FLSGP-T-80-009 c.2

FLORIDA SEA GRANT COLLEGE

Big Hickory Pass, New Pass, and Big Carlos Pass Glossary of Inlets Report No.8

by C. P. Jones

Report Number 37

October 1980

BIG HICKORY PASS, NEW PASS, and BIG CARLOS PASS
GLOSSARY OF INLETS REPORT #8

C. P. Jones
Coastal Engineering Specialist

Department of Coastal and Oceanographic Engineering
University of Florida
Gainesville, Florida 32611

State University System of Florida
Sea Grant Program
October 1980

TABLE OF CONTENTS

FOREWORD

The numerous inlets connecting Florida's inner waters to the Atlantic Ocean and the Gulf of Mexico are important from the consideration of recreational and commercial vessel traffic and also because they provide access to safe refuge for small boats during unexpected severe weather and waves. In addition, inlets act as flushing agents, providing renewal of bay waters by exchange with outer continental shelf waters. Inlets also serve as important migratory pathways for fish and shellfish. Unfortunately, inlets also contribute significantly to the serious beach erosion problem prevalent along most of Florida's shoreline. The complexities of the hydraulic and sediment transport mechanics in the vicinity of inlets present a formidable challenge to engineers and scientists. These factors, along with the interesting historical role that inlets have played in the early development of Florida have resulted in considerable documentation pertaining to the major inlets of the state.

This report on Big Hickory Pass, New Pass and Big Carlos Pass is one in a "Glossary of Inlets" series being prepared under the State University System Sea Grant project, "Nearshore Circulation, Littoral Drift and the Sand Budget of Florida." The purpose of this series is to provide for each inlet a summary of the more significant available information and to list known documentation. It is hoped that this series will yield an improved understanding of the overall effect of each inlet on the economics, recreation, water quality and shoreline stability of the surrounding area. The proper future management, use and control of Florida's inlets will require an appreciation of the evolution and past response as well as considerable future study.

ACKNOWLEDGEMENT

Most of the data and information contained in this report were collected by the author while employed at Suboceanic Consultants Inc., Naples, Florida. Their assistance in the preparation of this report is acknowledged, along with that of: Fred Bode, Big Hickory Fishing Nook, Bonita Beach; Wayne Johnson, Lee County Environmental Laboratory, Ft. Myers; J. M. Peterson, Florida Department of Transportation, Bartow. Comments by Dr. A. J. Mehta, Principal Investigator of the Sea Grant project, were most helpful during the preparation of this report.

I. INTRODUCTION

Big Carlos Pass, New Pass and Big Hickory Pass are undeveloped tidal inlets in southern Lee County, Florida, connecting Estero Bay with the Gulf of Mexico (Figs. 1.1 and 1.2). The inlets lie between latitudes 26° 24'N and 26° 22'N, and between 81° 53'W and 81° 52 W. They lie approximately 15 miles south of Fort Myers and 20 miles north of Naples, Florida. Gulf access from Estero Bay may also be obtained by traveling south through Fish Trap Bay, Little Hickory Bay and finally, Wiggins Pass (approximately 5½ miles south of Big Hickory Pass), or by traveling north through Matanzas Pass. The Gulf Intracoastal Waterway extends from the Caloosahatchee River north through Pine Island Sound, but does not extend south through Estero Bay. Several islands fall between Estero Island (Fort Myers Beach) and Little Hickory Island (Bonita Beach), and most are joined by a causeway that was constructed between 1963 and 1965 (Fig. 1.2). Big Carlos Pass separates Estero Island on the north from Black Island and Lovers Key to the south; New Pass separates what was once a small mangrove island to the north (now joined to Long Key and Black Island by the causeway) from Big Hickory Island to the south; Big Hickory Pass (now closed) separated Big Hickory Island on the north from Little Hickory Island on the south.

As can be seen in Figs. 1.3 and 1.4, Big Carlos Pass, New Pass and Big Hickory Pass are quite varied in size and configuration. The largest of the inlets, Big Carlos Pass, has remained essentially unchanged over the past century. The pass is approximately 1,600 ft. wide and has depths which exceed 20 ft. New Pass, on the other hand, has changed significantly (see Sec. 5.2). The present-day New Pass is approximately 800 ft. wide with a maximum depth of 18 ft. Big Hickory Pass has also undergone dramatic changes. The inlet closed in the fall of 1976, was reopened during November of that year, and is currently blocked once again.

Development in the area did not begin until the late 1800's, and even then was limited for the most part to isolated homesteads. As a result, no detailed information concerning Estero Bay and the various tidal passes exists for earlier periods. There are, however, several references that contain tales of the area during the Spanish occupations of Florida and the subsequent arrival of the early settlers (Beater, 1965; Brown and Brown, 1965; Fritz, 1968). Others describe the lifestyle and activities of the Calusa Indians (also referred to as the Caloosa), who inhabited the area prior to and through the Spanish occupation (Schell, 1962; Voegelin, 1977). Today the islands in the area are oriented cheifly toward tourism, and numerous motels, winter homes and condominiums line the shores of Estero Island and Little Hickory Island. Carl E. Johnson Park (a Lee County facility) is situated on Black Island and Lovers Key, the J. N. "Ding" Darling National Wildlife Refuge is located nearby on Sanibel Island, and public beaches are located throughout the area.

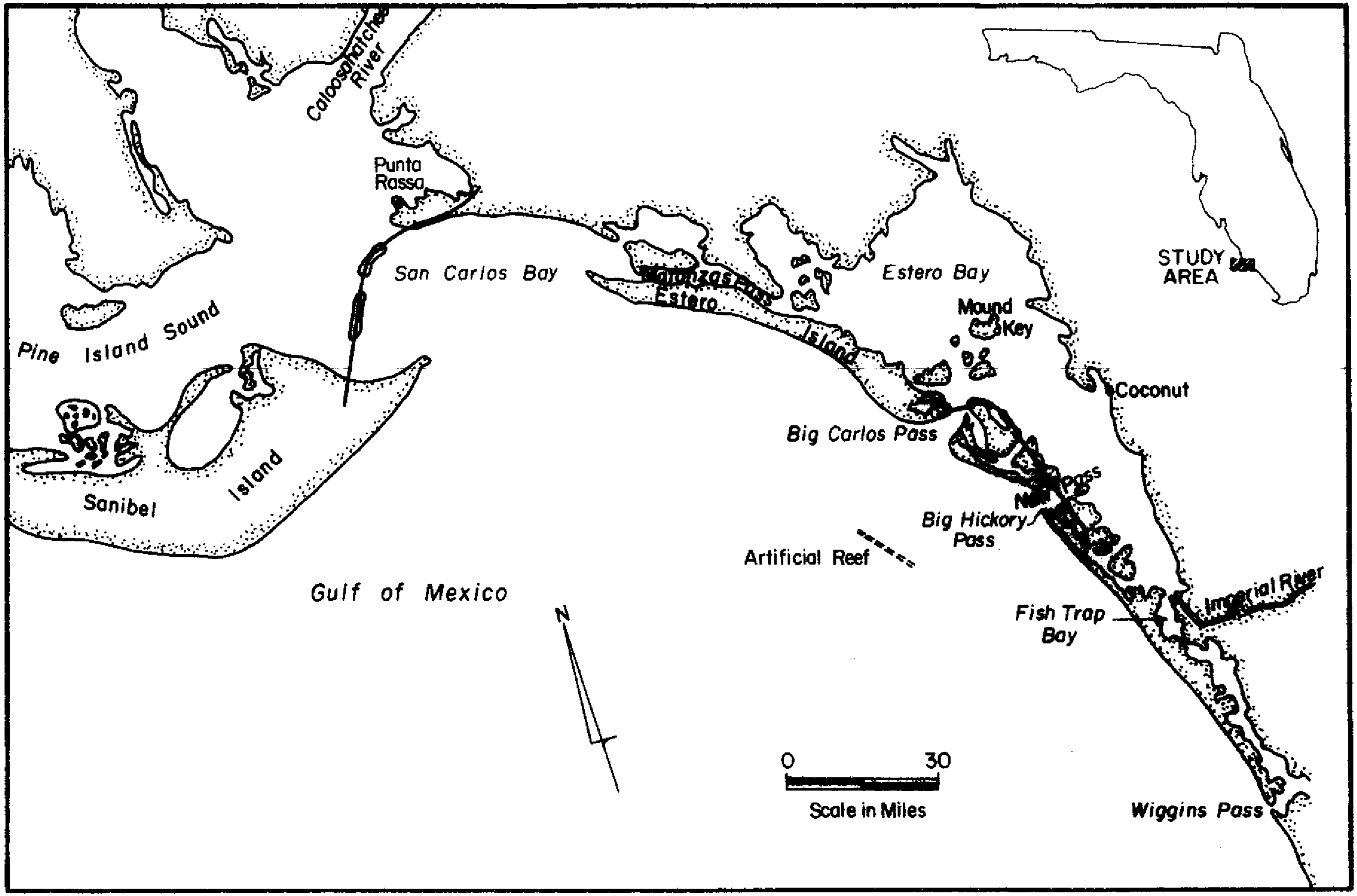

Fig. 1.1 Map of Estero Bay and Vicinity

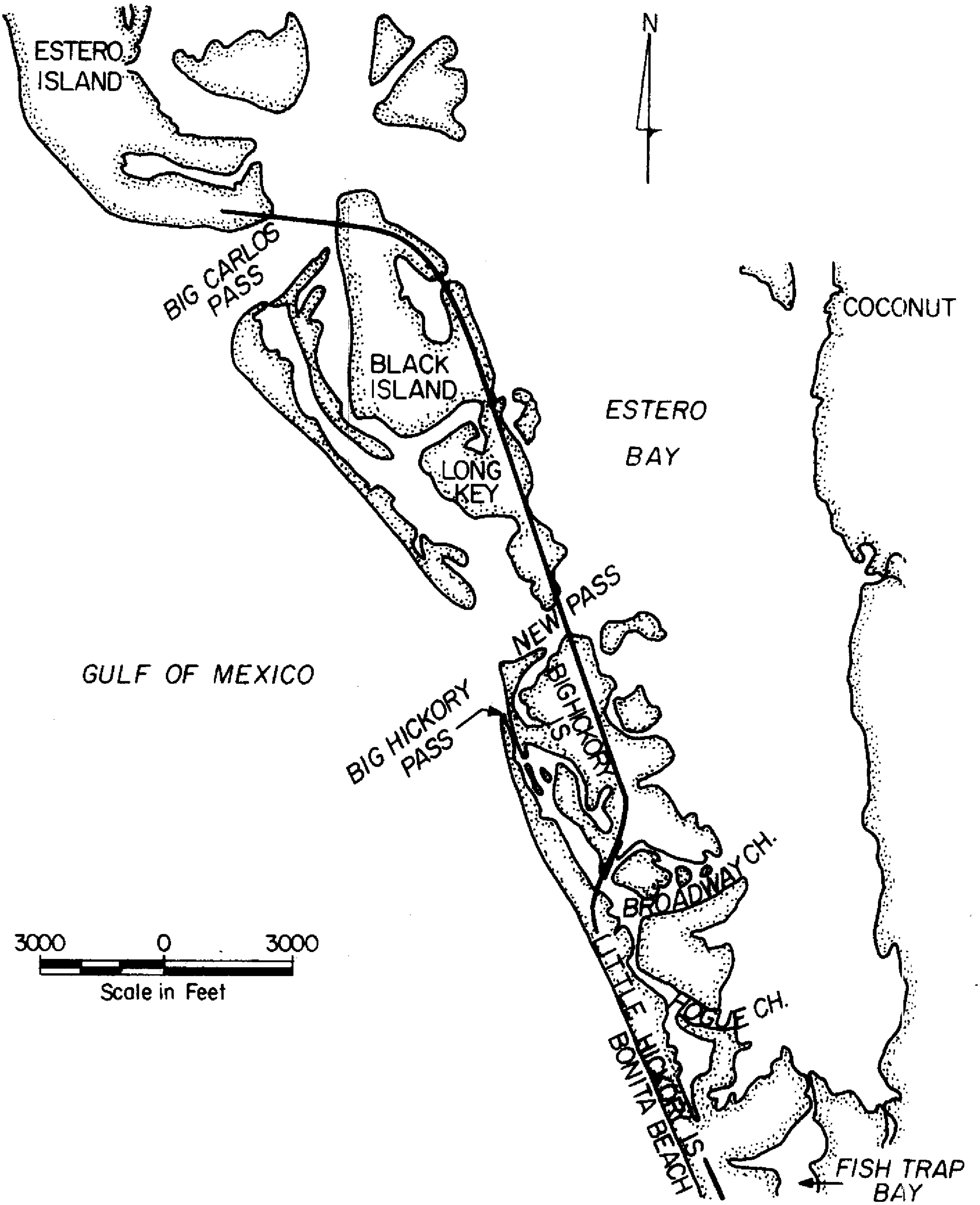

Fig. 1.2 Big Hickory Pass, New Pass, Big Carlos Pass, and Estero Bay (Suboceanic Consultants, Inc., 1978)

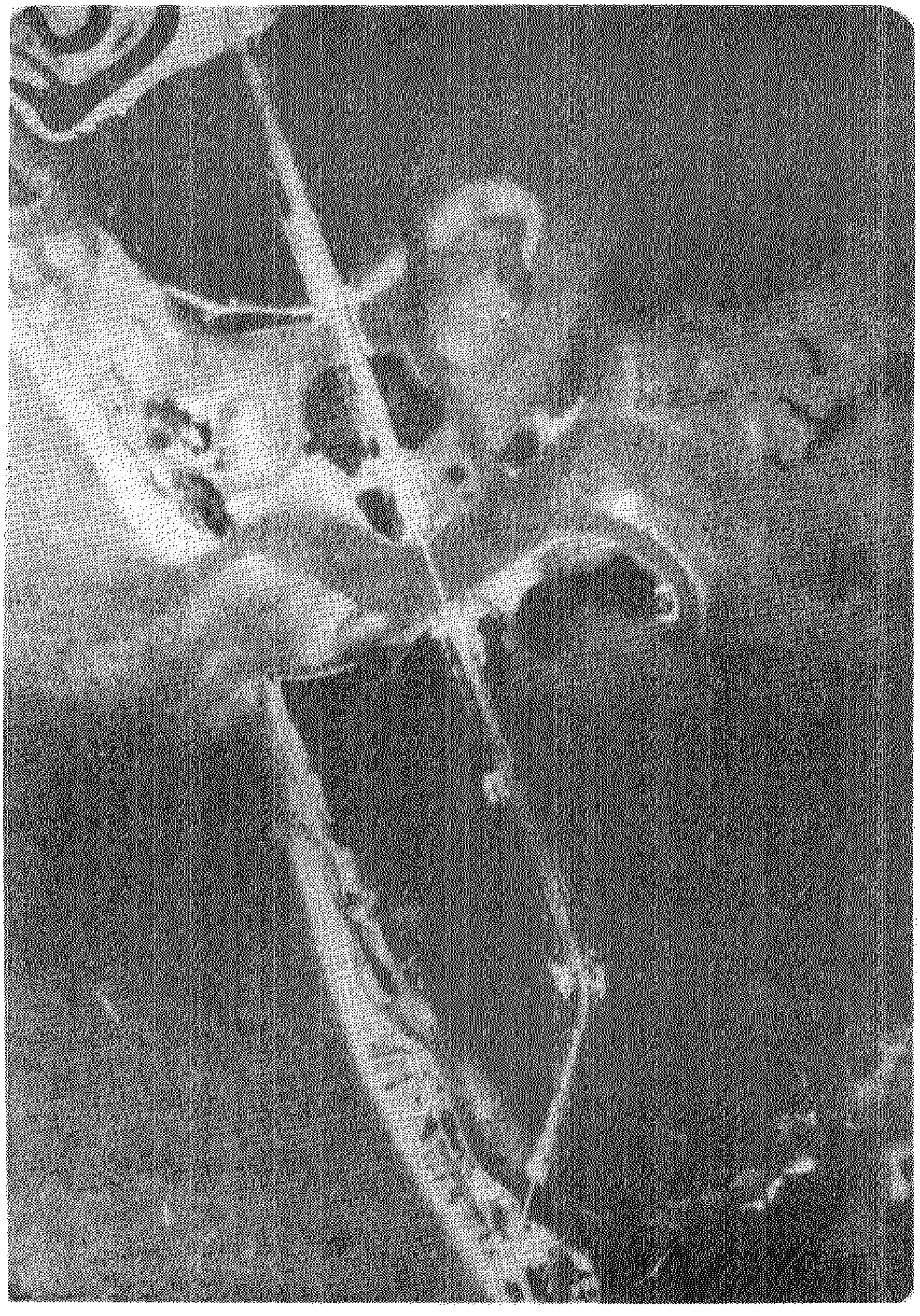

Fig. 1.3 Big Hickory Pass and New Pass in 1978

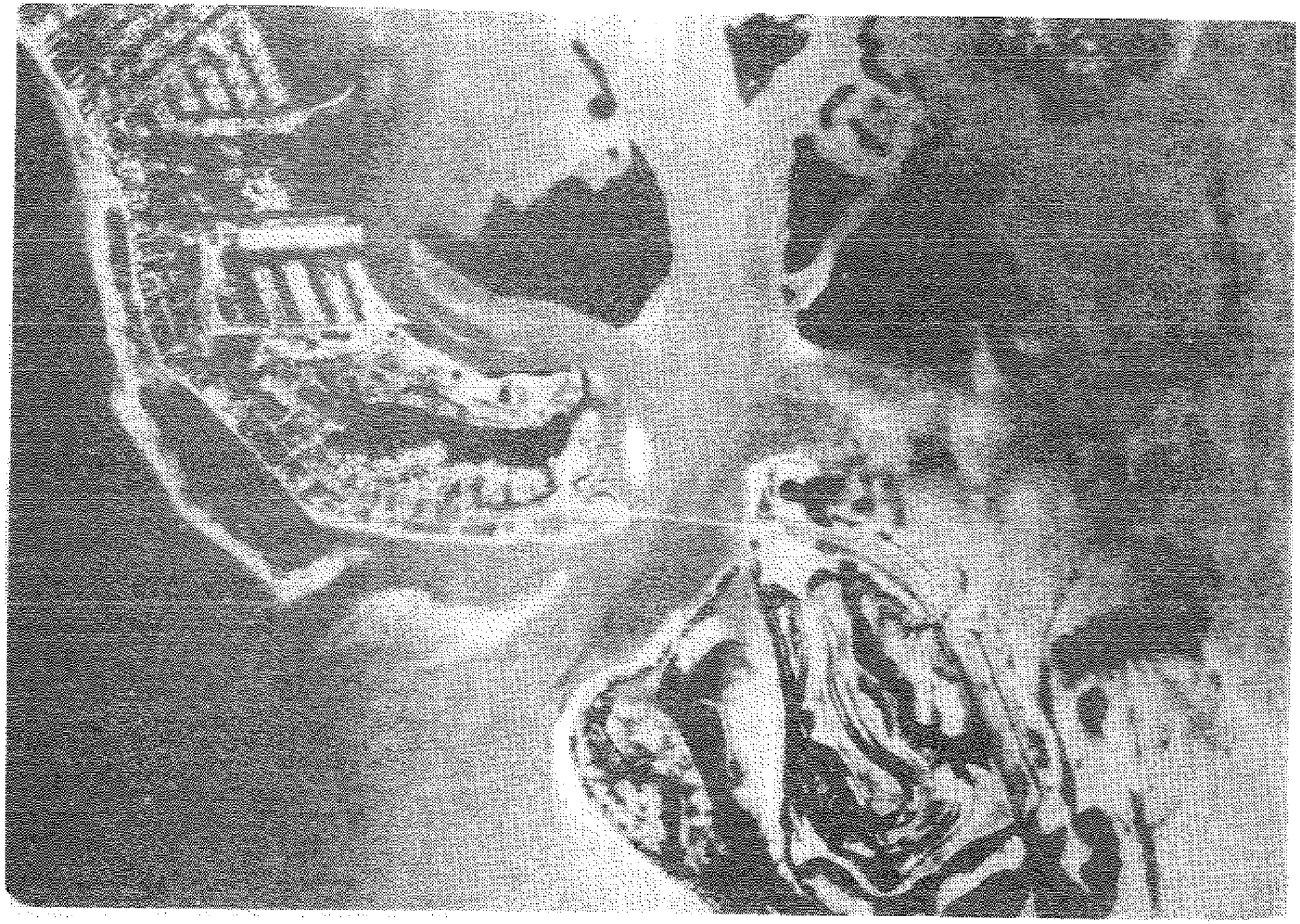

Fig. 1.4 Big Carlos Pass in 1978

II. GEOLOGIC SETTING

The coast of Lee County is similar to most of coastal Florida between the Ten Thousand Islands to the south and the Clearwater - Tarpon Springs area to the north. It is characterized by sandy, barrier islands backed by shallow bays, marsh and mangrove areas and a low elevation, low relief coastal plain. In the Estero Bay vicinity this plain is a part of the Pamlico Terrace, formed during the Pleistocene (approximately 240,000 years ago) when the sea level was approximately 25 feet higher than at present. Relict beach ridges are present on many of the older islands in the area (e.g., Sanibel Island and Estero Island) and are useful in describing the more recent geologic history (see Sec. 5.2).

Holocene sediments composed of quartz sand, shell and shell fragments overlay the Pleistocene features. The surface sediments tend to be sandy, poorly drained soils, as can be seen in Fig. 2.1 (Florida Department of Administration, 1975). The reader is referred to Section 7.1 for a more detailed description of the sedimentary characteristics in the vicinity.

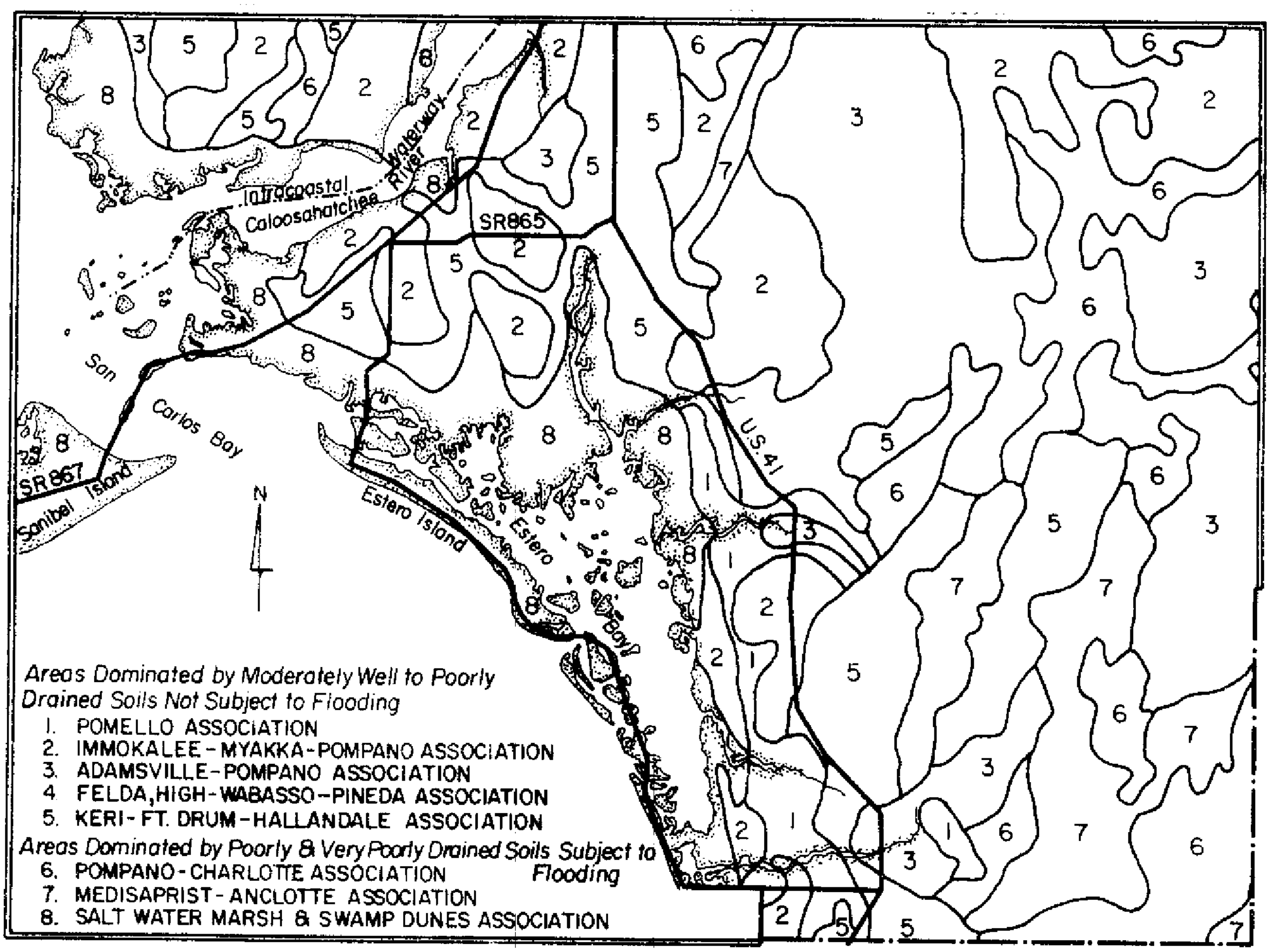

Fig. 2.1 Surficial Sediment Types (Fla. Dept. of Administration, 1975)

III. CLIMATE AND STORM HISTORY

3.1 Climate

The Estero Bay area experiences a humid, subtropical climate characterized by long summers and relatively mild winters. The average yearly temperature at the U.S. Weather Bureau Station at Page Field in Fort Myers is 73.7° F; the average yearly rainfall total is 53.5 in., and prevailing winds are easterly at about 8 mph (NOAA, 1972). Locally heavy afternoon and evening thundershowers occur frequently during the months of June through September, when approximately two-thirds of the average yearly rainfall total will fall. This and other pertinent information is summarized in Table 3-1.

Table 3-1

Average Monthly Weather Conditions

Month	Temperature (F°)	Rainfall (in.)	Wind	
			Prevailing Direction	Mean Speed (mph)
Jan	63.5	1.52	E	8.6
Feb.	65.2	2.21	E	9.2
Mar.	68.2	2.62	SW	9.6
Apr.	72.8	2.64	E	8.9
May	77.4	3.85	E	8.2
June	80.8	8.96	E	7.4
July	82.2	9.08	ESE	6.9
Aug.	82.7	7.38	E	6.9
Sep.	81.3	8.50	E	7.9
Oct.	76.1	4.09	NE	8.5
Nov.	69.2	1.20	NE	8.3
Dec.	65.0	1.29	NE	8.3
Avg/total	73.7	53.34	E	8.2

3.2 Storms

Tropical storms and hurricanes can effect the area dramatically in several ways, including: the erosion of beaches, the opening of new tidal inlets, and the damaging of structures due to wind and wave forces and tidal flooding. Several hurricanes have caused erosion and major changes in the configuration of the islands in the area (see Sec. 5.2). The 1926 hurricane opened Redfish Pass (between Captiva and North Captiva Islands, north of the study area). Numerous other hurricanes, including Donna in 1960, have caused widespread damage due to erosion and flooding.

Records indicate that, on the average, the Fort Myers area experiences hurricane force winds once every 11 years (NOAA, 1972). Simpson and Lawrence (1971) estimated that a tropical storm (winds 29 to 73 mph), a hurricane (winds 74 to 124 mph) and a great hurricane (winds greater than 125 mph) have the following probabilities of occurrence in any single year over a 50-mile segment of coastline that includes the study area:

All Tropical Storms: (including hurricanes and great hurricanes)	21%
All Hurricanes: (including great hurricanes)	9%
Great Hurricanes:	2%

It should be realized, however, that such storms may occur much more frequently or not at all during a short period of time; for example, 6 hurricanes passed within 100 miles of Black Island between 1944 and 1953 (COEL, 1974). Figure 3.1 shows the paths of the storms that passed by the study area between 1871 and 1970 (NOAA, 1973). Descriptions of some of the more damaging storms follow:

Oct. 11-18, 1910	This hurricane moved inland approximately 50 miles north of Fort Myers. Flooding 4 to 6 ft. deep was reported at Everglades, (65 miles south of Fort Myers), and damages of $258,000 were reported in Lee County (Corps of Engineers, 1969).
Oct. 21-31, 1921	Tides in the area were 7 to 11 ft. above normal in Lee County, and widespread flooding occurred along Captiva Island and Estero Island (Corps of Engineers, 1969). Brown and Brown (1965) and the Fort Myers News Press (Nov. 26, 1972) reported that this hurricane washed away the southern tip of Estero Island.
Sept. 6-22, 1926	This hurricane probably produced the most severe flooding on record on the Caloosahatchee River, with tides 12 ft. above mean sea level (MSL) at Punta Rassa. Water was reported to be shoulder deep along Estero Island (Corps of Engineers, 1970). The bridge to Fort Myers Beach was wrecked, as were many cottages there. Damages were estimated at $1 million in the Fort Myers area (Corps of Engineers, 1969). According to Beater (1965), it was this storm - not the 1921 hurricane - that washed away the southern tip of Estero Island.
Oct. 13-21, 1944	High tides and wave swept over Sanibel Island and Estero Island, with 3 to 6 ft. of flooding reported at Fort Myers Beach (Corps of Engineers, 1970).
Sept. 11-19, 1947	This hurricane entered Florida's east coast near Fort Lauderdale and exited just south of Lee County. Winds of 90 mph were reported at Fort Myers, along with 8 in. of rainfall in a 24-hr. period (Corps of Engineers, 1969).

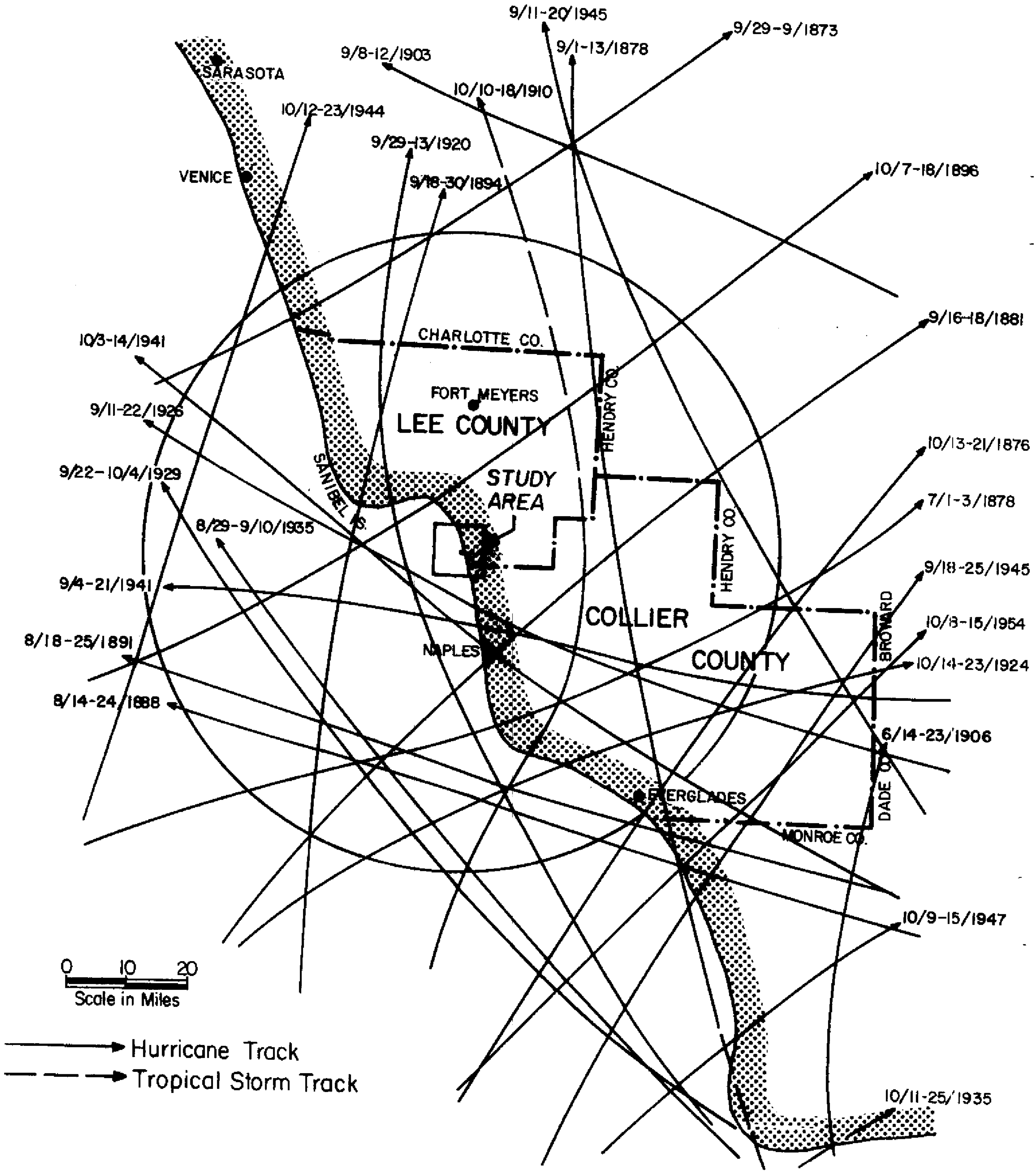

Fig. 3.1 Hurricane and Tropical Storm Tracks, 1871-1970 (NOAA, 1973)
50 Mile Radius from Study Area is Denoted by the Circle.

Aug. 29 -Sept. 13, 1960 Hurricane Donna probably produced the greatest known tidal flooding along the southern shoreline of Lee County. Peak high-water marks were measured 10 to 11 ft. above MSL on Estero Island and Little Hickory Island. Dune elevations of 5 to 7 ft. were lowered several feet, exposing and undermining foundations and toppling structures. High tides and waves caused several breakthroughs along Captiva Island; Blind Pass, situated between Sanibel Island and Captiva Island, was reopened by the storm. Tidal flood damages in Naples and Fort Myers Beach were nearly $11 million (Corps of Engineers, 1969, 1970).

3.3 Flooding

Since ground elevations in the study area are relatively low (generally less than 5 to 6 ft. MSL along the barrier islands), the area is susceptible to tidal flooding during most any tropical storm or hurricane. NOAA (1973) lists the following total tide elevations (astronomical tide plus storm tide) at Fort Myers Beach:

Return Period (years)	Total Tide (ft. MSL)
10	5.2
25	8.3
100	13.2
500	18.3

The Corps of Engineers (1970) delineated regions in southern Lee County that would be expected to be flooded during an Intermediate Regional Tidal Flood (100 year return period) and a Standard Project Tidal Flood (most severe tidal flood expected). These regions are shown in Fig. 3.2. Note that all of the islands in the area will be flooded by the Intermediate Regional Flood (IRTF) and the Standard Project Tidal Flood (SPTF).

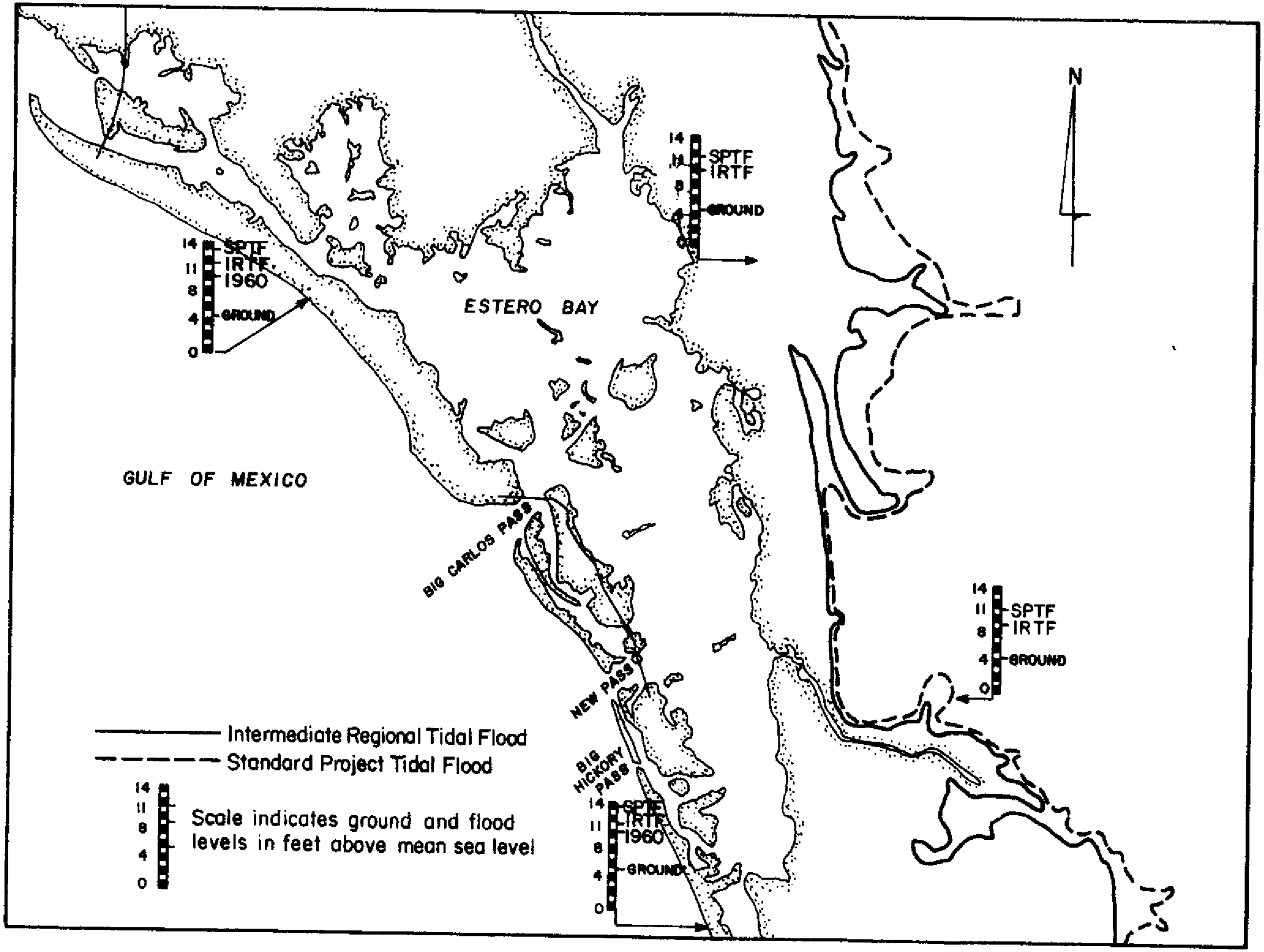

Fig. 3.2 Map Showing Expected Flood Areas for an Intermediate Regional Tidal Flood and a Standard Project Tidal Flood (Corps of Engineers, 1970)

IV. HISTORY OF THE INLETS

4.1 General

The coastal area of Southwest Florida has been inhabited for the past two thousand years. The earliest inhabitants were the ancestors of the Calusa Indians; the Spaniards, the Seminole Indians and the forerunners of the present inhabitants arrived later (Tebeau, 1966).

Early records of the Calusa are scarce, and our knowledge of them comes primarily from Spanish accounts of them and from archeological investigations of shell mounds throughout the area. The Calusa were, by many accounts, the most important Indian tribe in South Florida. They lived mostly along the southwest coast but smaller groups lived inland. Accordingly, they were a non-agricultural people, living from the foods obtained in the Gulf and inland waters. The Calusa were also a fierce, agressive people, and the fact that the Spanish did not persist in their early efforts to convert them attests to their fierce nature. In fact, it was nearly two centuries after the Spaniards discovered the Calusa that they established the first settlements in the area (Tebeau, 1966; Voegelin, 1977).

While many of the small shell mounds in the region are regarded as refuse and by-products of the Calusa existence, the largest of the mounds were skillfully designed and constructed to use the shell refuse as a building material (Tebeau, 1966). Mound Key, which lies east of Big Carlos Pass, is one of the largest of the Calusa sites. The 125-acre island was reportedly the stronghold of Carlos, the Calusa "cacique" (chief) in the region, and was used for religious and communal activities. Figure 4.1 shows a sketch of the topography of the key (Schell, 1962).

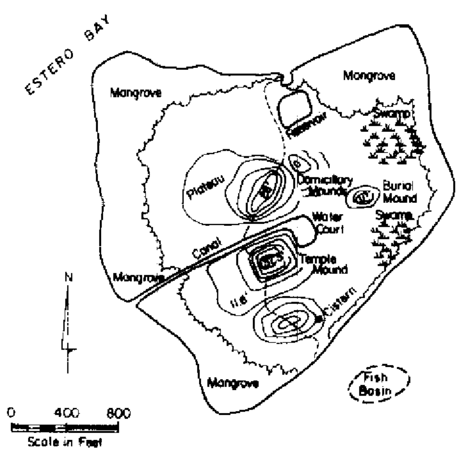

Fig. 4.1 Topography and Highlights of Mound Key (Schell, 1962)

The Calusa probably became extinct in the early nineteenth century. At that time, however, there were several different Indian groups in the area, one of which was the Seminole. The Seminoles came to the area as they were gradually forced southward through Florida during the Seminole Wars.

The next impetus for settlement of the area occurred during the late 1800's when Dr. Cyrus Teed established the Koreshan Unity's College of Life in Estero, approximately 16 miles south of Fort Myers. Many of the early settlers on the islands around Estero Bay were Koreshans, and the early development of Estero Island, in particular, was due in part to them. The history of the area from this point on is summarized below in a chronology of events.

4.2 Chronology of Events

1875	A meander line was established by the Federal Government around Estero Bay, and was later the subject of much controversy in conjunction with a proposed development in northern Estero Bay.
1891	The first land grant in the area was given to Frank M. Johnson by President Benjamin Harrison. The grant totaled 125 acres on Mound Key (Beater, 1965).
1894	Gustav Damkoeler deeded 300 acres on Estero Island to Cyrus Teed, founder of the Koreshan Unity. During this same year a sawmill was established on the southern end of Estero Island by the Koreshan Unity.
1898	Robert B. Gilbert was the first to file for homestead rights on Estero Island.
1908	Dr. Cyrus Teed died and was buried on the south end of Estero Island.
1921	A private company was formed to build a road and bridge to connect the northern end of Estero Island to the mainland.
1924	San Carlos Island (across Matanzas Pass at the north end of Estero Island) was promoted for residential development. The arch north of the swing bridge leading to Estero Island was built at this time (the arch was razed in order to construct the new bridge across the pass in the late 1970's).
1928	The first bridge across Matanzas Pass was replaced by the first swing bridge.
1939	The West Coast Intracoastal Waterway was recommended to Congress by the Corps of Engineers after a feasibility study was completed.
1945	Congress authorized construction of the West Coast Intracoastal Waterway between the Caloosahatchee River and the Anclote River (Pinellas County).

1955 Lee County authorized a feasibility study to examine the possibility of joining Fort Myers Beach with Bonita Beach via a series of bridges between the islands on the west side of Estero Bay.

1957 Lee County Commission adopted a resolution requesting that the Florida Trustees of the Internal Improvement Trust Fund not sell any more State lands in the Estero Bay area pending the planning of the causeway.

1959 The first permit application submitted in March for the proposed causeway showed bridges over Big Carlos Pass and New Pass. Big Hickory Pass, along with several other tidal channels were to be closed during the construction of the causeway. A revised application was submitted in July and called for the construction of a 200 ft. long trestle bridge across Big Hickory Pass with a corresponding shortening of the New Pass bridge. The application still called for the closure of numerous tidal channels (Fig. 4.2).

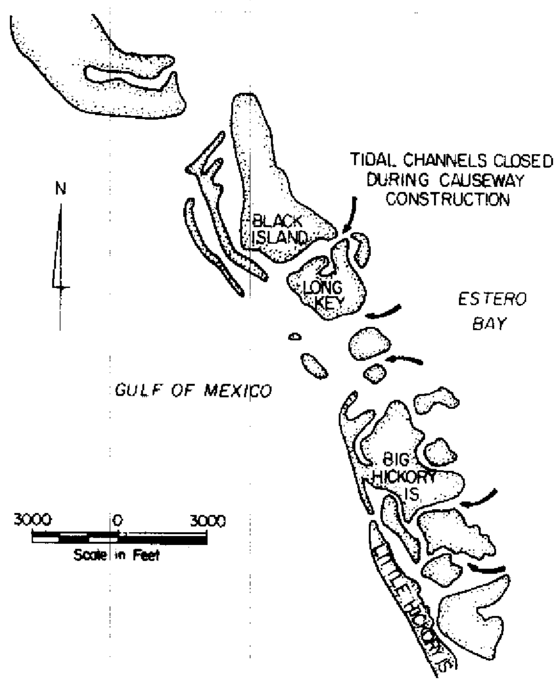

Fig. 4.2 Map Showing Tidal Channels Closed During Construction of Causeway, (Suboceanic Consultants, Inc., 1978).

1960	In June, dredging for the Intracoastal Waterway began at the Caloosahatchee River and proceeded northward through Pine Island Sound. The Federally maintained project has a project depth of 9 ft. and a project width of 100 ft. The waterway was completed during the late 1960's (WCIND, 1974). Hurricane Donna struck the area, causing nearly $1 million in damages in the Fort Myers - Naples area (see Sec. 3.2).
1961	The Koreshan Unity deeded 290 acres of land to the State of Florida, including 70 acres in Estero, 100 acres on both sides of the mouth of the Estero River and 120 acres on Mound Key. A Federal navigation project for Matanzas Pass (Fort Myers Beach Channel) was completed. It provided a channel 12 ft. deep and 150 ft. wide from that depth in San Carlos Bay into the pass, thence 11 ft. deep and 125 ft. wide into Matanzas Pass. The total project length was approximately 2.1 miles (Fig. 4.3) (Corps of Engineers, 1969).
1965	The 4.3 mile long causeway between Fort Myers Beach and Bonita Beach, begun in 1963, was completed at an approximate cost of $2.7 million.
1965-1966	The National Ocean Survey (NOS) maintained tide gages at three secondary stations around Estero Bay (Carlos Point, Coconut, Little Hickory Island) for a nine month period. Predictions for these stations may be found in the NOS <u>Tide Tables</u> (see Fig. 6.2 for the station locations).
1966	Maintenance dredging in the Fort Myers Beach Channel was completed, with approximately 60,000 cu. yds. of material removed. About 20,000 cu. yds. were placed in a spoil area north of the pass while the remaining 40,000 cu. yds. were placed on upland property on the north tip of Estero Island (Corps of Engineers, 1969) (refer to Fig. 4.3).
1968	A 2,000 ft. extension of the Fort Myers Beach Channel, including a turning basin was authorized.
1969	The Corps of Engineers, "Beach Erosion Control Study - Lee County, Florida," recommended restoration of the northern 24,500 ft. of Estero Island with a 600 ft. terminal groin at the north end. The volume of restoration material was estimated to be 325,000 cu. yds. and the renourishment requirements were estimated to be 120,000 cu. yds./yr. at that time.
1970	A "Special Flood Hazard Information Report on South Lee County Coastal Areas," was completed by the Jacksonville District of the Corps of Engineers. The study delinated areas that would be flooded by an "Intermediate Regional Tidal Flood" and a "Standard Project Tidal Flood" (see Fig. 3.2).

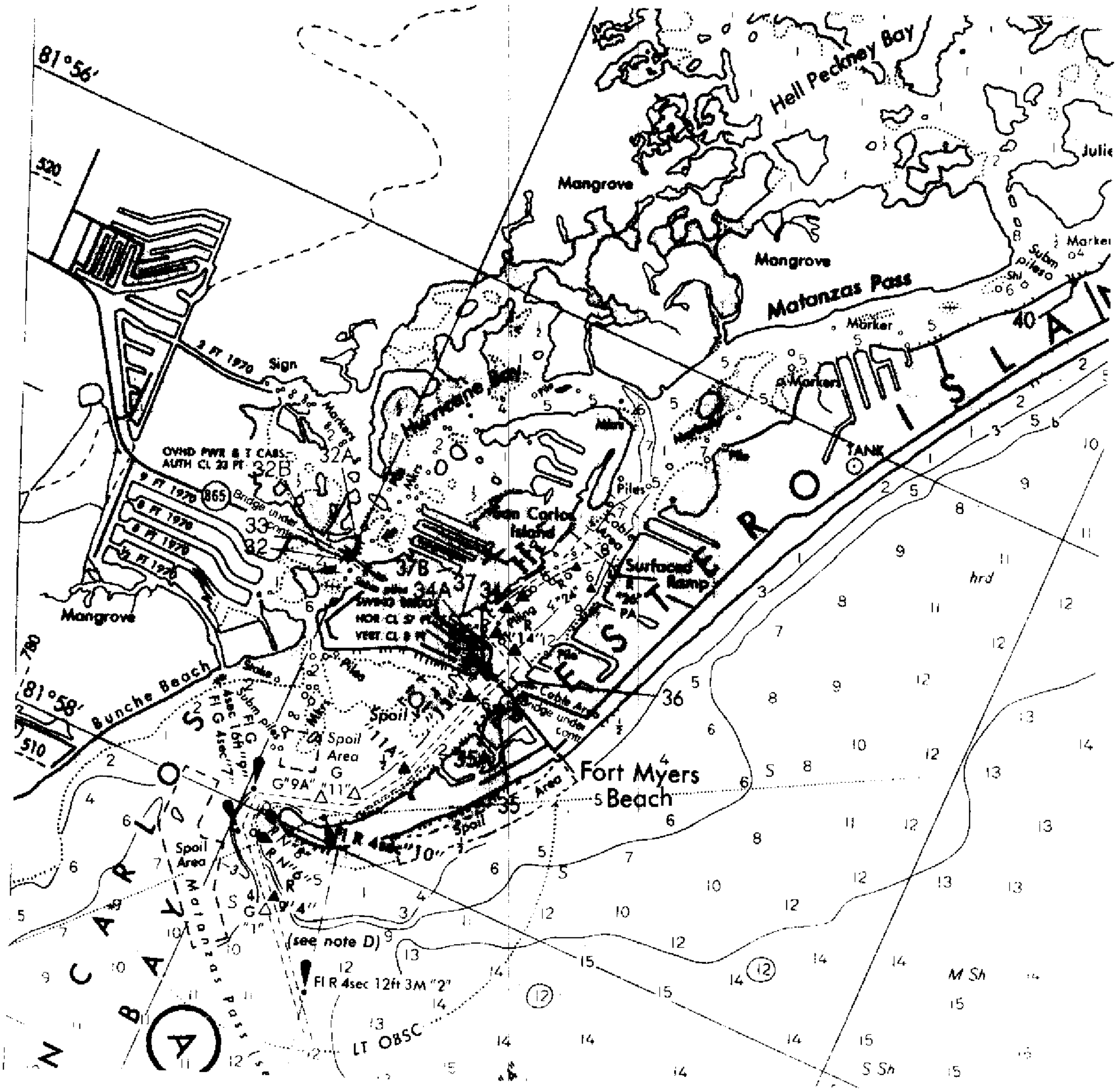

Fig. 4.3 Fort Myers Beach Channel, also known as Matanzas Pass, as it appeared in 1977 (Small Craft Chart 11427).

1971 A University of Florida study of Black Island and Lovers Key examined the development and stability of those islands (COEL, 1971).

1973 The Fort Myers Beach channel 2,000 ft. extension and turning basin authorized in 1968 were completed (see Fig. 4.3).

1975 The Coastal Construction Setback Line (now referred to as the Coastal Construction Control Line) was established, but Lee County adopted the first set of Coastal Construction Codes in lieu of the setback line. The codes establish three distinct hazard zones along the barrier islands, with a set of building codes for each zone (Stanley Hole and Associates - Suboceanic Consultants, 1975, 1976, 1977).

1976 Big Hickory Pass was closed during September by the spit which had been restricting the pass for several years (see Sec. 5.2). The Pass was reopened in November with a dragline by Lee County (Fig. 4.4).

1977 An artificial reef of concrete rubble and derelict vessels was constructed between January and August, about 2½ miles southwest of Big Carlos Pass. The reef is approximately one mile long, 300 ft. wide, and the top stands 10 ft. below mean low water (see Fig. 1.2). Lee County authorized a study of Big Hickory Pass, in November which was tending toward closure again.

1978 Suboceanic Consultants, Inc. made a hydrographic study of Big Hickory Pass for Lee County. The study was funded by the Florida Dept. of Environmental Regulation.

1979 In January, Big Hickory Pass closed for the second time.

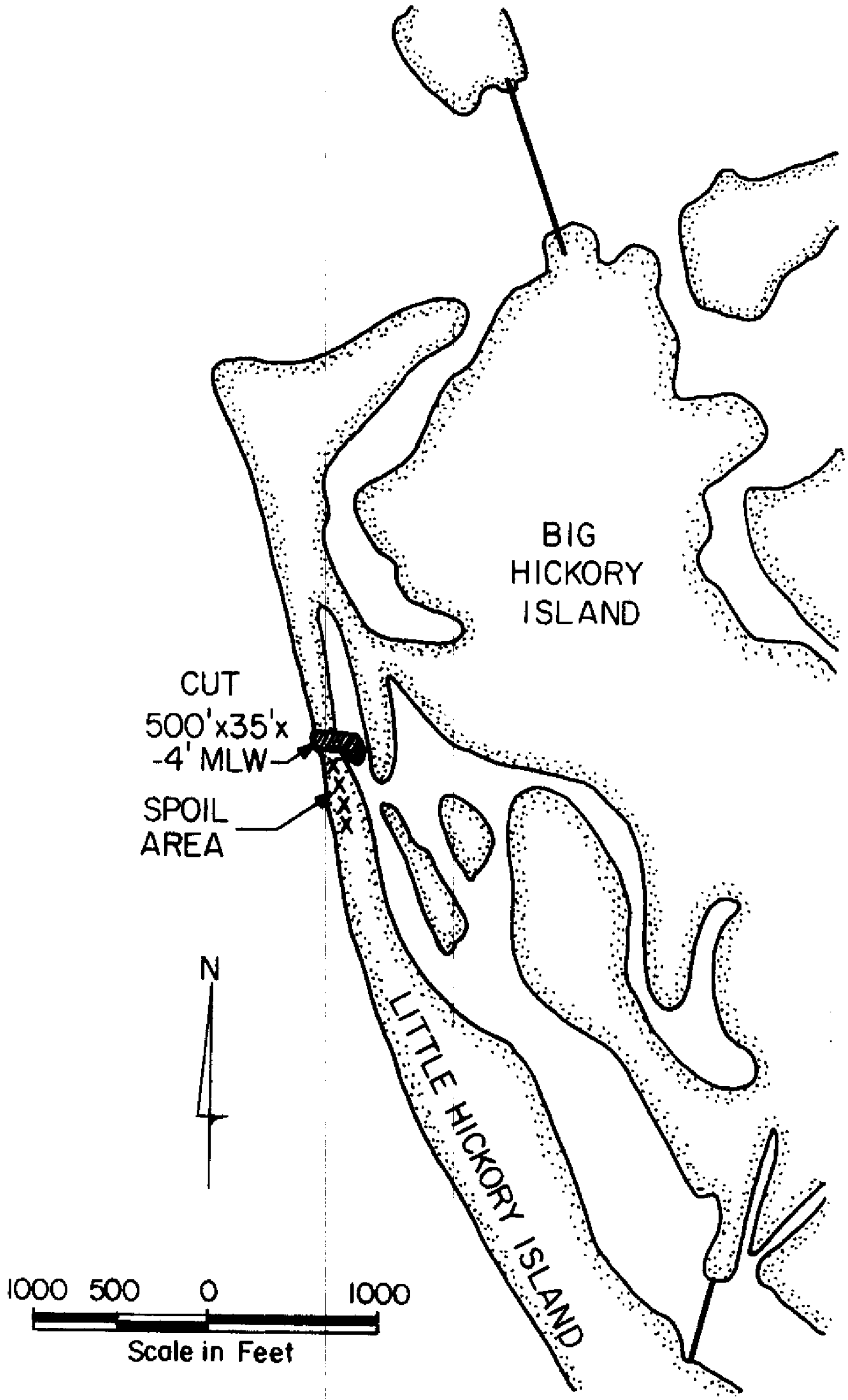

Fig. 4.4 Dredge and Spoil Area of Big Hickory Pass Reopening in 1976 (Suboceanic Consultants Inc., 1978)

V. MORPHOLOGICAL CHANGES

5.1 Maps, Surveys and Photographs

Big Hickory Pass, New Pass and Big Carlos Pass appear on the following charts and maps: NOS Small Craft Chart No. 11427 (replaces No. 856-SC), NOS Coast Chart No. 11426 (replaces No. 1255) and the USGS Bonita Springs, Estero and Fort Myers Beach Topographic Quadrangles, photorevised in 1972.

Surveys of the inlets in the area have been made infrequently, although the U.S. Coast and Geodetic Survey and the Corps of Engineers have made surveys of the offshore region since 1885. Figure 5.1 shows the 1885 survey, indicating the mean high water shoreline on the Gulf side of the islands in the area and the 6 ft. and 12 ft. depth contours (Corps of Engineers, 1969). Figure 5.2 shows a 1927 survey, indicating the mean high water shoreline (Corps of Engineers, 1969). Beach profiles were taken by the Corps of Engineers on Estero Island in 1967 in conjunction with the Beach Erosion Control Study. Profiles were also surveyed by the Florida Department of Natural Resources on the Gulf sides of Estero Island, Lovers Key and Little Hickory Island in 1974 prior to the determination of the recommended coastal setback line (presently referred to as the coastal construction control line). The locations of the DNR profile lines are indicated in Fig. 5.3 (COEL, 1975).

Aerial photographs of the inlets have been taken by several government agencies since 1944 and by Suboceanic Consultants, Inc. during its study of Big Hickory Pass in 1978. Barwis (1975) provides a listing of the aerial photographs taken by governmental agencies. Figure 5.4 through 5.8 show the inlets in 1944, 1953, 1958, 1965 and 1970.

5.2 Outercoast Shoreline Changes

It can be seen from Figs. 5.1 and 5.2 and from Figs. 5.4 through 5.8 that the islands in the area have undergone drastic changes in size and location over the past century. With the exception of Big Carlos Pass, which has remained in the same location, the inlets in the area have migrated and changed significantly. For this reason, a quantitative description of shoreline changes in the area between Estero Island and Little Hickory Island is not attempted here.

Before discussing the shoreline changes at specific locations it is instructive to look at the effects of hurricanes on the area in general. Shepard and Wanless (1971) examined early nautical charts and photographs of Sanibel Island and determined that several major hurricanes eroded the island severely during its development. The presence of older beach ridges at several locations on Sanibel Island that have been truncated by newer ridges, with the newer having formed at an angle to the older, indicate that the storms caused major adjustments of the shoreline. Similar adjustments can be seen at the southern end of Estero Island (see Fig. 5.4) where newer ridges have truncated older ridges. These adjustments could have been the result of shoreline erosion, the formation and/or alteration of inlets and changes in wave refraction and sediment transport in the vicinity of the inlets.

The 1885 survey of the area (Fig. 5.1) showed the opening of Big Hickory Pass was approximately 6,000 ft. south of the location where it closed in 1976. The survey also showed that Big Hickory Island was at that time a narrow barrier

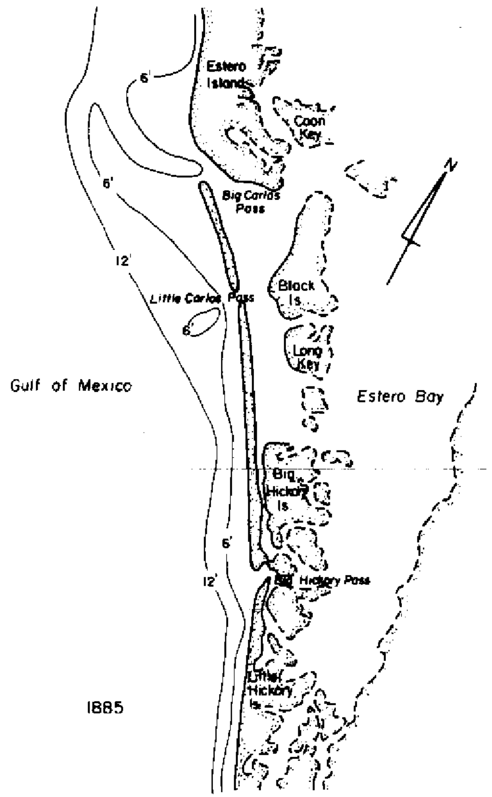

Fig. 5.1 Shoreline Configuration and Offshore Depth Contours, 1885 (Corps of Engineerings, 1969)

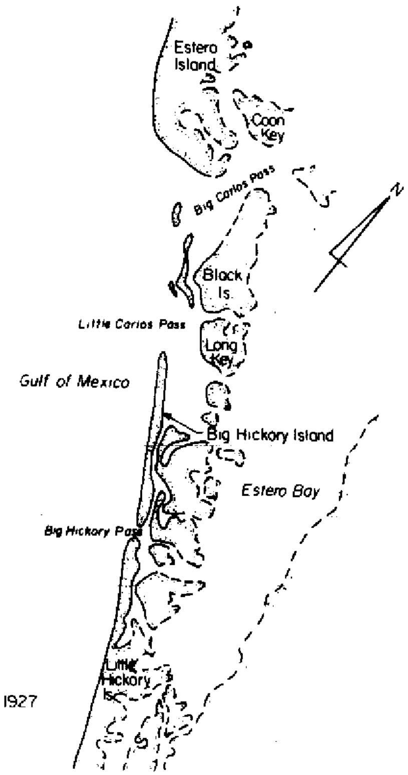

Fig. 5.2 Shoreline Configurations, 1927 (Corps of Engineers, 1969)

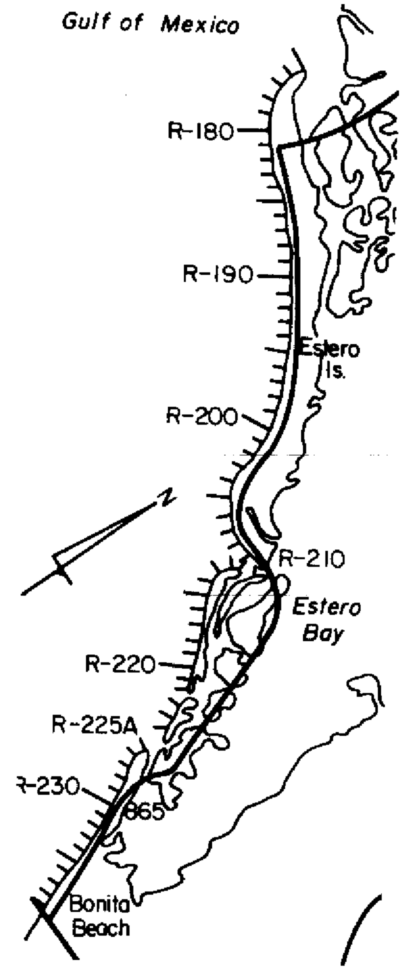

Fig. 5.3 Location of DNR Profile Lines for Determination of Coastal Setback Line, 1974

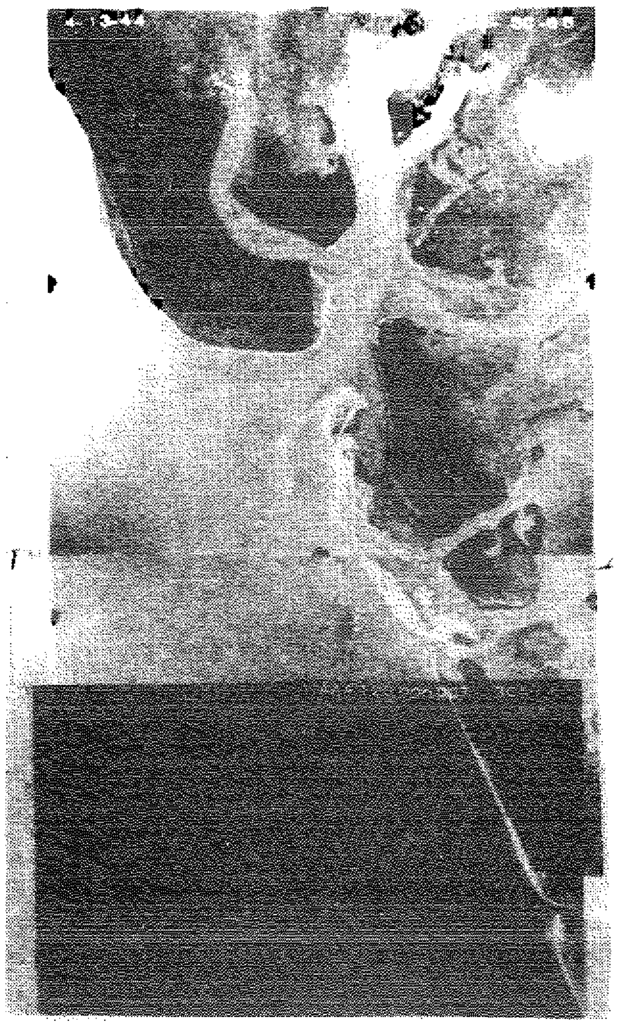

Fig. 5.4 Estero Bay and Vicinity, April 13, 1944

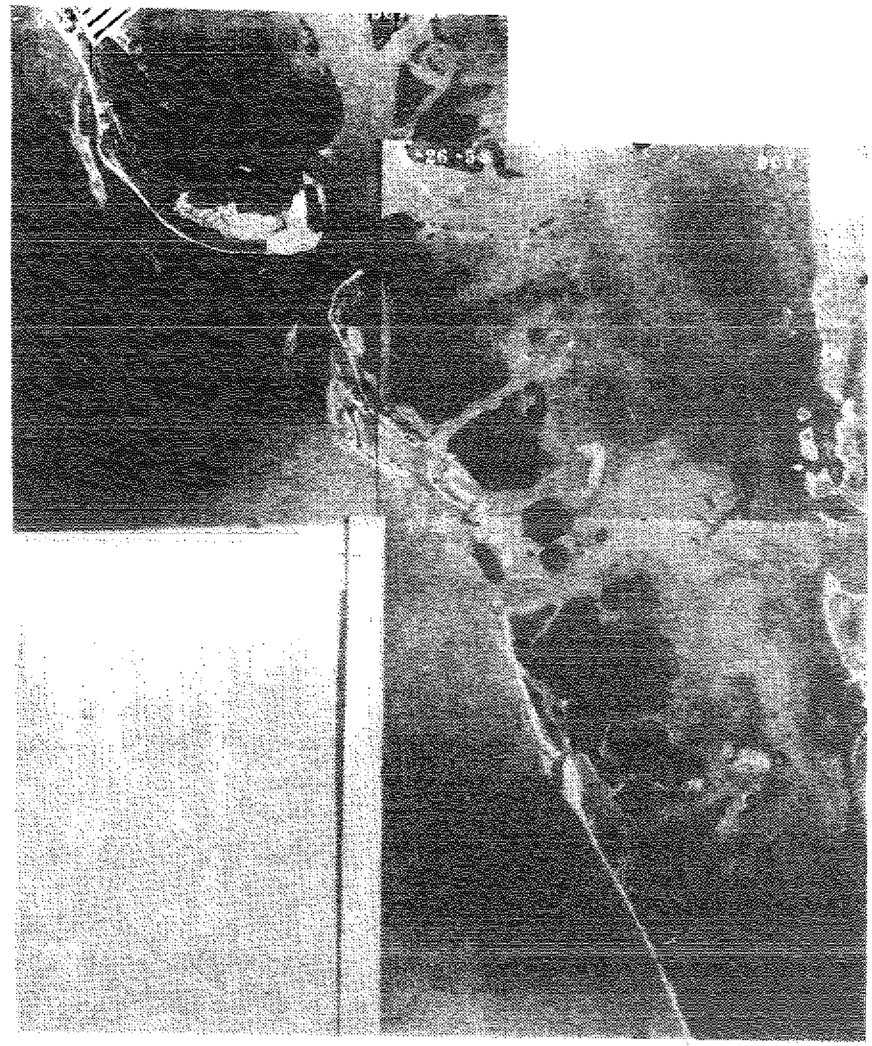

Fig. 5.5 Estero Bay and Vicinity, January 26, 1953

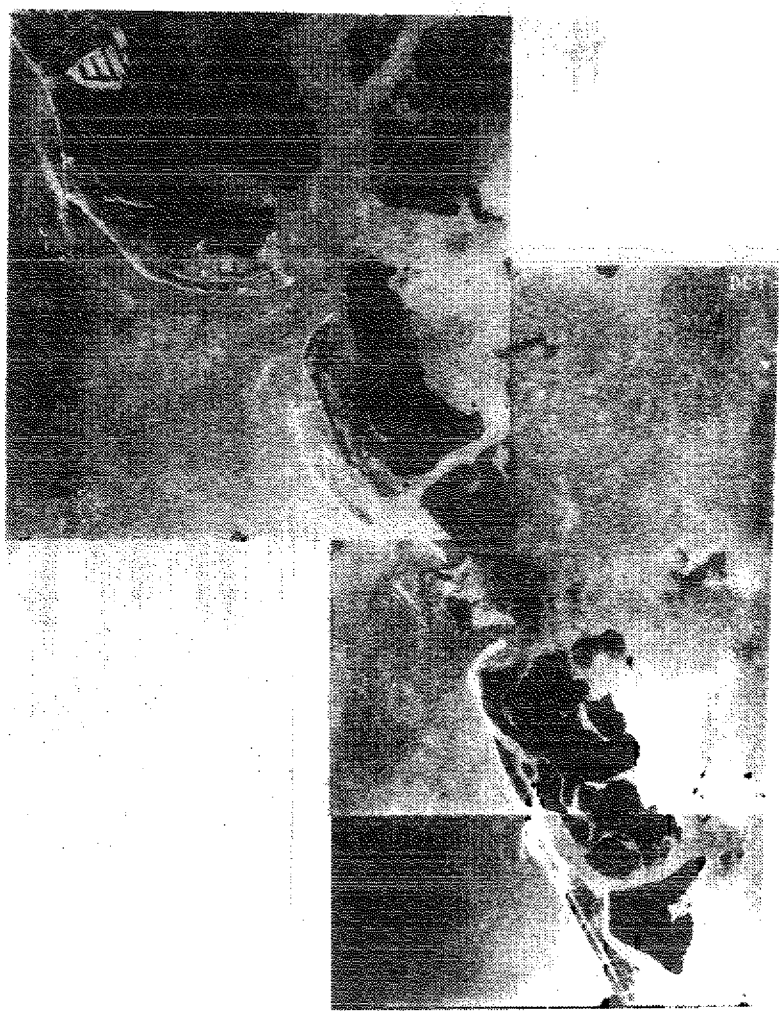

Fig. 5.6 Estero Bay and Vicinity, March 15, 1958

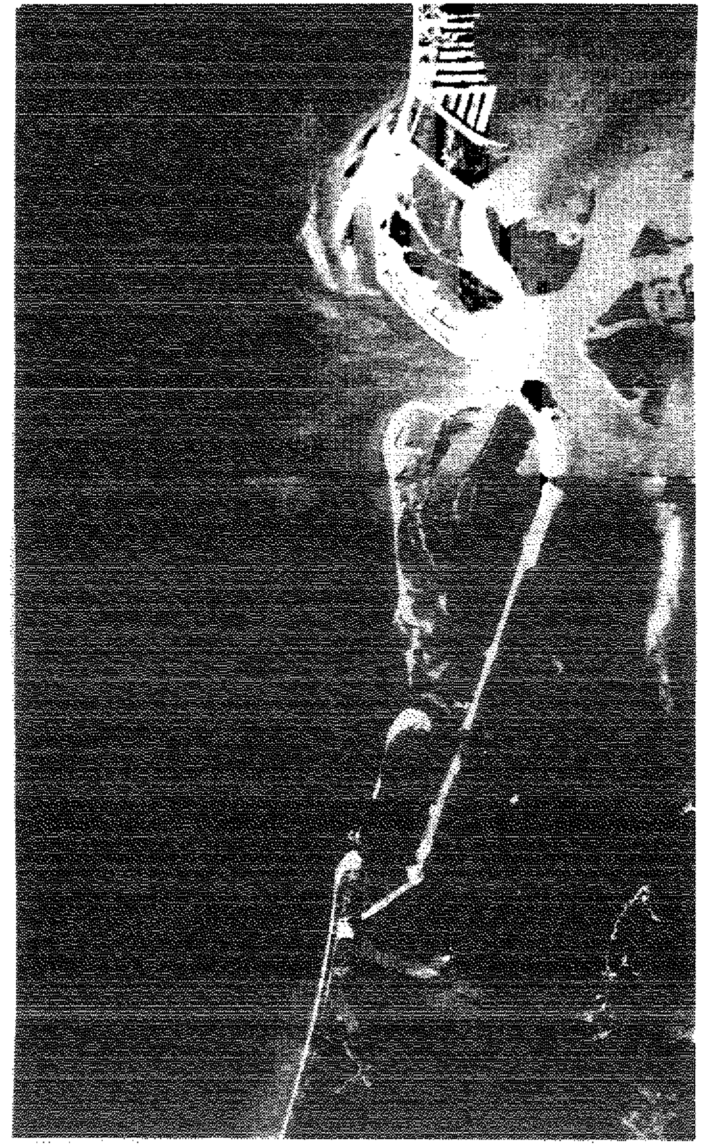

Fig. 5.7 Estero Bay and Vicinity, November 20, 1965

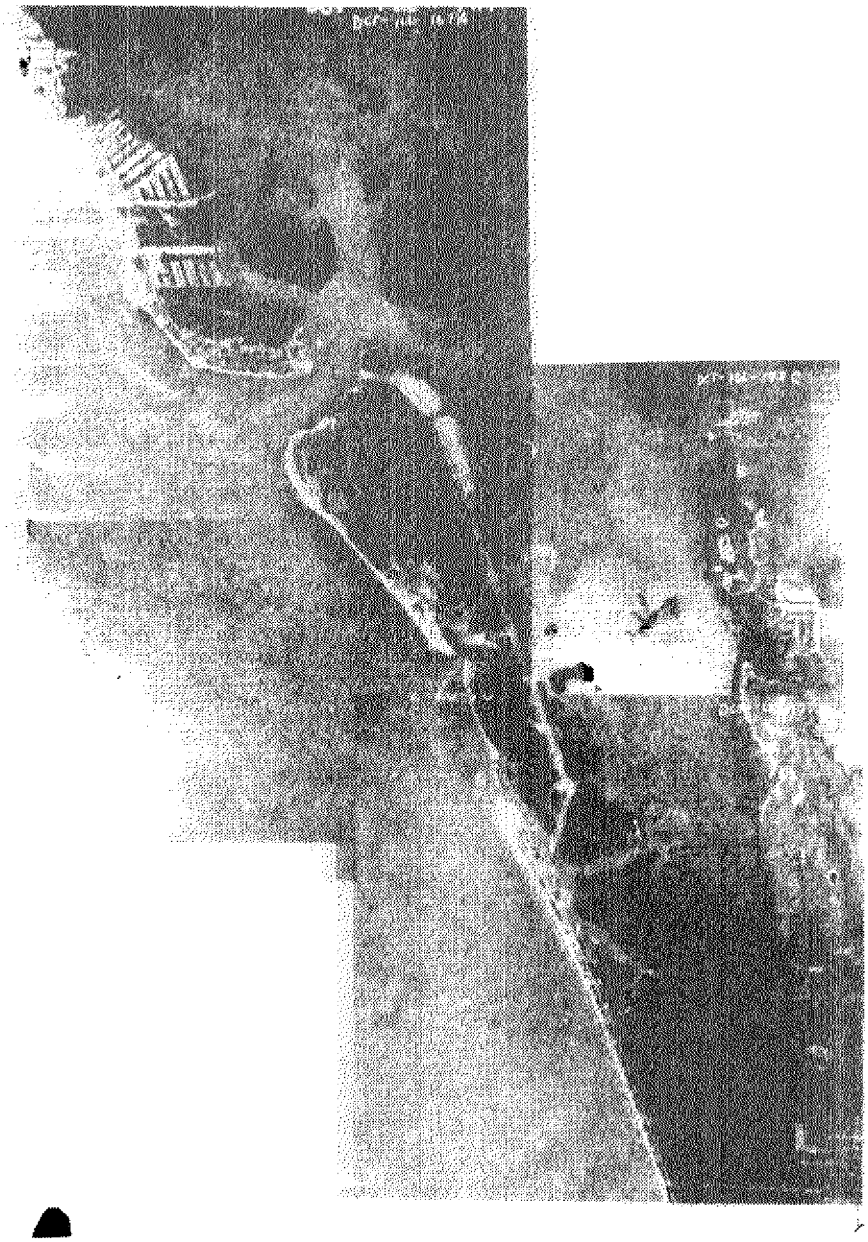

Fig. 5.8 Estero Bay and Vicinity, February 20, 1970

island extending from Big Hickory Pass north to Little Carlos Pass (now closed, but formerly about 6,000 ft. north of the present-day New Pass). Between 1885 and 1927 (Fig. 5.2), Big Hickory Island eroded at both the north and south ends, with Little Carlos Pass migrating southward approximately 3,000 ft. and Big Hickory Pass migrating northward approximately 1,300 ft.

Between 1926 and 1944 (Fig. 5.4), the north end of Big Hickory Island continued to move south while Big Hickory Pass continued to migrate to the north. It was during this time that another island emerged to the west of Long Key (COEL, 1971).

During the ten year period between 1944 and 1953, 6 hurricanes passed within 100 miles of the area, and caused significant changes. As seen in Fig. 5.5, the northern 2,800 ft. of Big Hickory Island eroded and the southern end moved eastward, attaching itself to what is known today as Big Hickory Island. With the erosion of the north end of Big Hickory Island, New Pass became the dominant inlet serving the central portion of Estero Bay. Big Hickory Pass continued its northward movement and migrated approximately 500 ft. during this period.

Between 1953 and 1958 (Fig. 5.6), the location of Big Hickory Pass remained nearly unchanged, although the inlet's main channel shifted from a southerly orientation to a more westerly one. During this period a spit grew northward from the tip of Big Hickory Island across the south side of New Pass, and the emergence and growth of the island west of Lovers Key (termed "Lovers Key 2" in the 1974 COEL study) continued.

The most important changes in the configuration of the islands between 1958 and 1965 (Fig. 5.7) were the result of the construction of State Road 865 between Estero Island and Little Hickory Island. The causeway closed several tidal channels between Black Island and Little Hickory Island (Fig. 4.2) and with these closures the islands west of Long Key emerged and attached themselves to Lovers Key. Big Hickory Pass continued to migrate northward during this period, and the spit across the south side of New Pass continued to grow.

Big Hickory Pass developed a pronounced updrift offset (build-up on the south side of the pass) during the late 1960's as the shoreline of Big Hickory Island retreated eastward and as the shoreline of Little Hickory Island advanced westward south of the inlet. By 1970 the tip of Little Hickory Island began to overlap the southern tip of Big Hickory Island (Fig. 5.8). It was after this overlap developed that the rate of migration of Big Hickory Pass accelerated and the shoaling in the pass entrance increased.

Since 1970 several important changes have taken place. The spit that was growing across New Pass was breached and disappeared, leaving a shallow, wide sand flat across the southern side of the inlet. The spit, however, has started to grow once again now that Big Hickory Pass is closed. Details of the first closure of Big Hickory Pass (September 1976), its reopening (November 1976) and its closure in January 1979 are described below. Figures 5.9 through 5.14 show the changes in the inlet between November 27, 1976 and June 17, 1978.

After Big Hickory Pass closed in 1976, the area behind the pass was designated a "Class B" emergency area because of complaints of deteriorating water quality. Lee County personnel reopened the pass with a dragline, spoiling material on the

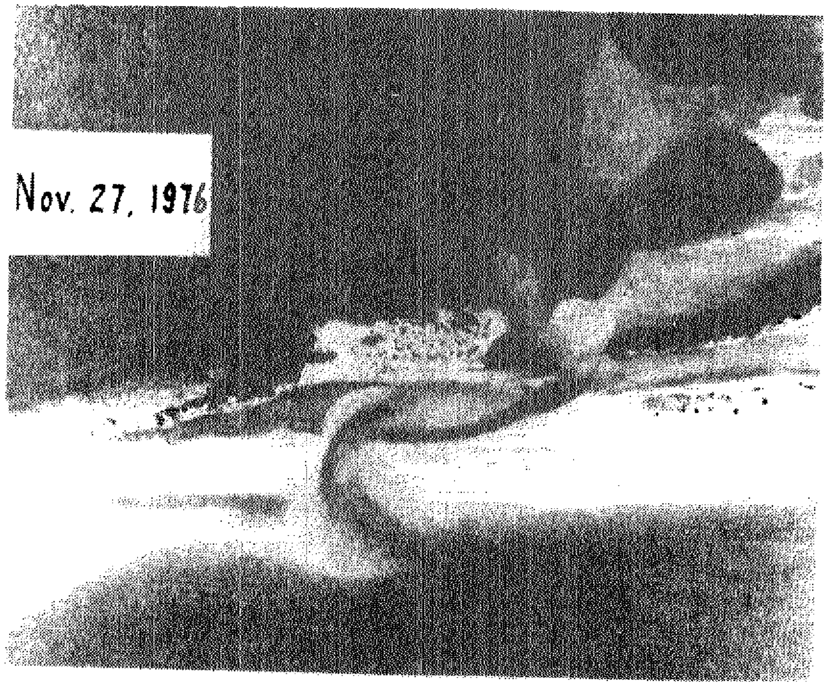

Fig. 5.9 Big Hickory Pass, November 27, 1976

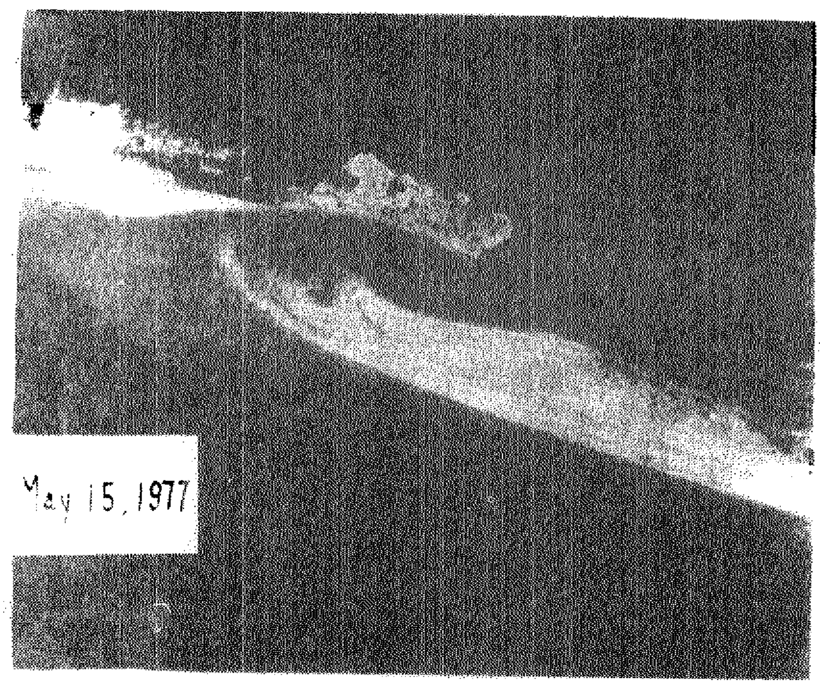

Fig. 5.10 Big Hickory Pass, May 15, 1977

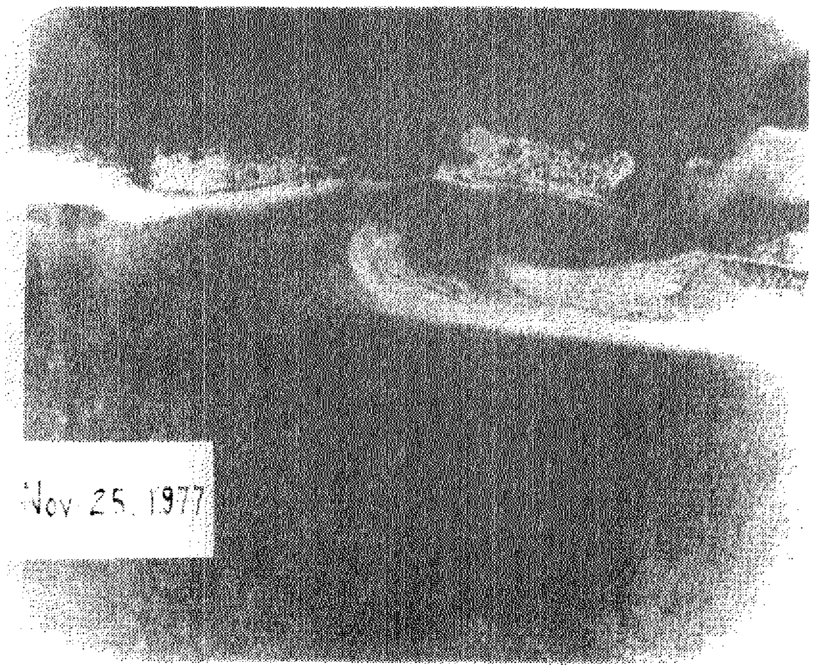

Fig. 5.11 Big Hickory Pass, November 25, 1977

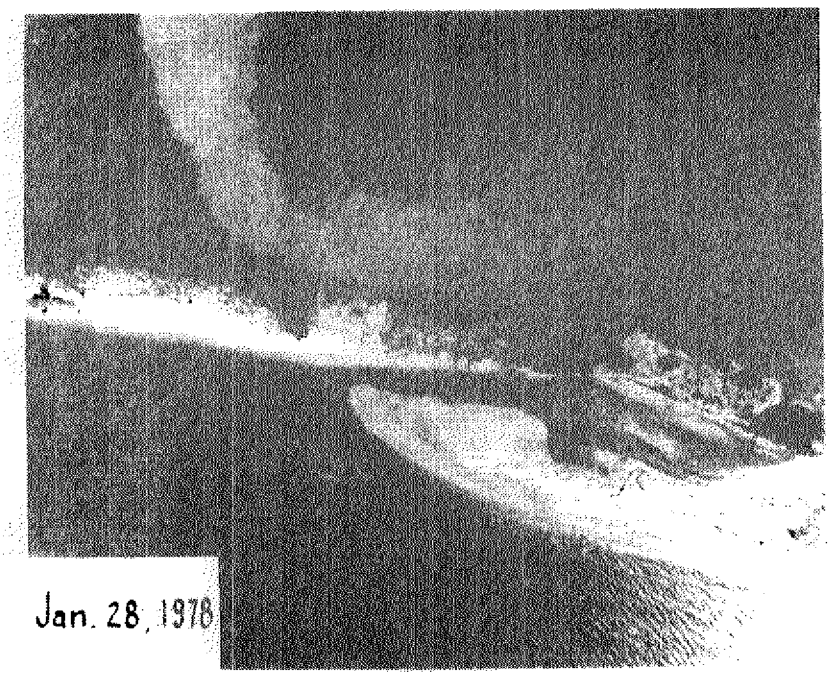

Fig. 5.12 Big Hickory Pass, January 28, 1978

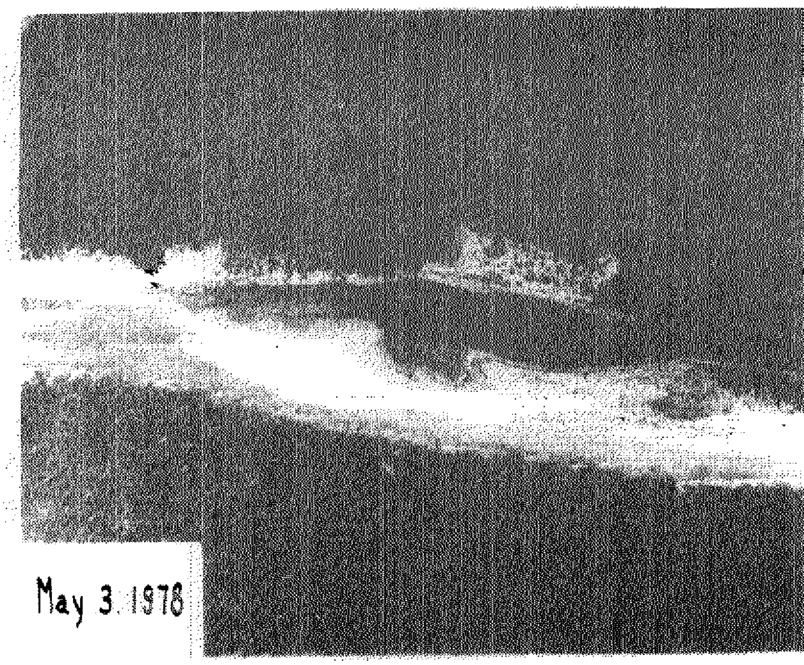

Fig. 5.13 Big Hickory Pass, May 3, 1978

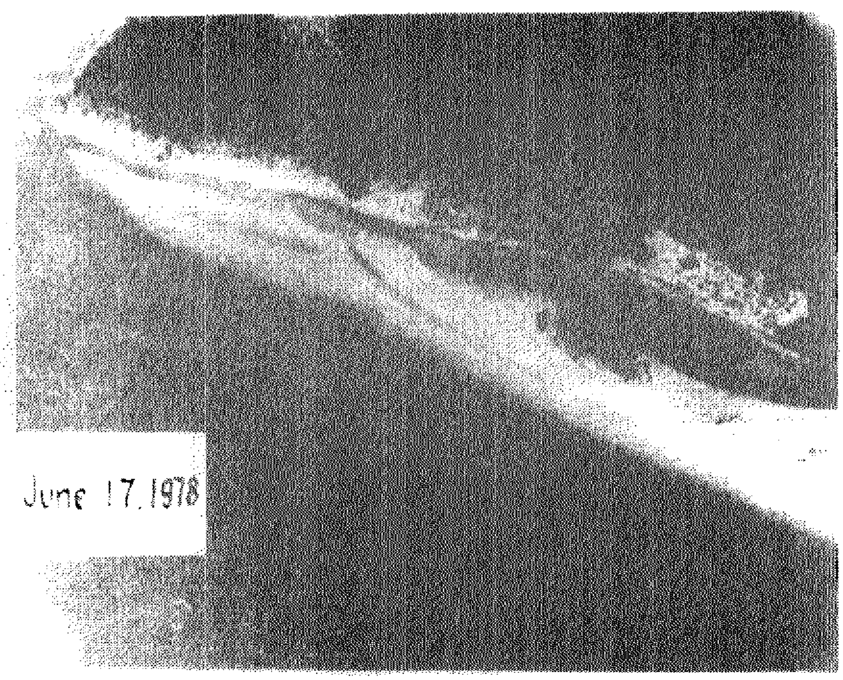

Fig. 5.14 Big Hickory Pass, June 17, 1978

south side of the reopened pass. Figure 5.9 was taken on November 27, 1976 (approximately three weeks after the reopening of the pass). At that time the inlet had a throat cross-sectional area of approximately 600 ft.^{2} (below MWL). The migration of the inlet continued once the inlet was open again (Figs. 5.10 through 5.14) and the development of a linear, subaerial bar north of the spit can be seen on the aerial photographs. The bar gradually emerged as the spit grew northward until the pass was completely closed again in January 1979 (Fig. 1.4). The location where the pass closed is about 1,000 ft. north of the point at which it closed in 1976.

5.3 Changes in the Tidal Cross-Sections

Figure 5.15 shows the cross-sections of Big Carlos Pass, New Pass and Big Hickory Pass as measured near the causeway bridges in 1978 and prior to their construction in 1960. Table 5-1 includes cross-sectional areas, widths and mean depths. Note that while the cross-sections measured at New Pass and Big Carlos Pass can be considered throat cross-sections, the cross-sections measured at Big Hickory Pass cannot; the throat section of Big Hickory Pass was near the pass opening rather than near the bridge.

It is apparent that the cross-sectional area of New Pass increased significantly between 1960 and 1978, as did the average and maximum depths. Big Carlos Pass, on the other hand, remained approximately the same in area but widened approximately 150 ft. The change in width took place during a southwest storm while the bridge over the pass was under construction, and necessitated a redesign and addition of three bents at the western end of the bridge (personal communication, J. M. Peterson, Florida Department of Transportation). The cross-section at Big Hickory Pass increased significantly between 1960 and 1978 and was probably due to the result of increased volume of flow through the inlet shortly after the causeway was constructed.

Table 5-1

CROSS-SECTIONAL AREA NEAR CAUSEWAY BRIDGES (Ft.^{2})

Location	1960	1978
Big Hickory Pass	2,060	3,040
New Pass	5,020	7,300
Big Carlos Pass	20,540	20,810

Table 5-2 shows estimated cross-sectional data for the Big Hickory Pass throat section between 1944 and 1978. The data from 1944 to 1970 were estimated by measuring the narrowest widths of the inlet on aerial photographs and then using a width-area relationship by Mehta (1976) and adjusting it to conform to actual field data. The data from 1976 and 1978 were taken from surveys of the inlet.

Table 5-2

BIG HICKORY PASS - CROSS-SECTIONAL DATA
(all measurements at MWL)

Year	W(ft.)	R(ft.)	A_c (ft.)
Apr. 1944[a]	350	6.6	2,300
Jan. 1953[a]	300	6.3	1,900
Mar. 1958[a]	290	6.2	1,800
Nov. 1965[a]	340	6.5	2,200
Feb. 1970[a]	210	5.6	1,200
Nov. 1976[b,c]	125	4.7	600
June 1978[b]	25	1.2	30

a - estimated from aerial photographs

b - taken from field surveys

c - after pass reopening

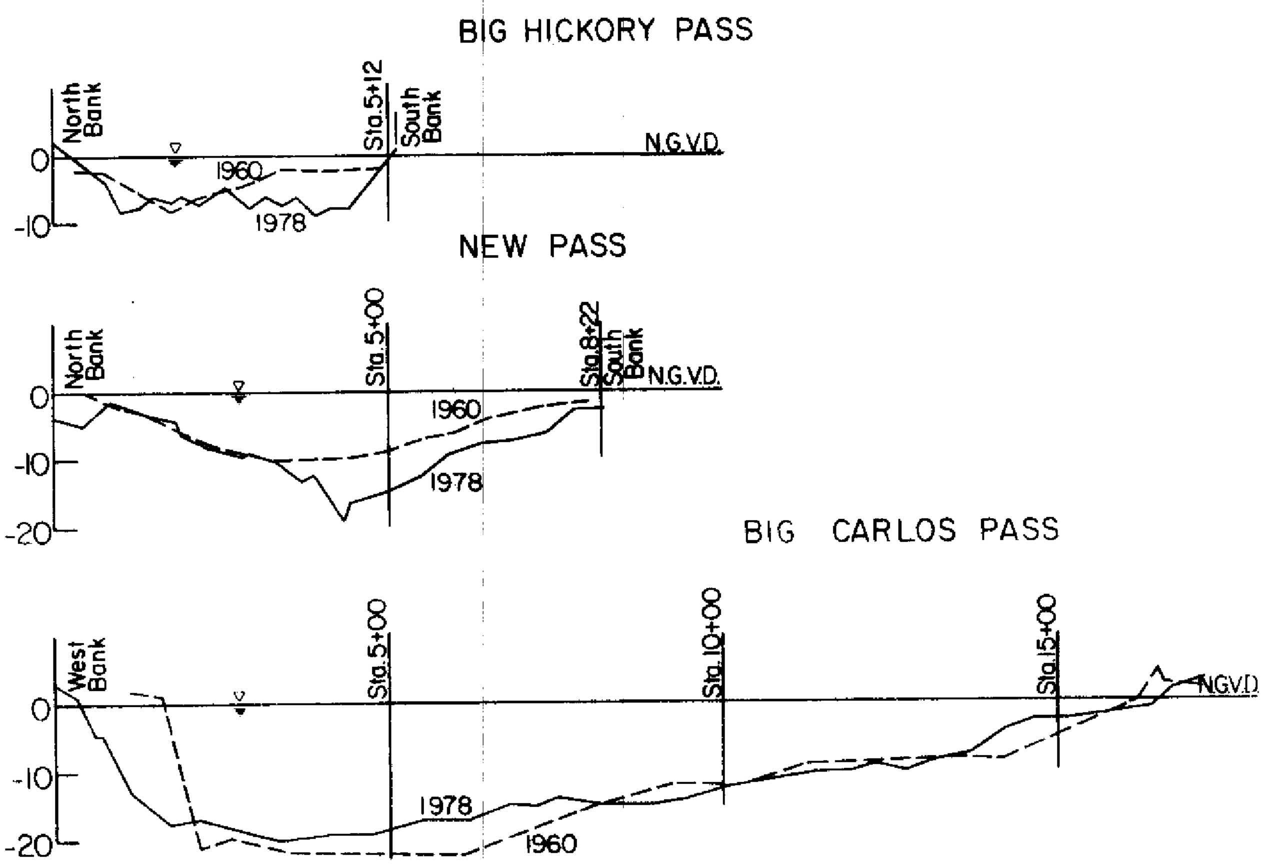

Fig. 5.15 Comparison of Cross-Sections of Big Hickory Pass, New Pass, and Big Carlos Pass. Measured Near Causeway Vicinity in 1960 and 1978 (Suboceanic Consultants, Inc., 1978)

VI. HYDRAULICS

6.1 Freshwater Discharge, Salinity and Water Quality

Although there are several small rivers and creeks discharging into Estero Bay, data exist only for the Imperial River, entering the southern portion of Estero Bay. The discharge data, recorded on the Imperial River east of Bonita Springs between 1940 and 1954, indicated that the average yearly discharge at that point was 89.9 cfs, with the maximum average yearly discharge occurring in 1947 (224 cfs) and the minimum average yearly discharge occurring in 1950 (31.1 cfs) (U.S. Department of the Interior, 1950, 1955). The data also show that there are seasonal variations in the discharge which correspond to local rainfall totals.

The average discharge of the Imperial River during the hydraulic measurements of February 1978 was estimated on the basis of historical discharge and rainfall data, and the rainfall data during the measurements. The discharge was estimated to be approximately 17.4 cfs at that time. However, the location of the discharge estimate on the Imperial River would indicate that the discharge farther downstream near the entrance to Estero Bay would be several times larger. Nevertheless, the discharge into Estero Bay is small compared to the tidal flow through the inlets. As seen in Table 6-1, the effect of freshwater discharge into southern Estero Bay is felt only near the Imperial River, where salinities are somewhat lower.

The locations of water quality measurements made by the Lee County Environmental Laboratory are shown in Fig. 6.1; some of the results are indicated in Table 6-1. The water quality study, performed as part of the hydrographic study of Big Hickory Pass during 1978, showed that despite the restricted flow through Big Hickory Pass, the water quality behind the pass and in Estero Bay was not depressed. The study concluded that a complete closure of Big Hickory Pass would only affect the areas immediately adjacent to the pass, and would not appreciably affect southern Estero Bay. There have been no recent water quality measurements made in the area since Big Hickory Pass closed again in January 1979.

6.2 Tides

The National Ocean Survey (NOS) maintains a tide gage at the Naples Municipal Pier, and has maintained gages at several other locations throughout the study area in the past. The tidal ranges from the NOS Tide Tables are included in Table 6.2; the locations of the NOS tide stations are shown in Fig. 6.2. These stations correspond to the station numbers indicated in Table 6.2.

The tides in the area are of the mixed type, and as seen from Table 6-2, the bay tidal range (obtained by averaging the last three stations) is approximately 0.94 times the open coast range (Naples). Figure 6.2 also shows the locations of the tide observations made during the Suboceanic Consultants hydrographic study of the area in February 1978. Figure 6.3 shows the tide data obtained at those locations on February 8. The data at Stations 2 and 4 (Naples Pier and Little Hickory Island) were obtained from tide gage records; the data at Stations 1, 3, 5, 6, 7 and 8 were obtained from observations at tide staffs at approximately 15-minute intervals at each location. The average bay tide range during ebb on February 8, 1978 was 1.77 ft. (averaging stations 3, 4, 5 and 6), while the Gulf range (Station 1) was 1.87 ft. Note that the tide curve outside at Big

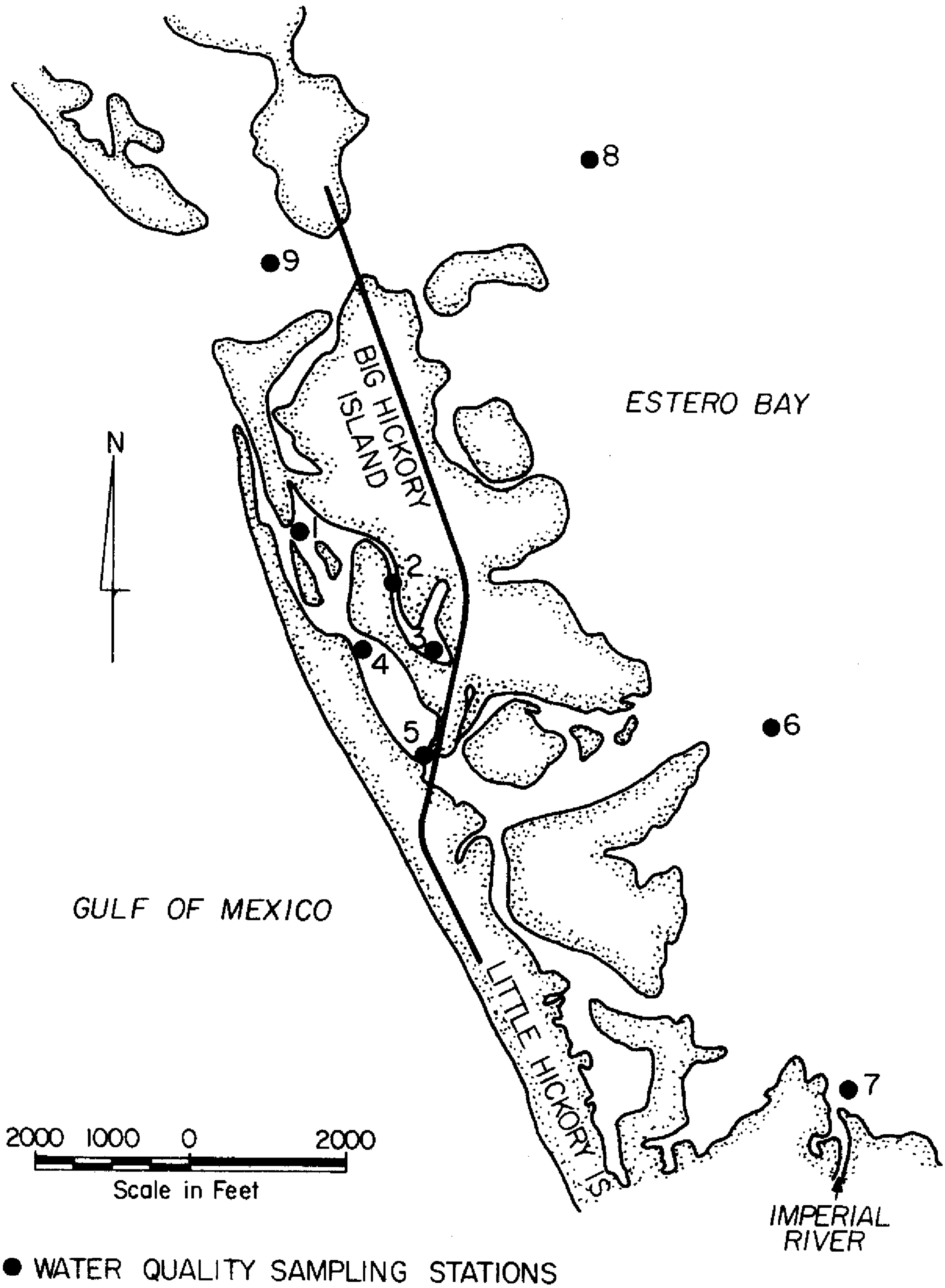

Fig. 6.1 Location of Water Quality Sampling Stations During 1978 Hydrographic Study of Big Hickory Pass (Suboceanic Consultants, Inc., 1978).

Table 6-1

WATER QUALITY IN ESTERO BAY

Sta.	Depth (ft)	Temp (°C)	Salinity (%)	D.O (mg/ℓ)
		Feb. 8, 1978 - low water		
4	1½	12	30.5	7.0
5	1½	12	29.0	7.8
6	5	13	31.5	7.2
7	2	13	20.0	8.1
8	2	13	32.9	8.1
9	8½	12	30.2	8.1
		Feb. 8, 1978 - high water		
4	3	14	32.5	8.4
5	2	14	33.5	8.1
6	8	14	33.8	8.4
7	4½	14	30.0	8.6
8	3	14	33.9	8.1
9	14	14	33.8	8.0
		May 24, 1978 - low water		
1	2	28	34.0	5.9
2	4½	28	-	5.4
3	2	28	33.0	4.4
4	3½	28	32.0	6.8
		May 24, 1978 - high water		
1	4	30	32.0	7.2
2	6	30	33.0	7.5
3	3	30	33.5	7.1
4	4½	30	32.5	7.6

Table 6-2

RANGE FROM NOS TIDE TABLES

Station	Station Number	Mean Range (ft.)	Diurnal Range (ft.)
Naples	2	2.1	2.8
Little Hickory Island	4	-	2.5
Coconut	7	-	2.7
Carlos Point	3	-	2.7

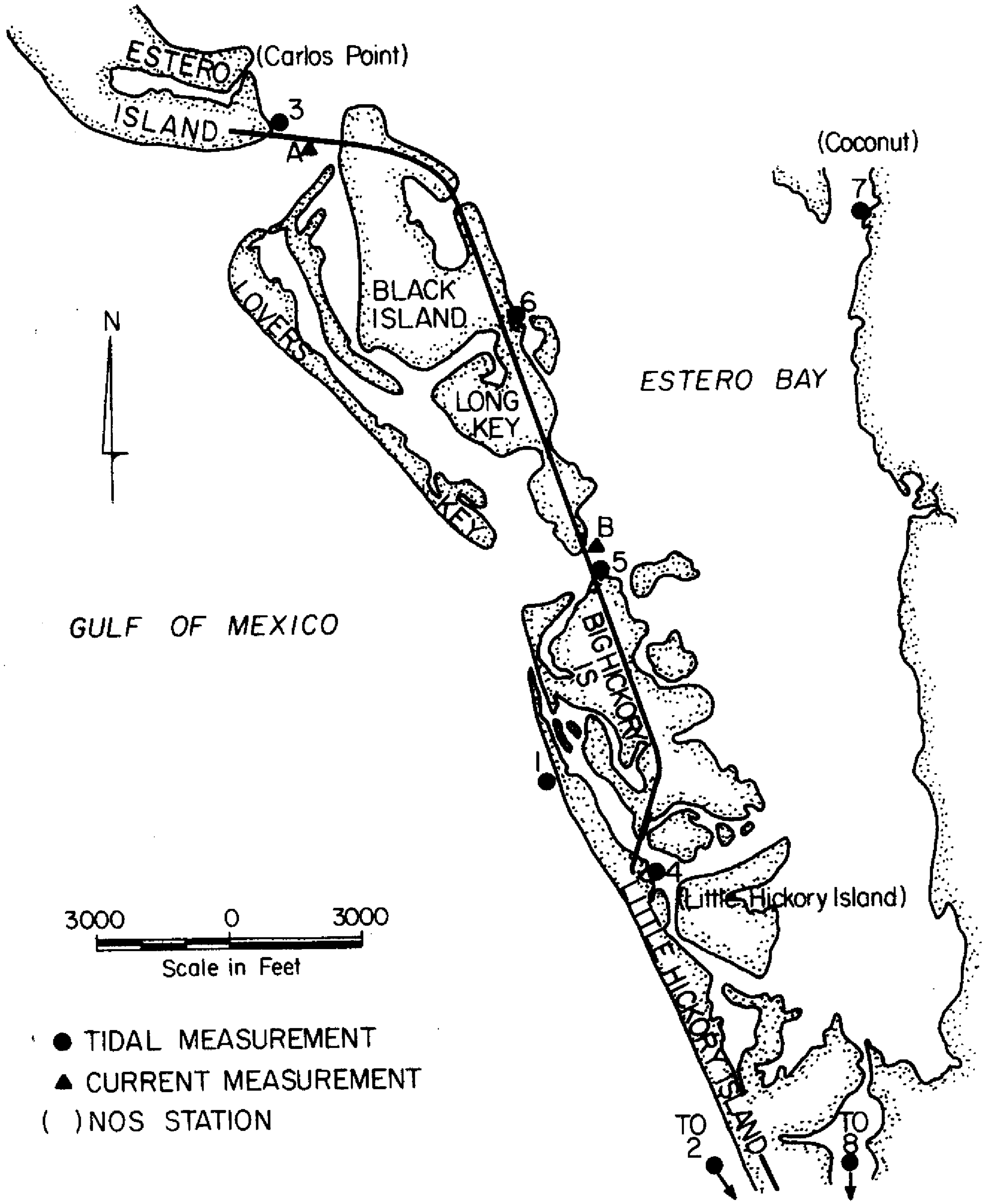

Fig. 6.2 Location of Tide Gages and Current Measurements During 1978 Hydrographic Study of Big Hickory Pass (Suboceanic Consultants, Inc., 1978)

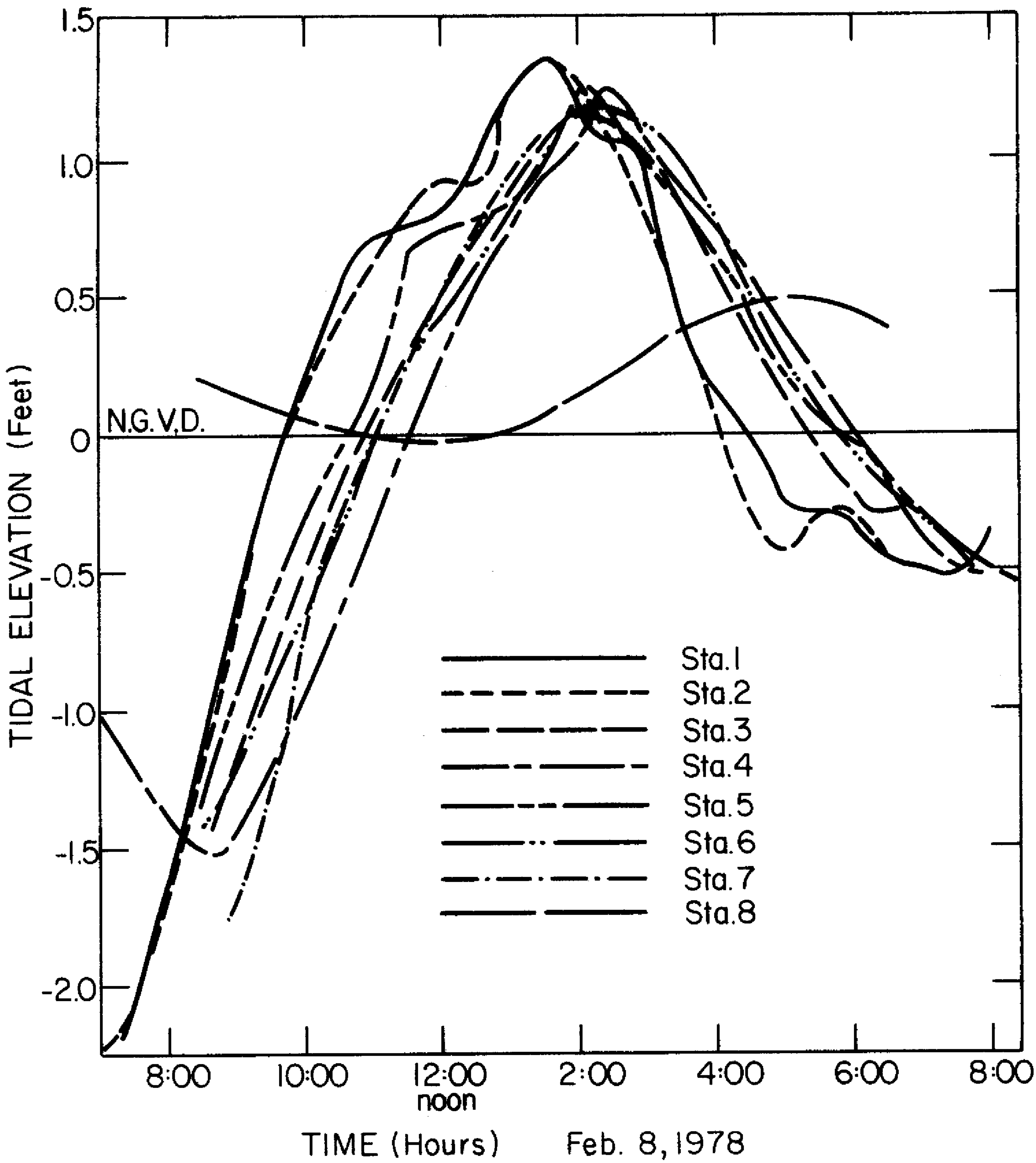

Fig. 6.3 Comparative Tide Data Obtained from Tide Gages (Suboceanic Consultants, Inc., 1978)

Hickory Pass (Station 1) was very similar to that at Naples (Station 2), and that the ratio of the bay range to the Gulf range of 0.95 was in good agreement with that obtained from the Tide Tables data.

6.3 Currents

Velocity measurements were made at Big Carlos Pass and New Pass on February 8, 1978 using self-recording current meters, and the data obtained were used in the one-point discharge model developed by Mehta et al. (1977) to calculate the cross-sectional average current velocities and discharges. The velocity curves are indicated in Fig. 6.4 and show the following:

Table 6-3

MAXIMUM CROSS-SECTIONAL AVERAGE VELOCITIES; FEBRUARY 8, 1978

Location	Maximum Cross-Sectional Average Velocity	
	Flood (fps)	Ebb (fps)
New Pass	2.57	2.12
Big Carlos Pass	2.46	2.66

At that time, as well as others, velocities through Big Hickory Pass were observed to be 3 to 5 fps.

6.4 Hydraulic Parameters

a. Tidal Prism

The flood tidal prism is defined as the volume of water entering an inlet during flood flow while the ebb tidal prism is the volume of water exiting an inlet during ebb. However, the flood and ebb prisms are not always the same. Such is the case with the inlets leading into Estero Bay. Table 6-4 shows the tidal prisms for the inlets leading into Estero Bay on February 8, 1978. The values for New Pass and Big Carlos Pass were obtained by integrating the discharge curves in Fig. 6.4, while the prism at Big Hickory Pass was estimated knowing the tide range and area of influence of the inlet on that day.

Table 6-4

TIDAL PRISMS - FEBRUARY 8, 1978

Inlet	Tidal Prism (ft^3)	
	Flood*	Ebb**
Big Hickory Pass	1.20×10^6	-
New Pass	2.71×10^8	2.02×10^8
Big Carlos Pass	8.19×10^8	5.75×10^8

*Flood tidal range: 3.53 ft. **Ebb tidal range: 1.87 ft

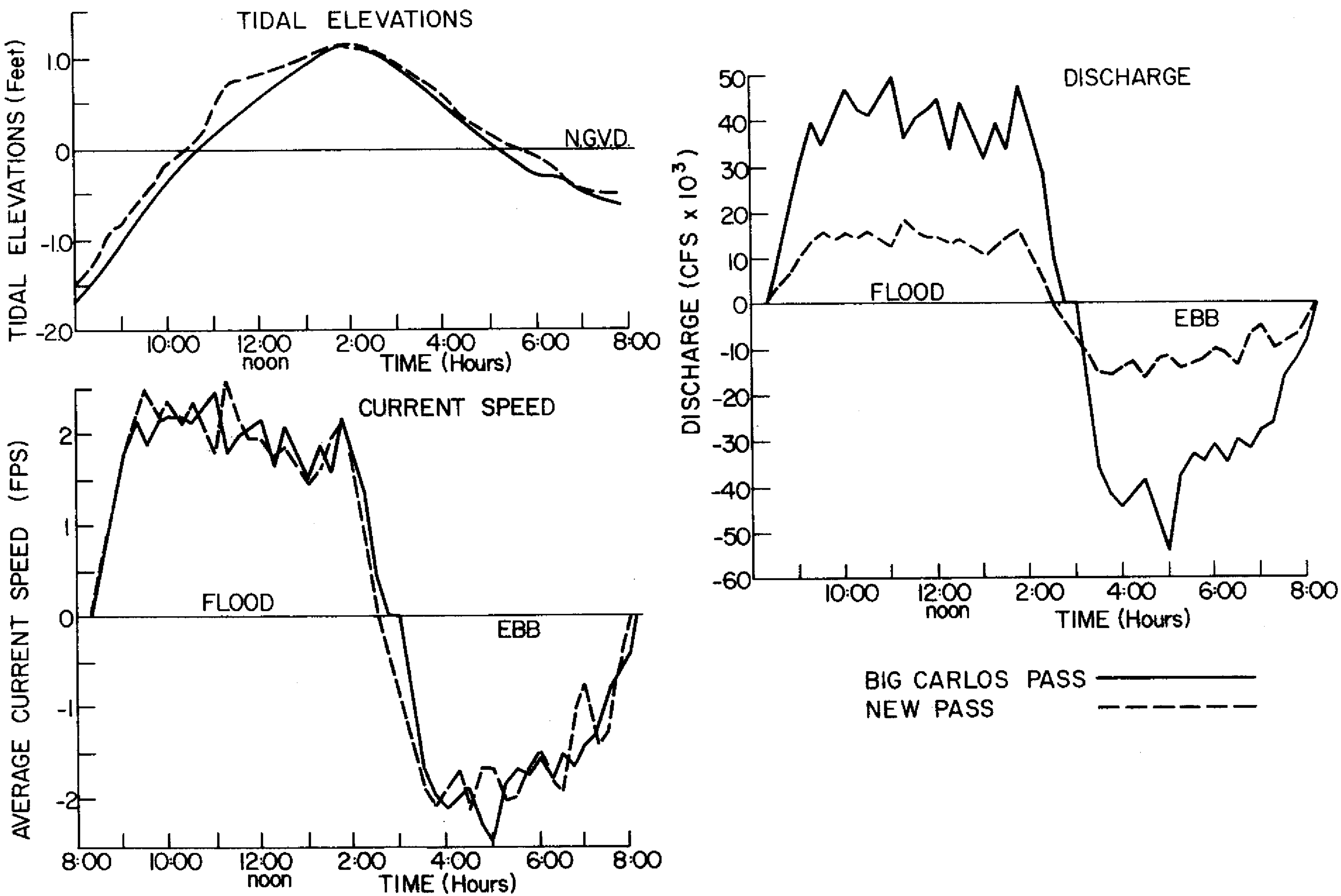

Fig. 6.4 Tidal Elevations, Current Speed, and Discharge of Big Carlos Pass and New Pass Obtained from Computer Model (Suboceanic Consultants, Inc. 1978)

b. Lag of Slack Water

It is observed from Fig. 6.3 that the average time lag of slack water after high water in the Gulf was approximately 40 minutes on Feb. 8, 1978. The lag at Station 4 (inside Big Hickory Pass) was approximately one hour on that date.

c. Bay Area

The approximate bay area (area of influence) of Big Carlos Pass, New Pass and Big Hickory Pass is obtained by dividing the sum of the individual tidal prisms by the average bay tidal range, i.e.:

$$1.0912 \times 10^9 \text{ ft}^3 / 3.32 \text{ ft} = 3.29 \times 10^8 \text{ ft}^2$$

The following hydraulic parameters have thus been obtained from the Feb. 8, 1978 data:

Ratio of average bay to Gulf tidal range = 0.94

Max. cross-sectional average velocity - Big Carlos Pass, flood = 2.46 ft/sec

Max. cross-sectional average velocity - Big Carlos Pass, ebb = 2.66 ft/sec

Max. cross-sectional average velocity - New Pass, flood = 2.57 ft/sec

Max. cross-sectional average velocity - New Pass, ebb = 2.12 ft/sec

Tidal prism - Big Carlos Pass (3.53 ft. tide range) = 8.19×10^8 ft^3

Tidal prism - New Pass (3.53 ft. tide range) = 2.71×10^8 ft^3

Bay area = 3.29×10^8 ft^3

Tidal period = 12.25 hours

Inlet throat cross-sectional area (below mwl) - Big Carlos Pass = 20,810 ft^2

Inlet throat cross-sectional area (below mwl) - New Pass = 7,300 ft^2

Inlet throat width - Big Carlos Pass = 1,620 ft

Inlet throat hydraulic radius (mean depth) - Big Carlos Pass = 12.85 ft

Inlet throat width - New Pass = 822 ft

Inlet throat hydraulic radius (mean depth) - New Pass = 8.88 ft

6.5 Wave Climate

The U.S. Army Coastal Engineering Research Center (CERC) operated a wave gage at the Naples Muncipal Pier between 1957 and 1975 (Thompson, 1977). Table 6-5 summarizes the wave characteristics derived from the step-resistance and continuous wire wave gages used by CERC. The significant wave height is the average of the highest one-third of the wave heights measured.

Table 6-5

WAVE CHARACTERISTICS FROM THE CERC WAVE GAGES AT NAPLES

Wave Characteristics	Mar. 1964-Apr. 1967 (5837 observations)	Dec. 1968-Dec. 1974 (2579 observations)
Ave. Significant Wave height (ft)	0.83	1.16
Variance (ft^2)	0.32	0.54
Standard Deviation (ft)	0.56	0.74
Ave. Wave Period* (sec)	4.23	4.71
Variance (sec^2)	2.58	4.49
Standard Deviation* (sec)	1.61	2.12

*omitting calms

Figure 6.5 and 6.6 show the offshore wave height and wave period roses, as constructed by Walton (1973) from the SSMO (Summary of Synoptic Meteorological Observations) published by the U.S. Naval Weather Service Command. Figure 6.7 shows a comparison of the offshore SSMO data, the CERC wave gage data and the SSMO data after being extrapolated to the coastline (Walton, 1973).

6.6 Inlet Stability

The long-term stability of a tidal inlet can be determined from a study of the inlet's past history, paying particular attention to changes in the size of the inlet, the flow through the inlet and the littoral drift in the vicinity of the inlet. The latter two can be thought of as opposing one another, with the littoral drift tending to restrict the size of the inlet as material is deposited there, and with the flow through the inlet tending to scour the material from its channels. Whenever the rate at which material is deposited inside an inlet exceeds the inlet's ability to remove it, the inlet will shoal; if this imbalance continues for a long period of time the inlet will close.

In looking at the multiple inlet system of Estero Bay, there were several factors which led to the closure of Big Hickory Pass. As the inlet migrated northward it became less efficient hydraulically. More importantly, a series of storms and the construction of the causeway enhanced the efficiency and stability of New Pass. Thus, as Big Hickory Pass grew ever more restricted, New Pass enlarged to preserve the total flow into the bay (during this time Big Carlos Pass has remained stable and essentially unchanged). As a result, the reopening of Big Hickory Pass in 1976 was short-lived. Unless the size and efficiency of New Pass are reduced while Big Hickory Pass is reopened, the latter will close again.

It is interesting to note, however, that just as the enlargement of New Pass caused Big Hickory Pass to close, the same forces prolonged the existence of Big Hickory Pass. If Big Hickory Pass had been the only inlet leading into

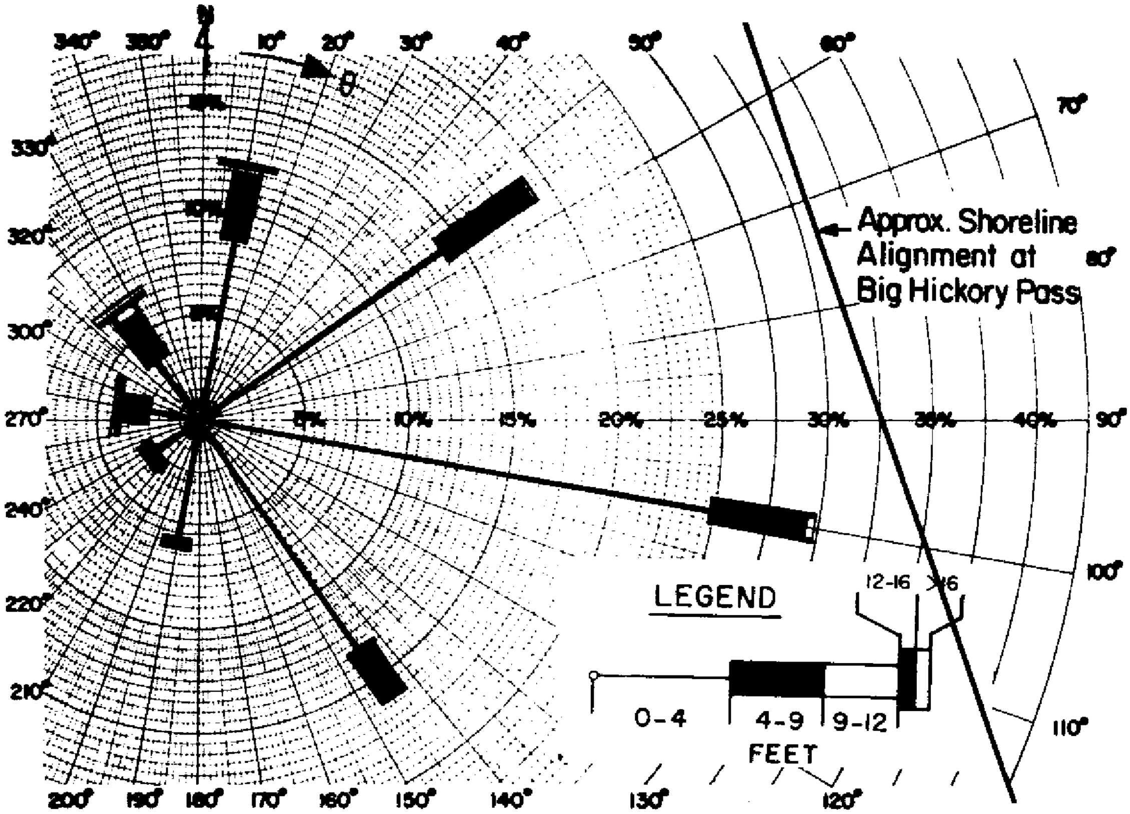

Fig. 6.5 Wave Height Rose for Offshore Wave Climate (Walton, 1973)

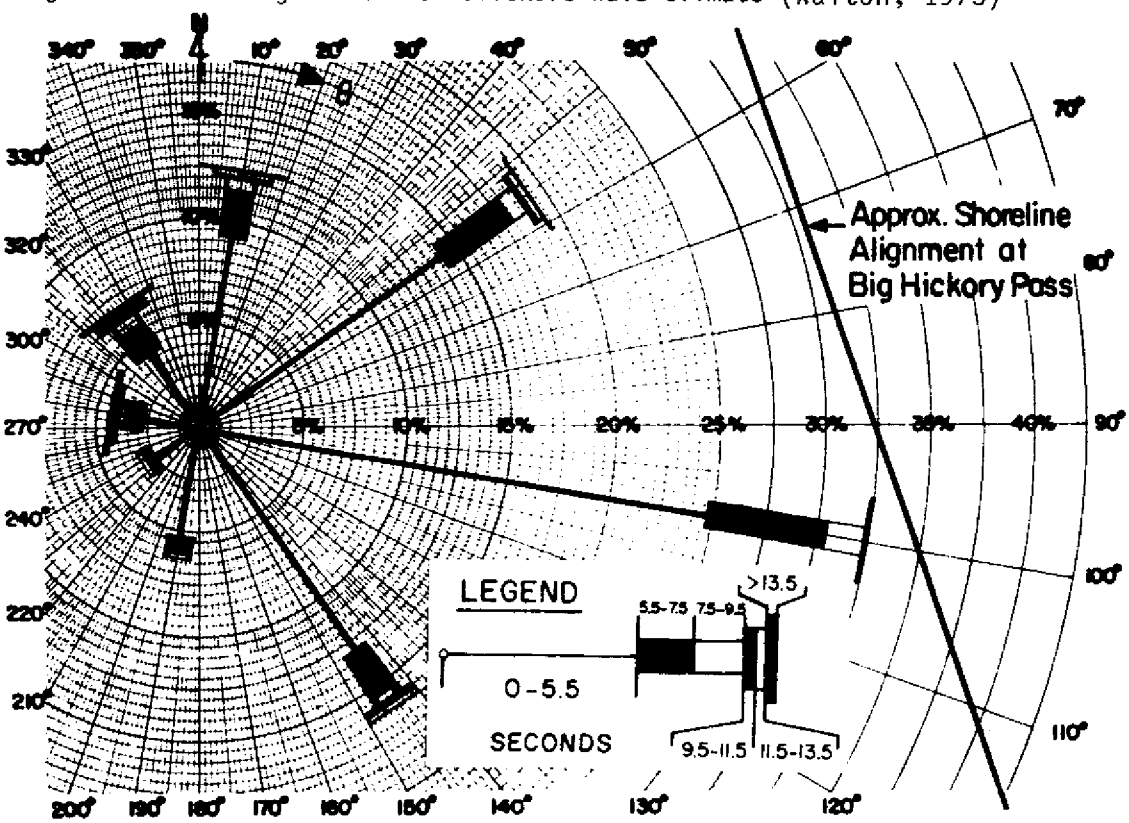

Fig. 6.6 Wave Period Rose for Offshore Wave Climate (Walton, 1973)

the bay, as the size of the inlet decreased, the velocities through the inlet, the tidal prism and, hence, the tidal range in the bay would have also decreased; the inlet would have closed long before it did. The presence of New Pass provided an alternate means of filling the bay, and as Big Hickory Pass decreased in size the tidal range in the bay did not decrease. As a result, the head difference across the pass did not decrease and high current velocities through Big Hickory Pass persisted until its closure. These velocities undoubtedly scoured material from the entrance of the pass, thereby prolonging its existence. Closure eventually resulted in January 1979, due to the slight imbalance of sedimentation forces and scouring forces, the sedimentation process being of greater magnitude than the scouring process.

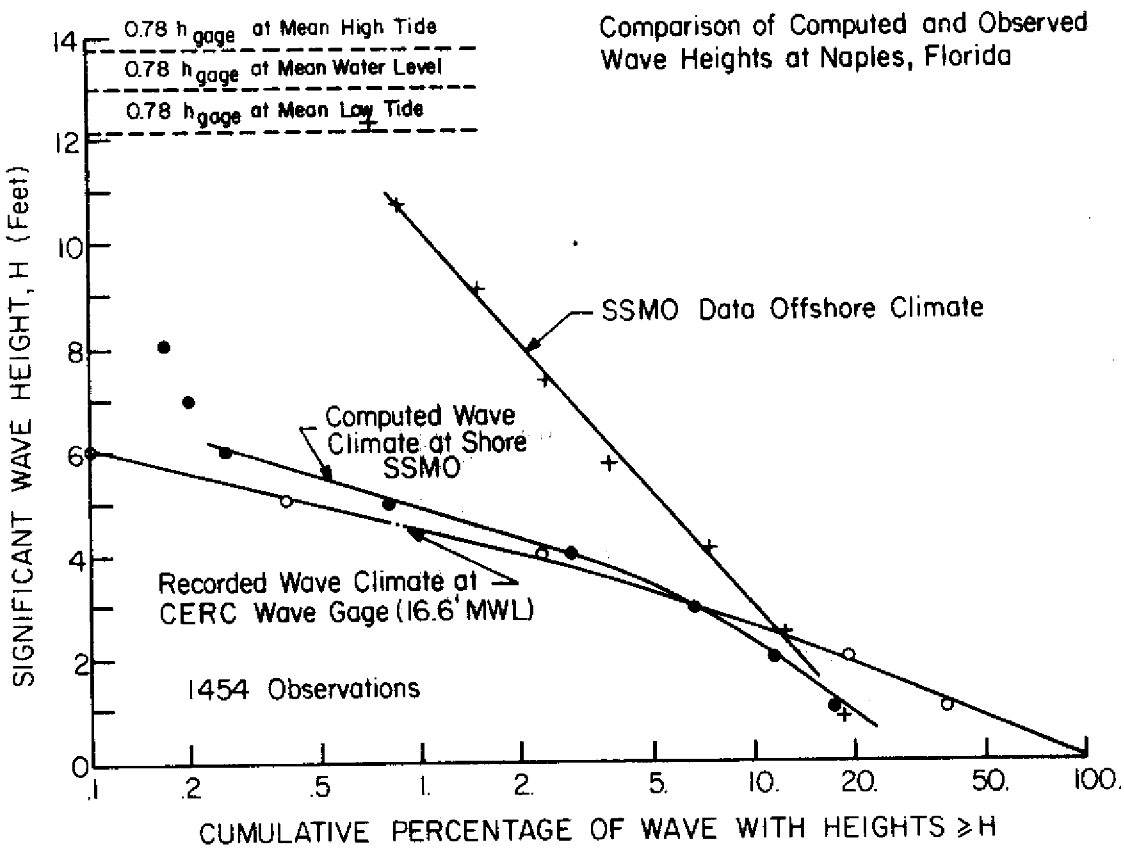

Fig. 6.7 Comparison of Computed and Observed Wave Heights at Naples, Florida

VII. SEDIMENTARY PROCESSES

7.1 Volumetric Changes

Sufficient survey data are not available to compute volumetric erosion and accretion rates in the area between Big Carlos Pass and Big Hickory Pass. However, such data do exist for Estero Island which is immediately north of Big Carlos Pass.

The Corps of Engineers (1969) estimated the average annual volumetric erosion over the length of Estero Island to be 138,000 cu. yds., between 1878-79 and 1967. This means that, on the average, each foot of beach along the 7-mile long island lost approximately 3.7 cu. yds. of material per year. Accompanying this loss was a general steepening of the offshore profile. During the period 1956 to 1967 the average annual volumetric loss over the length of Estero Island was 1,005,000 cu. yds., over seven times the long-term average annual loss.

7.2 Bar Volumes

Walton and Dean (1976) estimated the volumes of sedimentary materials lying in the offshore bars at Big Carlos Pass and New Pass to be 5.19×10^6 cu. yds. (based upon 1960-61 survey), and 0.54×10^6 cu. yds. (based upon 1965 survey), respectively. The bar volume represents the additional material in the vicinity of the inlet that has accumulated nearshore above the normal profile away from the inlet.

7.3 Littoral Drift

The direction of the littoral drift in the area varies, depending upon the effects of wave refraction over the offshore bars at the inlets and the degree of sheltering of the northwesterly waves by Sanibel Island. The drift at Big Hickory Pass (south side of New Pass) is northerly, and probably between 30,000 and 60,000 cu. yds. per year (Suboceanic Consultants, Inc., 1978). The Corps of Engineers estimated the drift along northern Estero Island to be approximately 22,000 cu. yds. per year in a northerly direction, while the drift over the remainder of the island was in a southerly direction.

7.4 Sedimentary Characteristics

The Corps of Engineers (1969) collected surficial sediment samples at several points along beach profiles on Estero Island, as well as other barrier islands to the north during the Beach Erosion Control Study. Table 7-1 shows the results of the grain size analysis performed on the samples.

Table 7-1

MEDIAN GRAIN SIZE - ESTERO ISLAND

Location of Sample on Profile	D_{50} (mm)
Dune	0.14
High Water	0.15
Low Water	0.26
-3'	0.10
-6'	0.10
-12'	0.27

The Florida Department of Transportation made an extensive core boring analysis of the locations where the bridges were built on the causeway between Ft. Myers Beach and Bonita Beach. Figure 7.1 shows a diagram of the core boring results at the New Pass bridge site. The results are typical for the area: sand, shell and mud over thin layers of limestone and shell marl, with thick layers of silty clay beneath.

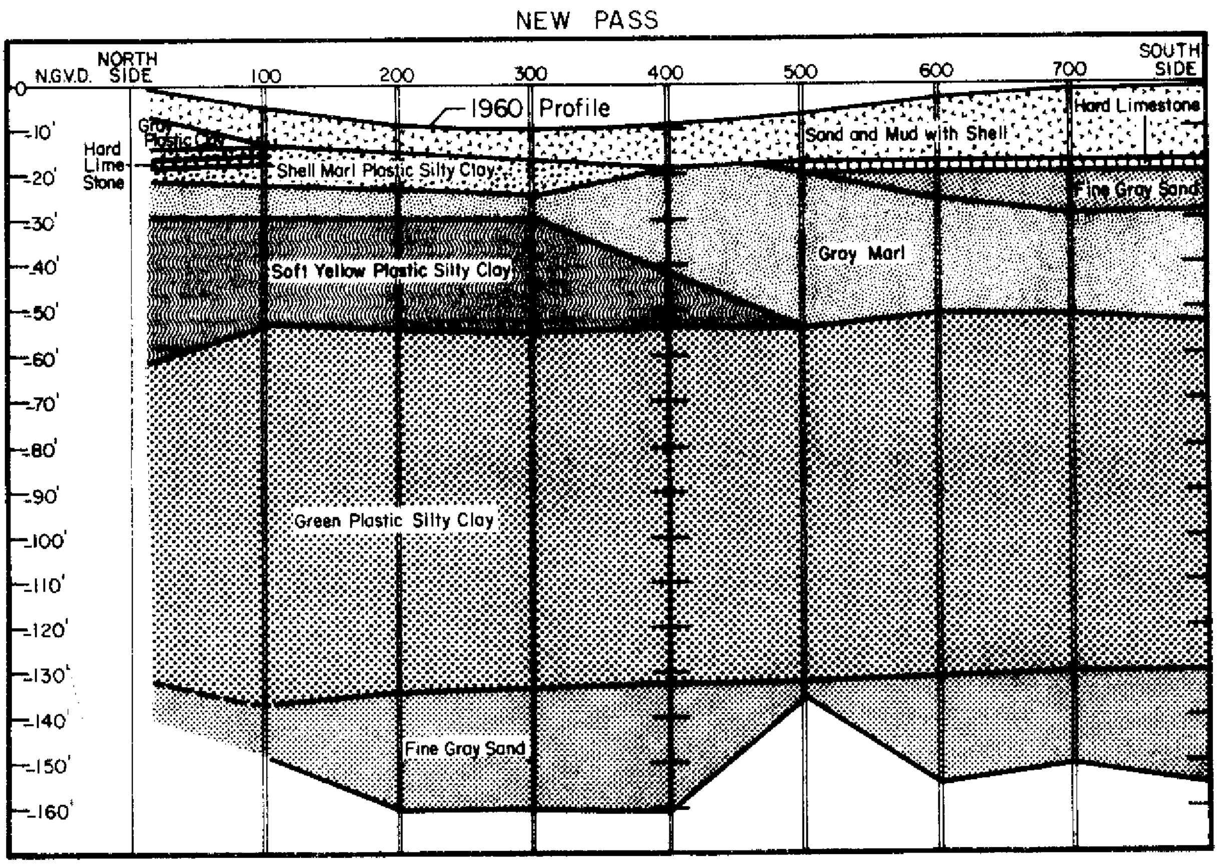

Fig. 7.1 Core Boring Results at New Pass Bridge Site

VIII. SUMMARY

Highlights of the information documented in this report are summarized below:

1. Big Carlos Pass, New Pass and Big Hickory Pass are natural inlets located between Fort Myers Beach and Bonita Beach in southern Lee County. Big Hickory Pass closed in 1976, was reopened, and closed again in January 1979. Big Carlos Pass and New Pass have remained open for at least the last 125 years.

2. The area is characterized by sandy, barrier islands backed by shallow bays, mangrove areas and a low elevation, low relief coastal plain - part of the Pamilco Terrace, formed approximately 240,000 years ago.

3. The mean yearly temperature in the area is 73.7° F and the average yearly rainfall total is 53.3 inches.

4. Records indicate that a hurricane will pass within 50 miles of the area, on the average, once every 11 years. Hurricane Donna (in 1960) was the last hurricane to strike the area.

5. A feasibility study was authorized in 1955 by Lee County in order to study the construction of a causeway between Fort Myers Beach and Bonita Beach. The causeway was built between 1963 and 1965 at an approximate cost of $2.7 million.

6. Big Hickory Pass closed in the fall of 1976 and was reopened. A study concluded that the closure was natural. The emergence of New Pass as a large, centrally located inlet serving Estero Bay was the cause for the closure. The enlargement of New Pass was due chiefly to the passage of several storms during the late 1940's and early 1950's, and to the construction of the causeway. Big Hickory Pass closed again in January 1979.

7. The cross-sectional area of Big Carlos Pass has remained at approximately 21,000 ft^2 since 1960. The cross-sectional area of New Pass enlarged from 5,000 ft^2 to 7,300 ft^2 between 1960 and 1978.

8. Pertinent hydraulic data include the following:

   Spring Gulf Tide Range = 3.53 ft.

   Ratio of Bay Tide Range to Gulf Tide Range = 0.95

   Bay Area = 3.29×10^8 ft^2

   Average Lag of Slack Water = 40 minutes

   Spring Tidal Prism - Big Carlos Pass = 8.19×10^8 ft^2

   Spring Tidal Prism - New Pass = 2.71×10^8 ft^2

9. The outer bars at Big Carlos Pass and New Pass contain approximately 5 million cu. yds. and one-half million cu. yds. of material, respectively.

10. Littoral drift in the area varies in direction, being northerly at Big Hickory Pass and variable along Estero Island.

11. Surface sediments in the area are fine sands with shell and shell fragments.

IX REFERENCES

Barwis, J. H., "Catalog of Tidal Inlet Aerial Photography," Coastal Engineering Research Center GITI Report 75-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, June 1975.

Beater, J., Tales of South Florida and the Ten Thousand Islands, Ace Press, Fort Myers, Florida, 1965.

"Black Island - Lovers Key Shoreline Stability and Coast Development," UF-COEL 71/007, Coastal and Oceanographic Engineering Laboratory, University of Florida, Gainesville, Florida, May 1971.

Brown, B. and Brown, A., A Short History of Fort Myers Beach, Estero Island Publishers, Fort Myers Beach, Florida, 1965.

Florida Department of Administration, "The Florida General Soils Atlas For Regional Planning Districts IX and X," Tallahassee, Florida, 1975.

Fritz, F., Unknown Florida, The University of Miami Press, Coral Gables, Florida, 1968.

Mehta, A. J., "Comment on the Stability of some New Zealand Coastal Inlets," New Zealand Journal of Marine and Freshwater Research, Vol. 10, No. 4, December 1976.

Mehta, A. J., Hayter, E. J., and Christensen, B. A., "A Generalized Point-Velocity Method for Discharge Computations in Tidal Waterways," Proc. ASCE Specialty Conference: Hydraulics in the Coastal Zone, College Station, Texas, August 1977.

National Oceanic and Atmospheric Administration, "Climate of Florida," Climatography of the United States No. 60-8, Silver Springs, Maryland, 1972.

National Oceanic and Atmospheric Administration, "Flood Insurance Study - Lee and Collier Counties, Florida," U.S. Department of Commerce, Silver Springs, Maryland, 1973.

"Recommended Coastal Setback Line for Lee County, Florida," UF-COEL 75/009, Coastal and Oceanographic Engineering Laboratory, University of Florida, Gainesville, Florida, 1975.

Schell, R. F., 1,000 Years on Mound Key, The Island Press, Fort Myers Beach, Florida, 1962.

Shepard, F. P., and Wanless, H. R., Our Changing Coastlines, McGraw Hill, New York, New York, 1971.

Simpson, R. H., and Lawrence, M. B., "Atlantic Hurricane Frequencies along the U.S. Coastline," NOAA Technical Memorandum NWS SR-58, Fort Worth, Texas, 1971.

Suboceanic Consultants, Inc., "Coastal Construction Codes for Estero Island," Naples, Florida, December 1975.

Suboceanic Consultants, Inc., "Coastal Construction Codes for Bonita Beach," Naples, Florida, April 1976.

Suboceanic Consultants, Inc., "Coastal Construction Codes for Lovers Key," Naples, Florida, June 1977.

Suboceanic Consultants, Inc., "Big Hickory Pass, Lee County, Florida - Hydrographic Study," Naples, Florida, August 1978.

Tebeau, C. W., Florida's Last Frontier, The University of Miami Press, Coral Gables, Florida, 1966.

Thompson, E. F., "Wave Climate at Selected Locations Along U.S. Coasts," U.S. Army Coastal Engineering Research Center Technical Report 77-1, Ft. Belvoir, Virginia, January 1977.

U.S. Army Corps of Engineers, "Beach Erosion Control Study on Lee County, Florida," Jacksonville, Florida, District, July 1969.

U.S. Army Corps of Engineers, "Special Flood Hazard Information Report on South Lee County Coastal Areas," Jacksonville, Florida, District, July 1970.

U.S. Department of Commerce, Tide Tables, East Coast of North and South America, 1978.

U.S. Department of the Interior, "Water Resources Data for Florida - Part I, Surface Water Records, Volume I: Streams," 1950, 1955.

U.S. Naval Weather Service Command, "Summary of Synoptic Meteorological Observations, Vol. 4, "Ashville, North Carolina, 1970.

Voegelin, B. D., South Florida's Vanished People, The Island Press, Fort Myers Beach, Florida, 1977.

Walton, T. L., Jr., "Littoral Drift Computations Along the Coast of Florida by Means of Ship Wave Observations," Technical Report 15, Coastal and Oceanographic Engineering Laboratory, University of Florida, Gainesville, Florida, February 1973.

Walton, T. L., Jr., and Dean, R. G., "Use of Outer Bars of Inlets as Sources of Beach Nourishment Material," Shore and Beach, Vol. 44, No. 2, July 1976.

West Coast Inland Navigation District, "West Coast Intracoastal Waterway - Guide Map," Sarasota, Florida, 1974.

Florida Sea Grant College is supported by award of the Office of Sea Grant, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, grant number 04-8-M01-76, under provisions of the National Sea Grant College and Programs Act of 1966. This information is published by the Marine Advisory Program which functions as a component of the Florida Cooperative Extension Service, John T. Woeste, dean, in conducting Cooperative Extension work in Agriculture, Home Economics, and Marine Sciences, State of Florida, U.S. Department of Commerce, and Boards of County Commissioners, cooperating. Printed and distributed in furtherance of the Acts of Congress of May 8 and June 14, 1914. The Florida Sea Grant College is an Equal Employment Opportunity-Affirmative Action employer authorized to provide research, educational information and other services only to individuals and institutions that function without regard to race, color, sex, or national origin.

Other Sea Grant Reports on inlet studies are: FORT PIERCE INLET, No.3; JOHN'S PASS AND BLIND PASS, No. 18; MATANZAS INLET, No. 21; PONCE DE LEON INLET, No. 23; SEBASTIAN INLET, No. 14 (out of print); SIKES CUT, No. 7; and ST. LUCIE INLET, No. 2.

Copies available from:

Marine Advisory Program
Florida Cooperative Extension Service
G022 McCarty Hall
University of Florida
Gainesville, FL 32611

9/1.5/80

This public document was promulgated at a cost of $477.10 or .32 cents per copy to provide current information to persons interested in the management, use, and control of Florida's coastal inlets.