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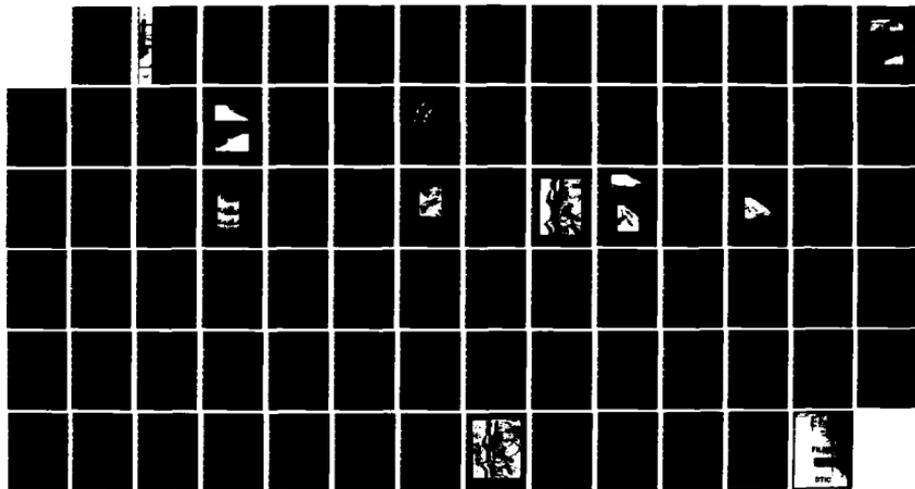
RECONNAISSANCE REPORT ON COASTAL EROSION AT FORT ORD
CALIFORNIA(U) COASTAL ENGINEERING RESEARCH CENTER
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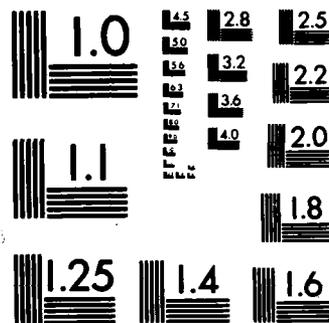
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MISCELLANEOUS PAPER CERC-83-10

RECONNAISSANCE REPORT ON COASTAL EROSION AT FORT ORD, CALIFORNIA

by

Orson P. Smith

Coastal Engineering Research Center
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180



December 1983
Final Report

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Prepared for Department of the Army, 7th Infantry Division
and Fort Ord
Fort Ord, California 93941

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These investigations were conducted under the direction of Dr. Robert W. Whalin, Chief, CERC, Dr. Dennis R. Smith, Acting Chief, EDD, and Dr. Fred E. Camfield, Chief, Coastal Design Branch.

Commander and Director of WES during the conduct of these investigations and the preparation of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, INCH-POUND TO METRIC (SI)
UNITS OF MEASUREMENT

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

Multiply	By	To Obtain
acres	0.4046873	hectares
acre-feet	1233.489	cubic meters
cubic yards	0.7645549	cubic meters
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
fathoms	1.828804	meters
feet	0.3048	meters
knots (international)	0.5144444	meters per second
miles (6.5 statute)	1.609347	kilometers
pounds (lb avoirdupois)	0.4535924	kilograms
pounds per cubic foot	16.01846	kilograms per cubic meter
square feet	0.09290304	square meters
tons (short, 2000 lb)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit readings, use the following formula: $C = (5/9)(F-32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F-32) + 273.15$.

RECONNAISSANCE REPORT ON COASTAL EROSION
AT FORT ORD, CALIFORNIA

PART I: INTRODUCTION

Objectives and Scope

1. The objectives of the investigations summarized in this Reconnaissance Report included provision of responses to all the specific requests made to the U. S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center (WES/CERC) by Department of the Army, Headquarters, 7th Infantry and Fort Ord, in the correspondence which initiated these efforts (see Appendix A). These requests were to do the following:

- a. Estimate current coastal erosion rates at the Fort Ord Ammo Supply Point and Stilwell Hall Recreational Center on Monterey Bay.
- b. Estimate when the existing structures at these areas would be rendered unusable by coastal erosion.
- c. Discuss what methods the Army could use to retard or prevent loss of these structures.
- d. Provide specific information, including structural design concepts and approximate material quantities and implementation costs, for shore protection measures at Stilwell Hall.

2. Restated in terms of the approach taken to prepare responses to the above requests, the objectives of this investigation are listed below:

- a. Review existing literature and readily available data pertaining to coastal erosion in southern Monterey Bay, California, with a view towards potential application to structural design efforts.
- b. Define the nature of the physical processes related to coastal erosion at Fort Ord as precisely as schedule and funding constraints allow, in order to:
 - (1) Estimate historical, current, and future shoreline retreat rates at the Fort Ord Ammo Supply Point and Stilwell Hall Recreational Center.
 - (2) Estimate the future time at which the existing structures at these two areas would be rendered unusable.
 - (3) Derive tentative design criteria for effective shore protection at Stilwell Hall.

(4) Estimate the long-term effects of any proposed shoreline structures.

c. Formulate structural design concepts which would retard or prevent the loss of the structures in question.

d. Estimate the approximate (order of magnitude) costs of the concepts formulated above.

e. Outline a comprehensive design program which would thoroughly and efficiently provide construction details and accurate cost estimates.

3. The scope of the efforts documented in this Reconnaissance Report was limited by the projects budget and schedule. A wealth of technical information on Monterey Bay and vicinity was located and reviewed. The physical processes affecting coastal erosion at Fort Ord revealed themselves to be highly complex and somewhat unique, with conflicting opinions by experts on some details. Only the principle conclusions of other study efforts that were well supported without contest were applied in computations for this project. A number of assumptions were necessary where data were not available or extensive data analyses were beyond the scope of this project. The extreme conditions prevalent along the shoreline of Fort Ord were found to be near or beyond the limits of current design guidance in several instances, and subjective decisions on some of the design criteria and project features were necessary.

Report Organization and Content

4. This Reconnaissance Report is organized into five basic parts offering a continuous discussion of the subject material, plus two appendices. Following this introduction, the continuous discussion first defines the nature of the physical processes affecting coastal erosion at Fort Ord and the problems caused by coastal erosion. The discussion then proceeds to describe alternative solutions to these problems, including both structural and nonstructural possibilities. The alternative solutions are then comparatively evaluated for effectiveness, and conclusions and recommendations are drawn from this evaluation. Appendices include pertinent correspondence and a recommended detail design program with corresponding costs for WES/CERC to do the work.

PART II. PROBLEM DEFINITION

Existing Conditions

Location

5. Fort Ord is located along the southern half of Monterey Bay on the central California coastline, approximately 118 miles* southeast of San Francisco (see Figure 1). Fort Ord is bounded on the north by the city of Marina and the Salinas River and on the south by the city of Seaside. It is approximately 7 miles northeast of the city of Monterey on State Highway 1, which parallels the coast. The post covers an area of approximately 28,028 acres, which includes 4-1/2 miles of coastline (Resources Planning Consultants 1980).

History

6. The general vicinity of Fort Ord is rich in historic background dating back to the first Spanish settlement of California in the 16th Century. Nearby Monterey became the Spanish capitol of California and later the Mexican capitol of California, until annexation by the United States in 1846. Fort Ord was originally developed in 1917 as an artillery range for the Army post at the Presidio of Monterey (now home of the Defense Language Institute); it was called the Gigling Field Artillery Range. In 1933, the reservation was renamed Camp Ord after LT Edward Ord, the original builder of the Presidio of Monterey. In 1940 the post was expanded to its present size and renamed Fort Ord.

7. Fort Ord became the home of the 7th Infantry Division in 1940, under the command of BG Joseph Stilwell. General Stilwell was primarily responsible for the 1941 construction at Fort Ord of Stilwell Hall Recreational Center. This distinctive Spanish style adobe-walled building encloses 51,882 sq ft and overlooks a spectacular view of Monterey Bay (see Figures 2 and 3). It is also known as "Soldiers Hall," since it was built for the use and with the contributions of enlisted men. Stilwell Hall was associated with the training and demobilization of large numbers of troops during World War II and the

* A table for converting the inch-pound units of measurement in this report to metric (SI) units is found on page 4.

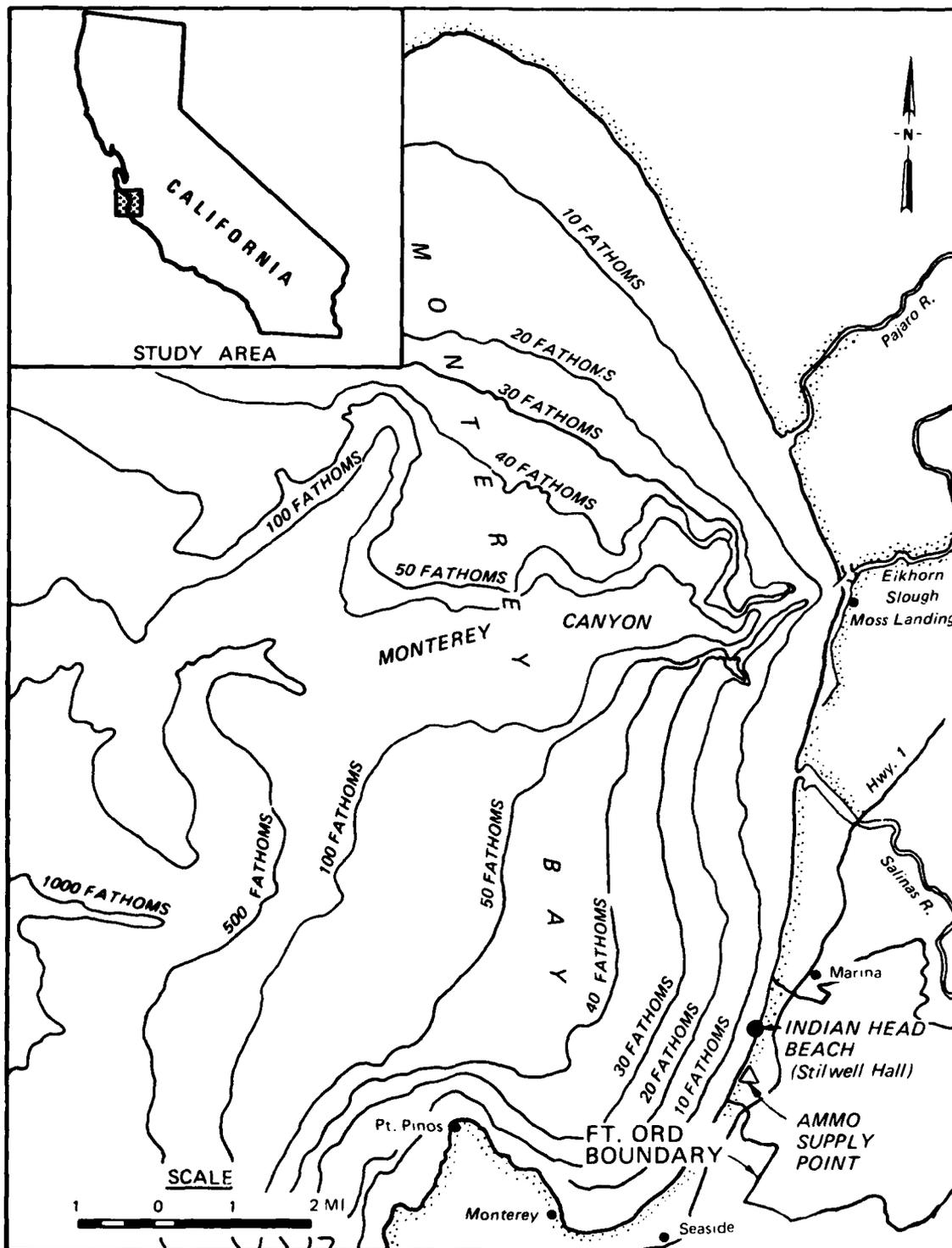


Figure 1. Monterey Bay, California



Figure 2. Stilwell Hall Recreational Center,
Fort Ord, California



Figure 3. Shoreline at Stilwell Hall, Fort Ord, California

Korean and Vietnam wars. It is still used for a variety of recreational activities (Swernoff 1979).

Land features

8. Monterey Bay is at the western end of a major structural low that serves as the outlet for drainage of the central valley between California's coastal ranges. The Salinas Valley is the largest of the valleys which drain into the bay. This valley possesses a wide, flat bottom between adjacent mountain ranges, and its center is covered with large areas of sedimentary fill. The mouth of the Salinas River is blocked off from the ocean by a wide sand bar, and the last few miles of the river form a lagoon. The Salinas Valley is a strongly linear drainage basin extending southeast from Monterey Bay nearly to Morro Bay and covering nearly 4,300 sq miles.

9. Bordering the Salinas Valley on the northeast is the Santa Clara Valley with its southern extension, the San Benito Valley, both of which are drained by the Pajaro River. This drainage region is structurally similar to the Salinas Basin, although it is only about 1400 sq miles in area. The gradient for this valley is not so low as the gradient for the Salinas Valley, and no lagoon is present at the mouth of the Pajaro River. The small year-round flow of water across the beach from the Pajaro River is not large enough to modify the beach profile created by the ocean waves.

10. San Lorenzo is the remaining major river which drains into Monterey Bay. This drainage basin is much smaller in area (140 sq miles) and has a higher gradient than either the Salinas or Pajaro basins; it has a bedrock valley basement, with small alluvial portions confined to areas near the mouth. The San Lorenzo River maintains a larger volume of runoff in the summer months than either the Salinas or Pajaro Rivers.

11. Granitic, or Franciscan, rock types everywhere form the basement rock of the drainage area of Monterey Bay, but in extensive areas they are deeply covered by Cretaceous and Tertiary sedimentary rocks. Bottom sediment samples obtained from Monterey Bay (Martin and Emery 1967) reveal granitic rocks on the south wall of Monterey Canyon, whereas Pliocene sedimentary rocks crop out on the north wall and along the shallower head regions of the canyon. Thick Pleistocene deposits floor the eastern portion of the bay in the region surrounding the head of Monterey Canyon and near the mouths of the Salinas and Pajaro Rivers.

12. That portion of Fort Ord which is adjacent to Monterey Bay lies atop sand dunes of the Flandrian Dune Belt, rising to elevations in excess of 100 ft msl in most areas. Cooper (1967) investigated the coastal dunes of California paying special attention to the Monterey dune complex, and recognized older dunes which are completely stabilized and extending several miles inland. These have come to be known as the pre-Flandrian dunes. These dunes are covered with vegetation and pine forests and are bordered along the coast by a zone of younger dunes extending an average of 3000 ft inland; they may reach elevations of 140 ft msl. Cooper (1967) was able to approximately radiocarbon-date the base of the younger Flandrian dunes at Ano Nuevo. Because of the close proximity, the age of the Flandrian dunes along the Monterey Bay coastline is assumed to be the same (Arnal, Dittmer, and Shumaker 1973).

13. The seismicity of central California is well known, and the famous San Andreas Fault, 17 miles to the northeast, provides the principle hazard to Fort Ord. The Palo Colorado Fault, 14 miles to the southeast, also could cause significant earthquake damage (Resources Planning Consultants 1980). Figure 4 illustrates the seismic hazards of the vicinity, as interpreted by

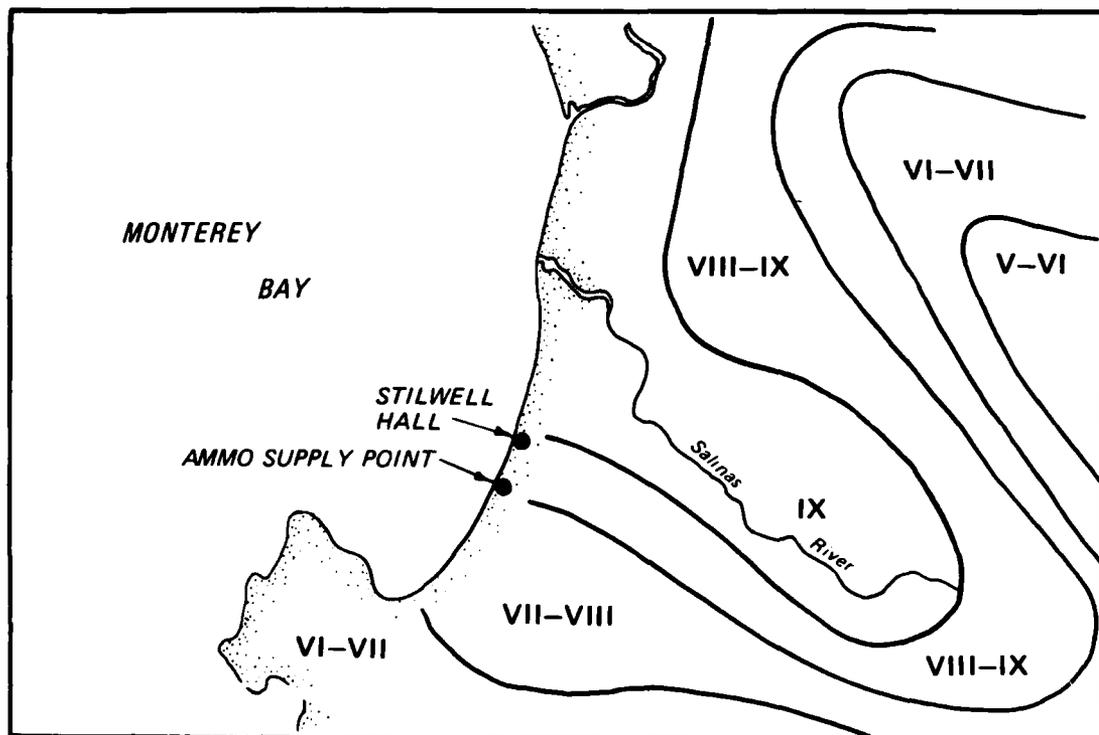


Figure 4. Seismic intensity zones for southern Monterey Bay, California (after Monterey County Planning Department 1980)

the U. S. Geological Survey (USGS), in terms of "Rossi-Forel Ground-Shaking Intensity" zones derived from the 1906 San Francisco earthquake (Monterey County 1980). Table 1 defines the Rossi-Forel scale.

14. Environmental Resources. Plant and wildlife on Fort Ord is characterized by a division into groups adapted to the coastal and the interior regions of the reservation. Predominant vegetation near the shoreline includes various species of beach grass, dune grass, ice plant, and wild flowers which serve a vital function in trapping wind-blown sand and stabilizing the dunes. These species are highly sensitive to human activity and have been severely impacted by developments all along Monterey Bay. Barren pathways through the dune plant life to the beach can easily become "blow-outs," which lower the coastal ramparts formed by the dunes and make them more susceptible to breaching by high water and wave action. Figure 5 shows the dunes south of Stilwell Hall looking towards the Ammo Supply Point. Figure 6 shows a similar view north of Stilwell Hall.

15. African ice plant has become the predominant dune-stabilizing species near Stilwell Hall and the Ammo Supply Point on Fort Ord. European beach grass, another import, is the second most dominant dune plant in these areas (Directorate of Facilities Engineering, Fort Ord 1975). African ice plant has recently become the victim of an insect blight in some areas. This phenomenon has not yet become a significant threat to dune stability, but no effective treatment for the blight is presently known.*

16. The dune plants gradually blend into low shrubs and on to larger spreading shrubs and broad-leaf plants as the protection from wind-blown sand increases inland. These species in turn blend into tall shrubs and the pine, oak, and cypress trees so well known in the Monterey area. The transitional and interior plants are not nearly so important as the dune species in withstanding the forces of the sea, but as part of the same ecosystem their welfare cannot be neglected.

17. A variety of wildlife, including over 200 species of vertebrates, exists on Fort Ord which is adapted to both the sandy coastal environment and the presence of humans. Like the interior plant life, the place of verte-

* Personal communication, August 1983, D. Shonman, Coastal Biologist, Pacific Grove, California.



Figure 5. Shoreline features south of Stilwell Hall
Fort Ord, California (January 1983)



Figure 6. Shoreline features north of Stilwell Hall
Fort Ord, California (January 1983)

brates in the coastal ecosystem is of concern, but it was not part of this investigation. Species inventories for both flora and fauna on Fort Ord are available through the Directorate of Engineering and Housing (Fort Ord, 1975).

Climate

18. The climate of the central California coast is typified by a lack of extreme variation between summer and winter temperatures. During the summer months, the air is cooled by upwelling currents in the Monterey Submarine Canyon and off the Continental Shelf; this cooling causes frequent fog and a consistent onshore breeze. Rain is infrequent in the summer due to a high-pressure air mass that usually settles offshore from April to October.

19. Typical winter weather involves warm air masses moving up from the south, with low-pressure fronts causing violent wind and rainstorms (Resources Planning Consultants 1980). Table 2 summarizes climatic data compiled at Fritzsche Airfield on Fort Ord from 1960-1967.

Oceanography

20. Monterey Bay is California's second largest bay. The bay is uniquely semicircular and opens due west. It is 12 miles wide in an east-west direction and 25 miles long in a north-south direction (see Figure 1). The outer limits of the bay floor correspond to the edge of the Continental Shelf. The bay contains the upper reaches of Monterey Canyon which has cut a deep trench across the floor of the bay all the way to the eastern shoreline at Moss Landing, where it becomes the seaward extension of the Elkhorn Slough. The character of the bay floor, consisting of smooth portions of Continental Shelf deeply cut by submarine canyons, is unusual and is restricted to the confines of Monterey Bay. Water depths reach 350 ft in many places outside of the channel to Monterey Canyon, which reaches a depth of 3000 ft at a distance of 12 miles from the shoreline (Yancey 1968).

21. Tides of Monterey Bay exhibit the diurnal inequality typical of most of the west coast of North America. The elevation datum for the U. S. west coast is mean lower low water (mllw), the average elevation of the lower of the two daily low tide levels. The presence in the bay of the Monterey Submarine Canyon tends to moderate both tidal ranges and tidal influence on coastal currents. The National Oceanic and Atmospheric Administration (NOAA) Tidal Current Tables (1980) list tidal currents for Point Pinos at the south and Point Santa Cruz at the north of Monterey Bay as "too weak and variable to

be predicted," which presumably means tidal currents seldom exceed 0.1 knot anywhere in the bay. The tabulation below lists tidal parameters for Monterey at the southern extreme of Monterey Bay (NOAA 1983).

Mean Range	3.5 ft
Diurnal Range	5.3 ft
Mean Tide Level	2.8 ft mllw

22. The climate, coastal conditions, and marine ecology of Monterey Bay are significantly affected by geostrophic ocean currents, as they are along most of the California coastline. The California Current, a continuation of the Aleutian or Japanese Current, flows south along the coast in early spring and summer. The current is displaced offshore in the winter by the Davidson Current flowing north. The upwelling of nutrient-rich deep ocean waters in the Monterey Submarine Canyon, caused by the interaction of the ocean currents with the Continental Shelf, is responsible for the prolific marine life in Monterey Bay. The current velocities involved are very small, leaving wave-induced transport as the principal cause of sediment movements in the bay (Wolf 1970).

23. The wave climate of Monterey Bay is characterized by both Pacific Ocean swell (wave periods of roughly 8 seconds and greater) and locally generated wind waves. Swell is the most significant source of wave energy in the bay and is more directly related to shoreline development, according to Johnson (1956). Early spring and summer are typically characterized by swell from the northwest, while fall and winter bring swell from the west and southwest. Since swell is generated by very large-scale synoptic weather patterns, the statistics prepared by National Marine Consultants (1960) for a station 55 miles off San Francisco gives an indication of the directional frequency of occurrence of swell in this part of California, as shown in Figure 7.

24. The sheltering effect of the headlands of the bay is illustrated in Figure 8. This figure shows the typical refraction of swells from the southwest, northwest, and west. The less bending by refraction of wave orthogonals generally means less energy is lost to interaction with the sea bottom. The presence of the Monterey Submarine Canyon reduces the span over which these waves "feel" the bottom. The canyon has something of a lense effect for southern Monterey Bay near Fort Ord, causing wave energy to

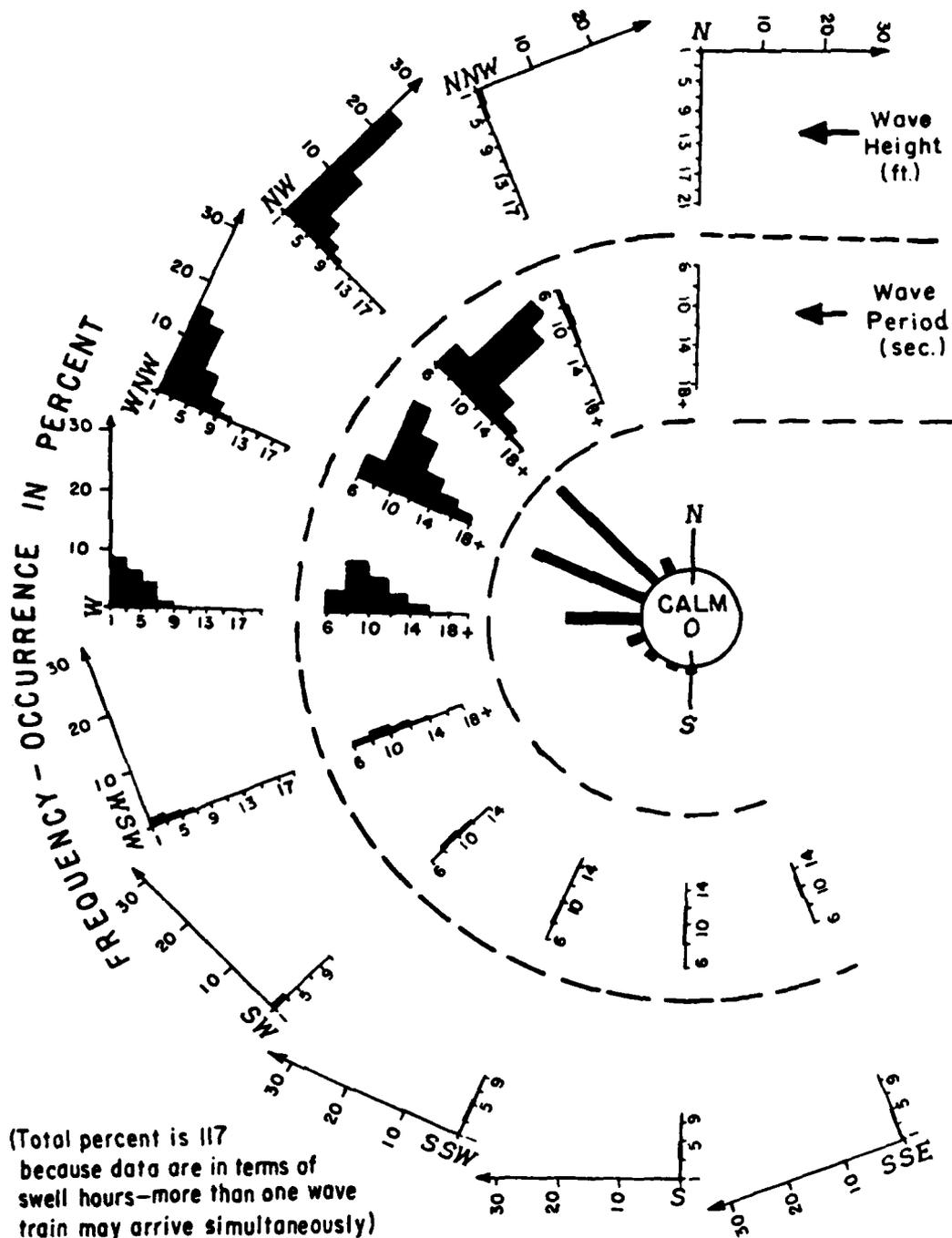


Figure 7. Average swell conditions offshore of central California (from Cherry 1964)

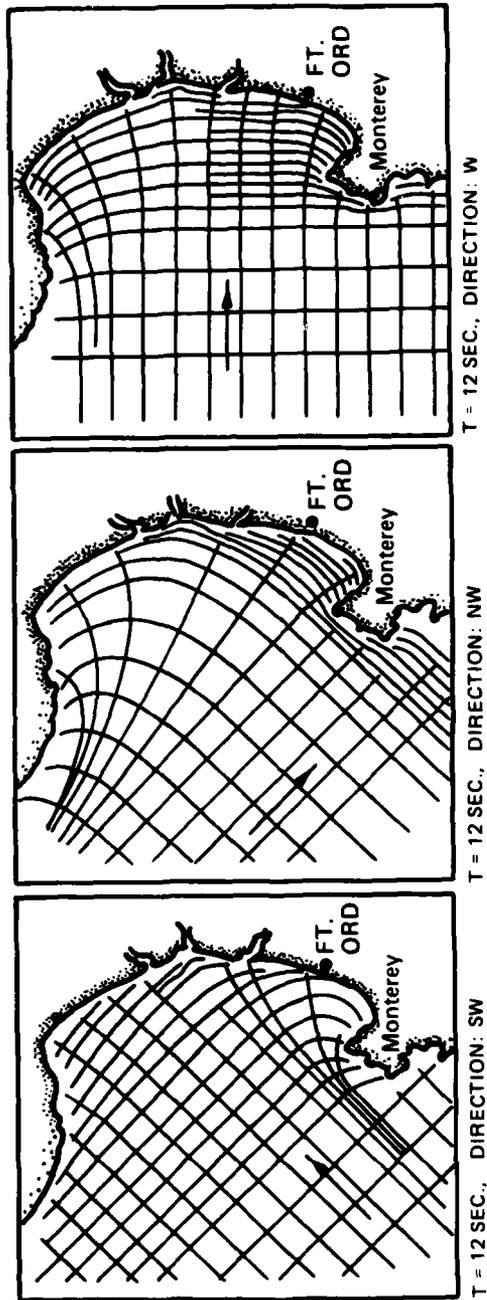


Figure 8. Wave refraction in Monterey Bay, California
(from Wiegel 1964)

converge in that area;* the straight orthogonals in Figure 8 for the northwest and west waves are an indication of this phenomenon. Storms west to northwest of Monterey Bay are known locally to have the worst consequences, and the Fort Ord coastline has been observed to have the highest breakers anywhere in Monterey Bay under these conditions.**

25. The U. S. Army Corps of Engineers and the State of California have maintained an expanding network of wave gages along the California coastline since 1976. A wave buoy has been in place in deep water off north Monterey Bay since October 1979, located approximately northwest of Fort Ord. A series of eight disastrous storms hit the California coastline during January through March 1983. The presence of these instruments has given engineers and scientists a unique opportunity to study the characteristics of extremely severe natural phenomena which caused the failure of many coastal structures. The severity of these storms was further affected by the El Nino climatic anomaly which caused a slowing of the California current and a general rise in sea level of about 8 in. Wave damages were aggravated by extreme astronomical tides which occurred coincidentally with some of these storms. Nearly all of the highest deepwater significant wave heights (to 24 ft) and many of the longest peak spectral periods (to 22 sec) were recorded at the north Monterey Bay buoy (Seymour 1983). The worst 1983 storm centers were located offshore such that waves must have been travelling to the southeast directly toward Fort Ord. Figure 9 shows the statistical (Weibull) distribution of the 10 percent highest significant wave heights recorded by the north Monterey Bay buoy from October 1979 to April 1983.

26. The results of a statistical analysis of extreme wave heights hindcast from over 75 years of weather records is presented in Table 3. This analysis hindcast waves in deep water, then estimated the shallow-water (20-ft depth) wave height at the site of interest at Monterey. The hindcast periods are notable, since they do not change with depth as do wave heights. The 22-sec peak spectral periods recorded in the winter of 1983 would appear to be

* Personal communication, August 1983, Dr. W. Thompson, Oceanographer, Monterey, California.

** Personal communication, August 1983, Dr. A. Sallenger, Jr., USGA, Menlo Park, California.

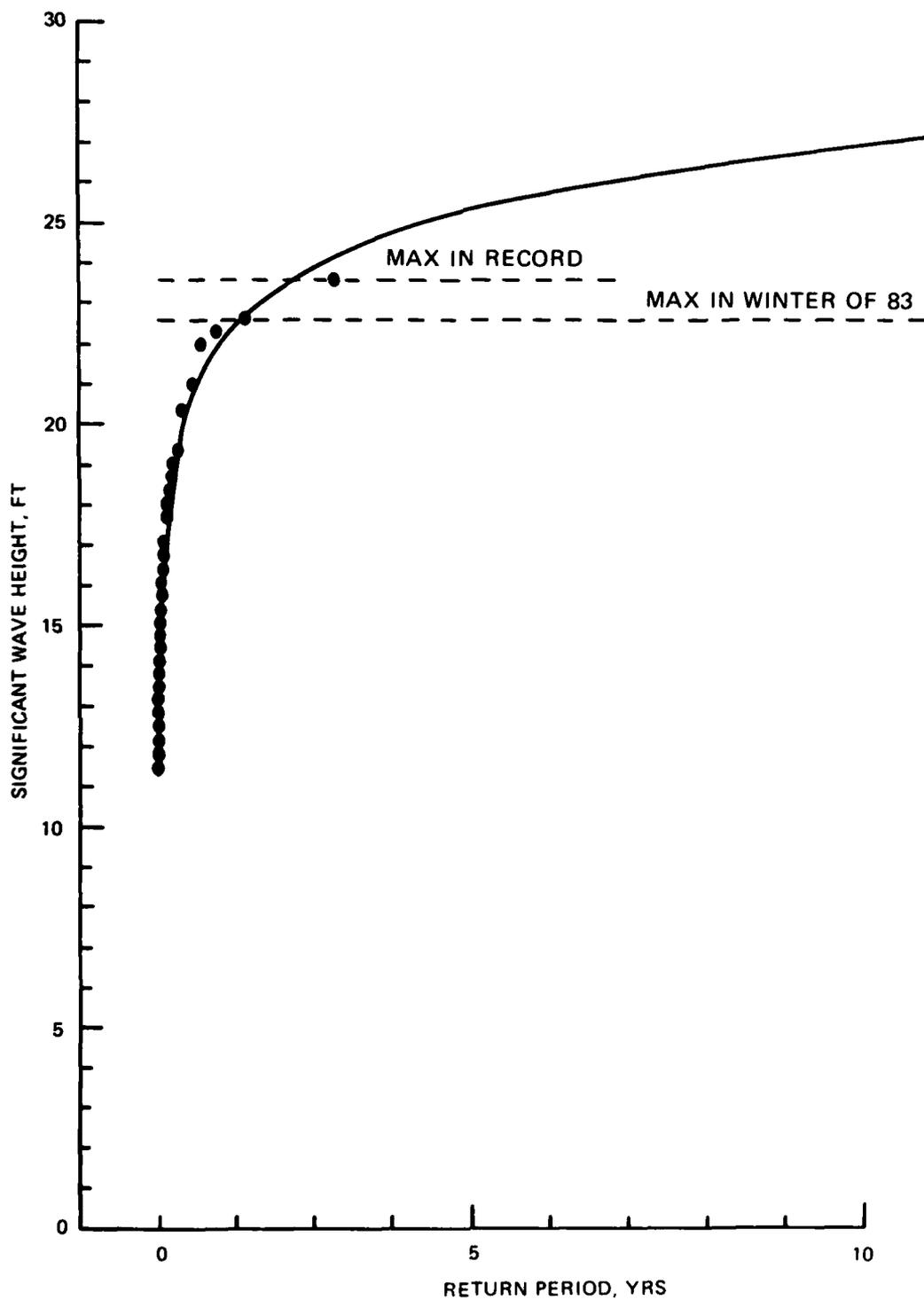


Figure 9. Statistical distribution of extreme significant wave heights measured in deep water off Monterey Bay, California (from Seymour 1983)

quite extreme according to this analysis, though the hindcasting procedure used to produce Table 3 is being reviewed in light of these measurements.*

27. The distribution of sediments in Monterey and the shape of the bay itself has occurred in close response to the wave climate. Shorelines tend to orient themselves toward the waves (the path of least resistance), and the combined average effect of the rocky headlands at Point Pinos and Point Santa Cruz and the Monterey Submarine Canyon is indeed to bend the wave fronts into a shape approaching that of the bay shoreline (see Figure 8). The shoreline shape in plan at the southern end of the bay follows the log spiral shape observed by Yasso (1964) at other similar headland-protected beaches (Hohenstein, Jaeger, and Jones 1965).

28. Sediments found near the shoreline, where wave effects on the bottom are strongest, tend to be more coarse as shown in Figure 10. Conversely, in the deeper parts of the bay the sea bottom is covered with fine material which settles after leaving the more turbulent nearshore areas. Grain size of sediments in Monterey Bay, particularly in the central portions to either side of the head of the canyon, tends to decrease uniformly with depth out to the edge of the Continental Shelf (Yancey 1969).

29. The sediment supplied to Monterey Bay by streams and by shoreline erosion is derived from the following three general types of rocks: (a) igneous and high-grade metamorphic rocks, (b) low-grade metamorphic rocks of the Franciscan Formation, and (c) sedimentary rocks overlying basements composed of the former two types (Yancey 1968). Stream discharge records provide an indication of the relative potential of each drainage system to transport sediment into Monterey Bay. The average discharge for the Salinas River is 320,000 acre-ft per year, that for the Pajaro River is about 120,000 acre-ft per year, and that for the San Lorenzo River is approximately 106,000 acre-ft per year. Over 90 percent of the runoff comes during the winter months from December to May. Most sediment transport to the beach takes place within this interval of time each year, especially during floods.

30. The regulation of the flow of the Salinas River, in combination with large climatic fluctuations, has markedly reduced the discharge of the Salinas

* Personal communication, September 1983, Dr. E. Thornton, U. S. Naval Postgraduate School, Monterey, California.

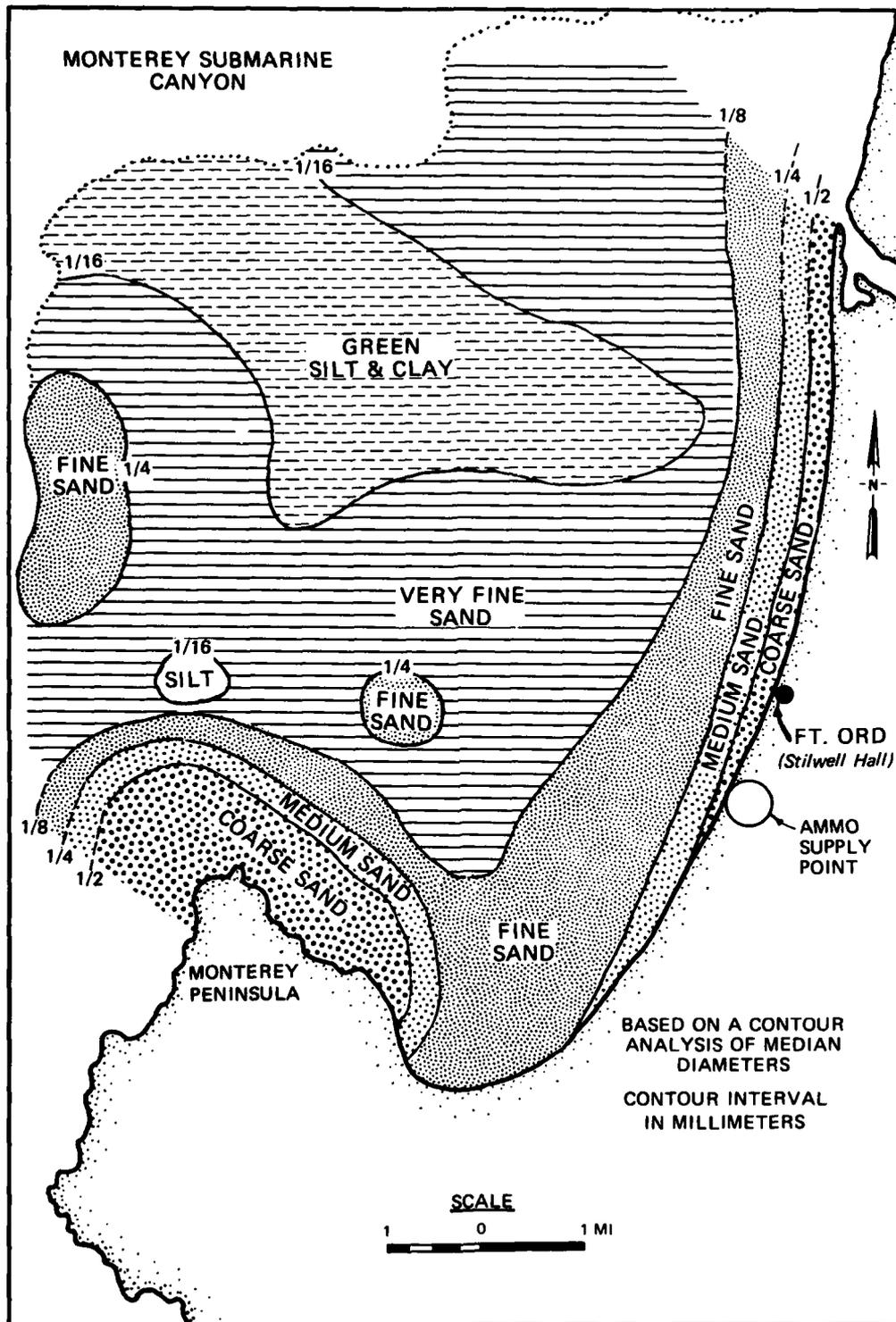


Figure 10. Sediment distribution in southern Monterey Bay, California (from Monteath 1965)

River. USGS (1971) data indicate that about 96,000 acre-ft of water per year are now removed from the Salinas River for irrigation and municipal use. The flow of this river has also been regulated partly by the Nacimiento Reservoir, beginning in February 1957, and partly by the San Antonio Reservoir, beginning in December 1965. In the first half of the century, the annual discharge of the Salinas River was more than 100,000 acre-ft greater than it is today. Accordingly, the sediment volume delivered to the ocean was higher. For all rivers discharging into Monterey Bay, total annual sand volume delivered prior to 1957 probably varied between 1,000,000 to 1,200,000 cu yds. Arnal, Dittmer, and Shumaker (1973) estimated recent discharges to be around 800,000 cu yds per year.

Coastal Erosion at Fort Ord

31. Existing evidence indicates that coastal erosion has taken place in Monterey Bay for a period of at least 50 years (Arnal, Dittmer, and Shumaker 1973). Cooper (1967) cites the extreme narrowing of the dune belt along the Flandrain Dune Belt of southern Monterey Bay during the past 3000 to 5000 years opposite Fort Ord as evidence of long-term coastal and dune erosion. This is a region where the heights of the dunes imply that a much broader belt should exist. In 1971, the Legislature of the State of California instructed the Department of Navigation and Ocean Development (DNOD) (1972) to evaluate the stability of the shoreline at Sand City (immediately south of Fort Ord) and to conduct a study on the feasibility of constructing a groin field to develop a public beach. DNOD determined from aerial photographs and topographic surveys that, between April 1944 and May 1961, there was a recession of 50 ft over this 17-year period, or an average of 3 ft per year. Between May 1961 and April 1967, the recession was 30 ft (over a period of 6 years), or 5 ft per year. Arnal, Dittmer, and Shumaker (1973) concluded that the average annual recession of the shoreline in the vicinity of Fort Ord, California, accelerated progressively from 1.5 to 2.0 ft per year in the 1920's, to around 3.0 ft per year in the 1950's, to around 5.0 ft per year in the 1960's.

32. More recent work by Thompson* indicates that average annual erosion rates (shoreline retreat) can be shown to steadily increase northward along the bay shoreline from around 1 ft per year at Monterey to over 3 ft per year around 3 miles south of Stilwell Hall in Fort Ord. A linear extrapolation of this information yields a tremendous retreat near Stilwell Hall, which has not been witnessed. It appears more likely that erosion rates increase to a point, then remain constant, going northward along the bay shoreline to Fort Ord. Charted depth contours tend to become perfectly parallel some 4 miles north of Monterey and remain so well beyond Stilwell Hall. Extrapolation to the starting point of the parallel contours yields a retreat rate of 6 to 7 ft per year, which better matches the observations of longtime Fort Ord employees.

33. The causes of erosion relate to long-term trends in the sediment budget for all of Monterey Bay, as well as to the gradual rise in sea level underway since the last glacial period (Monteath 1969). The Monterey Submarine Canyon is responsible for some sediment loss and, since its head is very near the shore at Moss Landing, tends to split the bay into two virtually independent halves for sediment budget purposes. The sediment budget and nearshore transport processes for Monterey Bay were studied in some detail by Dorman (1968) and Arnal, Dittmer, and Shumaker (1973). The various processes involved are illustrated in Figure 11.

34. It is plain that the forces causing loss of beach and dune materials near Fort Ord are not nearly matched by those supplying new sediments to the shoreline. It is important to understand and quantify the sediment transport mechanisms in any area before artificial stabilization is attempted, since long-term adverse effects to the adjacent shoreline can easily occur. This is particularly true if wave-induced longshore transport or "littoral drift" is the dominant mode. Investigators differ on the prevailing direction of longshore sediment transport in the immediate vicinity of Fort Ord. The net direction found by Arnal, Dittmer, and Shumaker (1973) as shown in Figure 12 can be seen to differ from that found by Dorman (1968) as shown in Figure 11. A net northward average annual longshore sediment transport rate at Fort Ord

*Personal communication, August 1983, D. W. Thompson, Oceanographer, Monterey, California.

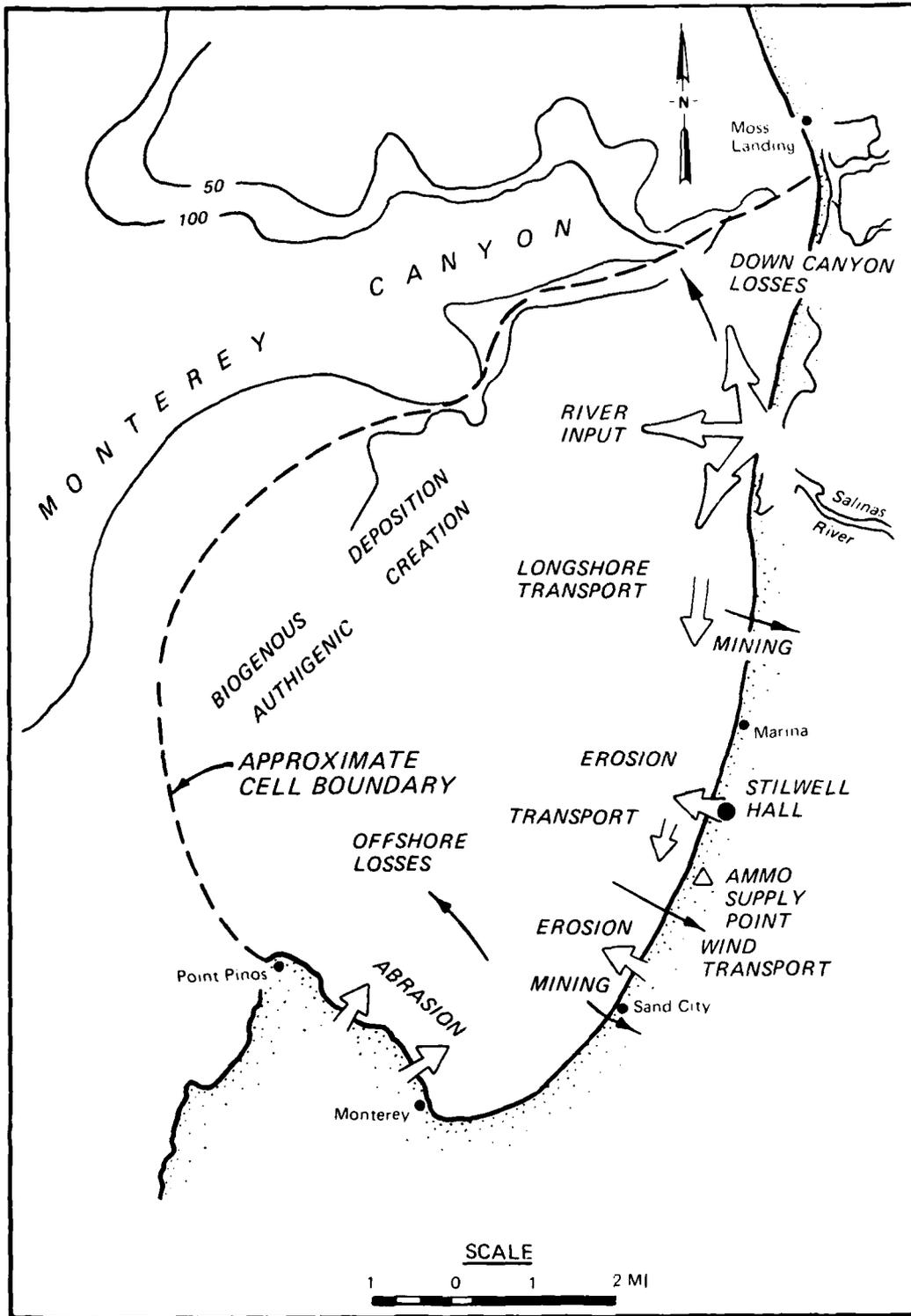


Figure 11. Sediment transport processes of southern Monterey Bay, California (from Dorman 1968)

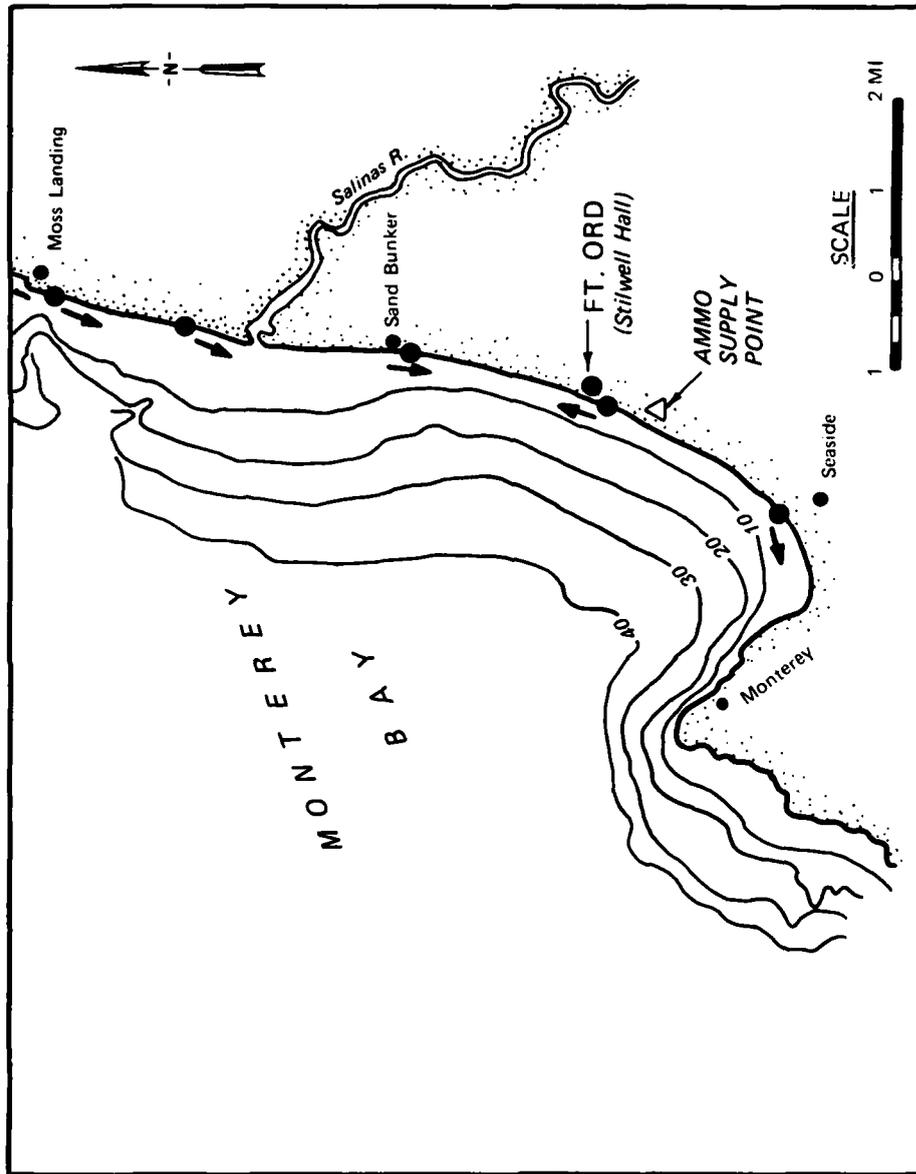


Figure 12. Longshore sediment transport directions predicted for Monterey Bay, California (after Arnal, Dittmer, and Shumaker 1973)

of 191,000 cu yd per year was computed by Arnal, Dittmer, and Shumaker (1973). Average monthly rates computed by Dorman (1968) are shown in Figure 13. These two investigations did agree that the magnitude of long-shore transport drops off near Fort Ord and that wave-induced onshore-offshore sediment transport is probably more significant in this immediate vicinity.

35. Laboratory tests (Chestnutt and Stafford 1977) and field studies (Nordstrom and Inman 1975) indicate that high winter storm waves breaking essentially perpendicular to the shoreline tend to move beach material in an offshore direction, while low summer waves move this same material back toward the beach. Additionally, when the waves break at some angle to the shoreline, there exists a complex combination of onshore/offshore movement and a long-shore component (Coastal Engineering Research Center 1977). If a coastal region is in an equilibrium condition, that material which moves in an offshore direction under storm waves will be returned to the beach during periods of mild wave conditions; also that material which moves downcoast when waves approach from one direction will be returned upcoast when the direction of wave approach reverses. Southern Monterey Bay, specifically the vicinity of Fort Ord, is definitely not in such an equilibrium environment: the wave energy impinging on the Fort Ord coastline is apparently so consistently direct and severe that offshore losses far exceed any onshore movement.

36. The quantity of sand moved toward or away from the shoreline may be determined from repetitive surveys of offshore profile lines (Nordstrom and Inman 1975), or by measuring the change in area within contours on bathymetric maps. The latter method was applied by Arnal, Dittmer, and Shumaker (1973) to bathymetric survey maps of 1910 and 1950. In that study, it was concluded that most of the deposition of nearshore sands eroded from the beach and dunes occurred at depths shallower than 120 ft. The total volume change for the south half of Monterey Bay (between Monterey and the Monterey Canyon) amounted to 87,000,000 cu yds for the 40-year period, or approximately 2,000,000 cu yds per year. Dune erosion was estimated to have been around 500,000 cu yds per year, or approximately 25 percent of the total material accumulating in the south half of Monterey Bay.

37. The presence of a severe wave climate causing significant offshore transport losses is further revealed by the unusually steep beach profiles which exist in the vicinity of Stilwell Hall on Fort Ord. Beaches with slopes

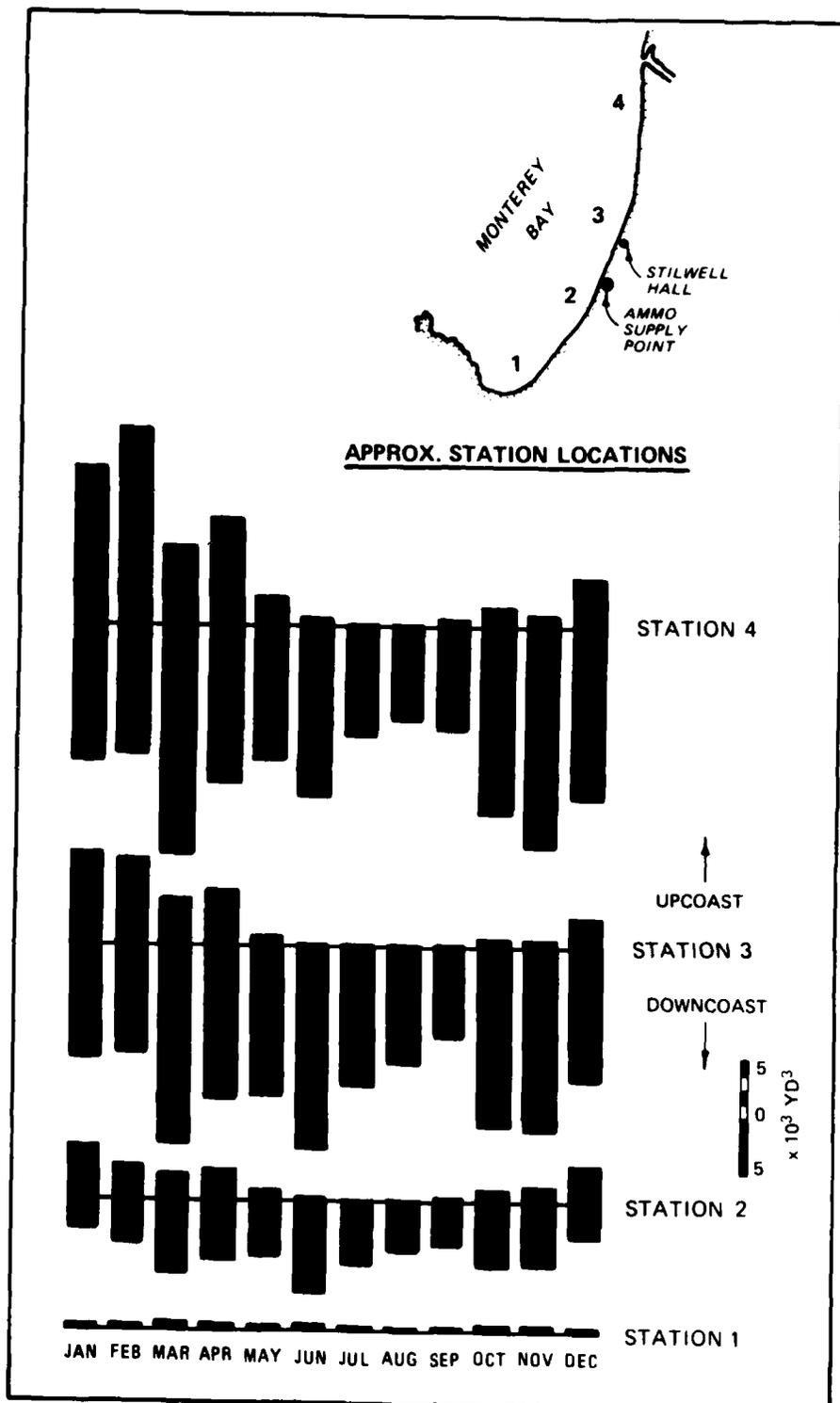


Figure 13. Longshore sediment transport rates predicted for Monterey Bay, California (after Dorman 1968)

of 1 vertical to 10 horizontal (1:10) are normally considered steep beaches. The beach slopes measured by Dittmer (1972) just north of Fort Ord were 1:7 to 1:11, and slopes of 1:6 were consistently measured by the USGS just a few hundred feet south of Stilwell Hall, as shown in the beach profiles of Figure 14.

38. A number of active beach sand mining operations exist along the Monterey Bay shoreline, within a few miles of Fort Ord and Stilwell Hall. While the volume of sand in the Flandrian Dunes may appear virtually limitless, the additional removal of significant amounts of sand each year from a naturally recessional coastline can only contribute detrimentally to the overall erosional process. Arnal, Dittmer, and Shumaker (1973) found that sand mining operators were very secretive about their production and sales. Questions raised in recent years regarding coastline recession due to mining have made the operators more conscious of the long-term effect of their mines. The sand losses due to mining in 1973 were estimated to have been in excess of 300,000 cu yds per year.

39. When it became apparent in the 1960's and 1970's that the general trend of gradual shoreline recession all along Monterey Bay would encroach upon the improved facilities at Fort Ord, the Department of the Army initiated efforts to stabilize the coastline in the vicinity of Stilwell Hall Recreational Center. Other areas of the military reservation were left to respond dynamically to the environmental forces to which they would be subjected. The initial stabilization efforts of the Army at Stilwell Hall Recreation Center consisted essentially of placing on the seaward side of the dune a revetment of quarried rock and broken concrete slabs resulting from the abandonment and demolition of building foundations and parking areas. This rubble varied in size from cobbles to the largest units which were roughly 3 ft by 3 ft by 3 ft. The rubble was transported by truck along a road which existed at that time approximately half-way up the side of the sand dune and was then dumped off the seaward side to stabilize the toe of the dunes in this region. With the passage of time, high tides and wave activity at the toe of the dunes caused sand to leach through the armor units. Plans dated May 1950 were located on Fort Ord for a multilayer rubble slope revetment resembling some surviving portions of the existing revetment. Whether these plans were ever closely followed when the original construction took place has not been

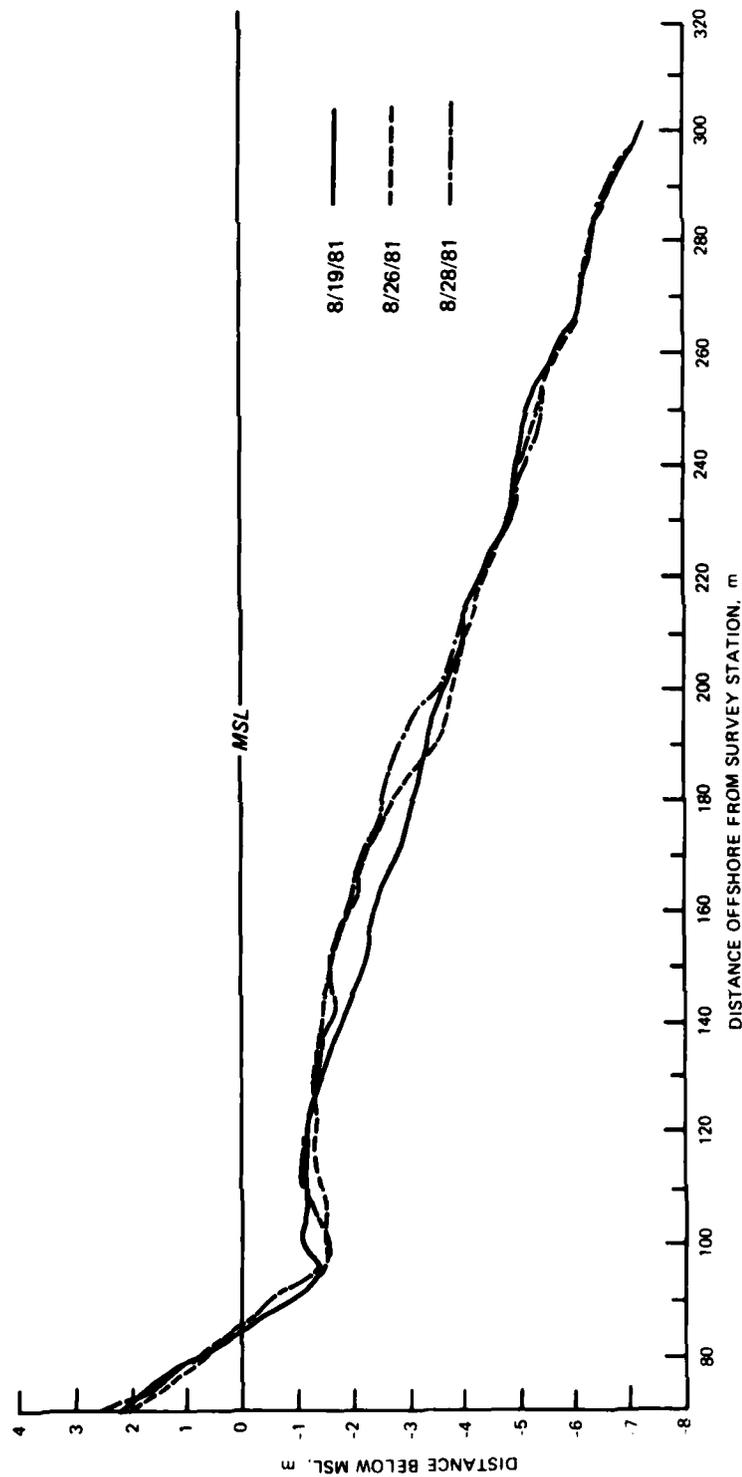


Figure 14. Nearshore profiles measured near Stilwell Hall, Fort Ord, California (unpublished data courtesy of A. Sallenger, Jr., USGS, Monterey, Calif.)

determined. The existing revetment at Stilwell Hall was apparently last maintained around 1972 with the placement of additional quarried rock (granite). Figure 15 is a photograph of a 4- by 8-in. notepad placed on one stone of the existing revetment.



Figure 15. Armor rocks of the existing revetment at Stilwell Hall, Fort Ord, California (August 1983)

40. The efforts expended in this manner have had a net positive effect of retarding the rate of coastline erosion at this area; however, the general shoreline on either side of Stilwell Hall Recreational Center has receded 50 to 100 ft. The resulting planform geometry of the shoreline reveals a partially stabilized region at Stilwell Hall Recreational Center appearing as

a peninsula jutting out from the otherwise uniformly receding coastline, as shown in Figure 16.

41. Consecutive visits to Fort Ord's Stilwell Hall and Ammo Supply Point by WES/CERC engineers in January 1983 and later in August 1983 revealed erosion of the dunes at these two sites to be in an advanced state. The January visit occurred during a lull in the series of devastating storms which attacked the entire coastline of the State of California during January through March 1983. These storms approached Monterey Bay from the northwest and produced several hours of sustained high winds, resulting in between 1 and 2 ft of storm surge which was superposed on the highest lunar tide of the year. The resulting still-water elevation was over 7 ft mllw, and runup was well above the toe of the sand dunes atop which were located Stilwell Hall and the Ammo Supply Point (see Figure 17). The turbulence associated with the breaking and runup process caused active sliding to occur along the seaward face of the sand dunes. The dune face was left in a state of pending motion, standing essentially at the angle of repose of the material (see Figure 18).

42. The August 1983 visit revealed that significant additional erosion had occurred since January at both sites. The damage of the first severe storms in January had left the dunes more susceptible to erosion, and the subsequent storms in February and March clearly had severe effects. These effects manifested themselves at Stilwell Hall in the formation of tremendous gulleys or scallops in the existing seaward slope, exceeding 130 ft in toe width. The top of one scallop reached within a few feet of the rear parking lot at Stilwell Hall, causing some concern for the safety of vehicular traffic in that area.

43. The major scallops at Stilwell Hall were four in number and were observed to coincide with sections where the existing rubble revetment had completely failed. This revetment, while partially effective during normal winter conditions, had been completely inundated by the 1983 storms. Revetments of this type are commonly known to fail because scour both at the toe and behind the crest ultimately results in a complete collapse (Smith and Chapman 1983), as illustrated in Figure 19. This is apparently what happened at Stilwell Hall. Figure 20 shows an August 1983 view of a failed portion of the revetment with a surviving section beyond. The typical plan and profile of the scallops at Stilwell Hall are shown schematically in Figure 21.



Figure 16. Stillwell Hall, Fort Ord, California (May 1983)



Figure 17. Waves striking the base of dunes below Stilwell Hall, Fort Ord, California (January 1983)



Figure 18. August 1983 shoreline at the Ammo Supply Point, Fort Ord, California (August 1983)

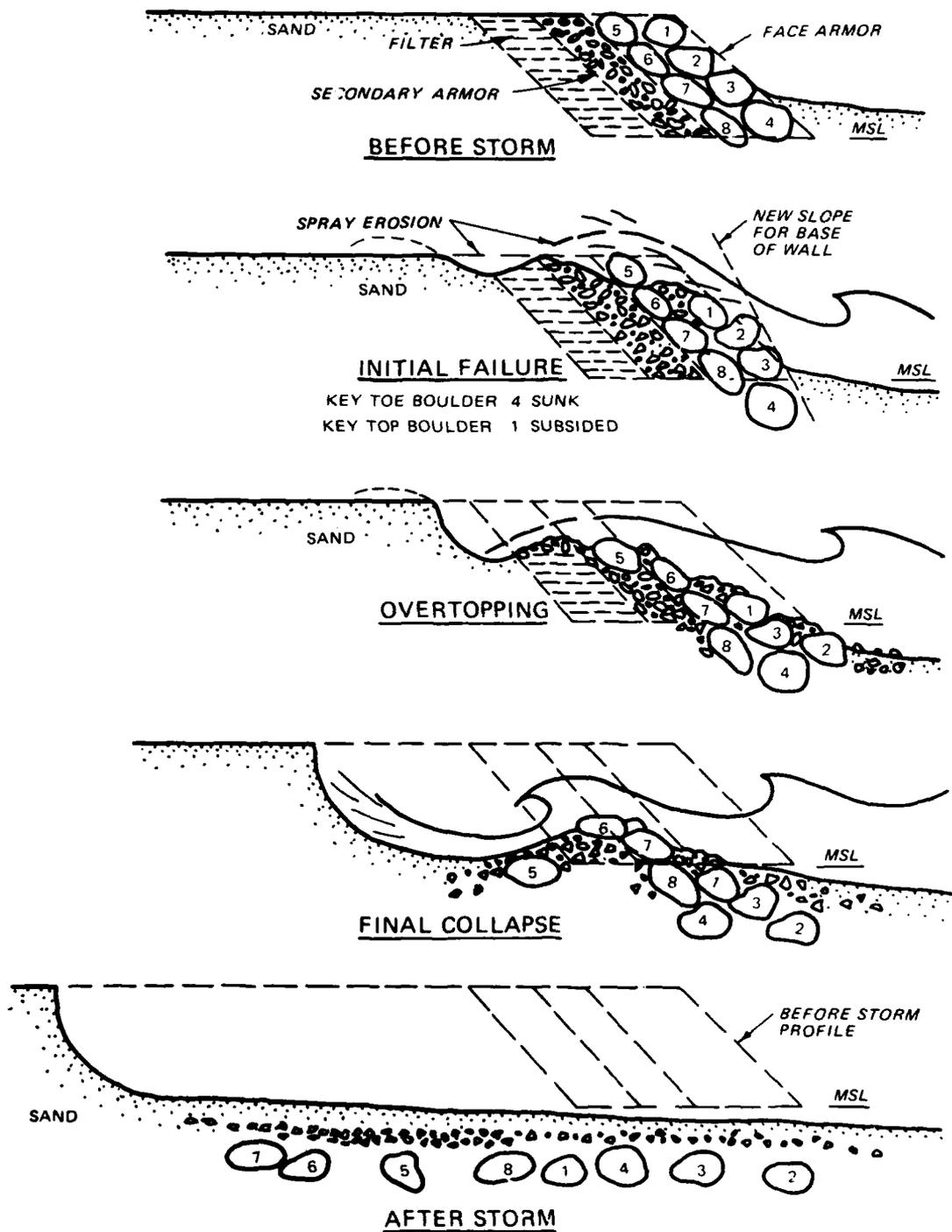


Figure 19. Typical failure sequence of a rubble revetment (after Smith and Chapman 1983)

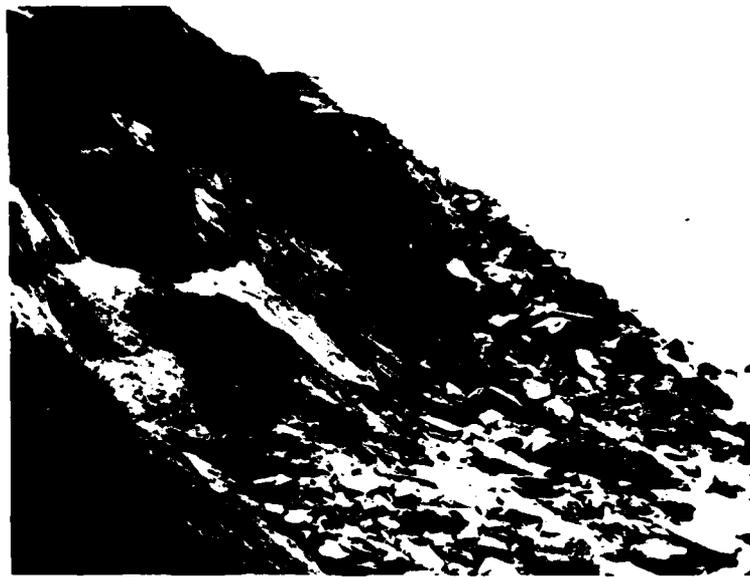


Figure 20. Existing revetment at Stilwell Hall,
Fort Ord, California (August 1983)

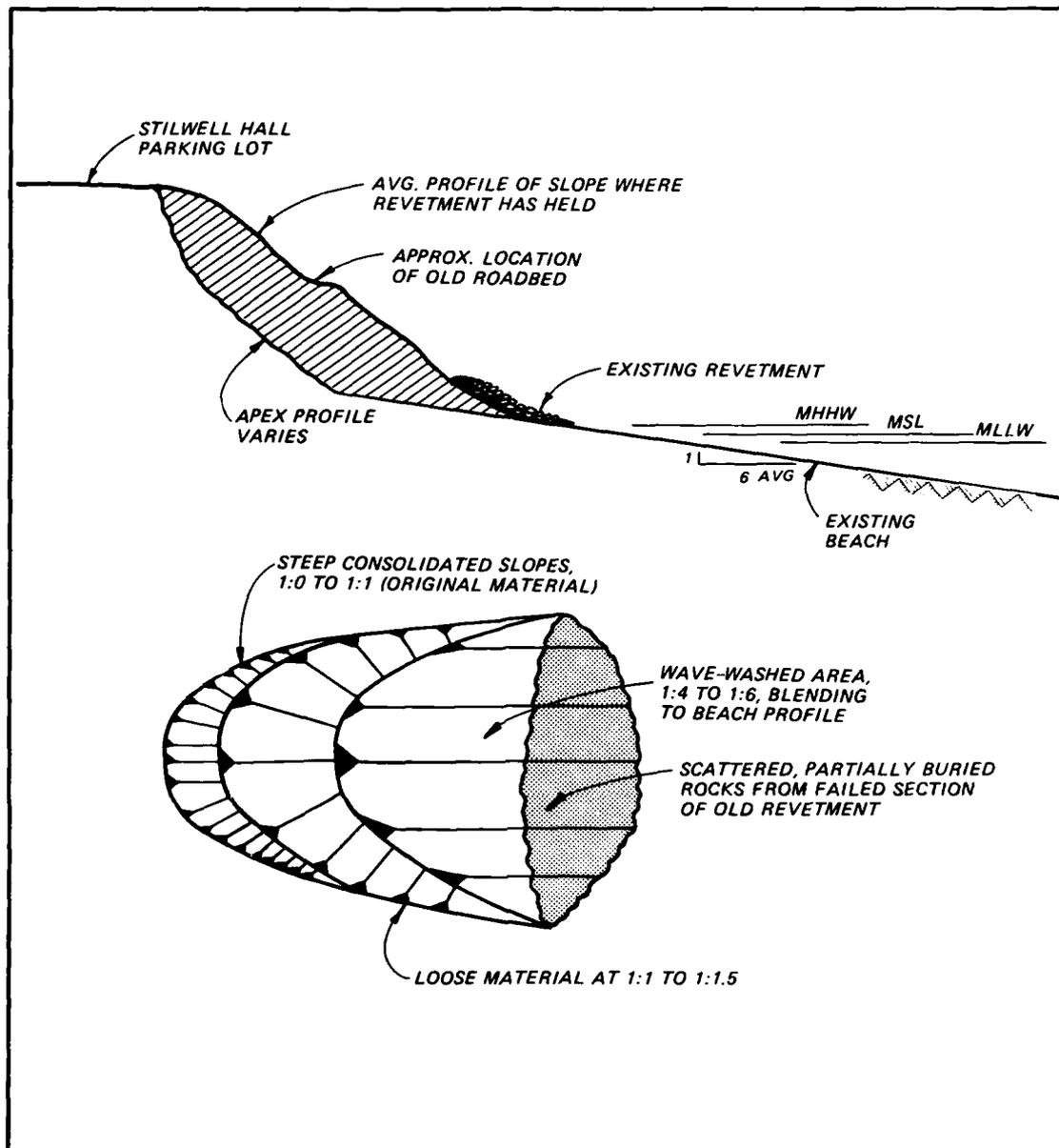


Figure 21. Profile and plan appearance of scallops observed on seaward face of dunes at Stilwell Hall, Fort Ord, California (August 1983)

44. Four different scenarios can be envisioned for the future of Stilwell Hall Recreational Center if only immediate emergency measures are considered: (a) if these measures are not instituted and severe storms recur, the Center will probably become unusable within 2 years, and failure could even be imminent; (b) if these measures are not instituted and only the average annual storm season prevails, the Center could be usable for up to 5 more years; (c) if the measures are instituted and severe storms recur, the Center will probably become unusable within 5 years; or (d) if the measures are instituted and only the average annual storm season prevails, the Center could be usable for another 8 years or longer. (These estimates are highly uncertain, based entirely on recent occurrences at the partially protected region near the Center and on the adjacent totally unprotected reaches of shoreline.) On the other hand, sufficient time probably exists for permanent protective measures to be designed and constructed at Stilwell Hall Recreational Center.

Fort Ord Ammo Supply Point

45. The Ammo Supply Point is located a few thousand feet south of Stilwell Hall on totally unprotected shoreline (see Figure 18). At the time of the January 1983 survey, the sand dunes had receded to the chain-link fence surrounding the Supply Point. Since that time, further erosion of the dunes has occurred and approximately 800 ft of the chain-link fence has collapsed into the surf. Because the ammunition bunker units inside the Ammo Supply Point are individual elements spaced at finite intervals, the collapse and failure of individual elements may not affect the use and operation of the remaining bunkers. Based on historical evidence, it appears that Bunkers number 1, 2, 3, and 6 may become unusable within 3 years. A level of effort comparable to the past beach stabilization efforts at Stilwell Hall could be considered desirable for the purpose of retarding the rate of shoreline recession at this location. In that event, the nearest ammunition bunker may be usable for another 6 years or longer.

PART III: ALTERNATIVE SOLUTIONS

Nonstructural Alternatives

46. The advanced stage of erosion at both Stilwell Hall and the Ammo Supply Point precludes any truly nonstructural plans from being effective in preventing or significantly retarding the loss of the structures in jeopardy. Protection of the dune vegetation by restricting human access to the dunes and beach can help prevent the erosion from accelerating further, however. Plantings of ice plant or beach grass in exposed areas on the face and crest of the dunes might also be helpful in this regard. Both of these options will increase the effectiveness of any structural plans considered.

47. The sandy dunes of the Fort Ord coastline are well drained, and erosion from surface runoff was not seen to be a measurable problem. The paved areas of Stilwell Hall might possibly concentrate enough runoff in isolated areas to be a minor cause of erosion or instability in the dunes. No such concentrations were apparent at the time of the WES/CERC site visits, but this possibility warrants further investigation. Drainage concentrations should be diffused or directed away from the face of the dunes.

48. The principle alternative to structural shore protection, though not a nonstructural plan in the strict sense, is the demolition of Stilwell Hall, with or without a replacement in kind. It is difficult to place a "book value" on the structure; certainly its intangible value is quite significant. A recreational facility for the Presidio of Monterey, intended to serve purposes similar to those of Stilwell Hall was in the planning stage at Fort Ord at the time of this investigation, the estimated construction cost of which was on the order of \$2.5 million. For environmental and aesthetic reasons, Stilwell Hall should not be allowed to collapse into the sea; its demolition was estimated to cost no more than \$1/2 million. Therefore an estimated value of \$3 million, sentimental value aside, can be placed on the facility.

49. The adobe and brick structure of Stilwell Hall precludes any practical approach to physically moving the structure to a safer location. Portions of the structure and its interior furnishings could be spared for their historical value and integrated into a replacement facility. Such an

effort would increase the cost of demolition and replacement probably no more than 33 percent for a maximum total project cost on the order of \$4 million.

50. Discussions with Ammo Supply Point and Fort Ord Facilities Engineering personnel revealed that (a) the ammunition bunkers would not warrant any significant expense for their protection and (b) a number of relatively low-cost options were available for replacing them. Their demolition would be somewhat expensive, due to their massive concrete construction; yet they should not be allowed to fall into the sea because their remains would accelerate erosion in the immediate vicinity by disrupting the natural processes of wave breaking and longshore transport. Action should be taken to dispose of these structures before work with heavy equipment in the area becomes too hazardous.

Categories of Structural Solutions

51. The following discussion will review the functions of some basic types of structural shore protection measures and subjectively eliminate all but those most likely to be effective and reliable for the conditions at Fort Ord. Potential structural alternatives include the following, which are well accepted from a coastal engineering standpoint; other concepts may also be rational.

- a. Offshore breakwater.
- b. Vertical sheetpile bulkhead.
- c. Slope revetment.
- d. Beach groins.

Offshore breakwater

52. An offshore breakwater, built parallel to the shoreline in the vicinity of the breaker zone, is usually intended to absorb and reflect wave energy such that a calm area exists in its lee. The physical presence of the structure, as well as its wave dampening effect, limit offshore losses of beach material. Furthermore, the shadow area shoreward of the breakwater disrupts the longshore transport of sediments, causing them to accumulate there. An advantage of offshore breakwaters in this respect is that they can be designed with a low or submerged crest so the disruption of longshore transport is not total. This feature allows some natural longshore transport

to occur during severe storms while protective material still accumulates in front of the beach. A "tombolo" can ultimately form which appears at low water levels as an isthmus extending out to the breakwater.

53. The extreme conditions prevalent at Fort Ord discourage the choice of an offshore breakwater as a structural measure. Since offshore breakwaters are usually detached from the shore, construction is always difficult, requiring heavy floating equipment. The consistently severe wave climate at Fort Ord greatly exaggerates this difficulty and consequent expense. Construction costs would be further magnified by the cost of the materials, particularly armor units. Wave heights are known to be limited by depth, but an offshore breakwater must be some distance offshore in order to function as intended. The steep (1:6) beach at Fort Ord would require the base of the breakwater to be in 30 ft of depth or more, thus making it subject to very large breaking waves. Both the total volume and the individual size of armor units and underlayers would have to be larger.

54. Another problem with offshore breakwaters is that their effectiveness is largely dependent on an accumulation of material transported longshore to their lee; i.e., some lead time is required for offshore breakwaters to reach an effective state. Longshore transport in the vicinity of Fort Ord is apparently less than in many areas of Monterey Bay. The Fort Ord shoreline may even be a divergent zone where transport is mostly offshore and away from the site, rather than flowing past it. Using artificial fill could reduce or eliminate the lead time to effectiveness for an offshore breakwater, but only by compounding the construction expense. An offshore breakwater is not recommended for the above reasons and will not be discussed further in this report.

Vertical sheetpile bulkhead

55. Vertical bulkheads constructed of concrete or steel sheetpiles near the toe of a slope serve to reflect wave energy away from the toe rather than to absorb it or disperse it in turbulence. They have the advantage of usually requiring only conventional construction techniques, though the materials are expensive. Vertical bulkheads are very strong, require little maintenance with proper design, and are relatively discrete in terms of volume and surface area; they are considered to be aesthetically objectionable in a coastal environment by many people, however. Their principle disadvantage as a shore

protection measure relates to their reflection of wave energy. The reflected energy tends to combine with incoming energy and cause accelerated scour seaward of the toe of the bulkhead. The short-term integrity of the bulkhead is often enhanced by placing scour protection along the toe, but the accelerated scour reaches beyond the immediate vicinity of the toe and artificial steeping of the beach profile often results over the long term. Despite these disadvantages, the relative ease of construction and structural strength of sheetpile bulkheads warrant further investigation at Fort Ord.

Slope revetment

56. A revetment, rather than performing the protective screen function of a wall or breakwater, serves primarily as a ballast to hold in place the slope on which it is founded. In the case of a rubble coastal revetment, wave energy is also absorbed and dissipated in turbulence, as well as being partially reflected. Since revetments are rarely placed out into deep water, their armor size is typically limited by depth limitations on wave height. Revetments have the advantage of being flexible; and, if properly designed, their partial damage will not necessarily lead to immediate catastrophic failure.

57. Critical features in proper design of slope revetments include protecting against (a) scour at the toe, (b) filtering of fine foundation materials through the revetment, and (c) scour behind the crest caused by overtopping. The existing revetment at Stilwell Hall was grossly under-designed in all these areas, but still provided significant protection to Stilwell Hall for many years. Emergency repair of the existing revetment roughly following the original design was recommended during the August WES/CERC site visit, in light of this fact. A more substantial slope revetment is considered to be worth further investigation as a permanent solution.

Beach groins

58. Beach groins are linear structures extending from the shore out into the surf zone, which are intended to disrupt the longshore transport of sediments. A variety of designs using many different materials and construction techniques have been built on beaches around the world. Their functional design remains the same in that they must be partially or totally impermeable to the materials they are intended to trap and must survive in the prevailing wave climate. By trapping sediments on one side, they can also starve the

other side for sediments needed to replace material scoured away by wave action. For this reason, and because erosion caused by onshore-offshore transport is apparently more significant than longshore transport at Fort Ord, beach groins are not recommended as a permanent solution.

Design Criteria

59. Principle criteria that must be established to proceed with refinement of design features include:

- a. Design water level.
- b. Design wave conditions for
 - (1) Structural survival (assuming at least 50 years useful life).
 - (2) Structural effectiveness (overtopping).

Considerable subjective judgement was necessary for this investigation since time and funds did not allow the extensive analyses required to accurately define the long-term distribution of wave heights and water levels. Likewise, many assumptions were made about the topography, hydrography, materials and other characteristics of the site without the availability of detailed survey data.

Design water level

60. An extreme high-water level should be chosen since both wave height and wave runup vary with the depths fronting the structure. The highest astronomical tide at Monterey was predicted to be 6.6 ft mllw in late January 1983 during the time when high water damage was worst. This was compounded by storm surge of 1 to 2 ft and an additional 0.7 to 0.8 ft attributable to the El Nino climatic anomaly (Seymour 1983). The cumulative exceedance probability for an astronomical higher high water at Monterey of 7.0 ft mllw in any year is approximately 1 percent (Harris 1981). The sum of these three effects ($7.0 + 0.8 + 2.0 = 9.8$) yields an extreme high-water level of 10 ft mllw, which is assumed to have a statistical return period of at least 50 years. It should be noted that storm surges exceeding 12 to 14 ft can occur in other areas of the United States, but the presence of the Monterey Canyon near Fort Ord, discourages these extremes.

Design wave conditions

61. Separate criteria for structural survival and effectiveness are often

chosen for cost-effective design of breakwaters or other shore protection works. This distinction is not considered appropriate for the situation at hand due to the precarious stance of Stilwell Hall at the very edge of the bluff. Since even minor overtopping of a permanent structure could have disastrous consequences, the same severe criteria defined for structural stability will be applied to estimate runup. (Runup, in this case, is the principle measure of effectiveness beyond structural survival. Wave transmission would also be considered in the design of a breakwater or groin.)

62. Wave height, period, and direction are all critical in defining the sea state in which a structure must survive and remain effective. The wave period is especially critical in the Fort Ord situation since both runup and depth limitations on wave height are sensitive to frequency (the inverse of wave period). The maximum peak spectral period measured at the north Monterey Bay buoy in the winter of 1983 was 22 sec. In the previous years of recordings, only one storm exceeded 17 sec for all the California gages. The 1983 peak waves were estimated to contain about 80 percent more energy than the largest of the previous 3 years (Seymour 1983). Review of the extreme waves hindcast from over 75 years of weather records presented in Table 3 (Thornton 1980) and the swell statistics illustrated in Figure 7 (Cherry, 1964) gives further indication of the extreme severity of the 22-sec peak spectral period. This period, or the corresponding frequency of 0.045 sec^{-1} , was used to estimate depth limitations on wave height, as well as runup elevations.

63. Wave energy at Fort Ord is most severe from the west-northwest to northwest direction, as discussed previously. Deepwater wave height is less critical than period, due to depth limitations at the site (for the structures under consideration). The deepwater significant wave height does enter into the depth limitation considerations since a measure of wave steepness (the relation of wave amplitude to wavelength) is required. Again, the extreme deepwater significant wave height (or spectral "zero movement" wave height) of over 23 ft computed from wave records during the winter of 1983 seems quite unique in light of the other available data, but a value of 24 ft in deep water was used for these preliminary design considerations. This value could correspond to maximum deepwater wave heights exceeding 36 ft (Seymour 1983)

and could also correspond to extreme breaker heights of 40 ft, which were estimated by some observers north of Fort Ord last winter.*

64. The guidance of Vincent (1981) was used in estimating depth-limited wave heights with a deepwater wave height $H_D = 24$ ft and a peak spectral period $T_p = 22$ sec. Depth-limited values varying from 9 ft in 5 ft of water to 17 ft in 19 ft of water were computed using this method. These wave height values exceed the wave breaking limitation of 0.78 times the depth for linear (monochromatic) waves. The combination of the steep beach (1:6) and the exceptionally long waves (nearly 2500 ft long in deep water) could possibly emulate laboratory results for solitary waves breaking on steep slopes (Street and Camfield 1966) where breaker heights consistently exceeded breaking depth. The wave heights computed according to Vincent (1981) were used for design in this investigation.

Design of a Rubble Slope Revetment

Primary armor size

65. The shape and stability of a rubble coastal structure tend to be functions of the outer armor material size. Primary armor is sized by weight as a function of the impinging wave height, the material density, the buoyant forces on the unit, the design slope, and an empirical stability factor K_D related primarily to its shape. Table 4 shows computations of armor size at two alternate design wave conditions for various types of concrete units, as well as for quarystone, according to the guidance of the Shore Protection Manual (U. S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center 1984 (in preparation)). A unit weight for rock of 168.3 lbs/cu ft was used to match that of stones currently available from Kaiser Sand and Gravel at Santa Margarita, California.** A unit weight of 156 lbs/cu ft was used for concrete, assuming no steel reinforcement. Two layers of randomly placed primary armor in breaking wave conditions were assumed in all cases. The unit heights referenced in Table 4 do not neces-

* Personal communication, September 1983, Dr. E. Thornton, U. S. Navy Postgraduate School, Monterey, California.

** Personal communication, September 1983, B. Martin, Kaiser Sand and Gravel Co., Santa Margarita, California.

sarily correspond to one half the primary armor layer. For example, two layers of 4.4-ton dolosse would have an average thickness of around 7 ft due to their complex interlocking shape. Figure 22 illustrates the shapes of the units in Table 4. Toskanes (not shown) are similar to dolosse in shape, but have two arrowhead shapes at right angles to each other at either end of a square central shaft.

66. A number of trial cross sections were drafted in order to estimate placement difficulties and runup. Runup proved difficult to estimate because of the steep beach slope, the depth-limited wave height, and the extremely long wave period (22 sec). According to the guidance of Ahrens (1977), Stoa (1978), Stoa (1979), and Ahrens (1981), waves could be expected to run up as high as 50 ft above the still water level on rubble slopes of 1:1.5 and 1:2.0.

67. Revetment slopes no steeper than 1:2.0 are preferred at Fort Ord due to the seismicity, but the steep, narrow beach and the condition of the bluff face required some compromise. Likewise, the depth to which the revetment would normally be extended was compromised since the deeper the structure, the higher the depth-limited waves and the larger the armor unit required. Any plan for excavation to prepare the foundation was avoided because excavation could aggravate erosion during the construction phase.

68. The cross section finally chosen for the purpose of estimating quantities is shown in Figure 23. A plan view showing the main trunk and the wings which tie the structure into the natural slopes at either end is presented in Figure 24. This drawing also shows the projected shoreline retreat with the structure at a rate of 6 to 7 ft per year, to illustrate the need for an extension of the revetment wings in about 30 years. Maintenance at roughly 10-year intervals would also be required to redress the revetment slopes and repair minor flanking.

Design of a Steel Sheetpile Bulkhead

69. After a number of trial cross sections were formulated and attempts made to compute wave forces in the specified conditions, the composite bulkhead revetment structure shown in Figure 25 was chosen to estimate material quantities. Detailed structural computations were not performed since the wave forces could not be satisfactorily estimated. Conservative estimates of

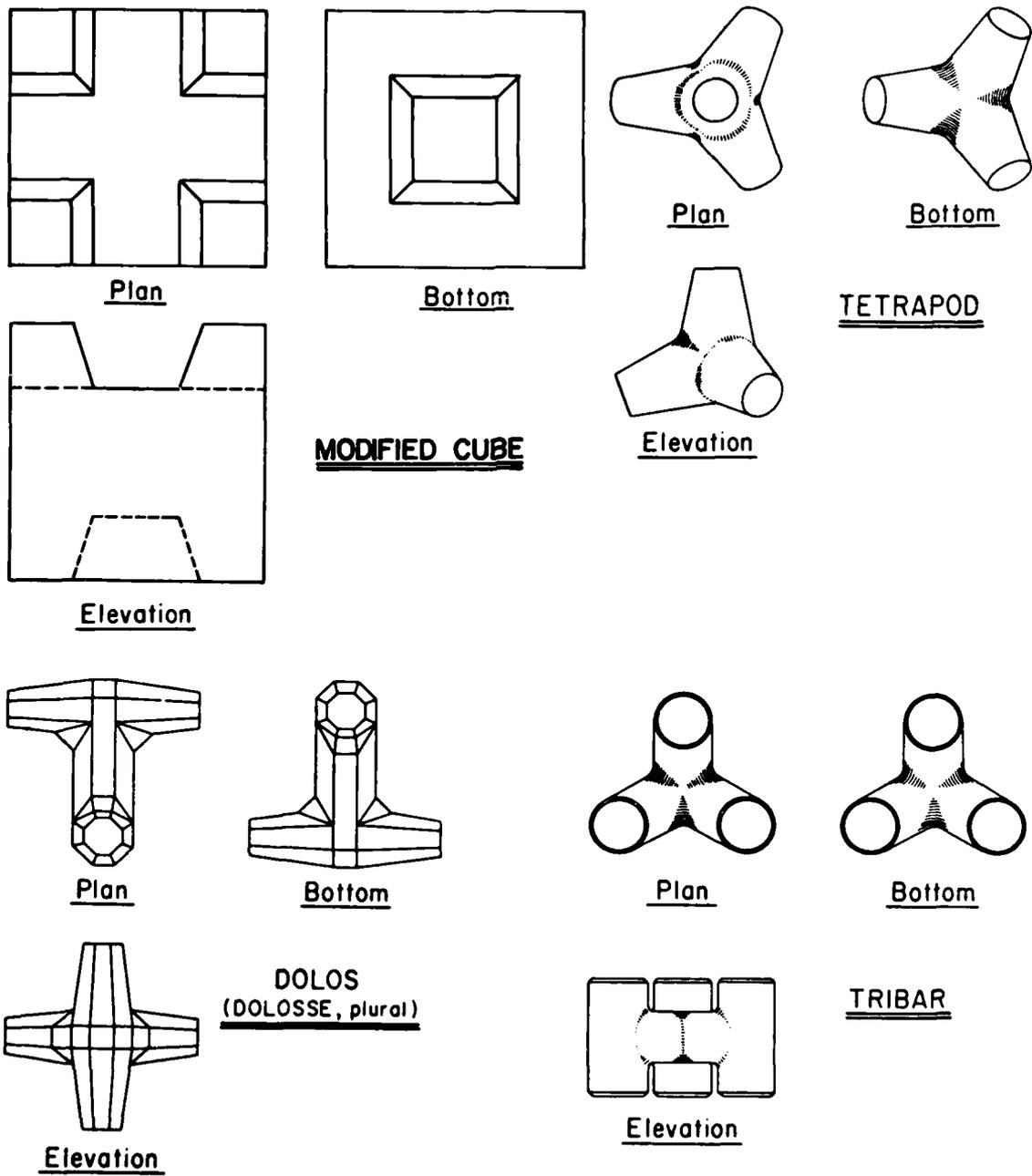


Figure 22. Concrete armor units

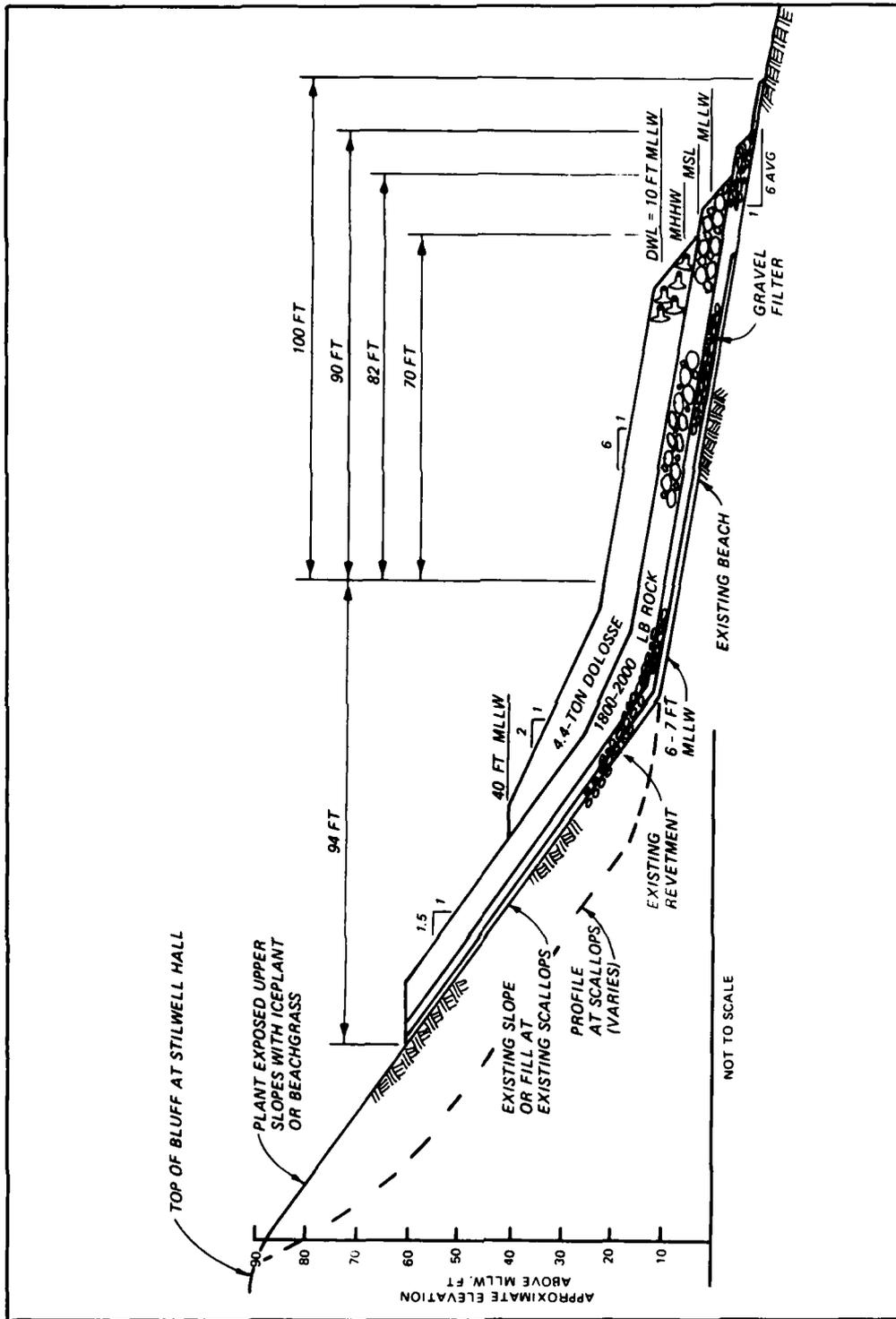


Figure 23. Profile of proposed rubble slope revetment at Stilwell Hall, Fort Ord, California

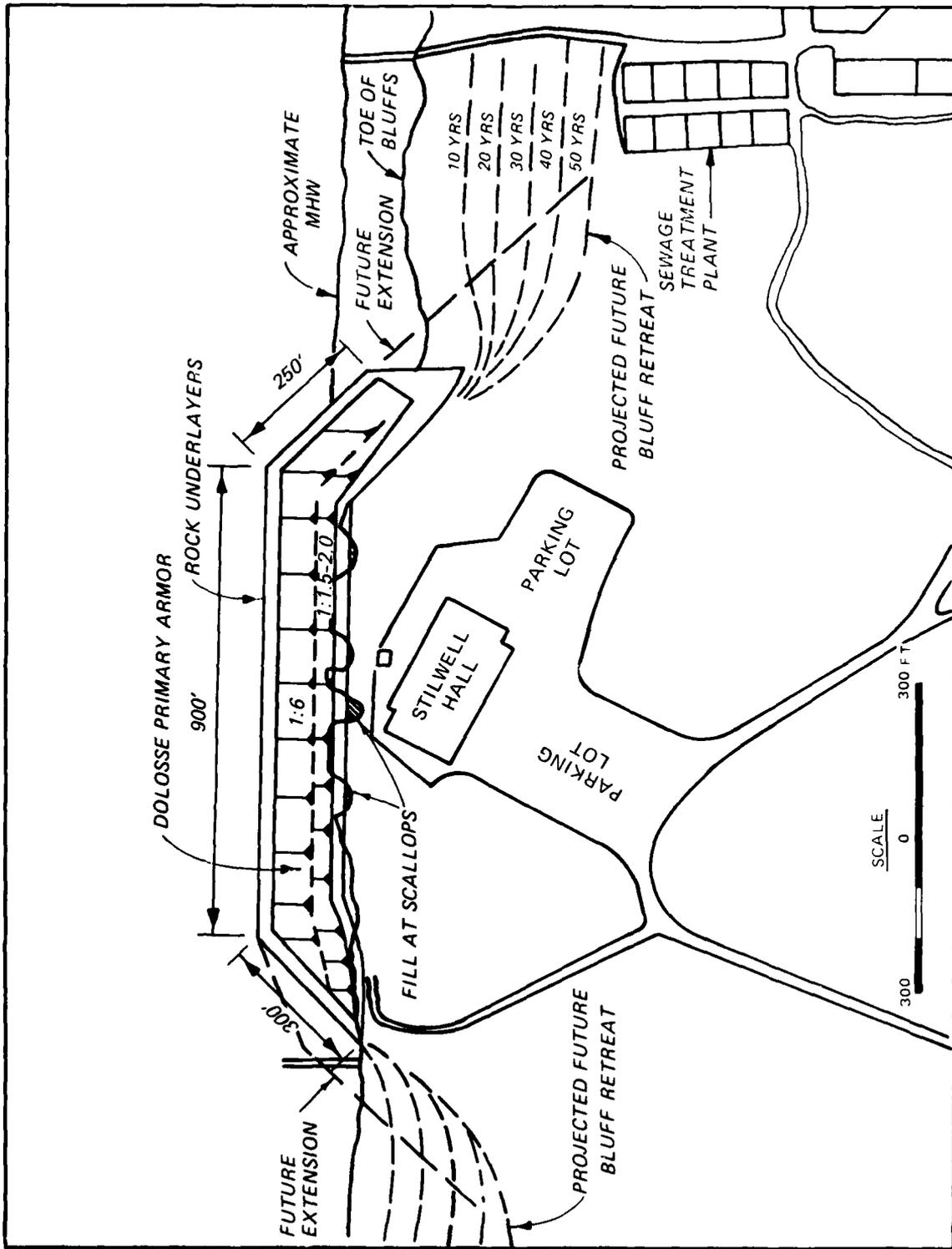


Figure 24. Plan view of proposed rubble slope revetment at Stilwell Hall, Fort Ord, California

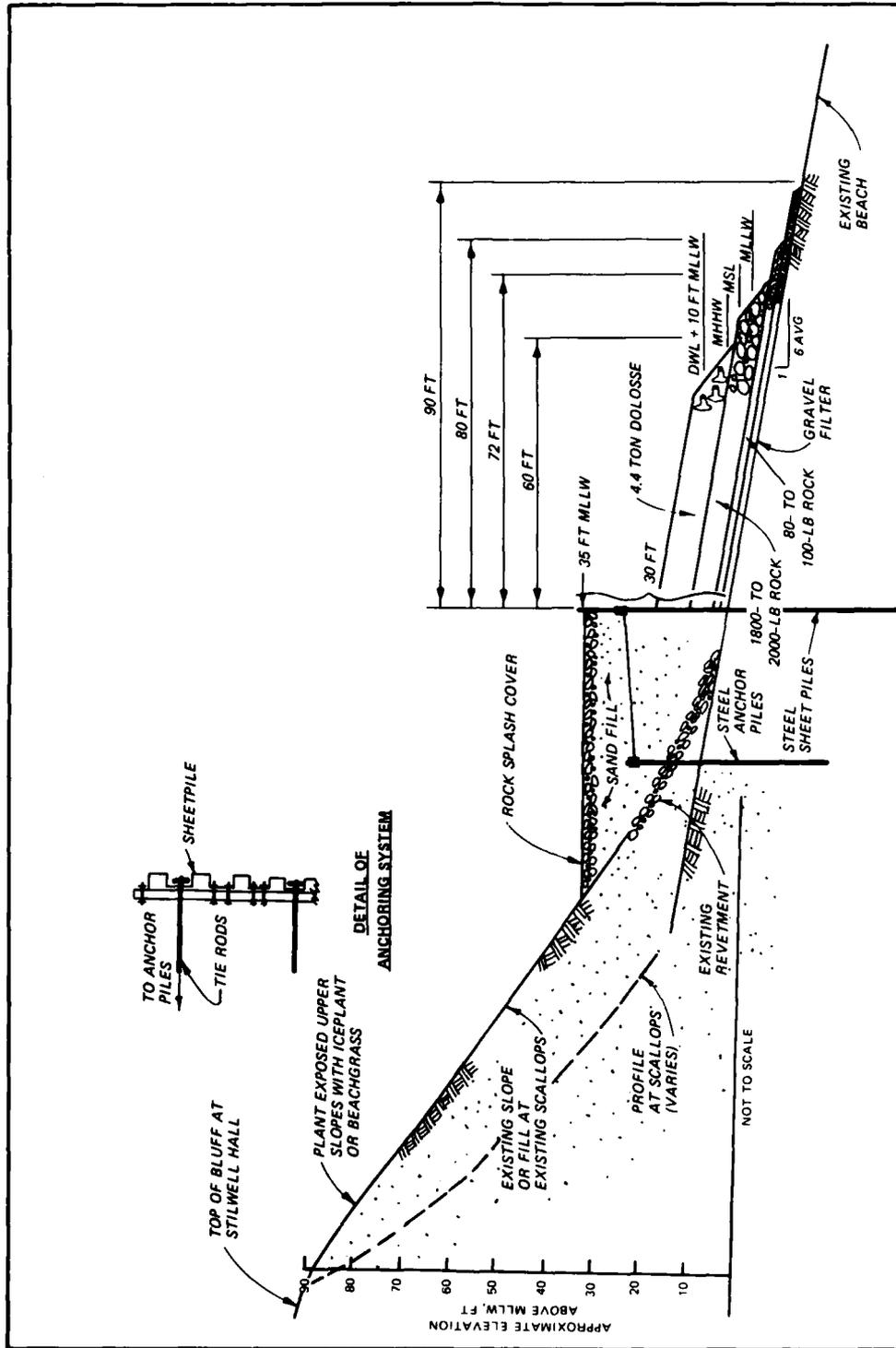


Figure 25. Profile of proposed sheetpile bulkhead at Stilwell Hall, Fort Ord, California

pile sections, anchor pile spacing, and burial depths were made based on experience at other projects. The scour protection for the toe of the bulkhead was ultimately chosen to be the same design as the rubble revetment, since the beach in front of the bulkhead will experience offshore losses during low-water period. The extent and shape of the rubble toe in both designs is intended to "fold" into the inevitably steepening beach profile and remain effective. This concept is unproven, however, either in prototype or in the laboratory.

70. One interesting feature of the bulkhead cross section is the fact that wave energy will be reflected nearly 100 percent and thus will not "run up" to the extent it would on a rubble slope. Splash protection must be provided for the fill behind the bulkhead, but overall the structure need not extend as far up the face of the bluff. Figure 26 shows the proposed plan view with features similar to the rubble revetment plan. Both plans include filling of the scallops and planting of the exposed upper slopes, which should be done soon as an emergency measure.

Quantity and Cost Estimates

71. Quantity and construction contract cost estimates for both the rubble revetment and steel sheetpile bulkhead are presented in Tables 5 and 6. Quantities correspond to the plans as presented in Figures 23 through 26. Unit prices are as of September 1983 and were determined from conversations with local contractors and materials suppliers and from review of recent cost estimates for similar work in California. A 250-ft extension of the rubble revetment in 30 years is estimated to cost \$2.31 million, based on the cost per linear foot of the original. Similarly, a 500-ft extension of the sheetpile bulkhead in 30 years is estimated to cost \$3.36 million. Maintenance of the rubble revetment at 10-year intervals is estimated to cost \$200,000 each time. Maintenance of the sheetpile bulkhead, consisting of replacing sacrificial anodes plus some of the steel and rubble, is estimated to cost \$425,000 each time. These estimates include only construction contract costs and not engineering/design costs or contract supervision and administration costs.

Life-cycle costs

72. The present worth of all costs, including the first cost, the

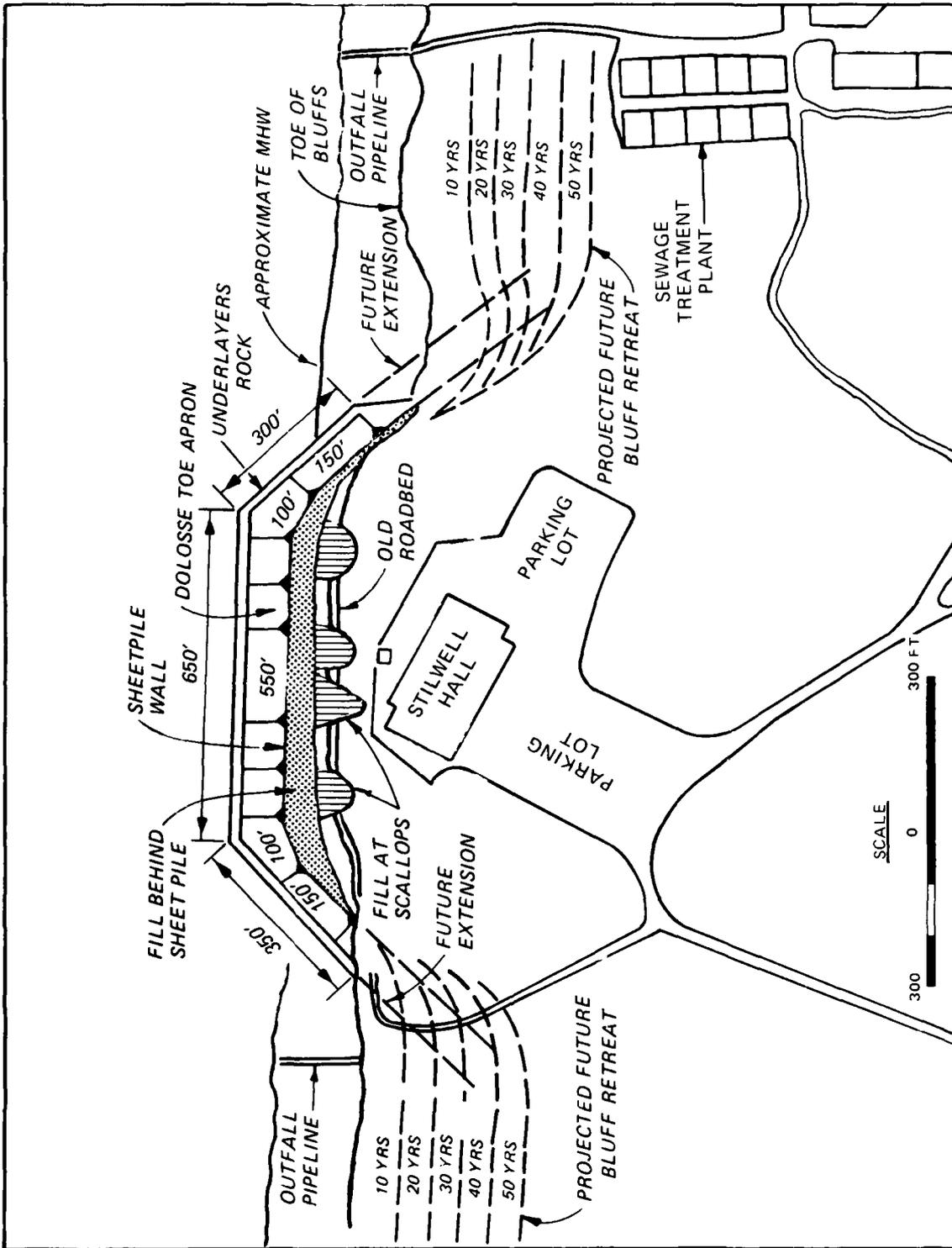


Figure 26. Plan view of proposed sheetpile bulkhead at Stilwell Hall, Fort Ord, California

extension cost at 30 years, and the cost of 10-year maintenance, was computed, assuming a 10 percent discount rate. The difference between the estimated present worth values for the rubble revetment and the steel sheetpile bulkhead turned out to be negligible: each was estimated to cost around \$7.48 million. This discounted cash flow technique is useful in comparing alternatives, but in this case, the practicalities of securing funds for original construction versus funds for maintenance or the 30-year extension may be more significant than the difference in life-cycle costs.

Evaluation of Alternatives

73. The higher cost of permanent protection of Stilwell Hall as opposed to its demolition and replacement, even allowing for salvage of some portions, is significant at \$3 to \$4 million. Emergency repairs could retard erosion until a permanent solution is chosen, but anything short of a permanent structure of the scope formulated in this investigation will mean the loss of Stilwell Hall in a few years' time. A commitment by the Army to save Stilwell Hall would likely be controversial in a community as environmentally aware as the Monterey area. A Section 404 permit from the U. S. Army Corps of Engineers, along with its statutory public review process, would be required prior to construction.

74. The two plans formulated here have similar costs and comparable effectiveness. They would have the similar long-term effects of gradually steepening the beach profile offshore of the structure and causing an artificial headland to form as the adjacent shoreline retreats. Some disruption of natural longshore transport would occur, but this does not appear to be of major concern at this site. Further detailed study of all potential impact would be required. The flexibility and permeability of a rubble structure is intuitively preferable, based on past Corps experience, but the bulkhead plan also has some advantages. The level fill behind the sheetpile, though not recommended for recreational use, would make a handy platform for maintenance and repairs. More of the upper slopes would be vegetated with the bulkhead plan, though the appearance of the steel itself offsets this aesthetic advantage.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

75. The coast of Fort Ord on Monterey Bay has been shown to be continuously eroding as indicated by a steady long-term retreat of this and the adjacent shoreline. The principle cause of this erosion appears to be the consistent and severe exposure of the beach and the toe of the sand dunes to combinations of high water and high waves. Offshore transport of sand removed from the beach and dunes appears to be the principle mode of sediment loss, with longshore transport of secondary importance. A long-term average shoreline retreat rate of at least 6 to 7 ft per year is in effect at Fort Ord as a result of these sediment losses.

76. The recent extreme storms of winter 1983 caused damage to much of the California coastline, including southern Monterey Bay and the Fort Ord shoreline opposite Stilwell Hall and the Ammo Supply Point. The existing rubble revetment at Stilwell Hall completely failed due to overtopping and toe erosion in four places, allowing tremendous scallops to develop in the seaward dune face. The lack of protection and steep slopes left at the scallops make these areas highly susceptible to continued erosion, thus compounding the threat to Stilwell Hall. Emergency repair of the scallops and the existing revetment is currently being pursued by Fort Ord.

77. Stilwell Hall has a distinctive appearance and a unique history. The structure was conceived for the use of soldiers and seen through to completion in 1940 by BG Joseph Stilwell, the first commander of the 7th Infantry Division at Fort Ord. Stilwell Hall is presently used for a variety of recreational purposes. In the face of the coastal erosion threat, however, the structure must soon be demolished or protected in a permanent fashion.

78. Four heavy concrete bunkers at the Fort Ord Ammo Supply Point are also in jeopardy from coastal erosion. These structures appear to be replaceable by affordable alternative ammunition storage facilities and will probably be abandoned. Their demolition, to prevent unnatural disruption of coastal processes, could be expensive and should take place while heavy equipment can still safely work around the bunkers.

79. The decision to permanently protect Stilwell Hall from loss due to

coastal erosion will depend on the value the Army places on the facility's historical and sentimental significance. The structure could probably be demolished and replaced in kind, using some existing fixtures, for less than \$4 million. The first cost for reliable permanent shore protection is estimated to exceed \$7 million, with maintenance expenses and eventual extension being a certainty.

80. The cost of permanent shore protection at Fort Ord is high because of the unusual severity of the wave climate and the advanced stage of the erosion at Stilwell Hall. Direct protection of the toe of the sand dunes, in the form of a steel sheetpile bulkhead with extensive toe protection or a heavily armored rubble slope revetment, are considered the only reliable practical alternatives. These two plans have comparable estimated life-cycle (present worth) costs of around \$7.48 million. (A sheetpile bulkhead is estimated to have slightly less first cost at around \$7.1 million, but would require more expensive maintenance and extension costs. A rubble slope revetment would cost slightly more to build at around \$7.2 million, but would be somewhat less costly to maintain and extend.) Generally, flexible and permeable structures such as rubble slope revetment are preferred in severe coastal environments over less flexible and impermeable structures such as the sheetpile bulkheads. The steel sheetpile bulkhead does have some practical advantages for construction and maintenance, however.

Recommendations

81. The first recommendation that must be made, in light of the above conclusions, is that Fort Ord and the Army carefully consider the extent of their commitment to preserve Stilwell Hall. Pending a favorable recommendation to preserve Stilwell Hall, structural shore protection measures should be followed as soon as possible with a continuous expedited design effort as outlined in Appendix B of this report. The emergency measures presently being taken by Fort Ord to repair the existing revetment should be maintained until a permanent structure can be completed.

REFERENCES

- Ahrens, John. 1977. "Prediction of Irregular Wave Overtopping," CERC Technical Aid 77-7, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Ahrens, John. 1981. "Irregular Wave Runup on Smooth Slopes," CERC Technical Aid 81-17, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Arnal, R. E., Dittmer, E., and Shumaker, E. 1973. "Sand Transport Studies in Monterey Bay, California," Technical Publication 73-5, Annual Report, Part 5, Moss Landing Marine Laboratories, Moss Landing, Calif.
- Cherry, J. A. 1964. "Sand Movement Along Equilibrium Beaches North of San Francisco," Journal of Sedimentary Petrology, Vol 36, No. 2.
- Chestnutt, C. B., and Stafford, R. P. 1977. "Movable Bed Experiments with $H_o/L_o = 0.021$; Laboratory Experiments in Beach Studies," CERC Miscellaneous Report MR-77-7, Vol II, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Coastal Engineering Research Center, Shore Protection Manual, Vols I through III, U. S. Government Printing Office, Washington, D. C., 1977.
- Cooper, W. S. 1967. "Coastal Dunes of California," Memorandum of the Geological Society of America, Vol 104.
- Department of Navigation and Ocean Development. 1972. "Sand City Feasibility Study for Groin and Public Beach," State of California, Memorandum Report, Sacramento.
- Directorate of Facilities Engineering, (Fort Ord). 1975. "Fort Ord Natural Resources Program, 1975 Report," Fort Ord, Calif.
- Dittmer, E. R. 1972. "A Sediment Budget Analysis of Monterey Bay," Masters Thesis, Department of Geology, California State University, San Jose, Calif.
- Dorman, Craig E. 1968. "The Southern Monterey Bay Littoral Cell: A Preliminary Sediment Budget Study," Masters Thesis, U. S. Naval Postgraduate School, Monterey, Calif.
- Hales, Lyndell Z. 1983. "Severe Beach and Dune Erosion, Fort Ord, California," unpublished, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Harris, D. L. 1981. "Tides and Tidal Datum in the United States," CERC Special Report No. 17, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.
- Hohenstein, C. G., Jaeger, J. W., and Jones, D. L. 1965. "A Study of Marked Sand Movement on Del Monte Beach, Monterey Bay, California," Masters Thesis, U. S. Naval Postgraduate School, Monterey, Calif.

Johnson, J. W. 1956. "Dynamics of Nearshore Sediment Movement," Bulletin of the American Association of Petroleum Geologists, Vol 40, No. 9.

Martin, B. D., and Emery, K. O. 1967. "Geology of Monterey Canyon, California," Bulletin of the American Association of Petroleum Geologists, Vol 51, No. 11.

Monteath, Gordon M., Jr. 1965. "Environmental Analysis of the Sediments of Southern Monterey Bay, California," Masters Thesis, U. S. Naval Postgraduate School, Monterey, Calif.

Monterey County Planning Department. 1980. "Environmental Constraints Analysis of Monterey County, Part I, Seismic and Geological Hazards," Monterey County, Salinas, Calif.

National Marine Consultants. 1960. "Wave Statistics for Seven Deep Water Stations Along the California Coast," Santa Barbara, Calif.

National Oceanic and Atmospheric Administration (NOAA). 1979. "Tidal Current Tables 1980, Pacific Coast of North American and Asia," U. S. Department of Commerce, Rockville, Md.

National Oceanic and Atmospheric Administration (NOAA). 1982. "Tide Tables 1983, West Coast of North and South American," U. S. Department of Commerce, Rockville, Md.

Nordstrom, C. E., and Inman, D. L. 1975. "Sand Level Changes on Torrey Pines Beach, California," CERC Miscellaneous Paper No. 11-75, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Resources Planning Consultants. 1980. "Fort Ord, Analysis of Existing Facilities/Environmental Assessment Report," for the U. S. Army Engineer District, Sacramento, Calif.

Seymour, Richard J. 1983. "Extreme Waves in California During Winter, 1983," State of California, Department of Boating and Waterways, LaJolla, Calif.

Smith, A. W., and Chapman, D. M. 1983. "The Behavior of Prototype Boulder Revetment Walls," University of Sydney, Sydney, Australia.

Stoa, Philip N. 1978. "Revised Wave Runup Curves for Smooth Slopes," CERC Technical Aid 78-2, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stoa, Philip N. 1979. "Wave Runup on Rough Slopes," CERC Technical Aid 79-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Street, R. L., and Camfield, F. E. 1966. "Observations and Experiments on Solitary Wave Deformation," Proceedings of Tenth Conference on Coastal Engineering, American Society of Civil Engineers, New York, N.Y.

Swernoff, Michael. 1979. Nomination of Stilwell Hall to the National Register of Historic Places, for Fort Ord Directorate of Facilities Engineering, Fort Ord, Calif.

Thornton, Edward. 1980. "Wave Design Criteria and Related Environmental Impacts for the Proposed Monterey Bay Aquarium," U. S. Naval Postgraduate School.

U. S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center (WES/CERC). 1984. Shore Protection Manual, 4th Edition, (in preparation), U. S. Government Printing Office, Washington, D.C.

U. S. Geological Survey (USGS). 1971. "Water Resources Data for California: Part I, Surface Water Records; Part II, Water Quality Records," Sacramento, Calif.

Vincent, C. Linwood. 1981. "A Method for Estimating Depth-Limited Wave Energy," CERC Technical Aid 81-6, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Ms.

Wiegel, R. L. 1964. Oceanographical Engineering, Prentice-Hall, Inc., Englewood Cliffs, N.J.

Wolf, S. C. 1970. "Current Patterns and Mass Transport of Clastic Sediments in the Near-Shore Regions of Monterey Bay," Masters Thesis, Department of Geology, San Jose State College, San Jose, Calif.

Yancey, T. E. 1968. "Recent Sediments of Monterey Bay, California," Technical Report HEL-2-18, University of California, Berkeley.

Yasso, W. E. 1964. "Plan Geometry of Headland Bay Beaches," Technical Report No. 7, Department of Geology, Columbia University, New York, N.Y.

Table 1
Rossi-Forel Ground Shaking Intensity Scale

Level	Definition
I	PERCEPTIBLE, only by delicate instruments
II	VERY SLIGHT, shocks noticed by few person at rest
III	SLIGHT SHOCK, of which duration and direction were noted by a number of persons
IV	MODERATE SHOCK, reported by persons in motion; shaking movable objects; cracking of ceiling
V	SMART SHOCK, generally felt; furniture; some clocks stopped; some sleepers awakened
VI	SEVERE SHOCK, general awakening of sleepers; stopping of clocks; some window glass broken
VII	VIOLENT SHOCK, overturning of loose objects; falling of plaster; striking of church bells; some chimneys fall
VIII	Fall of chimney; cracks in the walls of buildings
IX	Partial or total destruction of some buildings
X	Great disasters; overturning of rocks, fissures in surface of earth; mountain slides

Table 2
Fort Ord Climatic Data Summary*

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
<u>Temperature (°F)</u>													
Extreme maximum	79	76	75	91	73	85	82	86	91	103	88	77	103
Mean daily maximum	60	60	59	62	61	63	64	65	68	68	63	60	63
Mean daily minimum	36	42	41	46	48	51	52	53	52	49	43	38	46
<u>Precipitation Amount (in.)</u>													
Mean monthly	2.1	1.9	2.4	1.3	0.3	0.1	0.05	0.1	0.1	0.5	1.3	0.7	10.7
Maximum 24-hour	1.7	1.7	1.8	1.0	0.3	0.1	0.05	0.2	0.3	0.7	0.8	0.6	1.8
<u>Surface Wind (knots)</u>													
Prevailing direction	E	W	W	W	W	W	W	W	W	W	E	E	--
Mean speed	5	4	5	6	7	7	7	7	5	5	5	4	--
Extreme speed	42	44	37	40	32	38	26	28	25	40	32	35	--

* After Resource Planning Consultants 1980.

Table 3
Extreme Waves in 20-ft Depth at Monterey, California*

<u>Date</u>	<u>Wave Height (ft)</u>	<u>Period (sec)</u>	<u>Return Period (yr)</u>
4/29/15	21.0	12.9	75
2/9/60	19.5	15.0	38
12/13/67	16.8	18.4	19
11/14/58	15.7	12.0	---**
4/13/58	15.3	12.0	--
12/13/69	15.2	20.3	12
2/21/77	14.8	21.1	8
12/14/73	14.8	17.5	--
10/26/50	14.5	15.4	--
1/30/73	14.2	19.7	--
4/3/74	13.2	16.6	--
1/11/76	12.6	16.3	6
5/11/76	12.5	16.2	--
2/18/76	12.2	16.0	--
12/7/69	12.1	16.0	4
1/8/75	12.0	15.9	--
11/25/73	11.9	15.6	--
12/22/75	11.5	15.5	--
3/4/56	10.6	13.0	--
12/30/76	10.1	15.2	--
2/12/26	9.0	15.4	--

* From Thornton 1980.
 ** No computations made.

Table 4
Armor Unit Parameters

<u>Armor Unit</u>	<u>Height (ft)</u>	<u>Weight (lbs)</u>	<u>Weight (tons)</u>	<u>Volume/ea (cu yds)</u>	<u>Remarks</u>
Quarrrystone	17.2	49358	24.7	N/A	Probably not available
$K_D=2.0$	14.4	28964	14.5	N/A	Probably not available in quantity
Plain cubes	17.2	37945	19.0	9.0	6.3-ft cube
$K_D=3.5$	14.4	22267	11.1	5.3	5.1-ft cube
Modified cubes	17.2	20432	10.2	5.3	5.7-ft cube
$K_D=6.5$	14.4	11990	6.0	2.6	4.5-ft cube
Tetrapods	17.2	18973	9.5	4.5	Height 7.4 ft
$K_D=7.0$	14.4	11133	5.6	2.6	Height 6.3 ft
Tribars	17.2	14756	7.4	3.5	Height 4.8 ft
$K_D=9.0$	14.4	8659	4.3	2.1	Height 4.0 ft
Toskanes	17.2	12073	6.0	2.9	Height 9.5 ft
$K_D=11.0$	14.4	7085	3.5	1.7	Height 8.0 ft
Dolosse	17.2	8854	4.4	2.1	Height 7 ft
$K_D=15.0$	14.4	4196	2.6	1.2	Height 5 ft 10 in.

Table 5
Cost Estimate for Dolosse Revetment

Item	Quantity	Unit Price	Total
<u>Rock (in place)</u>			
Gravel, quarry run	10,000 cu yds	\$20/cu yds	200,000
80- to 100-lb. rock	18,500 cu yds	\$40/cu yds	740,000
1800- to 2000-lb. rock	37,600 cu yds	\$40/cu yds	1,504,000
<u>Concrete (in place)</u>			
4.4-ton dolosse (10,220 ea)	21,500 cu yds	\$130/cu yds	2,795,000
Fill at scallops	25,500 cu yds	\$8/cu yds	204,000
Prepare approach to beach	1	LS*	100,000
Mobilization/demobilization	1	LS	250,000
Subtotal			\$5,793,000
25% Contingencies			<u>1,447,000</u>
Total Construction contract cost			\$7,240,000

* Lump sum.

Table 6

Cost Estimate for Sheetpile Bulkhead

<u>Item</u>	<u>Quantity</u>	<u>Unit</u>	<u>Total</u>
<u>Steel (in place)</u>			
Sheetpile	2,494,000 lbs		
Wale	42,000 lbs		
Anchor piles (H)	169,600 lbs		
Tie rods, bolts, etc.	10,000 lbs		
All Steel	1,358 tons	2000/ton	\$2,716,000
<u>Galvanic Protection</u>	1		100,000
<u>Fill (in place)</u>			
Scallops	25,500	\$8	204,000
Behind wall	25,000	\$8	200,000
<u>Rock</u>			
1800- to 2000-lb rock	13,500	\$40	540,000
80- to 100-lb rock	11,000	\$40	440,000
Gravel	6,000	\$20	120,000
<u>Concrete</u>			
4.4-ton dolosse (3540 ea)	7,500	\$130	975,000
Prepare approach to beach	1	LS*	100,000
<u>Mobilization/demobilization</u>	1	LS	250,000
	Subtotal		\$5,645,000
	25% Contingencies		1,411,000
	Total construction contract cost		<u>\$7,056,000</u>

* Lump sum.

APPENDIX A: PERTINENT CORRESPONDENCE



DEPARTMENT OF THE ARMY
HEADQUARTERS, DEPARTMENT OF THE ARMY
FORT ORD, CALIFORNIA 94621

REPLY TO
ATTENTION OF

AFZW-EH-E

12 JAN 1983

SUBJECT: Ocean Dune Erosion

THRU: Commander
US Army Forces Command
ATTN: AFEN-MSE
Fort McPherson, GA 30330

TO: Commander and Director
US Army Engineer Waterways Experiment Station
ATTN: Mr. Eugene C. Chatham, C, Wave Dynamics Division
P.O. Box 631
Vicksburg, MS 39180

1. Fort Ord is experiencing continual erosion of the dunes facing the ocean. The erosion has progressed to the point where it is threatening improved property at Fort Ord Ammunition Supply Point and Stilwell Hall Recreational Center (an historic building).
2. A study is required to determine the following:
 - a. Currently, how fast is the erosion taking place?
 - b. In what estimated future time frame would specific structures be rendered unusable?
 - c. What methods, if any, could the Army use to slow or prevent future loss of these structures:
3. We have been informed by Dr. Lynn Hales of your office that your organization may be able to provide assistance. Perhaps someone from your organization could come to Fort Ord and survey the problem, give us an idea

12 JAN 1983

AFZW-EH-E

SUBJECT: Ocean Dune Erosion

of the assistance you could render and estimate of cost. Please advise if this is feasible.

FOR THE COMMANDER:


FREDERICK E. MEURER
LTC, CE
DEH



DEPARTMENT OF THE ARMY
HEADQUARTERS 3RD INFANTRY DIVISION AND FORT ORD
FORT ORD, CALIFORNIA 93941

REPLY TO
ATTENTION OF

AFZW-EH-EP

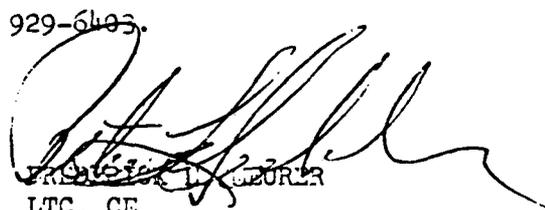
22 July 1983

SUBJECT: Shoreline Protection at Stillwell Hall, Fort Ord, CA

Commander
US Army Engineer Waterways Experiment Station
P.O. Box 631
Vicksburg, Miss. 39130

1. Reference: PHONECON Coastal Engineering Research Center, 19 July 1983, SAB.
2. Request you prepare Reconnaissance Report on permanent structure at Stillwell Hall location (Approx. 1000 ft. Shoreline). It is our understanding that this report will provide us with more specific information on the type of structure, as well as material quantities required and cost involved.
3. We sincerely appreciate your support to date and commend your staff for their diligence in expediting our request
4. DA Form 2544 is inclosed for transfer of funds.
5. POC is Bob Patterson, Autovon 929-6403.

1 Incl
as


ROBERT L. GEURTER
LTC, CE
DEH



REPLY TO
ATTENTION OF

WESCD-D

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P.O. BOX 631
VICKSBURG, MISSISSIPPI 39180

26 August 1983

MEMORANDUM FOR RECORD

SUBJECT: Trip Report: Ft. Ord Coastal Erosion, 9-12 August 1983

1. I traveled to Monterey, California on 9 August 1983 to consult with Ft. Ord Facilities Engineering (DFAE) as requested by AFZW-EH-EP letter dated 22 July 1983 (copy attached) and by DA Form 2544 dated 26 July 1983 (copy attached).
2. The morning of 10 August 1983, I met with Bob Patterson of DFAE and reviewed the materials he already had on hand which included recent aerial photos of the Ft. Ord shoreline (1:3600, 5/17/83) and various maps of Ft. Ord (1"=200', 1"=300' & 1"=500). I was introduced to Jack Massera and Liz Snyder of the Environmental Resources Office and to Don Kellogg and Hank Myers of Master Planning. These people were all of invaluable assistance in the gathering of pertinent information.
3. David Shonman, a local consultant for dune-related problems and faculty member at U.C. Santa Cruz, was the invited speaker at an informal "brown bag" luncheon at DFAE on 10 August, which I attended. His presentation accurately reviewed the common features of dune systems and some unique physical and ecological features of the southern Monterey Bay dunes. One point of interest was the recent occurrence of an insect blight on "ice plant," a dune stabilizing species common along the Ft. Ord shore. A species of butterfly, "Smith's Blue Butterfly," which are found on southern Monterey Bay, may be on the Federal endangered species list. Shonman mentioned several historical and ongoing efforts at erosion control, including one at Moss Landing to the north where a breach in the dunes had been repaired with driftwood and sandfill. Another effort, involving a rubble seawall at a residential area just north of Moss Landing, resulted in dramatic failure and expensive repairs, apparently due to inadequate foundation design.
4. Stilwell Hall and the adjacent beach areas were visited in the company of David Shonman, Jack Massera, Liz Snyder, and Bob Patterson, following Mr. Shonman's presentation. Beach access was limited by high water and wave runup, but erosion had clearly advanced since Dr. Hales' January visit. A second visit to the area was required at low water to better view the face of the eroding bluffs.
5. Following the 10 August inspection of Stilwell Hall, I visited the Environmental and Master Planning offices in search of pertinent data. The history of the existing revetment at Stilwell Hall was available only through second-hand

HYDRAULICS
LABORATORY

GEOTECHNICAL
LABORATORY

STRUCTURES
LABORATORY

ENVIRONMENTAL
LABORATORY

COASTAL ENGINEERING
RESEARCH CENTER

SUBJECT: Trip Report: Ft. Ord Coastal Erosion, 9-12 August 1983

hand knowledge since the last maintenance had occurred in 1972, and no records were maintained. This and previous work had apparently consisted of intermittent end dumping of rocks and concrete from a road which existed below the present bluff top until several years ago. The source and specs of the material were unknown, though inspection showed mostly quarried granite from 1 to 3 feet in largest dimension. Little concrete was visible.

6. Long-range plans, as formulated by the Master Planning Office, did not include any specific development of the Ft. Ord coastline near Stilwell Hall. The firing ranges on both sides, which are directed towards the ocean, will be needed for the indefinite future. Stilwell Hall's fate was a major question, however, both from the erosion and from its present use as a multipurpose recreational facility. The history of the facility is documented in a nomination for the National Register of Historic Places (of which I obtained a copy). Stilwell Hall seems to have greatest sentimental value to persons who knew of its use during World War II but is also remembered fondly by veterans of the Korean and Vietnam War eras. The building is not presently seeing full use, in part due to its isolation from the main Ft. Ord complex and due to competing facilities on post (the NCO Club) and in nearby Monterey (a 10-minute drive south). A multipurpose facility for the Presidio of Monterey (Defense Language Institute) is currently being planned at an estimated construction cost of around \$2.5 million. This was judged by some to be one measure of Stilwell Hall's value, historical significance aside (and not including demolition cost).

7. The morning of 11 August, I met with Mr. Yuchuek Hsia of the Monterey County Planning Office who supplied me with several reports with useful background data including seismic zones, soils data, drainage patterns, and meteorological data.

8. I met with Mr. Ben Hauman, Deputy Director of Engineering and Housing at Ft. Ord, later on the morning of 11 August. Mr. Hauman said the Army was strongly committed to save Stilwell Hall but not without limit. He requested some immediate advice on temporary measures and that the CERC report give specific recommendations on a permanent solution. I reviewed with him CERC's program for the Ft. Ord coastal erosion project, as previously arranged with Bob Patterson, which included a "Reconnaissance Report," to be submitted by 30 September, discussing:

a. A range of alternative responses to the erosion with concept drawings, basic dimensions, order of magnitude cost estimates and probable physical impacts.

b. The steps required to prepare a refined design, including estimated time and funds for CERC to perform this work.

Mr. Hauman agreed that this approach would serve his immediate needs and that any commitments beyond 30 September would depend on a number of factors, including the recommendations of the CERC report.

9. The Ammo Supply Point (ASP) was inspected with Bob Patterson (DFAE) and ASP personnel around 1300 on 11 August. Access to the beach and edge of the bluff

SUBJECT: Trip Report: Ft. Ord Coastal Erosion, 9-12 August 1983

was restricted by the security fence, since both adjacent firing ranges were in use. The physical dimensions of the endangered ammo bunkers were inspected first hand and operating personnel interviewed. Some bluff retreat data had been kept by ASP personnel, which will be forwarded by DFAE. A low-water visit was planned for the following morning.

10. Following the ASP inspection, I visited Professor Ed Thornton at the Naval Post Graduate School (NPGS) Oceanography Department (Monterey). Professor Thornton was very helpful in supplying useful references and reviewing NPGS experience with Monterey Bay. An extensive set of manually prepared refraction diagrams was available, as well as a number of student papers and Masters Theses with possible direct application to the Ft. Ord problem. Synoptic weather data, wave data, and wave hindcasts were also available from the Fleet Numerical Data Center, located at NPGS.

11. Both the ASP and Stilwell Hall were revisited in the company of Bob Patterson at low water on 12 August. Dimensions of individual erosion scallops in the bluff were estimated, along with failed sections of the existing revetment at Stilwell Hall.

12. Following the ASP and Stilwell Hall inspections on 12 August, Bob Patterson and I met with Dick Cotchett of Granite Construction Company (Monterey). Mr. Cotchett was very helpful in reviewing the range of unit costs his company offered or knew of for quarry stone and concrete shapes. The most favored quarry is operated by Kaiser to the south at Santa Margarita, producing large quantities of granite blocks to 5 tons at around \$55/ton (FOB plant). Concrete units cast at the Granite concrete plant would cost around \$85-\$100/CY. One CY (3'x3') concrete cubes are also available from Granite at around \$50 apiece or \$60 in place at nearby Ft. Ord (assuming beach access is not too difficult). Granite also had experience with Longard tubes and similar erosion control measures.

13. I later met with Dr. Warren Thompson, who is retired from full-time NPGS faculty membership and is now consulting in the local area on coastal erosion problems. Dr. Thompson was extremely knowledgeable on coastal erosion in southern Monterey Bay and was familiar with most or all of the literature on the subject. He offered a number of recent papers he had prepared relating to areas near Ft. Ord, some pending release by the study sponsors. He also discussed with me the details of the physical processes and the trends as he then perceived them. His studies have confirmed that erosion rates steadily increase from the south to at least the Ft. Ord boundary and probably beyond. The retreat of the bluff is due only in part to longshore transport and is primarily caused by exposure of the toe to wave action during storm surge and high tides. Longshore transport seems to either diverge or converge at Ft. Ord, depending on the source of data, but longshore transport apparently does drop off in that area. Chart contours in this area are the most parallel of any along southern Monterey Bay. Conflicting data and analyses currently exist on the transport rates and directions in the immediate vicinity of Ft. Ord. I promised Dr. Thompson I would send him the results of any additional analyses we performed at CERC on the subject.

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14. I made some concluding remarks to Bob Patterson and Peter Heckenlaible (Chief of Engineering, Plans and Services Division) regarding immediate steps which would be taken to retard the critical erosion at Stilwell Hall. My suggestions included controlling access to the dunes, closing off portions of the rear parking lot from vehicular access, relocating the range radar shack from the rear parking lot, plantings in barren areas of the dunes, and emergency revetment repair in a manner similar to the attached cross section. I carefully explained that this sketch represented a conceptual emergency measure, which would retard erosion now occurring in normal conditions. The emergency repair cross section is comparable to the existing revetment and would not survive extreme events, such as the storms of last winter (January and February 1983).

15. Summary of materials collected:

- a. Ft. Ord Maps: (1)1"=500, (3)1"=300, and (1)1"=100'
- b. Aerial photos: (48)1:3600 (1"=300')
- c. Nomination for National Register of Historic Places (Stilwell Hall)
- d. 1975 Report - Ft. Ord Natural Resources Program
- e. As Built Drawings - Ft. Ord Sewage Treatment Plant Modifications (includes coastal outfall)
- f. Ft. Ord March 1980 Environmental Assessment Report (2 Volumes)
- g. Monterey County Master Planning documents
 - (1) North County Land Use Plain (June 1982)
 - (2) Inventory and Analysis (February 1983)
 - (3) Seismic and Geological Hazards (June 1982)
 - (4) Physical Features and Natural Resources (December 1980)
- h. Annotated photos of progressive erosion at Stilwell Hall
- i. Masters Theses list for NPGS (to be sent by Professor Thornton)
- j. Selected references to papers on Monterey Bay coastal processes (provided by Drs. Thornton and Thompson)

16. Annotated copies of 17 May 1983 aerial photos of Stilwell Hall and the Ammo Supply Point are attached.

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ORSON P. SMITH
Coastal Design Branch

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STILWELL HALL 1" = 300'
 FT. ORD, CALIFORNIA

APPENDIX B: RECOMMENDED PROGRAM FOR ENGINEERING AND DESIGN
OF SHORE PROTECTION WORKS AT FORT ORD, CALIFORNIA

Objective

1. A detailed design effort for shore protection at Stilwell Hall on Fort Ord, as discussed here, would have as its objective the production of a document defining the following in precise quantitative terms: (a) the design features and long-term effects of the proposed construction project, (b) the construction equipment and techniques required, and (c) a detailed cost estimate for the first cost (construction contract cost), future extensions, and periodic maintenance. The document would be similar in content to "Design Memoranda" prepared by U. S. Army Corps of Engineers District Offices for most major construction projects. Most technical information included in this report should be transcribable without modification to contract documents. Contract documents would require more recent site surveys, however, that could result in minor changes to some details. An Environmental Impact Statement should also be prepared as an independent supplement, based on the long-term effects projected in the design document.

Scope

2. Achievement of the above objective would require a thorough investigation of the physical processes involved in the coastal erosion at Fort Ord, which would in turn require a comprehensive program of field measurements, numerical and physical modeling, and design analyses. As pointed out in the main body of this report, environmental conditions at Fort Ord are both severe and somewhat unique. This severity and uniqueness complicate the application of proven guidance for coastal design and place the effort at "the edge of the field" in terms of the analytical procedures that should be followed.

3. A program of field measurements, including hydrographic, topographic, and geophysical surveys, would be necessary, using conventional equipment and techniques. A long-term frequency distribution of water levels and wave heights at the site should be defined for the site through a program

of numerical modeling using both synoptic weather data and field measurements as input. The results of this program would be most reliable if state-of-the-art numerical models for wave transformation are used which can account for the severe wave climate as well as the unique coastal features known to exist at Fort Ord.

4. An extensive program of physical modeling would be required both to proof-test design cross sections in the conventional manner and to investigate wave breaking and runup extremes. An attempt should also be made to test the feasibility of the "folding toe apron" concept as proposed in this report. This presents a special problem for physical modeling, which would involve some experimental procedures intended for that specific purpose.

5. Projection of the long-term effects of shore protection on Fort Ord would center on predicting the response of the adjacent shoreline to the presence of a "hard point" and eventually an artificial headland at Stilwell Hall. The program of numerical modeling of wave transformation could be extended to achieve this objective through simulation of the potential changes in longshore and offshore transport and deposition that might occur.

6. The preparation of the design document itself should emphasize clear and concise presentation of the results of all the analytical efforts, as well as the resulting detailed design features and corresponding cost estimate.

WES/CERC Capabilities

7. The Waterways Experiment Station Coastal Engineering Research Center (WES/CERC), at Vicksburg, Mississippi, maintains an extensive set of capabilities for design assistance and applied research on coastal engineering problems. WES/CERC has applied physical and numerical modeling efforts to coastal engineering projects around the world. Additional WES facilities and staff are available, should assistance be required on a specific project, from the Environmental, Geotechnical, Hydraulics, and Structures Laboratories, as well as from WES's Automatic Data Processing Center, Instrumentation Services Division, and Publication and Graphic Arts Division. WES/CERC's capabilities for design assistance are comprehensive, highly refined, and available on a cost-reimbursable basis to most Federal Departments and Agencies.

Fort Ord Shore Protection Activities List

8. A list of individual activities in outline form is presented below, with the estimated duration of major activities noted. Some of these activities could be undertaken concurrently. This effort would cost approximately \$300,000 and require 16 to 18 months to complete if undertaken by WES/CERC. Completion time for WES/CERC is dependent on the continuity of funding and the specific time at which the project was begun in relation to other prior commitments.

a. Field Data Collection (4 to 6 months):

- (1) Gather additional existing technical data.
- (2) Gather additional cost estimating information.
- (3) Investigate institutional and regulatory requirements.
- (4) Hydrographic survey.*
- (5) Topographic survey.*
- (6) Geophysical investigations.*

b. Numerical Modeling of Wave and Water Level Climate and Shoreline Effects (4 to 6 months, concurrent with a):

- (1) Hindcast long-term deepwater wave climate from synoptic weather data.
- (2) Simulate transformation of deepwater waves into shallow water at the project site.
- (3) Correlate hindcast wave information with data measured near the project site (by the California Coastal Data Collection Program).
- (4) Simulate storm surge (extreme water level variation).
- (5) Estimate potential quantity and direction of longshore and offshore sand transport.
- (6) Investigate wave setup, breaking, reflection, and runup to establish structural design criteria.
- (7) Simulate shoreline response to shore protection measures at Stilwell Hall.

c. Design Analyses (2 months):

- (1) Reformulate basic plans based on results of numerical modeling.

*Services for these activities are available from U. S. Geological Survey Menlo Park, California.

- (2) Optimize armor size and design, structure slope, crest elevation, underlayer design, and other features based on computation.
- (3) Optimize plan features (length, orientation) based on sand transport and shoreline response projections.
- (4) Formulate a plan for future extension based on sand transport and shoreline response projections.

d. Physical Modeling (6 months including lead time on facilities and model construction):

- (1) Model structural stability of 2-dimensional design cross section, including measurements of wave breaking and runup (using irregular waves).
- (2) Model effectiveness of "folding toe apron" concept.
- (3) Refine design cross section based on first model test results and model refined cross section in the same manner.

e. Cost Estimate (1 month):

- (1) Define construction equipment and sequence of techniques required.
- (2) Estimate material quantities required.
- (3) Estimate initial construction contract cost.
- (4) Estimate frequency, scope, and cost of maintenance.
- (5) Estimate cost of future extension.
- (6) Compute life-cycle costs.
- (7) Refine design features to minimize life-cycle costs (while maintaining effectiveness).

f. Report Preparation (drafting, word processing, printing, and in-house review) (3 months).

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