**Title**
Monitoring Beach Erosion Control Alternatives - Southern California Examples

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# MONITORING BEACH EROSION CONTROL ALTERNATIVES
# SOUTHERN CALIFORNIA EXAMPLES

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## ABSTRACT

Survey monitoring methods are described which can be generally used to quantify the effectiveness of erosion control devices on sandy coastlines. Monitoring results of the Longard Tube installation at Del Mar, California are reported as an example. We conclude that due to high sand levels and low storm activity the tube has had insufficient interaction to assess its effectiveness. The baseline sand level data available on Del Mar beach illustrate the importance of detailed knowledge of the region of the erosion control device being assessed.

## 1. INTRODUCTION

Wide, sandy beaches provide the best shoreline protection and most desirable recreational possibilities on open ocean coastlines (Inman,1976). Studies and projects for sand beach enhancement, protection, stabilization, nourishment and restoration are often identified and implemented with high priority and cost in federal, state and local planning and action. With current and future demands for habitation and recreational uses placed on Southern California beaches, an increasing demand has arisen for low cost, environmentally sound, shoreline protection. Adequate monitoring programs enabling evaluation of new concepts and techniques are required to provide appropriate planning criteria. Unfortunately, there are many instances of installations where monitoring programs are inadequate, or lacking altogether.

The purpose of this paper is to describe and recommend survey monitoring methods which can be generally used to quantify the effectiveness of shoreline erosion control devices and methods on sandy , exposed shorelines and as an example to describe a program to document the performance of a Longard Tube installation in Del Mar, California. The results of this program illustrate the importance of detailed knowledge of the region of the erosion control device being assessed.

Due to high sand levels and relatively low waves, the Del Mar tube has not had severe wave exposure since it was installed in January 1981. A similar installation at San Clemente, California (Figure 1) is exposed to wave attack a greater proportion of time. Unfortunately, the baseline beach sand level data and the monitoring of the San Clemente tube configuration appear inadequate to assess its effectiveness.

Figure 1. Longard Tube installation at San Clemente, California. Photo taken in May 1982. Note, a total of three tubes have been installed parallel to each other in some places. Photo G. Kuhn.

A general study of low cost erosion protection structures and vegetation was carried out by the U.S. Army Engineers between 1974-1979 under the "Section 54" Shoreline Erosion Control Demonstration Act. The objectives of the program were to a) develop data on which to base logical selections of shoreline protection devices on inland or protected ocean coastlines of low or moderate wave energy, b) to develop techniques for making these selections and c) to disseminate the information gathered (Armstrong, 1976; Edge et al., 1976; Moffatt and Nichol, 1981). Many different types of materials and techniques were tried and monitored at a total of 37 sites on the Atlantic, Pacific, Gulf, Great Lakes, Alaska and Hawaii coasts. Monitoring efforts consisted of

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Littoral Environmental Observations (LEO), aerial and ground photography, sediment and vegetation sampling and beach and bathymetric surveys. In particular, Longard Tube installations were evaluated as bulkheads, low breakwaters and groins on the shores of the Great Lakes and at Alameda in San Francisco Bay. These were successful in holding sand against the shore (Alameda) and reducing bluff erosion (Great Lakes) for a short time. Vulnerability to vandalism and debris tearing the tube were cited as the main weakness of these installations.

About 10 years of experience has been gained with Longard Tubes in various configurations on the North Sea coast of Belgium and the East Frisian Islands of Germany. Typically, the tubes have been used to create a reinforced beach by stabilizing sand fill with a system of interconnected shore parallel and shore normal tubes. Two kilometers of coastal dunes have been protected at Klemskerke, Belgium since 1978 and about 2.5 kilometers of beach and dunes are sheltered at Langeoog, Germany. Unfortunately, no systematic wave observations are available for these installation sites. Therefore it is not possible to predict how these systems would work on the exposed, high energy Pacific coast.

## 2. SOUTHERN CALIFORNIA BEACHES

Sand level fluctuations on the Southern California coastline are driven by waves from the Pacific Ocean. On-offshore and longshore transport of sand is governed by the seasonal climatic variability of the wave energy and direction. The wave climate on the coastline is complicated by the presence of the Channel Islands offshore of the Southern California Bight (Pawka, in prep.). The Southern California coastline can be divided into discrete littoral cells or compartments, each containing a complete cycle of sand sources, sinks and transport paths (Inman and Chamberlain, 1960; Emery 1960; Inman and Frautschy, 1966). These general concepts have been useful in designing erosion control assessment programs.

Over the past 100 years the extensive urbanization of Southeren California has led to severe modifications in the natural sediment budget (Brownlie and Taylor, 1981) Although the tectonically active Southern California collision coastline (Inman and Nordstrom, 1971) has always been subjected to erosion by the natural forces, prior to man's intervention there apparently existed greater compensating natural beach replenishment (Inman,1982). This consisted of sediment transport to the shoreline by rivers and streams and material eroded from the unprotected coastal terrace, mainly the poorly consolidated bluffs. Much of this natural sand replenishment is being prevented by flood control and irrigation district dams that inhibit and control the natural runoff, and by coastal revetments which inhibit bluff erosion. Further, protective structures at harbor entrances have blocked longshore transport paths along the coast. This has contributed to periodic shortages of sand at downcoast beaches, as evidenced at Oceanside, California. On the other hand, creation of new harbors (Oceanside and Marina del Rey, for example) or expansion of existing harbors (San Diego Bay) has locally and intermittently contributed quantities of sand comparable to or larger than the natural supply. Maintenance dredging of harbors and lagoons has likewise intermittently nourished the coastal beaches.

Climatic cycles further modify the amount of sand reaching the coast and affect the transport rates and directions. Historical observations show that the area is dominated by two climate regimes conveniently called "wet" and "drought" periods. The droughts are usually longer (20-40 years) and characterized by relatively low rainfall, infrequent light or moderate storms from the west or northwest and relatively mild wave climate dominated by southward littoral transport in the northern littoral cells. By contrast, the wet regimes are shorter with less predictable weather, more rain, more extra tropical, southern storms and higher waves with increased northward littoral transport. From 1945 until 1977 the Southern California Bight had experienced a temperate drought with reduced sand supply and net southward littoral transport.

## 3. DEL MAR, CALIFORNIA LONGARD TUBE

Del Mar, California beach is a fine to medium grained sandy beach 1.8 kilometers in length terminated by narrow cliffed areas to the north and south and is situated to the west of the San Dieguito River flood plain (Figure 2). The

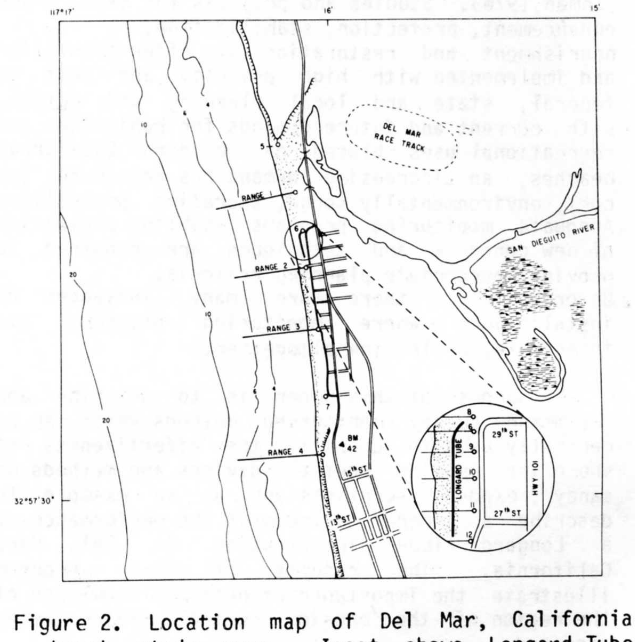

Figure 2. Location map of Del Mar, California beach study area. Inset shows Longard Tube plan profile and rangelines 8, 9, 10, 11 and 12 used to document tube and adjacent beach configuration changes. Rangelines 1, 2, 3 and 4 have been profiled regularly since 1974.

geologic history of the region has been dominated by a series of marine inundations since pre-Tertiary times (Inman,1982). The present day beach consists of Pleistocene sediments backed by low, active dunes which have been stabilized by modern residential development. In an effort to slow the beach erosion caused by both episodic and long term loss of beach sand, the City of Del Mar installed a test section of Longard Tube 200 meters in length between 27th and 29th Streets (Figure 2). The installation was completed in January 1981. In order to determine the effectiveness of the tube, an existing beach profile program sponsored by the City of Del Mar since 1974 (Figure 2, Ranges 1,2,3,4) was expanded to include additional profile ranges over and near the tube (Figure 2, inset, Ranges 8,9,10,11,12).

The Del Mar Longard Tube consists of a 1.75 meter diameter envelope of polypropylene fabric with an inner lining of waterproof polyethylene. Structural capability is provided by filling the tube with sand. A trench was dug to an elevation of 0.6 meters above Mean Sea Level (National Geodetic Vertical Datum, 1929) parallel to the shore line. Sand from the trench was piled on the seaward side of the installation to act as a buffer keeping the sea from filling the trench. The sand was later used to fill and bury the tube. The plastic envelope is unrolled and positioned in place. The sand filling process is accomplished by pumping a slurry of sand and water through a patented funnel device into one end of the tube. The sand is retained using a filter cloth which allows only water to pass out the far end.

A second sand filled tube 25 centimeters in diameter is connected to the base of the larger tube by a 3 meter length of filter cloth. The smaller tube is designed to protect the larger tube in the event of severe wave scour by dropping into the scour depression while the interconnecting filter cloth retains a berm of sand at the base of the larger tube. This is designed to allow for a maximum of about 2 meters of scour below the elevation at the base of the main tube.

Two 50 meter lengths and one 100 meter length were filled, coated with epoxy impregnated sand to protect the fabric from vandalism (Moffatt and Nichol, 1982) and buried beneath the beach face with earth movers. The northern end of the installation curves landward butting into the existing rip-rap shore protection (Figure 2, inset). The main length of the tube is parallel to the existing shore protection with an approximate 10 meter seaward offset. Lengths are butt jointed at their ends. The southern end of the installation does not curve into the existing shore protection, and initially was protected by large sand bags, but these were later replaced with rip-rap following displacement of the bags during the first winter storm in early 1981.

The data taken under this program to asses the Longard Tube performance include:

1.) Initial survey of the installation documenting the horizontal and vertical position of the Longard Tube, followed by subsequent surveys to monitor changes in configuration;

2.) Monthly beach profiles to document the response of the beach adjacent to the tube for comparison with known fluctuations before the tube was installed and with beach changes away from the tube. More frequent profiles are occupied as required to assess storm related changes;

3.) Visual wave observations used to compare the variation of the sediment driving forces from one season to another and to relate these forces to the observed fluctuations in the beach;

4.) Photographs taken to document storm related changes and seasonal sand fluctuations.

To provide vertical and horizontal reference points from which the configuration of the Longard Tube and the beach profiles could be measured, permanent bench marks were installed. These consist of a two meter long brass or stainless steel rod 1.3 centimeters in diameter driven into a stable portion of the beach backshore, and having the upper one meter anchored in place with 90 kilograms of concrete. Each bench mark has a brass name plate encased in the concrete with a unique number identifying the monument.

Sites for five bench marks were carefully chosen to be representative of the beach adjacent to the tube and to be in a stable backshore area. Three of the rangelines (9,10,11) divide the Longard Tube into equal parts. The other two bench marks (8,12) were installed up coast and down coast of the tube to document end effects of the tube. Three secondary reference points were chosen within a convenient distance of each bench mark, so that the bench mark could easily be relocated by swinging arcs with a tape measure from any two of the points. This, combined with thorough documentation of the bench mark locations (for detailed description of requirements, see for example Hemsley, 1981) yielded a reference point from which documentation of the changes in both the Longard Tube configuration and the beach profile measurements could be achieved.

## 4. BEACH PROFILE MEASUREMENTS

Measurements to assess the beach sand level changes and effects of the Longard Tube were conducted using a beach profiling method described by Inman (1953) and Inman and Rusnak (1956). Monthly onshore profiles were done to maximum wading depths at low tide (typically -2 meters M.S.L.) using an automatic surveyor's level and leveling rod for elevation measurements, and a stainless steel line to determine distance (Figure 3).

Bi-monthly offshore profiles are conducted at the high tide during the same day as the onshore profile. An attempt is always made to overlap the onshore and offshore profiles. However, because of wave conditions, this is not always possible .

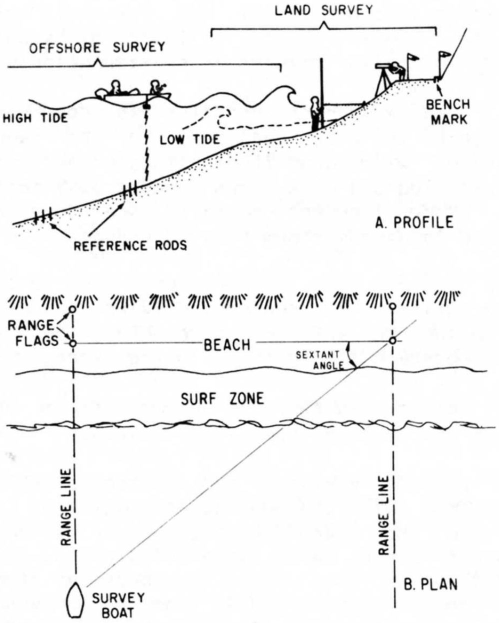

Figure 3. Schematic of beach profiling technique showing overlapping subaerial (land) and offshore survey methods.

To aid in removing wave induced uncertainty from using the sea surface datum in offshore fathometer profiles,brass reference rods approximately 1.25 meters long were placed in two arrays along each rangeline at approximately 6 and 10 meter depths. During the day offshore fathometer profiles are made, divers carefully measure the portion of the rod protruding above the sand surface, yielding the relative change in sand level. These measurements are accurate to one or two centimeters, and considerably increase the accuracy of offshore profiles.

The natural fluctuations of sand level on Del Mar beach change from profile range to profile range and over time. Figure 4 illustrates a few of the natural fluctuations in sand level which complicate the evaluation of experimental shore protection devices like the Longard Tube. The figure shows the volume changes per unit length of beach above an arbitrary datum for the subaerial profiles on Range 2. The sand volume is calculated by integrating the area betwen a given profile and an arbitrary vertical level well below any actual profile changes. This procedure gives an area (meters**2) or equivalently, a volume per unit length of beach (meters**3/meter). Figure 4 shows relatively large, seasonal sand level fluctuations with high levels usually during late summer to early winter (July-December) and lower levels from winter to early summer (January-June).

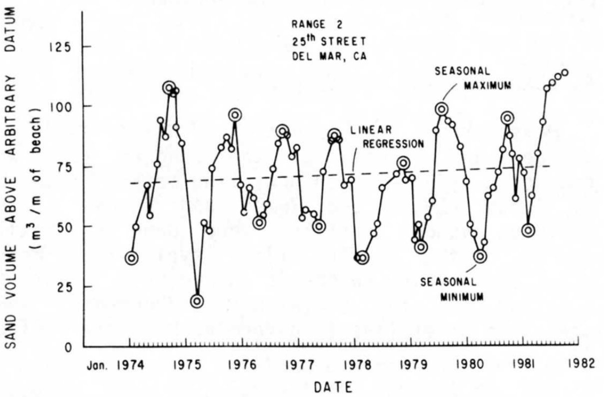

Figure 4. Sand volume per unit length of beach at Range 2 surveyed approximately monthly since 1974. Note slow erosion trend until 1979 followed by net accretion since that time.

The seasonal fluctuations at Range 2 are superimposed on a trend showing slight accretion over the period since 1974. More careful inspection shows that accretion has occurred between 1979 and present, but that slow erosion was occurring from 1974 through 1978. Data from Ranges 1, 3 and 4 (not shown) indicate seasonal fluctuations superimposed on net erosion over the same period.

These considerations are important to assessing the effectiveness of the Longard Tube. The tube was installed at a location on the Del Mar beach experiencing natural accretion. Had the background data not been available, and assuming that this portion of beach will continue to widen, the erroneous conclusion may have been drawn that the tube was responsible for the accretion.

Another aspect of the problem is the quantification of wave forces that drive the seasonal and long term sand level changes. Beginning in early 1981 the lifeguards at Del Mar have been making visual wave observations which are compiled and analyzed as part of the City of Del Mar sponsored survey project. This data set is not yet long enough to draw any conclusions and there are no other systematic wave observations at Del Mar.

The closest, continuous, published wave observations are from the Coastal Engineering Data Network (Seymour, et al., 1980) sensor off Oceanside pier and beach. The published daily maximum significant wave height is plotted in Figure 5. In a qualitative way, the averaging emphasizes large, persistant wave episodes. The seasonal changes in wave energy are clearly evident, with two distinct severe winters, 1977-1978 and 1979-1980 standing out. Note also the relatively low wave energy for most of the winter 1980-1981. Unfortunately the wave station was removed in early 1981.

The relatively mild winter waves followed by a very mild spring and summer wave climate has resulted in high sand levels at Del Mar and along most of the Southern California coast. Figure 6 shows the 1979 and 1981 seasonal maxima. Note that the 1981 beach width is about 20 meters wider than the 1979 berm width, which was the highest level since 1975 (see Figure 4). Also shown in

Figure 6 are the seasonal minimun profiles measured in 1980 and 1981. The vertical cut expected on Range 2 between maximum summer sand level and the typical minimum winter profile is at least 2 meters. Horizontally, the beach berm can be expected to receed 40 meters. Figure 7 shows the progradation of the subaerial beach from the 16 February 1981 minimum to the 13 October 1981 maximum. This accretion substantially buried the tube by about June.

Figure 8 shows the subaerial beach progradation over the Range 10 since 6 March 1981. It can be seen that the sequence is very similar to that observed on Range 2. Note that the placement of the Longard Tube (shown elongated due to the vertical exaggeration) is in the maximum offshore position that avoids the 2 meter vertical seasonal cuts that can be expected. The tube can be anticipated to prevent up to 1 meter of erosion which would otherwise normally occur landward of it's location. The tube can be expected to be exposed by about 1 meter, or half it's diameter during typical winter beach configurations.

The photographic record of the tube was begun during installation operations and is being kept current. Early photos show that the tube is long and smooth with no longshore perturbations (Figure 9).

Figure 10 shows the horizontal and vertical location of the tube (lower panels) relative to the new benchmarks 8, 9, 10, 11 and 12. Note the 20 centimeters dip near Range 10 associated with a joint between two of the three sections. During

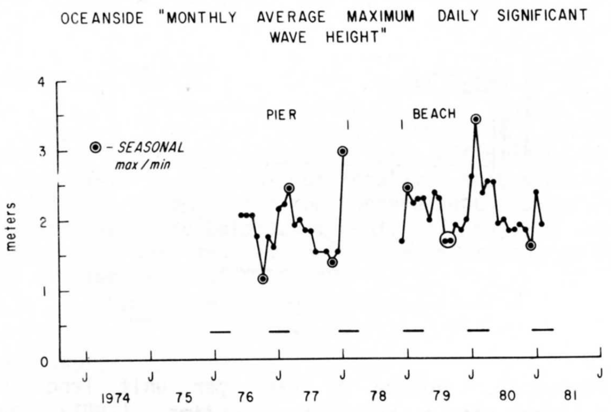

Figure 5. Summary wave statistics from California Coastal Data Colection Program pressure sensor at Oceanside. Note severe winter waves of 1977-78 and 1979-80.

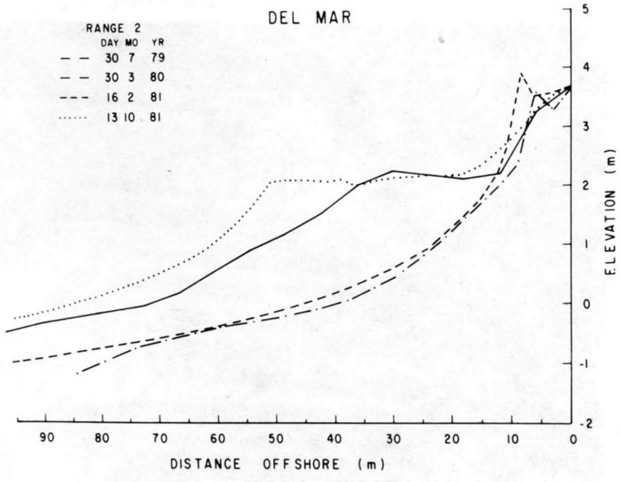

Figure 6. Profiles at Range 2 showing recent winter minimum and summer maximum configuration.

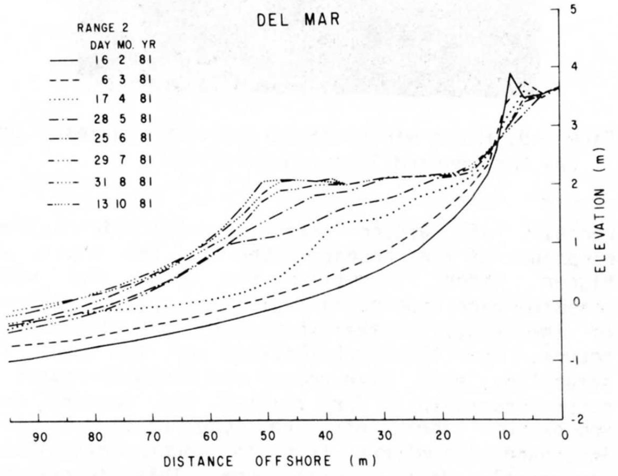

Figure 7. Beach progradation during 1981 from seasonal minimum 16 Feb 81 to maximum 14 Oct 81 at Range 2.

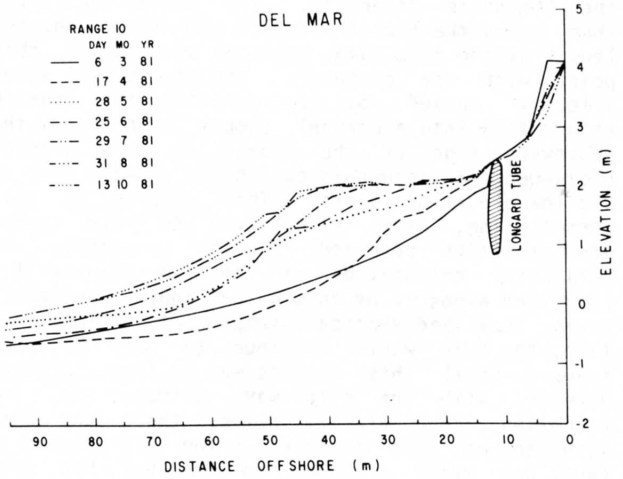

Figure 8. Natural progradation following installation of Longard Tube (Jan 81). Note that 10x vertical exaggeration distorts the cross section of the tube, which is actually round.

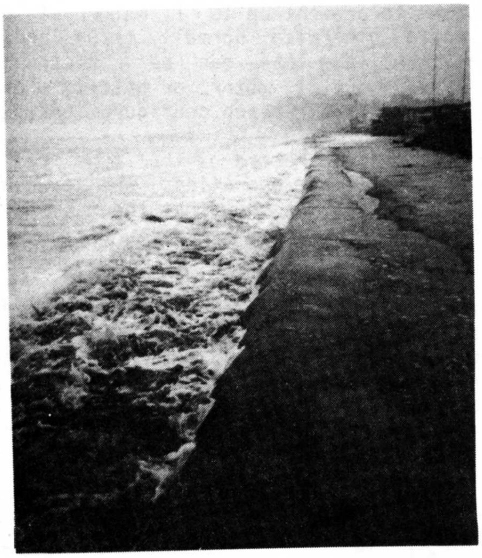

Figure 9. First winter storm activity against the Del Mar Longard Tube, January 1981.

periods of winter sand levels which allow exsposure of the Longard Tube by the waves at higher tides, inspection has shown that with repeated over topping by wave run-up, saturation of the sand on the shoreward side of the tube occurs. When the beach landward of the tube is saturated, each wave uprush and backwash causes a scour depression to form on both the seaward and shoreward sides of the tube caused by the increased turbulence (due to local reflection) immediately adjacent to the tube. This depression is generally deeper on the seaward side (20 to 30 centimeters) than on the shoreward side (10 to 20 centimeters) of the tube due to more intense wave reflection. However, once the depression is formed on the shoreward side of the tube, it acts as a channel for the overtopped water to flow in the longshore direction. The channelized flow then seeks the lowest point of elevation along the length of the tube and returns seaward at this point with the backwash. The increased water velocity caused by concentrating the seaward return flow into a channel scours sand from the shoreward side of the tube. As this process continues, a trough is cut on the seaward side at the low elevation points. This process is self perpetuating, and is believed to have caused irregularities observed in the vertical and horizontal orientation of the tube (Figure 11). Long term exposure of this nature could presumably cause localized vertical slumping of the tube. In time, the tube would continue to bury or roll seaward until this process was no longer active. However, with the mild wave climate and the accretion trend already noted, there has been insufficient wave interaction for this process to cause any major problems in the Del Mar test installation.

Figure 10 also shows changes in sand volume seaward (right) and shoreward (left) of the tube. As indicated, the tube has little effect on the sand levels since the beach has been in an accreting sequence since February 1981. This is shown on the seaward volume changes which all increase. Shoreward of the tube, there have been small changes at Range 10 and slightly larger changes at Range 12. The degree to which the tube is effective in retaining sand can be quantified with summaries like the upper part of Figure 10.

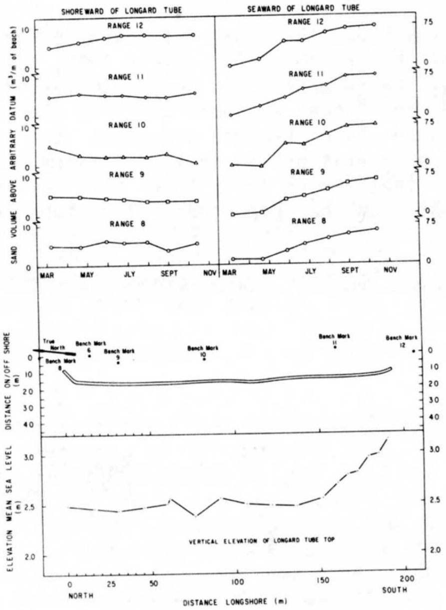

Figure 10. Volume of sand per unit length of beach as a function of time (1981) and separating sections of beach seaward and landward of the Longard Tube. Lower part of figure shows plan and elevation survey of Longard Tube after installation. Future changes in beach sand volume and Tube configuration can be compared with these baseline data to assess tube effectiveness.

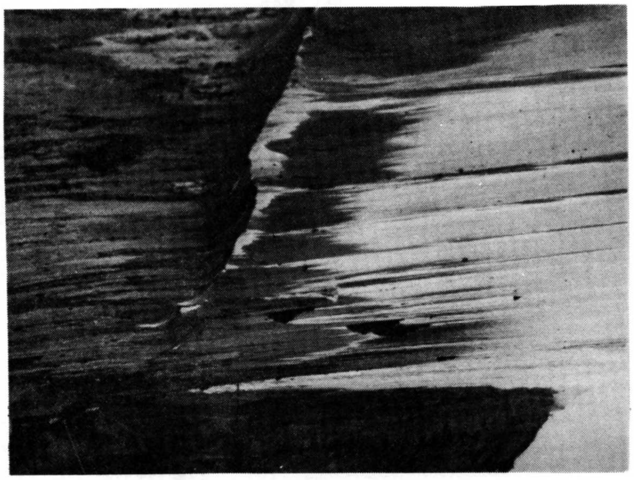

Figure 11. Del Mar Longard Tube, March 1981. Note perturbations in tube compared with Figure 9.

## 5. CONCLUSIONS

Successful monitoring programs of shore protection devices require adequate background information of the baseline and seasonal and longterm regional sediment fluctuations and driving forces. Measurements of sand level changes and wave forcing adjacent to the installation can then be compared to the background data to assess effectiveness. Low cost shore protection devices like the Longard Tube may be considered experimental on open ocean coastlines. Surveys and other detailed documentation of initial placement and configuration and changes in these are also crucial. The well documented tube at Del Mar, California has had insufficient wave exposure to assess its effectiveness, while the apparently active tube at San Clemente has been inadequately surveyed and monitored.

## ACKNOWLEDGEMENTS

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