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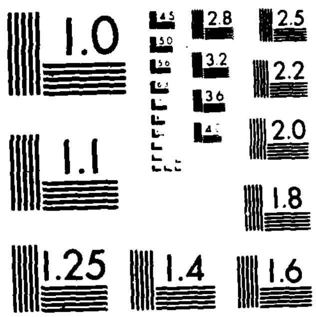

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US Army Corps of Engineers

COASTAL ENGINEERING RESEARCH CENTER

MISCELLANEOUS PAPER CERC-83-8

SHORELINE EROSION STUDY PLEASURE ISLAND, TEXAS

by

Curtis Mason, William Grogg, and Stephen Wheeler
Coastal Engineering Research Center
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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This report summarizes the results of a study of processes affecting Pleasure Island, Texas, an 18-mile-long island separating Sabine Lake from the Sabine-Neches Waterway at Port Arthur, Texas. Wave, current, and meteorological data collected during the summer of 1982 and the winter of 1982-83 were analyzed to assess the relative contributions of man-made and natural processes contributing to Pleasure Island shoreline erosion. A summary of

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20. ABSTRACT (Continued).

processes affecting erosion is presented, as are wave height distribution tables.

Ship wakes were found to be the primary long-term cause of the continuing erosion of unstable bank material, although extreme natural events may also play a role.

PREFACE

The work summarized in this report was funded by the U. S. Army Engineer District, Galveston, (SWG) as part of the congressionally-authorized "Pleasure Island at Port Arthur, Texas, Beach Erosion Study" and was performed in 1982 and 1983 by the U. S. Army Corps of Engineers Coastal Engineering Research Center (CERC). On 1 July 1983, CERC became part of the U. S. Army Engineer Waterways Experiment Station (WES) under the supervision of Dr. Robert W. Whalin.

The report was prepared by Curtis Mason, Chief, Field Research Facility (FRF) Group (CERC); Bill Grogg, FRF Instrumentation Technician; and Steve Wheeler, FRF Computer Specialist; under the general supervision of Mr. Rudy Savage, Chief, Research Division.

Review comments and District liaison were provided by Mr. J. M. Kieslich (SWG), and technical assistance was provided by Mr. Jay Stutes (Port Arthur Area Office, SWG).

Commander and Director of WES during the conduct of the study and the preparation and publication of this report was COL Tilford C. Creel, CE. Mr. F. R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, INCH-POUND TO METRIC (SI) UNITS OF MEASUREMENT

Inch-pound units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
miles (U. S. statute)	1.609347	kilometers
feet	0.3048	meters
knots	0.5144444	meters per second

SHORELINE EROSION STUDY, PLEASURE ISLAND, TEXAS

I. INTRODUCTION

A. Background.

Pleasure Island, Texas is an 18-mile*-long island separating the Port Arthur Canal and Sabine-Neches Canal of the Sabine-Neches Waterway from Sabine Lake (Figure 1). The island ranges in width from less than 50 ft to about 2500 ft, and contains a park and other recreational facilities, a marina, a National Guard Armory, fishing levees, and the Corps of Engineers' Port Arthur area office. Much of the island resulted from dredging of a land-cut in the early 1900's, but the remainder was formed from disposal of dredge material into Sabine Lake, which began in 1912. This unrestricted disposal continued until about 1967, and by 1969 material was being pumped into large diked disposal areas on the east side of the island. Over the past several years, extensive erosion of the island's western shoreline has occurred. In some areas, the state road running the length of the island is being threatened, and potentially valuable development property is also being affected by this erosion.

SWG has been requested by local interests to assist in protecting the island from shoreline erosion. However, in order for the District to assist in this effort, the erosion must be clearly the result of natural, as opposed to man-made, causes. At the request of the District, a study was undertaken to delineate the processes causing shoreline erosion at Pleasure Island, Texas, and in particular to identify the magnitude and duration of natural and man-made erosional events.

B. Objectives.

The objectives of the study were (1) to measure the physical processes contributing to erosion of the Sabine-Neches Canal and (2) to assess the relative contributions of man-made and natural erosion agents of the shoreline erosion.

C. Approach.

To meet the objectives of this study, the following approach was taken. First, since waves and currents were considered to be the most likely forces causing erosion, a two-part measurement effort was conducted. During August and September 1982, wave data were collected at a site near the Corps' area office. Currents were measured during an August spring tide range to determine the maximum current speeds associated with an average spring tide.

Wave measurements were repeated in January and February to determine the effect of winter storms on the ambient naturally-occurring wave conditions. Any other special conditions which could affect erosion rates along the banks were also noted. This report presents details of the data collection and analysis efforts, and a summary of results.

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* A table for converting the inch-pound units of measure in this report to metric (SI) units is found on page iii.

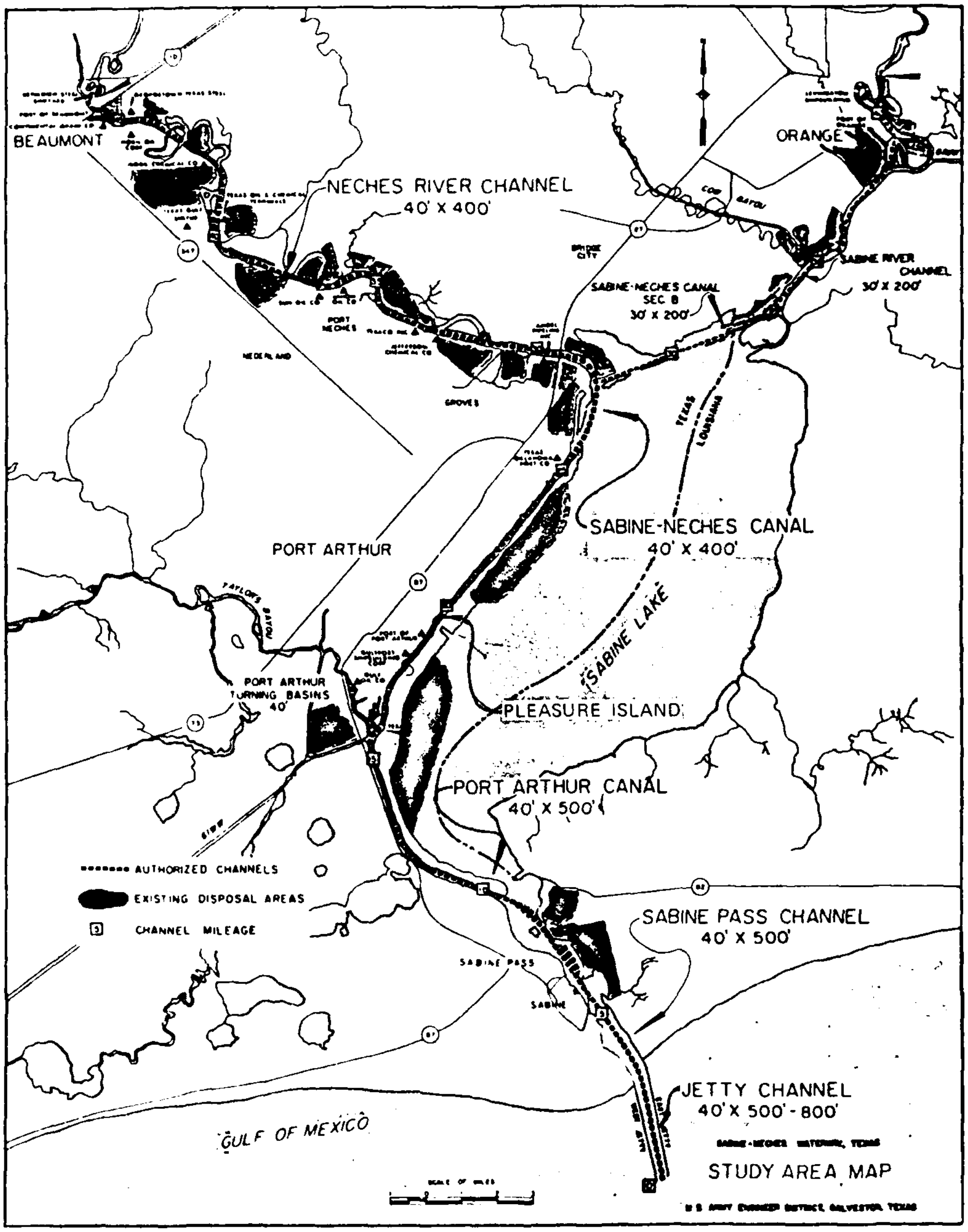

FIGURE 1 - Location Map

II. DATA COLLECTION

A. Wave Data.

In order to obtain accurate data on natural and man-made water level variations, a number of wave data collection systems were considered. The need to measure short period, high amplitude signals in shallow water rendered a pressure gage unsuitable. Similarly, rapid variations in salinity, and the need for a long-term, maintenance-free installation, ruled out capacitance or resistance gages. Therefore, a Baylor inductance wave gage was selected as the most appropriate gage to use (Miller, 1980).

The gage (Figure 2) consisted of two 10-ft long wires, powered by a 24VDC source. Although the gage output was dependent upon the water's salinity, extensive calibration tests at CERC's Field Research Facility provided a calibration curve to use in adjusting the data for in situ salinity variations (Figure 3).

Analog signals from the Baylor wave gage were transmitted through a cable to a Lockheed Store-7 tape recorder located in a secure room on shore. During the summer months, the room was air-conditioned, since the recorder calibration was temperature dependent. Twice each weekday, Mr. Jay Stutes (SWG) would mount a new tape on the recorder (at about 0700 and 1500). A strip chart recorder was allowed to run continuously throughout the study period as a backup. Dates and times of usable data collection runs are listed in Table 1.

B. Current Data.

To assess the possible role of tidal currents on shoreline erosion processes, data were collected during a representative spring tide on 14 and 15 August 1982. A Gurley-Price cup-type current meter was used to obtain current data at the channel ranges shown in Figure 4. Data were collected at 3 locations (surface currents at left and right channel margins and surface, bottom, and mid-depth measurements at the channel centerline on two ranges). Although the original plan called for bi-hourly collection over an entire tidal cycle, the presence of numerous fast-moving ships during the night and the occurrence of desirable peak ebb flows during daylight precluded round-the-clock operations. Measured current speeds and directions are summarized in Table 2.

C. Salinity Measurements.

Since salinity variations affect the wave gage calibration factor (which was set for 15 parts per thousand (o/oo)), daily values were obtained using a Yellowsprings Instrument Model 33 temperature-conductivity meter throughout

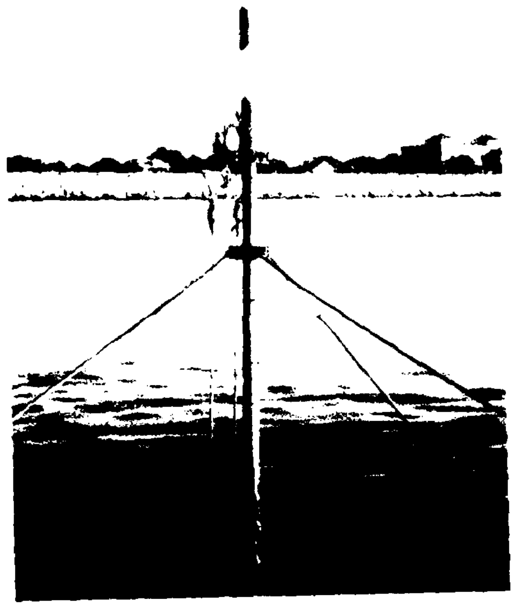

Figure 2 - Baylor Gage Installed at Port Arthur

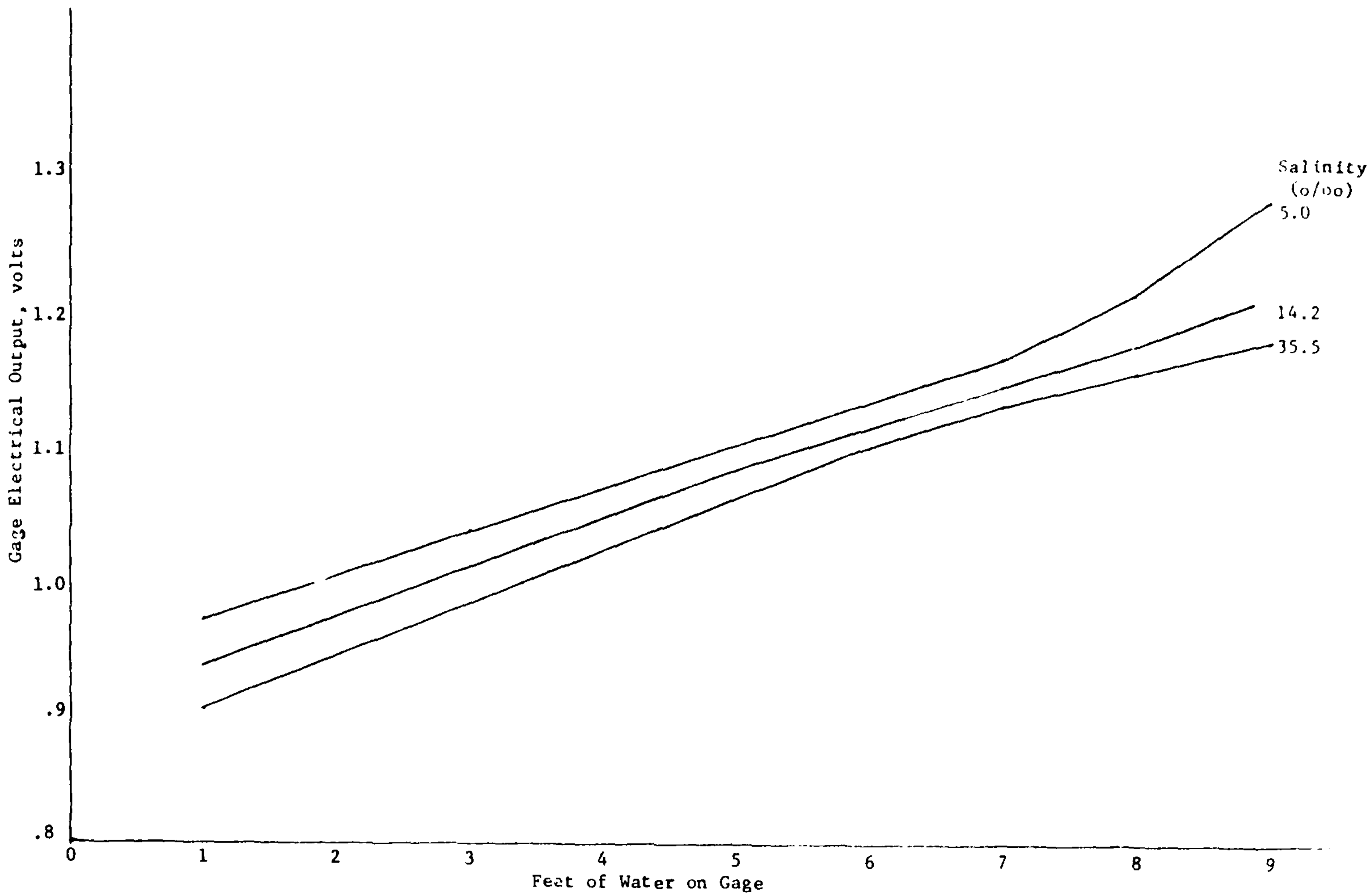

Figure 3 - Baylor Gage Output Salinity Dependence

Table 1 - Data Collection Periods

Date	Start Time (CDT)	End Time (CDT)	Tape #
8/16/82	0812	1534	5
	1547	2400	6
8/17/82	0751	1530	7
	1545	2344	8
8/18/82	0750	1523	9
	1530	2144	10
	2158	0611	11
8/19/82	0753	1458	12
	1513	2309	13
8/20/82	0748	1436	14
	1452	2157	15
8/23/82	0756	1518	16
	1525	2321	17
8/24/82	0752	1531	18
	1550	2346	19
8/25/82	0752	1514	20
	1521	2152	21
	2156	8/26-0552	22
8/26/82	0806	1528	23
	1544	2340	24
8/27/82	0752	1514	25
	1535	2331	26
8/30/82	0751	1547	27
	1551	2347	28
8/31/82	0748	1544	29
	1547	2343	30
9/1/82	0752	1514	31
9/2/82	0747	1509	33
	1541	2337	34
9/3/82	0746	1525	35
	1536	2042	36
	2103	9/4-0459	37
9/7/82	0756	1535	38
	1552	2348	39
9/8/82	0746	1434	40
	1541	2337	41
9/9/82	0747	1526	42
	1539	2335	43
9/10/82	0748	1527	44
	1540	2336	45
9/11/82	0736	1532	46
	1545	2341	47
9/12/82	0721	1517	48
	1630	9/13-0026	49
9/15/82	0808	1513	50
	1545	2341	51
9/16/82	0745	1251	52
1/18/83	1501	2240	101
1/27/83	0706	1536	103

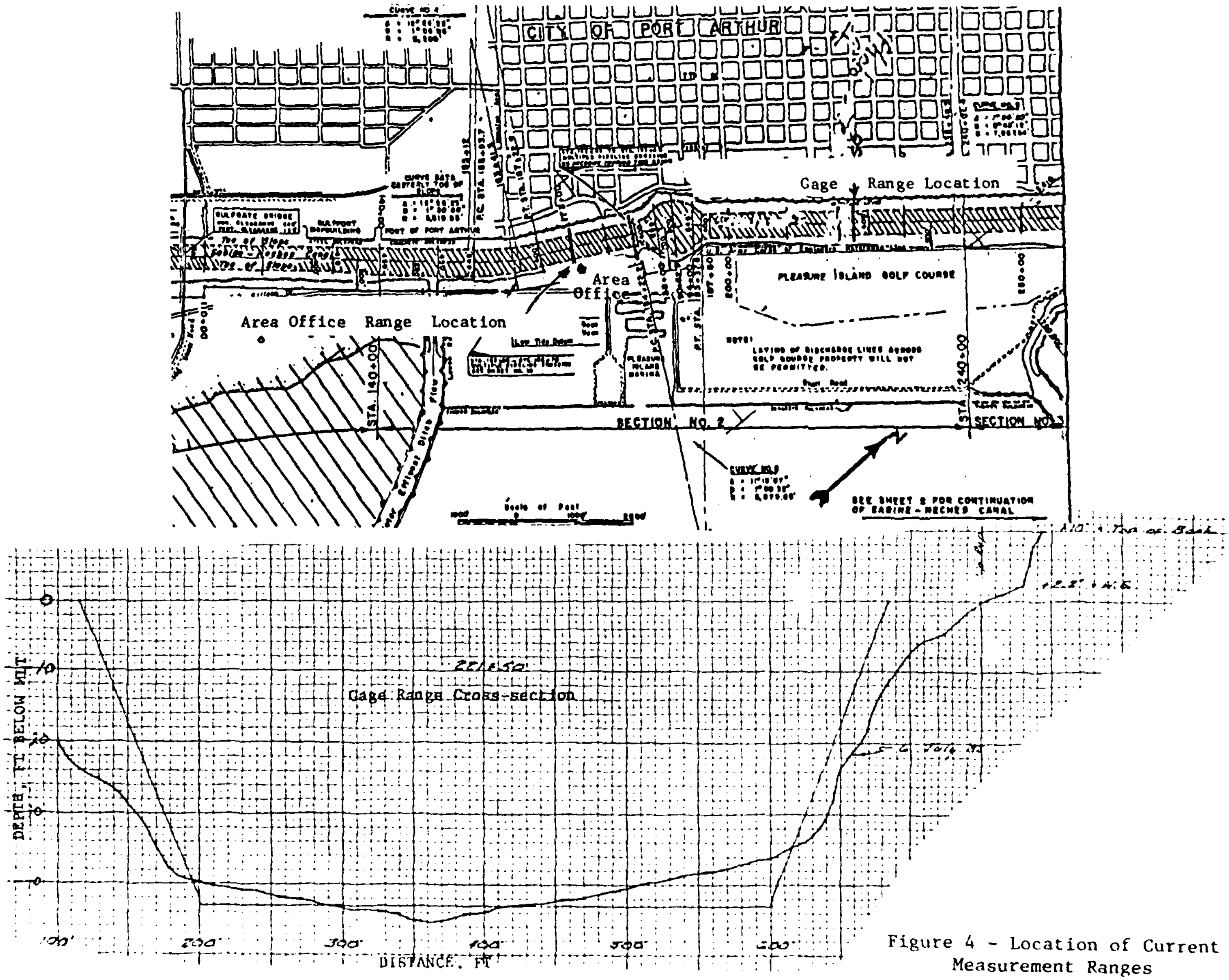

Figure 4 - Location of Current Measurement Ranges

Table 2 - Currents (cm/sec) Measured at Port Arthur, Texas
14-15 August 1982

GAGE RANGE

DATE	TIME	WEST SIDE - 15' from bank, 5½' Water Depth SFC CURRENT	CENTERLINE SFC	CENTERLINE 15 ft	CENTERLINE 30 ft	EAST SIDE- Near Baylor Gage, 5 ft Water Depth SFC CURRENT
14 Aug	1030	+7.91	+13.56	+6.78	+19.21	+2.26
	1215	+5.65	+ 3.39	0	+18.08	+1.13
	1445	-41.81	-27.12	-22.60	?	-13.56
	1610	-27.12	- 7.91	-49.72	-27.12	- 7.91
	1755	-36.16	-72.32	-70.06	-67.80	-32.77
	1945	-36.16	-92.66	-88.14	-97.18	-38.42
15 Aug	0620	0	+38.42	+61.02	+62.15	0

+ = Flood
- = Ebb

AREA OFFICE RANGE

DATE	TIME	WEST SIDE- 20' from bank, 4' water depth SFC CURRENT	CENTERLINE SFC	CENTERLINE 15 ft	CENTERLINE 30 ft	EAST SIDE- 20' from bank, 12' Water Depth SFC CURRENT
14 Aug	0930	-	?	+9.04	+12.43	+9.04
	1100	-	+4.52	+20.34	+20.34	-
	1200	+7.91	+7.91	-	+9.04	0
	1330	-	Weak and Variable			-11.30
	1430	-				-19.21
	1505	-3.39	-21.47	-24.86	-19.21	-22.60
	1640	-11.30	-73.45	-58.76	-40.68	-56.50
	1810	-32.77	-99.44	-89.27	-83.62	-61.02
	1920	-15.82	-106.22	-111.87	-93.79	-47.46
	2015		-103.96	-	-	-
15 Aug	0600	0	+45.20	+39.55	+37.29	+29.38

+ = Flood
- = Ebb
SFC = Surface

most of the August-September collection period (Table 3A). Although the meter and a backup malfunctioned between 1 and 14 September, salinity values both before and after this time period showed small variations from the mean value of 16 o/oo, so it was assumed that between these dates the salinity was approximately 16 o/oo. To assess the variation in salinity over a representative tidal cycle, measurements were made concurrently with current measurements on 14 and 15 August (Table 3B, 3C).

Both the long and short-term measurements indicated that surface salinity values ranged between 13 and 19.5 parts per thousand, with a mean value of about 16 ppt. Therefore, it is concluded that no appreciable error in the wave data occurred due to salinity variations.

D. Water Level Data.

During the current measurement period of 14 and 15 August, 1982, the hourly tide levels shown in Table 4 were obtained from the Corps' tide gage at the area office. Comparison with the predicted values shows good agreement on time of extremes, but poor agreement in absolute level.

E. Meteorological Data.

Wind speed and direction data were obtained for the Port Arthur Airport from the National Weather Service, and tabulated daily for two times within the usual wave data collection periods, 1100 and 2100 (CDT) (Table 5).

F. Miscellaneous Data.

On 15 and 16 September 1982, a vessel-passage survey was conducted by Messrs. Mike Kieslich and Larry Donovan (SWG). The purpose of the survey was to document the types and speeds of vessels passing the wave gage such that the wave gage record and the ship wake could be correlated to determine, if possible, characteristic "signatures" associated with vessel speed and type. Table 6 summarizes the results of the survey.

To obtain first-hand information on the bank stability conditions, an inspection of the west side of Pleasure Island was made on 29 March 1982. Along the north end, high vertical scarps of unconsolidated dredge material were seen to be actively eroding. Similar erosion was occurring along the lower banks of the southern portion, where local attempts to protect the shoreline with wooden bulkheads were largely unsuccessful. Many of the bulkheads were in partial or total disrepair. Unfortunately, no quantitative data were available to establish historical erosion rates in these areas.

III. DATA REDUCTION AND ANALYSIS

A. Wave Data Reduction.

Each analog tape of Baylor wave gage output was digitized at 1/4 second intervals and the resulting data stored in 17-minute blocks on magnetic tape.

Table 3 - Temperature and Salinity Measurements at Port Arthur, Texas

A. Area Office Range, 13 August - 16 September 1982

Date	Temperature (^{o}C)	Salinity (0/00)
8/13	-	17
8/14	-	17
8/15	-	14
8/16	-	18
8/17	30	17
8/19	30	17
8/20	30	16
8/23	30	15
8/27	31	16
8/30	31	18
8/31	31	18
9/15	31	15
9/16	31	13

B. Gage Range Centerline - 14-15 August 82

Date	Time	Current	SFC Temp(^{o}C)/Salinity		15 ft Depth Temp(^{o}C)/Salinity		30 ft Depth Temp(^{o}C)/Salinity	
14 Aug	1030	Flood	31	17	30	17.5	-	-
	1215	Flood	31	17	30	18.5	30	22.5
	1445	Ebb	30	18	29	19.5	29	24.2
	1610	Ebb	30	17.5	30	17.5	30	17.5
	1755	Ebb	31	15	31	15	31	16
	1945	Ebb	32	14	32	14	-	-
15 Aug	0620	Flood	31	15	31	16	31	18

C. Area Office Range - 14-15 August 82

Date	Time	Current	SFC Temp(^{o}C)/Salinity		15 ft Depth Temp(^{o}C)/Salinity		30 ft Depth Temp(^{o}C)/Salinity	
14 Aug	1100	Flood	30	17.5	-	-	30	21
	1200	Flood	30	17.5	30	18.5	30	22.5
	1505	Ebb	31	19.5	30	21	30	25
	1640	Ebb	31	17	31.5	17	-	-
	1810	Ebb	31	15	31	16	31	16
	1920	Ebb	31	15	32	15	32	15.5
15 Aug	0600	Flood	31	16.5	31	16	31	18

Table 4 - Tide Data for Port Arthur, Texas
14-15 August 1982

DATE	TIME	Measured Tide Height Above MLT (FT)	Range		Predicted Tide Height Above MLW (FT)
14 Aug	0300	-			+1.5
	0540	4.80			
	0640	4.75			
	0740	4.80			
	0840	4.75			
	0940	4.65			
	1040	4.80			
	1140	4.65	2.55 ← Range	→ 1.8	
	1240	4.65			
	1340	4.45			
	1440	3.80			
	1540	3.50			
	1640	3.20			
	1740	2.65			
	1840	2.35			-0.30
	1940	2.25			
	2040	2.30			
	2140	2.40			
	2240	2.80	2.15 ← Range	→ 2.0	
	2340	3.10			
15 Aug	0040	3.70			
	0140	4.20			
	0240	4.40			
	0340	4.40			+1.7
	0440	4.40			

Table 5 - Wind Speed and Direction
17 Aug to 16 Sep 82; 18 and 27 Jan 83
Port Arthur, TX

Date	Time (CDT)	Wind Speed (knots)	Direction
17 Aug 82	1100	07	300
	2100	06	130
18 Aug	1100	06	030
	2100	06	010
19 Aug	1100	08	050
	2100	04	160
20 Aug	1100	08	090
	2100	05	160
23 Aug	1100	10	240
	2100	06	190
24 Aug	1100	10	210
	2100	06	180
25 Aug	1100	09	220
	2100	06	170
26 Aug	1100	06	190
	2100	06	170
27 Aug	1100	10	210
	2100	05	170
30 Aug	1100	08	100
	2100	03	140
31 Aug	1100	06	100
	2100	06	100
1 Sep	1100	08	170
	2100	06	140
2 Sep	1100	03	240
	2100	04	340
3 Sep	1100	05	330
	2100	04	340
8 Sep	1100	13	050
	2100	08	050
9 Sep	1100	12 (gusts to 19)	030
	2100	08	050
10 Sep	1100	12	050
	2100	11	060
11 Sep	1100	16 (gusts to 23)	270
	2100	04	170
12 Sep	1100	14 (gusts to 22)	170
	2100	11	140
15 Sep	1100	05	030
	2100	04	250
16 Sep	1100	05	010
	2100	05	080
18 Jan 83	1100	15 (gusts to 20)	070
	2100	10	060
27 Jan 83	1100	13	360
	2100	Calm	

Table 6 - Vessel Passage Survey, Pleasure Island, Port Arthur, Texas

Type	Draft Feet	Direction	Velocity (knots)	Time and Wave Gage (CDT)	Date
Tug & Barge	-	Outbound	3.0	3:43 pm	15 September 1982
Tug & Barge	-	Outbound	4.3	3:43$^{\underline{15}}$ pm	"
Tug	-	Outbound	13.8	4:00 pm	"
Tug & 3 Barges	7	Outbound	7.9	4:07$^{\underline{35}}$ pm	"
Launch	-	Inbound	17.5	4:45$^{\underline{35}}$ pm	"
Tug & Barge	4	Outbound	6.3	7:47$^{\underline{50}}$ am	16 September 1982
Tug	-	Inbound	8.3	8:26$^{\underline{05}}$ am	"
Tug & 2 Barges	-	Inbound	5.9	8:45$^{\underline{15}}$ am	"
Tug & 4 Barges	2	Outbound	10.2	8:59$^{\underline{15}}$ am	"
Tug & 1 Barge	-	Inbound	4.1	9:45$^{\underline{35}}$ am	"
Tug & 4 Barges	2	Inbound	4.5	9:49$^{\underline{30}}$ am	"
2 Tugs & 3 Barges Lashed Together	-	Outbound	-	9:54 am	"
Tug & 4 Barges	9	Inbound	6.2	9:58$^{\underline{30}}$ am	"
Tug & 2 Barges	5.5	Outbound	5.4	10:07— am	"
Tug	11.5	Outbound	7.9	10:10$^{\underline{15}}$ am	"
Tug & 3 Barges	1	Inbound	7.5	10:30$^{\underline{20}}$ am	"
Tug & 2 Barges	-	Outbound	-	11:09$^{\underline{15}}$ am	"
Tug & 1 Barge	-	Outbound	-	11:14$^{\underline{50}}$ am	"
Tug	-	Outbound	-	11:14$^{\underline{50}}$ am	"

During the digitization, the data were filtered to eliminate background noise on the raw data tape. The mean and standard deviation of each 17-minute record were also computed, and a Fourier Transform technique (Thompson, 1977) was used to calculate the period associated with the maximum energy density. Although these parameters were not used in the final analysis, they provided an interim check of data quality.

B. Wave Data Analysis.

A zero upcrossing method similar to that described by Draper (1966) was used to analyze each 17-minute record. This program first calculates the mean value for an entire 17-minute record, subtracts the mean from each data point, and then determines the times associated with each "upcrossing" of the now "0" mean value by the data time-series (i.e. determines the times at which one negative data point is followed by a positive point). The maximum and minimum values between two such "zero upcrossings" are then taken as the wave crest and trough, respectively, and the corresponding wave height is defined as the difference between them. Wave period is defined as the time difference between two "zero upcrossings." After determining each wave height and period in a 17-minute record, the program sorted each set of values in descending order, and computed their distribution in 10% increments, as well as the upper 2% and 5% increments. A sample output of this analysis is shown in Table 7.

Following the analysis of each 17-minute record, another program was run to combine the results for each day, and summary tables were created which present the distribution of height and period in 10% increments, and for the upper 5% in 1% increments (Table 8 and Appendix A).

C. Analysis of Strip Chart Wave Records.

In addition to the computer-processed digital data, each strip chart was examined to determine the number and type of wakes generated by passing vessels (Table 9).

The number of detectable wakes within any 14-hour period varied between 13 and 44, with a mean value of 27. The strip chart records indicated that ship traffic was evenly distributed throughout any one 24-hour period, so there would be about 44 vessels passing daily which would create a detectable wake.

To obtain some indication of the relative magnitude of the wakes, they were sorted into 7 groups, based on their height and period, and a numerical rating (termed the wake factor) was assigned to each group according to the

Table 7 - Sample Output from One Data Record

8/16/82 1426 CDST

FILE NO. : 23 NO. OF UPCROSSINGS : 494 MWL = 4.07

WAVE HEIGHTS	MEAN:	.143 FT	MAX:	.780 FT	MIN:	.040 FT	STD:	.08
WAVE CRESTS	MEAN:	.086 FT	MAX:	.513 FT	MIN:	.033 FT		
WAVE TROUGHS	MEAN:	.057 FT	MAX:	.267 FT	MIN:	.007 FT		
WAVE PERIODS	MEAN:	2.032	MAX:	34.25	MIN:	.500	STD:	2.89

NO. OF WAVES WITH PERIOD OF 0.5 SECONDS = 9

DISTRIBUTION TABLE

	HEIGHTS	PERIODS
2%	.40 FT	11.75 SEC
5%	.28 FT	7.00 SEC
10%	.22 FT	3.75 SEC
20%	.18 FT	2.00 SEC
30%	.16 FT	1.50 SEC
40%	.14 FT	1.50 SEC
50%	.14 FT	1.25 SEC
60%	.12 FT	1.00 SEC
70%	.10 FT	1.00 SEC
80%	.08 FT	1.00 SEC
90%	.06 FT	.75 SEC
100%	.04 FT	.50 SEC

SIGNIFICANT HEIGHT = .221 FT
SIGNIFICANT PERIOD = 4.02 SEC

TEN HIGHEST WAVE HTS. & PERIODS

HEIGHTS	PERIODS
.78 FT	34.25 SEC
.58 FT	24.75 SEC
.54 FT	20.00 SEC
.44 FT	19.00 SEC
.44 FT	14.75 SEC
.42 FT	13.50 SEC
.42 FT	13.00 SEC
.42 FT	12.75 SEC
.42 FT	12.75 SEC
.40 FT	11.75 SEC

Table 8 - Sample Output from 1-Day Summary

DISTRIBUTION TABLE
FOR AUG. 16, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.36 FT	14.25 SEC
2%	.28 FT	9.25 SEC
3%	.24 FT	6.75 SEC
4%	.24 FT	5.50 SEC
5%	.20 FT	5.00 SEC
10%	.18 FT	3.00 SEC
20%	.14 FT	2.50 SEC
30%	.10 FT	2.00 SEC
40%	.10 FT	1.75 SEC
50%	.08 FT	1.50 SEC
60%	.08 FT	1.25 SEC
70%	.06 FT	1.00 SEC
80%	.06 FT	1.00 SEC
90%	.04 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .17 FT
SIGNIFICANT PERIOD = 4.10 SEC
TOTAL # OF WAVES = 26303

Table 9 - Wake Occurrences
16 Aug to 16 Sep 82
Port Arthur, TX

Date	Tape #	Number of Observations Wake Type 1	2	3	4	5	6	7	Total # of Wakes	Total Wake Factor
8/16	5	-	-	2	-	-	2	12	16	76
	6	-	-	-	2	-	-	12	14	
8/17	7	-	-	-	-	-	-	7	7	62
	8	-	1	2	-	-	2	7	12	
8/18	9	1	1	-	-	-	3	5	10	72
	10	-	-	2	1	-	-	4	7	
8/18 & 19	11	-	-	-	1	-	-	5	6	
8/19	12	1	-	-	1	-	-	6	8	56
	13	-	1	-	1	-	1	2	5	
8/20	14	1	2	2	-	1	3	10	19	192
	15	-	1	3	1	2	4	14	25	
8/23	16	1	1	1	2	4	3	5	17	152
	17	1	-	1	2	1	2	6	11	
8/24	18	-	1	-	1	1	4	12	19	102
	19	-	-	2	-	-	-	10	12	
8/25	20	-	1	-	1	1	2	12	17	122
	21	-	-	-	2	-	5	7	14	
8/25 & 26	22	1	-	3	1	1	3	3	12	
8/26	23	-	-	2	1	2	3	9	17	180
	24	-	1	1	3	1	3	6	15	
8/27	25	1	-	1	-	4	4	11	21	164
	26	-	1	-	3	1	3	9	17	
8/30	27	2	-	-	2	1	2	10	17	156
	28	1	-	3	2	3	1	11	21	
8/31	29	-	-	1	-	1	4	10	16	98
	30	-	-	-	-	1	2	8	11	
9/1	31	1	1	-	-	-	1	9	12	44
9/2	33	-	1	2	-	3	4	9	19	172
	34	1	-	1	1	2	4	8	17	
9/3	35	-	1	-	2	-	2	9	14	140
	36	3	-	-	-	1	4	5	13	
9/3 & 4	37	-	-	-	1	1	2	5	9	22 (9/4)
9/7	38	-	-	-	1	1	2	8	12	68
	39	-	-	-	-	1	1	6	8	
9/8	40	1	1	-	1	1	2	11	17	124
	41	1	-	-	-	2	3	5	11	
9/9	42	1	1	-	1	1	2	1	7	132
	43	2	1	-	1	5	-	2	11	
9/10	44	1	-	1	-	1	2	5	10	128
	45	-	3	1	-	2	4	-	10	
9/11	46	-	-	-	-	4	3	5	12	128
	47	3	-	1	-	1	1	4	10	
9/12	48	1	-	1	2	4	3	4	15	134
	49	-	-	2	2	2	1	3	10	
9/15	50	1	-	-	-	1	4	5	11	146
	51	2	1	-	-	3	3	7	16	
9/16	52	-	-	-	1	1	3	7	12	44

scheme shown below. For each day, the individual wake factors were totaled yielding a single number representing the relative magnitude of wake activity (Table 9).

WAKE GROUPS

Wake Class No.	Description	Wake Factor
1	Large (height at least 2 ft) long-period signature followed by many smaller waves	10
2	Same as class 1 but no smaller waves	10
3	Medium (height about 1 ft) long-period signature	6
4	Small (½ ft) long-period signature	2
5	Large (height at least 2 ft) short-period waves	10
6	Medium (height about 1 ft) short-period waves	6
7	Small (height ½ ft) short-period waves	2

The strip chart obtained concurrently with the vessel passage survey of 15 and 16 September was also analyzed to determine if particular ships created representative wake signatures. Figure 5 shows a selected portion of these wakes, as well as the wake classification assigned to each. Observations by the authors and results of the vessel passage survey, indicate that wake classes 1 thru 4 are associated with very large ships (tankers, freighters, etc.), while classes 5 thru 7 reflect the passage of smaller, faster vessels.

IV. RESULTS

Since the primary objective of this study was to determine the forces producing erosion of the Pleasure Island shoreline, the effect of each possible contributing factor will be evaluated based on the available data.

A. Bank Material Characteristics.

Much of the Pleasure Island shoreline consists of very fine, unconsolidated dredge material emplaced many years ago. Although now well vegetated on the surface, this material is extremely vulnerable to erosion, as exemplified by the active areas of slumping on the northern end of the island. The same type of material comprises the southern, land-cut portion of the island, and although one would expect slightly lower erosion rates because of higher cohesion of this undisturbed material, the basic vulnerability of this soil type to erosion remains the same.

B. Waves.

1. General Discussion of Digital Data. Waves, and their associated oscillatory currents, are generally the most significant cause of shoreline erosion. The rapid uprush of water dislodges poorly consolidated particles from the bank or shoreline, allowing them to be transported by currents

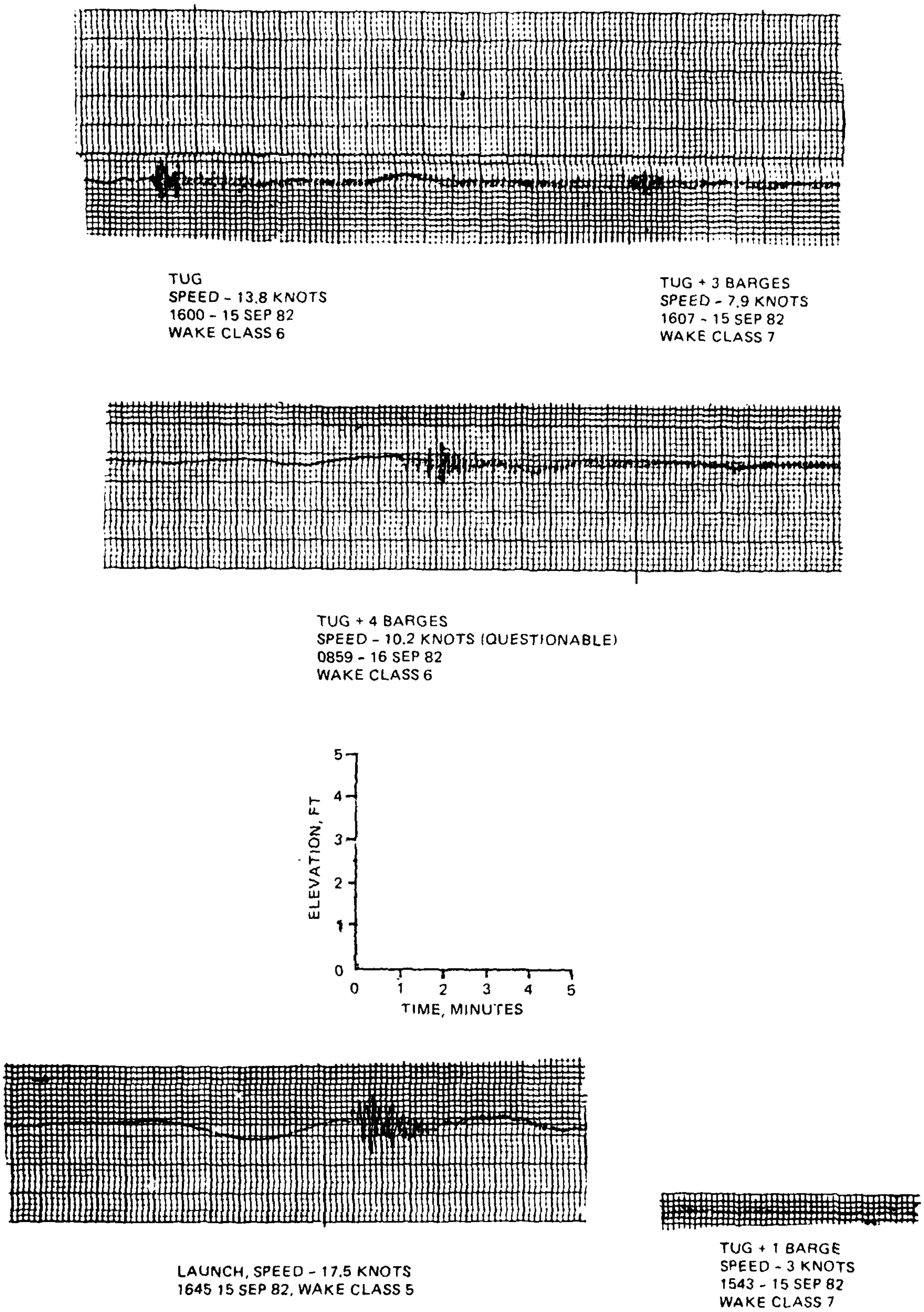

Figure 5 - Wakes from Identified Vessels

either along the shore or towards deeper water offshore. Data collected in this study were used to address the question of which types of waves contribute most to the erosional process.

The daily variation in wave intensity was examined first. Table 10 summarizes the daily wind conditions, wake factors, and three measurements of wave activity: the wave heights associated with the 1%, 10% and 20% exceedance levels (i.e. for the 1% wave height, 1% of all the waves were greater than the wave height value indicated, and, of course, 99% were lower).

To obtain a graphical representation of any possible relationships between wave heights and the wake factor, these data are also plotted in Figure 6 for times when both the wake factor <u>and</u> wave height data are available.

Figure 6 shows that, except for three days, the 20% wave height never exceeded 0.20 ft, with a median value of only 0.14 ft). The 10% height showed more variation, but the median was only slightly greater (0.18 ft). Thus, on days of low-to-moderate vessel activity, but with a wide variety of wind speeds and directions, at least 90% of the summer waves had wave heights less than 0.20 ft. Such small waves do, of course, have some energy available to transport small quantities of sediment. However, they are incapable of producing the wide-scale and sometimes rapid erosion occurring throughout the study area.

It was anticipated that waves generated by the passage of strong frontal systems during the winter (northers) would be significantly higher than those of the summer. Since winter strip chart data were not available to determine wake factors, the January 1983 data were not plotted. However, the 10% and 20% wave heights on 18 January were about double the summer median values (Table 10). Winds on that day were strong and gusty from the northeast. On 27 January, winds were also strong, but were blowing directly from the north, and the 10% and 20% heights were very close to the summer medians. Since the orientation of the channel between the Port Arthur turning basin and the Sabine River is NE/SW, it appears that strong winds blowing <u>along</u> the channel axis must generate waves significantly higher than normal. However, since northerly winds also tend to depress local water levels by driving inland waters into the Gulf of Mexico, the net erosion potential during such conditions is minimized. Therefore, we must turn our attention to the larger waves which occur less than 1% of the time.

Returning to Figure 6, note that the distribution of the 1% wave height generally shows a direct relationship with the wake factor, i.e. as the wake factor increases, so too does the 1% height. Although there is some scatter in the data (probably produced by the coarseness of the wake factor determination), it appears that for a wake factor of 0, the 1% height would roughly equal the 10% height. Therefore, it is apparent that during usual weather conditions, waves with significant erosion potential can only result from the passage of vessels in the waterway.

Table 10 - Wave Data Summary

Date	Wind Speed	Direction	Exceedence Wave Heights 1%	10%	20%	# of Waves	Wake Factor
8/16/82			.36	.18	.14	26303	76
8/17	7	215	.24	.14	.10	26304	62
8/18	6	20	.26	.14	.10	22936	22
8/19	6	105	.52	.30	.16	28852	56
8/20	6	125	.74	.50	.44	20980	192
8/23	8	210	.88	.68	.58	23491	152
8/24	8	195	.40	.22	.18	30886	102
8/25	7½	195	.42	.18	.14	28077	122
8/26	6	180	.46	.18	.14	29889	180
8/27	7½	195	.44	.20	.18	27465	164
8/30	5½	120	.52	.18	.14	21214	156
8/31	6	100	.87	.30	.23	18815	190
9/2	3½	290	.57	.17	.10	12129	172
9/3	4½	335	.47	.13	.10	11936	140
9/4			.30	.13	.10	5216	22
9/7			.23	.10	.07		68
9/8	10½	50	.40	.13	.10	14304	124
9/9	10(Gusty)	40	.50	.20	.17	14845	132
9/10	12	50	.57	.23	.17	13004	128
9/11	10(Gusty)	220	.53	.17	.13	15213	128
9/15	5	140	.47	.13	.10	20588	146
9/16	5	45	.37	.13	.10	9449	44
1/18/83	12½(Gusty)	65	.70	.37	.27	10798	
1/27	13	360	.60	.20	.13	4268	
2/7							
Median Values:			.46	.18	.14		

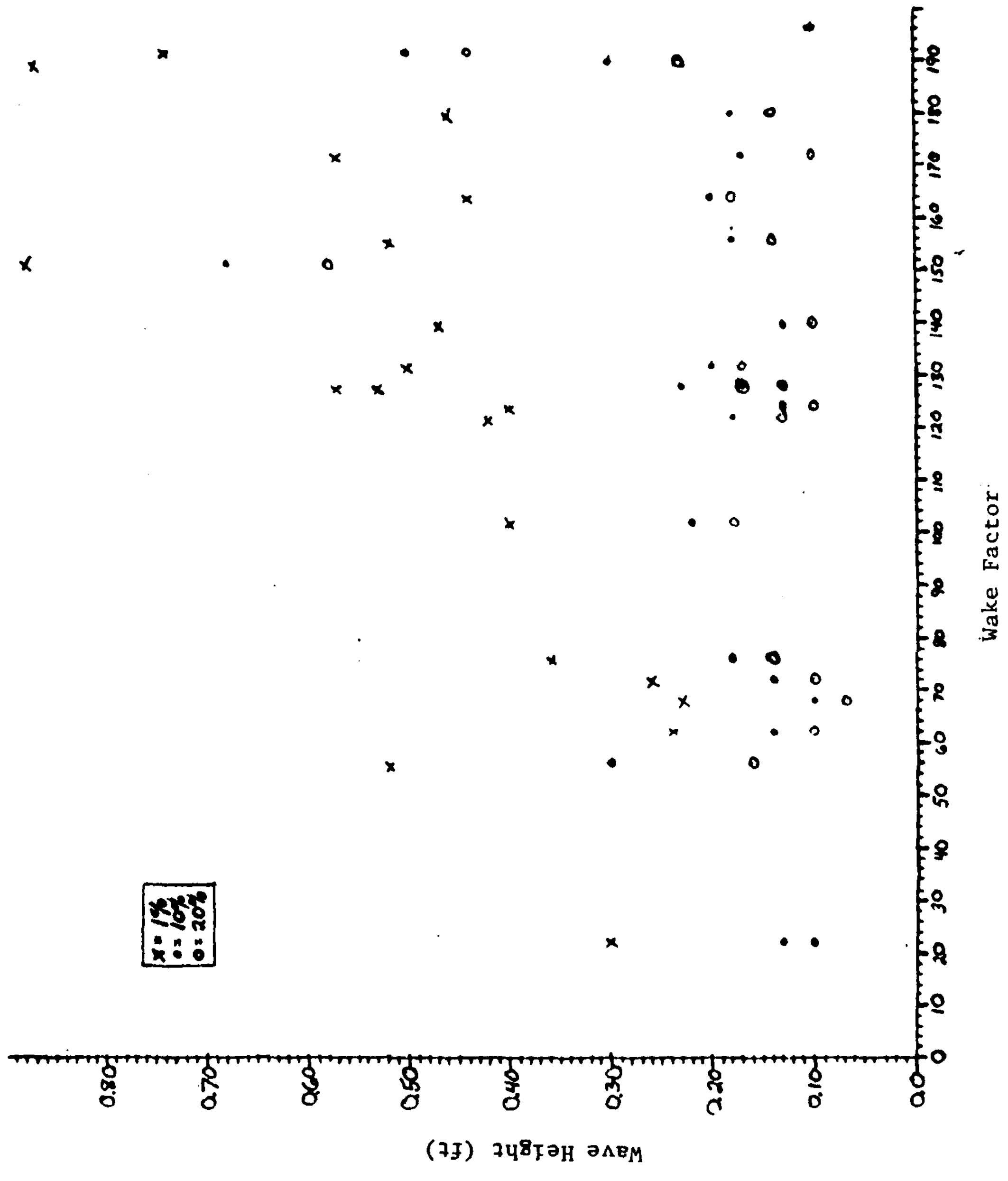

Figure 6 - Wave Exceedance Height vs. Wake Factor

2. Specific Wake Events. Extreme ship-wake events (Figure 7) can cause rapid oscillations in the water level of up to 4 ft, and have great potential for eroding the channel shoreline. During the current measurement survey, a large freighter traveling at about 5 knots passed by the measurement station. The long-period wake associated with this vessel measured only about 0.5 ft in height. However, current measurements made concurrently showed that near-bottom flows at the wave gage reached a maximum of 0.85 m/sec, and these produced a band of turbid water a considerable distance offshore. It would have been interesting, indeed, to have measured current speeds associated with the 3 ft wakes of Figure 7.

Observations during the passage of several tugs, launches, and other vessels which created large wakes confirmed the generation of highly-turbid water by disturbance of both bottom sediments and erosion of bank material. In fact, during the inspection survey of 29 March, slumping of the vertical banks along the northern end of Pleasure Island was observed to occur during such wake activity.

3. Extreme Natural Waves. The passage of Tropical Storm Chris through the Port Arthur area on 10 and 11 September 1982 fortuitiously coincided with this study's wave data collection. Since the center of the storm passed just to the east of Port Arthur during the early morning hours, magnetic tape data were not collected during peak wind and wave conditions. However, the backup strip chart provides an excellent history of the wave and water level fluctuations produced by the storm (Figure 8).

For the 24-hour period prior to 0300 CDT, 11 September, winds at Port Arthur increased from about 10 knots to about 16 knots, and were consistently from the northeast quadrant (60^{o}). By 0500, they had increased to 23 knots, and between 0500 and 0800 winds reached a maximum of 42 knots, and changed direction from ENE (60^{o}) to NNW (340^{o}).

Wind wave activity was slightly greater than normal during that time (mean height about 0.30 ft). However, beginning at about 0400, wave heights increased dramatically, reaching a maximum of about 2.2 ft, and these large waves persisted for about 3½ hours.

Wind wave magnitude showed the effects of the previously mentioned relationship between wind direction and channel orientation. Waves reached their maximum heights when winds were directed from the NE (i.e. along the channel axis), and diminished greatly as the wind shifted to the north and northwest. Most rainfall (0.35 inches) occurred between 0500 and 0700 on the 11th.

Long-period waves occurred just prior to, and for an extended time after, the passage of the storm surge crest. The initial periods averaged about 16 minutes, lengthening gradually to more than 40 minutes by mid-morning. In addition, a gradual rise in the water level began at 2100 on 10 September,

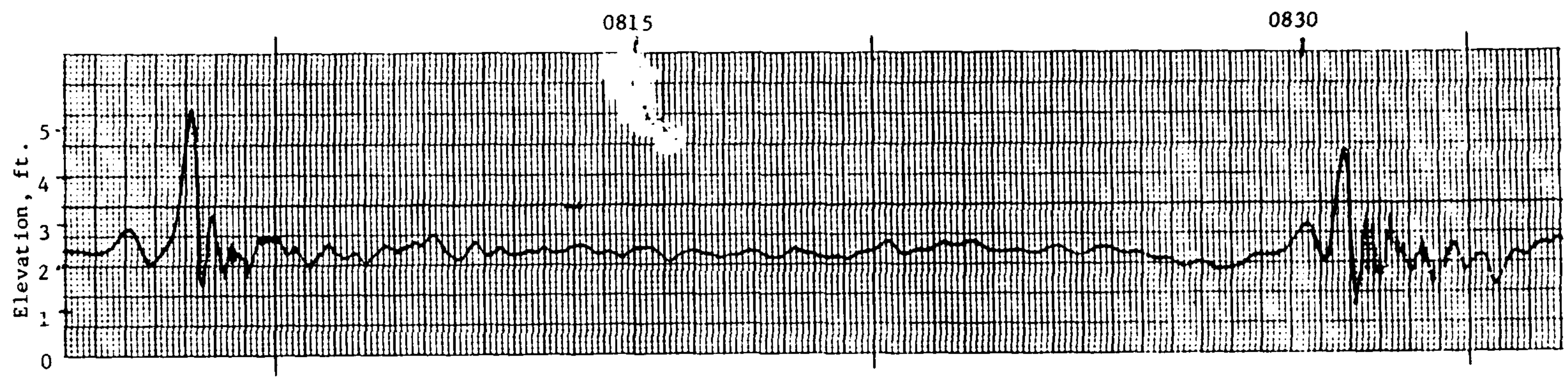

Figure 7 - Wave Record of Large Shipwakes, 10 September 1982

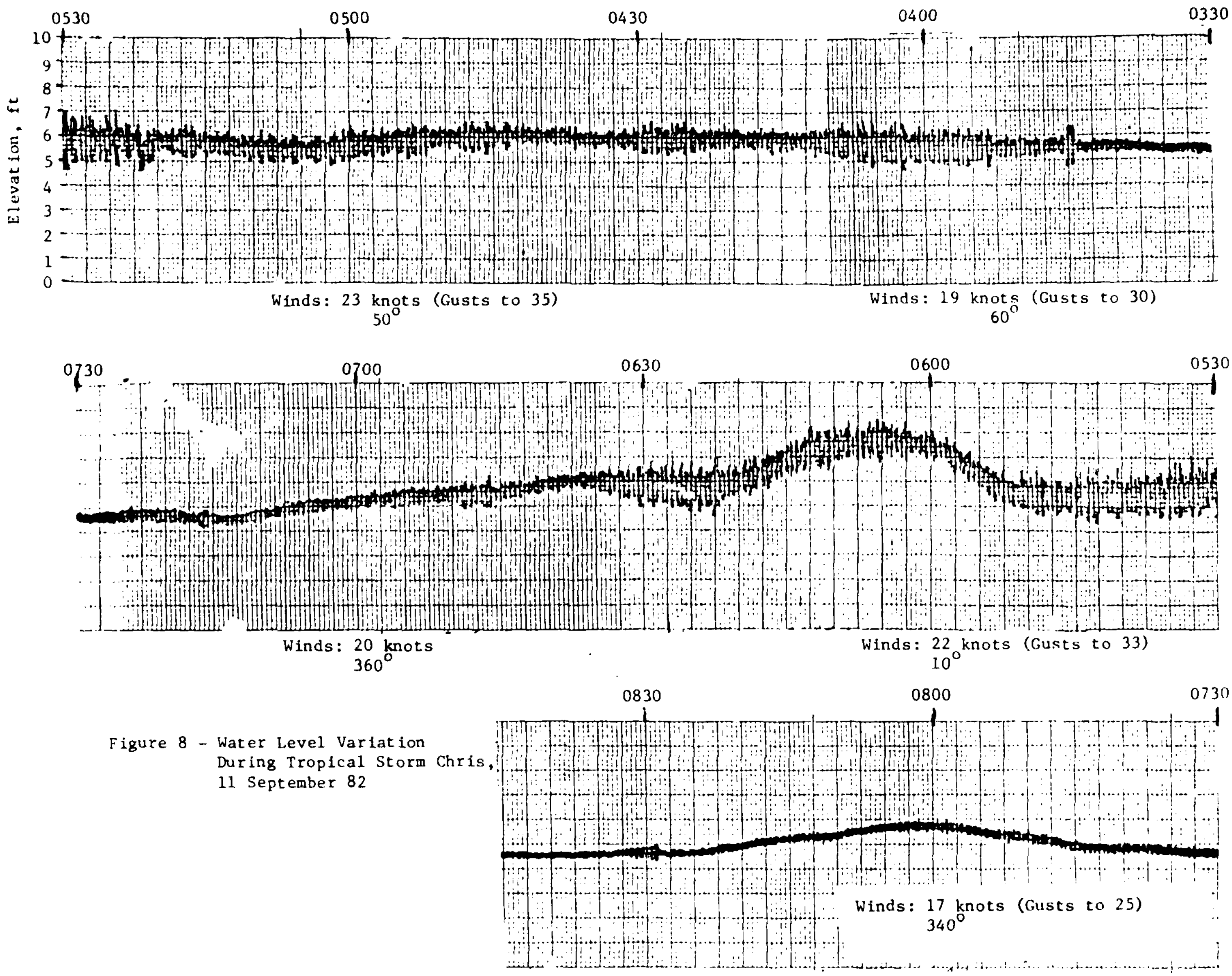

Figure 8 - Water Level Variation During Tropical Storm Chris, 11 September 82

and continued until about 0400 on 11 September. This occurred in spite of the fact that winds during this time averaged about 12 knots from the ENE. The storm surge magnitude was about 2 ft above the pre-surge level, and the crest passed the wave gage location in about 15 minutes (Figure 8).

Although no pre or post storm profiles are available, the combination of high water, relatively large wind waves, and rainfall undoubtedly caused some shoreline erosion. Larger storms and hurricanes making landfall within a few tens of miles of Port Arthur could cause widespread erosion. Such storms occur within 50 miles of Port Arthur about once every 5 years (data obtained from Neumann, 1978).

4. Effect of Water Levels on Bank Stability. Although the mean diurnal tide range at Port Arthur is only about 1 ft, storms and other short-term meteorological events can substantially affect the water levels along the shoreline. During periods of unusually low water, little erosion would be expected. High water levels would generally be associated with increased erosion for a number of reasons. First, the vertical banks characteristic of the study area would be saturated to a higher elevation, and therefore more unstable, than during periods of low water. Secondly, increased depths would allow higher waves to impinge upon the shoreline, with erosion of the already weakened shoreface. Finally, navigational requirements of very large, deep-draft vessels are often timed to coincide with high water. Thus, some of the most destructive wakes occur at the water level most conducive to shoreline erosion.

5. Currents. Current data collected during the spring tide of 14 and 15 August were examined to determine if tidal currents could be directly responsible for the shoreline erosion. Table 2 indicates that the maximum speed in 5½ ft of water about 15 ft from shore at the gage range was about 35 cm/sec. Currents at the shoreline itself would be substantially lower, and certainly insufficient to remove material directly. In the presence of wave action, such currents would provide a mechanism for transporting material away from the banks, and in that sense are partially responsible for bank erosion. However, waves must first put the material into suspension.

6. Rain and Aeolian Erosion. Any bare slope composed of unconsolidated material is subject to erosion by rain and wind. This is usually a slow process in comparison to wave-induced erosion at the water line. However, saturation of the silty banks by heavy rainfall would certainly enhance wave-induced erosional processes, and the Port Arthur area does experience substantial thunderstorm activity during the summer. In the case of Port Arthur, the lack of profile data precluded quantitative assessment of these erosional agents.

V. CONCLUSIONS

A. Ship wakes are the primary cause of the continuing erosion of unstable bank material along the west side of Pleasure Island, Texas.

B. Two types of vessels appear to be the major causes of high wake activity:

1. Large freighters or tankers, which produce a large pressure wave and, in the narrow Port Arthur channel, currents of sufficient magnitude to scour nearshore and bank areas; and

2. Smaller, fast-moving vessels, such as tugs, launches, etc., with wakes typically consisting of several waves, normally from 1 to 2 ft in height.

C. Naturally-occurring wave action is normally insufficient to produce the erosion experienced along much of the west bank of Pleasure Island, Texas. Larger waves associated with the passage of winter storms have greater potential for erosion, but their net effect is diminished by the simultaneous decrease in water level. Even larger natural waves occurred with high water levels during Tropical Storm Chris. Such extreme events, although infrequent, surely cause rapid, short-term bank erosion. Their net effect at Port Arthur is unknown.

D. Wave generation in the channel was highly dependent upon wind direction. Wind wave height maxima were associated with NE and ENE winds, which blow nearly parallel to the channel axis.

E. Erosion of the channel banks due to tidal currents is negligible compared to wave-induced processes.

F. High water levels and heavy rainfall can be considered to enhance wave-induced erosion processes. Both increase the water content of the silty Port Arthur Channel banks, and higher water levels allow larger waves to impinge on the shoreline.

G. Wave data have been collected to quantitatively define the distribution of wave heights and periods in the study area. If additional studies are conducted, similar quantification of the rates of erosion associated with the events is recommended. Additionally, a more comprehensive correlation between wake type and vessel characteristics and speed would be useful if navigational restrictions are to be imposed to mitigate shoreline erosion.

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* **Reports published by the U. S. Army Corps of Engineers Coastal Engineering Research Center are available from U. S. Army Engineer Waterways Experiment Station, Technical Report Distribution Section, P. O. Box 631, Vicksburg, Miss.**

APPENDIX A

Wave Height Distribution Tables

DISTRIBUTION TABLE FOR AUG. 16, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.36 FT	14.25 SEC
2%	.28 FT	9.25 SEC
3%	.24 FT	6.75 SEC
4%	.24 FT	5.50 SEC
5%	.20 FT	5.00 SEC
10%	.18 FT	3.00 SEC
20%	.14 FT	2.50 SEC
30%	.10 FT	2.00 SEC
40%	.10 FT	1.75 SEC
50%	.08 FT	1.50 SEC
60%	.08 FT	1.25 SEC
70%	.06 FT	1.00 SEC
80%	.06 FT	1.00 SEC
90%	.04 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .17 FT
SIGNIFICANT PERIOD = 4.10 SEC
TOTAL # OF WAVES = 26303

DISTRIBUTION TABLE FOR AUG. 17, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.24 FT	13.25 SEC
2%	.20 FT	8.00 SEC
3%	.18 FT	5.75 SEC
4%	.18 FT	5.25 SEC
5%	.16 FT	4.50 SEC
10%	.14 FT	3.00 SEC
20%	.10 FT	2.50 SEC
30%	.10 FT	2.25 SEC
40%	.08 FT	1.75 SEC
50%	.08 FT	1.50 SEC
60%	.06 FT	1.25 SEC
70%	.06 FT	1.25 SEC
80%	.04 FT	1.00 SEC
90%	.04 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .13 FT
SIGNIFICANT PERIOD = 4.00 SEC
TOTAL # OF WAVES = 26304

DISTRIBUTION TABLE
FOR AUG. 18, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.26 FT	18.50 SEC
2%	.22 FT	10.50 SEC
3%	.20 FT	7.75 SEC
4%	.18 FT	5.75 SEC
5%	.18 FT	5.25 SEC
10%	.14 FT	3.00 SEC
20%	.10 FT	2.75 SEC
30%	.10 FT	2.25 SEC
40%	.08 FT	1.75 SEC
50%	.08 FT	1.50 SEC
60%	.06 FT	1.25 SEC
70%	.06 FT	1.25 SEC
80%	.04 FT	1.00 SEC
90%	.04 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .14 FT
SIGNIFICANT PERIOD = 4.97 SEC
TOTAL # OF WAVES = 22936

DISTRIBUTION TABLE
FOR AUG. 19, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.52 FT	20.00 SEC
2%	.46 FT	9.75 SEC
3%	.44 FT	6.50 SEC
4%	.40 FT	5.25 SEC
5%	.38 FT	4.50 SEC
10%	.30 FT	3.00 SEC
20%	.16 FT	2.50 SEC
30%	.10 FT	2.00 SEC
40%	.10 FT	1.75 SEC
50%	.08 FT	1.50 SEC
60%	.08 FT	1.25 SEC
70%	.06 FT	1.25 SEC
80%	.04 FT	1.00 SEC
90%	.04 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .24 FT
SIGNIFICANT PERIOD = 4.88 SEC
TOTAL # OF WAVES = 28852

DISTRIBUTION TABLE FOR AUG. 20, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.74 FT	15.50 SEC
2%	.66 FT	8.75 SEC
3%	.62 FT	6.50 SEC
4%	.60 FT	5.25 SEC
5%	.58 FT	4.75 SEC
10%	.50 FT	3.00 SEC
20%	.44 FT	2.25 SEC
30%	.38 FT	2.00 SEC
40%	.32 FT	1.75 SEC
50%	.26 FT	1.75 SEC
60%	.18 FT	1.50 SEC
70%	.12 FT	1.25 SEC
80%	.10 FT	1.00 SEC
90%	.06 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .48 FT
SIGNIFICANT PERIOD = 4.43 SEC
TOTAL # OF WAVES = 20980

DISTRIBUTION TABLE FOR AUG. 23, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.88 FT	12.75 SEC
2%	.84 FT	7.00 SEC
3%	.78 FT	5.25 SEC
4%	.78 FT	4.50 SEC
5%	.74 FT	3.75 SEC
10%	.68 FT	2.75 SEC
20%	.58 FT	2.00 SEC
30%	.48 FT	2.00 SEC
40%	.30 FT	1.75 SEC
50%	.22 FT	1.75 SEC
60%	.16 FT	1.50 SEC
70%	.14 FT	1.50 SEC
80%	.10 FT	1.25 SEC
90%	.08 FT	1.00 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .62 FT
SIGNIFICANT PERIOD = 3.83 SEC
TOTAL # OF WAVES = 23491

DISTRIBUTION TABLE FOR AUG. 24, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.40 FT	7.25 SEC
2%	.34 FT	5.00 SEC
3%	.30 FT	4.00 SEC
4%	.28 FT	3.50 SEC
5%	.26 FT	3.25 SEC
10%	.22 FT	2.75 SEC
20%	.18 FT	2.00 SEC
30%	.14 FT	1.75 SEC
40%	.14 FT	1.50 SEC
50%	.10 FT	1.50 SEC
60%	.10 FT	1.25 SEC
70%	.08 FT	1.25 SEC
80%	.06 FT	1.00 SEC
90%	.06 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .21 FT
SIGNIFICANT PERIOD = 2.95 SEC
TOTAL # OF WAVES = 30886

DISTRIBUTION TABLE FOR AUG. 25, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.42 FT	13.00 SEC
2%	.32 FT	7.25 SEC
3%	.28 FT	5.25 SEC
4%	.24 FT	4.50 SEC
5%	.22 FT	3.75 SEC
10%	.18 FT	2.75 SEC
20%	.14 FT	2.50 SEC
30%	.10 FT	2.00 SEC
40%	.10 FT	1.75 SEC
50%	.10 FT	1.50 SEC
60%	.08 FT	1.25 SEC
70%	.06 FT	1.00 SEC
80%	.06 FT	1.00 SEC
90%	.04 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .17 FT
SIGNIFICANT PERIOD = 3.88 SEC
TOTAL # OF WAVES = 28077

DISTRIBUTION TABLE FOR AUG. 26, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.46 FT	19.00 SEC
2%	.34 FT	10.25 SEC
3%	.30 FT	7.50 SEC
4%	.26 FT	5.50 SEC
5%	.24 FT	5.25 SEC
10%	.18 FT	3.00 SEC
20%	.14 FT	2.50 SEC
30%	.10 FT	2.25 SEC
40%	.10 FT	1.75 SEC
50%	.10 FT	1.50 SEC
60%	.08 FT	1.25 SEC
70%	.06 FT	1.25 SEC
80%	.06 FT	1.00 SEC
90%	.04 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .18 FT
SIGNIFICANT PERIOD = 5.05 SEC
TOTAL # OF WAVES = 29889

DISTRIBUTION TABLE FOR AUG. 27, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.44 FT	10.50 SEC
2%	.34 FT	6.50 SEC
3%	.30 FT	5.25 SEC
4%	.28 FT	4.25 SEC
5%	.26 FT	3.75 SEC
10%	.20 FT	2.75 SEC
20%	.18 FT	2.25 SEC
30%	.14 FT	2.00 SEC
40%	.14 FT	1.75 SEC
50%	.10 FT	1.50 SEC
60%	.10 FT	1.25 SEC
70%	.10 FT	1.25 SEC
80%	.06 FT	1.00 SEC
90%	.06 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .21 FT
SIGNIFICANT PERIOD = 3.60 SEC
TOTAL # OF WAVES = 27465

DISTRIBUTION TABLE FOR AUG. 30, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.52 FT	24.00 SEC
2%	.38 FT	12.00 SEC
3%	.30 FT	8.25 SEC
4%	.28 FT	6.25 SEC
5%	.26 FT	5.25 SEC
10%	.18 FT	3.25 SEC
20%	.14 FT	2.50 SEC
30%	.10 FT	2.25 SEC
40%	.10 FT	1.75 SEC
50%	.08 FT	1.50 SEC
60%	.06 FT	1.25 SEC
70%	.06 FT	1.25 SEC
80%	.06 FT	1.00 SEC
90%	.04 FT	.75 SEC
100%	.02 FT	.50 SEC

SIGNIFICANT HEIGHT = .19 FT
SIGNIFICANT PERIOD = 5.49 SEC
TOTAL # OF WAVES = 21214

DISTRIBUTION TABLE FOR AUG. 31, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.87 FT	25.25 SEC
2%	.67 FT	13.25 SEC
3%	.57 FT	8.25 SEC
4%	.50 FT	6.75 SEC
5%	.43 FT	5.50 SEC
10%	.30 FT	3.50 SEC
20%	.23 FT	2.75 SEC
30%	.17 FT	2.50 SEC
40%	.17 FT	2.00 SEC
50%	.17 FT	1.50 SEC
60%	.13 FT	1.50 SEC
70%	.10 FT	1.25 SEC
80%	.10 FT	1.00 SEC
90%	.07 FT	.75 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .32 FT
SIGNIFICANT PERIOD = 6.12 SEC
TOTAL # OF WAVES = 18815

DISTRIBUTION TABLE FOR SEP. 2, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.57 FT	55.50 SEC
2%	.40 FT	24.25 SEC
3%	.33 FT	15.50 SEC
4%	.27 FT	10.75 SEC
5%	.23 FT	9.00 SEC
10%	.17 FT	5.25 SEC
20%	.10 FT	3.25 SEC
30%	.10 FT	2.75 SEC
40%	.07 FT	2.50 SEC
50%	.07 FT	2.25 SEC
60%	.07 FT	2.25 SEC
70%	.07 FT	2.00 SEC
80%	.03 FT	1.50 SEC
90%	.03 FT	.75 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .17 FT
SIGNIFICANT PERIOD = 9.16 SEC
TOTAL # OF WAVES = 12129

DISTRIBUTION TABLE FOR SEP. 3, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.47 FT	56.25 SEC
2%	.30 FT	27.00 SEC
3%	.27 FT	18.00 SEC
4%	.23 FT	12.75 SEC
5%	.20 FT	10.25 SEC
10%	.13 FT	5.25 SEC
20%	.10 FT	3.00 SEC
30%	.10 FT	2.75 SEC
40%	.07 FT	2.50 SEC
50%	.07 FT	2.50 SEC
60%	.07 FT	2.25 SEC
70%	.07 FT	2.00 SEC
80%	.03 FT	1.25 SEC
90%	.03 FT	.75 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .15 FT
SIGNIFICANT PERIOD = 9.56 SEC
TOTAL # OF WAVES = 11936

DISTRIBUTION TABLE FOR SEP. 4, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.30 FT	21.75 SEC
2%	.20 FT	12.75 SEC
3%	.20 FT	10.00 SEC
4%	.17 FT	8.00 SEC
5%	.17 FT	6.25 SEC
10%	.13 FT	4.25 SEC
20%	.10 FT	3.00 SEC
30%	.10 FT	2.75 SEC
40%	.07 FT	2.50 SEC
50%	.07 FT	2.25 SEC
60%	.07 FT	2.00 SEC
70%	.07 FT	1.75 SEC
80%	.03 FT	1.50 SEC
90%	.03 FT	1.00 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .13 FT
SIGNIFICANT PERIOD = 5.94 SEC
TOTAL # OF WAVES = 5216

DISTRIBUTION TABLE FOR SEP. 8, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.40 FT	36.00 SEC
2%	.27 FT	18.50 SEC
3%	.23 FT	12.25 SEC
4%	.20 FT	9.50 SEC
5%	.17 FT	8.00 SEC
10%	.13 FT	4.75 SEC
20%	.10 FT	3.00 SEC
30%	.07 FT	2.75 SEC
40%	.07 FT	2.50 SEC
50%	.07 FT	2.25 SEC
60%	.07 FT	2.00 SEC
70%	.03 FT	1.75 SEC
80%	.03 FT	1.25 SEC
90%	.03 FT	.75 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .13 FT
SIGNIFICANT PERIOD = 7.31 SEC
TOTAL # OF WAVES = 14304

DISTRIBUTION TABLE FOR SEP. 9, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.50 FT	39.00 SEC
2%	.37 FT	16.75 SEC
3%	.33 FT	11.00 SEC
4%	.30 FT	8.25 SEC
5%	.27 FT	7.00 SEC
10%	.20 FT	4.25 SEC
20%	.17 FT	3.00 SEC
30%	.13 FT	2.50 SEC
40%	.10 FT	2.25 SEC
50%	.10 FT	2.25 SEC
60%	.07 FT	2.00 SEC
70%	.07 FT	1.75 SEC
80%	.07 FT	1.50 SEC
90%	.03 FT	1.25 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .21 FT
SIGNIFICANT PERIOD = 7.42 SEC
TOTAL # OF WAVES = 14845

DISTRIBUTION TABLE FOR SEP. 10, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.57 FT	50.25 SEC
2%	.43 FT	24.75 SEC
3%	.37 FT	17.00 SEC
4%	.33 FT	13.00 SEC
5%	.30 FT	10.25 SEC
10%	.23 FT	5.25 SEC
20%	.17 FT	3.00 SEC
30%	.13 FT	2.75 SEC
40%	.10 FT	2.50 SEC
50%	.10 FT	2.25 SEC
60%	.07 FT	2.00 SEC
70%	.07 FT	1.75 SEC
80%	.07 FT	1.75 SEC
90%	.03 FT	1.25 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .29 FT
SIGNIFICANT PERIOD = 8.67 SEC
TOTAL # OF WAVES = 13004

DISTRIBUTION TABLE FOR SEP. 11, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.53 FT	34.00 SEC
2%	.37 FT	17.75 SEC
3%	.30 FT	11.25 SEC
4%	.27 FT	8.75 SEC
5%	.23 FT	7.25 SEC
10%	.17 FT	4.25 SEC
20%	.13 FT	3.00 SEC
30%	.10 FT	2.50 SEC
40%	.10 FT	2.25 SEC
50%	.07 FT	2.00 SEC
60%	.07 FT	1.75 SEC
70%	.07 FT	1.25 SEC
80%	.07 FT	1.00 SEC
90%	.03 FT	.75 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .18 FT
SIGNIFICANT PERIOD = 7.23 SEC
TOTAL # OF WAVES = 15213

DISTRIBUTION TABLE FOR SEP. 15, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.47 FT	26.00 SEC
2%	.33 FT	11.00 SEC
3%	.27 FT	7.25 SEC
4%	.23 FT	5.50 SEC
5%	.20 FT	5.25 SEC
10%	.13 FT	3.25 SEC
20%	.10 FT	2.75 SEC
30%	.10 FT	2.00 SEC
40%	.07 FT	1.75 SEC
50%	.07 FT	1.50 SEC
60%	.07 FT	1.00 SEC
70%	.07 FT	1.00 SEC
80%	.03 FT	.75 SEC
90%	.03 FT	.75 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .15 FT
SIGNIFICANT PERIOD = 5.30 SEC
TOTAL # OF WAVES = 20568

DISTRIBUTION TABLE FOR SEP. 16, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.37 FT	10.75 SEC
2%	.30 FT	6.00 SEC
3%	.23 FT	5.25 SEC
4%	.20 FT	4.25 SEC
5%	.20 FT	3.75 SEC
10%	.13 FT	2.75 SEC
20%	.10 FT	2.25 SEC
30%	.10 FT	2.00 SEC
40%	.07 FT	1.75 SEC
50%	.07 FT	1.00 SEC
60%	.07 FT	1.00 SEC
70%	.07 FT	1.00 SEC
80%	.03 FT	.75 SEC
90%	.03 FT	.75 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .15 FT
SIGNIFICANT PERIOD = 3.71 SEC
TOTAL # OF WAVES = 9449

DISTRIBUTION TABLE FOR JAN. 18, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.70 FT	17.75 SEC
2%	.60 FT	10.25 SEC
3%	.53 FT	8.00 SEC
4%	.50 FT	6.75 SEC
5%	.47 FT	6.00 SEC
10%	.37 FT	4.50 SEC
20%	.27 FT	3.25 SEC
30%	.20 FT	2.75 SEC
40%	.17 FT	2.75 SEC
50%	.13 FT	2.50 SEC
60%	.10 FT	2.25 SEC
70%	.07 FT	2.00 SEC
80%	.07 FT	1.75 SEC
90%	.03 FT	1.25 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .34 FT
SIGNIFICANT PERIOD = 5.31 SEC
TOTAL # OF WAVES = 10798

DISTRIBUTION TABLE FOR JAN. 27, 1982

	WAVE HEIGHTS	WAVE PERIODS
1%	.60 FT	102.75 SEC
2%	.43 FT	44.75 SEC
3%	.37 FT	24.25 SEC
4%	.30 FT	16.25 SEC
5%	.27 FT	13.00 SEC
10%	.20 FT	5.75 SEC
20%	.13 FT	3.00 SEC
30%	.10 FT	2.75 SEC
40%	.07 FT	2.75 SEC
50%	.07 FT	2.50 SEC
60%	.07 FT	2.50 SEC
70%	.07 FT	2.25 SEC
80%	.03 FT	1.75 SEC
90%	.03 FT	1.00 SEC
100%	.03 FT	.50 SEC

SIGNIFICANT HEIGHT = .30 FT
SIGNIFICANT PERIOD = 13.27 SEC
TOTAL # OF WAVES = 4268