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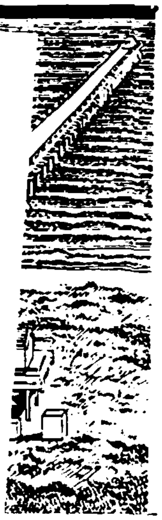

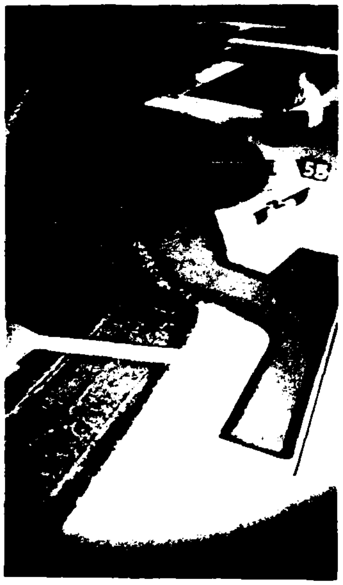

TECHNICAL REPORT CERC-90-4

# REDONDO BEACH KING HARBOR, CALIFORNIA, DESIGN FOR WAVE PROTECTION

## Coastal Model Investigation

by


Robert R. Bottin, Jr., Marvin G. Mize

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
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19 ABSTRACT (Continue on reverse if necessary and identify by block number)


A 1:75-scale, three-dimensional hydraulic model was used to investigate the design of proposed breakwater modifications at Redondo Beach King Harbor, California, with respect to wave conditions in the harbor. The model reproduced approximately 8,800 ft of the California shoreline and included the existing harbor and offshore bathymetry in the Pacific Ocean to a depth of -60 ft. Improvement plans consisted of raising the crest elevation of portions on the north breakwater both with and without installing a transition layer of small stone, and extending the length and crest elevation of the south breakwater. An 80-ft-long unidirectional, spectral wave generator, and an Automated Data Acquisition and Control System were utilized in model operation. It was concluded from test results that:

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18. SUBJECT TERMS (Continued).

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|---|---|
| Breakwaters | Redondo Beach King Harbor, California |
| Harbor, California | Wave damages |
| Hydraulic models | Wave protection |


19. ABSTRACT (Continued).

a. Existing conditions are characterized by very rough and turbulent wave conditions with wave heights up to 8 ft along the moles for 50-year conditions.

b. Of the original improvement plans tested with the seaward wing of the north breakwater raised to an elevation of +20 ft (Plans 1 through 7), Plan 6 provided the greatest wave protection within the harbor. Wave heights along the moles exceeded the criteria, however, by 1.0 ft for 50-year conditions.

c. Of the improvement plans tested with portions of the north breakwater raised to elevations of +24 and +20 ft (Plans 8 through 10), Plan 9 provided the greatest wave protection within the harbor. Wave heights exceeded the criteria along the moles by 0.7 ft for 50-year wave conditions.

d. Of the improvement plans tested with the seaward wing of the north breakwater sealed with small stone and raised to an elevation of +20 ft (Plans 10 through 14), Plan 12 provided the greatest degree of wave protection to the harbor. For 50-year wave conditions, wave heights met the established wave-height criteria along the moles within the harbor.

e. Of all the improvement plans tested (Plans 1 through 14), Plan 14 was considered optimal considering wave protection and construction costs.

f. Comprehensive wave-height tests conducted for Plan 14 indicated that the established wave-height criteria in the harbor would be met or only slightly exceeded for waves up to a 100-year recurrence from 240 and 260 deg. Waves in excess of 10 ft in height from 220 deg, however, in some cases, will significantly exceed the criteria particularly at Mole D and the entrance to Basin 3.


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# PREFACE

A request for a model investigation of wave conditions at Redondo Beach King Harbor, California, was initiated by the US Army Engineer District, Los Angeles (SPL), in a letter to the US Army Engineer Division, South Pacific. Authorization for the US Army Engineer Waterways Experiment Station (WES) to perform the study was subsequently granted by the Headquarters, US Army Corps of Engineers. Funds were authorized by SPL on 9 September 1988 and 7 November 1988.

Model testing was conducted at WES during the period from April through August 1989 by personnel of the Wave Processes Branch (WPB) of the Wave Dynamics Division (WDD), Coastal Engineering Research Center (CERC) under the direction of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Chief and Assistant Chief of CERC, respectively; and under the direct guidance of Messrs. C. Eugene Chatham, Jr., Chief of WDD; and Douglas G. Outlaw, Chief of WPB. The tests were conducted by Mr. Marvin G. Mize, Civil Engineering Technician, under the supervision of Mr. Robert R. Bottin, Jr., Project Manager. This report was prepared by Messrs. Bottin and Mize.

Prior to the model investigation, Messrs. Bottin, Mize, and Outlaw met with representatives of SPL and visited Redondo Beach King Harbor to inspect the prototype site and attend a general design conference. During the course of the investigation, liaison was maintained by means of conferences, telephone communications, and monthly progress reports.

The following personnel visited WES to observe model operation and participate in conferences during the course of the study:

| | |
|---|---|
| Mr. George Domurat | US Army Engineer Division, South Pacific |
| Mr. Carl Enson | US Army Engineer District, Los Angeles |
| Mr. Bob Hall | US Army Engineer District, Los Angeles |
| Mr. Art Shak | US Army Engineer District, Los Angeles |
| Mr. Chuck Mesa | US Army Engineer District, Los Angeles |
| Mr. Ken Montgomery | City of Redondo Beach, City Engineer |
| Mr. Wayne Sankey | City of Redondo Beach, Harbor Master |
| Ms. Sheila Schoettger | City of Redondo Beach, Harbor Director |
| Mr. Jim Bailey | City of Redondo Beach, Assistant Public Works Director |
| Mr. Terry Ward | City of Redondo Beach, Councilman, District 4 |
| Dr. Rich Kent | Consultant to City of Redondo Beach |

COL Larry B. Fulton, EN, was Commander and Director during the preparation and publication of this report. Dr. Robert W. Whalin was Technical Director.

CONTENTS

## CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

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

| Multiply | By | To Obtain |
|---|---|---|
| acres | 4,046.873 | square metres |
| cubic feet | 0.02831685 | cubic metres |
| degrees (angle) | 0.01745329 | radians |
| feet | 0.3048 | metres |
| inches | 2.54 | centimetres |
| knots (international) | 0.5144444 | metres per second |
| miles (US statute) | 1.609347 | kilometres |
| pounds (mass) | 0.4535924 | kilograms |
| square feet | 0.09290304 | square metres |
| square miles (US statute) | 2.589998 | square kilometres |
| tons (2,000 pounds, mass) | 907.1847 | kilograms |

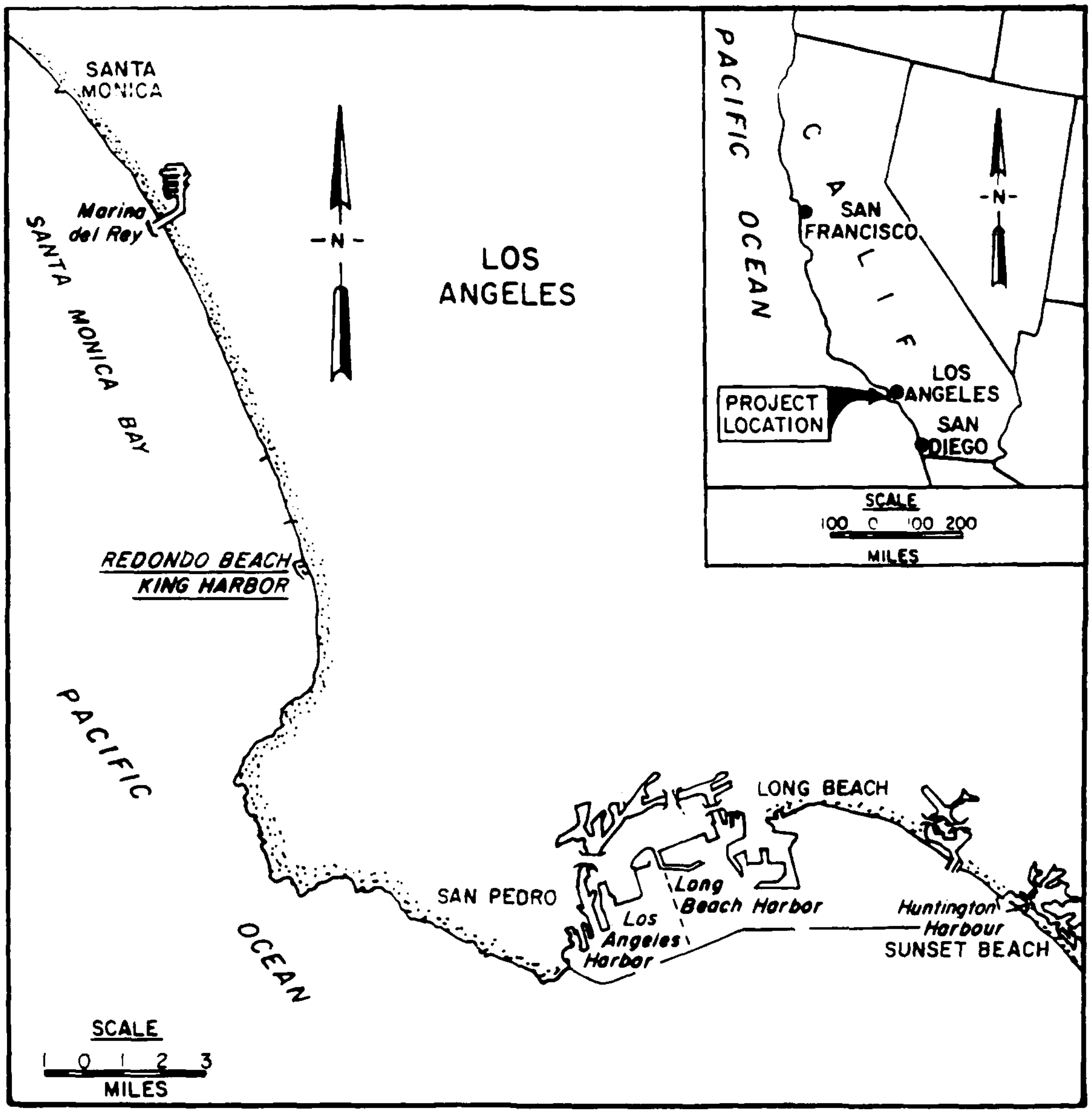


Figure 1. Project location

# REDONDO BEACH KING HARBOR, CALIFORNIA

## DESIGN FOR WAVE PROTECTION

Coastal Model Investigation

## PART I: INTRODUCTION

### The Prototype

1. Redondo Beach King Harbor (formerly Redondo Beach Harbor), California, is a small-craft harbor located on the Pacific coast at the southern end of Santa Monica Bay (Figure 1). It lies within the City of Redondo Beach, about 17 miles* southwest of the business center of the City of Los Angeles. The harbor is entirely man-made and serves as a port of call for visiting craft from the entire Pacific coast. Boats for hire and commercial, recreational, and sport fishing vessels serve local residents and tourists from throughout the Nation. The harbor is situated near productive fishing areas favorable to both sport and commercial fishing. It consists of about 55 acres of land and 112 acres of water. The harbor provides about 1,600 boat slips in three basins with a 77-acre mooring/anchorage area. The commercial and recreational facilities at Redondo Beach King Harbor attract approximately 8,000,000 visitors annually (US Army Engineer District (USAED), Los Angeles 1988).

2. Development of the harbor started in 1937 when a 1,470-ft-long stone breakwater was constructed. The harbor has undergone several modifications, improvements, repairs, etc., since initial construction (USAED, Los Angeles 1988; Bottin 1988), and currently consists of two permeable rubble-mound breakwaters which total 4,885 ft in length, three boat basins enclosed by moles, an entrance channel, and boat mooring area. An aerial photograph of the harbor is shown in Figure 2.

3. The south breakwater is 600 ft long and has an authorized crest elevation (el) of +12 ft.** The north breakwater is 4,285 ft long and has an authorized crest elevation of +14 ft for its outer 1,600 ft

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* A table of factors for converting Non-SI units of measurement to SI (metric) units is presented on page 3.

** All elevations (el) cited herein are in feet referred to mean lower low water (mllw).

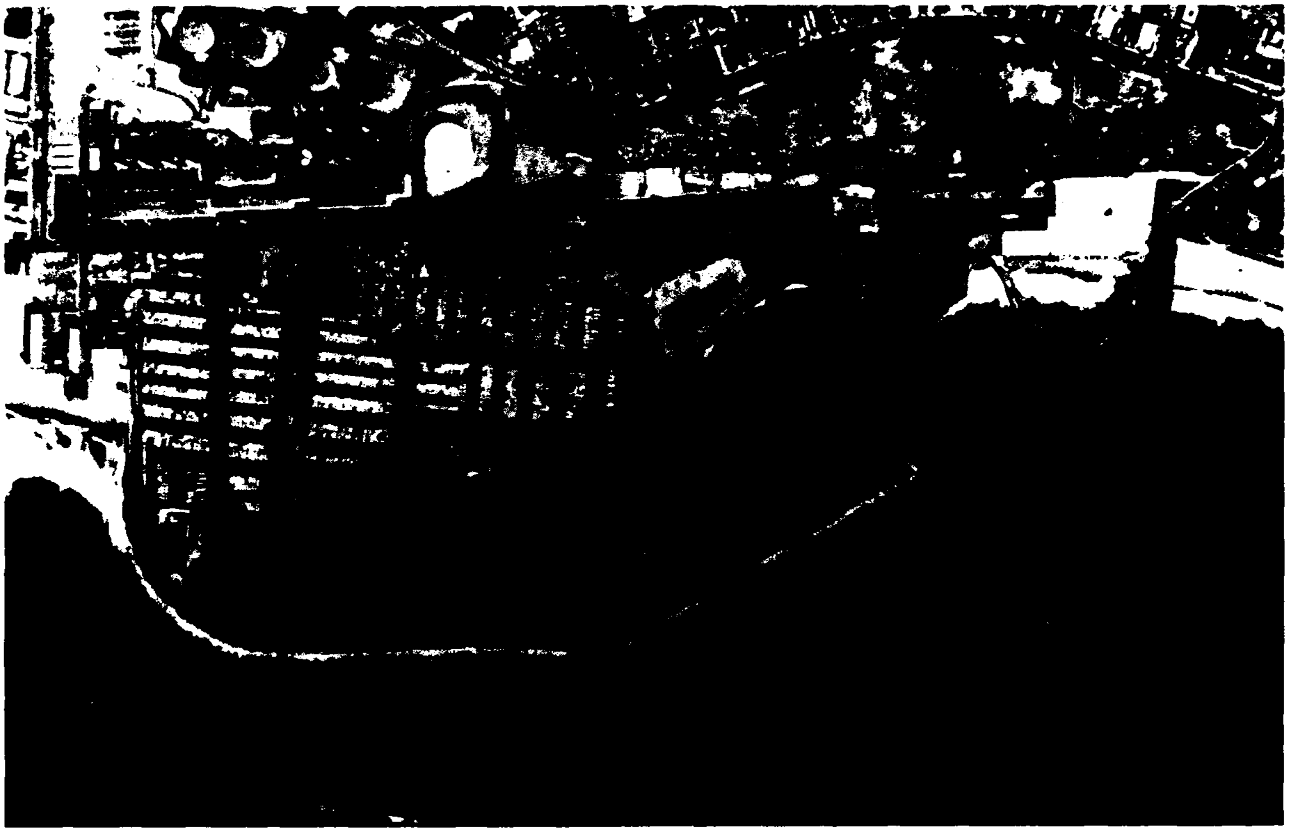


Figure 2. Aerial view of Redondo Beach
King Harbor

(sta 36+00 - 52+00), and +22 ft between sta 15+50 and 36+00. Actual elevations for the two sections average approximately +16 and +20 ft, respectively. The shoreward end of the north breakwater has a rubble-mound section (el +14 ft) with a concrete Galveston Seawall (el +20 ft). Wave protection baffles to the two northernmost basins (Basins 1 and 2) also have been constructed by the Federal government. Maintenance of the breakwaters is a Federal responsibility, whereas, the City of Redondo Beach is responsible for maintenance of the wave protection baffles and the concrete Galveston Seawall.

4. The City of Redondo Beach constructed and maintains the interior harbor, which consists of the three boat basins enclosed by moles, all with revetted slopes. The harbor entrance is formed by a 600-ft wide opening between the breakwaters for small-craft navigation. Natural depths through the entrance vary from 34 to 40 ft.

## The Problem

5. Redondo Beach King Harbor is susceptible to frequent damages when large winter storm waves occur in conjunction with high-water levels. The low-crested portion of the north breakwater is not adequate to dissipate wave energy for these storm events. The energy of overtopping waves, waves passing through the harbor entrance, and wave transmission through the rubble-mound structures result in adverse wave conditions in the harbor. Waves run up the revetment along the moles and result in revetment damage, land erosion, flooding, and structural failure of facilities bordering the water. Some of these facilities include hotels, restaurants, recreational facilities, and public and commercial buildings. Wave energy also passes through the mooring area and enters the boat basins, causing damage to boat hulls, mooring lines, and docking and launching facilities. These adverse conditions also make Redondo Beach King Harbor an unsafe port of refuge during times of high tides and large storm waves. Because of the frequency of these conditions, the city has been unable to increase mooring space in the lee of the low-crested north breakwater. Although waves overtop the higher section of the breakwater during extreme storms and high tides, much of the energy is lost and damage behind this portion is significantly less than storm damage behind the low-crested breakwater segment.

6. Storm damage potential ranges from damage to revetment and flooding that occurs annually, to catastrophic damages from storms with estimated recurrence intervals of 50 to 100 years. Average annual damages at the harbor are estimated at $962,300, while damages associated with a 100-year event are estimated to total $10,600,000 (USAED, Los Angeles 1988). The most damaging storm to date at Redondo Beach King Harbor occurred in January 1988 with damage estimates of $14,000,000. Some of these damages included destruction of substantial portions of three buildings; undermining of significant portions of revetment along the moles; sinking of six boats; damage to many other boats and piers; erosion of substantial land along the moles; damage to public parking areas, utilities, and fencing; and the loss of fueling facilities.

## Purpose of Model Study

7 At the request of the USAED, Los Angeles (SPL), a coastal hydraulic model investigation was initiated by the US Army Engineer Waterways Experiment Station's (WES) Coastal Engineering Research Center (CERC) to:

a. Study and define wave conditions in the existing harbor resulting from storm waves and high tide levels.

b. Evaluate the adequacy of proposed improvement plans with regard to desired storm wave protection levels.

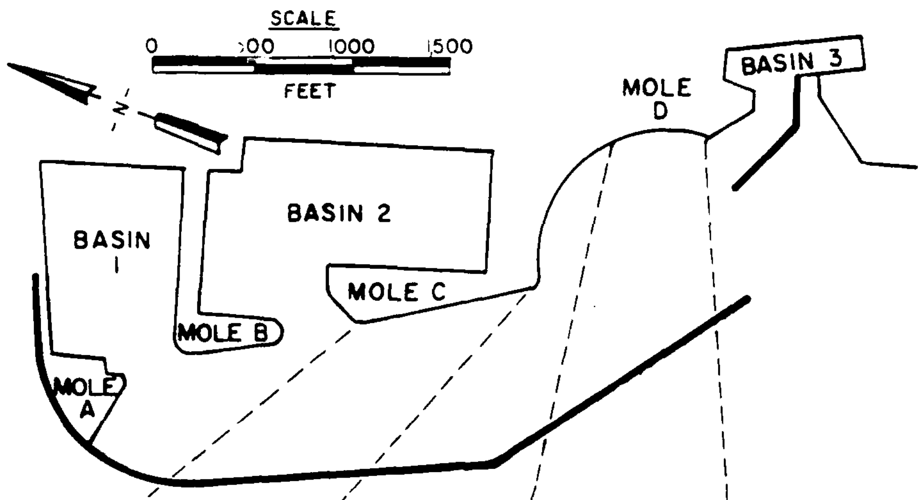
c. Develop remedial plans for the alleviation of undesirable wave conditions as found necessary.

d. Determine if suitable design modifications to the proposed plans could be made that would significantly reduce construction costs without sacrificing adequate wave protection.

A two-dimensional (2-D) model study was conducted to verify the stability and general overtopping conditions for the north breakwater design and is reported separately (Smith, Carver, and Dubose (in preparation)).

## Wave-Height Criteria

8. Completely reliable criteria have not yet been developed for ensuring satisfactory navigation and mooring conditions in small-craft harbors during attack by storm waves. For this study, however, SPL specified that for an improvement plan to be acceptable, maximum wave heights were not to exceed the criteria established in their Feasibility Report (USAED, Los Angeles 1988). These criteria varied at selected locations in the harbor for various return periods and are shown in Figure 3.




| RETURN PERIOD, YEAR | MOLE C STA 0+00–10+79 WAVE-HEIGHT CRITERIA, FT | MOLE C STA 11+00–20+00 WAVE-HEIGHT CRITERIA, FT | MOLE D STA 20+00–25+00 WAVE-HEIGHT CRITERIA, FT | BASIN 3 WAVE-HEIGHT CRITERIA, FT |
|---|---|---|---|---|
| 100 | 4.3 | 2.9 | 2.1 | 1.3 |
| 50 | 3.0 | 2.3 | 2.0 | 1.2 |
| 25 | 2.3 | 2.0 | 1.9 | 1.2 |
| 10 | 1.9 | 1.9 | 1.8 | 1.0 |
| 1 | 1.8 | 1.8 | 1.7 | 1.0 |

Figure 3. Wave-height criteria at selected locations in the harbor for various return periods

## PART II: THE MODEL

### Design of Model

9. The Redondo Beach King Harbor model (Figure 4) was constructed to a geometrically undistorted linear scale of 1:75, model to prototype. Scale selection was based on such factors as:

- a. Depth of water required in the model to prevent excessive bottom friction.
- b. Absolute size of model waves.
- c. Available shelter dimensions and area required for model construction.
- d. Efficiency of model operation.
- e. Available wave-generating and wave-measuring equipment.
- f. Model construction costs.

A geometrically undistorted model was necessary to ensure accurate reproduction of wave and current patterns. Following the selection of a linear scale of 1:75, the model was designed and operated in accordance with Froude's model law (Stevens et al. 1942). The scale relations used for design and operation of the model were as follows:

| Characteristic | Dimension* | Model-Prototype Scale Relations |
|---|---|---|
| Length | $L$ | $L_r = 1:75$ |
| Area | $L^2$ | $A_r = L_r^2 = 1:5,625$ |
| Volume | $L^3$ | $\forall_r = L_r^3 = 1:421,875$ |
| Time | $T$ | $T_r = L_r^{1/2} = 1:8.66$ |
| Velocity | $L/T$ | $V_r = L_r^{1/2} = 1:8.66$ |

* Dimensions are in terms of length and time.

10. The existing breakwaters and revetments at Redondo Beach King Harbor, as well as proposed improvements, included the use of rubble-mound structures. Experience and experimental research have shown that considerable wave energy passes through the interstices of this type structure; thus, the transmission and absorption of wave energy became a matter of concern in design of the 1:75-scale model. In small-scale hydraulic models, rubble-mound

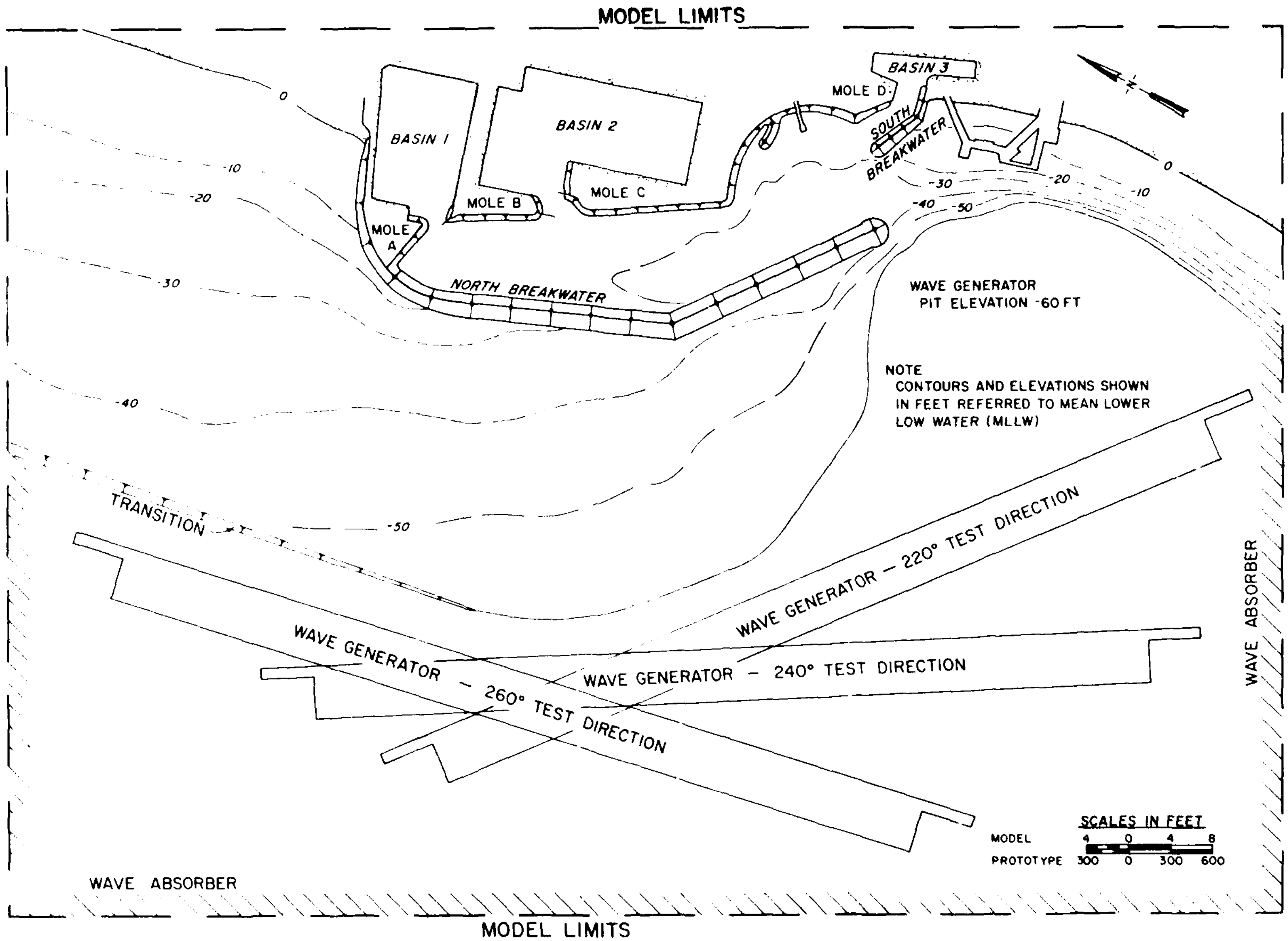



Figure 4. Model layout

structures reflect relatively more and absorb or dissipate relatively less wave energy than geometrically similar prototype structures (Le Méhauté 1965). Also, the transmission of wave energy through a rubble-mound structure is relatively less for the small-scale model than for the prototype. Consequently, some adjustment in small-scale model rubble-mound structures is needed to ensure satisfactory reproduction of wave-reflection and wave-transmission characteristics. In past investigations (Dai and Jackson 1966, Brasfeild and Ball 1967) at WES, this adjustment was made by determining the wave-energy transmission characteristics of the proposed structure in a 2-D model using a scale large enough to ensure negligible scale effects. A section then was developed for the small-scale, three-dimensional model that would provide essentially the same relative transmission of wave energy. Therefore, from previous findings for structures and wave conditions similar to those at Redondo Beach, it was determined that a close approximation of the correct wave-energy transmission characteristics could be obtained by increasing the size of the rock used in the 1:75-scale model to approximately 1.5 times that required for geometric similarity. Accordingly, in constructing the rubble-mound structures in the Redondo Beach King Harbor model, the rock sized were computed linearly by scale, then multiplied by 1.5 to determine the actual sizes to be used in the model.

## The Model and Appurtenances

11. The model reproduced about 8,800 ft of the California shoreline and included the harbor and underwater topography in the Pacific Ocean to an offshore depth of 60 ft. The total area reproduced in the model was approximately 10,300 sq ft, representing about 2.1 square miles in the prototype. A general view of the model is shown in Figure 5. Vertical control for model construction was based on mean lower low water (mllw). Horizontal control was referenced to a local prototype grid system.

12. Model waves were generated by an 90-ft-long, unidirectional spectral, electrohydraulic, wave generator with a trapezoidal-shaped, vertical-motion plunger. The wave generator utilized a hydraulic power supply. The vertical motion of the plunger was controlled by a computer-generated command signal, and the movement of the plunger caused a periodic displacement of water which generated the required test waves. The wave


Figure 5. General view of model

generator also was mounted on retractable casters which enabled it to be positioned to generate waves from the required directions.

13. An Automated Data Acquisition and Control System (ADACS), designed and constructed at WES (Figure 6), was used to generate and transmit control signals, monitor wave-generator feedback, and secure and analyze wave-height data at selected locations in the model. Basically, through the use of a VAX 750 computer, ADACS recorded onto magnetic discs the electrical output of parallel-wire, resistance-type wave gages that measured the change in water-surface elevation with respect to time. The magnetic disc output of ADACS then was analyzed to obtain the wave-height data.

14. A 2-ft (horizontal) solid layer of fiber wave absorber was placed around the inside perimeter of the model to dampen any wave energy that might otherwise be reflected from the model walls. In addition, guide vanes were placed along the wave generator sides in the flat pit area to ensure proper formation of the wave train incident to the model contours.

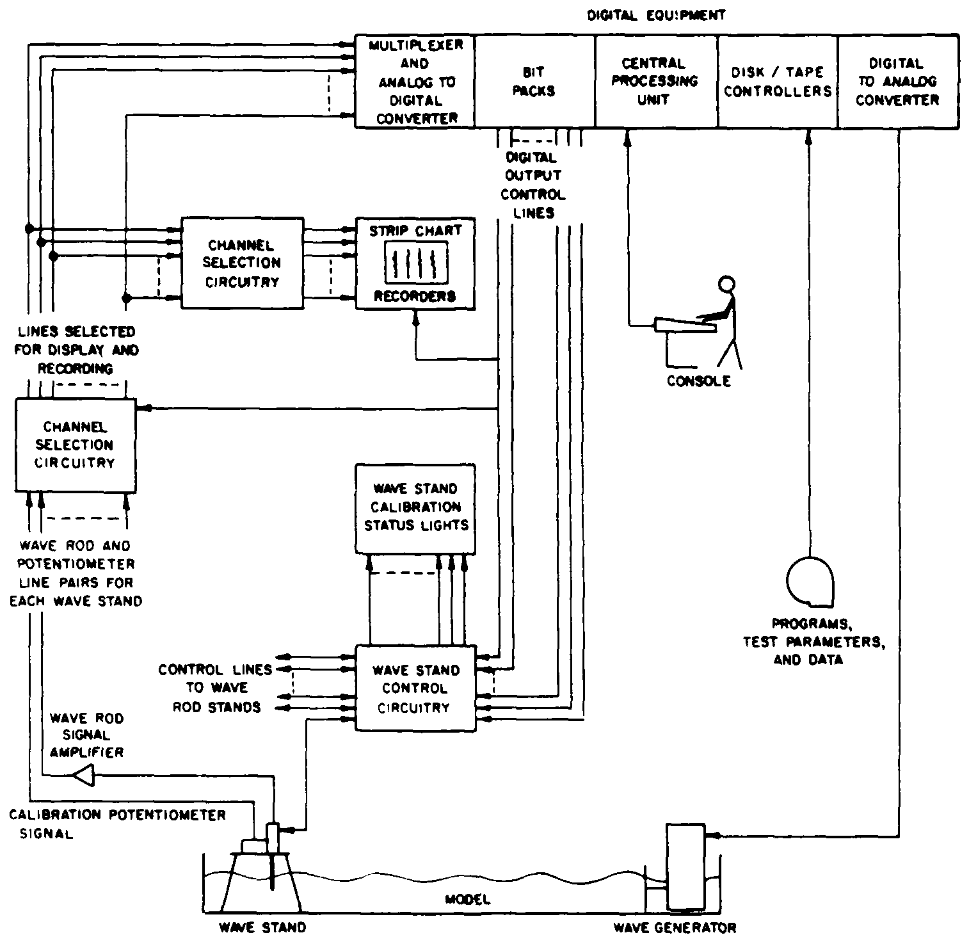



Figure 6. Automated Data Acquisition and Control System

## PART III: TEST CONDITIONS AND PROCEDURES

### Selection of Test Conditions

#### Still-water level

15. Still-water levels (swl's) for harbor wave action models are selected so that the various wave-induced phenomena that are dependent on water depths are accurately reproduced in the model. These phenomena include the refraction of waves in the project area, the overtopping of harbor structures by the waves, the reflection of wave energy from various structures, and the transmission of wave energy through porous structures.

16. In most cases, it is desirable to select a model swl that closely approximates the higher water stages which normally occur in the prototype for the following reasons:

- a. The maximum amount of wave energy reaching a coastal area normally occurs during the higher water phase of the local tidal cycle.
- b. Most storms moving onshore are characteristically accompanied by a higher water level due to wind tide, atmospheric pressure fluctuations, and wave setup.
- c. The selection of a high swl helps minimize model scale effects due to viscous bottom friction.
- d. When a high swl is selected, a model investigation tends to yield more conservative results.

17. Based on a review of 63 years of tide data from a gage located in Los Angeles Harbor, the annual and the 100-year return probability water levels at the site are +7.0 and +8.0 ft, respectively (USAED, Los Angeles 1988). Extreme water level predictions for Redondo Beach King Harbor are shown below. The data used for these extreme water level predictions include periods of storm activity when water level was elevated above the astronomical level due to surge components.

| Return Period years | Water Elevations ft above mllw |
|---|---|
| 100 | 8.0 |
| 50 | 7.9 |
| 25 | 7.8 |
| 10 | 7.6 |
| 1 | 7.0 |

SPL selected swl's of +7.0 and +8.0 ft for use during model testing. All improvement plans were tested with the +7.0 ft swl, while the +8.0 ft swl was used with testing of existing conditions and the most promising improvement plan.

Factors influencing selection
of test wave characteristics

18. In planning the testing program for a model investigation of harbor wave-action problems, it is necessary to select dimensions and directions for the test waves that will allow a realistic test of proposed improvement plans and an accurate evaluation of the elements of the various proposals. Surface-wind waves are generated primarily by the interactions between tangential stresses of wind flowing over water, resonance between the water surface and atmospheric turbulence, and interactions between individual wave components. The height and period of the maximum wave that can be generated by a given storm depend on the wind speed, the length of time that wind of a given speed continues to blow, and the water distance (fetch) over which the wind blows. Selection of test wave conditions entails evaluation of such factors as:

a. The fetch and decay distances (the latter being the distance over which waves travel after leaving the generating area) for various directions from which waves can attack the problem area.

b. The frequency of occurrence and duration of storm winds from the different directions.

c. The alignment, size, and relative geographic position of the navigation entrance to the harbor.

d. The alignments, lengths, and locations of the various reflecting surfaces inside the harbor.

e. The refraction of waves caused by differentials in depth in the area seaward of the harbor, which may create either a concentration or a diffusion of wave energy at the harbor site.

Prototype storm-wave data

19. Deepwater storm waves predominantly approach the outer continental shelf of the southern California coast from the northwest; however, storm waves generated by distant southern hemisphere disturbances occasionally approach from the westerly and southerly quadrants (USAED, Los Angeles 1988). Due to the shallow effects of the offshore Channel Islands, Redondo Beach King Harbor is exposed to large waves propagating from storms on the Pacific Ocean which travel eastward through three windows bounded by azimuths that measure 205 through 235 deg, 240 through 272 deg, and 283 through 290 deg (Figure 7). As described in Hales (1987), most storm waves in deep unsheltered water

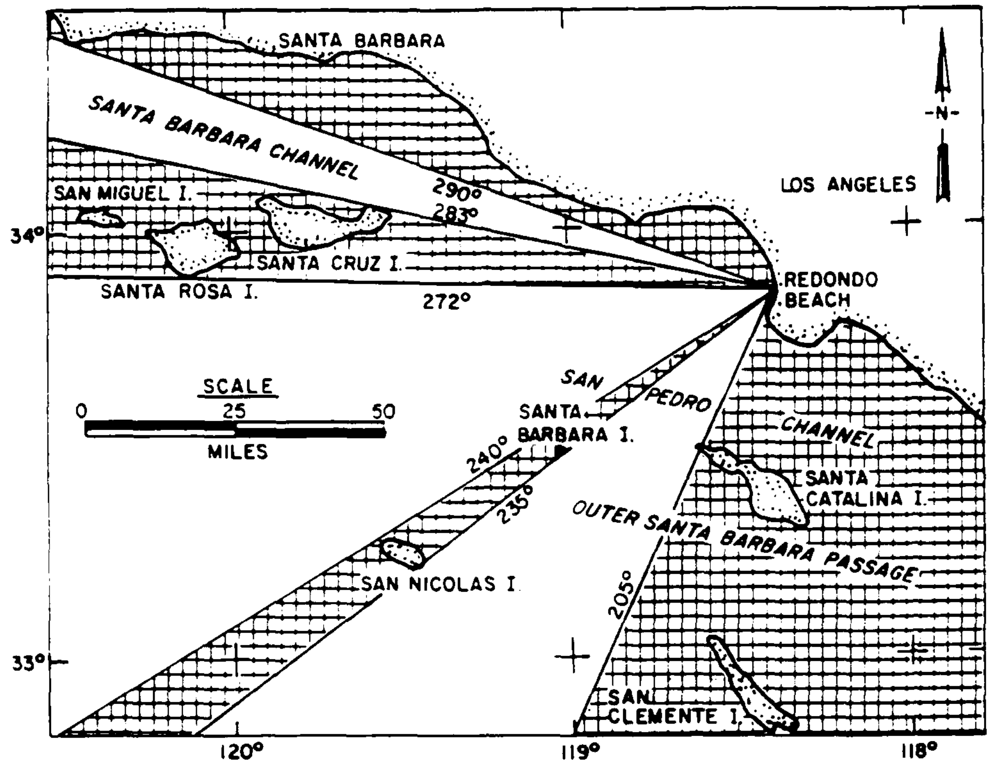



Figure 7. Redondo Beach King Harbor storm wave exposure windows

reaching Redondo Beach propagate essentially eastward through the wave exposure corridor bounded by azimuth 240 through 272 deg. This window reveals the harbor vulnerable to open ocean waves propagating from westerly directions, whereas storms arriving from directions northerly of 272 deg are significantly altered by Santa Rosa and Santa Cruz Islands, and the coastal mainland.

20. Deepwater unsheltered storm events occurring in southern California waters since 1900 have been analyzed by Moffatt and Nichol, Engineers (1983), Seymour et al. (1984), and Walker et al. (1984). In addition, statistically analyzed hindcast results which provide annual sea and swell wave heights at intermediate water depths along the coast of southern California are available in the Sea-State Engineering Analysis System (SEAS) of the US Army Corps of Engineers (Ragsdale 1983). From these data, unsheltered deepwater storm events may be summarized. However, since Redondo Beach King Harbor is sheltered by the offshore islands, waves from various directions of approach are blocked. This blocking action depends on both water depth and wave period, with long-period waves requiring deeper water for passage than short-period waves. With the aid of precise bottom contour charts, all such avenues of

approach were determined for Redondo Beach utilizing a numerical program developed by SPL. The results of these integrations provided sheltered storm wave characteristics on the shoreward side of the islands, but still in deep water. Table 1 provides unsheltered deepwater wave characteristics and approach azimuths as well as island sheltering coefficients and sheltered deepwater wave characteristics and approach angles seaward of the harbor for various storm events. These sheltered deepwater storm wave events still must be propagated to the harbor over the complex nearshore bathymetry of the Redondo Submarine Canyon. More detailed information on the island sheltering theory may be obtained from Hales (1987).

Wave refraction

21. When wind waves move into water of gradually decreasing depth, transformations take place in all wave characteristics except wave period (to the first order of approximation). The most important transformations with respect to the selection of test wave characteristics are the changes in wave height and direction of travel due to the phenomenon referred to as wave refraction. The change in wave height and direction may be determined by using the numerical Regional Coastal Processes Wave Transformation Model (RCPWAVE) developed by Ebersole (1985). This model predicts the transformation of monochromatic waves over complex bathymetry and includes refractive and diffractive effects. Diffraction becomes increasingly important in regions with complex bathymetry. Finite difference approximations are used to solve the governing equations, and the solution is obtained for a finite number of grid cells which comprise the domain of interest. Much of the early work in this area during the 1950's was based on wave-ray methods and manual construction of refraction diagrams using linear, gravity wave theory. During the 1960's and early 1970's, the linear wave-refraction problem was solved in a more efficient way through the use of the digital computer. All of these methods, however, addressed the refraction problem only.

22. The solution technique employed by RCPWAVE is a finite difference approach; thus, the wave climate in terms of wave height, $H$, wave period, $T$, and wave direction of approach, $\theta$, is available at a large number of computational points throughout the region of interest, and not just along wave rays. Computationally, the model is very efficient for modeling large areas of coastline subjected to widely varying wave conditions and, therefore,

is an extremely useful tool in the solution of many types of coastal engineering problems.

23. When the refraction coefficient ($K_r$) is determined, it is multiplied by the shoaling coefficient ($K_s$) and gives a conversion factor for transfer of deepwater wave heights to shallow-water values. The shoaling coefficient, a function of wave length and water depth, can be obtained from the Shore Protection Manual (1984).

24. An extensive wave refraction/diffraction/shoaling analysis using RCPWAVE was conducted for the Redondo Beach King Harbor site (Hales 1987). In general, it was determined that the Redondo Submarine Canyon near the head of the north breakwater, significantly affected wave height and direction as it redirected wave energy away from the canyon and toward the breakwater. Wave heights varied along the breakwater and due to a convergence zone, increased in height, particularly in the proximity immediately south of the dogleg in the north breakwater. In contrast, wave energy diverged around the harbor entrance and the head of the north breakwater, resulting in a significant wave-height reduction in this location. Also, the predominant wave direction of approximately 260 deg changed to about 240 deg along the southern portion of the north breakwater and the harbor entrance due to the effects of the canyon.

Selection of test waves

25. A design wave frequency analysis was performed by SPL on nearshore wave heights (including the January 1988 storm) to define wave conditions along the outer breakwater from which to select test waves. Based on this analysis, estimated wave-height recurrence at the north breakwater are listed below for various breakwater sections (shown in Figure 8).

| Return Period | Breakwater Section | | | |
|---|---|---|---|---|
| year | 34 - 38 | 39 | 40 | 41 |
| 100 | 22.3 | 22.9 | 18.5 | 13.0 |
| 50 | 20.2 | 20.8 | 17.2 | 12.2 |
| 25 | 18.0 | 18.6 | 15.9 | 11.5 |
| 10 | 14.8 | 15.5 | 14.1 | 10.4 |
| 1 | 10.6 | 12.5 | 12.5 | 10.2 |

In addition to the values above, SPL also requested that wave heights ranging from 10 to 28 ft with periods of 8 to 20 sec at the structure be tested in the model to bracket all possible conditions. Analysis of RCPWAVE refraction

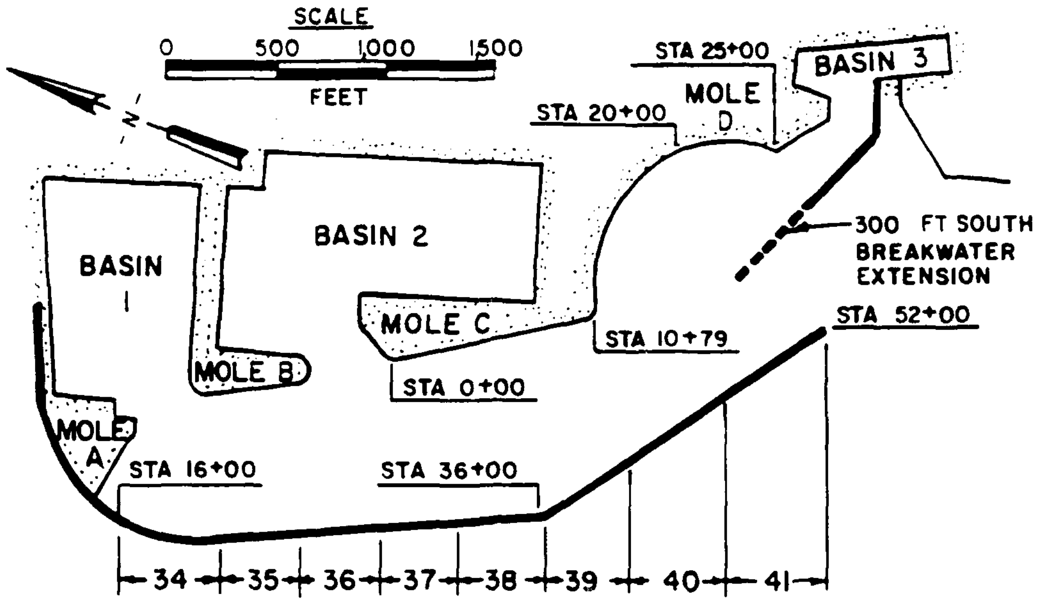



Figure 8. Redondo Beach King Harbor breakwater sections where wave-height recurrence were estimated

results for representative storm wave conditions indicated that wave heights at the approximate location of the wave generator in the model were about 80 percent of the values obtained in the convergence area at section 39 of the breakwater. Therefore, wave heights generated at the wave generator were about 80 percent of what were expected at section 39 of the north breakwater. Refraction in the model would increase the waves about 25 percent from the generator to the breakwater. Characteristics of test waves selected by SPL for use in the model are shown in the following tabulation:

| Direction(s) deg | Period(s) sec | Wave Height, ft Wave Generator | Wave Height, ft Section 39 of Structure |
|---|---|---|---|
| 260, 240 | 8,12,14,16,18 | 8.0 | 10.0 |
| | 15 | 10.0 | 12.5 |
| | 8,10,12,14,16,18,20 | 10.4 | 13.0 |
| | 15 | 12.4 | 15.5 |
| | 8,10,12,14,16,18,20 | 12.8 | 16.0 |
| | 15 | 14.9 | 18.6 |
| | 12,14,16,18 | 16.0 | 20.0 |
| | 15 | 16.6 | 20.8 |
| | 15 | 18.3 | 22.9 |
| | 14,16 | 19.2 | 24.0 |
| | 14,16 | 22.4 | 28.0 |

26. To represent short-period waves propagating toward the harbor entrance more normal to the south end of the north breakwater, the following waves also were selected for model testing:

| Direction deg | Period sec | Wave Height(s), ft, at Wave Generator |
|---|---|---|
| 220 | 12 | 10.4, 12.8 |
| | 15 | 10.0, 12.4 |
| | 16 | 10.4, 12.8 |

27. Unidirectional wave spectra for most of the selected test waves were generated (based on JONSWAP parameters) and used throughout the model investigation. Plots of typical wave spectra are shown in Figure 9. The dashed line represents the desired spectra while the solid line represents the spectra generated by the wave machine. A typical wave train time-history plot is also shown in Figure 10, which depicts wave height ($\eta$) versus wave period. Due to limitations of the model wave generator, some wave conditions used in the study were monochromatic (i.e., constant wave height and period). Monochromatic wave conditions were generated for test wave characteristics of 16 sec and 16 ft and above.

### Model adjustments for submarine canyon effects

28. As mentioned previously, the Redondo Submarine Canyon significantly affects wave heights as it redirects energy away from the canyon and results in a high degree of variability as waves approach the harbor. Refraction analysis indicates that wave heights seaward of the Redondo Beach King Harbor entrance are as much as 40 percent lower than they are at section 39 of the north breakwater. Due to time and funding constraints, the submarine canyon was not reproduced in the model, and it became necessary to reproduce a variable-height wave front seaward of the harbor. Due to characteristics of the wave machine, a variable-height wave front could not be generated; therefore, an alternate approach was required to reduce wave heights in selected areas. A series of fiber wave absorbers (filters) were placed in front of the portions of the wave generator where heights were to be attenuated. All test wave trains were run through these filters, and measurements were recorded. Tests indicated that one to four filter layers (depending on the test wave) were required to reduce wave heights to appropriate levels. Wave heights along the wave front, therefore, were variable in the model seaward of the harbor due to the filter system. Wave-height values generated in the area

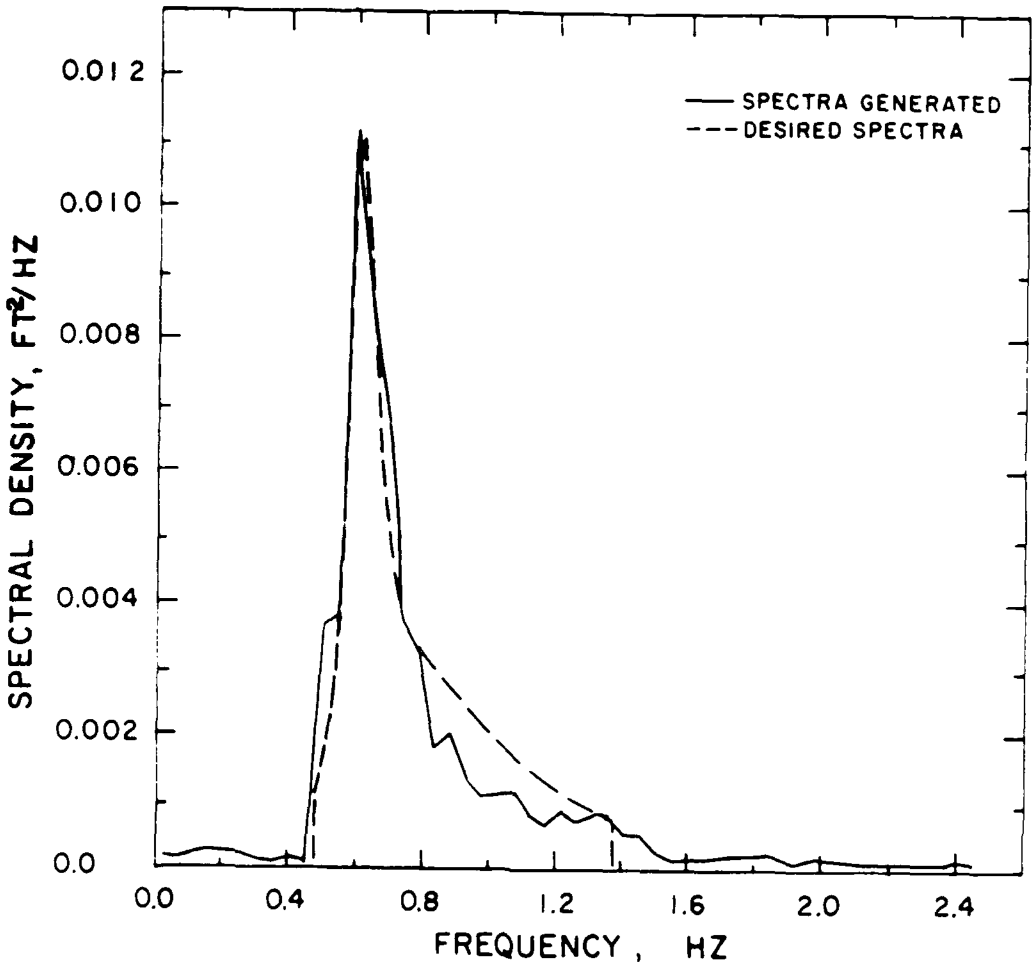



Figure 9. Typical wave spectra plot;
14-sec, 16-ft test waves

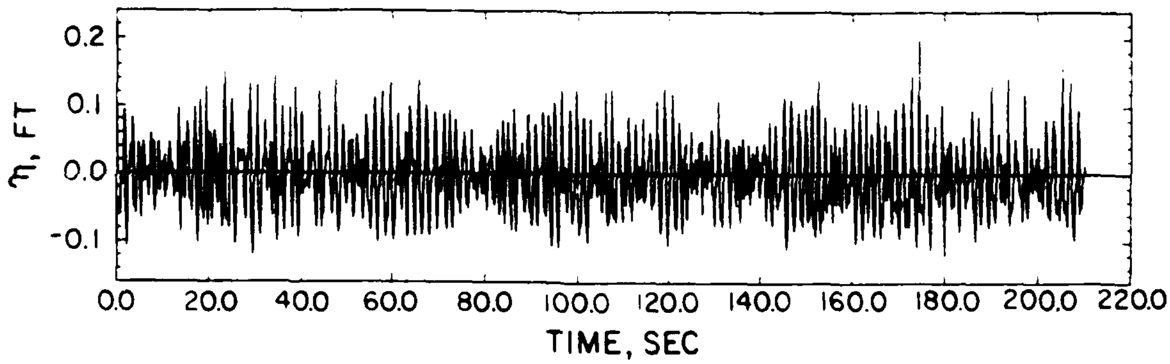



Figure 10. Typical wave train time-history;
14-sec, 16-ft test waves

directly over the submarine canyon were reduced to about 40 percent of those at section 39 of the north breakwater. These modifications simulated the submarine canyon effects on wave heights in the immediate vicinity of the harbor.

## Analysis of Model Data

29. Relative merits of the various plans tested were evaluated by:

   a. Comparison of wave heights at selected locations in the model.

   b. Visual observations, wave pattern photographs, and videotape footage.

In the wave-height data analysis, the average height of the highest one third of the waves recorded at each gage location was computed. All wave heights then were adjusted to compensate for excessive model wave-height attenuation due to viscous bottom friction by application of Keulegan's equation.* From this equation, reduction of wave heights in the model (relative to the prototype) can be calculated as a function of water depth, width of wave front, wave period, water viscosity, and distance of wave travel.

* G. H. Keulegan, 1950, "The Gradual Damping of a Progressive Oscillatory Wave with Distance in a Prismatic Rectangular Channel," Unpublished data, National Bureau of Standards, Washington, DC, prepared at the request of the Director, WES, Vicksburg, MS, by letter of 2 May 1950.

## PART IV: TESTS AND RESULTS

### The Tests

Existing conditions

30. Prior to testing of the various improvement plans, tests were conducted for existing conditions (Plate 1) to establish a base from which to evaluate the effectiveness of the plans. Wave-height data were secured at various locations throughout the harbor for the selected test waves from 240 and 260 deg. In addition, wave pattern photographs and videotape footage were obtained for representative test waves from three test directions.

Improvement plans

31. Wave heights and wave patterns were secured for 14 test plan configurations. Variations entailed changes in the cross sections, lengths, alignments, and crest elevations of the southern arm of the north breakwater and/or the south breakwater. Wave patterns and videotape footage were obtained for representative test waves for the improvement plans. Brief descriptions of the improvement plans are presented in the following subparagraphs; dimensional details are presented in Plates 2 through 9.

a. Plan 1 (Plate 2) consisted of raising a 1,000-ft-long portion of the north breakwater from +14 to +20 ft. The raised portion of the breakwater originated at the dogleg in the structure (sta 3600) and extended 1,000 ft southerly. The structure was raised by placing 11- to 19-ton stone on top of the breakwater and the shoreward slope.

b. Plan 2 (Plate 2) involved the elements of Plan 1 with a 150-ft seaward extension of the south breakwater. The extension had a crest elevation of +12 ft with 1V:2H and 1V:1.25H side slopes on the seaside and shore side, respectively. Stones ranging from 5 to 13 tons were used for the extension.

c. Plan 3 (Plate 2) entailed the elements of Plan 1 and 2, but the south breakwater extension was increased to 300 ft in length.

d. Plan 4 (Plate 3) consisted of the raised +20 ft north breakwater section of Plan 1, but the raised section was extended southerly from 1,000 to 1,600 ft in length.

e. Plan 5 (Plate 3) included the 1,600-ft-long raised north breakwater section of Plan 4 and the 150-ft-long south breakwater extension of Plan 2.

f. Plan 6 (Plate 3) involved the 1,600-ft-long raised north breakwater section of Plan 4 and the 300-ft-long south breakwater extension of Plan 3.

g. Plan 7 (Plate 4) entailed the raised +20 ft north breakwater section of Plan 1, but the raised breakwater was extended southerly from 1,000 to 1,300 ft. Also included was the 150-ft-long south breakwater extension of Plan 2.

h. Plan 8 (Plate 5) consisted of raising some portions of the north breakwater to +24 ft and others to +20 ft with 11- to 19-ton stone. From the dogleg in the north breakwater northward, the structure was raised from +20 to +24 ft for a distance of 300 ft, and from the dogleg southward the breakwater was raised from +14 to +24 ft for a distance of 500 ft. From the south end of the +24 ft section, the structure was raised from +14 ft to +20 ft for a distance of 800 ft. In addition, Plan 8 also included the 150-ft-long south breakwater extension of Plan 2.

i. Plan 9 (Plate 5) involved the elements of Plan 8 with a 300-ft-long portion of the existing south breakwater raised to an elevation of +16 ft. The raised section of the breakwater extended 125 ft shoreward and 175 ft seaward from the dogleg in the south structure. Stones ranging from 5 to 13 tons were placed on top of the breakwater and along the seaward face of the structure.

j. Plan 10 (Plate 6) entailed the raised north breakwater sections of Plans 8 and 9, but the +20 ft elevation section extended only 500 ft southerly (as opposed to 800 ft) at its junction with the +24 ft elevation portion. The 150-ft-long south breakwater extension and the raised 300-ft-long portion of the existing south structure of Plan 9 were also included in this plan.

k. Plan 11 (Plate 7) consisted of raising and sealing 1,600 ft of the southernmost portion of the north breakwater. Construction originated at the dogleg and extended southerly to the end of the structure. Small stone (200 lb to 1 ton) was placed on the shoreward side of the breakwater to an elevation of +8 ft and a thickness of 10 ft. This stone was capped with 11- to 19-ton stone to an elevation of +20 ft. The south breakwater was not extended, but a 300-ft section was raised to +16 ft (125 ft shoreward of the dogleg and 175 ft seaward).

l. Plan 12 (Plate 8) included the elements of Plan 11, but 425 ft of the existing south breakwater was raised to +16 ft (125 ft shoreward of the dogleg and 300 ft seaward). The 150-ft-long south breakwater extension of Plan 2 was also installed for this plan.

m. Plan 13 (Plate 8) involved the elements of Plan 12, but 1,300 ft of the north breakwater (as opposed to 1,600 ft) was raised and sealed. Construction originated at the dogleg of the north breakwater and extended southerly.

n. Plan 14 (Plate 9) entailed the 1,300-ft raised and sealed north breakwater section of Plan 13 with the 150-ft-long south breakwater extension of Plan 2 and a 300-ft-long raised portion (+16 ft) of the existing south breakwater (raised 125 ft shoreward of the dogleg and 175 ft seaward).

Wave-height tests and wave patterns

32. Wave heights and wave patterns for the various improvement plans were obtained for test waves from one or more of the selected test directions. Tests involving most improvement plans, however, were limited to the most critical direction of wave approach (i.e. 240 deg). The most promising test plan, Plan 14, was tested comprehensively for waves from all test directions. Wave-gage locations for each improvement plan are shown in Plates 2 through 9.

Videotape

33. Videotape footage of the Redondo Beach King Harbor model was secured for representative test waves for the various improvement plans. This footage was furnished to SPL for use in briefings, public meetings, etc.

## Test Results

34. In evaluating test results, the relative merits of the various plans were based on an analysis of measured wave heights along the mole areas in the harbor. Model wave heights (significant wave height, $H_{1/3}$ ) were tabulated to show measured values at selected locations.

Existing conditions

35. Results of initial wave-height tests conducted for existing conditions are presented in Table 2 for test waves from 260 and 240 deg. Maximum wave heights were 9.6 ft at the northern portion of Mole C (sta 0+00 and 10+79, Gages 3 and 4, respectively,) for 16-sec, 22.4-ft waves from 240 deg; 11.8 ft at the southern portion of Mole C (sta 11+00 to 20+00, Gage 5) for 14-sec, 19.2-ft waves from 240 deg; 10.3 ft at Mole D (sta 20+00 to 25+00, Gage 6) for 16-sec, 22.4-ft waves from 240 deg; 11.9 ft at the entrance to Basin 3 (Gage 7) for 16-sec, 22.4-ft waves from 260 deg; and 20.9 ft in the entrance to the harbor (Gage 9) for 14-sec, 22.4-ft waves from 240 deg.

36. These test results indicated that waves approaching the southern portion of the harbor were not being reduced in height due to the effects of the Redondo Submarine Canyon. Therefore, adjustments were made in the model to simulate the effects of the canyon (filters installed as discussed in paragraph 28). Meetings with personnel from the USAED, South Pacific (SPD), SPL, and the City of Redondo Beach and their consultants indicated that these adjustments resulted in realistic wave conditions at the harbor. Since previous tests indicated that the 240-deg test direction, in general, resulted in

higher wave heights in the model, this direction was considered the most critical and was selected for the development of a suitable improvement plan.

37. Results of wave height tests for existing conditions with model adjustments are shown in Table 3 for test waves from 240 deg. For waves with a 50-year recurrence interval (15-sec, 16.6-ft test waves), maximum wave heights were 6.5 ft at the northern part of Mole C (Gage 3); 8.0 ft at the southern portion of Mole C (Gage 5); 4.5 ft at Mole D (Gage 6); 4.5 ft at the entrance to Basin 3 (Gage 7); and 6.1 ft in the entrance to the harbor (Gage 9). Typical wave patterns obtained for existing conditions are shown in Photos 1 through 5 for test waves from 240 deg.

Improvement plans

38. Results of wave-height tests conducted for Plans 1 through 3 for representative test waves from 240 deg are shown in Table 4. For Plans 1 through 3, maximum wave heights for 50-year recurrence wave conditions were 4.6, 4.3, and 3.7 ft, respectively, at the northern portion of Mole C; 5.9, 5.5, and 5.2 ft, respectively, at the southern portion of Mole C; 2.9, 2.7, and 2.3 ft, respectively, at Mole D; and 5.0, 3.0, and 2.4 ft, respectively, at the entrance to Basin 3. Wave patterns obtained for Plans 1 through 3 are shown in Photos 6 through 8, respectively.

39. Wave-height test results obtained for Plans 4 through 6 are presented in Table 5 for representative test waves from 240 deg. For 50-year wave conditions, maximum wave heights were 3.9, 3.8, and 3.6 ft at the northern part of Mole C; 3.9, 3.6, and 3.3 ft at the southern portion of Mole C; 2.7, 2.8, and 2.5 ft at Mole D; and 2.8, 2.2, and 1.7 ft at the entrance to Basin 3 for Plans 4 through 6, respectively. Typical wave patterns secured for Plans 4 through 6 are shown in Photos 9 through 11.

40. Wave heights obtained for Plan 7 for representative test waves from 240 deg are shown in Table 6 and typical wave patterns in Photo 12. Maximum wave heights were 3.9 ft at the northern part of Mole C, 3.7 ft at the southern portion of Mole C, 2.7 ft at Mole D, and 2.3 ft in the entrance to Basin 3 for 50-year wave conditions.

41. Results of wave-height tests for Plans 8 through 10 are presented in Table 7 for representative test waves from 240 deg. For 50-year wave conditions, maximum wave heights for Plans 8 through 10 were 3.2, 2.9, and 2.9 ft, respectively, at the northern portion of Mole C; 2.9, 3.0, and 3.5 ft, respectively, at the southern part of Mole C; 2.6, 2.6, and 2.5 ft,

respectively, at Mole D; and 2.3, 1.8, and 1.7 ft, respectively, in the entrance to Basin 3 for Plans 8 through 10, respectively. Typical wave patterns obtained for Plans 8 through 10 are shown in Photos 13 through 15, respectively.

42. Wave-height measurements secured for Plans 11 through 14 are presented in Table 8 for representative test waves from 240 deg. For 50-year wave conditions, maximum wave heights were 3.0, 2.4, 2.3, and 2.4 ft at the northern part of Mole C; 2.7, 2.2, 2.1, and 2.0 ft at the southern portion of Mole C; 2.6, 1.6, 1.6, and 1.8 ft at Mole D; and 3.5, 1.4, 1.4, and 1.8 ft, respectively, in the entrance to Basin 3 for Plans 11 through 14, respectively. Wave patterns for Plans 11 through 14 are shown in Photos 16 through 19, resprctively.

43. Wave-height data obtained for Plan 14 for comprehensive test conditions (less the 15-sec waves) from 240 deg are presented in Table 9 for the +7.0 and +8.0 ft swls. For the +7.0 ft swl, maximum wave heights were 5.7 ft at the northern portion of Mole C; 4.6 ft at the southern portion of Mole C; 4.0 ft at Mole D; and 4.1 ft in the entrance to Basin 3. With the +8.0 ft swl, maximum wave heights were 4.6 ft at the northern portion of Mole C; 3.1 ft at the southern portion of Mole C; 2.9 ft at Mole D; and 3.7 ft at the entrance to Basin 3. Typical wave patterns for Plan 14 for test waves from 240 deg are shown in Photos 20 through 23.

44. Wave-height test results for Plan 14 for test waves from 220 deg are also presented in Table 9 with the +7.0 ft swl. Maximum wave heights were 3.3 ft at the northern portion of Mole C; 3.1 ft at the southern portion of Mole C; 4.9 ft at Mole D; and 3.9 ft in the entrance to Basin 3. Wave patterns obtained for Plan 14 for representative test waves from 220 deg are shown in Photos 24 and 25.

45. Results of wave-height tests for comprehensive test conditions from 260 deg for Plan 14 are presented in Table 10 with the +7.0 and +8.0 ft swls. Maximum wave heights, for the +7.0 ft swl, were 3.7 ft at the northern portion of Mole C; 3.6 ft at the southern portion of Mole C; 3.9 ft at Mole D; and 3.2 ft in the entrance to Basin 3. For the +8.0 ft swl, maximum wave heights were 4.4 ft at the northern portion of Mole C; 2.3 ft at the southern portion of Mole C; 3.2 ft at Mole D; and 2.3 ft at the entrance to Basin 3. Typical wave patterns secured for Plan 14 for representative test waves from 260 deg are shown in Photo 26 through 30.

Discussion of test results

46. As discussed earlier, wave heights obtained initially for existing conditions were excessive in the vicinity of the southern portion of the harbor since the submarine canyon effects were not reproduced. With model adjustments, however, the filtered wave conditions appeared realistic as agreed upon between representatives of SPD, SPL, WES, and the City of Redondo Beach and their consultants. Even after model adjustments, wave heights in the harbor indicated very rough and turbulent wave conditions along the moles with wave heights up to 8 ft for waves with a 50-year recurrence.

47. The wave-height criteria at various locations in the harbor (shown in Figure 3) varied for wave conditions with various return periods. Therefore, to evaluate the effectiveness of each test plan, the wave-height criteria for each return period were shown along with the measured values obtained for existing conditions and each test plan. These values are shown in Tables 11 through 15, for 1-, 10-, 25-, 50-, and 100-year recurrence intervals.

48. Results of wave-height tests with the original improvement plan (1,000 ft of the seaward wing of the north breakwater raised to an elevation of +20 ft) indicated that the wave-height criteria would be exceeded for test waves for all recurrence intervals (and particularly those with 25-, 50-, and 100-year return periods). Increasing the length of the south breakwater by 150 ft (Plan 2) and 300 ft (Plan 3) reduced wave heights, particularly in the area of Mole D and the entrance to Basin 3. Plan 3 resulted in wave heights which exceeded the criteria only by a few tenths of a foot in these locations for waves up to a 25-year return period; however, 50- and 100-year return periods significantly exceeded the criteria at Mole D and the entrance to Basin 3.

49. Wave-height test results with the entire 1,600-ft seaward wing of the north breakwater raised to +20 ft elevation, Plan 4, revealed that the criteria at various locations in the harbor would be exceeded by 0.6 to 1.1 ft with wave conditions up to a 25-year return period. For waves with 50- and 100-year return periods, however, the criteria would be exceeded by 1.9 to 3.1 ft at Mole D. The 150- and 300-ft-long south breakwater extensions (Plans 5 and 6, respectively), in general, reduced wave heights in the various harbor areas. Plan 6 resulted in wave conditions that exceeded the criteria throughout the harbor by 1.0 ft or less for waves up to a 50-year return

period. For 100-year waves, however, wave heights exceeded the criteria by 2.7 ft at the Mole D location and 1.8 ft in the southern portion of Mole C.

50. Test results for Plan 7 (1,300 ft of the seaward wing of the north breakwater raised to +20 and 150 ft extension of the south breakwater) revealed that the established wave-height criteria would be exceeded by 0.7 ft or less for waves up to a 25-year return period. A 50-year return period, however, will result in waves that exceed the criteria at the southern portion of Mole C by 1.4 ft; and a 100-year return period will exceed the wave height criteria at Mole D and the southern portion of Mole C by greater than 3 ft for Plan 7.

51. Test results to this point, with portions of the seaward wing of the north breakwater raised to an elevation of +20 ft (Plans 1 through 7), indicated that Plan 6 (1,600-ft north breakwater wing at +20 ft elevation and 300-ft south breakwater extension) provided the greatest protection for storm waves from 240 deg.

52. Results of wave-height tests with some portions of the north breakwater raised to an elevation of +24 ft and other portions to +20 ft along with a 150-ft south breakwater extension (Plan 8) revealed that the wave-height criteria along the moles would be exceeded by 0.6 ft for test waves with a 50-year recurrence; however, for 100-year wave conditions the criteria will be exceeded by 2.8 ft. Raising a portion of the south breakwater to +16 ft (Plan 9) reduced wave heights by 0.5 ft in the entrance to Basin 3 for 50-year conditions. With a 300-ft-long portion of the +20 ft elevation section of the north breakwater removed along with the raised south breakwater (Plan 10), the wave-height criteria at Mole C was exceeded by 1.2 ft for 50-year conditions. In general, Plan 11 provided the greatest wave protection to the moles and entrance to Basin 3 for this test plan series.

53. Wave-height test results with the seaward wing of the north breakwater sealed with small stone and raised to an elevation of +20 ft along with a 150-ft-long south breakwater extension (Plan 11) indicated that the wave-height criteria along the moles would be exceeded by 0.5 to 0.8 ft for waves ranging from 1- to 50-year recurrence intervals. For 100-year waves, however, the established criteria will be exceeded by 2.3 ft. By raising 425 ft of the south breakwater to an elevation of +16 ft (Plan 12), the established criteria was exceeded by only 0.2 ft considering wave conditions up to a 100-year recurrence. With 300 ft of the raised and sealed portion of

the seaward end of the north breakwater removed (Plan 13), the wave-height criteria inside the harbor was exceeded by 0.2 ft for waves up to a 50-year recurrence, and by 0.9 ft for 100-year wave conditions. Decreasing the length of the raised section of the south breakwater from 475 to 300 ft (Plan 14) resulted in the established criteria in the harbor being exceeded by 0.1 to 0.6 ft for wave conditions up to a 50-year recurrence, and by 1.5 ft for 100-year conditions.

54. A review cf test data obtained to this point indicated that Plan 14 appeared to be optimal, considering wave protection provided the harbor, benefits, and construction costs for the improvements.

55. Comprehensive wave-height tests for Plan 14 indicated that the established criteria at Mole D and the entrance to Basin 3 may be exceeded slightly, particularly for the larger waves from 240 and 260 deg. In most cases these criteria were exceeded by less than 1 ft, except with extreme wave conditions with recurrences of over 100 years. For test waves of 10 ft or greater from 220 deg, the wave-height criteria at Mole D and the entrance to Basin 3 were exceeded significantly, however. In some cases the wave heights in these locations were twice the criteria. Waves with heights of 10 ft or greater are considered to approach from 220 deg very infrequently. Based on test results, however, damages may occur in these locations during these periods.

# PART V: CONCLUSIONS

56. Based on the results of the hydraulic model investigation reported herein, it is concluded that:

<u>a</u>. Existing conditions are characterized by very rough and turbulent wave conditions with wave heights up to 8 ft along the moles for 50-year conditions.

<u>b</u>. Of the original improvement plans tested with the seaward wing of the north breakwater raised to an elevation of +20 ft (Plans 1 through 7), Plan 6 provided the greatest wave protection within the harbor. Wave heights along the moles exceeded the criteria, however, by 1.0 ft for 50-year conditions. For 50-year conditions, the established wave-height criteria varied from 2.0 ft at Mole D to 3.0 ft at Mole C.

<u>c</u>. Of the improvement plans tested with portions of the north breakwater raised to elevations of +24 and +20 ft (Plans 8 through 10), Plan 9 provided the greatest wave protection within the harbor. Wave heights exceeded the criteria along the moles by 0.7 ft for 50-year wave conditions.

<u>d</u>. Of the improvement plans tested with the seaward wing of the north breakwater sealed with small stone and raised to an elevation of +20 ft (Plans 10 through 14), Plan 12 provided the greatest degree of wave protection to the harbor. For 50-year wave conditions, wave heights met the established wave-height criteria along the moles within the harbor.

<u>e</u>. Of all the improvement plans tested (Plans 1 through 14), Plan 14 was considered optimal considering wave protection and construction costs.

<u>f</u>. Comprehensive wave-height tests conducted for Plan 14 indicated that the established wave-height criteria in the harbor would be met or only slightly exceeded for waves up to a 100-year recurrence from 240 and 260 deg. Waves in excess of 10 ft in height from 220 deg, however, in some cases, will significantly exceed the criteria particularly at Mole D and the entrance to Basin 3.

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Table 1

Unsheltered and Sheltered Deepwater Wave Characteristics Seaward of Redondo Beach King Harbor for Various Storm Wave Events

| Date of Storm | Unsheltered Deepwater Significant Wave Height ft | Wave Period sec | Unsheltered Deepwater Approach Azimuth deg | Island Sheltering Coefficient | Sheltered Deepwater Significant Wave Height ft | Sheltered Deepwater Approach Azimuth deg |
|---|---|---|---|---|---|---|
| January 1988 | 33.1 | 15.0 | 270 | 0.79 | 25.9 | 258 |
| September 1939 | 26.9 | 14.0 | 205 | 0.67 | 18.0 | 224 |
| April 1958 | 25.1 | 17.5 | 293 | 0.57 | 14.3 | 268 |
| March 1983 | 23.6 | 18.5 | 263 | 0.80 | 18.9 | 253 |
| January 1981 | 21.5 | 15.5 | 269 | 0.76 | 16.3 | 257 |
| January 1983 | 21.0 | 20.5 | 283 | 0.66 | 13.9 | 264 |
| November 1982 | 20.4 | 10.5 | 293 | 0.57 | 11.6 | 268 |
| February 1963 | 19.5 | 13.5 | 269 | 0.76 | 14.8 | 257 |
| January 1978 | 18.6 | 16.5 | 284 | 0.65 | 12.1 | 264 |
| February 1960 | 18.3 | 18.5 | 294 | 0.56 | 10.3 | 269 |
| January 1958 | 18.1 | 13.5 | 270 | 0.75 | 13.6 | 258 |
| March 1904 | 17.9 | 12.0 | 225 | 0.83 | 14.9 | 235 |
| March 1912 | 17.5 | 11.5 | 270 | 0.75 | 13.1 | 258 |
| February 1983 | 17.1 | 16.5 | 275 | 0.71 | 12.1 | 260 |
| February 1915 | 16.5 | 12.4 | 280 | 0.67 | 11.1 | 263 |
| January 1915 | 16.3 | 11.8 | 205 | 0.67 | 10.9 | 224 |

(Continued)

Table 1 (Concluded)

| Date of Storm | Unsheltered Deepwater Significant Wave Height ft | Wave Period sec | Unsheltered Deepwater Approach Azimuth deg | Island Sheltering Coefficient | Sheltered Deepwater Significant Wave Height ft | Sheltered Deepwater Approach Azimuth deg |
|---|---|---|---|---|---|---|
| January 1943 | 16.2 | 10.8 | 180 | 0.43 | 7.0 | 214 |
| January 1953 | 16.0 | 19.2 | 260 | 0.82 | 13.1 | 251 |
| February 1969 | 15.6 | 14.5 | 284 | 0.65 | 10.1 | 264 |
| February 1980 | 15.6 | 14.5 | 255 | 0.86 | 13.4 | 248 |
| January 1981 | 15.4 | 17.5 | 265 | 0.79 | 12.2 | 255 |
| December 1969 | 14.4 | 20.5 | 276 | 0.70 | 10.1 | 261 |
| January 1916 | 14.0 | 9.6 | 250 | 0.88 | 12.3 | 245 |
| December 1914 | 13.0 | 9.9 | 180 | 0.43 | 5.6 | 214 |
| February 1926 | 12.6 | 16.0 | 260 | 0.82 | 10.3 | 251 |
| April 1926 | 11.8 | 13.8 | 270 | 0.75 | 8.9 | 259 |
| March 1952 | 11.7 | 11.7 | 250 | 0.88 | 10.3 | 245 |
| December 1937 | 11.6 | 16.4 | 270 | 0.75 | 8.7 | 258 |
| August 1972 | 11.6 | 17.5 | 156 | ----* | ----* | ---* |
| September 1963 | 10.3 | 14.5 | 167 | 0.23 | 2.4 | 208 |
| September 1982 | 10.1 | 17.5 | 158 | ----* | ----* | ---* |

* Wave energy for this deepwater unsheltered direction of approach could not reach the structure.

Table 2

Wave Heights for Existing Conditions for Test Waves

from 260 and 240 degrees

| Direction deg | Test Wave Period sec | Test Wave Height ft | Wave Height, ft Gage 1A | Gage 2A | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | swl = +7.0 ft | | | | | | | |
| 260 | 8 | 8.0 | 0.3 | 0.8 | 0.8 | 1.4 | 1.4 | 1.7 | 2.0 | 1.0 | 2.2 | 7.9 | 6.1 | 6.3 |
| | | 10.4 | 0.4 | 0.9 | 1.0 | 1.7 | 1.8 | 2.2 | 2.7 | 1.2 | 3.1 | 10.0 | 7.8 | 8.0 |
| | | 12.8 | 0.5 | 1.0 | 1.2 | 2.3 | 2.4 | 2.6 | 3.9 | 1.6 | 4.5 | 12.3 | 10.9 | 10.4 |
| | 10 | 10.4 | 0.9 | 1.0 | 1.7 | 2.8 | 2.2 | 4.0 | 3.2 | 1.1 | 3.3 | 9.7 | 8.2 | 8.3 |
| | | 12.8 | 1.2 | 1.2 | 2.2 | 3.7 | 2.9 | 5.4 | 4.7 | 1.8 | 5.0 | 13.3 | 11.6 | 11.2 |
| | 12 | 8.0 | 1.2 | 1.0 | 1.9 | 2.4 | 2.2 | 4.6 | 2.6 | 1.3 | 3.3 | 9.2 | 7.0 | 6.3 |
| | | 10.4 | 1.5 | 1.3 | 2.3 | 3.2 | 3.0 | 5.6 | 3.4 | 1.7 | 4.5 | 11.8 | 9.5 | 8.3 |
| | | 12.8 | 1.8 | 1.5 | 2.7 | 3.9 | 3.7 | 6.7 | 3.9 | 2.4 | 5.8 | 14.6 | 11.9 | 10.8 |
| | | 16.0 | 2.0 | 1.9 | 3.2 | 4.7 | 4.5 | 7.7 | 6.4 | 3.1 | 7.3 | 17.9 | 16.3 | 13.7 |
| | 14 | 8.0 | 1.4 | 1.2 | 1.9 | 2.3 | 2.2 | 4.6 | 2.6 | 1.6 | 3.3 | 8.9 | 6.8 | 7.2 |
| | | 10.4 | 1.8 | 1.6 | 2.4 | 2.9 | 3.1 | 5.9 | 3.5 | 2.2 | 4.6 | 11.9 | 9.2 | 10.3 |
| | | 12.8 | 2.2 | 1.9 | 3.0 | 3.7 | 4.2 | 6.9 | 4.7 | 3.0 | 6.3 | 14.8 | 12.2 | 12.8 |
| | | 16.0 | 2.5 | 2.3 | 3.5 | 4.3 | 4.9 | 7.9 | 5.8 | 3.2 | 7.5 | 17.0 | 14.1 | 14.7 |
| | | 19.2 | 2.7 | 3.2 | 4.8 | 5.5 | 6.0 | 8.3 | 6.4 | 3.8 | 9.4 | 23.3 | 21.2 | 15.4 |
| | | 22.4 | 2.9 | 3.4 | 5.0 | 5.9 | 8.1 | 8.7 | 7.8 | 3.9 | 12.7 | 20.9 | 19.1 | 23.0 |
| | 15 | 10.0 | 2.0 | 1.7 | 2.4 | 2.8 | 3.3 | 5.5 | 3.7 | 2.6 | 5.2 | 11.7 | 9.5 | 10.0 |
| | | 12.4 | 2.2 | 2.0 | 2.9 | 3.6 | 3.9 | 6.0 | 4.3 | 3.1 | 6.0 | 14.2 | 11.8 | 12.3 |
| | | 14.9 | 2.5 | 2.3 | 2.7 | 4.3 | 4.8 | 7.1 | 5.4 | 3.7 | 7.6 | 16.2 | 14.0 | 15.1 |
| | | 16.6 | 2.7 | 3.0 | 2.4 | 5.5 | 7.6 | 9.3 | 9.7 | 5.9 | 13.6 | 16.9 | 19.9 | 20.0 |
| | | 18.3 | 2.7 | 3.4 | 2.7 | 5.5 | 8.3 | 10.2 | 9.3 | 5.7 | 17.2 | 18.0 | 20.6 | 20.7 |

(Continued)

Table 2 (Continued)

| Direction deg | Test Wave Period sec | Test Wave Height ft | Wave Height, ft Gage 1A | Gage 2A | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | swl = +7.0 ft (Continued) | | | | | | | | |
| 260 | 16 | 8.0 | 1.5 | 1.4 | 2.0 | 2.0 | 2.6 | 3.9 | 2.3 | 1.8 | 3.2 | 8.8 | 7.0 | 8.1 |
| | | 10.4 | 1.8 | 1.7 | 2.4 | 2.7 | 3.5 | 4.8 | 3.1 | 2.4 | 4.2 | 11.3 | 9.3 | 10.5 |
| | | 12.8 | 1.9 | 2.1 | 2.7 | 3.2 | 4.2 | 5.0 | 3.7 | 2.8 | 4.9 | 12.6 | 11.0 | 12.7 |
| | | 16.0 | 1.8 | 2.6 | 4.0 | 4.0 | 8.5 | 5.3 | 5.2 | 3.6 | 8.4 | 12.1 | 17.7 | 15.8 |
| | | 19.2 | 2.5 | 3.2 | 4.6 | 4.8 | 9.2 | 6.3 | 10.3 | 3.6 | 8.2 | 13.7 | 21.8 | 23.5 |
| | | 22.4 | 2.1 | 3.4 | 5.4 | 5.3 | 10.8 | 6.9 | 11.9 | 4.1 | 8.5 | 13.6 | 23.1 | 27.4 |
| | 18 | 8.0 | 1.5 | 1.4 | 1.9 | 2.2 | 2.7 | 3.3 | 2.5 | 2.0 | 3.3 | 9.9 | 7.7 | 8.1 |
| | | 10.4 | 1.7 | 1.7 | 2.3 | 3.0 | 3.4 | 4.2 | 3.4 | 2.4 | 4.2 | 12.6 | 9.9 | 10.5 |
| | | 12.8 | 2.3 | 2.3 | 3.0 | 4.1 | 4.6 | 5.3 | 4.9 | 3.2 | 5.7 | 16.3 | 13.8 | 13.0 |
| | | 16.0 | 2.5 | 1.6 | 1.8 | 4.6 | 5.6 | 4.0 | 4.7 | 1.8 | 6.8 | 17.3 | 14.1 | 16.7 |
| | 20 | 10.4 | 1.8 | 2.3 | 2.8 | 3.7 | 4.1 | 4.5 | 4.3 | 3.3 | 5.5 | 15.0 | 11.3 | 10.5 |
| ↓ | | 12.8 | 2.5 | 3.4 | 4.1 | 6.7 | 5.4 | 3.6 | 4.9 | 2.4 | 6.3 | 17.4 | 10.4 | 12.5 |
| | | | | | | swl = +8.0 ft | | | | | | | | |
| 260 | 12 | 16.0 | 2.2 | 2.1 | 3.6 | 5.5 | 4.8 | 7.9 | 6.6 | 3.4 | 7.8 | 17.6 | 15.4 | 13.6 |
| | 14 | 16.0 | 2.4 | 2.6 | 3.6 | 4.6 | 5.0 | 7.1 | 5.8 | 3.8 | 7.7 | 16.1 | 13.3 | 14.1 |
| | | 19.2 | 3.3 | 3.6 | 5.4 | 6.3 | 5.9 | 7.6 | 5.9 | 3.5 | 9.8 | 24.0 | 16.0 | 14.6 |
| | 16 | 16.0 | 2.9 | 2.8 | 4.4 | 5.8 | 8.3 | 5.0 | 6.3 | 2.0 | 6.2 | 11.2 | 16.1 | 19.0 |
| | | 19.2 | 3.5 | 3.5 | 5.0 | 7.2 | 10.2 | 6.4 | 8.4 | 4.7 | 6.2 | 12.3 | 18.9 | 24.4 |
| ↓ | 18 | 16.0 | 2.4 | 2.2 | 2.5 | 5.7 | 6.8 | 3.5 | 6.4 | 2.8 | 8.0 | 17.9 | 16.6 | 16.0 |
| | | | | | | swl = +7.0 ft | | | | | | | | |
| 240 | 8 | 8.0 | 0.9 | 0.8 | 1.2 | 2.0 | 2.4 | 3.2 | 2.2 | 1.7 | 3.7 | 7.2 | 7.3 | 8.0 |
| | | 10.4 | 0.9 | 0.9 | 1.5 | 2.5 | 2.8 | 4.0 | 2.8 | 1.8 | 4.6 | 8.9 | 9.2 | 9.7 |
| | | 12.8 | 1.1 | 1.1 | 1.9 | 2.5 | 3.8 | 5.4 | 4.1 | 2.3 | 5.9 | 12.0 | 12.1 | 12.7 |

(Continued)

Table 2 (Continued)

| Direction deg | Test Wave Period sec | Test Wave Height ft | Wave Height, ft Gage 1A | Gage 2A | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | swl = +7.0 ft (Continued) | | | | | | | | | | | |
| 240 | 10 | 10.4 | 0.9 | 0.9 | 2.9 | 3.7 | 3.1 | 6.1 | 3.1 | 2.0 | 4.0 | 9.1 | 8.8 | 9.4 |
| | | 12.8 | 1.3 | 1.2 | 4.0 | 5.1 | 4.2 | 8.5 | 4.6 | 2.7 | 5.7 | 12.7 | 12.2 | 12.8 |
| | 12 | 8.0 | 1.4 | 0.9 | 3.3 | 3.0 | 2.4 | 5.3 | 2.4 | 1.7 | 3.6 | 9.2 | 7.7 | 8.4 |
| | | 10.4 | 1.7 | 1.2 | 4.1 | 4.0 | 3.2 | 6.9 | 3.3 | 2.3 | 5.2 | 11.9 | 10.1 | 10.8 |
| | | 12.8 | 2.0 | 1.4 | 4.8 | 4.9 | 3.9 | 8.0 | 4.3 | 2.6 | 6.6 | 14.4 | 12.6 | 12.7 |
| | | 16.0 | 2.2 | 1.7 | 5.4 | 6.3 | 4.9 | 9.2 | 5.6 | 3.1 | 7.8 | 17.3 | 15.2 | 15.0 |
| | 14 | 8.0 | 1.7 | 1.1 | 2.9 | 2.6 | 2.7 | 4.5 | 2.3 | 2.2 | 3.9 | 7.5 | 7.3 | 6.9 |
| | | 10.4 | 2.0 | 1.4 | 3.7 | 3.6 | 3.8 | 6.0 | 3.2 | 2.7 | 5.8 | 9.9 | 9.3 | 9.2 |
| | | 12.8 | 2.4 | 2.0 | 4.6 | 4.8 | 5.1 | 7.4 | 4.4 | 3.3 | 7.6 | 13.0 | 11.8 | 11.9 |
| | | 16.0 | 2.6 | 2.4 | 5.9 | 6.3 | 6.2 | 9.2 | 5.7 | 3.7 | 9.1 | 15.2 | 14.7 | 13.6 |
| | | 19.2 | 3.0 | 5.5 | 8.0 | 8.7 | 11.8 | 7.1 | 11.6 | 3.0 | 20.0 | 16.7 | 24.9 | 12.4 |
| | | 22.4 | 3.3 | 5.2 | 7.7 | 8.9 | 11.3 | 8.2 | 11.8 | 3.1 | 20.9 | 17.0 | 22.4 | 15.2 |
| | 15 | 10.0 | 2.0 | 1.5 | 3.4 | 3.1 | 3.8 | 4.9 | 3.1 | 2.7 | 5.5 | 9.0 | 8.0 | 8.8 |
| | | 12.4 | 2.3 | 1.9 | 3.9 | 4.0 | 4.7 | 5.9 | 3.9 | 3.1 | 6.8 | 11.0 | 9.7 | 10.5 |
| | | 14.9 | 2.5 | 2.3 | 4.7 | 5.0 | 5.6 | 7.2 | 4.8 | 3.5 | 8.6 | 13.0 | 11.7 | 12.5 |
| | | 16.6 | 2.7 | 2.8 | 7.1 | 5.2 | 9.8 | 4.9 | 7.5 | 2.9 | 13.1 | 15.0 | 12.2 | 14.6 |
| | | 18.3 | 2.4 | 2.1 | 7.8 | 8.4 | 11.7 | 6.3 | 7.9 | 3.5 | 13.7 | 17.1 | 14.1 | 16.4 |
| | 16 | 8.0 | 1.7 | 1.4 | 2.8 | 2.5 | 2.5 | 3.9 | 2.7 | 2.5 | 4.0 | 7.4 | 6.4 | 7.6 |
| | | 10.4 | 2.0 | 1.7 | 3.2 | 3.4 | 3.5 | 4.9 | 3.4 | 2.9 | 5.4 | 9.9 | 8.4 | 9.8 |
| | | 12.8 | 2.3 | 2.1 | 3.8 | 4.5 | 4.5 | 6.3 | 4.2 | 3.2 | 6.6 | 12.6 | 10.6 | 12.0 |
| | | 16.0 | 2.0 | 3.2 | 5.0 | 6.5 | 5.3 | 7.2 | 6.3 | 4.8 | 11.1 | 11.8 | 10.3 | 16.4 |
| | | 19.2 | 2.1 | 3.4 | 5.0 | 8.3 | 7.0 | 8.6 | 8.7 | 5.4 | 14.0 | 14.5 | 12.5 | 18.7 |
| | | 22.4 | 2.3 | 3.9 | 6.0 | 9.6 | 7.1 | 10.3 | 9.5 | 5.2 | 14.8 | 16.7 | 15.2 | 25.9 |

(Continued)

Table 2 (Concluded)

| | Test Wave | | Wave Height, ft | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Direction deg | Period sec | Height ft | Gage 1A | Gage 2A | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
| | | | | | | swl = +7.0 ft (Continued) | | | | | | | | |
| 240 | 18 | 8.0 | 1.8 | 1.6 | 2.4 | 2.6 | 2.8 | 3.2 | 2.6 | 2.2 | 4.2 | 7.7 | 6.2 | 8.0 |
| | | 10.4 | 2.1 | 2.0 | 3.0 | 3.6 | 3.8 | 4.0 | 3.0 | 2.5 | 4.8 | 9.6 | 8.1 | 10.4 |
| | | 12.8 | 2.4 | 2.5 | 3.8 | 4.7 | 4.9 | 5.3 | 3.8 | 3.0 | 6.2 | 12.9 | 10.9 | 12.9 |
| | | 16.0 | 2.3 | 2.4 | 3.1 | 4.0 | 6.7 | 4.5 | 2.9 | 3.2 | 6.1 | 12.1 | 12.9 | 16.0 |
| | 20 | 10.4 | 2.1 | 2.6 | 3.4 | 4.2 | 4.9 | 4.5 | 3.2 | 2.7 | 5.1 | 12.7 | 10.1 | 12.3 |
| | | 12.8 | 3.0 | 2.8 | 4.9 | 5.9 | 7.3 | 3.1 | 2.5 | 3.2 | 6.0 | 15.6 | 16.1 | 14.0 |

Table 3

Wave Heights for Existing Conditions for Test Waves

from 240 degrees (Filters Installed)

| Test Wave Period sec | Test Wave Height ft | Wave Height, ft Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | swl = +7.0 ft | | | | | | | |
| 8 | 8.0 | 3.3 | 0.9 | 1.1 | 1.9 | 2.1 | 2.1 | 1.3 | 1.2 | 2.1 | 5.5 | 6.9 | 7.0 |
| | 10.4 | 3.9 | 1.0 | 1.3 | 2.5 | 2.5 | 2.5 | 1.7 | 1.4 | 2.4 | 6.8 | 8.4 | 8.6 |
| | 12.8 | 5.4 | 1.3 | 1.9 | 3.5 | 3.4 | 3.3 | 2.4 | 1.7 | 3.3 | 11.0 | 11.4 | 11.4 |
| 10 | 10.4 | 4.6 | 1.7 | 3.0 | 3.7 | 2.9 | 3.9 | 2.1 | 1.5 | 2.0 | 8.9 | 8.6 | 8.3 |
| | 12.8 | 5.3 | 2.2 | 3.9 | 5.1 | 3.6 | 5.0 | 2.7 | 1.7 | 3.2 | 12.2 | 11.4 | 10.5 |
| 12 | 8.0 | 3.7 | 2.0 | 3.3 | 3.0 | 2.0 | 3.2 | 1.7 | 1.4 | 2.1 | 8.1 | 7.0 | 6.9 |
| | 10.4 | 4.5 | 2.3 | 4.0 | 4.1 | 2.5 | 3.9 | 2.1 | 1.7 | 2.6 | 11.2 | 9.6 | 9.0 |
| | 12.8 | 5.4 | 2.5 | 4.7 | 5.0 | 3.1 | 4.6 | 2.5 | 1.9 | 3.2 | 13.8 | 11.6 | 10.9 |
| | 16.0 | 6.6 | 2.9 | 5.3 | 6.2 | 4.0 | 5.5 | 2.9 | 2.3 | 3.5 | 16.7 | 13.9 | 13.4 |
| 14 | 8.0 | 4.2 | 2.1 | 2.9 | 2.4 | 1.9 | 2.3 | 1.7 | 1.6 | 2.2 | 7.5 | 7.4 | 5.9 |
| | 10.4 | 5.1 | 2.5 | 3.9 | 3.5 | 2.7 | 3.0 | 2.2 | 1.9 | 2.8 | 10.0 | 10.1 | 8.0 |
| | 12.8 | 5.8 | 2.9 | 4.8 | 4.7 | 3.7 | 3.6 | 2.6 | 2.2 | 3.4 | 12.8 | 13.1 | 10.4 |
| | 16.0 | 5.9 | 2.9 | 5.5 | 5.7 | 4.4 | 4.6 | 3.0 | 2.6 | 3.9 | 18.3 | 14.3 | 11.9 |
| | 19.2 | 12.1 | 5.9 | 6.4 | 9.1 | 6.7 | 4.3 | 3.7 | 2.2 | 4.3 | 19.6 | 20.2 | 11.2 |
| | 22.4 | 11.9 | 5.5 | 6.4 | 9.5 | 9.0 | 5.4 | 4.7 | 2.0 | 4.3 | 21.4 | 23.7 | 11.1 |
| 15 | 10.0 | 4.9 | 2.5 | 3.6 | 3.2 | 2.6 | 2.6 | 2.5 | 2.1 | 2.9 | 9.1 | 9.7 | 7.6 |
| | 12.4 | 5.7 | 2.7 | 4.1 | 4.1 | 3.3 | 3.0 | 2.8 | 2.4 | 3.4 | 11.0 | 11.5 | 9.3 |
| | 14.9 | 6.5 | 2.9 | 4.8 | 5.2 | 4.4 | 4.1 | 3.4 | 2.7 | 4.3 | 14.0 | 13.0 | 11.4 |
| | 16.6 | 9.1 | 3.9 | 6.5 | 5.3 | 8.0 | 4.5 | 4.5 | 2.9 | 6.1 | 16.1 | 17.3 | 14.0 |
| | 18.3 | 9.1 | 3.6 | 6.6 | 6.6 | 11.1 | 7.0 | 5.4 | 3.0 | 8.6 | 21.1 | 19.5 | 21.7 |

(Continued)

Table 3 (Concluded)

| Test Wave | | Wave Height, ft | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period sec | Height ft | Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
| | | | | | | swl = +7.0 ft (Continued) | | | | | | | |
| 16 | 8.0 | 4.3 | 2.0 | 2.9 | 2.4 | 2.1 | 2.1 | 2.4 | 2.0 | 2.9 | 6.9 | 7.2 | 6.7 |
| | 10.4 | 5.0 | 2.4 | 3.4 | 3.3 | 2.8 | 2.5 | 2.8 | 2.3 | 3.6 | 9.1 | 9.5 | 8.6 |
| | 12.8 | 5.8 | 2.8 | 4.1 | 4.3 | 3.7 | 3.2 | 3.2 | 2.5 | 4.2 | 11.4 | 11.5 | 10.6 |
| | 16.0 | 10.8 | 2.3 | 6.3 | 5.9 | 4.1 | 4.9 | 5.1 | 5.0 | 6.8 | 9.5 | 10.4 | 9.5 |
| | 19.2 | 12.1 | 2.6 | 7.7 | 7.6 | 6.0 | 4.3 | 6.8 | 5.1 | 8.9 | 12.5 | 11.1 | 12.0 |
| | 22.4 | 13.0 | 3.3 | 7.2 | 8.9 | 8.5 | 4.1 | 7.1 | 5.6 | 9.9 | 24.9 | 13.7 | 16.4 |
| 18 | 8.0 | 4.1 | 1.8 | 2.5 | 2.8 | 2.4 | 1.9 | 2.3 | 2.0 | 3.2 | 7.4 | 7.4 | 7.3 |
| | 10.4 | 4.9 | 2.2 | 3.1 | 3.9 | 3.2 | 2.3 | 2.6 | 2.2 | 3.7 | 9.4 | 9.3 | 9.3 |
| | 12.8 | 5.9 | 2.7 | 4.2 | 5.3 | 4.5 | 3.2 | 3.2 | 2.6 | 4.4 | 12.2 | 12.0 | 12.0 |
| | 16.0 | 6.7 | 2.3 | 3.1 | 3.6 | 4.5 | 3.0 | 2.9 | 2.5 | 4.8 | 11.5 | 12.0 | 13.7 |
| 20 | 10.4 | 4.9 | 2.3 | 3.6 | 4.4 | 3.9 | 2.7 | 2.7 | 2.2 | 3.7 | 12.1 | 11.1 | 11.1 |
| | 12.8 | 7.2 | 3.1 | 5.7 | 5.9 | 7.8 | 3.5 | 3.1 | 1.6 | 5.5 | 14.0 | 15.2 | 14.3 |
| | | | | | | swl = +8.0 ft | | | | | | | |
| 12 | 16.0 | 7.2 | 3.2 | 5.8 | 6.7 | 4.4 | 6.0 | 3.3 | 2.6 | 3.7 | 17.8 | 14.8 | 13.8 |
| 14 | 16.0 | 6.2 | 3.2 | 5.6 | 6.1 | 4.7 | 4.8 | 3.2 | 2.8 | 4.0 | 16.8 | 14.1 | 11.7 |
| | 19.2 | 11.5 | 6.2 | 5.6 | 8.5 | 7.5 | 4.9 | 3.5 | 2.5 | 4.6 | 13 3 | 19.4 | 10.4 |
| 16 | 16.0 | 10.9 | 2.7 | 6.1 | 6.7 | 5.2 | 4.6 | 5.4 | 4.5 | 7.3 | 12.4 | 9.6 | 10.7 |
| | 19.2 | 12.9 | 2.6 | 7.2 | 9.1 | 8.2 | 4.4 | 6.5 | 4.8 | 8.8 | 15.6 | 11.8 | 15.0 |
| 18 | 16.0 | 7.3 | 3.5 | 4.0 | 6.2 | 6.3 | 4.4 | 4.6 | 3.1 | 5.9 | 13.2 | 13.0 | 13.2 |

Table 4

Wave Heights for Plans 1-3 for Representative Test Waves

from 240 degrees; swl = +7.0 ft

| Test Wave | | Wave Height, ft | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period sec | Height ft | Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
| | | | | | | | Plan 1 | | | | | | |
| 12 | 16.0 | 7.6 | 2.9 | 3.8 | 4.0 | 2.6 | 4.9 | 2.9 | 1.9 | 3.6 | 15.5 | 15.4 | 13.9 |
| 14 | 16.0 | 7.4 | 3.0 | 3.7 | 4.0 | 3.2 | 4.3 | 3.5 | 2.3 | 4.3 | 16.1 | 15.0 | 12.4 |
| 15 | 10.0 | 4.7 | 2.3 | 2.5 | 2.0 | 1.8 | 2.2 | 2.3 | 1.7 | 2.5 | 9.2 | 9.1 | 7.5 |
| | 12.4 | 5.4 | 2.5 | 2.7 | 2.5 | 2.1 | 2.5 | 2.7 | 1.9 | 3.0 | 10.9 | 11.2 | 9.0 |
| | 14.9 | 7.8 | 2.9 | 3.3 | 3.4 | 3.1 | 3.8 | 3.8 | 2.3 | 4.6 | 13.7 | 13.6 | 11.5 |
| | 16.6 | 10.8 | 3.8 | 3.8 | 4.6 | 5.9 | 2.9 | 5.0 | 2.7 | 6.2 | 14.1 | 18.2 | 14.1 |
| ↓ | 18.3 | 11.9 | 3.7 | 4.2 | 5.6 | 8.3 | 5.4 | 6.2 | 2.5 | 9.1 | 18.7 | 20.1 | 21.5 |
| 16 | 16.0 | 11.6 | 2.4 | 4.0 | 4.0 | 2.5 | 3.5 | 6.0 | 3.7 | 7.7 | 10.6 | 10.6 | 10.9 |
| 20 | 12.8 | 6.9 | 3.3 | 3.1 | 3.9 | 3.4 | 2.7 | 2.5 | 1.2 | 4.9 | 15.2 | 15.6 | 15.4 |
| | | | | | | | Plan 2 | | | | | | |
| 12 | 16.0 | 7.2 | 3.0 | 3.6 | 3.7 | 2.9 | 4.6 | 1.9 | 1.9 | 3.8 | 16.4 | 14.3 | 13.5 |
| 14 | 16.0 | 7.0 | 3.1 | 3.7 | 3.6 | 3.2 | 3.6 | 2.3 | 2.4 | 3.4 | 16.7 | 14.4 | 11.7 |
| 15 | 10.0 | 4.6 | 2.3 | 2.4 | 1.9 | 1.8 | 2.0 | 1.7 | 1.7 | 2.0 | 8.7 | 9.2 | 7.3 |
| | 12.4 | 5.3 | 2.5 | 2.7 | 2.4 | 2.2 | 2.2 | 1.9 | 1.8 | 2.3 | 10.9 | 10.8 | 8.9 |
| | 14.9 | 6.9 | 2.9 | 3.2 | 3.1 | 2.8 | 3.1 | 2.4 | 2.3 | 3.3 | 14.2 | 13.0 | 10.5 |
| | 16.6 | 10.1 | 3.7 | 3.5 | 4.3 | 5.5 | 2.7 | 3.0 | 2.6 | 5.4 | 14.3 | 20.1 | 13.6 |
| ↓ | 18.3 | 10.8 | 3.8 | 4.6 | 5.5 | 8.2 | 5.2 | 4.0 | 2.8 | 7.4 | 18.1 | 19.2 | 20.3 |
| 16 | 16.0 | 11.7 | 2.6 | 3.9 | 3.3 | 2.3 | 3.5 | 3.5 | 4.0 | 5.9 | 10.1 | 9.3 | 10.1 |
| 20 | 12.8 | 6.3 | 3.2 | 3.0 | 3.6 | 3.4 | 2.2 | 1.7 | 1.2 | 4.0 | 15.5 | 15.1 | 15.4 |

(Continued)

Table 4 (Concluded)

| Test Wave | | Wave Height, ft | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period sec | Height ft | Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
| | | | | | | Plan 3 | | | | | | | |
| 12 | 16.0 | 7.5 | 3.0 | 3.8 | 3.6 | 2.6 | 3.5 | 1.1 | 2.0 | 3.7 | 17.2 | 15.2 | 13.4 |
| 14 | 16.0 | 6.6 | 3.1 | 3.6 | 3.4 | 2.9 | 2.8 | 1.6 | 2.4 | 2.9 | 17.3 | 14.9 | 11.9 |
| 15 | 10.0 | 4.6 | 2.2 | 2.2 | 1.6 | 1.6 | 1.6 | 1.2 | 1.8 | 1.7 | 9.0 | 9.0 | 7.3 |
| | 12.4 | 5.0 | 2.5 | 2.6 | 2.1 | 1.9 | 1.8 | 1.3 | 1.9 | 1.9 | 11.0 | 10.8 | 8.7 |
| | 14.9 | 6.6 | 2.8 | 3.0 | 2.9 | 2.5 | 2.2 | 1.6 | 2.3 | 2.4 | 13.4 | 13.4 | 10.7 |
| | 16.6 | 8.4 | 3.4 | 3.4 | 3.7 | 5.2 | 2.3 | 2.4 | 2.6 | 3.5 | 14.6 | 18.9 | 13.0 |
| | 18.3 | 9.4 | 3.5 | 4.2 | 5.2 | 7.7 | 4.8 | 2.1 | 2.6 | 5.9 | 19.1 | 21.8 | 23.2 |
| 16 | 16.0 | 11.0 | 2.5 | 3.7 | 3.1 | 2.1 | 2.5 | 2.2 | 3.9 | 3.7 | 9.6 | 9.0 | 8.9 |
| 20 | 12.8 | 6.0 | 3.1 | 2.9 | 3.3 | 3.1 | 1.6 | 0.6 | 1.3 | 2.9 | 14.3 | 15.2 | 16.3 |

Table 5

Wave Heights for Plans 4-6 for Representative Test Waves from 240 degrees; swl = +7.0 ft

| Test Wave Period sec | Test Wave Height ft | Wave Height, ft Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Plan 4 | | | | | | | |
| 12 | 16.0 | 7.3 | 2.8 | 3.6 | 3.2 | 1.5 | 3.3 | 2.0 | 1.5 | 3.4 | 17.1 | 15.3 | 12.8 |
| 14 | 16.0 | 6.4 | 2.8 | 3.7 | 3.3 | 3.0 | 2.2 | 1.9 | 1.9 | 3.3 | 14.9 | 16.3 | 11.0 |
| 15 | 10.0 | 4.8 | 2.3 | 2.4 | 2.0 | 1.7 | 1.3 | 1.4 | 1.4 | 2.3 | 8.4 | 8.8 | 6.1 |
| | 12.4 | 5.1 | 2.5 | 2.6 | 2.0 | 1.6 | 1.9 | 1.6 | 1.6 | 2.8 | 10.3 | 10.7 | 7.4 |
| | 14.9 | 6.6 | 2.7 | 3.0 | 3.1 | 2.1 | 2.2 | 2.3 | 2.2 | 3.9 | 13.6 | 14.0 | 9.6 |
| | 16.6 | 9.2 | 3.6 | 3.5 | 3.9 | 3.9 | 2.7 | 2.8 | 2.5 | 5.3 | 14.3 | 19.7 | 11.8 |
| ↓ | 18.3 | 10.5 | 3.4 | 4.0 | 4.9 | 5.7 | 5.2 | 3.4 | 2.3 | 7.5 | 18.3 | 22.0 | 18.9 |
| 16 | 16.0 | 11.0 | 2.4 | 3.4 | 3.2 | 2.0 | 3.2 | 3.6 | 3.3 | 6.2 | 10.9 | 9.1 | 8.8 |
| 20 | 12.8 | 6.1 | 2.9 | 3.3 | 2.9 | 2.9 | 2.0 | 1.4 | 1.0 | 4.1 | 12.9 | 15.1 | 13.0 |
| | | | | | | Plan 5 | | | | | | | |
| 12 | 16.0 | 6.9 | 2.9 | 3.5 | 3.3 | 1.6 | 2.7 | 1.3 | 1.5 | 3.2 | 15.3 | 15.1 | 11.9 |
| 14 | 16.0 | 7.2 | 2.6 | 3.7 | 3.1 | 2.6 | 2.2 | 1.7 | 2.3 | 3.5 | 13.9 | 15.8 | 11.6 |
| 15 | 10.0 | 4.9 | 2.3 | 2.2 | 1.8 | 1.6 | 1.3 | 1.2 | 1.6 | 2.1 | 7.6 | 9.4 | 6.9 |
| | 12.4 | 5.5 | 2.5 | 2.5 | 2.1 | 1.4 | 1.6 | 1.4 | 1.8 | 2.3 | 9.5 | 12.1 | 7.3 |
| | 14.9 | 7.2 | 2.5 | 3.1 | 2.7 | 1.9 | 2.2 | 1.8 | 2.3 | 3.5 | 12.5 | 13.8 | 9.9 |
| | 16.6 | 9.7 | 3.6 | 3.2 | 3.8 | 3.6 | 2.8 | 2.2 | 2.6 | 5.4 | 14.3 | 18.8 | 11.6 |
| ↓ | 18.3 | 10.9 | 3.4 | 4.0 | 5.0 | 5.6 | 5.1 | 2.5 | 2.9 | 7.1 | 17.5 | 20.2 | 18.4 |
| 16 | 16.0 | 11.6 | 2.2 | 3.5 | 3.3 | 1.9 | 3.1 | 2.2 | 3.8 | 6.0 | 10.0 | 9.2 | 9.4 |
| 20 | 12.8 | 6.8 | 2.8 | 3 3 | 3.0 | 2.7 | 1.9 | 1.2 | 1.2 | 4.2 | 13.3 | 15.7 | 13.1 |

(Continued)

Table 5 (Concluded)

| Test Wave | | Wave Height, ft | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period sec | Height ft | Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
| | | | | | | Plan 6 | | | | | | | |
| 12 | 16.0 | 7.6 | 2.7 | 3.4 | 3.1 | 1.6 | 2.5 | 0.9 | 1.6 | 3.4 | 18.3 | 15.9 | 12.2 |
| 14 | 16.0 | 7.0 | 2.7 | 3.6 | 3.2 | 2.4 | 2.1 | 1.3 | 2.2 | 3.3 | 16.9 | 16.2 | 10.5 |
| 15 | 10.0 | 4.7 | 2.2 | 2.1 | 1.4 | 1.3 | 1.1 | 1.0 | 1.5 | 2.0 | 9.8 | 8.9 | 6.2 |
| ↓ | 12.4 | 5.2 | 2.3 | 2.3 | 1.6 | 1.1 | 1.3 | 1.2 | 1.7 | 2.2 | 11.8 | 11.1 | 7.2 |
| ↓ | 14.9 | 7.2 | 2.5 | 3.0 | 2.5 | 1.6 | 1.7 | 1.3 | 2.1 | 3.0 | 14.6 | 14.3 | 9.3 |
| ↓ | 16.6 | 8.9 | 3.4 | 3.2 | 3.6 | 3.3 | 2.5 | 1.7 | 2.2 | 4.0 | 17.7 | 19.5 | 11.5 |
| ↓ | 18.3 | 10.5 | 3.4 | 4.0 | 4.3 | 4.7 | 4.8 | 1.2 | 2.4 | 6.3 | 22.3 | 21.7 | 19.4 |
| 16 | 16.0 | 12.0 | 2.1 | 3.2 | 3.0 | 1.6 | 2.3 | 2.0 | 3.5 | 4.0 | 10.7 | 9.1 | 9.0 |
| 20 | 12.8 | 6.3 | 2.7 | 3.2 | 2.6 | 2.4 | 1.3 | 0.5 | 1.1 | 3.7 | 14.9 | 15.6 | 12.3 |

Table 6

Wave Heights for Plan 7 for Representative Test Waves

from 240 degrees; swl = +7.0 ft

| Test Wave | | Wave Height, ft | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period sec | Height ft | Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
| 12 | 16.0 | 7.7 | 2.6 | 3.5 | 3.1 | 1.6 | 2.7 | 1.4 | 1.6 | 3.3 | 15.8 | 17.7 | 12.4 |
| 14 | 16.0 | 7.0 | 2.9 | 3.8 | 3.2 | 2.6 | 2.5 | 1.8 | 2.2 | 3.4 | 16.1 | 16.7 | 10.9 |
| 15 | 10.0 | 4.9 | 2.4 | 2.4 | 1.8 | 1.6 | 1.3 | 1.2 | 1.7 | 2.2 | 8.4 | 8.8 | 6.7 |
| | 12.4 | 5.4 | 2.5 | 2.4 | 2.2 | 1.4 | 1.7 | 1.5 | 1.8 | 2.3 | 10.3 | 10.9 | 7.9 |
| | 14.9 | 7.3 | 2.7 | 3.0 | 2.7 | 2.0 | 2.3 | 1.9 | 2.0 | 3.6 | 14.2 | 14.9 | 10.4 |
| | 16.6 | 10.1 | 3.6 | 3.6 | 3.9 | 3.7 | 2.7 | 2.3 | 2.5 | 5.4 | 14.8 | 19.4 | 12.4 |
| | 18.3 | 11.7 | 3.6 | 4.2 | 4.7 | 6.0 | 5.2 | 2.6 | 2.8 | 7.0 | 19.4 | 22.4 | 21.8 |
| 16 | 16.0 | 11.6 | 2.3 | 3.3 | 3.2 | 2.0 | 3.1 | 2.3 | 3.6 | 5.9 | 10.6 | 9.8 | 8.9 |
| 20 | 12.8 | 6.6 | 2.9 | 3.1 | 2.8 | 2.9 | 1.9 | 1.2 | 1.0 | 4.3 | 13.1 | 15.8 | 12.9 |

Table 7

Wave Heights for Plans 8-10 for Representative Test Waves

from 240 degrees; swl = +7.0 ft

| Test Wave | | Wave Height, ft | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period sec | Height ft | Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
| | | | | | | Plan 8 | | | | | | | |
| 12 | 16.0 | 6.9 | 2.2 | 3.2 | 2.6 | 1.6 | 3.0 | 1.3 | 1.6 | 3.3 | 16.2 | 15.2 | 12.3 |
| 14 | 16.0 | 6.5 | 2.4 | 3.3 | 2.5 | 1.8 | 2.5 | 1.5 | 2.3 | 3.4 | 16.0 | 15.8 | 10.6 |
| 15 | 10.0 | 4.4 | 1.6 | 1.9 | 1.2 | 1.0 | 1.2 | 1.2 | 1.6 | 2.2 | 8.1 | 9.0 | 6.1 |
| | 12.4 | 4.8 | 1.8 | 2.2 | 1.4 | 1.2 | 1.5 | 1.3 | 1.8 | 2.6 | 9.9 | 10.8 | 7.1 |
| | 14.9 | 6.7 | 2.3 | 2.8 | 2.1 | 1.7 | 2.2 | 1.7 | 2.3 | 3.5 | 14.4 | 14.2 | 9.9 |
| | 16.6 | 9.4 | 3.1 | 2.4 | 3.2 | 2.9 | 2.6 | 2.3 | 2.7 | 5.7 | 15.7 | 18.1 | 13.4 |
| | 18.3 | 11.1 | 3.3 | 3.3 | 4.1 | 4.4 | 4.9 | 2.6 | 3.2 | 7.1 | 19.6 | 21.4 | 17.7 |
| 16 | 16.0 | 11.2 | 1.6 | 3.3 | 2.5 | 1.5 | 3.0 | 2.3 | 3.8 | 5.6 | 10.2 | 8.9 | 9.1 |
| 20 | 12.8 | 5.8 | 2.0 | 2.5 | 1.8 | 2.2 | 1.6 | 1.0 | 1.1 | 3.9 | 12.7 | 14.1 | 12.2 |
| | | | | | | Plan 9 | | | | | | | |
| 12 | 16.0 | 7.6 | 2.3 | 3.3 | 2.7 | 1.8 | 3.1 | 1.2 | 1.3 | 3.4 | 16.2 | 15.3 | 13.0 |
| 14 | 16.0 | 6.8 | 2.5 | 3.2 | 2.5 | 2.0 | 2.7 | 1.3 | 1.9 | 3.4 | 16.2 | 15.6 | 11.8 |
| 15 | 10.0 | 4.2 | 1.5 | 1.9 | 1.1 | 1.0 | 1.3 | 1.1 | 1.4 | 2.2 | 8.1 | 8.5 | 6.1 |
| | 12.4 | 4.7 | 1.7 | 2.1 | 1.3 | 1.2 | 1.5 | 1.2 | 1.5 | 2.5 | 9.8 | 10.4 | 7.4 |
| | 14.9 | 6.8 | 2.2 | 2.7 | 2.1 | 1.8 | 2.3 | 1.6 | 2.0 | 3.5 | 12.5 | 13.3 | 10.5 |
| | 16.6 | 9.4 | 3.1 | 2.4 | 2.9 | 3.0 | 2.6 | 1.8 | 1.9 | 5.3 | 14.5 | 19.6 | 13.3 |
| | 18.3 | 10.2 | 3.1 | 3.2 | 3.9 | 4.3 | 5.0 | 2.5 | 2.4 | 7.0 | 19.0 | 20.7 | 19.2 |
| 16 | 16.0 | 11.3 | 1.5 | 3.3 | 2.4 | 1.6 | 2.9 | 2.1 | 2.8 | 5.4 | 9.6 | 9.9 | 8.6 |
| 20 | 12.8 | 5.6 | 1.8 | 2.6 | 1.7 | 2.1 | 1.5 | 1.1 | 0.8 | 4.3 | 12.7 | 13.7 | 12.5 |

(Continued)

Table 7 (Concluded)

| Test Wave | | Wave Height, ft | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period sec | Height ft | Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
| | | | | | | | Plan 10 | | | | | | |
| 12 | 16.0 | 7.3 | 2.5 | 3.4 | 2.9 | 2.2 | 3.8 | 1.5 | 1.3 | 3.8 | 15.6 | 14.7 | 12.9 |
| 14 | 16.0 | 6.3 | 2.4 | 3.1 | 2.6 | 2.3 | 2.6 | 1.3 | 1.7 | 3.4 | 14.2 | 14.4 | 11.3 |
| 15 | 10.0 | 4.1 | 1.6 | 1.8 | 1.1 | 1.2 | 1.6 | 1.0 | 1.2 | 2.2 | 7.8 | 7.6 | 5.8 |
| | 12.4 | 4.6 | 1.7 | 2.0 | 1.3 | 1.5 | 1.7 | 1.1 | 1.4 | 2.5 | 9.3 | 9.1 | 6.8 |
| | 14.9 | 6.4 | 2.2 | 2.8 | 2.0 | 2.1 | 2.3 | 1.4 | 1.9 | 3.4 | 12.4 | 12.3 | 9.8 |
| | 16.6 | 8.6 | 3.0 | 2.4 | 2.9 | 3.5 | 2.5 | 1.7 | 1.7 | 5.3 | 14.5 | 18.1 | 13.0 |
| | 18.3 | 9.4 | 3.0 | 3.1 | 3.7 | 4.9 | 4.4 | 2.4 | 1.9 | 7.4 | 18.7 | 20.4 | 19.9 |
| 16 | 16.0 | 11.2 | 1.5 | 3.6 | 2.2 | 1.8 | 2.8 | 1.9 | 2.2 | 5.6 | 8.8 | 8.9 | 8.7 |
| 20 | 12.8 | 5.4 | 1.9 | 2.4 | 1.7 | 2.4 | 1.4 | 1.0 | 0.7 | 4.4 | 11.7 | 12.3 | 12.2 |

Table 8

Wave Heights for Plans 11-14 for Representative Test Waves

for 240 deg; swl = +7.0 ft

| Test Wave Period sec | Test Wave Height ft | Wave Height, ft Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Plan 11 | | | | | | | |
| 15 | 10.0 | 5.9 | 2.4 | 2.3 | 1.3 | 1.3 | 1.5 | 1.8 | 1.5 | 3.1 | 9.7 | 9.0 | 7.4 |
| | 12.4 | 6.4 | 2.5 | 2.6 | 1.5 | 1.5 | 1.7 | 1.9 | 1.6 | 3.5 | 11.5 | 10.7 | 8.6 |
| | 14.9 | 8.1 | 2.8 | 3.1 | 2.1 | 2.0 | 2.4 | 2.6 | 2.0 | 4.6 | 14.0 | 13.0 | 10.8 |
| | 16.6 | 11.1 | 3.4 | 3.0 | 2.5 | 2.7 | 2.6 | 3.5 | 2.1 | 5.9 | 13.6 | 15.5 | 12.0 |
| | 18.3 | 12.7 | 4.0 | 3.5 | 3.4 | 4.4 | 4.3 | 3.5 | 2.2 | 7.2 | 17.6 | 17.9 | 16.3 |
| | | | | | | Plan 12 | | | | | | | |
| 15 | 10.0 | 4.4 | 1.7 | 1.7 | 0.9 | 0.8 | 0.9 | 0.8 | 1.0 | 2.4 | 8.2 | 8.2 | 5.8 |
| | 12.4 | 5.2 | 1.9 | 1.9 | 1.1 | 0.9 | 1.0 | 0.9 | 1.2 | 2.7 | 10.2 | 9.3 | 7.2 |
| | 14.9 | 7.3 | 2.6 | 2.4 | 1.9 | 1.5 | 1.5 | 1.4 | 1.6 | 3.9 | 14.9 | 13.0 | 11.2 |
| | 16.6 | 9.3 | 3.3 | 2.3 | 2.4 | 2.2 | 1.6 | 1.4 | 1.5 | 5.3 | 14.6 | 17.0 | 11.2 |
| | 18.3 | 11.4 | 3.5 | 2.7 | 3.6 | 3.1 | 3.1 | 1.4 | 1.8 | 7.1 | 18.7 | 19.7 | 16.9 |
| | | | | | | Plan 13 | | | | | | | |
| 15 | 10.0 | 4.0 | 1.6 | 1.8 | 0.9 | 0.8 | 1.1 | 0.8 | 1.3 | 2.8 | 8.7 | 9.1 | 7.1 |
| | 12.4 | 4.7 | 1.8 | 2.1 | 1.0 | 0.9 | 1.1 | 0.9 | 1.4 | 3.0 | 10.1 | 11.5 | 8.8 |
| | 14.9 | 6.9 | 2.5 | 2.5 | 1.8 | 1.4 | 1.8 | 1.4 | 1.9 | 4.3 | 14.3 | 16.7 | 13.0 |
| | 16.6 | 8.7 | 3.4 | 2.2 | 2.3 | 2.1 | 1.6 | 1.4 | 1.8 | 6.4 | 13.6 | 21.8 | 13.8 |
| | 18.3 | 9.2 | 3.6 | 2.9 | 3.2 | 2.9 | 3.0 | 1.4 | 2.0 | 6.9 | 18.2 | 22.8 | 19.8 |
| | | | | | | Plan 14 | | | | | | | |
| 15 | 10.0 | 4.7 | 2.0 | 1.9 | 1.0 | 0.9 | 1.3 | 0.9 | 1.3 | 2.7 | 8.4 | 8.6 | 6.8 |
| | 12.4 | 5.5 | 2.5 | 2.3 | 1.3 | 1.1 | 1.6 | 1.2 | 1.5 | 3.0 | 11.2 | 11.3 | 9.1 |
| | 14.9 | 7.3 | 2.6 | 2.8 | 2.0 | 1.5 | 2.0 | 1.4 | 1.8 | 4.0 | 13.0 | 13.0 | 10.2 |
| | 16.6 | 9.5 | 3.4 | 2.3 | 2.4 | 2.0 | 1.8 | 1.8 | 1.7 | 5.8 | 13.2 | 17.0 | 10.9 |
| | 18.3 | 11.0 | 3.5 | 2.9 | 3.4 | 3.1 | 3.6 | 1.8 | 1.9 | 7.2 | 17.8 | 18.8 | 15.5 |

Table 9

Wave Heights for Plan 14 for Test Waves from 240 and 220 degrees

| Direction deg | Test Wave Period sec | Test Wave Height ft | Wave Height, ft Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | swl = +7.0 ft | | | | | | | |
| 240 | 8 | 8.0 | 4.0 | 0.6 | 0.7 | 0.6 | 0.8 | 1.2 | 0.9 | 0.6 | 2.1 | 8.3 | 7.3 | 6.3 |
| | | 10.4 | 4.8 | 0.8 | 0.8 | 0.7 | 1.0 | 1.5 | 1.1 | 0.8 | 2.6 | 8.8 | 9.0 | 7.8 |
| | | 12.8 | 6.2 | 1.0 | 1.0 | 0.9 | 1.2 | 1.9 | 1.3 | 0.9 | 3.4 | 11.5 | 11.9 | 9.8 |
| | 10 | 10.4 | 5.3 | 1.4 | 1.7 | 1.3 | 1.2 | 2.4 | 1.5 | 0.8 | 2.5 | 9.0 | 9.3 | 7.6 |
| | | 12.8 | 5.8 | 1.6 | 2.3 | 1.7 | 1.3 | 2.6 | 1.6 | 1.0 | 3.2 | 9.6 | 11.8 | 10.1 |
| | 12 | 8.0 | 4.1 | 1.5 | 2.3 | 1.2 | 0.9 | 2.0 | 1.0 | 0.8 | 2.0 | 6.5 | 7.2 | 6.8 |
| | | 10.4 | 5.0 | 1.8 | 2.6 | 1.4 | 1.0 | 2.4 | 1.3 | 1.0 | 2.7 | 8.5 | 9.1 | 9.2 |
| | | 12.8 | 5.9 | 1.9 | 2.8 | 1.6 | 1.1 | 2.7 | 1.4 | 1.2 | 3.2 | 10.6 | 11.3 | 10.3 |
| | | 16.0 | 6.8 | 2.2 | 3.2 | 2.0 | 1.4 | 3.2 | 1.6 | 1.4 | 3.7 | 12.7 | 13.3 | 12.1 |
| | 14 | 8.0 | 4.1 | 1.8 | 2.0 | 1.1 | 1.0 | 1.6 | 1.2 | 1.0 | 1.8 | 5.4 | 6.7 | 4.9 |
| | | 10.4 | 4.9 | 2.1 | 2.4 | 1.4 | 1.2 | 1.9 | 1.4 | 1.3 | 2.2 | 7.7 | 8.9 | 6.7 |
| | | 12.8 | 5.9 | 2.4 | 3.0 | 1.9 | 1.5 | 2.2 | 1.6 | 1.6 | 2.7 | 10.4 | 11.9 | 8.5 |
| | | 16.0 | 6.9 | 2.6 | 3.4 | 2.4 | 1.8 | 2.4 | 1.6 | 1.7 | 3.8 | 15.8 | 15.0 | 12.1 |
| | | 19.2 | 12.7 | 3.7 | 3.9 | 4.2 | 3.6 | 2.7 | 1.5 | 1.3 | 5.6 | 16.1 | 24.5 | 9.0 |
| | | 22.4 | 13.4 | 3.7 | 3.1 | 5.7 | 4.1 | 4.0 | 1.9 | 1.6 | 6.5 | 23.6 | 26.9 | 12.4 |
| | 16 | 8.0 | 4.8 | 1.7 | 1.8 | 1.1 | 1.0 | 1.5 | 1.6 | 1.3 | 2.5 | 5.6 | 6.1 | 5.6 |
| | | 10.4 | 5.4 | 2.0 | 2.1 | 1.3 | 1.1 | 1.5 | 1.7 | 1.4 | 2.6 | 7.5 | 9.0 | 7.5 |
| | | 12.8 | 6.1 | 2.3 | 2.5 | 1.7 | 1.4 | 1.9 | 1.9 | 1.6 | 3.0 | 9.5 | 10.8 | 9.4 |
| | | 16.0 | 11.3 | 1.8 | 3.4 | 2.4 | 1.5 | 2.3 | 2.6 | 2.4 | 5.9 | 9.2 | 8.0 | 9.2 |
| | | 19.2 | 12.7 | 1.8 | 4.0 | 2.9 | 1.9 | 2.4 | 3.0 | 3.3 | 6.9 | 14.9 | 12.2 | 11.6 |
| | | 22.4 | 14.6 | 2.4 | 5.2 | 3.4 | 4.6 | 3.4 | 4.1 | 4.0 | 9.6 | 24.1 | 13.2 | 14.2 |

(Continued)

Table 9 (Concluded)

| Direction deg | Test Wave Period sec | Test Wave Height ft | Wave Height, ft Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | swl = +7.0 ft (Concluded) | | | | | | | |
| 240 | 18 | 8.0 | 4.6 | 1.8 | 1.8 | 1.4 | 1.1 | 1.3 | 1.5 | 1.2 | 2.7 | 7.5 | 7.2 | 7.1 |
| | | 10.4 | 5.3 | 2.0 | 2.1 | 1.6 | 1.3 | 1.5 | 1.7 | 1.4 | 3.1 | 9.2 | 9.0 | 8.9 |
| | | 12.8 | 6.7 | 2.3 | 2.8 | 2.0 | 1.7 | 1.8 | 2.0 | 1.6 | 3.6 | 12.1 | 11.8 | 11.7 |
| | | 16.0 | 7.0 | 1.9 | 2.3 | 1.3 | 1.6 | 1.9 | 1.7 | 2.2 | 4.0 | 10.4 | 11.3 | 11.4 |
| | 20 | 10.4 | 5.2 | 1.9 | 2.4 | 1.7 | 1.8 | 1.5 | 1.6 | 1.3 | 2.9 | 11.5 | 10.8 | 10.8 |
| | | 12.8 | 7.4 | 2.7 | 3.2 | 2.3 | 2.3 | 1.9 | 1.8 | 1.2 | 4.3 | 12.5 | 15.4 | 13.2 |
| | | | | | | | swl = +8.0 ft | | | | | | | |
| 240 | 12 | 16.0 | 8.4 | 2.6 | 3.6 | 2.5 | 1.6 | 2.9 | 1.6 | 1.4 | 3.6 | 16.8 | 15.2 | 12.2 |
| | 14 | 16.0 | 7.2 | 2.9 | 3.7 | 2.7 | 2.1 | 2.6 | 2.0 | 1.9 | 3.6 | 14.5 | 14.4 | 10.5 |
| | | 19.2 | 9.7 | 5.1 | 4.2 | 3.9 | 3.1 | 2.5 | 1.5 | 1.3 | 5.3 | 11.6 | 18.6 | 8.2 |
| | 16 | 16.0 | 10.9 | 1.4 | 4.4 | 2.9 | 1.6 | 2.1 | 2.9 | 2.7 | 5.0 | 11.3 | 8.7 | 8.8 |
| | | 19.2 | 13.8 | 1.6 | 4.6 | 3.3 | 2.1 | 2.2 | 3.7 | 3.2 | 7.3 | 16.4 | 11.3 | 11.1 |
| | 18 | 16.0 | 8.3 | 2.3 | 2.7 | 2.2 | 2.1 | 2.3 | 2.4 | 2.5 | 4.3 | 10.4 | 11.6 | 11.4 |
| | | | | | | | swl = +7.0 ft | | | | | | | |
| 220 | 12 | 10.4 | 11.6 | 2.6 | 3.0 | 2.0 | 2.7 | 4.6 | 3.2 | 1.8 | 8.9 | 10.7 | 11.1 | 12.4 |
| | | 12.8 | 14.4 | 2.8 | 3.3 | 2.3 | 2.8 | 4.9 | 3.7 | 2.0 | 10.1 | 12.3 | 13.0 | 14.7 |
| | 15 | 10.0 | 11.6 | 1.9 | 2.7 | 2.0 | 2.4 | 3.8 | 2.7 | 2.2 | 8.0 | 9.0 | 8.7 | 10.8 |
| | | 12.4 | 13.2 | 2.1 | 3.1 | 2.3 | 2.8 | 4.3 | 3.6 | 2.5 | 9.1 | 11.1 | 10.6 | 12.7 |
| | 16 | 10.4 | 10.8 | 1.8 | 2.6 | 2.0 | 2.6 | 3.5 | 2.9 | 2.4 | 7.5 | 9.5 | 8.7 | 12.1 |
| | | 12.8 | 13.7 | 2.1 | 3.2 | 2.3 | 3.1 | 4.3 | 3.9 | 2.7 | 9.1 | 11.0 | 10.7 | 14.4 |

Table 10

Wave Heights for Plan 14 for Test Waves from 260 degrees

| Test Wave Period sec | Test Wave Height ft | Wave Height, ft Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | swl = +7.0 ft | | | | | | | |
| 8 | 8.0 | 4.5 | 0.8 | 0.7 | 0.6 | 0.5 | 0.9 | 1.2 | 0.5 | 1.5 | 8.2 | 7.5 | 6.7 |
| | 10.4 | 6.5 | 0.9 | 0.8 | 0.7 | 0.6 | 1.0 | 1.4 | 0.6 | 1.8 | 10.1 | 9.8 | 8.3 |
| | 12.8 | 6.7 | 1.1 | 1.0 | 0.9 | 0.8 | 1.4 | 1.7 | 0.8 | 2.7 | 12.5 | 12.1 | 11.2 |
| 10 | 10.4 | 6.7 | 1.4 | 1.5 | 1.2 | 0.9 | 2.2 | 1.9 | 0.6 | 2.2 | 9.4 | 9.0 | 9.0 |
| | 12.8 | 6.8 | 1.5 | 1.7 | 1.5 | 1.1 | 2.5 | 1.8 | 0.8 | 2.7 | 11.8 | 10.2 | 10.3 |
| 12 | 8.0 | 4.6 | 1.2 | 1.5 | 1.1 | 0.9 | 2.0 | 1.2 | 0.7 | 2.1 | 8.2 | 6.2 | 5.5 |
| | 10.4 | 5.4 | 1.8 | 2.1 | 1.4 | 1.1 | 2.4 | 1.5 | 0.8 | 2.3 | 11.6 | 10.0 | 7.2 |
| | 12.8 | 6.3 | 1.9 | 2.4 | 1.7 | 1.3 | 2.6 | 1.7 | 1.1 | 2.6 | 13.9 | 12.2 | 8.4 |
| | 16.0 | 7.3 | 2.0 | 2.6 | 1.9 | 1.5 | 2.9 | 1.9 | 1.4 | 2.9 | 16.7 | 14.9 | 10.5 |
| 14 | 8.0 | 3.4 | 1.4 | 1.4 | 1.0 | 0.8 | 1.8 | 0.9 | 0.6 | 1.7 | 7.0 | 5.9 | 5.6 |
| | 10.4 | 4.1 | 1.6 | 1.7 | 1.2 | 1.0 | 2.1 | 1.0 | 0.8 | 2.0 | 9.8 | 8.2 | 7.4 |
| | 12.8 | 5.0 | 1.9 | 2.0 | 1.4 | 1.3 | 2.4 | 1.2 | 1.2 | 2.4 | 13.0 | 10.6 | 9.6 |
| | 16.0 | 6.1 | 2.3 | 2.6 | 1.8 | 1.6 | 2.8 | 1.5 | 1.8 | 3.1 | 16.2 | 13.4 | 12.2 |
| | 19.2 | 9.6 | 2.9 | 3.5 | 1.7 | 1.8 | 3.8 | 1.7 | 0.9 | 3.4 | 19.9 | 16.7 | 23.6 |
| | 22.4 | 11.5 | 3.3 | 3.2 | 2.4 | 3.6 | 3.7 | 2.3 | 1.3 | 6.8 | 20.3 | 20.8 | 25.7 |
| 15 | 10.0 | 4.1 | 1.6 | 1.6 | 1.1 | 1.1 | 2.1 | 1.0 | 0.9 | 2.0 | 9.3 | 8.0 | 8.5 |
| | 12.4 | 4.6 | 1.8 | 1.8 | 1.2 | 1.3 | 2.3 | 1.1 | 1.0 | 2.2 | 11.3 | 9.5 | 9.9 |
| | 14.9 | 6.0 | 2.2 | 2.3 | 1.6 | 1.7 | 2.7 | 1.5 | 1.5 | 3.2 | 14.1 | 12.1 | 11.9 |
| | 16.6 | 6.1 | 2.8 | 1.6 | 2.6 | 1.8 | 2.7 | 1.6 | 1.3 | 4.8 | 17.4 | 11.3 | 11.5 |
| | 18.3 | 6.6 | 4.1 | 3.7 | 2.4 | 2.4 | 3.9 | 2.1 | 1.4 | 6.9 | 19.8 | 21.4 | 14.0 |
| 16 | 8.0 | 3.7 | 1.6 | 1.3 | 1.0 | 1.0 | 1.8 | 1.1 | 0.9 | 1.9 | 7.9 | 6.8 | 7.8 |
| | 10.4 | 4.6 | 1.9 | 1.6 | 1.1 | 1.2 | 2.1 | 1.2 | 1.1 | 2.3 | 10.3 | 8.8 | 9.5 |
| | 12.8 | 4.9 | 2.2 | 2.0 | 1.3 | 1.4 | 2.2 | 1.4 | 1.3 | 2.5 | 11.9 | 10.2 | 11.2 |
| | 16.0 | 7.1 | 1.5 | 1.4 | 1.8 | 1.9 | 3.2 | 1.5 | 1.1 | 3.1 | 8.9 | 14.3 | 22.1 |
| | 19.2 | 8.2 | 1.7 | 2.6 | 2.1 | 2.1 | 3.2 | 1.8 | 1.3 | 4.1 | 12.6 | 16.7 | 30.6 |
| | 22.4 | 9.7 | 3.0 | 3.1 | 2.3 | 2.5 | 3.5 | 3.2 | 1.8 | 4.7 | 15.3 | 22.7 | 32.5 |

(Continued)

Table 10 (Concluded)

| Test Wave | | Wave Height, ft | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period sec | Height ft | Gage 1 | Gage 2 | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 | Gage 8 | Gage 9 | Gage 10 | Gage 11 | Gage 12 |
| | | | | | | swl = +7.0 ft (Concluded) | | | | | | | |
| 18 | 8.0 | 3.8 | 1.6 | 1.3 | 0.9 | 1.0 | 1.5 | 1.1 | 1.1 | 2.0 | 8.9 | 7.5 | 7.6 |
| | 10.4 | 4.3 | 1.9 | 1.7 | 1.1 | 1.2 | 1.8 | 1.2 | 1.3 | 2.3 | 11.4 | 9.2 | 9.6 |
| | 12.8 | 5.1 | 2.6 | 2.3 | 1.7 | 1.6 | 2.1 | 1.5 | 1.7 | 2.8 | 15.6 | 12.0 | 12.0 |
| | 16.0 | 5.5 | 3.6 | 1.7 | 2.5 | 2.1 | 1.4 | 1.2 | 1.6 | 3.1 | 20.3 | 15.5 | 16.0 |
| 20 | 10.4 | 4.7 | 1.9 | 1.9 | 1.5 | 1.6 | 1.6 | 1.4 | 1.6 | 2.6 | 14.8 | 10.8 | 9.5 |
| | 12.8 | 6.1 | 2.7 | 1.6 | 1.3 | 0.9 | 0.8 | 1.3 | 0.8 | 3.0 | 17.4 | 9.4 | 8.4 |
| | | | | | | swl = +8.0 ft | | | | | | | |
| 12 | 16.0 | 7.7 | 2.3 | 3.0 | 2.4 | 1.7 | 2.9 | 1.8 | 1.5 | 3.4 | 18.3 | 14.7 | 11.1 |
| 14 | 16.0 | 5.9 | 2.6 | 3.0 | 2.1 | 1.5 | 2.4 | 1.7 | 1.9 | 2.9 | 17.1 | 12.7 | 12.0 |
| | 19.2 | 9.1 | 3.3 | 4.4 | 1.8 | 1.9 | 4.1 | 1.6 | 0.9 | 3.5 | 18.6 | 14.1 | 19.9 |
| 16 | 16.0 | 8.9 | 1.9 | 2.3 | 2.2 | 1.6 | 3.0 | 1.7 | 1.5 | 3.8 | 12.2 | 13.4 | 21.1 |
| | 19.2 | 10.9 | 2.4 | 2.9 | 3.1 | 1.7 | 3.2 | 2.3 | 2.0 | 3.9 | 11.0 | 16.1 | 26.3 |
| 18 | 16.0 | 4.6 | 4.2 | 2.3 | 3.6 | 2.3 | 2.0 | 2.3 | 1.1 | 3.4 | 22.8 | 18.0 | 17.1 |

Table 11

Comparison of Wave Heights from 240 degrees for 1-year Wave Conditions for 15-sec, 10-ft Waves

| | Wave-Height Criteria or Measured Wave Height, ft, at Selected Location | | | | |
|---|---|---|---|---|---|
| | Northern Portion of Mole C | | Southern Portion of Mole C | Mole D | Entrance to Basin 3 |
| | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 |
| Wave-Height Criteria | 1.8 | 1.8 | 1.8 | 1.7 | 1.0 |
| Existing Conditions | 3.6 | 3.2 | 2.6 | 2.6 | 2.5 |
| Plan No. | | | | | |
| 1 | 2.5 | 2.0 | 2.0 | 1.8 | 2.2 |
| 2 | 2.4 | 1.9 | 1.8 | 2.0 | 1.7 |
| 3 | 2.2 | 1.6 | 1.6 | 1.6 | 1.2 |
| 4 | 2.4 | 2.0 | 1.7 | 1.3 | 1.4 |
| 5 | 2.2 | 1.8 | 1.6 | 1.3 | 1.2 |
| 6 | 2.1 | 1.4 | 1.3 | 1.1 | 1.0 |
| 7 | 2.4 | 1.8 | 1.6 | 1.3 | 1.2 |
| 8 | 1.9 | 1.2 | 1.0 | 1.2 | 1.2 |
| 9 | 1.9 | 1.1 | 1.0 | 1.3 | 1.1 |
| 10 | 1.8 | 1.1 | 1.2 | 1.6 | 1.0 |
| 11 | 2.3 | 1.3 | 1.3 | 1.5 | 1.8 |
| 12 | 1.7 | 0.9 | 0.8 | 0.9 | 0.8 |
| 13 | 1.8 | 0.9 | 0.8 | 1.1 | 0.8 |
| 14 | 1.9 | 1.0 | 0.9 | 1.3 | 0.9 |

Table 12

Comparison of Wave Heights from 240 degrees for 10-year Wave Conditions for 15-sec, 12.4-ft Waves

| | Wave-Height Criteria or Measured Wave Height, ft, at Selected Location | | | | |
|---|---|---|---|---|---|
| | Northern Portion of Mole C | | Southern Portion of Mole C | Mole D | Entrance to Basin 3 |
| | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 |
| Wave-Height Criteria | 1.9 | 1.9 | 1.9 | 1.8 | 1.0 |
| Existing Conditions | 4.1 | 4.1 | 3.3 | 3.0 | 2.8 |
| Plan No. | | | | | |
| 1 | 2.7 | 2.5 | 2.1 | 2.5 | 2.7 |
| 2 | 2.7 | 2.4 | 2.2 | 2.2 | 1.9 |
| 3 | 2.6 | 2.1 | 1.9 | 1.8 | 1.3 |
| 4 | 2.6 | 2.0 | 1.6 | 1.9 | 1.6 |
| 5 | 2.5 | 2.1 | 1.4 | 1.6 | 1.4 |
| 6 | 2.3 | 1.6 | 1.1 | 1.3 | 1.2 |
| 7 | 2.4 | 2.2 | 1.4 | 1.7 | 1.5 |
| 8 | 2.2 | 1.4 | 1.2 | 1.5 | 1.3 |
| 9 | 2.1 | 1.3 | 1.2 | 1.5 | 1.2 |
| 10 | 2.0 | 1.3 | 1.5 | 1.7 | 1.1 |
| 11 | 2.6 | 1.5 | 1.5 | 1.7 | 1.9 |
| 12 | 1.9 | 1.1 | 0.9 | 1.0 | 0.9 |
| 13 | 2.1 | 1.0 | 0.9 | 1.1 | 0.9 |
| 14 | 2.3 | 1.3 | 1.1 | 1.6 | 1.2 |

Table 13

Comparison of Wave Heights from 240 degrees for 25-year Wave Conditions for 15-sec, 14.9-ft Waves

| | Wave-Height Criteria or Measured Wave Height, ft, at Selected Location | | | | |
|---|---|---|---|---|---|
| | Northern Portion of Mole C | | Southern Portion of Mole C | Mole D | Entrance to Basin 3 |
| | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 |
| Wave-Height Criteria | 2.3 | 2.3 | 2.0 | 1.9 | 1.2 |
| Existing Conditions | 4.8 | 5.2 | 4.4 | 4.1 | 3.4 |
| Plan No. | | | | | |
| 1 | 3.3 | 3.4 | 3.1 | 3.8 | 3.8 |
| 2 | 3.2 | 3.1 | 2.8 | 3.1 | 2.4 |
| 3 | 3.0 | 2.9 | 2.5 | 2.2 | 1.6 |
| 4 | 3.0 | 3.1 | 2.1 | 2.2 | 2.3 |
| 5 | 3.1 | 2.7 | 1.9 | 2.2 | 1.8 |
| 6 | 3.0 | 2.5 | 1.6 | 1.7 | 1.3 |
| 7 | 3.0 | 2.7 | 2.0 | 2.3 | 1.9 |
| 8 | 2.8 | 2.1 | 1.7 | 2.2 | 1.7 |
| 9 | 2.7 | 2.1 | 1.8 | 2.3 | 1.6 |
| 10 | 2.8 | 2.0 | 2.1 | 2.3 | 1.4 |
| 11 | 3.1 | 2.1 | 2.0 | 2.4 | 2.6 |
| 12 | 2.4 | 1.9 | 1.5 | 1.5 | 1.4 |
| 13 | 2.5 | 1.8 | 1.4 | 1.8 | 1.4 |
| 14 | 2.8 | 2.0 | 1.5 | 2.0 | 1.4 |

Table 14

Comparison of Wave Heights from 240 degrees for 50-year Wave Conditions for 15-sec, 16.6-ft Waves

| | Wave-Height Criteria or Measured Wave Height, ft, at Selected Location | | | | |
|---|---|---|---|---|---|
| | Northern Portion of Mole C | | Southern Portion of Mole C | Mole D | Entrance to Basin 3 |
| | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 |
| Wave-Height Criteria | 3.0 | 3.0 | 2.3 | 2.0 | 1.2 |
| Existing Conditions | 6.5 | 5.3 | 8.0 | 4.5 | 4.5 |
| Plan No. | | | | | |
| 1 | 3.8 | 4.6 | 5.9 | 2.9 | 5.0 |
| 2 | 3.5 | 4.3 | 5.5 | 2.7 | 3.0 |
| 3 | 3.4 | 3.7 | 5.2 | 2.3 | 2.4 |
| 4 | 3.6 | 3.5 | 3.9 | 3.9 | 2.7 |
| 5 | 3.2 | 3.8 | 3.6 | 2.8 | 2.2 |
| 6 | 3.2 | 3.6 | 3.3 | 2.5 | 1.7 |
| 7 | 3.6 | 3.9 | 3.7 | 2.7 | 2.3 |
| 8 | 2.4 | 3.2 | 2.9 | 2.6 | 2.3 |
| 9 | 2.4 | 2.9 | 3.0 | 2.6 | 1.8 |
| 10 | 2.4 | 2.9 | 3.5 | 2.5 | 1.7 |
| 11 | 3.0 | 2.5 | 2.7 | 2.6 | 3.5 |
| 12 | 2.3 | 2.4 | 2.2 | 1.6 | 1.4 |
| 13 | 2.2 | 2.3 | 2.1 | 1.6 | 1.4 |
| 14 | 2.3 | 2.4 | 2.0 | 1.8 | 1.8 |

Table 15

Comparison of Wave Heights from 240 degrees for 100-year Wave Conditions for 15-sec, 18.3-ft Waves

| | Wave-Height Criteria or Measured Wave Height, ft, at Selected Location | | | | |
|---|---|---|---|---|---|
| | Northern Portion of Mole C | | Southern Portion of Mole C | Mole D | Entrance to Basin 3 |
| | Gage 3 | Gage 4 | Gage 5 | Gage 6 | Gage 7 |
| Wave-Height Criteria | 4.3 | 4.3 | 2.9 | 2.1 | 1.3 |
| Existing Conditions | 6.6 | 6.6 | 11.1 | 7.0 | 5.4 |
| Plan No. | | | | | |
| 1 | 4.2 | 5.6 | 8.3 | 5.4 | 6.2 |
| 2 | 4.6 | 5.5 | 8.2 | 5.2 | 4.0 |
| 3 | 4.2 | 5.2 | 7.7 | 4.8 | 2.1 |
| 4 | 4.0 | 4.9 | 5.7 | 5.2 | 3.4 |
| 5 | 4.0 | 5.0 | 5.6 | 5.1 | 2.5 |
| 6 | 4.0 | 4.3 | 4.7 | 4.8 | 1.2 |
| 7 | 4.2 | 4.7 | 6.0 | 5.2 | 2.6 |
| 8 | 3.3 | 4.1 | 4.4 | 4.9 | 2.6 |
| 9 | 3.2 | 3.9 | 4.3 | 5.0 | 2.5 |
| 10 | 3.1 | 3.7 | 4.9 | 4.4 | 2.4 |
| 11 | 3.5 | 3.4 | 4.4 | 4.3 | 3.5 |
| 12 | 2.7 | 3.6 | 3.1 | 3.1 | 1.4 |
| 13 | 2.9 | 3.2 | 2.9 | 3.0 | 1.4 |
| 14 | 2.9 | 3.4 | 3.1 | 3.6 | 1.8 |

Photo 1. Typical wave patterns for existing conditions; 12-sec, 12.8-ft test waves from 240 deg; swl = +7.0

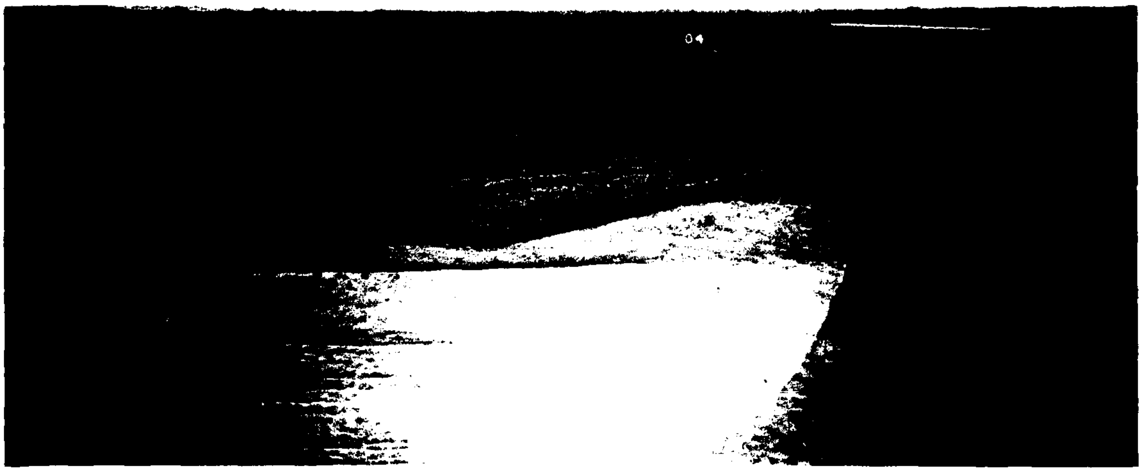


Photo 2. Typical wave patterns for existing conditions; 14-sec, 16.0-ft test waves from 240 deg; swl = +7.0

Photo 3. Typical wave patterns for existing conditions; 15-sec, 10.0-ft test waves from 240 deg; swl = +7.0

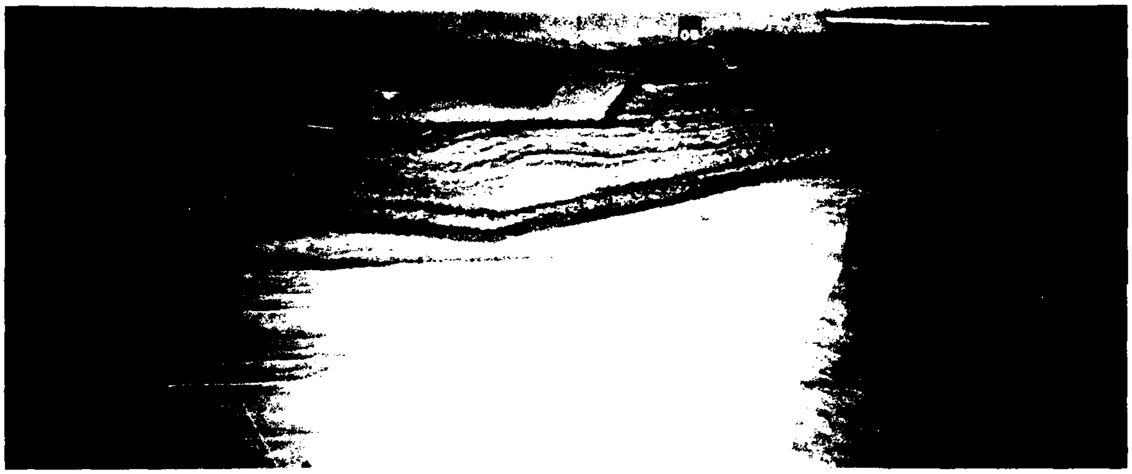


Photo 4. Typical wave patterns for existing conditions; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0

Photo 5. Typical wave patterns for existing conditions; 16-sec, 19.2-ft test waves from 240 deg; swl = +8.0

Photo 6. Typical wave patterns for Plan 1; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

Photo 7. Typical wave patterns for Plan 2; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

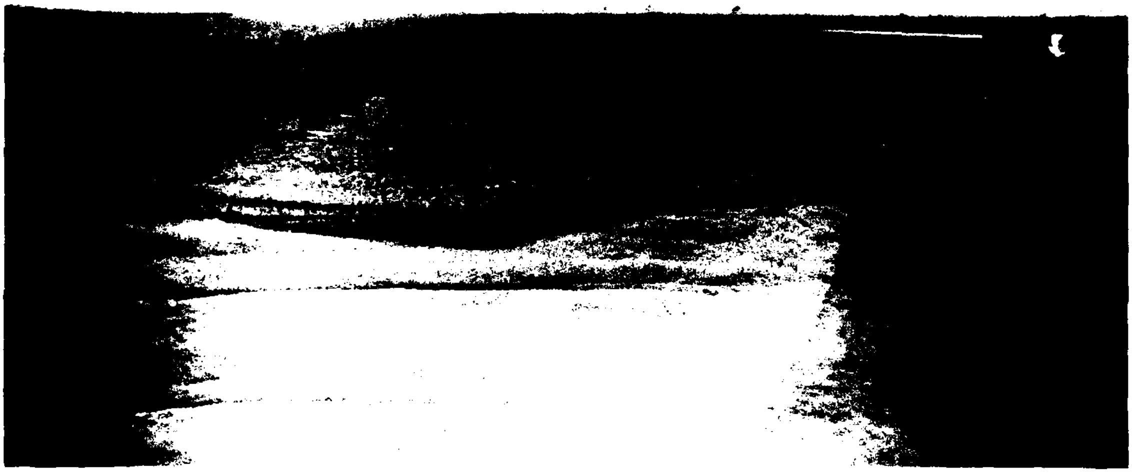


Photo 8. Typical wave patterns for Plan 3; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

Photo 9. Typical wave patterns for Plan 4; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

Photo 10. Typical wave patterns for Plan 5; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

Photo 11. Typical wave patterns for Plan 6; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

Photo 12. Typical wave patterns for Plan 7; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

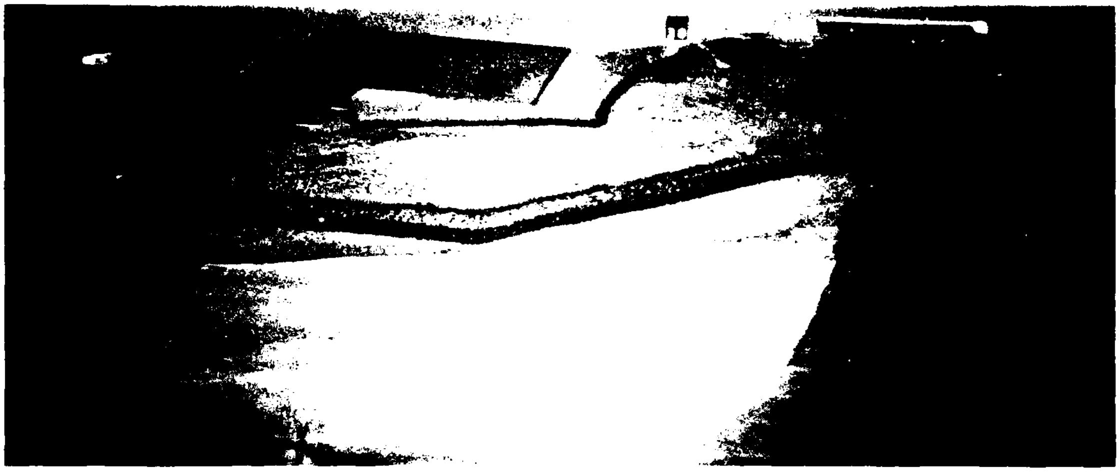


Photo 13. Typical wave patterns for Plan 8; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

Photo 14. Typical wave patterns for Plan 9; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

Photo 15. Typical wave patterns for Plan 10; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

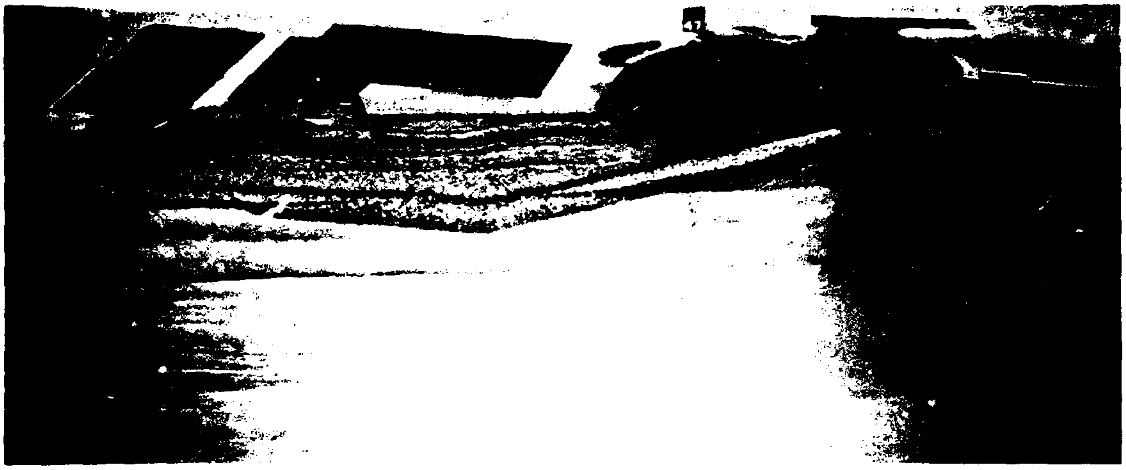


Photo 16. Typical wave patterns for Plan 11; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

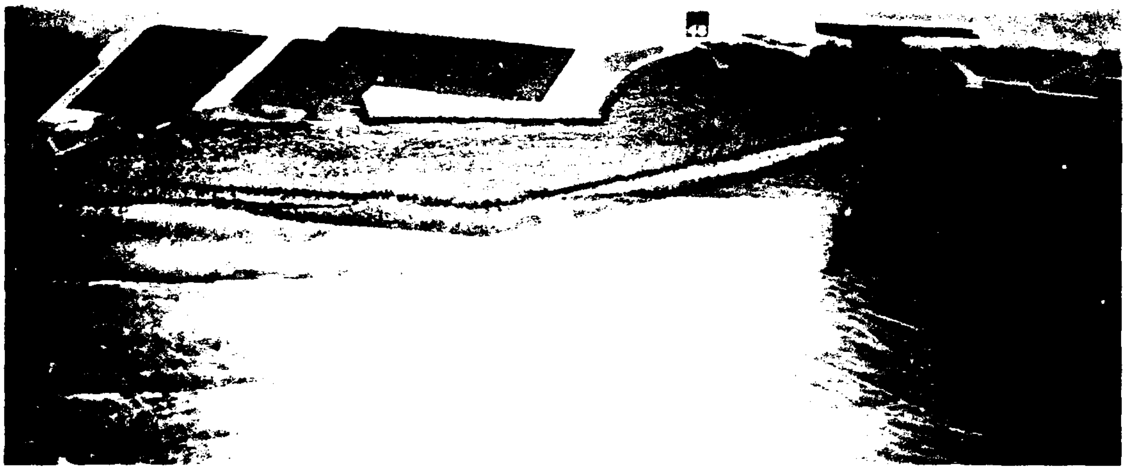


Photo 17. Typical wave patterns for Plan 12; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

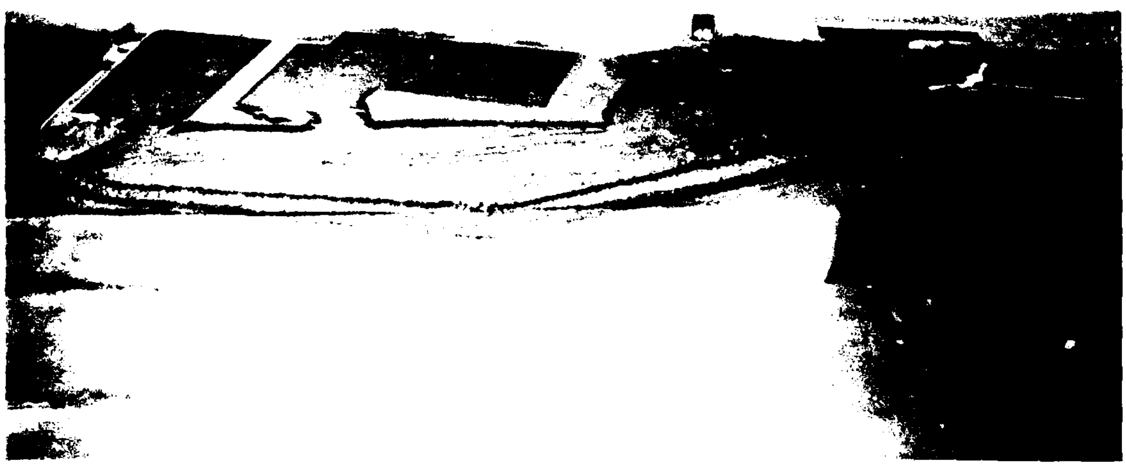


Photo 18. Typical wave patterns for Plan 13; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

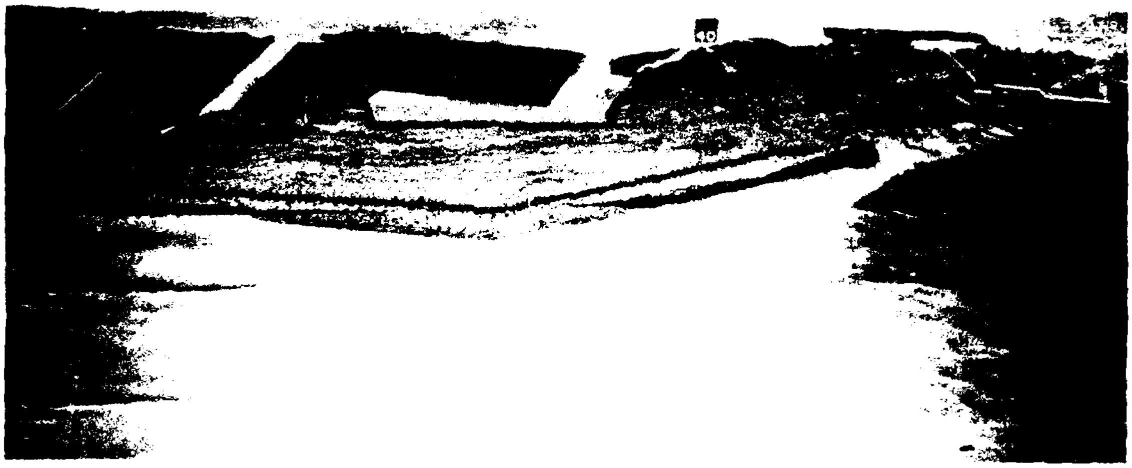


Photo 19. Typical wave patterns for Plan 14; 15-sec, 16.6-ft test waves from 240 deg; swl = +7.0 ft

Photo 20. Typical wave patterns for Plan 14; 12-sec, 12.8-ft test waves from 240 deg; swl = +7.0 ft

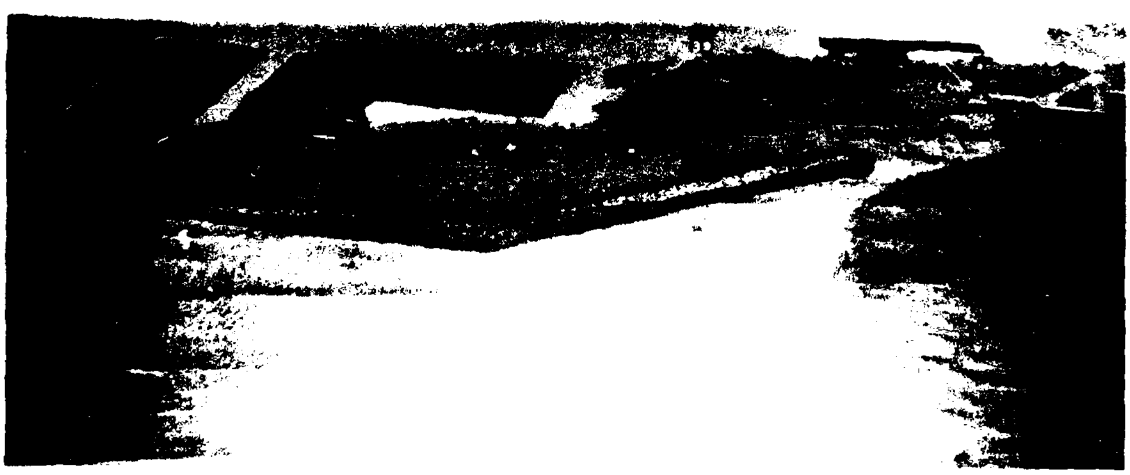


Photo 21. Typical wave patterns for Pla 14; 14-sec, 16.0-ft test waves from 240 deg; swl = +7.0 ft

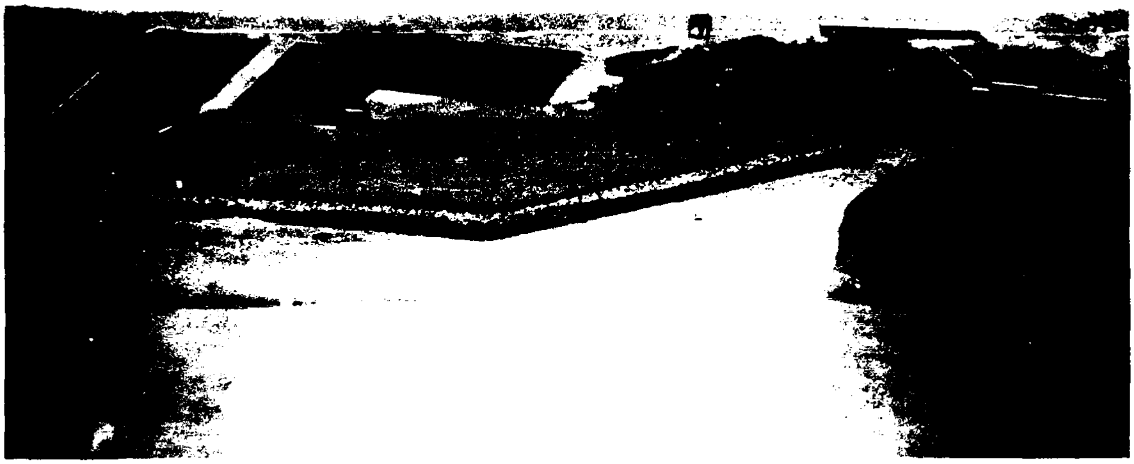


Photo 22. Typical wave patterns for Plan 14; 15-sec, 10.0-ft test waves from 240 deg; swl = +7.0 ft

Photo 23. Typical wave patterns for Plan 14; 16-sec, 19.2-ft test waves from 240 deg; swl = +8.0 ft

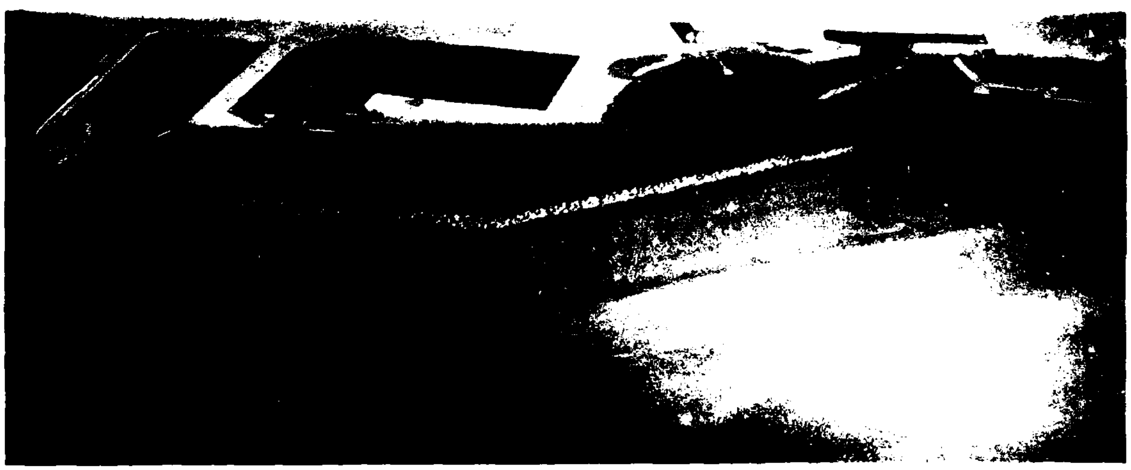


Photo 24. Typical wave patterns for Plan 14; 12-sec, 10.4-ft test waves from 220 deg; swl = +7.0 ft

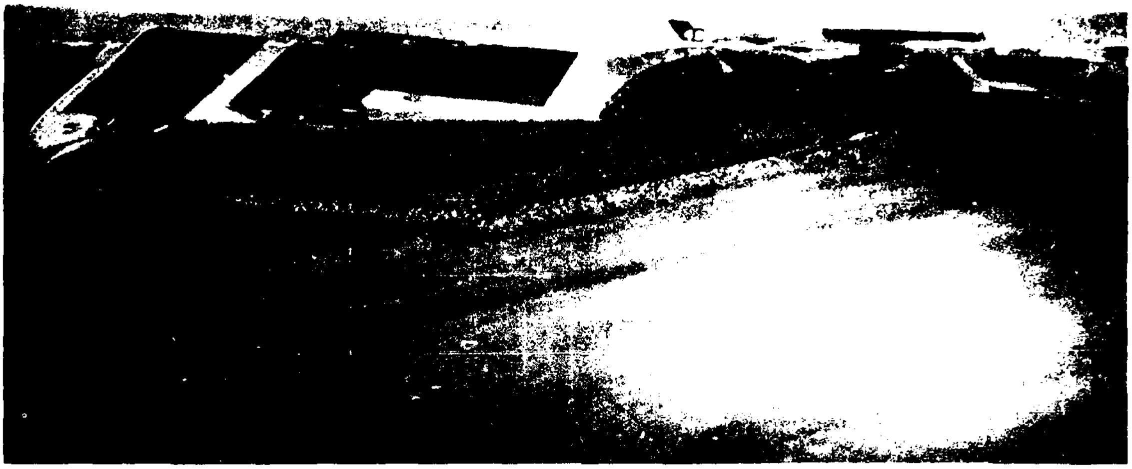


Photo 25. Typical wave patterns for Plan 14; 16-sec, 12.8-ft test waves from 220 deg; swl = +7.0 ft

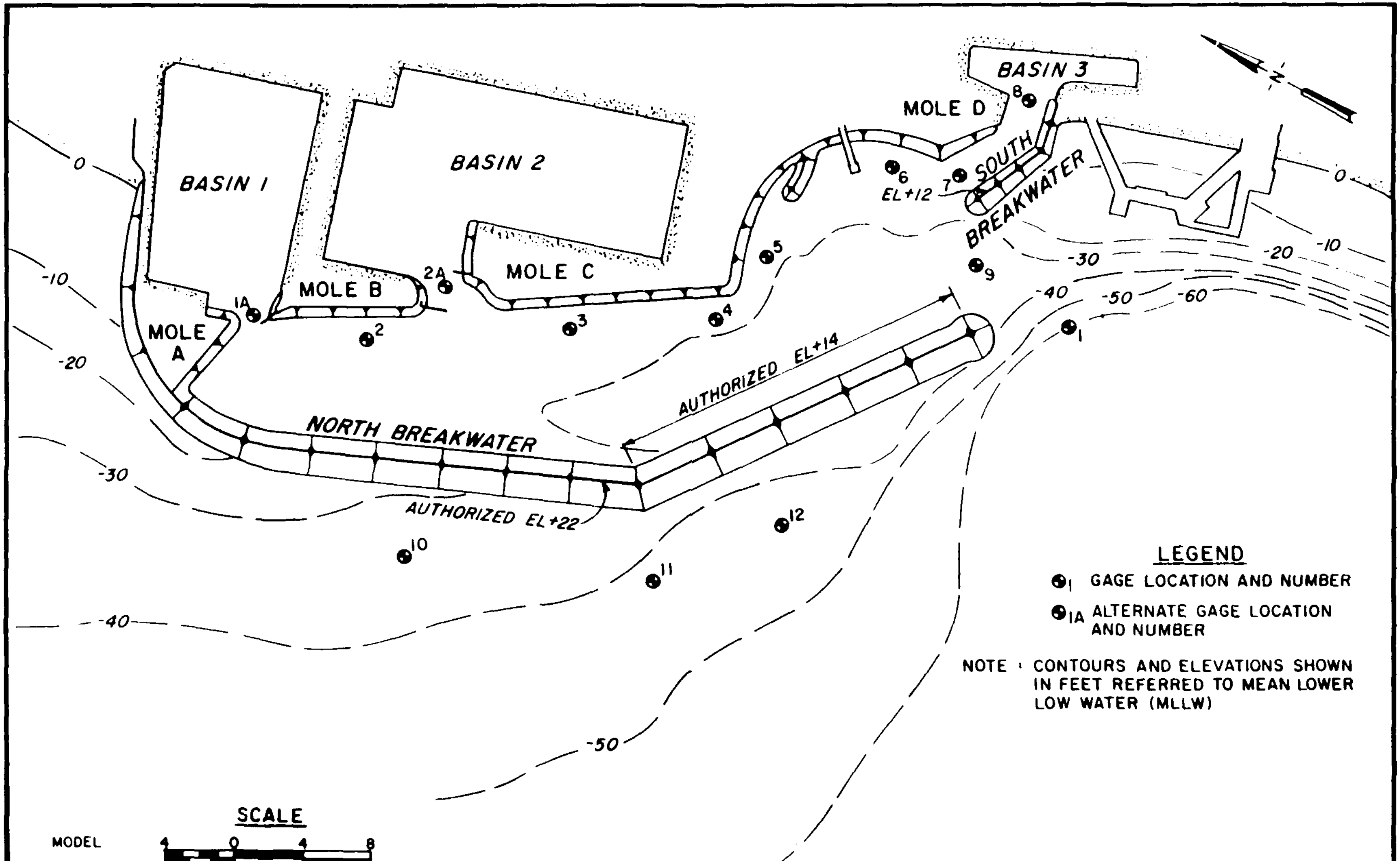
Photo 26. Typical wave patterns for Plan 14; 12-sec, 12.8-ft test waves from 260 deg; swl = +7.0 ft

Photo 27. Typical wave patterns for Plan 14; 14-sec, 16.0-ft test waves from 260 deg; swl = +7.0 ft

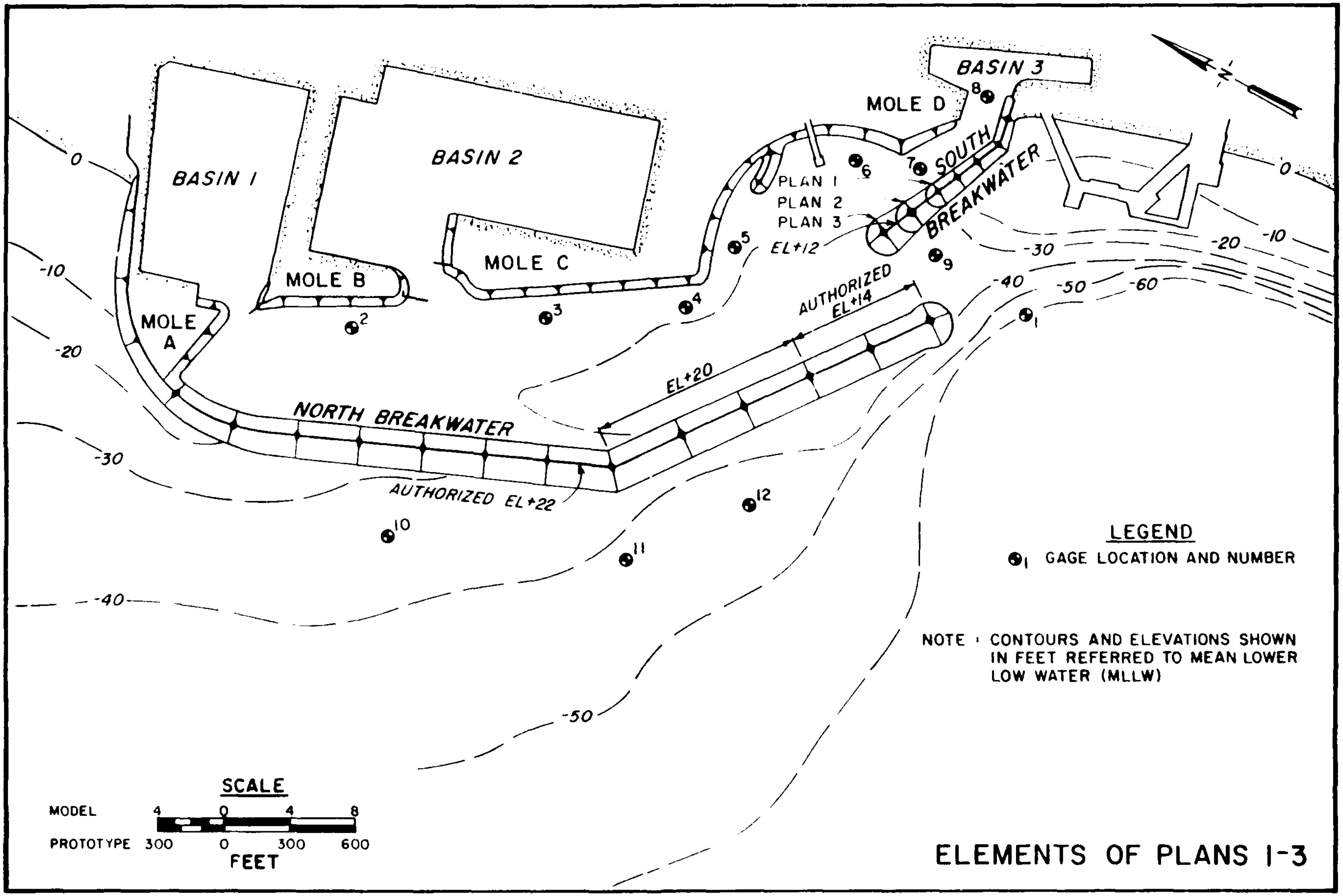
Photo 28. Typical wave patterns for Plan 14; 15-sec, 10.0-ft test waves from 260 deg; swl = +7.0 ft

Photo 29. Typical wave patterns for Plan 14; 15-sec, 16.6-ft test waves from 260 deg; swl = +7.0 ft

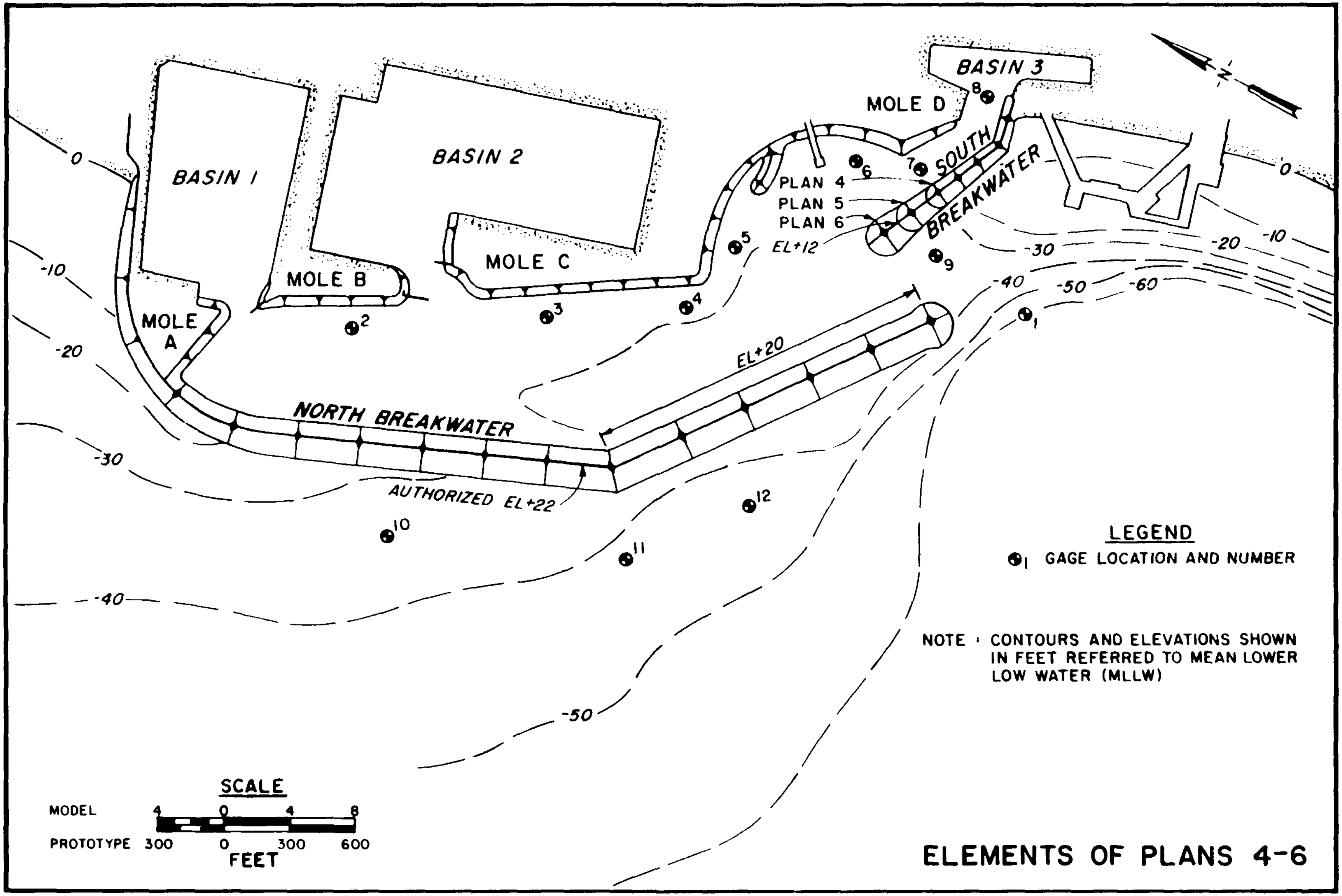
Photo 30. Typical wave patterns for Plan 14; 16-sec, 19.2-ft test waves from 260 deg; swl = +8.0 ft



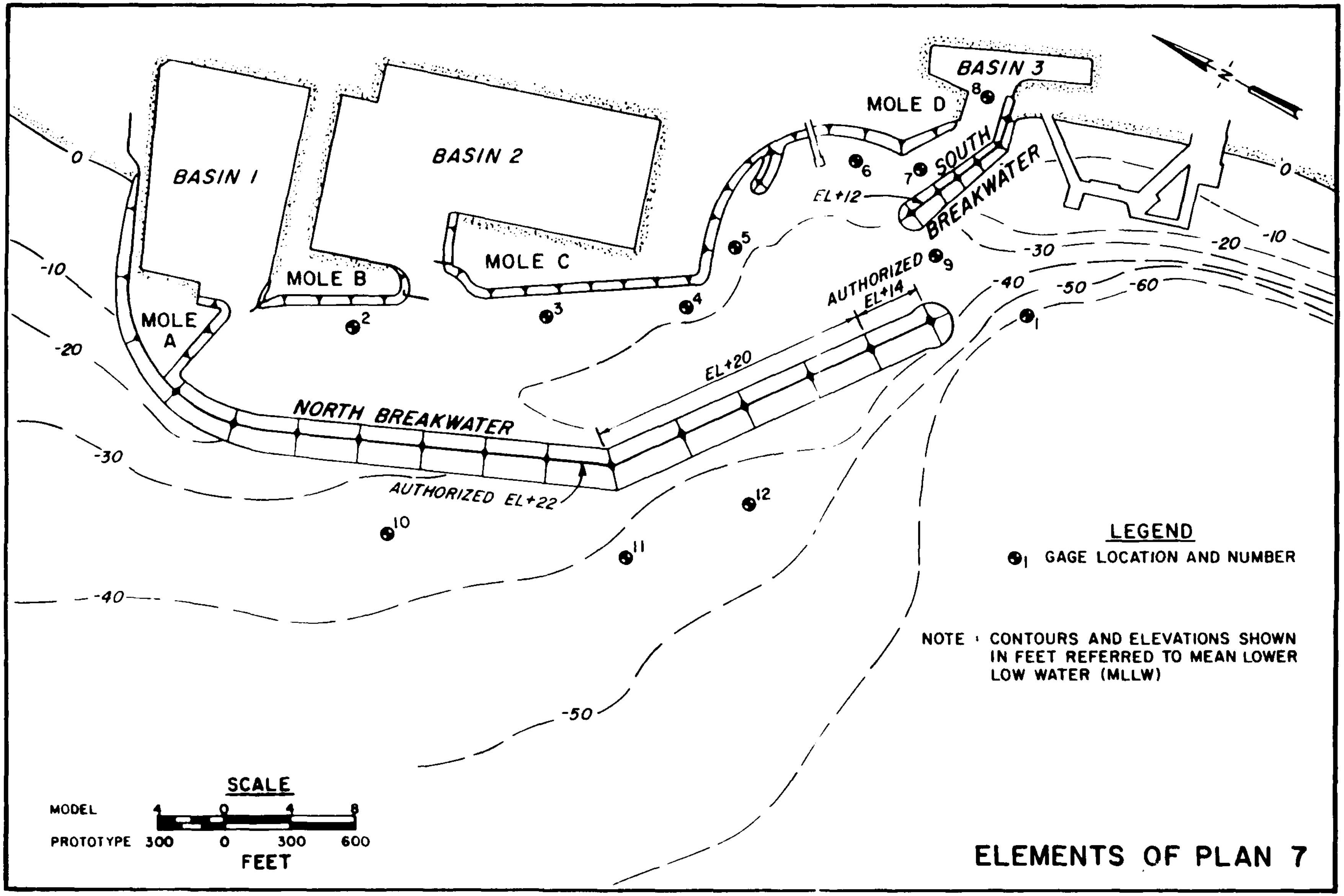

EXISTING CONDITIONS



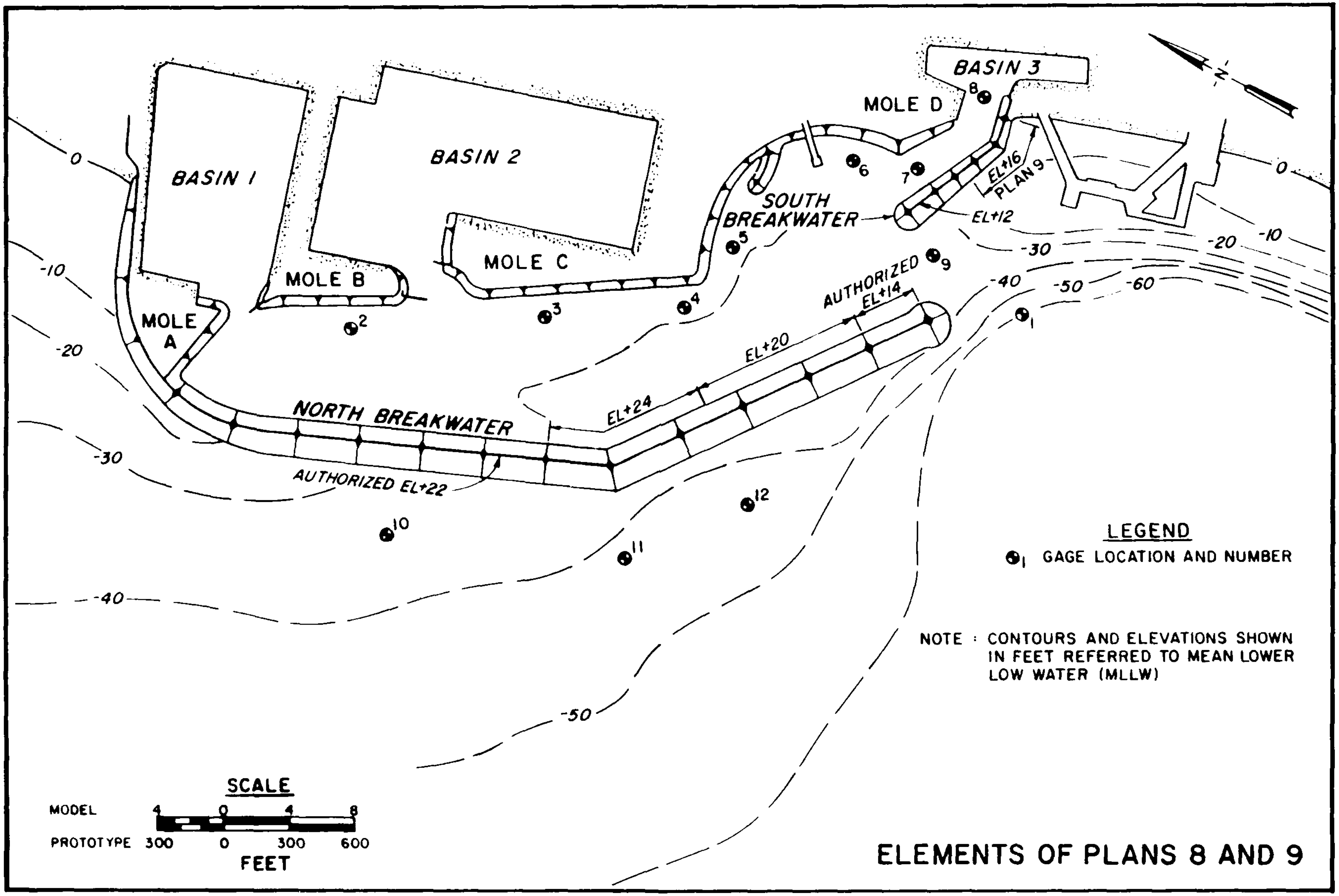
BASIN 1
BASIN 2
BASIN 3
MOLE A
MOLE B
MOLE C
MOLE D
NORTH BREAKWATER
SOUTH BREAKWATER
PLAN 1
PLAN 2
PLAN 3
EL+12
EL+20
AUTHORIZED EL+14
AUTHORIZED EL+22
N
0
-10
-20
-30
-40
-50
-60
1
2
3
4
5
6
7
8
9
10
11
12
LEGEND
GAGE LOCATION AND NUMBER
NOTE : CONTOURS AND ELEVATIONS SHOWN IN FEET REFERRED TO MEAN LOWER LOW WATER (MLLW)
SCALE
MODEL 4 0 4 8
PROTOTYPE 300 0 300 600
FEET
ELEMENTS OF PLANS 1-3



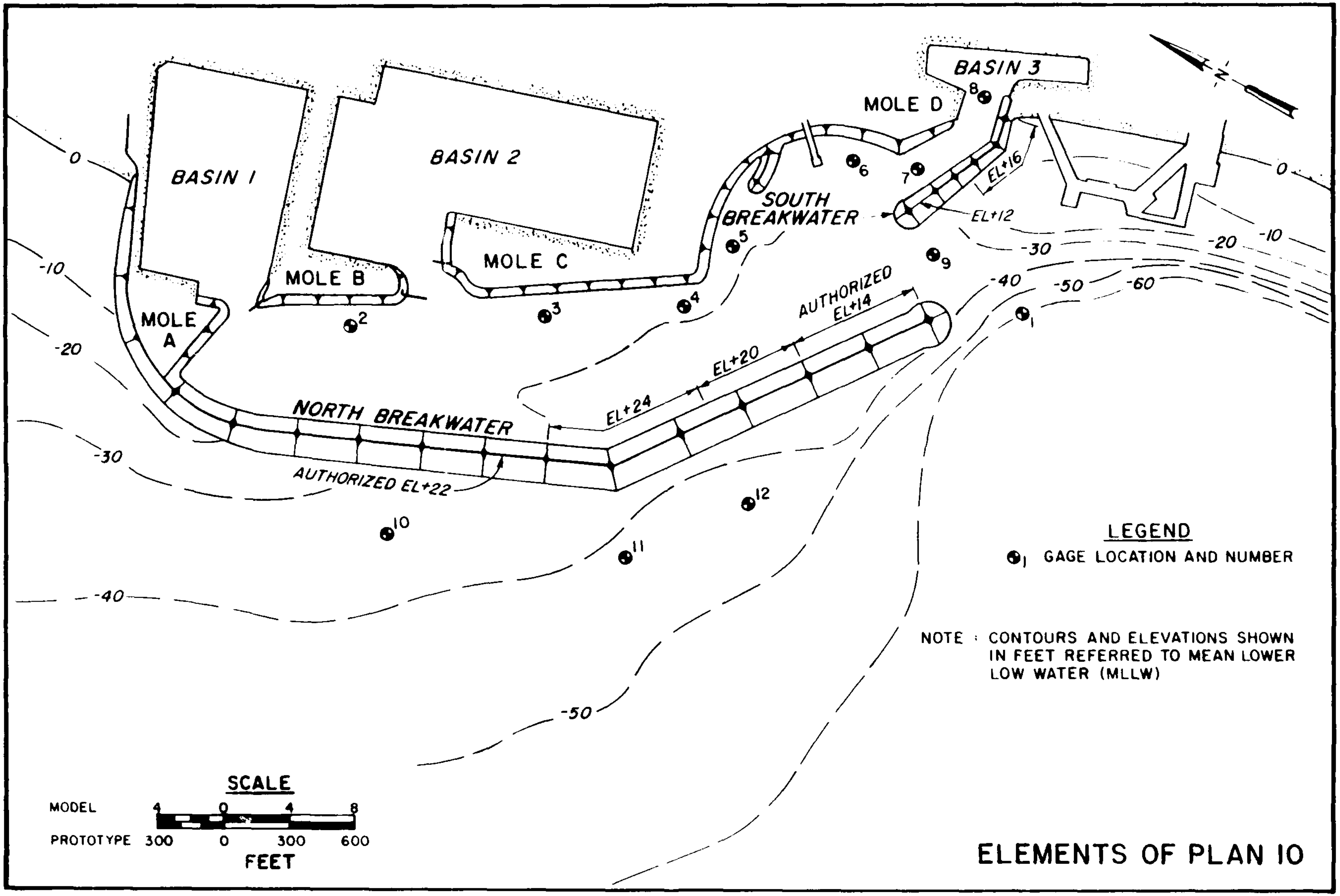

ELEMENTS OF PLANS 4-6



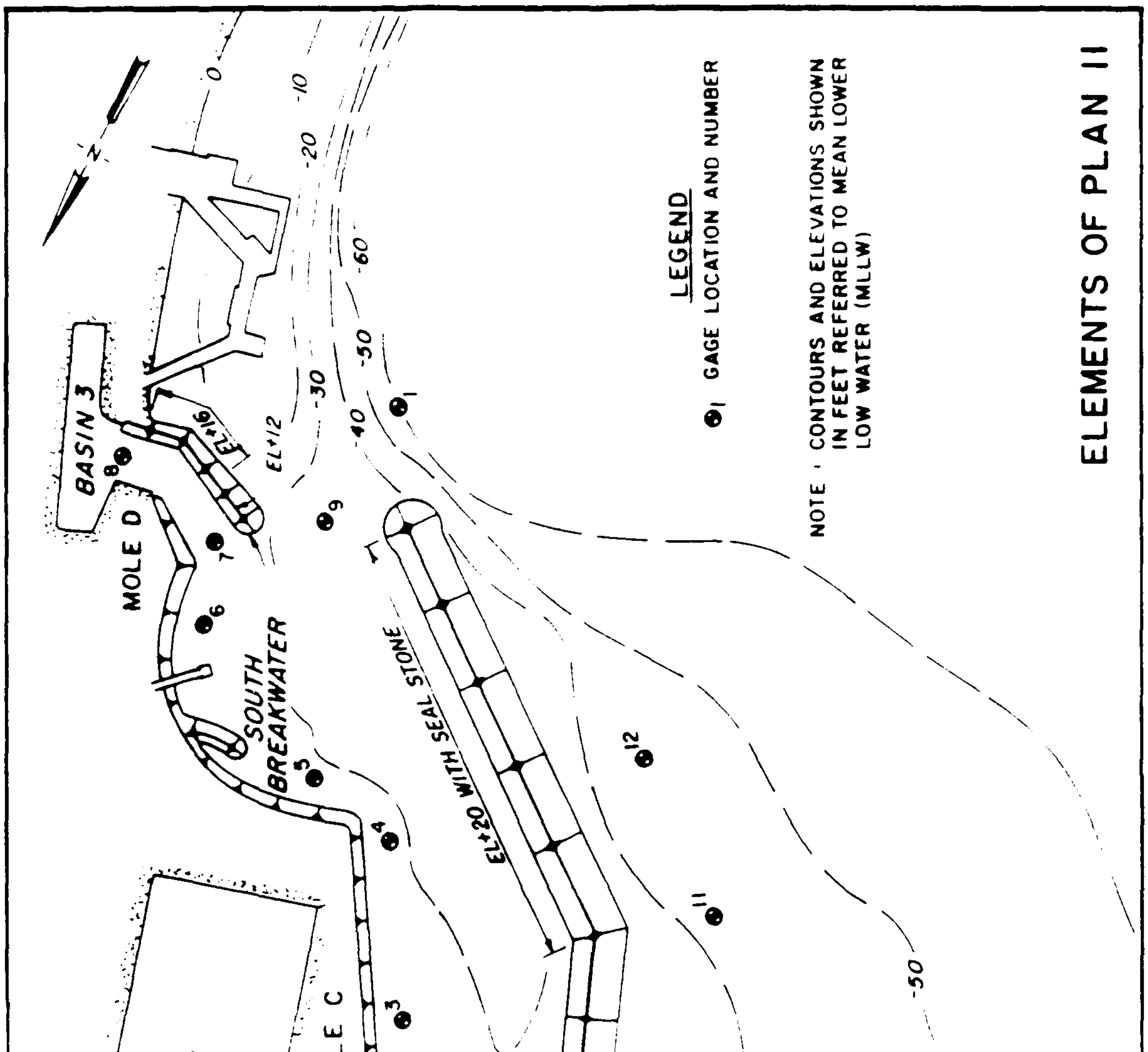

ELEMENTS OF PLAN 7



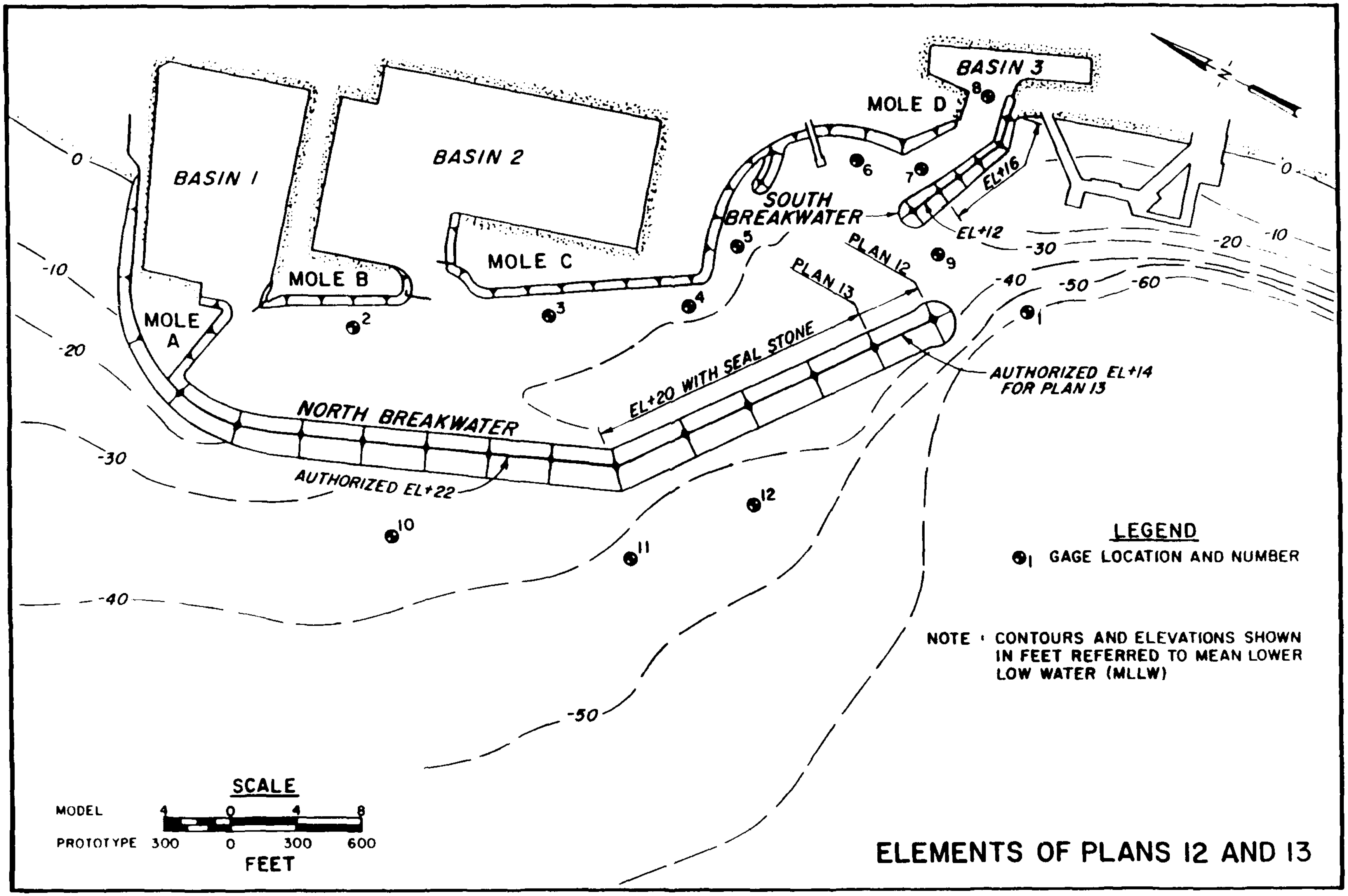

ELEMENTS OF PLANS 8 AND 9



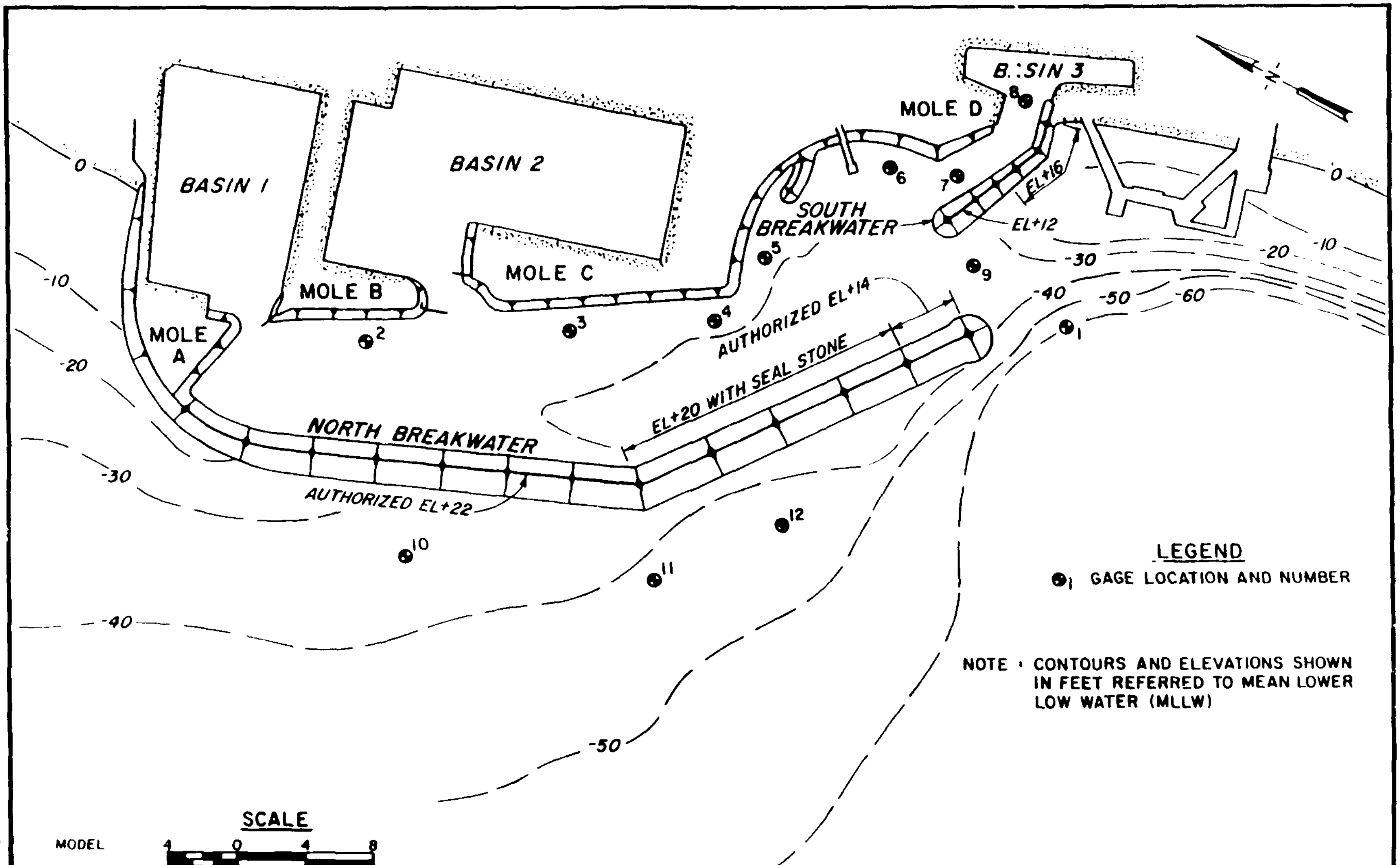

ELEMENTS OF PLAN 10




ELEMENTS OF PLAN II




ELEMENTS OF PLANS 12 AND 13




ELEMENTS OF PLAN 14