SEA GRANT PROGRAM

Geomorphology and Oceanography of Topanga Beach, California, in Relation to a Small-Boat Launching Facility

by Michael Leneman

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GEOMORPHOLOGY AND OCEANOGRAPHY OF TOPANGA BEACH, CALIFORNIA, IN RELATION TO A SMALL-BOAT LAUNCHING FACILITY

by

Michael Leneman

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LOS ANGELES, CALIFORNIA 90007

This thesis, written by

Michael Leneman

under the direction of his *Thesis Committee, and approved by all its members, has been presented to and accepted by the Dean of The Graduate School, in partial fulfillment of the requirements for the degree of*

Master of Science

Dean

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THESIS COMMITTEE

Richard O. Stone
Chairman

Bernard W. Pipkin

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ABSTRACT

A tethered float breakwater system is proposed for the southeastern part of Topanga Beach, California to facilitate the launching of small boats. A breakwater system at Topanga which reduces the incident wave height 50 percent will reduce the skill required for boat launching from an intermediate level to a novice level on an average day, and will produce no long-term adverse environmental impacts. It is predicted that the beach behind the breakwater will prograde, flatten its profile, and then stabilize.

Topanga Beach is a suitable beach for open-ocean boat launching because it has a sandy beach, low surf, and along-shore winds. Offshore mapping showed that a rocky substrate exists along the northwestern part of the beach and a sandy substrate throughout the southeastern portion; sediment size decreases offshore, except where rip currents occur. Beach profiles revealed that erosion occurs in late winter, accretion in summer, and gentle profiles are created after periods of high wave approach angles and/or extreme tides. Longshore currents,

measured with fluorescene dye patches, flow eastwardly and vary in velocity with respect to the orientation of the beach and wind-wave dynamics.

PREFACE

This thesis is part of a Sea Grant report which encompasses the research of a marine biologist, an urban planner, and the author. The Sea Grant paper develops the concept of open water boat launching facilities, assesses the demand for such facilities, and then the new concept is applied to Topanga Beach, a test site. A facility design is presented and the environmental consequences, biological, urban, and geological discussed.

This paper, being a Master's thesis, includes only those parts undertaken solely by the author. This does not leave a disjointed paper, but rather one with a decidedly geological viewpoint. Non-geological sections are included to show the context in which the geology was done.

INTRODUCTION

This thesis is a feasibility study of open water boat launching facilities along the southern California coastline. The first section is a summary of the facility concept with an assessment of its physical parameters. The concept is applied to Topanga Beach, California in the second section.

The basic concept and the specific design application was developed with the following objectives in mind:

1. Minimal environmental impact.
2. Best utilization of a scarce regional resource.
3. Reversibility--the ability to remove the facility should it adversely alter the environment.
4. Compatibility with other beach uses.
5. Economy.

To fulfill these objectives, one must have knowledge of the environment in which the concept is to be applied. The author's 13 years of boating experience in southern California and abroad provided the base upon which the generalized concept was developed. The research which led to the formation of the concept was non-methodically accomplished over the years and is not presented in this report since it encompasses general geologic knowledge, sailing experiences, and a wide variety of personal communications with fellow boaters. The application of the concept to a specific test site, however, required *in situ* research, to which the majority of this paper is devoted.

ACKNOWLEDGMENTS

The author is indebted to Dr. Richard O. Stone who supervised the research and to Drs. Bernard W. Pipkin and Donn S. Gorsline for critically reading the manuscript. Ray Emerson served as a diving partner while collecting data for the biological counterpart of this thesis. Generous field assistance was provided by Cherri Briggs and Barry Leneman. Personal communications with Shelley Butler, Topanga Beach lifeguard, and Dr. Richard Seymour, Scripps Institute of Oceanography, provided additional data. The project was supported by the University of Southern California Sea Grant Programs under contract number 04-3-158-36.

THE CONCEPT

The natural condition of the southern California coastal region makes it difficult to meet rapidly increasing recreational demand, particularly those of the recreational boater. Wide, sandy, year-round beaches are plentiful but they are under constant attack by moderate sized waves. Natural harbors and protected waters are scarce and those which exist are presently over-crowded, and the construction of artificial harbors is both costly and often detrimental to the biological, geological, and urban ecologies. The question is no longer one of natural versus artificial environments or of alteration of the environment versus no alteration of the environment. The very existence of recreators on the beaches alters the natural environment.

Undoubtedly, new recreational facilities will be built, but minimizing environmental impact, avoiding adverse environmental impact and, where possible, providing beneficial impacts should be the major concern of any design which attempts to accommodate the increase in coastal recreational demand. The best utilization of this scarce regional resource, the reversibility of any construction, and compatibility with other beach uses should also be part of proper environmental planning.

The basic concept presented here takes the abovementioned factors into account. The proposed facility would be an open beach, small boat launching area with an on-site storage area for a limited number of boats, and would have the following characteristics:

The facility would be placed on a sandy beach which has predominately low surf, prevailing winds which are not directly onshore, and which is not suitable for other specialized beach uses, such as surfing or tidepooling. Choosing an area of natural low surf reduces the need for an offshore structure to reduce the surf size; winds which are not directly onshore make boat launching easier, as will be shown in the section on boat launching parameters; and surfing, tidepooling are not compatible with boat launching, although they may exist adjacent to one another.

The launching ramp would be a flexible ramp which would be rolled out like a mat when the facility is in use and rolled up at night and during stormy weather. It may be constructed of wood, plastic, or steel slats tied together with wire or rope. Such a ramp would allow the beach to change its profile without permanently affecting the launching ramp. Whatever the change in profile, each day the mat-ramp would be rolled out on top of the sand.

Such a ramp would be inexpensive and easy to remove from the site, should it prove to be undesirable.

Where necessary, the surf zone adjacent to the launching ramp would be modified with the use of an off-shore floating breakwater. This type of breakwater decreases the size of the surf and changes the profile of the beach, making launching an easier process; it is less expensive than conventional, total protection breakwaters and has many environmental advantages. Floating break-waters can be designed so that they do not interfere with the natural movement of sand along the beach. In addition, they provide unlimited water circulation, allowing the water behind the breakwater to remain unpolluted and well oxygenated.

Provisions for both on-site storage and trailer launching would be provided where possible. On-site storage expands the potential use of the facility to people who utilize non-automotive means of transportation since all the equipment and accessories required for boating can be stored at the facility. Road traffic is reduced in this manner because every boat stored on the beach means one less trailer on the road and every boater who uses public transportation or a bicycle to get to the facility means one less car on the road. On-site storage presents a major disadvantage in that it utilizes valuable beach space, but if limited in number, boat storage on on near the beach can be a positive aesthetic factor and it provides a center of interest. For those boaters who prefer the flexibility of keeping their boats on trailers at home, trailer parking and appropriate access roads to the launching ramp would be provided. Boats which are stored out of the water do not need toxic bottom paints and consequently they do not pollute the water with heavy metals. Compact dry storage facilities also save space and create less visual impact as compared to wet storage. Storing boats in the water at marinas is not presently deemed desirable by the South Coast Coastal Commission due to the ecological disadvantages associated with marinas.

A small boat launching facility, as proposed here, would accommodate trailer-carried boats which are capable of being launched through low surf by either rowing or sailing. To reduce noise pollution and increase safety, use of auxillary power (outboard motors) at these facilities would be restricted to those waters which were more than 1000 feet from shore. This restriction would not exclude the launching of small motorboats but would require all boats to use either oars or sails to go through the surf. Not all boats are suited for beach launching, and not all boaters have the required expertise to launch their boats through the surf. Consequently, educational seminars and/or trained personnel would be provided to help the novice boater select a suitable boat and learn proper launching procedure.

Envisioned is a number of these small, inexpensive launching facilities along the coast, each with a maximum capacity of 100 to 200 boats, and each compatible with existing beach activities. Coastal highway congestion, boating density and adverse environmental impact will thus all be lessened.

PARAMETERS FOR A SMALL-BOAT LAUNCHING FACILITY

General Statement

The primary function of any open-water boat launching facility is to provide an area where boats can be successfully transported from the water's edge to beyond the surf so that they may be sailed freely on the open ocean. Retrievability, the ability to return a boat to its dry-land base, is also implied in this primary function.

The following discussion excludes those methods of boat transportation which are externally mechanical, such as motors, boat hoists, sky ramps, thereby limiting the modes of power to paddles and/or sails and the path travelled from the beach to the open ocean to the surface. Given these limitations, the ability to launch a boat into open water is a function of boat type, surf height and form, wind velocity and direction, and sailor skill. The trend in facility design in southern California has been towards maximum alteration of the surf to provide a quiet body of water in which to launch boats. There are viable alternatives to this standard design. Certain boat types do not need quiet water and can be launched on open beaches with no alteration in surf dynamics; surf dynamics can be partially altered by submerged or floating breakwaters; proper choice of facility sites can assure more favorable winds and lower natural surf; and educational programs with on-site experience can raise the general level of sailing skill.

Each of the foregoing factors will be discussed separately and rated as to its influence on the launching process; then the total process of launching will be analyzed. The concluding analysis will relate the sailing skill required to launch a boat into the open ocean, to the physical conditions present at the launch site and the type of boat used. The purpose of this analysis is to provide a criterion for rating the suitability of any beach environment for small boat launching and to determine the degree of alteration needed to provide a facility for sailors of a particular skill level.

This analysis was based on the author's previous boat launching experiences coupled with interviews with local boaters and confirmed by the theoretical analysis. The total analysis was drafted, reviewed by a number of experienced sailors, and accordingly revised.

For the reader who is not familiar with boating and beach terms, a glossary is provided at the end of this thesis.

Boat Type

Seafaring cultures throughout the ages, from the Polynesian Islands to the North Atlantic coasts, have pushed, rowed and sailed their boats through the surf. Their boats are built to withstand the physical demands of the local environment. North Atlantic boats have high bows, sturdy planked hulls and are rowed over the short steep surf of the Atlantic, whereas the Polynesians have flexible outriggers which are sailed through the long swells of the Pacific.

The trend in modern recreational boats has been weighted toward boats which require calm water for launching or mooring but there has been a slight trend reversal towards boats which can be used in more out-of-the-way or raw environments. This trend, partially motivated by the desire to expand the potential number of recreational boating areas, has led to the production of small multihulled sailboats, self-draining monohulls, rowboats, dories, kayaks, and surfboard-sailboats. Each of these boat types has advantages and disadvantages in terms of launchability through the surf. A few words about the basic designs as related to beach launching seem appropriate.

The great majority of boats stored on southern California beaches and launched through the surf are small multihulls from 4 to 7 m (12 to 20 feet) in length. These boats are prevalent on the beaches because they exhibit a variety of characteristics which are advantageous during launching and retrieving through the surf. They are stable in the surf zone and easily accelerate to high speeds enabling them to pass through the surf quickly. Their long, narrow, sealed hulls present unsinkable, low-drag forms to the breakers. The absence of centerboards (or dagger-boards) and the existence of retractable beaching rudders on many modern multihulls further facilitate beach use.

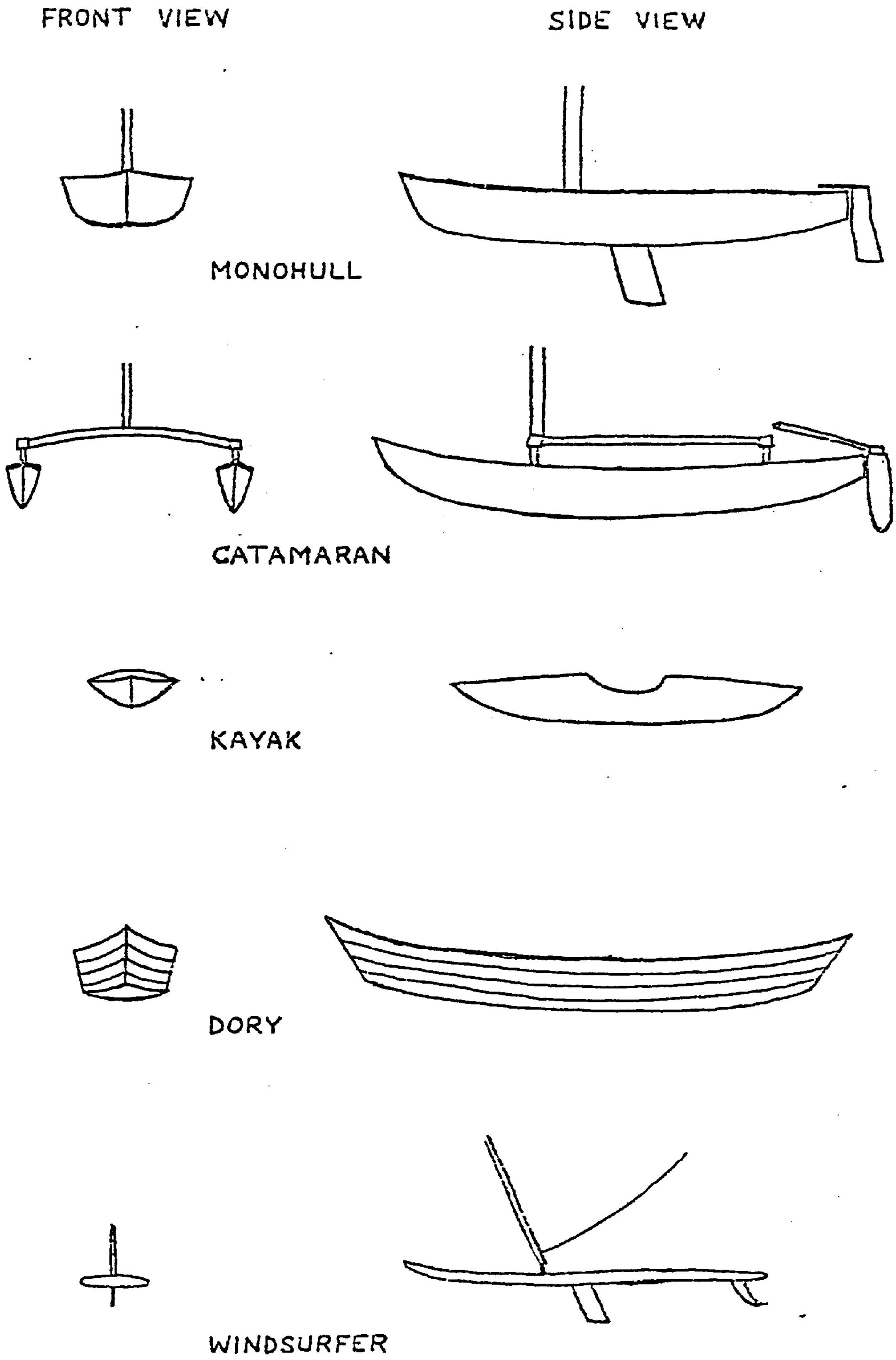
Monohulls 3 to 7 m (10 to 20 feet) in length, without fixed keels, also are capable of being launched through sizeable surf, providing they are equipped with self-draining cockpits. In Holland, boats of this type are stored on the beach and launched through the surf into the open North Sea, an area not generally noted for its calm seas. Such open-water launching is not common in southern California partially because monohulls are less stable and slower than multihulls and quiet water facilities have been readily available in the past. Monohulls also present a higher drag form to oncoming breakers and have initial launching difficulties caused by the centerboard.

Rowboats come in a variety of sizes and shapes, but only certain types are adaptable to beach launching. The two types most used in this area are the dory and the kayak. Dories have high bows and self-draining cockpits. They do not present a particularly low drag shape to the waves and they do not show a high degree of lateral stability, but if rowed by an experienced crew there is rarely a set of wave conditions in southern California through which a dory cannot be launched. Kayaks, like dories, exhibit poor lateral stability but can be righted by a twist of the paddle and their drag profile to waves is low.

A combination of surfboard and sailboat, the Windsurfer (a patented design), can be either paddled like a surfboard through high surf, or sailed through small- to medium-sized surf, depending on the skill of the sailor. These boats have versatility, low drag profiles, unsinkable hulls and are light weight, but as other monohulls they need a daggerboard in order to sail against the wind. This means that these boats cannot be sailed in water of less depth than the length of their daggerboards (1 m) which makes launching a very wet process. Surfboard-sailboats also exhibit extremely poor stability in the surf zone.

A critical factor in boat launchability is the boat velocity versus cross-sectional drag ratio. The greater the boat's velocity in relation to the drag presented to the oncoming waves, the easier that boat will get through the surf. Figure 1 shows a comparison of cross-sections

Figure 1. Side and front views of 5 boat types which are suitable for open-ocean beach launching.


FRONT VIEW
SIDE VIEW
MONOHULL
CATAMARAN
KAYAK
DORY
WINDSURFER

for the four types of boats discussed. The potential velocities of these boats is examined in the discussion on wind velocity and direction.

Surf

The shoreward energy of a breaking wave is proportional to the square of its height. Hence, it would appear to be logical to assume that the difficulty in sailing through a breaking wave is proportional to the square of the wave's height. Practical experience indicates that launching difficulties are also related to wave form, "set" patterns, and wave period, making the relationship between breaker height and launching difficulty unclear. With all other factors held constant, the greater the breaker height the greater the launching difficulty, but the sea is never that simple and does not hold constant.

Ocean swells often come in "sets," periods of higher surf action and periods of lower surf action or "lulls." An observant sailor will launch his boat during a lull period so that he may take advantage of the lower surf condition.

The bottom profile of a beach alters the form of incoming waves, determining how far from shore they will break and often what form they will have. Surf which breaks far from shore, resulting from a shallow slope beach profile, makes launching a lengthier process, but the reduced swash velocities and wide surf zone allow the launching boat time to gain momentum before going through the drop zone, that is, the zone in which the wave has just broken. The drop zone is the most difficult portion of the surf zone in which to launch because the breaking wave form is at a maximum. A wide surf zone also allows the monohull sailor time to partially lower his center-board and rudder, yielding greater maneuverability and less lateral slip.

A steep beach profile produces a narrow surf zone and in the extreme case, a shore break, where there is no real surf zone, just a swash zone (Fig. 2). Waves which shorebreak cause high shoreward swash velocities. In conjunction with the narrow surf zone, these high swash velocities make launching extremely difficult and hazardous because the sailor does not have sufficient time to gain momentum or control of his boat before he reaches the drop zone. Low amplitude, shorebreaking waves under 0.6 m high, make launching easier for some boats because it is possible to simply walk-push a boat through a small shore-break while holding on to the back of the boat. For Windsurfers, the technique is to throw the board (hull) and the sail over the waves and then swim out to the boat, set it up, and sail away.

Wave shape is a factor which is a function of both

Figure 2. The effect of beach slope (profile) on surf zone width.

Figure 3. Profile form of spilling and plunging waves.

Figure 4. The effect of a parabolic beach profile on wave form and surf zone width.

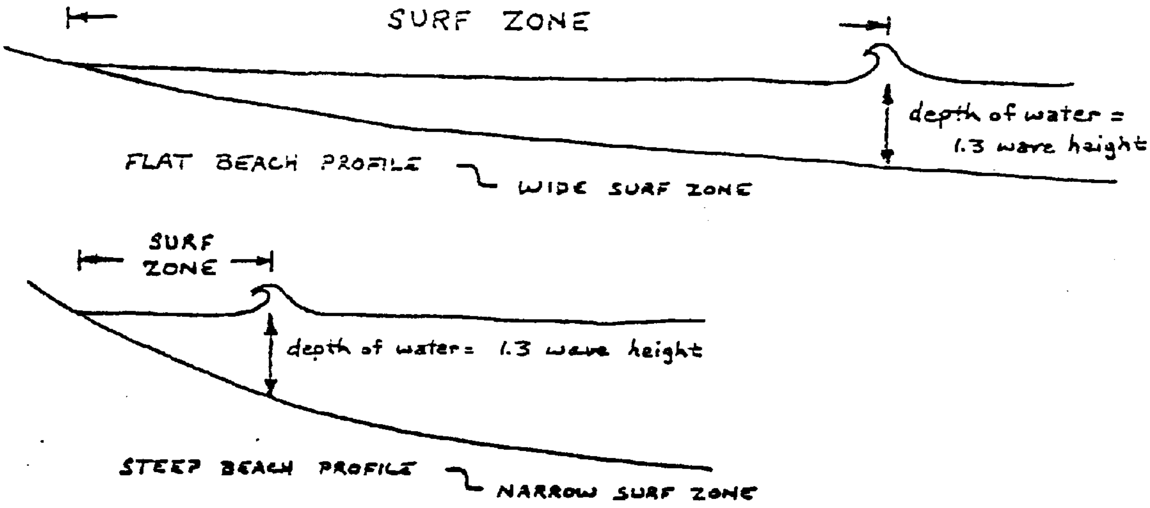


FIGURE 2

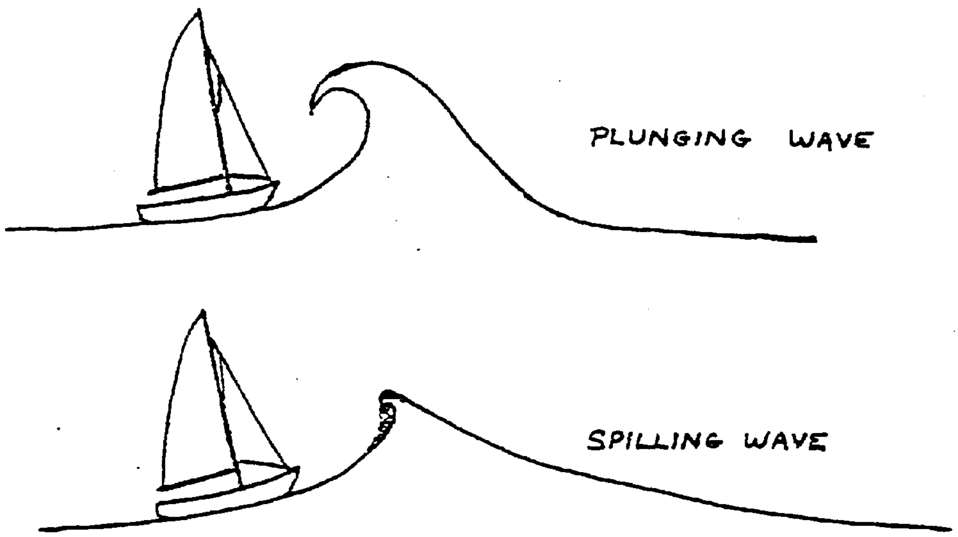


FIGURE 3

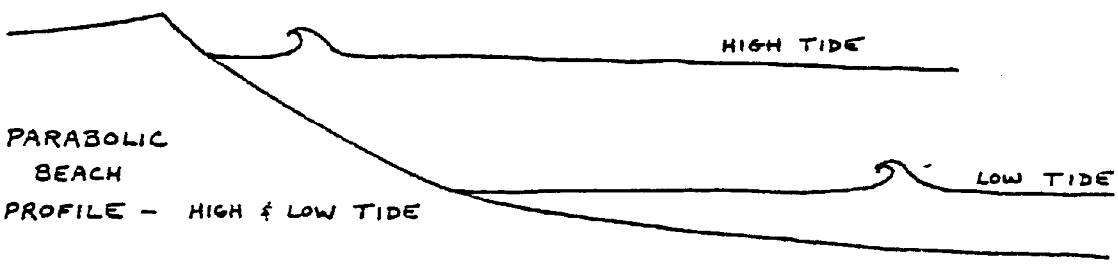


FIGURE 4

beach profile and deep-water wave steepness. A plunging wave (Fig. 3) is the result of a steep deep-water wave and/or a steep beach profile beneath the breaking wave. The top of a plunging wave outruns the base of the wave and topples forward, often in free fall, creating a tube-like form. Due to their steepness, rapid collapse, and near vertical flow of water, plunging waves are more difficult to launch a boat through than spilling waves. Spilling waves are formed when the deep-water form of the wave is low in profile and/or the beach profile is gentle (small slope angle). The top of a spilling wave does not rapidly outrun its base. The collapse is slow and the wave "mushes," the top spilling down the face of the wave which never becomes very steep.

Tidal level may have a profound effect on wave shape. Many beaches have a parabolic profile causing steeply dipping breach profiles at high tide and shallow dipping profiles at low tide (Fig. 4).

In general, launching difficulty increases with increasing wave height and steepness, and decreasing surf zone width (with the exception of small shorebreaks). Table I rates launching difficulty as a function of surf height; corrections for variability in form and surf zone width are provided. In summary, between surf heights of 0 to 0.6 m (2 feet), wave form and surf zone width are not

Table I. Scale of wind velocities and their Beaufort number, description of sea state, psychological scale, and launching difficulty rating

Beaufort No.	Wind Vel. Knots	Description of Sea	Psychological State	Launching Rating
0	1	Sea like a mirror		
1	1- 3	Ripples	Boredom	12
2	4- 6	Small wavelets, crests have a glassy appearance	Mild pleasure	10-8
33	7- 1	Large wavelets, crests begin to break	Pleasure	5-3
4	11-16	Small waves becoming longer, fairly frequent white caps	Great pleasure	0
5	17-21	Moderate waves, taking a more pronounced long form, many white caps	Delight	3-7
6	22-27	Large waves begin to form, extensive white caps, some spray	Delight tinged with anxiety	9
7	28-33	Sea heaps up and white foam begins to be blown in well-marked streaks with the wind	Anxiety tinged with fear	10 (properly reefed)
8	34-40	Moderately high waves, edges of crests break into spindrift	Fear tinged with terror	12 (properly reefed)
9	41-47	High waves, spray may affect visibility, sea begins to roll	Great terror	Off the scale
10	48-55	Very high waves with overhanging crests, surface of sea appears white, rolling sea heavy and shock-like	Panic	Off the scale

very important to the launching process, but as the surf size increases to the 1 to 1.5 m (3 to 5 foot) range, these factors can spell the difference between a wave set in which only advanced sailors can launch and one in which a beginner can launch. When waves are over 1.5 m (5 feet) high, regardless of their form, advanced skills are required. The ability to "read" the wave sets and launch during the lull periods is very important for successful launching through high surf.

Wind

Both the direction and the velocity of the wind are of concern to the sailor who wishes to launch his boat through the surf. If the wind is too light, the boat will not have sufficient velocity to overcome the shoreward push of the waves inside the surf zone. If the wind is too strong, the sailor will not be able to sail his small boat at all, regardless of surf conditions. Wind direction is important because a boat must be kept somewhat perpendicular to the waves when launching or retrieving (Just, 1970) and sailboats typically can only sail as close as 45^{o} to the direction of the wind. Thus, there are certain wind directions in relation to the surf line which make sailing perpendicular to the waves impossible.

Looking closer into the effect of wind velocity on boat velocity, one finds that the relation is not linear.

The force applied to a sail by the wind can be expressed as:

$$F_t = \frac{1}{2} \rho v^2 A C_L \qquad \text{(after Marchaj, 1964)}$$

where

ρ is the density of air

v is the velocity of the apparent wind

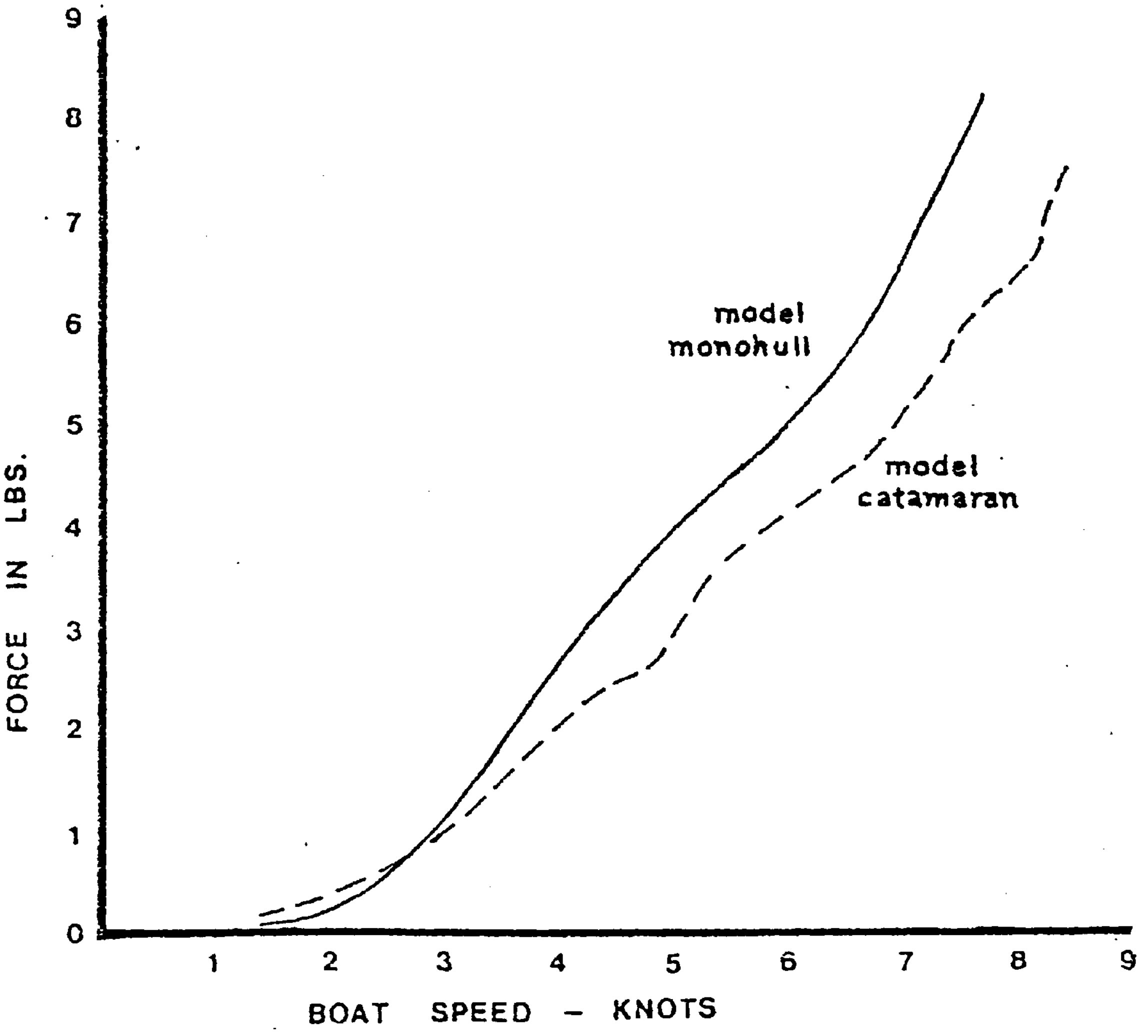
A is the sail area

C_L is the aerodynamic force coefficient

Note that the force applied to a sail is proportional to the square of the velocity of the wind. The hydrodynamic resistance of a hull, though more complicated, can be expressed as the summation of skin friction, wave-making resistance, induced resistance or resistance due to leeway, and heeling resistance (Marchaj, 1964). The last two components, resistance due to leeway and heeling resistance, can be neglected because their contribution to the total hydrodynamic resistance is minimal for the types of boats discussed in this report. Within the range of velocities of concern here, skin friction is proportional to the square of the velocity of the water with respect to the boat, thereby mostly compensating for the squared effect of the wind's force on the sails. The real variability lies in the wave-making resistance which is proportional to the square of the height of the bow wave caused by the motion of the boat through the water. At low velocities wave-making resistance is small and a small increase in wind velocity will result in a large increase in boat speed. This effect is important when considering the minimum wind velocity needed to launch a boat. As the wind velocity and resultant boat velocity increases, the height of the induced hull wave from light-weight monohulls, multihulls, and surfboard-sailboats rises, but not linearly, as is basically the case with heavy, displacement hull boats. At a certain velocity, light weight monohulls and surfboard-sailboats begin to plane, deriving a degree of lift from the water. The narrow hulls and associated wave coupling of a multihull produce an erratic drag curve which at low velocities is greater than that produced by a monohull of equal weight, and at high velocities considerably less than that produced by a monohull. The hull drag versus velocity curves for a typical model monohull and small model catamaran are shown in Figure 5.

Boat velocity is related to successful surf launching and so it is possible to relate wind velocity and boat launching ease. Below a wind velocity of 3 to 4 knots sailboats using only sail power cannot launch through the surf. Between a wind velocity of 3 to 6 knots launching is possible, but often difficult, depending on wave conditions. Launching in winds of 6 to 18 knots is best, whereas 10 to 12 knots is optimum for most boats. Above a wind velocity of 18 knots small boats are difficult to

Figure 5. The relationship between applied force and resultant boat velocity of a model monohull and model catamaran (after Marchaj, 1964).


FORCE IN LBS.
0
1
2
3
4
5
6
7
8
9
model
monohull
model
catamaran
1
2
3
4
5
6
7
8
9
BOAT SPEED – KNOTS

sail either through the surf or in the open ocean. This is shown in Table I which is a scale of wind velocities, their Beaufort number, sea state, psychological scale and, most importantly, a numerical rating of launching ease under those wind velocities.

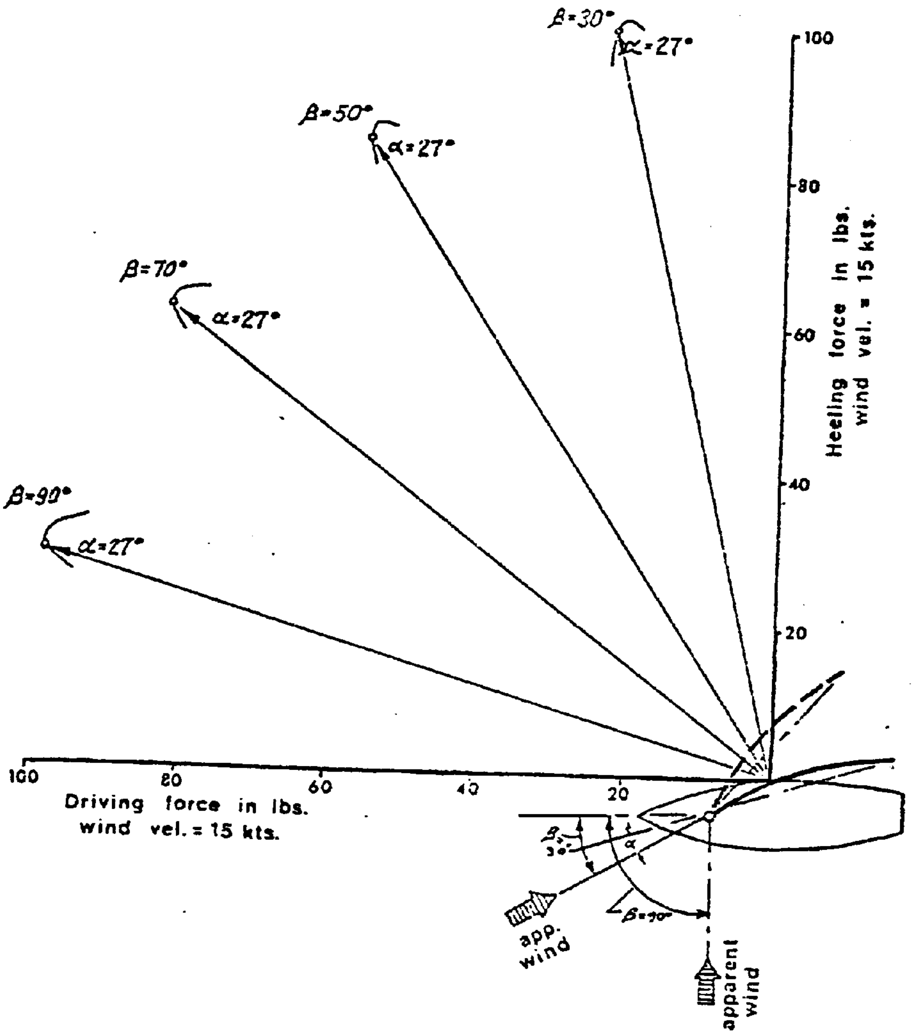
The proper wind direction for boat launching is more crucial than sufficient wind velocity for, in most cases, if there is enough wind to motivate the sailor to rig his boat, there is enough wind to sail through the surf, providing the wind is from the proper direction and the surf is moderate.

In the launching process, a sailboat should be kept perpendicular to the surf, which is only possible when the wind blows at an angle greater than 45° from the perpendicular to the wave fronts. Within the surf zone wave fronts are generally parallel to the shoreline, so for ease of reference wind direction will be stated in terms relative to the shoreline, not the wave fronts. In small surf under 1 m (3 feet) launching or retrieving may be accomplished at a slight angle to the perpendicular to the shoreline, extending the range of favorable wind directions. In surf under 30 cm (1 foot) high, launching is possible regardless of wind direction.

As the angle between the shoreline perpendicular and the direction of the wind increases, the angle of wind incidence to boat direction increases, which results in a greater component of wind-derived propulsion being directed forward. The greater the component of forward force applied to the boat, the greater the boat's resistance to shoreward moving surface waters (wave swash) and the greater the potential boat speed. Figure 6 illustrate this relationship between the angle of wind incidence to the sail and the resultant lateral and forward forces. The combined effect of wind direction variability and hull configuration on boat velocity (Fig. 7) indicates that incident wind directions between 80° and 100° from the centerline of the boat produce the greatest velocities and therefore present the best conditions for boat launching. Such variability in speed as a function of wind incidence is more pronounced with multihulls than with monohulls (Fig. 7).

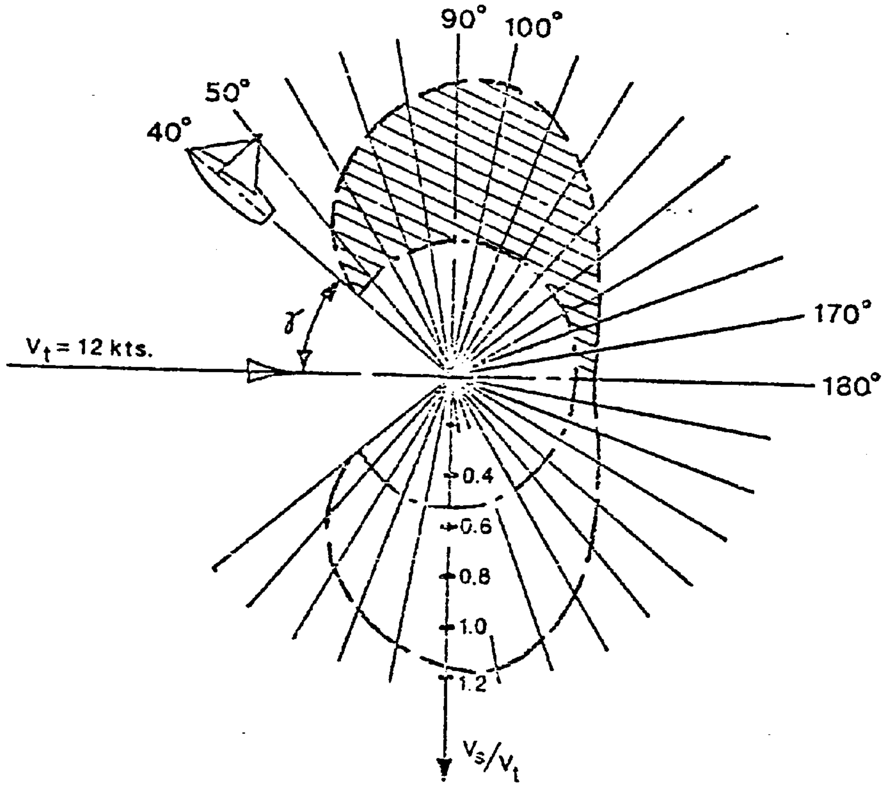
Recalling from the previous section that the amount of forward directed wind force is not linearly related to boat speed in flat water, it is further noted that a boat being launched through the surf zone is usually accelerating or decelerating. Therefore, at any moment in time a boat may have zero velocity and a large amount of wind force directed forward. The amount of forward driving force is more important than boat speed, for if the driving force is greater than the drag force applied by the waves the boat will eventually sail through the surf zone. High boat speed between waves does not

Figure 6. The relationship between the angle of attack of the wind with respect to the centerline of a boat and the resultant heeling and driving force, at optimum sail setting (27°) (after Marchaj, 1964).



β=30° α=27°
β=50° α=27°
β=70° α=27°
β=90° α=27°
100
80
60
40
20
Heeling force in lbs.
wind vel. = 15 kts.
100
80
60
40
20
Driving force in lbs.
wind vel. = 15 kts.
β=30°
α
β=90°
app. wind
apparent wind

Figure 7. The net result of the relationships depicted in Figures 5 and 6; boat velocity in terms of wind velocity ($^{Vs}/_{Vt}$) for various incident wind angles. Outer line is for a catamaran, inner line for a monohull.



90°
100°
50°
40°
γ
V_t = 12 kts.
170°
180°
0.4
0.6
0.8
1.0
1.2
V_s/V_t

always insure a successful launching.

A rating of the favorability of various wind directions is shown in Table IV. Winds blowing alongshore are the most favorable and winds blowing directly onshore the least favorable. Because both launching and retrieving are taken into account, the ratings are nearly symmetrical with respect to the shoreline. Retrieving requires less force, making offshore winds slightly more favorable than onshore winds.

Total Process

By combining the effect of all the parameters, the total launching process can be analyzed. When the surf is low and the wind is both moderate and parallel to the shoreline, conditions are ideal for open beach launching and a novice sailor should have no difficulty in launching a suitable boat off the beach. High surf and onshore winds which are either very light or very strong are conditions which make launching difficult, regardless of the type of boat used. Between these two extremes are a myriad of conditions which might be present at any one time at a specific beach.

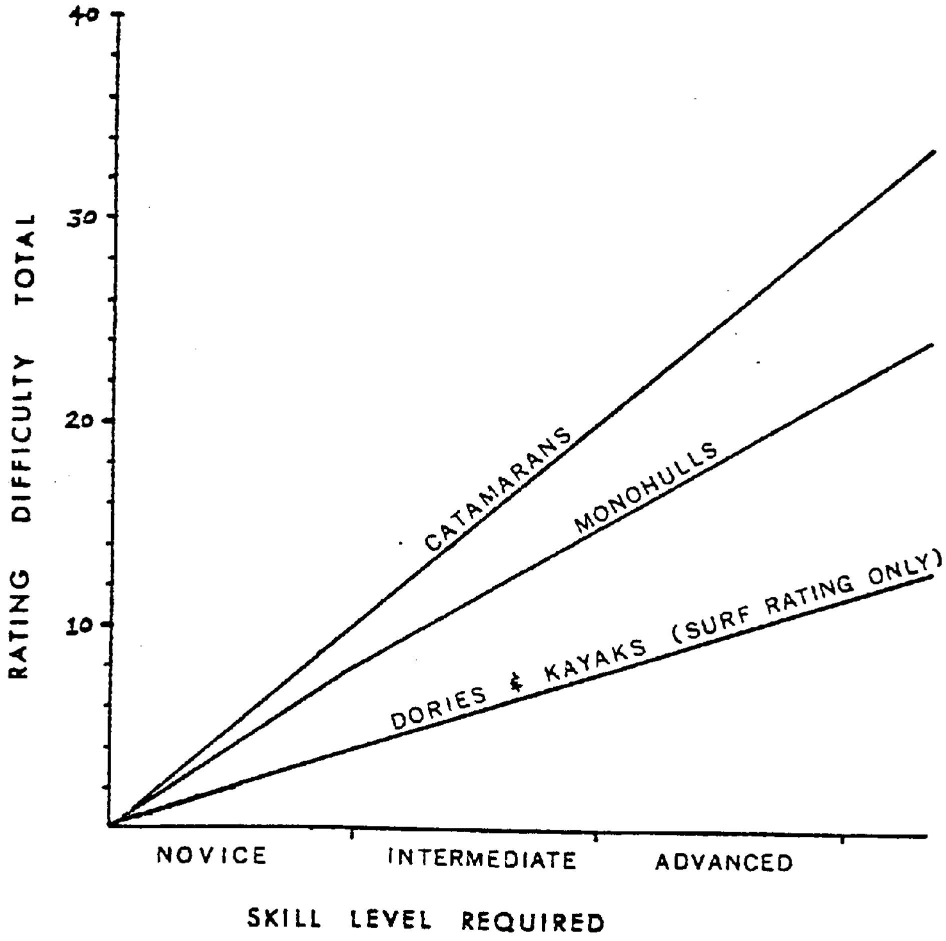
Tables II through IV are summations of the previous three sections on surf, wind velocity, and wind direction. Each chart gives a "difficulty rating" to each parameter. A total difficulty rating is arrived at by a summation of ratings for each parameter for a given weather condition (except for rowboats, where only the surf rating is used). Then, by applying this rating number to the appropriate boat type in Table V, the total launching difficulty which is defined in terms of sailing skill can be determined. The rougher the conditions, the greater the sailing skill required to launch a boat. For the purpose of classifying sailing skill, the terms novice, intermediate and advanced sailor are used, but they are only approximate evaluations and there is obviously a continuous gradation as one moves along the abcissa of Table V.

The year-round suitability of a particular beach can be determined by applying the daily weather conditions of that beach to Table V. One can then determine how many days out of the year a novice, intermediate or advanced sailor will be able to use the beach.

By altering the environment, man can change the number of suitable launching days in any of the skill categories or, by raising the level of sailing skill, change the number of people in each. Since wind velocities and directions are hard to change, the only major physical parameter capable of being altered is the surf size and form. The objective then would be a compromise between patron use (maximum range of skill levels, not number of users *per se*) and concern for the environmental effect of the alteration.

CHART V

TOTAL PROCESS



TOPANGA BEACH - A CASE STUDY

Introduction

The first step in applying the open beach launching concept is to find a beach which meets the aforementioned criteria. The beach should be sandy and not suitable for other special beach activities. Prevailing surf should be small and the average afternoon winds should not blow directly onshore. The southeastern portion of Topanga Beach meets these criteria and because it is also newly acquired public land, was chosen as a test site. Theoretically, the year-round weather conditions at Topanga Beach should have been applied to the tables developed in the previous section (Tables II-V) to determine the applicability of the beach to the concept, but these charts were developed after the test site was chosen. This sequence of events was unavoidable, given the time scale of the project. The general year-round physical environment of Topanga, and the requirements for boat launching, were known to the author before this project was started and therefore it was possible to select Topanga as a potential site prior to developing Tables II-V).

The second step is to investigate the environment of the test site. The information thus obtained can then be used to determine the most advantageous placement for launching ramps, roads, and storage areas, the degree of wave attenuation needed for safe boat launching, and the environmental impact of the facility.

Methodology

Underwater Morphology Mapping

Little work has been undertaken in the field of offshore, total coverage, underwater mapping. Due to the vast area of the ocean bottom, limited visibility, and inaccessibility, most mapping has been done by either remote sensing as sonar and seismic profiles or by point sampling from the surface. The former method results in a series of transect lines providing information about the topography, bottom composition, or substrate, depending on the frequency range of the sending and recording units. The geology between the transects is inferred, based on the trends of the closest transects. Point sampling is also accomplished from the surface and generally consists of obtaining bottom samples at pre-determined locations and inferring the geology between the points. In conjunction with fathometer readings, the point sampling method gives both topography and bottom composition with reliability dependent on the sampling interval.

Within the near offshore, though, in depths of water accessible to the SCUBA divers, it is possible to actually map underwater, visibility permitting. The only reference material found pertaining to this type of mapping was Hendricks (1972) and a survey of the Los Angeles County coastline (Egstrom, 1974) for which this author was a part-time diver.

The survey technique used by Egstrom was quick but lacking in accuracy. Divers swam compass courses from well-located points along the beach to approximately 1000 feet offshore, recording data and water depth (with capillary or oil pressure gauges) along the way. The recorded data were later geographically plotted by correlating the recorded depth measurements and compass course with available topographic maps. There are two major possible sources of error in this technique: (1) water depths determined by either capillary or oil pressure gauges are influenced by waves passing on the surface and are only accurate in still water to about 5 percent at best, and (2) topographic maps do not reflect the fact that topography in the near offshore constantly changes. The data presented (Egstrom, 1974) introduces a horizontal placement error of ± 33 feet on a 3 percent slope (typical of the offshore at Topanga) for every 1 foot error in measurement of water depth. Errors in depth measurements probably exceeded ± 3 feet at times, which would introduce a horizontal placement error of at least ± 100 feet.

Hendricks (1972) attempted three different approaches to field survey techniques in the near offshore:

1. Surface work - hand soundings from a surfboard to obtain bathymetry using range poles and a plane table station for locationing.
2. Hand leveling underwater with range poles and a level to obtain bathymetric and bottom composition data and biological samples.
3. Fixed point transects laid on the bottom with both ends located by triangulation to obtain bottom composition data and biological samples.

None of these methods seemed completely suitable for making a detailed morphological map of the near offshore at Topanga Beach. Surface work did not yield sufficient information and was unreliable because without seeing the area surrounding the sample, one might be getting anomalous data. Line leveling yielded sufficient data but was too slow and physically impossible at an open-ocean beach like Topanga where surges are common. Fixed point transects were the most promising, but alone were not sufficient.

The morphological map presented in the report was prepared by collating data from an existing topographic land map prepared by the Los Angeles County Engineers from transects that extended from the beach to 1000 feet offshore and from surface location of underwater divers "walking" the contacts.

Transects were accomplished with the aid of a 1000-foot dacron line (low stretch, non-buoyant) which was marked off in 10-foot intervals and tagged every 100 feet. One end of the transect line was staked on shore and located by obtaining compass bearings on known objects. The other end of the line was transported beyond the surf zone by either a rowboat or paddleboard, stretched taut, and then anchored to the bottom. Divers would then swim to the buoyed, seaward end of the transect line, descend along the buoyed line and initiate the transect. Starting at the seaward end of the transect allows the diver to do the deepest part of the dive first, aiding in decompression when necessary. Swimming in this direction also makes it easier for the diver to extend the transect as far into the surf zone as is visually and physically possible. Where only shallow work was involved, swimming from the shallow end to a boat at the seaward end of the transect proved to be quite useful. The boat could then transport the diver's gear and samples back to the beach. Ideally, if one had two transect lines laid out, a diver could swim out on one line and back on another. The horizontal accuracy of this method is estimated to be ± 5 feet. Inaccuracies generally occurred when the transect line would stretch, creating an error in recorded distance from the beach (maximum ± 5 feet), and when the line would sag downcoast under the influence of the longshore current. This sag was compensated for and approximately measured but an error of ± 5 feet in location along the beach may still have resulted.

Along the transect line, changes in topography, bottom composition, and ripple mark wavelength and orientation were noted and recorded on lucite tablets. At 100-foot intervals bottom samples were obtained and the depth of water recorded. Biological data were also recorded on the transects by Ray Emerson for University of Southern California Sea Grant Project R/CM3.

Before determining the number of transects to be made along Topanga Beach, the entire area was surveyed by a group of volunteer divers. These divers were sent into the water at a variety of locations, given a compass course to follow, and asked to record what they saw. The resulting information enabled the author to obtain the general "feel" for the area in a short period of time and aided in the determination of sampling intervals. One thousand feet was chosen as a transect length for three reasons. First, the proposed breakwater falls within the 1000 foot mark offshore, second, it is a distance which can easily be managed with one 72 cubic foot tank of air and allow time for sampling, and third, 1000 feet offshore the water depth is approximately 30 feet and in this area 95 percent of wave energy is dissipated (Dietz and Fairbridge, 1968).

Walking the contacts is a method used in geologic mapping on land. In its underwater application the technique consists of one or more divers who follow or swim along a contact; in this case the contact between rocky bottom and sandy bottom. The diver has a safety-communications line attached to his waist which leads to a small boat on the surface. As the diver swims the contact, the boat on the surface locates the diver by triangulation on predetermined sighting points on the beach. If the diver wants a fix (location reading) taken, he can then communicate with the boat through his safety line by a series of jerks. Hooka diving gear with a diver-to-boat communication system would be the best type of apparatus to use with this method but unfortunately none was available at the time of the surveys. Accurate depth measurements can be made simultaneously with location by simply marking off the safety line in one-foot or one-half foot intervals. This method of walking the contacts proved to be very useful and with the aid of a Suunto sighting compass, a fix could be made in less than one minute.

Where spot samples were needed to fill in the gaps between transects, a small boat would position into place, drop a weighted line and a diver would descend down the line and recover a sample. The small boat most often used was an 8-foot Sabot-type dingy.

These techniques appear to be simple and crude, but it must be remembered that the near offshore is a difficult environment in which to work and as is often the case, only the most simple techniques work. Of the myriad of adverse influences, bottom surges and restricted visibility are the most difficult with which to cope. Bottom surge, which increases as one approaches the shore, makes sampling or measuring difficult, for it is almost impossible to stay on location. Visibility in the near offshore is never good along a sandy, open-ocean beach and at Topanga Beach average visibility ranged from 0.5 to 2 feet in shallow water (5 to 15 feet) and from 2 to 15 feet in deeper water (15 to 35 feet). Aside from occasionally losing sight of the transect line, anything that drifted more than a foot away was generally lost forever.

The techniques used were effective and resulted in much greater accuracy than those methods previously cited. The techniques were time consuming at first, but once perfected, mapping proceeded rapidly. A combination biological-geological 1000-foot transect was successfully completed in a few hours, including set-up time.

The extent to which an offshore survey should be made is dependent upon the data received from the reconnaissance dives and the purpose of the survey. It is felt that the construction of any offshore structure should be accompanied by a detailed survey of at least the accuracy and extent presented here, although with better equipment and more experience such a survey could be accomplished in less time and with less expense. (Fig. 8).

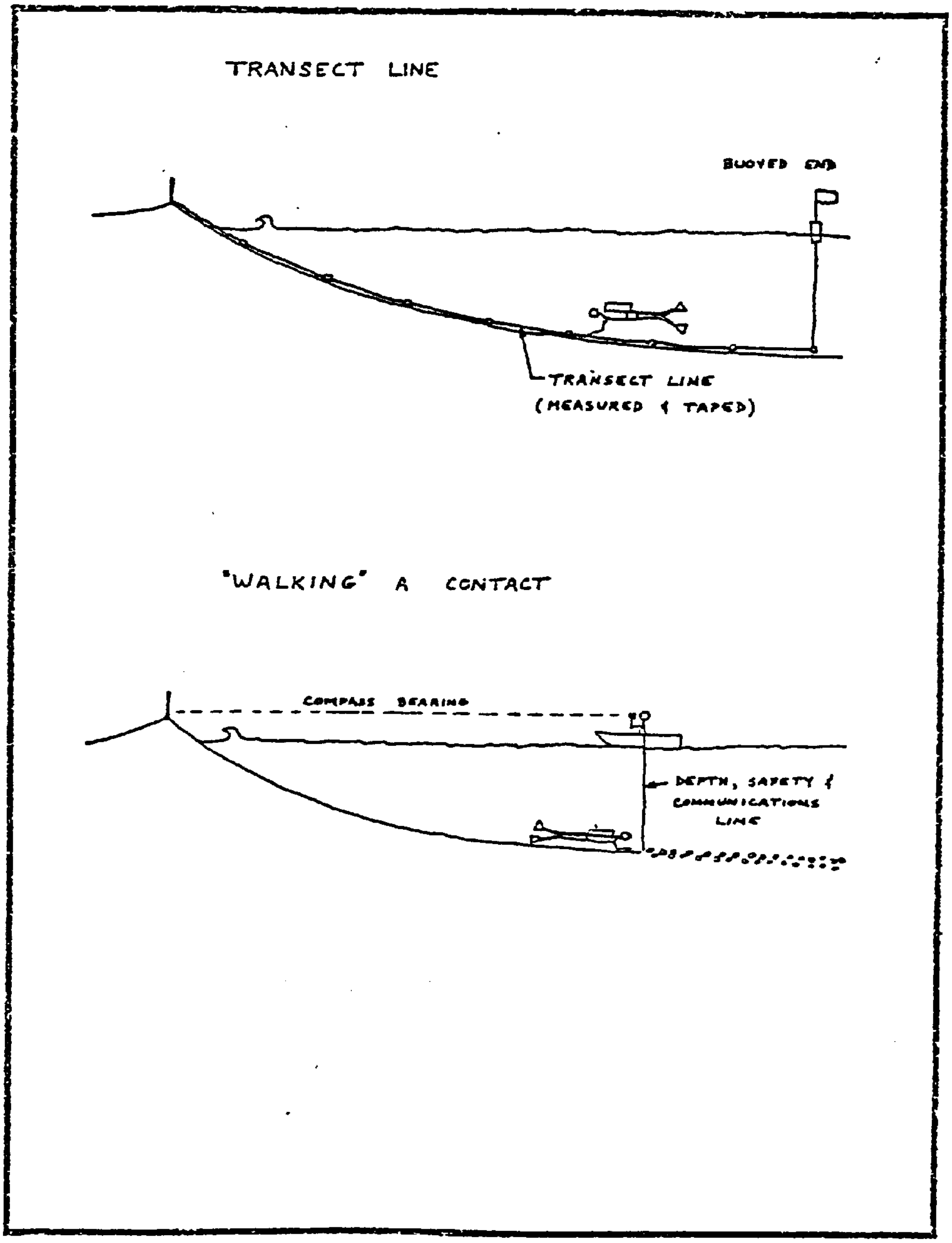
Bathymetry

Offshore bathymetry measurements were done with the aid of a weighted handline and a Ray Jefferson Model 5240 fathometer. Using the same 9-foot dingy that was used to lay out the transect lines, a number of handline soundings were taken. Location of the soundings were obtained by triangulation to known points on land using a Suunto hand-bearing compass. Soundings were corrected for tidal level and then translated onto the base map, from which contour lines were drawn. Fathometer runs were made to determine the nature of the bathymetry between the handline soundings in deep water. The bathymetry at Topanga Beach is quite shallow and it is not possible to bring a boat equipped with a fathometer close to shore. The combination of hand-line sounding with fathometer readings provided the accuracy of handline soundings with the rapid coverage of area only possible with a fathometer.

Beach Profiles

Determination of the profile of Topanga Beach was

Figure 8. Pictorial representation of underwater mapping methodology.


TRANSECT LINE
BUOYED END
TRANSECT LINE
(MEASURED & TAPED)
'WALKING' A CONTACT
COMPASS BEARING
DEPTH, SAFETY &
COMMUNICATIONS
LINE

made with the aid of two transect poles, a measured dacron line and a Brunton compass. Using a method similar to the one outlined by Emery (1961), two range poles were staked out perpendicular to the shoreline at a predetermined horizontal distance apart; the difference in ground height between the range poles was then obtained by using the Brunton compass as a hand-bearing line-of-sight leveler. Emery used a third pole and a bubble level to determine the difference in height between the range poles. His method is more accurate but slower. Accuracy was not the foremost criterion, however, since this report is concerned only with the more gross changes in the profile of the beach.

Current Study

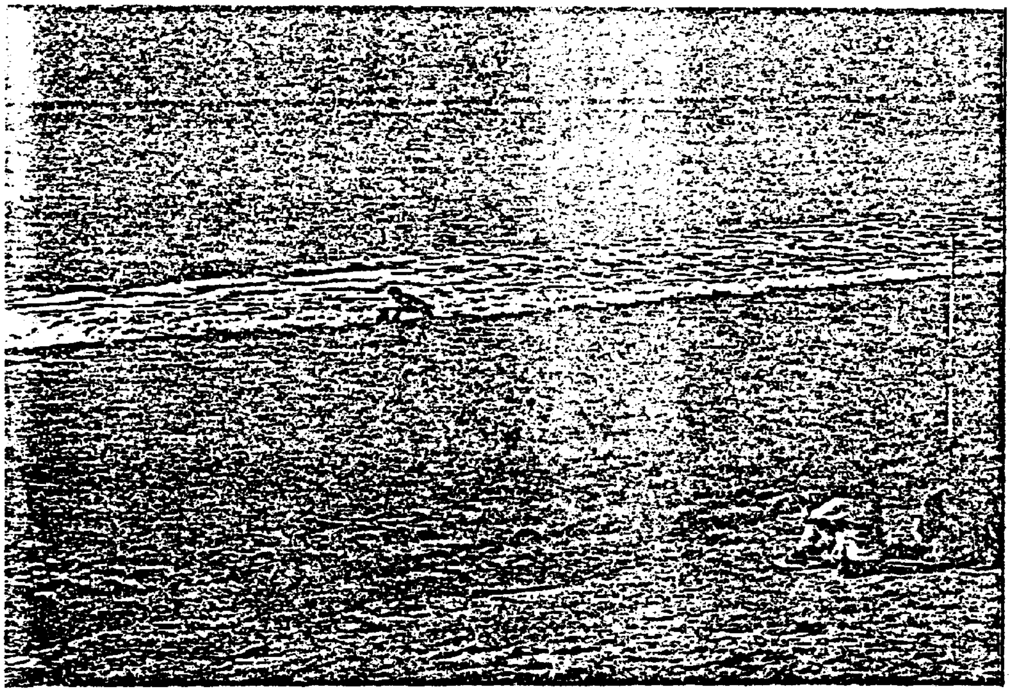
Longshore current velocities and directions were calculated by observing the movement of fluorescein dye patches along the beach. Two to three teaspoons of fluorescein dye were dissolved in a bucket of seawater and then released in the middle of the surf zone. The velocity of the dye patch was measured by recording its time of transit between two transect poles staked on the beach parallel to the shoreline. Greater accuracy was obtained by releasing a number of small dye patches along the beach as compared to releasing one large patch and attempting to record its change in velocity as it traversed the entire beach. Photographs 1 through 4 show the fluorescein dye studies in progress.

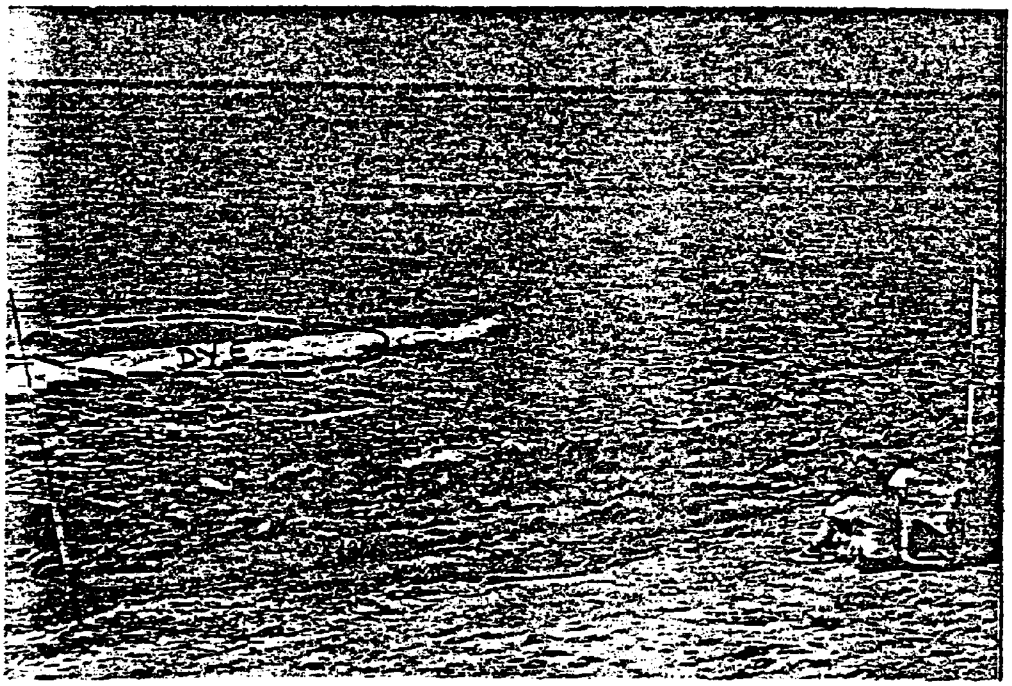
Location

Topanga Beach is on the shoreline of Santa Monica Bay, approximately 5 km (3 miles) northwest of the city of Santa Monica and 10 km (6 miles) southeast of Malibu Creek (Fig. 9). Owned by the State of California and operated by the Los Angeles County Department of Beaches, this 2 km (1.1 mile) stretch of beach is separated into two areas, North and South Topanga Beach with the Chart House Restaurant dividing the two areas. North Topanga Beach is the study area. This 1 km (0.5 mile) stretch of beach is bounded to the north by a steel jetty 60 m (200 feet) north of the Topanga Creek outlet and to the south by the Chart House Restaurant. The width of the beach ranges from 90 m (300 feet) at the northwestern end near Topanga Creek to less than 30 m (100 feet) at the southeastern end near the restaurant. Pacific Coast Highway is along the top of the coastal bluff which marks the landward extent of the beach.

Photographs 1 and 2:

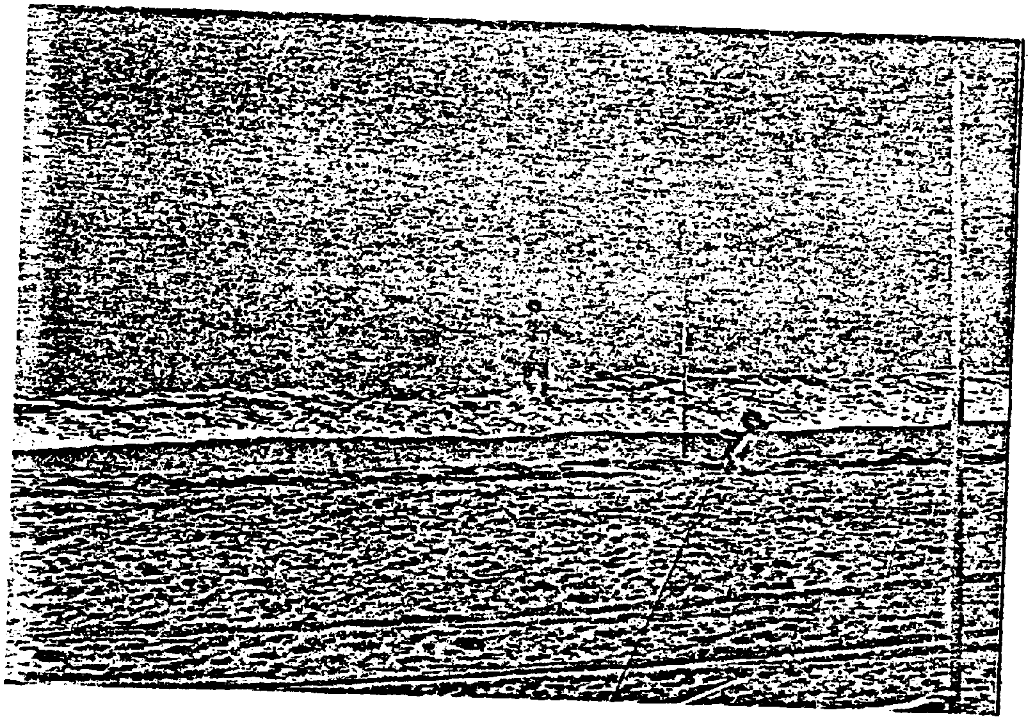
Fluorescein dye experiment in progress along the northwestern part of Topanga Beach.





Photographs 3 and 4:

Fluorescein dye experiment in progress along the southeastern part of Topanga Beach.



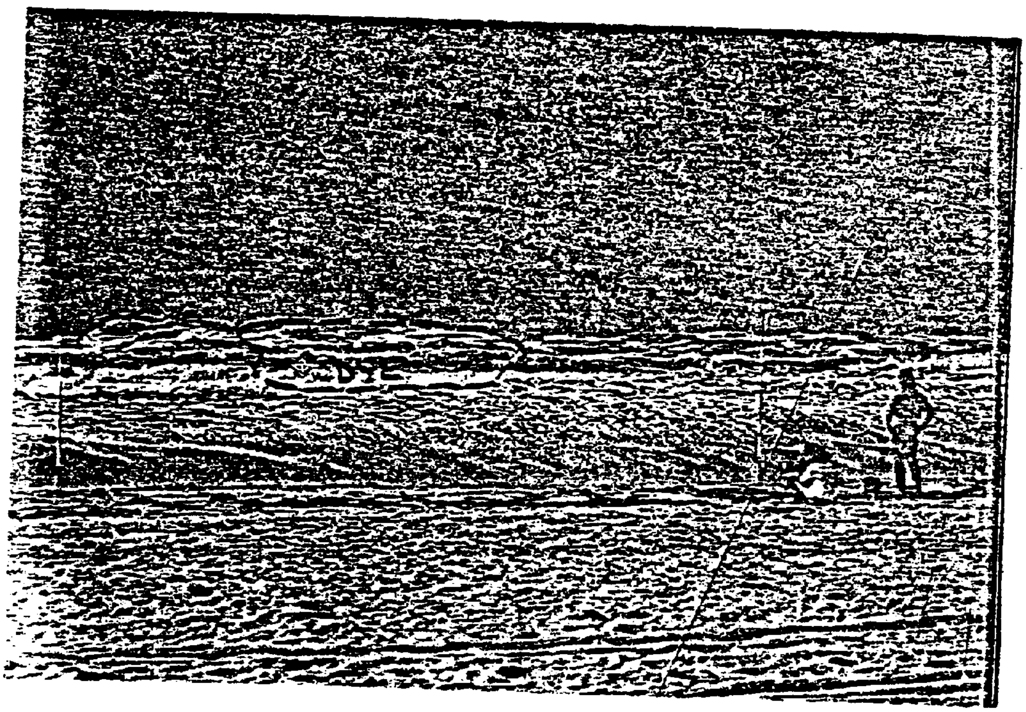
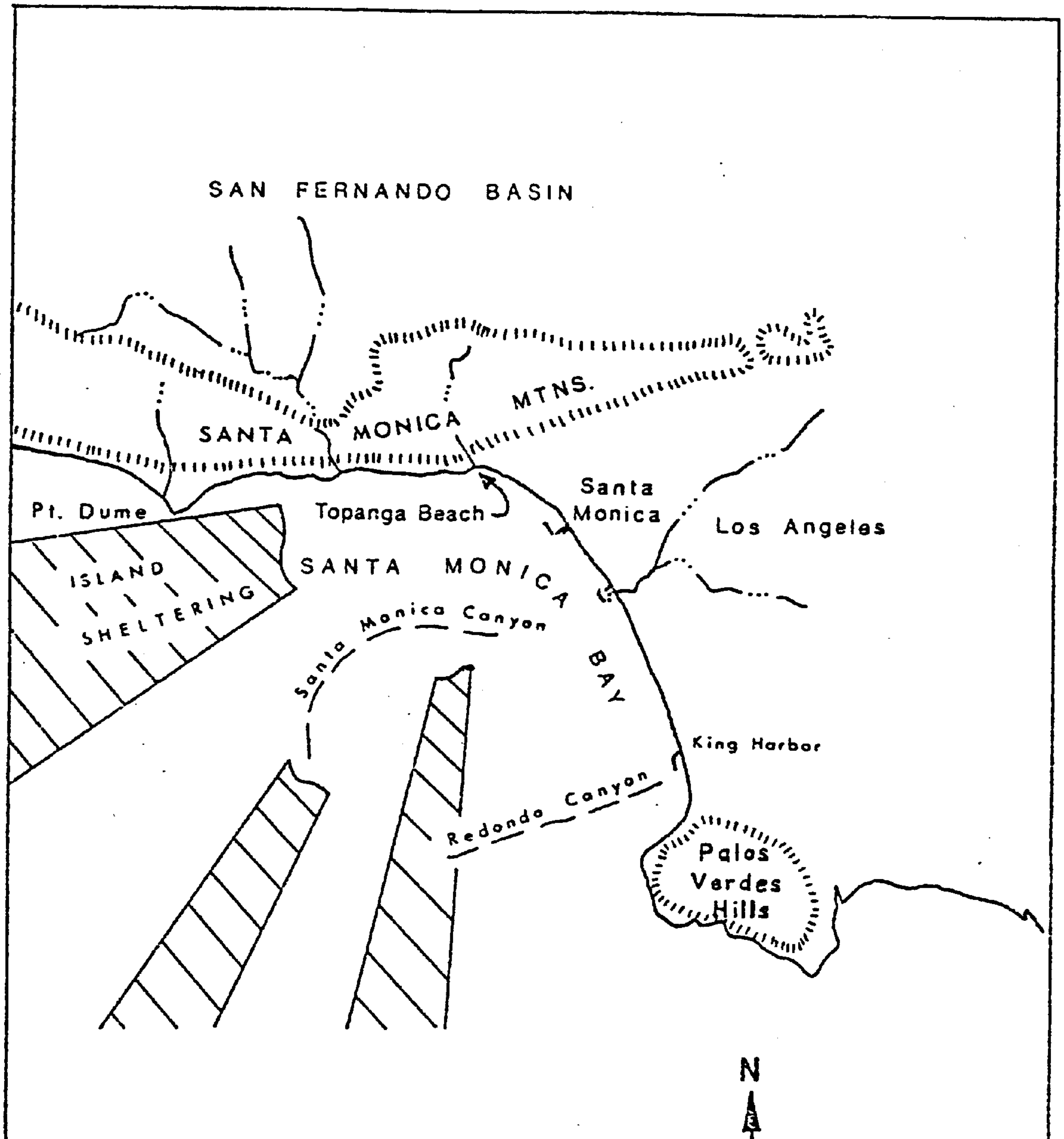


Figure 9. Location map and island sheltering effect.



SANTA MONICA BAY
AND
SURROUNDING AREA

Climate*

Southern California has a Mediterranean type climate with a coastal Maritime fringe. Average annual precipitation for the Topanga watershed is 31.5 cm (25.4 inches). Average annual temperature is 16.4° C (61.4° F).

Regional and Site Geology

Topanga Beach is situated along the northern edge of a crescent-shaped indenture of the California coastline called Santa Monica Bay. The Bay is bound by three physiographic provinces: the Santa Monica Mountains on the north, the Los Angeles coastal plain to the east, and the Palos Verdes Peninsula on the south. The Santa Monica Mountains, which form the northern backdrop to Topanga Beach, trend east-west and range in elevation from 360 m in the east to more than 900 m at the western end, approximately 40 km to the west. Rocks exposed in the mountains adjacent to Topanga Beach range in age from Cretaceous to Quaternary.

Low sea-cliffs form the local backdrop to the beach. They are approximately 6 m and are described as Miocene volcanics to the west of Topanga Creek in thrust

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* U. S. Weather Bureau, 1914-1962, Los Angeles County Flood Control District, 1948.

fault contact with Upper Cretaceous marine sediménts (Chico and Martinez formation) to the east of the creek (Hoots, 1930).

Tides

The mean tidal range at Topanga Beach is 1.16 m (3.8 feet) with a maximum diurnal range of 1.65 m (5.4 feet); the extreme tidal range is 3.05 m (10.0 feet) and the mean sea level, measured from mean lower low water, is .85 m (2.8 feet).

General Topography and Morphology

The western end of North Topanga Beach is rocky from below mean low tide to approximately 180 m (600 feet) offshore and the eastern end of the beach which is sandy throughout, from the seacliffs which form the backdrop to at least 600 m offshore.

Seismology

Topanga Beach is in the seismically active area assigned to Zone 3, Seismic Risk Map of the United States (1969) and has a rating of two (moderage probable damage) in the South Coast Commission Regional Geology report. Although no field evidence has been found that would indicate recent seismic activity, a number of earthquakes have occurred nearby in recent years. Movement on the

Newport-Inglewood and Charnock Fault zones, 16-20 km respectively, east of the site have produced earthquakes of magnitude 4.5 to 4.9 on the Richter scale. A 5.9 magnitude earthquake occurred on February 21, 1973 offshore from Pt. Mugu about 40 km east of the site and a 5.2 magnitude quake was recorded on August 30, 1930 in Santa Monica Bay about 30 km south of the site. On February 6, 1971 a 6.4 magnitude quake occurred near San Fernando 50 km northeast of the site. The Malibu Coast Fault parallels the shoreline one mile offshore from the site but has not been recently active.

General Sedimentary Cycle

Topanga Beach is part of the Santa Monica littoral cell. This cell contains a complete cycle of littoral transportation and sedimentation, including sources and sinks of sediment and transport paths (Inman and Brush, 1973). Rivers emptying into the Santa Monica Bay are the principal sources of sediment, contributing an average of 12,000 cubic meters (16,000 yd^3) a year (Southern California Coastal Water Research Project, 1973). The flow rate of these sediments is erratic and governed by rainfall. During the days following precipitation, large amounts of sediment are transported to the beaches, while during dry periods streams contribute little or no new sediment. Contribution of any one stream is difficult to trace owing to the similar mineralogical nature of stream samples from the Santa Monica Mountains (Handin, 1951). Studies by Pipkin (1967) indicate that coastal erosion contributes less than 10 percent of the sediment to the beaches in this area.

Sediment which is brought to the beaches by the rivers is transported along the coast and offshore by waves and currents. The primary alongshore "conveyor belt" is the longshore current, a nearshore current within the surf zone created when waves approach a beach at an angle. The component of wave energy which is directed parallel to the shoreline is the driving force of this current. This longshore component and associated sediment transport is a function of wave power flux, angle of wave attack, and bottom profile. The wave power flux is dependent on weather and wave conditions and is at a maximum during storms when waves are at maximum height and frequency. The angle of wave approach varies considerably in Santa Monica Bay but is restricted by headlands and offshore islands and altered by offshore topography.

Local storms occur during any season, producing northerly to westerly short period (10 sec or less) waves. Some storms also produce southerly waves because of pre-frontal winds. These storms tend only to occur during the winter months. Storms from the North Pacific generally occur from late fall to early spring and produce northwesterly to westerly waves with periods from 10 to 18 sec. Mexican tropical storms and Antarctic storms occur in late spring through early fall and produce southerly waves with periods between 10 and 24 sec.

These varied wave conditions cause many beaches along the Santa Monica Bay to experience longshore currents in both a northerly and southerly direction, depending on the wave approach angle. The net sediment drift is southeasterly, from Pt. Dume to Redondo, and is estimated at 188,000 to 218,000 cu m (250,000 to 300,000 yd^3 per year along Santa Monica Beach (Bascom, 1964, and Southern California Coastal Water Research Project, 1973). From Palos Verdes Point to Redondo Beach there is no net drift.

The sediment which travels in the littoral "conveyor belt" is either eventually transported offshore and deposited on the continental shelf or transported along the shore until it reaches an active submarine canyon which serves as a pathway to the floors of the offshore basins. Of course, man-made obstructions such as dams, groins and breakwaters can alter this natural flow of sediment causing accretion or erosion.

There are two submarine canyons in Santa Monica Bay: the Santa Monica Canyon and the Redondo Canyon. The head of the Santa Monica Canyon is 8 km off the coast of Venice Beach (8 km south of Topanga Beach) at a depth of 80 m.

The canyon is 13 km long and extends to a depth of 500 m. It is not believed to be an active path for sediment movement. The head of the Redondo Canyon, however, is near the entrance to King Harbor at a depth of 20 m and is known to be an active canyon. Redondo Canyon is approximately 13 km in length and reaches to a depth of 700 m. It has been shown that sand-sized sediment which is not deposited on the beaches in Santa Monica Bay and is not transported offshore is transported down the Redondo Canyon into the Catalina Basin.

Coastal Processes

Waves

Wave dynamics are an important physical parameter in this project for two reasons: first, they are a major factor in open beach boat launching, and second, they are the motivating force behind coastal currents. Presented here are the general wave characteristics of Topanga Beach. The daily wave data collected by Topanga lifeguards is shown later in this report in correlation with beach profile changes (refer to section on Beach Profile Alteration).

Long period waves approach Topanga Beach by means of three "channels" owing to the sheltering effect of offshore islands and banks (Fig. 9). The three channels are between azimuths of 265° and 237°--between the Channel Islands and San Nicolas-Santa Barbara Island; 214° and 205°--between Santa Barbara Island and Cortes-Tanner Banks; and 192° and 182°--between Cortes Bank and Santa Catalina-San Clemente Island (Army Corp of Engineers, 1974). The Mexican and Antarctic storm-produced southerly waves approach the beach from the 182° to 192° and the 205° to 214° pathways. North Pacific storm-produced westerly waves approach from the 237° to 265° pathway. Short period waves, with periods of less than 10 seconds, can be formed locally and may approach from almost any direction except those restricted by the mainland itself, azimuths between 150° and 265°.

Wave heights range between 0.3 and 1.2 m (1 and 4 feet) although extreme heights of 4.5 m (15 feet) have been recorded. Wave refraction causes the western end of the beach, Topanga Point, to have the highest surf. The waves here always break to the right (looking from the wave shoreward); that is, they break in a southeasterly direction. The surf zone usually is wide in this area and the waves are of a spilling or plunging type, depending upon the tidal level and incident wave form. The southeastern section of the beach has lower surf, often one-half the height of the surf at the Point. The surf zone is narrow and "shorebreaks" are common.

The largest waves occur during the summer months when waves approach the beach from the southern sector and pathway. These large, long period waves do not continue very long and they do not have as strong an erosive effect on Topanga as is found elsewhere, a point discussed later. Despite occasional large waves the average sea state in summer is noticeably less severe than during winter.

Long period waves, tsunamis and storm surges, are not common along Santa Monica Bay beaches. When they do occur, they are not very large. Tsunamis strong enough to cause damage have never been reported in the vicinity of Topanga Beach and storm surges rarely exceed 0.2 m (0.6 feet) (U. S. Army Corp of Engineers paper, 1974).

Winds

Wind velocity in the Santa Monica Bay is generally low. Monthly winds average between 5 and 8 knots. The windiest months are March and April, although strong winds up to 33 knots (Force 7) may blow in the months of November through May. During the months of June through September winds are mild; 17 to 21 knot winds (Force 5) occur less than 1 percent of the time and recording of winds over Force 5 is rare.

Winds in the bay usually blow from the southwest to west. This is more common in the summer than in the winter for there is a gradual increase in the percentage of time the wind blows from the southwest to west as summer approaches. In December and January the winds are westerly approximately 22 percent of the time and in July this figure reaches a maximum of 60 percent (Synoptic Weather Report, Los Angeles International Airport).

During the summer months a regular pattern of wind develops at Topanga Beach. At night and during the early morning hours a mild, offshore breeze blows from either the north, down Topanga Canyon, or from the east. Mid-morning hours are generally calm and by late morning the westerly wind usually appears. The westerly increases in strength, reaching a velocity of 10 to 14 knots by mid-afternoon, and then slowly dies down until sunset. Early night hours are calm.

The direction of the westerly winds shifts as one approaches the shore. There is a noticeable tendency for the wind to blow more onshore along the shoreline. This shift in wind direction is significant in relationship to boat launching and will be treated further in the assessment of the applicability of Topanga Beach as a boat launching site.

The U. S. Coast Pilot No. 7 (Dept. of Commerce, 1968) lists only one wind related hazard to mariners in the Santa Monica Bay: Santa Ana winds. Santa Ana's are dry, desert winds which blow from the north-northeast. They can reach velocities up to 50 knots over the water and even higher velocities have been recorded in the restricted canyons of the Santa Monica Mountains. These winds generally occur during the fall months and can be very localized. Northeasterly winds over 30 knots can occur at Topanga Beach, at the base of Topanga Canyon, while less than 3.2 km away in front of Santa Monica Beach the wind will be calm. Upwelling and beach sediment transport can be caused by these winds. At Marina del Rey, 7.2 km south of Topanga, wind-related sediment transport in a southerly direction is estimated to be 7600 cu m (10,000 yd^3) per year. The wind fetch over the beach for northerly winds at Topanga is very short, however, and weekly surveys showed that little aeolian transport occurs.

Nearshore Currents

There are two major types of currents in the nearshore zone which transport significant amounts of sediment: longshore currents and cell-circulation currents. The latter are a combination of rip currents and associated longshore currents. Tidal currents and oscillatory water motion caused by surface waves also are important currents but have less net effect and will be discussed later.

Longshore currents caused by oblique wave approach have for many years been the topic of theoretical and experimental work. Many hypotheses have been developed to explain their generation and predict their magnitude.

Recent work by Bowen (1969a) attributes longshore current generation to the longshore component of the radiation stress from shoaling waves. The flux towards the shoreline (x-direction) of the momentum directed parallel to the shoreline (y-direction) is determined to be:

$$S_{xy} = E\, n \sin\alpha \cos\alpha \qquad (1)$$

where E is the energy density of the waves in deep water, n is the ratio of group (energy) velocity to phase velocity, and α is the waves angle of incidence. Using this radiation stress approach Longuet-Higgins (1970) derived the following relationship for the longshore current velocity:

$$\overline{V}_{\ell} = \frac{5\pi}{8} \frac{\tan\beta}{cf} u_m \sin\alpha_b \cos\alpha_b \qquad (2)$$

where c_f is the drag coefficient, u_m is the maximum value of the horizontal orbital velocity evaluated at the breaker zone, $\tan\beta$ is the slope of the beach, and α_b is the wave angle at the breaker line. Based on sand transport data and current velocity measurements in the field, Komar and Inman (1970) arrived at a similar relationship:

$$\overline{V}_{\ell} = 2.7\, u_m \sin\alpha_b \qquad (3)$$

The difference between the two is basically whether the beach slope and the drag coefficient (c_f) increase proportionally, and thereby remain a constant factor, or whether they are variables. Komar (1975) suggested that

$$\frac{\tan\beta \cos\alpha_b}{c_f} = \text{constant} \qquad (4)$$

and that equation (3) is valid and consistent with field data. One can see from these equations that the longshore current velocity and associated transport is a function of wave dimensions (height, period and steepness) which affects wave orbit diameter (u_m) and the angle of wave approach. Topanga Beach is susceptible to considerable variation in both of these factors. The general pattern of incident wave dimensions and approach angles already has been discussed and is treated further in the section on onshore-offshore movement of sediment. In addition to this long-term variability of longshore current power owing to variation in incident wave power, there exists a variability along the coastline at Topanga caused by the offshore topography and coastline orientation.

Topanga Beach consists of a headland at the mouth of Topanga Creek and a gently curving bay which terminates at the Chart House Restaurant. This nonlinear configuration of the beach and offshore topography changes the angle of wave incidence along the beach and concentrates wave energy on the headland, producing a longshore current maximum at some point along the beach between the headland and the bay, and a longshore current minimum at the bay head and headland.

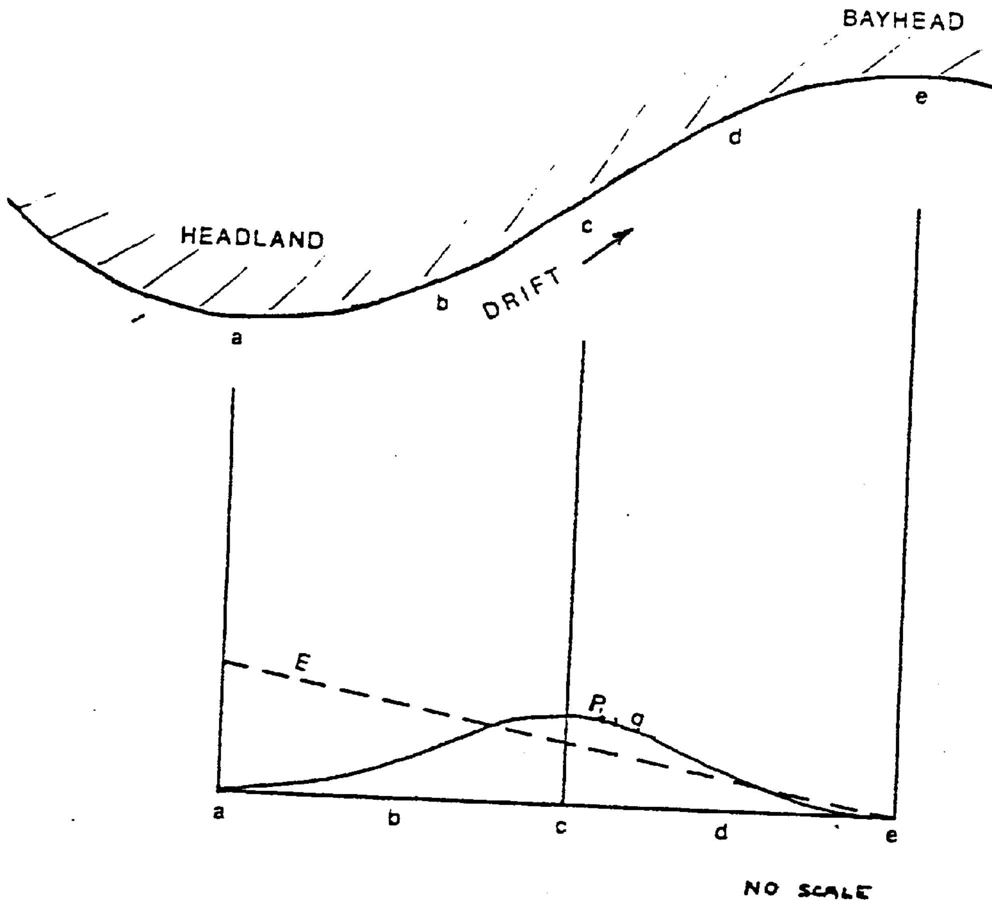
This variability in longshore current along the coast is best explained by the theoretical discussion of May and Tanner (1972) in which it is noted that the longshore component of wave power (P_ℓ) that is effective in transporting sediment in the longshore direction is:

$$P_{\ell} = 0.5 \, P_b \sin 2 \qquad (5)$$

where P_b equals wave power per unit width of crest at the breaker line and β is the wave angle. At the headland there is a point where the wave crest is parallel to the coastline, giving β a value of zero; sin 2β is therefore also zero and $P_{\ell} = 0$. The same condition will prevail at some point along the bay. Somewhere between the headland and the bay β is at a maximum and therefore, for a constant P_b, P_{ℓ} will be at a maximum. However, the wave power per unit width of crest at the breaker point (P_b) does not remain constant. Wave energy is concentrated at headlands and is dissipated along bays, and P_b ranges from a maximum at the headland to a minimum at the bay. This variability in P_b does not change the "zero" points, only the point at which maximum P_{ℓ} will occur. Figure 10 shows in graphic form the variability in longshore current velocity on a nonlinear beach. Note that equation (3) also can be used for this argument.

At Topanga wave direction does not remain constant and the "zero" points as well as points b, c, and d (Fig. 10) will be subject to large changes in position. At Topanga Beach the prevailing wave direction does not generally allow for the existence of "zero" points; the wave approach (β) is almost always greater than zero so that longshore current minimums, not zero points, are

Figure 10. Unscaled relationship between shoreline configuration and littoral drift (after May and Tanner, 1972).



E = Wave energy density

P_L = Littoral power

q = Sand volume delivery rate

produced at the headland and along the bay with a maximum somewhere in between. Because wave energy is concentrated at the headland, the longshore current is greater there than at the bay for the same wave approach angle (β).

If such a variability in longshore current and related sediment drift occurs along Topanga Beach, then the headland should be eroding and the bayhead accreting, but such is not precisely the case. Over a period of approximately 10 years Topanga has not shown any appreciable differential accretion or erosion (personal communication, Shelley Butler, Topanga lifeguard). During periods of low surf (low current velocity) and/or rapid influx of new sediment (because of recent rainfall), the bay head accretes, only to be eroded at some later date by large surf. Between the headland and the bay head little accretion or erosion occurs and one must conclude that the rocky intertidal nature of this stretch of beach is a lag deposit of large rocks and boulders from Topanga Creek. The longshore current, which is at a relative maximum here, is always strong enough to remove fine sediment (sand) from the area but too weak to transport the boulders and the coarse sand trapped between them. The upper foreshore generally remains sandy because this zone is only occasionally, during high tide, under the influence of wave attack.

Estimates of longshore current velocities at Topanga Beach were obtained by putting fluorescein dye in the surf zone. The results of this study confirm the theoretical analysis. Longshore current velocities at the headland and bay head were small in comparison with the velocities found between these two areas.

It was also determined that local wind velocity and direction had a profound effect on the sea conditions and consequently on the magnitude of the longshore current. During calm winds, south to southwesterly swells produced very weak, westerly moving longshore currents near the Chart House Restaurant and the area immediately west of Topanga Point. When the normal, afternoon westerly wind began to blow, the drift direction reversed and flowed eastwardly, following the general current direction along the rest of the beach. Currents which were eastwardly during calm wind conditions increased in velocity and maintained their eastwardly direction under the influence of a westerly wind. It is suggested that during winter months, when the swell approach angle is more westerly, the currents are everywhere eastwardly and possibly stronger than those observed during the summer months.

During summer, longshore current maximums were found along that stretch of beach which is at the greatest angle to the incoming surf line and has the largest wave "set up," a rise in the mean water level above still water level (Station 3 to 3.5, Fig. 11). One to 3-foot surf from the south-southwest produced measured eastwardly current velocities of 9 to 14.5 cm per sec (cm/s) in this area, as compared to 5 cm/s eastwardly currents at Topanga Point and 3 cm/s at the Chart House Restaurant. The same ocean swells, 3 hours later in conjunction with a 10 to 12 knots westerly wind, produced eastwardly currents ranging from 16.5 to 22.5 cm/s in front of the Lifeguard Tower (Station 3.5), 9 to 11.5 cm/s at the point, and 9 cm/s along the bay.

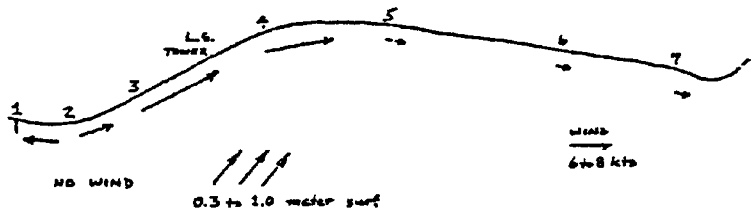
With wave heights of .6 to 1.2 m (2 to 4 feet) from the south and light winds, current maximums of 15 to 45 cm/s were recorded in front of the Lifeguard Tower. Currents along the bay were slower, 6 to 16.5 cm/s, and at the Chart House Restaurant almost nonexistent.

Figure 11 graphically depicts the results of the current study. The data sheets are presented at the end of this thesis.

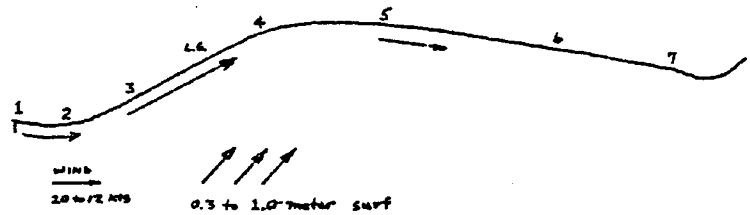
Cell-circulation with rip currents and feeding longshore currents is also evident at Topanga Beach. These currents are caused by a variation in breaker wave height along a beach. Such wave height variation can be caused by either topographic variations offshore or the interaction of incoming waves with edge waves trapped within the nearshore region (Bowen and Inman, 1969). The larger the breaker wave height, the greater the wave set-up (rise

Figure 11. Results of the fluorescein dye experiment and rip current observations.

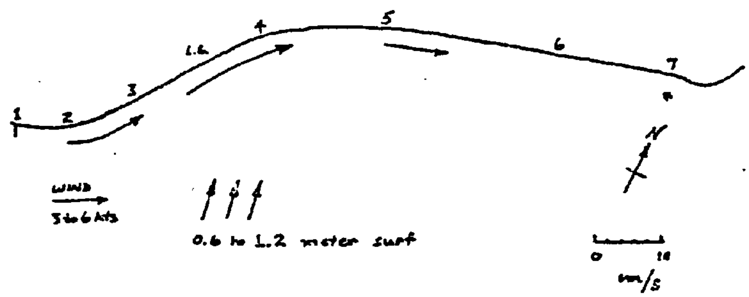
July 31, 1975 10:00 to 11:00 MEDIUM TIDE (+3 ft) 1 METER



July 31, 1975 13:30 to 14:30 HIGH TIDE (+4 ft) 1.3 METERS



August 27, 1975 10:00 to 11:00 MEDIUM TIDE



in the mean water level above still water level) within the surf zone. Bowen (1969a) and Bowen and Inman (1969) demonstrated that the variation in wave set-up is probably the driving force behind cell-circulation. Water flows from areas of greater wave set-up to areas of lesser wave set-up, creating a feeder longshore current, and then flows seaward as a rip current, dissipating beyond the surf line.

Although the entire circulation-cell can move along the coast, as is noted by Shepard and Inman (1950), rip currents may also be self-perpetuating at times. Rip currents acting on a sandy beach can scour a path seaward as well as alter the form and height of incident waves. Once a scoured path has been made by a rip current, incident waves can travel further inshore before breaking, owing to deeper water depths. Seaward flow of water will tend to reduce incident wave height and alter its mode of breaking. Both of these effects can reduce the amount of wave set-up in the area of the rip current allowing for a continuous variation in set-up along the beach.

For purposes of identification, cell-circulation currents are separated into three parts: (1) "feeder currents" flowing parallel to the shore inside the breakers, (2) the "neck" where the feeder currents converge and flow through the breakers in a narrow band or "rip," and (3) the "head" where the current widens and slackens outside the breaker line (Szuwalski, 1970).

Rip currents are of major concern along swimming beaches because they can pull an unsuspecting swimmer out to sea. They can also be efficiently utilized by surfers and boaters as a "free ride" through the surf line. Topanga Beach, with its generally small surf and oblique orientation to incident waves, is not known to have significant rip currents (personal communication, Shelley Butler, Topanga lifeguard). Local hazards are related more to topographic variations offshore and bottom material.

Mild rip currents were occasionally observed at Topanga, especially during high surf conditions. These rip currents were recognizable by the traditional indicators used by lifeguards: a narrow channel of murky, turbulent water flowing seaward through an area of reduced surf height and sometimes an associated plume of discolored water beyond the surf zone. The fluorescein dye current study did not markedly show these currents.

The observed rip currents were at the westerly end of the slightly curved sandy bay, near Lifeguard Tower 2 and at the west end of the Chart House Point on the east end of the bay (Fig. 11). The rip current near Lifeguard Tower 2 (R.C. 1) occurs where the longshore current rapidly diminishes and incident wave energy is low because of refraction. The strong longshore current to the west of R.C. 1 transports water towards this area, causing the water to stack up and flow seaward, hence R.C. 1.

The mild rip current in front of the Chart House Restaurant Point is probably caused by the deflection of the longshore current seaward by the large boulders. These boulders protrude from the Restaurant, forming a point of land which is not topographic expressed very far offshore.

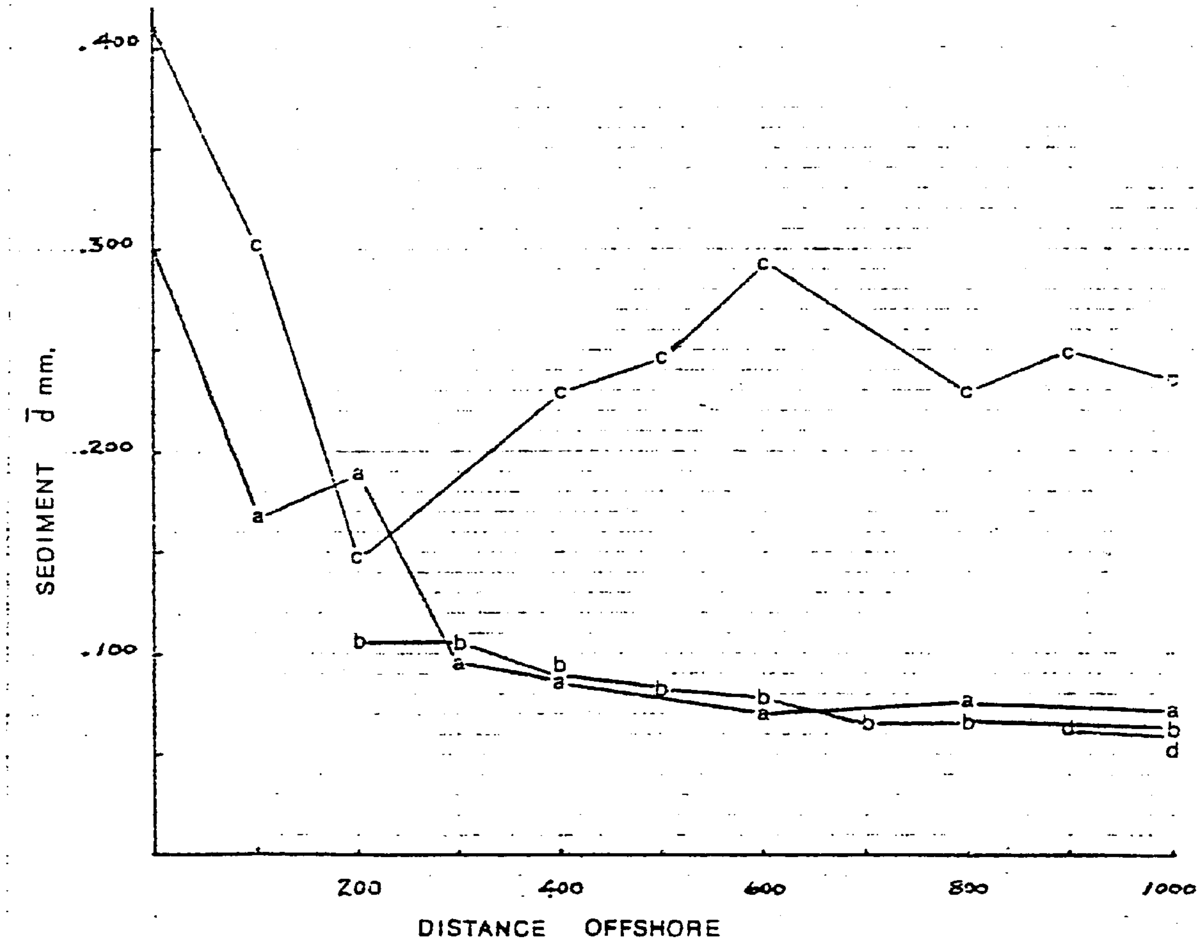
Sediment Size

In an effort to determine the distribution of sediment size at Topanga, 29 sand samples were taken: 6 along the beach and 23 along the offshore transects A through D (Base Map). The samples were recovered from the surface layers (crests of the ripple marks where present) and represent recent sedimentation. Size analysis was accomplished with an Emery-type settling tube (Emery, 1961).

The general pattern was found to be normal, that is, the mean diameter of the sediment samples decreased offshore (Fig. 12). The beach and foreshore at Topanga is composed of coarse-to medium-grained sand from .404 mm to .164 mm in diameter which accounts for its steep profile. The offshore area, from the surf zone to approximately 270 m (800 feet offshore) was found to be composed of medium to fine sand from .294 mm to .065 mm.

The coarsest offshore sand exists along transect C where mean diameters ranged from .227 mm to .294 mm. This

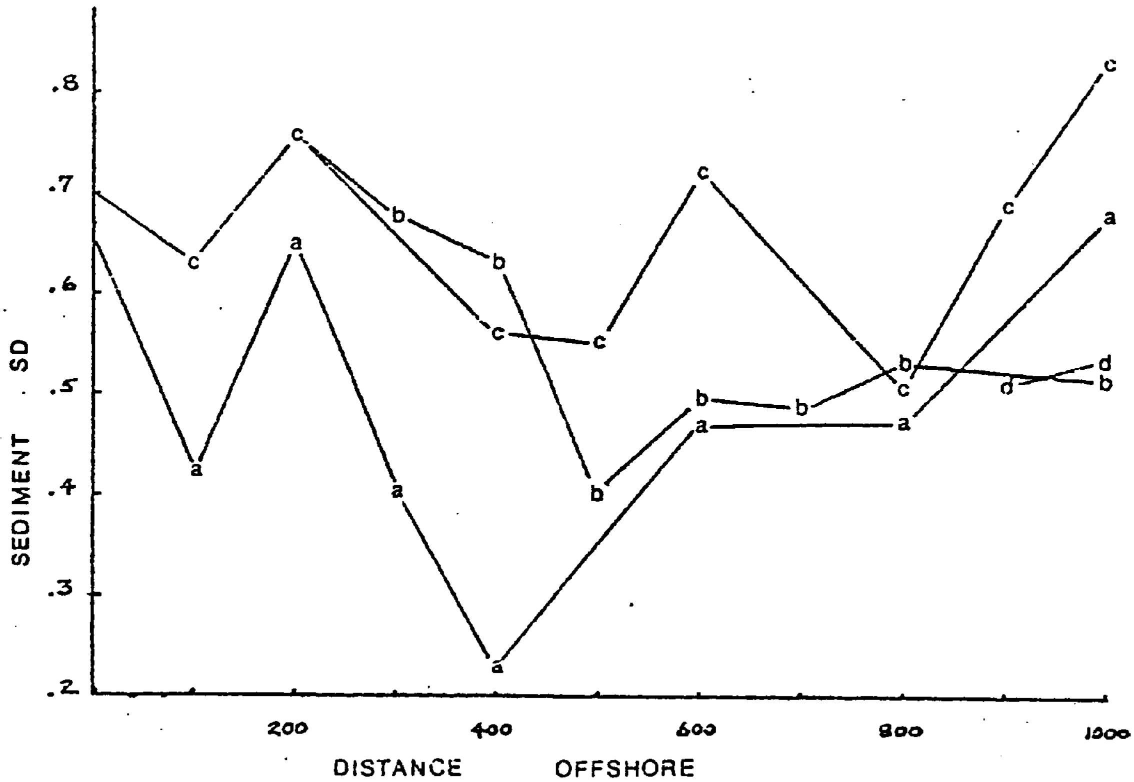
Figure 12. Distribution of sediment size at Topanga, Transect A-D (mean diameter).


.400
.300
.200
.100
SEDIMENT d̄ mm.
200
400
600
800
1000
DISTANCE OFFSHORE

is in marked contrast to the other transects which ranged from .104 mm to .065 mm. It is postulated that both high waves and rip currents in this area explain this pattern. The only major rip current at Topanga, R.C. 1, flows seaward in the area of transect C. This rip current with its high transporting capacity would tend to keep this area cleared of fine sediment. In addition, in the week preceding the data collection along transect C, surf heights reached 5 feet (average is 2 to 3 feet) which would produce strong coastal currents. The fine-grained sample 70 m (200 feet) from the cliff in the surf zone (sample C-200, $\bar{d}$ = .145 mm) can be explained by the fact that samples C-000, C-100, and C-200 were taken on a low surf day, whereas samples C-300 to C-1000, as mentioned before, were obtained shortly after a high surf period.

Inman (1953) concluded that the foreshore should exhibit the best sorting, the surf zone the worst sorting, and between the surf zone and the 100 foot depth contour sediments should be well sorted (but less so than the foreshore) and fine. Topanga Beach does not entirely follow this pattern. As can be seen in Figure 13, the foreshore (100 feet from the cliff) is better sorted than the back beach (samples - 000) or the surf zone (samples - 200), but the best sorted sediments are between 300 and 400 feet offshore (400 to 500 feet from the seacliff).

Figure 13. Sorting (standard deviation) as a function of distance from the seacliff.



SEDIMENT . SD
.8
.7
.6
.5
.4
.3
.2
200
400
600
800
1000
DISTANCE OFFSHORE

Figure 14. Sediment sample data.

SEDIMENT SAMPLES

SAMPLE AREA		MEAN DIAMETER				
TRANS.	DIST. FROM BLUFF	ϕ	MM.	STANDARD DEVIATION	SKEWNESS	KURTOSIS
C	000	1.30	0.4036	0.70	-0.56	0.51
	100	1.72	0.3025	0.63	-0.17	0.61
	200	2.78	0.1449	0.76	-1.40	4.45
	400	2.11	0.2302	0.56	-1.00	1.17
	500	2.02	0.2455	0.55	-0.40	-0.49
	600	1.76	0.2940	0.72	-0.61	1.08
	800	2.13	0.2269	0.51	-0.73	-0.54
	900	2.00	0.2493	0.69	-0.35	1.92
	1000	2.07	0.2368	0.83	1.10	2.05
A	000	1.74	0.2983	0.67	-0.86	4.48
	100	2.60	0.1643	0.42	1.56	8.71
	200	2.39	0.1895	0.65	-1.34	5.01
	300	3.37	0.0962	0.40	-4.86	45.90
	400	3.50	0.0883	0.23	0.09	15.86
	600	3.79	0.0718	0.47	0.64	-0.98
	800	3.73	0.0752	0.47	0.15	5.61
	1000	3.80	0.0714	0.65	-1.68	6.41
B	200	3.23	0.1060	0.76	-1.01	2.72
	300	3.26	0.1042	0.68	-0.26	0.06
	400	3.49	0.0889	0.65	-1.33	5.30
	500	3.62	0.0812	0.40	0.51	4.13
	600	3.76	0.0734	0.50	-0.58	8.83
	700	3.91	0.0661	0.49	0.25	-1.75
	800	3.88	0.0678	0.53	-0.77	7.18
	1000	3.95	0.0646	0.52	-0.49	3.23
D	900	3.94	0.0649	0.51	0.03	-1.56
	1000	3.98	0.0629	0.53	-0.31	-1.15
TOPANGA	LOBE	1.84	0.2777	0.54	0.40	-0.56
	CREEK	1.60	0.5253	0.70	-0.35	0.17

This may be the area in which the rip current dissipates and deposits its load, which would explain the unsorted nature of the sediment. Further sediment sampling and analysis in this area would further define the limits of the rip current and its effects.

Ripple Marks

Ripple marks are features which form on sediment surfaces by fluid flow. In the nearshore oceanic environment they generally are the result of oscillatory water motion produced by surface waves. This oscillatory motion of water forms symmetrical ripple marks, as opposed to unidirectional currents which generate asymmetrical ripple marks. Fossilized ripple marks are common and are used by geologists to interpret ancient environments. Recent ripples, *in situ*, can also lend insight to the interpretation of the present hydraulic environment under which the ripples were formed. Towards this purpose, measurements of ripple mark wavelengths, sediment sizes and orientations were obtained in the near offshore area at Topanga Beach. There are two relationships of concern here: the one between the ripple length λ and the water orbital diameter d_o immediately above the ripples, and the relation between ripple orientation and the direction of wave travel. D_o is theoretically defined as:

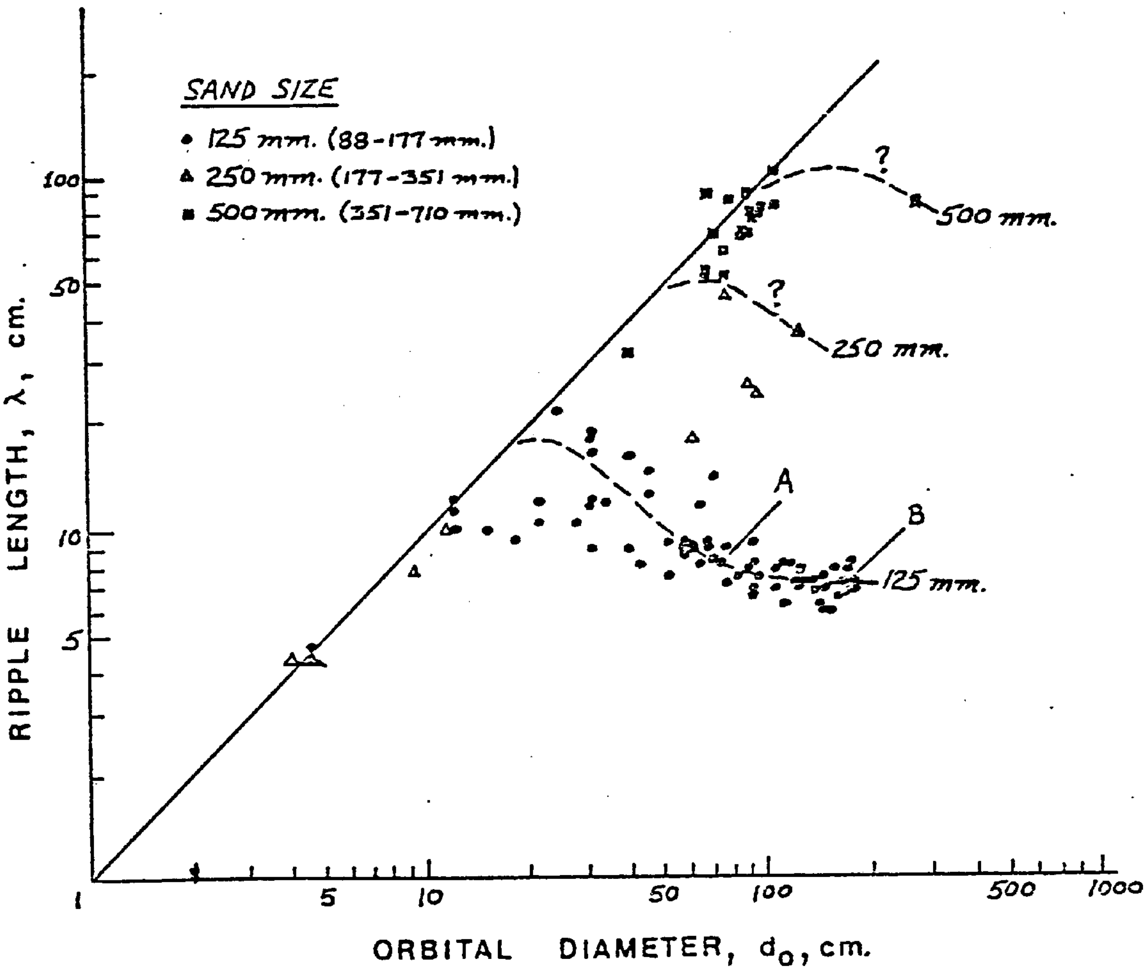
$$d_o = \frac{H}{\sinh} (2n\ h/L)$$

where H is wave height, L is wavelength, and h is the water depth.

Work by Inman (1957) indicates, for sand with a mean diameter between 88 and 177 mm, that ripple wavelength λ is approximately equal to the orbital diameter d_o when d_o is below 20 cm, beyond which λ decreases with an increase in d_o. Close to shore a value of d_o is reached which causes sheet sand movement and no ripple marks are found. It is postulated that the same type of relationship, with different cut-off points, exists for larger sediment (Fig. 15).

Two different d_o values, therefore, can produce the same ripple mark λ , a point that Komar (1974) claims has caused considerable confusion in environmental interpretations. Komar (1974) also observed that the $\lambda = d_o$ and $\lambda < d_o$ re-ions of Figure 14 generally indicate different environments and wave regimes. The $\lambda = d_o$ situation (more exactly $\lambda = 0.8\ d_o$) usually is present in lake environments, a relationship supported by the work of Evans (1942). Here threshold velocities are reached by short period waves in shallow water and λ tends to increase with d_o as one moves onshore. Under oceanic conditions $\lambda < d_o$ generally prevails and threshold velocities are created by longer period waves in deeper water. It is noted by Komar

Figure 15. Comparison of ripple wave length, λ, and orbital diameter, d_o (after Inman, 1957).



SAND SIZE
125 mm. (88-177 mm.)
250 mm. (177-351 mm.)
500 mm. (351-710 mm.)
500 mm.
250 mm.
125 mm.
A
B
?
?
RIPPLE LENGTH, λ, cm.
ORBITAL DIAMETER, d_o, cm.

(1974) that d_o values in the range of λ under oceanic conditions do not have sufficient maximum velocities to transport sediment (except where sediment is very coarse and resultant λ long) and therefore almost all ripple marks formed in the ocean are formed under conditions in which $d_o > \lambda$. Under these conditions, λ often decreases as one moves onshore. These relationships are confirmed by the data recovered at Topanga Beach and by observations by the author in the Pacific, East Atlantic, Mediterranean and Red Sea.

Another regime occurs at Topanga Beach (and elsewhere). Between the sheet flow near the breaker zone and the symmetrically rippled area seaward is a zone where asymmetrical ripples are formed. Each surge, seaward or shoreward, in this area produces a unidirectional flow of water and a corresponding asymmetrical ripple. The ripples are formed with their steep face shoreward, destroyed, and reformed with their steep face seaward with each passing wave.

Ripple mark wavelength also is related to sediment size. Research by Inman (1957) and others has shown that increased sediment size will result in longer ripple lengths. Of course, there is a limit to this relationship when the threshold velocity of the sediment exceeds the maximum velocity created by wave motion.

The ripple mark pattern at Topanga Beach (refer to

Base Map, in pocket) supports both of the above-mentioned relationships. On transects A and B mean sediment size ranges from .065 mm to .105 mm and ripple mark wavelengths decrease onshore from 8 cm in 9 m of water to 6.5 cm in 2.6 m of water. Mean grain size increases onshore which should cause an increase in λ onshore. It is evident, therefore, that the survey area is within the regime where $d_o > \lambda$ (part A-B of Figure 15) and that d_o has an overriding effect on sediment size in determining λ, within the range presented here. Where orbital diameters are approximately equal in the survey are ripple wavelength varies directly with sediment size. At the seaward end of transects A through D, for example, sediment size ranges from .063 mm to .065 mm to .071 mm to .237 mm while λ respectively ranges from 7 cm to 7.5 cm to 8 cm to 9 cm under similar d_o conditions. This trend occurs throughout the survey area.

Sediment size along transect C ranges from .227 mm to .294 cm (mean grain size), ripple wavelength is consequently longer (8 to 10 cm), and no noticeable variation in λ with depth is found. This is not inconsistent with Figure 15 because mean grain size is no longer within the range of the .125 mm curve. Transect C is in the range of the .250 mm curve. This curve is questionable because of insufficient data. The .250 mm curve may be horizontal within the range of orbital diameters encountered in this survey and consequently little variation in λ should occur.

Ripple marks, being caused by to and fro water motion, have crests which are parallel to the wave crests which form them. By plotting the orientations of the crests of the ripple marks, one can obtain a crude estimate of the refraction pattern of the longer waves, assuming that it is the longer waves which form the ripples. This may not be the case in shallow water, however, where unrefracted, short period waves superimposed on longer waves also may influence the formation of ripples. The pattern developed by plotting the wave crest orientations did reveal refraction of up to 25^{o} from the seaward end of the transect to the point at which symmetrical ripples ceased to exist. This is by no means the maximum refraction these waves have undergone. The transects start in 25 to 28 feet of water and it is evident that appreciable refraction already has occurred by the time the waves reach the survey area. A complete refraction pattern could not be arrived at by this method since a large percentage of the offshore area at Topanga is rocky and void of ripples.

Topanga Creek - Morphology

The most dynamic morphological feature at Topanga Beach is the mouth of Topanga Creek. With a gradient of

230 feet per mile, the ephemeral Topanga Creek flows out on the western part of the beach, forming Topanga Point. During the dry season a sandy berm dams the mouth of the creek forming a small lagoon. The limited amount of water which flows into the lagoon at this time is usually balanced by a subterranean flow of river water under the berm into the sea. At very low tides this flow is observable from the seaward side of the berm.

When rainfall occurs a predictable sequence of events takes place. The lagoon fills with river water until the berm is breached. The berm-dam is then rapidly eroded and a channel is cut, allowing river water to flow freely into the sea, depositing a lobe or small delta of sand on the rocky inter-tidal area immediately in front of the river mouth. As the flow of water diminishes, the longshore current begins to build a new dam of sand. This new dam begins as a sand spit connected to the up-current side of the channel opening, which diverts the flow of the river water so that it meanders around the forming sand spit. As the sand spit continues to enlarge, the river outlet continues to meander downcurrent. Eventually, the sand spit closes off this meandering channel and joins the remainder of the beach berm, which completes the dam. The deposited lobe of sand is transported downcurrent by the longshore current, eventually losing its form. One such lobe appeared as a mid-foreshore beach ridge in the beach profile taken March 20, 1975. This entire sequence of events often was observed during the 1974-75 rainy season (winter and spring). The maximum extent to which the river channel meandered was 80 m (250 feet), with dam rebuilding occurring within one week after the rainfall stopped. The Base Map (in pocket) shows the morphology of the creek during a period shortly after rainfall and runoff have occurred; the channel is open, a sand spit has started to form, and a sand lobe is present in the intertidal area adjacent to the river channel.

During the unusually rainy season of Spring 1969, the Topanga Creek outflow meandered 1000 feet downcurrent. The sand spit which was built from the effluent and longshore drift covered the entire rocky intertidal area, creating an 800-foot long stream channel which extended parallel to the beach before turning seaward. Months were required for the beach to return to its natural configuration (personal communication with and photos from Lloyd Ahern, Topanga resident).

The normal sequence of filling and draining of the Topanga lagoon often is altered by the Los Angeles County maintenance crews who occasionally dig an artificial channel for the river. The presence of a lagoon is considered a health hazard because of mosquitos and harmful bacteria in the stagnant water.

IMPACT OF FLOATING BREAKWATER

Parameters

The purpose of placing an offshore floating breakwater at Topanga Beach is to alter the prevailing surf height. Reducing the surf height (incident wave energy) on the beach will change the profile of the beach as well as the mode of the breaking waves. Reduction of surf height and the change in the mode of the breaking waves from the present surging-plunging wave to a more offshore spilling wave will facilitate boat launching (Tables II-V). Reduction of incident wave energy also will decrease the competency of the longshore current. The breakwater should therefore be designed to allow the continued existence of downcurrent (eastward) sediment transport. Insufficient allowance for sediment transport will cause the area behind the breakwater to collect silt and the beaches downcurrent to be denuded. An effort was made to choose an appropriate breakwater and predict its effects. This was based upon a review of the available literature and an analysis of its applicability to Topanga Beach in view of the beach profile changes that occur at Topanga.

Most research on beach profiles centers on laboratory and field studies which examine the effect of only one factor while attempting to hold the other factors constant. Some studies suggest that within a certain range beach profiles are a function of only a single factor: sediment size (Bascom, 1951 and Bagnold, 1940). Other studies indicate that over the complete range of possibilities the profile of a beach is a function of sediment availability and size, wave dynamics (height and steepness), wind velocity and direction, and the tides (King, 1959 and Hayes, 1972).

There can be no beach without sediment. Simple as this may sound, there has been no integrated effort to assure a continuous supply of sediment to the beaches of southern California, and yet people desire beaches for recreation. The amount and type of sediment which reaches a beach are important in determining how much beach will be present. They are also factors which partially determine the profile of a beach.

The profile of a beach undergoes constant change because there is always some sediment being washed up and down the face of the beach. Sediment in the nearshore, however, can be considered to be in a state of dynamic equilibrium; the component force of gravity acting in a seaward direction being balanced by the net landward movement of water. Coarse sediment forms steep-sloped beaches because the net landward movement of water above the sediment surface is high and equilibrium can occur only if the gravitational force component parallel to the surface is also large; the steeper the face of the beach, the greater the component of gravitational force parallel to the sediment surface. The net landward movement of water above the sediment surface is high on coarse beaches because of percolation. On an impermeable beach the water which moves up the beach must also return seaward, resulting in no net landward movement of water. As the permeability of the beach increases (a function largely of increased sediment size), then a percentage of the landward-rushing water percolates through the sediment and returns seaward under the surface. On some cobble beaches percolation is so rapid that there is virtually no backwash. All of the water which is pushed up the face of the beach percolates through the cobbles and returns seaward beneath the surface. Bascom (1951) and Inman (1953) showed in field studies that the mid-tide slope of a beach was a direct but nonlinear function of sediment size; the finer the median diameter of the sediment, the flatter the profile of the beach.

If the angle of repose of the sediment on a beach is a function of the balance between gravitational forces and hydraulic forces, then the waves which produce the hydraulic forces must also be a factor in beach profiles.

Work by Rector (1954), King (1959), Inman (1966) and others have shown that wave height and steepness are the wave parameters which most significantly affect both beach erosion and beach profiles. Steeper waves are more destructive and generally result in beach erosion, whereas shallow waves cause sediment accretion. Whether any set of waves is ultimately destructive or constructive depends upon the size of the sediment on the beach. For each sediment size there is a different wave steepness which marks the transition between destructive waves and constructive waves.

Studies by Ingle (1966) indicate that wave breaker height may be a better index of accretion and erosion on natural beaches than wave steepness, large waves being more destructive than small waves. Wave height and wave steepness are difficult parameters to separate into independent factors because they often go hand-in-hand when local storms are considered. Local storms usually are destructive to the beaches for not only are the waves large but owing to their recent formation, they are also steep. Such storm waves may supersede other wave types in coastal erosion (Thornbury, 1969) but they occur infrequently and their destructiveness is usually balanced by longer periods of smaller, shallower waves which are constructive.

Aside from their constructive and destructive influence, waves can alter the slope of a beach in that they determine what size sediment will remain on a beach. Large waves and waves which break close to shore produce high swash velocities, thereby winnowing the finer sediment and allowing only the coarser sediment to remain on the beach. The steeper the face of the beach, the closer in-shore the waves will break. Shallow profile beaches cause waves to break further from shore which results in low swash velocities which permit fine sand to remain on the beach and thereby perpetuate the profile of the beach. Laboratory experiments by Rector (1954) showed that when wave dynamics changed, the profile of the beach was altered and that the original beach profile had little effect on the final equilibrium profile. There is a time lag, however, between a change in wave dynamics and the formation of a new equilibrium profile. This time lag, due to the original profile of the beach and the time needed to redistribute the sediment in order to reach a new profile produces a normalizing effect.

The angle of wave approach also can affect swash velocities and consequently influence the profile of the beach. Swash which does not run orthogonal to the beach slope will have a smaller component of velocity directed along the dip of the beach slope than swash of equal intensity which is orthogonal to the beach slope. This is evident at Topanga where the average slope of the southeastern part of the beach, where swash is orthogonal to the beach, is 6°. In contrast, the slope along the area between the headland and the southeastern section, where wave swash is at an angle to the orthogonal, is between 3° and 4°.

The influence waves have on beach profile is a result of their influence on the movement of sediment of different sizes. Experiments with sediment movement due to shoaling waves led to the following pertinent conclusions: (1) the tendency for beach material to move shoreward increases if the grain size increases (Rector, 1954); (2) steeper waves transport material seaward inside the breaker zone (Watts, 1954 and Ingle, 1966); and (3) flatter waves move material landward in all depths (Watts, 1954).

These findings not only confirm the previously described relationships between wave height, wave steepness and beach profile but they also aid in understanding the parabolic shape of most beach profiles. If coarser sediment tends to move onshore, then one would expect to find a sorted beach grading from coarse sediment on the upper foreshore to finer sediment seaward. The coarse sediment transported to the high foreshore would produce a steeper slope than the finer sediment that exists further seaward. This relationship has been reported (Inman, 1953) with the exception that the coarsest sediment occurred in the surf zone immediately under the breaking point of the waves and not at the top of the foreshore. Sediment within this zone does not appreciably influence the profile of the beach, though.

Tides are another factor in the formation of parabolic beach profiles. The top of the foreshore of a beach is only subjected to the leveling effect of breaking waves at high tide, whereas the lower foreshore is almost constantly under the dual influence of waves, namely, swash at low tide and oscillatory water movement beneath the waves at high tide. Once a parabolic profile has been formed, it is somewhat self-perpetuating. High tides will present a steep beach profile to incoming waves which will concentrate wave energy by allowing the waves to break closer to shore. The resulting increase in swash velocities will then perpetuate the existence of coarser sediment on the upper foreshore, and hence a steep profile. At low tide a shallower profile will be presented to incoming waves, the surf zone will be wide, swash velocities low, and finer sediment be present on the lower foreshore (Fig. 4).

Tides also affect the profile of a beach in that they determine the width of wave attack. The greater the width of wave attack, the flatter the profile on the beach. Beaches which have large tidal ranges therefore have flatter profiles than beaches which are subject to smaller tidal ranges. The tidal range at any one location will also influence the profile of a beach. Shepard (1950) noted that berms are widest during neap tides and narrowest during spring tides. Seawater level changes because of storm-induced surges or water stacking is yet another factor. In combination with a high tide, the resulting abnormally high stand of water can be highly destructive because waves are then able to attack the back beach. Water stacking is not a major problem on southern California beaches since local storms are not severe. Topanga Beach is especially immune to this influence since it faces south and the majority of storms produce northwest winds.

The last factor to be considered is the direction and velocity of the wind. Ocean swells can be modified by local wind patterns. Winds which blow offshore tend to reduce surf size and flatten wave profiles which reduces their destructive effect. Offshore winds also create shoreward-moving bottom currents which aid onshore movement of sediment. Onshore winds tend to steepen waves, increase their height, and create seaward-moving bottom currents. All of these aid in the destruction or erosion of a beach. Along-shore winds will aid in the longshore transport of sediment, as shown earlier.

Case Study - Santa Monica Breakwater

In light of the relationships just discussed, one can state with reasonable certainty that an offshore breakwater which reduces the height of incoming waves, especially steep waves, will reduce swash velocities and allow finer sand, if available, to stand on the beach face. The beach slope will thereby be reduced and incident waves will break relatively further from shore. Sand accretion also should occur.

Santa Monica Harbor provides an example of the foregoing relationship. This harbor, only 6.4 km (4 miles) southeast of Topanga Beach, is protected by a detached breakwater which is 600 m (2000 feet) long and positioned approximately 600 m (2000 feet) offshore. Since the construction of this breakwater in 1933, sand deposition has occurred along the beach behind the breakwater. This accretion of sand is due to the reduction in competence of the longshore current and breaker action (Grant and Shepard, 1940; Johnson, 1948; and Handin and Ludwick, 1950). The average grain size of the sediment behind the breakwater also has decreased. Before the breakwater was constructed the mean grain size was 0.360 mm (Handin and Ludwick, 1950). In 1940 the mean grain size was 0.230 mm (Handin, 1951) and in 1962 it was 0.191 mm on the foreshore and 0.150 mm just seaward of the breaker zone (Ingle, 1966). The average size of the sediment upcoast and away from the influence of the breakwater also decreased over the years. In 1962 the mean diameter was 0.270 mm as compared to 0.360 mm in 1933. This general decrease in mean diameter was probably caused by either the decrease in sediment availability caused by man-made structures up-current trapping the coarser sediment or normal seasonal variation in beach sediment size. Nonetheless, the breakwater did cause a decrease in the mean diameter of the sediment found on the beach behind the breakwater as compared to the sediment found on adjacent beaches. Corresponding with this decrease in sediment size, the slope of the beach has decreased. At present (August 1975), the slope of the beach is 2^{o} to 2.5^{o} behind the breakwater and 5^{o} on the beaches to the north of the breakwater.

If the breakwater had remained as effective as it was in 1933 in stopping wave energy, it was predicted that the whole harbor would eventually silt up and a tombolo (or sand spit) would form from the shore to the breakwater (Handin and Ludwick, 1950). Over the years, however, the breakwater has deteriorated and today the breakwater is only partially effective in stopping incoming waves. This is evidenced by the fact that neophyte surfers use the beach behind the breakwater. At present the beach has reached an equilibrium point and sand accretion no longer occurs. Wave energy which is transmitted through and is diffracted around the breakwater produces a longshore current of sufficient capacity to maintain a flow of sediment past the harbor (Mankiewitz, 1972).

The Santa Monica breakwater is only one example of a semi-permeable breakwater. There are many breakwater designs which are intentionally permeable. The 1974 Floating Breakwater Conference Paper (Kowalski, 1974) and the Small-craft Harbors: Design, Construction, and Operation (Durham, 1974) papers describe the prevalent designs and discuss their applicability. After reviewing these papers, the floating tethered design by Seymour and Issacs (1974) was found to be the most suitable for Topanga Beach.

Topanga Beach Profiles

Before the tethered breakwater design could be applied to Topanga Beach, a series of beach profiles had to be made to determine the general cycle of erosion, accretion and slope change.

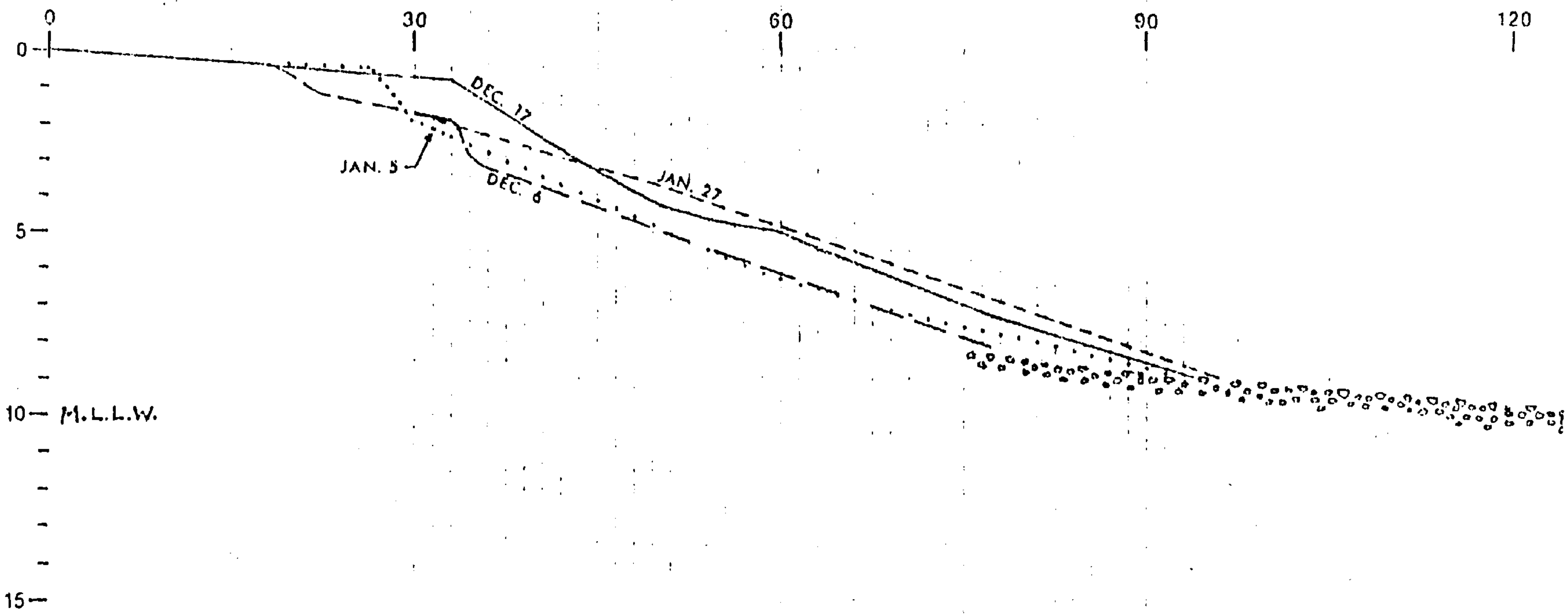
Between the dates of December 6, 1974 and June 10, 1975 a series of 12 beach profiles were measured at two locations using a modified Emery (1961) method (see Methodology). Initially three to four profiles were measured at stations along the beach but it was determined that only two profiles were required as the entire southeastern part of the beach had a uniform profile. These indicative profiles, labeled C and D (Figs. 16-22), correspond to the beach transects of the same letter designation. Accompanying the profiles are graphs showing the tidal cycles, wave heights, wave periods and wave approach angles for the time periods covered by the beach profiles.

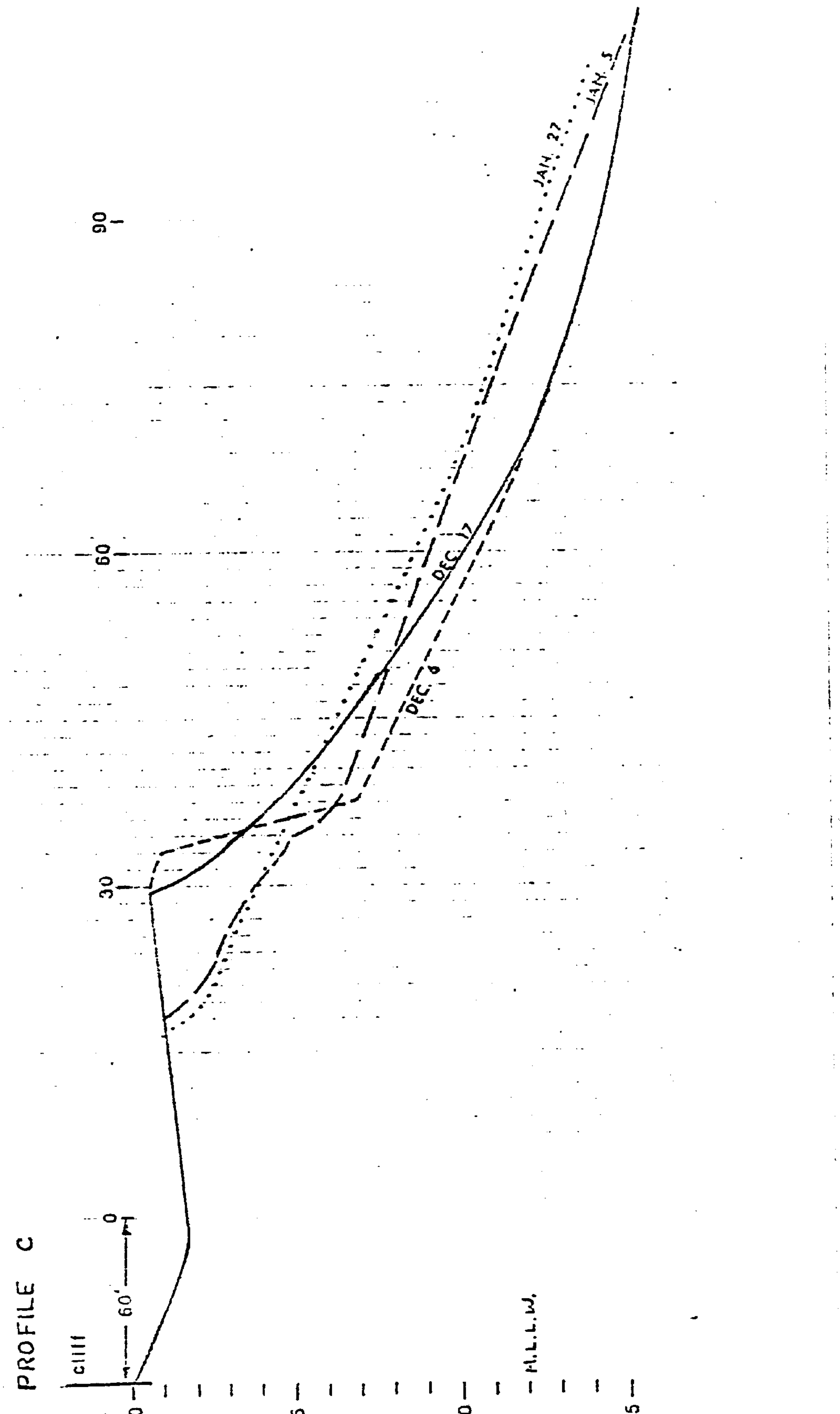
The wave height, period and approach angle data was extrapolated from the Los Angeles County Engineers Wave Study EG 16 which is a compilation of daily reports by lifeguards. Unfortunately, the accuracy of these data are sometimes questionable and spotty. The Los Angeles County engineers lost the data sheets for the months of November, December 1974 and June 1975. Data for December was consequently extrapolated from the log book of the Topanga Beach lifeguards and that for November and June is not presented. The wave height and period data is reasonably accurate, but the angle of wave approach data is not. Directions of north and northwest were often recorded as wave approach angles. This is not possible, because the orientation of the coastline precludes this condition. Topanga Beach faces south and only wave approach angles of 90° to 270° are possible (east, south and west). One can only assume that some of the lifeguards thought that the beach was oriented north-south and recorded wave approach directions from the southwest as coming from the northwest, etc. Such liberal interpretation is shown in the wave approach directions in Figures 16-26.

Figures 16-26

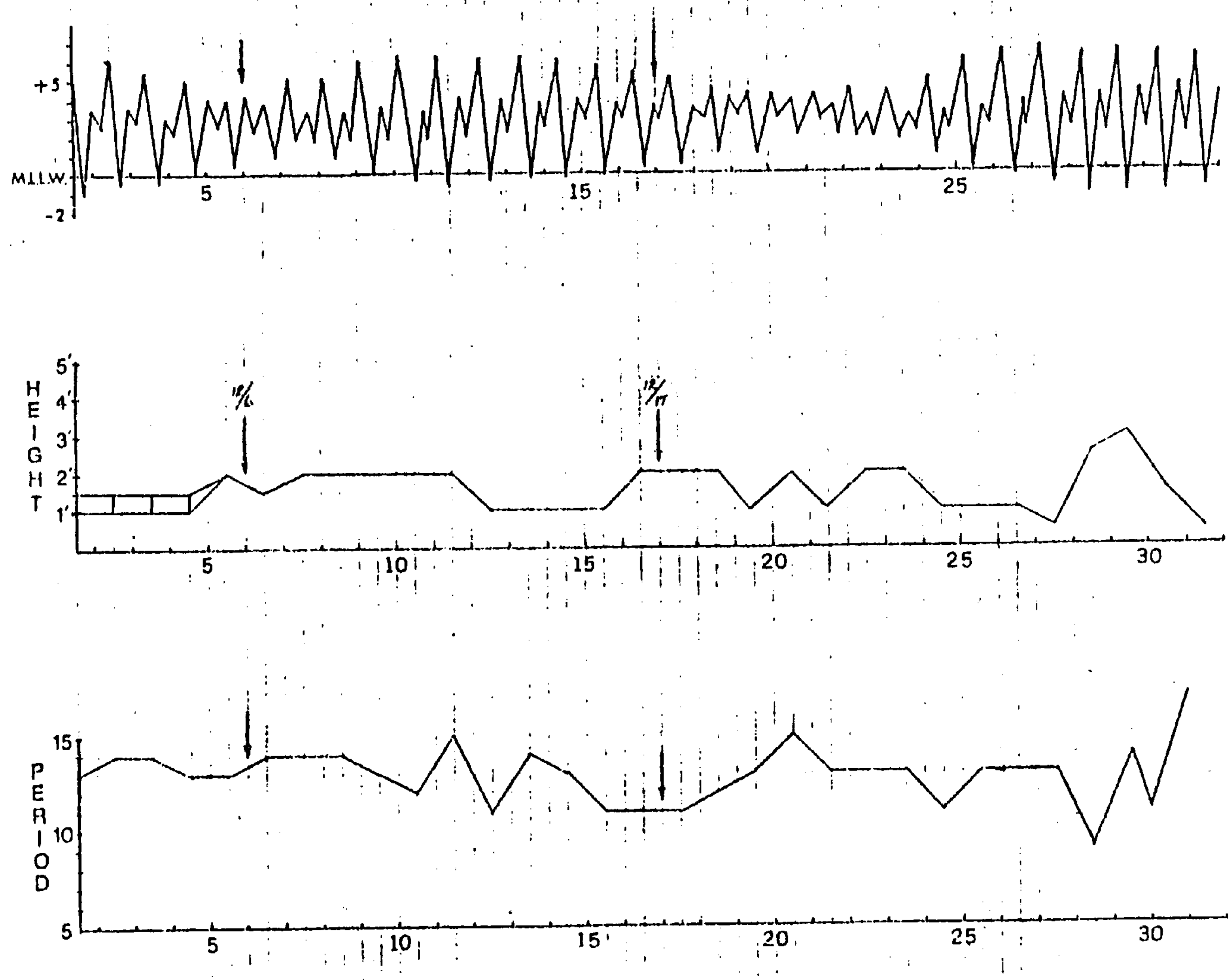
Beach profiles from Topanga Beach, December 6, 1974 to June 10, 1975, and concurrent data on total level, surf height and period, and direction of wave approach.

PROFILE D - DECEMBER 6 to JANUARY 27



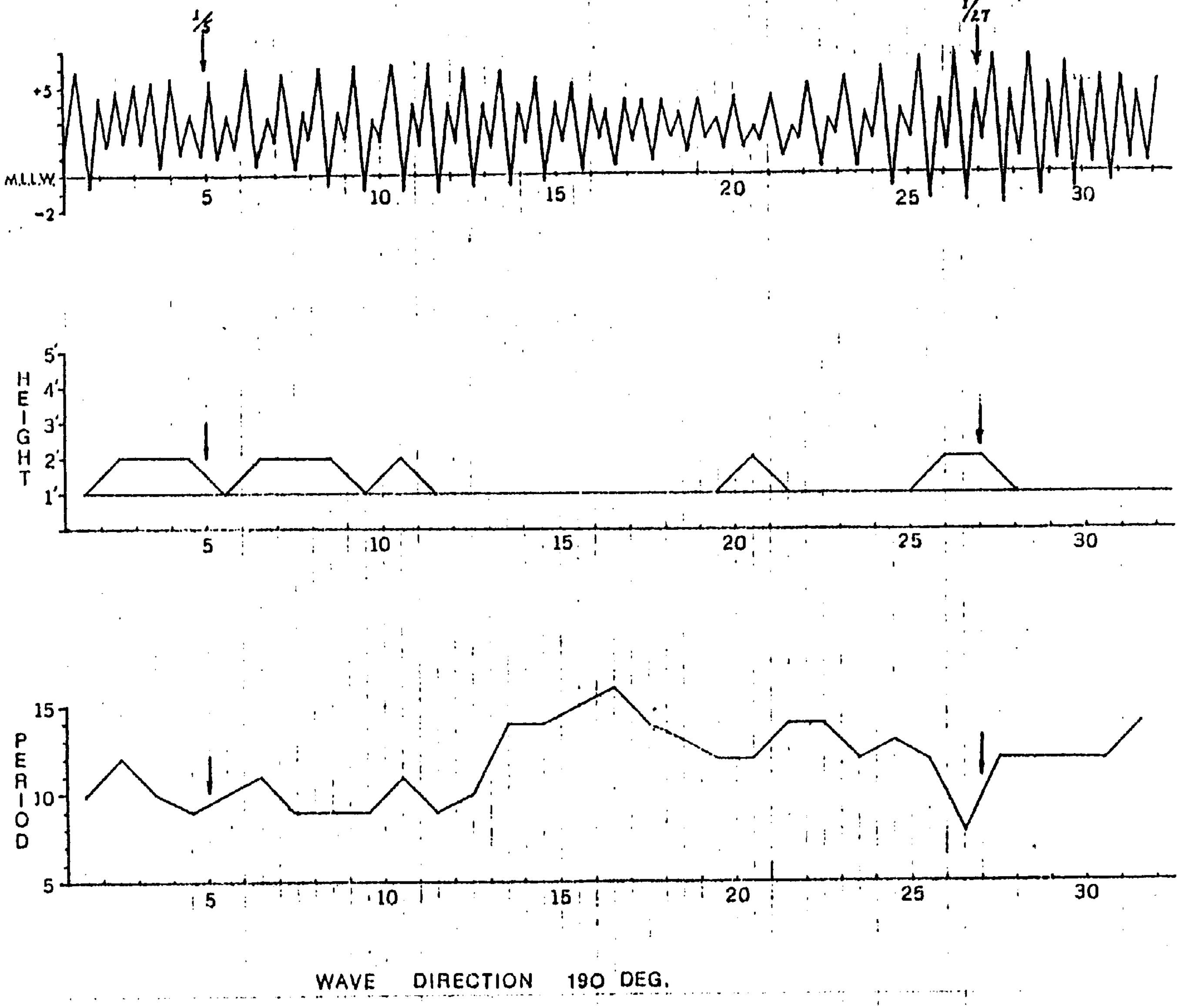

PROFILE C
60'
0
30
60
90
M.L.L.W.
0
5
10
15
DEC. 6
DEC. 17
JAN. 5
JAN. 27

TIDAL LEVEL, WAVE HEIGHT, and PERIOD — DECEMBER 1 to JANUARY 1

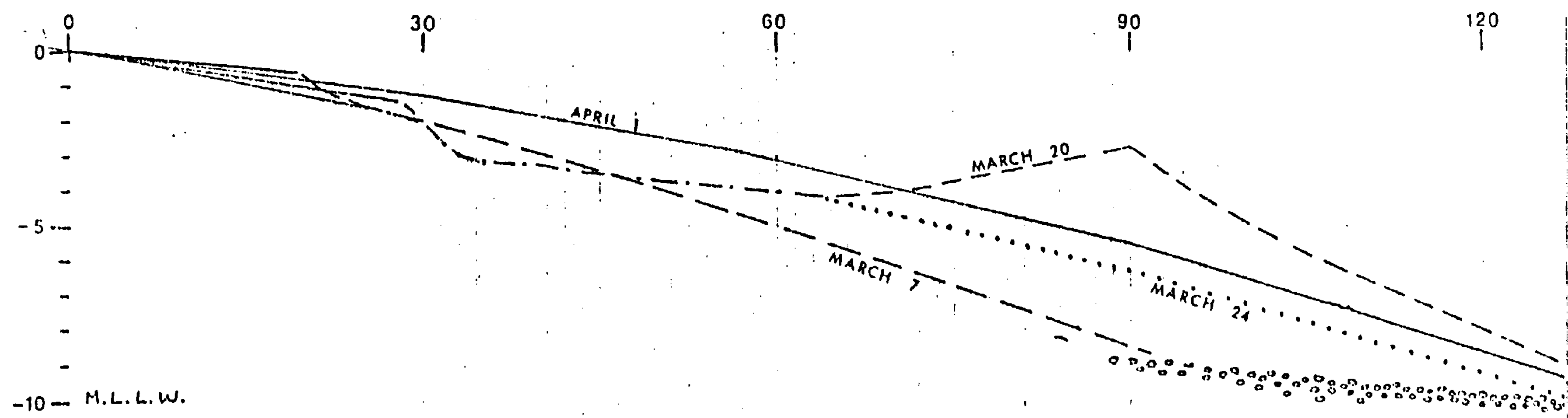


WAVE DIRECTION 180 - 200 DEG.

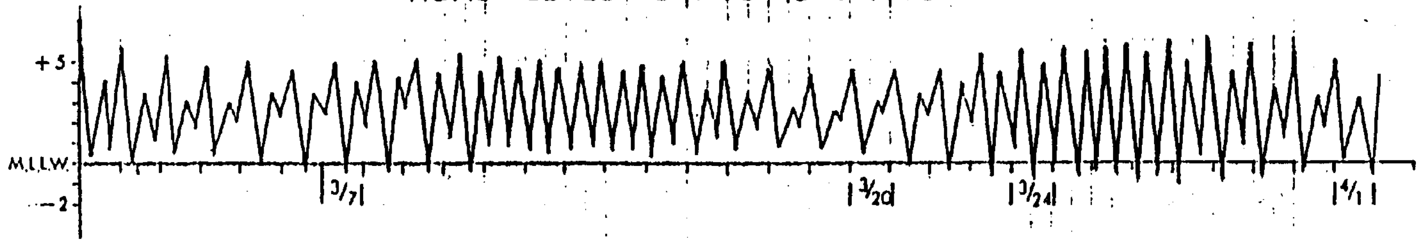
TIDAL LEVEL, WAVE PERIOD, and HEIGHT — JANUARY 1 to FEBRUARY 1



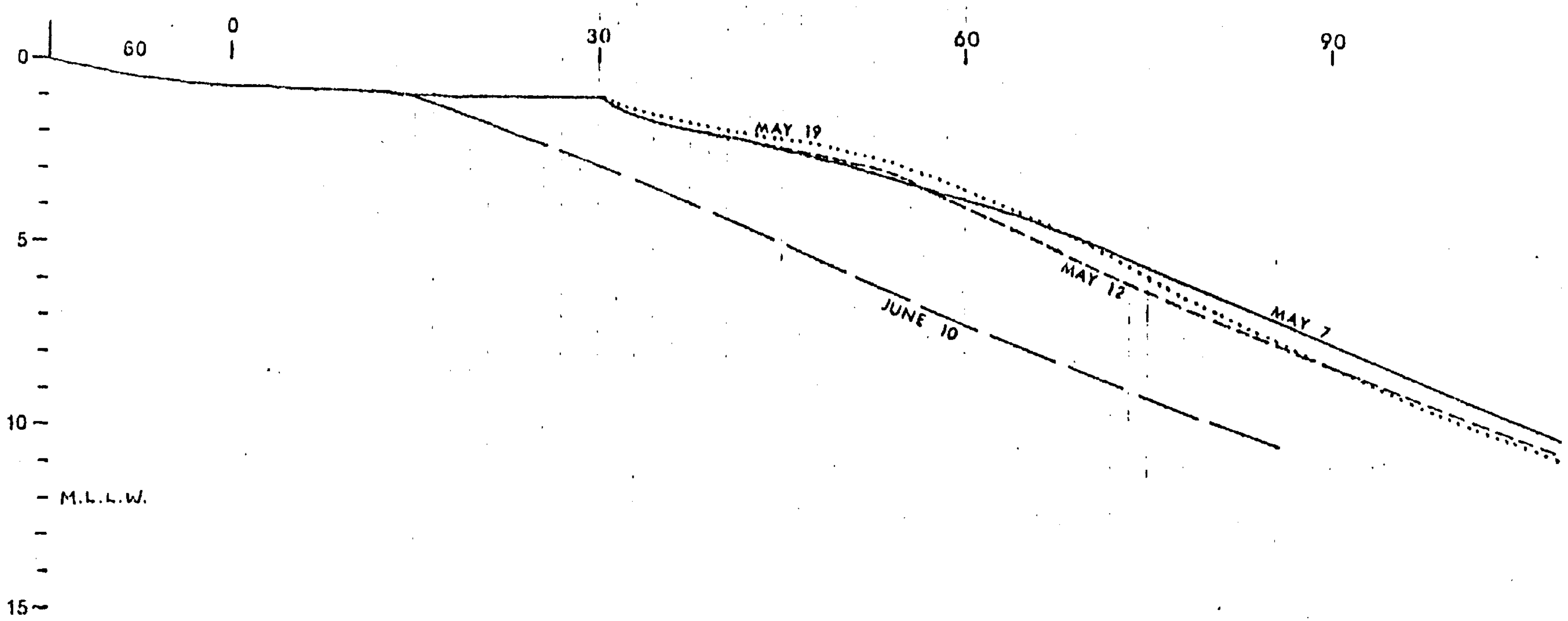
PROFILE D - 3-7-75 to 4-1-75



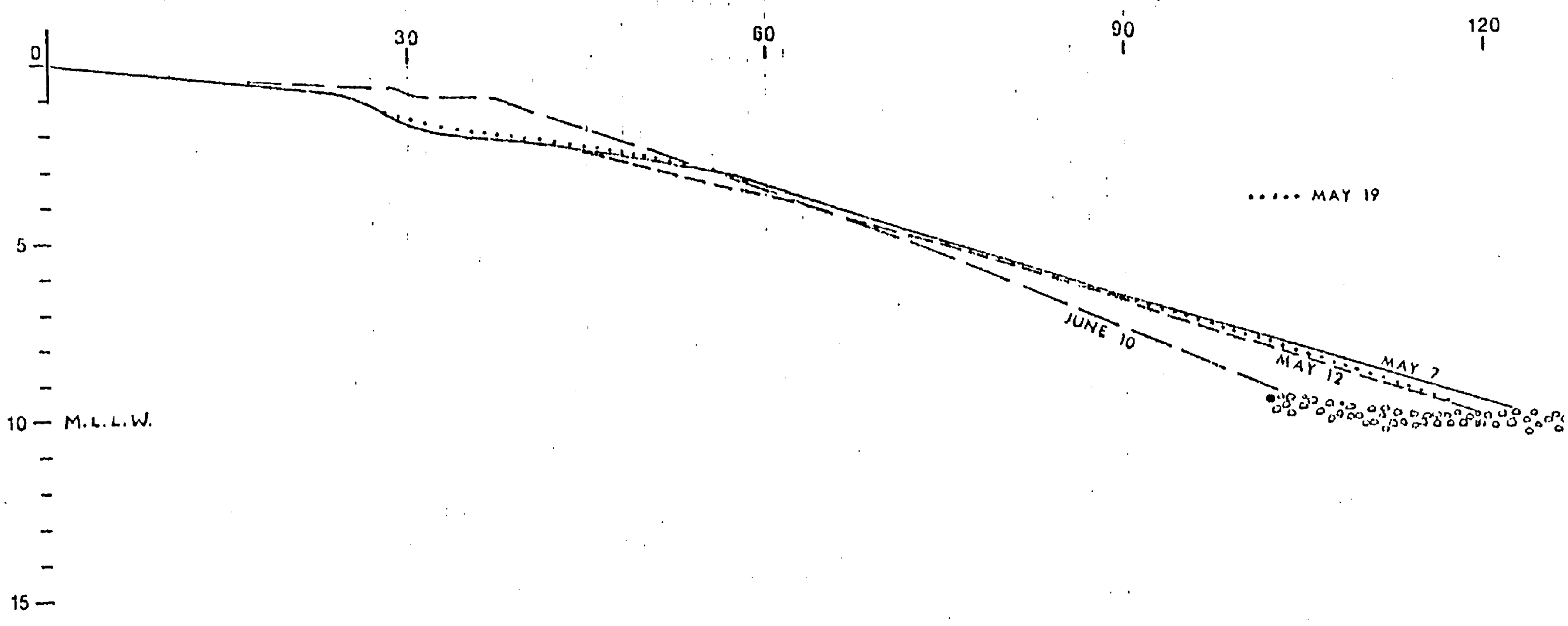
TIDAL LEVEL 3-1-75 to 4-1-75

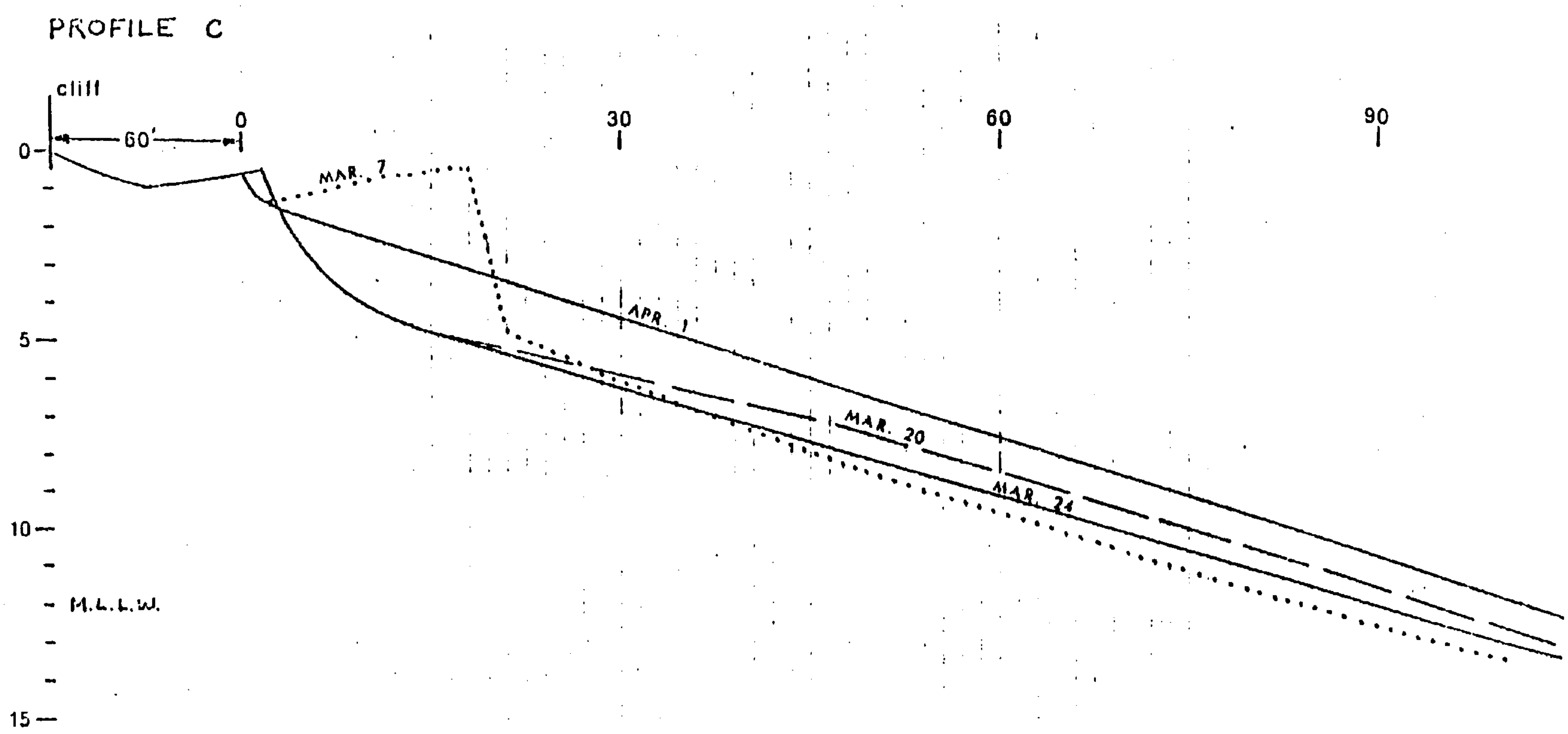


PROFILE C

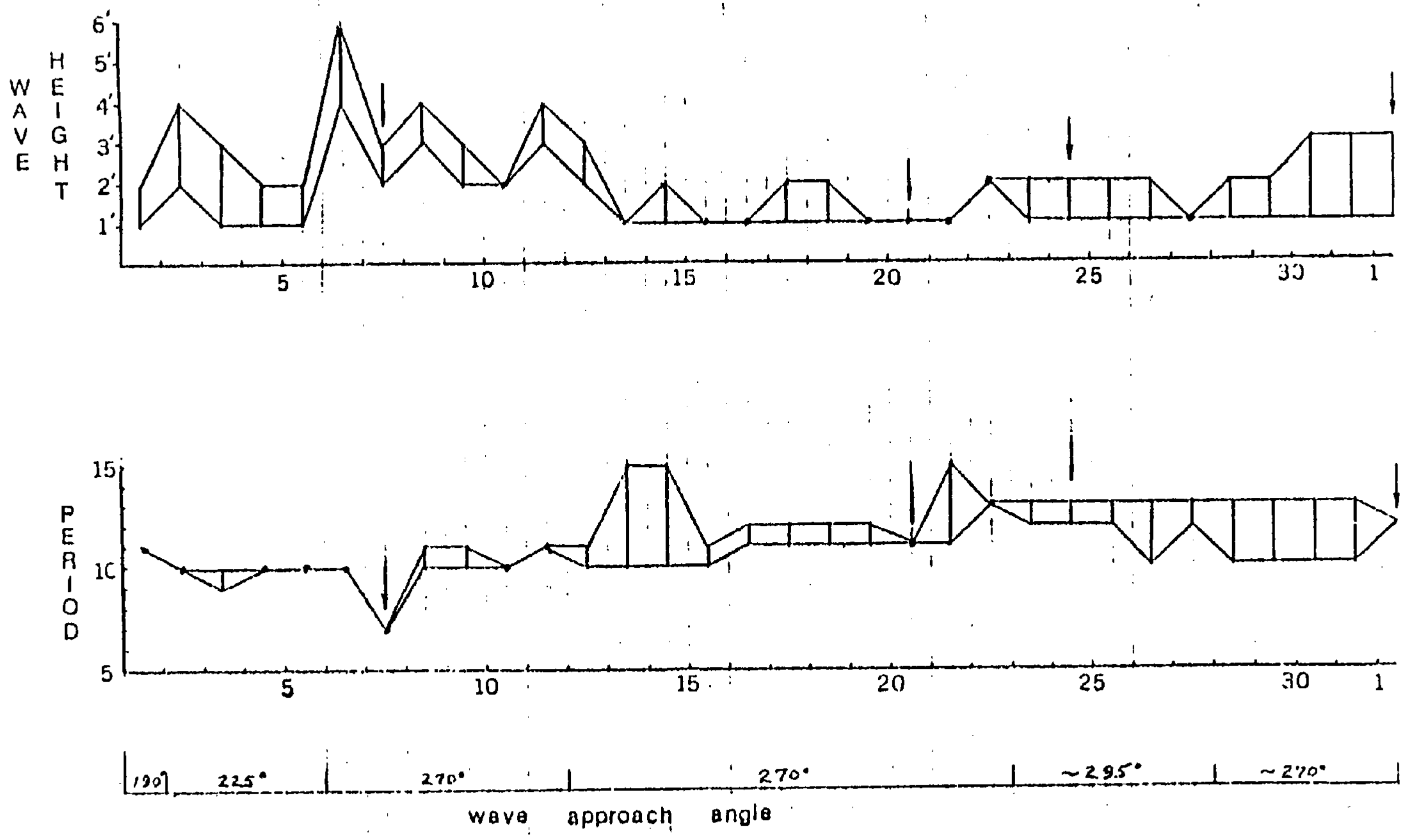


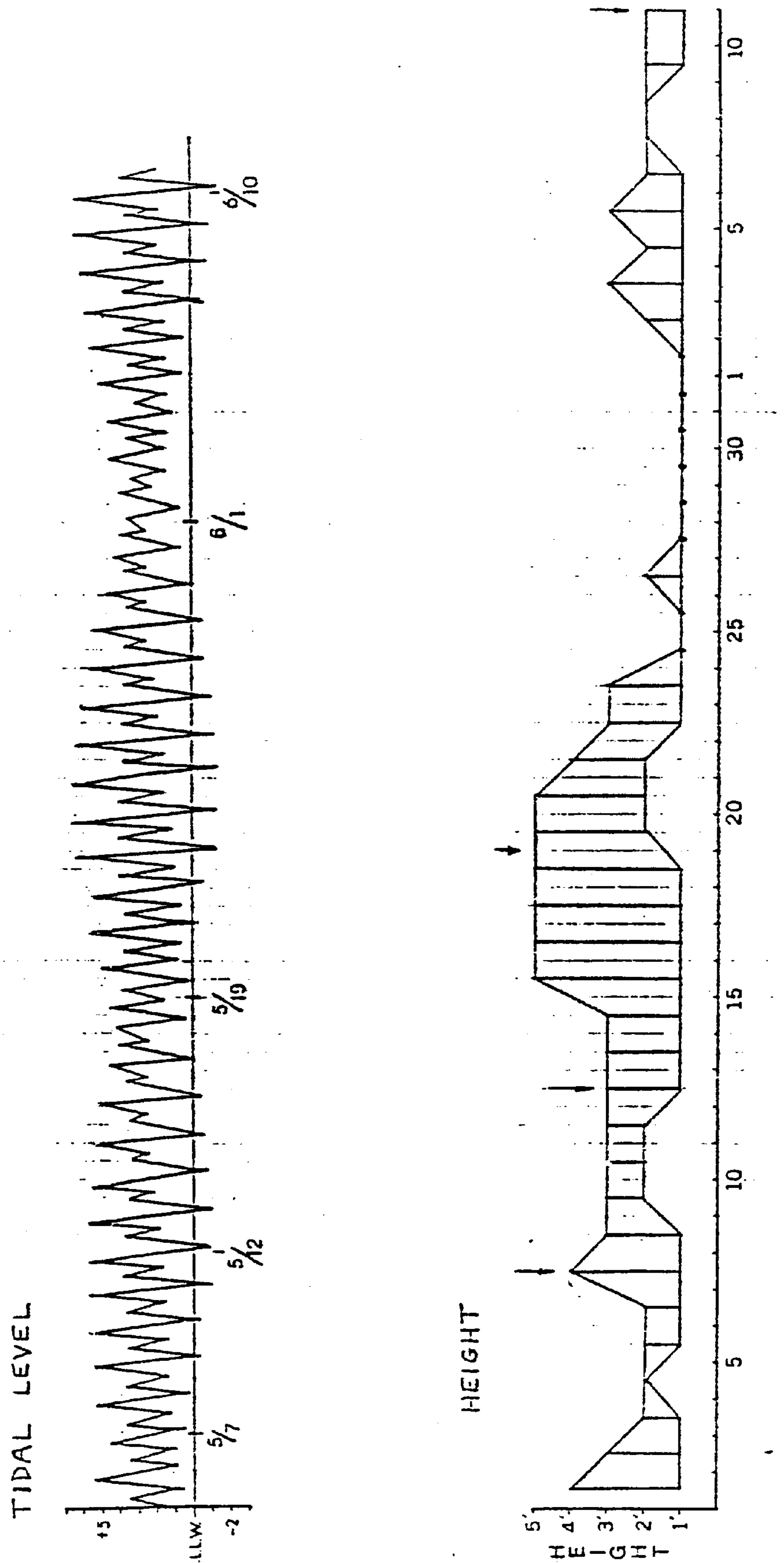
PROFILE D

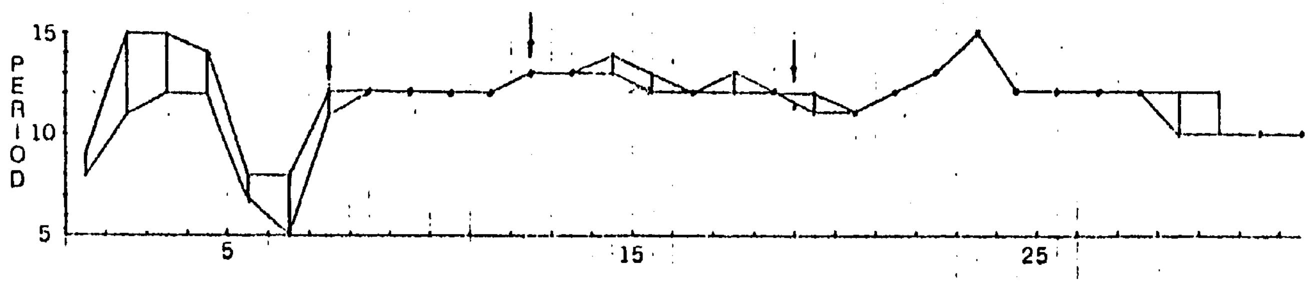



PROFILE C
cliff
60'
0
30
60
90
0
5
10
15
M.L.L.W.
MAR. 7
APR. 1
MAR. 20
MAR. 24

WAVE HEIGHT and PERIOD - MARCH 1 to APRIL 1




TIDAL LEVEL
+5
M.L.L.W.
-2
5/7
5/12
5/19
6/1
6/10
HEIGHT
5'
4'
3'
2'
1'
HEIGHT
5
10
15
20
25
30
1
5
10



WAVE DIRECTION 210 - 230 DEG.

WAVE PERIOD - MAY 1 to JUNE 10

Changes in beach profile and the factors affecting that change can be summarized as follows:

<u>December 6-December 17</u>

Profile C - The Steep, 6-foot berm scarp was smoothed out. Some headward erosion occurred on the upper foreshore which was equalized by a deposition in the middle foreshore. Lower foreshore was unaltered.

Profile C - General accretion occurred at all levels and the profile was smoothed with a minor ridge remaining in the middle foreshore.

Conditions - Light rain brought a small amount of new sediment to the beach. Tides: spring, profile taken as tidal cycle approaches neap tides. Surf: small, 1 ft to 2 ft; period was long, 11 to 15 secs from the south and southwest.

Analysis - The profiles were smoothed because of the large tidal range; accretion was due to small surf with long periods and the influx of river sediment.

<u>December 17-January 5</u>

Profile C - Accretion of lower foreshore and erosion of upper foreshore occurred; upper foreshore profile is now irregular and stepped.

Profile D - Erosion occurred at all levels. Small berm scarp is now present.

Conditions - Two inches of rain fell. Tides: full cycle, profile taken at the end of spring tide. Surf:

generally 1 ft to 2 ft with peaks of 3 ft; period is erratic, 9-16 secs.

Analysis - The extreme tides flattened the profile further, short period waves caused stronger longshore current (less wave refraction) which eroded profile D and caused some accretion on the lower foreshore of profile C where the longshore current is naturally slower.

January 5-January 27

Profile C - Some general accretion occurred and the upper foreshore was smoothed and slightly eroded.

Profile D - A small amount of headward erosion occurred with general accretion occurring elsewhere.

Conditions - Sediment from Topanga Creek influxed. Tides: the profile was taken in the middle of some of the most extreme spring tides of the year. Surf: very small, average 1 ft to 2 ft; period was erratic, increasing to 16 secs and then dropping to 8 secs shortly before the profile was recorded.

Analysis - Small waves and sediment influx caused accretion and extreme tides smoothed the profile.

January 27-February 21

Little change occurred. There was some accretion but no profiles were recorded.

February 21-March 7

Profile C - Erosion of upper foreshore and formation of 5-foot berm scarp occurred. There were no changes on the lower foreshore.

Profile D - Minor erosion occurred.

Conditions - Tides: medium, between spring and neap. Surf: small through February (1 ft to 2 ft) but reaching a peak of 4 ft to 6 ft shortly before the profile was taken; period, 10 to 12 secs except for the large waves which had 7 to 10 sec periods.

Analysis - The large waves with short periods caused the erosion and formation of berm scarp on the upper shore on Profile C but had little effect on Profile D. Medium ranged tides probably minimized the erosional effect of the large waves.

March 7-March 20

Profile C - Headward erosion (15 ft) of upper foreshore occurred and the berm scarp was smoothed.

Profile D - Massive accretion and formation of a new berm, 60 ft seaward of the old berm, occurred.

Conditions - It rained and sediment influxed from Topanga Creek. Tides: neap. Surf: decreasing from 2 ft to 4 ft on the 11th to 1 ft on the 20th; period was long, 11 to 15 secs.

Analysis - The influx of sediment from Topanga Creek caused the accretion along Profile D. Continuing high surf and higher tides after March 7 caused the headward erosion along Profile C.

March 20-March 24

Profile C - Accretion on lower foreshore occurred.

Profile D - The profile was smoothed and the beach ridge and new berm eroded.

Conditions - Tides: going into spring tides. Surf: 1 ft to 2 ft, 11 to 15 secs period.

Analysis - The increase in tidal range washed away the massive beach ridge along Profile D. Small, long period surf and new sediment from the creek caused accretion of Profile C.

March 24-April 1

Profile C - There was general accretion (about 2 ft) which produced a very flat profile.

Profile D - General accretion occurred.

Conditions - Tides: spring into neap. Surf: 1 ft to 3 ft with medium periods of 10 to 13 secs.

Analysis - The accretion was caused by an influx of sediment rather than the particular wave conditions.

April 1-May 7

Profile C - General accretion occurred, moving the berm 30 ft seaward.

Profile D - A small amount of accretion on the upper foreshore occurred but there was erosion on the lower foreshore.

Conditions - Tides: neap. Surf: small in middle April (1 ft) rising to 1 ft to 4 ft in early May with periods ranging from 5 to 15 secs; the larger surf was associated with medium periods (9-11 secs). The wave direction was more southerly than the previous month.

Analysis - The wave direction changed from 270-295° in March to 210-230° in April and May. This change could produce a slower longshore current which coupled with an influx of sediment from the Santa Monica Mountains could produce accretion.

<u>May 7-May 12</u>

Profiles C and D - A small amount of erosion on lower foreshore occurred.

Conditions - Tides: neap to spring. Surf: 1 ft to 3 ft, 12 sec period.

Analysis - The low tides caused the minor erosion.

<u>May 12-May 19</u>

Profiles C and D - A small amount of accretion occurred.

Conditions - Tides: spring to neap. Surf: 1 ft to 5 ft; period 11 to 12 secs.

Analysis - Larger waves do not necessarily cause erosion, especially if they have long periods.

<u>May 19-June 10</u>

Profile C - Erosion occurred at all levels.

Profile D - Erosion of lower foreshore and accretion of upper foreshore occurred.

Conditions - Tides: spring. Surf: 1 ft to 3 ft, 10 sec period, no data available for June 1-10.

Analysis - The surf height was not extreme and wave frequency data was not available so analysis is difficult. Shorter period waves may have caused the erosion.

June 10-end of Summer 1975

No profiles were taken during this time period. The largest surf conditions recorded were 8 to 9 ft high waves with 17 to 23 sec periods (from New Zealand on September 24, 1975), decreasing to 4 to 5 ft high in four days. Wave interference occasionally produced periods of 10 secs. The beach was eroded, and a 6-foot berm cliff was cut, however, it was quickly filled in a few days. Beach erosion from this storm was more severe on beaches further south.

In summary, the beach shape at Topanga is affected by tides, surf dynamics, and sediment availability. In the time period covered, the beach was most eroded during March and most prograded during late May. This cycle of erosion in late winter and early spring and accretion during early summer appears to be a function of wave approach angle as well as wave height steepness. Winter storms, which occurred in early spring, caused steep westerly waves of moderate height, 2 to 6 ft, which eroded the beach, especially in conjunction with high tides. The influx of sediment from Topanga Creek altered the profile at this time but did not seem to have a long-term prograding effect. In late spring the average wave approach was southwesterly and accretion occurred. Wave periods were slightly longer during this time but wave heights were greater than average. Very small, long period waves from the south in January 1974, however, did not appreciably accrete the beach. Sediment movement did not take place due to the extremely low wave energy.

Beach profiles were most gentle after periods of accretion, high wave approach angles, and/or extreme tides. Accretion and high wave approach angles are most likely accompanied by a decrease in mean sediment size; extreme tides increase the width of wave influence. The most gentle profile was recorded after a period of moderate surf (1 to 3 ft), maximum wave approach angle (270°) and extreme tides in which both diurnal tides had a large range.

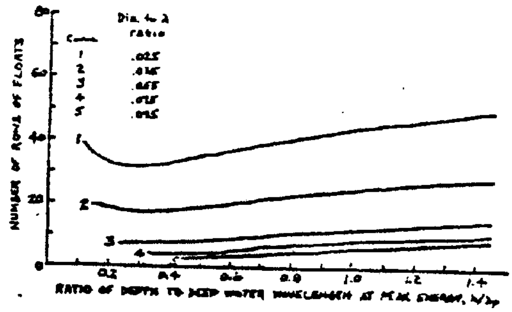
Tethered Float Breakwater Design

> The tethered float breakwater system is composed of a very large number of independently operating floats, each of which is quite small compared with a wave length. In a typical configuration, the floats are spherical, with high buoyancy, and are tethered just below the surface in a depth of water many times the float diameter. There is at least one diameter clear space between floats in all directions (Seymour and Issacs, 1974).

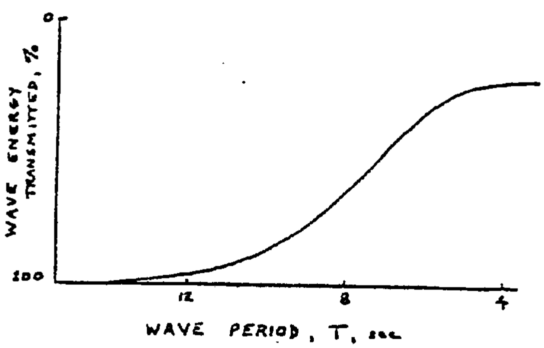
The width parallel to the shore of the breakwater is determined by the topography and the desired width of wave shadow. The number of tethered rows controls the degree of wave attenuation (Fig. 27).

Figure 27. The relationship between the number of rows of floating, float diameters, and water depth for a 50 percent reduction of wave height (after Seymour and Issacs, 1974).

Figure 28. Transmitted wave energy as a function of wave period (approximate).



Array size for 50% wave height reduction.
(After Seymour & Isaacs)



Design restraints imposed by the site are the range of water depths available for breakwater construction and the tidal range. The only free variables left to the designer are the number of tethered rows and the float diameter. Pertaining to these variables, the following relationships have been experimentally determined by Seymour and Issacs (1974): (1) performance of the breakwater is relatively insensitive to tether length, (2) performance improves with increasing float diameter, but at a decreasing rate (Fig. 27), (3) reasonable diameters for the breakwater floats are the same order as the significant wave height (mean height of the highest one-third waves) and reasonable depths of water are 5 to 20 times the significant wave height, and (4) wave attenuation is proportional to the number of tethered rows.

This design concept, which has been proven in wave tank experiments and field experiments along the shoreline near Scripps Institute of Oceanography, San Diego, provides the following environmental advantages over standard riprap type breakwaters:

1. Unrestricted water circulation - The porous nature of the breakwater allows tidal and wind driven currents to circulate the water behind the breakwater, thereby maintaining water quality.

2. Biological impact minimized - Continued circulation of water and nutrients behind the breakwater allows

marine life in the area affected by the breakwater to continue and remain virtually unaltered.

3. Visual impact minimized - The tethered breakwater is almost invisible from the shoreline. Only the tide adjusting floats and navigational buoys are visible.

4. Reversibility assured - Since the breakwater is only minimally anchored to the bottom, it can be partially or totally removed with ease. Within one working day the entire breakwater can be unanchored and towed away.

5. Construction disturbance minimized - The tethered breakwater is fabricated out of the water and is either towed to or assembled at the site. Heavy equipment is not required and the waters around the breakwater site are not appreciably disturbed.

6. Geologic - Morphologic impact minimized. By adjusting the degree of wave attenuation, the continuation of longshore sediment transport can be assured. Beaches downcurrent therefore will not be endangered by this type of breakwater.

The proposed facility at Topanga Beach would require a tethered breakwater approximately 240 m (800 feet) long placed 210 to 240 m (700 to 800 feet) offshore in front of the southeastern portion of the beach. This is an area not suited for other specialized uses (refer to the Base Map). The southern end of the breakwater would be slightly sailor's skill. Reducing a 4-foot surf day the same percentage would change the difficulty rating from 18 (intermediate to advanced) to 12 (intermediate to novice).

A floating breakwater, 22 rows wide, with float diameters of 5 feet, placed in 25 feet of water could provide the desired degree of wave attenuation. A breakwater this size would cause a 50 percent reduction in the height of waves with 8 sec periods (personal communication, Dick Seymour). Waves of a longer period would be less affected and waves which have a shorter period would be more affected (Fig. 28). The breakwater could not be placed further offshore due to the conflict of interest with the surfing activities off Topanga Point and the degree of wave shadow desired for boat launching. Further reduction of surf size is not possible owing to the prohibitive number of tethered floats required and concern for the continuation of coastal currents.

Impact of Breakwater

The effect of an offshore tethered breakwater at Topanga Beach would be to reduce the size of the surf and the size of the sediment that would stand on the beach and thereby reduce the average foreshore slope. Waves which diffract around the tip of the breakwater would strike the beach at an angle, causing the beach profile to be further reduced. Aggradation of the beach would occur at first and then stabilize when the beach profile reached an equilibrium with the transmitted and diffracted wave energy. The cycle of beach erosion and deposition would still occur but not as pronounced as is presently observed. Long period, constructive waves would be less affected by the breakwater than short period destructive waves. Occasional large, long period waves, such as those which reached the beach on September 24, 1975 (17-23 sec period, 8 feet high) would be virtually unaffected by the breakwater and would have a tendency to flush the aggraded beach behind the breakwater. No long-term effects should occur on beaches down current from Topanga Beach. Should adverse impact be noticed, the breakwater either could be easily reduced in size and effectiveness or removed altogether.

CONCLUSIONS

As a result of the geologic and oceanographic investigation of the proposed small-boat launching facility at Topanga Beach, the following conclusions were reached.

Boat Launching

1. Successful small-boat launching on open beaches is a function of boat type, surf height and form, wind velocity and direction, and sailor skill.

2. Light weight multihulls, self-bailing monohulls, dories and kayaks are boat types best suited for open water launching.

3. Launching difficulty is directly related to surf height and wave steepness. Winds which blow along-shore at a velocity of 10 to 12 knots are optimum for launching.

Boat Launching - Topanga Beach

Topanga Beach is a suitable beach for a boat launching facility because:

1. Natural surf is low, 0.6 to 1.2 m (2 to 3 feet), and can be easily altered with minimal adverse environmental impact.

2. The southeastern section of the beach, where the launching ramp would be placed, is sandy and not useful for other specialized beach activities.

3. The prevailing afternoon winds blow alongshore with a velocity of 8 to 10 knots.

Morphology and Currents

1. The offshore area adjacent to Topanga Beach is both rocky and sandy. The southeastern part of the beach is sandy with mean sediment diameters of 0.17-0.30 mm on the foreshore, decreasing to 0.06 mm, 270 m (900 feet) offshore, except where the rip current flows. The northwestern part of the beach is a rocky area which extends from the inter-tidal zone to 180 to 270 m (600-800 feet) offshore.

2. Longshore currents flow predominantly eastwardly. The strongest flow is along the section of beach which is at the greatest angle to incoming waves--between Topanga Point and the southeastern part of the beach. Minimum current velocities are found to the west of both Topanga Point and Chart House Point.

3. Only one major observable rip current is present. This rip current flows seaward where the long-

shore current decreases in velocity--between Topanga Point and the southeastern part of the beach. Coarse sediment is found on the sea bottom beneath the rip current.

4. Beach erosion occurs most often in late winter, under the influence of steep, westerly waves. Accretion occurs in summer, under the influence of long, southerly waves. The beach profile is most gentle after periods of high wave approach angles and/or extreme tides.

5. Ripples offshore are formed by wave-motion orbital diameters which are much greater than ripple spacing (wave length). Ripple wave lengths increase onshore and where independent of other factors vary directly with sediment size.

Breakwater and Effect

1. A tethered float system is the most ecologically compatible breakwater for Topanga Beach.

2. A floating breakwater, 270 m (800 feet) long, 22 rows wide with float diameters of 1.5 m (5 feet), placed 270 m (800 feet) offshore would alter the average boat launching conditions at Topanga Beach from its present "intermediate skills required" level to a "novice skills required" level.

3. This breakwater would reduce the size of the surf (50 percent for waves with 8 sec periods) and the size of the sediment that would remain on the beach, reduc-

ing the average foreshore slope, all of which will make boat launching easier.

4. The beach behind the breakwater would prograde but no long-term, adverse impacts would occur at Topanga or along beaches downcurrent. Long period waves would move accreted material out of wave shadow.

REFERENCES

REFERENCES

Bagnold, R. A., 1940, Beach formation by waves; some model experiments in a wave tank: Jour. Inst. Civ. Eng., v. 15, p. 27-52.

Bascom, W. N., 1951, The relationship between sand size and beach face slope: Trans. Am. Geophys. Union, 32, v. 6, p. 866-874.

________, 1964, Waves and beaches: Doubleday and Co., New York, 204 p.

Bowen, A. J., 1969a, The generation of longshore currents on a plane beach: Jour. Marine Res., v. 27, p. 206-215.

________, 1969b, Rip currents: Jour. Geophys. Res., v. 74, p. 5467-5478.

Bowen, A. J. and D. L. Inman, 1969, Rip currents: Jour. Geophys. Res., v. 74, p. 5479-5490.

Chapman, C. F., 1972 (revised), Piloting, seamanship and small boat handling: Stratford Press, Inc., New York, 639 p.

Dunham, J. W. and A. A. Finn, 1974, Small-craft harbors: design, construction, and operation: Special report no. 2, U. S. Army Corps of Engineers, 375 p.

Egstrom, Glen, 1974, L. A. County underwater resource inventory: October 1972 to September 1974: Department of Kinesiology, University of California at Los Angeles, 284 p.

Emery, K. O., 1938, Rapid method of mechanical analysis of sands: Jour. Sed. Petrology, v. 20, no. 4, p. 220-223.

________, 1961, A simple method of measuring beach profiles: Liminology Oceanography, v. 6, p. 90-93.

Evans, O. F., 1942, The relationship between the size of wave-formed ripple marks, depth of water, and the size of the generating waves: Jour. Sed. Petrology, v. 12, p. 31-35.

Fairbridge, R. W. (ed.), 1968, The encyclopedia of geomorphology--Encyclopedia of earth science series: v. 3, Reinhold Book Corp., New York, 1295 p.

Galvin, Cyril J., 1972, Waves breaking in shallow water: in Waves on beaches, Meyer, R. E. (ed.), Academic Press, London, p. 413-451.

Grant, U. S. and F. P. Shepard, 1940, Shallow-water sediment-shifting processes along the southern California coast: 6th Pacific Sci. Congress, 1939, Proc., v. 2, p. 801-805.

Handin, J. W. and J. C. Ludwick, 1950, Accretion of beach sand behind a detached breakwater: U. S. Corps of Engineers Beach Erosion Board, Tech. Memo., no. 16, 13 p.

Handin, J. W., 1951, The source, transportation and deposition of beach sediment in southern California: U. S. Corps of Engineers Beach Erosion Board, Tech. Memo., no. 22, 113 p.

Hayes, M. O., E. H. Owens, D. K. Hubbard, and R. W. Abele, 1972, The investigation of form and process in the coastal zone: in Coastal Geomorphology, Donald R. Coates (ed.), Binghamton, New York, p. 11-43.

Hendricks, J., 1972, Materials and methods for surveying the near offshore: Unpublished Master's thesis, Dept. of Geography, University of California at Santa Cruz, 62 p.

Hoots, H. W., 1930, Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California: Professional Paper 165-C, U. S. Dept. Interior, 134 p.

Ingle, James C., Jr., 1966, The movement of beach sand: Developments in sedimentology, v. 5, Elsevier Publ. Co., New York, 221 p.

Inman, D. L., 1953, Areal and seasonal variations in beach and nearshore sediments at La Jolla, California: U. S. Corps of Engineers Beach Erosion Board, Tech. Memo., no. 39, 82 p.

Inman, D. L., 1957, Wave-generated ripples in nearshore sands: U. S. Corps of Engineers Beach Erosion Board, Tech. Memo., no. 100, 66 p.

Inman, D. L. and B. R. Brush, 1973, The coastal challenge: Science, v. 181, p. 20-31.

Just, V. L., 1970, Techniques of sailing and racing the Malibu Outrigger: in Proceedings of the 2nd A.I.A.A. Symposium on the aero/hydronautics of sailing, v. 9, Western Periodicals Co., Los Angeles, p. 87-106.

King, C. A. M., 1959, Beaches and coasts: Edward Arnold (Publ.), Ltd., St. Martins Press, London, 403 p.

Komar, P. D. and D. L. Inman, 1970, Longshore sand transport on beaches: Jour. of Geophys. Res., v. 75, p. 5914-5927.

Komar, P. D., 1971, The mechanics of sand transport on beaches: Jour. Geophys. Res., v. 76, no. 3, p. 713-721.

_______, 1974, Oscillatory ripple marks and the evaluation of ancient wave conditions and environments: Jour. of Sed. Petrology, v. 44, no. 1, p. 169-180.

_______, 1975, Nearshore currents: Unpublished, chapter 7, 62 p.

Kowalski, T. (ed.), 1974, 1974 floating breakwater conference papers: Sea Grant, Marine Technical Report Series, no. 24, 301 p.

Longuet-Higgins, M. S., 1970, Longshore currents generated by obliquely incident sea waves: Jour. Geophys. Res., v. 75, no. 33, p. 6778-6801.

Los Angeles County Engineers, 1974-75, Wave study (EG 16), November 1974 to July 1975: Unpublished internal report, 24 p.

Los Angeles County Flood Control District, 1948, Annual Report, 326 p.

Mankiewitz, Paul, 1972, Sediment movement behind the Santa Monica breakwater: Term paper, unpublished, University of California at Los Angeles, Dept. of Geology, 30 p.

Marchaj, C. A., 1964, Sailing theory and practice: Dodd, Mead and Co., New York, 450 p.

May, James P. and W. F. Tanner, 1973, The littoral power gradient and shoreline changes: in Coastal Geomorphology, Donald R. Coates (ed.), Binghamton, New York, p. 43-60.

Pipkin, B. W., 1973, Progress report on study of beach nourishment along the southern California coastline: Dept. of Water Resources, State of California, 59 p.

Rector, R. L., 1954, Laboratory study of the equilibrium profiles of beaches: U. S. Corps of Engineers Beach Erosion Board, Tech. Memo., no. 41, 32 p.

Seismic Risk Maps of the United States, 1969: in South coast regional plan, geology element (preliminary draft), 110 p.

Seymour, Dick and John D. Issacs, 1974, The tethered float breakwater system: in Floating breakwater conference papers, Sea Grant, Marine Technical Report Series, No. 24, p. 55-71.

Shepard, F. P., 1950, Beach cycles in southern California: U. S. Corps of Engineers Beach Erosion Board, Tech. Memo, no. 20, 26 p.

Shepard, F. P. and D. L. Inman, 1950, Nearshore water circulation related to bottom topography: Trans. Am. Geophys. Union, v. 31, no. 4, p. 555-565.

South Coast Commission Regional Geology report, 1975, South coast regional plan (preliminary draft), Geology element, 110 p.

Southern California Coastal Water Resource Project, 1973, Southern California coastal water research project, Annual Report, Los Angeles County, 52 p.

Synoptic weather report, 1951 to 1961, Los Angeles International Airport, Dept. of Interior, 12 p.

Szuwalski, Andre, 1970, Littoral environment observation program in California, preliminary report, U. S. Army Coastal Engr. Research Center, Miscellaneous Paper 2-70, Washington, D. C., 242 p.

Thornbury, W. D., 1969, Principles of geomorphology: John Wiley and Sons, New York, 594 p.

U. S. Army Corps of Engineers, 1974, Las Tunas Beach Park: U. S. Army Engineer District, Los Angeles, preliminary field draft, unpublished, 26 p. plus appendices.

United States Coast Pilot 7, 1968, Pacific coast, Dept. of Commerce, 10th edition, U. S. Government Publ., p. 109-130.

United States Weather Bureau, Climatological data, annual summary--California: 1914-1962 (Santa Monica Pier), 12 p.

Watts, G. M., 1954, Laboratory study of the effects of varying beach wave periods on beach profiles: U. S. Corps of Engineers Beach Erosion Board, Tech. Memo., no. 53, 19 p.

Zenkovitch, V. P., 1967, Processes of coastal development, Oliver and Boyd, London, 738 p.

APPENDICES

Appendix A. Glossary of terms.

APPENDIX A

Glossary of Terms

beaching rudder - a rudder which pivots in poace so that it can be quickly or automatically raised or lowered.

bow wave - the wave created at the front (bow) of a boat by the boat's forward motion.

centerboard - a flat board which is pivoted into the water from the centerline of a boat in order to provide lateral resistance (resistance to sideward motion).

daggerboard - a centerboard which does not pivot into the water but is pushed through a slotted well into the water. It is less advantageous in the surf than a centerboard.

deep-water wave - a wave traveling in water deeper than one-half the wave's wavelength; such a wave has not been affected by the bottom topography yet. An open ocean wave.

displacement hull boat - a boat which always displaces its weight in water.

driving force - that component of wind force directed parallel to the boat's motion.

heeling force - that component of wind force directed perpendicular to the boat's motion.

heeling resistance - resistance induced by the heeling (tilting over) of a boat.

hull - the floating structural body of a boat.

induced resistance - resistance induced by a boat's sideward or non-forward component of motion.

keel - a fixed, permanent centerboard, usually with ballast.

monohull (sailboat) - a boat with one hull.

multihull (sailboat) - a boat with more than one hull. Catamaran - two hulls; trimaran - three hulls.

resistance due to leeway - induced resistance.

self-bailing boat - a boat whose lower deck lies above the waterline so that when the boat is swamped with water, it will not sink but rather will slowly drain itself.

shallow-water wave (shoaling wave) - a wave traveling in water less than one-half of the wave's wavelength; such a wave is affected by the bottom topography.

skin friction resistance - the frictional resistance caused by the movement of the surface (skin) of a boat's hull through the water.

soup - the foamy, turbulent water which moves onshore after the collapse of a wave. The wave form after its collapse.

swash - the run up and run down of the water right at the water's edge caused by shoaling waves.

wave-making resistance - the resistance caused by the waves which are created by the boat's movement through the water.

Appendix B. Current study data sheets.

APPENDIX B

LONGSHORE CURRENT DATA

RUN # 1
July 31, 1975
Time: 10:00 to 11:00
Tide: MEDIUM, +1 METER (3 ft)

BEACH LOCATION	SURF HEIGHT / DIRECTION	WIND VEL. (kts)	CURRENT VELOCITY	CURRENT DIRECTION
No. 1 Steel Groin	0.3 to 1.0 meters S.W.	0	5.8 cm/s	W
No. 2 Topanga Point	0.3 to 1.0 S.W.	0	5.8	E
No. 3 1st Building	0.3 to 1.0 S.W.	0	9.0 11.4 19.8	E
No. 4 Dead Tree	0.3 to 1.0 S.W.	0	7.5 10.5 10.5	E
No. 5 L.G. Tower 2	0.3 to 0.6 S.W	5	3.0	E
No. 6 Yellow House	0.3 to 0.6 S.W.	6-8	2.4	E
No. 7 Chart House	0.3 to 0.6 S.W	6-8	3.0 0.0	E

RUN #2
July 31, 1975
Time: 13:30 to 14:30
Tide: High 1.2 meters (4 ft)

LOCATION	SURF HEIGHT (meters) & DIRECTION	WIND VEL. (kts)	CURRENT cm/s	CURRENT DIRECTION
No. 1	0.3 to 1.0 S.W.	10-12 W	9 11.4 8.1	E
No. 3	0.3 to 1.0 S.W.	10-12 W	20.2 22.5 16.5	E
No. 5	0.3 to 0.6 S.W	10-12 W	9.0 9.0	E

RUN #3
August 27, 1975
Time: 10:00 to 11:00

No. 2	0.6 to 1.2 S	3-6 W	16.5	E
No. 3.5	0.6 to 1.2 S	3-6 W	45.0 15.0	E
No. 5	0.6 to 1.0 S	0-5 W	16.8 6.3	E
No. 7	0.6 to 1.0 S	0-5 W	—	W