

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TIDAL RELATIONS ALONG THE INTRACOASTAL WATERWAY,

PALM BEACH COUNTY, FLORIDA

By

James J. Schneider

OPEN-FILE REPORT

73-253

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with
PALM BEACH COUNTY

Tallahassee, Florida

1973

CONTENTS

	Page
Abstract	5
Introduction	6
Acknowledgments	8
Method of investigation	8
Results of investigation	9
Mean high water	13
Mean low water	15
Mean tidal range	15
Mean half tide and sea level	16
Tidal time difference	16
Storm tides	18
Rising sea level	18
Glossary	21
References	22

ILLUSTRATIONS

Page

Figure 1. Map showing the area of investigation and location of gaging stations, Palm Beach County, Florida	7
2. Graphs showing typical tidal fluctuations at three locations on the Intracoastal Waterway, Palm Beach County, Florida, May 1-10, 1972.	12
3. Graphs showing the seasonal change of the monthly mean high and low water at Miami Beach and three locations on the Intracoastal Waterway, Palm Beach County, Florida	14
4. Graphs showing the seasonal change of the monthly mean half-tide at Miami Beach and three locations on the Intracoastal Waterway, Palm Beach County, Florida	17
5. Graphs showing the effects of strong easterly winds of Dec. 21-25, 1971 on tide patterns at Miami Beach and three locations on the Intracoastal Waterway, Palm Beach County, Florida	19
6. Graph showing variation of yearly mean water level at Miami Beach, Florida	20

TABLE

	Page
Table 1. Mean values of high and low water, sea level, half tide, tidal range and time difference from September 1, 1971 through August 31, 1972	10
2. Monthly maximum and minimum water levels for September 1971 through August 1972	11

TIDAL RELATIONS ALONG THE INTRACOASTAL WATERWAY,
PALM BEACH COUNTY, FLORIDA

By

James J. Schneider

ABSTRACT

From September 1, 1971 through August 31, 1972, mean high water along the Intracoastal Waterway in Palm Beach County ranged from 1.71 to 1.87 feet above mean sea level, datum of 1929. The mean tidal range varied from 2.33 to 2.69 feet. The difference between half tide and mean sea level varied between -0.01 foot at Delray Beach to +0.05 foot at Juno Beach with a zero variation at Southern Blvd. and Blue Heron Blvd. The average time difference for high tides referred to Miami Beach, ranged from plus 20 minutes at Riviera Beach to plus 1 hour and 50 minutes at Delray Beach.

INTRODUCTION

In Palm Beach County, the Intracoastal Waterway is a natural channel separated from the Atlantic Ocean by a heavily urbanized offshore bar extending from the Broward County line on the south to the city of North Palm Beach. From North Palm Beach to the Jupiter Inlet, the waterway is a canal dredged about 1 mile inland from the ocean. Tidal interchange between the ocean and the waterway is provided by Jupiter, Palm Beach (Lake Worth), Boynton, and Boca Raton Inlets in Palm Beach County and, Hillsboro Inlet in Broward County (fig. 1).

Prior to this investigation there was little tidal data for the Intracoastal Waterway in Palm Beach County. The purpose of this study, therefore, was to determine for this reach of the waterway: 1) mean high water; 2) mean low water; 3) mean sea level; 4) mean half tide; 5) mean tidal range; and 6) average tidal time difference, and to relate these values to the ocean tides at Miami Beach. In this study the method of establishing these tidal characteristics was to observe the everchanging tidal water surface elevations continuously over the period of Sept. 1, 1971 to August 31, 1972 at four selected sites and to compute from these records the desired information.

The terminology of this report follows that adopted by the American Society of Civil Engineers (1962) and Bowditch (1966). Precise definitions of most of the terms are given in the glossary at the end of the report.

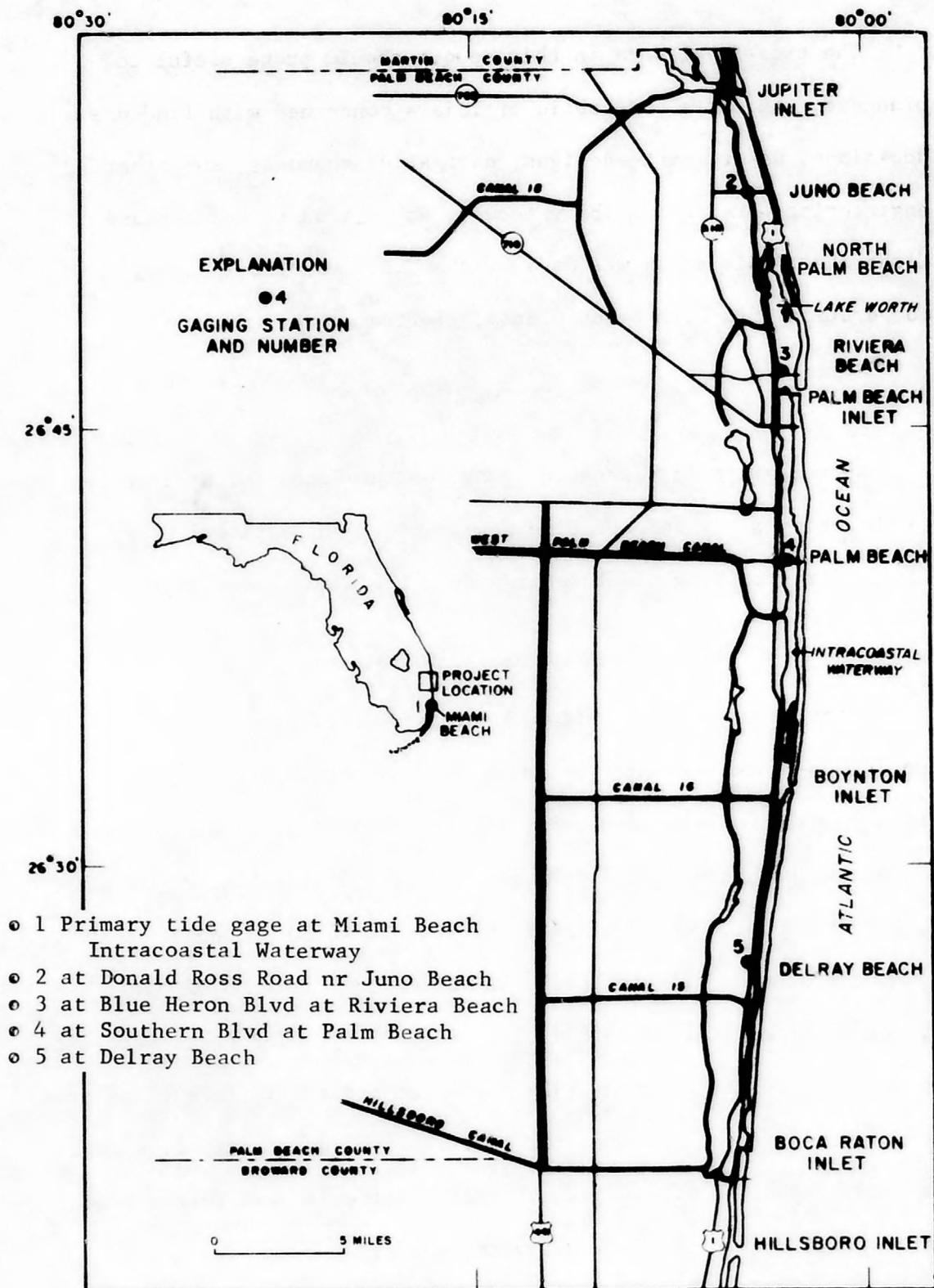


Figure 1.--Area of investigation and location of gaging stations, Palm Beach County, Florida.

The tide-level data in this report should prove useful to planners, engineers and public officials concerned with land use decisions, water intake designs, navigation channels, and other engineering works along the waterway, as well as to boaters and fishermen. This study was made by the U.S. Geological Survey in cooperation with Palm Beach County, Florida.

ACKNOWLEDGMENTS

Appreciation is expressed to Mr. George Panos for assistance in obtaining sites for the tide gages and to the National Ocean Survey for supplying tidal records from the Miami Beach gage.

METHOD OF INVESTIGATION

Water level gaging stations equipped with float activated, continuous-trace, graphic recorders were established during early 1971 at four numbered locations along the waterway (fig. 1) as follows:

- 2, Donald Ross Road near Juno Beach (Lat $22^{\circ}52'55''$, long $80^{\circ}04'12''$);
- 3, Blue Heron Blvd. at Riviera Beach (Lat $26^{\circ}46'50''$, long $82^{\circ}02'39''$);
- 4, Southern Blvd. at Palm Beach (Lat $26^{\circ}40'30''$, long $80^{\circ}02'45''$); and
- 5, Delray Beach (Lat $26^{\circ}27'53''$, long $80^{\circ}03'51''$). The gages were set to mean sea level, datum of 1929, by first order spirit leveling from nearby bench marks. Records for 1931-72 from the primary tide gage at Miami Beach, 48 miles south of tide-level gage 5 at Delray Beach, were obtained from the National Ocean Survey.

The recorder charts were reduced by manual computation and by mechanical processing with an electronic digitizer. Daily maximum and minimum water levels from the four waterway stations are published in the U.S. Geological Survey annual report series "Water Resources Data for Florida--Part 1. Surface Water Records, Volume 2: Streams".

Tidal characteristics presented in this report are based on records collected from September 1, 1971, through August 31, 1972. The record from gage 2, Donald Ross Road near Juno Beach, was missing for most of April 1972. The record was estimated by correlating the monthly means with records from gage 3, Blue Heron Blvd. at Riviera Beach. The estimates are accurate within ± 0.10 foot.

RESULTS OF INVESTIGATION

Listed in table 1 are the values of mean high and low water, sea level, half tide, tidal range and tidal time difference. Time difference indicates the difference between times of predicted high and low tides at Miami Beach and at each of the other four stations. The monthly maximum and minimum water levels are listed in table 2.

The tidal range at the various stations indicate a fairly free tidal interchange between the ocean and the waterway and along the length of the waterway. Typical tidal patterns at three of the gages, for May 1-10, 1972 are illustrated in figure 2.

Table 1.--Mean values of high and low water, sea level, half tide, tidal range and time difference from September 1, 1971 through August 31, 1972.

No. on Fig. 1	STATION NAME AND NUMBER	MEAN <u>1/</u>					TIME DIFFERENCE <u>2/</u>			
		High Water (feet)	Low Water (feet)	Sea Level (feet)	Half Tide (feet)	Tidal Range (feet)	High Tide hr. min.	Low Tide hr. min.		
1.	Miami Beach Primary Tide Station National Ocean Survey	1.77	-0.69	0.55	0.54	2.46	-	-	-	-
2.	Intracoastal Waterway at Donald Ross Road near Juno Beach (02277730) <u>3/</u>	1.71	-0.62	0.59	0.54	2.33	+0	40	+0	50
3.	Intracoastal Waterway at Blue Heron Blvd. at Riviera Beach (02277960)	1.82	-0.87	0.48	0.48	2.69	+0	20	+0	30
4.	Intracoastal Waterway at Southern Blvd. at Palm Beach (02277990)	1.79	-0.64	0.58	0.58	2.43	+1	00	+1	20
5.	Intracoastal Waterway at Delray Beach (02279520)	1.87	-0.62	0.61	0.62	2.49	+1	50	+2	10

NOTES: 1/ Datum is mean sea level, datum of 1929.

2/ Added to predicted time at Miami Beach Station.

3/ U.S. Geological Survey nationwide downstream order station identification number.

Table 2.--Monthly maximum and minimum water levels for September 1971 through August 1972. Datum is mean sea level datum of 1929.

INTRACOASTAL WATERWAY

	Primary Tide Gage at Miami Beach		at Donald Ross Rd near Juno Beach		at Blue Heron Blvd in Riviera Beach		at Southern Blvd. in Palm Beach		in Delray Beach	
	Max. feet	Min. feet	Max. feet	Min. feet	Max. feet	Min. feet	Max. feet	Min. feet	Max. feet	Min. feet
September 1971	2.30	-1.50	2.88	-1.53	2.48	-1.30	2.93	-1.32	2.82	-1.35
October	3.10	-1.20	2.95	- .96	3.07	-1.26	3.02	- .95	3.13	- .78
November	2.80	-1.10	3.29	- .94	3.24	-1.28	3.37	- .85	3.44	- .77
December	2.80	-1.40	2.78	-1.51	2.65	-1.73	2.74	-1.39	3.03	-1.31
January 1972	2.54	-1.56	2.29	-1.69	2.45	-1.91	2.40	-1.57	2.36	-1.48
February	2.36	-1.55	2.10	-1.38	2.40	-1.70	2.28	-1.32	2.33	-1.27
March	2.59	-1.69	2.34	-1.49	2.64	-1.69	2.48	-1.37	2.39	-1.27
April	2.11	-2.27	2.16	-1.85	2.30	-2.05	2.34	-1.70	2.33	-1.62
May	2.50	-1.82	2.66	-1.28	2.78	-1.85	2.74	-1.28	2.63	-1.15
June	2.30	-1.65	2.69	-1.39	2.78	-1.71	2.80	-1.32	2.63	-1.28
July	2.01	-1.73	2.21	-1.64	2.43	-1.88	2.32	-1.46	2.25	-1.36
August	2.23	-1.61	1.95	-1.45	2.26	-1.72	2.29	-1.25	2.32	-1.19
Period	3.10	-2.27	3.29	-1.85	3.24	-2.05	3.37	-1.70	3.44	-1.62

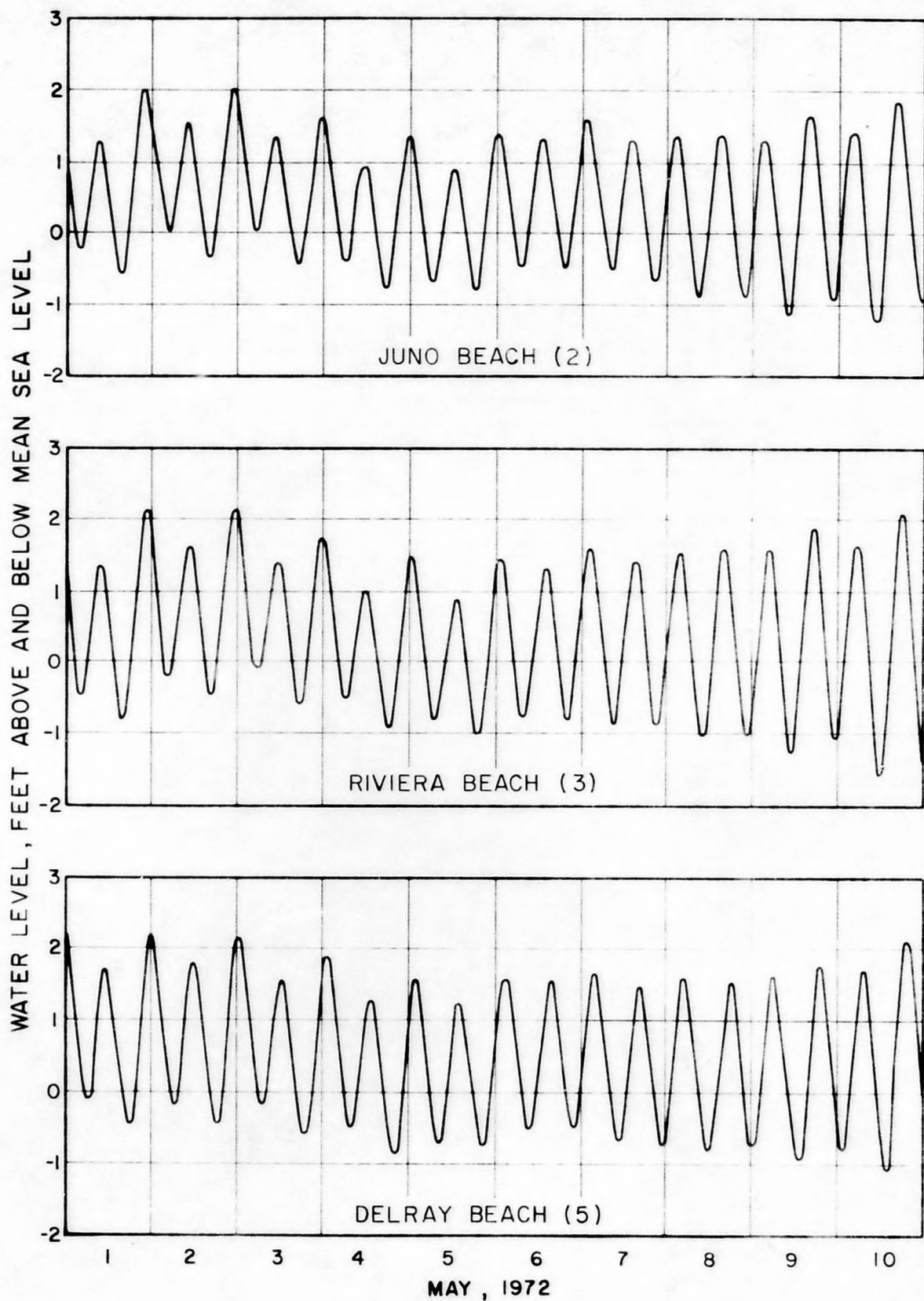


Figure 2.--Typical tidal fluctuations at three locations on the Intracoastal Waterway, Palm Beach County, Florida, May 1-10, 1972.

The records from Miami Beach (1) and Palm Beach (4) are not illustrated. They are comparable to the records from Riviera Beach (3) and Juno Beach (2), during the period illustrated. The gage at Riviera Beach (3) is within a mile of the Palm Beach (Lake Worth) Inlet, a major ship channel. The tides recorded at Riviera Beach are believed to be comparable to ocean tides.

Mean High Water

The elevation of mean high water along the waterway (table 1) ranged between 1.87 feet at Delray Beach and 1.71 feet at Juno Beach. The higher water levels at Delray Beach, 0.05 foot higher than at Riviera Beach, were probably due to the discharge of fresh water into the waterway from Canals C-15 to the south and C-16 to the north of the gage and the absence of an inlet in the vicinity of the gage. The nearest inlet is Boynton Inlet, 6 miles north. Figure 3 shows the seasonal variation in the monthly mean high water at three locations along the waterway and at Miami Beach. Tides averaged highest during October and November which is the latter part of the hurricane season in the area. The highest water levels during the observed 12-month period (table 2) occurred during November at the waterway stations and during October at Miami Beach. The record from Palm Beach (4), not illustrated, is comparable to that at Juno Beach.

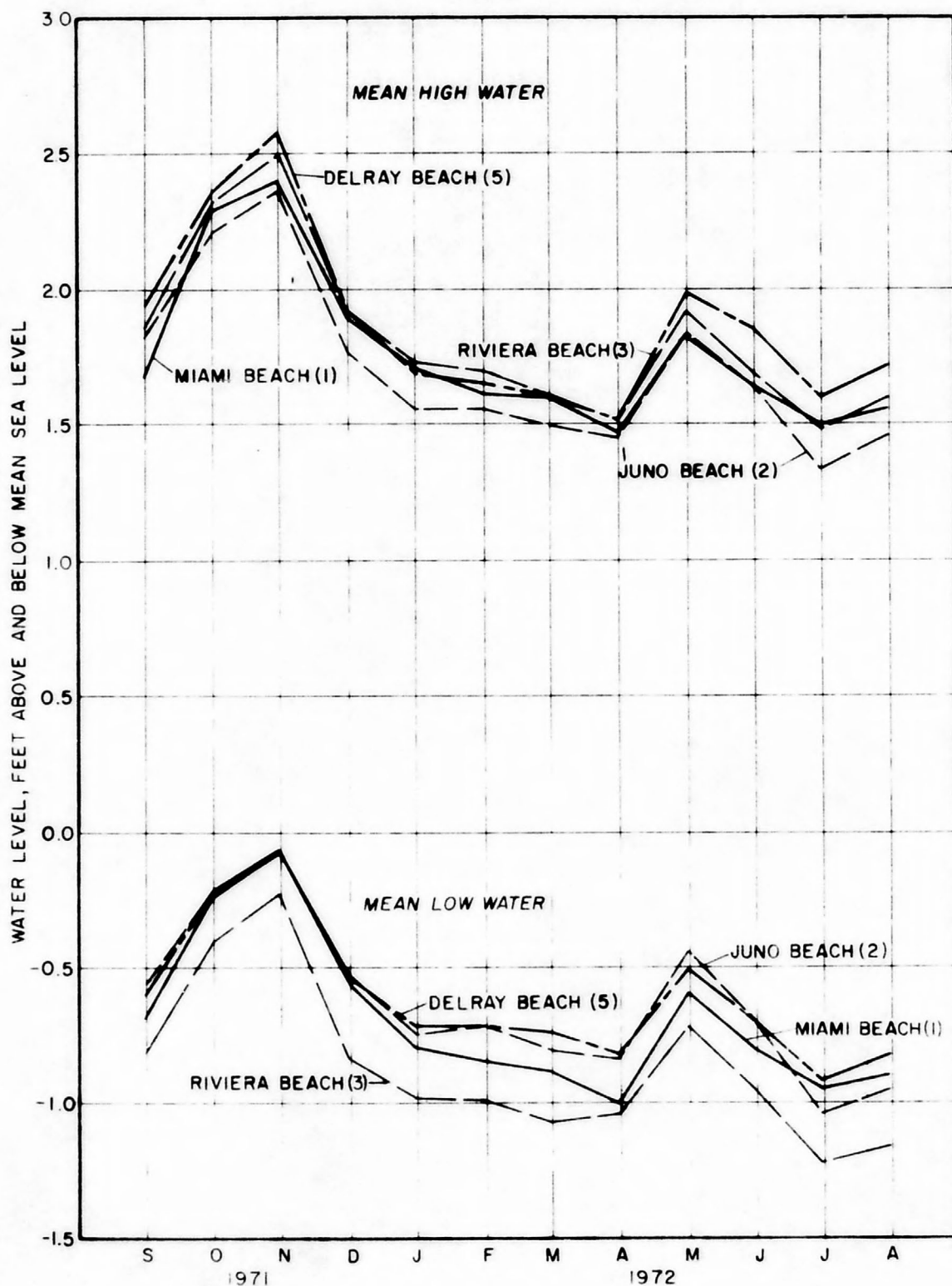


Figure 3.--Seasonal change of the monthly mean high and low water at Miami Beach and three locations on the Intracoastal Waterway.

Mean Low Water

The elevation of mean low water along the waterway (table 1) ranged between -0.62 foot at Delray Beach and Juno Beach and -0.87 foot at Riviera Beach. The mean low water at Miami Beach was -0.69 foot, 0.18 foot higher than at Riviera Beach. Figure 3 shows the seasonal variation in the monthly mean low tides. Tides averaged lowest in July along the waterway and in April at Miami Beach. The lowest water levels during the 12-month period (table 2) occurred during April at the waterway stations and at Miami Beach.

Mean Tidal Range

The tidal range varied between 2.33 feet at Juno Beach to 2.69 feet at Riviera Beach (table 1). The range at Miami Beach was 2.46 feet. A check of the tide tables indicates that the tidal range increases northward along the Florida east coast. The range at the primary tide gage at Mayport near Jacksonville, Florida is approximately 4 feet or about 1.5 feet greater than at Miami Beach. This possibly explains the increase in tidal range at Riviera Beach over that recorded at Miami Beach although, the increase could be caused by local conditions. The decrease in tidal range at the other stations on the waterway is due to the greater distance from an inlet.

Mean Half Tide and Sea Level

The elevation of mean half tide at Miami Beach was 0.54 foot (table 1). The elevation of mean half tide along the waterway varied between 0.48 foot at Riviera Beach and 0.62 foot at Delray Beach. Figure 4 shows the variation in monthly mean half tide at Miami Beach, Juno Beach, Riviera Beach and Delray Beach. The mean half tide equals the mean sea level if the tidal fluctuation follows a symmetrical pattern. During the study period, the maximum difference between mean half tide and mean sea level at four of the five stations was 0.01 foot. The difference at Juno Beach was 0.05 foot. The mean half tide and mean sea level values were virtually identical and could be used interchangeably.

Tidal Time Difference

To determine the time of high or low tide at a selected station, the time difference in table 1 should be added to the time of predicted high or low tide at Miami Beach, which is published in the National Ocean Survey Tide Tables. The average time difference for high tide ranged from plus 20 minutes at Riviera Beach to plus 1 hour and 50 minutes at Delray Beach. The differences are not proportional to the distance from Miami Beach, but are affected by local conditions.

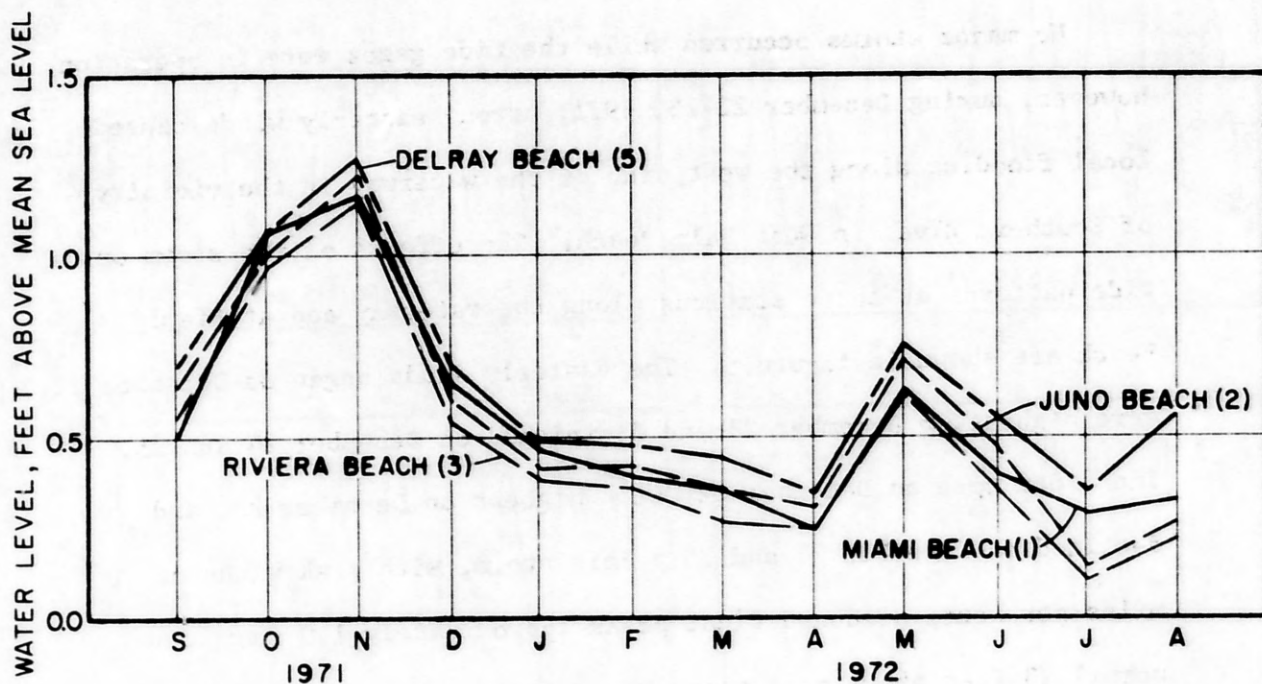


Figure 4.--Seasonal change of the monthly mean half-tide at Miami Beach and three locations on the Intracoastal Waterway.

Storm Tides

No major storms occurred while the tide gages were in operation. However, during December 22-25, 1971, strong easterly winds caused local flooding along the west side of the waterway in the vicinity of Southern Blvd. in West Palm Beach. The effects of the storm on tide patterns at three stations along the waterway and at Miami Beach are shown in figure 5. The easterly winds began on December 22, were highest on December 23 and diminished on December 24 and 25. The tides rose on December 22, were highest on December 23, and declined on December 24 and 25. This storm, with peak winds of 40 miles per hour, produced tidal peaks approximately 1.0 foot above normal (3 feet above msl) along the waterway.

Rising Sea Level

The record of tide levels at Miami Beach shows that since 1931, sea level is following a rising trend relative to the Sea Level Datum of 1929 as indicated in figure 6. The rise has averaged about 0.01 foot per year. This rising trend was investigated by H. A. Marmer in 1951. The mean water level at Miami Beach, Sept. 1, 1971 to Aug. 31, 1972, was 0.55 foot above the Sea Level Datum of 1929. This was 0.18 foot above the mean water level for the 19-year period 1953-71.

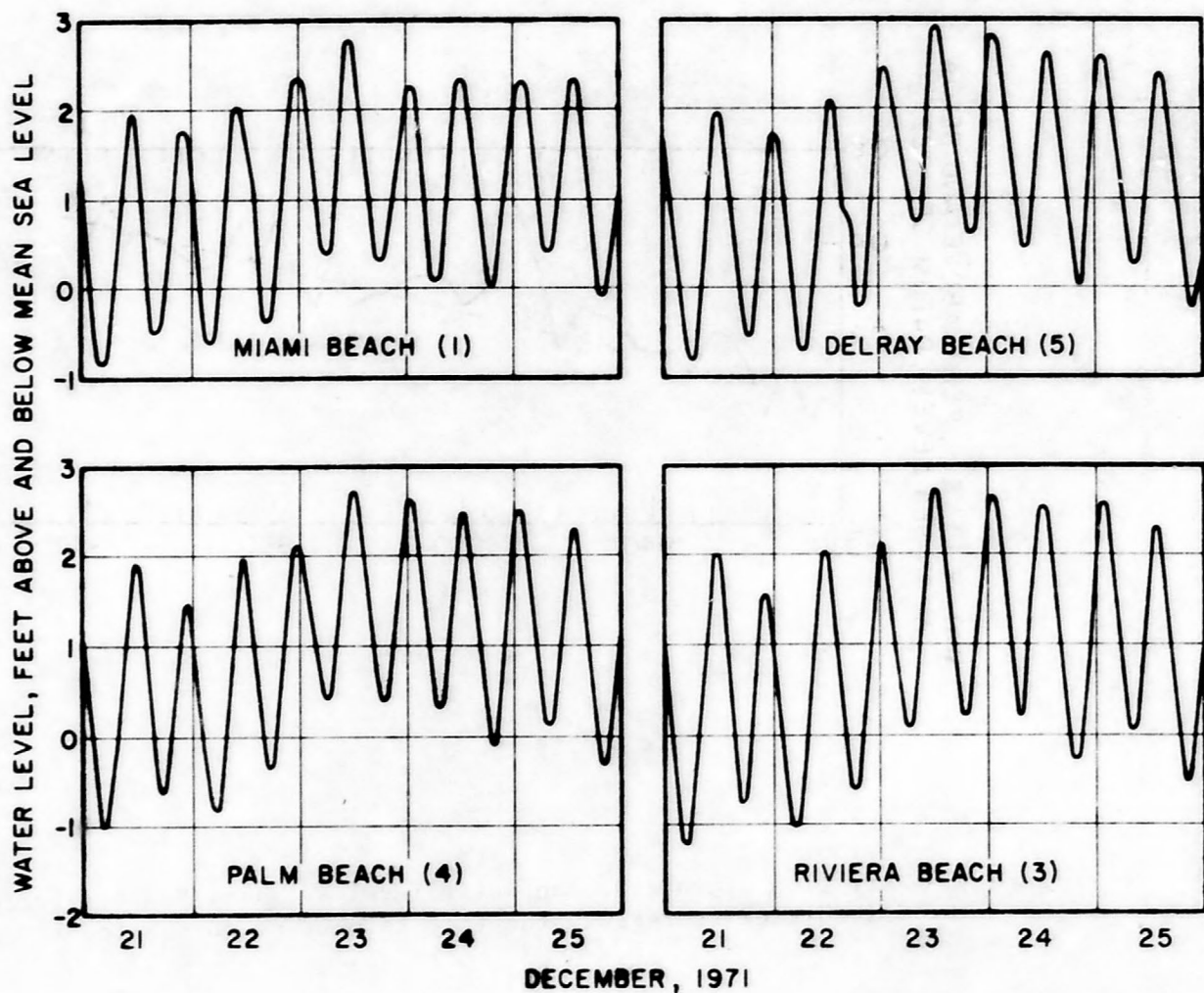


Figure 5.--Effects of strong easterly winds, December 22-25, 1971, on tide patterns at Miami Beach and three locations on the Intracoastal Waterway.

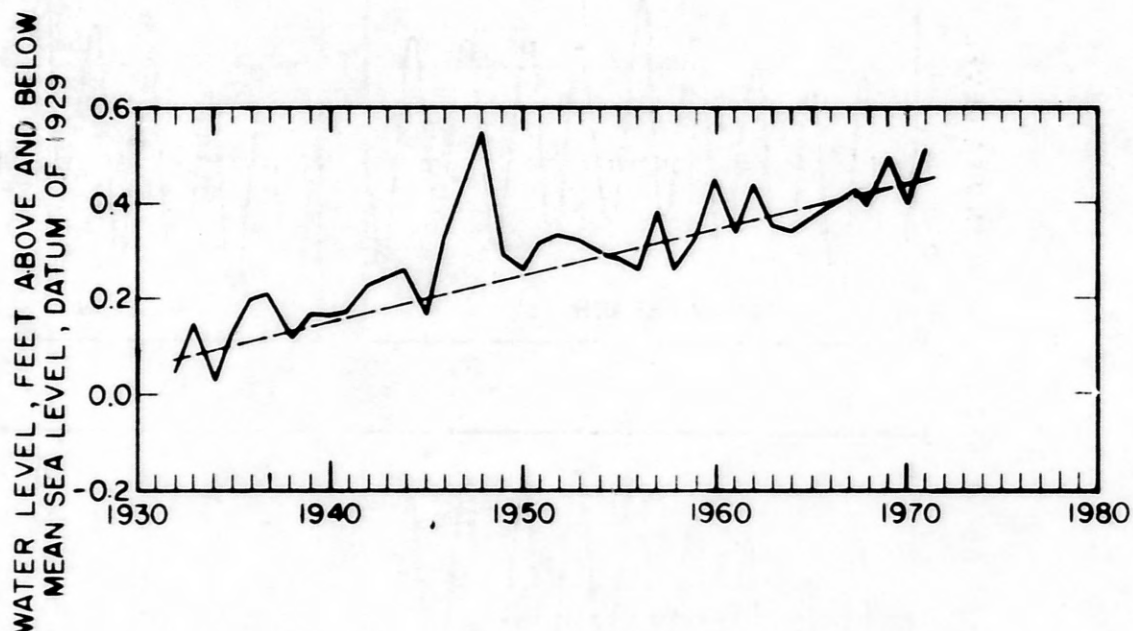


Figure 6.--Variation of yearly mean water level at Miami Beach, Florida. The dashed line represents the long term trend in sea level.

GLOSSARY

Mean High Water: The average level of all high waters of a series of observations.

Mean Low Water: The average level of all low waters of a series of observations.

Mean Half Tide: The average of mean high and mean low waters.

Mean Water Level (Mean Sea Level): The average water level over a period of time.

Mean Tidal Range: The difference between the mean high and mean low water.

Time difference: The amount of time to be added or subtracted to the time of the predicted high or low tide at some reference station.

Note: National Ocean Survey normally uses observation over a 19 year period to determine mean high water, mean low water, etc. for a given location. Unless otherwise specified, mean water levels presented in this report are based on observations made within a 1-year period.

REFERENCES

- American Society of Civil Engineers, 1962, Nomenclature for hydraulics: Manual No. 43.
- Bowditch, Nathaniel, 1966, American practical navigator: U.S. Navy Hydrographic Office, 1524 p.
- Marmer, H.A., 1951, Tidal datum planes: U.S. Dept. of Commerce, Coast and Geodetic Survey, Spec. Pub. No. 135, Revised edition, p. 58-60.
- Schneider, J.J., 1970, Tidal Relations along the Intracoastal Waterway, Broward County, Florida. U.S. Geol. Survey Open-file report.