US Army Corps
of Engineers
Waterways Experiment
Station

Preliminary Data Summary for September 1994 CERC Field Research Facility

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Coastal Engineering Research Center

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Prepared for Headquarters, U.S. Army Corps of Engineers

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Preface

This report provides a summary of basic oceanographic, meteorological and bottom profile data for the month. The data were obtained as part of the Measurements and Analysis work units at the U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center's Field Research Facility (FRF) in Duck, North Carolina. The FRF staff collected and analyzed these data. These summaries are intended to make the data readily available to all FRF users, and comments on their content and usefulness are invited.

Several substitutions were made in this report relative to other months.

1) Wave direction information was computed from a pressure gauge and current meter (gauge 3511) and is substituted for the 8 Meter Array (gauge 3111). 3511 is at the same location as the 8 Meter Array.

2) Suvey line 62, located 407m north of the pier, is being substituted for line 188, which is located 517m south of the pier.

3) Precipitation was recorded daily rather than four times a day.

1 Introduction

The U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center's (CERC) Field Research Facility (FRF) is located on the Outer Banks of North Carolina, near the village of Duck (Figure 1).

The FRF research program provides a means for obtaining high-quality field data, particularly during storms, in support of the U.S. Army Corps of Engineers' coastal engineering research missions. The research pier is a reinforced concrete structure supported on 0.9-m-diam steel piles spaced 12.2 m apart along the pier's length and 4.6 m apart across the width. The pier deck is 6.1 m wide and extends from behind the duneline to about the 6-m water depth contour at a height of 7.75 m above the National Geodetic Vertical Datum (NGVD) of the year 1929.

One of the responsibilities of the FRF research program is the collection, analysis and dissemination of data on local bathymetric, oceanographic, and meteorological conditions. This summary is intended to provide basic data as soon as possible after they are obtained. Questions and/or comments concerning the data may be directed to Mr. Clifford F. Baron at (919) 261-3511.

Chapter 2 presents the meteorological data; Chapters 3 through 6 present oceanographic data; Chapter 7 presents nearshore profiles and bathymetry; and Chapter 8, if included, documents special events that occurred at the FRF during the month.

Table 1 is a list of instruments used and their operational status during the month. Figure 2 shows weather and ocean conditions for the month. Table 2 and Figure 3 identifies the location of the instruments. The water depths at the wave gauges and current meters vary and may be determined from information contained in Figure 9. Other installation information is contained in Table 1.

Times given in the report are referenced to eastern standard time (EST).

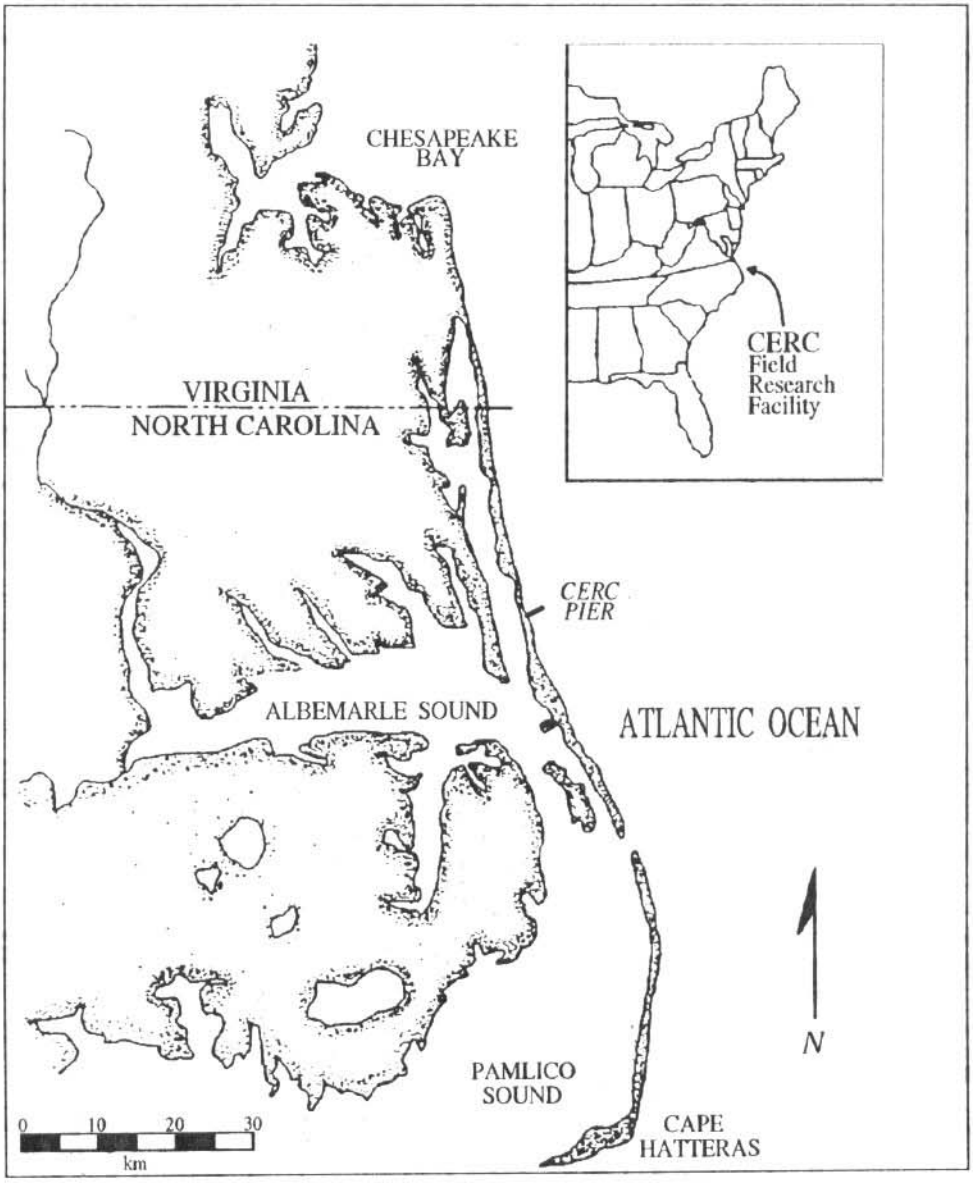

Figure 1. FRF Location Map

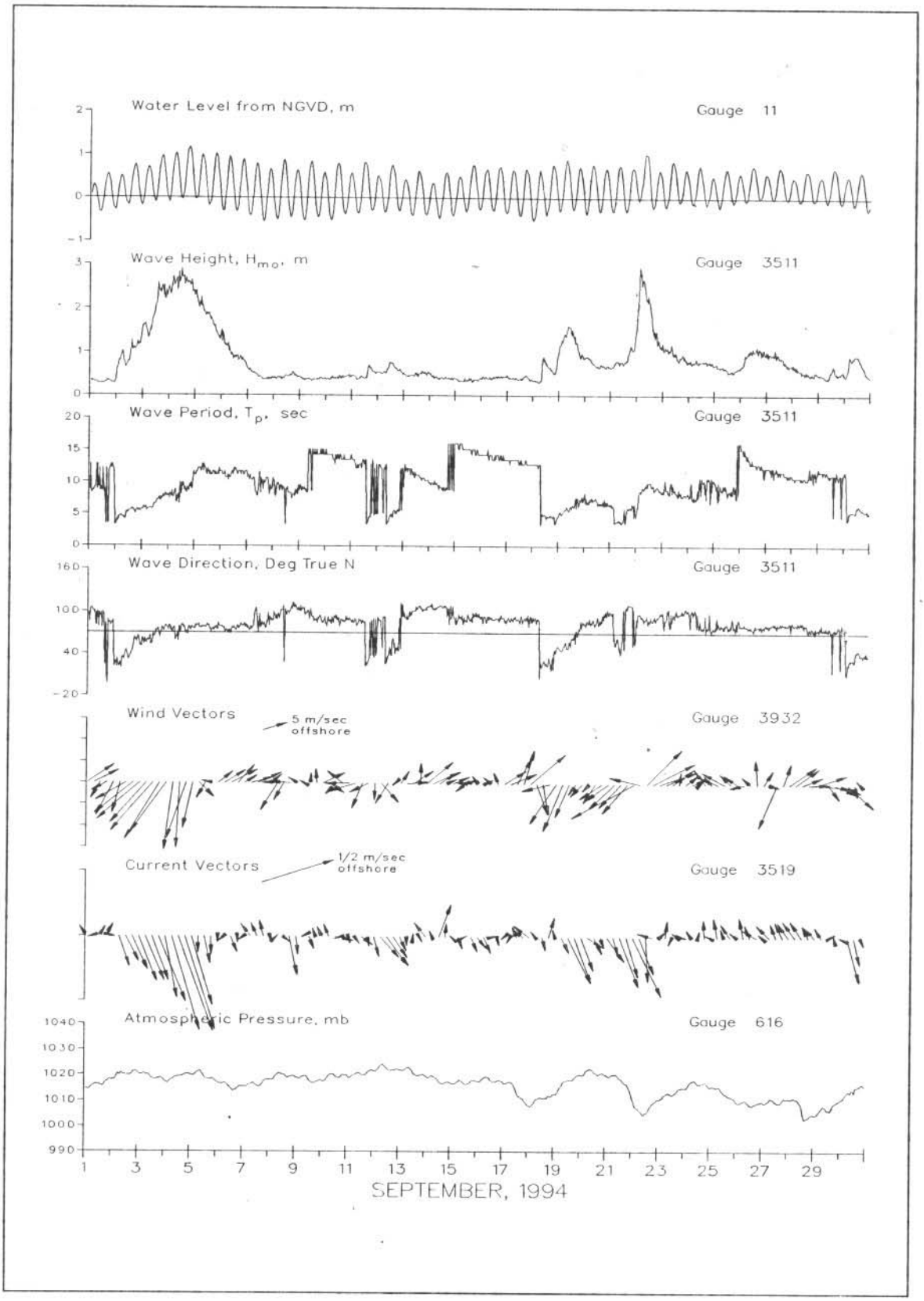

Figure 2. Month at a Glance

Table 1
Instrument Status/Data Availability

September 1994

Day of the month

Gauge ID	Description/Remarks		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
616	Atmospheric Pressure	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
604	Precipitation	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
624	Air Temperature	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	/	/	/	
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	/	/	/	
3932	Anemometer	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
641	Pressure Gauge on FRF pier	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
625	Baylor staff on FRF pier	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3111	8 Meter Array 309 m north of FRF	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
111	Pressure Gauge center of 8 Meter Array	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
630	Waverider buoy 4.0 km offshore	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3519	Current meter and	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3511	Pressure Gauge 434 m north of FRF pier (0.9 km offshore)	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
11	NOAA tide gauge at end of pier	Gauge Status	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
		Data Collected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Visual Observations (daily oceanographic and meteorological observations)		Daily observation	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Gauge Status * = Operational / = Partial - = Non-Operational
Data Collected * = All / = Partial - = None
Visual Observations * = Complete / = Partial - = None

Table 2
Gauge Locations

Gauge ID	Description	Latitude Degrees N	Longitude Degrees W	FRF Coordinates Crosshore m	FRF Coordinates Longshore m	Gauge Depth NGVD, m	Water Depth NGVD, m
616	Atmospheric Pressure	36 10′ 57.03"	75 45′ 5.50"	11.60	569.00	-----	-----
3932	Anemometer	36 11′ 1.23"	75 44′ 43.07"	585.20	517.30	19.50	-----
641	Pressure Gauge	36 10′ 57.71"	75 44′ 56.23"	239.11	516.64	-1.64	-1.96
625	Baylor Staff	36 11′ 1.04"	75 44′ 43.72"	568.00	516.64	Surface	-8.36
3111	8 Meter Array North	36 11′ 19.14"	75 44′ 36.41"	915.23	990.16	-7.50	-7.90
	8 Meter Array South	36 11′ 11.28"	75 44′ 33.28"	914.20	735.37	-7.42	-7.90
	8 Meter Array East	36 11′ 13.70"	75 44′ 32.56"	954.51	800.58	-7.62	-8.13
	8 Meter Array West	36 11′ 12.48"	75 44′ 37.11"	834.66	800.37	-6.98	-7.44
111	Pressure Gauge in center of 8 M Array	36 11′ 14.06"	75 44′ 34.39"	914.43	825.52	-7.76	-8.08
630	Waverider Buoy	36 10′ 5.10"	75 41′ 59.30"	3934.96	-2400.81	Surface	-17.00
3519	Current Meter	36 11′ 17.90"	75 44′ 35.93"	914.76	950.00	-5.30	-7.90
3511	Pressure Gauge	36 11′ 17.90"	75 44′ 35.93"	914.76	950.00	-6.70	-7.90
11	NOAA Tide Gauge	36 11′ 1.25"	75 44′ 42.60"	596.49	514.20	Surface	-7.62

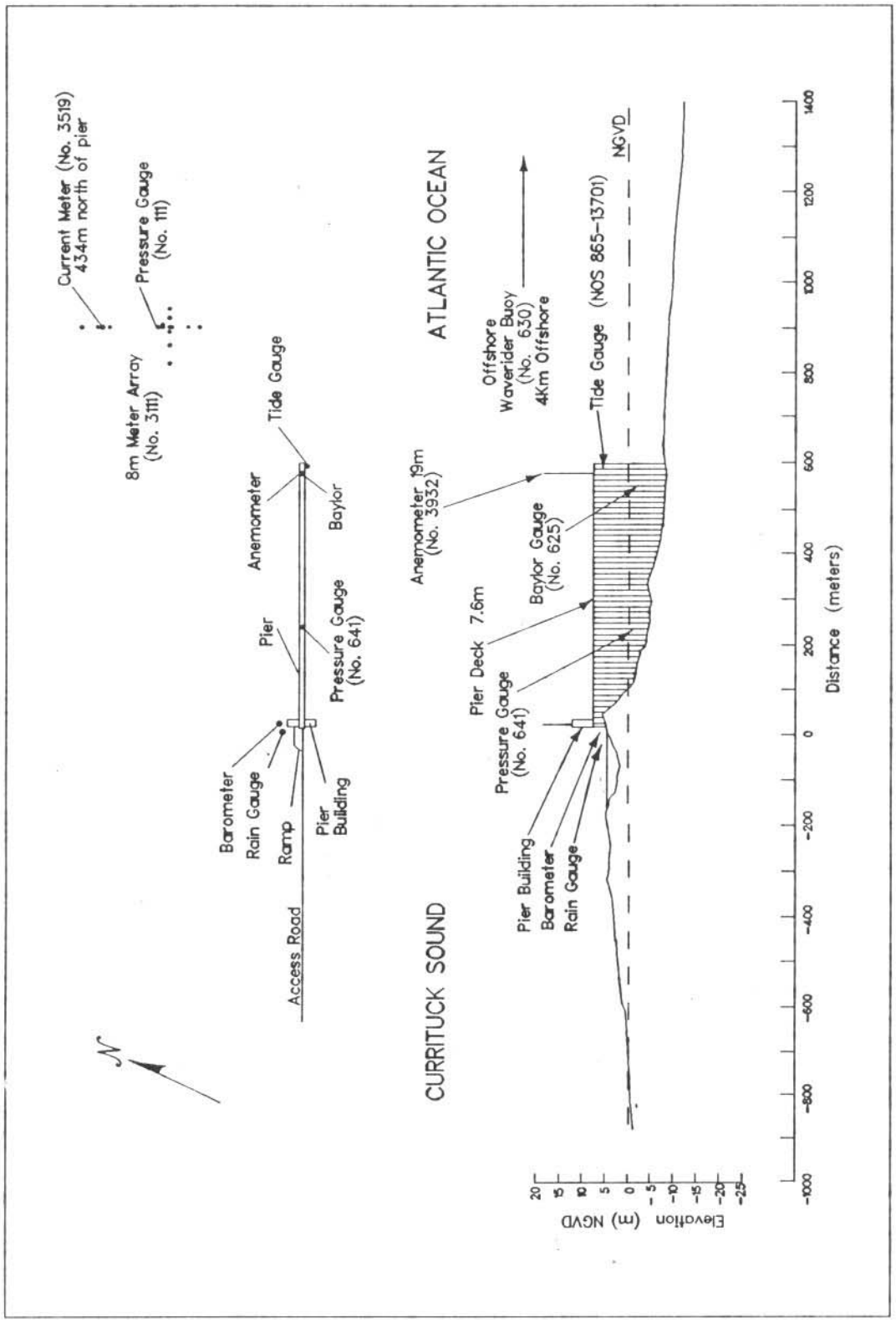

Figure 3. Instrument Locations, Elevations From NGVD

2 Meteorological Data

A variety of instruments have been installed at the FRF (Figure 3) to monitor the meteorological conditions. The data presented in Table 3 are collected and stored using a Digital Equipment Corporation VAXstation 4000. For each instrument identified in Table 1, a log is maintained and the records are stored for future reference.

Winds were measured at the end of the pier at an elevation of 19 m (Figure 4) using a WeatherMeasure Skyvane anemometer. Monthly resultant wind speeds and directions are determined by vector averaging the data. Wind directions indicate where the wind is coming from. Temperature and atmospheric pressure means are the average of the values presented for the month. Total precipitation is the sum for the month.

The following may be useful for converting the data in Table 3 to other frequently used units of measurement:

1. Millimeters (mm) to inches (in.) -
   mm x .03937 = in.

2. Millibars (mb) to inches of mercury (in. Hg) -
   mb x 0.02953 = in. Hg

3. Degrees Celsius (C) to degrees Fahrenheit (F) -
   (C x 9/5) + 32 = F

4. Meters per second (m/s) to knots (kn) -
   m/s x 1.943 = kn

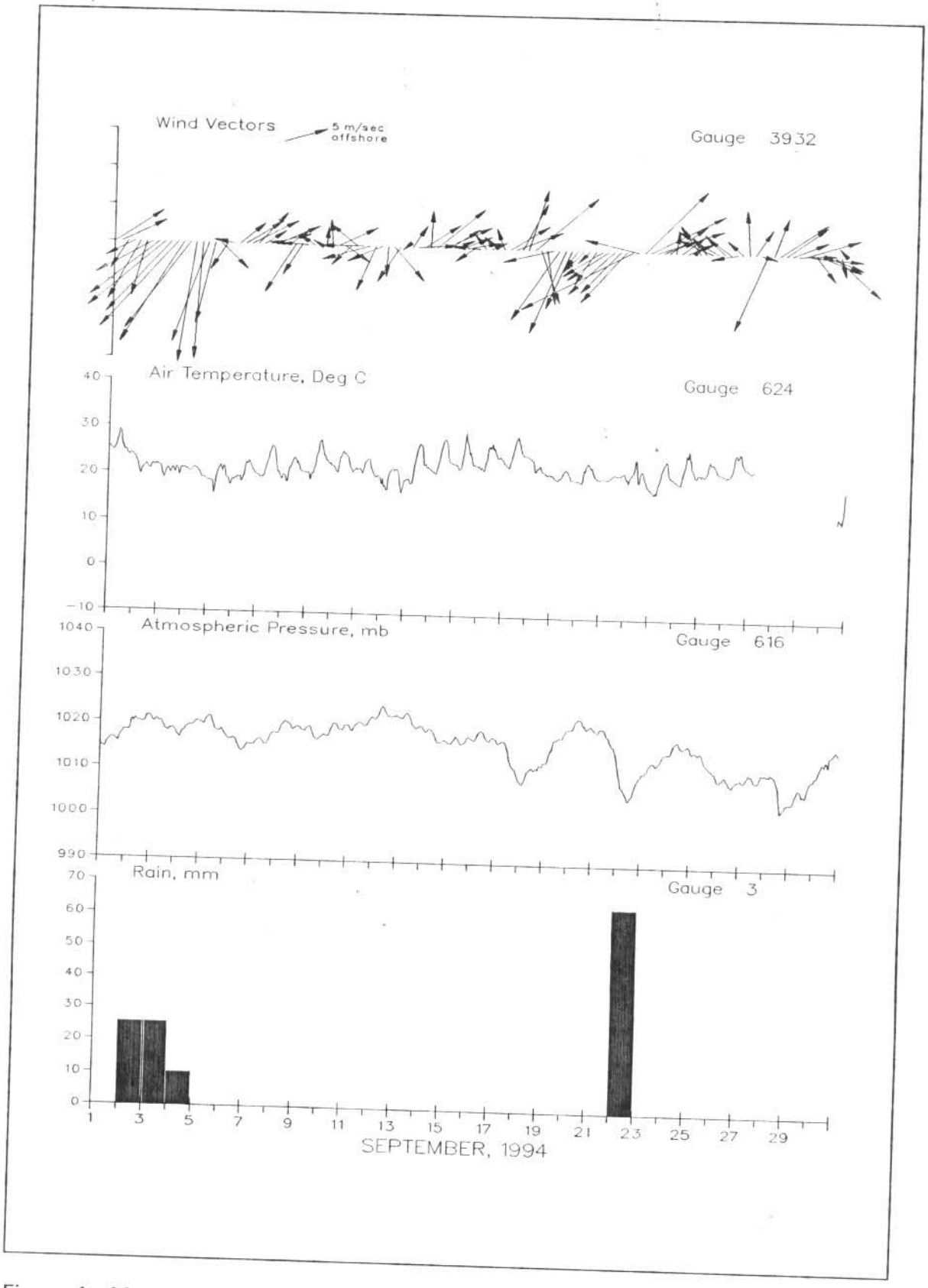

Figure 4. Meteorological Monthly Summary

Table 3
Meteorological Data

Sep 1994

Day	Hour	Wind Speed m/sec	Wind Direction deg TN	Temperature deg C	Atm Pressure mb	Precipitation mm
1	100	7	231	25.5	1014.6	0
	700	6	239	25.4	1015.7	0
	1300	4	27	25.9	1016.4	0
	1900	4	57	23.8	1016.9	0
2	100	8	24	23.6	1018.1	0
	700	7	12	19.5	1020.5	25
	1300	8	56	21.9	1020.2	0
	1900	11	46	21.8	1020.2	0
3	100	12	44	21.5	1020.9	0
	700	12	37	19.8	1020.5	25
	1300	14	36	20.8	1019.1	0
	1900	15	27	20.9	1018.7	0
4	100	13	31	21.2	1017.5	0
	700	16	6	20.4	1018.1	10
	1300	15	2	21.0	1019.4	0
	1900	14	16	19.2	1019.9	0
5	100	11	10	18.6	1020.0	0
	700	4	318	17.4	1021.1	0
	1300	4	27	21.1	1019.6	0
	1900	2	101	19.0	1018.2	0
6	100	4	225	18.7	1017.3	0
	700	5	233	19.4	1016.6	0
	1300	6	238	22.5	1015.2	0
	1900	5	217	21.3	1014.4	0
7	100	3	233	19.9	1015.6	0
	700	5	252	20.1	1016.4	0
	1300	5	242	25.2	1016.1	0
	1900	1	85	21.6	1016.7	0
8	100	3	228	20.1	1018.1	0
	700	7	27	21.4	1019.8	0
	1300	4	27	23.4	1020.4	0
	1900	4	92	20.8	1019.1	0
9	100	2	124	20.6	1019.4	0
	700	1	124	21.2	1019.2	0
	1300	2	184	27.1	1018.4	0
	1900	3	175	23.2	1017.0	0
10	100	5	240	22.1	1017.9	0
	700	4	308	21.9	1019.4	0
	1300	3	40	24.6	1020.1	0
	1900	4	131	21.7	1019.3	0

Table 3
Meteorological Data (continued)

Sep 1994

Day	Hour	Wind Speed m/sec	Wind Direction deg TN	Temperature deg C	Atm Pressure mb	Precipitation mm
11	100	5	88	21.4	1019.5	0
	700	6	70	21.3	1020.2	0
	1300	6	19	23.7	1020.5	0
	1900	4	61	19.9	1020.5	0
12	100	4	2	18.5	1021.8	0
	700	6	322	19.3	1023.4	0
	1300	5	28	21.4	1023.0	0
	1900	1	44	18.0	1022.1	0
13	100	3	209	19.5	1022.2	0
	700	4	266	19.1	1022.5	0
	1300	5	232	26.4	1021.9	0
	1900	5	181	22.6	1019.7	0
14	100	7	225	21.6	1019.7	0
	700	6	242	21.8	1019.7	0
	1300	4	232	27.4	1018.0	0
	1900	2	244	24.0	1016.9	0
15	100	4	244	23.0	1016.9	0
	700	4	257	22.6	1017.5	0
	1300	3	49	27.5	1016.9	0
	1900	3	93	22.8	1017.3	0
16	100	2	146	22.6	1017.7	0
	700	2	241	23.5	1018.9	0
	1300	2	134	26.9	1018.6	0
	1900	3	160	24.5	1017.6	0
17	100	5	233	23.5	1017.6	0
	700	6	244	23.4	1017.4	0
	1300	7	203	28.6	1014.6	0
	1900	8	194	25.5	1011.3	0
18	100	10	224	24.8	1008.5	0
	700	7	342	21.8	1010.3	0
	1300	7	351	22.4	1011.3	0
	1900	6	73	21.2	1012.0	0
19	100	11	29	20.8	1012.9	0
	700	12	19	20.6	1015.7	0
	1300	8	20	22.3	1018.2	0
	1900	3	32	20.1	1018.9	0
20	100	4	39	20.1	1020.3	0
	700	2	40	21.8	1022.0	0
	1300	5	28	23.1	1022.0	0
	1900	5	52	20.8	1020.7	0

Table 3
Meteorological Data (concluded)

Sep 1994

Day	Hour	Wind Speed m/sec	Wind Direction deg TN	Temperature deg C	Atm Pressure mb	Precipitation mm
21	100	6	50	20.4	1020.2	0
	700	8	42	20.3	1020.4	0
	1300	7	39	21.5	1019.1	0
	1900	8	36	21.3	1016.8	0
22	100	15	57	20.4	1011.4	0
	700	6	104	21.7	1006.9	64
	1300	11	219	19.9	1005.6	0
	1900	10	238	20.4	1008.9	0
23	100	8	247	18.1	1010.8	0
	700	4	244	19.1	1012.5	0
	1300	5	228	23.1	1012.7	0
	1900	3	187	21.2	1014.2	0
24	100	3	227	20.2	1015.2	0
	700	3	243	20.9	1017.4	0
	1300	1	222	25.3	1017.0	0
	1900	4	148	21.8	1017.0	0
25	100	3	143	21.8	1015.4	0
	700	4	115	22.0	1015.4	0
	1300	5	122	23.9	1013.6	0
	1900	3	137	22.0	1012.0	0
26	100	4	128	21.6	1010.2	0
	700	3	76	21.9	1009.9	0
	1300	3	135	26.1	1009.2	0
	1900	6	176	24.0	1009.3	0
27	100	4	209	22.7	1009.9	0
	700	2	288		1010.5	0
	1300	11	19		1010.1	0
	1900	5	197		1010.1	0
28	100	7	231	Gauge	1011.2	0
	700	6	229		1011.2	0
	1300	4	244		1008.9	0
	1900	4	267		1003.8	0
29	100	7	249		1004.9	0
	700	6	275	Inoperative	1007.1	0
	1300	4	326		1006.6	0
	1900	5	295		1008.9	0
30	100	4	294		1010.7	0
	700	7	315		1013.3	0
	1300	3	348		1014.2	0
	1900	1	141	12.4	1016.0	0
		Resultant		Mean	Mean	Total
		1	7	20.6	1016.1	124

3 Wave Data

Wave data are collected from three different sets of instruments, as shown in Table 1 and Figure 3. The first consists of a pressure gauge co-located with a biaxial electromagnetic current meter, collectively referred to as gauge number 3511. The current meter measures two orthogonal horizontal water velocities, U and V, and the pressure sensor measures water depth and dynamic wave pressure P. The computation of wave height and direction is based on the first five Fourier coefficients of the auto- and cross-spectra of pressure and current velocity. The second is a Baylor staff gauge (625) and a pressure gauge (641), both attached to the pier. The third is a Waverider buoy (630). The data are collected, analyzed, and stored on optical disc using a Digital Equipment Corporation VAXstation 4000. Data is sampled at 2 hertz, with five contiguous 34 minute records, for a total collection period of nearly 2 hours and 51 minutes. This report reflects the data collection periods of 0100, 0700, 1300, and 1900 EST. The results are based only on the first 34 minute record.

Wave height H_{mo} is an energy-based statistic equal to four times the standard deviation of the sea surface elevations. Wave height reported from the pressure gauge has been compensated for hydrodynamic attenuation using linear wave theory. Wave period is identified from the computation of a variance (energy) spectrum with 60 degrees of freedom calculated from a 34-min record. Peak wave period T_p is defined as the period associated with the maximum energy in the spectrum.

Table 4 presents the wave heights and periods for each wave record obtained at 6 hr intervals during the month. The monthly means and standard deviations from the means shown in Table 4 are average values computed from this data. Figure 5 is a time history of all H_{mo} and T_p values obtained for all gauges.

Differences in wave periods between wave gauges (Table 4 and Figure 5) may be the result of wave breaking, wave reformation, the presence of multiple wave trains containing nearly equal energy, and statistical variations in spectral estimations.

Table 4
Wave Data

Sep 1994

Day	Hour	641 Pressure Gauge Hmo,m	641 Pressure Gauge Tp,sec	625 Baylor Gauge Hmo,m	625 Baylor Gauge Tp,sec	3511 8 Meter PUV Hmo,m	3511 8 Meter PUV Tp,sec	3511 8 Meter PUV Dir,TN	630 Waverider Hmo,m	630 Waverider Tp,sec
1	0100	0.23	8.9	0.35	8.6	0.35	8.9	98	0.43	7.8
	0700	0.20	9.2	0.27	8.9	0.28	12.9	81	0.32	8.6
	1300	0.21	8.1	0.28	12.2	0.28	12.2	77	0.31	8.9
	1900	0.23	9.2	0.32	9.5	0.31	12.2	83	0.40	3.7
2	0100	0.50	3.9	0.69	3.8	0.61	3.8	28	0.75	3.9
	0700	0.62	4.7	0.82	4.2	0.82	4.5	33	0.94	4.2
	1300	0.76	5.5	0.93	5.5	0.95	5.5	30	1.06	5.4
	1900	0.75	5.6	1.08	5.7	1.13	5.5	58	1.43	5.9
3	0100	0.74	5.7	1.51	5.6	1.59	5.6	49	1.75	5.6
	0700	0.92	5.9	1.35	5.7	1.46	5.9	60	1.55	5.7
	1300	0.80	6.6	1.92	6.3	2.09	6.6	65	2.37	6.3
	1900	1.11	7.0	2.27	7.8	2.46	7.4	69	2.65	7.8
4	0100	0.83	7.4	2.06	7.2	2.42	8.1	77	2.47	7.8
	0700	1.19	8.1	2.31	7.2	2.64	8.9	77	2.97	8.3
	1300	0.87	10.3	2.35	9.9	2.70	9.9	79	2.90	8.1
	1900	1.33	7.2	2.31	8.9	2.61	8.6	67	2.65	8.6
5	0100	0.81	13.5	2.12	11.7	2.40	11.2	76	2.36	10.7
	0700	1.18	12.9	1.87	12.2	2.05	12.2	76	2.15	12.9
	1300	0.79	12.2	1.75	12.2	1.90	11.7	82	1.76	12.2
	1900	0.89	11.7	1.36	11.2	1.47	11.2	73	1.47	12.2
6	0100	0.60	11.7	1.17	11.7	1.24	11.7	78	1.27	11.2
	0700	0.59	11.2	0.93	11.7	1.02	11.2	72	1.15	11.2
	1300	0.36	12.2	0.77	11.7	0.90	11.7	76	0.88	11.7
	1900	0.49	11.7	0.76	11.2	0.83	11.2	77	0.84	11.7
7	0100	0.32	11.2	0.55	11.2	0.62	10.7	81	0.66	10.3
	0700	0.36	7.4	0.44	11.2	0.52	10.7	79	0.55	8.1
	1300	0.20	11.1	0.39	10.7	0.40	8.3	97	0.44	8.3
	1900	0.23	7.6	0.34	9.9	0.38	10.7	77	0.41	7.6
8	0100	0.17	10.3	0.37	9.2	0.42	9.9	89	0.42	9.2
	0700	0.29	9.5	0.42	8.9	0.37	9.5	90	0.49	9.5
	1300	0.28	3.7	0.47	8.3	0.43	8.9	103	0.51	8.9
	1900	0.34	7.8	0.49	8.3	0.50	8.1	103	0.60	8.9
9	0100	0.22	17.1	0.39	8.9	0.40	9.5	105	0.45	9.2
	0700	0.23	16.0	0.34	8.9	0.38	8.9	95	0.39	8.6
	1300	0.19	15.1	0.31	15.1	0.37	15.1	93	0.37	8.6
	1900	0.22	15.1	0.35	15.1	0.41	14.3	89	0.41	14.3
10	0100	0.22	15.1	0.35	14.3	0.36	15.1	92	0.34	14.3
	0700	0.19	14.3	0.37	14.3	0.41	14.3	82	0.40	13.5
	1300	0.28	14.3	0.43	14.3	0.46	14.3	91	0.45	14.3
	1900	0.25	13.5	0.41	13.5	0.43	13.5	85	0.43	14.3

Table 4
Wave Data (continued)

Sep 1994

Day	Hour	641 Pressure Gauge Hmo,m	Tp,sec	625 Baylor Gauge Hmo,m	Tp,sec	3511 8 Meter PUV Hmo,m	Tp,sec	Dir,TN	630 Waverider Hmo,m	Tp,sec
11	0100	0.28	12.9	0.42	13.5	0.46	13.5	87	0.44	12.9
	0700	0.25	12.9	0.47	12.2	0.39	12.2	83	0.50	12.9
	1300	0.32	12.2	0.45	12.9	0.41	13.5	83	0.52	12.9
	1900	0.47	4.8	0.65	4.9	0.57	12.9	85	0.73	4.8
12	0100	0.42	4.8	0.52	4.8	0.54	5.1	43	0.63	4.7
	0700	0.32	4.8	0.54	5.4	0.54	12.2	93	0.57	5.0
	1300	0.61	4.5	0.65	4.6	0.75	5.0	49	0.77	4.8
	1900	0.39	4.9	0.56	5.5	0.57	5.6	49	0.68	5.2
13	0100	0.37	5.5	0.44	12.2	0.49	9.2	110	0.51	12.2
	0700	0.22	12.9	0.43	11.7	0.48	11.7	95	0.48	8.6
	1300	0.33	11.7	0.42	11.2	0.51	11.2	101	0.50	10.7
	1900	0.27	10.7	0.51	10.3	0.52	10.7	103	0.59	10.7
14	0100	0.31	9.9	0.41	9.9	0.51	9.9	106	0.56	9.9
	0700	0.20	17.1	0.41	9.5	0.42	9.9	102	0.42	9.9
	1300	0.27	9.2	0.33	9.2	0.40	9.2	108	0.48	9.2
	1900	0.24	16.0	0.36	9.2	0.39	8.9	104	0.43	8.9
15	0100	0.25	16.0	0.34	16.0	0.38	16.0	90	0.46	16.0
	0700	0.27	16.0	0.30	16.0	0.33	16.0	94	0.41	15.1
	1300	0.26	15.1	0.34	15.1	0.41	15.1	92	0.40	15.1
	1900	0.29	15.1	0.37	15.1	0.36	15.1	92	0.42	15.1
16	0100	0.22	14.3	0.34	15.1	0.38	14.3	93	0.41	14.3
	0700	0.24	14.3	0.34	14.3	0.39	15.1	86	0.45	14.3
	1300	0.23	13.5	0.41	14.3	0.41	13.5	88	0.42	14.3
	1900	0.28	14.3	0.39	14.3	0.44	13.5	92	0.45	13.5
17	0100	0.21	13.5	0.37	13.5	0.41	13.5	83	0.49	13.5
	0700	0.21	13.5	0.33	13.5	0.38	13.5	86	0.44	13.5
	1300	0.22	12.9	0.35	13.5	0.37	13.5	88	0.41	13.5
	1900	0.30	13.5	0.38	13.5	0.43	12.9	87	0.63	12.9
18	0100	0.23	12.9	0.37	12.9	0.34	12.9	85	0.56	12.9
	0700	0.26	13.5	0.35	13.5	0.33	12.9	90	0.54	12.9
	1300	0.56	4.6	0.76	4.6	0.71	4.7	28	0.90	4.7
	1900	0.49	4.6	0.56	4.8	0.54	4.5	16	0.67	4.7
19	0100	0.58	4.8	1.18	4.6	1.17	4.9	52	1.37	5.1
	0700	1.04	5.5	1.39	5.9	1.37	5.6	50	1.63	5.7
	1300	0.62	6.0	1.38	6.1	1.42	6.0	55	1.63	6.0
	1900	0.62	5.6	0.88	7.2	0.98	6.5	66	1.18	7.4
20	0100	0.43	5.4	0.77	8.3	0.90	8.3	82	0.89	8.1
	0700	0.46	4.6	0.73	7.4	0.77	7.6	81	0.91	7.4
	1300	0.28	13.5	0.67	7.4	0.67	6.6	88	0.75	6.8
	1900	0.42	4.9	0.68	7.2	0.66	7.4	89	0.82	7.0

Table 4
Wave Data (concluded)

Sep 1994

Day	Hour	641 Pressure Gauge Hmo,m	Tp,sec	625 Baylor Gauge Hmo,m	Tp,sec	3511 8 Meter PUV Hmo,m	Tp,sec	Dir,TN	630 Waverider Hmo,m	Tp,sec
21	0100	0.37	4.2	0.69	6.3	0.66	6.3	100	0.78	6.3
	0700	0.58	3.8	0.81	4.2	0.79	3.9	55	0.96	3.9
	1300	0.43	3.8	0.76	4.1	0.76	3.9	60	0.91	4.2
	1900	0.77	4.3	1.06	4.2	1.16	5.9	109	1.29	4.4
22	0100	0.85	7.0	1.74	7.2	1.83	5.2	61	2.13	6.8
	0700	1.20	9.5	2.29	9.5	2.66	8.9	90	2.59	9.5
	1300	0.81	9.2	1.65	10.3	2.02	9.9	88	2.07	9.2
	1900	0.84	8.6	1.16	9.2	1.33	9.2	88	1.66	8.9
23	0100	0.62	8.1	1.04	8.1	1.09	8.6	96	1.20	8.3
	0700	0.72	7.8	1.02	8.3	1.02	8.3	100	1.16	8.1
	1300	0.50	8.1	0.77	8.3	0.94	8.3	90	0.91	8.6
	1900	0.56	7.4	0.83	7.8	0.95	7.8	96	0.95	7.6
24	0100	0.46	8.1	0.71	8.1	0.76	7.8	101	0.88	7.8
	0700	0.48	7.4	0.64	7.4	0.84	7.4	97	0.86	7.2
	1300	0.40	7.2	0.71	7.6	0.79	10.7	77	0.83	11.2
	1900	0.39	7.0	0.66	10.3	0.75	10.3	75	0.79	9.9
25	0100	0.35	6.3	0.64	9.5	0.70	9.9	75	0.67	9.9
	0700	0.31	6.6	0.59	8.9	0.66	8.9	77	0.76	6.8
	1300	0.29	6.5	0.53	8.9	0.52	7.8	82	0.61	9.5
	1900	0.27	17.1	0.56	7.8	0.58	9.5	82	0.63	9.2
26	0100	0.37	16.0	0.63	16.0	0.67	16.0	83	0.76	16.0
	0700	0.67	5.5	0.88	14.3	0.97	13.5	79	1.12	14.3
	1300	0.60	13.5	0.94	13.5	1.01	12.9	75	1.03	12.9
	1900	0.52	12.2	0.88	12.2	1.04	12.2	79	1.05	12.9
27	0100	0.42	12.9	0.87	12.2	0.92	12.2	81	0.93	12.2
	0700	0.46	11.2	0.86	11.2	0.91	12.2	80	0.94	11.2
	1300	0.45	11.7	0.75	11.7	0.88	11.7	80	0.86	11.7
	1900	0.33	11.7	0.66	11.7	0.66	11.2	80	0.76	11.2
28	0100	0.31	11.2	0.52	10.7	0.73	10.7	81	0.61	10.7
	0700	0.24	10.3	0.50	10.3	0.58	10.7	85	0.65	10.3
	1300	0.28	10.7	0.45	11.2	0.57	10.3	81	0.51	11.2
	1900	0.20	12.9	0.46	9.5	0.46	11.7	72	0.51	10.7
29	0100	0.23	10.7	0.45	11.7	0.47	12.2	74	0.51	12.2
	0700	0.17	12.2	0.40	11.7	0.41	11.7	73	0.47	11.7
	1300	0.37	4.2	0.61	11.2	0.60	11.2	72	0.66	10.7
	1900	0.30	4.3	0.49	10.7	0.50	10.7	72	0.56	11.2
30	0100	0.28	4.6	0.43	11.2	0.44	11.7	79	0.58	11.2
	0700	0.49	5.4	0.72	5.5	0.80	5.4	31	1.16	5.3
	1300	0.61	5.4	0.77	5.4	0.90	6.0	42	1.18	6.3
	1900	0.35	5.4	0.54	5.9	0.57	5.5	35	0.69	5.9
Mean		0.45	9.6	0.76	9.8	0.82	10.0	79	0.90	9.6
Std dev		0.26	3.9	0.51	3.2	0.58	3.1	18	0.61	3.2

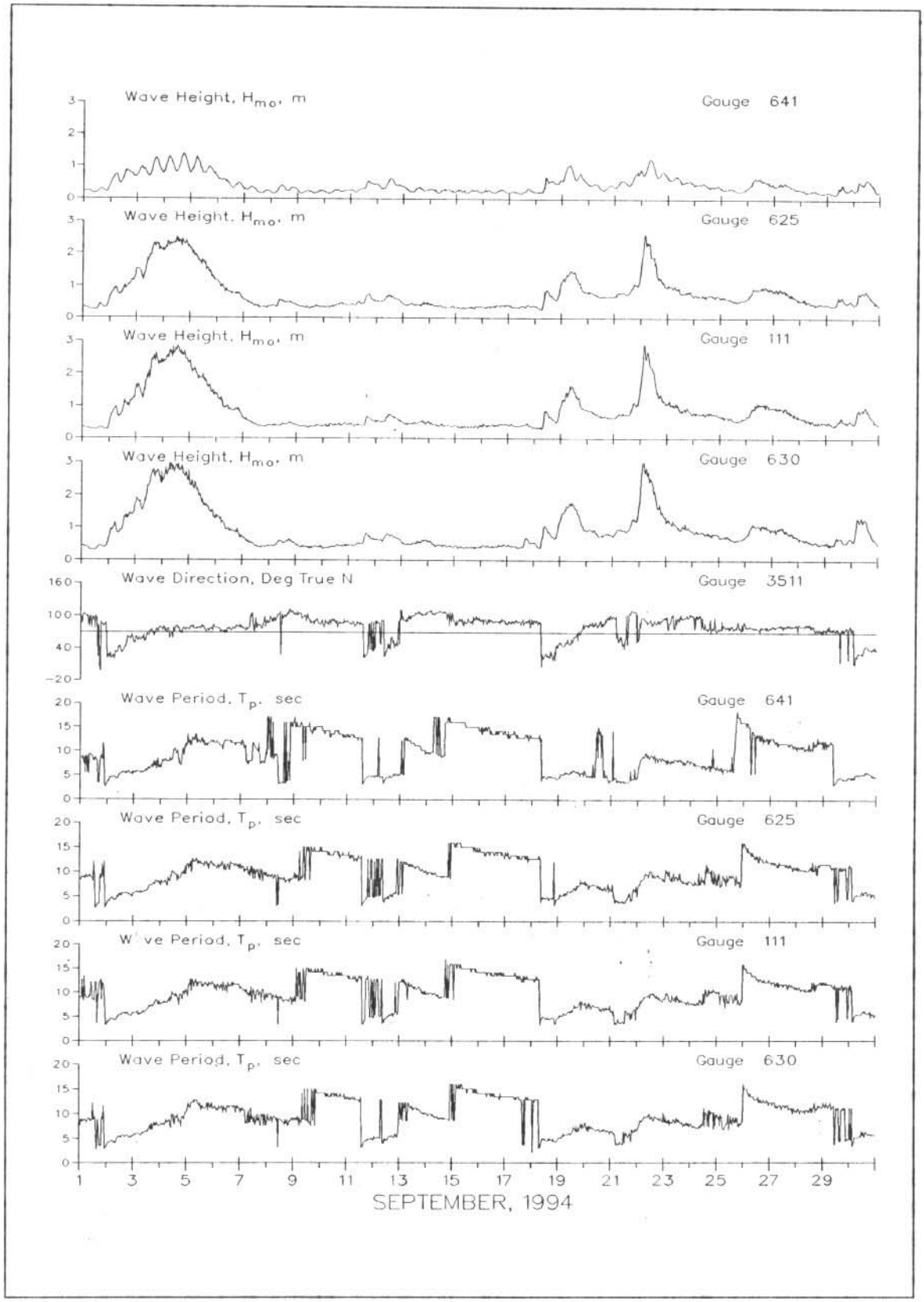

Figure 5. Wave Heights and Periods

4 Current Data

Current data (Table 5) are collected from a Marsh-McBirney electromagnetic biaxial current meter and by visually observing the movement of small drogues on the water surface in the surf and at the seaward end of the pier, as well as 500 m updrift of the pier, approximately 12 m offshore (Table 6).

Since the shoreline orientation is approximately N20W, longshore currents flow either toward 340 deg (i.e. northward) or toward 160 deg (i.e. southward). Similarly, cross-shore currents are either onshore (westward) or offshore (eastward). All current speeds are given in centimeters per second (cm/sec). Resultant speeds and directions are determined by vector averaging the cross-shore and longshore data. Current directions indicate the direction that the current is moving towards. Current data are plotted in Figure 2.

Table 5
Current Meter Data - Gauge 3519

SEPTEMBER 1994

Day	Time	Cross Shore	Long Shore	Speed	Dir
1	100	-1	-8	9	329
	700	-3	0	4	253
	1300	6	-4	8	29
	1900	7	-6	10	26
2	100	1	1	2	102
	700	-1	24	25	164
	1300	1	22	22	156
	1900	1	28	28	159
3	100	0	37	37	161
	700	0	37	37	160
	1300	0	36	36	162
	1900	0	54	54	160
4	100	-8	48	49	171
	700	-7	75	75	166
	1300	-3	77	77	163
	1900	-5	75	75	164
5	100	-4	55	55	165
	700	-3	12	13	179
	1300	-3	21	21	170
	1900	-4	13	14	179
6	100	-1	4	5	183
	700	-4	2	5	226
	1300	0	13	13	161
	1900	0	5	5	177
7	100	-4	2	5	230
	700	-2	-10	11	327
	1300	0	-10	11	340
	1900	2	-11	13	348
8	100	0	5	5	168
	700	1	0	2	43
	1300	3	6	7	134
	1900	-4	30	30	170
9	100	-3	14	14	175
	700	0	0	0	
	1300	0	10	10	161
	1900	0	-6	7	343
10	100	0	-7	8	336
	700	0	-9	10	341
	1300	10	7	13	104
	1900	-4	0	5	252
11	100	0	5	5	165
	700	2	6	6	147
	1300	5	9	10	128
	1900	0	7	8	170
12	100	-1	16	16	167
	700	7	19	20	142
	1300	6	26	27	147
	1900	3	18	18	150
13	100	0	11	11	158
	700	-1	7	7	176
	1300	1	-1	3	7
	1900	1	4	4	153
14	100	-2	-12	13	325
	700	0	-4	5	337
	1300	16	-20	26	18
	1900	5	-9	11	4
15	100	0	-1	2	315
	700	0	9	9	163
	1300	2	0	2	63
	1900	0	12	12	159
16	100	3	10	10	145
	700	0	13	13	159
	1300	5	0	5	74
	1900	0	6	6	168
17	100	-1	1	2	226
	700	-3	3	5	210
	1300	1	-8	9	344
	1900	-3	-8	9	315
18	100	-6	-11	14	311
	700	0	-5	6	326
	1300	0	10	10	168
	1900	9	-12	16	14
19	100	0	-5	6	344
	700	1	12	12	157
	1300	2	39	39	157
	1900	-1	37	37	163
20	100	0	27	27	162
	700	7	11	13	125
	1300	1	13	13	156
	1900	0	8	8	163
21	100	5	21	22	148
	700	-1	14	14	167
	1300	-1	41	41	162
	1900	-2	32	32	165
22	100	2	49	49	157
	700	0	30	30	161
	1300	-9	33	34	177
	1900	-7	-5	10	288
23	100	6	-2	7	42
	700	6	-11	13	6
	1300	-3	4	6	203
	1900	-2	-4	6	312
24	100	1	1	1	107
	700	0	-6	7	331
	1300	3	-4	5	13
	1900	4	-13	14	358
25	100	-2	-3	5	296
	700	3	-14	15	351
	1300	0	-6	7	342
	1900	-1	-11	12	330
26	100	-2	-5	7	311
	700	3	-14	16	350
	1300	0	-9	10	341
	1900	-6	-8	11	304
27	100	-1	-3	4	313
	700	-3	-11	13	320
	1300	0	-11	12	342
	1900	0	-12	13	338
28	100	-2	-13	14	328
	700	-2	-14	15	327
	1300	-2	-14	15	330
	1900	0	-9	10	337
29	100	-3	-10	11	321
	700	0	-8	9	334
	1300	6	0	6	58
	1900	0	-1	2	345
30	100	0	0	0	
	700	-3	35	35	167
	1300	-2	21	21	169
	1900	0	6	6	157

KEY:

+cross-shore = offshore, cm/sec
-cross-shore = onshore, cm/sec
+longshore = south, cm/sec
-longshore = north, cm/sec
Speed = Resultant speed, cm/sec
Dir = Resultant direction, degrees true north

Table 6
Visually Observed Current Data

Sep 1994

	Pier End				Mid-Surf Zone				Beach		
Day	Cross Shore	Long Shore	Speed	Dir	Cross Shore	Long Shore	Speed	Dir	Location	Speed	Dir
1	11	-12	16	22	5	-8	10	11	South	8	N
2	0	30	30	160	0	47	47	160	North	46	S
3	-24	41	47	191	0	68	68	160	North	32	S
4	0	122	122	160	0	102	102	160	North	81	S
5	0	47	47	160	0	68	68	160	no observation		
6	13	10	16	70	0	23	23	160	North	8	N
7	-8	-10	13	301	7	10	12	70	North	3	N
8	-14	9	16	218	-8	12	14	193	North	8	S
9	-4	16	17	174	0	6	6	160	North	9	S
10	-7	15	17	187	-26	22	34	210	North	4	S
11	-8	5	9	216	-4	13	13	177	North	9	S
12	0	41	41	160	0	28	28	160	North	43	S
13	10	10	14	115	8	10	13	70	no observation		
14	9	10	14	70	10	10	14	70	South	9	N
15	7	8	11	118	3	10	11	70	North	5	S
16	0	15	15	160	0	10	10	160	North	0	
17	10	10	14	70	12	20	24	70	South	3	S
18	0	34	34	160	0	24	24	160	North	43	S
19	0	47	47	160	0	76	76	160	North	79	S
20	0	28	28	160	0	3	3	160	North	3	S
21	0	21	21	160	0	28	28	160	North	12	S
22	0	-22	22	340	0	-87	87	340	no observation		
23	5	-12	13	2	0	-15	15	340	South	27	N
24	0	0	0		0	-10	10	340	South	8	N
25	0	-28	28	340	0	-17	17	340	no observation		
26	0	-11	11	340	0	-29	29	340	North	38	N
27	4	-14	14	357	0	-30	30	340	South	23	N
28	0	-34	34	340	7	-23	24	357	South	3	N
29	11	11	16	115	7	14	16	133	North	11	S
30	0	76	76	160	0	76	76	160	North	18	S

KEY:
+cross-shore = offshore, cm/sec
-cross-shore = onshore, cm/sec
+longshore = south, cm/sec
-longshore = north, cm/sec
Speed = Resultant speed, cm/sec
Dir = Resultant direction, degrees true north

5 Visual Observations

Visual wave direction measurements (Table 7) of both the primary wave train (i.e. that having the higher wave heights) and the secondary wave train (which must be clearly distinguishable as a wave train separate from the primary waves but not surface chop or capillary waves) are taken daily at the seaward end of the pier. The direction of the primary wave train just north of the seaward end of the pier is also determined using a Raytheon Marine Pathfinder radar and measuring the alignment of the wave crests at approximately the same location as the visual measurements. The pier axis (considered perpendicular to the beach at the FRF) is oriented 70 deg east of true north; consequently, wave angles greater than 70 deg indicate that the waves were coming from the south side of the pier.

The width of the surf zone (seawardmost breaker position to shoreline) is determined from the pier deck.

Measurements of surface water temperature, density, and visibility are also taken daily at the seaward end of the pier. A Bucket Thermometer is lowered about 0.3 m into the water and allowed to remain for at least one minute. The temperature is then read, and a hydrometer is used to determine the density. A Secchi disc is used to determine the depth of visibility.

Table 7
Visual Observations

Sep 1994

Day	Time	Wave Approach Angle at Pier End deg from True N Primary	Secondary	Radar Wave Angle deg from True N	Width of Surf Zone,m	Water Characteristics at Pier End Temp.,C	Density g/cc	Secchi Vis.,m
1	0645	90			21	23.3	1.0230	4.0
2	0700	50		45	96	23.9	1.0229	2.4
3	0730	60		45	169	22.8	1.0191	1.8
4	0920	55			352	21.9	1.0171	0.6
5	0830	65			296	21.1	1.0194	0.6
6	0630	65			99	21.1	1.0222	0.6
7	0640	75			6	21.7	1.0234	0.9
8	0740	85	40		9	21.7	1.0226	2.1
9	0640	90	45		4	22.5	1.0193	4.3
10	0955	40			6	22.8	1.0210	3.0
11	0914	40			12	22.8	1.0214	3.7
12	0710	55			108	22.2	1.0210	3.7
13	0650	90	30		128	22.5	1.0199	4.3
14	0710	90			63	22.5	1.0206	2.7
15	0700	100			9	22.8	1.0212	3.7
16	0640	90			50	23.9	1.0205	4.6
17	0810	75				23.3	1.0216	3.4
18	0815	40			6	21.1	1.0250	2.1
19	0710	50				22.2	1.0234	1.2
20	0700	65	75		101	22.2	1.0198	3.7
21	0730	70	80		77	22.2	1.0188	2.7
22	0640	92			352	22.2	1.0198	1.5
23	0620	100			104	21.7	1.0228	1.2
24	0620	90			113	22.7	1.0228	1.5
25	0640	85			82	22.2	1.0228	2.1
26	0710	80			113	21.9	1.0230	1.8
27	0708	60	75		124	21.9	1.0234	0.9
28	0755	80			34	21.7	1.0240	1.5
29	0815	65	355		29	21.1	1.0242	1.5
30	0758	25			56	21.1	1.0206	1.5

6 Water Levels

Since 1978, the National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) has operated a primary tide station (No. 865-1370) at the seaward end of the FRF pier. A NOS acoustic tide gauge (Next Generation Water Level Measurement System, NGWLMS) is used to collect water level data every 6 minutes throughout the month.

The variation in water level during the month is shown in Figure 6 along with a list of means and extreme values. This presentation is useful in identifying effects of both meteorological and astronomical forces on the open coast water level. Table 8 contains the range, high, low, and mean water level for each 12.42-hr tidal cycle.

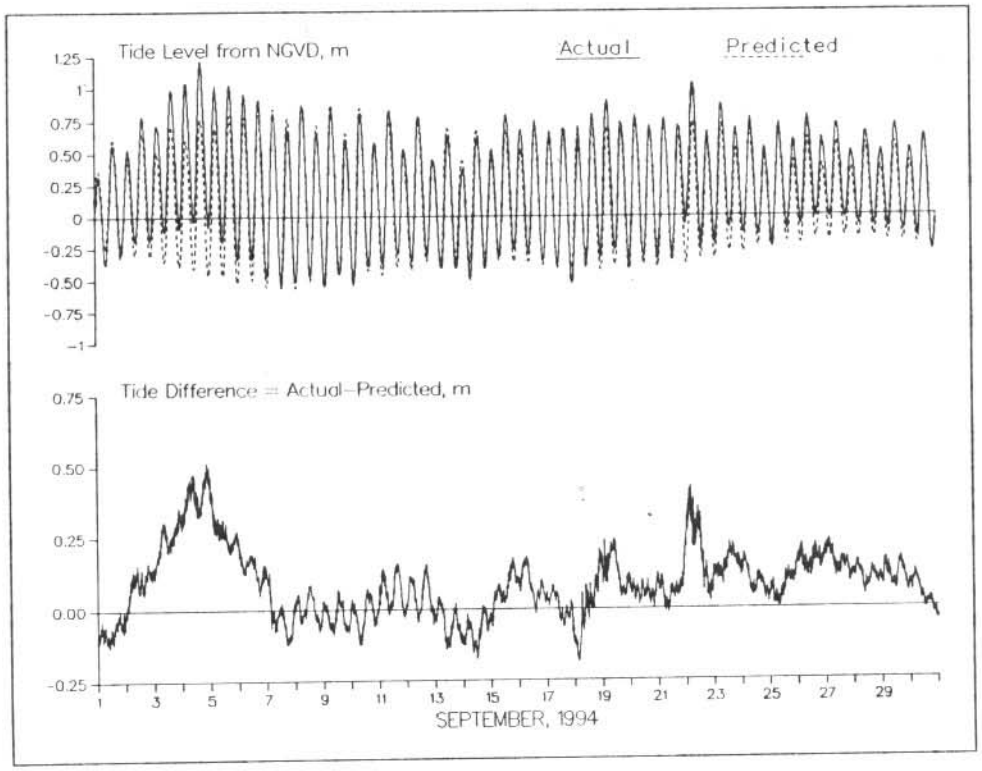

Figure 6. Water Level Variation

Table 8
Water Levels, m NGVD

SEP 1994 Tide Levels

High			Low			Mean	Range	High			Low			Mean	Range
Day	Time	m	Day	Time	m	m	m	Day	Time	m	Day	Time	m	m	m
1	0324	0.32	1	0924	-0.37	-0.02	0.70	16	0454	0.68	16	1036	-0.30	0.20	0.97
1	1536	0.57	1	2148	-0.32	0.12	0.89	16	1642	0.75	16	2242	-0.36	0.19	1.11
2	0412	0.53	2	1036	-0.19	0.16	0.73	17	0530	0.66	17	1142	-0.41	0.13	1.07
2	1630	0.79	2	2224	-0.20	0.29	0.99	17	1700	0.68	18	0006	-0.53	0.09	1.21
3	0430	0.71	3	1112	-0.12	0.32	0.84	18	0612	0.70	18	1148	-0.41	0.11	1.11
3	1724	0.99	4	0000	-0.10	0.45	1.09	18	1812	0.80	19	0024	-0.34	0.25	1.14
4	0530	1.04	4	1206	-0.04	0.50	1.08	19	0700	0.90	19	1312	-0.27	0.32	1.17
4	1806	1.22	5	0018	-0.09	0.56	1.30	19	1830	0.74	20	0118	-0.37	0.20	1.11
5	0630	1.02	5	1224	-0.20	0.40	1.22	20	0700	0.79	20	1336	-0.34	0.23	1.13
5	1848	1.03	6	0054	-0.34	0.36	1.37	20	1912	0.70	21	0130	-0.34	0.19	1.05
6	0700	0.96	6	1336	-0.34	0.30	1.30	21	0800	0.76	21	1354	-0.32	0.23	1.08
6	1942	0.91	7	0224	-0.47	0.22	1.38	21	1948	0.70	22	0130	-0.08	0.33	0.78
7	0818	0.81	7	1430	-0.56	0.13	1.38	22	0912	1.03	22	1506	-0.26	0.42	1.29
7	2006	0.68	8	0230	-0.52	0.08	1.19	22	2100	0.66	23	0306	-0.23	0.22	0.89
8	0900	0.87	8	1512	-0.47	0.20	1.34	23	0854	0.87	23	1506	-0.11	0.36	0.98
8	2054	0.67	9	0318	-0.55	0.07	1.22	23	2130	0.69	24	0342	-0.14	0.26	0.83
9	1000	0.84	9	1606	-0.46	0.18	1.29	24	1006	0.76	24	1600	-0.16	0.28	0.93
9	2206	0.58	10	0424	-0.54	0.04	1.13	24	2218	0.53	25	0424	-0.23	0.16	0.76
10	1030	0.81	10	1654	-0.40	0.19	1.21	25	1036	0.72	25	1700	-0.12	0.28	0.83
10	2236	0.58	11	0548	-0.38	0.10	0.95	25	2248	0.59	26	0430	-0.08	0.25	0.67
11	1206	0.83	11	1830	-0.30	0.26	1.13	26	1112	0.78	26	1742	-0.02	0.36	0.80
11	2342	0.53	12	0636	-0.36	0.10	0.89	26	2318	0.61	27	0612	-0.02	0.28	0.63
12	1242	0.78	12	1930	-0.32	0.23	1.10	27	1148	0.71	27	1900	-0.03	0.34	0.74
13	0100	0.43	13	0742	-0.41	0.03	0.83	28	0006	0.50	28	0630	-0.08	0.22	0.58
13	1348	0.62	13	2006	-0.41	0.11	1.03	28	1306	0.65	28	1948	-0.08	0.29	0.73
14	0248	0.36	14	0836	-0.50	-0.04	0.87	29	0212	0.51	29	0742	-0.11	0.22	0.62
14	1518	0.60	14	2048	-0.41	0.11	1.02	29	1412	0.71	29	2036	-0.13	0.29	0.85
15	0330	0.52	15	0854	-0.32	0.10	0.84	30	0230	0.52	30	0824	-0.17	0.19	0.69
15	1554	0.80	15	2154	-0.27	0.26	1.07								

7 Bathymetry

A. Nearshore Profiles. In order to document profile response away from the pier, surveys of four profile lines extending 900 to 1,000 m from shore and located 489 and 581 m north and 517 and 608 m south of the FRF pier are conducted bi-weekly, after storms, and during more complete bathymetric surveys.

These profiles are obtained using the CRAB-Geodimeter surveying system; a Geodimeter 140-T self-tracking, electronic theodolite, distance meter, in combination with the Coastal Research Amphibious Buggy (CRAB), a 10.7 m high, self-powered, mobile tripod on wheels.

Figure 7 shows the last survey in August 1994 and the survey(s) in September 1994 on profile line 62, located 407 m north of the pier.

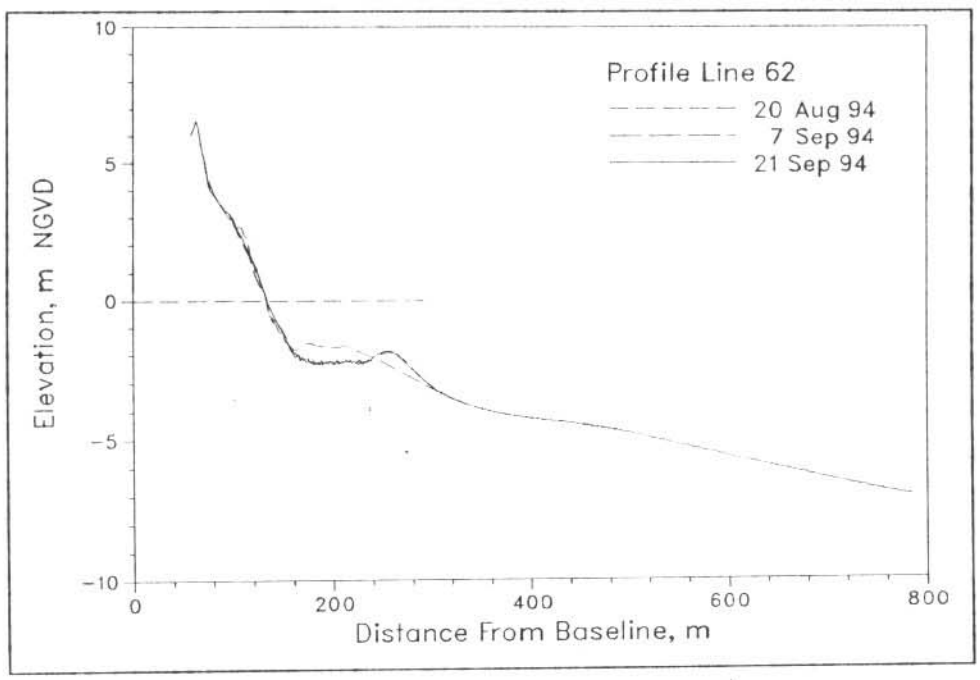

Figure 7. Monthly CRAB Profiles on Profile Line 62.

The profile envelope (Figure 8) reflects the maximum changes that occurred on the profile during 1994. Cross-hatched areas indicate changes to the annual envelope which occurred in September.

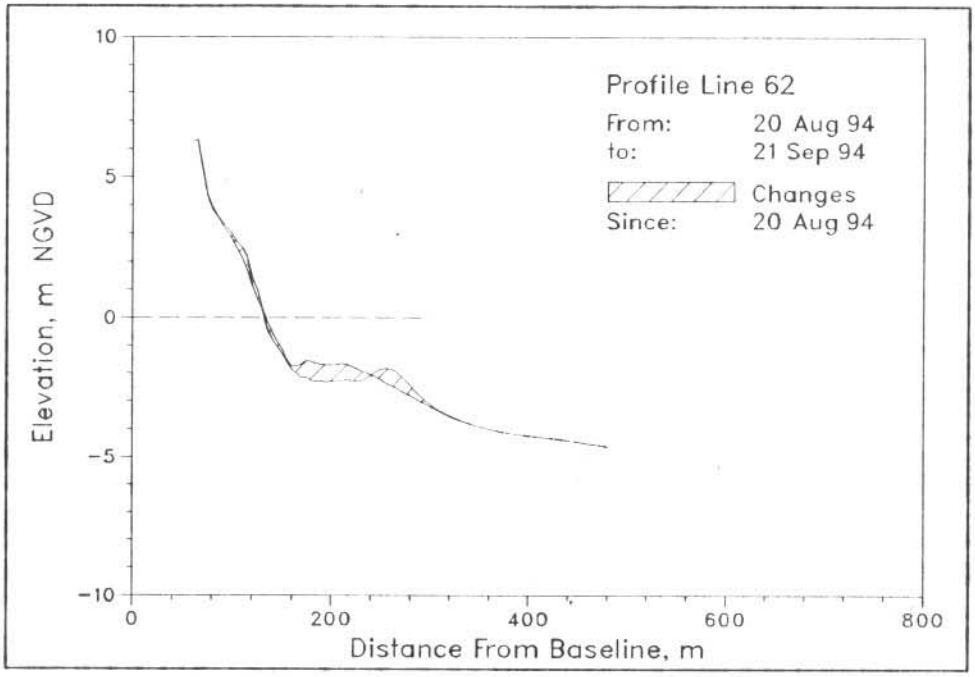

Figure 8. Profile Envelope - Profile Line 62.

B. Bathymetry. Figure 9 includes a two- and three-dimensional contour map and a change plot derived from the bathymetric survey on 20 September. Wide contour lines on the change diagram represent eroded areas; thin lines indicate deposition.

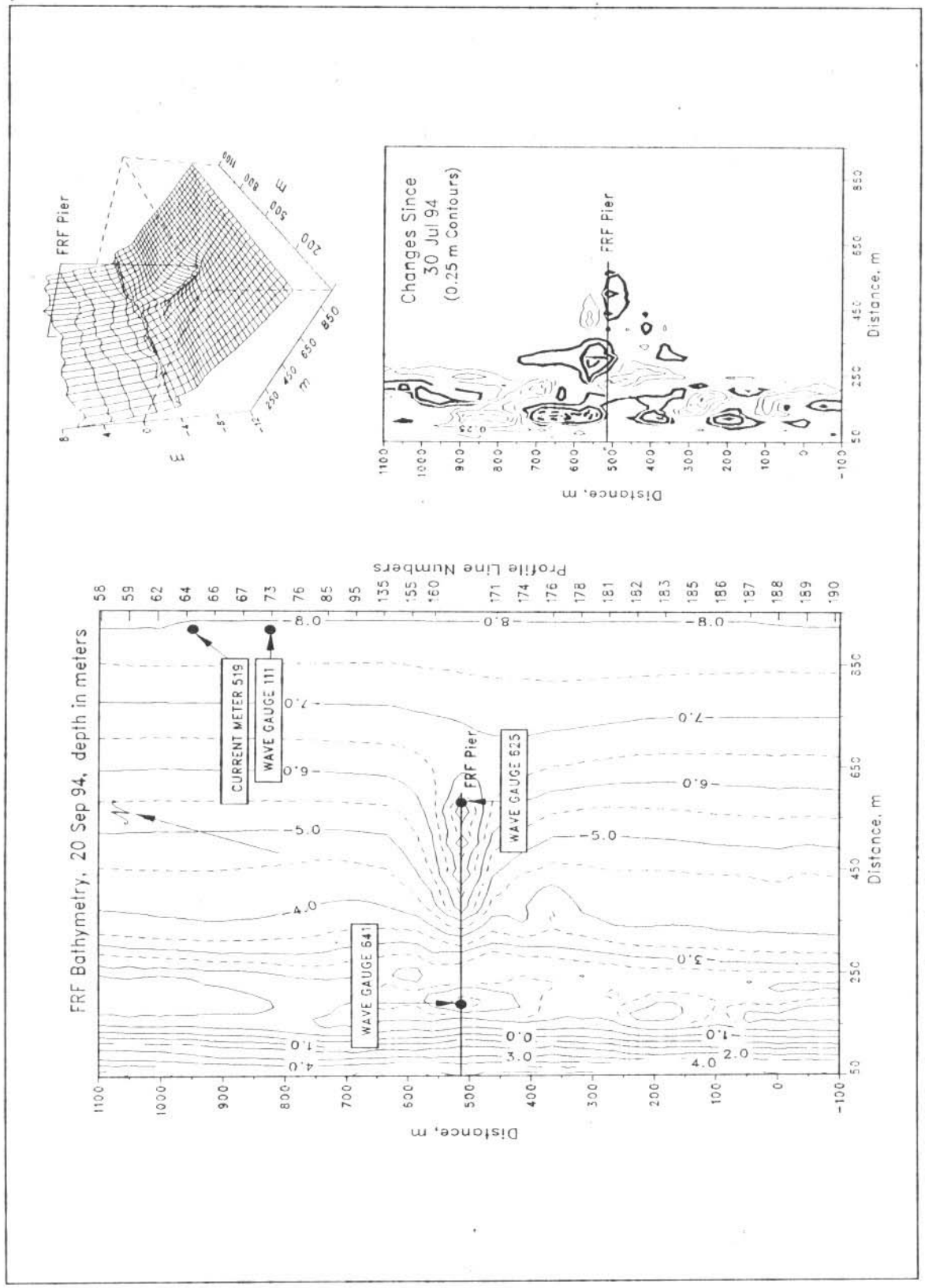

Figure 9. FRF Bathymetry, Depths Relative to NGVD

8 Special Events

A. Storm Data Collection. The following list identifies times when the wave height H_{mo} at the seaward end of the pier exceeded 2 m.

Start	End
3 Sep (1334)	5 Sep (0316)
22 Sep (0208)	22 Sep (0842)

B. Storm Synopsis.

3-5 Sep Northeasterly winds were funneled between a Canadian low pressure system and a high pressure system over Cape Hatteras. Winds intensified as the low pressure system moved south to the North Carolina coast and began moving out to sea by the morning of 5 September. Maximum onshore winds (NE) reached 16 m/s at 1000 EST on 4 September. The maximum H_{mo}, at gauge 630, reached 2.9 m (T_p=8.0 s) at 1300 EST on 4 September. There was 10 mm of precipitation.

22 Sep Northeasterly winds were funneled between a high pressure system to the west and a low pressure system NE of Cape Hatteras. Maximum onshore winds (NE) reached 17 m/s at 0316 EST. The maximum H_{mo}, at gauge 630, reached 3.5 m (T_p=8.5 s) at 0316 EST. There was 64 mm of precipitation.

Distribution List

Government Agencies:

Back Bay National Wildlife Refuge
USACE-OCE
USACE-SAD
USACE-NAP
USACE-SAW
USACE-WES
NAVSAC
NOAA/NOS/OMS
National Marine Fisheries
U.S. Geological Survey
U.S. Library of Congress
U.S. National Park Service
U.S. National Weather Service
U.S. Naval Academy
U.S. Naval Civil Eng. Lab
U.S. Naval Oceanographic Off.
U.S. Naval Research Lab

Colleges/Universities:

Bucknell University
California Inst. of Tech.
Duke Marine Lab
East Carolina University
Florida Inst. of Tech.
M.I.T.
Naval Post Graduate School
NC State University
Old Dominion University
Oregon State University
Prince George's College
Scripps Institution of Oceanography
Stockton State College
University Calif-Berkeley
University of Florida
University of Maryland-College Park
University of Maryland-Baltimore
University of North Carolina
University of N C-Seagrant Program
University of Virginia
Va. Inst. of Marine Science
Rutgers University

Others:

Allied Signal Aerospace Co.
Applied Physics Lab
Cape Hatteras Nat. Seashore
Coastal and Est. Res., Inc.
Coastal Science & Eng., Inc.
Dr. Cy Galvin
GEOMET Tech., Inc.
Mr. Hodges
Dr. Hylton
Mr. Mason
Mr. Rodgers
WCTI-TV
MEC Systems Corporation
Moffatt & Nichol, Eng.
N.C. Div. Coastal Management
Oregon Inlet & Waterways Commis.
Raleigh-Durham Airport
Mr. Rowland
Mr. Savage
Science Application Int'l. Corp
Sherwood Industries
SEASUN Power Systems

Foreign:

Christchurch, Barbados
Ministry of Works, Bahamas
Dalhousie University, Halifax Nova Scotia
Queen's University, Ontario (Canada)
Ministry of Construction, Coastal Division (Japan)
Norwegian Hydrodynamic Laboratories (Norway)
University of Sydney (Australia)