Photo 14. Typical wave patterns approaching Buhne Point for 5-sec, 7-ft waves from northwest for maximum flood; +3.2 ft swl
Photo 15. Typical wave patterns approaching Buhne Point for 11-sec, 10-ft waves from northwest for maximum flood; +3.2 ft swl
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Photo 17. Typical wave patterns approaching Buhne Point for 5-sec, 7-ft waves from northwest for maximum ebb; +3.7 ft swl
Photo 18. Typical wave patterns approaching Buhne Point for 11-sec, 10-ft waves from northwest for maximum ebb; +3.7 ft swl
Photo 19. Typical wave patterns approaching Buhne Point for 15-sec, 9-ft waves from northwest for maximum ebb; +3.7 ft swl
Photo 20. Typical wave patterns approaching Buhne Point for 5-sec, 7-ft waves from northwest; +6.7 ft swl
Photo 21. Typical wave patterns approaching Buhne Point for 11-sec, 10-ft waves from northwest; +6.7 ft swl
Photo 22. Typical wave patterns approaching Buhne Point for 15-sec, 9-ft waves from northwest; +6.7 ft swl
Photo 23. Typical wave patterns approaching Buhne Point for 5-sec, 7-ft waves from northwest; +9.5 ft swl
Photo 24. Typical wave patterns approaching Buhne Point for 11-sec, 10-ft waves from northwest; +9.5 ft swl
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Photo 39. Typical wave patterns approaching Buhne Point for 11-sec, 10-ft waves from west; +9.5 ft swl
Photo 38. Typical wave patterns approaching Buhne Point for 5-sec, 7-ft waves from west; +9.5 ft swl
Photo 37. Typical wave patterns approaching Buhne Point for 15-sec, 11-ft waves from west; +6.7 ft swl
Photo 36. Typical wave patterns approaching Buhne Point for 11-sec, 10-ft waves from west; +6.7 ft swl
Photo 35. Typical wave patterns approaching Buhne Point for 5-sec, 7-ft waves from west; +6.7 ft swl
Photo 34. Typical wave patterns approaching Buhne Point for 15-sec, 11-ft waves from west for maximum ebb; +3.7 ft swl
Photo 33. Typical wave patterns approaching Buhne Point for 11-sec, 10-ft waves from west for maximum ebb; +3.7 ft swl
Photo 32. Typical wave patterns approaching Buhne Point for 5-sec, 7-ft waves from west for maximum ebb; +3.7 ft swl
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Photo 30. Typical wave patterns approaching Buhne Point for 11-sec, 10-ft waves from west for maximum flood; +3.2 ft swl
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Photo 59. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 15-sec, 9-ft waves from northwest; +6.7 ft swl
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* INDICATES NO CURRENT MOVEMENT
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Plates 10

HOXTON CHANNEL (C13)

MAGNITUDE

TIME, HOURS

DEGREES FROM NORTH

HUMBOLDT BAY CURRENT DATA, FILTER = 4 HRS (4/1/82 - 4/3/82)
HUMBOLDT BAY CURRENT DATA, FILTER - 4 HRS (4/1/82 - 4/3/82)
LEGEND
WAVE GAGE LOCATION AND NUMBER

NOTE: CONTOURS AND ELEVATIONS SHOWN IN FEET, REFERRED TO LOW WATER (MLW).

PLATE 22
Plate 23. Wave fronts for test waves approaching Buhne Point from north; 0.0-ft swl
Plate 24. Wave fronts for test waves approaching Buhne Point from north for maximum flood; +3.2 ft swl
Plate 25. Wave fronts for test waves approaching Buhne Point from north for maximum ebb; +3.7 ft swl
Plate 26. Wave fronts for test waves approaching Buhne Point from north; +6.7 ft swl
Plate 27. Wave fronts for test waves approaching Buhne Point from north; +9.5 ft swl
Plate 28. Wave fronts for test waves approaching Buhne Point from northwest; 0.0-ft swl
Plate 29. Wave fronts for test waves approaching Buhne Point from northwest for maximum flood; +3.2 ft swl
Plate 30. Wave fronts for test waves approaching Buhne Point from northwest for maximum ebb; +3.7 ft swl
Plate 31. Wave fronts for test waves approaching Buhne Point from northwest; +6.7 ft swl
Plate 32. Wave fronts for test waves approaching Buhne Point from northwest; +9.5 ft swl
Plate 33. Wave fronts for test waves approaching Buhne Point from west; 0.0-ft swl
Plate 34. Wave fronts for test waves approaching Buhne Point from west for maximum flood; +3.2 ft swl
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Plate 38. Averages of wave fronts approaching Buhne Point from north for various swl's
Plate 37. Wave fronts for test waves approaching Buhne Point from west; +9.5 ft swl
Plate 36. Wave fronts for test waves approaching Buhne Point from west; +6.7 ft swl
Humboldt Bay, CA : Time 8.0 Hours

4 Contours
Contour Levels from 10. to 70.
Contour Interval of 20.

Plate 54. Bottom stress contours (dyne/cm²) within Humboldt Bay at ebb tide: existing conditions.
Humboldt Bay, CA : Time 16.0 Hours

4 Contours
Contour Levels from 10. to 70.
Contour Interval of 20.

Plate 55. Bottom stress contours (dyne/cm²) within Humboldt Bay at flood tide:
existing conditions
Plate 56. Bottom stress contours (dyne/cm²) within Humboldt Bay at slack water: existing conditions.
Plate 57. CELC3D computations of surface elevation, tidal currents, and bottom stresses at sta 1 (opposite north spit), 1-3 April 1982
Plate 58. CELC3D computations of surface elevation, tidal currents, and bottom stresses at sta 4 (north of Buhne Point), 1-3 April 1982
Plate 59. CELC3D computations of surface elevation, tidal currents, and bottom stresses at sta 11 (near Buhne Point), 1-3 April 1982.
Plate 60. CELC3D computations of surface elevation, tidal currents, and bottom stresses at sta 13 (Fields Landing Channel), 1-3 April 1982
Plate 61. CELC3D computations of surface elevation, tidal currents, and bottom stresses at sta 16 (Humboldt Bay Entrance), 1-3 April 1982.
4 Contours
Contour Levels from 10. to 70.
Contour Interval of 20.

Plate 63. Bottom stress contours (dyne/cm²) within Humboldt Bay at flood tide: proposed improvement plan.
Humboldt Bay, CA : Time 24.0 Hours

4 Contours
Contour Levels from 10. to 70.
Contour Interval of 20.

Plate 64. Bottom stress contours (dyne/cm²) within Humboldt Bay at slack water: proposed improvement plan
Plate 65. Tidally induced residual currents within Humboldt Bay, 1-3 April 1982, existing conditions.
Plate 66. Tidally induced residual currents within Humboldt Bay, 1-3 April 1982, proposed improvement plan
Station 01 (Depth = 3.87 m)

(a) Wave-Induced Orbital Velocity

(b) Wave-Induced Bottom Stress

Plate 67. Wave-induced bottom orbital velocity and bottom stress at sta 1; 11-ssec, 10-ft waves from the northwest; maximum flood; +3.2 ft swl; cnoidal wave theory (solid lines) and linear wave theory (dashed lines)
Station 04 (Depth = 4.11 m)

(a) Wave-Induced Orbital Velocity

(b) Wave-Induced Bottom Stress

Plate 68. Wave-induced bottom orbital velocity and bottom stress at sta 4; 11-sct, 10-ft waves from the northwest; maximum flood; +3.2 ft swl; cnoidal wave theory (solid lines) and linear wave theory (dashed lines)
Plate 69. Wave-induced bottom orbital velocity and bottom stress at sta 11; 11-sec, 10-ft waves from the northwest; maximum flood; +3.2 ft swl; cnoidal wave theory (solid lines) and linear wave theory (dashed lines)
Plate 70. Wave-induced bottom orbital velocity and bottom stress at sta 12; 11-sec, 10-ft waves from the northwest; maximum flood; +3.2 ft swl; cnoidal wave theory (solid lines) and linear wave theory (dashed lines)
Station 13 (Depth = 8.38 m)

(a) Wave-Induced Orbital Velocity

(b) Wave-Induced Bottom Stress

Plate 71. Wave-induced bottom orbital velocity and bottom stress at sta 13; 11-sec, 10-ft waves from the northwest; maximum flood; +3.2 ft swl; cnoidal wave theory (solid lines) and linear wave theory (dashed lines)
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Plate 74. Wave-induced bottom orbital velocity and bottom stress at sta 4; 11-sec, 10-ft waves from the northwest; maximum ebb; +3.7 ft swl; cnoidal wave theory (solid lines) and linear wave theory (dashed lines)
Station 11 (Depth = 2.65 m)

(a) Wave-Induced Orbital Velocity

(b) Wave-Induced Bottom Stress

Plate 75. Wave-induced bottom orbital velocity and bottom stress at sta 11; 11-s ec, 10-ft waves from the northwest; maximum ebb; +1 ft sw; cnoidal wave theory (solid line) and linear wave theory (dashed line).
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\(^*\) At approximate location of wave generator in model.

\(^{**}\) At 117-ft depth (110-ft pit elevation with 7-ft tide conditions superimposed).
rectangular depth grid 24.8 miles by 12.6 miles which paralleled the shoreline in the vicinity of the project area. Limits of the depth grid used are shown in Plate A1. The grid spacing was 600 ft and depths were taken from the latest hydrographic survey charts. Storm conditions were represented by superimposing a water level of 7.0 ft on the depth grid.

4. Wave orthogonals were produced for 5-, 7-, 9-, 11-, 13-, 15-, 17-, and 19-sec waves from north, northwest, west, and southwest. The plots obtained are shown in Plates A2-A33.

5. Refraction coefficients and shallow-water orthogonal directions obtained for the various wave periods from the four deepwater wave directions are presented in Table A1. These values represent an average of the orthogonals in the immediate vicinity of the harbor site (approximately the location of the wave generator in the model). Shoaling coefficients of 1.00, 0.99, 0.94, 0.92, 0.92, 0.93, 0.96, and 0.99 for 5-, 7-, 9-, 11-, 13-, 15-, 17-, and 19-sec wave periods, respectively, were computed for a 117-ft water depth corresponding to the simulated depth at the model wave generator. The wave-height adjustment factor is obtained by multiplying $K_r$ times $K_s$ and can be applied to any deepwater wave height to obtain the corresponding shallow-water value.

6. Based on the refracted directions secured at the model contours for each wave period, four wave generator positions were available for model testing representing the various deepwater directions. The following tabulation shows the deepwater directions and the corresponding shallow-water test directions.

<table>
<thead>
<tr>
<th>Deepwater Direction, Azimuth, deg</th>
<th>Corresponding Shallow-Water Test Direction, Azimuth, deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>North, 360</td>
<td>346</td>
</tr>
<tr>
<td>Northwest, 315</td>
<td>308</td>
</tr>
<tr>
<td>West, 270</td>
<td>277</td>
</tr>
<tr>
<td>Southwest, 225</td>
<td>254</td>
</tr>
</tbody>
</table>

The shallow-water wave directions were taken to be the average directions of the refracted waves for the significant wave periods noted from each deepwater direction.
APPENDIX A: WAVE REFRACTION ANALYSIS FOR HUMBOLDT BAY

1. Prior to the hydraulic model investigation of Humboldt Bay, a wave refraction analysis was conducted at the US Army Engineer Waterways Experiment Station (WES) to determine the shallow-water wave height and the refracted wave direction at the model wave generator pit for representative wave periods from the critical directions of deepwater wave approach. This analysis was conducted using a linear wave refraction theory originally developed at Stanford University by Dobson (1967)* and modified by WES in 1971. All computations and plotting were done using an Electronic Associates, Inc. (EAI) Pacer 100 minicomputer and Versatec electrostatic plotter at WES.

2. In this analysis, the effects of both reflection and diffraction are neglected. These assumptions are valid except in convergence areas where caustics occur and linear theory does not apply. Therefore the major assumption in determining the wave height at any point on a wave orthogonal, within the limits of the linear theory, is that no energy is transmitted perpendicular to the orthogonal along the wave crest, in which case the height at any given point is given by

\[ H = H^K_0 K_r \]

where

- \( H_0 \) = wave height in deep water
- \( K_s \) = shoaling coefficient
- \( K_r \) = refraction coefficient

This assumption has been shown to be reasonable for mild slopes which induce only gradual bending of the orthogonals. For areas of extreme refraction, failure to consider the flow of energy along the wave crests can lead to significant errors in the computed wave height. Since previous research at WES by Whalin (1971, 1972) has shown that wave energy will tend to flow along the wave crests in areas of energy concentration, a maximum refraction coefficient of 1.4 and a minimum refraction coefficient of 0.45 were selected as being reasonable values.

3. Refraction diagrams for Humboldt Bay were produced from a

* See References at the end of main text.
Station 15 (Depth = 11.13 m)

(a) Wave-Induced Orbital Velocity

(b) Wave-Induced Bottom Stress

Plate 78. Wave-induced bottom orbital velocity and bottom stress at sta 15; 11-sec, 10-ft waves from the northwest; maximum ebb; +3.7 ft swl; cnoidal wave theory (solid lines) and linear wave theory (dashed lines)
Station 13 (Depth = 8.38 m)

(a) Wave-Induced Orbital Velocity

(b) Wave-Induced Bottom Stress

Plate 77. Wave-induced bottom orbital velocity and bottom stress at sta 13; 11-sec, 10-ft waves from the northwest; maximum ebb; +3.7 ft swl; cnoidal wave theory (solid lines) and linear wave theory (dashed lines)
Station 12 (Depth = 2.16 m)

(a) Wave-Induced Orbital Velocity

(b) Wave-Induced Bottom Stress

Plate 76. Wave-induced bottom orbital velocity and bottom stress at Sta 12; 11-sec, 10-ft waves from the northwest; maximum ebb; +3.7 ft swl; cnoidal wave theory (solid lines) and linear wave theory (dashed lines)
WAVE PERIOD 5 SEC DEEPWATER DIRECTION NORTHWEST
APPENDIX B: NOTATION

A  Area
b  Shallow-water orthogonal spacing
b_o  Deepwater orthogonal spacing
(b_o/b)_{1/2}  Refraction coefficient, r
D_{50}  Median particle diameter
H  Shallow-water wave height
H_o  Deepwater wave height
H_{1/3}  Significant wave height
K_r  Refraction coefficient
K_s  Shoaling coefficient
L  Length
Q  Discharge
T  Time
V  Velocity
V  Volume
\gamma  Specific weight
\gamma'  Apparent specific weight
\eta_D  Ratio of median particle diameter
\eta'_Y  Ratio of apparent specific weights
\Lambda  Horizontal scale
\mu  Vertical scale
END

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