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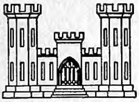
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS



THE

BULLETIN

OF THE

BEACH EROSION BOARD

OFFICE, CHIEF OF ENGINEERS
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RECENT CONTRIBUTIONS OF WAVE RESEARCH TO HARBOR ENGINEERING

The following article was first published in limited issue as Technical Report HE-116-267, Fluid Mechanics Laboratory, University of California. It is reproduced here to disseminate valuable wave concept principles among coastal engineers and other persons having an interest in the action of waves and surf. The paper was prepared by Mr. J. W. Johnson, University of California, July 1948.

The planning and execution of the extensive amphibious operations during the recent war stimulated extensive research in the problems of waves, surf, and related phenomena. The results of some of these investigations have definite peacetime application to harbor engineering, and a review of these developments to acquaint engineers with the methods appears desirable at this time. The principal problems that are discussed pertain primarily to the compilation of basic design data and the use of these data in the design, construction, and operation of engineering structures exposed to wave action. This discussion is confined to a consideration of waves caused by wind. Other waves, such as surging in harbors or seismic sea waves are relatively less important in most engineering investigations. Only the broad aspects of the problem of wave action are presented; however, sufficient references are given to permit the interested reader to study further into the details of the techniques of application. The principles apply equally well to wave action either on the ocean or on lakes and protected bays.

The Characteristics of Waves

The waves under consideration in this paper are those generated by the action of wind on the water surface. Such waves are characterized primarily by two factors: the height which is the difference in elevation between the trough and crest of the wave, and the period which is the time between the passage of two consecutive crests past a fixed point. Other characteristics, such as wave length and wave velocity, may be derived from the wave period. The characteristics of the waves generated in a particular storm depend on three factors: the fetch which is the distance the wind blows over the water surface; the average speed of the wind over the fetch; and the length of time that the wind blows. In general, the longer, farther, and faster the wind blows, the higher will be the waves and the greater their period, length and velocity. For a particular fetch and wind speed there is a maximum wave height regardless of how long the wind blows; or for a particular wind speed, either fetch or wind duration might limit the maximum height.

On the Pacific Coast the height of the wave usually is limited by the wind duration, because in the major genrating areas the fetches are so long and the wind speed so high that a relatively long duration would be required for the waves to reach the limiting height. Such durations are rather infrequent. In lakes and land-locked bays the fetch is limited by the size of the body of water, and large waves, therefore, cannot be formed. Within the generating area, steep, short-crested waves of all possible heights, lengths, and period are present, and many of them break as whitecaps. The waves which leave a generating area and move into relatively calm water (commonly called the decay area) are known as swell. The length, period, and velocity of the swell gradually increase with distance from the generating area; whereas, the height gradually decreases. In the Pacific Ocean where the generating areas may be several thousand miles from the coast, the decay distances are relatively large. The waves which travel such long distances become very regular, and when they reach the coast they become a series of long, low, and fairly regular undulations which usually are called ground swells. In deep water the presence of this swell may be almost totally obscured by small waves which are newly formed by local winds. It should be mentioned that in relatively small bodies of waters, as lakes and bays, which are subjected to wind action the entire water surface usually is a generating area. There is no decay area in such instances and the waves lose their energy during the storm by breaking on an adjacent shore.

Waves usually are classed as either deep-water or shallow-water waves. When waves are moving in water depths less than half the wave length, their motion is influenced by the bottom. Thus, waves moving in depths greater than half a wave length are termed deep-water waves, and when moving in lesser depths they are considered as shallow-water waves. Shallow-water waves moving into shoaling water undergo important transformations. The velocity and length of the waves decrease, while the period remains the same, and the total energy is slightly reduced by bottom friction. Except for a small initial decrease in height when the wave first "feels the bottom", and height usually increases up to the point of breaking. If waves approach a shore line at an angle, the inshore portion of the wave travels at a lower velocity than the portion in deeper water. The result of refraction is a change in the wave heights and the direction of travel, with the wave fronts becoming oriented nearly parallel to the bottom contours. These factors may vary considerably at closely adjacent points on a coast, due solely to the underwater topography. For example, refraction concentrates wave energy over submarine ridges, causing the waves to increase considerably in height. Over a submarine canyon, on the other hand, low wave heights occur due to the spreading of wave energy. Methods of estimating the changes in wave heights and direction of travel are discussed subsequently.

For waves with a relatively large ratio of height to length in deep water (usually short-period waves) the breaker height is about the same as the wave height in deep water, but for waves with a small height-length ratio in deep water (usually long-period waves) the breakers become much higher than the deep-water height. A long low swell which hardly may be observed in deep water can thus cause higher breakers than short period waves of much greater deep-water height (Figure 1). It is the swell which usually is responsible for the predominant breakers in the surf zone and for damaging coastal structures.

Since there is considerable variability in wave height and wave length in the waves leaving a generating area, it is necessary to define statistically the significance of the waves. Actually the higher waves are the most important from an engineering standpoint; hence, in stating the mean height of the waves that exist over a period of an hour or two it is advisable to consider only the higher of the waves that are present. Obviously, every ripple should not enter into forming an average. As a consequence of these considerations the present practice in stating the average wave height is to give the average height of the higher one-third of all observed waves. Where the observation is precise, as in analyzing the records of wave recorders, the average of the higher one-third of the major train of waves is used. This average is called the "significant wave height".

Compilation of Design Data

An engineer engaged in the design of coastal works must have a method of estimating the highest waves which might be expected due to a given design wind or, perhaps of more importance, he should have adequate data on the characteristics of the waves to be expected for the different seasons at any particular point. For the engineer engaged in construction work or in handling floating equipment, statistical information alone is insufficient for his operations. He must have definite information on the wave conditions that will exist at the time of his operations. Methods and instruments for providing such information are available and are now in use. Statistical data on the frequency of occurrence of waves of various heights at any given locality can be assembled from direct observation over a period of time, much as is done in assembling stream flow data for flood-flow predictions. This procedure, of course, requires the installation of suitable recorders for measurement of the height and period of the waves. Several years of record also must be assembled before reliable average conditions can be determined.

The Department of Engineering at the University of California, in cooperation with the U. S. Navy, has had wave recorders in operation for almost a year at Point Sur, California, and Hecta Head, Oregon. These recorders will provide sufficient coverage of the Pacific coast to permit a compilation of statistical data on wave conditions at selected points along the coast. Wave data for intermediate localities can be estimated by interpolation. Records from the wave records also provide a means of checking the method of forecasting waves from weather charts as discussed later.

A brief discussion of the instruments which have been developed for recording waves is of interest at this point. For coastal points, the swell, as previously mentioned, is the predominate factor to consider in the design of structures; hence, wave recorders such as those installed on the Pacific coast are designed for obtaining information on only the larger waves or what is called the "significant" waves. Of the various recorders which have been developed by the University of California, all operate on the method of recording pressure fluctuations at the sea bottom and transposing these values to a surface wave height (Figure 2). The fundamental principle of the method is that surface waves induce pressure fluctuations in the entire column of water between the surface and the sea bottom. For a particular depth of water and wave height, the amplitude of these fluctuations depends on the wave period. These fluctuations are filtered out by hydrodynamic action for the very short period waves, and only the fluctuations for the longer period waves are recorded. The instrument consists simply of an underwater unit to pick up and convert pressure fluctuations into electrical signals which are transmitted through a cable to a strip chart recorder on shore. Two types of units have been employed. In one of these instruments the pressure fluctuations at the sea bottom actuate a small potentiometer through a system of bellows, and these signals are transmitted to a bridge and recorder unit on shore. A "slow leak" device in the underwater unit eliminates the effect of tides and other very long waves. In the second type of instrument the underwater pressure unit consists of an air-filled rubber bellows which contains a thermopile. The changes in pressure due to the passage of a wave causes a change in temperature of the air in the bellows. This change in temperature is related to the wave period and the height of the wave at the surface and is recorded on a instrument located on shore. Programming switches usually are provided so that the recorders will operate at high speed for 20 minutes in each 6-hour period. This high speed record permits the determination of both height and period of the waves; whereas, the low-speed record permits only height determinations. From the high-speed section of the recorder charts the average height of the highest one-third of the waves is determined and recorded as the significant waves occurring at that time (Figure 3).

For recording wave characteristics on relatively small bodies of water, such as lakes and bays, the same basic principle of using an underwater unit to screen out the relatively small waves is employed. The details of the units differ due to the relatively small-pressure fluctuations which exist and due to the response characteristics of the recorders.

In addition to the use of wave recorders, statistical information on wave conditions at a given locality can be assembled from established relationships between the characteristics of the waves and the fetch and generating wind. These relationships were developed by The Scripps Institution of Oceanography of the University of California and have been presented in graphical form. These graphs permit the determination of the height and period of the wave which will result from a wind of given speed and duration blowing over a given fetch. The wave height given by these relationships is the significant wave height as previously mentioned; that is, it is the average height of the highest one-third of all waves present. These curves originally appeared in the U. S. Navy Hydrographic Office publication, "Wind Waves and Swell, Principles in Forecasting", Misc. Report No. 11,275. As additional data on wave conditions were obtained from shore recorders the curves were revised and presented in Wave Report No. 73 of the Scripps Institution of Oceanography in March 1948. Also see the Bulletin of the Beach Erosion Board, Special Issue No. 1, July 1, 1948.

The character of the significant waves in a generating area can be obtained from the Scripps charts provided the variables of wind velocity, fetch, and duration are known. In lakes or protected bays, local wind records are suitable for estimating the wave conditions that can exist at any particular locality. In fact, all past wind records of velocity, direction, and duration can be used in conjunction with the charts and a statistical compilation then made of the anticipated wave conditions at a selected point. These data on wave heights then can be summarized in the form of direction roses. Information of this type is of considerable value to the designing engineer, as it not only gives the wave characteristics which structures must be designed to withstand, but it also permits an investigation to be made as to whether structures are economically justified in view of the frequency of occurrence of waves of a damaging character.

For a locality on an exposed coast, where critical wave conditions result from swell which is generated by storms occurring at considerable distance from the coast, local wind records are of relatively small value in the compilation of significant wave characteristics. Thus, where large scale wind patterns are involved, there are seldom sufficient weather reports to determine these patterns directly from ship or island observations. However, there is a very close relationship between the speed and direction of the wind and the atmospheric pressure gradient. This latter factor can be determined from a weather chart. The pressure field is not difficult to determine, even from only widely scattered reports. The winds, therefore, are computed from the pressure gradient scales from a weather chart and whatever wind observations are available are used to check the computed values. A consideration of the orientation of the isobars on a weather chart also permits an estimate to be made of the extent of the generating area and, consequently, the value of the fetch and the direction of wave propagation. By these methods of forecasting, a statistical study can be made of the waves reaching a region of the coast. Such an analysis has been made by the Scripps Institution of Oceanography in cooperation with the Los Angeles District for Pacific coast stations. The results of the studies have been compiled into wave "roses" for five stations located along the Pacific coast at approximately 150 mile intervals from San Diego, California, to Cape Blanco, Oregon. These statistical summaries, Figure 4, give wave conditions in deep water and are basic data in the design of all future works on this portion of the coast.

The use of weather charts in estimating wave conditions at a particular locality can be used to advantage by engineers involved in constructing coastal works or in using floating equipment which is exposed to wave action. Although engineers usually plan their immediate work on the local weather reports, in many cases it is the swell, coming from storms occurring several days previously at a distant locality, which actually affects their operations. A 24-hour forecast of wave conditions that might exist at a particular point for a short time in the future would be of unquestioned value to the construction engineer. Usually it is not possible to make a reliable forecast for more than two days in advance. The details of utilizing daily weather charts for making wave forecasts or in using historical weather charts for compiling statistical data on waves that probably resulted from storms in the past is beyond the scope of this paper. For the techniques of the procedure the reader is referred to Hydrographic Office Publication No. 11, 275 mentioned above. For a complete description of the theory involved reference should be made to U. S. Navy Hydrographic Publication 601, "Wind Sea and Swell: Theory of Relations for Forecasting", by Sverdrup and Munk, March 1947. The accuracy of wave predictions which are made from weather charts is of interest to engineers who rely on such information. To provide such data forecasting of sea and swell for comparison with observations was initiated shortly after the installation of the wave recorders at Point Sur and Heceta Head. Several months of wave records have permitted a statistical analysis to be made of the accuracy of the forecasting method. The comparison at Point Sur covered about 270 forecasts from April to December 1947. At Heceta Head comparisons covered the period May to December 1947 and involved about 200 forecasts. The actual comparison of recorded to forecast values was, in general, good. A statistical analysis shows that 97 per cent of the recorded significant increases in wave height were forecast. Sixty-nine of the arrival times were predicted within six hours. The arrival times usually were predicted earlier than those actually occurring. Fifty-three per cent of the forecast wave heights were within one foot of the recorded heights, and eighty per cent were within two feet. Sixty-three per cent of the forecast periods were within two seconds of the recorded periods. The forecast periods usually were lower than the recorded periods. In general, it can be stated that the forecasting technique results in a high degree of reliability for forecasting the arrival of significant increases in wave height, and for prognosticating the heights of the waves. These two factors are the important items controlling marine and shore activities. A complete discussion of the accuracy of forecasting appears in the article "A Comparison Between Recorded and Forecast Waves on the Pacific Coast" by J. D. Isaacs and Thorndike Saville, Jr., which was presented before the New York Academy of Sciences, March 1948.

Refraction of Waves

As mentioned above, when waves move shoreward and approach a shore line at an angle, refraction occurs and important changes to the height and direction of travel of the waves results. The magnitude of these changes is best considered to be a map which shows the wave crests at a given time, or the successive positions of a particular wave as it moves shoreward. Figure 5 shows a typical diagram which was prepared for the area in the vicinity of Moss Landing in Monterey Bay, California. Note that on this diagram there are a series of lines, orthogonals, drawn perpendicular to the wave crests. These orthogonal lines are used in estimating variations in wave height due to refraction. Such estimates are made by assuming that the wave energy between any two orthogonals remains constant and, for steady state conditions, the same energy should flow past all positions between the orthogonals. A consideration of the fundamental equation for the power of a wave shows that the ratio of wave height between two points is

$$\frac{H_1}{H_2} = \frac{b_2}{b_1}$$

where b_2 and b_1 are the distances between orthogonals at points 2 and 1, respectively. The right-hand member of this equation is termed a "refraction coefficient". A convergence of orthogonals indicates a concentration of wave energy (large wave heights), and a divergence of orthogonals indicates a spreading out of energy (low wave heights).

A refraction diagram can be prepared for a selected locality by merely tracing, from a vertical aerial photograph, the wave crests onto a transparent overlay; however, to cover the whole range of wave periods and directions that a compilation of statistical data on wave characteristics indicate as being possible, refraction diagrams are constructed graphically by means of special scales. The details of this graphical method are described in the publication "Graphical Construction of Wave Refraction Diagrams", U. S. Navy Hydrographic Publication No. 605.

Once a series of refraction diagrams for various periods and directions have been prepared for a given locality, orthogonals to the wave crests can be constructed and refraction coefficients then computed by the above equation from measurements taken directly from the diagrams. Such coefficients afford a convenient method of comparing wave heights at various localities. On Figure 5, for example, refraction coefficients (that is, ratios of wave height at given points to the deep-water wave height) are given for various points along the shore for 10-second period waves from WSW. Examination of this figure indicates that wave heights near Moss Landing would be approximately half of the deep-water height. That such a condition exists under actual wave conditions is indicated by Figure 6 which shows an aerial photograph of Moss Landing and vicinity. Note the "flat" water at the end of the pier where the Monterey Canyon approaches the shore. Small boat operators have long recognized that the sea is relatively calm at the head of a submarine canyon.

Wave refraction analyses are rapidly approaching the status of a standard component of shore line investigations. The primary value of refraction diagrams is in evaluating the relative degrees of exposure of coastal points to wave action; that is, their application permits the determination of the critical direction and wave period from which damage can be expected. When used in connection with wave forecasts from synoptic weather charts, refraction diagrams permit the forecaster to predict, for at least a day in advance, the wave conditions that will exist at a given point. Such forecasts are of great importance to the construction engineer engaged in operations along the coast. The decision as to the most desirable location for a permenent installation such as a breakwater or docking facilities must be made by the design engineer using statistical wave data and refraction diagrams. Usually only a few periods and directions need be drawn even for quantitative use, the remaining conditions being supplied by inspection and interpolation. After some experience an engineer very often can substitute a mental construction of a refraction diagram for the graphical development.

In addition to the evaluation of the relative degree of exposure of coastal points to wave action, refraction diagrams also can be used to determine prevailing directions of littoral currents and other factors which are of great importance in the transportation of beach materials. Thus, from a refraction diagram the angle between the wave front at the point of breaking and the shore and the breaker height can be determined. The strength of the littoral current is a function of this breaker angle, the beach slope, and the breaker height. The interruption of the normal movement of littoral drift by the installation of coastal structures may and has had serious effects in the vicinity of the works. For example, at Santa Monica and Santa Barbara, California, the construction of breakwaters so interferred with the wave action (and consequently the littoral drift) that heavy deposits of sand occurred upcoast from the structures and serious erosion resulted to the beaches on the downcoast side. Both the Santa Monica breakwater and the original breakwater at Santa Barbara were constructed approximately parallel to the shore with the expectation that the sand transported by littoral currents would continue to move uninterrupted down the coast. Wave refraction around the breakwater, however, was such that the littoral current carrying the sand was greatly reduced in strength with the result that serious shoaling occurred to the lee of the structure. Similar difficulty of upcoast deposits and downcoast scour has occurred at Oceanside, Alamitos Bay, and Port Hueneme, California, where jetties more or less perpendicular to the coastline has been constructed in an attempt to stabilize the harbor entrances. Periodic pumping of the sand from the upcoast deposits to the opposite side of these entrances appears to be the only solution in keeping the harbors open and in supplying sand to the downcoast beaches.

In addition to the refraction of waves due to bottom effects, refraction can result in some instances from tidal currents. A current which opposes waves entering an inlet may have the effect of increasing the steepness of the waves and cause them to break. Such conditions very often occur on the ebb tide at many harbor entrances and may prove extremely hazardous to shipping operations. A consideration of the wave and current characteristic permits a designer to orient a harbor entrance so that the undesirable effects of wave refraction by currents can be greatly minimized.

Wave Diffraction

Wave diffraction is considered to be the phenomenon in which water waves are propagated into a sheltered region formed by a breakwater or similar barrier which interrupts a portion of an otherwise regular wave train. A knowledge of diffraction behavior has important application in the design and location of breakwaters in connection with harbor development. It also appears to have an application to the distribution of wave energy along beaches located in the lee of headlands and offshore islands.

The sheltering effect of a breakwater of finite length and vertical impermeable walls depends upon diffraction of the incident waves around the ends of the breakwater. The phenomenon is analagous to the diffraction of light, and a theory of breakwater diffraction has been adapted from the theory of physical optics. To check the applicability of this theory to problems of breakwater design a series of model studies was made in the wave tank at University of California, Berkeley, California. The tests consisted primarily of generating waves which moved toward a model breakwater that could be given various orientations. Heights of the incident waves as well as wave heights at various points in the lee of the breakwater were measured by recording instruments. The conclusions from these tests were that the general form of the wave-diffraction theory was verified. Good agreement was obtained for the region sheltered by the breakwater for all angles of incidence investigated (that is, from 0° to 135°). Outside of the geometric shadow the experimental wave heights were considerably less than the theoretical heights. In general the theoretical solution may be applied to the location and design of breakwaters with conservative results. In other words, the predicted wave heights in disturbed regions in the lee of the breakwater will be somewhat larger than the height of waves that may be expected in nature. No effect on diffraction resulted from rounding the tip of the breakwater. It should be noted that the diffraction theory applies only to waves in deep water; that is, refraction effects are not included in the treatment.

The use of the wave diffraction theory in breakwater design problems is made convenient when summarized in a diagram which shows curves of equal values of diffraction coefficients on a coordinate system in which the origin is at the breakwater tip; the diffraction coefficient in this instance being defined as the ratio of the diffracted wave height to the incident wave height. Figure 7 shows such a generalized diagram where coordinates at a particular point are expressed as a multiple of the wave length. It is of interest to note on this diagram that along the geometric shadow the wave heights are one-half of the height of the incident waves, and that waves slightly greater in height than the incident waves are possible beyond the breakwater.

The use of a diffraction diagram in arriving at the most desirable alignment of a breakwater first necessitates the selection of the design wave from a consideration of the factors discussed above; that is, the height, period and direction of the incident wave from which protection is to be provided. A large scale map of the general area at the proposed breakwater is required and the direction (or directions) of the critical waves is indicated. For the given wave period the wave length is computed and a diagram showing curves of equal wave diffraction coefficients similar to Figure 7, is plotted on transparent paper with the same length scale as the map of the general area. This transparent paper with the same length scale as the map of the general area. This transparent overlay then may be moved around on the map(keeping the geometric shadow parallel to the direction of wave travel) until the desired degree of protection for a selected reach of the shore line has been obtained. The location of the breakwater tip is thus determined. For example, Figure 8 shows such an analysis for the orientation of proposed breakwaters at Hunters Point in San Francisco Bay, California. From an analysis of available wind observations it was found that relatively high waves of 3.6-second period (wave length of 66 feet) could be expected from the SE and from SSE. For this period a diffraction coefficient diagram was computed and plotted on transparent paper. With a specified clearance of 2,700 feet between the pier and the proposed breakwater and the specification that the docking facilities would not be subjected to waves more than one-half the height of the incident waves, the overlays were shifted over the map until the desired degree of protection was attained. Examination of this figure shows that waves from the SE were used at the northerly end of the breakwater and waves from the SSE were used for the southerly end, as these conditions were considered to be the most serious. Thus, for waves approaching Hunters Point from the SE to SSE sector the breakwater orientation shown in Figure 8 assures the designer that wave heights in the docking area will be sufficiently small so as not to interfere with normal operations. For this orientation two positions of the southern tip are shown--one for present development and a second for ultimate development. For the latter condition, note that by placing a portion of the southern end of the breakwater at an angle to the main section the same degree of protection can be achieved at the dock area with a shorter overall length of breakwater.

The treatment of diffraction problems, as discussed above, is concerned with waves moving past a breakwater tip with an infinite expanse of water existing off the tip. In many harbors, however, waves may move through a relatively narrow gap in a breakwater; hence, diffraction takes place at the tip on the two sides of the gap and changes in wave height in the lee of breakwater will be different than if a single tip existed. A theory for this condition also has been developed, and model studies for verification have been made. As in the case of diffraction at a single breakwater tip, the application of the results to the determination of wave heights within a harbor is made convenient by the use of transparent overlays.

The generalized diagrams for determining sheltering effects due to the diffraction of waves and the generalized scales for the graphical construction of refraction diagrams are of considerable value to the design engineer. These aids permit the analytical solution of many problems connected with harbor design and eliminate the necessity, in many instances, of relatively expensive model studies.

Wave Action on Structures

Considerable attention has been devoted in the past to the structural design of installations exposed to wave action. A review of the principles employed in stress determinations is beyond the scope of this paper, and the discussion above is confined entirely to the methods of determining the characteristic of the waves which would impose the most critical stresses. Thus, the height, period, and direction of the highest waves, that are possible at a specified offshore point in deep water, can be estimated by an examination of past weather charts (in the case of the sea coast) or from wind records (for a lake or bay). The principles of refraction and diffraction permit a designer to determine the characteristics of these same waves at any other point after they have moved shoreward. That location where a structure will receive the most favorable protection from wave action, therefore, can be selected with confidence.

It should be recognized that maximum stresses are developed when waves break directly on a structure. Even though wave heights at a structure may be less than the offshore waves, as a result of refraction or diffraction, the breaking of these waves may induce relatively high stresses; consequently, the expected point at which waves will break should be considered in the final analysis of a design. In some cases it is possible to avoid excessive stresses induced by breaking waves, by orienting the structure such that much of the wave energy is reflected by the structure itself, or much of the wave energy may be dissipated by forcing the wave to break before it reaches the structure.

As previously mentioned, wind generated waves usually are the most important to consider in harbor design. However, in areas subject to long-period ground swell, surging often becomes a serious problem because the period of the ground swell may be close to the fundamental, or first, or second harmonic of the natural period of oscillation of the body of water within the harbor. In many instances the natural period of a basin and, therefore the possibility of surging, can be determined by simple computation from the dimensions of the body of water. In harbors of relatively complicated dimensions, however, a resort to model studies may be necessary to completely solve the problem of surging.

Acknowledgment

With the exception of the wave forecasting method which was developed at the Scripps Institution of Oceanography, La Jolla, the various developments described above resulted from investifations made at the University of California by the Department of Engineering, Berkeley. This work was sponsored by the Bureau of Ships and the Office of Naval Research.

* * * *

Figure 1. Aerial photograph showing wave conditions at Morro Bay, California. Small wind waves and a long low swell are present. Note that the swell is almost invisible in deep water but peaks up near shore to form the predominant breakers.

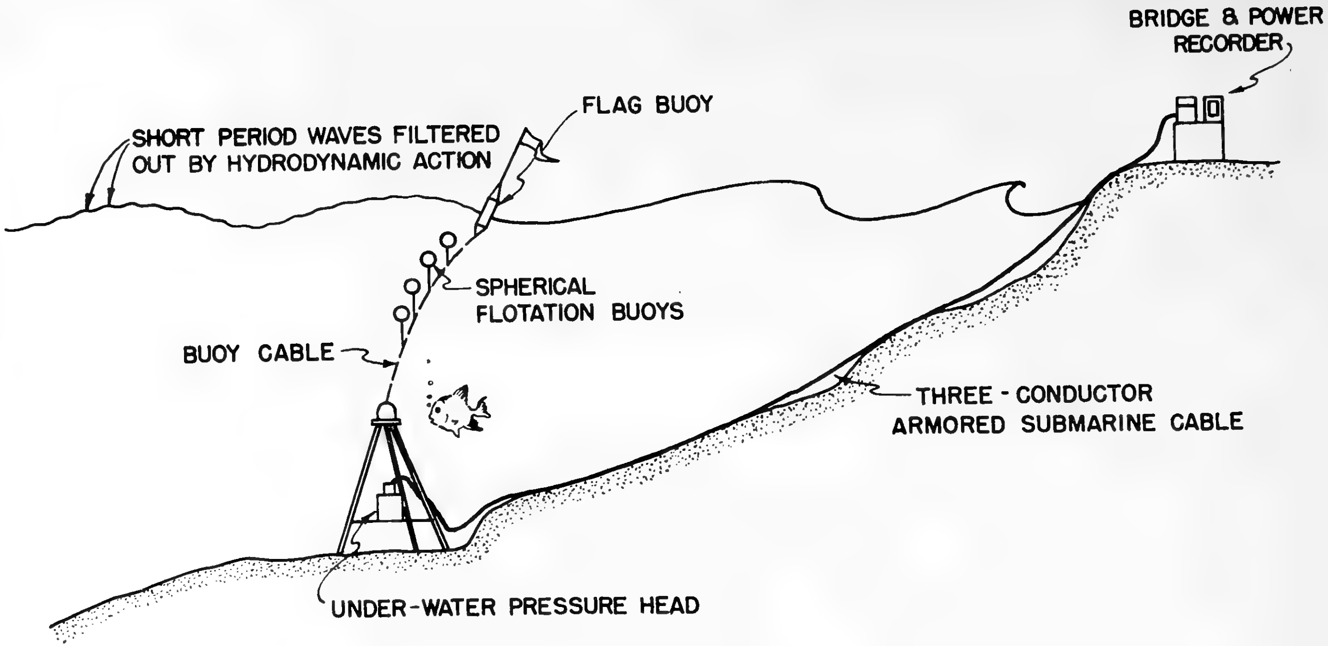


Figure 2. Schematic diagram of a typical shore wave recorder.

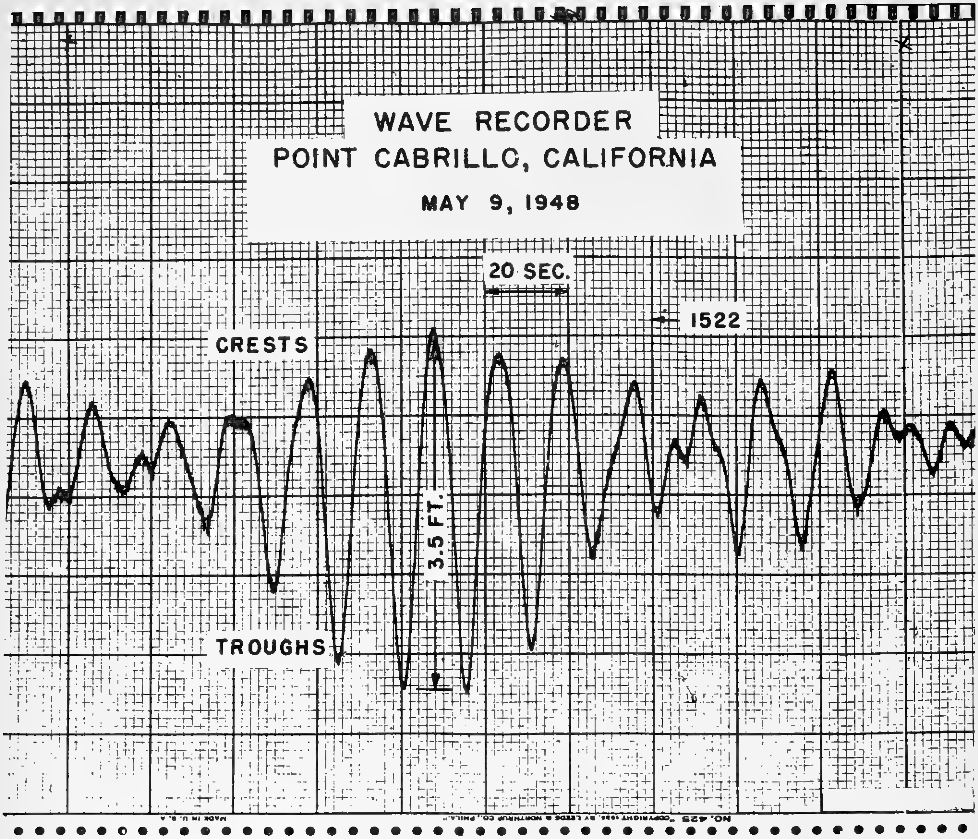


Figure 3. Sample chart from a shore wave recorder. Note the typical variation in the height and period of the waves.

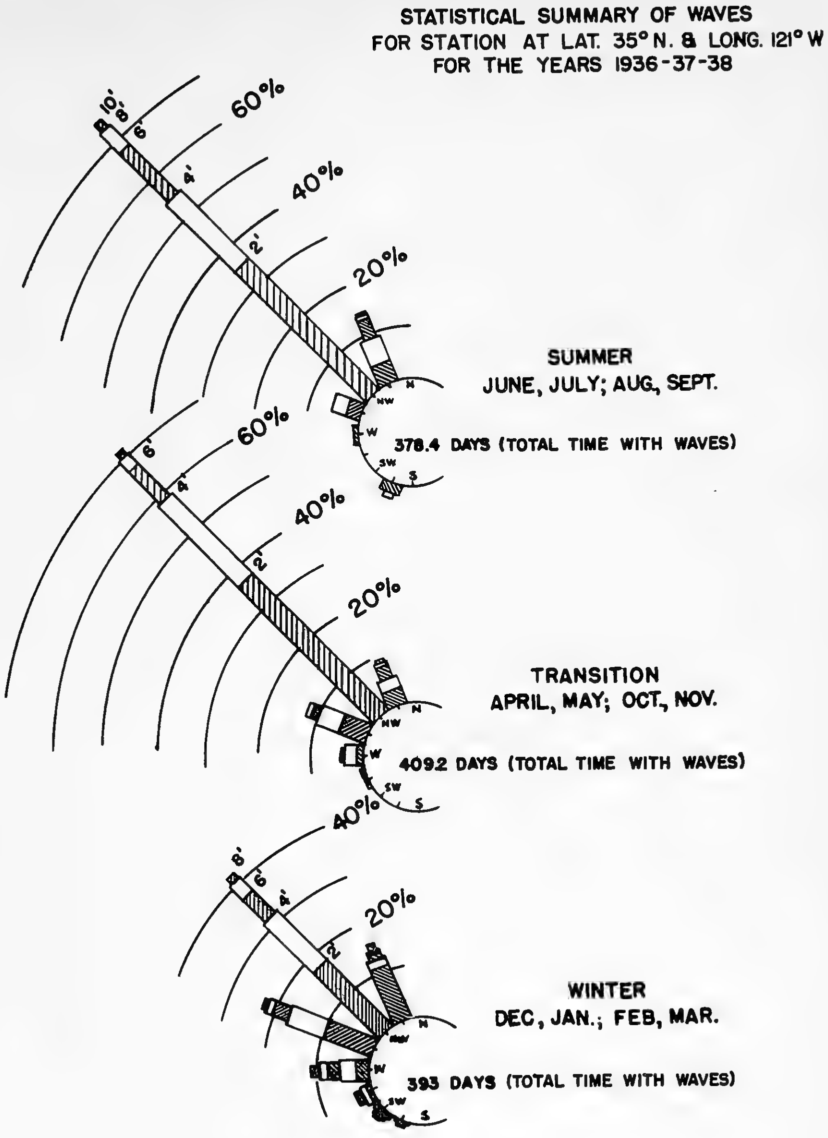


Figure 4. Typical direction roses which show the percentage of total days when wave heights were less than a given value.

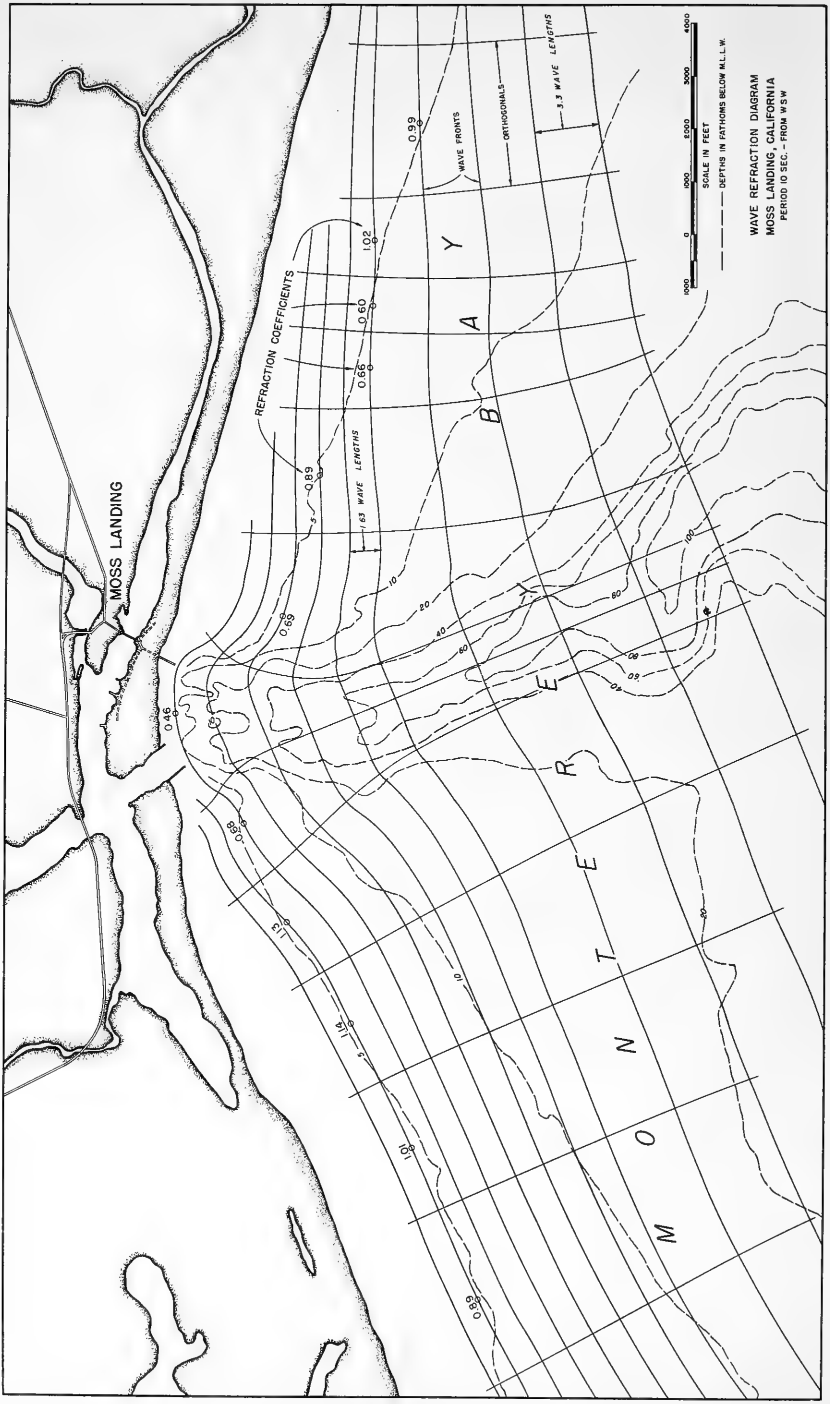
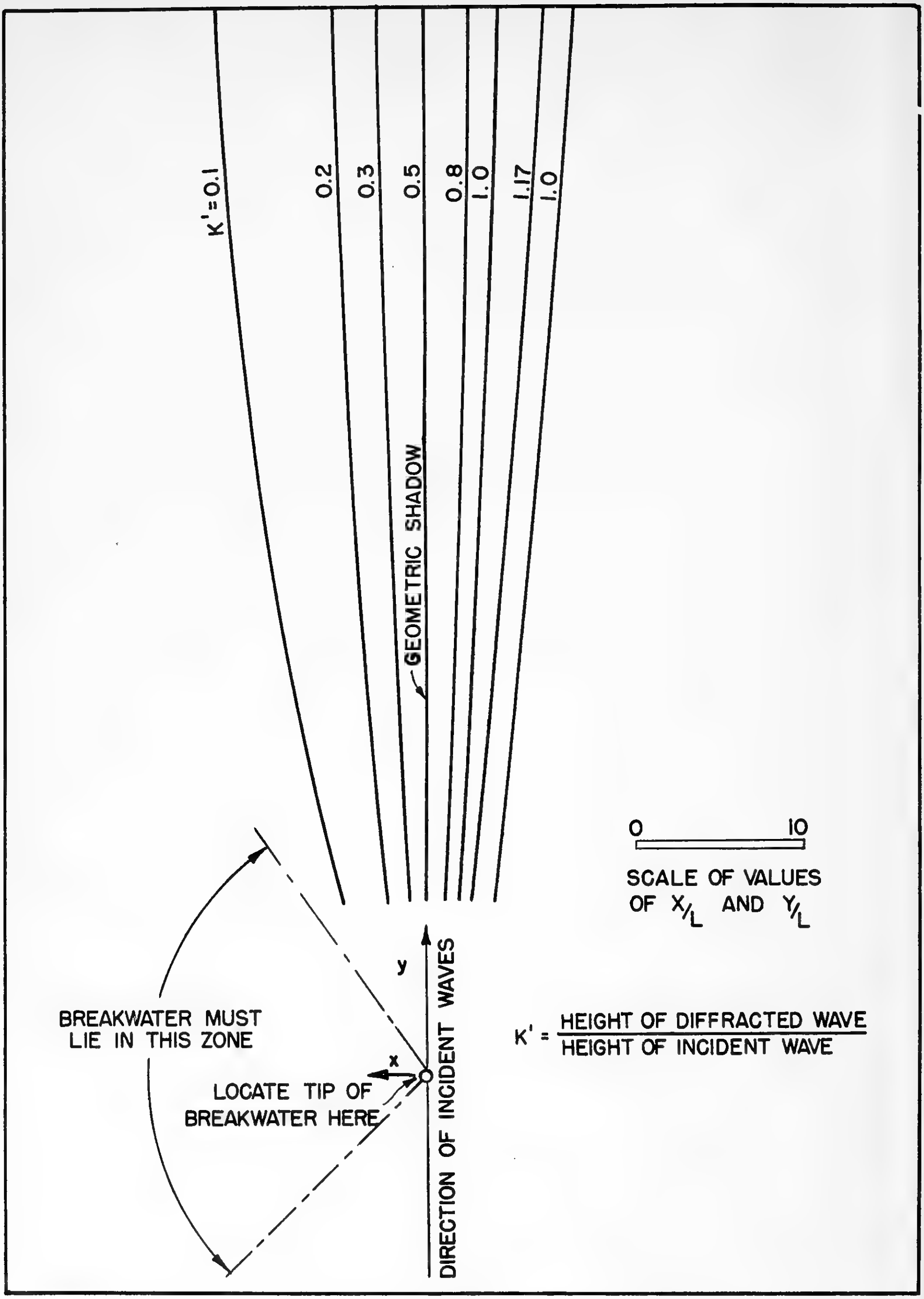

MOSS LANDING
REFRACTION COEFFICIENTS
WAVE FRONTS
ORTHOGONALS
3.3 WAVE LENGTHS
1.63 WAVE LENGTHS
M O N T E R E Y B A Y
0.99
1.02
0.60
0.66
0.89
0.69
0.46
0.68
1.13
1.14
1.01
0.89
5
10
20
40
60
80
100
SCALE IN FEET
1000 0 1000 2000 3000 4000
DEPTHS IN FATHOMS BELOW M.L.L.W.
WAVE REFRACTION DIAGRAM
MOSS LANDING, CALIFORNIA
PERIOD 10 SEC. - FROM WSW

FIG. 5

Figure 6. Aerial photograph showing typical wave conditions at Moss Landing, California.



WAVE DIFFRACTION BEHIND A VERTICAL IMPERMEABLE BREAKWATER

FIG. 7

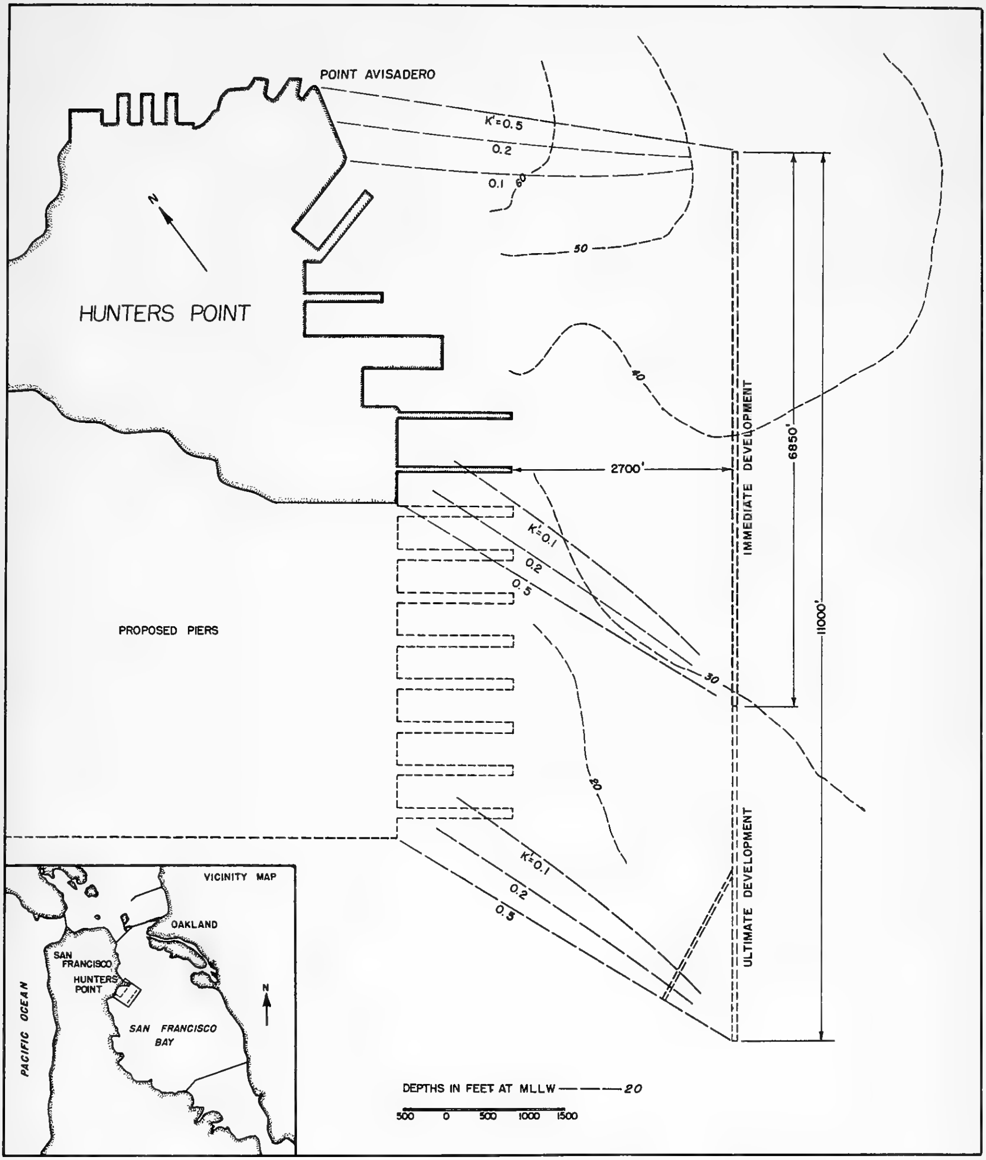
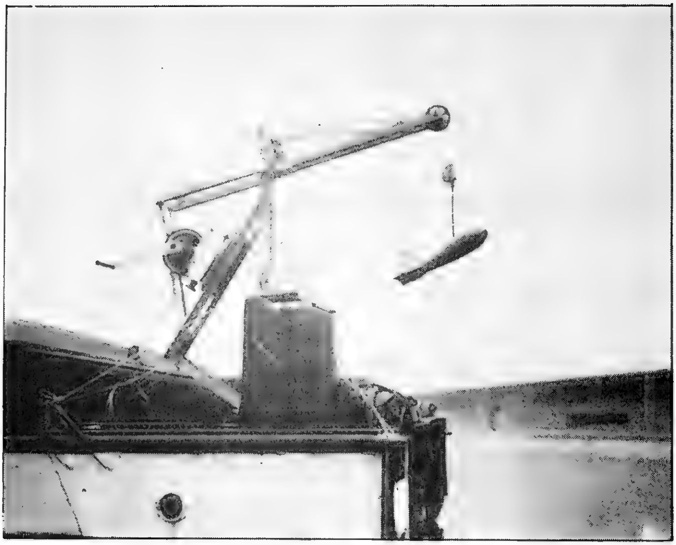
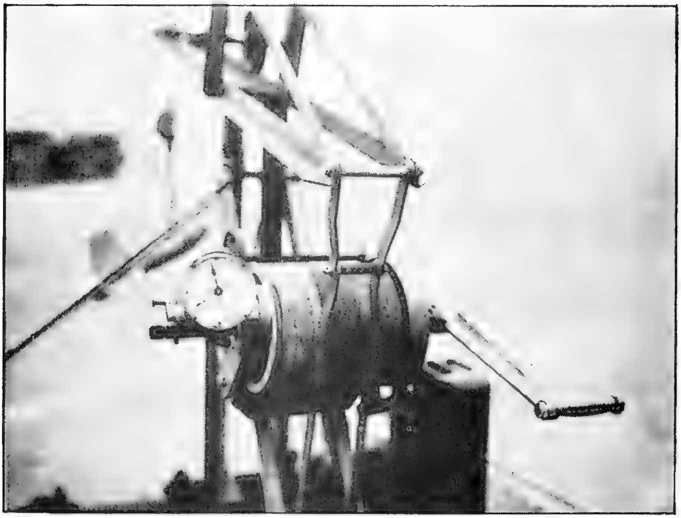


FIGURE 8 - ILLUSTRATION OF THE USE OF DIFFRACTION DIAGRAMS IN DETERMINING THE ORIENTATION OF BREAKWATERS WHICH GIVE THE GREATEST DEGREE OF PROTECTION AGAINST WAVE ACTION



STREAM GAGING UNIT MOUNTED ON STERN OF DUKW
FIGURE 1



WINDING DRUM AND COUNTING DEVICE OF THE STREAM GAGING UNIT
FIGURE 2

COMBINING LEADLINE AND ECHO-SOUNDING METHODS IN SURVEYS OF SUBMARINE CANYONS

The Field Research Group of the Beach Erosion Board was required in connection with littoral drift studies to make an accurate hydrographic survey of the head of the submarine canyon off Redondo Beach, California. The walls of the canyon are very steep, often exceeding slopes of 1:1, and the use of an echo sounder for determining submarine relief in this case was not considered sufficiently accurate.

The usual survey procedure of the Field Research Group is to take echo soundings on given ranges, starting from deep water and running shoreward. The echo-sounding equipment is operated from an amphibious truck (DUKW) and horizontal control is maintained by two radio-equipped shore stations. It was desirable to continue utilizing this method as far as possible, however the working schedule of the Group did not allow time for detailed leadline sounding by this process. A more rapid method was devised using heavy duty stream gaging equipment in conjunction with the echo sounder.

A standard stream gaging unit was borrowed from the Los Angeles Office, U.S. Geological Survey, consisting of a 100-pound streamlined lead weight fastened to a stainless steel wire and supported by a collapsible boom, see Figure 1. The wire winding drum is equipped with a counting device (Figure 2) that reads to tenths of feet. This equipment is normally used for stream gaging from bridges with either a 100- or 50-pound lead weight.

Operational tests were conducted with both the 50- and 100- pound weight, to determine the optimum operating speed of the DUKW, and the feasibility of running ranges both seaward and landward. It was found that by reducing the speed of the DUKW from about 450 feet per minute (normal operating speed) to 180 feet per minute, and using the 100-pound weight the sounding line would not "bow" or "drag" appreciably in depths as great as 150 feet. The characteristics of the depth counter are such that if the weight was allowed to run nearly free, the instant the lead weight touched bottom and the line slacked the counter would stop long enough for a reading to be taken before continuing to indicate. Thus by running the range seaward, or downslope, the leadline could be dropped and the brake applied as soon as the indicator showed bottom, the forward speed of the DUKW then would quickly drag the weight into deep water, the line would resume vertical, and another sounding could be taken. It was found after a few hours training that the leadsman could take leadline soundings at 15 to 20 second intervals (45 to 60 feet sounding interval) in depths as great as 150 feet.

While the echo-sounder recording does not show true vertical depths it is useful to show the relative detail in the vicinity of the leadline soundings.

The working procedure of the group was to start from the shore end of the canyon and travel seaward at a rate of 180 feet per minute, using both the echo sounder and the leadline. The leadsman would take soundings as rapidly as possible. The operator of the echo sounder would watch the leadline and as the lead struck bottom, mark a "fix" on the echo-sounder recording and call "fix" over the radio to signal the shore stations to cut in the horizontal position of the DUKW. By utilizing this procedure accurate leadline soundings were plotted every 45 to 60 feet and the echo-sounder recordings were used to fill in details between successive leadline soundings.

The characteristics of submarine canyons make this sounding technique practical. The relatively steep slopes of the canyon are usually firm sand, clay or rock thus eliminating the possible objection of sinkage into the bottom of the 100-pound lead weight.

It is believed that the combination of leadline and echo sounder methods described provides a satisfactory means of obtaining relatively accurate depth information on the slopes of submarine canyons or other very steep submarine slopes.

* * * *

FORECASTING BREAKERS AND SURF ON A STRAIGHT BEACH OF INFINITE LENGTH

GENERALIZED DIAGRAMS FOR FORECASTING BREAKERS AND SURF ON A STRAIGHT BEACH OF INFINITE LENGTH

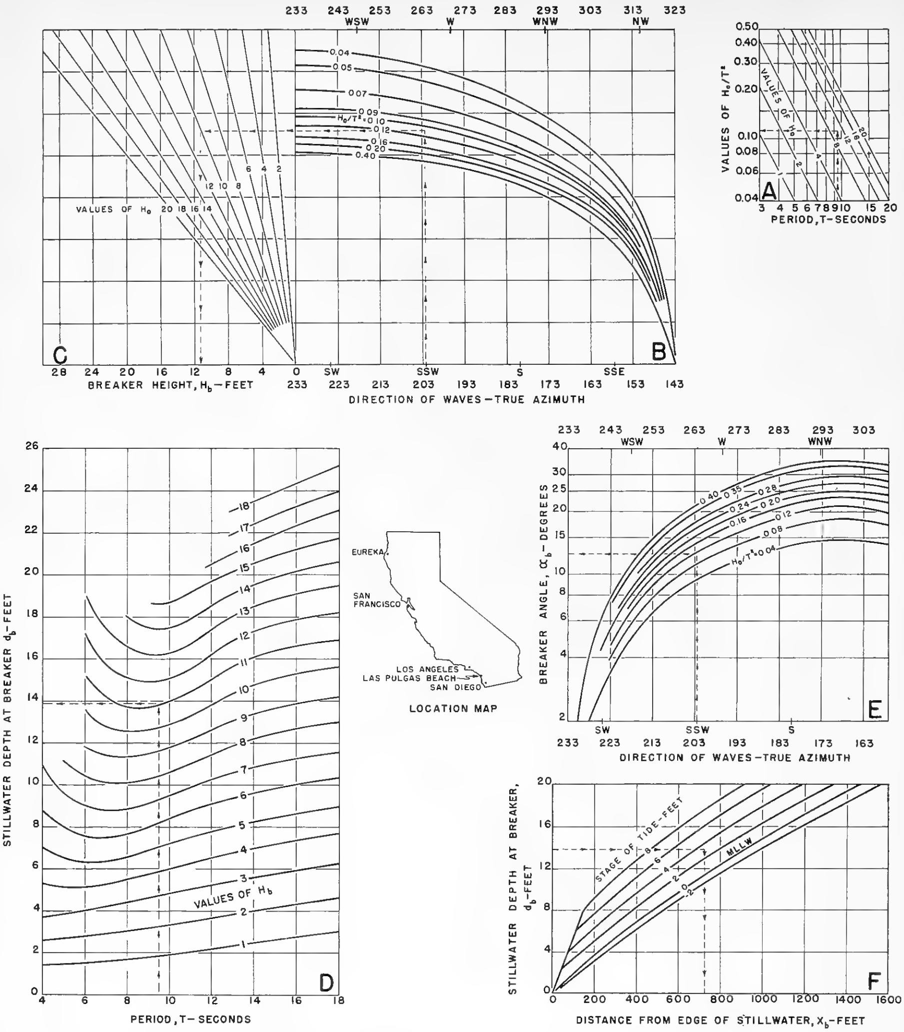
The following memoranda were first published in limited issue as Technical Reports HE-116-13 and HE-116-67, Fluid Mechanics Laboratory, University of California. They are reproduced here to bring the wave forecasting methods therein to the attention of research workers and other persons interested in wave forecasting. The memoranda were prepared by the staff of the Department of Engineering, University of California, February 1947.

In forecasting the characteristics of breakers and surf at a particular beach, the process is simplified with the aid of diagrams. From a deep water forecast of wave height (H_o), period (T), and wave direction, a forecast also may be made of breaker height (H_b), depth at breaker (d_b), angle of breaker with the bottom contours (α_b), and distance from edge of still water to breaker (X_b). The surf forecasts are made simple with the aid of diagrams presented in "Breakers and Surf, Principles in Forecasting", H.O. No. 234, and supplementary data; however, the forecast can be simplified further by means of other diagrams obtained by replotting the curves in Manual No. 234. Figure 1 shows such a plot in which all forecast computations are made graphically from diagrams appearing on a single page. This figure applied only to Las Pulgas Beach near Oceanside, California; however, many of the diagrams are general in character and can be used at any locality by merely shifting scales. Figure 2 shows the basic diagrams which can be adapted to any beach. The discussion to follow describes the method of plotting each of the individual diagrams as well as explaining the steps necessary in adapting the data to any beach such as Las Pulgas Beach (Figure 1).

Breaker Height

When waves with a particular steepness in deep water (H_o/L_o) approach a straight shore line of infinite length with wave crests parallel to the bottom contours, the height of the waves changes according to the curve of H/H'_o as a function of d/L_o shown in Plate I of H.O. Manual No. 234. The value of d/L_o at which the waves break depends on the initial steepness (H_o/L_o). If, however, the waves in deep water make an angle α_o with the shore, as they move into shallow water, refraction occurs and wave heights are reduced. The angle with which the waves make with the bottom contours depends on the value of d/L_o and the deep water angle α_o. This relationship is shown in Plate II (H.O. No. 234). Also shown in this plate are corresponding values of k, the correction factor to wave height because of refraction.

By definition, the following relationships may be expressed: $k = \dfrac{H'_o}{H_o}$ (1)



WAVE CHARACTERISTICS FROM FORECAST:- H_o=10 FT., T=9.5 SEC., AZIMUTH=202.5 DEG. DETERMINE SURF CHARACTERISTICS WHEN THE STAGE OF TIDE IS +3.5 FT.

FROM CHART A: FOR T=9.5 SEC., H_o/T^2=0.11

FROM CHART B: FROM INTERSECTION OF THE CURVE H_o/T^2=0.11 AND AZIMUTH OF 202.5 DEG. DRAW HORIZONTAL LINE TO CURVE OF H_o=10 FT. ON CHART C; THEREFORE, BREAKER HEIGHT, H_b=11.1 FT.

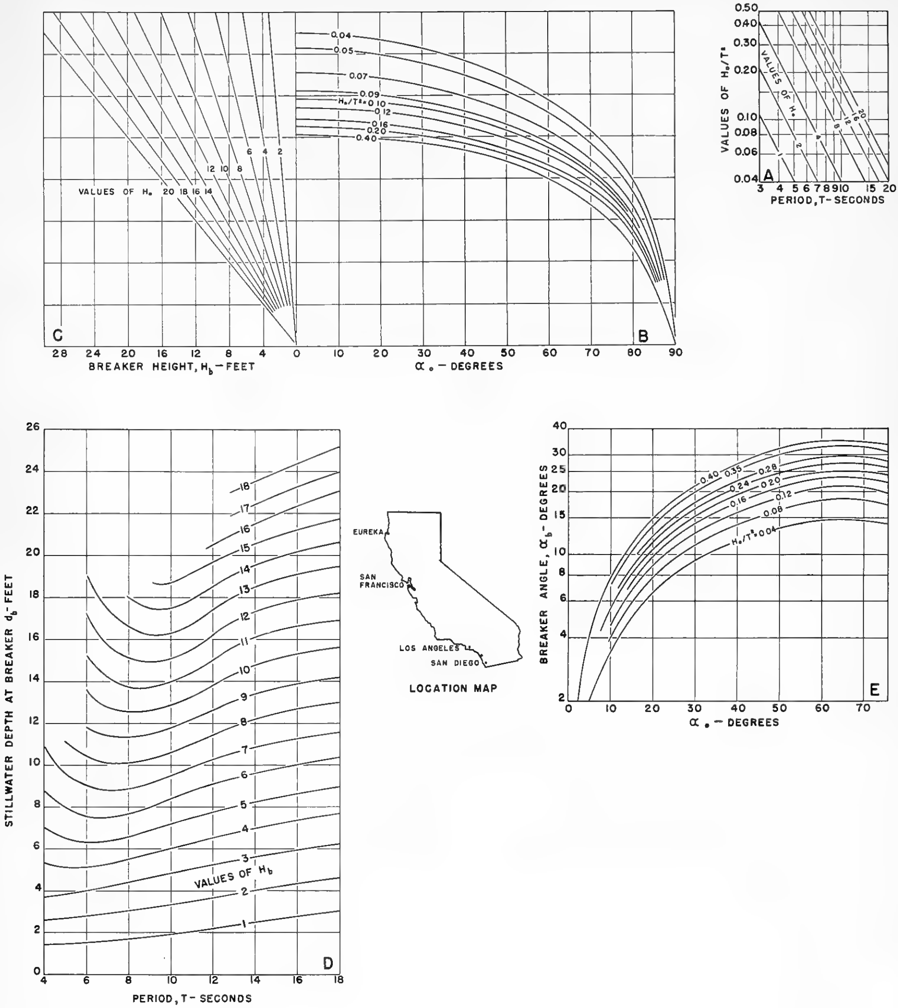
FROM CHART D: FOR T=9.5 SEC. AND H_b=11.1 FT., DEPTH AT BREAKER, d_b=13.9 FT.

FROM CHART E: FOR H_o/T^2=0.11 AND AZIMUTH OF 202.5 DEG., α_b=12.5 DEG.

FROM CHART F: FOR d_b=13.9 FT. AND A TIDE OF +3.5 FT., X_b=725 FT.

SURF FORECASTING CHART
FOR
LAS PULGAS BEACH

FIGURE I



SURF FORECASTING CHART

FIGURE 2

or

$$k = \frac{H'_o/L_o}{H_o/L_o}$$

Replacing L_o in the denominator by $5.12T^2$

$$k = \frac{(H'_o/L_o)}{(H_o/T^2)} \times 5.12 \qquad (2)$$

By a combination of Plates I and II (H.O. No. 234) and the use of Equation (2) a curve to show the relationship between H_b/H_o and α_o can be constructed (Diagram B of Figure 2). Breaker height H_b then can be obtained from another diagram which shows values of H_b/H_o plotted against H_b with curves of constant H_o (Diagram C, Figure 2).

The procedure in computing data for plotting Diagram B is as follows:

Assume a value of $H_o/L_o = 0.0780$

Then $H_o/T^2 = 0.078 \times 5.12 = 0.40$

For various assumed values of d_b/L_o computations are made in tabular form, (Table I).

TABLE I

PLOTTING DATA FOR DIAGRAM B

$H_o/L_o = 0.078$ ($H_o/T^2 = 0.40$)

Assumed Value of d_b/L_o	H'_o/L_o	H_b/H'_o	k	H_b/H_o	α_o deg.	α_b deg.
	From Plate I (H.O. No. 234)		$H'_o/L_o \div H_o/L_o$	Col. 3 times Col. 4	From Plate II H.O. No. 234 with Cols. (1) and (4) as Arguments	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0.06	0.0445	1.03	0.570	0.59	74.3	34.0
0.07	0.052	1.02	0.666	0.68	68.5	34.7

Computations as shown in Table I are made with other values of H_o/L_o. Cross plots then permit a diagram to be constructed with H_b/H_o plotted against α_o for various constant values of H_o/L_o or H_o/T^2 (see Diagram B, Figure 2). In order to eliminate a slide-rule computation of H_o/T^2 from the forecast values of H_o and T, Diagram A has been prepared.

It is to be noted that for a particular beach the scale showing values of α_0 in Diagram B could be replaced by a scale which shows the true azimuth of the wave direction. For example, in the diagram for Las Pulgas Beach (Figure 1) the true azimuth of the beach is 233 degrees; hence, this azimuth is equivalent to an α_0 of zero degrees. Points of the compass also may be indicated on the scale.

Diagram C is plotted alongside Diagram B with a common ordinate scale, H_b/H_o. Thus, for a particular wave direction α_0 and value of H_o/T^2 obtained from Diagram A, H_b/H_o is obtained from Diagram B. For this value of H_b/H_o, the breaker height H_b is obtained from Diagram C for the forecast value of H_o.

Breaker Depth

To obtain the depth of breaking for breakers of a certain height and period, the data is Plate III of H.O. No. 234 has been replotted to give Diagram D. For a particular period the depth of breaking, d_b, is obtained from Plate III for various breaker heights, H_b. These plotting data are given in Table II.

TABLE II

VALUES AT DEPTH OF BREAKING

(Obtained from Plate III. H.O. No. 234)

T (sec.) H_b (ft.)	4	5	6	7	8	9	10	12	14	16	18
1	1.2	1.3	1.5	1.8	1.8	2.0	2.0	2.1	2.4	2.8	3.0
2	2.5	2.6	2.8	3.0	3.2	3.3	3.4	3.6	3.9	4.4	4.6
3	3.7	3.8	4.0	4.2	4.4	4.6	4.8	5.2	5.5	6.0	6.2
4	5.3	5.1	5.1	5.3	5.5	5.7	6.0	6.5	7.0	7.3	7.7
5	7.0	6.5	6.3	6.5	6.6	6.9	7.3	7.7	8.2	8.6	9.0
6	8.7	8.0	7.5	7.5	7.7	8.0	8.4	9.1	9.5	10.0	10.4
7	10.9	9.5	9.1	8.8	8.8	9.2	9.5	10.3	10.8	11.2	11.6
8		11.1	10.4	10.1	10.1	10.3	10.6	11.4	12.2	12.6	13.0
9			11.8	11.4	11.3	11.5	11.8	12.6	13.5	13.8	14.2
10			13.5	12.7	12.5	12.6	12.9	13.8	14.8	15.2	15.6
11			15.2	14.2	13.7	13.7	14.0	15.0	16.2	16.5	16.9
12			17.2	15.7	15.1	14.9	15.1	16.2	17.3	17.8	18.2
13			19.1	17.4	16.6	16.2	16.3	17.4	18.5	19.0	19.5
14					18.0	17.5	17.5	18.5	19.5	20.1	20.6
15							18.7	19.7	20.5	21.1	21.7
16								20.5 20.8	21.4	22.35	23.3 22.9
17									21.4	23.2	24.0
18									23.5	25.3	25.2
19											26.5
20											27.9

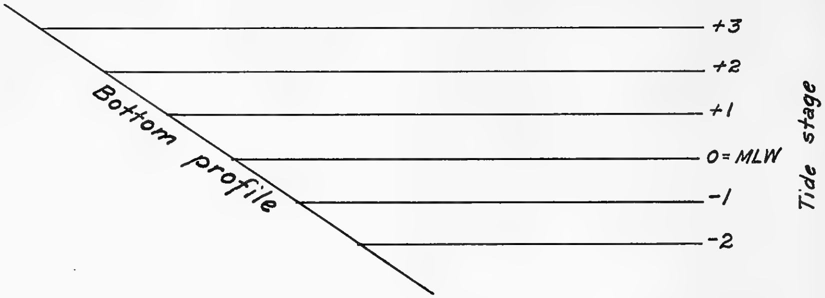
The depth of breaker, d_b, is determined from Diagram D for the forecast period, T, and the breaker height, H_b, obtained from Diagram C.

Breaker Angle

The angle with which the breakers make with the bottom contours is obtained from the same data used in preparing Diagram B. Referring to Table I, it is noted that breaker angle, α_b, and deep water wave direction α_o, will give a family of curves of constant H_o/T^2. Such a plot is shown in Diagram E, Figure 2. As in the case of Diagram B, the scale of α_o may be replaced by true azimuth when a particular beach is under consideration. Thus, in Figure 1 for Las Pulgas Beach, the true azimuth and compass points are shown instead of the deep water angle, α_o.

Distance to Breaker from Edge of Still Water

The distance X_b from the edge of still water to the point of breaking is a function of the bottom profile and the stage of the tide. A simple diagram to give this distance would be merely a bottom profile with various stages of the tide indicated as shown in the following sketch.



With the stage of tide known and the depth at breaking determined from Diagram D, the point at breaking can be located. The distance from this point to the edge of still water is scaled from the sketch. Because such a diagram requires a sliding scale, a family of profile curves is used to simplify the procedure. The intersections between the water surface (at various stages of the tide) and the bottom are determined, and the profiles below these points then are plotted with the above mentioned intersections at a common point. Diagram F (Figure 1) shows such a diagram for Las Pulgas Beach. It is to be noted that Diagrams A-E, inclusive, are general in character and apply to any straight beach with proper notation as to the α_o scales in Diagrams B and E; however, Diagram F is different for each locality and therefore is omitted from the general diagrams, Figure 2.

When available it is also planned to include a diagram for forecasting the strength of the littoral current.

MEMORANDUM CONCERNING THE WATER DEPTH AND WAVE ANGLE AT THE POINT OF BREAKING

Methods in use for determining the water depth and the angle between the wave crest and the depth contour, at the point at which waves break, appear to be susceptible to some simplification for straight shore lines. Only the breaker condition is desired. The quantities given by the forecast are α_o, T, and H_o. The refraction coefficient, k or H_o'/H_o, is a function of α_o and d/T^2 only. Using these quantities and the experimentally determined breaking conditions from Plate I of "Breakers and Surf, Principles in Forecasting", H. O. No. 234, the curves are as shown in Figure 1.

The method of solution is to assume values of (d_b/T^2) and obtain $\frac{H'_o}{H_o}$ from the curve for the pertinent value of α_o. Multiply the true value of $\frac{H_o}{T^2}$ by $\frac{H'_o}{H_o}$ and compare with the value of $(\frac{H_o}{T^2})b$. At the breaking condition,

$$\left(\frac{H_o}{T^2}\right)b = \left(\frac{H_o}{T^2}\right) \cdot \left(\frac{H_o'}{H_o}\right)$$

As an example of the method, assume the following conditions:

$\alpha_o = 40^\circ$

$H_o = 5$ ft.

$T = 10$ sec.

Therefore

$$\frac{H_o}{T^2} = 0.05$$

By trial and error,

Assume d_b/T^2	$(H_o/T^2)b$	$\left(\frac{H'_o}{H_o}\right)$	$\left(\frac{H_o}{T^2}\right) \times \left(\frac{H'_o}{H_o}\right)$
0.10	0.052	0.88	0.044
0.09	0.044	0.88	0.044

The correct value of d_b/T^2, therefore, is 0.09 and the corresponding values of other terms are:

$$\left(\frac{H_o}{T^2}\right)b = 0.044$$

and the depth at breaking is,

$$d_b = 0.09 \times 10^2 = 9 \text{ ft.}$$

From Figure 1,

$$\frac{H_b}{H_o} = 1.47$$

and the height of the breaker is,

$$H_b = 1.47 \times 5 = 7.4 \text{ ft.}$$

From Plate II of "Breakers and Surf", H. O. No. 234, (Figure 2) a copy of which is attached for convenience, the breaker angle is computed as follows:

$$\frac{d_b}{L_o} = \frac{9}{(5.12)\ (10)^2} = 0.0176$$

Then from Plate II, for this value of d_b/L_o and $\alpha_o = 40^\circ$, the breaker angle is,

$$\alpha_b = 12^\circ$$

This method of computation is an alternate method to the generalized diagrams for forecasting breakers and surf presented above.

It involves a trial and error computation; whereas, the method utilizing generalized diagrams does not, all computations being made graphically.

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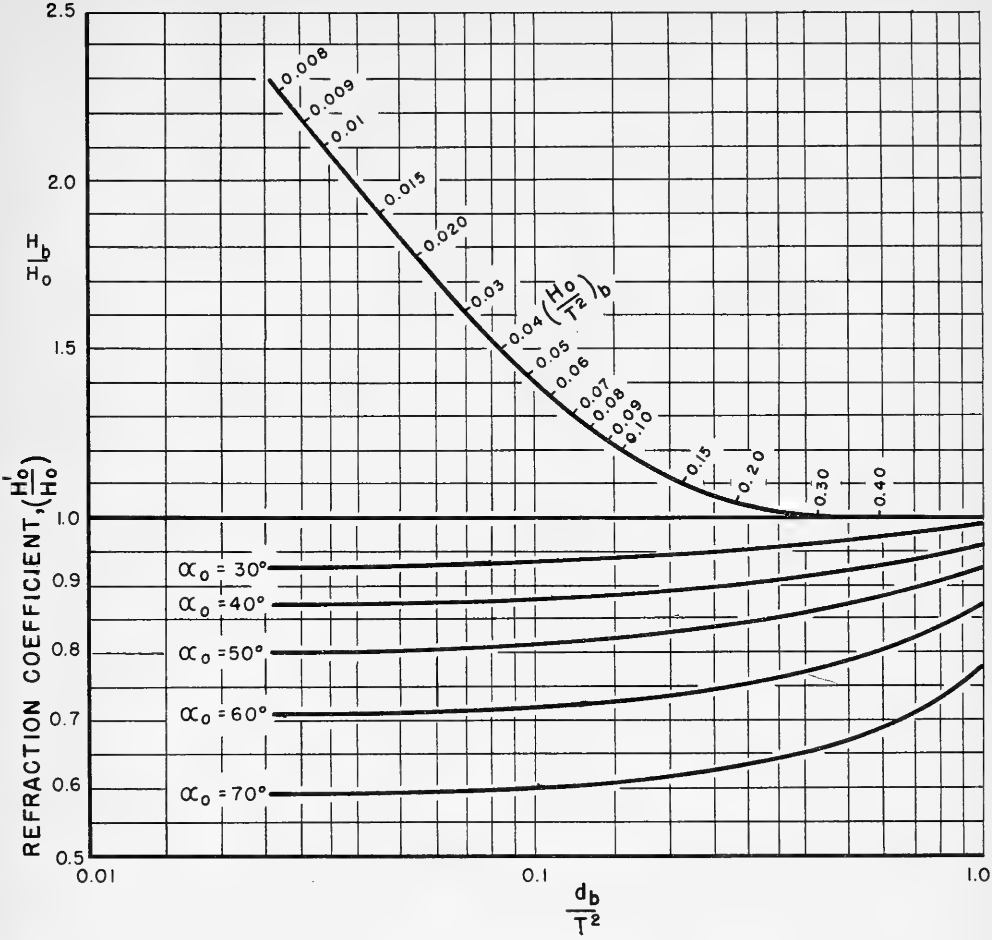

BREAKER CHARACTERISTICS

DETERMINATION OF WAVE HEIGHT AND DEPTH OF WATER AT POINT OF BREAKING FOR WAVES ON A BEACH OF INFINITE LENGTH

FIGURE I

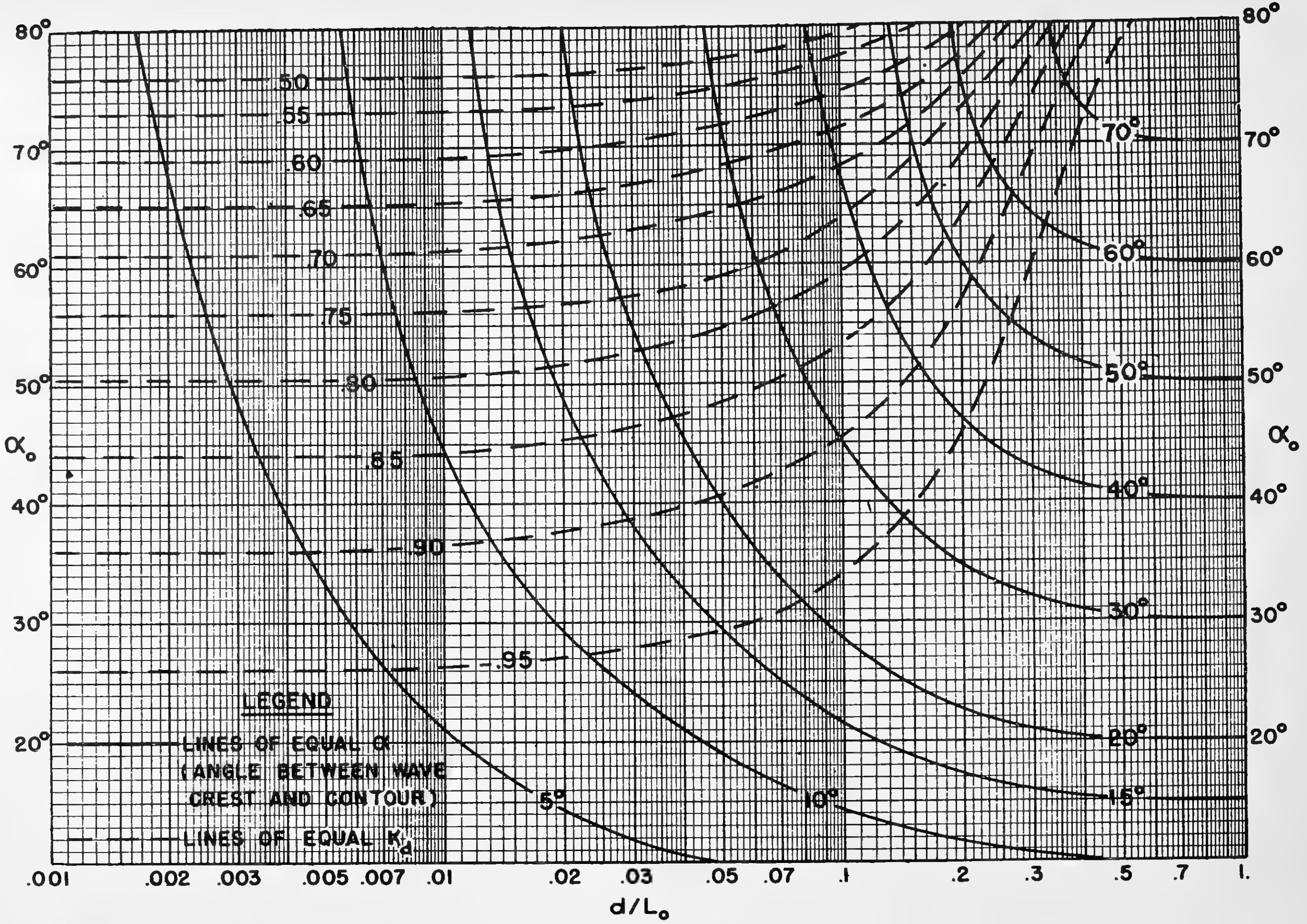

Fig. 2. Change in Wave Direction and Height Due to Refraction on Beaches with Straight, Parallel Depth Contours

CONSTRUCTION OF ADDITIONAL BEACH EROSION BOARD RESEARCH FACILITIES

The Beach Erosion Board research facilities are being expanded by the construction of a large wave tank and a coast model test basin. Plans and specifications for the tanks were prepared in conjunction with the District Engineer, Corps of Engineers, Washington, D. C. and the construction is being performed under the general supervision of the District Engineer. The contractor is Blackwell Engineering Company, Warrenton, Virginia. The work is to be completed in 270 calendar days for a total contract cost of $354,958. This contract is about 25 per cent complete at the time this publication goes to press.

Wave Tank

The wave tank will be 635 feet long, 15 feet wide, and 20 feet deep. Generation of waves is to be accomplished by a pusher-type wave generator capable of producing a maximum wave 6 feet in height and 300 feet in length, in a normal water depth of 15 feet. The tank will be built of reinforced concrete with the top of the tank 4 feet above the finished grade. A working platform traveling longitudinally on rails, anchored to top of the tank wall will provide access and measurement facilities during the experiments. Three stop-log slots will be built in the walls to allow partition of the tank into variable lengths and reduce water requirements. The tank will be used for the study of the design of upstream slope protection for earth dams, sea walls, breakwaters, other harbor protective structures, and other structures subject to wave action.

The design of the large wave tank presented numerous problems which were studied in a 1:12 scale model in the Board's laboratory to assist in the actual design of the tank.

Coast Model Test Basin

The basin will be 300 feet by 150 feet in plan and 3 feet deep. Reinforced concrete construction is to be used throughout the basin structure with the 3 feet perimeter wall extending above finished grade. A test area of about 200 feet by 100 feet, with a water depth of 2 feet in the offshore, will be utilized in conducting tests. Wave generators will produce a maximum wave in the magnitude of 2/3 feet in height in the 2-foot water depth. In order to provide flexibility in the location and arrangement of the wave generating equipment, the equipment will be constructed in several units. The type of wave generator to be utilized in the coast model basin is being investigated by small scale model studies. In conjunction with the basin a storage reservoir 40 feet square and 11 feet deep will be constructed to function as a sump, with pump facilities, for simulating tides. Two pumps, one 4,500 gpm and the other 2,200 gpm, will provide for water circulation to the basin.

The basin will be used to study methods of controlling inlets to prevent damage to adjacent shores; means of reducing wave and current action on beaches; the general behavior of barrier beaches; methods of protecting and building beaches without damaging adjacent beaches; plans to prevent shoaling of navigation channels; and specific areas of severe coastal erosion when warranted.

* * * * *

BEACH EROSION STUDIES

The principal types of beach erosion reports of studies at specific localities are the following:

a. Cooperative studies (authorization by the Chief of Engineers in accordance with Section 2, River and Harbor Act approved on 3 July 1930).

b. Preliminary examinations and surveys (Congressional authorization by reference to locality by name).

c. Reports on shore line changes which may result from improvements of the entrances at the mouths of rivers and inlets (Section 5, Public Law No. 409, 74th Congress).

d. Reports on shore protection of Federal property (authorization by the Chief of Engineers).

Of these types of studies, cooperative beach erosion studies are the type most frequently made when a community desires investigation of its particular problem. As these studies have, consequently greater general interest, information concerning studies of specific localities contained in these quarterly bulletins will be confined to cooperative studies. Information about other types of studies can be obtained upon inquiry to this office.

Cooperative studies of beach erosion are studies 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 on 3 July 1930. By executive ruling the cost of these studies is divided equally between the United States and the cooperative agency. Information concerning the initiation of a cooperative study may be obtained from any District 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. A list of cooperative studies now in progress follows:

COOPERATIVE BEACH EROSION STUDIES IN PROGRESS

NEW HAMPSHIRE

HAMPTON BEACH. Cooperative Agency: New Hampshire Shore and Beach Preservation and Development Commission.

Problem: To determine the best method of preventing further erosion and of stabilizing and restoring the beaches; also to determine the extent of silting and erosion in the harbor.

MASSACHUSETTS

METROPOLITAN DISTRICT BEACHES, BOSTON. Cooperating Agency: Metropolitan District Commission (for the Commonwealth of Massachusetts).

Problem: To determine the best methods of preventing further erosion, of stabilizing and improving the beaches, and of protecting the sea walls of Lynn Shore Reservation, Nahant Beach Parkway, Revere Beach, Quincy Shore, Nantasket Beach.

SALISBURY BEACH. Cooperating Agency: Department of Public Works (for the Commonwealth of Massachusetts).

Problem: To determine the best methods of preventing further beach erosion. This will be a final report to report dated 26 August 1941.

CONNECTICUT

STATE OF CONNECTICUT. Cooperating Agency: State of Connecticut (Acting through the Flood Control and Water Policy Commission).

Problem: To determine the most suitable methods of stabilizing and improving the shore line. Sections of the coast will be studied in order of priority as requested by the coöperating agency until the entire coast is included.

NEW JERSEY

OCEAN CITY. Cooperating Agency: City of Ocean City.

Problem: To determine the causes of erosion or accretion and the effect of previously constructed groins and structures, and to recommend remedial measures to prevent further erosion and to restore the beaches.

VIRGINIA

VIRGINIA BEACH. Cooperating Agency: Town of Virginia Beach.

Problem: To determine the methods for the improvement and protection of the beach and existing concrete sea wall.

SOUTH CAROLINA

STATE OF SOUTH CAROLINA. Cooperating Agency: State Highway Department.

Problem: To determine the best method of preventing erosion, stabilizing and improving the beaches.

LOUISIANA

LAKE PONTCHARTRAIN. Cooperating Agency: Board of Levee Commissioners, Orleans Levee District.

Problem: To determine the best method of effecting necessary repairs to the existing sea wall and the desirability of building an artificial beach to provide protection to the wall and also to provide additional recreational beach area.

TEXAS

GALVESTON COUNTY. Cooperating Agency: County Commissioners Court of Galveston County.

Problem: To determine the best method of providing a permanent beach and the necessity for further protection or extending the sea wall within the area bounded by the Galveston South Jetty and Eight Mile Road.

CALIFORNIA

STATE OF CALIFORNIA. Cooperating Agency: Division of Beaches and Parks, State of California.

Problem: To conduct a study of the problems of beach erosion and shore protection along the entire coast of California. The initial studies are to be made in the Ventura-Port Hueneme area and the Santa Monica area.

WISCONSIN

RACINE COUNTY. Cooperating Agency: Racine County.

Problem: To prevent erosion by waves and currents, and to determine the most suitable methods for protection, restoration and development of beaches.

ILLINOIS

STATE OF ILLINOIS. Cooperating Agency: Department of Public Works and Buildings, Division of Waterways, State of Illinois.

Problem: To determine the best method of preventing further erosion and of protecting the Lake Michigan shore line within the Illinois boundaries.

OHIO

STATE OF OHIO. Cooperating Agency: State of Ohio (Acting through the Superintendent of Public Works).

Problem: To determine the best method of preventing further erosion of and stabilizing existing beaches, of restoring and creating new beaches, and appropriate locations for the development of recreational facilities by the State along the Lake Erie shore line.

TERRITORY OF HAWAII

WAIKIKI BEACH. Cooperating Agency: Board of Harbor Commissioners, Territory of Hawaii.

Problem: To determine the most suitable method of preventing erosion, and of increasing the usable recreational beach area, and to determine the extent of Federal aid in effecting the desired improvement.

* * * *

BEACH EROSION LITERATURE

There are listed below some recent acquisitions of the Board's library which are considered to be of general interest. Copies of these publications can be obtained on 30-day loan by interested official agencies.

"Sea Waves and Microseisms," J. Darbyshire, Admiralty Research Laboratory, Teddington, England, A.R.L./R. 1/103.50/W, March 1948.

The paper reports the comparison of wave records at Perranporth with with simultaneous seismorgraph records at Kew made to detect the influence of two mid-Atlantic storms on microseismic activity. Meteorological charts for the storms are shown. Graphs show the spectra of the waves and microseisms obtained by submitting the records to frequency analysis. One of the conclusions states that the period of the waves is double that of the corresponding microseisms.

"A Theory of Microseism Generation," M. S. Longnet-Higgins, Admiralty Research Laboratory, Teddington, England, A.R.L./R.2/103.50/W, August 1948.

In the report a theoretical justification is given for the theory that microseisms of period 3 to 10 seconds originate in regions of wave interference in the sea. It is shown that the unattenuated pressure variations in a standing wave are due to simultaneous changes in the vertical momentum of the whole wave train. Variations in the mean pressure occur only when there is interference between groups of waves of the same frequency travelling in opposite directions, they are twice the wave frequency and are proportional to the product of the amplitudes of the two opposing groups. Simultaneous pressure variations over a wide area will give rise to compression in the water and sea bed. By considering the effect of an application of pressure to the surface of the water it is shown that the displacement of the ground should be of the same order of magnitude as that observed. The conditions of wave interference necessary for microseism generation should occur in a moving cyclonic depression or to a less extent when waves are reflected from a steep coast. The doubling of the wave frequency implied by theory is well supported by observation.

"Water Tables in Marine Beaches," K. O. Emery and J. F. Foster, Journal of Marine Research, Vol. VIII, No. 3, November 1948.

An attempt to learn the relationships between beach characteristics and changing water levels within the beach is made in this study. Measurements of the changing water table profiles in several beaches throughout a tidal cycle show the presence of an interchange of water between the ocean and the sand pores. Water escapes from the beach during ebb tide with a velocity sufficient to elutriate silt grains. Some water is drawn by capillarity to the sand surface where it evaporates, cementing the sand into a hard crust. Water table profiles are shown for the ebbing and flooding tides.

"Influence of the Water Table on Beach Aggradation and Degradation," U. S. Grant, Journal of Marine Research, Vol. VII, No. 3, November 1948.

Large waves provide the dynamic factors in rapid beach erosion, but the wetness or dryness of the beach contributes in an important manner to its erosion or aggradation. A high water table accelerates beach erosion, and conversely, a low water table may result in pronounced aggradation of the foreshore. A sensitive water table on a beach will have an important bearing on the method of artificial sand replenishment by sluicing.