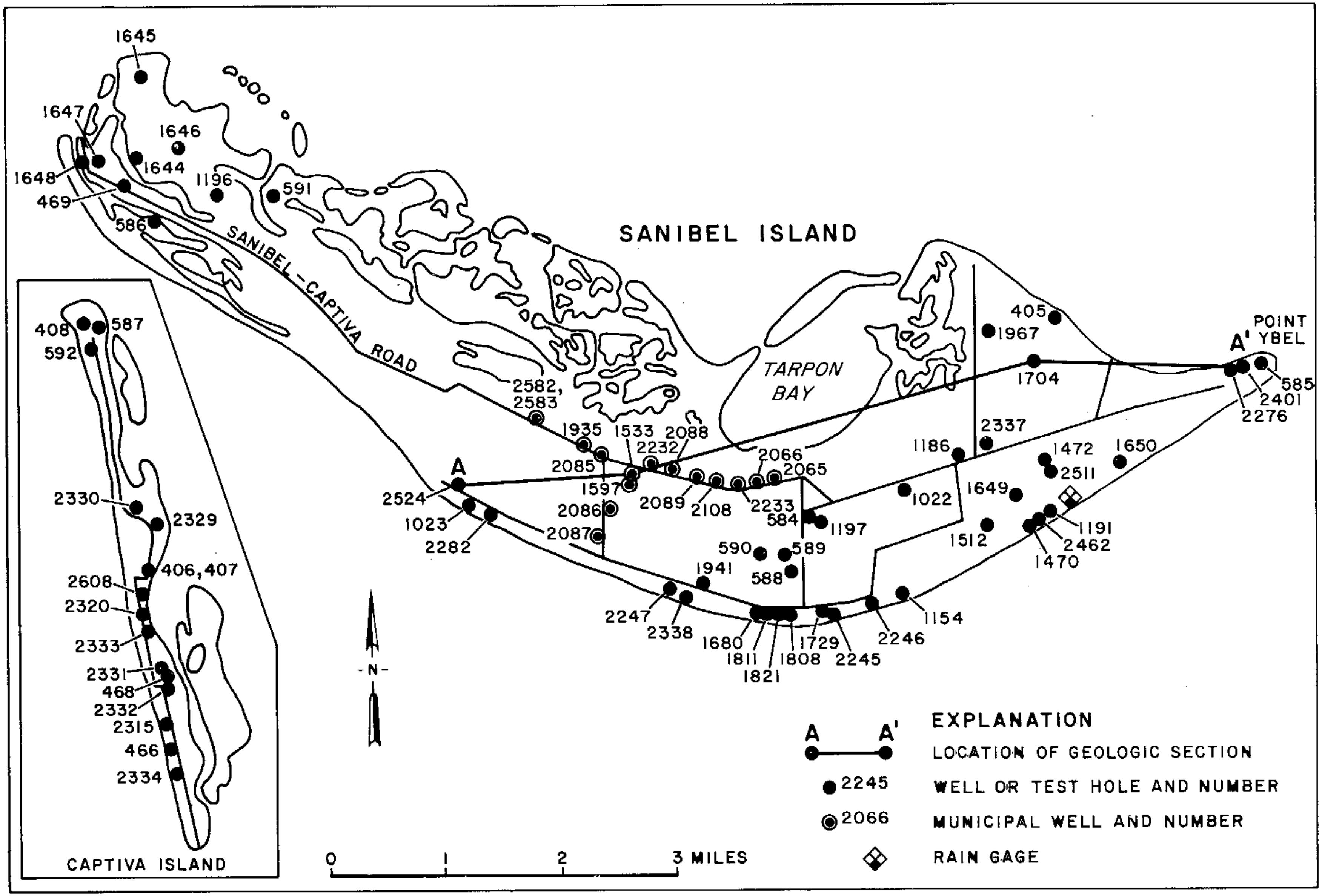

Figure 2.--Location of wells and test holes on Sanibel and Captiva Islands.

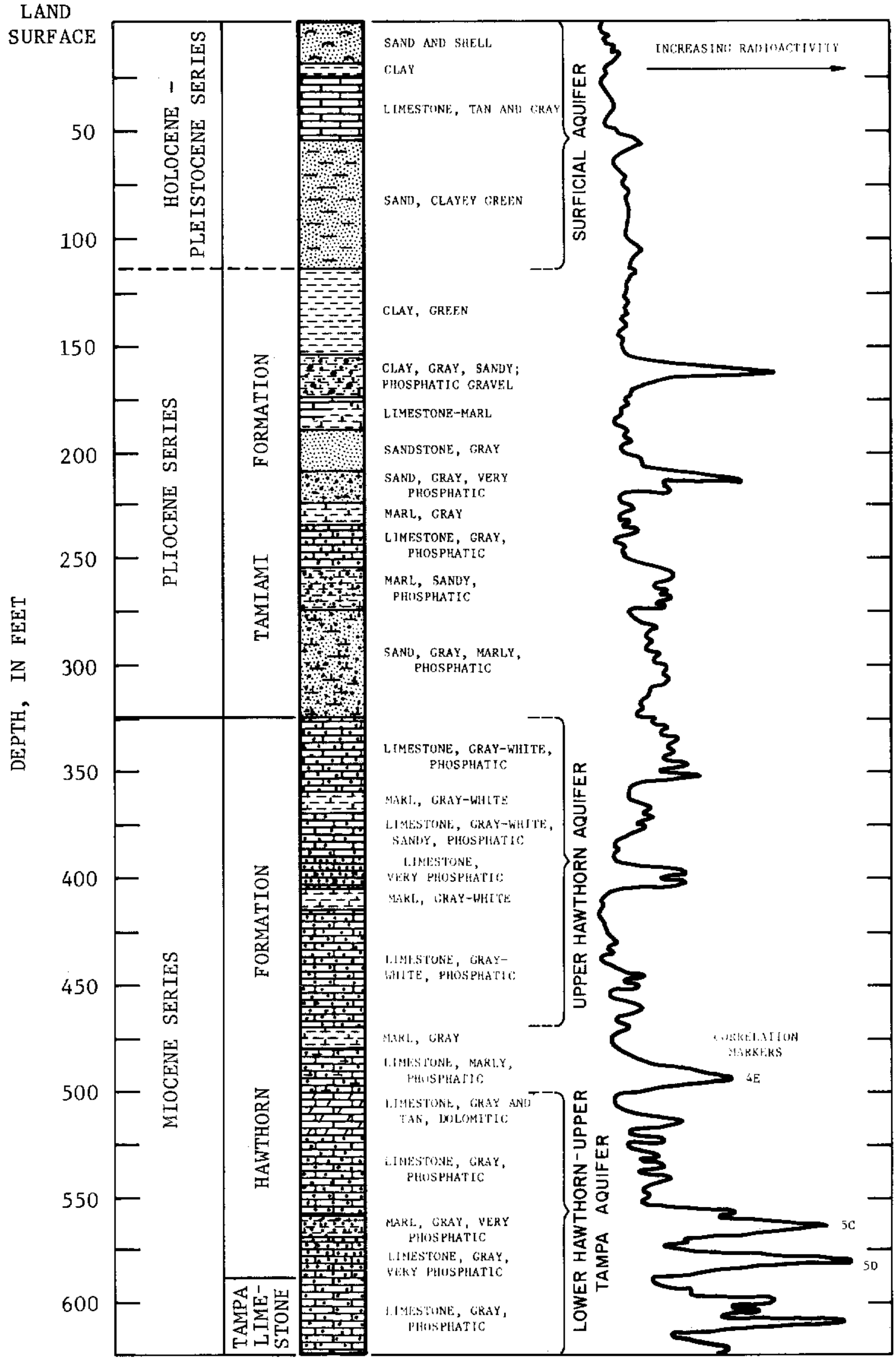

Figure 3.--Lithologic and gamma-ray log of test well 2524 on Sanibel Island.

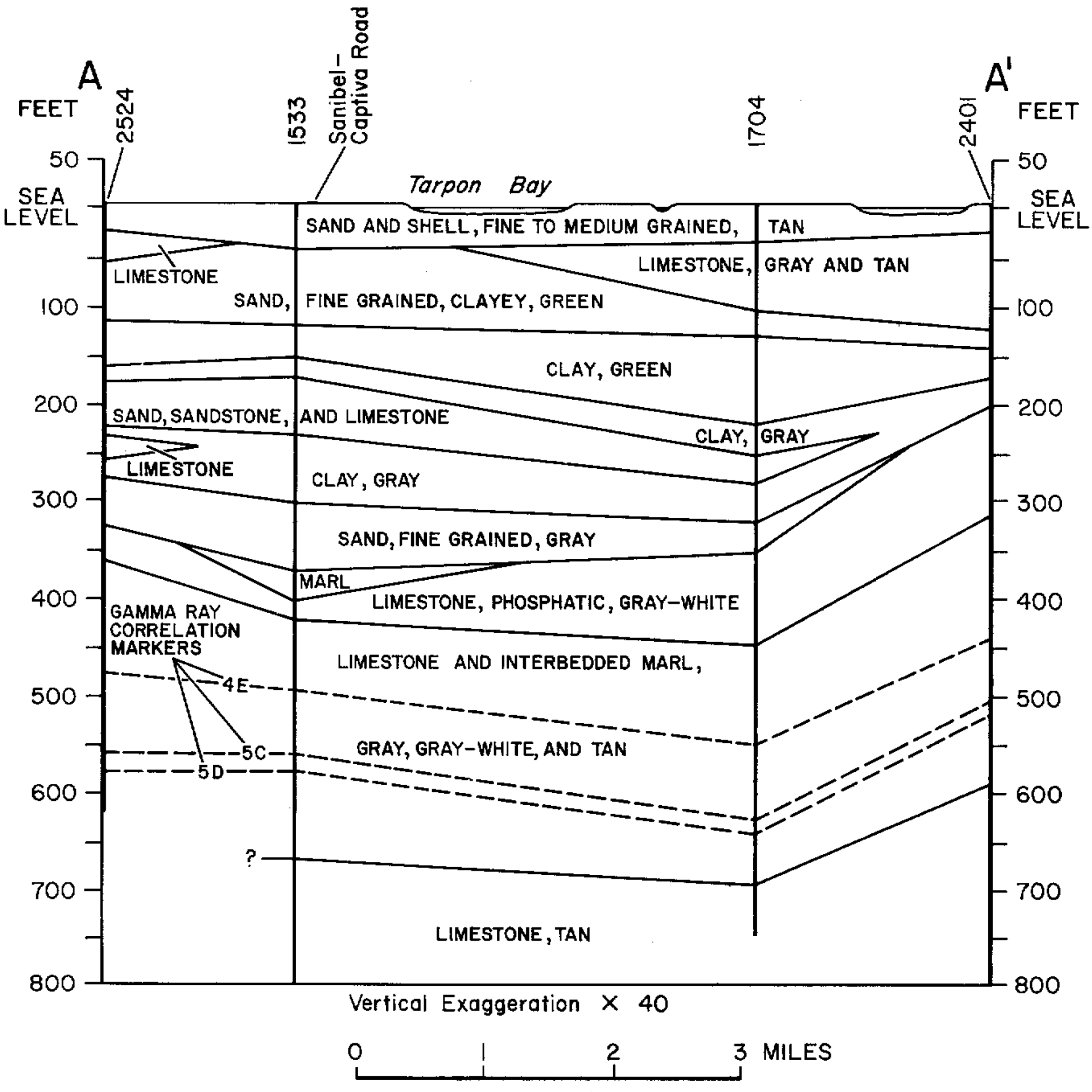

Figure 4.--Generalized geologic section across Sanibel Island.

have shown by seismic reflection profiles that folding has occurred in the Hawthorn Formation underlying the Caloosahatchee River. The inferred vertical displacement of beds beneath Sanibel Island may be related to folding due to differential subsidence.

Seismic-reflection profiles were made during this study by the U.S. Geological Survey in several areas around Sanibel Island including Pine Island Sound and the Gulf of Mexico. These profiles indicate folding with vertical displacement of about 75 feet from trough to crest over a lateral distance of about 0.5 mile in Pine Island Sound approximately 2 miles east of the south end of Captiva Island. The seismic-reflection profiles could be made in navigation channels only, and most of the data were obtained offshore. Consequently, they may not be representative of formations underlying the islands.

AQUIFERS

The uppermost 15 to 30 feet of sand, shells, silt, and clay underlying Sanibel and Captiva Islands comprise the water-table zone of the surficial aquifer. This zone yields small amounts of water to shallow wells. The permeability of these materials decreases with depth because of a gradual decrease of sand particle size and an increase of silt and clay. Below the water-table zone is a gray and tan sandy limestone that comprises the shallow artesian zone and that extends from a depth of about 30 feet to more than 120 feet beneath Sanibel Island.

Thin beds of sand, sandstone, and limestone within the Tamiami Formation yield small amounts of water to wells but do not constitute a significant source of water in the islands.

Underlying the Tamiami Formation are two deep artesian aquifers which are the principal sources of water supply on the islands. A zone of permeable materials in the upper part of the Hawthorn Formation constitutes the upper artesian aquifer, locally referred to as the upper Hawthorn aquifer. The upper Hawthorn aquifer is a source of water both on Captiva and North Captiva Islands as well as the northwestern part of Sanibel Island, although the upper Hawthorn aquifer contains saline water on much of Sanibel Island. Wells drilled into the upper Hawthorn aquifer flow as much as 15 gal/min.

Clay and marly limestone separate the upper Hawthorn aquifer from the underlying permeable limestone in the lower part of the Hawthorn Formation and the upper part of the Tampa Limestone, locally referred to as the lower Hawthorn aquifer. Wells that tap the lower Hawthorn-upper Tampa aquifer flow as much as 160 gal/min.

Permeable zones in the lower part of the Tampa Limestone and in the upper part of the Suwannee Limestone also constitute a source of water (Sproul and others, 1972). Few wells tap this source, however, and its hydrologic and chemical quality characteristics are not well known.

RECORDS OF WELLS

An important part of the investigation was the collection of data on wells that tap the Hawthorn Formation, Tampa Limestone, and Suwannee Limestone (table 1). Information was collected for 76 wells ranging in depth from 335 to 896 feet--60 on Sanibel Island and 16 on Captiva. Eleven wells tap the upper Hawthorn aquifer; 57 wells tap the lower Hawthorn-upper Tampa aquifer; 2 wells tap both the upper Hawthorn and the lower Hawthorn-upper Tampa aquifers; 3 wells tap both aquifers in the lower Hawthorn, Tampa, and Suwannee; 1 well taps the lower Tampa and Suwannee aquifer; and for 2 wells the water-producing zones are not known (table 1).

Most wells inventoried on Sanibel and Captiva Islands were drilled by the cable tool (percussion) method. When cable-tool equipment is used, the steel well casing is driven into place as the well is drilled. Rotary dilling has become popular in recent years, and many of the newer wells were drilled by rotary. When rotary drilling is used, a hole is first drilled, then either metal or polyvinyl chloride (PVC) casing is installed and cemented into the hole. After the casing is cemented, an open hole is drilled below the bottom of the casing. The open-hole section is open to one or more water-yielding zones which yield water to the well. The length of open hole is determined largely by the quantity and quality of the water encountered.

Wells on both islands are cased to greater depths than similar wells on the adjacent mainland because of poor quality water in the shallow deposits on the islands. The cased depth of wells on the islands range from 319 to 700 feet and averages 458 feet. According to Boggess (1974b, p. 28), the average depth of casing in similar wells on the adjacent mainland was 202 feet. More casing is required in wells on the two islands to case out saline water in the Tamiami Formation and overlying deposits. Metal cased wells not protected by cement grout corrode and eventually develop holes opposite the zones of saline water. This potential problem increases both with age of the well and salinity of adjacent formation water. When holes develop in the casing, water either leaks out of the well, or saline formation water leaks into the well. Consequently, usable water is either lost to the adjacent formation or the usable water is contaminated by saline water leaking into the well. Under normal conditions, water leaks outward from the well because of high artesian pressure. Where the artesian pressure has been lowered by pumping, however, water will leak inward. Contamination from inward leakage of poor quality water would be greatest in the zone where the salinity is high and the artesian pressure in the underlying deeper aquifers is low. Salinity monitoring in areas where this condition is present can help detect possible leakage through holes in well casings.

WATER LEVELS IN WELLS

Water in the deep artesian aquifers is generally under sufficient pressure to cause wells to flow at land surface. On Sanibel Island, the average water level in the upper Hawthorn aquifer is 7 feet above land surface, and in the lower Hawthorn-upper Tampa aquifer, 18 feet above land surface. On Captiva Island, average water levels are slightly lower.

Table 1.--Description of wells and test holes drilled on Sanibel and Captiva Islands

Well No.	Depth (ft)	Casing (ft)	Diameter (in)	Land surface altitude (ft)	Water level above land surface (ft)	Date of measurement	Flow (gal/min)	Temperature (°C)	Chloride (mg/L)	Date of sample collection	Source of water 1/	Year well plugged
						SANIBEL ISLAND						
405	500	-	6	4	26.6	1970	-	26	2/1,040	1946	LH-UT	
469	400	370	4	4	8.0	1946	7	26	3/ 380	1946	UH	
					5.5	1977						
584	421	393	4	4	-	-	-	-		-	UH	
585	475	335	6	2	25.1	1964	50	27	1,530	1964	UH,LH-UT	
586	700	415	8	4	23.3	1964	100	27	1,390	1964	LH-UT	
588	557	403	4	3	13.1	1964	60	27	3/1,000	1970	LH-UT	
589	609	380	6	4	14.4	1964	100	27	920	1975	LH-UT	
590	620	464	4	4	14.0	1964	60	28	1,150	1964	LH-UT	
591	654	405	6	3	24.2	1964	60	27	3/ 950	1970	LH-UT	
1022	631	440	4	4	20.5	1970	-	26	3/1,000	1970	LH-UT	
1023	490	461	6	7	-	-	-	-	510	1979	LH-UT	
1154	400	388	4	6	-	-	2	-	3/ 340	1970	UH	
1186	700	500	6	5	17.2	1970	-	-	3/1,020	1970	LH-UT	
1191	600	-	6	5	24.5	1970	-	-	1,500	1970	LH-UT	
1196	600	-	6	6	19.1	1970	-	27	3/ 980	1970	LH-UT	
1197	500	480	4	4	13.6	1977	5	-	3/ 600	1971	LH-UT	
1470	542	420	4	6	16.7	1971	-	-	1,050	1971	LH-UT	
1472	786	660	4	5	-	-	125	31	5,850	1971	LH-UT	1971

1/ UH, upper Hawthorn Formation; LH-UT, lower Hawthorn Formation-upper Tampa Limestone; LT-SU, lower Tampa Limestone-Suwannee Limestone.

2/ Chloride concentration 950 mg/L in 1970.

3/ Analysis of major constituents listed in table 2.

Table 1.--Description of wells and test holes drilled on Sanibel and Captiva Islands--Continued

Well No.	Depth (ft)	Casing (ft)	Diameter (in)	Land surface altitude (ft)	Water level above land surface (ft)	Date of measurement	Flow (gal/min)	Temperature (°C)	Chloride (mg/L)	Date of sample collection	Source of water[1]	Year well plugged
SANIBEL ISLAND (Continued)												
1512	565	465	6	5	22.8	1977	25	27	[3] 2,300	1972	LH-UT	
1533	895	496	4	4	-	-	150	28	1,050	1972	LH-UT, LT-SU	1972
1597	575	503	10	3	17.4	1972	45	-	[3] 680	1972	LH-UT	1978
									1,940	1977		
1644	335	319	4	3	7.8	1972	-	26	200	1972	UH	
1645	540	442	4	4	7.8	1972	5	27	[3] 300	1972	LH-UT	
1646	673	382	4	5	19.8	1972	40	27	[3] 840	1972	LH-UT	
1647	444	415	4	4	11.4	1972	3	26	[3] 460	1977	UH	
1648	388	342	-	4	5.8	1977	15	26	[3] 230	1977	UH	
1649	622	442	8	6	17.4	1977	30	27	[3] 880	1972	LH-UT	
1650	613	462	6	6	20.9	1972	75	29	[3] 1,400	1972	LH-UT	
1680	700	-	4	6	14.1	1973	30	26	1,520	1973	LH-UT	
					7.4	1977						
1704	732	546	8	4	20.9	1978	130	30	[3] 900	1973	LH-UT, LT-SU	
1729	600	-	4	4	-	-	5	28	1,050	1973	LH-UT	1973

1/ UH, upper Hawthorn Formation; LH-UT, lower Hawthorn Formation-upper Tampa Limestone; LT-SU, lower Tampa Limestone-Suwannee Limestone.

2/ Chloride concentration 950 mg/L in 1970.

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Table 1.--Description of wells and test holes drilled on Sanibel and Captiva Islands--Continued

Well No.	Depth (ft)	Casing (ft)	Diameter (in)	Land surface altitude (ft)	Water level above land surface (ft)	Date of measurement	Flow (gal/min)	Temperature (°C)	Chloride (mg/L)	Date of sample collection	Source of water 1/	Year well plugged
SANIBEL ISLAND (Continued)												
1808	640	-	4	6	11.8	1977	-	-	1,880	1973	LH-UT	
1811	500	-	4	6	-	-	2	-	1,220	1973	LH-UT	
1821	860	-	6	6	9.7	1977	-	-	1,360	1977	LH-UT, LT-SU	
1935	549	-	8	5	2.9	1976	-	-	3/8,500	1974	LH-UT	1978
1941	525	-	4	5	2.0	1977	-	-	580	1977	LH-UT	
1967	896	700	6	3	-	-	250	-	2,030	1974	LT-SU	
2065	627	501	10	4	-	-	160	26	3/1,380	1975	LH-UT	
2066	608	507	10	4	-	-	-	27	3/450	1977	LH-UT	
2085	651	561	-	5	-	-	-	27	3/1,200	1975	LH-UT	
2086	580	455	10	4	-	-	-	26	3/1,600	1975	LH-UT	
2087	600	-	-	6	-	-	-	26	3/1,300	1975	LH-UT	
2088	634	500	-	4	-	-	-	26	3/1,400	1975	LH-UT	
2089	620	516	10	4	-	-	80	26	3/1,200	1975	LH-UT	
2108	609	495	10	6	-	-	150	27	3/690	1975	LH-UT	
2232	635	480	10	4	-	-	-	-	-	-	LH-UT	
2233	623	500	10	5	-	-	-	28	3/800	1977	LH-UT	
2245	-	-	6	5	-	-	5	27	1,050	1975	-	
2246	-	-	8	5	10.5	1977	40	27	3/1,200	1975	LH-UT	
2247	600	-	4	6	-	-	15	27	3/950	1975	LH-UT	

1/ UH, upper Hawthorn Formation; LH-UT, lower Hawthorn Formation-upper Tampa Limestone; LT-SU, lower Tampa Limestone-Suwannee Limestone.

2/ Chloride concentration 950 mg/L in 1970.

3/ Analysis of major constituents listed in table 2.

Table 1.--Description of wells and test holes drilled on Sanibel and Captiva Islands--Continued

Well No.	Depth (ft)	Casing (ft)	Diameter (in)	and surface altitude (ft)	Water level above land surface (ft)	Date of measurement	Flow (gal/min)	Temperature (°C)	Chloride (mg/L)	Date of sample collection	Source of water 1/	Year well plugged
SANIBEL ISLAND (Continued)												
2276	472	354	4	4	23.7	1976	13	28	3/780	1976	UH, LH-UT	
2282	600	-	4	6	19.1	1976	-	28	3/880	1976	LH-UT	
2337	423	395	6	5	11.0	1978	160	29	11,800	1976	UH	
2338	-	-	6	7	-	-	-	-	1,100	1978	LH-UT	
2401	591	470	6	5	26.6	1977	-	28	1,350	1977	LH-UT	
2462	600	450	8	4	-	-	-	28	1,160	1978	LH-UT	
2511	-	-	8	4	-	-	-	-	740	1978	-	
2524	625	512	4	5	14.5	1977	40	27	3/440	1977	LH-UT	
2582	650	610	10	4	21.0	1978	-	28	620	1978	LH-UT	
2583	650	610	4	4	20.5	1978	60	-	600	1978	LH-UT	

1/ UH, upper Hawthorn Formation; LH-UT, lower Hawthorn Formation-upper Tampa Limestone; LT-SU, lower Tampa Limestone-Suwannee Limestone.
2/ Chloride concentration 950 mg/L in 1970.
3/ Analysis of major constituents listed in table 2.

Table 1. Description of wells and test holes drilled on Sanibel and Captiva Islands--Continued

Well No.	Depth (ft)	Casing (ft)	Diameter (in)	Land surface altitude (ft)	Water level above land surface (ft)	Date of measurement	Flow (gal/min)	Temperature (°C)	Chloride (mg/L)	Date of sample collection	Source of water 1/	Year well plugged
CAPTIVA ISLAND												
406	572	422	6	5	19.0	1977	-	28	3/ 900	1946	LH-UT	
407	500	-	4	5	-	-	-	-	880	1946	LH-UT	
408	600	-	4	4	-	-	-	-	1,180	1946	LH-UT	
466	756	432	6	5	16.5	1946	220	27	920	1946	LH-UT	
468	689	438	4.5	5	15.8	1946	-	26	3/ 690	1946	LH-UT	
					19.1	1977						
587	456	437	4	3	5.2	1964	5	27	3/ 200	1977	UH	
592	724	367	4	3	25.4	1977	40	28	3/ 1,320	1977	LH-UT	
2315	600	535	6	5	14.4	1977	75	28	3/ 780	1977	LH-UT	
2320	416	372	4	6	11.9	1977	6	27	3/ 560	1976	UH	
2329	-	-	4	5	4.8	1977	1	26	3/ 120	1977	UH	
2330	-	-	6	5	18.1	1977	-	-	-	-	LH-UT	
2331	-	-	7	6	-	-	-	-	800	100	LH-UT	
2332	-	-	4	7	14.0	1977	-	-	-	-	LH-UT	
2333	-	-	4	6	13.0	1977	-	28	3/ 1,100	1977	LH-UT	
2334	-	-	6	6	18.0	1977	-	28	3/ 1,100	1977	LH-UT	
2608	415	385	6	7	4.5	1978	-	24	220	1978	UH	

1/ UH, upper Hawthorn Formation; LH-UT, lower Hawthorn Formation-upper Tampa Limestone; LT-SU, lower Tampa Limestone-Suwannee Limestone.

2/ Chloride concentration 950 mg/L in 1970.

3/ Analysis of major constituents listed in table 2.

Water-level measurements for the lower aquifer indicate that water levels are lowest where ground-water pumping is most intense. The frequency of measurement is not adequate to determine when pumping began to affect water levels areally, although water-level measurements were made as early as 1946 in wells tapping both aquifers.

Most of the wells that tap the upper Hawthorn aquifer are on Captiva Island and the northwest tip of Sanibel Island. Water levels have ranged from 11.4 (1972) to 4.8 feet (1977) above land surface or about 8 to 15 feet above sea level.

Many of the water-level measurements in wells that tap the lower Hawthorn-upper Tampa aquifer were made in July and November 1977. These measurements show that the potentiometric surface was lowest, less than 10 feet above sea level, in the central part of Sanibel Island, and highest, more than 30 feet above sea level, at the east end of Sanibel Island (fig. 5).

The low artesian pressure in the central part of Sanibel Island results from pumping the production wells of the Island Water Association located along the Sanibel-Captiva Road (fig. 2). Hydrographs of wells 1935 and 585 (fig. 6) and wells 589 and 2524 (fig. 7) illustrate pressure fluctuations in the lower Hawthorn-upper Tampa aquifer. Although these hydrographs are short term and the frequency of measurement is not always adequate, some conclusions can be made from them. The large range of fluctuations in wells 589, 1935, and 2524 shows the influence of pumping from the production wells in central Sanibel. The subdued fluctuation in well 585 suggests normal changes in water level at the east tip of Sanibel, somewhat unaffected by the pumping.

A bar graph of the monthly pumpage from the Sanibel well field is shown at the top of figure 8, and a bar graph of the precipitation on Sanibel is shown at the bottom. These graphs show that pumping decreases as rainfall increases. The water level in well 1935 was highest, about 19 feet above land surface, late in 1977 when none of the production wells were being pumped. Lower water levels shown on the graph are largely the effects of pumping of nearby wells. The range in water-level fluctuation of 18 feet in well 1935 in 1977 contrasts with a range of less than 3 feet in well 585 over the same time period.

The periodic water-level measurements made in wells 589 and 2524 in the central part of Sanibel Island indicate that both wells are affected by pumping of nearby wells as shown in figure 7, but not necessarily by the same pumping wells. For example, during the latter part of 1978 when the water level in well 589 was rising, the water level in well 2524 about 3 miles away was declining to a new low at the end of November. The upward trend of water level in well 589 and downward trend in well 2524 were still occurring in 1979 and may have been caused by a westward shift of pumping in the well field.

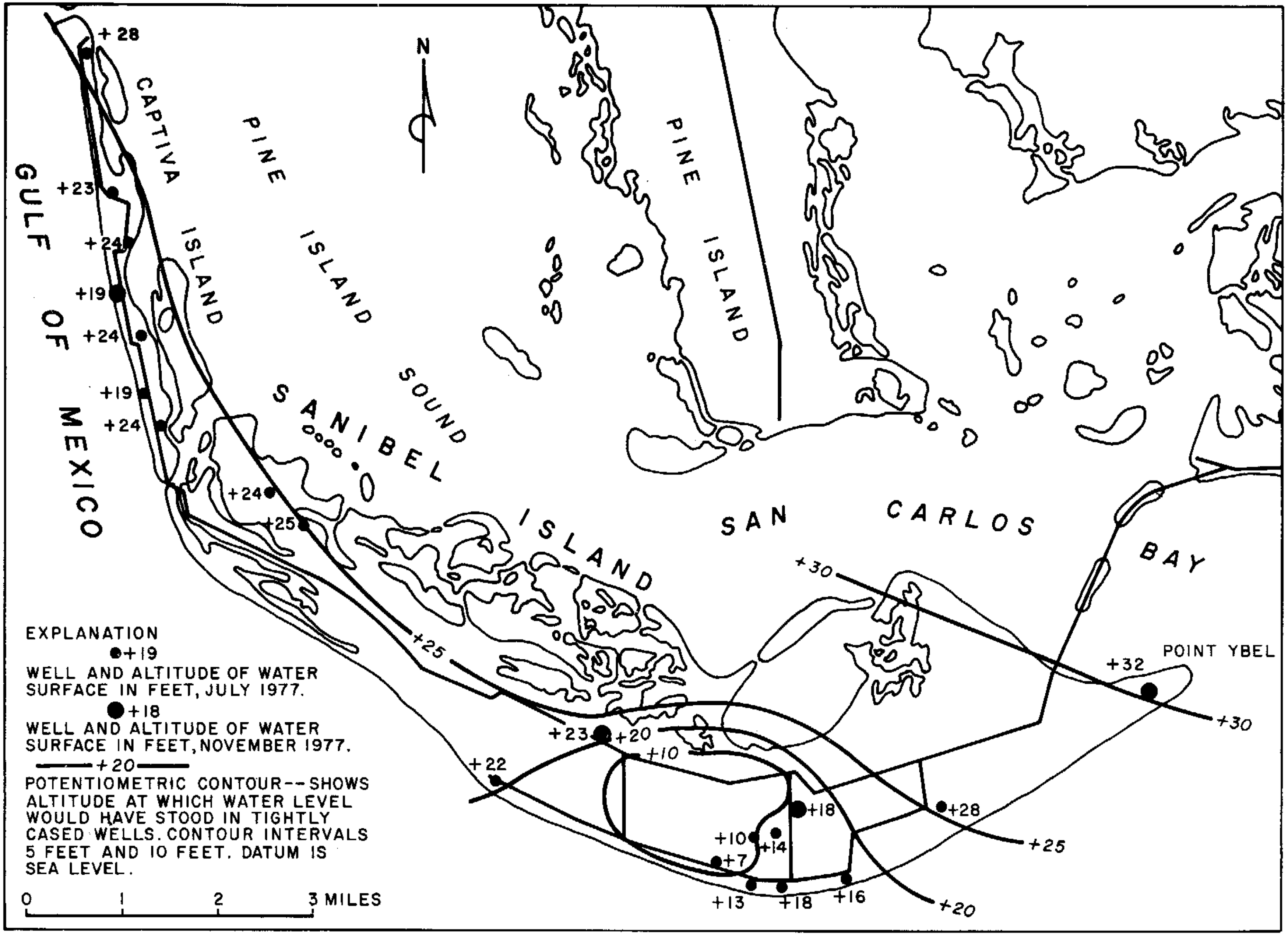

Figure 5.--Potentiometric surface of the lower Hawthorn-upper Tampa aquifer, July and November 1977, Sanibel and Captiva Islands.

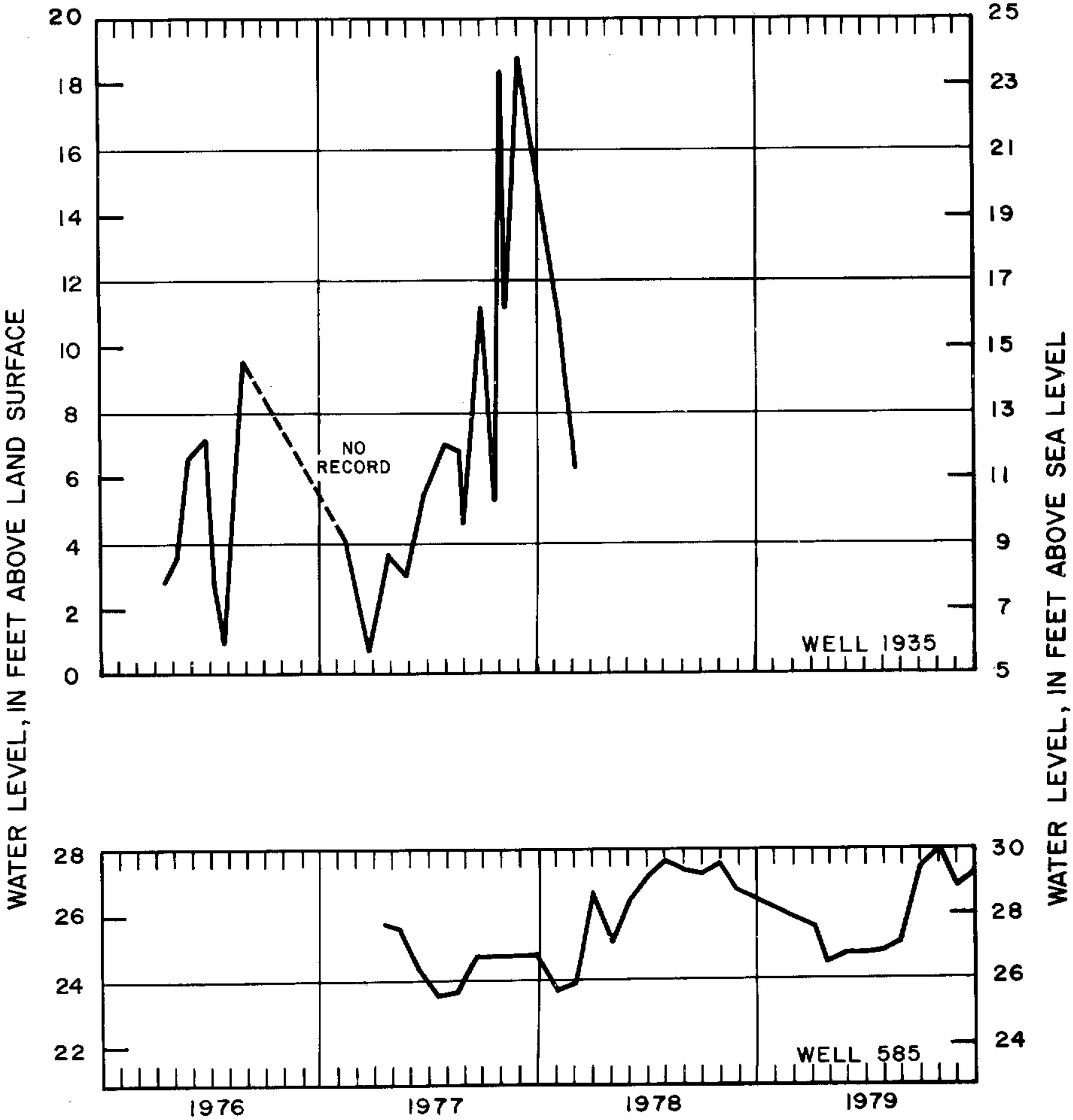

Figure 6.--Hydrographs of well 1935, April 1976 through February 1978, and well 585, April 1977 through December 1979, lower Hawthorn-upper Tampa aquifer, Sanibel Island.

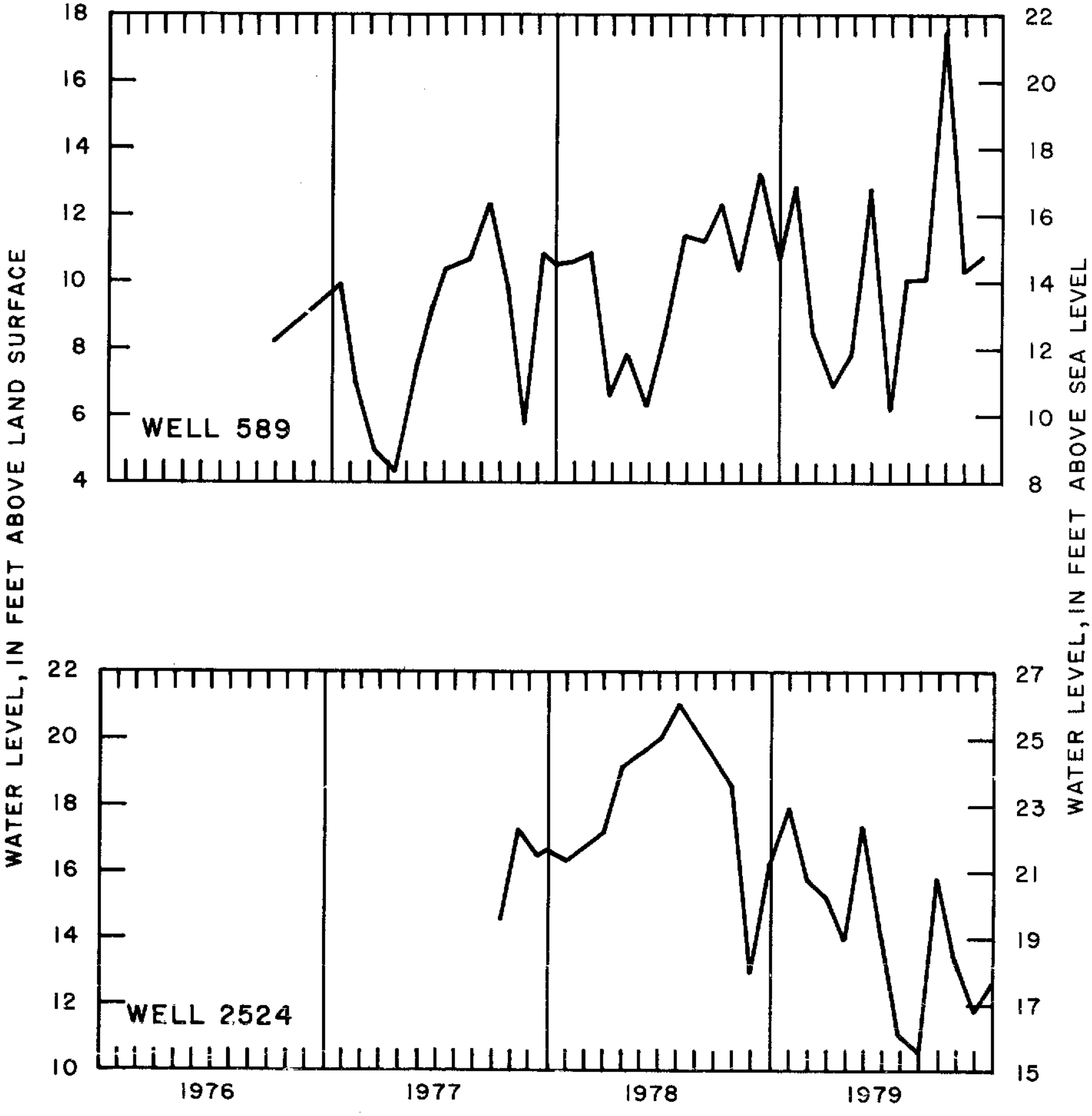

Figure 7.--Hydrographs of well 589, October 1976 through November 1979, and well 2524, October 1977 through December 1979, lower Hawthorn-upper Tampa aquifer, Sanibel Island.

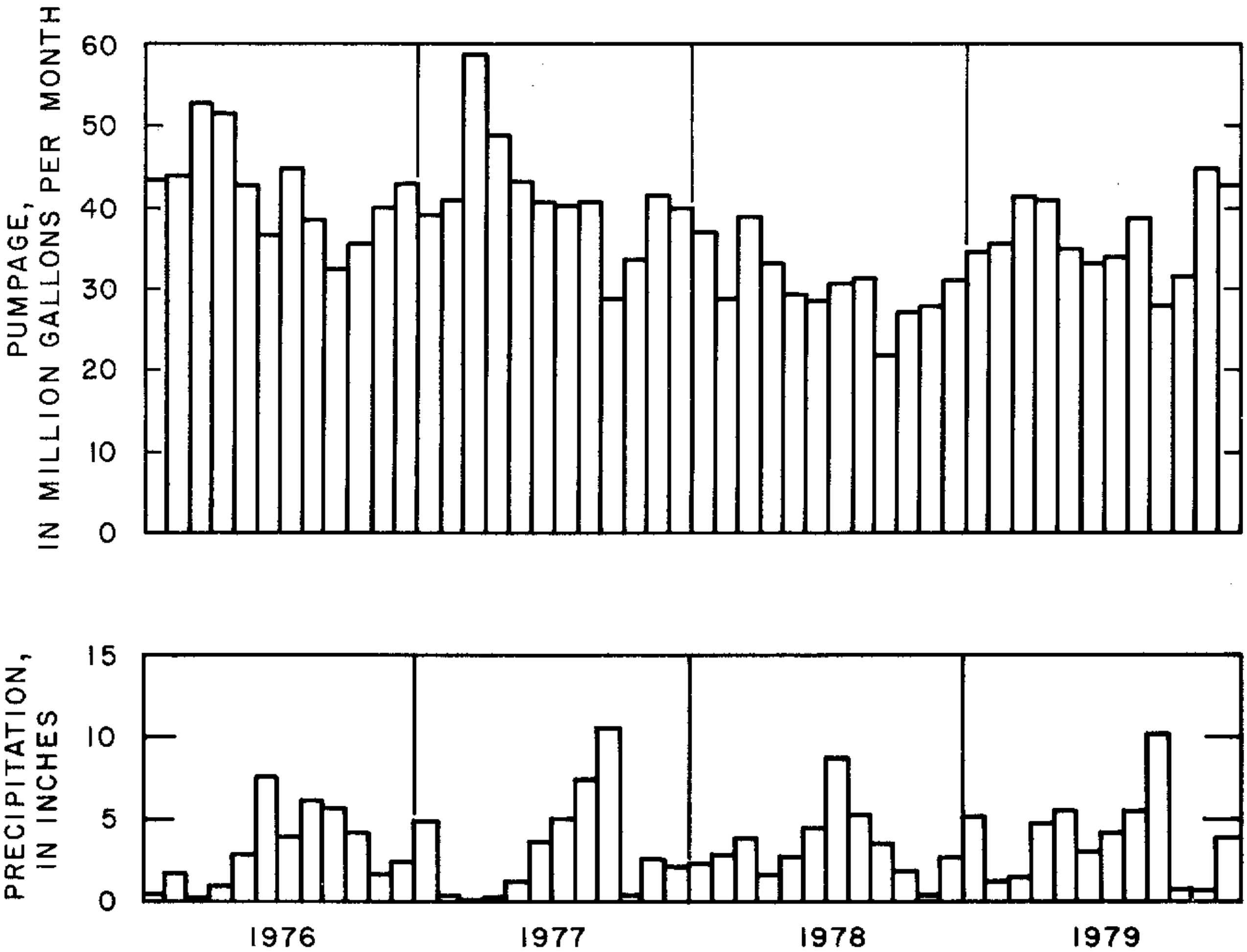

Figure 8.--Monthly pumpage from the Sanibel well field, and monthly precipitation on Sanibel Island, 1976-79. (Pumpage data from Island Water Association of Sanibel. Precipitation data from USGS rain gage.)

The changes in water level in well 585, by far the most subdued of the four hydrographs shown in figures 6 and 7, indicate little evidence of the pumping effects compared to the hydrographs of the other three wells. A short period of continuous water-level measurements in well 585 and continuous tidal stages of the Gulf of Mexico in March 1971 indicate that the levels in the well closely follow and are approximately in phase with tidal fluctuations. A tidal variation of 1 foot caused a change in water level of about 0.3 foot (fig. 9). This suggests that the daily fluctuation of water level in well 585 is produced by tidal loading, causing water levels to rise on an incoming tide and to fall during ebb tide.

Periodic measurements in well 585 (fig. 6) show that during 1978 and 1979, water levels seasonally fluctuated about 4 feet. Seasonal tide variations are typically about 2 feet, and seasonal changes in tidal range can account for no more than half of the seasonal water-level fluctuation in well 585.

WATER QUALITY

The chemical quality of ground water underlying Sanibel and Captiva Islands varies widely with location and depth. The chloride concentration of water in the upper part of the surficial deposits from near land surface to a depth of about 30 feet commonly is less than 1,000 milligrams per liter (mg/L) (Boggess, 1974a). At greater depths chloride concentrations increase to that of seawater, about 19,000 mg/L.

Water quality is highly variable in the underlying shallow artesian zone, 30 to about 120 feet below land surface, at some locations on Sanibel Island. In the upper part of this zone, chloride concentrations range from 2,250 to 30,900 mg/L (Boggess, 1974a, p. 51). In the deeper part of the zone, little is known of the water quality. A water sample obtained during drilling from the upper part of the zone at a depth of 62 feet at well 1472 (eastern Sanibel) contained 24,600 mg/L of chloride, and a water sample from the lower part of the zone at well 1533 (central Sanibel) contained 12,000 mg/L of chloride.

Analyses of water collected from well 1533, at about 200 to 350 feet as it was being drilled through the permeable beds of sand and limestone within the Tamiami Formation, had chloride concentrations ranging from 2,000 to 4,000 mg/L (Boggess, 1974a, p. 11).

Chemical analyses are available for water from many of the wells drilled to or through the two deep artesian aquifers. Table 2 lists analyses of major constituents in water from 9 wells tapping the upper Hawthorn aquifer and from 36 wells tapping the lower Hawthorn-upper Tampa aquifer.

In water from the upper Hawthorn aquifer, dissolved solids concentrations range from 721 to 2,390 mg/L, averaging 1,540 mg/L for the 9 analyses. The predominant chemical constituents are sodium, sulfate, chloride, and bicarbonate. In water from the lower aquifer, dissolved solids concentrations range from 1,700 to 4,130 mg/L, averaging 2,570 mg/L for the 36 analyses. The predominant chemical constituents in this water are sodium, sulfate, and chloride.

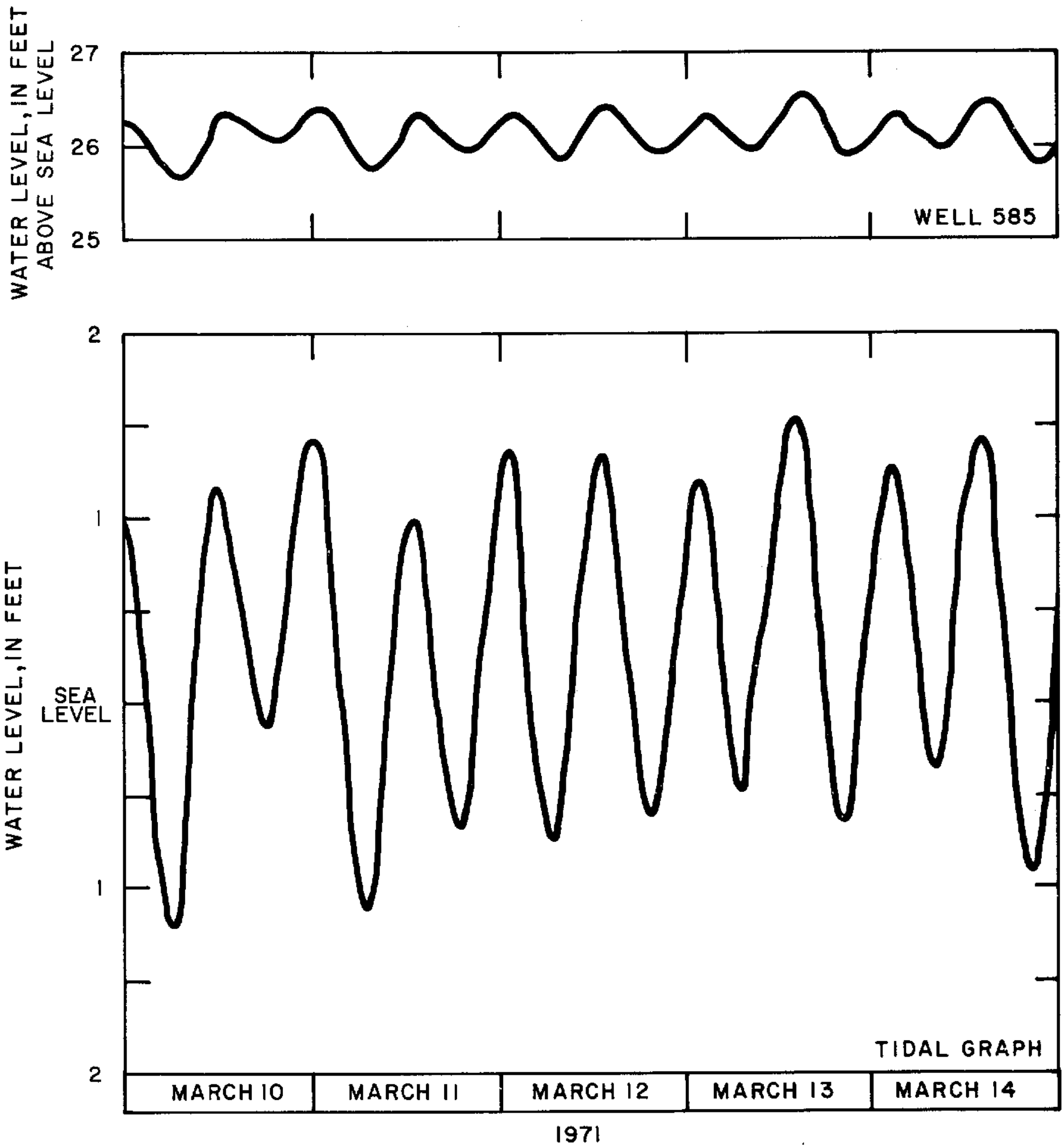

Figure 9.--Hydrograph of well 585, Sanibel Island, and graph of tidal fluctuation in the Gulf of Mexico (Point Ybel), March 10-14, 1971.

Table 2.--Chemical analyses of water from wells on Sanibel and Captiva Islands

[All values in chemical constituents are in milligrams per liter]

Well No.	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Bicarbonate (HCO_3)	Hardness as $CaCO_3$: Calcium-Magnesium	Hardness as $CaCO_3$: Non-carbonate	Dissolved solids (residue at 180°C)	Specific conductance (micromhos at 25°C)	pH	Temperature (°C)
UPPER HAWTHORN AQUIFER																	
469	11/77	50	73	55	3.3	600	34	440	730	2.0	270	410	190	2,120	3,400	7.5	27
587	6/77	27	21	19	0.2	210	18	100	190	3.2	286	130	0	721	1,230	7.9	26
1154	11/77	38	57	52	3.1	360	30	260	540	2.6	220	360	180	1,490	2,500	7.6	26
1644	11/77	34	29	22	1.1	280	24	180	240	2.4	340	160	0	931	1,550	7.6	26
1647	2/75	61	41	36	1.4	700	40	770	460	3.4	427	250	0	2,390	3,600	7.7	26
1648	2/75	43	31	27	1.2	440	30	380	310	5.7	391	190	0	1,480	2,410	8.0	25
2320	11/77	41	75	60	4.1	440	28	260	680	2.6	200	440	280	1,720	2,850	7.4	27
2329	11/77	35	18	13	0.6	240	20	130	140	3.0	340	99	0	722	1,185	7.8	26
LOWER HAWTHORN-UPPER TAMPA AQUIFER																	
406	6/77	25	90	84	9.8	510	31	360	860	2.2	193	580	420	2,160	3,500	7.6	28
468	6/77	32	70	64	6.4	480	34	360	740	2.6	213	450	270	1,970	3,250	7.5	27
588	3/75	32	95	88	7.0	600	40	320	910	2.4	204	610	440	2,350	4,610	7.6	28
589	3/75	24	110	96	11.0	570	40	270	920	2.1	191	680	530	2,300	4,470	7.5	28
591	3/75	14	56	84	7.4	570	32	360	870	2.0	217	490	320	2,090	4,020	7.8	26
592	6/77	20	100	110	20.0	710	34	380	1,300	2.0	182	720	570	2,930	4,800	7.5	28
1022	3/75	31	120	98	7.0	590	42	410	1,000	2.1	191	710	550	2,430	4,640	7.6	27
1186	3/75	43	100	98	4.8	940	60	630	1,300	2.5	217	660	480	3,280	5,440	-	24
1196	7/77	40	77	77	4.5	850	42	700	1,100	2.4	288	510	270	2,990	4,400	7.3	26
1197	11/77	47	55	47	2.2	600	34	520	600	2.6	280	330	100	2,000	3,180	7.9	26

Table 2.--Chemical analyses of water from wells on Sanibel and Captiva Islands--Continued

[All values in chemical constituents are in milligrams per liter]

Well No.	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Bicarbonate (HCO_3)	Hardness as $CaCO_3$ Calcium-Magnesium	Hardness as $CaCO_3$ Non-carbonate	Dissolved solids (residue at 180°C)	Specific conductance (micromhos at 25°C)	pH	Temperature (°C)
LOWER HAWTHORN-UPPER TAMPA AQUIFER (Continued)																	
1512	12/76	16	160	180	24.0	1,000	40	300	2,200	1.2	192	1,200	1,000	4,130	7,200	7.7	28
1597	3/74	25	140	150	17.0	1,000	55	360	1,900	1.7	194	990	830	3,800	6,320	7.4	27
1645	1/77	45	44	34	1.5	680	39	890	340	3.6	425	250	0	2,290	3,310	7.6	27
1646	1/77	42	79	70	3.2	640	42	470	825	2.4	249	490	210	2,350	3,910	7.6	26
1649	7/76	33	76	73	5.2	680	41	520	860	2.1	227	500	310	2,460	3,950	7.6	27
1650	7/76	34	150	160	16.0	1,000	44	300	1,900	2.5	182	1,000	850	4,080	6,600	7.7	28
1680	12/76	24	120	120	13.0	650	41	330	1,200	1.7	195	810	650	2,730	4,200	7.8	27
1704	1/77	22	130	140	18.0	800	34	300	1,600	1.5	195	920	760	3,180	7,300	7.6	28
1935	8/76	37	70	75	4.4	700	40	390	1,100	1.1	228	490	330	2,500	4,200	7.5	26
2065	1/77	39	72	58	4.0	440	40	450	550	2.0	213	420	240	1,750	2,600	7.5	27
2066	11/77	35	73	58	4.4	500	29	410	620	1.9	220	430	250	1,840	2,950	7.5	28
	1/77	44	50	45	3.3	490	37	530	450	2.9	220	310	130	1,790	3,150	7.6	27
2085	3/75	27	94	100	9.1	720	40	380	1,200	2.1	202	660	490	2,750	4,800	7.5	27
2086	3/75	42	100	110	7.4	1,000	60	340	1,600	2.7	226	710	530	3,530	6,400	7.6	26
2087	3/75	54	67	70	3.5	900	58	360	1,300	3.5	274	460	230	2,930	5,800	7.6	26
2088	3/75	24	130	110	13.0	720	46	320	1,400	2.2	187	790	640	2,940	5,420	7.5	26
2089	3/75	27	110	110	11.0	630	35	290	1,200	2.0	191	740	580	2,700	4,920	7.5	26
2108	4/75	35	81	75	4.5	440	36	340	690	2.1	206	520	350	1,950	3,030	7.4	27
2233	1/77	35	86	77	5.0	510	40	350	800	2.9	202	540	370	2,090	3,150	7.6	28
2246	12/76	20	120	120	-	600	34	290	1,200	1.5	192	810	650	2,690	4,000	7.7	27
2247	1/77	46	60	49	1.7	520	40	470	560	2.5	256	350	140	1,880	2,780	7.7	27
2276	12/76	38	66	71	5.0	510	35	310	760	2.4	220	460	280	1,930	3,300	7.8	28
2282	12/76	9	-	83	1.8	560	35	300	880	1.8	128	410	300	2,010	3,240	-	28
2315	8/76	19	91	80	5.8	470	38	310	860	2.3	196	560	400	2,080	3,380	7.8	28
2333	6/77	25	81	88	13.0	660	38	390	1,100	2.0	198	580	420	2,610	4,200	7.6	28
2334	6/77	25	100	88	8.4	620	36	360	1,100	2.2	201	620	450	2,550	4,200	7.7	28
2401	11/77	16	120	110	9.2	740	24	273	1,350	1.1	200	760	600	2,900	5,000	7.5	29
2524	10/77	46	48	40	1.9	460	14	490	440	2.7	280	290	57	1,700	2,900	7.6	27

The distribution of dissolved solids in water from wells tapping both the upper and lower aquifers on Sanibel and Captiva Islands is shown in figure 10. Generally the water from wells on the east end of Sanibel Island have the highest concentrations, more than 4,000 mg/L in wells 1650 and 1512 in the lower Hawthorn-upper Tampa aquifer. In the central part of the island, dissolved solids concentrations range from 1,700 mg/L in well 2524 to 3,800 mg/L in well 1597; both wells tap the lower Hawthorn-upper Tampa aquifer. On the northwest end of Sanibel Island and on Captiva Island, water bearing zones in both the upper and lower aquifers have been equally developed for domestic use. In most of that area, dissolved solids concentrations are slightly less in water from the upper Hawthorn aquifer than from the lower aquifer.

Only wells 587 and 2329 on Captiva Island and well 1644 on Sanibel Island, which tap the upper Hawthorn aquifer, yield water which meets the recommended limit of 250 mg/L of chloride and 250 mg/L of sulfate for drinking water. None of the water analyzed meets the recommended limit of 500 mg/L for dissolved solids. The calcium magnesium hardness of water in the upper Hawthorn aquifer ranges from hard (121 to 180 mg/L) to very hard (more than 180 mg/L) (Swenson and Baldwin, 1965, p. 17); water from well 2320 had a hardness of 440 mg/L. Water from the lower Hawthorn-upper Tampa aquifer is classed as very hard, ranging from 290 to 1,200 mg/L (table 2).

The quality of the water obtained from wells on the islands depends, in part, on the well location and the water-yielding zone penetrated. Water enters the well bore at one or more intervals between the bottom of the well casing and the bottom of the well. As previously described, wells drilled into the Hawthorn penetrate the shallow artesian zone containing highly saline water as well as other shallower zones that may also contain salty water. Where water from any part of these saline water zones enters the well as a result of improper sealing of the well casing, inadequate length of well casing, or deterioration of the casing from corrosion, the water quality in the well will be degraded.

As reported by Boggess (1974a), water quality in the deep artesian aquifers underlying Sanibel and Captiva Islands is highly variable, both vertically and horizontally (table 2). Because of this variability, it is difficult if not impossible, using data at hand, to determine the reasons for poor water quality in any given well without a considerable amount of field research. For example, well 1512 near the east end of Sanibel Island had the highest concentration (4,130 mg/L) of dissolved solids in water from any well in the deep artesian aquifers on the islands. Water from this well also contains the highest concentrations of calcium, magnesium, sodium, and chloride. This well is 565 feet deep and contains 465 feet of 6-inch metal casing. Well 1649, less than 0.5 mile from well 1512, is 622 feet deep and contains 442 feet of 8-inch metal casing. Well 1649, however, yields water containing about half the concentration of dissolved solids (2,460 mg/L) and lower concentrations of most other chemical constituents. Therefore, saline water from a shallower water zone evidently is entering well 1512 probably because of corroded metal casing, casing damaged during construction of the well, or downward leakage of saline water along the outside of the well casing.

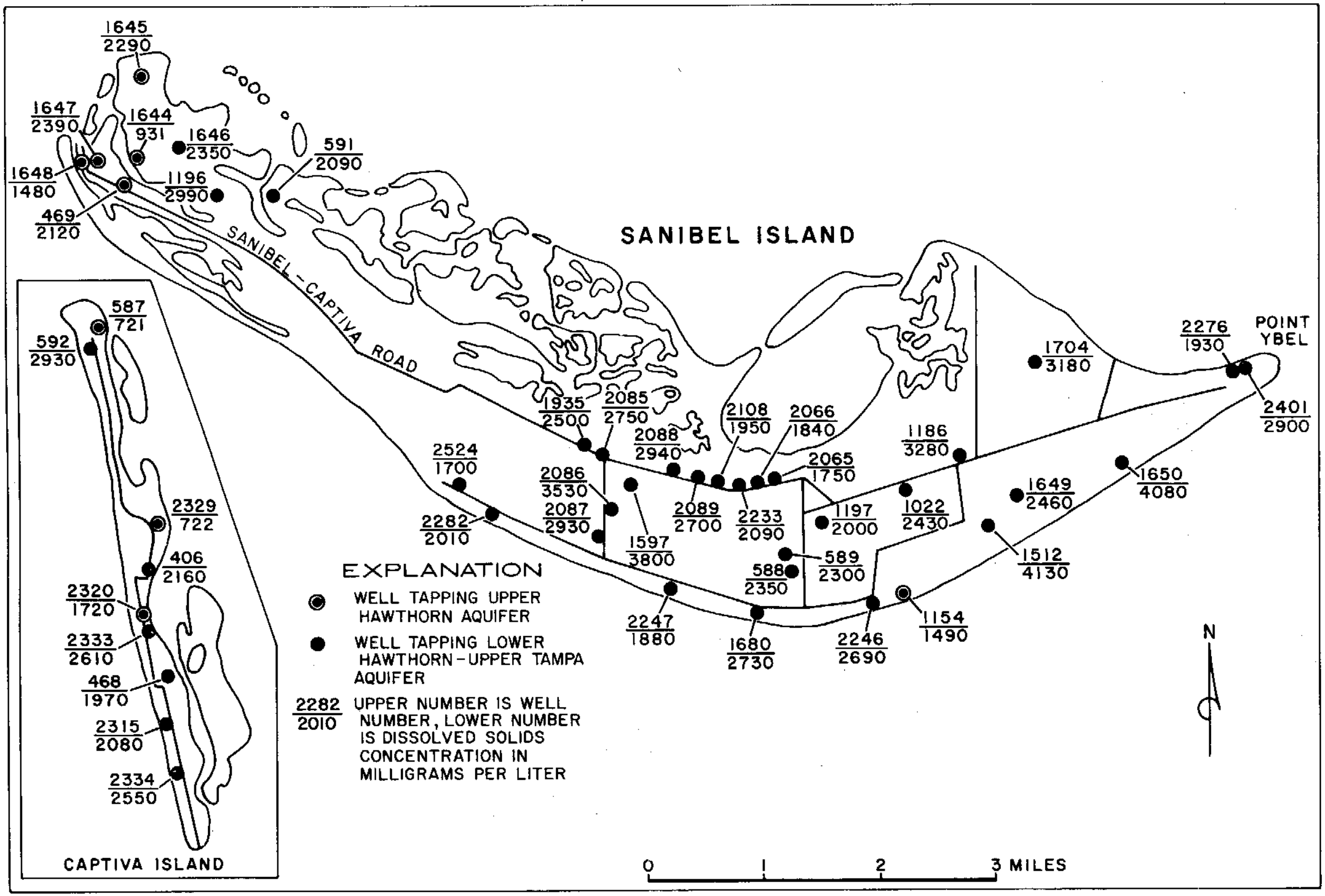

Figure 10.--Dissolved solids concentration in water from wells tapping the upper Hawthorn aquifer and the lower Hawthorn-upper Tampa aquifer, Sanibel and Captiva Islands.

The relation of chloride concentrations to dissolved solids concentrations in water from the lower Hawthorn-upper Tampa aquifer is shown in figure 11. Data for this figure are from analyses of water samples collected from wells on Sanibel and Captiva Islands. This diagram also illustrates the variability of the quality of water from the lower Hawthorn-upper Tampa aquifer, with chloride concentrations ranging from less than 500 mg/L to more than 2,000 mg/L and dissolved solids concentrations ranging from about 1,700 mg/L to more than 4,000 mg/L. If the value for one of the parameters is known, then the other parameter can be estimated from the diagram.

The lowest dissolved solids concentration in water from the lower Hawthorn-upper Tampa aquifer was found in observation well 2524 in the central part of Sanibel Island. This well is 625 feet deep and contains 512 feet of 4-inch PVC well casing cemented in place. Water from this well in 1977 contained 1,700 mg/L dissolved solids, 440 mg/L chlorides, and 460 mg/L sodium concentrations. This well also contained water with the lowest calcium magnesium hardness (290 mg/L) of any well on the islands tapping the lower aquifer. This comparatively low dissolved solids concentration may be consistent through a considerable depth range. For example, well 1023 (near well 2524) open to an interval from 461 to 490 feet yielded water in 1979 with a chloride concentration of 510 mg/L (table 1), similar to that in the water from well 2524. This indicates (fig. 11) a dissolved solids concentration of about 1,700 mg/L, or about the same as in well 2524. The two wells span the depth interval 461 to 625 feet, indicating that water in the lower Hawthorn-upper Tampa aquifer in the vicinity of these wells and within that depth range may be less saline than elsewhere in the islands. This presumed uniformity is apparently an exception. In general, variation in quality, both vertically and horizontally, is the rule.

Heavy pumping from wells may cause changes in the quality of water from them or from nearby wells, as suggested earlier. For example, in 1972 production well 1597 (now plugged) contained water with a chloride concentration of 680 mg/L when drilled in an area where the overlying deposits contain water with as much as 12,000 mg/L chloride concentration. By March 1974, the chloride concentration in the well had increased to 1,900 mg/L (table 2). This well, drilled at the site of test well 1533, was 575 feet deep and contained 503 feet of 10-inch casing.

Pumping of well 1597 over a period of several years may have caused some downward leakage of saline water, which resulted in a substantial increase in chloride concentration. Well 1935, also a production well now plugged, may have undergone similar water-quality degradation. In 1974, it yielded water containing 8,500 mg/L of chloride, although a sample collected in 1976 contained only 1,100 mg/L of chloride, about average for that sequence of deposits open to the well.

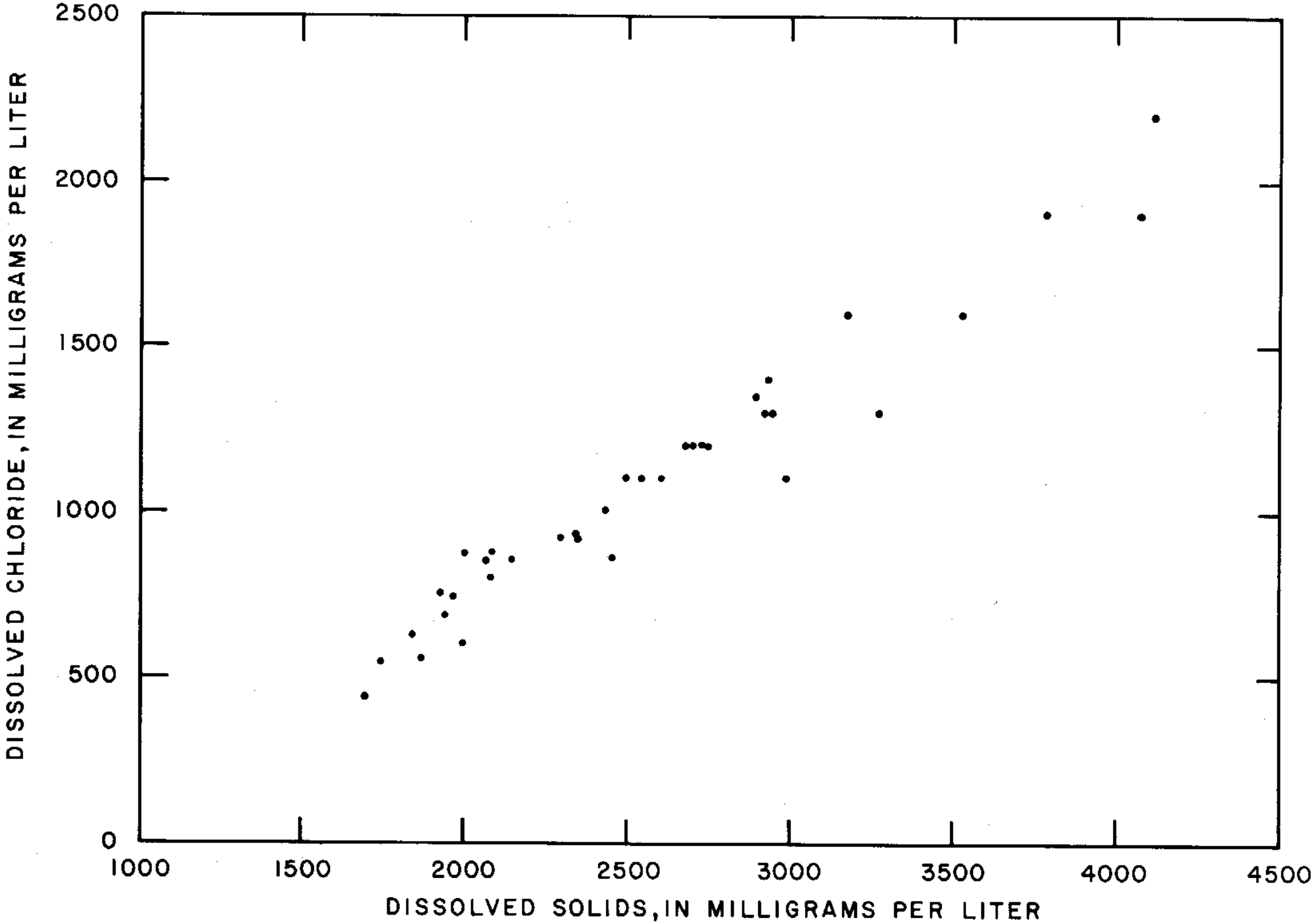

Figure 11.--Relation of chloride to dissolved solids concentration in water from the lower Hawthorn-upper Tampa aquifer, Sanibel and Captiva Islands.

If wells tapping water-bearing zones are being degraded by saline water entering the wells through the casing or by other means, more detailed field study will be required to determine the mechanism by which the degradation is occurring. Of 24 wells from which water samples were collected at least 1 year apart, the chloride concentration increased in 3, decreased in 10, and remained the same in 5. The pattern is random, and there is no relation between increase in chloride concentration and distance to the center of pumping.

A summary of selected chemical constituents in water from the deep aquifers is shown on table 3. When comparing the range in chemical constituents and their averages, it is evident that the water from the lower Hawthorn-upper Tampa aquifer is generally more saline. Chloride, magnesium, and calcium concentrations in water from this aquifer are at least twice as great as in water from the upper Hawthorn aquifer; sulfate is about the same, and bicarbonate is less. Water from the upper Hawthorn aquifer, however, has a greater range in concentrations of chemical constituents.

WATER USE

Two deep artesian aquifers are the principal sources of water supply on Sanibel and Captiva Islands. Most of the water used is obtained from deep wells that tap the lower aquifer in the lower part of the Hawthorn Formation and the upper part of the Tampa Limestone, chiefly those wells of the Island Water Association which treat and distribute water throughout the islands. The average pumpage from these wells in 1977 was 1.4 Mgal/d or 496 Mgal for the year (table 4). This water is processed through a desalination plant on Sanibel Island before distribution. Additional treated water is purchased from the Greater Pine Island Water Association, when needed, and is transmitted to the island through a pipeline underlying San Carlos Bay. About 22 Mgal were purchased in 1977. In addition, wells 408 and 587 on the northern part of Captiva Island are used as an emergency supply for the Island Water Association. In 1977, the two wells produced about 300,000 gallons.

Most of the remaining deep artesian wells on Sanibel and Captiva Islands are used for irrigation of lawns and golf courses. Private pumpage in 1977 from wells in both of the deep artesian aquifers for all purposes is estimated at about 135 Mgal (0.37 Mgal/d) on Sanibel and about 59 Mgal (0.16 Mgal/d) on Captiva. Most of this water was withdrawn during the dry season, November to June.

The total volume of water withdrawn in 1977 from the deep aquifers was estimated to be 690 Mgal, an average of about 1.9 Mgal/d. The total capacity of all existing wells tapping the deep artesian aquifers is estimated at about 6 Mgal/d, or about 3 times the 1977 daily average use.

Table 3.--Summary of selected constituents in water from the upper Hawthorn aquifer and from the lower Hawthorn-upper Tampa aquifer, Sanibel and Captiva Islands

[All values in milligrams per liter]

	Upper Hawthorn aquifer		Lower Hawthorn-upper Tampa aquifer	
	Average	Range	Average	Range
Calcium	43	18-75	94	48-160
Magnesium	35	13-60	92	40-180
Sodium	439	230-700	664	440-1,000
Potassium	29	18-40	39	14-60
Sulfate	379	100-890	381	270-700
Chloride	403	140-730	1,078	440-2,200
Fluoride	3.2	2.0-3.6	2.2	1.1-3.5
Bicarbonate	322	200-427	210	128-288
Carbonate hardness	254	99-440	610	290-1,200
Dissolved solids	1,540	721-2,390	2,571	1,700-4,130

Table 4.--Monthly water pumpage from Island Water Association wells on Sanibel Island

[Millions of gallons]

Month	1974	1975	1976	1977	1978	1979
January	-	1/35.2	43.5	39.2	37.1	34.4
February	-	24.1	43.8	41.0	29.0	35.7
March	-	1/33.7	52.4	58.4	39.1	41.4
April	36.2	40.0	51.6	48.7	33.4	41.0
May	1/34.2	41.9	42.7	43.3	29.5	34.8
June	1/30.7	43.5	36.5	40.5	28.6	33.3
July	1/33.0	38.8	44.8	40.1	30.7	33.9
August	1/28.1	39.3	38.5	40.9	31.1	38.8
September	25.4	29.6	32.1	28.9	21.9	27.9
October	21.2	33.2	35.7	33.7	27.4	31.5
November	31.3	38.0	39.9	41.6	27.9	44.7
December	29.3	42.1	43.2	40.0	31.0	42.6
Total	269.4	439.4	504.7	496.3	366.8	440.0
Daily Average	1.0	1.2	1.4	1.4	1.0	1.2

1/ Estimated

SUMMARY AND CONCLUSIONS

Sanibel and Captiva Islands are underlain by a series of freshwater and saline-water zones. The water-table zone, from land surface to a depth of about 15 to 30 feet, commonly contains freshwater in the upper part of the zone and saline water in the lower part. A shallow artesian zone underlies the water-table zone and extends from a depth of about 30 to as much as 120 feet. This aquifer contains saline water with chloride concentrations ranging from 2,250 to 30,900 mg/L. The Tamiami Formation, which underlies the shallow artesian zone, locally provides small amounts of potable water to wells, although at some localities this zone contains salty water.

The Hawthorn Formation and Tampa Limestone successively underlie the Tamiami Formation. These formations consist predominantly of gray-white phosphatic limestone with interbedded carbonate clay or marl. The Hawthorn Formation and Tampa Limestone contain two widely used artesian aquifers: (1) the upper Hawthorn aquifer in the upper part of the Hawthorn Formation, and (2) the lower Hawthorn-upper Tampa aquifer in the lower part of the Hawthorn Formation and upper part of the Tampa Limestone.

Water from the upper Hawthorn aquifer is used to supply water mostly to residents on North Captiva Island, Captiva Island, and northwestern Sanibel Island. Water from this aquifer is usually better quality than that from the lower Hawthorn-upper Tampa aquifer. North Captiva Island, Captiva Island, and northwestern Sanibel Island are areas where the water can be used without desalination. Water from the upper Hawthorn aquifer contains dissolved solids concentration which averages 1,540 mg/L. The water contains about 440 mg/L of sodium, 400 mg/L of chloride, and 380 mg/L of sulfate plus smaller concentrations of other chemical constituents. Water levels in wells that tap the upper Hawthorn aquifer range from 8 to 15 feet above sea level; most wells flow at land surface.

The lower Hawthorn-upper Tampa aquifer is the principal source of water supply for most uses on Sanibel and Captiva Islands. Desalinated water from this aquifer constitutes part of the public supply for these islands. Wells that tap this lower aquifer may flow at rates as much as 160 gal/min. The water ranges in calcium magnesium hardness from 330 to 1,200 mg/L. The dissolved solids concentration in water ranges from 1,700 to 4,130 mg/L and averages 2,570 mg/L. The water contains about 660 mg/L of sodium, 1,080 mg/L of chloride, and 380 mg/L of sulfate. Between July and November 1977, water levels in the aquifer ranged from about 7 to 32 feet above sea level throughout Sanibel and Captiva. Water levels were lowest in the central part of Sanibel Island where most of the production wells for the Island Water Association are located.

Pumpage from both deep artesian aquifers for all purposes during 1977 was about 690 Mgal, averaging 1.9 Mgal/d. During 1977, pumpage from wells of the Island Water Association open to the lower Hawthorn-upper Tampa aquifer averaged about 1.4 Mgal/d.

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