CHAPTER 11

FIELD INVESTIGATION OF SUSPENDED SEDIMENT IN THE SURF ZONE

George M. Watts
Hydraulic Engineer, Beach Erosion Board
Department of the Army, Washington, D.C.

INTRODUCTION

Purpose - This paper presents the results of a number of field observations made at Pacific Beach near San Diego, California with a suspended sediment sampler. A detailed description of the laboratory and field development of the sampler is presented in the Beach Erosion Board Technical Memorandum No. 34 entitled "Development and Field Tests of a Sampler for Suspended Sediment in Wave Action". The laboratory development involved: a circulating system which provided various current velocities and concentration patterns at the test section; the testing of various size nozzles; the study of particle size distribution of samples obtained by the nozzles; and the development of correction factors for field conditions. It was concluded from the laboratory study that a pump-type sampler could be adapted to the study of suspended material movement in wave action. The principal result from the laboratory tests was a tentative finding that by pumping through a vertically disposed 1/2-inch nozzle with a velocity approximately twice the maximum orbital current velocity in a wave, samples could be obtained which were representative in weight (even without a correction factor) to within about 15 per cent of the true suspension.

When the Field Research Group of the Beach Erosion Board was making a study of shore line changes in the Mission Bay area, near San Diego, California, from March 1949 to March 1951, opportunity was afforded to make field tests of a suspended sediment sampler designed in accordance with the laboratory findings. The purpose of the field program was threefold, as follows:

a. To test the adaptability of the suspended sediment sampler to use off a pier in open water;

b. To determine the suspended sediment concentration at various points in and immediately outside the surf zone over as wide a range of wave conditions as practicable; and

c. To analyze the results of sampling to obtain an indication of whether or not the suspended load is of sufficient magnitude to play a significant role in the alongshore transport of littoral materials.

Description of Area - The Mission Bay area is shown on Figure 1. It lies between the La Jolla and Point Loma headlands. The shore area includes Pacific, Mission and Ocean Beaches. Pacific and Mission Beaches, which appear to be essentially stable, extend southward from the La Jolla headland in a gently curving arc to the jetties at the entrance to Mission Bay. Throughout most of that length the beach is broad and flat with the crest of the beach berm approximately 11 feet above mean lower low water. Seaward from the beach berm the slope is relatively steep, gradually becoming flatter at the approach to the low tide terrace. A low bar is usually present seaward of the terrace.

Tidal Data - The tides are of the mixed type with a diurnal inequality. The mean range of tide in this locality is about 3.6 feet, and the mean diurnal range is about 5.2 feet.

Wave Characteristics - From January to December 1950, visual observations were made twice daily of the wave height, period, and direction. During part of 1950 an underwater pressure-type wave gage was operated from Crystal Pier at Pacific Beach. Observed and recorded wave data were supplemented by hindcast wave data using synoptic weather charts for 6-hour intervals. The results have been compiled into a wave diagram (Figure 2), which presents an estimate of deep water wave conditions for 1950. Because of the lack of weather data for the region south of latitude 15° North, the southern limit of hindcast waves was about 260° azimuth. Also, the northern limit of observed directions was approximately 290° azimuth; waves on the graph with directions north of 290° azimuth were hindcast. Since these latter waves were not observed, it is possible that diffraction around offshore islands altered the direction of waves before they reached Pacific Beach. Thus the sector of wave approach actually observed has as its limits azimuths of 180° and 290°. Percentages of time shown total more than 100 percent since often two or more wave systems occurred simultaneously.

Suspended Sediment Sampler - The sampler was designed to gather a sediment sample by pumping a quantity of sediment-laden water from a selected point. The water was discharged back into the ocean after passing through a filter which removed the sediment. The amount of water pumped was measured by a meter connected in series with the filter.

The sampler and appurtenances are shown on Figure 3. The apparatus consists of a 1/2-inch intake nozzle, a filter case, a modified filter core, standard check valve, a submersible pump, a standard pipe tee and plug for priming, and a water meter (modified by filling the dial chamber with light oil and replacing the glass face plate with a lucite face plate). The filter paper was 10 ply, Z-fold embossed; the openings in the paper being rated as passing only solids of less than 25 microns diameter. When within 1 to 4 feet of the bottom, the intake nozzle opening was positioned with respect to the ocean bottom by means of a positioning unit which consisted of a round plate attached to the sampler by iron supports. The plate had a spur which penetrated the ocean bottom thereby eliminating any latteral movement of the sampler during operation. The sampling unit was lowered into and removed from the water by means of a block and tackle.

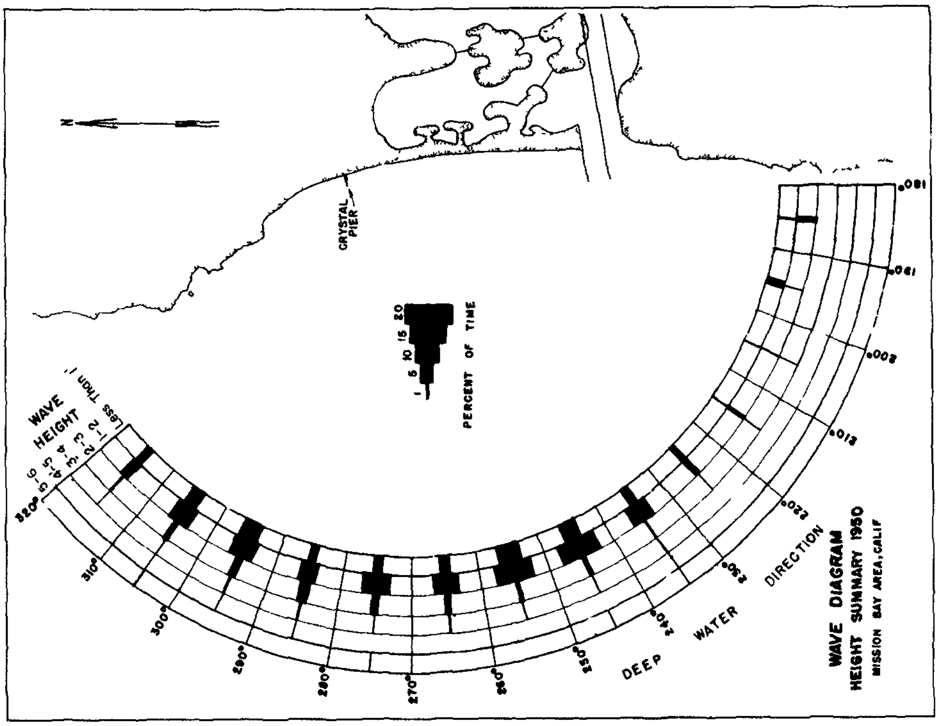

WAVE DIAGRAM
HEIGHT SUMMARY 1950
MISSION BAY AREA, CALIF
DEEP WATER DIRECTION
WAVE HEIGHT
LESS THAN 1
PERCENT OF TIME
CRYSTAL PIER
N

Fig. 2.

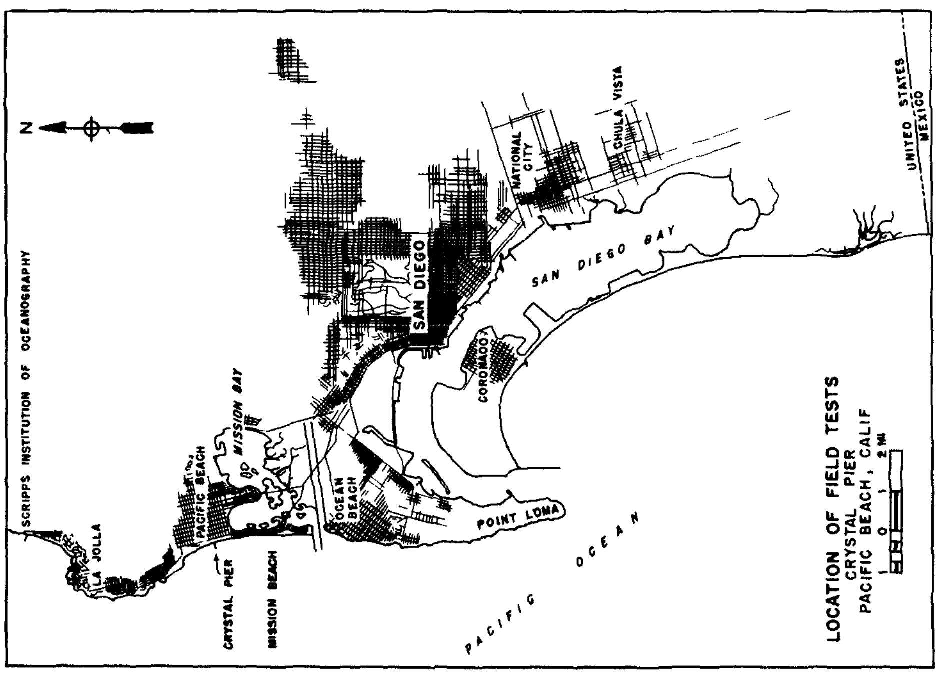
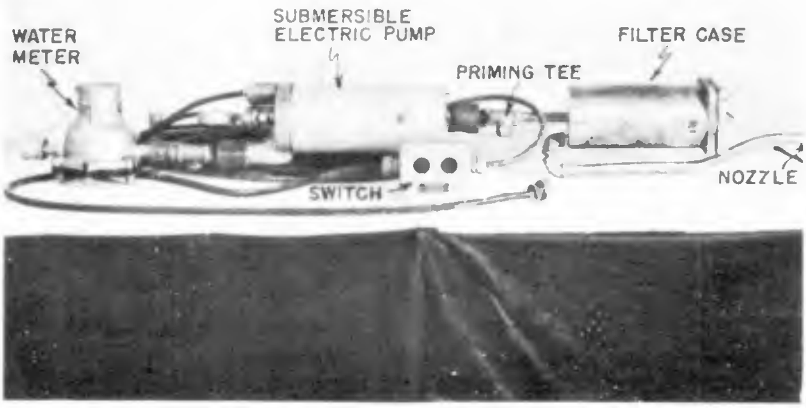

LOCATION OF FIELD TESTS
CRYSTAL PIER
PACIFIC BEACH, CALIF
SCRIPPS INSTITUTION OF OCEANOGRAPHY
LA JOLLA
PACIFIC BEACH
MISSION BAY
CRYSTAL PIER
MISSION BEACH
OCEAN BEACH
SAN DIEGO
POINT LOMA
PACIFIC OCEAN
CORONADO
SAN DIEGO BAY
NATIONAL CITY
CHULA VISTA
UNITED STATES
MEXICO
N

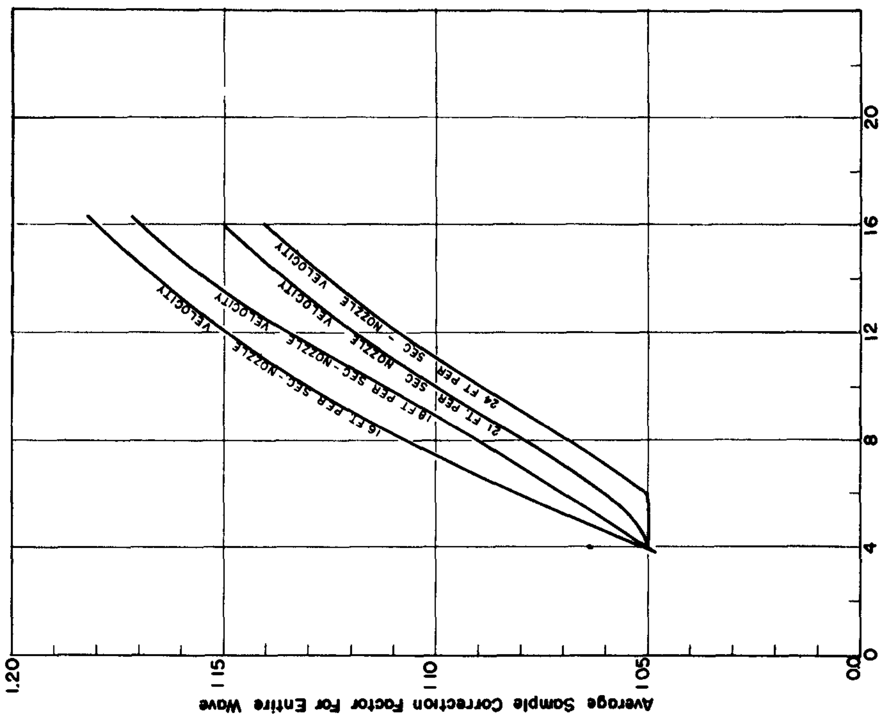
Fig. 1.



3-a. Component Parts Of Sampler.

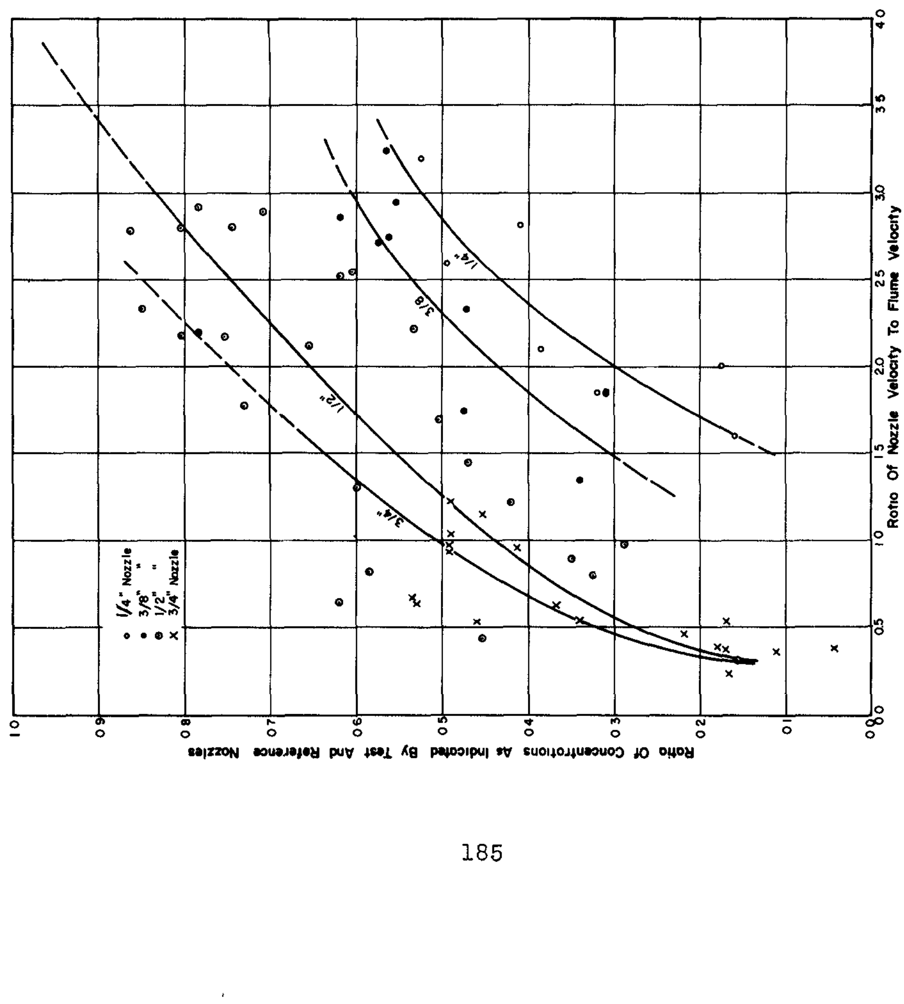
3-b. Sampler And Hoist

SUSPENDED SEDIMENT SAMPLER
Fig. 3.



CORRECTION FACTOR FOR ENTIRE WAVE IN BREAKER ZONE

Fig. 5.



SAMPLING EFFICIENCY

Fig. 4.

The efficiency curve for the sampler equipped with a 1/2-inch diameter intake nozzle was determined from laboratory tests and is shown on Figure 4. The sampler was designed to pump with a nozzle velocity of about 18 feet per second. The laboratory development tests indicated that the sampler will pump at an average sampling efficiency of 94 percent when the internal orbital velocity of the wave is from 0 to 5 feet per second. Therefore, for that part of the wave cycle in which the internal orbital velocity is less than 5 feet per second, a sampling efficiency of 94 percent can be assumed. For nozzle velocity-current velocity ratios less than 3.5 the sampling efficiency falls off rapidly, being only 44 percent when the ratio is unity. In view of these findings a correction factor was developed (Figure 5) which varied with the internal current velocity in the wave.

FIELD TESTS

Procedure - All suspended sediment samples were taken from Crystal Pier, a structure located at Pacific Beach. The pier, shown in an aerial photograph on Figure 6, is approximately 1,000 feet in length. Due to limitations of personnel and time for hydrographic survey work at Mission Bay, the suspended sediment sampling program was conducted only on days of poor visibility, excessively rough seas, or when it was impractical to attempt hydrographic work. Consequently, sampling was done only for a limited number of wave conditions. Samples were taken on 23 days between 15 January 1950 and 15 May 1951. The total number of samples procured was 290. Samples taken with an intake nozzle velocity less than 15 feet per second were not included in the compilation since these low intake velocities were generally the result of seaweed or debris clogging the nozzle which would greatly influence the accuracy of the indicated sample concentration. Most of the samples were obtained landward of the breaker line since the waves generally broke before reaching the seaward end of the pier. Although 52 samples were obtained seaward of the breaker line, 30 had intake nozzle velocities less than 15 feet per second. The 22 acceptable samples were insufficient in number to make any detailed study in this zone. Of the 238 samples taken landward of the breaker line, 170 were acceptable. A typical field data sheet, Figure 7, illustrates the information recorded for each sample.

Pumping Time Per Sample - The influence of pumping time for an individual sample was given careful consideration. It was believed that sampling should be continuous during the passage of at least 15 to 20 wave crests to obtain a representative sample. As noted in the wave summary study there were frequent times when inconsistent or combination wave trains approached the shore thereby creating a rather complex wave period record. However, it appears on the average that a wave period of approximately 13 to 15 seconds prevailed. On this basis it was assumed that a sampling duration of 5 minutes would extract samples of the suspended material from the sea over approximately 15 to 20 wave passages and should provide a representative sample for the prevailing wave characteristics. An analysis of samples taken over a period of approximately 10 minutes indicated a considerable reduction in intake nozzle velocity due generally to the head loss in overloading the sampler filter.

1 FEB. 1951 SCALE 1:5,000

CRYSTAL PIER, PACIFIC BEACH, CALIF.
Figure 6

SUSPENDED SAND DETERMINATION
Crystal Pier
Mission Bay, California

Sample No. 63
Date 7 Mar. 50
Time 1340

Sta. of observation 9+75
Sta. of breaker line 8+50
Sta. of uprush limit 2+50
Sample taken (~~shoreward~~) (seaward) of breaker line.
Estimated wave height at sampling point 2 ft
Estimated wave period at sampling point 15 sec
Water depth at sampling point 11.3 ft
Height of intake nozzle above bottom 9 ft
Duration of run 5 min 0 sec (5.00 min)
Meter reading after run 637.9
Meter reading before run 631.0

Water pumped 6.9 cu ft (x 64.0 =) 442 lbs sea water
Rate of pumping 1.38 cu ft per min
Intake nozzle velocity (cu ft per min x 12.3) 17.0 ft per sec
Max. orb. wave velocity (from curves) 1.7 ft per sec (from ~~recorded~~ estimated wave data)
Correction factor for this sample (from curves) 1.05
Weight of sample less foreign matter, oven-dry 21.6 grams (x 0.0022) 0.0475 lbs
Corrected weight of sample 22.7 grams (x 0.0022) 0.0499 lbs
Parts of sand per thousand parts of water by weight 0.113
Parts of sand per thousand parts of water by volume 0.043
(by weight x 0.379, assuming sp. gr. sand at 2.70 and sea water at 1.025)

Recorded wave height 1.0 ft
Recorded wave period 14.1 sec
Time of wave record 1500
Depth of water at recorder 29.5
Wave direction (observed from shore station) 270°
Time of wave direction observation 1500
Type of breaker Plunging
Littoral drift direction N
Littoral drift velocity 15 ft per min
Time of littoral drift observation 1200
Median grain size of nearest bottom sample 0.165 mm
Sample number of nearest bottom sample 69
Other data on bottom sample
Median grain size of nearest beach sample 0.170 mm
Sample number of nearest beach sample 68
Other data on beach sample
Median grain size of suspended sand sample 0.117 mm
Description of foreign material in sample

REMARKS

FIELD DATA SHEET

FIG. 7

Data Obtained - All data obtained on sediment concentrations in individual samples taken landward of the breaker line are given in Table 1. In view of the inaccuracies of estimated wave heights, it was necessary to group the data into classes. The data in Table 1 are grouped by classes of wave heights, water depths and sampling elevations from the bottom. An arithmetical mean concentration is derived for each water depth - sampling elevation - wave height combination.

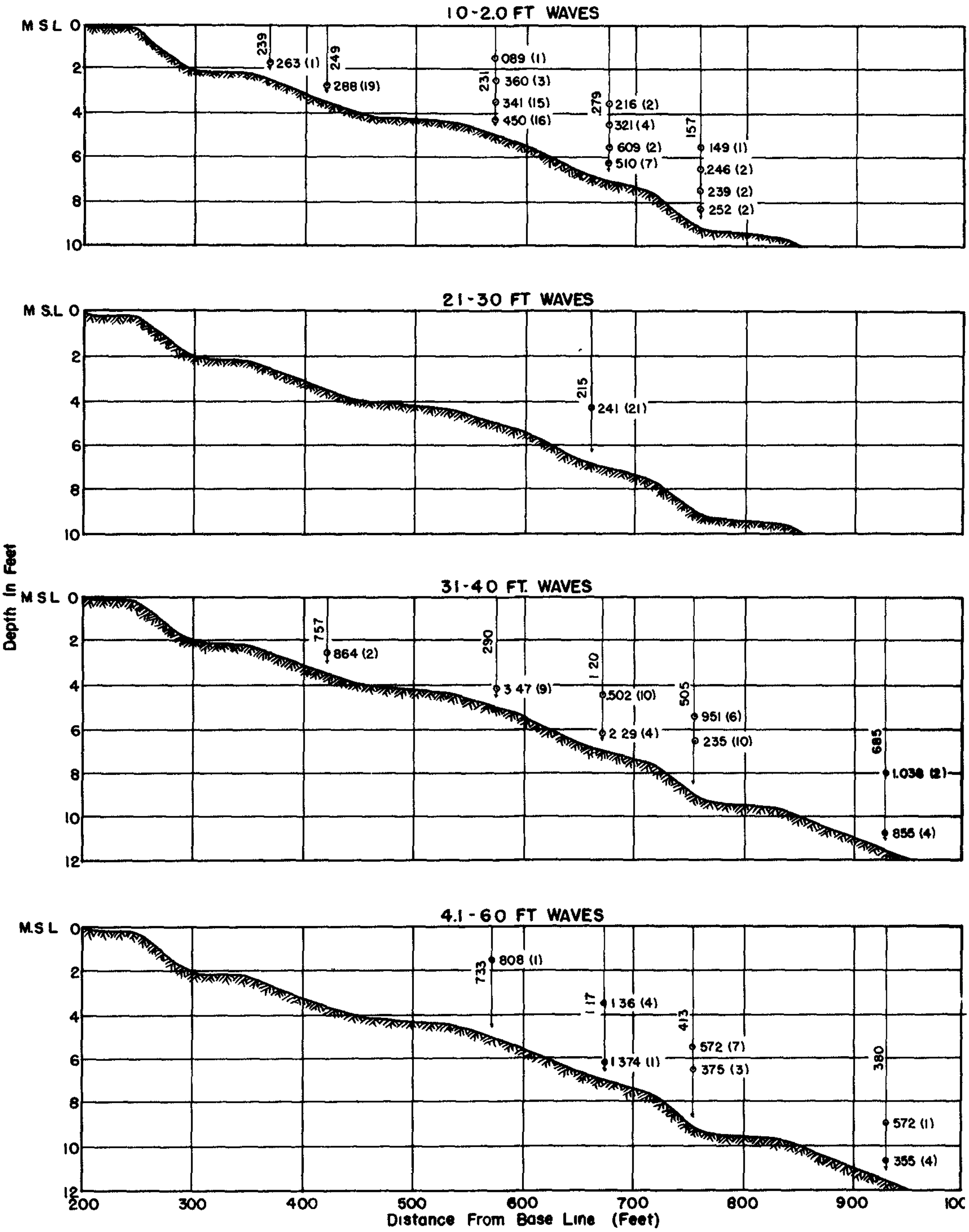
PRESENTATION OF DATA

Concentration Distributions Along Profile - The mean concentration values from Table 1 were plotted (according to their respective water depth -- sampling elevation -- wave height classes) in relation to a hydrographic profile which is representative of the Crystal Pier location. Figure 8 shows the plotted concentration values for four wave height classes. Where concentration values are indicated at the various depths at a station on Figure 8, an average concentration value for that station also is indicated. This average concentration value for each indicated station was derived by plotting the concentration values between the water surface and 0.5 foot from the bottom, (plots with individual values not shown) then drawing a curve to define the vertical concentration distribution. In establishing the curve, consideration was given to the evidence found in Figure 10 which indicates that the concentration is fairly constant between about two-tenths and six-tenths of the depth from the bottom.

The average concentration at each station for each wave height class as established in Figure 8 was plotted as shown on Figure 9. These plots of the suspended sediment data represent the average concentration profiles. Curves of visual best fit have been drawn for various wave height classes between the limits of available data. They have been extrapolated thence to the mean sea level shore line and to the 11-foot depth contour for purposes of estimating material movement past the profile.

Data for all acceptable samples are given in Table 2 by Z/H ratios and wave height classes; Z being the distance from the bottom to the nozzle intake, and H being the total water depth at the sampling station. The arithmetic means of the concentration values for each wave height class were then plotted against Z/H as shown in Figure 10. These plots represent the vertical concentration profile when all Z/H values are considered for each wave height class.

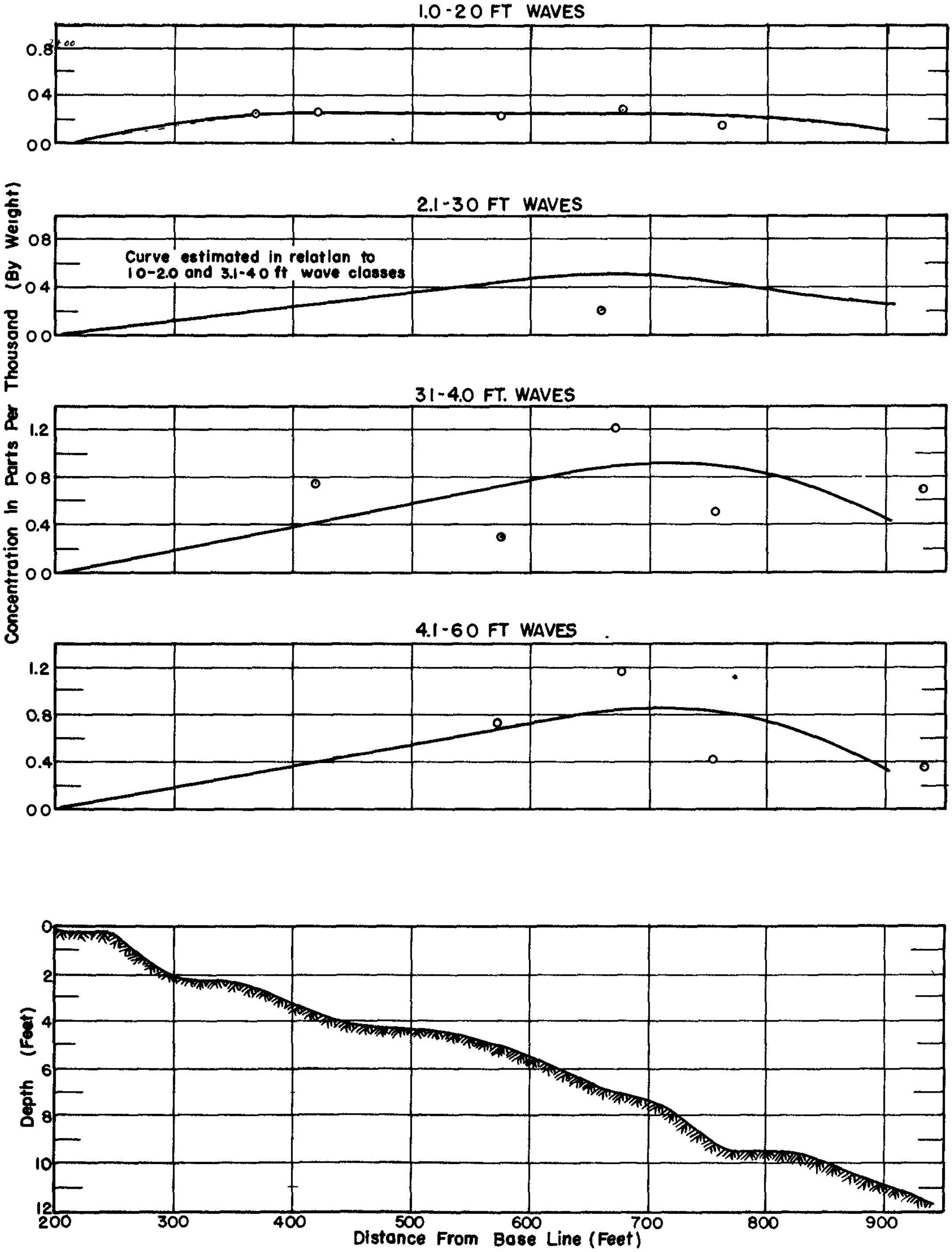
Total Material in Suspension - In order to investigate the average concentration distribution shown on Figure 9 in terms of total material in suspension, a tabulation of volumes of sand per linear foot of shore, between the shore and the 10-foot depth (Stations 250 to 850), is presented in Table 3. As can be seen Table 3 utilizes the suspended sediment concentrations, as arrived at from the sampling program, to deduce the average amount of material in suspension in the surf zone, (between the shore and the 10-foot depth contour) for various wave height classes. The volume of material in suspension was computed as $V\rho_w \not{c}/\rho_s$



NOTE Each point is the average concentration in P.P.T of all samples taken at that particular water depth and elevation above the bottom. The number in brackets by each concentration value is the number of samples averaged to arrive at the indicated concentration. The average concentration between the water surface and 0.5 ft from the bottom is indicated at each sampling station. (see fig. 19)

SUSPENDED SEDIMENT CONCENTRATIONS ALONG PROFILE

Figure 8



NOTE: Plotted points indicate average concentrations between the water surface and 0.5 ft from the bottom. (From fig. 18)

CONCENTRATION DISTRIBUTION ALONG PROFILE
Figure 9

Table I

Concentrations of Individual Samples For Various Combinations of Water Depth - Sampling Elevation - Wave Height Classes

Water Depth Class (ft)	Sampling Elev. Class (ft, from bottom)	Wave Height Class (ft.)	Concentrations of Individual Samples In Parts Per Thousand by Weight	Arithmetic Mean
2.0 - 3.0	0.6 - 1.0	1.0 - 2.0	0.263	0.263
3.1 - 4.0	0.6 - 1.0	1.0 - 2.0	0.098, 0.142, 0.154, 0.180, 0.183, 0.234, 0.235, 0.266, 0.268, 0.273, 0.287, 0.290, 0.295, 0.318, 0.324, 0.367, 0.399, 0.420, 0.740	0.288
	0.6 - 1.0	3.1 - 4.0	0.651, 1.077	0.864
4.1 - 6.0	0.6 - 1.0	1.0 - 2.0	0.031, 0.086, 0.122, 0.131, 0.163, 0.193, 0.224, 0.225, 0.274, 0.324, 0.352, 0.430, 0.773, 0.867, 1.442, 1.570	0.450
	0.6 - 1.0	3.1 - 4.0	1.460, 1.980, 2.170, 2.340, 2.910, 3,410, 4.430, 4.610, 7.910,	3.47
	1.1 - 2.0	1.0 - 2.0	0.070, 0.072, 0.083, 0.093, 0.168, 0.204, 0.219, 0.237, 0.287, 0.288, 0.329, 0.455, 0.860, 0.874, 0.877	0.341
	2.1 - 3.0	1.0 - 2.0	0.123, 0.429, 0.529	0.360
	3.1 - 4.0	1.0 - 2.0	0.089	0.089
	3.1 - 4.0	4.1 - 6.0	0.808	0.808
6.1 - 8.0	0.6 - 1.0	1.0 - 2.0	0.179, 0.252, 0.416, 0.450, 0.582, 0.646, 1.045	0.510
	0.6 - 1.0	3.1 - 4.0	1.150, 2.500, 2.540, 2.960	2.29
	0.6 - 1.0	4.1 - 6.0	1.374	1.374
	1.1 - 2.0	1.0 - 2.0	0.558, 0.661	0.609
	2.1 - 3.0	1.0 - 2.0	0.194, 0.234, 0.333, 0.524	0.321
	2.1 - 3.0	2.1 - 3.0	0.155, 0.165, 0.171, 0.172, 0.175, 0.177, 0.181, 0.204, 0.206, 0.208, 0.230 0.232, 0.238, 0.244, 0.247, 0.252, 0.274, 0.316, 0.358, 0.384, 0.482	0.241
	2.1 - 3.0	3.1 - 4.0	0.182, 0.197, 0.240, 0.330, 0.426, 0.427, 0.565, 0.590, 0.736, 1.330	0.502
	3.1 - 4.0	1.0 - 2.0	0.188, 0.244	0.216
	3.1 - 4.0	4.1 - 6.0	1.002, 1.290, 1.310, 1.840	1.36
8.1 - 10.0	0.6 - 1.0	1.0 - 2.0	0.233, 0.272	0.252
	1.1 - 2.0	1.0 - 2.0	0.120, 0.358	0.239
	2.1 - 3.0	1.0 - 2.0	0.026, 0.467	0.246
	2.1 - 3.0	3.1 - 4.0	0.126, 0.152, 0.182, 0.220, 0.221, 0.244, 0.246, 0.257, 0.314, 0.388	0.235
	2.1 - 3.0	4.1 - 6.0	0.324, 0.375, 0.424	0.375
	3.1 - 4.0	1.0 - 2.0	0.149	0.149
	3.1 - 4.0	3.1 - 4.0	0.712, 0.756, 0.908, 1.058, 1.133, 1.140	0.951
	3.1 - 4.0	4.1 - 6.0	0.363, 0.443, 0.471, 0.577, 0.703, 0.715, 0.732	0.572
10.1 - 13.0	0.6 - 1.0	3.1 - 4.0	0.403, 0.541, 0.547, 1.930	0.855
	0.6 - 1.0	4.1 - 6.0	0.244, 0.258, 0.318, 0.604	0.355
	2.1 - 3.0	4.1 - 6.0	0.572	0.572
	3.1 - 4.0	3.1 - 4.0	0.880, 1.196	1.038

Table 2

SEDIMENT CONCENTRATIONS OF SAMPLES BY Z/H AND WAVE HEIGHT CLASSES

Note: Z = Distance from bottom to nozzle intake; H = Water depth at sampling point; Concentrations in part per thousand by weight

Z/H Class	0.06 to 0.10	0.11 to 0.15	0.16 to 0.20	0.21 to 0.25	0.26 to 0.30	0.31 to 0.35	0.36 to 0.40	0.41 to 0.45	0.46 to 0.50	0.51 to 0.55	0.56 to 0.60	0.61 to 0.65
1.0 - 2.0 Ft. Wave Class												
	0.233	0.252	0.031	0.120	0.098	0.026	0.083	0.072	0.070	0.123	0.188	0.089
	0.366	0.272	0.086	0.122	0.154	0.142	0.237	0.149	0.093		0.244	
	0.377	0.461	0.163	0.131	0.180	0.168	0.287	0.194	0.204		0.429	
	0.768	0.646	0.179	0.224	0.235	0.183	0.327	0.234	0.288			
	[illegible]	1.016	0.193	0.225	0.290	0.263	0.860	0.333	0.329			
			0.274	0.266	0.318	0.273		0.542	0.529			
			0.324	0.268	0.324	0.455		0.874	0.877			
			0.358	0.287	0.324	0.661						
			0.430	0.295	0.420							
			0.450	0.352	0.558							
			1.442	0.367	0.740							
			1.570	0.399								
				0.773								
				0.867								
Avg	0.436	0.535	0.458	0.335	0.331	0.271	0.359	0.342	0.341	0.123	0.287	0.089
2.1 - 3.0 Ft. Wave Class												
	0.133						0.149	0.155	0.238			
							0.177	0.165				
							0.206	0.171				
							0.230	0.172				
							0.232	0.175				
							0.244	0.181				
							0.247	0.204				
							0.252	0.208				
							0.274	0.358				
							0.316	0.482				
							0.384					
Avg	0.133						0.246	0.227	0.238			
3.1 - 4.0 Ft. Wave Class												
	0.403	1.150	1.46	0.651	1.077	0.126	0.152	0.590	0.712			
	0.541	2.50	1.98	2.34		0.182	0.182	0.756	1.058			
	0.547	2.54	2.17	3.41		0.220	0.197	0.908				
	1.93	2.96	2.91	4.43		0.221	0.240	1.130				
				4.61		0.246	0.244	1.140				
				7.91		0.257	0.330	1.33				
						0.314	0.426					
						0.388	0.427					
							0.565					
							0.736					
							0.880					
							1.196					
Avg	0.855	2.288	2.13	3.892	1.077	0.244	0.465	0.976	0.885			
4.1 - 6.0 Ft. Wave Class												
	0.244	1.374			0.572	0.324	0.042	0.363		1.002		0.808
	0.258					0.375	0.471	0.443		1.29		
	0.318					0.424	0.577	0.703		1.31		
	0.604							0.715		1.84		
								0.732				
Avg	0.356	1.374			0.572	0.374	0.363	0.591		1.361		0.808

Table 3

MATERIAL IN SUSPENSION PER LINEAR FOOT OF SHORE BY WAVE HEIGHT CLASSES

Station Limits Along Profile	Average Water Depth Within Station Limits	Volume of Water Within Station Limits	WAVE HEIGHT CLASSES							
			1.0 - 2.0 ft.		2.1 - 3.0 ft.		3.1 - 4.0 ft.		4.1 - 6.0 ft.	
			Avg. Conc.	Mat'l in Susp.	Avg. Conc.	Mat'l in Susp.	Avg. Conc.	Mat'l in Susp.	Avg. Conc.	Mat'l in Susp.
Ft.	Ft.	Cu. Yds.	P.P.T.	Cu. yds.	P.P.T.	Cu. Yds.	P.P.T.	Cu. yds.	P.P.T.	Cu. Yds.
				$\times10^{-4}$		$\times10^{-4}$		$\times10^{-4}$		$\times10^{-4}$
250 - 350	0.9	3.33	0.15	3.2	0.12	2.6	0.19	4.1	0.19	4.1
350 - 450	2.5	9.27	0.23	13.8	0.25	15.0	0.38	22.7	0.38	22.7
450 - 550	4.0	14.80	0.23	22.0	0.35	33.4	0.57	54.4	0.57	54.4
550 - 650	4.8	17.80	0.23	26.4	0.45	51.7	0.79	90.7	0.70	80.4
650 - 750	6.5	24.00	0.23	35.6	0.50	77.4	0.90	139.3	0.85	131.6
750 - 850	8.5	31.40	0.20	40.5	0.39	79.0	0.82	166.1	0.75	151.9
			Totals	141.5		259.1		477.3		445.1

Table 4

INDICATED ANNUAL SUSPENDED LITTORAL DRIFT FOR ASSUMED NET LITTORAL CURRENT VELOCITIES

Velocity of Littoral Current (Assume Direction Constant)	WAVE HEIGHT CLASSES				Total Littoral Drift
	1.0 - 2.0 ft.	2.1 - 3.0 ft.	3.1 - 4.0 ft.	4.1 - 6.0 ft.	
	Suspended Material Passing Unit Width (%Yearly Occurrence of Wave Ht. Class = 60)	Suspended Material Passing Unit Width (%Yearly Occurrence of Wave Ht. Class = 19)	Suspended Material Passing Unit Width (%Yearly Occurrence of Wave Ht. Class = 4)	Suspended Material Passing Unit Width (%Yearly Occurrence of Wave Ht. Class = 1.3)	
Ft. Per Min.	Cu. Yds. Per Year	Cu. Yds Per Year	Cu. Yds. Per Year	Cu. Yds. Per Year	Cu. Yds. Per Year
1	4462	2587	1000	304	8353
5	22310	12935	5000	1520	41765
10	44620	25870	10000	3040	83530
15	66930	38805	15000	4560	125295
20	89240	51740	20000	6080	167060
25	111550	64675	25000	7600	208825
30	133860	77610	30000	9120	250590
40	178480	103480	40000	12160	334120
50	223100	129350	50000	15200	417650
60	267720	155220	60000	18240	502180
70	312340	181090	70000	21280	584710

Note: The percentages of occurrence of wave height classes total 84.3% of time, the remaining percentage comprises

Table 5

MEDIAN DIAMETERS OF SUSPENDED SEDIMENT SAMPLES

Z/H Class	0.00 to 0.05	0.06 to 0.10	0.11 to 0.15	0.16 to 0.20	0.21 to 0.25	0.26 to 0.30	0.31 to 0.35	0.36 to 0.40	0.41 to 0.45	0.46 to 0.50	0.51 to 0.55	0.56 to 0.60	0.61 to 0.65	0.66 to 0.70	0.71 to 0.75	0.76 to 0.80	0.81 to 0.85
1.0 - 2.0 Ft. Wave Class																	
	0.118	0.116	0.131	0.160	0.136	0.120	0.130	0.120	0.112	0.120	0.162	0.108	0.130	0.138	0.170		0.141
	0.090	0.139	0.113	0.143	0.125	0.150	0.163	0.140	0.130	0.172		0.119					
	0.180	0.145	0.155	0.184	0.093	0.145	0.115	0.152	0.122			0.130					
	0.187	0.100	0.118			0.093	0.118		0.164								
	0.096	0.098	0.112				0.092		0.085								
	0.103	C.097	0.135														
	0.098	0.099	0.150														
	0.099		0.096														
	0.107		0.098														
Avg	0.120	0.113	0.123	0.162	0.118	0.127	0.124	0.137	0.123	0.146	0.162	0.119	0.130	0.138	0.170		0.141
2.1 - 3.0 Ft. Wave Class																	
	0.200	0.120	.0.122	0.150	0.141			0.141	0.114	0.170		0.163					0.152
	0.160	0.122			0.143					0.157							0.149
										0.141							
Avg	0.180	0.121	0.122	0.150	0.142			0.141	0.114	0.156		0.163					0.151
3.1 - 4.0 Ft. Wave Class																	
		0.170	0.190	0.200	0.195	0.189	0.170	0.190	0.190								
		C.173		0.160	0.172		0.169		0.170								
Avg		0.172	0.190	0.180	0.184	0.189	.0.170	0.190	0.180								
4.1 - 6.0 Ft. Wave Class																	
		0.190	0.184			0.190	0.160	0.185	0.165		0.160						
			0.184				0.160		0.165		0.157						
							0.190		0.190								
Avg		0.190	0.184			0.190	0.170	0.185	0.173		0.174						

V - Volume of water in cubic yards
ρ_w - Density of sea water in lbs per cubic yard
$\not{c}$ - Concentration in parts by weight
ρ_s - Bulk density of sand, taken as 2700 lbs per cubic yard

Although the degree of accuracy of this computation cannot be stated with certainty at this time, it is believed that the amount of material in suspension indicated by these computations is of the correct order of magnitude.

Indicated Annual Suspended Littoral Drift - The next step, shown in Table 4, introduces the yearly percentages of occurrence of the various wave height classes and an assumed net rate of alongshore current to illustrate the net rate of alongshore drift which could be attributed to suspended material (as contrasted to creep, or bed load transport). It is recognized that the assumptions behind these computations are rather broad and it is not intended that these results be accepted for quantitative application to shore erosion studies. However, it is believed that the rate of longshore drift indicated by the computations serves to show that the suspended load is potentially a sizeable factor in the longshore drift picture.

Grain Size of Suspended Sediment - Data on the median diameters of a number of samples obtained are given in Table 5. The presentation of data in Table 5 is similar to that in Table 2 with respect to Z/H ratios and wave height classes.

ANALYSIS OF RESULTS

Adaptability of Sampler - In this series of tests approximately 71 percent of the total number of samples obtained were employed in studying the suspended material movement. This could be considered as a relatively poor sampling efficiency; however, the sampling efficiency for this particular type of sampler will be a function of the local conditions. In the area where the samples were taken, there was on occasions a considerable amount of eel grass in suspension which clogged the sampler intake nozzle and reduced the intake nozzle velocity so that the sample was of questionable value. The number of acceptable samples would be increased where only a nominal amount of this type of foreign material was in suspension at the sampling point.

No satisfactory operational procedure has been developed for this sampler which would facilitate the procurement of samples other than from a fixed structure. The shore structure undoubtedly had some influence on the sample results, but the magnitude of such influence could not be evaluated. Precautions were taken to obtain samples at a point as far from a structural member of the pier as possible, the sampler also being positioned about 10 feet away from the pier. Sampling was done from the side of the pier toward the direction from which waves were approaching.

Table 1 shows that when a number of samples were taken with a specific water depth, sampling elevation, and wave height class, the maximum and minimum values of sample concentrations frequently differed by a factor of 3 to 5. This difference is appreciable and serves to show that the suspended concentration pattern, in relation to time, must be exceedingly complex. The spread in concentration values might be expected to become somewhat less if the class limits (water depth, sampling elevation, and wave height) were decreased. However, the following tabulation is presented to illustrate that repetitive sampling (samples taken as often as possible, under essentially identical conditions) seems to indicate a similiar spread in concentration values, therefore the order of magnitude of spread in concentration values for the class limits used could be expected.

TABLE 6 - REPETITIVE SAMPLING DATA

Estimated wave height at sampling point - 3 feet
Water depth at sampling point - 6.8 feet
Height of intake nozzle above bottom - 3 feet

22 Jan 1951, Time	1354	1404	1414	1428	1445	1454	1505
Concentration of Sample (P.P.T. by Wt.)	0.204	0.155	0.175	0.208	0.482	0.171	0.165

Although the concentration values vary appreciably, it is believed that they indicate the range between the limits of which the true value probably lies; the true value probably not being greatly different than the mean of the group.

When the mean values of concentration for various depth and wave height classes are plotted as shown in Figure 8, it can be seen that many more samples would be desirable in order to establish the average concentration profile at each station for each wave height class. Nevertheless, the average concentration value computed for each station indicated in Figure 8 seems to provide a logical and reasonable concentration pattern when plotted as shown in Figure 9. Approximately 70 percent of the suspended sediment data falls into the 1.0 to 2.0 and 3.1 to 4.0-foot wave height classes and there seems to be a reasonable correlation in Figure 9 for these wave height classes. The 2.1 to 3.0-foot wave height class contains only one point and this falls slightly above the average concentration for the 1.0 to 2.0-foot wave height class. The line indicating an average concentration profile for this wave height class is undoubtedly questionable, but was sketched in relation to the 1.0 to 2.0 and 3.1 to 4.0-foot classes, for use in the computations in Table 3. The scattered data for the 3.1 to 4.0-foot and 4.1 to 6.0-foot wave classes in Figure 9 do not indicate any significant difference between the average concentration profiles for the two classes. The fact that the 4.1-6.0 wave class concentration profile does not indicate greater concentrations is probably due to lack of data.

The concentration profiles in Figure 9 indicate that the greatest amount of material, in this area, is thrown into suspension between the 4 and 8-foot depth contours which is the area slightly landward of the breaker line. There is some evidence that the difference of the average concentration of suspended material at any station between the breaker line and approximately the 2-foot depth is not great; rather it could be more of a uniform concentration of suspended material between these two points. This fact seems to be brought out in the data tabulated in Table 2 and plotted on Figure 10. Here concentration values at all stations on the profile for each wave height class have been plotted against Z/H classes. For each wave height class, this plot tends to indicate that at any station along the profile there is a depth range where the concentration is fairly uniform and since Z/H values are used for all depths, this uniform concentration zone would extend throughout the surf area. For the 1.0 to 2.0-foot wave height class the range of uniform concentration extends from the two-tenths to the six-tenths depth; the 2.1 to 3.0-foot wave height class has an insufficient number of points and the limits of the range cannot be established; for the 3.1 to 4.0 and 4.1 to 6.0-foot wave height classes the lower portion of the range is indicated to be around the three or four-tenths depth, the upper limit cannot be established due to lack of data.

Littoral Drift Computations - Although additional samples would have been desirable, the 170 acceptable samples used for this study seem to present a reasonable concentration distribution when the results are resolved into averages. The overall accuracy of the average concentration values cannot be evaluated at this time, therefore the accuracy of the quantitative computations in Tables 3 and 4 cannot be assessed. As far as is known, no other method has been developed to date, that will give any indication as to the magnitude of the concentrations of suspended material in the nearshore zone. The results, as shown in Table 3, indicate that the suspended load is potentially a sizeable factor in the movement of material alongshore.

Grain Size of Samples - The data were studied to determine if a correlation between grain size in suspension and distance from the bottom could be established for various wave characteristics. No trend toward any relationship of this type is apparent from the number of observations taken in this study. It appears that many samples must be taken at each station along a profile under a wide variation of wave characteristics in order to establish this relationship. An analysis of the beach and bottom samples at or near Crystal Pier indicates that the beach and offshore bottom sediments can be divided into three size classes. At the intersection of the plane of mean tide level with the beach the median diameter of the sand is about 0.22 millimeter; from this zone to the 20-foot depth the median diameter of the sand is about 0.15 millimeter; and from the 20-foot to the 50-foot depth the median diameter is about 0.10 millimeter. The suspended sediment samples were taken, in general, landward of the 13-foot depth and analysis of all the suspended samples indicates an average median diameter of about 0.14 millimeter, which compares favorably with the 0.15 millimeter sand size found from mean tide to the 20-foot depth contour.

CONCLUSIONS

The field tests of the suspended sediment sampler indicate that the number of acceptable samples procurable with the sampler is dependent on local conditions. Where excessive foreign material is present in suspension, it may clog the nozzle and make the sample unusable. It was found that only 71 percent of the total samples procured at Crystal Pier could be employed in evaluating the data. By averaging the data from acceptable samples a reasonably logical correlation between suspended sediment concentration, water depth, and wave height can be made. The results presented for this series of observations are not of a high degree of accuracy but tend to indicate that the total suspended material movement can be an important factor in a littoral drift analysis.