DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

THE
ANNUAL

BULLETIN

OF THE

BEACH EROSION BOARD

OFFICE, CHIEF OF ENGINEERS
WASHINGTON, D.C.

(THIS ISSUE INCLUDES ANNOTATED LISTING OF CONTENTS OF ALL PREVIOUS ISSUES OF THE BULLETIN AND OTHER TECHNICAL PUBLICATIONS OF THE BEACH EROSION BOARD)

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ADDITIONAL WAVE STATISTICS FOR STATIONS ON LAKE MICHIGAN AND LAKE ERIE

by

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In 1953 for use in the survey report on Great Lakes Levels, the Great Lakes Division of the Corps of Engineers (now U. S. Army Engineer Division, North Central) obtained from the United States Weather Bureau, Department of Commerce, a five-year period of recorded hourly observations of winds taken at first order weather stations along the perimeter of the Great Lakes. Also, for use in the before-mentioned report, wave hindcasts were made for the 5-year period 1948-1952 by engineers in the Chicago, Buffalo and Milwaukee Districts and by the writer. Fetches used are shore-to-shore straight line distances in the direction of the wind as determined at the shore station. A further analysis of the results obtained from the hindcasts made in 1953 is presented herein. The basic data and original sheets of the hindcasts are in the files of the Division Engineer, U. S. Army Engineer Division, North Central.

For each storm occurrence, as indicated by the wind records, the highest wave over 4 feet occurring during the storm was determined and tabulated as one occurrence of that specific height. The hindcasts are for deep water waves, not affected by refraction or shoaling, and were obtained by use of curves derived by Sverdrup and Munk (1)* and revised by Arthur (2) and Bretschneider (3). The hindcast procedure is described in paragraphs 1.232 and 1.233 of Beach Erosion Board Technical Report Number 4 (4). Data on wave periods and wave duration are not available for use in this paper; therefore the statistics presented are in effect occurrence of storm winds of sufficient strength to cause the formation of waves of the stated height. The number of occurrences per year are average values derived from the expression $F = N/T$, where F is the number of occurrences per year, N is the total number of occurrences, and T is the period of record in years. The stations considered are Muskegon, Michigan and Milwaukee, Wisconsin on Lake Michigan; and Buffalo, New York and Cleveland, Ohio on Lake Erie. The locations of the sites are shown on Figures 1 and 2.

Figures 3-6 each contain two curves which are plots of the average number of times per year that waves of various increments of height were predicted to occur during the ice-free portion of the year and during the full year. The ice-free year is considered to be that portion of the year between 1 April and 31 December. Also shown on Figures 3-6 are plotted frequency data (solid symbols and dashed curves) from the hindcast statistics for the 3-year period 1948-1950 presented by Saville (5, 6). Differences between the frequency of occurrence of specific

* Numbers in parentheses refer to Bibliography at end of text.

wave heights as indicated by the writer's hindcast data and the curves presented by Saville are shown in Table 1 and plotted in Figure 7. These differences are discussed below.

a. Milwaukee, Wisconsin. At this station wave heights on the full year basis for the various frequencies were lower by about 1.5 to 2.0 feet. A storm which would produce waves greater than 15 feet did not recur during the additional years of the longer period of record; therefore, the assumed frequency of a 15-foot wave decreased from once in 3 years to once in 5 years. Very good agreement resulted for frequencies obtained for the ice-free period.

b. Muskegon, Michigan. For the full year lower wave heights were obtained for occurrences of more than once in 7 years and higher waves for frequencies of occurrence of less than once in 7 years. Apparently a smaller number of less severe storms occurred during 1951 and 1952. In 1951 an additional storm occurred which produced wave heights of 14 feet and in November 1952 a storm occurred which produced wave heights of 19 feet. The inclusion of these higher storms increased the rate of occurrences of wave height throughout the curve for the ice-free period.

c. Cleveland, Ohio. For both the full year and the ice-free period rarer frequencies were derived for Cleveland. During 1951 and 1952 storms affecting Cleveland were less severe than during 1948-1950.

d. Buffalo, New York. For Buffalo a slightly larger number of storms with higher wave heights occurred during the full year period. Good agreement was obtained for the ice-free year curve.

The probable major reasons for variance in the results of the two hindcasts are considered to be that: (a) the length of the period of record is different, one 3 years and the other 5 years; (b) the hindcasts were made by different forecasters with probable differences in interpretation of data; (c) wind data used in this paper are from a single shore station for each location while in the earlier paper synoptic weather charts were used as a basis. The amount of variance is considered relatively small and indicates the validity of using for the Great Lakes area this shorter method of single station wind data applied over a shore-to-shore straight line fetch in the direction of the station wind.

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TABLE 1

COMPARISON OF FREQUENCY OF OCCURRENCE OF WAVE HEIGHTS
FROM BEB CURVES FOR 1948-1950 TO THOSE BY LEE FOR 1948-1952

	Wave Height in Feet-Full Year			Wave Height in Feet-Ice Free Year		
Frequency	1948-50	1948-52	Difference	1948-50	1948-52	Difference
			BUFFALO - LAKE ERIE			
1 Month	8.6	11.6	+3.0	6.8	8.0	+1.2
6 Months	12.5	13.6	+1.1	10.7	11.1	+0.4
1 Year	14.1	15.2	+1.1	12.2	12.3	+0.1
2 Years	15.7	16.8	+1.1	13.5	13.5	0.0
3 Years	16.6	17.7	+1.1	14.2	14.1	-0.1
4 Years	17.5	18.3	+0.8	14.8	14.6	-0.2
5 Years	17.8	18.8	+1.0	15.1	15.0	-0.1
10 Years	20.0	20.4	+0.4	16.4	16.2	-0.2
			CLEVELAND - LAKE ERIE			
1 Month	6.8	6.6	-0.2	5.8	5.7	-0.1
6 Months	10.0	8.7	-1.3	8.9	7.4	-1.5
1 Year	11.4	9.6	-1.8	10.2	8.1	-2.1
2 Years	12.5	10.5	-2.0	11.4	8.7	-2.7
3 Years	13.2	11.0	-2.2	12.0	9.2	-2.8
4 Years	13.8	11.3	-2.5	12.5	9.4	-3.1
5 Years	14.0	11.6	-2.4	12.7	9.6	-3.1
10 Years	15.4	12.4	-3.0	14.1	10.3	-3.8
			MILWAUKEE - LAKE MICHIGAN			
1 Month	7.8	6.7	-1.1	5.7	5.4	-0.3
6 Months	12.0	10.5	-1.5	8.6	8.4	-0.2
1 Year	13.5	12.0	-1.5	9.6	9.5	-0.1
2 Years	15.2	13.5	-1.7	10.9	10.7	-0.2
3 Years	16.1	14.4	-1.7	11.6	11.4	-0.2
4 Years	16.8	15.1	-1.7	12.1	11.9	-0.1
5 Years	17.2	15.5	-1.7	12.4	12.3	-0.1
10 Years	19.0	17.0	-2.0	13.6	13.6	0.0
			MUSKEGON - LAKE MICHIGAN			
1 Month	9.0	8.1	-0.9	7.3	7.2	-0.1
6 Months	13.5	12.3	-1.2	11.2	11.3	+0.1
1 Year	15.4	13.8	-1.6	12.6	12.9	+0.3
2 Years	17.2	15.5	-1.7	14.2	14.4	+0.2
3 Years	18.3	16.7	-1.6	15.0	15.5	+0.5
4 Years	19.2	17.8	-1.4	15.8	16.7	+0.9
5 Years	19.5	18.8	-0.7	16.1	17.7	+1.6
10 Years	21.3	22.3	+1.0	18.4	21.3	+2.9

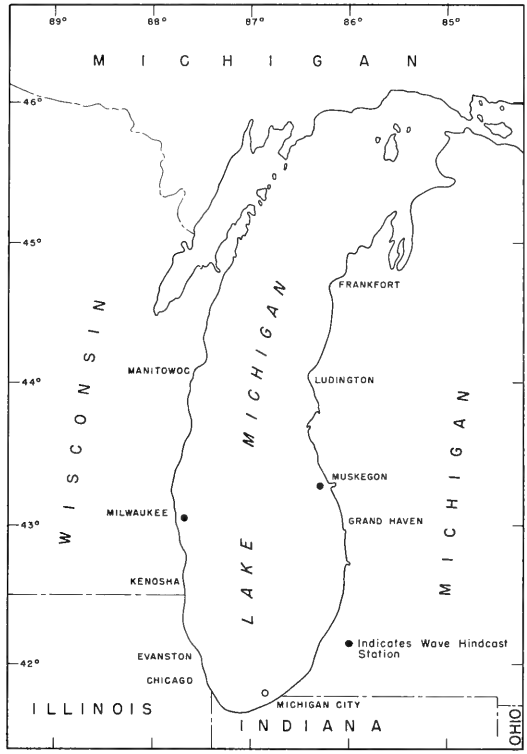

FIGURE 1. LAKE MICHIGAN

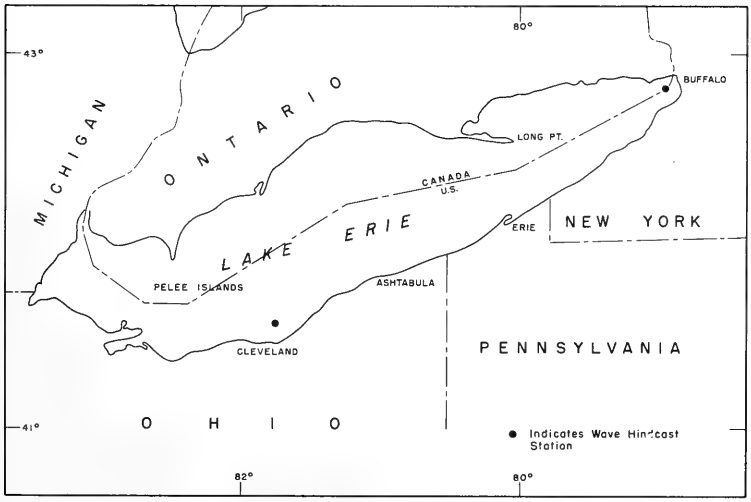

FIGURE 2. LAKE ERIE

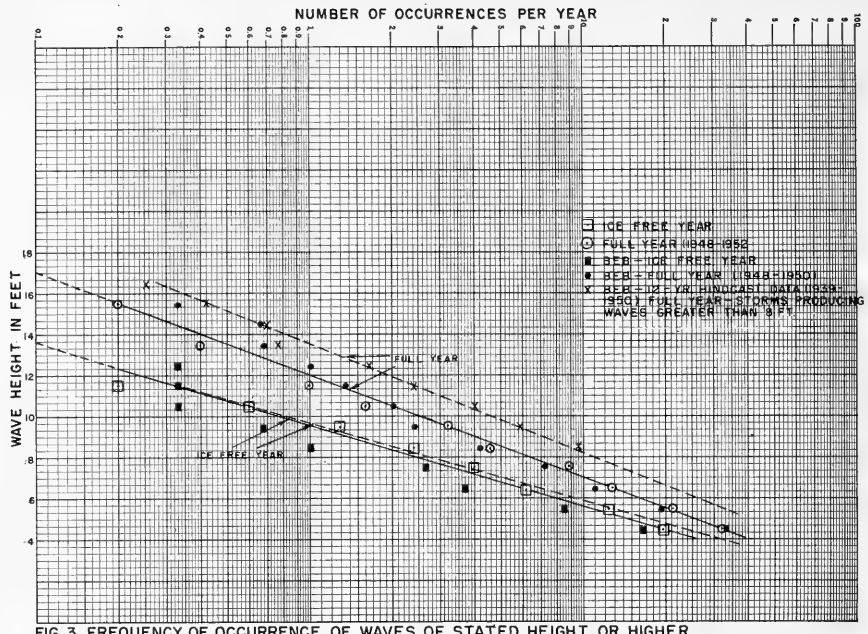

FIG. 3 FREQUENCY OF OCCURRENCE OF WAVES OF STATED HEIGHT OR HIGHER
MILWAUKEE, WISCONSIN

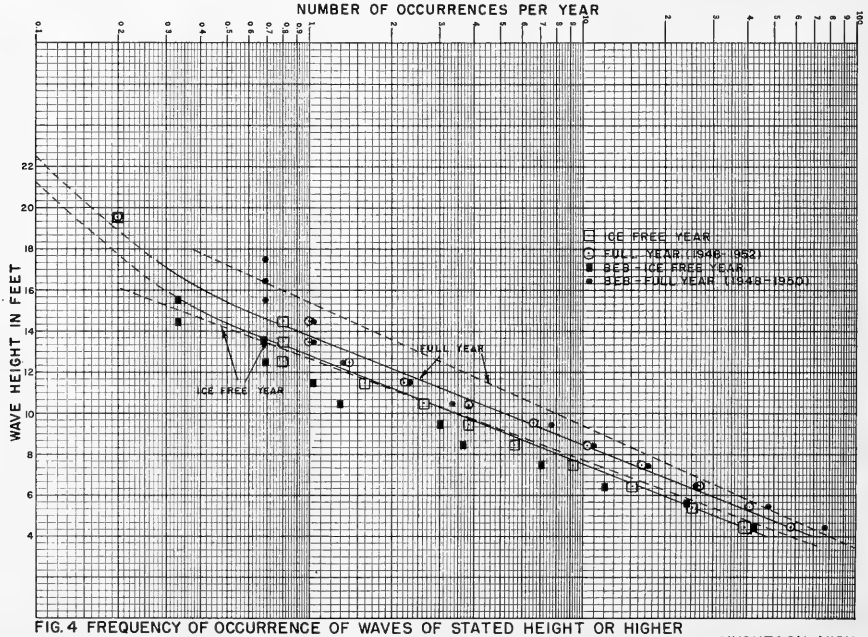

FIG. 4 FREQUENCY OF OCCURRENCE OF WAVES OF STATED HEIGHT OR HIGHER
MUSKEGON, MICH.

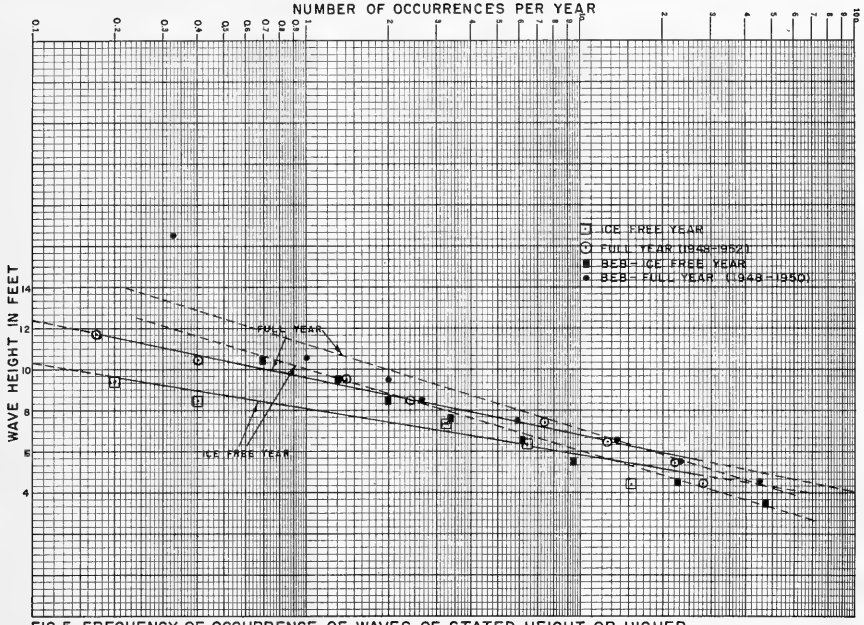

FIG. 5 FREQUENCY OF OCCURRENCE OF WAVES OF STATED HEIGHT OR HIGHER

CLEVELAND, OHIO

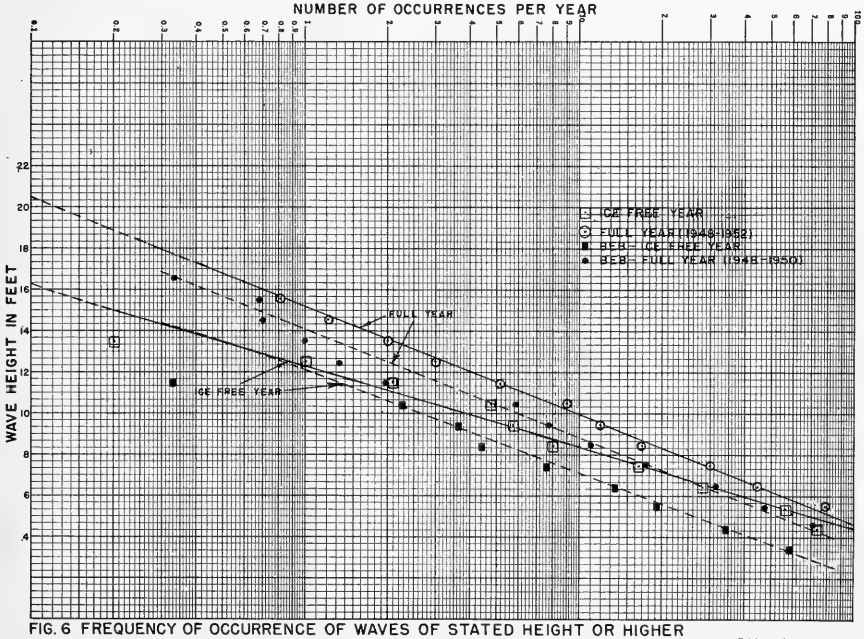

FIG. 6 FREQUENCY OF OCCURRENCE OF WAVES OF STATED HEIGHT OR HIGHER

BUFFALO, N. Y.

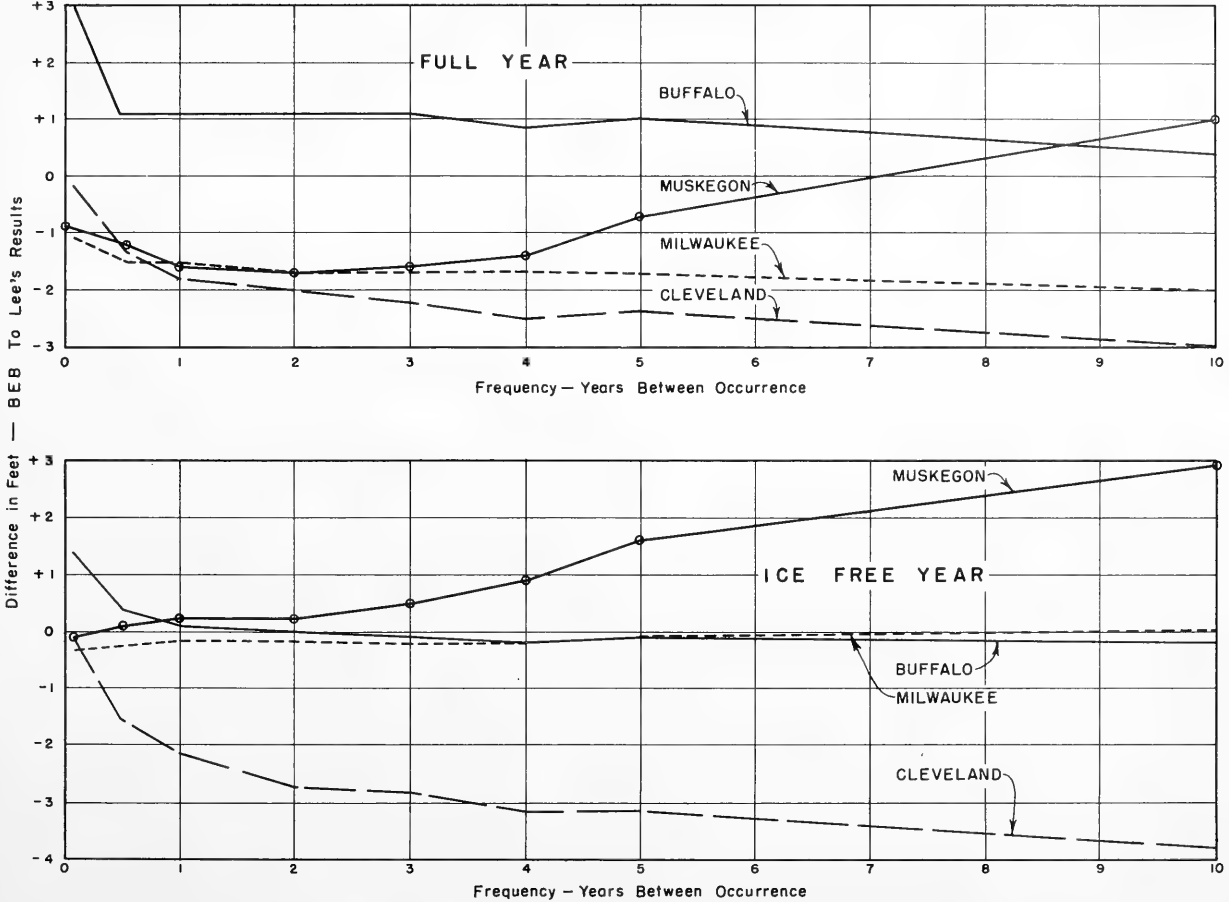

FIGURE 7. DIFFERENCE IN HINDCAST WAVE FREQUENCY

MODEL STUDY OF WAVE SET-UP INDUCED BY HURRICANE WAVES AT NARRAGANSETT PIER, RHODE ISLAND

by

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Introduction

In compliance with a request from the U. S. Army Engineer Division, New England, certain model tests to determine wave set-up (super-elevation of the water surface over normal surge elevation due to onshore mass transport by wave action alone) at Narragansett Pier, Rhode Island have been performed at the Beach Erosion Board laboratory. It was recognized that onshore wind action tends to pile up the waters at the shore; it was desired to learn if wave action alone acts to give an additional rise, or set-up, of the average water level when the waves are dissipated as breakers.

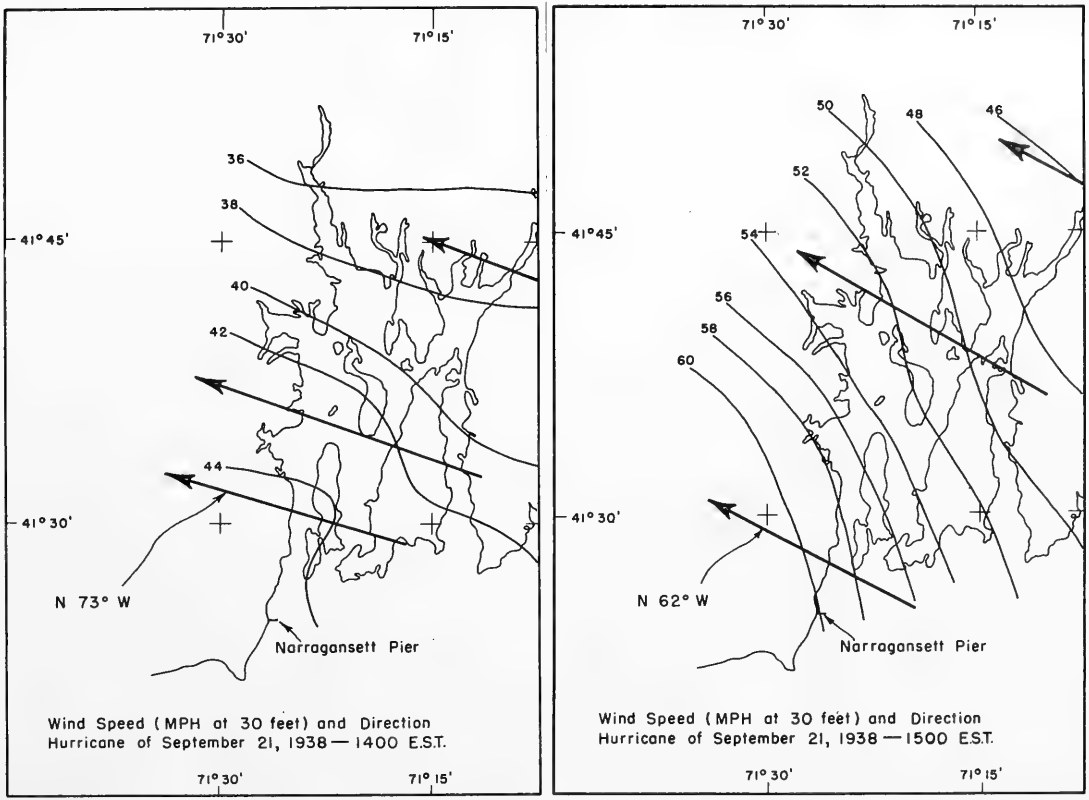
Purpose

The purpose of the tests was to determine: (1) if the wave set-up would occur on a model beach scaled to the average offshore profile at Narragansett Pier, and (2) if wave set-up were in evidence, to evaluate the amount of still water level rise (wave set-up) caused by selected conditions of water depth and wave characteristics. Also, estimates of any significant wave run-up were desired in conjunction with the wave set-up tests. This information was desired as a possible explanation of an observed difference of about 3 feet in maximum water level elevations for the 1938 hurricane for the relatively exposed area of Narragansett Pier, where wave action was dissipated as surf, and the calmer waters off Newport. From considerations of surge distribution and wind set-up alone, it was generally assumed that these two levels would be identical, however the 3-foot difference had been noted. Should wave set-up be identified as a partial cause of this difference, it would have important connotations for determining design and danger criteria in many areas subject to storm waves.

Selection of Profiles for Model Scale Tests

It was desired to simulate in the model wave tank the average offshore profile at Narragansett Pier to as large a scale as tank dimensions would permit. In keeping with this requirement and the wind directions from the isotach charts of the hurricane of September 21, 1938 (Figure 1)* eight profiles (two oriented in the wind directions from each of four

*Obtained from Memorandum HUR 7-4, March 1, 1956, Hydrometeorological Section, U. S. Weather Bureau, Subject: "Wind Over Narragansett and Buzzard's Bay in Hurricane of September 21, 1938 for Aid in Consideration of Design Hurricane".



(From Memorandum HUR 7-4, March 1, 1956, Hydromet. Section, US Weather Bureau)

FIGURE 1. ISOTACH CHARTS OF THE NARRAGANSETT BAY AREA FOR 1400 AND 1500 E.S.T. FOR THE HURRICANE OF SEPTEMBER 21, 1938

points on the Narragansett Pier shoreline) were plotted using the hydrographic data on the U. S. Coast and Geodetic Survey boat chart H-8315. The locations of the four points mentioned above, indicated in Figure 2 (map inset), were selected so as to blanket the Narragansett Pier shoreline. The general location of this area is shown on U. S. Coast and Geodetic Survey chart 1210. The actual profiles extend from the MHW line to a water depth of 90 feet (MLW). The two profiles at each of the four points on the shoreline referred to above, Figure 2 (map), have bearings of N 73° W and N 62° W, respectively. These directions were chosen to correspond with storm wind directions for the 1938 hurricane at 1400 and 1500 EST respectively, as determined from the isotach charts (Figure 1). As shown in Figure 2 (map) the four profiles at the two locations in the northern sector have a sandy shoreline, whereas the four profiles at the two locations in the southern sector have a rocky shoreline.

The profiles described above were superposed on a common plot for each direction and averaged in order to arrive at a profile which would be representative of the average offshore hydrography at Narragansett Pier (see Figure 2). The averaging process was carried out by selecting a common (equal) distance seaward of the MHW line for each profile and then averaging the respective depths of the several profiles at this point. This process was repeated until a sufficient number of points had been obtained to plot the average profile. The average profile determined from the data is shown on Figure 3 (dashed line).

Model Beach Installation

The average offshore profile at Narragansett Pier, derived as described in the preceding section, was divided into four straight line sections, making construction of the simulated profile in the wave tank more convenient. The selected scale of 1 to 75 was a compromise among several factors. These were tank dimensions, distance offshore or depth where bottom has a significant effect on the wave characteristics, and the assurance of sufficient depth in the model to permit generation of the wave heights desired for testing.

The actual bottom surface of the model profile was smooth concrete (3 to 1 mixture of fine sand and cement). The concrete layer 1/4 to 1/2 inch thick was applied directly to a sand foundation previously molded to the approximate slopes desired. As seen from Figure 3, the straight line portion of the beach slope farthest seaward was not modeled to scale but was arbitrarily selected and installed as a 1 on 16 slope. In selecting this slope for the most seaward section of the model profile, the assumption was made that the wave characteristics in the two systems, natural and model, were similar at the shoreward end (top) of the 1:16 slope. The prototype water depth at this point was 50 feet.

Wave and Water Level Conditions

Two water depths were investigated for wave set-up in the test program. These were for water levels at 1.75 and 8 feet above MSL. The

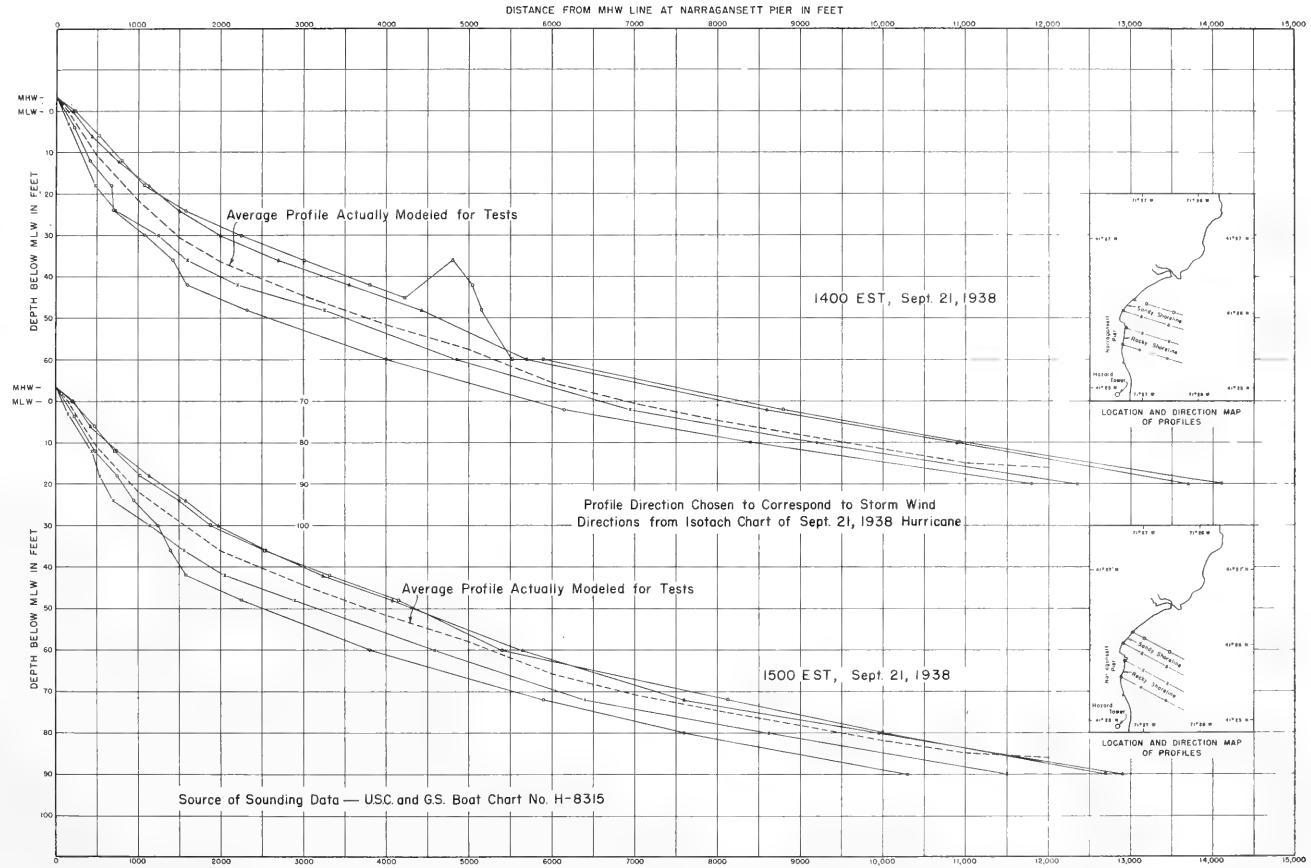


FIGURE 2. ACTUAL PROFILES OF OFFSHORE HYDROGRAPHY AT NARRAGANSETT PIER

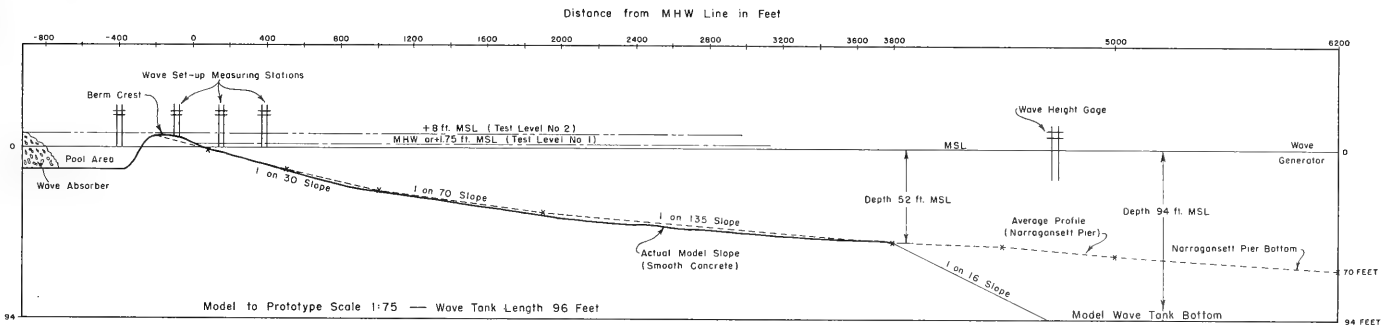


FIGURE 3. SECTION OF MODEL WAVE TANK SHOWING MODEL BEACH PROFILE SCALED FROM NARRAGANSETT PIER AVERAGE PROFILE AND SCHEMATIC OF MODEL LAY OUT FOR WAVE SET-UP TESTS

first of these depths (water level at plus 1.75 feet MSL) is equivalent to that at mean high water at Narragansett Pier, and is believed to simulate ordinary storm conditions. The 8 foot level was selected as that more nearly approximating a true hurricane condition. For each water depth two wave periods (9 and 15 seconds) were tested for waves up to 30 feet in height about 1 mile offshore (prototype). The actual wave heights, periods, and water levels tested are given in Table 1. It is to be noted that the values below and any other numerical values of the model tests mentioned in this report are expressed as prototype figures.

TABLE 1

TABULATION OF PROTOTYPE CONDITIONS TESTED

Period (T) (seconds)	Wave Heights in Feet					
	Water depth 1.75 feet above MSL					
9	30	25	20	15	10	5
15	30		20	15	10	5
	Water depth 8 feet above MSL					
9	30	20	15	10		
15	30	20	15	10		

Test Equipment and Procedure

The model wave tank used for the tests was 96 feet long, 1-1/2 feet wide and 2 feet deep. The wave generator was a vertical bulkhead-pusher type and was powered by an electric motor controlled by vari-drive speed control.

Parallel wire resistance type wave gages and Brush recording equipment were utilized to measure wave height and set-up. Measurement of wave set-up employed a normal wave gage contained in a plastic stilling basin just large enough to house the gage probes. Near the bottom of the stilling basin a small hole allowed water to enter or leave the stilling basin during the course of the wave action. The stilling basin damps out the major portion of the wave oscillation and thus renders a more accurate determination of the average still water level.

The schematic drawing, Figure 3, shows four wave set-up measuring stations. Actually, however, only two gages, one fixed and the other movable, were utilized to measure wave set-up at the four stations. This was done by leaving one gage in a fixed position for three constant condition runs during which time the movable gage was shifted for the second and third of the three runs. In this manner, three independent measure-

ments of wave set-up were obtained for one station plus one independent measurement for each of three other stations. This gave wave set-up values at four points relative to the shoreline and also some indications from the fixed gage station data (3 values) of the reproducibility of the model tests. The variability of a wave set-up value for an initial test run and for the same run repeated was generally of the order of 0.2 foot or less. The fixed gage stations for the 1.75-foot and the 8-foot water levels were 200 feet seaward and 375 feet landward respectively of the MHW line. These stations were the farthest landward of the four stations for each water level and therefore may be expected to reflect the maximum wave set-up for a given test condition.

Test Operation

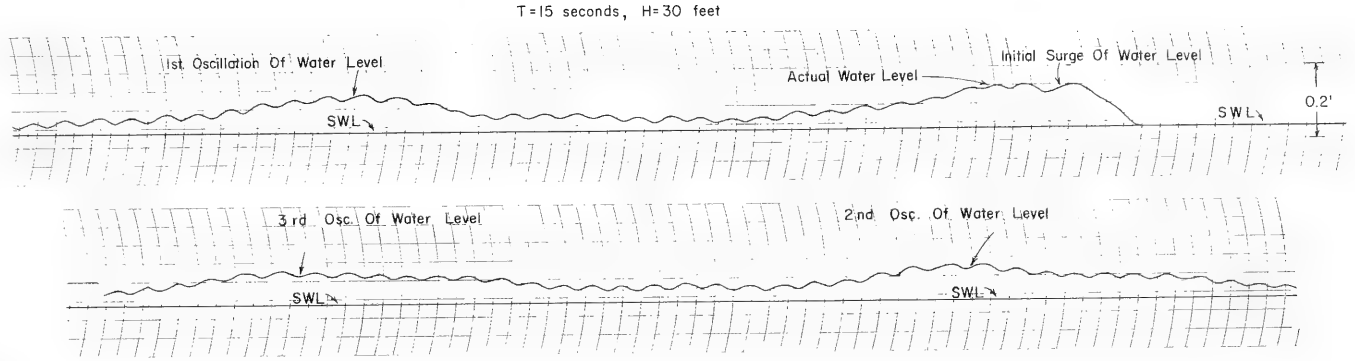
The steps taken prior to an actual test run were: adjustment of water level in the model tank for proper test depth, setting speed control on wave generator for the correct wave period, proper placement of the wave set-up gages, and adjustment of eccentric setting for the correct wave height. The last of these steps, eccentric setting for the correct wave height, required that one or more trial runs be made during which time the wave height was measured and checked for agreement with the desired wave height.

As the first waves reached the beach in the test runs, the still water level increased sharply, and then oscillated about a mean level as the initial increase was reflected from the onshore area and created a surge in the tank. The magnitude of this oscillation decreased with time until an essentially constant still water level was obtained (see Figure 4). Therefore, during the actual test run, the equipment was operated for a period of 5 to 10 minutes to insure that the wave set-up had become stabilized to the extent that an essentially constant set-up stage was observed. In general, the set-up for larger wave heights and longer wave periods required more running time to become stabilized than did the set-up for the smaller wave heights and shorter wave periods.

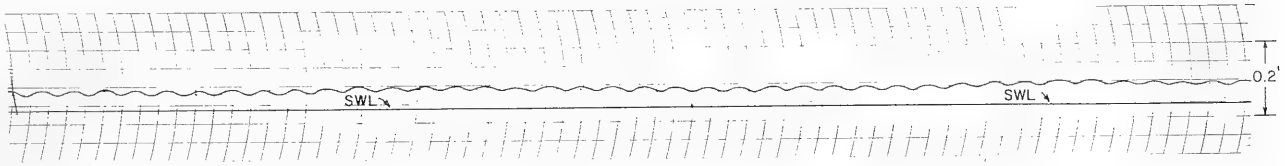
Analysis of Results and Conclusions

Analysis of the test data indicates that there is a rise in the average water level due to the wave conditions tested; this rise is called the wave set-up. The amount of the wave set-up appears to depend on several factors among which are distance from the shoreline (depth), wave height, and wave period. The relations between the wave set-up and the several factors mentioned above are shown in Figure 5.

There is reason to believe that the surge elevation measurements at Narragansett Pier may have occurred in a low-lying area formed in back (landward) of the MHW line during hurricane wave conditions. Because of this, a pool area landward of the berm crest (Figure 3) was included

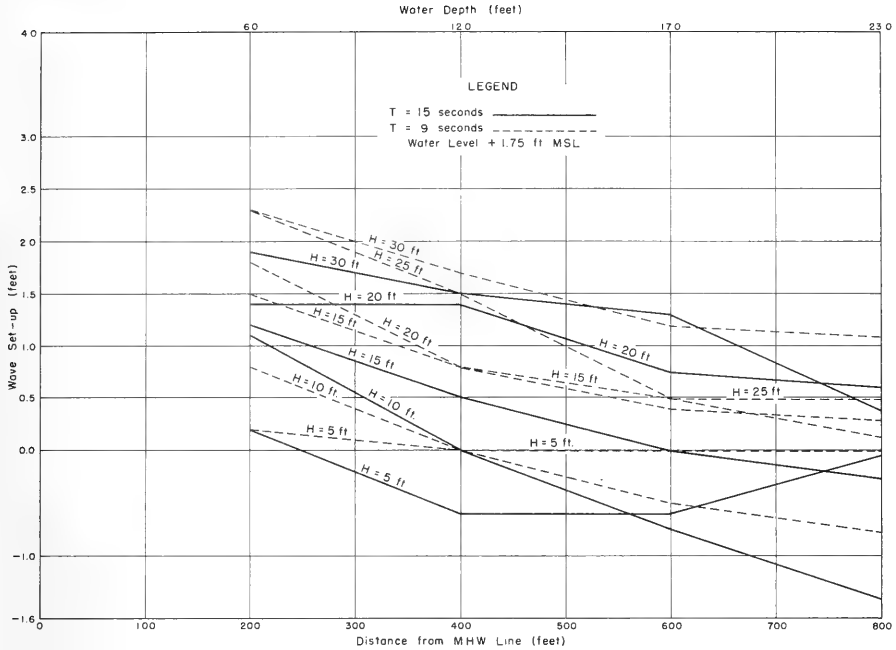


Wave Set-Up Record For Initial Period Of Wave Action,
Showing Initial Rise And Major Oscillation Of Water Level.



Wave Set-Up Record Under Same Wave Condition As Above But After 10
Minutes Duration, Showing Stabilized Stage Of Wave Set-Up.

FIGURE 4. TYPICAL RECORD OF WAVE SET-UP
ILLUSTRATING INITIAL SURGE AND OSCILLATION,
AND SUBSEQUENT STABILIZATION UNDER SUSTAINED WAVE ACTION



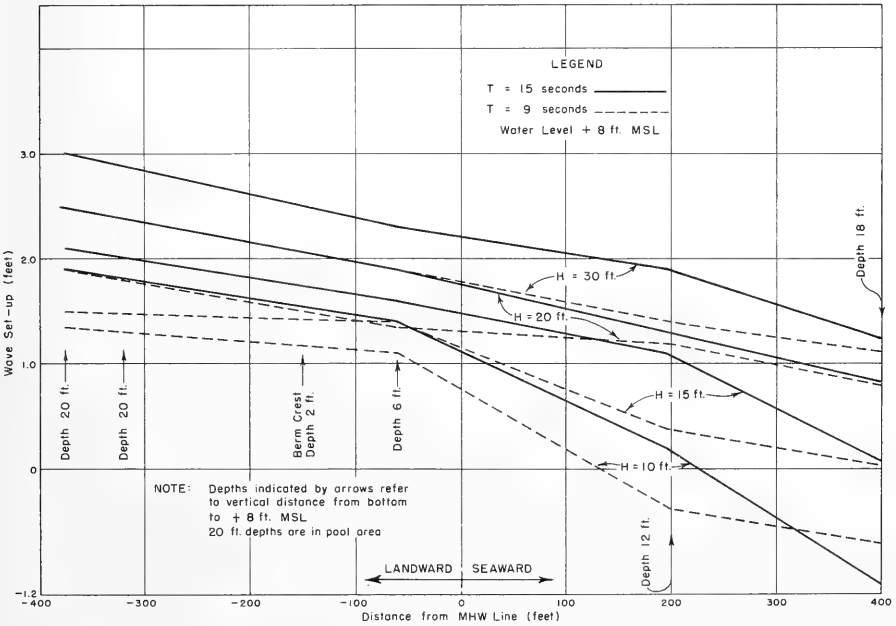


FIGURE 5. WAVE SET-UP VERSUS DISTANCE FROM THE MHW LINE AND DEPTH FOR DIFFERENT VALUES OF WAVE HEIGHT AND WAVE PERIOD

in the model test set-up in an effort to simulate, at least qualitatively, the natural (prototype) regime wherein the measurements in question may have occurred.

Figure 5 shows experimental curves of wave set-up versus wave height and distance from the shoreline. These curves show, for the two water levels tested (1.75 and 8 feet MSL), that at a selected depth and distance from the shore there is, in general, an increase of wave set-up with increase of wave height, and that for a constant wave height in deep water (90 feet in the model), there is, in general, an increase of wave set-up toward the shore. These wave set-up results have been found for one value of the nearshore beach slope only (1 on 32) and also for only one bottom material, smooth concrete. Other tests in the Beach Erosion Board laboratory have shown that for considerably steeper beach slopes (1 on 3 and 1 on 6) and waves of somewhat lesser height (2 to 4 feet), there is no wave set-up but rather there is wave set-down. It would appear from the diversity of these two indications, probably extremes, that the effect of slope on wave set-up may be quite large. It is presently contemplated that further generalized study of wave set-up will be made in the near future. One objective of such additional study would be to determine the effect of beach slope.

The maximum values of wave set-up for the initial five to ten waves generated, not to be confused with the stabilized maximum values, have been tabulated in Table 2 for two stations only. Values have been tabulated at one station for each water level. These stations were 200 feet seaward of the MHW line for the ordinary storm water level (1.75 feet MSL) and 375 feet landward of the MHW line and in the pool area for the hurricane storm water level (8 feet MSL). The maximum value of wave set-up measured for a stabilized condition of wave action (after 5 to 10 minutes running time) was 3 feet. This value was obtained in the pool area landward of the berm crest. The test conditions for this measurement were: wave height 30 feet, wave period 15 seconds, depth 20 feet, and a hurricane storm water level of 8 feet MSL. Smaller values of wave set-up were measured for wave and water level conditions below the maximum and the wave set-up values for these and the maximum value are all given in Table 2. From this information on the model test results, it appears reasonable to predict stabilized wave set-up values up to 3 feet for the maximum wave and water level conditions tested.

As seen from Table 2 the initial values of wave set-up exceed considerably the stabilized values; it is, therefore, emphasized that these values existed only temporarily, that is for the first five or so waves generated. For all practical purposes, this phenomenon has no real counterpart in nature, since ordinarily, and also for storm conditions, there is a gradual build-up of wave intensity at the coast and not the sudden onshore rush of water from maximum wave conditions as was observed in the model tests. This information was included mainly as a matter of general interest to show the magnitude of wave set-up for the initial waves as experienced in the model. It is interesting to note, however, the

TABLE 2

WAVE SET-UP IN FEET
STILL WATER LEVEL MHW OR 1.75 FEET MSL

Dist. from MHW (ft)		200	200	400	600	825	Average
depth (ft)		6	6	12	17	23	Run-up
H(ft)	T(sec)	Initial	Stabilized				(feet)
30	9	4.5	2.3	1.7	1.2	1.1	2.6
25	9	4.0	2.3	1.5	0.5	0.5	2.9
20	9	3.5	1.8	0.8	0.4	0.3	2.7
15	9	2.5	1.5	0.8	0.5	0.1	2.1
10	9	1.7	0.8	0.0	-0.5	-0.8	1.7
5	9	0.5	0.2	0.0	0.0	0.0	1.3
30	15	4.1	1.9	1.5	1.3	0.4	-
20	15	2.3	1.3	1.5	0.75	0.6	-
15	15	2.2	1.2	0.5	0	-0.3	2.7
10	15	1.5	1.1	0.0	-0.75	-1.5	2.7
5	15	0.8	0.2	-0.6	-0.6	0	1.7

STILL WATER LEVEL 8 FEET MSL

Dist. from MHW (ft)		-375	-375	-60	195	412
depth (ft)		20	20	5	12	18
H(ft)	T(sec)	Initial	Stabilized			
30	9	3.4	2.5	1.9	1.4	1.1
20	9	2.3	1.9	1.35	1.2	0.75
15	9	2.1	1.5	1.4	0.38	0
10	9	1.5	1.35	1.1	-0.38	-0.75
30	15	3.8	3.0	2.3	1.9	1.2
20	15	3.0	2.5	1.9	1.3	0.8
15	15	2.3	2.1	1.6	1.1	0
10	15	1.8	1.9	1.4	0.2	-1.2

Values obtained in model wave tank 96 feet long, 2 feet deep, and 1.5 feet wide; model to prototype scale 1:75. Note initial wave set-up values at one station only for each water depth. All other values are for a stabilized condition of wave set-up.

much greater increase of the initial over the stabilized wave set-up (up to 100%) for the case of the ordinary storm water level (1.75 feet MSL) as compared to the relatively moderate increase of initial over stabilized wave set-up (average below 30%) for the case of the hurricane storm water level. The lower initial wave set-up values for the hurricane storm water level is probably due to the model regime, wherein the water depth over the berm crest and the calmer and deeper water of the pool area serve to dampen the initial surge of water level due to the wave action.

The maximum wave run-up for the ordinary storm water level (1.75 feet MSL) was estimated as approximately 3 feet above SWL. The estimated values are indicated in Table 2. The wave run-up for the hurricane storm water level (8 feet MSL) was essentially nil. This was due to the wave absorber placed at the shoreward end of the pool area which absorbed essentially all of the energy which remained in the waves at this point.

PROGRESS REPORTS ON RESEARCH SPONSORED BY THE BEACH EROSION BOARD

Summaries of progress made during Fiscal Year 1958 on the several research contracts in force between universities or other institutions and the Beach Erosion Board, together with brief statements as to the status of some research projects being prosecuted in the laboratory of the Beach Erosion Board, are presented below. These summaries supplement and continue those contained in prior issues of the Bulletin.

I. University of California, Contract DA-49-055-eng-8, Sources of Beach Sand.

Seasonal sampling of Point Reyes beach and other beaches in the San Francisco area was continued. In addition to Point Reyes Beach, two other beaches north of San Francisco Harbor entrance (the beach at Drakes Bay and Stintson Beach opposite Bolinas Bay) are being studied. Four beaches south of San Francisco Harbor are being occupied. These are the beaches off Golden Gate Park, Fleischacker Zoo, Sharps Point, and Rockaway Beach. These beaches have been occupied at from 2 to 6 week periods during the last two years, and a report is now being prepared on the data obtained. Fairly abrupt changes occur at times on these beaches and consideration is now being given to an intensive study of the ranges over a much shorter time interval.

II. Massachusetts Institute of Technology, Contract DA-49-055-eng-16, Sorting of Beach Sand by Waves.

A report entitled "The Mechanics of the Motion of Discrete Bottom Sediment Particles Due to Shoaling Waves" was published as Technical Memorandum No. 104 of the Board. This report is an explanation of the sorting caused by shallow water waves in an experimental wave channel. A series of experiments concerning wave-induced incipient and established net motion of discrete spherical particles was made on both smooth and artificially roughened slopes. An equation of net sediment motion is derived, and applied to field data from natural beaches. Additionally, some tests were carried out involving the direct measurement of bottom shear stresses in oscillatory waves. These measurements were made by inserting a thin plate suspended from a force balance in a false bottom in the wave channel. Bottom shearing stresses on this plate were measured under a wide range of waves. These data are now being analyzed and a report is being prepared.

III. University of California, Contract DA-49-055-eng-17, Fundamental Mechanics of Sand Movement by Waves.

Additional data on the velocity pattern near the bed were gathered with a revised pitot tube type of gage. Measurements were first made with a smooth plate to check data previously obtained. Measurements have been made with both two-dimensional and three-dimensional rough-

nesses. The data obtained so far are now being organized so that a final conclusion may be reached that will describe the motion in the general case. The contract work has been expanded during the next year to include some preliminary field work on the transportation of sand by wind.

IV. University of California, Contract DA-49-055-eng-31, Wind Action Over Shallow Water.

Wind set-up in shallow water was studied in a laboratory channel with a reef, with various widths of openings, located near the center of the channel. Measurements were also taken with various slopes of the channel bottom other than horizontal. Data indicate that the set-up was increased by a factor of as much as two over a smooth bottom condition with the installation of a solid reef, and somewhat less than this if the reef had an opening. Data were also gathered on the motion of water particles with various wind velocities and water depths under steady-state conditions. In addition, certain data were taken to determine such questions as: (1) is there an overshoot of set-up, and if so, what is its magnitude compared with the steady state condition; and (2) does the water circulation follow the water set-up exactly. These data are now being analyzed. The funds for this study were provided to the Beach Erosion Board by the U. S. Army Engineer District, Jacksonville.

V. University of California, Contract DA-49-055-eng-44, Laboratory Study of Wave Refraction.

Laboratory studies to determine the application of Snell's law to wave refraction were continued, and a report "Model Study of Wave Refraction" was published as Technical Memorandum No. 103 of the Board. This report showed that Snell's law was valid over most of the range tested, which involved deep water angles of incidence between 10 and 70 degrees and four slopes ranging from vertical to 1 on 10. Occasional wide discrepencies were, however, observed. Some of these discrepencies may be associated with the formation of multiple crests from a single wave crest as the wave moves into shoal water. Additional laboratory data were therefore taken on the criteria for the formation of multiple crests. From these, it appears that the criterion for their formation developed by Miche is valid.

VI. University of Florida, Contract DA-49-055-eng-55, Analysis of Existing Data on Tidal Inlets.

Additional tidal data have been examined, and a final report prepared. This report investigates existing data on a number of tidal entrances in the United States and abroad and examines conditions for the stability of cross-sections in light of existing theory on cross-section stability of rivers and canals, in particular utilizing Bretting's approach. A stability shear stress is defined and compared with values recommended by Lane. This study is administered by the Beach Erosion Board for the Corps of Engineers' Tidal Hydraulics Committee.

VII. Agricultural and Mechanical College of Texas, Contract DA-49-055-Civ-eng-56-4 and eng-58-9, Estimation of Hurricane Surges.

Additional work was done on the surge problem in Narragansett Bay (eng-56-4) including some adjustments made for the presence of barriers in the Bay. Some of the work applicable to Narragansett Bay was also utilized in estimating surge conditions in portions of Long Island Sound and Buzzards Bay. Considerable effort, too, has been made in connection with the periodic tide problem for a complex bay system such as Narragansett Bay. Some preliminary work has also been done in connection with the feasibility of two-dimensional methods of analyzing storm surge generation on the continental shelf. Analysis of storm surge data in the New York Harbor entrance area (eng-58-9) is now under way, and prediction methods for the New York area are being developed and tested. Funds for these two studies were provided by the U. S. Army Engineer Division, New England and the U. S. Army Engineer District, New York.

VIII. Dr. W. C. Krumbein (Consultant). Study of Beach Sampling Methods.

A report entitled "A Method for Specification of Sand for Beach Fills" was published as Technical Memorandum No. 102 of the Board. This report presents a method of determining design slopes and material characteristics for beach fills from samples from an eroded beach and its condition at the time of survey. Additional data pertaining to this study are being gathered and analyzed.

IX. Dr. John H. Davis. Contract for Study of Dune Stabilization.

A report entitled "Dune Formation and Stabilization by Vegetation and Plantings" was published as Technical Memorandum No. 101 of the Board. The report discusses the stabilization of dunes by plants in the various coastal regions of the United States. It presents data on the history of several continuing efforts to stabilize dunes by planting vegetation.

X. Beach Erosion Board Staff.

(a) Wave Forces on Structures

Numerous measurements have been made of the wave forces on a vertical 12-inch pile with a 3-foot sensitive (instrumented) section. The pile is cantilevered from a frame at the top of the tank and may be raised or lowered to place the 3-foot sensitive section at various elevations. Waves with periods ranging from 5 to 16 seconds, and heights ranging from 2 to 6 feet have been tested in water depths ranging from 7 to 15 feet. The forces on the 3-foot sensitive section ranged from 20 to 100 pounds for nonbreaking waves, and breaking waves produced forces of short duration as high as 1,000 pounds. These data are being analyzed and prepared for publication. Wave forces on a 1 on 3 and 1 on 6 stoned levee structure were obtained for waves ranging from 1.5 to 5 feet.

(b) Wave Run-up

A report entitled "Wave Run-up on Roughened and Permeable Slopes" was published by the American Society of Civil Engineers. This report indicates the effect of roughness and permeability on wave run-up on slopes. As might be expected, the data show that both slope roughness and permeability reduce wave run-up considerably below that observed for smooth slopes, the degree of reduction decreasing with both roughness and permeability. A number of large scale tests involving waves up to 5 feet in height were made to determine whether or not model scale affected values of wave run-up obtained. These tests were made on slopes of 1 on 3 and 1 on 6. The data are now being analyzed; the preliminary analysis indicates that a scale effect does exist. Wave run-up values for the large-scale tests were higher by about 10 to 15%, and wave overtopping values were higher by 25% on an average. These tests were made with a smooth board slope in which the roughness of the slope was essentially the same as that in the small-scale laboratory tests. To better scale up the roughness from that of the smaller scale tests, a very few tests were made with a single layer of sand glued to the larger scale slope. This sand roughness reduced the run-up somewhat below that observed on the smooth slope, but the reduction was not great enough to bring these run-up values in line with those determined at small scale. A report "Run-up on Composite Slopes" was presented at the 6th Coastal Engineering Conference. This report presents methods of determining run-up for structures of any variable slope based on run-up data for smooth slopes.

(c) Study of Sand By-passing Operations

As a continuation of the observational program, a survey of the Port Hueneme area was made in June 1958. These data together with the earlier data are now being analyzed. Consideration is being given to use of **an adapted** (radioactive) density gage and a velocity meter for use on by-pass operations to determine quantity and rate of pumping.

(d) Laboratory Study of Effects on a Groin Field on the Littoral Drift Passing the Field

The new trapping and sand-moving system using eductors to transfer the trapped sand to a weighing basin in the feeder beach area was tested, and has proved very satisfactory. Tests were made involving a low short groin, a high short groin, and a high long groin. Tests are now being continued. Tests are also being initiated to study the movement of sand along a steeper beach. The initial tests have been made on a 1 to 20 slope, and tests now are being made also on a 1 to 10 slope in an adjacent wave basin. Preliminary results indicate that the rate of movement along the steeper slope is 2 to 3 times that along the 1 on 20 slope with the same wave conditions.

(e) Measurement of Suspended Material in Laboratory Wave Tanks

Additional sampling has been carried out, and the data are being

analyzed. Additional tests have been performed to delineate the effect of temperature on the amount of sand in suspension, confirming earlier results that the suspended amount is materially increased for colder water.

(f) Wave Forecasting

Utilizing additional observed data, slight revisions to previously developed forecasting curves have been presented at the 6th Coastal Engineering Conference in a report entitled "Revisions in Wave Forecasting: Deep and Shallow Water". Work has been continued on the development of the joint distribution for heights and lengths, and heights and periods. Using the general form of a theoretical joint distribution, a derivation may be given for a family of theoretical energy spectra. These spectra are to be compared with those previously proposed by others. Methods for predicting waves under hurricane conditions have been derived and are reported on in an article entitled "Hurricane Design Wave Practices" published by the American Society of Civil Engineers.

(g) Equilibrium Profile Tests

Tests made in the prototype tank involving waves up to 5-1/2 feet in height were also tested in small wave tanks at scales of 1 to 10 and 1 to 15, utilizing the same sand material. These tests indicate, as suspected, that an appreciable scale effect exists. The critical steepness value of .02 to .025, which has been found in small scale tests to delineate the capability of waves to erode or accrete material on a beach, was found not to apply in the larger scale tests, with steepness as low as .005 still eroding a beach with an initial 1 on 15 slope. Lower density material is now being obtained for tests in small scale tanks to attempt to determine the criteria for scale reproduction. It is thought that this may be on a settling velocity ratio.

(h) Hurricane Studies

The staff of the Board has continued to support the present hurricane study program of the Corps of Engineers. Considerable work has been done by the staff in developing and improving simplified methods for estimating storm surge elevations and wave heights under a variety of shoreline conditions. Wave forces, wave run-up and wave overtopping phenomena connected with seawall, dike, and barrier design under hurricane conditions have also been studied. Studies have indicated that a wave set-up exists in areas of strong wave attack, and that this increase in water elevation due only to the action of the waves may amount to as much as 3 feet with incident waves of 25 to 30 feet in height. This set-up effect appears also to be dependent on slope, with the set-up being highest for relatively gentle beach slopes. Tests with 1 on 3 and 1 on 6 levee slopes with an offshore 1 on 10 slope have revealed a zero or even small negative set-up where 25 and 30 foot waves on offshore 1 on 70 slopes have shown positive set-ups as high as 3 feet.

(i) Recorded Wave Characteristics

Routine compilations of recorded wave characteristics at Huntington Beach, California; Atlantic City, New Jersey; Naples, Florida; Palm Beach, Florida; and Port Hueneme, California have been continued.

(j) Re-examination of Beach Protection Projects

A continuing program is being carried out on the re-examination of artificially nourished beaches to determine the effectivemess of the fill material within the beach zones, and to better establish the factors upon which the design characteristics of fill material are based. Studies presently underway include Virginia Beach, Virginia; Plum Island, Masschusetts; Presque Isle, Pennsylvania; Harrison County, Mississippi; and El Segundo and Newport Beach, California. A continuing examination of the asphalt groins at Ocean City, Maryland has been made and a preliminary report prepared. Study of other asphalt groins is also being made.

(k) Technical Report No. 4, "Shore Protection Planning and Design"

A continuing study is being made to improve and supplement present chapters of this publication. General corrections and addenda were published and disseminated during the year.

(l) Regional Studies

Data on the geomorphology and characteristics of littoral materials are now being compiled for the south shore of Long Island, and the shore sector between Cape Henlopen, Delaware to Cape Charles, Virginia.

(m) Rubble Mound Stability

Large scale tests are being carried out on rubble mound stability to spot check results of many smaller scale tests made at the Waterways Experiment Station. Tests at the Board will involve stone of roughly 150-pound weight on slopes of 1 on 1-1/2 and 1 on 2-1/2. The first test breakwater has now been installed, and testing should be initiated in the near future.

(n) Development of In-Place Sediment Density Gage

An in-place sediment density gage has been developed utilizing a radioactive source in the probe. Laboratory tests of this gage in especially prepared mud and chemical mixtures have been made, enabling a calibration of the gage. One field test was carried out in the Savannah River in cooperation with the Savannah District of the Corps of Engineers. This test was handicapped by flood stages in the river, but indicated a satisfactory usage of the gage. A report describing the gage and its potentialities is underway.

BEACH EROSION STUDIES

Beach erosion control studies of specific localities are usually made by the Corps of Engineers in cooperation with appropriate agencies of the various States by authority of Section 2 of the River and Harbor Act approved 3 July 1930. By executive ruling the costs of these studies are divided equally between the United States and the cooperating agencies. Information concerning the initiation of a cooperative study may be obtained from any District or Division Engineer of the Corps of Engineers. After a report on a cooperative study has been transmitted to Congress, a summary thereof is included in the next issue of this Bulletin. Summaries of reports transmitted to Congress since the last issue of the Bulletin and lists of completed and authorized cooperative studies follow.

SUMMARIES OF REPORTS TRANSMITTED TO CONGRESS

HUMBOLDT BAY (BUHNE POINT), CALIFORNIA

Humboldt Bay, located on the Pacific Coast of California about 225 nautical miles north of San Francisco, is about 14 miles long and from 1/2 to 4 miles wide. Two long narrow sand spits separate the bay from the ocean. The entrance has been stabilized by jetties under a Federal navigation project, which also includes improvement of interior channels north and south of the entrance. The principal community of the bay is the city of Eureka with a population of about 23,000 in 1950. The problem area comprises the sandy bluff known as Buhne Point on the east shore of the bay directly opposite the entrance to the bay, and adjacent low lands. Sand spits at the north and southwest ends of the problem area are respectively Elk River Spit and Buhne Spit. All the shore of the problem area is privately owned. The problem area is exposed to ocean waves entering the bay through the jettied inlet. Waves of 18 feet and less in height cross the bay and break at distances from the shore depending upon their initial height and the depth of water at the time. The tide in Humboldt Bay is diurnal, with a mean diurnal range of 6.5 feet. The estimated highest tide is 9.5 feet above mean lower low water. Material eroded from Buhne Point has moved partly northward to form Elk River Spit and partly southwestward to form Buhne Spit. With recent development of a large power plant at Buhne Point, its shore has been stabilized by a heavy stone revetment about 3,200 feet long. North of that structure, frontage belonging to the Northwestern Pacific Railroad Company is protected by a timber bulkhead 200 feet long and a low rubble-mound seawall 3,000 feet long. These structures stabilize the shore, but waves overtopping the low wall delay railroad traffic. Elk River Spit north of the railroad frontage is undeveloped and its protection is not required. Buhne Spit extending southwestward from Buhne Point is the site of a fishing resort. Its shore is subject to erosion, the eroded material moving southwestward and shoaling the Fields Landing channel of the Federal navigation project.

The district and division engineers and the Beach Erosion Board concluded that the most effective and economical plan for the protection

of the shores of the study area are as follows:

a. North of Buhne Point. Extension and maintenance of the existing seawall. Elimination of traffic interruptions could be accompanied by relocation of the railroad 100 feet landward of its present location.

b. Buhne Spit. Construction of one impermeable groin 790 feet long and 800 feet of rubble-mound seawall.

They also found that the project for Buhne Spit is economically justified, and that the benefits from reduction of Federal maintenance costs of the navigation channel warrant Federal participation in amount of 21 percent of the first costs. They therefore recommended adoption of a project authorizing Federal participation, subject to certain conditions, by contribution of funds in an amount equal to 21 percent of the first costs of 800 feet of rubble-mound seawall and a 790-foot groin at Buhne Spit. They further recommended that local interests consider adoption, based on their own determination of economic justification, of the plan for extension and maintenance of the seawall north of Buhne Point and relocation of the railroad. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

SANDY HOOK TO BARNEGAT INLET, NEW JERSEY (REVIEW)

This report is in review of the beach erosion control report on Sandy Hook to Barnegat Inlet, New Jersey, submitted to Congress by the Secretary of the Army on March 7, 1956, printed in House Document No. 361, 84th Congress, and summarized in Volume 10-No. 1 (July 1956) of the Bulletin of the Beach Erosion Board.

The section of shore from Sea Bright to Ocean Township, about 12 miles in length, is a highly developed summer recreational area. About 30 percent of the shore is publicly owned, and about one-quarter of the remainder is open to public use. In the report under review a plan was recommended for this section which comprised restoration and protection by artificial placement of approximately 10,100,000 cubic yards of suitable sand to widen the beach to a minimum width of 100 feet at elevation 10 feet above mean low water. Stability of the restored shore would be provided under the plan by periodic nourishment at an estimated rate of 115,000 cubic yards of suitable sand annually and by construction of 23 new groins and extension of 14 existing groins.

The section of shore from the north city limit of Asbury Park to the jettied Manasquan Inlet is about 9 miles in length. Shark River Inlet with twin jetties is within this section, which is extensively developed as a summer resort. About 98.5 percent of the shore in this section is now publicly owned. In the report under review, a plan was recommended which included restoration and protection of the shore from Asbury Park to Manasquan by artificial placement of approximately 2,400,000 cubic yards of suitable sand to widen the beach to a minimum width of 100 feet at elevation 10 feet above mean low water. Stability

of the restored shore would be provided under the plan by periodic nourishment at an estimated rate of 250,000 cubic yards of suitable sand annually.

The section from Point Pleasant Beach to Seaside Park, about 14 miles in length, is an extensively developed summer resort area. About 27 percent of the shore is publicly owned, and about two-thirds of the remainder is open for public use. In the report under review a plan was recommended for this section which comprised restoration and protection by artificial placement of approximately 1,500,000 cubic yards of suitable sand to widen the beach to the same minimum dimensions as those recommended for the other sections. Stability of the restored beach would be provided by periodic nourishment at an estimated rate of 200,000 cubic yards of suitable sand annually.

The district and division engineers and the Beach Erosion Board found that the public interest associated with prevention of damages to public property, reduction of maintenance costs of existing structures, and recreational benefits to the general public, is sufficient to warrant adoption of a project authorizing Federal participation in the initial and periodic nourishment costs of restoring and protecting the shores of New Jersey from Sea Bright to Seaside Park. They recommended adoption of a project by the United States authorizing Federal participation by the contribution of Federal funds toward the initial costs of beach restoration and subsequent periodic nourishment costs for the shores from Sea Bright to Seaside Park, New Jersey, substantially in accordance with the plan presented in House Document No. 361, 84th Congress. Federal participation in periodic nourishment costs would be authorized initially for a period of 10 years from the year that the total quantity of fill placed in any section has equalled that required to restore the beach to project dimensions in that section. The recommended Federal shares are 20.1 percent for the Sea Bright-Ocean Township section, one-third for the Asbury Park-Manasquan section and 30.5 percent for the Point Pleasant Beach-Seaside Park section. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

BERRIEN COUNTY, MICHIGAN

The study area comprises a portion of the shore of Berrien County about 32 miles in length from the north city limit of Benton Harbor to the Michigan-Indiana State line. Its southern limit is located about 50 miles east of Chicago, Illinois. The study area includes shores fronting the cities of Benton Harbor and St. Joseph, the village of Shoreham, and Lincoln, Lake, Chikaming and New Buffalo Townships. The shores of Benton Harbor, St. Joseph and Shoreham village are extensively developed, primarily for residential and recreational use. A main line right-of-way of the Chesapeake and Ohio Railway also fronts directly on a portion of the lake shore in the city of St. Joseph. South of Shoreham village the shore is developed to a limited extent for residential use. About 9.35 percent of the shore of the study area is publicly owned, the public property being made up largely of a number of small parks. The shore of the principal problem area from Elm Street in St. Joseph to the

south limit of Shoreham village consists of two sections; the northerly section 13,360 feet long to the south end of the State Highway protective works including the city and railroad frontages being 31.9 percent publicly owned and the southerly section developed for residential use being entirely privately owned. The 1950 population of Berrien County was 115,702. The larger cities of St. Joseph and Benton Harbor and populations of 10,223 and 18,769 respectively. The population of the smaller resort communities are greatly increased during the summer months.

The Berrien County shore is characterized by high sandy clay bluffs and sand dunes fronted generally by narrow sand beaches, especially narrow at high lake stages. High sandy clay bluffs extend alongshore from the vicinity of the city of St. Joseph water-supply pumping station to the northern portion of Lincoln Township, including Shoreham village. Sand dune regions exist along the shores of Lincoln Township in the vicinity of Grand Marais Lakes and south thereof, Lake Township and in New Buffalo Township south of Galien River. A Federally maintained harbor at St. Joseph includes two parallel entrance jetties and a navigation channel of 21-foot depth. The St. Joseph and Paw Paw Rivers discharge into Lake Michigan through the harbor. The shores for about a mile north of the harbor structure and 1,200 feet south thereof have been advancing lakeward since the entrance structures were built. South of the latter accreting area, however, erosion of the bluffs has been severe, causing the loss of or necessitating the movement of a number of valuable residences and threatening a railroad and public highway. Numerous protective structures have been erected but have exhibited only moderate effectiveness. Foremost of these measures are an extensive bulkhead and groin system erected to protect the railroad right-of-way, and a groin system erected by the Mighican State Highway Department for protection of the bluff fronting U. S. Highway No. 12.

Lake Michigan is over 300 miles long, and about 70 miles wide opposite St. Joseph. The highest monthly mean lake level recorded since 1900 was 4.2 feet above low water datum. Short period fluctuations up to about 1.8 feet, caused by winds and differences in barometric pressures, occur with annual frequency. The design lake stage is 5 feet above low water datum. Of winds which generate waves affecting the area, those from the north have the greatest fetch, about 225 miles. Those from the southwest have a fetch of about 50 miles. During severe storms with a frequency of about once a year, waves may range up to 11 feet in height in deep water, but ordinarily waves of this height break before reaching the shore structures. Waves from both the northwest and southwest quadrants cause movement of beach material, but as evidenced by the much greater accumulation of material north of the St. Joseph Harbor structures, the predominant direction of littoral transport is southward. The navigation channel at St. Joseph Harbor is dredged annually to maintain project depth, and for this reason little or no beach building material is believed to pass the harbor entrance and reach the downdrift shore. The rate of littoral transport is estimated at 100,000 cubic yards per year.

The district and division engineers and the Beach Erosion Board concluded that the most suitable plan of preventing erosion and stabilizing the bluffs and shores of the study area consists of providing, by direct placement of sand fill, a protective beach with berm elevation 10 feet above low water datum at the base of the bluff and 50-foot width at elevation 8 feet, to be maintained by periodic nourishment of the material in the northernmost mile of the sand fill area.

They further concluded that protection of a 13,360-foot reach of shore in the city of St. Joseph by placement of a protective beach is justified by evaluated benefits. Accordingly they recommended adoption of a project by the United States authorizing Federal participation in the first and periodic nourishment costs of a plan for protection of the shore of the City of St. Joseph, Michigan from Elm Street to the southern extremity of the State protective works, comprising direct placement of suitable sand to form a protective beach with berm elevation 10 feet above low water datum at the base of the bluff and 50 feet in width at elevation 8 feet. The plan contemplates periodic nourishment commencing during the initial placement of the protective beach. Federal assistance would entail contribution of funds in amount of 22.6 percent of the initial construction costs of the protective beach and of the costs of periodic nourishment for a period of 10 years after the year of completion of the initial construction. The Board further recommended that local interests consider direct placement of a protective beach fill along the Shoreham village shore, based on their own determination of its economic justification. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

STATE OF CONNECTICUT - THAMES RIVER TO NIANTIC BAY (AREA 10)

Area 10 of the State of Connecticut study comprises the shores of Long Island Sound in the southeastern part of Connecticut between New London Harbor and Niantic Bay. It includes the shores of the city of New London and the town of Waterford, a total shore frontage of about 8-1/2 miles. The city of New London occupies the west bank of the Thames River at its mouth and about 2-1/4 miles of the shore of Long Island Sound west of the river. This shore area is extensively developed for year-round residential use. The permanent population of New London and Waterford is about 40,000. There is little seasonal change in population. The principal publicly owned sections of the shore in the study area are Ocean Beach in New London, owned by the city, Harkness Memorial State Park and the Seaside Sanatorium in Waterford, both State owned. Long Island Sound is a tidal arm of the Atlantic Ocean. Tides are semi-diurnal, the mean range increasing from 2.6 feet at New London Harbor to 2.7 feet at Millstone Point, near the west limit of the study area. The spring ranges are respectively 3.1 and 3.2 feet. The maximum tide of record at New London was 11.1 feet above mean low water or 8.5 feet above mean high water. Tides 3 feet or more above mean high water occur about once a year. With a tidal stage of 3 feet above mean high water, the maximum height of breakers landward of the low water line is about 5 feet. Larger waves can reach the shore only during infrequent higher tides. Ocean swells entering Long Island Sound

between Race Point and Little Gull Island probably have little effect on the shores of the study area because of the shelter afforded by Fishers Island. The waves of primary importance are those generated in the sound. Ordinary short storm waves cause littoral movement and loss of beach material to the offshore zone. The influence of swells is probably sufficient to cause only minor return of material from offshore by wave action. There appears to be little predominance in the direction of littoral transport, except that it is away from projecting points and northward along shores oriented generally in a north and south direction. The study area is characterized by rocky headlands and headlands of unconsolidated glacial material. In a few localities wave-built bars or spits have been formed. The headlands formerly supplied material to the intervening beaches, but are now generally eroded to bed rock or otherwise protected. The supply of material has thus been reduced or eliminated and consequently the beaches have slowly deteriorated. Groins have been found to be capable of causing minor accretion areas and stabilizing a narrow bank along the upper portion of the beach in some sections, but the natural supply of material is insufficient for the formation of adequate protective beaches by groins alone. The building and maintenance of adequate beaches may be accomplished by artificial placement of sand. The rate of loss of fill can be reduced by groins.

The division engineer and the Beach Erosion Board concluded that practicable plans which merit consideration for the protection and improvement of beaches within the study area are as follows:

a. West Shore of New London Harbor, New London. Construction of an impermeable groin.

b. Neptune Park and Ocean Beach, New London. Widening to a 125-foot width by direct placement of sand fill, 800 feet of beach in front of the existing seawalls at Neptune Park, the width to diminish southward along the north end of Ocean Beach.

c. Goshen Cove Inlet, Waterford. Jetties or a culvert to maintain flow into the cove, and revetment of the banks of the inlet channel.

The division engineer and the Beach Erosion Board found that protection and improvement of the shore at Neptune Park and Ocean Beach is not justified by evaluated benefits and further found other projects considered were ineligible for Federal assistance. They recommended no project be adopted by the United States for protection of the shores of the study area, but that protective measures which may be undertaken by local interests, based on their own determination of economic justification, be accomplished in accordance with the methods proposed in this report. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

PALM BEACH COUNTY FROM LAKE WORTH INLET TO SOUTH LAKE WORTH INLET, FLORIDA

The study area comprises the 15.6-mile reach of shore on the east coast of Florida between Lake Worth Inlet and South Lake Worth Inlet. The town of Palm Beach occupies the northern 10.5 miles of the sandy barrier beach island about 70 miles north of Miami. The remainder of the island is in the towns of Lake Worth, Lantana, and Manalapan. The island, especially that portion in Palm Beach, is extensively developed as a high-class winter resort. The permanent and winter populations of the island are respectively about 5,000 and 25,000. About 1.3 miles of the ocean shore is publicly owned, most of which is used for public bathing beaches. The shore of the study area is exposed to waves of the Atlantic Ocean. To the northeast the fetch is unlimited, but to the east and southeast the incidence of swells is influenced by the shelter afforded by the islands of the Bahama group. The predominance of energy components is such as to produce a dominant southward littoral transport. However, reversals in direction of transport occur, principally in the summer. The mean and spring tidal ranges are respectively 2.8 and 3.3 feet. The two highest tides of record, 11.2 and 8.7 feet above mean low water, occurred during hurricanes in 1928 and 1936 respectively. A tide of 7 feet is considered suitable for design purposes, as a tide of this height can be expected during hurricanes of medium intensity.

Lake Worth Inlet was opened by dredging and two protective jetties were constructed between 1918 and 1925. Since completion of the structures, littoral drift has been impounded nearly to the capacity of the north jetty, and the deficiency in supply has resulted in erosion of the shore south of the inlet, in spite of artificial placement of about 3,500,000 cubic yards of sand on the beaches from 1944 to 1953, and construction of numerous bulkheads, walls, and groins. The total cost of protective measures since 1926 has been estimated as approaching 4 million dollars.

The only apparent natural source of littoral material to supply the problem area is the eroding beaches north of Lake Worth Inlet. The accumulation of sand at that inlet indicates a littoral drift rate of about 230,000 cubic yards annually. This rate compares with losses from the island due to deficiency of supply from 1929 to 1955 of 200,000 cubic yards landward of the 18-foot depth contour. However, 250,000 cubic yards of material were lost annually between the 18 and 30-foot contours during the same period. In order to obtain a reasonably uniform supply of material to the problem area, at the time the study was made the cooperating agency was proceeding with the construction of a sand-transfer plant on the north jetty at Lake Worth Inlet. It is estimated that the plant will transfer an average of about 100,000 cubic yards of sand across the inlet annually.

A Federal project, adopted May 17, 1950, authorized Federal participation, subject to certain conditions, in the improvement and protection of the shore at Palm Beach by placing up to 1,000,000 cubic yards of suitable material on the beach in five stockpiles. The authorized Federal participation is one-third of the costs of this work

chargeable to the publicly owned frontage. In 1948 local interests placed about 2,000,000 cubic yards of sand substantially in accordance with the project plan, but no contribution has been made for the Federal share of the costs thereof. The widened beach was to be maintained by periodic replenishment of the material in the stockpiles at an estimated rate not in excess of 200,000 cubic yards annually.

The district and division engineers and the Beach Erosion Board concluded that the most practicable plan of shore protection consists of artificial placement of a protective and recreational beach and construction of a sand-transfer plant at Lake Worth Inlet. Periodic nourishment by artificial placement of material from Lake Worth would be required in addition to operation of the sand-transfer plant to provide for stability of the protective beach. They found that this plan of protection was economically justified. They therefore further concluded that the public interest associated with protection of public lands and improvements, and restoration and stabilization of public beach areas was sufficient to warrant adoption of a project authorizing Federal participation in the cost of protecting the shore of Palm Beach Island, the share of the expense thereof to be borne by the United States being one-third of the costs of the work applicable to publicly owned shores, and one-third of the costs adjusted by the ratio of public to total benefits for those privately owned shores where public benefits arise, in accordance with the provisions of Public Law 826, 84th Congress. In addition benefits to the Federal navigation project for Lake Worth Inlet (Palm Beach Harbor) warrant Federal aid in the costs of constructing and operating a sand-transfer plant at that inlet, based on the relative benefits to be anticipated from the sand-transfer operation compared to the total nourishment operation.

The district and division engineers and the Beach Erosion Board recommended modification of the existing project for Palm Beach, Florida, authorized by the River and Harbor Act approved May 17, 1950, to authorize Federal participation in the costs of a plan for protection of the shore of Palm Beach Island, comprising restoration of a protective beach with berm elevation of 10 feet above mean low water, to a general width of 150 feet at mean high water from Lake Worth Inlet to a point about 1,000 feet south of Southern Boulevard extended, thence with a general width of 100 feet to South Lake Worth Inlet, construction and operation of a sand-transfer plant at Lake Worth Inlet, and additional periodic nourishment from Lake Worth or other suitable source. Federal assistance would entail contribution of funds in amount of 4.7 percent of the initial construction costs of the beach restoration and appurtenant drainage work, and of the expenditures for periodic nourishment from Lake Worth for a period of 10 years from the year of the initial placement, plus 19.3 percent of the expenditures for construction, and for operation, maintenance and current replacements of parts of the sand-transfer plant for the same period. Continuation of Federal participation after the initial 10-year period will be subject to review of benefits, methods and techniques. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

SOUTH SHORE OF KEY WEST, FLORIDA

The study area comprises the south shore of Key West and is about 4 miles in length, the problem area being about 6,200 feet in length and lying just east of the middle of the study area. Key West is one of the Florida Keys, near the western end of the chain which separates the Straits of Florida from the Gulf of Mexico. The island is developed as a winter resort. Local interests estimate that 200,000 tourists visit Key West annually. The estimated permanent population of the island in 1957 was 32,000, in addition to about 23,000 Navy personnel and their dependents. The entire 6,200-foot frontage of the problem shore is publicly owned. The shore of the study area is exposed to waves of the Straits of Florida, but large waves are broken up to considerable extent by a reef lying about 5 miles offshore. The predominance of energy components in deep water is such that a westward littoral transport would be expected. However, due to lack of sand on the shallow rocky bottom, no signs of appreciable littoral drift are apparent. The mean and spring tidal ranges are respectively 1.3 and 1.6 feet. The highest tide of record, 3.8 feet above mean low water, occurred during a hurricane in 194[illegible].

The district and division engineers concluded that the most practicable plan of improvement consists of artificial placement of a protective and recreational beach along South Roosevelt Boulevard, and that such work is economically justified by prospective benefits. They also concluded that the public interest associated with protection of public lands and improvements, and restoration of public beach areas was sufficient to warrant adoption of a project authorizing Federal participation in the cost of protecting the shore of Key West, the share of the expense thereof to be borne by the United States to be one-third of the cost of the work, in accordance with the provisions of Public Law 826, 84th Congress.

They accordingly recommended adoption of a project for Key West, Florida, to authorize Federal participation by the contribution of funds in amount of one-third of the first costs and one-third of the periodic nourishments costs to replace alongshore losses for a period of 10 years from the year of completion of the initial placement, of a plan for protection comprising restoration of a protective beach with a berm 100 feet wide at elevation of 4 feet above mean low water along a section of South Roosevelt Boulevard approximately 6,200 feet in length. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

COMPLETED COOPERATIVE BEACH EROSION STUDIES

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	PUBLISHED IN CONG.	FEDERAL PROJECTS RECOMMENDATION	FEDERAL PROJECTS AUTHORIZED BY CONGRESS
	ALABAMA				
Perdido Pass (Alabama Pt.)	18 Jun 54	274	84	Unfav.	
	CALIFORNIA				
Santa Barbara - Initial	15 Jan 38	552	75	Unfav.	
Suppl.	18 Feb 42				
Final	22 May 47	761	80	Unfav.	
Ballona Creek & San Gabriel R. (Partial)	11 May 38			Unfav.	
Orange County	10 Jan 40	637	76	Unfav.	
Coronado Beach	4 Apr 41	636	77	Unfav.	
Long Beach	3 Apr 42			Unfav.	
Mission Beach	4 Nov 42			Unfav.	
Pt. Mugu to San Pedro BW	27 Jun 51	277	83	Fav.	3 Sep 54
Carpinteria to Pt. Mugu	4 Oct 51	29	83	Fav.	3 Sep 54
Oceanside, Ocean Beach, Imperial Beach & Coronado, San Diego County	26 Jul 55	399	84	Fav.	3 Jul 58
Santa Cruz County	13 Sep 56	179	85	Fav.	3 Jul 58
Humboldt Bay (Buhne Pt.)	29 Mar 57	282	85	Fav.	3 Jul 58
	CONNECTICUT				
Compo Beach, Westport	18 Apr 35	239	74	Unfav.	
Hawk's Nest Beach, Old Lyme	21 Jun 39			Unfav.	
Ash Crk. to Saugatuck R.	29 Apr 49	454	81	Fav.	17 May 50
Hammonasset R. to East R.	29 Apr 49	474	81	Fav.	3 Sep 54
New Haven Hbr. to Housatonic R.	29 Jun 51	203	83	Fav.	3 Sep 54
Conn. R. to Hammonasset R.	28 Dec 51	514	82	Unfav.	
Pawcatuck R. to Thames R.	31 Mar 52	31	83	Unfav.	
Niantic Bay to Conn. R.	11 Jul 52	84	83	Unfav.	
Housatonic R. to Ash Creek	12 Mar 53	248	83	Fav.	3 Sep 54
East R. to New Haven Hbr.	15 Nov 55	395	84	Fav.	3 Jul 58
Saugatuck R. to Byram R.	14 Nov 56	174	85	Fav.	3 Jul 58
Thames R. to Niantic Bay	17 June 57			Unfav.	
	DELAWARE				
Kitts Hummock to Fenwick Is.	11 Feb 57	216	85	Fav.	3 Jul 58

LOCATION	BEB REPORT COMPLETED	H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	FEDERAL PROJECTS AUTHORIZED BY CONGRESS
FLORIDA					
Blind Pass (Boca Ciega)	1 Feb 37	187	75	Unfav.	
Miami Beach	1 Feb 37	169	75	Unfav.	
Hollywood Beach	28 Apr 37	253	75	Unfav.	
Daytona Beach	15 Mar 38	571	75	Unfav.	
Bakers Haulover Inlet	21 May 45	527	79	Unfav.	
Anna Maria & Longboat Keys	12 Feb 47	760	80	Unfav.	
Jupiter Island	13 Feb 47	765	80	Unfav.	
Palm Beach (1)	13 Feb 47	772	80	Fav.	17 May 50
Pinellas County	22 Apr 53	380	83	Fav.	3 Sep 54
Palm Beach County (Lk. Worth Inlet to S. Lake Worth I.)	12 Jul 57	342	85	Fav.	3 Jul 58
Key West	10 Mar 58	413	85	Fav.	
GEORGIA					
St. Simon Island	18 Mar 40	820	76	Unfav.	
HAWAII					
Waikiki Beach	5 Aug 52	227	83	Fav.	3 Sep 54
Waimea & Hanapepe Bay, Kauai	17 Jan 56	432	84	Fav.	3 Jul 58
ILLINOIS					
State of Illinois	8 Jun 50	28	83	Fav.	3 Sep 54
LOUISIANA					
Grand Isle	28 Jul 36	92	75	Unfav.	
Grand Isle	28 Jun 54	132	84	Unfav.	
MAINE					
Old Orchard Beach	20 Sep 35			Unfav.	
Saco	2 Mar 56	32	85	Unfav.	
MASSACHUSETTS					
South Shore of Cape Cod (Pt. Gammon to Chatham)	26 Aug 41			Unfav.	
Salisbury Beach	26 Aug 41			Unfav.	
Winthrop Beach	12 Sep 47	764	80	Fav.	17 May 50
Lynn-Nahant Beach	20 Jan 50	134	82	Fav.	3 Sep 54
Revere Beach	12 Jan 50	146	82	Fav.	3 Sep 54
Nantasket Beach	12 Jan 50			Unfav.	
Quincy Shore	2 May 50	145	82	Fav.	3 Sep 54
Plum Island	18 Nov 52	243	83	Unfav.	
Chatham	22 Oct 56	167	85	Unfav.	

(1) A cooperative study of experimental steel sheet pile groins was also made, under which methods of improvement were recommended in an interim report dated 19 Sep 1940. Final report on experimental groins was published in 1948 as Technical Memo. No. 10 of the Beach Erosion Board.

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	AUTHORIZED BY CONGRESS
	MICHIGAN				
Berrien County, (St. Joseph)	17 Jun 57	336	85	Fav.	3 Jul 58
	MISSISSIPPI				
Hancock County	3 Apr 42			Unfav.	
Harrison County - Initial	15 Mar 44				
Harrison County - Suppl.	16 Feb 48	682	80	Fav.	30 Jun 48
	NEW HAMPSHIRE				
Hampton Beach	15 Jul 32			Unfav.	
Hampton Beach	14 Sep 53	325	83	Fav.	3 Sep 54
	NEW JERSEY				
Manasquan Inlet & Adj. Beaches	15 May 36	71	75	Unfav.	
Atlantic City	11 Jul 49	538	81	Fav.	3 Sep 54
Ocean City	15 Apr 52	184	83	Fav.	3 Sep 54
Sandy Hook to Barnegat Inlet	24 Mar 54	361	84	Fav.	
Review Report - Sandy Hook to Barnegat Inlet	6 May 57	332	85	Fav.	3 Jul 58
	NEW YORK				
Jacob Riis Park, Long Island	16 Dec 35	397	74	Unfav.	
Orchard Beach, Pelham Bay, Bronx	30 Aug 37	450	75	Unfav.	
Niagara County	27 Jun 42	271	78	Unfav.	
South Shore of Long Island	6 Aug 46			Unfav.	
Selkirk Shores State Park	21 Oct 53	343	83	Fav.	3 Sep 54
Fair Haven Beach State Park	18 Jun 54	134	84	Fav.	3 Jul 58
Hamlin Beach State Park	20 Sep 54	138	84	Fav.	3 Jul 58
Braddock Bay State Park	15 Apr 55			Unfav.	
Fire Island Inlet to Jones Inlet	10 Feb 56	411	84	Fav.	3 Jul 58
	NORTH CAROLINA				
Fort Fisher	10 Nov 31	204	72	Unfav.	
Wrightsville Beach	2 Jan 34	218	73	Unfav.	
Kitty Hawk, Nags Head & Oregon Inlet	1 Mar 35	155	74	Unfav.	
State of North Carolina	22 May 47	763	80	Unfav.	
	OHIO				
Erie County - Vic. of Huron	26 Aug 41	220	79	Unfav.	
Michigan Line to Marblehead	30 Oct 44	177	79	Unfav.	

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	AUTHORIZED BY CONGRESS
OHIO (cont'd)					
Cities of Cleveland & Lakewood	22 Mar 48	502	81	Fav.	3 Sep 54
Chagrin River to Fairport	22 Nov 49	596	81	Unfav.	
Vermillion to Sheffield Lake Village	24 Jul 50	229	83	Fav.	3 Sep 54
Fairport to Ashtabula	1 Aug 51	351	82	Unfav.	
Ashtabula to Penna.St. Line	1 Aug 51	350	82	Unfav.	
Sandusky to Vermilion	7 Jul 52	32	83	Unfav.	
Sandusky Bay	31 Oct 52	126	83	Unfav.	
Sheffield Lake V. to Rocky R.	31 Oct 52	127	83	Unfav.	
Euclid to Chagrin River	25 June53	324	83	Unfav.	
PENNSYLVANIA					
Presque Isle Peninsula, Erie (Interim)	3 Apr 42				
(Final)	23 Apr 52	231	83	Fav.	3 Sep 54
PUERTO RICO					
Punta Las Marias, San Juan	5 Aug 47	769	80	Unfav.	
RHODE ISLAND					
South Shore (Towns of Narragansett, South Kingstown, Charlestown & Westerly)	4 Dec 48	490	81	Fav.	3 Sep 54
South Kingstown & Westerly	27 Jan 58			Fav.	
SOUTH CAROLINA					
Folly Beach	31 Jan 35	156	74	Unfav.	
Pawleys Is., Edisto Beach & Hunting Island	24 Jul 51			Unfav.	
TEXAS					
Galveston (Gulf Shore)	10 May 34	400	73	Unfav.	
Galveston Bay, Harris County	31 Jul 34	74	74	Unfav.	
Galveston (Gulf Shore)	5 Feb 53	218	83	Unfav.	
Galveston (Bay Shore)	19 Jun 53	346	83	Unfav.	
VIRGINIA					
Willoughby Spit, Norfolk	20 Nov 37	482	75	Unfav.	
Colonial Beach, Potomac River	24 Jan 49	333	81	Fav.	17 May 50
Virginia Beach	25 Jun 52	186	83	Fav.	3 Sep 54

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	AUTHORIZED BY CONGRESS
	WISCONSIN				
Milwaukee County	21 May 45	526	79	Unfav.	
Racine County	5 Mar 52	88	83	Unfav.	
Kenosha	16 Sep 54	273	84	Unfav.	
Manitowoc County	15 Apr 55	348	84	Fav.	3 Jul 58

CURRENTLY AUTHORIZED COOPERATIVE BEACH EROSION STUDIES

CALIFORNIA

STATE OF CALIFORNIA. Cooperating Agency: Department of Public Works, Division of Water Resources, State of California.

Problem: To conduct a study of the problems of beach erosion and shore protection along the entire coast of California. The current studies cover the Orange County and San Diego County Areas, and a review for the entire area from Point Conception to the Mexican Boundary.

FLORIDA

PALM BEACH COUNTY. Cooperating Agency: Board of County Commissioners, Palm Beach County.

Problem: To develop the most economical means of restoring the beaches along the Atlantic Ocean shore of Palm Beach County to a satisfactory condition and protecting the restored beaches and shore property from future erosion. The current study covers the area north of Lake Worth Inlet and south of South Lake Worth Inlet.

FERNANDINA BEACH (AMELIA IS.). Cooperating Agency: City of Fernandina Beach.

Problem: To determine the best method for restoring and retaining an adequate beach for recreation and protection of oceanfront properties and improvements.

MASSACHUSETTS

PEMBERTON PT. TO PROVINCETOWN. Cooperating Agency: Department of Public Works.

Problem: To determine the most suitable methods of shore protection, prevention of further erosion and improvement of beaches. Current studies cover the shore from Pemberton Point to Cape Cod Canal in Massachuettts and Cape Cod Bays where development of specific plans are desired for protection of Crescent Beach, the Glades, North Scituate Beach, Brant Rock and Warren Cove; and from Cape Cod Canal to Provincetown in Cape Cod Bay where detailed study is desired for problems at Town Beach, Spring Hill Beach, East of Sesuit Harbor, Brewster Bluffs, Griffin Island, Pilgrim Beach, and shore immediately south of Hatches Harbor.

WESSAGUSSETT BEACH, WEYMOUTH. Cooperating Agency: Town of Weymouth

Problem: To determine the best method for restoration and stabilization of the public beach and stabilization of the bluff.

NEW BEDFORD. Cooperating Agency: City of New Bedford.

Problem: To determine the best method of restoring and stabilizing the public beaches to protect the boulevard and provide public bathing area.

NEW JERSEY

STATE OF NEW JERSEY. Cooperating Agency: Department of Conservation and Economic Development.

Problem: To determine the best method of preventing further erosion and stabilizing and restoring the beaches, to recommend remedial measures, and to formulate a comprehensive plan for beach preservation or coastal protection. Current studies cover the Atlantic Ocean shore from Barnegat Inlet to Cape May Canal, Cape May Canal to Maurice River in Delaware Bay, South Amboy to Shrewsbury River in Raritan and Sandy Hook Bays.

ATLANTIC CITY. Cooperating Agency: City of Atlantic City.

Problem: To determine the effect of Public Law 826, 84th Congress on the existing authorized project for beach erosion control.

NEW YORK

SUFFOLK COUNTY (ATLANTIC COAST BETWEEN MONTAUK POINT AND FIRE ISLAND INLET). Cooperating Agency: Department of Public Works, State of New York.

Problem: To determine the most practicable and economic method of restoring adequate recreational and protective beaches and providing continued stability to the shores.

NORTH CAROLINA

CAROLINA BEACH. Cooperating Agency: Town of Carolina Beach.

Problem: To determine the best method of preventing erosion of the beach.

OCRACOKE ISLAND. Cooperating Agency: Department of Conservation and Development, State of North Carolina.

Problem: To determine the best method of protecting the ocean and Pamlico Sound shores of the island against erosion by waves and currents, and providing protection to State highway and other property.

FORT MACON - ATLANTIC BEACH. Cooperating Agency: Department of Conservation and Development, State of North Carolina.

Problem: To develop permanent solutions to halt erosion and protect resort improvements at Atlantic Beach and protect park facilities and historic Fort Macon.

OHIO

MICHIGAN LINE TO MARBLEHEAD. Cooperating Agency: Division of Shore Erosion, Department of Natural Resources, State of Ohio.

Problem: To determine the best method of protecting the shores of the study area, including typical methods of protection for publicly and privately owned shores, especially to determine whether any changes should be made in recommendations contained in H.D. No. 177, 79th Congress in view of changed conditions and additional data; and to develop specific plans of restoration and protection of the shores of Metzgar Marsh, Crane Creek State Park and East Harbor State Park, and general plans for the protection of privately owned property.

PENNSYLVANIA

PRESQUE ISLE. Cooperating Agency: Department of Forests and Waters, Commonwealth of Pennsylvania.

Problem: To determine rates of loss and movement of sand fill, the nourishment requirements of the existing shore protection project and its eligibility for Federal participation in the cost of periodic beach nourishment in accordance with provisions of Public Law 826, 84th Congress.

PUERTO RICO

PT. SALINAS TO PT. VACIA TALEGA (SAN JUAN). Cooperating Agency: Department of Public Works, Commonwealth of Puerto Rico.

Problem: To determine most practical and economical method of preventing further erosion of the shore and stabilizing or restoring the beach, especially aimed to protect existing upland properties and future recreational, industrial or residential development areas.

TEXAS

ROLLOVER FISH PASS. Cooperating Agency: Game and Fish Commission, State of Texas.

Problem: To determine the best method of providing a stabilized pass at Rollover Inlet from the Gulf of Mexico into East

Galveston Bay, including stabilization of adjacent shores.

VIRGINIA

VIRGINIA BEACH. Cooperating Agency: Virginia Beach Erosion Commission.

Problem: To determine to what extent assistance from the Federal Government may be extended under the provisions of Public Law 826, 84th Congress, in carrying out the periodic nourishment program of the existing beach restoration project at Virginia Beach.

ANNOTATED LISTING OF PUBLICATIONS OF THE BEACH EROSION BOARD

Publications of the Beach Erosion Board are listed chronologically under the three groupings of BULLETINS, TECHNICAL MEMORANDA and TECHNICAL REPORTS.

Brief annotations or abstracts are given arter the titles of technical articles appearing in the Bulletin, and for the technical memoranda and reports.

Roman numeral and capital letter designators appearing to the left of the titles classify the subject matter of the text according to the following general groupings:

I Laboratory Investigations

II Prototype (Field and Theoretical) Investigations

- A Wave Action
- B Beach Material Characteristics
- C Shore Processes
- D Survey and Measurement
- E Protective Measures
- F Miscellaneous

BULLETINS OF THE BEACH EROSION BOARD

VOLUME 1 - 1947

ISSUE NO. 1 - 1 April 1947

II-D "Test of Aerial Photogrammetry in Making Beach Surveys"

Obtaining topography of two barrier islands off the Gulf coast of Florida by plane table and aerial photogrammetry is discussed and methods compared.

I-C "Laboratory Study of Equilibrium Beach Profiles"

Description of laboratory tank tests to define the influence of wave characteristics in shaping the equilibrium beach profile. Preliminary results are presented.

"Beach Erosion Studies"

Listing of cooperative beach erosion control studies completed by the Board and those still in progress.

"Beach Erosion Literature"

Acquisitions to the Board's Library which are deemed of general interest are abstracted.

"Publications of the Board"

The Board's publication media are defined, and those published to date listed.

ISSUE NO. 2 - 1 July 1947

II-D "Hydrographic Survey Operations of Field Research Group"

Organization, equipment and operational procedures of a Field Research Group of the Board's staff are described. Hydrographic survey experience of this group is particularly discussed.

II-D "Comparison of Leadline and Echo Sounding Results Using Amphibious Trucks"

A series of underwater bottom profiles were obtained by the Board's Field Research Group utilizing both methods, and compared. The echo sounder method was concluded to be far superior to leadline in that it is more accurate, gives more detail, and is considerably faster.

I-F "A Study of Comparative Action of Waves on Model Beaches of Different Scales"

Laboratory tank tests to define with some exactness the conditions under which a model involving wave action on a moving sand beach can be expected to accurately reproduce the action of the prototype and how to correct the results if faithful reproduction is not obtainable, are described. Some preliminary results are presented.

II-F "The Importance of Shore Protection Studies" by Dr. Martin A. Mason

The first of a series of four articles delivered as lectures in the Advanced Course of the Engineer School at Fort Belvoir, Va.

"Beach Erosion Studies"

Listing of cooperative studies completed since last issue of the Bulletin and those still in progress.

"Procedure for Initiating Cooperative Beach Erosion Studies"

Information presented to assist local agencies in applying for cooperative studies.

"Beach Erosion Literature"

Abstract of acquisitions to the Board's Library.

ISSUE NO. 3 - 1 October 1947

II-F "Radio Equipment for Field Research Party"

Description of equipment and operating experience.

II-D "Notes on Comparisons of Echo Sounders"

An article covering basic operating principles of echo sounders, listing of various features by which different models of echo sounders can be compared, a specific comparison of two types of commercial echo sounders pointing out essential differences, and a discussion of difficulties in making echo soundings over unconsolidated bottoms.

II-C "Basic Knowledge of Shore Phenomena" by Dr. Martin A. Mason

The second of a series of four articles delivered as lectures in the Advanced Course of the Engineers School at Fort Belvoir, Va. A brief outline of shore phenomena and discussion of the elements of the philosoply on which methods of solution are based are presented. Concepts of the physiographic unit and material-energy balance within the unit are introduced.

"The Coastline of England and Wales"

A brief review of a book of this title by J. A. Steers, President of St. Catherine's College, England and Cambridge University Lecturer in geography. Mr. Steer's book is cited as a comprehensive physiographical treatment of the English coast.

"Beach Erosion Studies"

Listing of cooperative studies completed since last issue of the Bulletin and of those still in progress.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

VOLUME 2 - 1948

ISSUE NO. 1 - 1 January 1948

II-C E "Recent Storm Damage Along the Coasts of Florida and Mississippi"

Description and discussion, including photographs, of damages on the Florida and Mississippi coasts resulting from two hurricanes occurring in September 1947.

II-C E "Methods of Solution of Shore Problems"

Completion of a series of articles by Dr. Martin A. Mason delivered as lectures in the Advanced Course of the Engineer School at Fort Belvoir, Virginia. Six basic questions are posed, the answers to which develop the solution to a shore erosion problem.

"Det Marine Forland"

A brief review of a book of this title by Axel Schou of the University Laboratory at Copenhagen. Mr. Schou's book relating to the coast of Denmark covers the historical aspects of the problem, the forces involved, the forms, the form complexes, the landscapes, the general picture, and features of the cultural geography of the marine foreland.

"Beach Erosion Studies"

Summary of the completed report on the South Shore of Long Island, New York and listing of studies still in progress.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

ISSUE NO. 2 - 1 April 1948

II-C E "An Engineer Looks at Waikiki Beach" by Donald F. Horton

A report, illustrated with photographs, of an inspection of Waikiki Beach, Territory of Hawaii, by an engineer of the Board's staff. The inspection was made prior to developing a study program for a cooperative study of erosion problems at this beach.

II-D "Review of Shallow Water Survey Methods"

A preliminary report of information received on questionnaires submitted to Districts of the Corps of Engineers. Percentages of survey work accomplished by echo sounder and contact methods are given. Suggestions made by District Engineers as possible means of improving shallow water survey methods are also presented.

I-A "Theoretical Studies on Surface Gravity Waves"

Results of theoretical studies of phenomena concerning surface gravity waves made by a group working in the Institute for Mathematics and Mechanics, New York University, are reported in abstracts of a series of papers.

"Beach Erosion Studies"

Listing of cooperative studies completed since last issue of the Bulletin and of those still in progress.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

ISSUE NO. 3 - 1 July 1948

II-C D "Littoral Drift Study Los Angeles, California"

Field operations to provide data for studying behavior of extensive beach fills at Surfside and Sunset Beach colonies near Anaheim Bay Harbor and at the El Segundo area of Santa Monica Bay in California are briefly described.

II-E "Beach and Channel Improvement Measures at Atlantic City, New Jersey"

A brief description with photographs of beach restoration at Atlantic City in 1948 by placement of hydraulic fill.

II-D "The Use of Historical Surveys in Beach Erosion Studies" by Harold A. Ward

Sources of historical survey data and importance of reducing old survey to present day projection and datum for comparative purposes are discussed.

"Beach Erosion Studies"

Summary of completed report on Harrison County, Mississippi is presented. Listing of all completed cooperative studies and those still in progress is also presented.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

SPECIAL ISSUE NO. 1 - 1 July 1948

II-A "Oscillatory Waves - Diagrams and Tables of Relationships Commonly Used in Investigations of Surface Waves"

A compilation of data assembled to provide easy accessibility to the various functions that are used most frequently in investigations involving surface wave phenomena.

ISSUE NO. 4 - 1 October 1948

II-F "Federal Responsibilities in Shore Protection"

Extracts from a lecture by Donald F. Horton at the Engineer School, Fort Belvoir, Virginia. Federal Beach Erosion Laws are presented and discussed.

II-A C "An Elementary Discussion of Tides, Currents, and Wave Action in Beach Erosion"

Extract from a lecture by Joseph M. Caldwell at the Engineer School, Fort Belvoir, Virginia. Includes very brief general discussion tidal phenomena and wave generation and behavior on moving into shallow coastal waters.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

VOLUME 3 - 1949

ISSUE NO. 1 - 1 January 1949

II-E "A Formula for the Calculation of Rock Fill Dikes"

An English translation of a paper by Ramon Iribarren Cavanilles in Spanish. A formula is developed for determining stable rock sizes and side slopes for rock structures exposed to wave action.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on Winthrop Beach, Mass., the State of North Carolina,

Jupiter Island, Fla., Palm Beach, Fla., Anna Maria and Longboat Keys, Fla., Santa Barbara, Calif., and Punta Las Marias, San Juan, Puerto Rico are presented. Listing of studies still in progress is also given.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

ISSUE NO. 2 - 1 April 1949

II-C "Sand Movement Study at Long Branch, New Jersey"

Summary of a report on actual field tests to determine feasibility of using material dredged by hopper dredges from coastal harbors to nourish nearby beaches. About 600,000 cubic yards of material dumped offshore from Long Branch, N. J. was studied to trace its movement. About 125,000 cubic yards of this material was eroded from the dumped pile between April and October 1948, but there was no indication of this material having moved shoreward in significant quantity to nourish the beach.

II-D "Surveying in Haze and Fog"

A mercury vapor lamp installed on the hydrographic survey vessel utilized by the Field Research Group of the Board's staff increased its visibility from shore by 50 to 75 percent when operating in haze and fog off the Southern California coast. Survey time lost due to haze and fog was estimated to have been reduced by 50 percent during operation extending over a several months period.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

ISSUE NO. 3 - 1 July 1949

"Beach Erosion Board Research"

Extracts from a speech by Lt. Col. Wm. B. Stelzenmuller at the Great Lakes Conference on Lake Shore Erosion Control

Problems in May 1949. Mission and research program of the Beach Erosion Board is briefly outlined.

"New Jersey Creates Beach Erosion Committee"

The State of New Jersey by action of its legislature 9 April 1949 provided for creation of a commission to consider and provide ways and means to protect and preserve the beaches and shore front of the State by the erection and construction of protective works, dredging, and other suitable methods. The enabling act is quoted.

II-A "The Causes of Plunging and Spilling Breakers"

Notes prepared by Dean M. P. O'Brien, University of California, January 1946. Conditions causing plunging and spilling breakers are listed as determined from field observations and photographs. The role of bottom slope and wave steepness and ratio of breaker height to water depth is discussed.

II-E "Discussion - A Formula for the Calculation of Rock Fill Dikes" by Mr. R. M. McCrone, Lower Mississippi Valley Division, Corps of Engineers

Points out that for protection against wave action or erosion due to river currents a homogeneous non-erosible monolith of sand asphalt mixtures is preferable to heterogeneous masses of riprap even if rock sizes are adequate. Cites discussion in Proceedings of ASCE, December 1948.

II-F "Comite Central D'Oceanographie et D'Etude des Cotes"

Briefs of information of general interest contained in periodic Information Bulletin issued by above French organization. Includes notes on erosion and protective measures at Pointe de Grave, France, description of the Center for Research and Oceanographis Studies, and description of a recording manometer for submarine pressures.

I-A D "Measurements of Heights by Resistance Elements" by J. R. Morison, University of California

A method of measuring wave heights in a laboratory wave tank utilizing wire resistance elements and a recording oscillograph is summarized.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

ISSUE NO. 4 - 1 October 1949

II-A "Recent Contributions of Wave Research to Harbor Engineering" by J. W. Johnson, University of California, July 1948

Results of extensive research into wave problems and related phenomena stimulated by World War II have definite peacetime application to harbor engineering. Principal problems discussed are confined to wind-generated waves and are presented in broad aspect as characteristics of waves, compilation of design data, wave refraction and diffraction, and wave action on structures.

II-D "Combining Leadline and Echo-Sounding Methods in Surveys of Submarine Canyons"

In surveying a steep-sided submarine canyon where an echo sounder alone would not give sufficiently accurate results, a standard stream gaging unit, consisting of a 100-pound streamlined lead weight fastened to a stainless steel wire on a winding drum equipped with a counter, was utilized for quick accurate soundings. Soundings could be taken at 15 to 20-second intervals in depths as great as 150 feet.

II-A "Forecasting Breakers and Surf on a Straight Beach of Infinite Length"

Memoranda prepared in the Department of Engineering, University of California in February 1947. Generalized diagrams for simplifying surf forecasts (breaker height and depth and angle with bottom contours) are presented and discussed.

I-F "Construction of Additional Beach Erosion Board Research Facilities"

The large outdoor wave tank (635 feet in length and wave generator capable of producing waves up to 6 feet in height) and the shore processes test basin which were under construction in 1949 are described.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

VOLUME 4 - 1950

ISSUE NO. 1 - 1 January 1950

II-A C "Wave Refraction at Long Beach and Santa Barbara, California" by Dean M. P. O'Brien, University of California, May 1947.

Examples of wave refraction analysis are presented and discussed which offer rational explanations of unusual observations at Long Beach and Santa Barbara, California.

II-C "A Formula for the Calculation of the Tidal Discharge Through an Inlet" by Dr. Garbis H. Keulegan, National Bureau of Standards and J. V. Hall, Jr., Beach Erosion Board Staff

A formula for maximum discharge through an inlet based on a known tidal prism is developed and checked for four locations where measured plans have been made.

II-A "Characteristics of Measured Wave Action on the Basis of the Frequency Distribution of Wave Length, Wave Height and Steepness" by H. Ehring, 1940

Translation of a paper originally published in German. Classification of wave data measured by wave gages according to frequency of occurrence of various classes of wave dimensions rather than by a mean or particular value is discussed. Examples and advantages are given.

II-A F "Comite Central d'Oceanographie et d'Etude des Cotes"

Briefs of information of general interest contained in periodic information bulletin of the above French organization. Includes "Remarks on Wave Forecasting", "Relations Between Microseismic Activity and Waves", "Wave Diffraction", and "An Explanation of Certain Marine Currents".

"Wave Tank Progress Photographs"

A series of photographs depicting new research facilities under construction at the Beach Erosion Board's plant in 1949.

"Beach Erosion Studies"

Summary of completed cooperative study report on Colonial Beach, Virginia, and listing of studies still in progress.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

ISSUE NO. 2 - 1 April 1950

II-A "Wave Dimensions in the North and Baltic Seas" by E. Mewes, October 1937

Translation of a paper originally published in German. Results of observations and measurements of the state of the sea made in 1936-37 are reported and evaluated. Recorded and estimated wave dimensions are compared. Wave dimensions for different states of the sea are discussed.

II-A D "A Method of Estimating Wave Direction" by D. R. Forrest

A sighting bar attachment for an ordinary transit, enabling wave direction to be estimated is described and its use discussed.

"Expansion of Beach Erosion Board Research Facilities"

Photographs of large outdoor wave tank and shore processes test basin under construction.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on South Shore of State of Rhode Island, Ash Creek to Saugatuck River and Hammonasset River to East River in the State of Connecticut, Atlantic City, New Jersey, and Cleveland and Lakewood, Ohio are presented. Listing of studies still in progress is also given.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

ISSUE NO. 3 - 1 July 1950

II-A C "Southern Hemisphere Swell and Waves from a Tropical Storm at Long Beach, California" by Paul L. Horrer

Characteristics of waves destructive to harbor breakwaters in the Long Beach-San Pedro area are examined for Southern hemisphere swell occurring in 1930 and waves from a tropical storm in the North Pacific Ocean occurring in 1939. Refraction analysis are made, and hindcast of wave conditions occurring in the 1939 storm is made from available weather data.

II-C "The Wind Element in Beach Erosion" by Dr. Martin A. Mason

Presented at Symposium on Hydrometeorological Problems, American Geophysical Union, 2 May 1950. The role of the wind in removing sand from the beaches is discussed, and relative importance of effects of wind-generated water waves and direct effects of the wind on the shore face is discussed. Relationships of wind velocity and sand movement developed by other investigators are given.

I-D F "The Lag and Reduction of Range in Tide Gage Wells" by Morrough P. O'Brien, University of California

Theoretical analysis and experimental study of the problem of lag of high and low water and reduction of range in a tidal gage well are presented. Theoretical curves are concluded to be more reliable because error in the experimental results is relatively great.

"Beach Erosion Studies"

Summary of completed cooperative study report on Lake County, Ohio is presented. Listings of all completed cooperative studies and those still in progress are also included.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

ISSUE NO. 4 - 1 October 1950

II-C "Munch-Petersen's Littoral Drift Formula"

Translation of a paper presented by Mr. Sv. Svendsen before the Association of Government and Harbor Engineers at Helsingfors in August 1938. A formula developed by the late Danish Professor Munch-Petersen giving the material-moving power of the waves at a point on the

coast in terms of wind speed and frequency, available fetch lengths and direction, and a constant to be evaluated, is presented, discussed, and examples of its application to North and Baltic Sea Coasts given.

II-A F "Surging in Depoe Bay, Oregon"

A report by Mr. Willard Bascom, University of California. An unusual surging condition occurring in Depoe Bay Harbor in October 1947 is described. Measurements were recorded.

II-A D "Stereophotogrammetric Wave Measurement" by Mr. Lewis A. Dickerson, Army Map Service

A report on investigations and experiments to determine feasibility of measuring heights of ocean waves by photogrammetric means. Use of this method is concluded to be possible, but extremely difficult.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

VOLUME 5 - 1951

ISSUE NO. 1 - 1 January 1951

II-F "British Coast Protection Act of 1949"

Summary of the more important parts and sections of an amendment to British Law relating to protection of its coast against erosion and encroachment by the sea.

II-B "Generalization of the Formula for Calculation of Rock Fill Dikes and Verification of its Coefficients" by Ramon Iribarren Cavanilles

Translations from the author's article in the Spanish Language. The author's formula for determining stable

rock size presented in an earlier Bulletin article (Vol. 3 - No. 1) is discussed and certain modifications and generalizations are introduced bearing on evaluation of the constant term as based on 12 years experience since the original formula was introduced.

II-B "Application of Asphalt in Hydraulic Engineering Works" by J. H. Van der Burgt

A translation of a Dutch paper describing use of asphalt in hydraulic works in The Netherlands. General standards and uses for asphalt are discussed and detailed description (with photographs) of actual coastal projects in The Netherlands are presented.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

ISSUE NO. 2 - April 1951

I-A "Limiting Batter (Slope) Between the Breaking and Reflection of Waves" by Ramon Iribarren Cavanilles and Castro Nogales y Olano

A formula previously presented by the authors, expressing the limiting slope of a structure in terms of incident wave characteristics where slopes flatter than the limiting slope result in breaking waves and steeper slopes result in reflected waves, is discussed and re-examined in light of further experimental work by other investigators. The limiting slope given by the formula is verified to be the mean slope between that resulting in total breaking and that resulting in total reflection.

II-A "Wave Diffraction for Oblique Incidence" by Henri Lacombe

Translation from the French language of an article appearing in December 1950 Information Bulletin of the Comite Central d'Oceanographie et d'Etude des Cotes. Theoretical solution of this problem is discussed in relation to simplified solution by others.

II-C "Observations Made on Karentes Beach" by Professor W. W. Williams and Miss C. A. M. King, Cambridge University

Translation of a technical note appearing in the Information Bulletin of the Comite Central d'Oceanographie et d'Etude des Cotes in December 1950. Bar formations were studied in detail from surveys made over a 3-year period on a beach area subject to a small tidal range (less than 1/2 foot).

II-A "Comparison of Observed Wave Direction With a Refraction Diagram" by Donald R. Forrest

During a period of exceptionally good visibility observations of offshore wave direction at Mission Bay, California were made with the transit sighting bar (described in Vol. 4 - No. 2 of Bulletin) and compared with directions obtained from wave refraction analysis. On the whole, agreement is good.

"Beach Erosion Studies"

Summary of completed cooperative study report of Nantasket Beach, Massachusetts is presented. Listing of those cooperative studies still in progress also included.

"Beach Erosion Literature"

Listing of subjects and authors of papers presented at the Institution on Coastal Engineering, University of California, at a conference in Long Beach, California.

ISSUE NO. 3 - 1 July 1951

II-C "Bypassing Littoral Drift at a Harbor Entrance"
E
F

Translation of a pamphlet in Spanish entitled "Draja Fija" published in 1950 by "Junta Directiva de Puertos Libres Mexicanos". The shoaling problem in the Free Port of Salina Cruz, Mexico is described, and a stationary dredging plant nearing completion for bypassing the littoral drift is described in detail with photographs.

I-A "Calculation of Diffracted Wave Height Behind A Semi-Infinite Jetty" by C. Carry and E. Chapus, La Houille Blanche, January-February 1951

Curves giving diffracted wave height for incident waves normal, 45 degrees and 135 degrees to a breakwater are

given using results derived by the method developed by Putnam and Arthur, and are compared with results of laboratory experiments.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on Quincy Shore, Revere Beach, and Lynn-Nahant Beach, Massachusetts are presented. Listings of all completed cooperative study reports and those still in progress are also presented.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

ISSUE NO. 4 - 1 October 1951

II-A "A Method for Drawing Orthogonals Seaward From Shore" by Thorndike Saville, Jr.

Detailed description of the method is presented including drawings of protractors to be used in applying the method. A comparison is shown between the orthogonal drawn from shore out with that drawn from deep water into shore.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

"Beach Erosion Development Studies"

The General Investigations and Research Programs of the Beach Erosion Board are outlined.

"Beach Erosion Literature"

Abstracts of acquisitions to the Board's Library.

VOLUME 6 - 1952

ISSUE NO. 1 - 1 January 1952

I&II-A B C D "Summary Report on Studies of Sand Transportation by Wave Action"

This report is a summary of investigations conducted by

the Department of Engineering, University of California under contract to the Beach Erosion Board. The studies summarized are grouped under general headings of Model Studies, Field Studies, and Wave Recorders and Wave Data.

II-A "Discussion - A Method for Drawing Orthogonals Seaward from Shore" by Kenneth Kaplan, U. S. Army Engineer District, San Francisco

Points out that Mr. R. W. Lome, formerly with the San Francisco District, had previously developed a method for solving this problem without the need for special protractors.

II-A "On the Expansion of Sea Waves Due to the Effect of Wind"

An abstract of the translation from the German of a paper by Hans Ulrich Roll which appeared in "Deutsche Hydrographische Zeitschrift". Wave and wind measurements made in tidal waters of "Neuwerk Shallows" in the North Sea are compared with theoretical results based on methods of Sverdrup and Munk. Differences are pointed out and discussed. However, the author regards the results of the Neuwerk measurements as a verification of the Sverdrup-Munk theory.

II-A "The Generation of Wind Waves"

An abstract of the translation from the German of a paper by Gerhard Neumann which appeared in "Deutsche Hydrographische Zeitschrift". A new treatment of theory of wave generation by wind is presented. Height and length of initial waves generated by incident winds of different velocities for both deep and shallow water are computed and compared.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

"Beach Erosion Literature"

Contents of the Proceedings of the First Conference on Coastal Engineering are listed.

ISSUE NO. 2 - 1 April 1952

II-E "Effective Height of Seawalls" by Kenneth Kaplan, Beach Erosion Board

A comprehensive discussion of the factors involved in determining the efficiency of vertical face and curved re-entrant face seawalls in turning back damaging wave action. Criteria for height required for total effectiveness and a basis for establishing relative effectiveness of walls of lesser height are presented.

I-D "Laboratory Study of an Electromagnetic Current Meter"

Description of laboratory tests made to develop a meter capable of measuring and recording internal water velocities associated with wave motion. The electromagnetic meter studied was unsatisfactory as the velocity-induced voltages were to a great extent masked by chemically-induced voltage.

"Progress Reports on Research Contracts"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities of other institutions. Among a number of other items, an abstract of a detailed report by Parker D. Trask of the University of California based on his inspection of the stationary sand bypassing plant at Salina Cruz Harbor, Mexico is presented. Functional aspects of the plant are reviewed and its operation discussed.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on Pawleys Island, Edisto Beach and Hunting Island, South Carolina, State of Ohio-Fairport to Ashtabula, and State of Ohio - Ashtabula to the Pennsylvania State Line are presented. Listing of those cooperative studies still in progress is also presented.

ISSUE NO. 3 - 1 July 1952

II-A "A Method of Separating Multiple Systems of Ocean Waves for Detailed Study of Directions and Other Properties" by H. A. Ward, Beach Erosion Board

The technique described is applied to aerial photographs whereby wave crests from obvious directions are blocked

out by a system of parallel lines thereby causing wave crests from less obvious directions to stand out which could otherwise go unnoticed.

II-C E "Developments in the Science of Coastal Engineering" by Captain Peter Somers, Executive Officer, Beach Erosion Board

A brief general description of the physical factors involved in solution of shore problems, functional methods of correcting the problem, and research studies to provide new knowledge of these factors and functions.

II-E "Notes on Determination of Stable Underwater Breakwater Slopes" by Kenneth Kaplan, Beach Erosion Board

A brief discussion of the applicability of the original Iribarren formula to the underwater slopes of rubble mound breakwaters.

II-A "A New Method for the Graphical Construction of Wave Refraction Diagrams" by T. Saville, Jr. and K. Kaplan, Beach Erosion Board

The new method is developed and discussed in detail including drawings of protractors or overlays to be used in its application. An example case with results by other methods as well as the new method of Saville and Kaplan is presented and the relative accuracy discussed.

"Beach Erosion Studies"

Summary of a completed cooperative study report on State of Connecticut - Connecticut River to Hammonasset River is presented. Listings of all completed cooperative studies and those still in progress are also presented.

ISSUE NO. 4 - 1 October 1952

II-A D "Description and Operating Instructions for Wave Gage WH-1"

Detailed description (including photographs) and operating instructions for an underwater pressure response type of wave gage are presented. The gage is designed for use in water depths up to 60 feet and does not require a structure to support it.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities or other institutions, and brief statements regarding the status of research projects being prosecuted in the Board's own laboratory are presented.

"Beach Erosion Studies"

Summary of a completed cooperative study report on the Illinois Shore of Lake Michigan and a listing of cooperative studies still in progress are presented.

"Beach Erosion Literature"

The contents of the Proceedings of the Second Conference on Coastal Engineering, held at Houston, Texas in November 1951, are listed.

VOLUME 7 - 1953

ISSUE NO. 1 - 1 January 1953

II-C "Longshore and Coastal Currents at Scripps Institution Pier" by F. P. Shepard and D. B. Sayner, Scripps Institution of Oceanography

Current direction and velocity were measured at three locations along the 1,000-foot pier at Scripps Institution in La Jolla, California. Measurements were made inside the breakers, just outside the breakers and at the end of the pier, and wind, wave, and weather conditions recorded. The data is analyzed and discussed and relationships between currents inside and outside the breakers established.

II-E "Charts and Tables for Determining Surface Stone Sizes for Rubble Mound Structures in Wave Action" by W. H. Vesper and Kenneth Kaplan, Beach Erosion Board

Application of the Iribarren formula as modified by Hudson to make it dimensionally homogeneous is discussed for both

surface and subsurface stones. Charts and Tables facilitating solution of the basic equation are presented.

II-F "Japanese Research in Physical Oceanography, 1948-1950"

Information prepared by Dr. Koji Hidaka, Geophysical Institute, Tokyo University, summarizing research efforts in physical oceanography in Japan. Japanese agencies involved with the program, periodicals and journals issued by Japanese institutions and societies, and a list of Japanese references are also included.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities and other institutions, and brief statements regarding the status of research projects being prosecuted in the Board's own laboratory are presented.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on California - Carpinteria to Point Mugu, Connecticut - Pawcatuck River to Thames River, and Ohio Shoreline of Lake Erie - Sandusky to Vermilion, and listing of those cooperative studies still in progress are presented.

SPECIAL ISSUE NO. 2 - March 1953

II-A "Shore Protection Planning and Design (Preliminary Issue)"
C
E

A preliminary printing of a comprehensive manual for technical persons concerned with design of shore protection measures. Comments were invited from those receiving this preliminary issue, and the manual has subsequently been completed in final form.

ISSUE NO. 2 - 1 April 1953

I-A "The Reflecting Power of Maritime Works Exposed to Action of the Waves" by M. Miche

An abstract of a translation of Mr. Miche's paper originally appearing in June 1951 in the Annals of the Highway Department, National Press (France). Mr. Miche's work is an extension of the work of Iribarren and Nogales

reported in Vol. 5 - No. 2 of the Board's Bulletin. Relationships useful in design for determining the amplitude of the reflected wave for particular incident waves and types of slopes of the intercepting structures are evolved.

II-A "Notice of Publication for New Method of Drawing Wave Refraction Diagrams"

The new method by R. S. Arthur, W. H. Munk and J. D. Isaacs presented in an article published elsewhere is described and a drawing of the protractor to be used with the method is included. The new method is considered to be simpler and quicker at no sacrifice in accuracy than other methods in general use.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several contracts in force between the Beach Erosion Board and universities or other institutions, and brief statements regarding the status of research projects being prosecuted at the Board's own laboratory are presented.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on Connecticut - Niantic Bay to Connecticut River and Racine County, Wisconsin, and listing of those cooperative studies still in progress are presented.

"Beach Erosion Literature"

Abstracts of four reports on research performed by the University of California for the Office of Naval Research.

ISSUE NO. 3 - 1 July 1953

II-A "Calculation of Refraction Factor Along a Wave Ray" by Robert S. Arthur, Scripps Institution of Oceanography

Application of theory for calculating the refraction factor along a single ray without drawing a second ray is discussed, and an example is worked out. The method is time consuming however, and is suggested for special rather than general use.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities or other institutions, and brief statements regarding the status of research projects being prosecuted at the Board's own laboratory are presented.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on Ohio Shoreline of Lake Erie - Sheffield Lake Village to Rocky River, Ocean City New Jersey, Virginia Beach Virginia, and Sandusky Bay Ohio, and a listing of those cooperative studies still in progress are presented.

ISSUE NO. 4 - 1 October 1953

II-A "Comparison of Deep Water Wave Forecasts by the Darbyshire and Bretschneider Methods and Recorded Waves for Point Arguello, California, 26-29 October 1950"

The major disparity observed from the comparison was in the time element. Highest significant wave heights from the Darbyshire method were about 16 hours later than those recorded with the wave gage, while those obtained with the Bretschneider revised Sverdrup-Munk method were about 2 hours early.

II-A "A Comparison of Observed and Hindcast Wave Characteristics off Southern New England" by Robert F. Dearduff, Beach Erosion Board

Time phase element between observed and hindcast wave patterns for times of greatest wave height and period showed good agreement. Hindcasts were made by Bretschneider-revised Sverdrum-Munk method. Observed wave lengths were generally 50 percent less than theoretical lengths computed by $L_o = 5.12\ T^2$, and thus supports findings of other investigators.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and

universities or other institutions, and brief statements regarding the status of research projects being prosecuted at the Board's own laboratory are presented.

"Beach Erosion Studies"

Summaries of completed beach erosion control study reports on Plum Island Massachusetts, State of Connecticut - New Haven Harbor to Housatonic River, Cold Spring Inlet (Cape May Harbor) New Jersey, Presque Isle Peninsula Pennsylvania, Ohio Shoreline of Lake Erie - Vermilion to Sheffield Lake Village, and Waikiki Beach Territory of Hawaii, and a listing of those studies still in progress are presented.

"Beach Erosion Literature"

The contents of the Proceedings of the Third Conference on Coastal Engineering, held at Boston, Massachusetts in October 1952, are listed.

VOLUME 8 - 1954

ISSUE NO. 1 - 1 January 1954

I-A "Ripple Tank Studies of the Motion of Surface Gravity-Waves" by Osvald Sibul, University of California

Discussion and photographs of wave refraction and diffraction phenomena under various types of problem conditions as illustrated by a ripple tank.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities or other institutions, and brief statements regarding the status of research projects being prosecuted at the Board's own laboratory are presented.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on Gulf Shore of Galveston Island Texas, State of Connecticut -

Housatonic River to Ash Creek, and State of California - Point Mugu to San Pedro Breakwater, and a listing of those cooperative studies still in progress are presented.

ISSUE NO. 2 - 1 April 1954

II-D "Tidal Current Meters"

A description with photographs of modifications made by personnel of the U. S. Bureau of Reclamation to the Peagram Meter originally designed by Dean G. B. Peagram of Columbia University to measure water velocities. Modifications to the meter described permit its use for measuring flow in natural channels under influence of tides.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities or other institutions, and brief statements regarding the status of research projects being prosecuted at the Board's own laboratory are presented.

"Beach Erosion Studies"

Summaries of completed beach erosion control study reports on Hampton Beach New Hampshire, Selkirk Shores State Park New York, State of Ohio - Euclid to Chagrin River, Lake Erie Shore of the State of Ohio, Shore of Galveston Bay from April Fool Point to Kemah Texas, and Anaheim Bay Harbor California, and a listing of those studies still in progress are presented.

ISSUE NO. 3 - 1 July 1954

II-E "Shore Protection in Harrison County, Mississippi" by Francis F. Escoffier and William L. Dolive, U. S. Army Engineer District Mobile.

A description of the construction and effectiveness of the Federally authorized beach erosion control project. A protective beach was provided for about 25 miles of Mississippi Sound shoreline and repairs made to an existing seawall.

"Comparison of Hindcast and Observed Waves Along the New Jersey Coast for the Storm of November 6-7, 1953" by Kenneth Kaplan and Thorndike Saville, Jr., Beach Erosion Board

Wave hindcast data determined by students in a class on wave phenomena held at the Beach Erosion Board and by the Board's staff instructors (the authors) is compared and differences discussed. Comparison is also made between results obtained by the Bretschneider-revised-Sverdrup-Munk method and by Pierson-Neumann method of wave forecasting.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities or other institutions, and brief statements regarding the status of research projects being prosecuted at the Board's own laboratory are presented.

"Beach Erosion Studies"

Summary of a completed cooperative study report on Pinellas County, Florida is presented. Listings of all completed cooperative studies and those still in progress are also presented.

ISSUE NO. 4 - 1 October 1954

I-A "A Statistical Study of the Effect of Wave Steepness on Wave Velocity" by Rudolph P. Savage, Beach Erosion Board

Wave velocities determined theoretically by Airy theory neglecting effect of wave steepness and by Stokes theory considering wave steepness are compared with wave velocities measured in a laboratory wave tank. The relative effects of the steepness function and the depth-wave length function on the theoretical velocity correction for the effect of wave steepness is also investigated.

II-C "Travelling Forelands and the Shore Line Processes Associated With Them" by Francis P. Escoffier, U. S. Army Engineer District Mobile

The importance of the angle of incidence of waves causing the cuspate foreland to migrate and grow is discussed.

The concept of a most favorable drift-producing angle is used to explain the processes involved.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities or other institutions, and brief statements regarding the status of research projects being prosecuted at the Board's own laboratory are presented.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

VOLUME 9 - 1955

ISSUE NO. 1 - 1 January 1955

II-A "A Simplified Method of Determining Durations and Frequencies of Waves Greater or Less than a Specified Height" by Thorndike Saville, Jr., Beach Erosion Board

A method is shown whereby forecasts can be made determining whether waves are greater or lesser than a pre-determined limiting height without forecasting the actual height. This simplifies the procedure considerably for cases where actual wave heights are not required.

II-A "A Comparison of Deep Water Wave Forecasts by the Pierson-Neumann, the Darbyshire, and the Sverdrup-Munk-Bretschneider Methods with Recorded Waves for Point Arguello, California for 26-29 October 1950" by Robert F. Dearduff, Beach Erosion Board

The relatively new Pierson-Neumann or Wave Spectra Method for forecasting resulted in higher average wave heights than the other methods, and even higher heights than were recorded by the wave gage were indicated for part of the storm's duration. Difficulties encountered in application of the new method and probable sources of error are discussed.

II-C
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"Status of Sand Bypassing Plant at Salina Cruz Harbor, Isthmus of Tehuantepec, Mexico"

A brief report on the general progress of this bypassing plant since 1952. Measures taken to retard the flow of sand to this plant are described.

"Progress Report on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities or other institutions, and brief statements regarding the status of research projects being prosecuted at the Board's own laboratory are presented.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

ISSUE NO. 2 - 1 April 1955

II-C
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"Sand Bypassing at Hillsboro Inlet, Florida" by Thelbert K. Hodges, U. S. Army Engineer District Jacksonville

A plan to be accomplished by local interests for maintaining navigation facilities in the inlet and supplying sand to nourish downdrift beaches under the same operation is described.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Abstracts from progress reports on the several research contracts in force between the Beach Erosion Board and universities or other institutions, and brief statements regarding the status of research projects being prosecuted at the Board's own laboratory are presented.

"Beach Erosion Studies"

Listing of cooperative studies in progress.

VOLUME 10 - 1956

ISSUE NO. 1 - July 1956

II-A "Wind Distribution Over Sea Waves" by Ulrich Roll

A translation made at the University of California of a paper originally published in the German language in 1948 in "Naturwissenschaften". Wind velocity measuremants in the air layer immediately adjacent to the water surface were made simultaneously with wave measurements in shallow water of the tidal flats off Neuwerk Island in the North Sea. Transformation of wind energy to waves on the basis of the measurements is discussed in relation to theory and model studies by others.

II-C E "Beach Erosion at Durban, South Africa"

A presentation of information obtained from correspondence with Colonel David E. Paterson, Beach Consultant to the City Council of Durban. A description (with photographs) of a beach erosion problem downdrift from harbor entrance structures and of efforts by local people to alleviate the problem, including sand bypassing, is presented.

I-C "Sediment Motion at the Vicinity of a Littoral Barrier" by Ning Chien, University of California

Laboratory model study to investigate the possible mode of sediment transportation at the vicinity of a littoral barrier such as a projecting cliffed headland. Sand transport rate for this condition is measured and compared to that for a normal sand beach, and model scale effects discussed.

I-A F "An Electronic Gage for Measurement of Small Waves and Ripples" by Francis W. Kellum, Beach Erosion Board

Detailed descriptions of circuits and elements of the gage, and its calibration, are presented. It is not necessary for this gage to touch the water surface. Its action depends on the variation of dielectrical capacity in the air space between the water surface and a probe.

I-B D "Development of a Suspended Sediment Sampler for Laboratory Use Under Wave Action" by John C. Fairchild, Beach Erosion Board

Factors affecting accuracy of sampling of suspended sediment load are investigated. Equipment suitable for sampling suspended sediment load in laboratory tanks is described and procedures for its use discussed.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Summaries of progress made during the previous year on the several research contracts in force between universities or other institutions and the Beach Erosion Board, together with brief statements regarding the status of some research projects being prosecuted in the Board's laboratory are presented.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on Grand Isle Louisiana, Fair Haven Beach State Park New York, Hamlin Beach State Park New York, Kenosha Wisconsin, Manitowoc County from Two Rivers to Manitowoc Wisconsin, State of New Jersey - Sandy Hook to Barnegat Inlet, Braddock Bay State Park New York, Perdido Pass (Alabama Point) Alabama, Oceanside - Ocean Beach - Imperial Beach - Coronado of San Diego County California, State of Connecticut-East River to New Haven Harbor, Atlantic Coast of Long Island-Fire Island Inlet and Shore Westerly to Jones Inlet - New York, and Waimea and Hanapepe - Kauai Territory of Hawaii, are presented. Listings of all completed cooperative study reports and those studies still in progress are also presented.

VOLUME 11 - 1957

ISSUE NO. 1 - July 1957

I-A E "Model Tests of Wave Run-up for Hurricane Protection Project" by Rudolph P. Savage, Beach Erosion Board

Wave run-up data is evaluated for certain beach and dune and tide conditions from small scale investigations in a laboratory wave tank.

II-A F "Wave Refraction Plotter" by R. Q. Palmer, Honolulu Area, U. S. Army Engineer District San Francisco

A plotter devised for constructing wave refraction diagrams is depicted and procedures for its use explained. The plotter is attached to a standard drafting machine. More than twice the production, with fewer errors, is claimed through use of the plotter when compared with use of the standard template or protractor.

II-A C E "Status of Research in Shore Line Protection" by Joseph M. Caldwell, Beach Erosion Board

An unpublished paper delivered before the American Society of Civil Engineers in August 1955. A rather complete summary regarding the status of investigation and knowledge in the field of coastal engineering is presented under three general headings of Wave Action, Shore Processes and Improvement Works. A bibliography of 41 references is also included which present the details of the material summarized.

II-D "Tests of River Crest Stage Gage Under Wave Action" by Thorndike Saville, Jr., Beach Erosion Board

A river crest stage gage is investigated to determine feasibility of its use to measure maximum water elevations in estuaries and adjacent low-lying areas resulting from hurricane surges. It was found that the gage could be modified to permit its use for this purpose with a maximum error of only a few tenths of a foot even under conditions of relatively high wave action.

"Progress Reports on Research Sponsored by the Beach Erosion Board"

Summaries of progress made during the previous year on the several research contracts in force between universities or other institutions and the Beach Erosion Board, together with brief statements regarding the status of some research projects being prosecuted in the Board's laboratory, are presented. A list of all Technical Memoranda (Nos. 1-97) published by the Beach Erosion Board through June 1957 is included.

"Beach Erosion Studies"

Summaries of completed cooperative study reports on Saco Maine, Chatham Massachusetts, State of Connecticut -

Saugatuck River to Byram River, Santa Cruz County California, and State of Delaware - Kitts Hummock to Fenwick Island, are presented. Listings of all completed cooperative study reports and those studies still in progress are also presented.

NO. 1 - May 1940

I-E "A Model Study of the Effect of Submerged Breakwaters on Wave Action" by 1st Lt. William C. Hall, CE

A general model study to determine the effect, under varied conditions, of underwater sills upon wave heights and the power of the waves. General conclusions are drawn regarding shape and effectiveness of such structures.

NO. 2 - February 1942

I-B C "Abrasion of Beach Sand" by Dr. Martin A. Mason

A study to examine into the rate of loss by abrasion with a view to ascertaining its importance in beach erosion processes. Work by others as well as experiments at the Beach Erosion Board Laboratory submitting anthracite coal to wave action in a laboratory wave tank are discussed. Conclusions state that loss of beach material ascribable to abrasion is of very minor importance compared to losses and gains of material ascribable to littoral movement.

NO. 3 - May 1944

II-B C "Shore Processes and Beach Characteristics" by W. C. Krumbein

Natural variables required for study to specify physical laws controlling environmental behavior are discussed. The problem for study was formulated as follows: given a bay with associated headlands, beach, and cliffs, to evaluate the physical processes which occur there. Relations between wave energy, beach slopes, sand size, erosion and deposition were studied and are discussed for the compartmented coastal region of Halfmoon Bay, California.

NO. 4 - May 1944

II-C F "Surface Features of Coral Reefs" by Dr. Lincoln Dryden

Data obtained by investigators who have measured and

studied surface features of coral reefs are briefly summarized and application of these basic data to the interpretation of aerial photographs of coral reefs is discussed. 44 photographs depicting variable and common surface features of coral reefs are included and discussed.

NO. 5 - May 1944

I-D "A Wave Method for Determining Depths Over Bottom Discontinuities" by Dr. Martin A. Mason and Dr. Garbis H. Keulegan

A method is presented for determining water depth over bottom discontinuities by measuring comparative wave lengths from aerial photographs. The formula of comparison was determined experimentally in a model wave tank for reefs of three different physical conditions, but field check of the experimental results was not possible at the time.

NO. 6 - October 1948

II-A D "An Ocean Wave Measuring Instrument" by Joseph M. Caldwell

Methods for measuring height and period of water waves and their relative advantages and disadvantages are discussed. The development of a step-resistance staff gage for measuring fluctuations of the sea surface at the gage site is described in detail and is concluded to be a satisfactory and accurate instrument. The gage is not suitable for use in locations where a suitable supporting structure is not available.

NO. 7 - September 1944

I-C "Shore Currents and Sand Movement on a Model Beach" by W. C. Krumbein

Uniform waves were run at an angle to a sloping sand beach in a laboratory wave tank, and the alongshore current and sand movement measured. Relation of alongshore current velocity, rate of sand movement, and wave characteristics were studied on a small scale basis, but utilizing dimensionless parameters. Relations of beach slope and sand sorting to wave characteristics were also studied.

NO. 8 - July 1945

II-D "Depths of Offshore Bars" (Dr. G. H. Keulegan)

A method for predicting depths over crests and in troughs of offshore bars is outlined. Information on the position and size of bars gathered from existing literature and laboratory tests is briefly discussed and summarized.

NO. 9 - July 1948

II-D "Proof Test of Water Transparency Method of Depth Determination" by J. V. Hall, Jr.

A report on field tests made to determine practicability of a method developed by the British Army during World War II to determine water depths from aerial photographs. Conclusions reached indicate the method to be unsuitable for either military or civil application due to extreme difficulties encountered in obtaining suitable photography and controlling results through strict laboratory procedure. Strict criteria for meteorological and oceanographic conditions are necessary to obtain usable photographs.

NO. 10 - 1948

II-E "Experimental Steel Pile Groins Palm Beach, Florida"

Five experimental steel sheet pile groins were constructed on the Atlantic Coast at Palm Beach, Florida. Steel was donated by 5 steel companies, designs made by the Beach Erosion Board, and construction by the City of Palm Beach. Observations regarding deterioration of steel and protective coatings over a period of 10 years are reported and conclusions drawn regarding the manner of deterioration.

NO. 11 - November 1949

I-A "Reflection of Solitary Waves" by Joseph M. Caldwell

A laboratory study to determine and evaluate the effect of the several variables controlling the amount of wave energy reflected by representative beach or shoreline structures. Solitary waves were run against four simu-

lated conditions for shore structures and incident and reflected wave heights measured. Empirical relations are determined between the amount of energy absorbed for permeable and impermeable faces and such variables as thickness of structure, rock diameter, void percentage, and slope of seaward face.

NO. 12 - February 1952

II-E "Durability of Steel Sheet Piling in Shore Structures" by A. C. Rayner and Culbertson W. Ross

153 groups of steel sheet piling structures along the Atlantic Coast of the United States and the Gulf coast of Florida were studied and classified. Structures were selected for various conditions of exposure and treatment and types. Measurements and observations were made over a 10 year period and general conclusions presented regarding useful life of steel sheet piling. Measured and observed data are tabulated and appended to the report.

NO. 13 - January 1950

II-C "Longshore Current Observations in Southern California" by Dr. Francis P. Shepard

Currents were measured in the surf zone at frequent intervals throughout a year along the Southern California coast. Study shows the dominant currents in the area from the Mexican Border to Newport to be to the south. North currents prevail during a large part of the summer and fall. Strong alongshore currents exist even during times when large waves approach from directions essentially normal to the beaches. Importance of currents moving along the shore away from points of wave convergence is demonstrated.

NO. 14 - March 1950

II-C "Report on Beach Study in the Vicinity of Mugu Lagoon, California" by D. L. Inman

An investigation to determine the relative stability of the beaches and sand spits in the vicinity of Point Mugu and to make recommendations for their preservation. Investigations show beaches and sand spits bordering Mugu

Lagoon are not stable. The effect of spring tide, high waves, and direction of alongshore transport of sand on the stability of the spits bordering Mugu Lagoon is discussed.

NO. 15 - January 1950

II-C "Longshore - Bars and Longshore Troughs" by Dr. Francis P. Shepard

The submerged longshore-bars and longshore-troughs which skirt the shores off most sandy beaches are described and explained. The depths of the bars and troughs are shown to be related to wave and breaker heights. Analysis of hundreds of profiles taken mostly on the west coast of the United States is the chief basis for conclusions in the report.

NO. 16 - May 1950

II-B C "Accretion of Beach Sand Behind a Detached Breakwater" by John W. Handin and John C. Ludwick

The problem of sand transport by longshore current is clarified by observing effects of the detached offshore breakwater at Santa Monica, California. Correlation is attempted between transporting power of longshore forces, median grain sizes of the beach sand, and the position of the breakwater.

NO. 17 - June 1950

II-C E "Test of Nourishment of the Shore by Offshore Deposition of Sand" by J. V. Hall, Jr. and W. J. Herron

Field investigations to test the feasibility of nourishing eroded shores with spoil from hopper dredges are reported. Test included deposition, in 38 feet of water about half a mile offshore from Long Branch, N. J., of about 600,000 cubic yards of sand dredged in maintenance of New York Harbor channels, and a study of its movement by natural forces.

NO. 18 - July 1950

II-A "The Rayleigh Disk as a Wave Direction Indicator" by J. V. Hall, Jr.

The principles of operation of the Rayleigh Disk in stream

flow and wave systems are presented, and its erratic behavior when used as a wave direction gage under natural conditions at Long Branch, N. J. and Huntington Beach, Calif. is discussed.

NO. 19 - July 1950

II-B C "Submarine Topography and Sedimentation in the Vicinity of Mugu Submarine Canyon, California" by D. L. Inman

The bathymetry of the adjacent shelf and the submarine canyon heads adjacent to the beach and lagoon is presented and described. Mugu Submarine Canyon has two branches at its head, each having an isolated ridge protruding from the floor parallel to the canyon axis. The relation of sediment type and bottom topography is investigated.

NO. 20 - July 1950

II-C "Beach Cycles in Southern California" by Francis P. Shepard

From a mass of records and data accumulated on California beaches, salient features observed are discussed and their interpretation attempted. Features discussed include seasonal changes both offshore-onshore and lateral movement, long term trends, changes associated with engineering structures, and relationship of permanent and temporary losses.

NO. 21 - November 1950

I&II-A "The Interpretation of Crossed Orthogonals in Wave Refraction Phenomena" by Dr. Willard J. Pierson, Jr.

The theory of wave refraction is critically reviewed. Analytical examples of caustic curves are given, and it is shown that the theory of wave refraction as based upon geometrical optics fails at the caustic. More refined techniques lead to the result that there is a phase shift through the caustic and that the waves remain finite in height, and possible results of the solution are discussed. Results of other investigators are applied to a model study of refraction of waves over a clock glass, and the 180-degree phase shift through a caustic is demonstrated. The orthogonal method of refraction analysis is applied for

Long Branch, N. J., and caustic curves and overlapping wave trains are found. More accurate techniques for use after a sufficient number of orthogonals have been constructed are described, and evidence is given confirming theoretical deductions of this paper. It is shown that further theoretical and practical studies are needed, and specific suggestions for future research are given.

NO. 22 - March 1951

II-B C "The Source, Transportation, and Deposition of Beach Sediment in Southern California" by John W. Handin

Detailed description of beaches and coastal physiography from Carpinteria to Point Fermin, California is presented. Details of submarine geology and wind and wave forces are also given. A detailed petrographic analysis of beach, stream and dune sands is presented and sources of beach sediments discussed. Discussion of the transportation and deposition of beach sands (littoral drift) is also included.

NO. 23 - May 1951

II-B "The Use and Accuracy of the Emery Settling Tube for Sand Analysis" by D. M. Poole, W. S. Butcher and R. L. Fisher

The accuracy of the Emery Settling Tube for the analysis of sand particles has been investigated. This method is more rapid than dry sieving and gives equivalent, or settling, diameters rather than geometric diameters. The paper confirms the reproducibility of the results obtained from the settling tube, the close correlation with sieve analysis, and gives a detailed recommended procedure. For size ranges of most beach sands the accuracy of the two methods is nearly the same.

NO. 24 - April 1951

II-A "The Accuracy of Present Wave Forecasting Methods with Reference to Problems in Beach Erosion on the New Jersey and Long Island Coasts" by Willard J. Pierson, Jr.

A study is made to attempt to determine whether or not wave forecasting techniques can yield the observed values of wave parameters within the choices possible for selecting forecasting parameters under limitations

of available data. Detailed weather data and wave data were obtained for the period from 22 April to 31 May 1958. In general good agreement between observed and forecasted significant wave heights is obtained. Statistical study of results indicates forecasted significant periods are not accurate and are not distributed according to the distribution of observed significant periods. It is shown that forecasted values for deep water were so inaccurate that verification of the refraction diagram for Long Branch, N. J. was not possible. The data are considered sufficiently accurate to permit qualitative discussion of problems connected with beach erosion. Some of the effects of an east coast storm on the shoreline are described, and statistical properties of east coast storms given.

NO. 25 - November 1951

II-C "The Slope of Lake Surfaces Under Variable Wind Stresses" by B. Haurwitz

The inclination of a lake surface caused by a wind stress shows a distinct time lag in adjusting itself to changing winds. This phenomenon is analyzed utilizing hydrodynamic equations simplified by integrating over the whole depth of the lake, and it is found a priori that the time required depends on the length of the seiche periods. Particular attention is given to a wind shift which took place during the passage of a hurricane, 26-27 August 1949, over Lake Okeechobee, Florida, when the wind turned through about 180 degrees during a time of roughly three hours. The turning of the wind was accompanied by a turning of the height contours of the lake surface, but the latter rotated more slowly so that for some time the wind blew parallel to them. It is shown that the theory explains this behavior of the lake surface.

NO. 26 - November 1951

II-C "Sand Movement on the Shallow Inter-Canyon Shelf at La Jolla, California" by F. P. Shepard and D. L. Inman

The nature of changes in sand level of a beach and shallow shelf area between two submarine canyon heads has been indicated by eight repeated surveys accompanied by five sampling operations, which are believed to establish significant changes out to depths of at least 100 feet. Wave

observations were also obtained and refraction analysis made. Sand level changes between surveys are plotted and sand movement over the shelf analyzed.

NO. 27 - June 1952

II-A C "Wind Set-up and Waves in Shallow Water" by Thorndike Saville, Jr.

Results of an analysis of certain wind, wave, and water level data obtained in Lake Okeechobee, Florida, during the passage of two hurricanes, one in August 1949 and the other in October 1950, are presented. Observed wind set-up and wave heights are related to wind velocity, fetch, water depth, and surface shape of the lake. Coefficient evaluated in the expression for wind set-up is in close agreement with those previously developed by others from model experiments and data taken in the Zuiderzee.

NO. 28 - October 1952

II-B C "Source of Beach Sand at Santa Barbara, California as Indicated by Mineral Grain Studies" by Parker D. Trask

Mineralogical study of sand grains in Santa Barbara Harbor and along the coast west and north of the harbor for a distance of more than 250 miles were made. A series of 300 samples of beach, river, and offshore sands were collected amd analyzed. It is shown that a significant proportion of the sand at Santa Barbara comes from a distance of more than 100 miles upcoast, and that this sand moves around Point Conception. The distribution of minerals along the shore is described and the mechanism of transport around promontories and the Santa Barbara breakwater is discussed.

NO. 29 - December 1952

II-E "Artificially Nourished and Constructed Beaches" by Jay V. Hall, Jr.

Criteria for design of artificially nourished beaches are outlined. Four types of artificial nourishment methods that have been tried in the United States are described; namely offshore dumping, stockpiling, continuous supply, and direct placement methods. Brief histories of five areas where these methods have been employed are presented. A tabular record of a great number of artificially nourished and constructed beaches including factors relating to their placement and economic life is appended.

NO. 30 - February 1953

II-A F "Annotated Bibliography on Tsunamis" by Marcial P. Cuellar

A bibliography of 195 items prepared and annotated as a project of the Committee for the Study of Tsunamis, American Geophysical Union.

NO. 31 - February 1953

I-A "Laboratory Study of Wave Energy Losses by Bottom Friction and Percolation" by Rudolph P. Savage

The theory for dissipation of wave energy by bottom friction (Putnam and Johnson) and by percolation in a permeable sea bottom (Putnam) were checked by laboratory experiment. The experimental data were obtained in a wave flume divided by a splitter wall, one side of which had a smooth bottom with essentially no bottom friction or percolation and the other side a rough (rippled) or a permeable sand bottom. Energy losses were measured as reduction in wave height. Experimental losses due to friction agreed reasonably well with those given by theory for conditions of natural ripples, but were substantially greater for artificial ripples dissimilar to natural ripples. Experimental losses due to percolation were far less than theoretical values, the difference apparently varying with water depth.

NO. 32 - March 1953

II-D "Accuracy of Hydrographic Surveying in and Near the Surf Zone" by Thorndike Saville, Jr., and Joseph M. Caldwell

The results of a study to determine on a statistical basis the degree of accuracy that can be expected in hydrographic survey work where comparability of successive surveys is a prime consideration are presented. Test surveys to determine the magnitude of sounding error (accuracy with which the deduced profile actually represents the bottom hydrography along the particular range being sounded) and spacing error (accuracy with which the particular profile portrays the characteristics of its assigned section of beach or bottom) were made at Mission Beach, California. Application of the results of these tests indicates that serious misinterpretations of volumetric information derived from comparative surveys can result in the probable survey error is not considered.

NO. 33 - March 1953

I-A "Laboratory Investigations of the Vertical Rise of Solitary Waves on Impermeable Slopes" by Jay V. Hall, Jr., and George M. Watts

Empirical relationships between wave height, water depth, slope angle, and maximum elevation reached by a solitary wave running up the slope are derived by laboratory experiment. Measured wave velocity is also compared with theoretical values.

NO. 34 - March 1953

II-C D F "Development and Field Tests of a Sampler for Suspended Sediment in Wave Action" by George M. Watts

The development of a mechanical sampler to extract a representative sample of suspended sediment and measure the quantity of water from which it is extracted where material is in suspension due to wave action is described. Results of field tests with analysis of their significance made at Pacific Beach, California are also presented.

NO. 35 - March 1953

II-A "Analysis of Moving Fetches for Wave Forecasting" by Kenneth Kaplan

An analysis is presented in the interest of standardizing and simplifying wave forecasting procedures, and of making possible accurate wave forecasts by those with only a cursory knowledge of meteorological and wind wave theories. Changing weather situations which are possible between weather charts are grouped in eight categories according to relative positions of fetch front and rear and the energy front on successive weather charts, and relative lengths of the first chart's measured and minimum fetches. The eight situations are analyzed and forecasting procedures developed for each.

NO. 36 - March 1953

II-A C "Wave and Lake Level Statistics for Lake Michigan" by Thorndike Saville, Jr.

Detailed statistical wave data for deep water, based on hindcasts from synoptic weather charts for the 3-year

period 1948-1950, are presented for five stations on Lake Michigan. An example of the method for obtaining wave data for shallow water at a point between stations by interpolation and refraction analysis is worked out. Frequency data on lake levels are also presented.

NO. 37 - March 1953

II-A C "Wave and Lake Level Statistics for Lake Erie" by Thorndike Saville, Jr.

Detailed statistical wave data for deep water, based on hindcasts from synoptic weather charts for the 3-year period 1948-1950, are presented for four stations on Lake Erie. Frequency data on lake levels are also presented.

NO. 38 - March 1953

II-A C "Wave and Lake Level Statistics for Lake Ontario" by Thorndike Saville, Jr.

Detailed statistical wave data for deep water, based on hindcasts from synoptic weather charts for the 3-year period 1948-1950, are presented for three stations on Lake Ontario. Frequency data on lake levels are also presented.

NO. 39 - March 1953

II-B C "Areal and Seasonal Variations in Beach and Nearshore Sediments at La Jolla, California" by Douglas L. Inman

The nature of the seasonal distributions of certain physical properties of sediments on the beach and shallow shelf area between two submarine canyon heads was studied. Series of bottom samples were obtained periodically. Topographic surveys showing the changes in sand level were made concurrently with sediment sampling operations. Emphasis in the laboratory analysis of the sediments was on distribution of particle size, but other properties such as shape, roundness, heavy mineral and carbonate content were also measured. Movement of beach and bottom materials and areal distribution of their physical properties are presented and discussed.

NO. 40 - March 1953

I-A "The Mechanics of Deep Water, Shallow Water, and Breaking Waves" by Jack R. Morison and R. C. Crooke

Experimental data are presented for deep water, shallow water, and breaking waves with respect to the wave surface time history, the horizontal and vertical particle velocities and the particle orbits. The measurements are compared where applicable to Stokes wave theory. Results show that Stokes wave theory and other wave theories are in good agreement with the measurements for deep water conditions even to d/L values of approximately 0.2. The theories do not show agreement with measurements for shallow water conditions where d/L values are appreciably less than 0.2 and the waves have an appreciable steepness.

NO. 41 - August 1954

I-C "Laboratory Study of Equilibrium Profiles of Beaches" by Ralph L. Rector

Results of laboratory experiments utilizing regular wave trains of laboratory size with varying height-length ratios and four sizes of natural beach sands to determine the physical factors controlling the equilibrium profile of a beach and the interrelationships of these factors, are reported. Processes involved in the shaping of a beach profile by wave action are discussed, and empirical relations between profile shape and wave and sand size are involved.

NO. 42 - October 1953

II-C "A Study of Sand Movement at South Lake Worth Inlet, Florida" by George M. Watts

Results are reported for a study made in connection with the operation of a sand bypassing plant to investigate the effectiveness of the operation of such a fixed plant and to relate the volume of sand reaching the pump intake to the wave energy reaching adjacent shores. Field work included measurement of volume of material bypassed by the plant, recording of wave height, period and direction, measurement of alongshore currents, and procurement of sand samples. An empirical relationship between the rate of nearshore littoral movement and the shallow water wave energy is developed.

NO. 43 - December 1953

II-A "On Ocean Wave Spectra and a New Method of Forecasting Wind-Generated Sea" by Gerhard Neumann

Based on recent observations of the composite nature of wind-generated waves and on theoretical reasoning, the spectrum of ocean waves is derived for a continuous sequence of wave components. The properties of the wave spectrum are developed, and it is shown that the spectrum has an optimum band where most of the spectral energy is concentrated, and that the product of the frequency of the optimum band and wind speed is constant. The range of periods with a significant amount of energy, the width of the spectrum, determines the actual wave pattern. It depends upon the wind speed and the state of development of the waves at limited fetches and durations of wind action. For practical purposes, a number E with dimensions $(\text{feet})^2$ is introduced, which is proportional to the accumulated energy in the wave spectrum. This value E is derived by integrating the wave spectra, and permits easy determination of height characteristics of the composite wave motion. Results are presented in the form of co-cumulative power spectra for convenient use in practical wave forecasting.

NO. 44 - June 1954

II-C E "Coast Erosion and the Development of Beach Profiles" by Per Bruun

The first part of this paper consists of a study of the Danish North Sea coast including the following factors: coastline development; development of beach profiles including comparison for different wind/wave conditions; coast erosion and quantity of littoral drift; and forecasting future development of shoreline and beach profiles. Depth soundings since 1874 on the Lime Inlet Barriers are used and treated statistically, explaining development of these barriers and adjacent coasts. The second part consists of a study of the Mission Bay, California area, including study of: development of beach profiles with comparison for different wave conditions; seasonal fluctuations of profiles; and comparison of Danish and California data.

NO. 45 - October 1954

II-A "Modification of Wave Height Due to Bottom Friction, Percolation and Refraction" by C. L. Bretschneider and R. O. Reid

A report on a theoretical investigation of the transformation (including energy loss) of waves in shallow water by bottom friction, percolation, refraction and shoaling. Using dissipation functions introduced by Putnam and Johnson (1949), derived from the theory of progressive waves of small amplitude, a general solution of the steady state energy equation is obtained. For the case of a bottom of uniform slope and the case of a bottom of constant depth, the solutions are presented in convenient graphical form, making it possible to obtain the reduction factor due to friction or percolation for any bottom slope, depth, initial wave height or period if the friction factor and permeability coefficient for the bottom are known. An example involving refraction is also presented.

NO. 46 - September 1954

II-A "Field Investigations of Wave Energy Loss in Shallow Water Ocean Waves" by C. L. Bretschneider

Results of a field investigation of loss of wave energy from ocean waves passing through shallow coastal waters in the Gulf of Mexico off the coast of Louisiana and Texas are reported. Results from field observations are compared with existing theoretical treatments for losses due to bottom friction. As apparent friction factors determined appeared to be relatively high, energy losses due to oscillatory adjustment of the bottom to variation in wave pressure caused by the passage of surface waves are also considered. Analysis of recorded wave data for this project are included for comparison with previously published data on statistical distribution of wave heights in ocean wave trains.

NO. 47 - July 1954

I-A
F "Stability of Oscillatory Laminar Flow Along a Wall" by Huon Li

Results are reported for a laboratory study of the transition from laminar to turbulent flow in an oscillatory boundary layer near the solid bottom caused by a surface wave. For experimental convenience observations were made at a plate oscillating in still water. The relationships between the two flow conditions are discussed, and experimental results including observations for both smooth and rough surfaces are given.

NO. 48 - August 1954

I-A
C "Sand Movement by Waves" by Theodore Scott

A series of two-dimensional experiments were carried out in a laboratory wave flume using waves of both high and low steepness ratios to investigate the movement of sand along the bottom. Results presented are primarily on the effect of long and short period waves on beach and bar formation and onshore-offshore transport of material. Importance of relative amplitudes of vertical and horizontal components of orbital wave motion on sand movement and bottom ripple formation is discussed. Information is also presented on the mechanics of ripple formation and their relation to onshore-offshore movement.

NO. 49 - August 1954

II-B
C "Bore Hole Studies of the Naturally Impounded Fill at Santa Barbara, California" by Parker D. Trask and Theodore Scott

A series of 7 bore-holes were drilled in the accumulated fill area west of the breakwater and the cores analyzed. The fill area overlays areas formerly covered by sea water and thus information was obtained as to how sand accumulates both offshore and on the beach. Analysis and results of the study are presented.

NO. 50 - August 1954

II-B D "Statistical Significance of Beach Sampling Methods" by W. C. Krumbein

Beach sampling methods in terms of statistical principles are reviewed for the purpose of suggesting tentative plans for improving the representativeness in samples. Statistical methods used are discussed. Results of the study indicate no radical revisions of current sampling procedures are needed, but recognition of explicit design elements in the sampling plan can result in greater reliability of the data for comparable expenditure of time and effort.

NO. 51 - October 1954

II-A "Generation of Wind Waves Over a Shallow Bottom" by C. L. Bretschneider

A method is presented for predicting properties of waves generated in shallow water, obtained by a numerical combination of the relationships for (deep water) ocean wave generation devised by Sverdrup and Munk and revised by Bretschneider, with the theory of wave energy losses in shallow water devised by Putnam and Johnson and revised by Bretschneider and Reid. The method is essentially that of successive approximations wherein wave energy is added due to wind stress and subtracted due to bottom friction and percolation.

NO. 52 - December 1954

I-C "Laboratory Study of Effect of Tidal Action on Wave-Formed Beach Profiles" by George M. Watts and Robert F. Dearduff

Some two-dimensional tests to study equilibrium profiles of beaches previously made in a laboratory wave tank utilizing uniform wave trains were repeated introducing a tidal system and resulting profiles compared. Results indicate that introduction of tidal action causes no appreciable changes in foreshore and offshore slopes, but greater movement of material throughout the profile results in proportion to the tidal range, creating higher beach berms and recession of the shoreline. Formation of offshore bars and troughs inherent in the non-tidal tests due to wave reflections was inhibited by introduction of the tidal system.

NO. 53 - September 1954

I-A C "Laboratory Study of Effect of Varying Wave Periods on Beach Profiles" by George M. Watts

Tests were made in a laboratory wave tank to determine desirable magnitude and frequency of variations in wave periods in wave tank tests in order to eliminate irregularities in resulting beach profiles accentuated by use of a constant fixed period, and, thereby, more nearly approximate the profiles resulting in nature from wave trains with a variety of components. Profiles resulting from these tests were compared with those from similar tests utilizing constant wave periods, and foreshore and offshore slopes were found to be essentially identical. In general the variable period tests resulted in less actual material movement from the same test time. Offshore bar and trough formations inherent in constant period tests were greatly reduced by varying the wave period.

NO. 54 - November 1954

I&II-D F "Laboratory and Field Tests of Sounding Leads" by George M. Watts

Results of tests to determine the relationship between various sizes, shapes and weights of sounding leads, and the degree of penetration of the leads into bottom materials of various physical properties are presented. Tests were made both in the laboratory and in the field, and field data were compared with echo soundings. Of the leads tested, the spherical-shaped lead demonstrated characteristics more nearly approaching those needed for a "practical" shaped sounding lead.

NO. 55 - November 1954

II-A "North Atlantic Coast Wave Statistics Hindcast by Bretschneider-Revised Sverdrup-Munk Method" by Thorndike Saville, Jr.

Detailed statistical wave data for deep water, based on hindcasts from synoptic weather charts for the 3-year period 1948-1950, are presented for four stations in the North Atlantic off Penobscot Bay, Maine; off Nauset Beach, Cape Cod, Mass.; off New York harbor entrance; and off Chesapeake Bay entrance. An example of the method for

obtaining shallow water wave data at a point between stations by interpolation and refraction analysis is worked out for Long Branch, N. J.

NO. 56 - October 1954

II-A F "An Electronic Wave Spectrum Analyzer and Its Use in Engineering Problems" by Willard J. Pierson, Jr.

The theory of a wave spectrum analyzer designed and constructed by S. S. Chang (see BEB Tech. Memo No. 58) is described and the operation of the filters in the analyzer explained theoretically. Methods for computing information on the free surface wave spectrum, the energy flux in the surf beats and in the waves, and the average "period" are developed. These methods are simplified to make them practical, and techniques for rapid evaluation of data are developed. A detailed example is carried out. Several other possible applications to engineering usage are shown.

NO. 57 - February 1955

II-A "North Atlantic Coast Wave Statistics Hindcast by the Wave Spectrum Method" by G. Neumann and R. W. James

Detailed statistical wave data for deep water off the North Atlantic Coast based on hindcasts from synoptic weather charts for the 3-year period 1947-1949, are derived by the relatively new wave spectrum method as developed by Neumann, Pierson and James, for the same offshore stations for which data was developed in Technical Memorandum No. 55. The wave statistics are presented in comparable parameters to those previously derived by the Sverdrup-Munk method and given in Technical Memorandum No. 55.

NO. 58 - July 1955

II-A F "A Magnetic Tape Wave Recorder and Energy Spectrum Analyzer for the Analysis of Ocean Wave Records" by Sheldon S. Chang

An instrument which produces a wave record on magnetic tape and from this tape produces a power (energy) density spectrum as a function of frequency is described. Photographs and detailed drawings are included. The instrument analyzes a 20-minute wave record in approximately three minutes and records the resulting power spectrum on chart paper.

NO. 59 - February 1955

I-A "Laboratory Study of Shock Pressures of Breaking Waves" by Culbertson W. Ross

Results of a laboratory study to investigate the high-intensity shock pressures on structures as contrasted to the much smaller hydrostatic pressures developed by rise of the wave against the face of the structure are presented. The laboratory waves were from 3.5 to 7.5 inches in height, producing maximum observed shock pressures of 21 psi. Data were insufficient to establish definitely the relation between pressure and wave height, but an approximate linear relationship is indicated.

NO. 60 - January 1955

I-A "Generalized Laboratory Study of Tsunami Run-Up" by
F Kenneth Kaplan

Results of a laboratory study made on generalized beach and structure shapes for the relation of tsunami run-up to the characteristics of the wave are presented. It is found that the relative run-up can be related to the wave steepness, and relationships are evaluated for certain slopes and structure types. For Hilo Bay, Hawaii, this study indicates that a run-up of at least two wave heights at the shore line is possible.

NO. 61 - August 1955

I-C "Laboratory Study of Wind Tides in Shallow Water" by
F O. Sibul

Laboratory tests were made to enable some quantitative intepretation of bottom effects, water depth and wind strength on wind tide (set-up). Experiments were conducted with smooth and rough bottom conditions. Results indicate a rapidly increasing set-up when still water depth decreases below a certain limit. There were no indications that bottom roughness affects set-up for relatively deep water, however rougher bottom conditions results in higher set-ups in very shallow water. The trend is especially pronounced for higher wind velocities.

NO. 62 - November 1954

II-C "Restudy of Test - Shore Nourishment by Offshore Deposition of Sand, Long Branch, New Jersey" by Robert L. Harris

New surveys of offshore stockpile deposit area and associated shore region for tests previously described in Technical Memorandum No. 17 are analyzed and results presented. New measurements and analysis substantiate original findings that there is no evidence that material moved onshore from the stockpile or that the shore was benefitted by the offshore deposit.

NO. 63 - September 1955

I-A C "A Study of Sediment Sorting by Waves Shoaling on a Plane Beach" by Arthur T. Ippen and Peter S. Eagleson

This report presents results of theoretical and experimental investigation into the mechanics of processes by which beach sediments are sorted selectively when acted upon by shoaling waves. Net sediment motion is found to be due essentially to inequality of hydrodynamic drag and particle weight with a position of equality separating zones of net onshore and net offshore motion. Net onshore particle velocities were found proportional to the indicated mass transport velocity and approached it as the fall velocity of the particles became negligible. A theoretical analysis is presented which yields a general functional equation for net particle velocities.

NO. 64 - October 1955

I-A E "Laboratory Data on Wave Run-up and Overtopping on Shore Structures" by Thorndike Saville, Jr.

Experimental data from scale model laboratory tests are presented in tabular form on wave run-up values and rate of overtopping for a number of different test conditions of wave characteristics, beach slopes, and wall shape and height. Curves are also presented showing relation of overtopping rate to elevation of wall crest for different test conditions. For convenience in visualizing the quantitative application of the data, wave characteristics, wall dimensions, run-up and overtopping are presented as prototype equivalents.

NO. 65 - October 1955

II-B C "Sand Variation at Point Reyes Beach, California" by Parker D. Trask and Charles A. Johnson

Characteristics of the beach sands and their variability were investigated by taking a series of samples during three seasons, June at the end of the winter season, October at the end of the summer season, and February and March during the middle of the winter season. The sediments on the beach are highly variable and the average variation within a distance of 16 feet of selected points is 60 to 65 percent of the total variation encountered. Samples taken in October at the end of the summer season are definitely more fine-grained than in June or January. The sediments show a distinct relationship to position on the beach, coarse on the lower foreshore, fine on the upper foreshore, and slightly coarser on the berm than on the upper foreshore. The grain size shows no variation with slope of the beach, which is a steep beach, sloping in general 6 to 12 degrees.

NO. 66 - December 1955

II-B F "Factors Affecting the Economic Life of Timber in Coastal Structures" by R. A. Jachowski

Information concerning durability of timber in coastal structures including such factors as marine borers, geographic factors affecting deterioration, and methods of protection and treatment, is presented. Appendices showing intensity of marine borer attack by geographic location and data from service records of timber coastal structures are also included.

NO. 67 - December 1955

I-A "A Model Study of the Run-Up of Wind-Generated Waves on Levees With Slopes of 1:3 and 1:6" by Osvald J. Sibul and Ernest G. Tickner

Wave run-up under wind action was investigated in a laboratory wind tunnel to determine relative importance of the wind force in increasing run-up over that observed for mechanically-generated waves or that might be observed in nature under calm conditions. For lower wind velocities

relative run-up values were indicated to be the same as for mechanically-generated uniform waves. For higher wind velocities, the run-up increases with increasing wind velocity and may reach double the value of run-up where no wind is involved. Run-up on the 1:3 slope was found to be considerably higher than that on the 1:6 slope, confirming the trend found by others using uniform waves.

NO. 68 - February 1956

II-A
B
C "Wave Action and Sand Movement Near Anaheim Bay, California" by Joseph M. Caldwell

The purpose of the study was to determine the degree to which mass alongshore sand movement on the beach and offshore bottom can be correlated with characteristics of ocean waves impinging on the beach. Field data were collected in connection with a beach fill operation for shore protection immediately south of the Anaheim Bay jetties. Analyses are made of wave energy, sand characteristics, and volumetric changes. An approximate relationship for net alongshore sand movement in cubic yards per day in terms of intensity of net alongshore wave energy is worked out. This relationship is in substantial agreement with one derived earlier from data for another part of the U. S. Coast (Tech. Memo. No. 42).

NO. 69 - December 1954

II-A
F "Wave Forces on Piles: A Diffraction Theory" by R. C. MacCamy and R. A. Fuchs

An exact mathematical solution is presented for the linearized problem of water waves of small steepness incident on a circular cylinder. In addition to the formal mathematical treatment, some simple deductions based on the assumption of very small ratio of cylinder diameter to incident wave lengths are made. Suggestions for possible extension of the theory to more extreme wave conditions and other obstacle shapes are also presented. Application of the theory to computation of actual wave forces on cylindrical piles is attempted for tests performed in a small wave channel, and agreement is found to be quite good in the region for which the assumptions of the theory are fairly closely realized.

NO. 70 - December 1954

II-A "The Effect of Fetch Width on Wave Generation" by Thorndike Saville, Jr.

A method of determining the effect of fetch width on wave generation is presented, primarily for use in predicting wave characteristics in inland waters. Use of this method with actual fetch shapes where the fetch is limited in a direction coincident with the wind direction but stretches out longer in directions at an angle to the wind, could result in an effective fetch length actually greater than the (limited) distance in the direction of the wind due to added angular components. Normally, however, use of the method would be expected to result in a lesser effective fetch length.

NO. 71 - April 1955

I&II-A F "Re-Analysis of Existing Wave Force Data on Model Piles" by R. Curtis Crooke

This report presents an examination of previous work on this subject and attempts to reconcile inconsistencies observed therein by utilizing a somewhat different method of analysis.

NO. 72 - March 1955

I-A "Laboratory Study of the Generation of Wind Waves in Shallow Water" by Osvald Sibul

Wave generation in shallow water was studied in a small enclosed wind-wave tank in the laboratory for both smooth and rough bottom conditions. The data indicate Sverdrup-Munk-Bretschneider curves may be used to predict wave height and period for relatively deep water, but in shallow water (d/H_o less than 5) the depth starts to affect the wave height, resulting in heights considerably less than predicted. Wave periods are also affected by depth but to a lesser degree than wave heights, the reduction being noticed when d/L_o is less than 0.2.

NO. 73 - April 1955

II-A "Graphical Approach to the Forecasting of Waves in Moving Fetches" by Basil W. Wilson

Development and application of a graphical technique to the determination of maximum significant wave heights and periods attained by waves in moving wind systems are described. Existing Sverdrup-Munk-Bretschneider deep water forecasting data are assembled in a single chart over which a space-time wind-field representing any given moving wind system (in relation to a particular point on the coast) can be placed by superposition for the evaluation of the characteristics of the waves generated at any specific point in space and time within the windfield. The method is applicable to both approaching and receding storms and permits of decay aspects being taken into account in the usual way. An example is given of application of the method to forecasting wave conditions in the path of a hurricane.

NO. 74 - May 1955

I-A
F "Water Surface Roughness and Wind Shear Stress in a Laboratory Wave Channel" by Osvald Sibul

Vertical wind velocity profiles were measured in a laboratory wave channel by use of a Pitot tube, simultaneously with observation of wave heights, periods and water surface slopes. The velocity profiles were analyzed for resistance coefficient, characteristics roughness length, and shear stress exerted by the wind on the water surface. Methods for extending the data to field conditions are given. The laboratory results compare favorably with field measurements. It is concluded that small scale laboratory equipment can be used to study mechanics of energy transfer between wind and water.

NO. 75 - June 1955

I-C "Mechanics of Bottom Sediment Movement Due to Wave Action" by Madhav Manohar

Results are presented from an analytical and experimental (laboratory) investigation of the motion of sediment induced by action of surface waves of large length and small amplitude in relatively deep water.

It is found that there are initial and general movements of sediment; and initiation, various stages of development, and complete disappearance, of bed ripples. The initial and general motion of small sizes of sediment occur in the laminar boundary layer and are caused by laminar shear, while similar motions of large sizes of sediment are caused by lift forces in a turbulent boundary layer. Ripples in general are not formed unless the flow is turbulent in the boundary layer. All motion in turbulent flow and the various stages of ripple development are dound to be functions of a dimensionless function representing intensity of flow near the bottom. The phenomena of initiation of turbulence and motion of sediment in the boundary layer at the bottom are expressed in terms of characteristics of the surface waves.

NO. 76 - June 1955

II-B
C "Movement of Sand Around Southern California Promontories" by Parker D. Trask

A series of 19 profiles and 175 bottom samples off three rocky promontories - Points Arguello, Conception and Dume - show clearly that sand moves around these promontories. The sand moves in three distinct ways: along the beach and surf zone, in the water from sea level to a depth of 30 feet, and between depths of 30 and 60 feet. Beyond a depth of 60 feet relatively little sand moves. Underwater diving operations at Point Dume indicate that 60 feet marks the outer limit of ripple formation and distrubance of the bottom by waves.

NO. 77 - February 1956

II-B
C
E "Behavior of Beach Fill at Ocean City, New Jersey" by George M. Watts

Field survey data taken in connection with a beach fill operation completed in 1952 at Ocean City, N. J. are presented and analyzed to evaluate the movement and effectiveness of the fill. The rate of loss of the fill substantially exceeded the estimated rate, and conclusions are drawn regarding the reasons for this. Conclusions are also drawn relative to future work.

NO. 78 - March 1956

II-F "Hurricanes Affecting The Coast of Texas From Galveston To Rio Grande" by W. Armstrong Price

This report presents a collection of available data on hurricanes reaching and passing inland over the Texas coast between Galveston and the Rio Grande, and certain statistical conclusions as to frequency of occurrence are derived. Detailed data on the storms and paths from 1818 to 1955 are presented as appendices.

NO. 79 - March 1956

II-A D F "Orbital Velocity Associated With Wave Action Near The Breaker Zone" by D. L. Inman and Noriyuki Nasu

The orbital velocity associated with ocean surface waves in shallow water was measured for various wave conditions at La Jolla, California. Measurements were made near the bottom and just seaward of the breaker zone in water depths ranging from about 5 to 15 feet and for wave heights as great as 7-1/2 feet, and are presented. Observed maximum horizontal velocities compare favorably with those predicted from solitary wave theory when the ratio of wave height to water depth is greater than about 0.4, the agreement with theory being somewhat better for longer period waves.

NO. 80 - April 1956

I-A "Model Study of Overtopping of Wind-Generated Waves On Levees With Slopes of 1:3 and 1:6" by Osvald J. Sibul and Ernest G. Tickner

The overtopping of wind-generated waves on levees with slopes of 1:3 and 1:6 was studied in a laboratory wind-wave tunnel and compared with other experiments utilizing mechanically-generated uniform waves not affected by wind. For low wind velocities results are similar, but for higher wind velocities additional overtopping occurs due to action of the wind so that total overtopping may be separated into that due to wave action and that due to wind action. Criteria for estimating additional overtopping due to wind are presented and discussed.

NO. 81 - June 1956

I-A "A Laboratory Study of Short-Crested Wind Waves" by G. C. Ralls, Jr., and R. L. Wiegel

Results are presented from a three-dimensional study of fundamental characteristics of short-crested waves in a laboratory wind-wave tunnel. General characteristics of the waves are shown for varying wind speeds, water depths, and fetch lengths. Several methods of analyzing short-crested waves to obtain quantitative data on wave parameters are discussed, and the results of the methods compared. It was found that the crest length as well as the wave length could be described by a Gaussian distribution.

NO. 82 - July 1956

II-B "Changes in Sand Level on the Beach and Shelf at La Jolla, C California" by D. L. Inman and G. S. Rusnak D

A technique is developed for establishing a reference level on the bottom from which small net changes in sand level can be measured by swimmers equipped with self-contained underwater breathing apparatus. Bottom changes were measured periodically over a 3-year interval at stations from near the surf zone to the 70-foot depth. Standard error of the measurements was about $\pm$ 0.05 foot per survey for determination of net sand level. Estimates of sand level variation are made for monthly and seasonal periods and correlated with depth. Comparison is also made with sonic (echo) soundings, indicating day-to-day accuracy for the latter method on the order of $\pm$ 0.5 foot.

NO. 83 - June 1956

II-C "Approximate Response of Water Level on a Sloping Shelf F to a Wind Fetch Which Moves Towards Shore" by R. O. Reid

A procedure for evaluating the approximate response characteristics of water level at the shore of a sloping shelf due to a wind fetch moving directly onshore is described. The theory is based upon the linear one-dimensional wave equation and employs the method of characteristics as a means of solution by graphical technique. A total of about 55 separate cases for

different values of fetch length and storm speed were investigated numerically, and the primary results summarized in graphical and tabular form.

NO. 84 - December 1956

II-A "Wave Forecasting Relationships for the Gulf of Mexico" by Charles L. Bretschneider

The methods utilized in obtaining hindcast statistical wave data for locations in the Gulf of Mexico (presented in Technical Memoranda Nos. 85-89) are discussed. A numerical method of forecasting wave generation and propagation over a sloping bottom taking into account both generation by wind and dissipation by bottom friction is demonstrated. Also shown are the averaging techniques used to apply the method to statistical accumulation of hindcast data in the Gulf of Mexico.

NO. 85 - September 1956

II-A "Wave Statistics for the Gulf of Mexico off Brownsville, Texas" by Charles L. Bretschneider and Roy D. Gaul

Detailed statistical wave data for deep water, 96, 48, 24, and 12-foot depths, based on hindcasts from synoptic weather charts for the 3 years 1950, 1952, 1954, are presented. Refraction coefficients and final wave direction at those depths are also presented graphically as a function of wave period and deep water wave direction.

NO. 86 - September 1956

II-A "Wave Statistics for the Gulf of Mexico off Caplen, Texas" by Charles L. Bretschneider and Roy D. Gaul

Detailed statistical wave data for deep water, 96, 48, 24, and 12-foot depths, based on hindcasts from synoptic weather charts for the 3 years 1950, 1952, 1954 are presented. Refraction coefficients and final wave direction at those depths are also presented graphically as a function of wave period and deep water wave direction.

NO. 87 - October 1956

II-A "Wave Statistics for the Gulf of Mexico off Burrwood, Louisiana" by Charles L. Bretschneider and Roy D. Gaul

Detailed statistical wave data for deep water, 96, 48, 24, and 12-foot depths, based on hindcasts from synoptic weather charts for the 3 years 1950, 1952, 1954, are presented. Refraction coefficients and final wave direction at those depths are also presented graphically as a function of wave period and deep water wave direction.

NO. 88 - October 1956

II-A "Wave Statistics for the Gulf of Mexico off Apalachicola, Florida" by Charles L. Bretschneider and Roy D. Gaul

Detailed statistical wave data for deep water, 96, 48, 24, and 12-foot depths, based on hindcasts from synoptic weather charts for the 3 years 1950, 1952, 1954 are presented. Refraction coefficients and final wave direction at those depths are also presented graphically as a function of wave period and deep water wave direction.

NO. 89 - October 1956

II-A "Wave Statistics for the Gulf of Mexico off Tampa Bay, Florida" by Charles L. Bretschneider and Roy D. Gaul

Detailed statistical wave data for deep water, 96, 48, 24, and 12-foot depths, based on hindcasts from synoptic weather charts for the 3 years 1950, 1952, 1954, are presented. Refraction coefficients and final wave direction at those depths are also presented graphically as a function of wave period and deep water wave direction.

NO. 90 - September 1956

II-B D "Relative Efficiency of Beach Sampling Methods" by W. C. Krumbein and H. A. Slack

This is an extension to the work reported in Technical Memorandum No. 50 in that this report presents the results of several sampling experiments designed to show more explicitly how estimates of certain beach material properties may vary as a result of the sampling plan adopted. A number of sampling designs applied to

areas along Lake Michigan near Waukegan, Illinois, and at Ocean Beach, Maryland, are compared to indicate some of the factors involved in beach sampling for different purposes.

NO. 91 - November 1956

II-B C "Changes in Configuration of Point Reyes Beach, California 1955-1956" by Parker D. Trask

This is a continuation of the study reported in Technical Memorandum No. 65. Surveys were made at 8 intervals between August 1955 and June 1956, and variations in sediment characteristics were investigated and correlated with changes in cusp formations and cut and fill on the beach.

NO. 92 - March 1957

II-C E "Sand Bypassing at Port Hueneme, California" by Rudolph P. Savage

Discussion of a novel method of bypassing sand from an accreted area updrift of a jetty to an eroding downdrift shore is presented. The method involved first the dredging of a large lagoon in back of the beach, leaving a barrier to serve as protection for the dredge, and then dredging cuts through the barrier. Results of the operation as indicated by periodic surveys after its completion are presented, and in general indicate the method to be successful. However, modifications are suggested should any similar operations be planned for the future.

NO. 93 - February 1957

II-F "Modification of the Quadratic Bottom - Stress Law for Turbulent Channel Flow in the Presence of Surface Wind-Stress" by R. O. Reid

In this paper a generalized formula for velocity profile and bottom stress is derived which takes the influence of surface stress into account. In general, the effect of the wind stress is such that, for a given current, the effective resistance to the flow is reduced for a following wind and increased for an opposing wind, relative to the resistance which exists in the absence of the surface stress. The steady state case with zero

mean flow is treated as a special case of the general theory, and the ratio between bottom stress and surface stress is found to be dependent upon the ratio of depth to bottom roughness, and is generally less than 0.1.

NO. 94 - May 1957

I-C "Preliminary Report: Laboratory Study of The Effect of an Uncontrolled Inlet on the Adjacent Beaches" by Thorndike Saville, Jr., Joseph M. Caldwell, and Henry B. Simmons

Initial results of a series of laboratory tests made to determine the manner in which beach processes in the vicinity of a tidal inlet differ from those outside the influence of the inlet, and the adjustments which can be expected to occur in a previously unbroken beach following introduction of an inlet, are presented. The laboratory tests were run in two parts, one without the inlet in place and one with the inlet cut through. No attempt was made to model any particular inlet in nature or any hypothetical prototype. Results are presented in photographs and hydrographic sheets in color.

NO. 95 - May 1957

I-A "Effect of Bottom Roughness on Wind Tide in Shallow Water"
C by E. G. Tickner
F

This report presents the results of a laboratory study of the effect of bottom roughness on both set-up and wave generation, utilizing equally spaced strips of window screening to represent the roughness. It is shown that roughness increased the set-up over that for smooth bottom conditions by as much as two times when the water depth was slightly above the roughness top, though decreasing it to a negligible amount when the water depth was about half-way up on the roughness strips. Wave heights were not appreciably affected for large depths over the roughness tops, but were reduced for small depths; generally wave heights could be predicted adequately by using an "effective" depth equal to the depth over the roughness.

NO. 96 - June 1957

II-E
F "Factors Affecting Durability of Concrete in Coastal Structures" by Bryant Mather

Both internal and external factors which affect the durability of concrete structures are discussed in detail. Mixing and construction practices are discussed at length. Test data from several agencies, service records of concrete structures at numerous locations, and a substantial list of references are appended.

NO. 97 - July 1957

I-A
F "Turbulent Flow Near an Oscillating Wall" by George Kalkanis

Results of theoretical and experimental work to define a law describing the flow near the bottom due to surface waves are presented. Flow conditions are described mathematically for the case of waves of low amplitude in deep water and a smooth bottom. Coefficients are defined by experiment using an oscillating bed in a laboratory tank.

NO. 98 - June 1957

II-A "Hurricane Wave Statistics for The Gulf of Mexico" by Basil W. Wilson

This report contains the results of a statistical hindcast study of heights and periods of significant waves generated by hurricanes in the Gulf of Mexico in the period 1900 to 1949. Results are presented in a series of polar plots of frequencies of occurrence of waves of given height and period at 5 deep water (100 fathoms) stations offshore in the Gulf of Mexico. This report complements Technical Memoranda Nos. 84 to 89 which presented statistical summaries for all or ordinary wind waves hindcast for the same stations.

NO. 99 - September 1957

I-A
E
F "Model Tests on a Triple-Bulkhead Type of Floating Breakwater" by Culbertson W. Ross

Test procedures and results are summarized for a laboratory model study to test the effectiveness of a particular design

of a floating breakwater acted on by several wave trains from different directions and to measure stresses in its mooring cables. Tests were performed at a 1 to 24 linear scale. The efficiency of the breakwater in reducing wave heights drops off rapidly with an increase in wave period beyond 8.5 (prototype) seconds or when the wave length approximates the width of the breakwater section from front to back. Forces required to hold the breakwater in place against larger waves (greater than 9 to 10 feet prototype) exceeded 200,000 pounds per anchor chain, and prototype stresses in some of the braces and struts exceeded present practical design limits.

NO. 100 - October 1957

II-A "Wave-Generated Ripples in Nearshore Sands" by Douglas L.
B Inman
C
D

A study of the occurrence of sand ripples generated by wave action in the nearshore area has been made based on observations by swimmers equipped with self-contained underwater breathing apparatus. The wave length, crest length, height and symmetry of the ripples were measured and compared with size of the sand and with orbital displacement and velocity of the wave motion generating the ripples. In general ripple size increased with sand size and, to a certain extent, with water depth. Ripples in exposed areas were generally larger than those in sheltered bays. Ripples were always present when the orbital velocity was between about 0.3 and 3 feet per second.

NO. 101 - October 1957

II-C "Dune Formation and Stabilization by Vegetation and Plantings"
E by Dr. John H. Davis
F

A discussion of the effectiveness of various plants in dune formation and stabilization is presented. Methods for establishing plantings are included. Also included are performance records of several dune vegetation installations in various parts of the country. A tabulation of plants which are numerically important toward dune stabilization in the United States and their frequency of occurrence for various parts of the United States coast is appended.

NO. 102 - October 1957

II-B E "A Method for Specification of Sand for Beach Fills" by W. C. Krumbein

Factors involved in selection of suitable material for beach fills are examined. Properties of natural beach materials governing specifications for a beach fill are discussed. Procedure for analysis of materials available for use as fill is presented which permits selection of that material most nearly satisfying requirements, or which, after consideration of comparative costs of material from alternative sources, will be most economical to employ without sacrificing the benefits sought. The report is concerned with the methods of interpreting data obtained by sampling with particular regard to the employment of statistical analysis as it may be applicable to objectives described above.

NO. 103 - December 1957

I-A "Model Study of Wave Refraction" by R. L. Wiegel and A. L. Arnold

Tests were made in a laboratory wave tank to verify applicability of Snell's Law in water wave refraction. Results indicate Snell's Law applies over much of the range tested, but some discrepancies occurred. The discrepancies may be associated with the formation of multiple crests from an initially single wave as the wave moves into shoal water.

NO. 104 - February 1958

I-A C "The Mechanics of the Motion of Discrete Spherical Bottom Sediment Particles Due to Shoaling Waves" by P. S. Eagleson, R. G. Dean and L. A. Peralta

Laboratory investigation in extension of that reported in Technical Memorandum No. 63 is continued into mechanics of processes by which beach sediments are sorted selectively when acted upon by shoaling waves. Incipient and net motions of discrete spherical sediment particles of different diameter and specific gravity were studied statistically on smooth and roughened surfaces of different slope under several conditions of equivalent deep water wave steepness. Theoretical analysis

is presented yielding an equation for net onshore/ offshore velocity of a given spherical sediment particle. The equation is verified by laboratory measurements and extended.

NO. 105 - March 1958

I&II-C
D
F "Movement of Bottom Sediment in Coastal Waters by Currents and Waves; Measurements with The Aid of Radioactive Tracers In the Netherlands" by J. J. Arlman, P. Santema, and J. N. Svasek

Sediment movement by currents and waves and ordinary methods of measurement are discussed. Procedures for marking and following movement of bottom sediments by radioactive tracers are also discussed, and characteristics of a number of suitable radioactive isotopes are tabulated. Pilot experiments to investigate tracing of sediment movement by use of radioactive tracers are described and it is concluded such a method can be safely employed by ordinary field survey parties. However, manufacture and placement of the radioactive material must be supervised by experts, after which brief safety control is sufficient.

NO. 1 - May 1941

I-A "A Study of Progressive Oscillatory Waves in Water" by Dr. Martin A. Mason

Results of experimental laboratory studies seeking confirmation of classical wave theories of Gerstner, Stokes, Levi-Civita and Laplace-Airy are reported. Confirmation of the irrotational wave theories of Stokes and Levi-Civita is shown. Description of previous investigations by others relative to the verification of wave theory is appended.

NO. 2 - November 1941

I-A "A Summary of the Theory of Oscillatory Waves" by Morrough P. O'Brien and Dr. Martin A. Mason

A summary of the theoretical treatments of oscillatory wave motion on a free water surface is presented. Mention is made of the extent to which confirmation of the theory has been obtained by experiment. A list of basic references is included.

NO. 3 - August 1948

I-C F "An Experimental Study of Submarine Sand Bars" by Dr. Garbis H. Keulegan

Results of laboratory experiments made to determine the existence of basic relationships governing bar phenomena are reported. Observations were made of the form, dimensions, and number of bars; wave characteristics; ripple formation; and nature and volume of sand movement involved in bar formation. Certain qualitative observations on some of the factors affecting the mechanism of bar formation and movement were also made during the investigation.

NO. 4 - June 1954

II-A "Shore Protection Planning and Design"

B

C A comprehensive manual detailing practices and pro-

D cedures currently used in functional planning and

E design of shore protective structures. Detailed

F information is included for such subjects as wave forecasting, wave characteristics, tides and other changes in water levels, beach materials, littoral processes, types of protection, forces involved, structural analysis, and miscellaneous design practices. Numerous examples are given. Appendices include a glossary of terms, list of common symbols, bibliography, miscellaneous tables and graphs, miscellaneous derivations, and an example beach erosion control study.