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Hydrography of the Grand Canal and Heron Lagoon Waterways, Siesta Key, Florida

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NEW COLLEGE, SARASOTA, FLORIDA

A REPORT
ON
THE HYDROGRAPHY AND BIOLOGY OF TWO MAN-MADE CANAL SYSTEMS - HERON LAGOON AND GRAND CANAL - ON SIESTA KEY SARASOTA COUNTY, FLORIDA[1]

By

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[1] Supported by a grant from the New College Environmental Studies Fund, a grant from Bayside Club, Inc., a special gift to the New College Biology Program from Paul and Stanley Paver, and the Division of Natural Sciences.

This report was to the Citizens Advisory Committee of the New College Environmental Studies Program. Accordingly, the report does not include all of the original data of the research project.

This does not constitute publication.

Price: $5.00

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ACKNOWLEDGEMENTS

We wish to thank the following persons for the information and suggestions they provided during the course of this study:

Mrs. Doris Davis, Sarasota Historical Society

Mr. Jim Slader, Sarasota County Engineering Department

Derr Real Estate Company, Sarasota, Florida

Mr. John Zillas, Sarasota County Soil Conservation District

Mr. William Murphy, Siesta Key Utilities Association

Mr. Ralph Davis, Sarasota County Engineering Department

Mr. Millar Brainard, Siesta Key, Florida

We thank Mr. J. J. Steinmetz for copies of photographs of the two canal systems. Keith Williams, Karen Siedenburg, Nancy Wiedirhold, Sandra Morrill and Becky Ireland helped in the field and lab. Willie Mitchell and his crew at Siesta Key Marina kept our power boat running. Bernie Vossler of the Division of Natural Sciences helped to maintain our collecting gear in operating condition. Furman Arthur of the New College Public Relations Office helped to publicize our project and inform the public of our strange behavior in the canals at odd hours of the day.

Finally, we are indebted to Ms. Madeline McDermott for preparing the diagrams, to Mrs. Mary Gall for typing the report and to Ms. Pat Bryant for obtaining materials on interlibrary loan. Without these three persons the report may never have been completed.

TABLE OF CONTENTS

INTRODUCTION

Today "we all know that dead end finger canals and upland canals adversely affect the ecology of the aquatic environment as well as periodically and then chronically cause considerable displeasure to those who have come to Florida seeking a pleasant life." This general impression is supported in a report by Barada and Partington (1972) to Governor Askew. This report with its eighty-six references is a powerful document on the adverse effects of man-made canals.

The authors of this report point out that a review of the existing literature revealed that a complete ecological study of private canal systems had never been made and recommended such studies be initiated in order to develop adequate guidelines for any future canal construction. Their own recommendations and guidelines included:

1) Periodic testing of canal waters for coliform bacteria and gas gangrene bacteria.

2) Elimination of box cut excavations.

3) Limiting canal depths to allow maximum sunlight penetration to bottom sediments (i.e., 6 feet or less).

4) Require sides of canals to have an adequately wide berm and sloping bottom similar to natural waterways. The sides of the canals should be planted with appropriate native soil-holding shoreline vegetation.

5) Canal widths should be in relation to depth and length of canals.

6) Canals should have adequate circulation and flushing characteristics (i.e., guidelines of Bruun & De Grove, 1959).

7) Standardized methods for measuring water quality and sediment quality should be established.

These recommendations supplement and echo those of Woodburn (1963).

Subsequent to the Barada-Partington report the Department of Pollution Control and the Department of Natural Resources of the State of Florida as well as a variety of Federal agencies, particularly the U. S. Army Corps of Engineers and the Federal Environmental Protection Agency, began to develop stringent guidelines and permit criteria for dredge and fill operations of all kinds to slow down the rates of deterioration of the "quality" of natural waters.

In the last four years the guidelines, recommendations and requirements have increased at an exponential rate. At the same time, ecological studies have been made, and others initiated on the short term and long range effects of man made canal and marina systems. One of the earliest of these was that of Taylor and Saloman (1968) on the effects of hydraulic dredging in Boca Ciega Bay, Florida. A more recent study on the fishes, macroinvertebrates and hydrological conditions in a newly created upland canal system in Tampa Bay is reported by Lindall et al (1973). Other studies include a comparison of phytoplankton in salt marsh channels and man-made canal systems, West Bay, Texas (Corliss & Trent, 1971), a survey of water quality in waterways and canals in the Florida Keys, with proposed guidelines for developmental activities in Florida's coastal zone (Dept. Poll. Control, 1973), a preliminary study of a Florida dead end canal (Mook, 1974) and a report on the ecology of small boat marinas in Rhode Island (Nixon et al. 1973).

In addition, unpublished reports on particular canal systems have been made (i.e., Marco Island Canal Study Report, Cape Coral Canal system, hydrographic study). Such reports are becoming routine in the development of environmental impact statements. Their availability varies; they are being generated by both private and public sectors of the community as well as by county, state and federal agencies concerned with water quality and fisheries resources. As the pressure mounts for more people wanting to live along the coast as close to water as possible we may expect increasing numbers of ecological studies of existing and proposed canal systems in Florida and the southeast. For example, Dr. Oscar L. Paulson, University of Southern Mississippi recently initiated a reconaissance of flushing in coastal canals and its effects on water quality.

The present study was undertaken to compare the water quality and marine life in two dead end canal systems on Siesta Key, Florida and the bays with which they connect. As described in our original proposal we chose the Heron Lagoon waterway system as a canal system which appeared to meet several of the criteria desired by governmental agencies and the Grand Canal system which exemplified some of the concerns of the governmental agencies. Other complex dead end canals in Sarasota County like those in Whitaker Bayou, Hudson Bayou, Phillipi Creek, Curry Creek, Hachett Creek, Godfrey Creek, Lyons Bay, Sackett Creek, Forked Creek and Bishops Bayou remain to be studied as do dead end finger canals. The latter are numerous and of different ages thereby providing the potential for studies on ecological succession and alterations of water quality over long periods of time.

PROPOSAL

At the present period of development of the South Florida area, conservationists are concerned with the question of whather or not it is ecologically healthy for developers to create canals in order to provide the public with waterfront housing. Only within the past decade have we begun to realize the extent of the deterioration that takes place in aging canals. To date very few studies have been done on these man-made ecosystems. In the Canal Evaluation Report, which was sent to the governor, the Ecological Information Service describes the effects of closed-end canals on their surrounding environments and includes recommendations for the development of canal systems that would not cause marked changes in neighboring marine and terrestrial environments. Unfortunately, the report was more a collection of "concensus of opinion" rather than a complete ecological study. Along the Florida coasts, man-made finger canals are an integral part of housing developments which advertise waterfront access. These canals vary in width and depth according to the amount of fill the developer needed to raise the elevation of the development above the mean high water line.

The new canal typically begins as an ecologically sterile environment surrounded on three sides by a concrete seawall. As the canal ages, organic sediment accumulates from various sources. Since the canal is a semi-dead end system, tidal flow may not flush it clean, and the organic rich sediment accumulates, providing a nutrient medium in which offensive and/or harmful bacteria may thrive.

Some few developers do not use sea-walls, but instead plant natural shoreline vegetation. Mangrove is the logical choice as it is adapted to this role and thrives in such an environment. The eventual effect natural vegetation may have on the condition of the canal bottom has not been extensively studied.

In an attempt to add to the ecological data on canal systems we propose to establish a survey of seawalled finger canals and "natural" canals to discover what changes occur with age. Data taken will include:

1) Hydrography: consisting of dissolved oxygen content, salinity, temperature, currents, and water exchange. These figures will give us some idea of the water quality.

2) Benthos: This will give us comparative data as to the amount of plant and animal material that is present in the natural and artificial canal systems.

3) Sedimentation vs. original depth: this study can give information about the age, location, use, and water flow in the comparative systems.

4) Phytoplankton: these investigations can give us the density and composition of the phytoplankton in the different canal systems, and may possibly reveal an indicator species of plankton that would demonstrate the water quality in each canal.

When the study has been completed and the data compiled, we may better understand what happens in an artificial canal as it ages. We hope to be able to suggest modifications in the design and execution of canal building which will prevent further damage to the waterways of the Sarasota Bay area.

The canals we plan to investigate are:

1) The Grand Canal on Siesta Key. This is a long, intricate system, bounded by sea walls, which winds like a maze throughout the northern end of Siesta Key. It is heavily built up with single family houses and receives the effluent from the Siesta Key Utilities Sewage treatment plant. Its only outlet is into Roberts' Bay at the north end of Little Sarasota Bay.

2) Heron Lagoon. This is a long "natural" canal system, sea walled along few of the many properties lining its shores. The houses are relatively far apart and set well back from the water's edge. Nearly all are connected to the SKUA Sewage system; there are no known sewage outfalls into the lagoon. It is heavily planted with mangrove, alternating with some areas of sloped grassy lawn or ground cover and various sorts of trees and shrubs. Its only outlet is at its extreme northern end, where it receives tidal flow through a pipe leading under Midnight Pass Road to North Basin, which opens into Little Sarasota Bay. Heron Lagoon runs down the southern extension of Siesta Key.

Some of the questions we will try to answer are as follows:

1. What happens to a canal with age?
2. Are there any "good" canal systems?
3. Do canals present a public health hazard?
4. If there are any "good" ones, why are they good?
5. Is there any way to design the new or restructure the old so that they can also become "good"?

CONCLUSIONS

In our original proposal we listed five questions concerning the water quality and marine life in canal systems. In retrospect this study does not provide direct answers to these questions. Rather it revealed the complex nature of two canal systems thereby providing a preliminary analytical model with overt cautionary undertones regarding premature "obvious" conclusions from superficial observations and data collected at only one season of the year.

Of the two canal systems the overall water quality and diversity of marine life is greater in the Heron Lagoon system than in the Grand Canal system. In the latter system sluggish tidal circulation and nutrient enrichment appear to be the primary causes of "undesirable" water quality conditions and the development of organically rich,soft bottom sediments and their communities of macro and micro-organisms. Neither canal system appears to constitute a health hazard at the present time. However, unless corrective measures are taken, waters in sections of the Grand Canal system will continue to deteriorate and ultimately influence the water quality and marine life in the adjoining areas of Roberts Bay.

The Heron Lagoon system is a potential model for designing new canal systems and illustrates the guideline principles for upland canals and waterways described by state and federal agencies. Yet even here our study shows improvements in water circulation and shoreline management are desirable. The three mile long dead-end lagoon is a critical part in the maintenance of water quality in this sytem and illustrates a possible way for the construction of upland canal systems in certain areas.

Some of the ways of maintaining and improving the water quality in these two systems and other canal systems are outlined under RECOMMENDATIONS.

RECOMMENDATIONS

The water quality management and improvement in both the Heron Lagoon and Grand Canal systems include several measures that are feasible, simple,relatively cheap and applicable to other canals and others that are possible but probably not feasible until some sector of the public becomes sufficiently aroused. Improvement of maintenance of water quality and marine life in the Grand Canal system is complicated by the outfall of the major sewage treatment plant on Siesta Key. Given these reservations we proffer the following recommendations (not necessarily in order of priority).

1) The degree and rate of tidal flushing in the two canal systems could be increased. In the case of the Heron Lagoon waterways, box culverts instead of the present circular 30-inch concrete pipes beneath the roads, especially at the Midnight Pass Road culvert would increase circulation and reduce eddy currents and debris and organic sediment accumulation in the vicinities of the culverts. A flow-through tidal current circulatory system would further increase tidal flushing. One possible site for a second opening to the Bay or Gulf is Sanderling Beach at the west side of Heron Bay. Indeed during Hurricane Agnes, June 1972, such a breakthrough nearly occurred. Had this "Act of God" succeeded Little Sarasota Pass would exist again.

Increasing the tidal flushing in the upper reaches of the Grand Canal system would be more difficult. The natural drainage area leading to the pond in Sands Cove is the most obvious place to consider for a second opening. At one time this pond and its upland drainage area did discharge into the Gulf of Mexico. In the Siesta Isles area a connecting waterway to Roberts Bay via the Royal Palm Harbor Canal would be one way of increasing tidal flow in this section of the Grand Canal system. The Palm Island loop could be connected to either (or both) the Siesta Isles or the Sarasands Canal sections. Whether such connections would actually function as planned would require hydraulic engineering studies and models. Furthermore, such proposals would meet strenuous objections from all sides. At the very least the quality of the waters of the Palm Island, Siesta Isles and Sarasands-Harmony Shores sections might first have to be improved before various agencies would permit it to enter the Bay or Gulf.

2) The shoreline vegetation needs to be pruned and managed to reduce the amount of leaf fall entering the waterways and canals. Submerged branches that impede waterflow should be removed. Debris that collects at the upper ends of the dead end canals should be removed with dip nets. In the case of developed lots, the residents should be encouraged via constructive education to maintain their water fronts as they

do the rest of their property. In the case of undeveloped lots and public owned lands along the canals either the local government, the local development association such as the Siesta Key Club of Heron Lagoon or the Siesta Key Association could assume this responsibility.

3) Consideration should be given to an overall removal of ninety percent total nitrogen and carbonaceous matter in the discharge water of the SKUA facility.

4) Application of biocides and fertilizers to the uplands bordering the canal systems should be confined to periods of low rainfall in March-May and October-December to reduce the amount of surface runoff of these materials into the canal systems.

5) Ways of increasing the levels of dissolved oxygen economically in the bottom waters of canal sections with little circulation should be explored. If the dissolved oxygen in these waters were kept above 2.0 ppm, the nitrogen and phosphate compounds in the bottom sediments would enter the overlying water slowly and tend to remain trapped in the sediments (Fillos and Molof, 1972). Devices such as submerged perforated air lines and agitators are currently employed throughout the country to improve the water quality in ponds, settling basins, etc. This remedial measure, if applied to the dead end canals, would not only aerate the water but improve the circulation in these canals as well as retard the accumulation of organic matter in the sediments and maintain an aerobic microbial flora in the surface layers of the sediments.

6) The water quality and marine life should be monitored at intervals throughout the year for several years to determine the changes in ecological conditions in these canal systems. In addition, short term perturbations such as those associated with Hurricane Agnes should be studied.

7) Surface runoff water discharges into the canal systems following heavy rainfalls via storm sewer point source outfalls should be minimized wherever possible. Discharges from storm sewers not only involve large amounts of freshwater but contain such toxic pollutants as lead, mercury, automobile fuel wastes and also dirt, animal feces, plant materials and other BOD and COD substances. Consideration should be given to diverting storm sewer discharges, construction of proper drainage swales along existing roads neighboring the canals and the use of porous asphalt as paving material for roads and driveways so that surface water in these areas may percolate into the ground directly.

THE HISTORY OF HERON LAGOON
AND THE GRAND CANAL ON SIESTA KEY

Until 1907 Siesta Key was undeveloped and largely unoccupied because no bridge connected it to the mainland. In that year Harry L. Higel,[1] the Mayor of Sarasota, showed his awareness of the island's potential by organizing the Siesta Land Company with Captain Louis Roberts and E. M. Arbogast. They platted the town of Siesta, but found they had picked the wrong moment in time. The depression of 1907 ruined their plans, but only temporarily. Between 1911 and 1913 Bayou Hansen, Bayou Nettie, and Bayou Louise were dredged and canals opened. In 1912 they replatted the first subdivision "Siesta Subdivision". Thereafter the Key was known as Siesta Key. The Board of Geographic Names, however, officially titled it "Sarasota Key" on February 1, 1922, but since no one seemed to know where "Sarasota Key" was and everyone was familiar with "Siesta Key", the name was officially changed on July 3, 1952. 1917 saw the opening of the first Siesta Bridge and partial development of the town was begun. The development rush began later with the construction of Stickney Point Road and Bridge in 1926-27. The original Siesta Bridge, built of wood, was considered unsafe by then, and a new Siesta Bridge was erected in 1927.

Heron Lagoon. Before 1921[2] the southern end of the key had a very different appearance from the present (Figure 1). What is now Heron Lagoon was the northern half of Little Sarasota Pass. The Pass opened into Little Sarasota Bay in the vicinity of Bird Keys. There was no Midnight Pass then. Little Sarasota pass cut north between the southern tail of Siesta Key on the east and the northernmost stretch of Casey Key, an area then known as Treasure Island, on the west, and opened into the Gulf of Mexico through what is now known as Sanderling Beach. The Pass was 8 to 10 feet deep, including its opening into the Gulf. When the 1921 hurricane struck, the Gulf broke through Casey Key at the southern end of Little Sarasota Pass and formed "Musketeer's Pass", now known as Midnight Pass. In 1926 another hurricane dumped masses of sand and shell into the center of Little Sarasota Pass where there were once two small mangrove islands, and the Pass was cut in half. However, according to Bruun, et al. (1962), this pass was closed and the present day Midnight Pass formed during the 1947 hurricane. The Gulf opening of the Pass had been practically filled with sand by the first storm; the second succeeded in closing it completely. The result was a landlocked Heron Lagoon nearly two miles long (Figures 2, 3, 4). The southern end of Little Sarasota Pass is known today as Blind Pass and opens rather tortuously into Midnight Pass.

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1. "The Story of Sarasota," Karl H. Grismer, M. E. Russell, 1946.

2. Information received from Mrs. Dotty Davis of the Sarasota County Historical Society.

Figure 1 Map of southern end of Siesta Key 1883. Adopted from U. S. Coast and Geodetic Hydrographic Survey Chart 1884. The map shows the entrance to Little Sarasota Pass just south of Point of Rocks.

Figure 2 Map of southern end of Siesta Key after 1926. Map adapted from U. S. Geological Survey Quadrangle Map (Bird Keys Quadrangle) 1944 based on aerial photographs of 1942 of Army Map Service. The map shows the land locked Heron Lagoon prior to the construction of waterways and connection to Little Sarasota Bay in 1950.

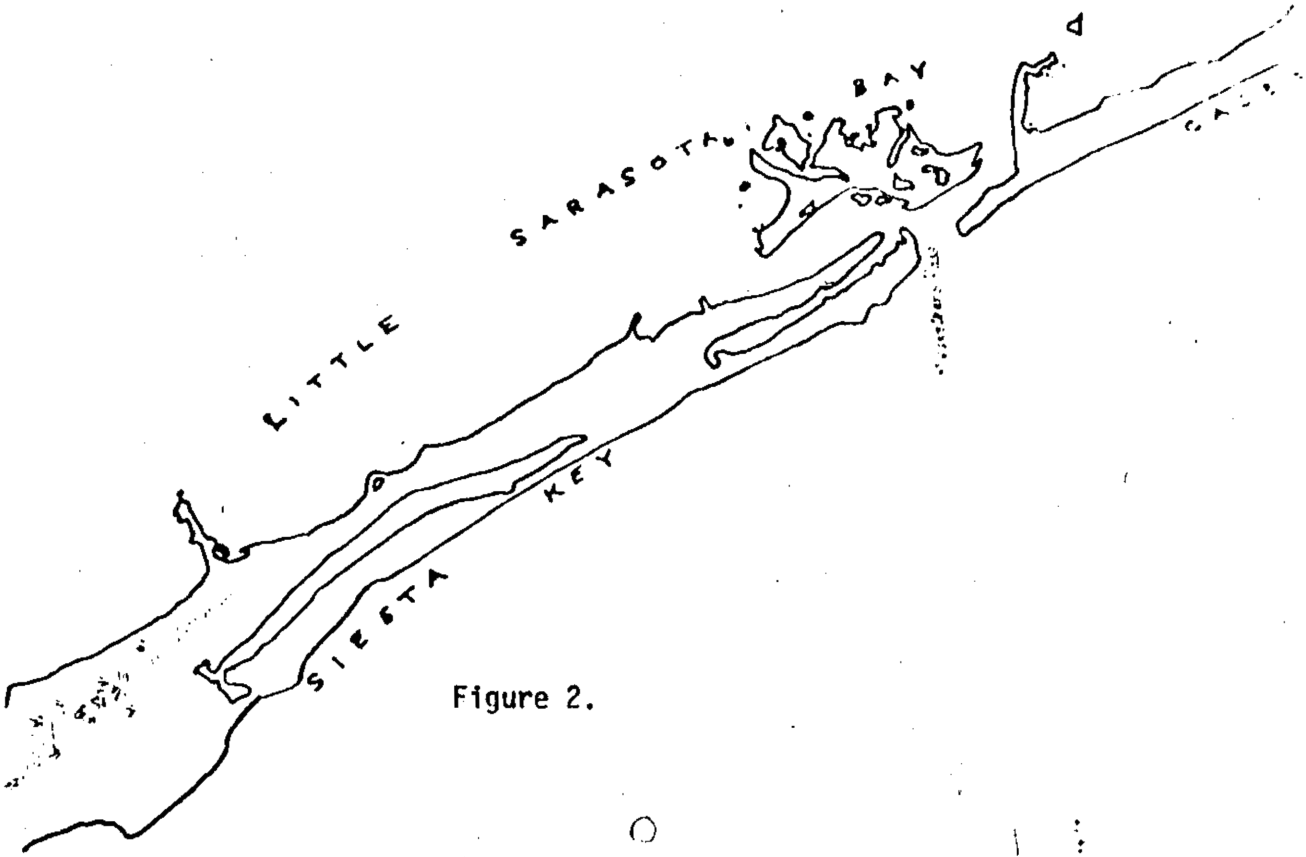

Figure 2.

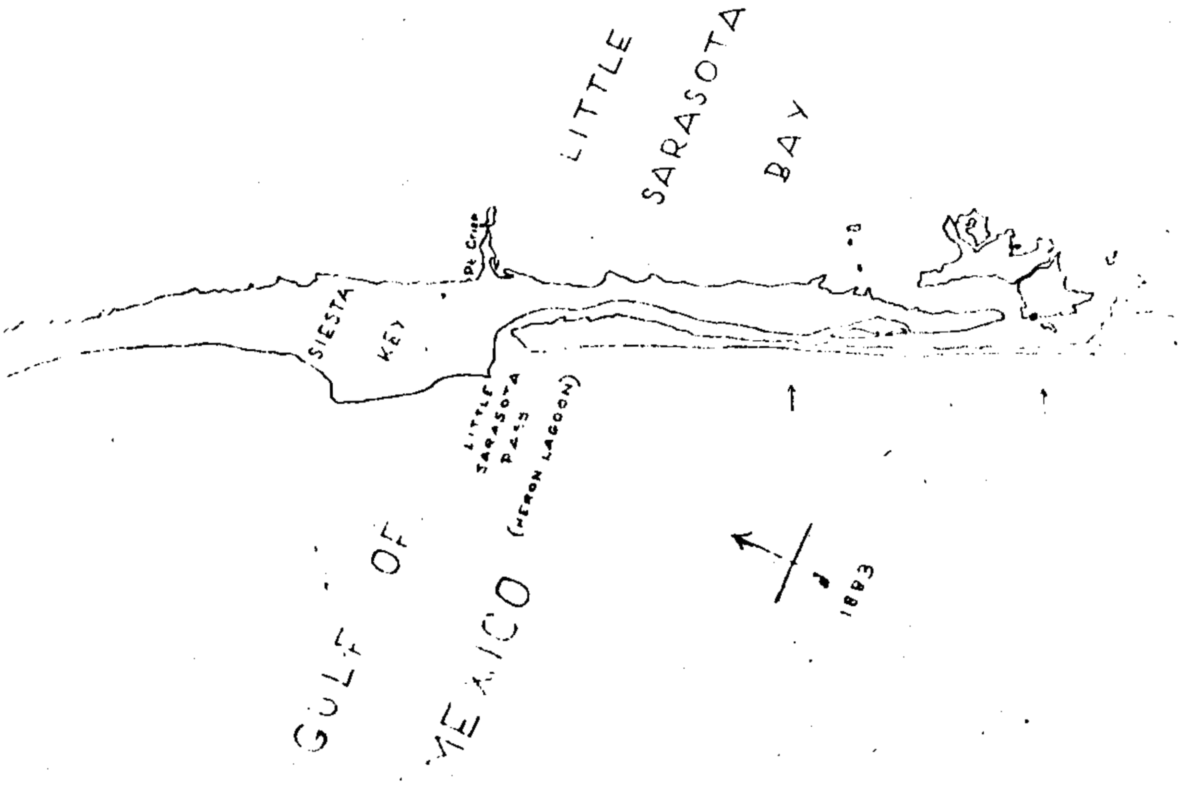

Figure 1.

Figure 3. Aerial photo (February 21, 1951). Heron Lagoon looking north toward Point of Rocks. Photo courtesy of J. J. Steinmetz, Sarasota. At this date one waterway existed in the pine flat woods at the north end of the canal. Note the mangrove shore along the west side of Heron Lagoon.

Figure 4. Aerial photo (February 21, 1951) Heron Lagoon looking east toward Point Crisp, Siesta Key and Little Sarasota Bay. Photo courtesy of J. J. Steinmetz, Sarasota. Note the mangrove forest at the easterly tip of Point Crisp. The present day seawalled development on the eastern shore of Little Sarasota Bay was a series of oyster bars and mangrove islands in 1951 as shown by this photo.

Figure 8. Aerial photo 1970 of Grand Canal and Roberts Bay. In the foreground is Waterside Way Canal (Station 16). In the center Waterside East Canal (Station 17 at upper end of one arm of the Canal). To the left of Grand Canal entrance is Bay Point Canal (Station 2). Photo courtesy of Hente, Sarasota.

Figure 9. Aerial photo of Palm Island area of Grand Canal, February 21, 1951. Lower foreground is Gulf of Mexico beach. Photo courtesy of J. J. Steinmetz, Sarasota.


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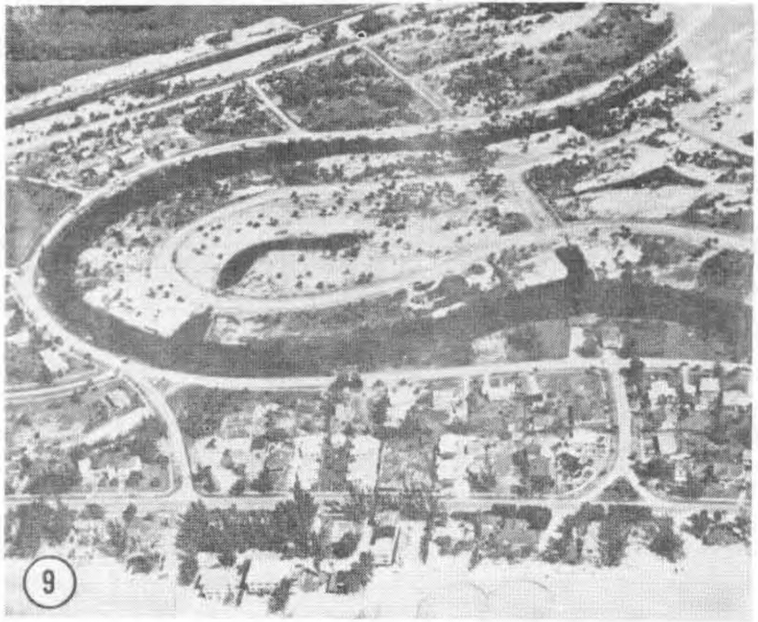
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The first lots platted on Heron Lagoon were part of a Government subdivision. Miramar was platted on April 17, 1925. This development is on the east side of the Lagoon and runs southward from the middle of the length of the Lagoon.[3] It meets with land once owned by Mr. and Mrs. G. W. Crist, Jr., who sold the land to the Government. This piece is called Ocean View and was platted on September 5, 1925. Ocean View adjoins Heron Lagoon Lodges, owned by Mr. and Mrs. G. A. Fuller. This land was surveyed in April and platted in May of 1954 as a private club. Just north of Miramar are The Cedars of Siesta Key, originally owned by Mr. and Mrs. R. M. Lock, who had the small property surveyed and platted in March of 1946.

The rest of the Heron Lagoon area was bought in 1940 by Mr. Eldridge S. Boyd, a land collector, who owned and developed Hidden Harbor, Coconut Bayou, and other areas on the Key. He incorporated his holdings on Heron Lagoon in 1945 and called them "Siesta Properties, Inc." They were developed in four units. Unit #1, platted on July 27, 1946, comprised all of his holdings on Heron Lagoon proper, including the land north of The Cedars, around the northern end of the Lagoon and the entire west bank between the Lagoon and the Gulf. The plat shows a proposed sixty foot canal running north through the marshy area adjoining the Lagoon.

Boyd began selling lots as early as 1941.[4] By 1950 a "sixty foot wide canal" became the completed East Waterway, over a quarter of a mile long. The West Waterway was well begun, with plans to continue it up to an existing curved section that connected with the East Waterway through a thirty inch culvert. All of that area was platted as Unit #2 in July of 1950. Unit #3 was platted at the same time and included the land around the Boat Basin, a dead end docking canal just east of Midnight Pass Road (formerly Siesta Boulevard). A double culvert led under the road to connect the East Waterway with the Boat Basin. Heron Lagoon was no longer landlocked; tidal flow passed throughout the new system of canals into Heron Lagoon.

The last area to be platted was Unit #4, the man made island west of Mid Waterway. This completed Siesta Properties, Inc. in March of 1959. All the waterways and all road construction were complete and interconnected. East, Mid and West Waterways were connected to each other and Heron Lagoon through culverts under Sanderling Road. Melaleuca Way, Pine Needle Road, Turnstone Road, and Plover's Way (Fig. 5) led to the new residences springing up along the banks of the waterways.

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3. Information, County Engineering. Ctsy Mr. Slade.

4. Information ctsy Derr Real Estate.

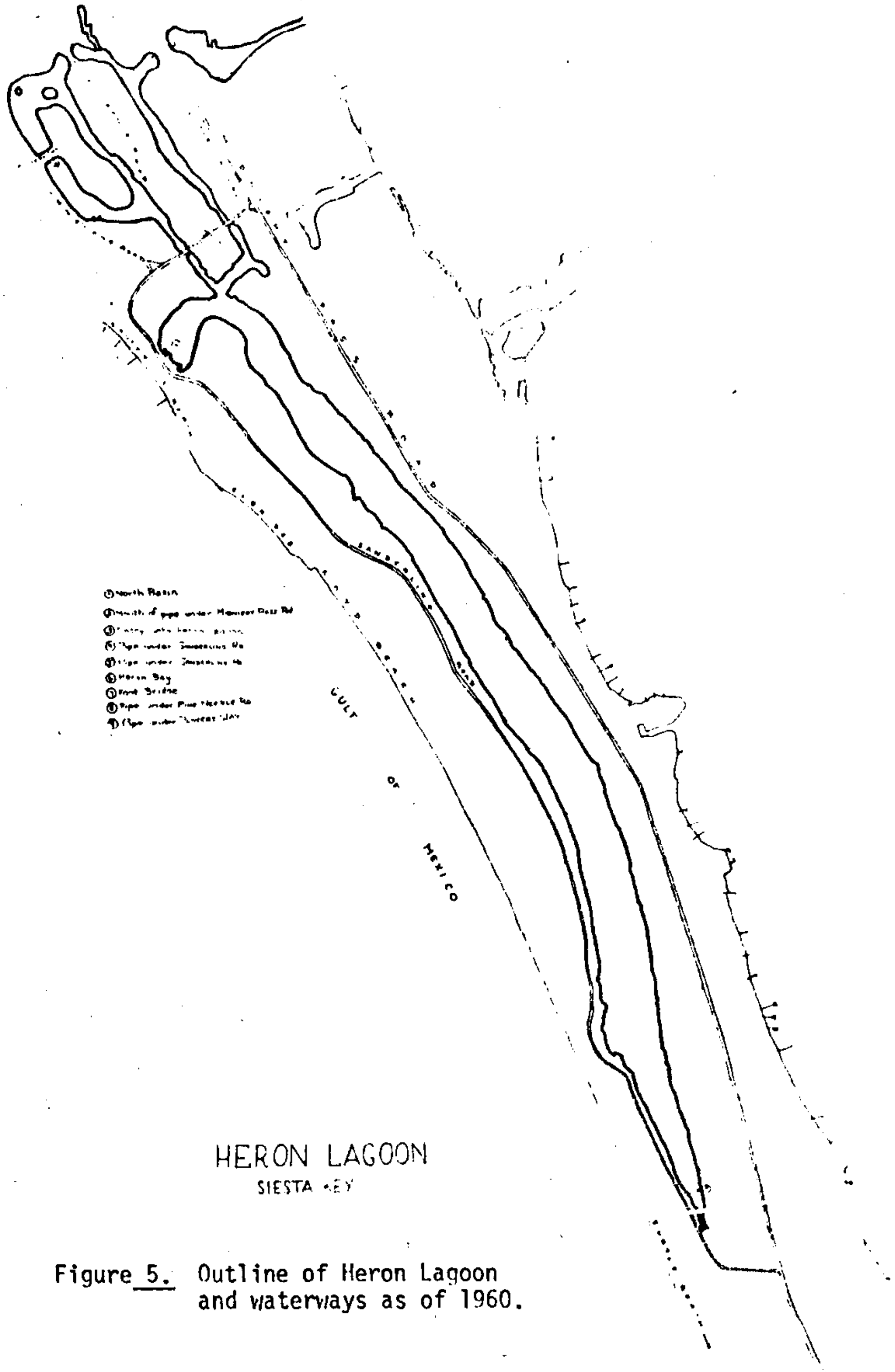


Figure 5. Outline of Heron Lagoon and waterways as of 1960.

Grand Canal. The history of the growth of the Grand Canal system of canals is summarized in Figs. 6 & 7 and Table 1. The main portion of the Grand Canal, including Palm Island, was dredged in 1925.[1] The Canal followed a natural drainage ditch that wound through saw grass flats from the Bay. Palm Island was created with the fill from the dredging. Archibald's Canal was the Canal's first name, since it was the then mayor of Sarasota, Frank Archibald, who had the work done. A few houses were built on and around Palm Island. This seemed to satisfy the needs of the time for there was no further development for twenty-seven years except for a single dead end canal north of Avenida del Mayo that joined the Grand Canal east of Palm Island.

The boom began in 1952. Ocean Beach, a small area growing out of the first curve of the Canal, was platted in that year and was followed by Harmony in 1954-55. Sarasands mushroomed in 1957. It joined Harmony via Siesta Manor and Paradise Island in 1958. Today this whole complex, from Ocean Beach through Sarasands, is a maze of long, narrow, dead end canals.

In 1960 Siesta Key Utilities Authority (SKUA) was built to provide water and sewage treatment to the growing numbers of people crowding onto the Key. At the same time, the neck of what would become Siesta Isles was dug. 1962 saw the first area of Siesta Isles designed somewhat differently from the rest of the Canal. The finger canals were short and wide, not dead water traps (Fig. 7). As the rest of this area was dredged someone apparently became aware of water quality at last. The three main canals of Siesta Isles interconnect and provide free tidal flow from the Grand Canal (Fig. 7). Siesta Isles was complete and platted by 1964.

Unfortunately the Siesta Isles design was not continued in later developments along the Grand Canal. Waterside Wood and Waterside West, 1966, are both dead end canals (Figs. 7 & 8). Bay Point, 1968, has innovations including a circular flow of water within itself. It also has a culvert leading to the Bay, providing a free flow of water. Waterside East, 1970, the most recent addition on the Grand Canal, consists of two dead end canals forking off an entrance from the Grand Canal (Fig. 8). They are wider than the older canals.

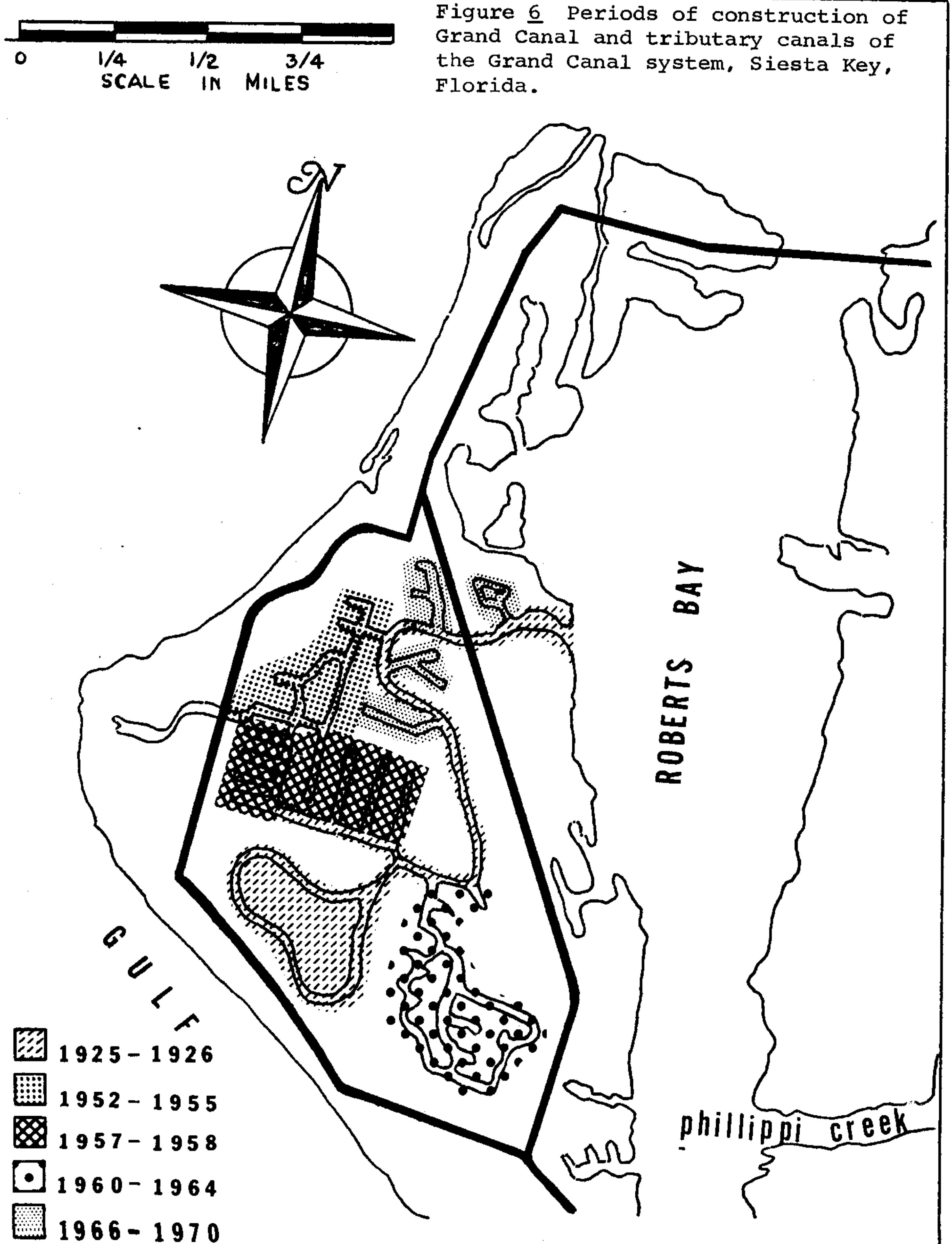
Table 1.

AGE AND AVERAGE DEPTH OF WATERWAYS AND CANALS OF GRAND CANAL SYSTEM, SIESTA KEY.

Canal	Year Constructed[1]	Age in Years	Average Depth in Feet.
Grand Canal - Palm Island Loop	1925-26	47	6 - 10
Ocean Beach	1952	20	5
Harmony	1954-55	18	7 - 8
Sarasands	1957	15	4 - 5
Paradise Island	1958	14	5
Siesta Manor	1958	14	4 - 5
Siesta Isles, North	1960	12	7 - 8
Siesta Isles, West	1962	10	7 - 8
Siesta Isles, East	1964	8	7 - 8
Waterside Way	1966	6	8
Waterside Wood	1966	6	8
Bay Point	1968	4	9
Waterside East	1970	2	8

[1] From Plat records, Engineer's Office, Sarasota County.

Figure 6 Periods of construction of Grand Canal and tributary canals of the Grand Canal system, Siesta Key, Florida.



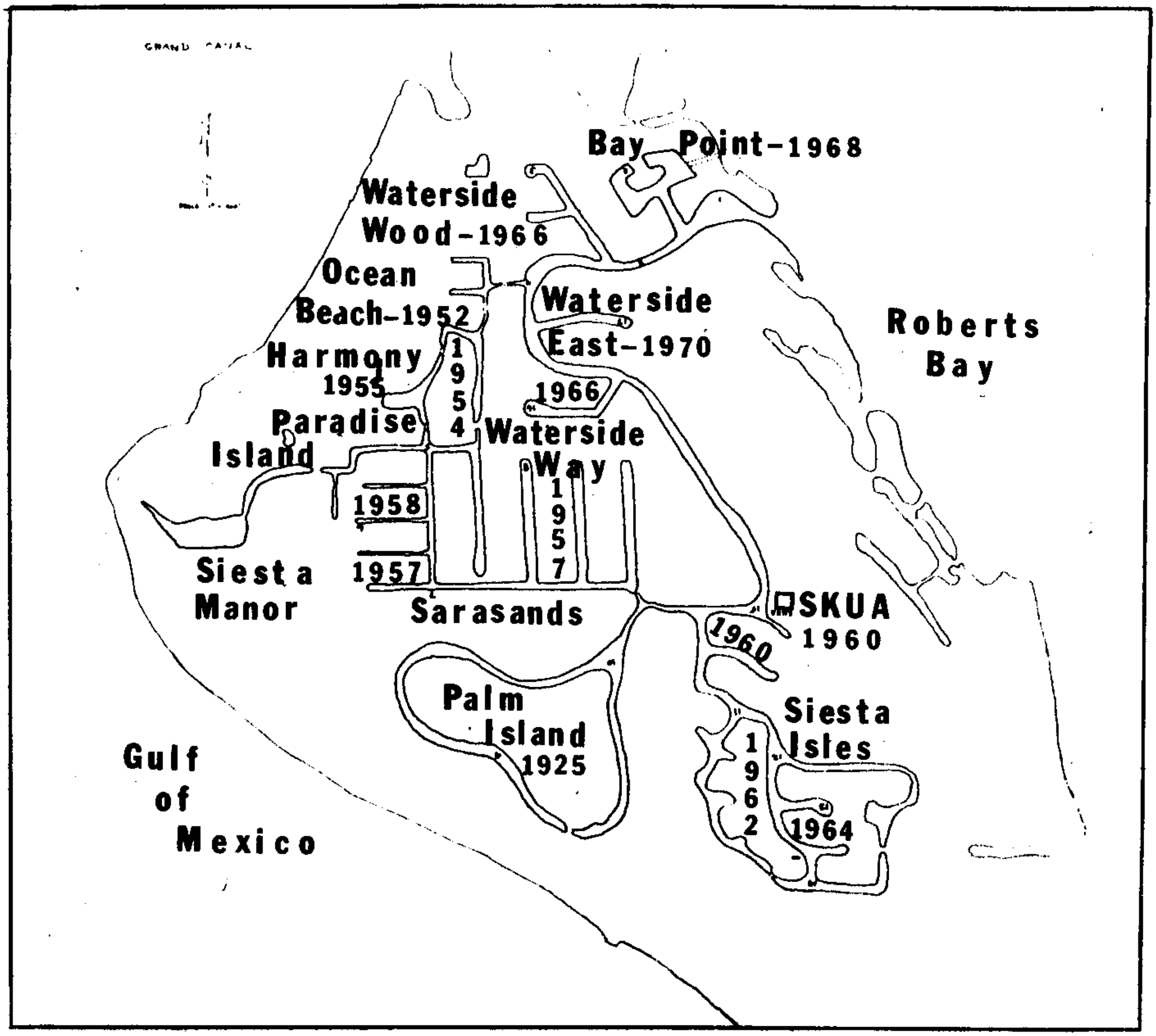


Figure 7. Dates of construction and names of sections and subdivisions of the Grand Canal system.

PHYSIOGRAPHY AND BATHYMETRY
IN HERON LAGOON AND THE GRAND CANAL

Siesta Key is little more than two large sandspits coalesced near Point of Rocks. In some areas there are outcroppings of limestone and sandstone. The water table is normally within 3 to 5 feet of the surface, although it descends in droughts of any duration. The soils in the vicinity of Heron Lagoon and the Grand Canal are primarily coastal beach ridge and Arzell fine sand, shell phase (Wildermuth and Powell, 1959).

According to Wildermuth and Powell coastal beach ridge soils consist of thick beds of sand mixed with shell fragments that run in parallel, low uneven ridges 3 to 4 feet high. This is best seen in the 1948 aerial photo of Sarasota County. This soil has a low moisture holding capacity and rapid internal drainage. Typical native vegetation includes: cabbage palmetto, saw palmetto, wiregrass, myrtle, cedar, bracken fern and Spanish Bayonet.

Between the coastal beach ridges, Arzell fine sand, shell phase soil occurs naturally. (This alkaline, poorly draining soil is found beneath the filled areas at the north end of Heron Lagoon and in Sarasands as well as is the low lying sections around the Grand Canal where there were once broad swales such as Harmony Isles and Siesta Isles). This soil is particularly low in organic matter and deficient in plant nutrients. Its' water table is high and the root zone of plants relatively shallow.

The distribution of both soil types on Siesta Key is clearly shown in the 1948 aerial photos in the Sarasota County Soil Survey of Wildermuth and Powell (1959).

What may prove of interest is that the Canal systems and upland development to the north and south of Palm Island are located in Arzell fine sand soil areas. What does this mean? First, the canals have been dug through soils that were at the surface of a ground water aquifer; second, the present uplands bordering the canals are composed of this same soil type removed in the course of canal construction. Thus surface water and waterborn materials probably readily percolate through the soils into the canals proper. That this may be the case is reflected by anomalous salinity and temperature changes we observed during this study in the waters of these canals.

Physiography

The several physiographic features of the two canal systems are summarized in Table 2. The data in the table were obtained by measurements from maps of known scale and from field observations in counting residences, building lots and powerboats.

Heron Lagoon. There are 41 acres of open water in Heron Lagoon proper and 11 acres in its man made canals. With the exception of approximately 1,000 feet of sea wall, concrete bag or rip rap on the east shore of Heron Lagoon, the shore line is vegetated. In many of the shore properties grass, vines or other ground cover extend down the low banks to the mean high tide line. Palm trees, gold trees, jacaranda, palmetto and "weedy" Brazilian pepper trees grow along the water's edge. In several waterways Brazilian pepper trees and other shore vegetation have extended over the water and affect the tidal flow. Australian pines are prevalent. Much of the shoreline, however, is vegetated with red, white and black mangrove. Some property owners trim the mangroves to hedge height or lower (Fig. 10); others prune the trees to more natural looking bush-like growths (Fig. 13). The original mangrove forest fringing the west shore of Heron Lagoon (Fig. 4) has been largely preserved. In one instance (Fig. 11) the red and white mangroves have been pruned to hedge height while the lower branches of the black mangroves have been pruned, resulting in an ecologically desirable and esthetically pleasing managed natural shore line. Where people have removed the natural mangrove vegetation along the shore erosion has and is occurring. In one yard the shore has been stabilized by the owners leaving one relatively large black mangrove whose pneumatophore-root system extends nearly 50 feet along the shore (Fig. 12). At the same time, the tree itself provides an attractive area of shade.

We have then in the Heron Lagoon area many examples of how water front properties may be landscaped with native species of plants to stabilize shorelines and to provide esthetically pleasing "greenery". While all three species of mangroves - red, white, black - can be transplanted and pruned, it appears that each has its own set of optimal values. The unsung white mangrove is by far the best for the development of quick growing hedges. The black mangrove is best as a shade tree. The red mangrove will tolerate more submersion in salt water but is slow to become established in an area. For further information see Savage (1972a,b). We are currently studying various parameters of mangrove ecology in the Sarasota Bay area and are in the preliminary phases of mangrove horticulture.

Grand Canal. The Grand Canal system of some 9 miles of waterways has 89 acres of water surface. Over 13 miles of canal banks are sea walled (Figs. 14, 15 & 18) while 5 miles are vegetated with native or cultivated plants. Here again weedy species of ornamentals have grown into the canals (Figs. 16 & 17).

TABLE 2. Physiographic data for the Heron Lagoon and Grand Canal systems, 1972-1973.

	Surface Area Acres	Perimeter Shoreline Feet	Shoreline		Waterways Miles	Upland Drainage Basin/Acres	Ratio Canal Area/ Drain Basin
			Seawall Feet	Vegetated Feet			
Heron Lagoon System	52	25,900	1,000	24,700	2.26	132	1/2.5
Heron Lagoon	41	14,850	1,000	13,650		44	1/2.1
H.L.Upland Canals	11	11,050	0	11,050		84	1/4.1
Grand Canal	89	96,600	70,400	26,200	9.11	531	1/5.8

	Number of Residences 4/73	Number of Empty Lots 4/73	Number of Powerboats Dockside 8/72	Number of Powerboats Dockside 4/73
Heron Lagoon System	115		5	6
Heron Lagoon	80			
H.L.Upland Canals	35			
Grand Canal	739	98	346	291

Figure 10 Pruned red mangrove hedge along private driveway near Station 2, Heron Bay.

Figure 11 Black mangrove tree canopy with hedge height red mangrove understory on developed shore, west side of Heron Lagoon. Pruning the understory provides this owner both privacy and a view of the Lagoon.

Figure 12 Black mangrove tree, pruned to form a shade tree at the edge of the sloping lawn. Note the well developed aerial root system which serves to stabilize the shore and the bank.

Figure 13 A non-seawalled sloping bank vegetated with salt tolerant grasses and bushy white mangroves. Photo, July 1952, courtesy of J. J. Steinmetz.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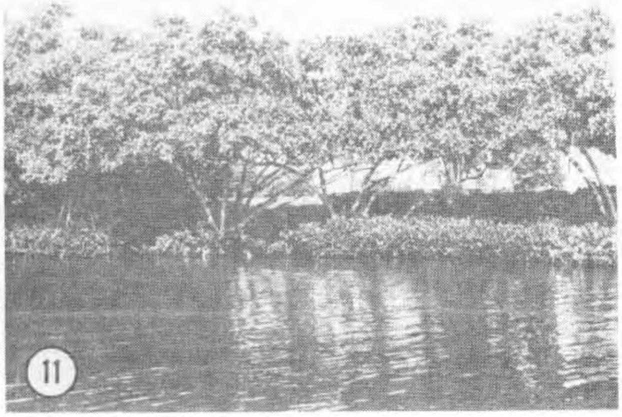
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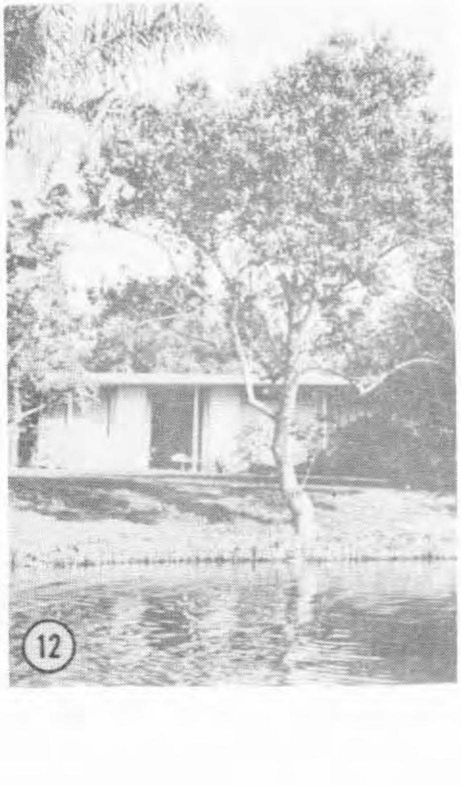
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Figure 14 Seawalled canals, Siesta Isles, Grand Canal. Note the narrow barnacle-oyster zone on the seawall in the lower left foreground.

Figure 15 Sea walled canal, Siesta Isles.

Figure 16 Palm Island section of canal with overgrowths of shore vegetation south of Calle Florida bridge.

Figure 17 Palm Island canal, non sea walled section, looking north from Calle Florida bridge. The overgrowth of shore vegetation is primarily Brazilian pepper bushes.


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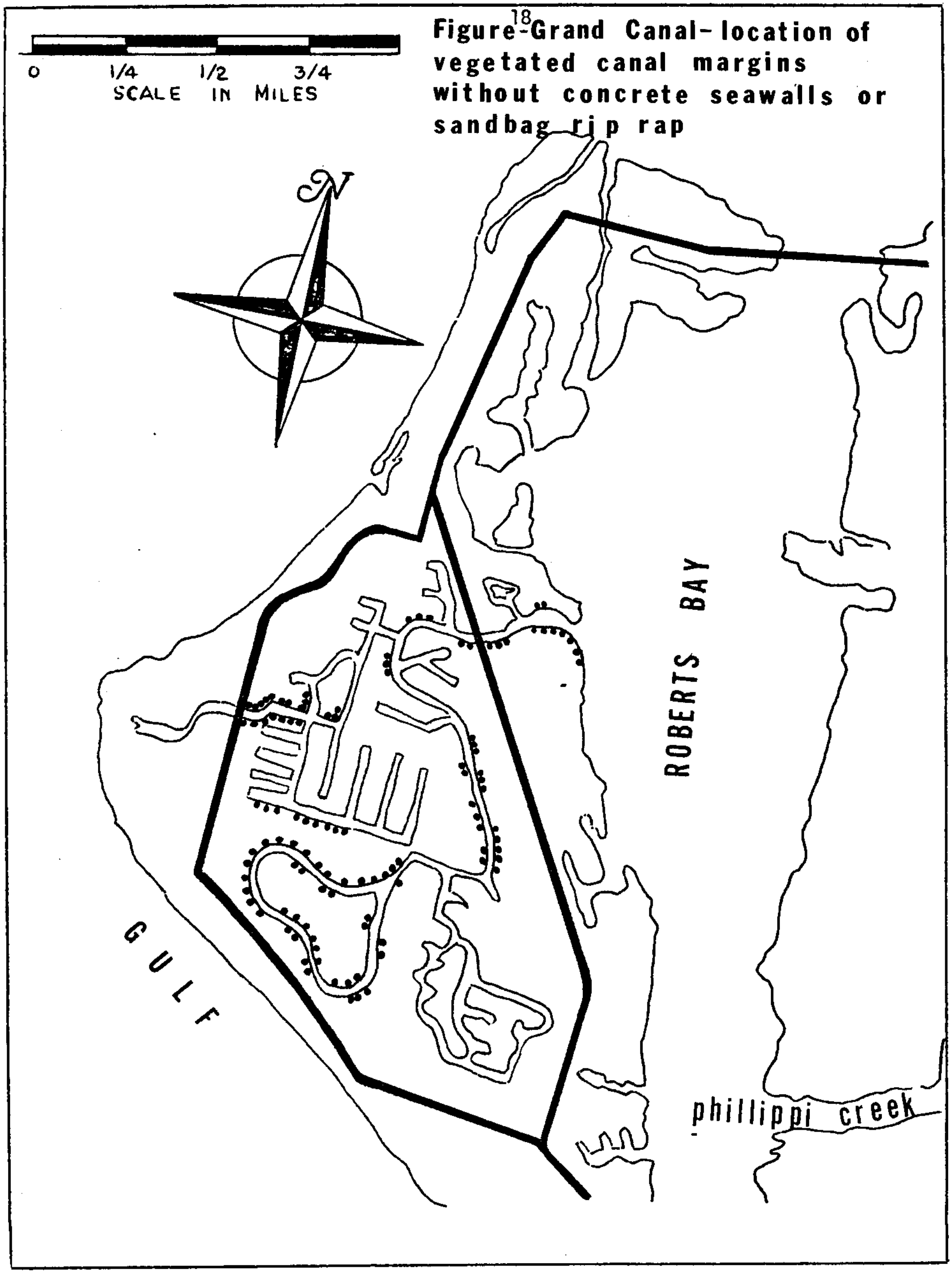
Figure 18-Grand Canal-location of vegetated canal margins without concrete seawalls or sandbag rip rap



Bathymetry - Descriptions of Heron Lagoon and the Grand Canal

Heron Lagoon. Heron Lagoon proper varies between 7.5 and 11.5 feet deep. Little dredging is evidenced here except in Heron Bay by Sanderling Beach where fill for Sanderling Road has been removed. The deepest areas are in the central and northern ends of the Lagoon. The east shore of the Lagoon is steeper than the west shore and drop-offs of 5 to 10 feet within 6 feet of the shore prevail.

Heron Bay is shallow with depths between 1.5 and 3.5 feet except along its northern perimeter where a 10-20 foot wide channel 6.5 feet deep was dredged, probably for land fill.

The depths of the 50 to 100 foot wide waterways at the north end of Heron Lagoon vary from 2 to 7 feet except for shallow sandbars in the vicinity of road culverts. The deepest areas are in the northern ends of West and Mid Waterway; the shallowest around the small island at the northern end of the East Waterway. One may speculate that the depths of these man made waterways are proportional to the fill requirements in the adjoining uplands. The North Boat Basin east of Midnight Pass Road is 5 to 6 feet deep by the boat docks and 7 to 8 feet deep in the basin and waterway proper leading to Little Sarasota Bay.

Periodically the areas in the vicinity of the culverts are dredged to maintain tidal flow. However, the two long 30 inch diameter culverts under Midnight Pass Road do not appear to be maintained to prevent the build-up of oysters that further restrict the tidal flow at this point.

Grand Canal. The general distribution of depths in the Grand Canal system is summarized in Fig. 19 and Table 1. The depths of the Grand Canal proper range from 8 to 10 feet with holes such as at Hydrographic Station 2 near the entrance and Station 15 near SKUA as deep as 12 feet. In the Palm Island loop depths range from 5 to 10 feet. The fingerlike dead end canals north and west of the Grand Canal range from 7 to 9 feet. However, in the Ocean Beach and Sarasands most of the canals are less than 5.5 feet and in some places less than 3 feet at MLW, especially the oldest canal along Avenida del Mayo. The vicinities of road box culverts and bridges where the canals narrow are shallower than other areas.

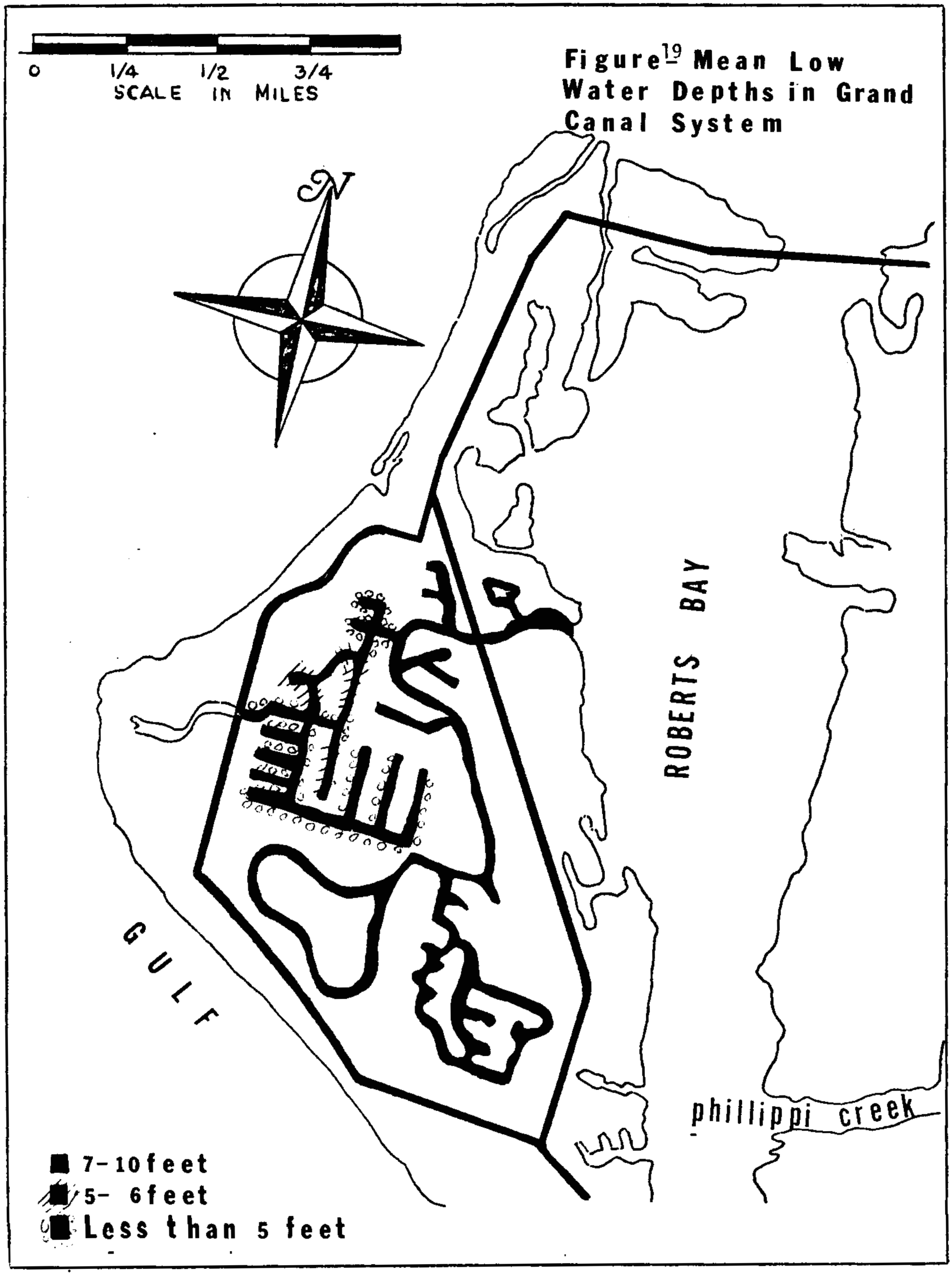


Figure 19 Mean Low Water Depths in Grand Canal System

POTENTIAL SOURCES OF "POLLUTION"
IN HERON LAGOON AND THE GRAND CANAL

"The Obvious And The Unknown"

The most obvious sources of "pollution" in these canal systems include: 1) surface sheet water run off from the adjoining developed uplands; 2) ground water seepage bearing biocides, fertilizers, and septic tank leachates; 3) storm sewer outfalls whose waters carry urban pollutants from roads and developed uplands; 4) sewage treatment plant outfalls such as SKUA.

Less obvious sources include: 1) powerboat effluents; 2) plant litter such as grass clippings, dead leaves, and pollen that are thrown or fall into the canals; 3) rainfall which transfers atmospheric pollutants to the open water directly; and 4) waters of the adjoining bays that enter the canal systems on rising tides and may at times result in the accumulation of masses of algae, waterweeds like water hyacinth and human garbage.

In the paragraphs that follow we will review some of these sources in regard to the two canal systems.

Heron Lagoon. The upland drainage basin of Heron Lagoon and its upland waterways is approximately 132 acres (Table 2). The drainage basin is delineated by several roads that surround the area. The amount of pollutants from the uplands appear minimal except in times of heavy rainfall when surface sheet run off can carry fertilizers and biocides over the vegetated banks into the waterways. No storm sewers empty into the Lagoon or waterways. Nearly every house is on SKUA sewage lines. The few septic tanks still in use along the west shore of Heron Lagoon are located so their drainage fields are toward the Gulf of Mexico. While septic tanks along the east shore of Heron Lagoon do drain into the Lagoon, they are associated with single family residences.

Pollution from human effluents seems minimal. This is further evidenced by examination at low tide during the winter months of the intertidal areas along the shores. At this time of the year sources of ground water seepage from septic tanks and washing machines can be pinpointed by patches of the green alga Enteromorpha in the intertidal zone. We observed only ten patches in the Heron Lagoon system during this study. Fecal nutrient enrichment of these waters then is primarily from fecal wastes of marine life, birds and other wildlife. Biological Oxygen Demand (B.O.D.) tests of water samples collected May 17, 1972 showed that the B.O.D.s of water from hydrographic Stations 1 through 7 and Station 8, Little Sarasota Bay ranged from 1.5 to 1.7 ppm. (Tests, courtesy of SKUA).

A half dozen small outboard motor boats are docked along the east shore of Heron Lagoon. Four to six power boats with 60-100 H.P. motors are docked in the North Boat Basin. Motor boat pollution appears minimal in the Heron Lagoon system.

From time to time following major storms and fresh water discharges water hyacinths may be driven by wind and tides into the boat basin and accumulate in decaying masses along the shore by the Midnight Pass Road culvert and around the oysters on the boat dock pilings. One such occurrence took place August, 1973 following heavy rains, abnormally high tides, and southeasterly winds for two days. In one four foot square area beneath the Boat Basin dock some 80 water hyacinth plants were removed and later dried at 100°C for 24 hours. Their combined dry weight was 5.5 kilograms.

The potential significance of this chance observation is that structures like pier pilings, docks, and overhanging, submerged shore vegetation provide potential traps for materials carried by the tides. This is a nuisance factor, but equally important is the fact that when these materials are water hyacinths, the filter feeding organisms dwelling on pilings and submerged branches of shore plants are subjected to abnormally low oxygen tensions as the water hyacinths decompose. Furthermore, drifting water hyacinths have the potential of catching on the oyster growths within road culverts and thereby affect the normal tidal flow. Finally, the massing and subsequent decay of these plants in restricted areas like canals provide an additional source of nutrients for the support of local plankton blooms. Another potential source of "pollution" in both canal systems, but particularly in the Heron Lagoon system, is the annual rain of leaf, fruit and twig litter as well as aerial pollen of pines and other plants into the waterways. Not all of the shoreline of the Heron Lagoon system is vegetated with mangroves. The waterways are overgrown with Brazilian peppers (Figs.34,35,36) and bordered by Australian pines in several areas. One can readily see the accumulation of leaves and pine needles in slack water areas of waterways and eddies near culverts (Fig.37). In these spots the bottom is covered with soft organic deposits.

While the significance of these accumulations is not known, their potential for lowering or altering "water quality" is present. On the one hand, the decaying litter may provide both organic and inorganic nutrients for marine food chains. The active microbial activity involved in decomposing this litter can lower oxygen tensions in the water. Organic substances present in the litter of upland species of native plants as well as ornamentals may actually be as poisonous to marine life as the more obvious man made biocides.

We do not know how much plant litter enters the Heron Lagoon waterways annually nor the effects of this litter on marine life. One pilot experiment, however, showed that over a three day period in November, 1973 some

19.3 gm (dry wt.) of Australian pine needles and fruit fell on a 3 square meter dock surface. Few plants grow beneath Australian pines. Is this because their litter releases plant growth inhibitors? We do not know the answer, but if this were the case we might expect similar inhibitory effects on the phytoplankton and macro-algae in the water. At the very least the litter from the shore and upland plants is partially responsible for the brownish color of the water in the Lagoon and waterways. At the same time, the seasonal rain of pollen forms the yellow green "scum" on the water's surface as well as providing a rich source of organic nutrients for the microbial flora in the water.

Grand Canal. The upland drainage basin delineated by roads around the peripheries of the canal system is approximately 531 acres. As of March 1973 some 739 residences fronted on the canal and 98 lots remained undeveloped. The number of dockside powerboats was 346 in July, 1972 and 291 in March, 1973. It is unknown how many others were in use at the times of counting. These boats ranged in size from 12 foot outboard runabouts to cabin cruisers. The pollution potential from motor boat activity is there but yet to be studied.

Because all the houses on the canal system are on SKUA lines there is little pollution from domestic wastes. Abandoned septic tank systems do occur in the older subdivisions. The major human waste discharged into the Grand Canal, Roberts Bay and Big Sarasota Bay are summarized in Table 3. Next to the City of Sarasota's discharge into Whitaker Bayou, SKUA's daily treated discharge into the Grand Canal is the largest single sewage discharge entering the Sarasota Bay system (McNulty et al., 1972). While the SKUA outfall water is treated and monitored to meet State of Florida standards, "adverse" conditions have prevailed, especially during and following major storms like the one of June, 1972 when about 5.6 inches of rain fell in 36 hours.

In addition to the SKUA discharges the water quality in the canal may be affected by discharges from Phillippi Creek which drains both urban and agricultural lands. While the actual distribution of Phillippi Creek discharges is not known, fragmentary hydrographic data indicate that at least part of the discharge enters Roberts Bay and thus could enter the Grand Canal system.

Interestingly, variations in discharges from Phillippi Creek parallel monthly rainfall (Figs. 20 & 21) thus confusing the general impression that freshwater runoff into the canals is a major contribution to altered water quality in the canals. No one knows how much freshwater runoff actually enters the canals. Most houses along the canal are built on "raised pads" of soil and the yards slope toward the seawalled canals. Since the sea walls are capped and extend a few inches above the ground they form a dam for sheet water run off in all but the heaviest rains. Furthermore, the soil is porous, well drained and has little water holding capacity. Thus until proven otherwise we propose that the major routes of surface water run off into the canals are through public storm sewers, cracks and subsurface tile drains in the sea walls, and ground water intrusion through the canal beds proper which act as chemical filters.

Table 3

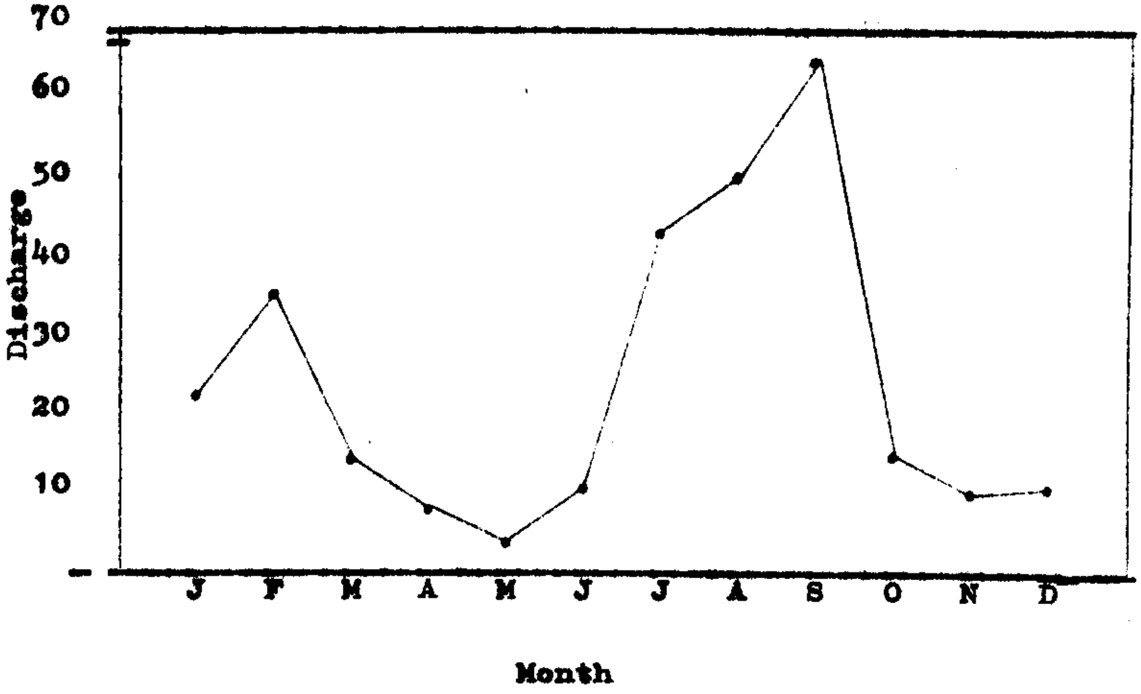
MAJOR WASTE WATER DISCHARGES ENTERING ROBERT"S BAY DIRECTLY OR INDIRECTLY VIA GRAND CANAL OR PHILLIPPI CREEK. (Adapted from McNulty et al., 1972.)

Source of Waste Discharge	Receiving Waters	Average Daily Discharge or Capacity in Gallons/day.
SKUA	Grand Canal	800,000[1]
Casa Mar Apts.	Grand Canal	9,000
Nine Outfalls	Phillippi Creek	457,000
Field Club	Robert's Bay	6,000
Sarasota (City)	Whitaker Bayou	6,200,000

[1] As of June, 1972, discharge water contained 7-10 ppm phosphate; 0.7, 0.9 ppm chlorine after 6 hours of contact. Nitrate-nitrite not measured. (W.Murphy, personal communication, June, 1972). Estimated average 5-day B.O.D. in discharge of 16 ppm (McNulty et al., 1972).

FIGURE 20

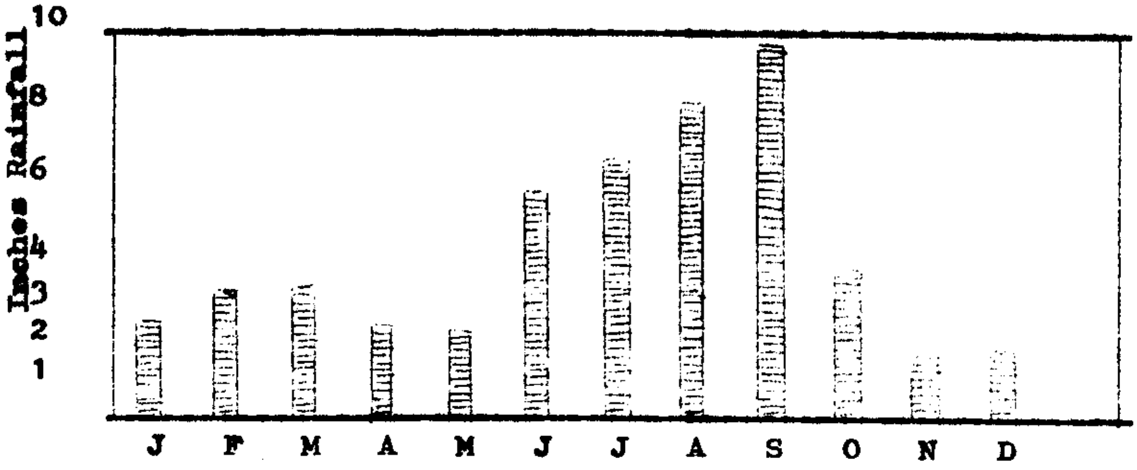
Philiippi Creek stream discharge to Robert's Bay and Little Sarasota Bay. Mean monthly discharge in cubic feet per second for 1963 - 1966, U.S.Geological Survey Station 2-2997.5* (McNulty et al., 1972).



* Drainage area 24 square miles.
Maximum discharge 826 C.F.S., July 30, 1965

FIGURE 21

Twenty-five year averages of monthly precipitation, Sarasota, Florida (From H. Bacon, *Come on in the Weather's Fine*. Sarasota Bank and Trust Company).



As in Heron Lagoon, ornamental and native plant litter is a hidden pollution factor in the Grand Canal System. In parts of the Palm Island Circle Canal the Brazilian pepper trees have overgrown the canal margins. (Fig. 16).

A final source of "pollution" in the canals as well as bays is rainfall. While outside the pervue of the present study, it is an environmental parameter the New College Environmental Studies Program is eminently qualified to pursue. The nutrient potential in rainfall resulting in eutrophic conditions (algal blooms) in canal systems is illustrated in two recent studies. Reimold and Daiber (1967) report that total phosphorus concentrations in rainwater collected at Lewis, Delaware varied from 4.9 ug A per liter in winter-spring to 150 ug A per liter in the summer. The authors conclude that "atmospheric eutrophication" may be the cause of unusual phosphorous cycles in the marshes and coastal waters along the eastern coast of the United States. In another study (Allen et al., 1968) in Great Britain, total quantities of major plant nutrients in rainfall were (Kg/ha/annum) nitrogen 8.7-19.0, phosphorus 0.2-1.0, potassium 2.8-5.4, calcium 6.5-24.0, magnesium 2.9-6.1 and sodium 1.4.0-51.0. In a recent study titled Eutrophication Factors in North Central Florida Lakes (Environmental Protective Agency, Water Pollution Control Research Series 16010 BON02/72) Putnam et al. found that the nutrient content of rainfall varied as follows: total nitrogen, 0.01-0.67 mg/l; NH_3-N 0.01-0.86 mg/l; NO_3-N, 0.04-0.94 mg/l; organic PO_4, 2.2-230.0 ug/l; total PO_4, 20-70 ug/l.

Vitale and Sperry in their 1973 report to the Federal EPA titled Total Urban Water Pollution Loads: The Impact of Storm Water show that partially treated sewage is only one of the sources of urban water pollution. Between 40% and 80% of the total annual BOD and COD (chemical oxygen demand) entering receiving waters from the city is caused by sources other than treatment plants. Dog feces, papers, litter and plant materials are major factors. Natural processes of weathering of man made structures contribute large amounts of water borne inorganic materials including heavy metals.

It is interesting that the Grand Canal system is "peppered" with storm sewer outfalls (Figure 21a) draining surface waters from roads, non-guttered and curbed road margins, driveways, etc. Many of these outfalls are located at the upper ends of deadend canals. The Palm Island Loop of the Grand Canal alone has at least 13 storm sewer outfalls and concrete aprons draining directly from the perimeter roads into the Canal. Interestingly, the Palm Island Loop was one of the lowest water quality areas with the least number and kinds of benthic invertebrates we encountered in our study. It also has a very sluggish tidal circulation. This section of the canal functions then as an oversized cesspool. While it is yet to be demonstrated, one may expect accumulations of organic matter and toxic substances such as heavy metals in the vicinity of these outfalls.

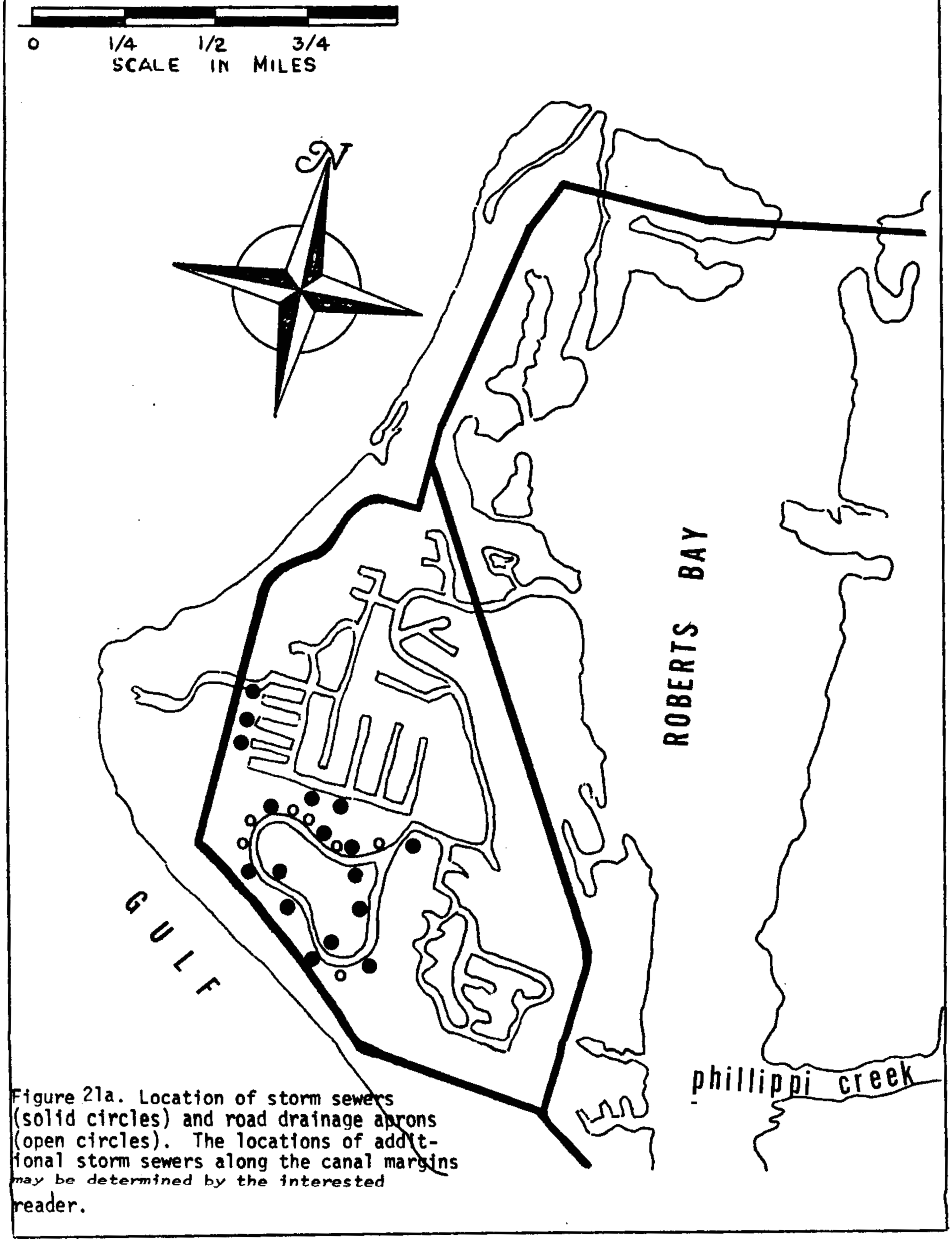


Figure 21a. Location of storm sewers (solid circles) and road drainage aprons (open circles). The locations of additional storm sewers along the canal margins may be determined by the interested reader.

HYDROGRAPHY

Two major hydrographic surveys were conducted on the Grand Canal (July 8-9, August 7-8) and Heron Lagoon (July 2-3, August 14) in 1972. Additional hydrographic data were obtained at irregular intervals before and after these studies. The field and analytical procedures are summarized in Appendix A.

The selection of hydrographic sampling stations was eventually limited by the accessibility of a station and the number of stations that could be sampled within a 2-hour interval. The collection of samples for chemical assays was limited to dawn and dusk surface water samples at 6 stations in each of the two canal systems because of limited manpower and laboratory facilities.

Sampling Stations. Figure 22 shows the locations of the eighteen hydrographic stations for the Grand Canal system. Table 4 describes the location of the stations. Dawn and dusk sampling for chemical analysis were limited to Stations 1, 4, 15, 10, 9, and 14 which were located along the Grand Canal between the entrance (Sta. 1), SKUA (Sta. 15), Palm Island (10, 9) and Siesta Isles (14).Figures 23-28 show views of the Canal at these hydrographic stations. The hydrographic stations in the Heron Lagoon system (Fig. 29, Table 5) were selected mainly on their accessibility from nearby roads. Again dawn and dusk samples for chemical analysis were taken at all stations except Stations 2 and 5. Figures 30-35 show views of the Heron Lagoon Waterways at several hydrographic stations.

Rainfall and Tides. During the course of this study the monthly cumulative rainfall reported in the Sarasota Herald Tribune was as follows: June, 6.96 inches of which some 6.5 inches occurred during Hurricane Agnes; June 12, ; July, 3.82 inches; August, 7.07 inches. No rain fell during or on the day prior to each of the hydrographic surveys. Thus we conclude that the hydrographic conditions in the canals and bays during this study were not directly affected by rainfall.

Since the water in the canals and bays is affected by the ebb and flood of tides as well as day-night light cycles the times and heights of Sarasota Bay tides for the sampling dates are summarized in Table 6. We tried to choose sampling dates in July and August where the times of high and low water were similar. However, this was not operationally possible. As we later learned (Langdon Ross, Florida Pollution Control Board, personal communication), water sampling programs of canals should strive to sample the canal waters at dawn on ebbing tides since this is when the canal waters are expected to have the lowest "quality" with respect to pH, D. O., and nutrients. In our study dawn samples were collected on rising tides and dusk samples on ebbing tides.

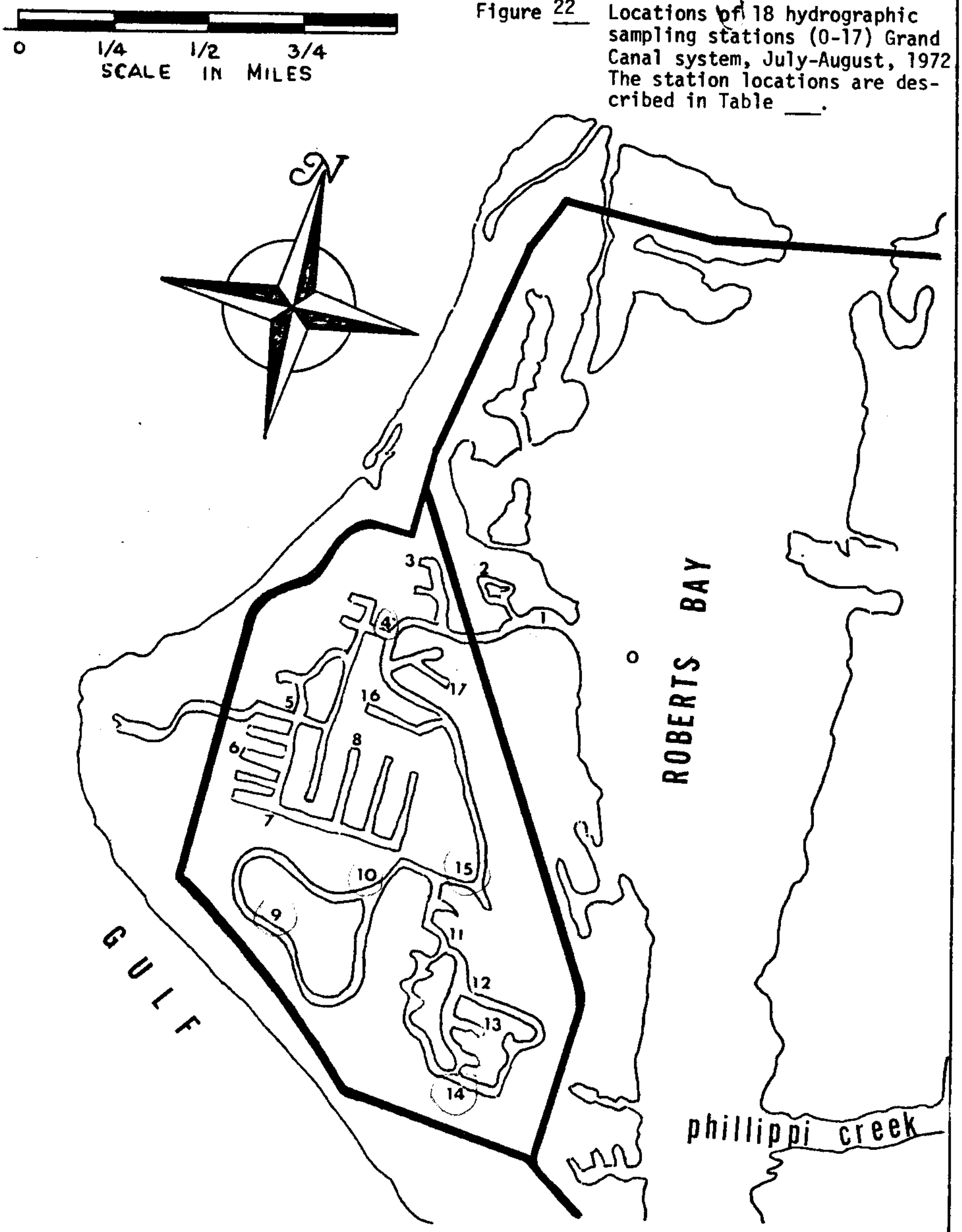


Figure 22 Locations of 18 hydrographic sampling stations (0-17) Grand Canal system, July-August, 1972. The station locations are described in Table ___.

TABLE 4

HYDROGRAPHIC STATIONS GRAND CANAL SYSTEM

JULY - AUGUST, 1972

Station No.	Location
0	Roberts Bay 200 yards southeast of entrance to Grand Canal and south of large spoil island.
1	Bend in Canal 50 yards west of Canal entrance.
2	West arm of Bay Point Canal.
3	Upper end of Waterside Wood Canal.
4	Grand Canal at junction with Ocean Beach Canal east of Higel Avenue.
5	Junction of Harmony Canal and Paradise Island Canal systems.
6	Dead end of one Paradise Island Canal.
7	Junction of Sarasand and Siesta Manor Canals.
8	Dead End of one Sarasand Canal.
9	West side of Palm Island north of Calle Florida Bridge.
10	Junction of Palm Island Canal loop.
11, 12, 13, 14	Siesta Isles Canal system.
15	Grand Canal 20 feet off of SKUA outfall.
16	Dead end Waterside West Canal.
17	West branch, Waterside East Canal.

Figure 23. Grand Canal, area of Station 1 near entrance to Grand Canal.

Figure 24. View from Higel Avenue bridge of Station 4 at the junction of the side canal and Grand Canal in the background.

Figure 25. Grand Canal at Station 15. The sea wall at the left is the edge of SKUA property. Barely visible in the upper left area of the waterway is a mass of white foam near the SKUA outfall.

Figure 26. View of Palm Island area. Station 10. In the foreground is a pruned hedge of white mangroves along the non-seawalled shore of the Avenue del Norte Parkway.

Figure 27. Palm Island Waterway. Adjacent to Canal Road, Station 9.

Figure 28. Siesta Isles Waterway in vicinity of Station 14.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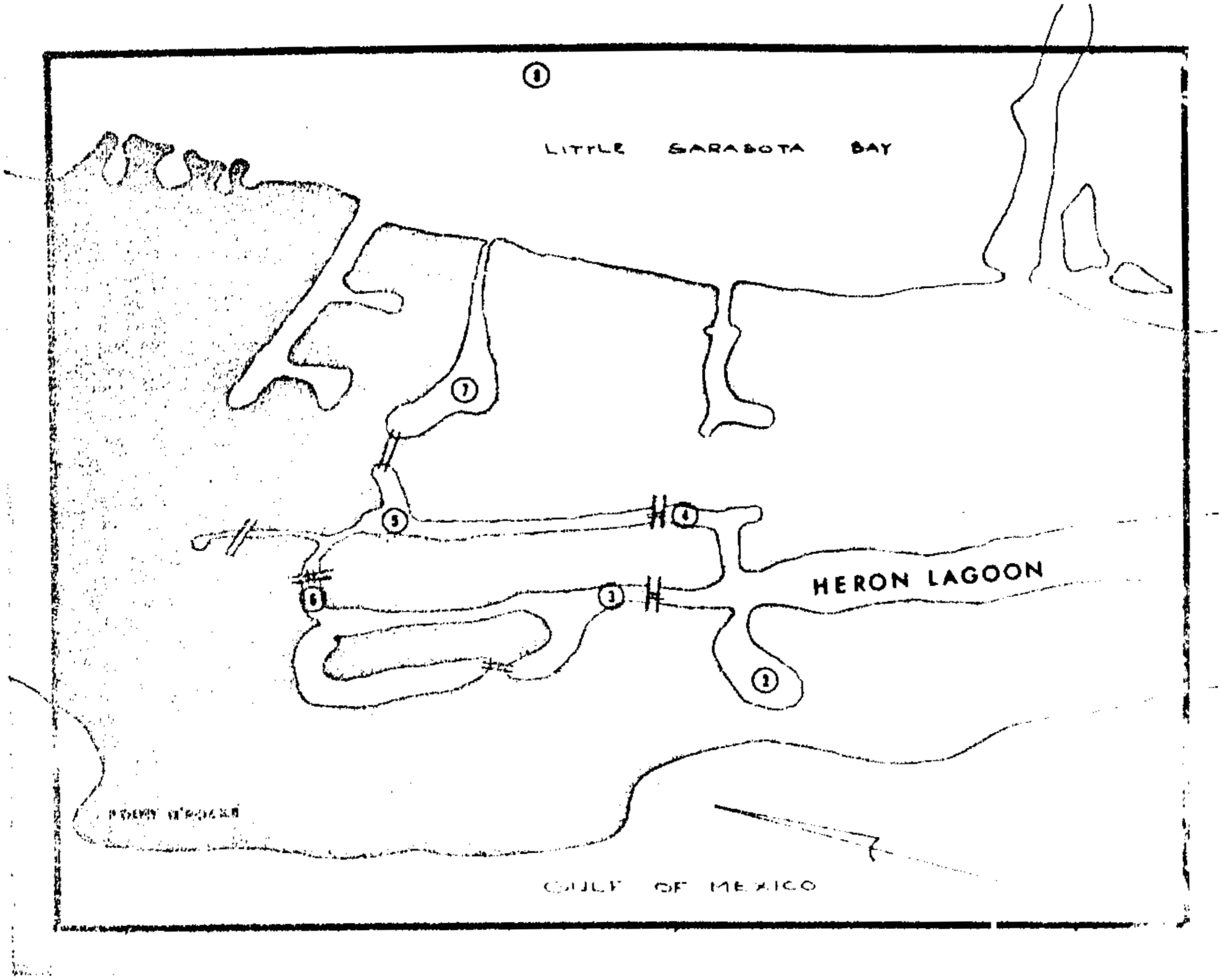

Figure 29 Location of hydrographic stations 2 through 8 in the Heron Lagoon system. Station 1 was the foot bridge at the southern end of Heron Lagoon proper. The stations are described in Table 5.

TABLE 5

HYDROGRAPHIC STATIONS IN HERON LAGOON

WATERWAY SYSTEM, JULY - AUGUST, 1972

Station No.	Location
1	Center of foot bridge south end of Heron Lagoon.
2	Heron Bay by Sanderling Road.
3	Midwaterway culvert, Sanderling Road.
4	East Waterway culvert, Sanderling Road.
5	Dock, north end East Waterway.
6	Pine Needle Road culvert, North Waterway.
7	Boat Basin, Siesta Club.
8	Little Sarasota Bay, 100 yards east of entrance to Siesta Club Boat Basin.

Figure 30. Heron Lagoon, boat basin, Station 7.

Figure 31. Heron Lagoon, Station 2 looking east from Sanderling Road.'

Figure 32. Heron Lagoon East Waterway. Station 4 looking south. Note that the lawn of the yard extends over the 3 to 4 foot high bank down to the pruned red mangroves.

Figure 33. Heron Lagoon, East Waterway. Station 4, looking north. The overgrowth of vegetation is primarily Brazilian pepper and white mangroves.

Figure 34. Heron Lagoon, Mid Waterway. Station 3, looking north.

Figure 35. Heron Lagoon, Mid Waterway, Station 3, looking south toward Heron Lagoon. The Waterway is partially overgrown by Brazilian pepper and mangroves.

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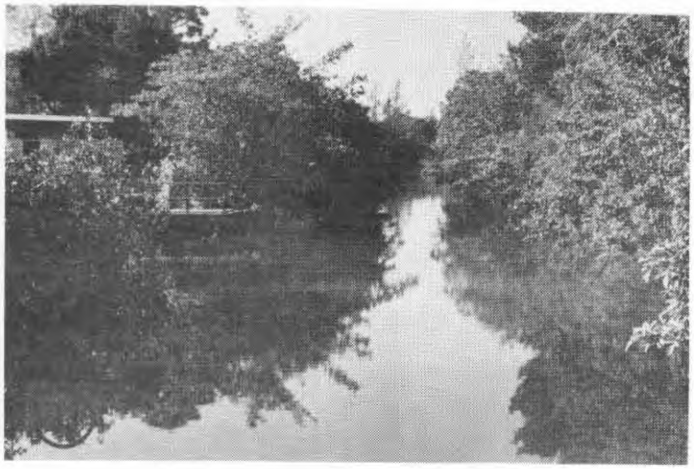

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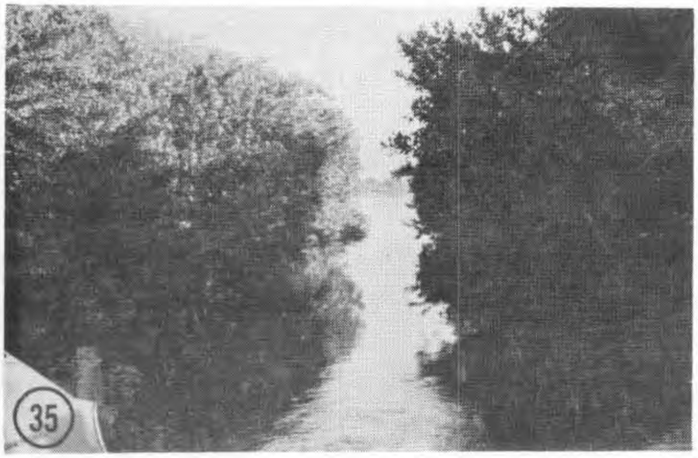

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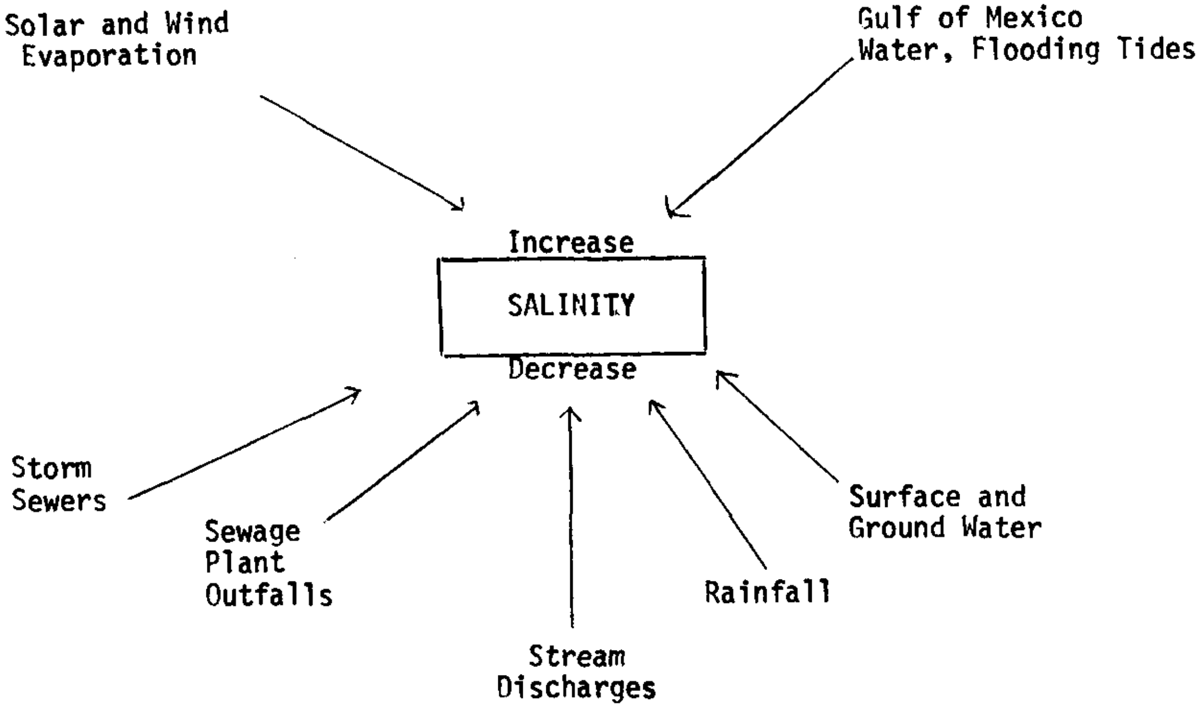
Table 6 Sarasota Bay tides for dates of hydrographic surveys, July, August 1972. Times of high and low water and height in feet above mean sea level are from the "Sarasota Herald Tribune".

	High	Low	High	Low	High	Low	High	Low
Grand Canal								
July 8	1011	2.6	1930	-0.2	-	-	-	-
July 9	1107	2.7	2021	-0.3	-	-	-	-
August 7	0240	1.5	0604	1.2	1301	2.5	2111	0.2
August 8	0249	1.5	0704	1.1	1348	2.4	2135	0.4
Heron Lagoon								
July 2	0534	1.7	1147	1.0	1655	1.8		
July 3	-	-	0015	0.5	0615	1.8	1317	0.8
August 14	0354	2.0	1116	0.6	1652	1.7	2249	1.1

Salinity

Daily and seasonal fluctuations in the salinity of surface and subsurface waters in the two canal systems and their adjoining bays are summarized below.



Among the questions we examined were: 1) differences in salinities of surface, mid depth and bottom waters in the canals and bays over day-night and tidal cycles, 2) salinity fluctuations within each canal system, 3) fluctuations in surface water salinity following heavy rainfall, and 4) the distances which water from the bays may extend into the canal systems.

Grand Canal. During July and August, 1972 the salinity in the bay varied from 36‰ to 28‰. Our measurements represent then salinity condictions in these months when there is little or no rainfall. Figure 36 illustrates the variations in salinities of surface waters on flood tide at dawn and ebb tide at dusk in different regions of the Grand Canal system. Our data from two hydrographic surveys indicate the salinity profiles in the canal system are affected by freshwater discharges ground water seepage and stratification of water layers.

On flood tide the salinity of the surface water decreases from the Roberts Bay to Station 15. Above Station 15 there is a measurable drop in salinity in the Palm Island, Siesta Isles and Sarasands - Paradise Isle areas. The surface water salinity at Station 7 is particularly low suggesting a local source of freshwater intrusion in this area of the canal system or else water from the SKUA outfall being transported into this and other areas of the upper canal system. In the dead end canals off the Grand Canal bayward of Station 15 the surface salinities are relatively high.

The surface water salinities on ebb tide (Fig. 36) differ from those on flood tide. One could expect increases in salinities resulting from solar evaporation during the day. Contrarily, freshwater discharges or seepage would cause decreases in salinities at the canal stations. In the Grand Canal proper there is a general increase in salinity from Palm Island to the Bay. However, there is a marked decrease in salinity at Station 15 reflecting the freshwater discharge of the SKUA outfall. The influence of this fresh water discharge results in a measurably lower salinity at Stations 1 and 4 in the canal proper and possibly the waters in the dead end canals of Stations 16 and 17, but not Stations 2 and 3. On the other hand, lowered salinities at Stations 16 and 17 on ebb tide at dusk may reflect local sources of ground water intrusion in these canals.

In the Siesta Isles area (Stations 11, 13 and 14) the slightly lower salinity on ebb tide at the end of a bright sunny day could be caused by intrusion of outfall waters from SKUA and local ground water seepage. The latter possibility appears to exist in the Sarasands - Paradise Isles area (Stations 5, 6, 7, 8 - Fig. 36). Remember that the canals in this area were cut through poorly drained Arzell fine sand. That ground water intrusion is occurring at different places in the canal system is suggested by the bottom water salinities summarized in Table 7. The data indicate ground water intrusion is occurring at Stations 5, 6, 7, 8, 9, 13 and 14. While under normal conditions it is probably not sufficient to create brackish water conditions relative to the Bay, such ground water may carry nutrients and other materials into the canal in these areas.

Table 7 Heron Lagoon, minimal salinities (‰) in surface water on ebb tides

	Hydrographic Stations							
Date	1	2	3	4	5	6	7	8
May 18-19, 1972	34.6	35.1	35.5	35.8	35.4	36.3	36.3	37.5
*June 18, 1972					18.4			
July 3, 1972	33.8	34.2	34.2	34.2	-	33.6	34.0	34.8
Aug. 14, 1972	35.5	35.5	36.0	35.8	-	35.8	36.3	35.7
**Sept. 11, 1973	-	-	-	-	15.7	-	-	-
Sept. 12, 1972	-	-	-	-	21.4	-	-	-
Sept. 16, 1973	-	-	-	-	29.0	-	-	-
*** Dec. 16, 1973	-	-	-	-	9.6			

* 2 hours after rains of Hurricane Agnes ceased

** 1 hour after afternoon showers

*** 1 hour after rain storm

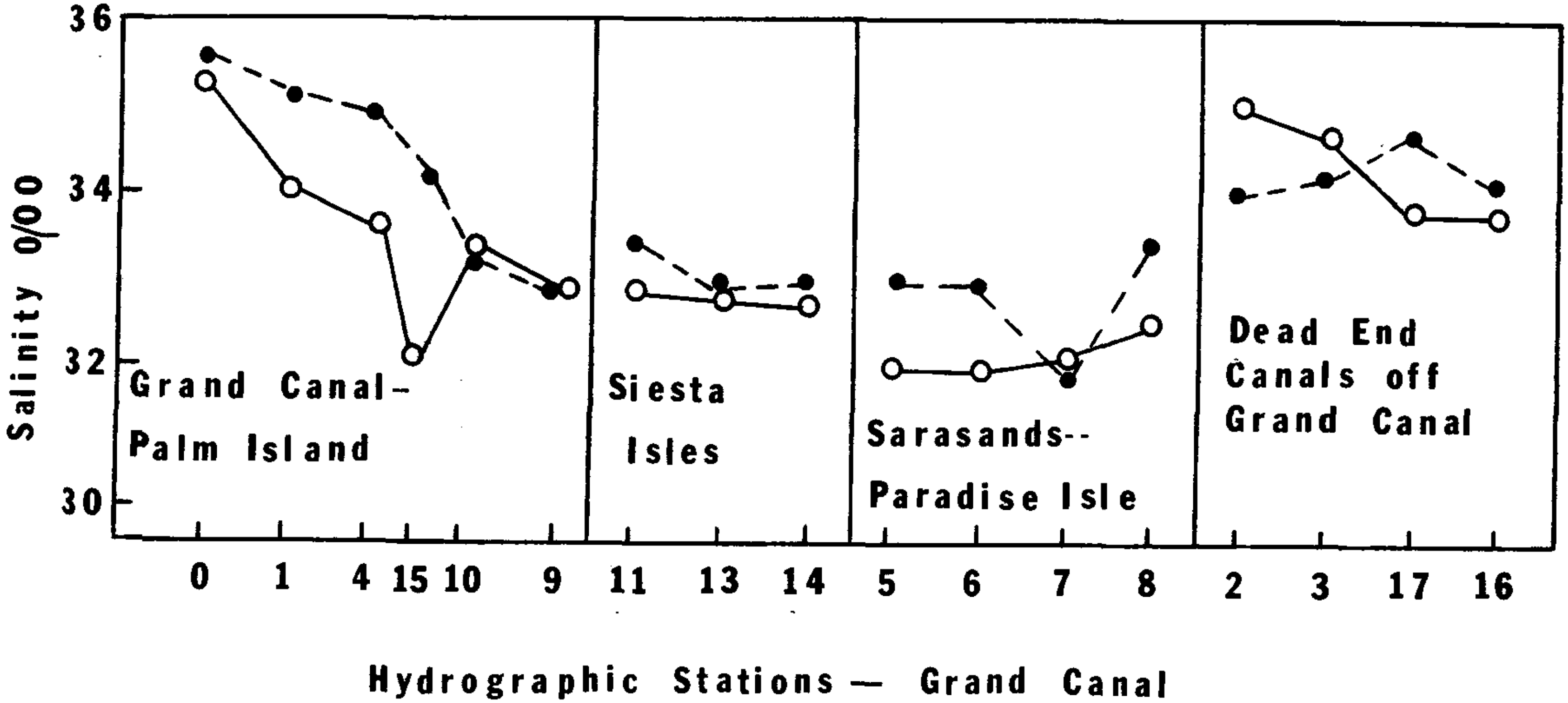


Figure 36 Surface water salinity (‰) hydrographic stations in Roberts Bay (Sta. 0) and the Grand Canal system July 8-9, 1972. Solid circles, dawn, flood tide; open circles, dusk, ebb tide.

Heron Lagoon. Table 7 shows that the minimal salinities at the sampling stations in Heron Lagoon proper and its waterways are similar to those in Little Sarasota Bay (Station 8) in May, July and August. The high salinity in the Bay on May 18-19 correlates with the low rainfall and solar evaporation typical for this month. While the salinities in the Heron Lagoon system are similar to those in Little Sarasota Bay there is evidence that the water from the Bay is being diluted by sources of fresh water seepage or discharge in the Lagoon system. Typically the salinity at Station 1 at the southern end of Heron Lagoon is one to two parts per thousand lower than at Station 7 in the Boat Basin near the entrance to the Bay. This is also reflected in the distribution of several species of macro invertebrates in Heron Lagoon.

Salinity readings taken at Station 5 following heavy rainfall (Table 7) show that the surface salinity in the waterways may fluctuate temporarily from 35.4‰ to at least 9.6‰. Interestingly enough, this latter salinity value was obtained 1 hour after a 3 hour thunderstorm. Within 12 hours later the salinity at this station had risen to 20‰.

From these sketchy data we conclude that the surface water salinity in the Heron Lagoon system may fluctuate widely throughout the year. Because of the relatively high perimeter to surface area ratio of this canal system ground water and surface water run off from the upland properties are the major causes of sudden decreases in salinity during and following rains.

Tidal Currents

A common belief is that there is little, if any, tidal circulation in dead end canal systems and that there is relatively little exchange of water in dead end canals with adjoining open waters of bays. However, the water level in canals rises and falls with the normal tides indicating a certain degree of exchange. Furthermore, our observations on surface and subsurface salinities throughout the Grand Canal and Heron Lagoon systems indicated there were tidal exchanges and flushing activity between these canals and adjoining bays. In order to determine the qualitative character of these exchanges we performed several preliminary tidal current studies using one gallon plastic bottles to follow tidal flow in the surface and subsurface waters of the canals during tidal cycles. While our results are of the most preliminary nature we include them here if only to raise questions that lead to future studies.

Grand Canal.On August 24, 1972 floats at the surface and 4 feet below the surface (mid-depth) were released at Station 1 at the beginning of a 6 hour flooding tide (Fig. 37). Within 5.5 hours both floats reached Station 15. The mid-depth float continued as far as Palm Island. Then when the tide turned to ebb both surface and mid-depth floats descended the Grand Canal proper reaching the entrance to the Bay in 4.5 hours, nearly 3 hours before low water. Neither sets of floats tended to drift into the dead end canals along the main canal.

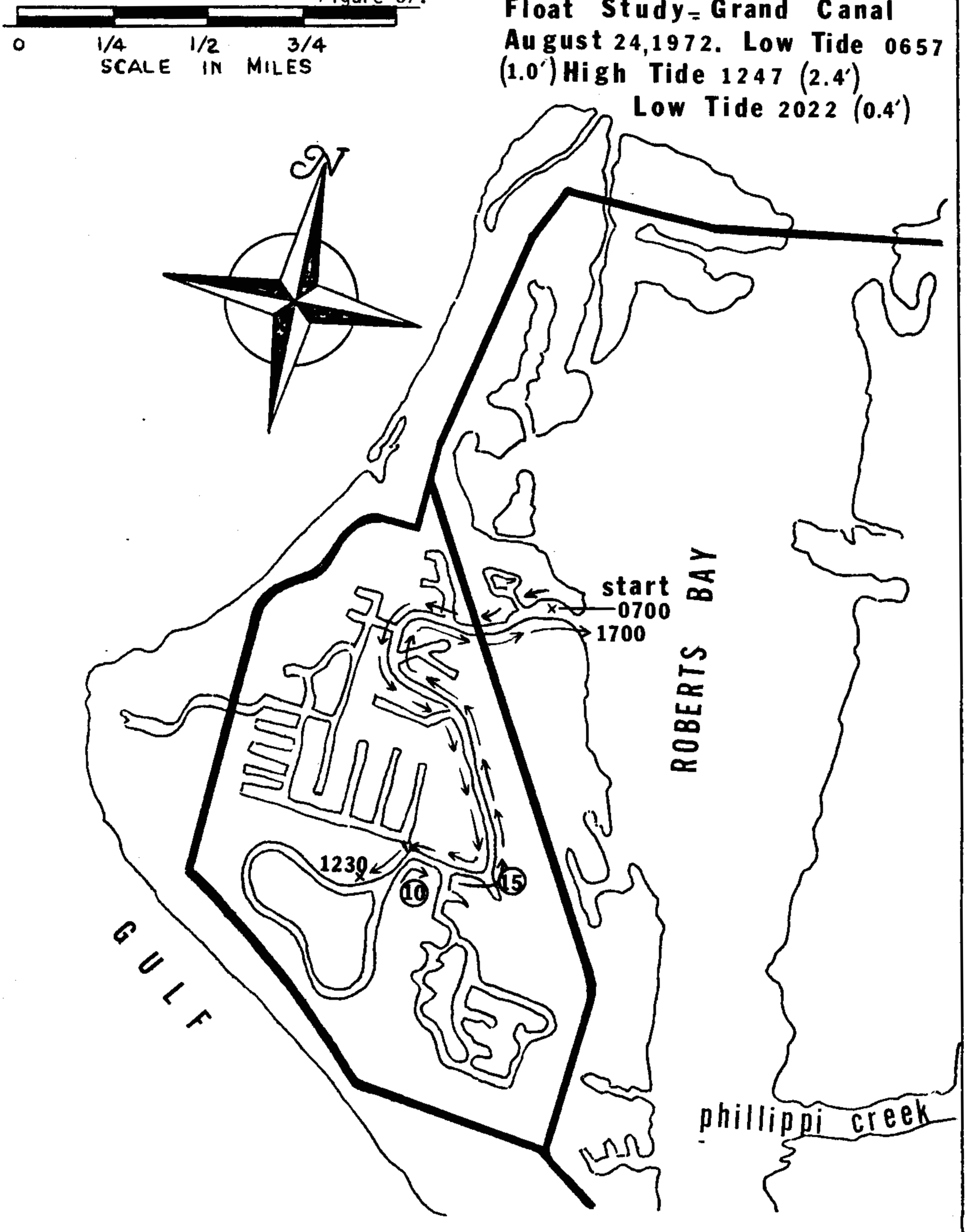


Figure 37.

Float Study - Grand Canal
August 24,1972. Low Tide 0657 (1.0′) High Tide 1247 (2.4′)
Low Tide 2022 (0.4′)

We tentatively concluded that the main tidal exchange of water between the Bay and the canal system occurred within the Grand Canal proper and that tidal exchange occurred between Station 10 and the Bay during most tidal cycles. Tidal exchange may be expected to be more extensive during spring tides and longer tidal cycles.

On August 28 and 29, 1972 surface and mid-depth floats were released on ebb tides in the Palm Island loop (Fig. 38) and near Station 12, Siesta Isles (Fig. 39). In both instances the floats traveled only a few hundred feet over a 4 to 5 hour period before the tide turned and began to flood. This suggests rather sluggish tidal circulation patterns and little flushing activity in these two segments of the canal system. While we know nothing about tidal circulation patterns in the Harmony Isles - Sarasands section of the Grand Canal system, we would expect tidal exchanges similar to that in the Siesta Isles area.

In addition to our own current studies, the only other current study on the Grand Canal is that of Benson and Brainard (unpublished) who determined tidal current velocities at the Midnight Pass bridge over 14 days in July, 1972. Once their data were "digested" it would be possible to determine the volume of water in the canal system that enters Roberts Bay on an average tidal cycle as well as tidal flushing exchanges.

Heron Lagoon. Preliminary tidal current studies in the Heron Lagoon waterways revealed complex patterns of circulation in the waterways. These patterns are difficult to interpret and would require an analysis beyond the scope of our investigation. In general there is tidal exchange between the northern end of Heron Lagoon, the waterways, and Little Sarasota Bay through the several road culverts. We do not know the rate of exchange of bay water with the waters of Heron Lagoon proper. From field observations we hypothesize that there is little tidal exchange in the southern half of Heron Lagoon.

Our tidal float study in the East Waterway is summarized in Fig. 40. Surface and mid-depth floats released at the Pine Needle Road culvert took 2 hours to reach the Midnight Pass Road culvert on an ebb tide. The surface floats tended to drift southward toward the Sanderling Road culvert. Floats released at this latter culvert tended to "waltz" in the area in eddy currents. Floats released on flood tide at the Midnight Pass Road culvert drifted down the East Waterway rather than toward the Pine Needle culvert. At the junction of the waterways (Fig. 40) surface floats tended to move in a large circle.

From these data we tentatively conclude that bay water enters the waterways and flows through the East Waterway on flood tide. On ebb tide Mid-Waterway via Pine Needle culvert is the main route of water movement. It appears that tidal circulation here involves a circular movement through the waterways thereby creating an open ended flow through tidal water movement in the equivalent of a dead end canal system. The role the water in

Figure 38.

Float Study, Palm Island Grand Canal Siesta Key

August 28, 1972

High Tide 1610 (1.7')

Low Tide 2147 (1.1')

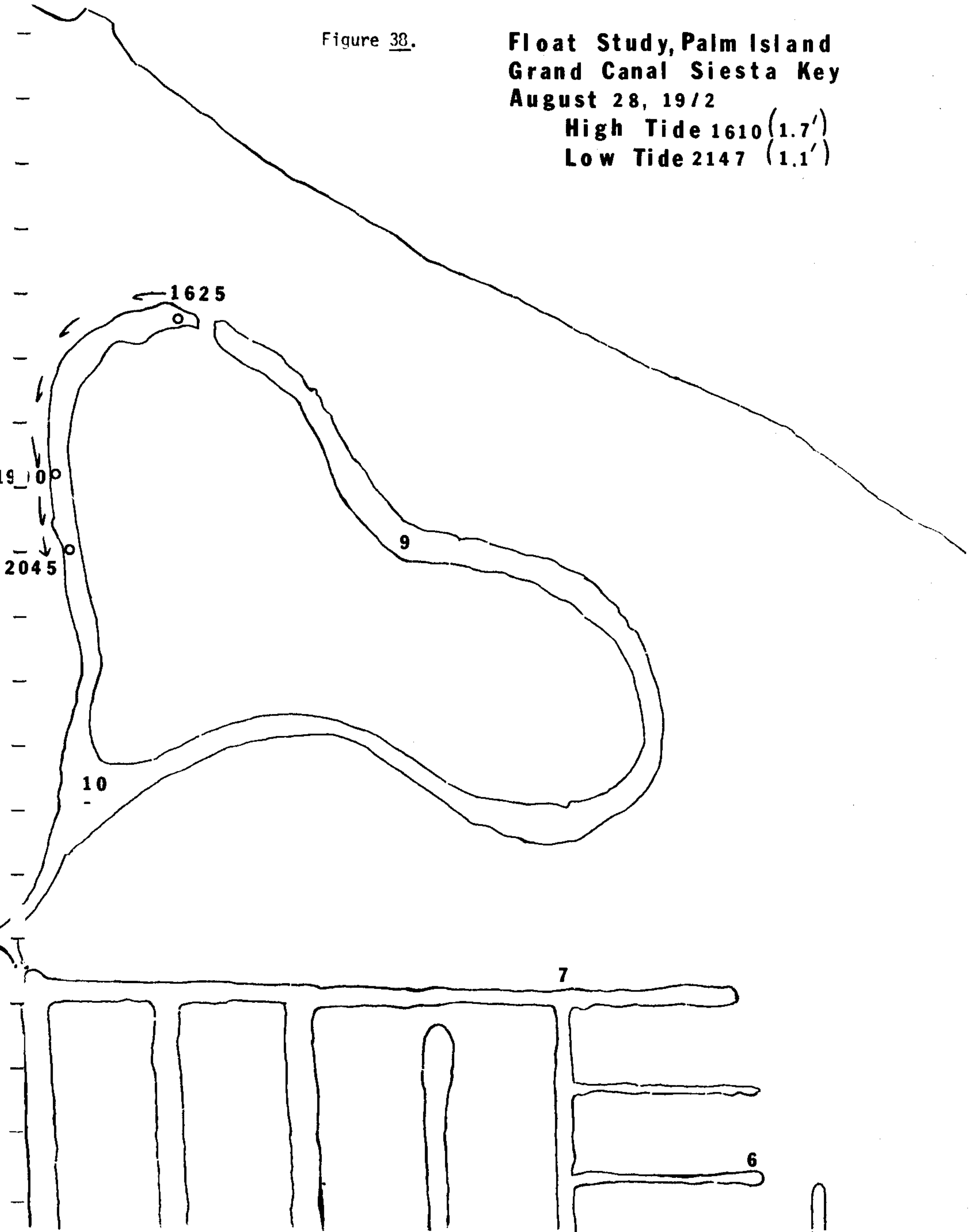
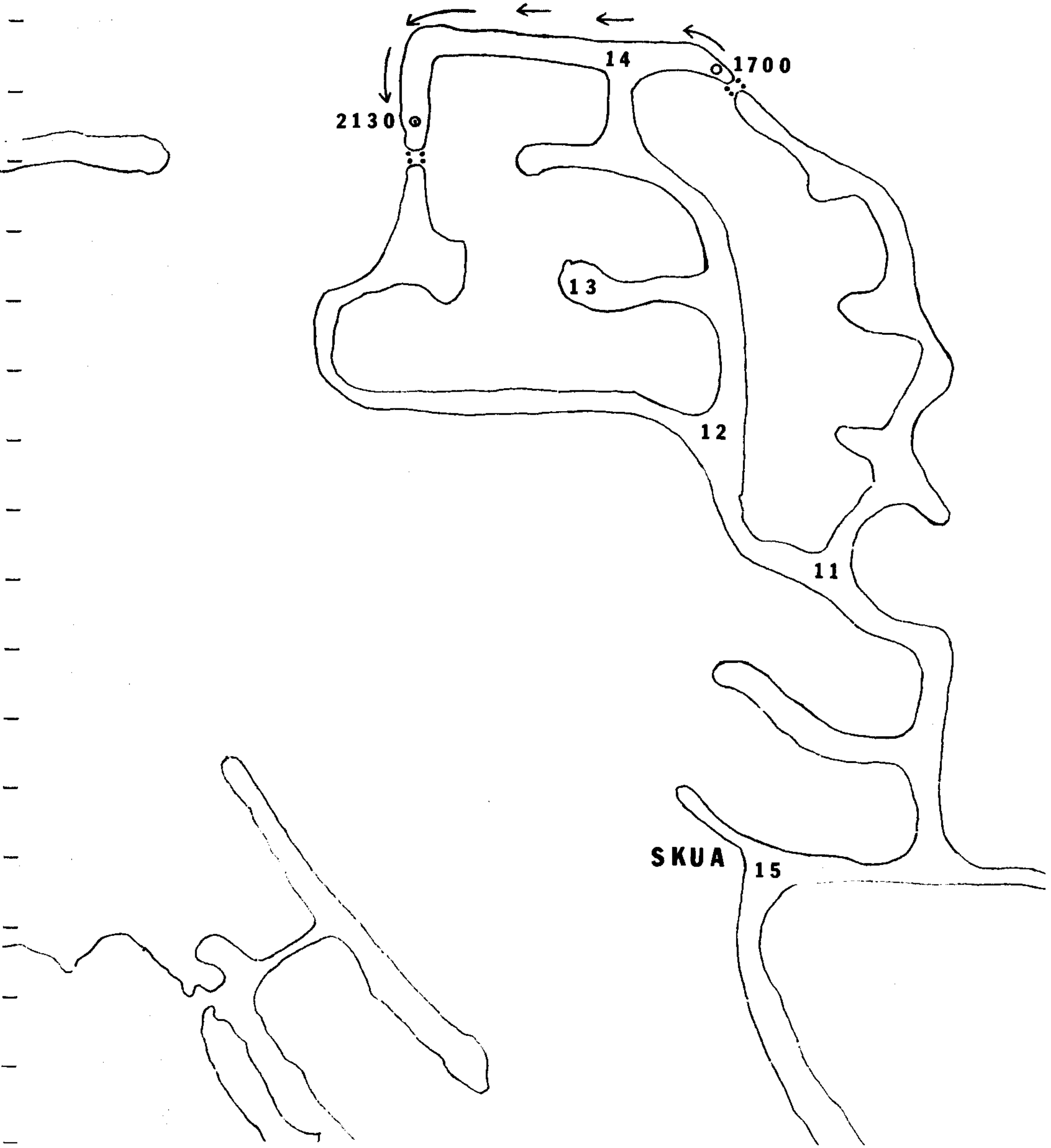


Figure 39.

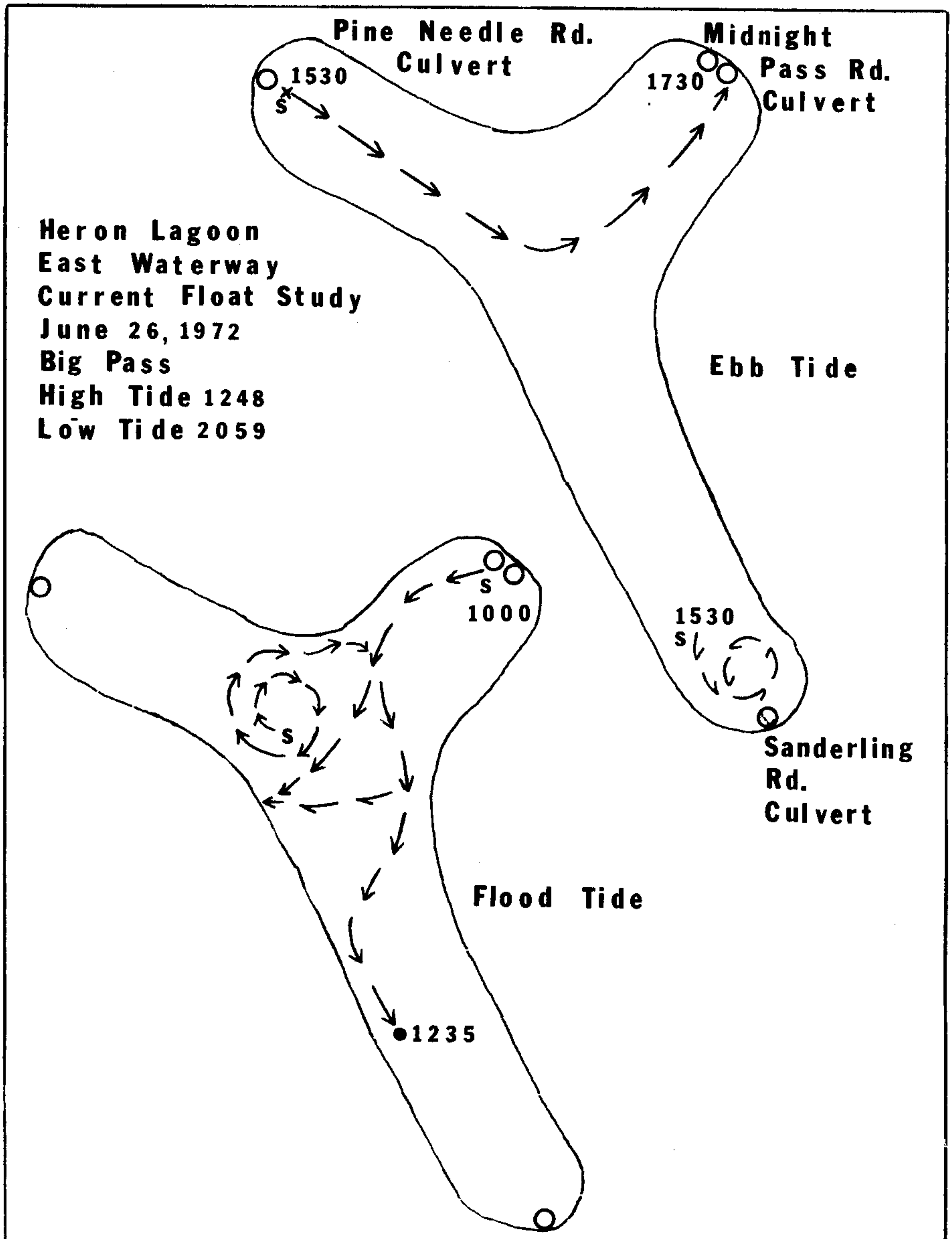
Float Study Siesta Isles
Ebb tide, August 29, 1972
High tide 1722 (1.5′)
low tide 2156 (1.2′)



Heron Lagoon plays in the hydrodynamics of tidal circulation here is not known. From an engineering vantage point this system is a model worthy of further study since it could provide clues as to how to improve tidal circulation in sections of the Grand Canal system and other upland canal systems.

On June 13 current velocities were measured with current meters at three waterway culverts - East Waterways, Station 4; Mid-Waterway, Station 3; and Pine Needle Culvert, Station 5 - during a tidal cycle. The results (Fig. 41) show that the velocities increased during flood tide at each station with the velocity highest at Station 4. Interestingly, the tide turned and ebbed first at Station 5. After the tide turned at Stations 3 and 4 the current velocity decreased and then increased before decreasing again. Whether this rebound effect as well as the actual velocities are due to the culverts themselves are not known. However, the general picture shown by these tidal current velocity data are not inconsistent with our tidal float data.

In summary, our sketchy tidal flow data of the two canal systems demonstrate that tidal circulation and tidal exchange is complex. More detailed studies are required before one draws conclusions regarding circulation patterns and particularly the amount of water in these canal systems that actually enters the adjoining bays. It is quite possible that during ordinary tidal cycles the bulk of the water that enters the bay on ebb tide is the same water mass that entered the canal system on flood tide. Water masses in the upper segments of both canal systems may only exhibit a slow exchange and mixing with bay water over long periods of time. If this were the case, then the pollution of the bays by canal waters may need to be reassessed.



Heron Lagoon
East Waterway
Current Float Study
June 26, 1972
Big Pass
High Tide 1248
Low Tide 2059

Figure 40.

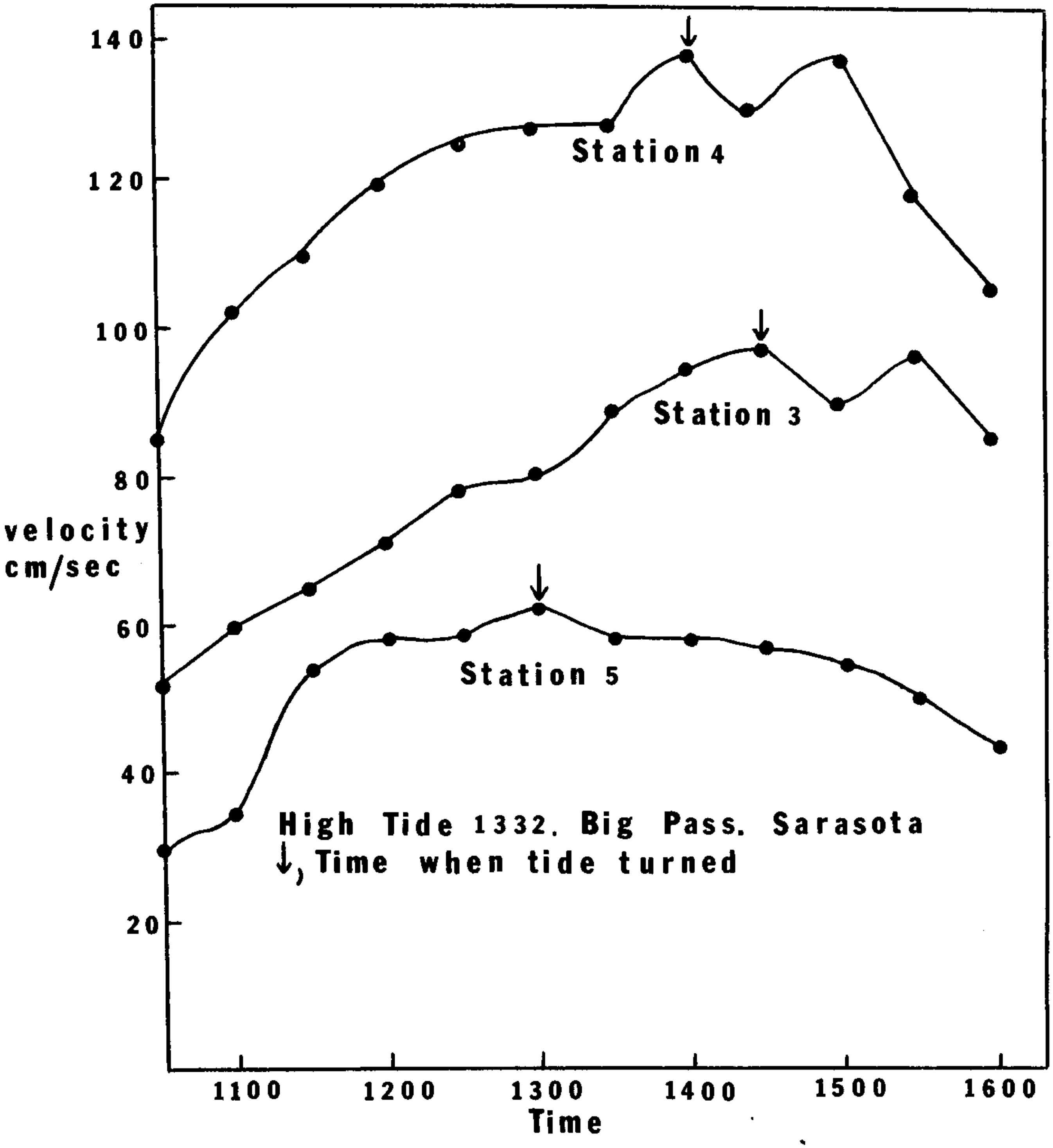


Figure 41. Current velocity during flood and ebb tide at hydrographic stations 3, 4 and 5, Heron Lagoon, June 13, 1972. Current readings taken at openings of 38 inch diameter road culverts.

DISSOLVED OXYGEN

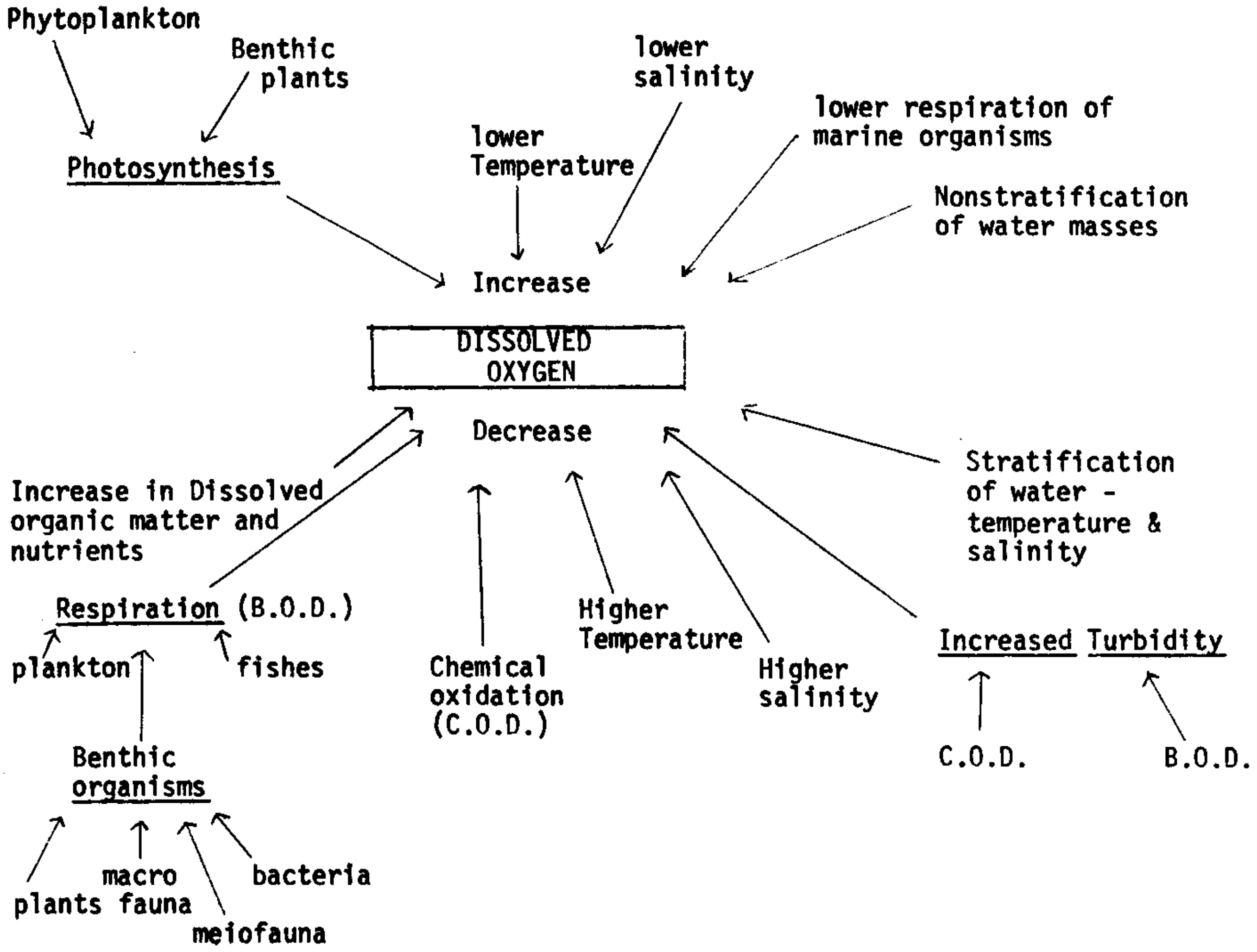
The amount of oxygen in the water and the daily fluctuations of oxygen concentrations at different depths during tidal regimes are the most frequently used measurement of assessing water quality. Throughout the literature on water quality there are statements indicating dissolved oxygen (D.O.) levels below 4.0 ppm are deleterious to marine life, particularly fishes. However, the dissolved oxygen requirements and tolerance limits of all but a few marine organisms are unknown. Of those organisms whose respiration and survival at different levels of dissolved oxygen is known, many are able to survive D. O. levels of 1.0 ppm for a few hours and D.O. levels of 2.0 ppm for several days (i.e., Federal Water Pollution Control Adm., 1968; Vernbetl, 1971; Doudoroff & Shumway, 1967). Pamatant (1971) found that benthic community respiration was relatively constant with decreasing oxygen tension to a critical level of 1 ml/liter.Fillos and Malof (1972) found that there was no appreciable release of nutrients, phosphate and ammonia from benthic deposits until the D.O. fell below 1.5 ml/liter. The literature on the comparative physiology of marine organisms shows that benthic organisms readily adapt to sudden changes in D.O. (i.e., Mangum, 1972). Nevertheless, the general impression is that chronically low D.O.s as well as occasional lowering of the D.O. in surface and bottom waters is biologically damaging (i.e., Dept. Poll. Control, 1973). In artifically created bodies of water like canals water movement is frequently minimal and the minimal D.O. levels lower and diurnal fluctuations greater than in adjoining waters of the bays. Whether one is dealing with the open waters of the bays or the waters of canals variations in D.O. are a function of the interaction of several factors outlined below. Briefly this function involves discharge of soluble organic material, nutrients, oxygen demand and rate of uptake of benthic deposits, photosynthesis and respiration by plankton and benthic plants, water temperature, freshwater input and tidal exchange.

In the present study we were interested in the following:

1) The maximal and minimal dissolved oxygen levels in various sections of the canal systems and the adjoining bays.

2) The maximal and minimal dissolved oxygen levels in the surface, mid-depth and bottom waters of the canals.

Although we measured dissolved oxygen at 6-hour intervals over 24-hour periods and complete tidal cycles, we limit our presentation here to measurements taken at dawn when D.O. values were minimal and dusk when D.O. values were maximal.


Phytoplankton
Benthic plants
Photosynthesis
lower Temperature
lower salinity
lower respiration of marine organisms
Nonstratification of water masses
Increase
DISSOLVED OXYGEN
Decrease
Increase in Dissolved organic matter and nutrients
Stratification of water - temperature & salinity
Respiration (B.O.D.)
plankton
fishes
Benthic organisms
plants
macro fauna
meiofauna
bacteria
Chemical oxidation (C.O.D.)
Higher Temperature
Higher salinity
Increased Turbidity
C.O.D.
B.O.D.

During the period of our study the 100% saturation level of dissolved oxygen in the waters of the canals and bays was approximately 4.5 ppm. Thus values above this level represent supersaturation. In the winter months higher saturation levels are to be expected.

Grand Canal. Figure 42 shows the maximal (dusk) and minimal (dawn) D.O. values in Roberts Bay and at six stations in the Grand Canal for July and August. The Bay shows the least dawn-dusk fluctuations in D.O.; Stations 15,14,10 and 9 the greatest fluctuations. Dawn surface D.O.s were lowest at Station 9. The highest D.O. readings were at Station 14 and correlate with high chlorophyll measurements at this station.

The differences in D.O. in surface and bottom waters at the 18 stations are illustrated in Table 8 . This table shows that the lowest surface (dawn) D.O. readings were in the Sarasands-Harmony Shores section of the canal system and Station 9, Palm Island as were the bottom water D.O.s. Low D.O.s occurred in the bottom waters at Stations 2, 16 and 17 at the upper ends of dead end canals (Figure 43). In mid-afternoon on the same date there was a marked stratification of dissolved oxygen in the upper sections of the canal system illustrated as follows:

Station	D.O. ppm Surface	Bottom
14	8.3	2.9
5 and 6	7.1	2.7

This D.O. stratification correlated with a salinity and temperature stratification. Interestingly, Stations 2 and 17 exhibited the lowest bottom water D.O.s at all times even though no marked stratification of salinity or temperature occurred at these stations.

Figure 43 shows that in the Grand Canal proper there was a progressive decrease in dissolved oxygen in the bottom waters between the canal entrance and Palm Island. However, at dusk on ebb tide the D.O. at Stations 0, 1, 4 and 15 was above the 100% saturation level. The D.O. in the bottom water above Station 15 had increased at Station 10, decreased at Station 9 and remained approximately the same at Stations 11, 13 and 14 in the Siesta Isles section compared to the dawn readings.

Heron Lagoon. The maximal (dusk) and minimal (dawn) D.O. values obtained for surface water at the eight hydrographic stations in the Heron Lagoon system are shown in Figure 44 . The minimal D.O. values at dawn were as low or lower than those for the Grand Canal. The maximal D.O. values were comparable to those from the Grand Canal system. The diurnal fluctuations were least at Station 8, Little Sarasota Bay and greatest at Station 2, Heron Bay.

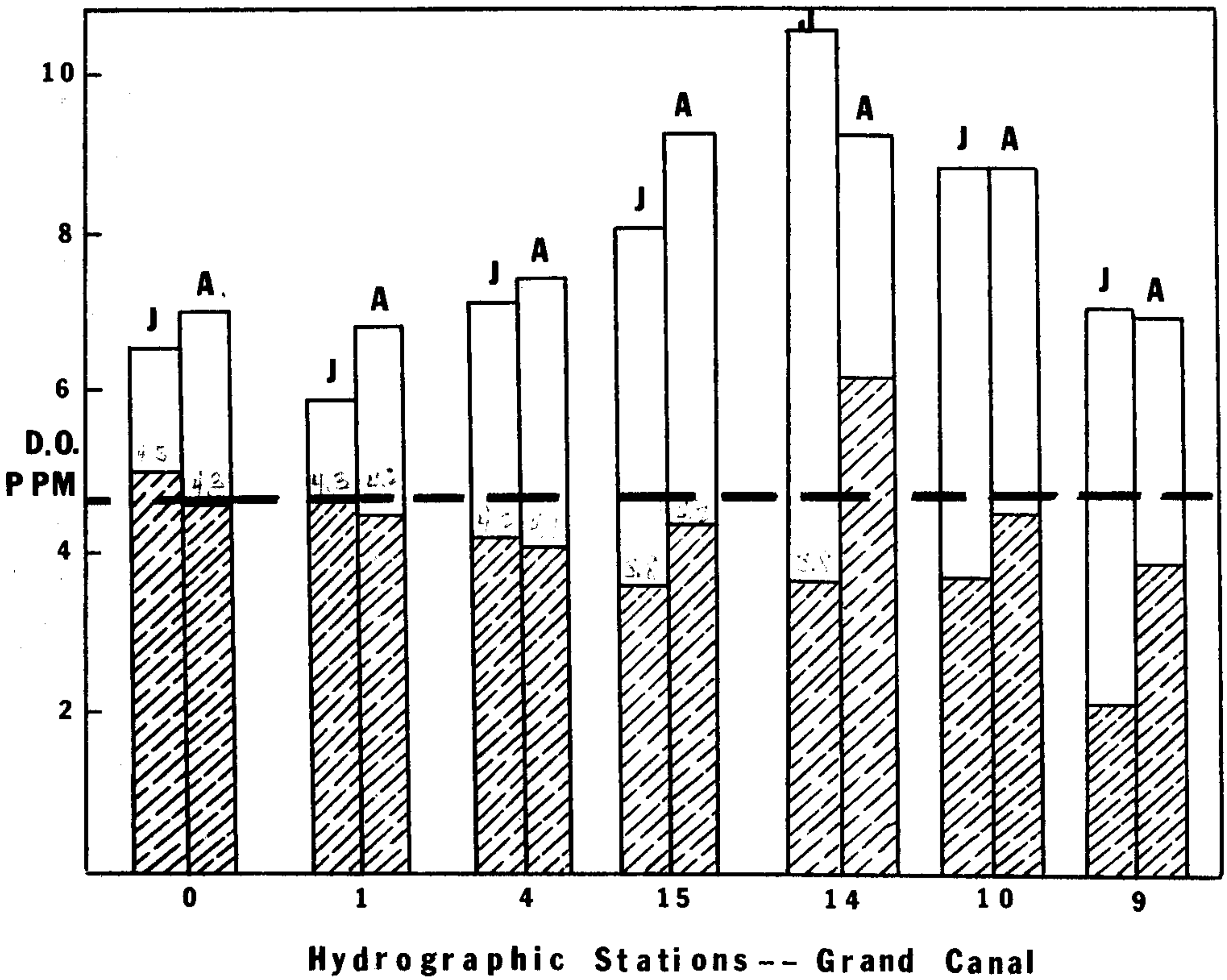
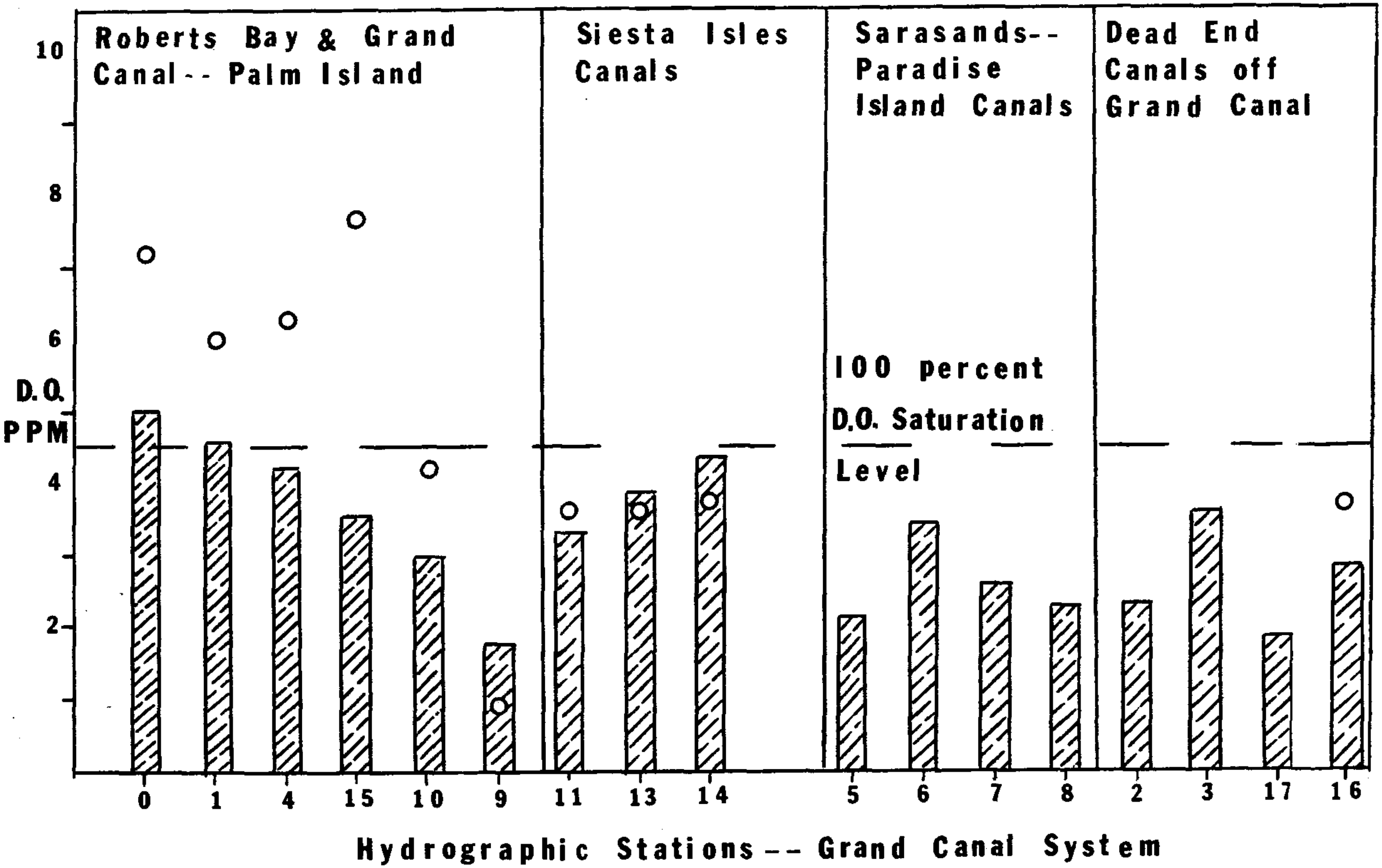


Figure 42 Maximum (dusk) and minimum (dawn) dissolved oxygen (ppm) 1 foot below surface in the Grand Canal system, July (J) 8, 9 and August (A) 7, 1972.

Table 8 Dissolved Oxygen, Temperature and Salinity in Surface and Bottom Water Grand Canal System, July 9, 0700 - 0900, Rising Tide

Station	Depth	Dissolved O_2(ppm)		Temp°C		Salinity ‰	
		Surface	Bottom	Surface	Bottom	Surface	Bottom
0	5	4.8	5.0	28.5	28.0	35.5	35.1
1	12	4.5	4.6	28.5	28.0	35.1	35.1
2	7.5	4.2	2.3	28.5	29.0	34.0	35.3
3	7	4.0	3.7	29.0	29.0	34.2	35.1
4	4	4.1	4.2	28.5	28.5	34.9	35.1
5	3	2.8	2.2	28.5	29.0	32.9	33.4
6	4	2.5	3.4	29.0	29.0	32.9	32.9
7	3	2.6	2.6	28.5	28.5	31.9	32.9
8	4.5	2.3	2.3	28.5	28.5	33.4	33.4
9	8	2.0	1.8	29.5	29.0	32.9	32.9
10	6	3.5	3.0	29.0	29.5	33.4	34.0
11	8	4.2	3.3	29.0	29.0	33.4	34.5
13	6.5	3.9	3.9	29.5	29.5	32.9	32.9
14	6	4.4	4.4	29.0	29.5	32.9	32.9
15	8	3.4	3.6	29.0	28.5	32.9	32.9
16	8	5.5	2.9	28.5	29.0	34.0	34.7
17	7	3.8	1.9	29.0	28.5	34.7	35.1

Figure 43 Dissolved Oxygen (ppm) Grand Canal System in water 1 foot above bottom of canals.
▨ Flooding tide down (0600-0800) July 9; O. Ebbing tide, dusk (17-1900), July 9, 1972
Note: No ebb tide readings for Stations 2,3,5,6,7,8 and 17.



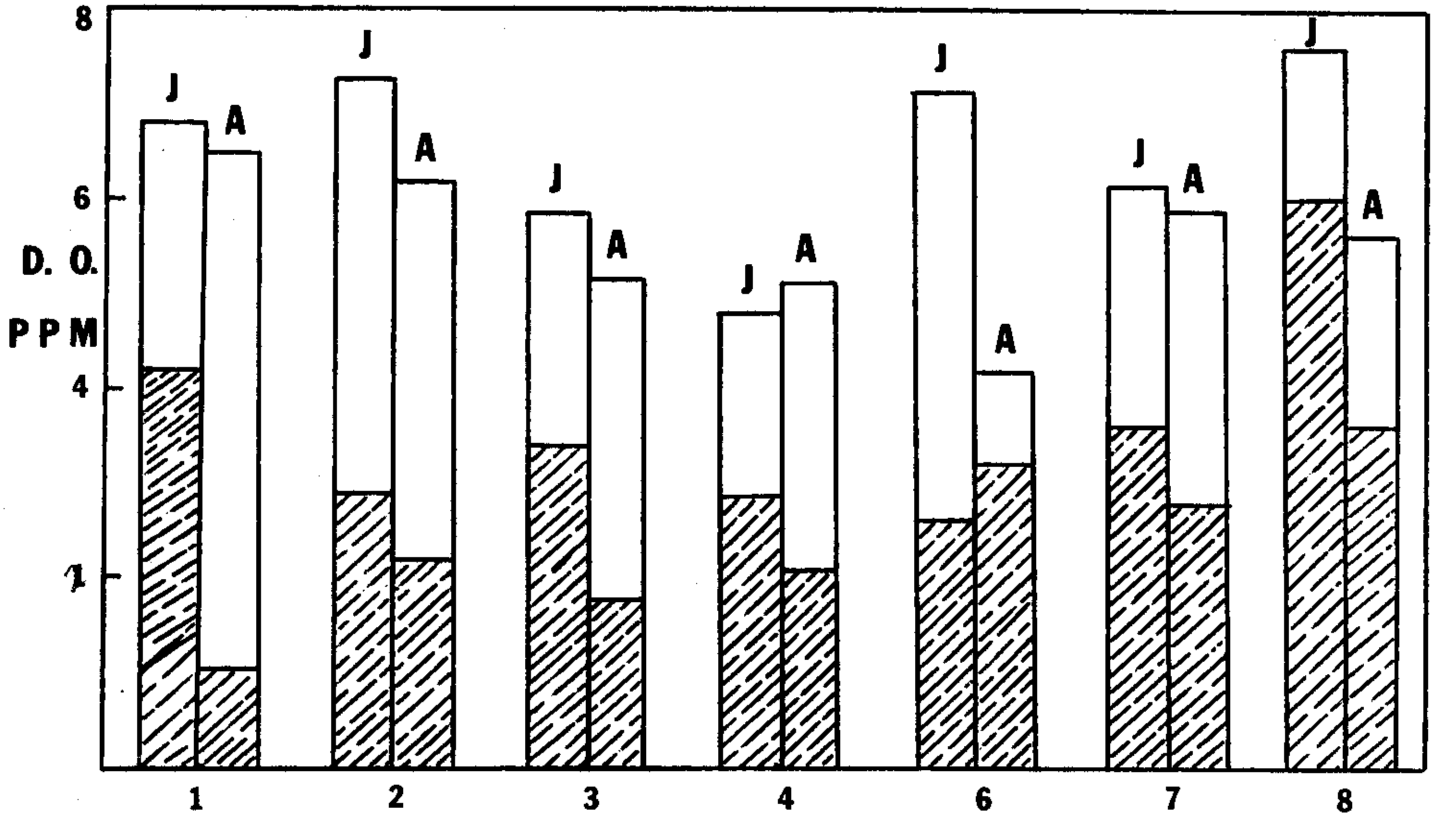


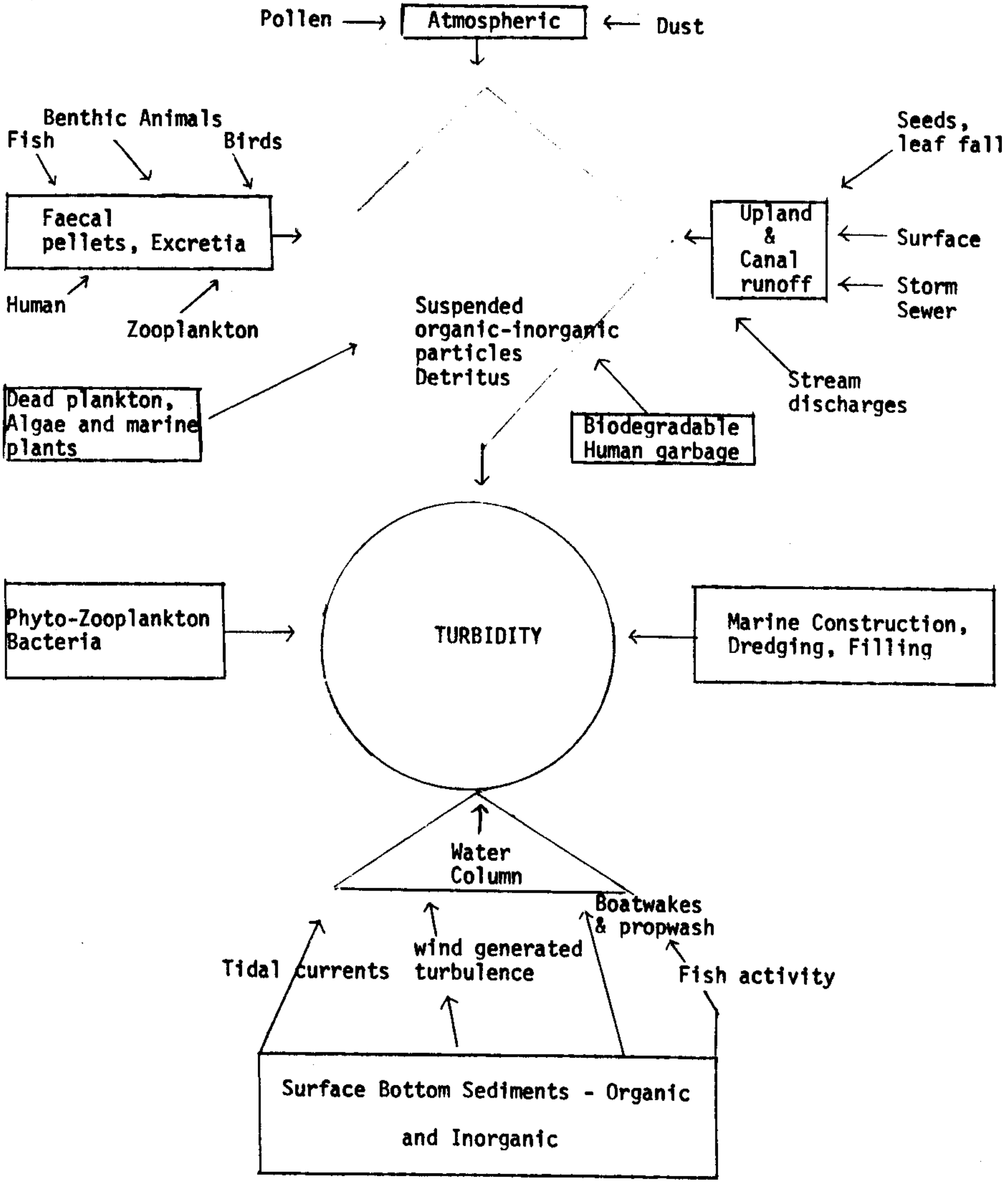
Figure 44 Maximum (dusk) and minimum (dawn) dissolved oxygen (ppm) 1 foot below surface in the Heron Lagoon system July (J) 3 and August (A) 14, 1972.

In conclusion, the larger diurnal D.O. fluctuations in the surface waters in the canal systems compared to the adjoining bays are probably due to the relatively large phytoplankton populations in the canal waters (Barda and Pantington, 1972). The photosynthetic activity of the phytoplankton during the day results in elevated D.O. values; at night phytoplankton and microbial respiration markedly lower the oxygen in the surface waters. The percent difference between dawn and dusk D.O. values may be used as a measure of eutrophication and basic productivity of waters in different sections of the canal systems. The low D.O. values in the bottom waters in the canal systems, particularly the upper sections and dead end canals of the Grand Canal system, are associated with chemical oxidation and microbial respiration at the surface of the bottom sediments and the relatively weak tidal circulation in these areas.

Studies on the oxygen uptake (respiration) by subtidal natural benthic marine communities show that up to 70% of the respiration can be due to bacteria (Kanwisher, 1962). In a recent study Smith (1973) found in a subtidal community off Sapelo Island, Georgia that macrofaunal respiration comprised 5 to 20%; bacteria 30 to 60%; and meiofauna 25 to 58% of the total community respiration. Sediment chemical oxidation in July accounted for about 8% of the total oxygen uptake.

TURBIDITY

Although there is a general lack of information on the effects turbidity has on marine organisms over long periods of time, turbidity is frequently measured in water quality studies. According to the Florida State water quality standards the turbidity of Class IV waters - agricultural and industrial water supply - "shall not exceed fifty (50) Jackson Units as related to standard candle turbidimeter above background." However, the use of Jackson Turbidity Units to measure turbidity has been criticized by May (1973) who points out that turbidity meter readings are unreliable and a questionable measure of the suspended solids in water. In the present study we used both a Secchi disk and a millipore filter technique for suspended matter [See Manheim et al. (1970) for a critique of the millipore method and open ocean values.] The degree of turbidity is a measure of the number of particles in suspension. An increase in the number of suspended particles increases the absorption of light in the water. In the shallow bays of the west coast of Florida nearly all the light is absorbed in the top 6 feet. This means that the euphotic zone of phytoplankton and benthic plants is limited to depths less than 6 feet. Periodic and seasonal variations in turbidity occur naturally. Dredging, spoiling and urban-agricultural runoff increase the turbidity thereby reducing the euphotic zone to less than 1 foot at times. In general, increases in turbidity result in lower oxygen concentrations in the water particularly at night; but the qualitative character of turbidity varies. The potential nature of the suspended particles causing turbidity is outlined below.


Pollen
Atmospheric
Dust
Benthic Animals
Fish
Birds
Faecal pellets, Excretia
Human
Zooplankton
Seeds, leaf fall
Upland & Canal runoff
Surface
Storm Sewer
Stream discharges
Suspended organic-inorganic particles Detritus
Dead plankton, Algae and marine plants
Biodegradable Human garbage
Phyto-Zooplankton Bacteria
TURBIDITY
Marine Construction, Dredging, Filling
Water Column
Boatwakes & propwash
Tidal currents
wind generated turbulence
Fish activity
Surface Bottom Sediments - Organic and Inorganic

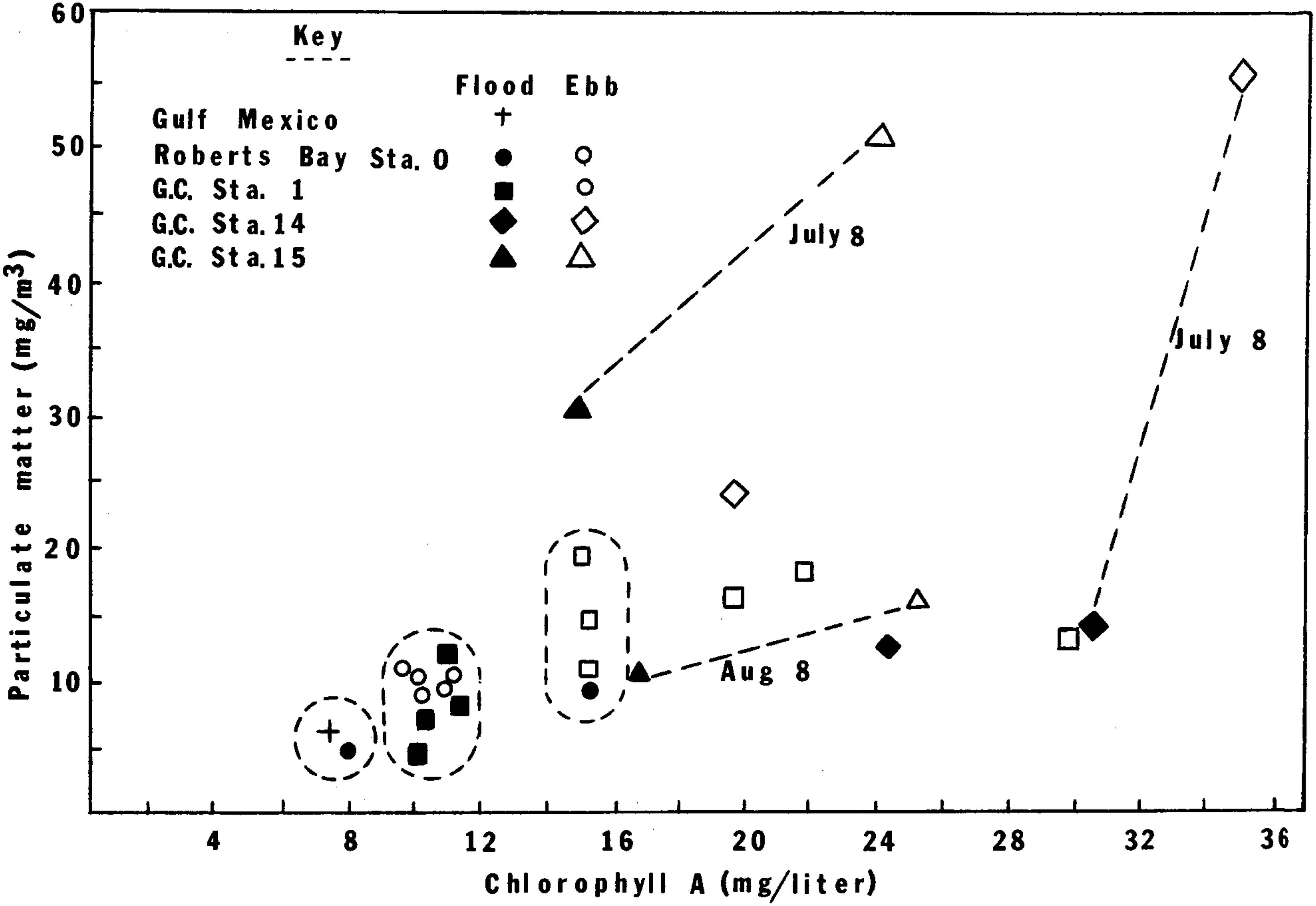
Increases in turbidity then can result in the following adverse conditions: 1) lower light levels and narrower euphotic zones, shorter submarine days, increased surfaces for bacterial adsorption and growth, competition with marine plants for minerals and other plant nutrients, and increases in the B.O.D. and C.O.D. levels in the water. At the same time resuspension of bottom sediments do provide a major source of nutrients for the production of organic matter by phytoplankton, bacteria and benthic plants. The complexities of increases in turbidity on water quality are illustrated in various reports and reviews (i.e., Gustafson, 1972; Oschwald, 1972; Manheim et al., 1970; Pionke and Chesters, 1973; Berg, 1970; Buchan et al., 1967; Trevallian, 1967; and Marshall and Orr, 1964).

In the present study we first attempted to measure turbidity or transparency of the water in the bays and canal systems using a Secchi disc. In general, the depth below the surface at which an 8-inch white disc is no longer visible approximates the depth of the euphotic zone at the time of measurement. In the Heron Lagoon system on July 3, 1972 Secchi disc readings ranged from 3.5 feet at Station 8, Little Sarasota Bay to 3.0 feet at Station 4, East Waterway to 2.5 feet at Station 1, south end of Heron Lagoon. Secchi disc readings on other dates were similar. All indicated a general increase in turbidity between the Bay and Heron Lagoon. In the Grand Canal system Secchi disc readings on July 8 ranged from 3.0 feet, Roberts Bay to 2.0 feet at Stations 15 and 9 to 1.5 feet at Station 16, a dead end canal.

To further study the nature of the turbidity and its variations in the canal systems we measured both the amount of particulate matter (suspended solids) and chlorophyll a in water samples from the several hydrographic stations on flood and ebb tides. The data for the two canal systems are summarized in Table 11 and Fig. 45. In general, the particulate matter and chlorophyll a in the bays and canals were lower on flood than ebb tides. The amount of chlorophyll a (measure of the amount of phytoplankton) was highest in the upper reaches of the Grand Canal system at dusk on ebb tides (Fig. 45). Our data indicate that much of the suspended particulate matter and resultant turbidity in both canal systems is associated with large populations of phytoplankton. However, organic-inorganic resuspended sediments, bacteria and dead phytoplankton in dead end canals like Waterside Wood, Station 16, Grand Canal may be the major cause of turbidity in those areas with sluggish tidal flow.

In Fig. 45 we have circled three sets of chlorophyll a particulate matter points to illustrate the comparison between Gulf of Mexico water, open bay water and water at the entrance to the Grand Canal.

Figure 45. Relation of Chlorophyll a and particulate matter in surface water samples July 8-9 and August 7, 8 and 10, 1972. Flood tide at dawn; ebb tide at dusk.



CHLOROPHYLL-A AND PHYTOPLANKTON

The amount of chlorophyll a per unit volume of water is frequently used as one measure of the amount of phytoplankton present and is indicative of the amount of basic productivity and degree of eutrophication and water quality.

In the present study chlorophyll a values in the Grand Canal system were an order of magnitude higher than those in the Heron Lagoon system (Table 10). The highest values obtained were in the Siesta Isles section of the Grand Canal at dusk on ebb tides.

While plankton samples were collected in both canal systems, time permitted only the analysis of the phytoplankton from one set of samples from Heron Lagoon. As seen in Table 9 the phytoplankton community of Little Sarasota Bay and Heron Lagoon is dominated by the diatom *Skeletonema costatum*. Preliminary examinations of the Grand Canal samples indicated *S. costatum* was also the dominant phytoplankton in the Grand Canal. However, our sampling and preservation procedures may have resulted in a great reduction in numbers of dinoflagellates in the samples.

Quantitative data on chlorophyll a and phytoplankton fluctuations are so sketchy for the west coast of Florida (See Saunders *et al*., 1965) it is difficult to assess the significance of our data. High chlorophylla values, high phytoplankton counts coupled with the phytoplankton community dominated by a single species are frequent signs of plankton blooms, eutrophication and resultant adverse water quality conditions. However, Saunders *et al*., (1965) found *S. costatum* the dominant diatom in most of their inshore samples for most months of the year. Diatom communities dominated by large numbers of this species may actually be well balanced. For a brief synopsis on the biology of this diatom see Steidinger (1964). The phytoplankton numbers in samples from natural waters along the west coast of Florida are so high relative to studies in other areas that eutrophication levels of chlorophylla a and phytoplanton values from other areas may not apply locally.

One can expect qualitative and quantitative seasonal fluctuations in the phytoplankton populations (i.e., Carpenter, 1971, Hulbert, 1970) in the bays and canals to be related in part to seasonal variation and distribution of dissolved nutrients, particularly nitrogen (i.e., Thayer, 1971, 1974; Fournier, 1966). At the same time, rapidly growing and photosynthesizing live phytoplankton and dead phytoplankton release extracellular products (i.e., Samuel *et al*., 1971) that stimulate microbial growth and respiration (i.e.,Bell & Mitchell,1973)or that inhibit the growth of natural heterotrophic aquatic bacteria as well as coliform and pathogenic bacteria (i.e., Sieburth & Pratt, 1962; Sieburth, 1965; Duff, *et al*., 1966).Thus without additional studies on the phytoplankton populations in these canal systems it is difficult to determine their overall contribution to the water quality.

A few of the many factors associated with chlorophyll a concentration and phytoplankton density are summarized below.

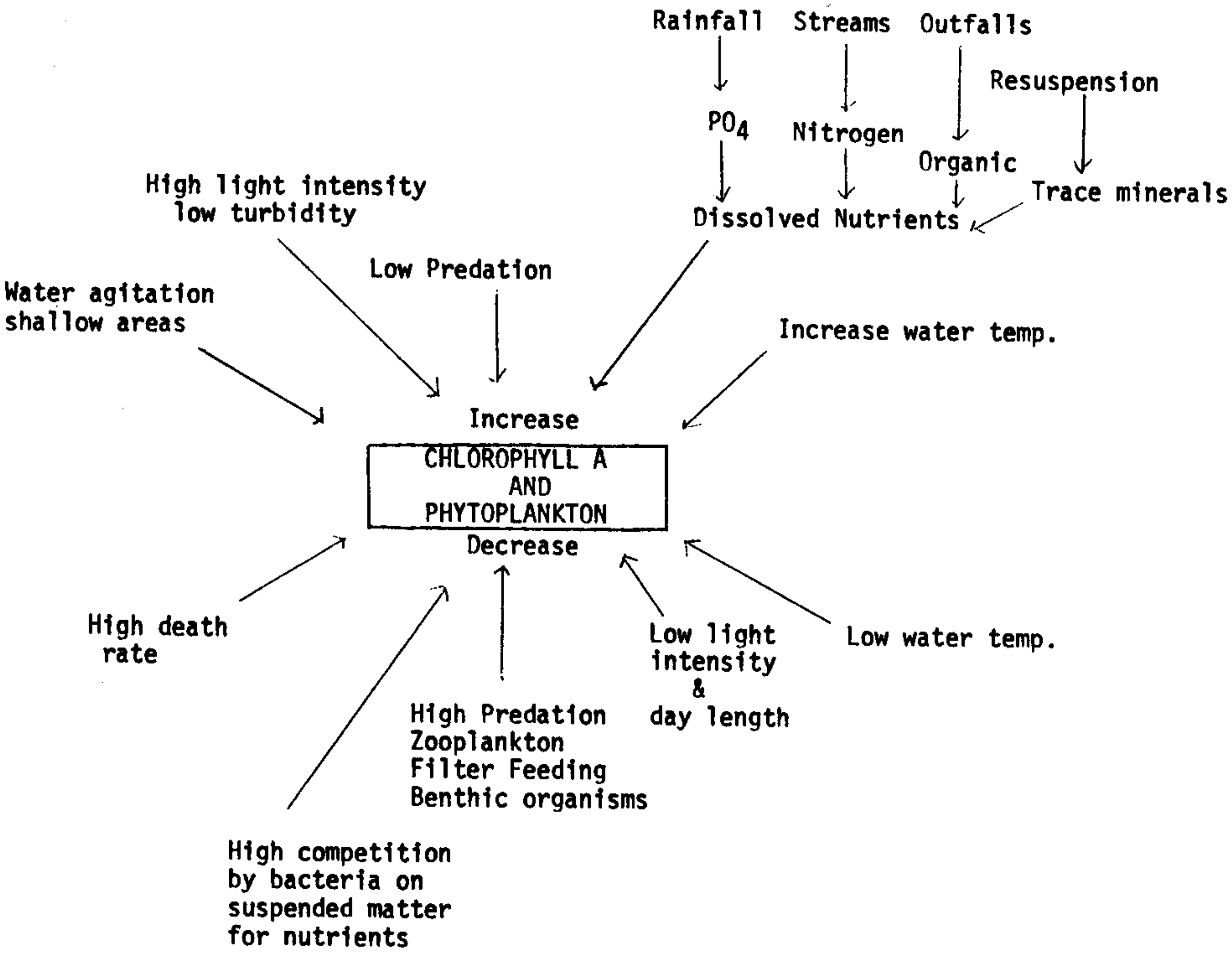

Rainfall
Streams
Outfalls
Resuspension
PO_4
Nitrogen
Organic
Trace minerals
Dissolved Nutrients
High light intensity low turbidity
Low Predation
Water agitation shallow areas
Increase water temp.
Increase
CHLOROPHYLL A AND PHYTOPLANKTON
Decrease
High death rate
Low light intensity & day length
Low water temp.
High Predation Zooplankton Filter Feeding Benthic organisms
High competition by bacteria on suspended matter for nutrients

Table 9 Percent composition of the ten most abundant phytoplankton in plankton collections from the Heron Lagoon System, June 27, 1972

	Flooding Tide (0700) - Dawn					
Phytoplankton Species	Station Number					
	1	3	4	5	6	8
Skeletonema costatum	51.3%	89.1%	91.0%	79.0%	93.3%	86.6%
Chaetoceros sp.	28.3	7.0	7.3	17.1	5.7	10.2
Rhizosolenia setigera	4.0	0.9	0.4	0.1	0.1	0.3
Thalassionema nitzchiodes	5.0	0.2	*	0.1	*	0.4
Nitzchia closterum	2.7	0.6	0.4	1.9	0.2	0.8
Nitzchia longissima	1.2	0.1	*	-	*	*
Nitzchia pangens	*	1.0	0.7	-	-	-
Paralia sulcata	4.4	*	*	*	*	*
Gonyaulax polyramma	2.3	0.1	0.1	*	*	-
Peridinium conicum	0.8	-	0.1	*	*	*

	Ebbing Tide - (1800) - Dusk					
Skeletonema costatum	83.2	91.4	68.5	89.2	82.0	88.5
Chaetoceros sp.	12.2	3.8	28.8	9.4	10.9	8.1
Rhizosolenia setigera	1.0	0.3	0.2	0.1	0.1	0.1
Thalassionema nitzchiodes	*	0.6	*	0.2	0.1	0.4
Nitzchia closterum	2.6	0.3	0.2	0.3	1.5	0.3
Nitzchia longissima	0.7	0.1	-	*	0.1	-
Nitzchia pangens	-	2.6	1.6	0.8	4.8	2.4
Paralia sulcata	*	*	-	*	-	-
Gonyaulax polyramma	*	0.4	0.1	0.1	*	-
Peridinium conicum	*	*	0.1	0.1	*	*

Table 10 Maximum concentrations of cholorophylla, total phosphate, total nitrate-nitrite and dissolved oxygen observed at Dusk (1700-1880) July & August 1972.

	Station Number	Chlorophylla (mg/m3)		Total PO_4 (ug/l)		Total NO_3-NO_2 (ug/l)		Dissolved O_2 (ppm)	
		July	Aug.	July	Aug.	July	Aug.	July	Aug.
Grand Canal System	0	10.5	20.0	4.3	6.8	0.2	0.3	-	-
	1	22.4	29.8	7.7	6.6	0.4	-	5.9	6.8
	4	29.8	27.1	10.6	8.3	0.4	0.4	7.1	7.4
	15	15.0	25.4	25.1	22.5	13.3	9.4	7.0	9.2
	10	31.6	26.1	12.6	9.7	0.2	0.3	9.0	8.8
	9	31.8	24.9	13.2	12.0	0.3	0.3	10.5	6.9
	14	35.7	20.5	12.3	10.3	0.2	0.3	8.0	9.2
Heron Lagoon System	8	7.5	15.0	5.0	3.7	1.0	0.5	7.4	5.6
	7	7.0	14.1	4.8	3.3	0.7	0.6	6.5	5.9
	6	15.6	19.8	5.5	3.6	1.2	0.7	5.6	4.2
	4	18.4	13.4	5.8	4.1	0.9	0.6	5.6	5.1
	3	21.0	10.8	4.3	4.3	0.8	0.7	5.8	5.2
	1	11.7	18.2	4.2	3.4	3.1	0.6	5.8	6.5

NITROGEN AND PHOSPHORUS

Measurements of surface water nitrate-nitrite and inorganic-organic phosphate in the two canal systems in July and August, 1972 were significant in furthering our understanding of the water quality in the two canal systems. In the Grand Canal system the P-N data show there is a major source of P-N rich water in the Canal at Station 15 (Table 10 & 11). During an ebb tide, July 9 and August 7, both the nitrate and inorganic phosphate values decreased markedly bayward of Station 15 as well as in the Siesta Isles, Palm Island sections of the Canal. The most likely explanation for this is that these dissolved nutrients were assimilated in rapidly growing phytoplankton populations.

These data coupled with the chlorophyll a data (Table 11) and tidal current movements indicate that the inorganic nutrients released at the SKUA outfall are rapidly incorporated by phytoplankton and bacterial populations in the canal system proper. Thus in the upper reaches of the canal system where tidal flow is sluggish plankton blooms tend to occur. In the canal system bayward of Station 15 the assimilated nutrients enter Roberts Bay in planktonic organisms. Thus the direct inorganic nutrient enrichment of Roberts Bay by the Grand Canal may be minimal.

The nitrogen and phosphorus values in the Heron Lagoon system were on the whole measurably lower than those from the Grand Canal system (Tables 10 & 11) as might be expected. Samples from July 3, however, had relatively high nitrite values indicating ground water seepage into the system.

The general picture that emerges from Table 11 is that during July and August of 1972 the nutrient enrichment of the waters of the Grand Canal primarily by the SKUA outfall resulted in elevated levels of particulate matter (phytoplankton), chlorophyll a and supersaturation of dissolved oxygen in the surface waters of the canal system as compared with Roberts Bay, Little Sarasota Bay and the Heron Lagoon Waterway system. How deleterious this is to Roberts Bay is subject to argument and opinion.

A comparison of water quality parameters - chlorophyll a, total phosphate and nitrate-nitrite - in Roberts Bay, the Grand Canal, Station 15 and other estuaries and bays along the west coast of Florida is given in Table 12. We leave it to the reader to draw his own conclusions. The complexities associated with any evaluation of levels and fluctuations in these water quality parameters are amply illustrated in the literature (i.e., Likens, 1972; Wilkinson, 1964; Johannes, 1968; Jones and Stewart, 1969; Ryther and Dunstan, 1971; Sutcliffe, 1972; Kerr et al., 1973).

Table 11 Summary of physical and chemical data of surface waters at dusk for hydrographic stations, Grand Canal and Heron Lagoon systems, July and August 1972.

	Station	D.O. ppm	I-PO_4 ugA/l	O-PO_4 ugA/l	NO_3-NO_2 ugA/l	Chl.a mg/l	Part Matter mg/m^3	Dates
Grand Canal System	1	5.9	7.5	0.2	0.39	22.4	17.1	
	4	7.1	9.5	1.1	0.39	29.8	15.3	July 9
	15	8.0	24.6	0.5	13.26*	15.0	29.6	1972
	10	9.0	11.4	1.2	0.23	31.6	32.0	1700 -
	9	7.0	11.9	1.2	0.30	31.8	16.3	1800
	14	10.5	11.5	0.7	0.23	35.7	55.7	Ebb tide
	1	6.8	7.0	0.6	-	29.8	13.9	
	16	7.4	7.5	0.8	0.41	27.1	47.0	August 7
	15	9.2	20.6	2.9	9.35**	25.4	16.6	1972
	10	8.8	7.7	2.0	0.27	26.1	10.7	1730-1900
	9	6.9	9.4	1.6	0.27	24.9	12.8	Ebb tide
	14	9.2	8.4	1.9	0.34	20.5	24.3	
Little Sarasota Bay - Heron Lagoon System	8	7.4	4.0	1.9	3.11***	7.5	17.0	
	7	6.5	3.8	1.2	0.84***	7.0	15.2	July 3, 1972
	6	5.6	3.8	1.5	0.94***	15.6	14.8	
	4	5.6	4.3	1.7	1.20***	18.4	14.8	1800
	3	5.8	3.1	1.1	0.66***	21.0	12.8	Flood tide
	1	5.8	2.3	1.0	1.04***	11.7	16.4	
	8	5.6	3.4	0.4	0.48	15.0	12.5	August 14
	7	5.9	2.8	0.6	0.55	14.1	7.1	
	6	4.2	3.2	0.5	0.73	19.8	20.3	1800-1900
	4	5.1	2.9	1.2	0.64	13.4	8.3	Ebb tide
	3	5.2	3.1	1.3	0.66	10.8	8.5	
	1	6.5	2.6	0.8	0.57	18.2	22.3	

* 13% NO_2

** 24% NO_2

*** 10-35% NO_2

Table 12-Comparison of Chlorophyll A, total dissolved phosphate and nitrate - nitrate measurements in Roberts Bay and station 15 on the Grand Canal with other surface water sample studies along the west coast of Florida.

Area	Chlorophyll A mgm.^{3}			Total Phosphate ugA/L			Nitrate-Nitrate ugA/L			Reference
	July	Aug.	Annual	July	Aug	Annual	July	Aug	Annual	
Roberts Bay Sta. o. Dusk Ebb	10.5	20		4.3	6.8		0.2	0.3		
Roberts Bay Sta. o. Dawn Flood	15.2	10.2		5.1	3.2		0.5	0.3		
Grand Canal Sta.15,Dusk,Ebb	22.7	25.4		25.1	23.5		13.2	9.3		
Grand Canal Sta.15,Dawn,Flood	15.0	17.5		10.3	14.0		1.1	0.5		
Gulf Mexico off Charlotte Harbor			1.1-1.9			1.4-1.6				Dragovich et al 1968
Lower Charlotte Harbor			2.4			10.4				
Myakka River			5.2			6.3				
Tampa Bay entrance	2.9-8.4	2.8-6.9							21-39	Taylor et al 1968
Boca Ciega Bay		3.9-28.2			7.1	7.9			32-45	
Tampa Bay	5.1-10.6	3.9-12.7	3.1			14.5			36-57	
Old Tampa Bay	5.1-20	3.9-26.6								
Upper Tampa Bay	12.4	5								Hagan 1969
Hillsborough Bay	48.8		35.2	Annual Range		165-2340	10.0	30.0		
Wacassa Estuary, Fla.	15	5				82*			34	Putnam 1967
Alligator Harbor, Fla.	Max. 14.6		4.3							Marshall 1956
/mc. South Alligator Harbor		3.4								
Fenholloway Estuary	Max 23.8		7.6		2.8-5.2	L2.5			0.1-2.4	Saville 1966
Waccassa Estuary	30.6	21.3	13.3			20-100			10	

* 73% of total po_4 was organic po_4

WATER QUALITY - A SYNTHESIS

In order to provide a comparative picture of the water quality in the two canal systems and their adjoining bays the data for eight hydrographic parameters are displayed in polygraphs. As seen in Figure 46 which is a key to the graphs that follow, each of the eight parameters - dissolved oxygen, dissolved carbon dioxide, pH, inorganic (ortho) phosphate, organic phosphate, nitrate-nitrite, chlorophyll a and particulate matter - is plotted along a radius. When the individual points are connected the shape of the polygon for a particular sampling station may be quickly compared with those of other sampling stations.

Figure 47 shows that on a flood tide, August 24, 1972, the chemical characteristics of the surface water in the Gulf of Mexico 2 miles west of Midnight Pass differed from those in Little Sarasota Bay, especially in the segment of the Bay north of Point Crisp. The major differences at the four sampling stations were chlorophyll a, nitrate-nitrite and dissolved organic phosphate.

Figure 48 illustrates the variation in water quality at four hydrographic stations in the Heron Lagoon system at dawn and dusk, July 3, 1972. Compared to the water quality pictures of the Gulf of Mexico and the Intracoastal Waterway in Little Sarasota Bay (Fig. 47), these graphs emphasize the increase in nitrate-nitrite and chlorophyll a in the Heron Lagoon system. They also show a sharp attenuation of nitrate and nitrite on flood tide at dawn between Stations 8 and 6 and Stations 3 and 1.

The water quality picture for Station 0, Roberts Bay, for June and July and Station 1, Grand Canal for June, July and August shown in Fig. 49 illustrates the variation in water quality on different dates even when the samples are taken at the same time of day and at similar phases of a tidal cycle. The June and July graphs show that the water entering the Bay from the Grand Canal differs from the water of Roberts Bay. An additional ebb tide graph for Station 1, July 9, is shown in Fig. 50. This figure also shows the marked differences in the water quality of four stations (1, 4, 14 and 15) in the Grand Canal system at dawn and dusk. Furthermore, the water quality picture of these four stations differs from the four Heron Lagoon stations in Fig. 48 as well as from the station in Roberts Bay (Fig. 47) and stations in Little Sarasota Bay (Figs. 47 & 48).

In the course of this study 71 water samples were assayed for ten chemical and hydrographic parameters. The water samples included those

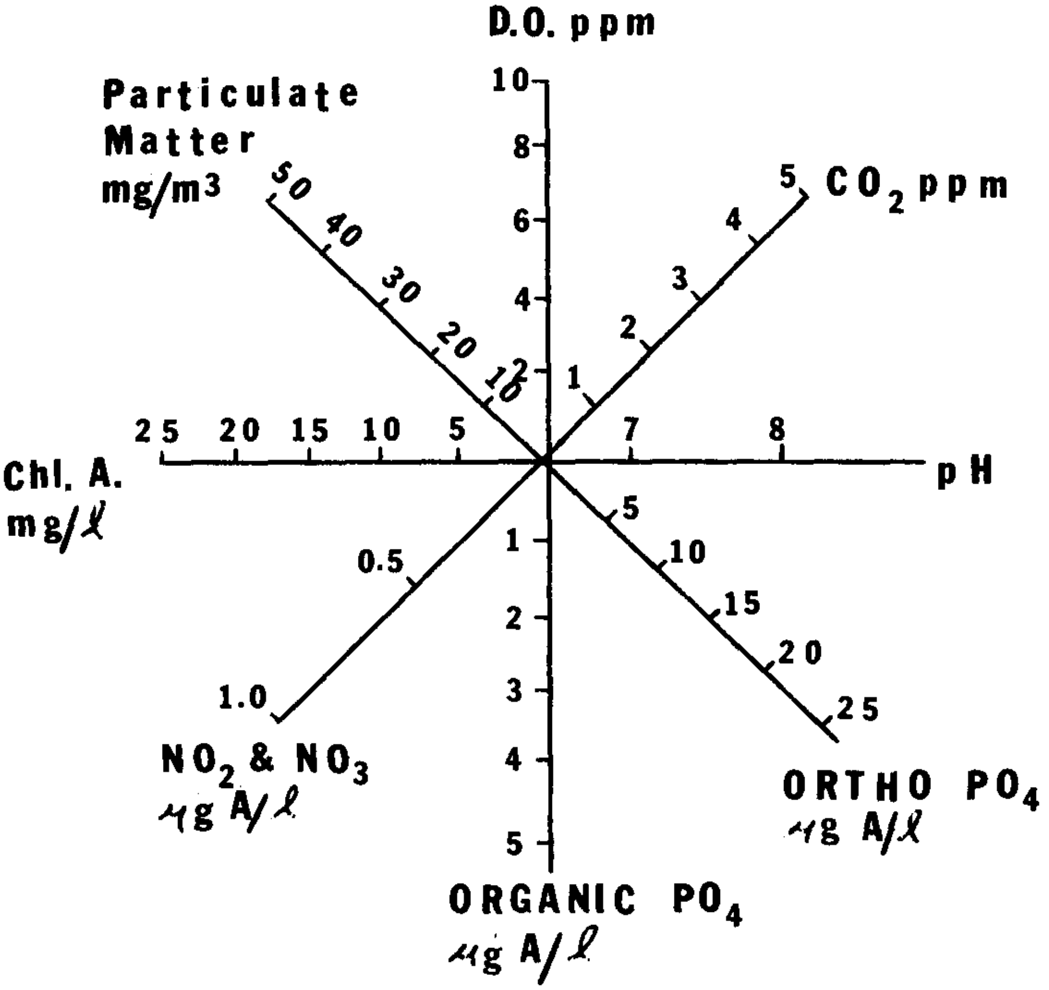
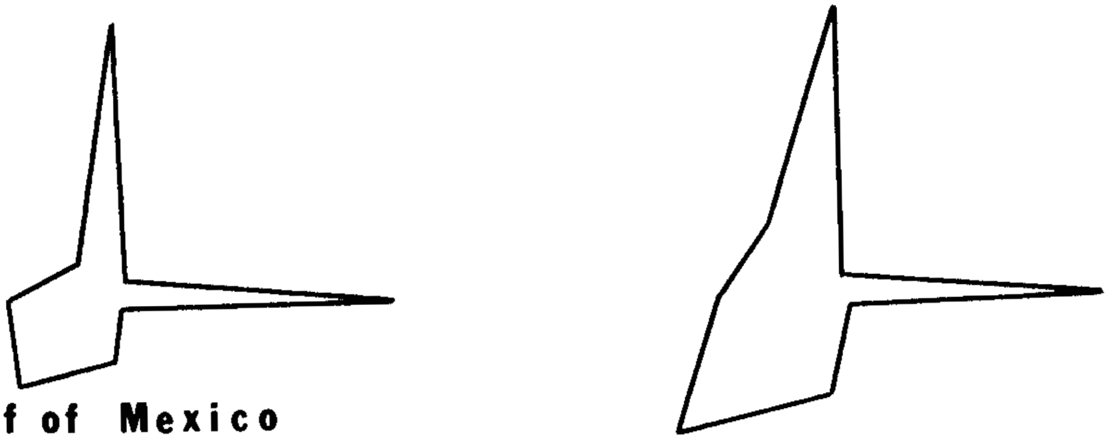


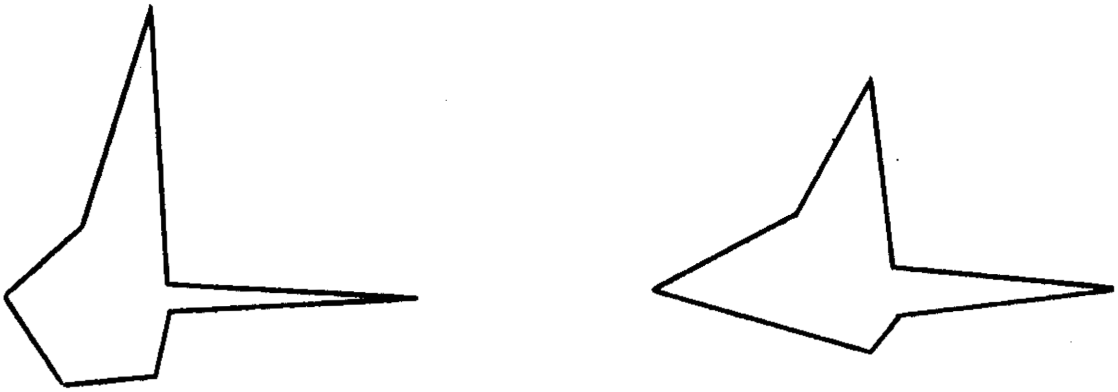
Figure 46 Key and scales for polygonal graphs of eight hydrographic parameters measured in surface water samples from the Gulf of Mexico, Little Sarasota Bay, the Heron Lagoon Canal system, Roberts Bay and the Grand Canal system.



Gulf of Mexico
2 miles West of
Midnight Pass

Midnight Pass

August 24, 1972
1300--1400
Flooding Tide



Little Sarasota Bay
I.C.W. Marker 49
South of Point Crisp

Little Sarasota Bay
I.C.W. Marker 57
North of Point Crisp

Figure 47 Polygonal graphs of surface water at four hydrographic stations. See Figure 46 for Key.

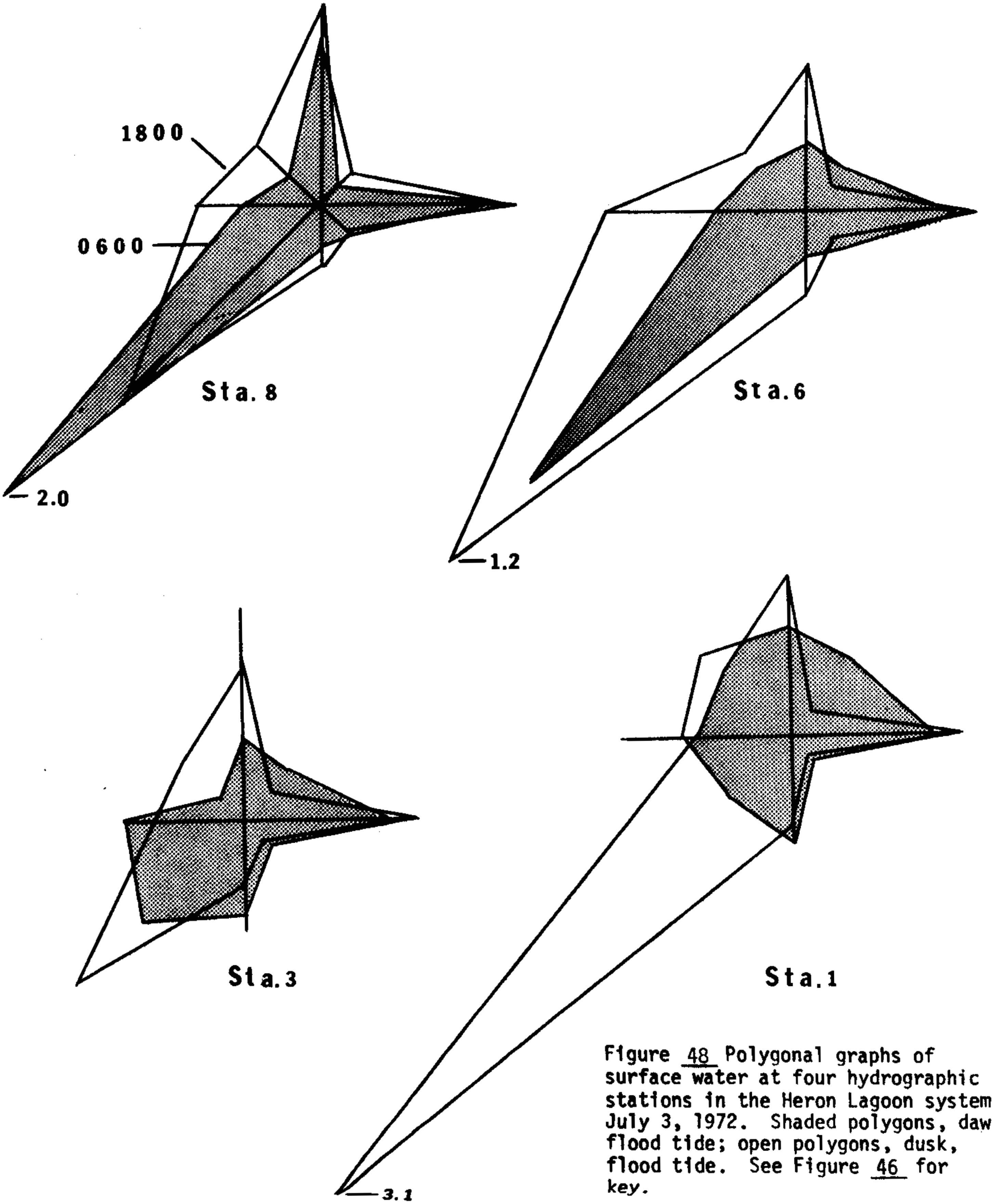
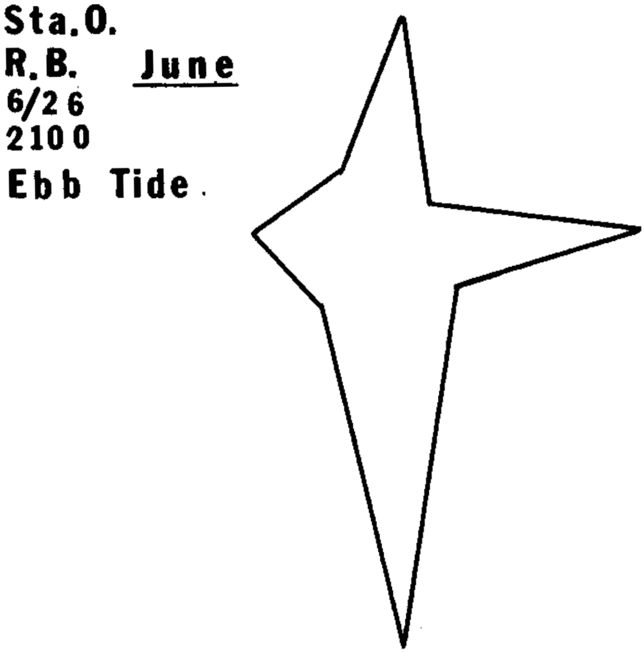
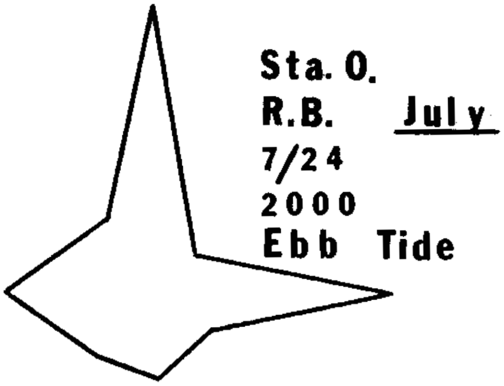
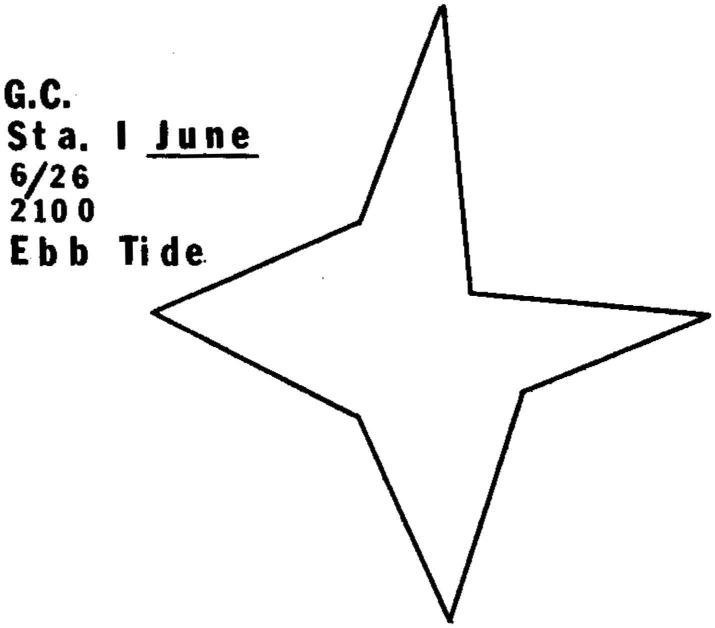


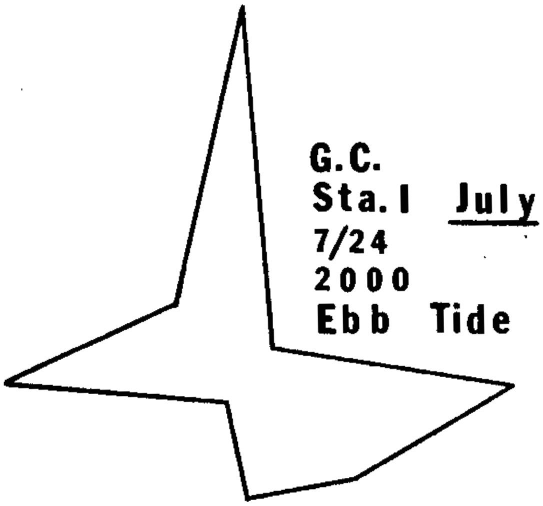
Figure 48 Polygonal graphs of surface water at four hydrographic stations in the Heron Lagoon system July 3, 1972. Shaded polygons, dawn, flood tide; open polygons, dusk, flood tide. See Figure 46 for key.

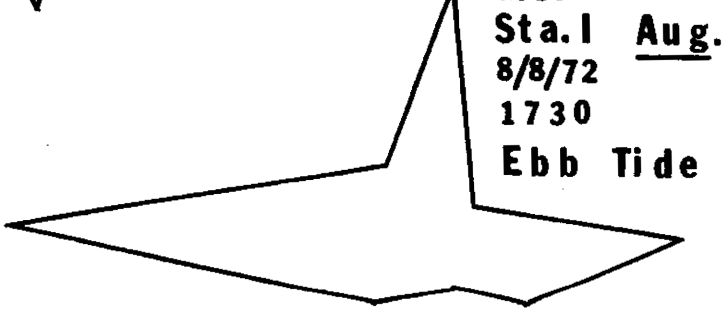
Figure 49 Comparison of water quality polygonal graphs of Roberts Bay and Grand Canal, Station 1 on ebb tides at dusk, June, July and August 1972.











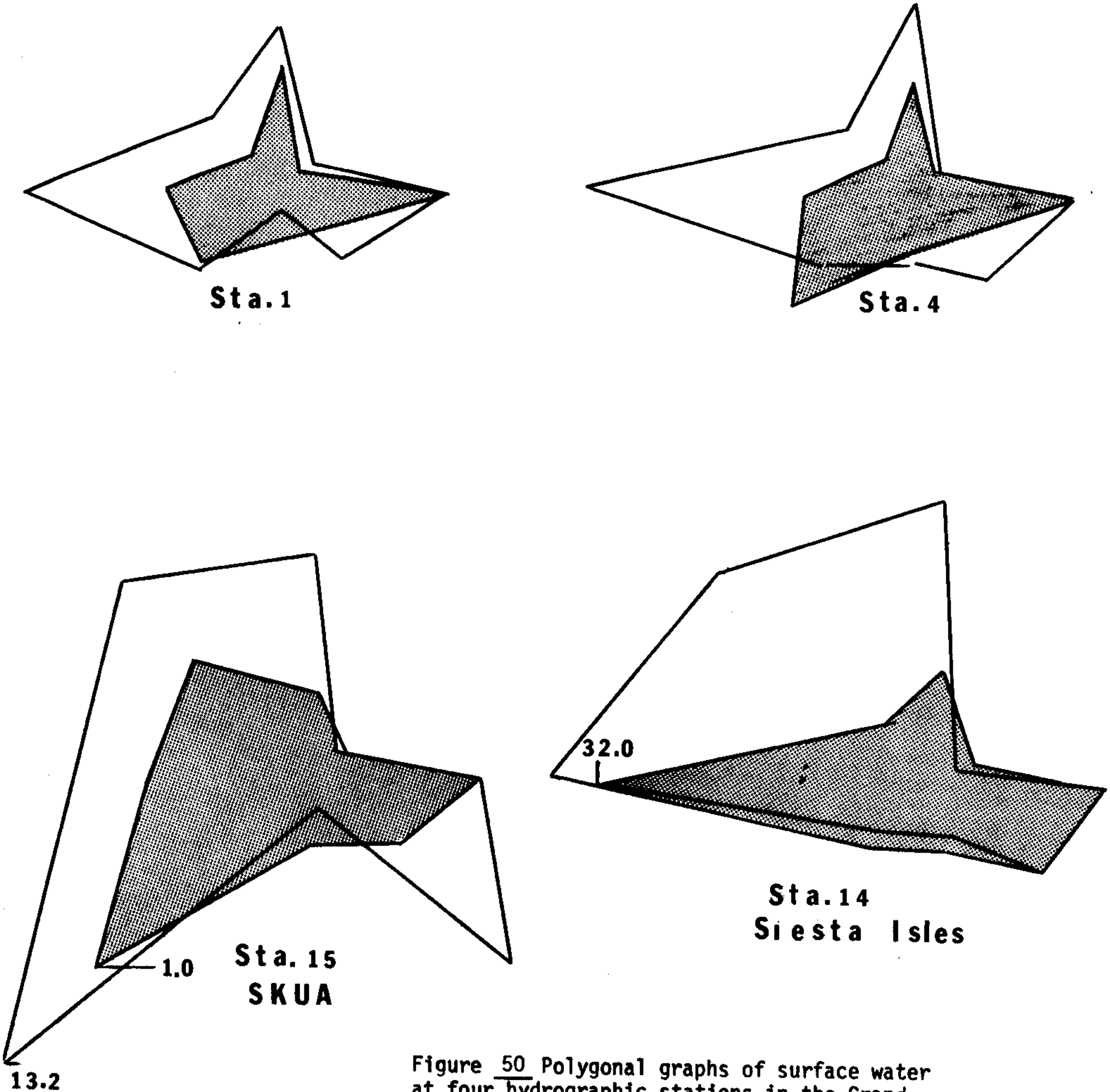


Figure 50 Polygonal graphs of surface water at four hydrographic stations in the Grand Canal system, July 9, 1972. Shaded polygons, flood tide, dawn; open polygons, ebb tide, dusk. See Figure 46 for Key.

from the Heron Lagoon and Grand Canal systems as well as South Coconut Bayou and a relatively natural mangrove pond system south of the Grand Canal. Multivariate analyses of principal components were performed on raw and log transformed data and mapped on two-dimensional plots (Foster, 1974) summarized in Fig. 51. This figure shows that with respect to the water quality parameters measured, the waters of the Heron Lagoon system are "rawther" distinct from those of the Grand Canal system. However, to paraphrase Foster "we leave it to the interested to explore the significance of the plots, the polygonal graphs and the raw data". Our knowledge of the dynamics of the bio-geochemical processes, the biota of the past, present and future in the canal systems and the adjoining bays is too fragmentary to warrant drawing firm conclusions and developing predictions.

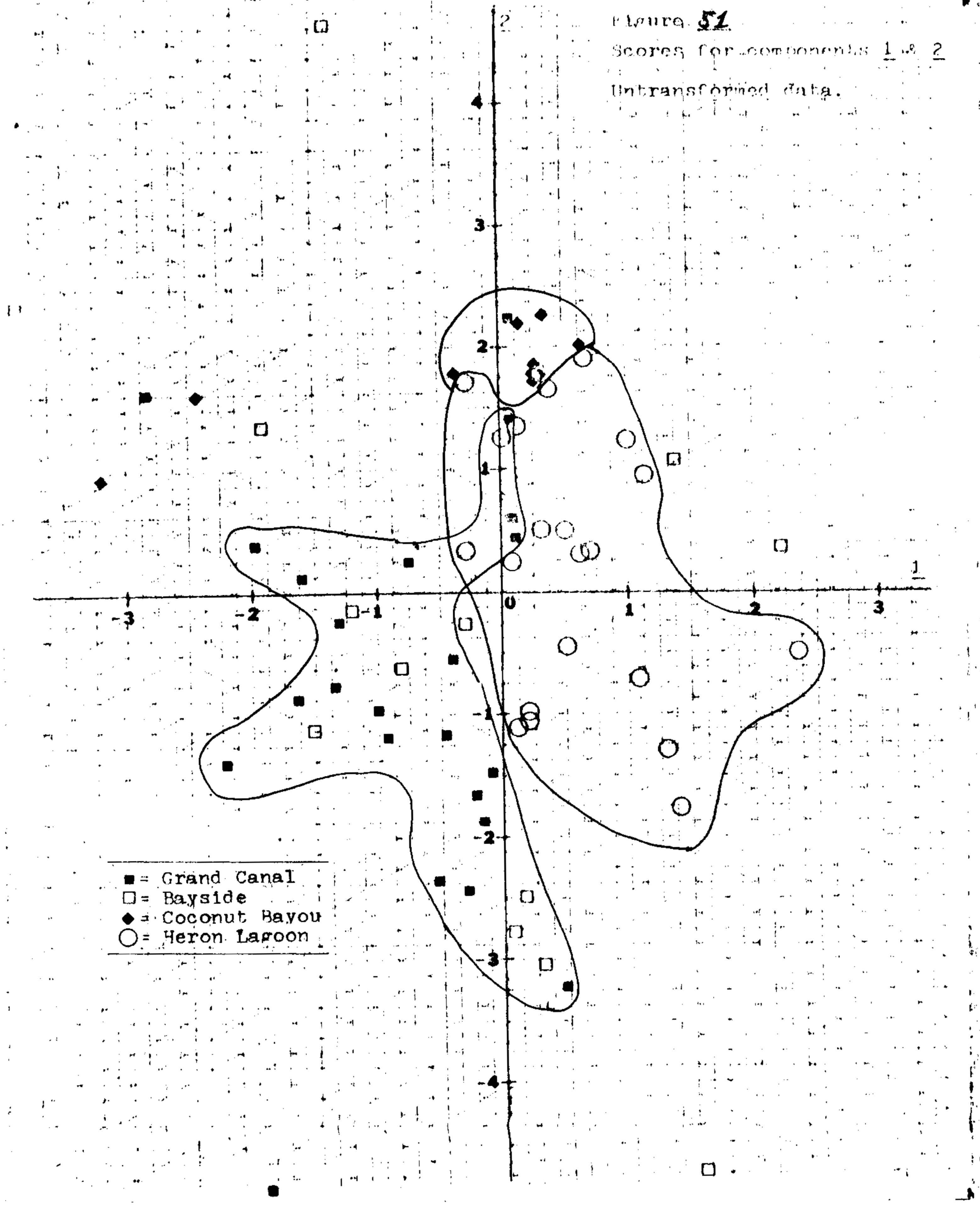
Figure 51. Scatter plot diagram of the first and second principle components of a product-moment correlation coefficient matrix analysis of ten environmental factors - salinity, alkalinity, pH, CO_2, O_2, inorganic PO_4, organic PO_4, $NO_2 + NO_3$, Chlorophyll a, and particulate matter from 71 stations. Each symbol in the figure represents the principle component resultant for either a dawn or dusk surface water sample from one station. Data and figure from Foster, 1974.

This diagram can be used to map areas of water based on these parameters. As the reader may perceive the water in the Grand Canal system is quite different from that in the Heron Lagoon system. The Coconut Bayou system represents a third water area. The waters in the natural mangrove swamp system of Bayside exhibited the greatest variations.

Figure 51

Scores for components 1 & 2

Untransformed data.



BENTHIC AND EPIBENTHIC ORGANISMS

The distribution of macroscopic invertebrates and marine plants in the two canal systems was surveyed via qualitative field observations and semi-quantitativesampling of the canal bottoms at different locations with a 1/64 m^2 plug sampler (Taylor and Salomon (1969) and a bucket dredge (Taylor, 1965)). We were particularly interested in what animals and plants, if any, occurred in the seemingly soft, organically rich bottom sediments in the canal systems as compared to bottoms of similar depths in the adjoining bays. We also were interested in epibenthic or fouling organisms such as oysters, barnacles and tunicates that grow on sea walls, floats, pier pilings and submerged branches of shore vegetation. These latter organisms are primarily filter feeders which feed on phytoplankton and other particulate matter. Thus they can when present play a significant role in controlling phytoplankton blooms in canals and waterways. Finally, we studied the distribution of benthic algae and sea grasses in the canals and waterways.

Semi-quantitative benthic samples. In the Heron Lagoon system benthic plug samples were taken at eight stations, July 20-21, 1972. The locations of the stations are given in Table 13. At each station four plug samples were taken at A, M.L.W. intertidal zone; B, L.L.W. (Low low water); and C, in the Center of the Waterway (4-5 ft.). The samples were screened through 1/16 inch mesh screening; the numbers of individuals of each species of invertebrate recorded; and dry weights of the sea grass (Cuban shoal weed), algae and detritus determined. These data are summarized in Table 14. In general, the soft bottom sediments in the Little Sarasota Bay (Station 8) as well as in the waterways consisted of worms, detritus, and filter feeding bivalve molluscs, and brittle stars. The total number of species and individuals decreased between the Bay and the southern end of Heron Lagoon (Station 1). Table 15 shows the presence of the 10 most common benthic macroinvertebrates at the eight sampling stations. We cannot conclude whether the differences in number of species and individuals per unit area of bottom reflect sampling errors, adverse water quality, amount of food, recruitment of juveniles, or physical-chemical differences in the bottom sediments.

The field data from this study were further analyzed by Foster (1974). He found that the amount of detritus in the bottom sediments decreased with increasing water depths and distance from the vegetated shore. The greatest amount of detritus was obtained in samples from the center of the waterways at Stations 3, 4, 5, and 7 where the shores were heavily vegetated. Most of the detritus in these samples consisted of partially decomposed leaves, twigs and fruits of neighboring trees. Of the 50 species of macroinvertebrates in 21 samples, 13 occurred in at least four samples. Eight of these were polychaete worms and five bivalve molluscs. The 13 species formed four faunistic associations. The first consisted of all but one

Table 13

BENTHIC SAMPLING STATIONS

HERON LAGOON WATERWAY SYSTEM, JULY 21, 1972

Station No.	Location
1	Foot bridge, south end Heron Lagoon.
2	Heron Bay.
3	Junction West Waterway and Midwaterway.
4	East Waterway, south of Sanderling Road.
5	North end of East Waterway.
6	North Waterway.
7	Boat Basin, Siesta Club.
8	Little Sarasota Bay, outside of entrance to Siesta Club Boat Basin.

Table 14 Number of individuals/species of macrointervertebrates and amount of Cuban shoal weed, algae, and detritus in 12 plug samples (3/16m^2) at 8 benthic sampling stations in the Heron Lagoon system and Little Sarasota Bay, July 20-21, 1972.

	Sample Stations							
	1	2	3	4	5	6	7	8
Annelids	6/3	43/6	24/2	65/13	6/5	51/7	135/16	136/13
Molluscs								
Snails	0	0	0	0	0	4/1	0	2/1
Bivalves	6/1	12/4	48/5	7/2	15/3	49/5	27/6	58/9
Echinoderms	0	0	5/3	0	0	3/2	1/1	5/1
Crustacea								
Amphipods	0	0	0	0	0	0	0	0
Decapods	0	0	0	0	0	0	0	0
Total No. Spec.	4	10	10	15	8	15	23	24
Total No. Individ.	12	55	77	72	21	107	163	201
Gm dry wt/ 3/16 m^2								
Cuban Shoal weed	10.9	25.3	2.8	0	0	9.2	0	5.1
Algae	0	0	0	0	0	0	1.9	0.3
Detritus	20.3	4.0	47.4	73.3	56.1	23.8	43.8	19.5

Table 15 Presence of the 10 most common species in benthic samples from Heron Lagoon-Little Sarasota Bay, July 1972.

	Benthic Sample Stations								
Species	1	2	3	4	5	6	7	8	Remarks
Annelids									
Brachioacyhis americana	+	+	+	+	+	+	+	+	Cuban shoal weed
Cerratulus sp.	-	-	-	+	-	+	+	-	
Cirriformia filopodia	+	+	-	+	-	+	+	+	Sandy, strong current
Diopatra cuprea	+	+	-	+	+	+	+	+	Sandy mud
Melinnia maculata	-	-	-	+	-	-	+	+	Soft bottom
Onuphis emerita	-	+	-	-	+	+	+	+	Cuban shoal weed
Spiochaetopterus	-	-	+	+	-	-	+	+	Soft sandy mud
Molluscs									
Anamalocardia cunermus	+	+	+	-	-	+	+	+	Sandy mud
Semele proficna	-	+	+	+	+	+	+	-	Sandy, intertidal
Crustacea									
Tubiculous amphipod Tubes	-	+	-	+	-	+	+++	+	Sand, but most abundant on soft, organic mud

of the polychaetes; the second, suspension feeding bivalve molluscs; the third, deposit feeding bivalve molluscs; the fourth, a single species of polychaete, Brachyiosyhchus americana. The first and third associations showed a preference for the upper tidal zones along the margins of the waterways. The second and fourth associations were located in the softer sediments in deeper water. Foster (1974) concludes that in spite of the relatively "poor" faunal diversity in the Heron Lagoon system, the diversity has reached a high level for this particular environment because of the degree of interrelated organization and maximal partitioning of niche space. In an academic sense the invertebrate communities in this system are probably stable under normal environmental conditions but are unable to maintain their form under environmental stress. However, these benthic samples were taken one month after Hurricane Agnes. The data and their multivariate analysis may reflect the aftermath of the environmental stresses caused by the hurricane as well as seasonal aspects of the several communities.

Benthic samples were collected in the Grand Canal system at nine of the hydrographic stations. A single dredge bucket sample was collected at each station. Table 16 shows that the maximum number of species and individuals were found in Roberts Bay (Station 0) in a firm sandy-mud bottom. The number of individuals and species decreased measurably in the Grand Canal up to Station 15. Table 17 shows the presence of the fourteen most common macroinvertebrates in the benthic samples.

Although not present in the dredge bucket samples, the soft canal bottoms are populated by dense beds of a tubiculous amphipod. From a review of the literature it appears little is known about the biology - ecology of this animal. Our observations indicate it is most frequent and abundant in soft, organically rich types of bottom sediments whether in dead end canals or turtle grass flats or other soft bottoms in the open bays. Since they form small "leathery" tubes and feed on bacteria and protozoa on the surfaces of fine detrital particles, these amphipods may play important roles in stabilizing the superficial bottom sediments and metabolizing the organic matter and microorganisms at the sediment water interface. In addition, they may be an important link in certain marine fish food chains.

Another invertebrate characteristic of soft bottoms is the tubiculous polychaete worm Spiochaetopterus. Tubes of this worm occurred in samples from Stations 0, 1, 4, 10, 14 and 16. Tubes of the tubiculous worm, Onuphis emerita occurred in samples from Stations 0, 1, 4, 10, 11 and 15. Some 160 of these tubes occurred at Station 15 while only one to a few occurred in the other samples. Finally, tubes of the tubiculous worm, Maldane sarsi occurred in samples from Stations 0, 1, 4 and 9.

Table 16 Number of individual species of macroinvertebrates and amount of detritus collected with a bucket dredge at 10 sampling stations in the Grand Canal and Roberts Bay, Aug. 9 and 18, 1972.

Macroinvertebrates	Sample Stations								
	0	1	4	15	11	14	10	9	16
Annelids	49/11	60/8	26/8	0	0	0	0	0	0
Molluscs									
Snails	1/1	7/3	6/2	2/2	0	0	0	0	0
Bivalves	78/7	5/2	0	1/1	0	0	0	0	0
Echinoderms	6/3	1/2	1/1	0	0	0	0	0	0
Crustacea									
Amphipods	5/2	2/2	6/1	5/2	0	0	0	0	0
Decapods	0	10/3	0	0	0	0	0	0	0
Tunicata - ascidians	9	4/1	2/1	0	0	0	0	0	0
Sipunculids	0	11/1	14/1	4/1	0	1/1	0	0	0
Coelenterates	0	8/1	0	0	0	0	0	0	0
Total No. Species	34	24	16	9	0	1	0	0	1
Total No. Individ.	139	108	58	11	0	1	0	0	2
Detritus gm dry wt/ bucket	2.6	2.6	37.4	28.4	17.0	11.4	14.9	28.1	11.8

Table 17 Presence of the 14 most common species in benthic samples from Grand Canal-Roberts Bay, August 1972.

Species	Benthic Sample Station Number									Remarks
	0	1	4	15	10	9	11	14	16	
<u>Annelids</u>										
Branchiomma nigromaculata	+	+	+							
Cirratulus sp.		+								
Clymenella torquata	+									
Diopatra cuprea	+		+							
Hypsicomus elegans	+	+								
Loimia medusa	+	+								
Onuphis eremita	+	+	+	+	+		+			
Pista palmata	+	+	+							
Spiochaetopterus sp.	+	+	+		+				+	
Sipunculids Phascalosoma sp.		+	+	+				+		
<u>Molluscs</u>										
Anamalocardia cunermus	+									
Tellina versicular	+			+						
Pluroplaca gigantea		+	+							
<u>Crustacea</u>										
Tubiculous amphipod	+				+		+	+	+	

We conclude from these few samples that the macrobenthic invertebrate communities of the Grand Canal system are composed primarily of soft sediment tubiculous annelids and crustacea that feed on detritus and fine particulate matter. They help to stabilize physically the bottom sediments and are involved in the biogeochemical processes at the bottom sediment water interface.

As might be expected in a sea walled canal system, the amount of detritus was considerably greater than in the unvegetated bay bottom (Table 16). The macrodetritus in the canal samples consisted of grass clippings, pine needles, leaves of shrubs, seeds and twigs. Such material supplements the rain of dead phytoplankton and adds to the B.O.D. and C.O.D. of the surficial bottom sediments in those regions of the canal system with sluggish tidal circulation.

Epifaunal or fouling (pier piling) community organisms. A variety of invertebrates may live on the surface of the bottom as well as on the surfaces of submerged pilings, floating docks, boat hulls, branches of trees and shrubs along the shore, ropes, and other submerged solid substrata. These invertebrates are primarily detritus feeders or scavengers (i.e., the king crown snail (*Melongena corona*), blue crabs, green crabs, spider crabs (*Libinea* sp.) and young stone crabs) or filter feeders (i.e., sponges, oysters, mussels, barnacles, tunicates or sea squirts and tubiculous feather duster or plume worms).

In the Heron Lagoon system there was a considerable variety of these organisms attached to solid substrata especially pilings, floats and submerged branches of shore plants along the waterways. From the Boat Basin through the waterways to the northern half of Heron Lagoon suitable solid substrata were colonized by filter feeding solitary tunicates (*Styela partita* and *Molgula manhattenesis*), colonial tunicates (*Botryllus schlosseri*), colonial bryozoa (*Bugula* sp.), oysters (*Crossostracea virginica* and *Ostrea frons*), barnacles (*Balanus* sp.), sponges (*Halicondria* sp.), colonies of tube worms (*Sabella* sp., *Spirobis* sp.,) and mussels (*Mytilus* sp.). These animals occurred between M.S.L. and one foot below M.L.W. wherever there were suitable solid surfaces. Floating submerged branches in the narrow waterways were frequently festooned with growths of these gregarious animals. Collectively these animals serve as important biological filters for both plankton and fine detritus in the flowing water. Their combined activities reduce the amount of living and dead organic matter in the water. At the same time, they contribute to the rain of dead organic matter that settles to the waterway bottoms via faecal pellets and pseudofaecal pellets which are eaten by various benthic worms, brittle starfish and clams.

Interestingly, the most well developed communities of fouling organisms occurred where the tidal currents were relatively strong and where solid substrata were floating beneath the water surface. In other words, floating submerged surfaces several feet from the waterway shores, especially along the heavily vegetated East and North Waterway shores had the best developed fouling communities. With respect to water quality the presence of these organisms from the Boat Basin to Heron Lagoon is probably an important factor along with tidal flushing in maintaining the water quality in the waterways. In sections of the waterways and Heron Lagoon proper lacking suitable solid submerged surfaces or where the tidal currents were "sluggish" these organisms were absent.

Certain of these filter feeders also occurred on the bottoms of the waterways. These included 2 species of sponges and the tunicate Styela partita.

In Heron Lagoon suitable submerged solid surfaces were less abundant than in the waterways and the fouling community less well developed except where there were pilings at the southern end of Heron Lagoon. Here in the vicinity of the foot bridge (Hydrographic Station 1) an interesting intertidal mussel (Conrad's false mussel, Congeria leucophaeta) occurred in large numbers. This mussel is limited to brackish water where the salinity fluctuates. This is the only area we have found this animal to date.

In contrast to the well developed filter feeding fouling organism communities in the Heron Lagoon system such communities were poorly developed in the Grand Canal system. Here only barnacles, oysters and mussels were found on sea walls above the Midnight Pass Road bridge. From this bridge to the upper reaches of the canal system the relative abundance of these animals decreased becoming minimal in the Palm Island area. We can only guess that the absence of some species and reduction in numbers of other species is primarily due to the sluggish tidal circulation in the upper reaches of this canal system. Sluggish tidal flow will impair both filter feeding activity and recruitment of the planktonic larvae of the majority of species of the fouling community.

In conclusion the diversity and abundance of fouling organisms in the Heron Lagoon system as compared to the Grand Canal system could be used as a simple biological indicator of the differences in overall water quality in these two canal systems. Of course, one can argue that concrete sea walls are not optimal substrata for larval forms of fouling organisms to settle on. The potential for the development of filter feeding, fouling communities in the Grand Canal system could be tested experimentally by suspending submerged plates, rope and floats in different areas of the canal system. Such a study could be extremely important to discussions on improving the water quality and water circulation in the Grand Canal system.

Marine grasses and macrobenthic algae. We observed no marine grasses along the canal margins, the berms or sloping bottoms of the canals anywhere in the Grand Canal system even though there were substrates and depths suitable for the growth of marine grasses. The absence of grasses is probably due to impaired recruitment from grass beds in Roberts Bay. However, other factors may be involved.

Contrarily, patches of the marine grass Cuban shoal weed (*Diplanthera wrightii*) occurred in the Heron Lagoon system along the eastern shore of Heron Lagoon, in the shallows of Heron Bay and along the berms of the West and Middle Waterways. The patches of Cuban shoal weed in the waterways were probably derived from grass beds in Heron Bay.

It is possible that marine grasses may be transplanted successfully on the berms and bottom slopes in the Grand Canal system (see Fuss and Kelly, 1969; Kelly *et al.*, 1971). However, the successful establishment of these grasses may occur only where the tidal currents fall within certain velocity ranges (Conover, 1967).

The most common macro-algae in the two canal systems were the red algae *Gracilaria* sp. and *Acanthophora* sp. which drift into the canal systems from the bays along the bottom on flooding tides. Once in the canal systems they may continue to grow, provide shelter for various animals and then die thereby contributing to the food chains and accumulation of organic matter. A third green alga, *Caulerpa mexicana*, was common in the waterways of the Heron Lagoon system but apparently absent in the Grand Canal System. In the Heron Lagoon waterways and boat basin it grew on the soft sediments of the bottoms as well as on solid submerged substrates. The rather prolific growths of this algae at certain seasons (July - November) may reflect the presence of nitrogen enriched waters. We have observed large growths of this alga in other parts of the Sarasota Bay system where nutrient enrichment occurs. Similarly, extensive growths of the macro red algae occur seasonally and locally in association with high levels of dissolved nitrogen compounds (i.e., Hagan, 1969). During September-November 1973 the numbers of these drifting algal plants in the grass flats of Roberts Bay appeared to shade the sea grasses and cause the death of their leafy shoots. Similarly, under certain tidal and wind regimes these algae may be expected to accumulate in sections of both canal systems and contribute to the B.O.D., especially in the water near the canal bottoms.

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Appendix A

METHODS

Currents. Direction and rate of flow of tidal currents were measured by following the drift of one gallon plastic bottles weighted to float just below the water surface. To follow the water movement 4 feet below the surface a weighted one gallon bottle was suspended by a string from a balloon floating on the surface. Current velocities at the culverts in the Heron Lagoon system were measured with General Oceanics digital flowmeters Model 2030.

Hydrography. Depth, temperature, dissolved oxygen, pH and conductivity were recorded with a Hydrolab Surveyor (Hydrolab Corp.). Salinity was also measured with standardized hydrometers. In the laboratory the field pH measurements were repeated with a Corning Model 12 Research pH meter. Inorganic phosphate, nitrate, nitrite, chlorophyll *a* and suspended particulate matter were determined according to the methods of Strickland and Parsons (1968). Dissolved CO_2 was calculated from alkalinity according to Strickland and Parsons (1968). Dissolved organic phosphate was determined by difference after all phosphates in the millipore filtered sample were transformed to the inorganic form by oxidation with pensulfate according to the method of Menzel and Corwin (1965). All optical measurements were made on a Gilford 240 spectrophotometer with 1 cm light path cuvettes. Degree of light penetration of water was determined with a standard 8 inch secchi disk.

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