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PERFORMANCE DOCUMENTATION OF THE LONGARD TUBE AT DEL MAR, CALIFORNIA 1980—1983

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ABSTRACT

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The Longard Tube experimental revetment installed in Del Mar, California in December 1980 has been monitored and its performance documented until it subsided and became ineffective during the severe winter storms of December 1982 to March 1983. The data suggest that the tube had no measurable effect on the sand level at Del Mar beach. The beach profile monitoring program conducted by Scripps in Del Mar since 1974 served as important background information for the design and interpretation of the monitoring program measurements.

The tube experienced relatively minor storm wave interaction during winter 1980—1981. This was followed by heavy beach accretion on the entire reach in spring 1981 and an unusually mild winter of 1981—1982. By July 1982 the tube was totally buried behind a berm extending 35 m seaward. The severe winter storm waves of 1982—1983 coupled with high sea level due to high spring astronomical tides, sustained onshore westerly winds and low atmospheric pressure, eroded the sand level on Del Mar beach to the lowest level in at least 10 years. The Longard Tube settled differentially by up to 2 m and was continually overtopped at high tide, rendering it ineffective by late January 1983. It was removed in March 1983. The principal conclusion of the study is that the Longard Tube configured as it was in the Del Mar test is not a substantial enough barrier to effectively prevent beach sand erosion during severe storm events on the Southern California coast.

INTRODUCTION

Wide, sandy beaches provide the best shoreline protection and the most desirable recreational possibilities on open-ocean coastlines. As these coastlines are developed, and overdeveloped, a demand has arisen for protection from both episodic and long-term erosion. The types of protection vary widely in type and cost and range from legislated, "institutional" restrictions such as increased setbacks where this is still realistic, to monumental structures to protect the most valuable coastal real estate (Edge et al., 1976). In

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this array of alternatives, there is a group loosely called "low cost" shore protection devices suitable for relatively low-energy shorelines and affordable by local jurisdictions, individual homeowners or groups of homeowners. Low cost is of course a relative term, but a good rule of thumb definition is the one used by the Army Corps of Engineers Low Cost Shore Protection (Section 54) demonstration program of $50 per lineal foot for materials if no heavy equipment is needed for installation, or $125 per lineal foot for materials, labor and needed equipment at 1975 prices (Moffatt and Nichol, 1981). In view of the cost constraints, the devices would not be expected to be effective in "a more vigorous storm than may be expected to occur on the average of once in any 10-year span" according to the same source.

Longard Tubes are low cost, sand-filled plastic tube devices that have been used in a variety of configurations and environments and for different purposes on the North Sea coast of Europe, in the Great Lakes and in a few California coastal applications (see Armstrong and Kureth, 1979; Moffat and Nichol, 1981; Waldorf and Flick, 1982). The tubes were developed for temporary or emergency use on coastal construction sites, to build causeways or as toe protection for conventional structures, for example. An application manual has recently been published by the Longard Company (Anonymous, 1983).

About 10 years of experience has been gained with Longard Tubes in various configurations on the North Sea coast of Belgium and 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 km of beach and dunes are sheltered at Langeoog, Germany. Unfortunately, no systematic observations are available for these installation sites. 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 as part of the Section 54 project. These tubes 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.

The purpose of the present paper is to present the results of the Longard Tube monitoring program in Del Mar, California. This project has the advantage of having systematic monthly subaerial beach profile measurements available since 1974 as a background. It will be shown how important these background measurements are to assessing the effectiveness of devices like the Longard Tube.

BACKGROUND

Del Mar, California beach is a fine to medium grain sand beach, 1.8 km long and terminated by narrow cliffed areas in the north and south. The offshore area has a smooth sand bottom with relatively straight, parallel contours. The beach is located to the west and south of the San Dieguito River flood plain (Fig. 1) and consists of Pleistocene sands backed by low barrier dunes stabilized by residential development since about 1930. The longshore and on-offshore sand transport in the area is driven mainly by the swell waves generated by distant Pacific storms and by locally generated waves in the inter-Channel Island fetch. Visual wave observations were gathered as part of this work and these data are used to distinguish qualitatively between relatively calm and relatively stormy periods over the length of the study.

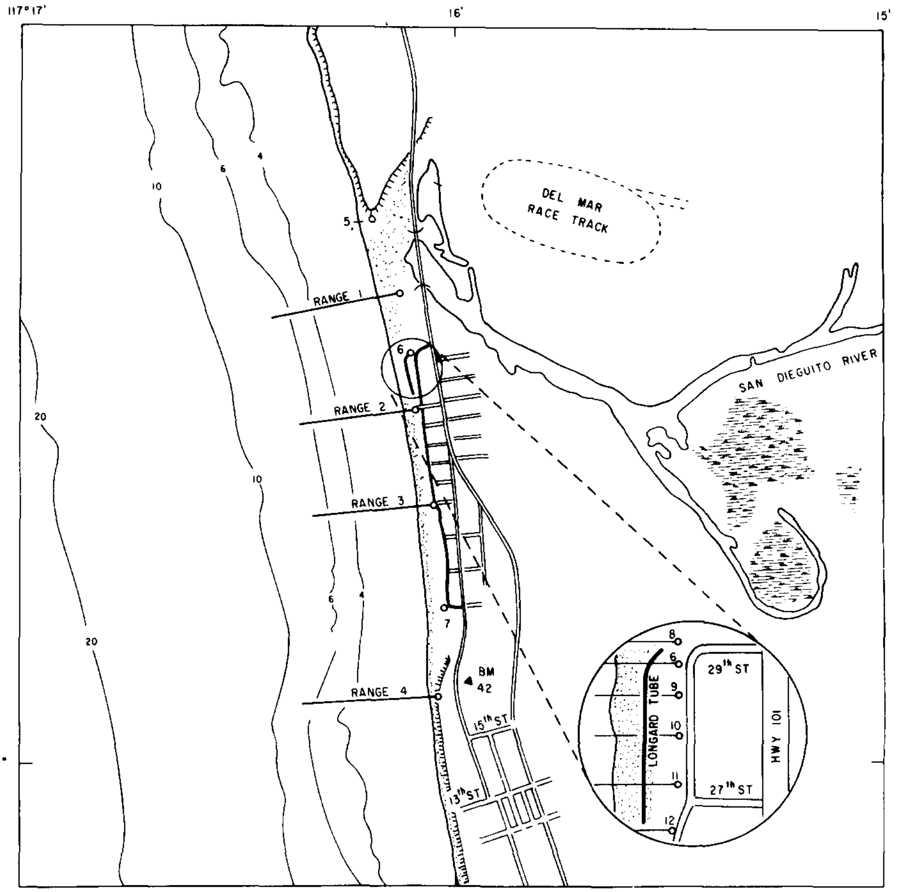

Fig. 1. Location map of Del Mar, California beach stuay area.

Beach profile measurements

Systematic beach profile measurements have been collected at Del Mar since early 1974. From 1974 through 1980, subaerial surveys to wading depth were conducted approximately monthly at the locations marked Range 1 to 4 in Fig. 1. Since early 1981, directly following installation of the Longard Tube, the survey program was expanded to include monthly profiles measured at Ranges 8, 9, 10, 11 and 12 (Fig. 1, inset) over and near the tube as well as offshore fathometer profile measurements to 10 m depth at quarterly intervals on Ranges 1, 2, 3, 4 and 10 (Waldorf and Flick, 1983).

The subaerial profiles provide important background information on particularly the seasonal fluctuations of sand level on the exposed beach face. The location and amount of typical berm build-up and retreat can be accurately quantified, for example. The details of these measurements and how they are applied to the monitoring and evaluation of the Longard Tube are presented below.

DEL MAR, CALIFORNIA LONGARD TUBE

A 200-m test section of 1.75-m diameter Longard Tube was installed on Del Mar beach between 27th and 29th Streets in December 1980 (Fig. 1, inset). It was installed parallel to the existing predominantly wooden or concrete seawalls with approximately a 10-m seaward offset in an effort to stabilize the beach backshore. The tube was not designed to prevent erosion or property damage during severe beach cuts or extremely high sea level events such as those of winter 1982—1983, although the popular concept fueled by newspaper accounts seemed to be that the tube was a panacea. The intention was to provide a first line of defense for the beach backshore by attempting to prevent about 1 m vertical cut of the berm which occurred regularly during a typical winter beach configuration. The installation cost of the tube was $95,700, shared by the adjacent property owners ($55,542), the City of Del Mar ($21,633), the State of California Coastal Conservancy ($12,000) and the Longard Company ($6,525). A trench was dug at the installation site so that the elevation of the tube top was about 2.5 m above MSL. Two 50-m and one 100-m length of tube were sand filled, butt joined together and coated with epoxy impregnated sand to protect the fabric from accidental damage and vandalism.

The Del Mar design specified toe protection in the form of a smaller, 25-cm tube installed parallel to and in front of the main tube. This secondary tube was attached to the main tube with a section of filter cloth. In the event of severe scour, the small tube was intended to prevent the large tube from slumping by falling into the scour depression while the filter cloth retained the intermediate sand toe.

Winter 1980—1981

Installation of the tube was completed in early January 1981. In mid-January the first, and most intense storm of the winter season eroded the beach foreshore to the extent that waves interacted with the Longard Tube

Fig. 2. Wave interaction with Longard Tube during first winter storm, 22 January 1981.

(Fig. 2). Wave energy was reflected on the seaward side of the tube, while the tube retained sand in a perched beach, on the shoreward side. It should be noted however that no significant sand loss occurred in the backshore anywhere on Del Mar beach during this winter.

On the extreme southern end of the tube large sand bags placed to tie back the tube to the existing seawalls were undermined and fell seaward (Fig. 3). In this local area further wave overtopping of the tube produced localized sand scour on the shoreward side as water returned seaward in the area of the slumped sand bags. Minor localized loss of sand behind the tube occurred as a consequence.

Fig. 3. South end of Longard Tube showing failure of sand-filled bags used as tie-back to effectively hold sand behind the installation during moderate storm of mid January 1981.

Two more winter storms during the 1980—1981 season produced waves large enough to interact with the Longard Tube. During these periods, observations revealed a problem that eventually contributed to tube failure. During brief intervals when storm waves occurred during high tide, wave overtopping rapidly saturated the sand shoreward of the tube and water returning seaward with the wave backwash poured over the tube top at localized areas of lowest elevation. Water from wave overtopping scoured small longshore channels on the tube's shoreward side, which funneled more water into the areas of low vertical elevation. As the scouring continued the water returning seaward pouring over the tube began to also scour channels on the tube's seaward side as shown in Fig. 4. This process is self-perpetuating, and continuous exposure eventually caused localized vertical slumping of the tube as it was undermined by local scour. This process contributed to the rapid subsidence of the tube during the severe beach cut and overtopping in winter 1982—1983.

Fig. 4. Photo taken 5 March 1981 showing first stages of localized scour depressions on the seaward side of the tube formed by seaward return flow over tube at points of lowest vertical elevation. This photo taken after the tide had dropped and shows only the remnants of the scour channels which are filled in as over-topping of the tube ceases.

In 1980—1981 this process was only active during periods of the highest spring tides combined with moderate low winter beach foreshore sand levels. By placing the tube on the beach backshore, with the tube top at an elevation of 2.5 m above MSL (Fig. 5) only three storm events produced waves large enough to reach the tube. The duration of wave exposure was insufficient to cause any major localized tube slumping.

Accretion 1981—1982

Following the mild winter of 1980—1981, the beach prograded rapidly in a typical accretionary sequence (Fig. 5) removing the tube from wave interaction. By September 1981 the tube was almost entirely buried as shown in Fig. 6. Sand levels at this time were very high as shown by a 10-year time

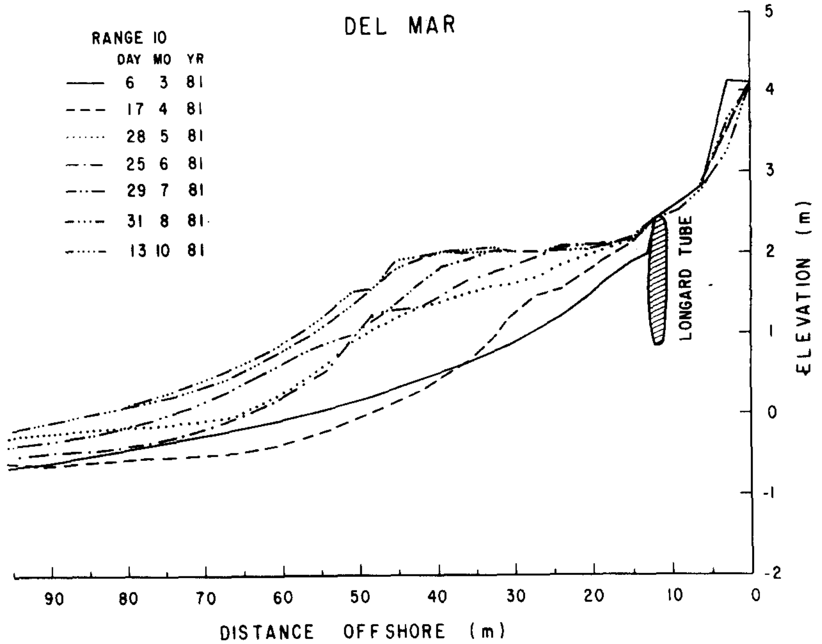

Fig. 5. Beach profiles at Range 10 showing accretion with time. Tube cross-section actually round, but vertical exaggeration of 10 times causes vertical elongation.

series of beach foreshore sand volume fluctuations at Range 2 (Fig. 7). Sand volume is calculated by integrating the area between a given profile and an arbitrary datum. This gives an area (m^2) or equivalently, a volume per unit length of beach (m^3/m), representing the average gain or loss of sand volume.

Rangeline 2 is located 100 m south of the Longard Tube installation, and is representative of the beach foreshore sand level fluctuations at the site that occurred before, during, and after the presence of the tube. The dashed line shown in Fig. 7 is the annual mean volume for a given calendar year, and shows a general erosional period from 1974 to 1980, followed by a strong accretionary trend until the winter of 1982—1983.

These longer term data are important in assessing the effectiveness of the Longard Tube. The tube was installed during a period of natural foreshore accretion which limited wave interaction with the tube by shielding it with a natural, wide sand beach. As Fig. 7 shows, following the mild spring and summer of 1981, the winter period of 1981—1982 was unseasonably mild. In fact, the winter seasonal minimum sand volume experienced during 1981—1982 was actually higher than the 1978 summer maximum. Figure 8 shows the beach configuration after the most severe storm of the 1981—1982 winter. By June 1982 the tube was completely buried by additional accretion (Fig. 9). Del Mar beach was experiencing the highest beach foreshore sand volumes of the past 10 years. Obviously, this mild period did not provide a test of the Longard Tube as a useful shoreline revetment.

Fig. 6. Accretion of beach during late spring and summer 1981 essentially buried the Longard Tube and removed it from wave interaction. Photo looking south along tube axis taken 2 September 1981. See Fig. 6 for accretionary profile sequence.

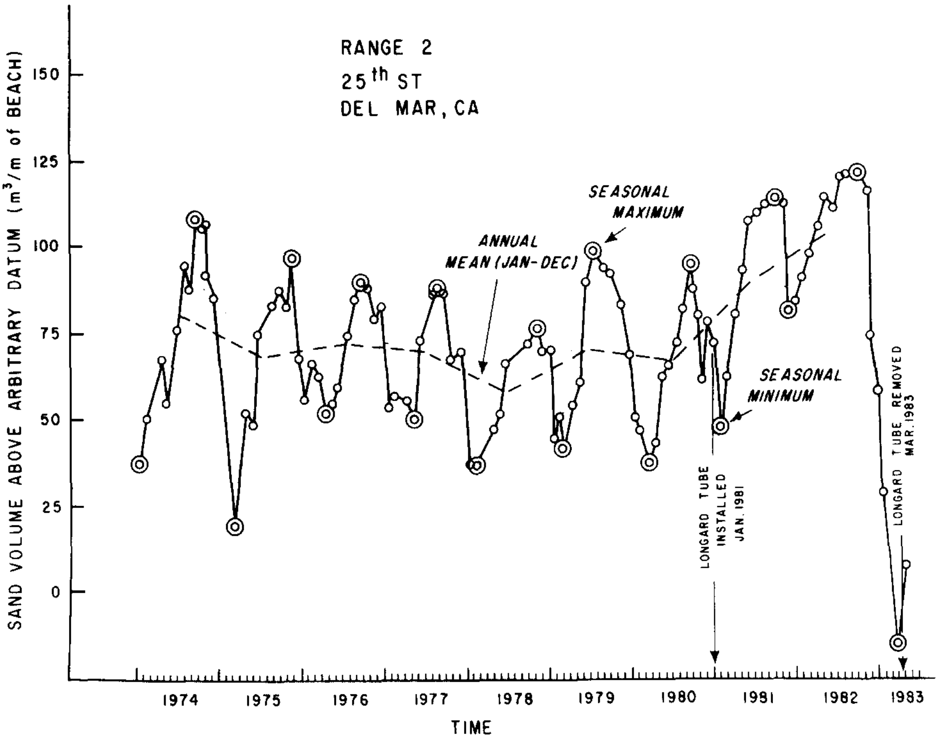

Fig. 7. Sand volume per unit length of beach foreshore versus time at Range 2. See Fig. 15 for location of Range 2 relative to Longard Tube.

Winter 1982—1983

In sharp contrast, Fig. 7 shows the large sand loss that occurred during the 1982—1983 winter, resulting in the lowest beach foreshore sand volumes experienced in at least the past 10 years. This occurred in a series of storms which initially removed the wide sand beach by moving sand from the beach foreshore and depositing it in sand bars offshore in depths of about 3 to 4 m below MSL.

The first major winter storm reached the Del Mar area on 30 November and lasted until 2 December 1982 (Fig. 10). This storm coincided with a spring tide period allowing the waves to act on areas of the beach backshore. This one storm period reduced the foreshore sand volume by about 45 m^3/m to a level lower than it had been during the 1981—1982 winter (Fig. 7), and exposed about one half of the Longard Tube diameter (Fig. 10). While this first storm caused minor localized slumping of the tube, its main effect was to transport large quantities of sand offshore, thereby exposing the tube to the next, even more severe sequence of storm waves (Figs. 11, 12).

The most intense storm waves to batter the Southern California coastline during the recent winter occurred in the last week of January, 1983 and

Fig. 8. Mild winter of 1981—1982 produced only minor removal of sand near Longard Tube. Photo 12 November 1981.

Fig. 9. Mild winter of 1981—1982 and continuing accretion caused Longard Tube to be completely buried by date of this photo (looking north) 28 June 1982.

Fig. 10. Photo taken 2 December 1982 showing perched beach and substantial removal of sand seaward of Longard Tube during first winter storm of 1982—1983. Profile change and tube subsidence shown in Fig. 12.

coincided with unusually high sea level due to the combined effect of high spring astronomical tides, persistent onshore westerly winds and low atmospheric pressure. Water level observations at Scripps Institution Pier 10 km south of Del Mar and at a depth of about 6 m indicated sea surface elevations as much as 30 cm higher than both the predicted high tide of 2.3 m above MLLW and the predicted low tides. Visual observations of breaker height at Del Mar beach conducted by experienced lifeguard observers indicated peak heights of 3—4 m. Sustained wave heights averaged about 2 m over the 5-day period from 25—29 January 1983.

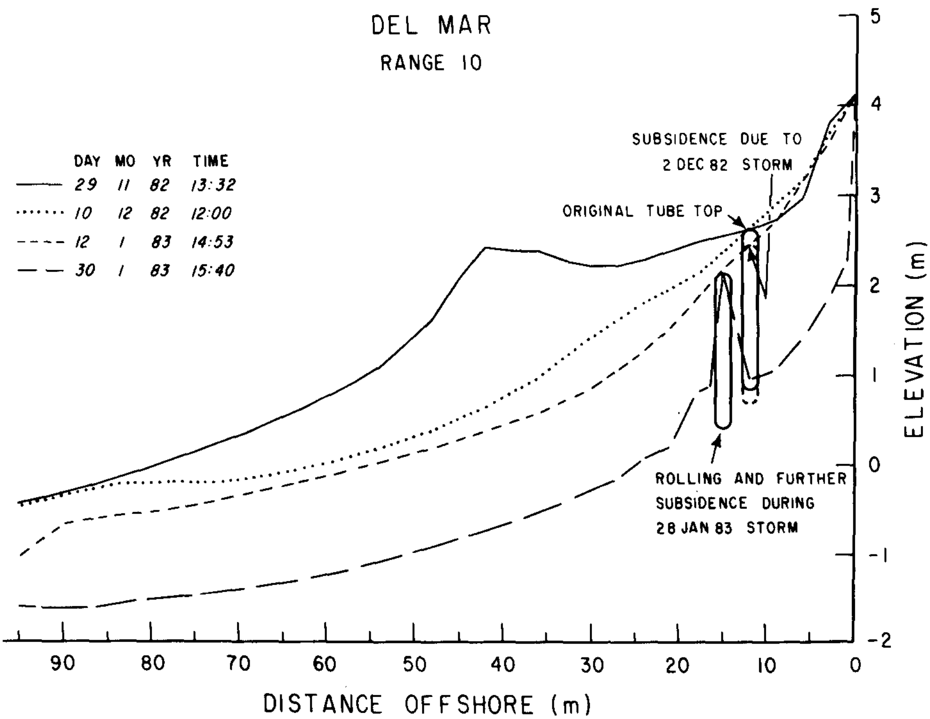

Fig. 11. Beach and tube configuration changes during severe 1982—1983 winter storms at profile Range 10. Note wide beach in 29 November 1982 profile, followed by severe beach erosion, Longard Tube subsidence and offshore rolling in storms of 2 December 1982 and 26—28 January 1983.

Within one day, on 27 January 1983, the sand shoreward of the tube had been removed by wave action (Fig. 12). The 25-cm diameter tube originally attached to the filter cloth beneath the main tube was ripped from the filter cloth and thrown over to the shoreward side of the main tube. Visual observations indicated that during this time the tube was effective in reflecting a portion of the wave energy during medium tide levels. It is notable that no structural damage occurred to the main tube as a result of wave action during this first day of the storm period. However, during peak tide levels, the

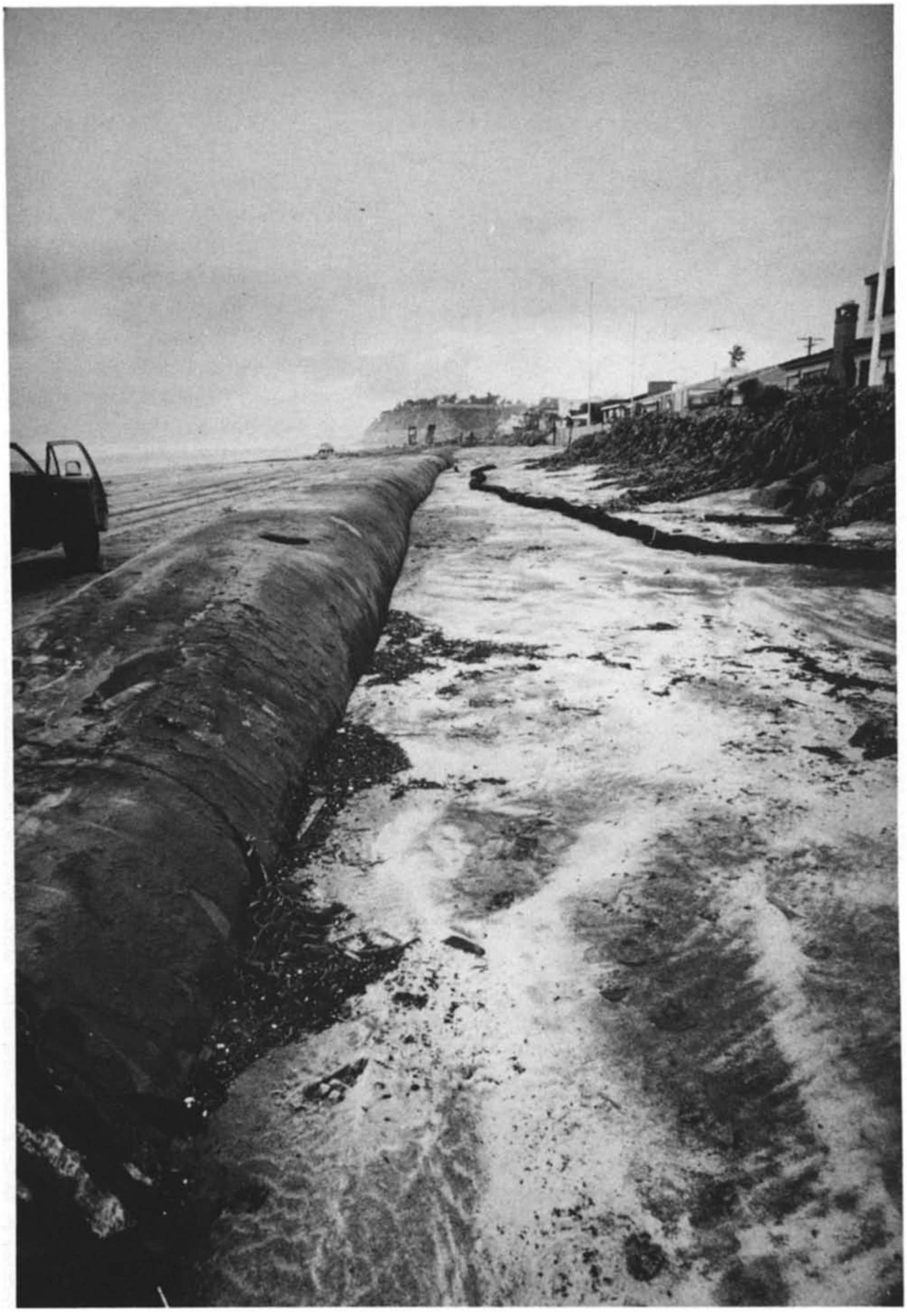

Fig. 12. Photo taken 27 January 1983 showing severe beach erosion, particularly sand removed from shoreward side of Longard Tube. Note 25-cm tube intended as toe protection for main tube thrown shoreward.

tube was easily overtopped to the degree that it provided an insufficient barrier to the storm waves. Storm waves and high sea level continued the next day, 28 January 1983, and with already reduced sand levels on the beach fore and backshore, waves eroded areas farther shoreward. During the period of high tide, major tube subsidence and localized undulations occurred due to continued wave overtopping (Figs. 13, 14).

During the 27—30 January 1983 storm period, the tube also rolled seaward slightly (Fig. 11). However, displacement in the cross-shore direction was not a significant problem. The subsidence of the tube along with the beach sand level and local scour depressions were the primary cause of tube failure and the magnitude of these are shown in Fig. 15. The tube subsided due to undermining of the beach sand beneath it, and in localized spots sank by as much as 2 m. One point of major subsidence came from a hole punctured in the tube's fabric by a large piece of debris carried by wave action at high tide. The sand near the hole leaked out, leaving the tube deflated in this area. Also, a bulldozer delivering rip-rap drove over the northern 15 m of tube, tearing the fabric and allowing sand to leak out in this section as well. The lowest undulations over the length of the tube actually channeled wave backwash producing temporarily accelerated scour and sand removal from the backshore area.

Fig. 13. Photo taken 28 January 1983 during 2—3 m high tide showing tube subsidence and undulations. Overtopping waves scoured sand from shoreward side of tube. Loose bricks on this patio and other property damage indicated maximum uprush of about 4 m above mean sea level.

Fig. 14. Photo taken 28 January 1983 at low tide looking north and showing major undulations and scour depressions in Longard Tube. Note exposed filter cloth previously attached to 25 cm diameter toe protection tube now flung over stair case on shoreward side. Extensive rock rip-rap was placed all along Del Mar beach during the storm episode.

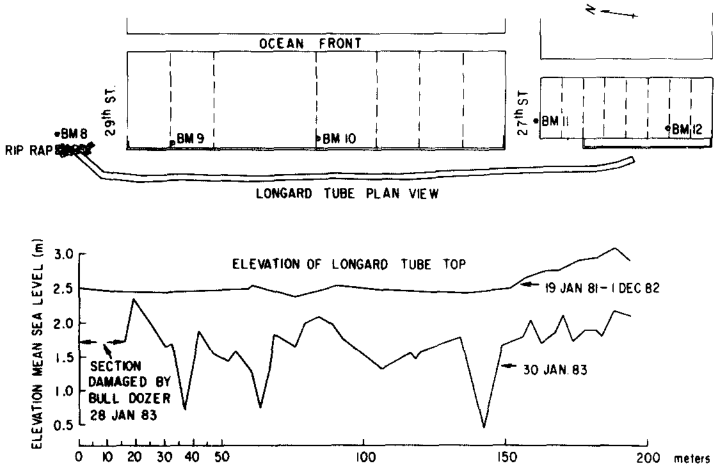

Fig. 15. Plan view location (upper) and elevation (lower) along Longard Tube showing configuration changes during monitoring program. Plan shows location of bench marks. Lower section shows initial elevation of tube top which was stationary from 19 January 1981 to 1 December 1982, and lower elevation after January 1983 storms.

The foreshore sand volume changes at the Longard Tube are shown in Fig. 16. Beach profiles taken at each rangeline were separated into portions shoreward and seaward of the tube axis. In the case of the control rangelines to the north and south (Ranges 8 and 12, Fig. 15), the longshore extrapolated axis of the tube was used to separate the shoreward and seaward sections of the profiles. Also shown in Fig. 16 is the relative wave energy from visual wave height observations plotted on the same time scale as the volume data to show the relative size of wave episodes.

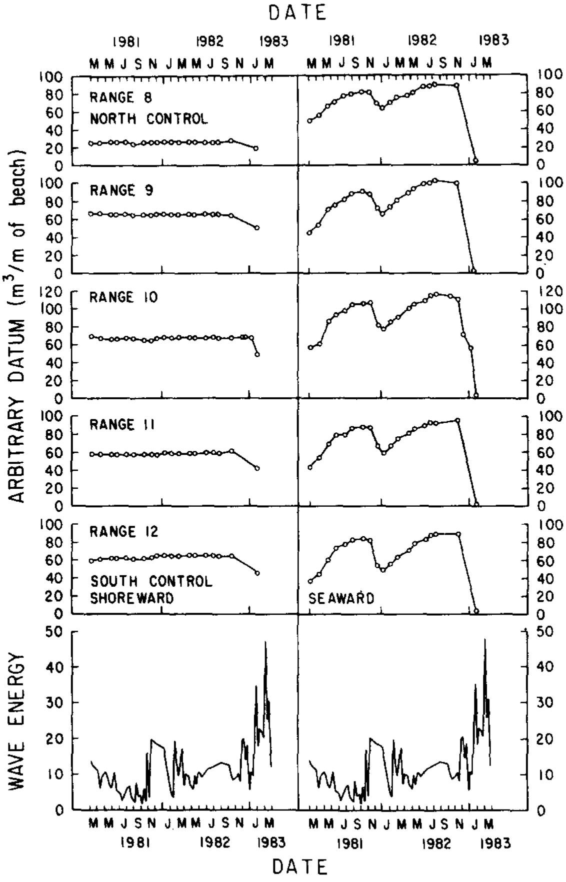

Fig. 16. Sand volume changes at Ranges 9, 10, 11 crossing the tube and at control Ranges 8, 12. Profile volumes calculated separately seaward and shoreward of the tube location (or extrapolation). Lower panels show relative wave energy (arbitrary units) from visual observations for the same time period.

Figure 16 clearly shows that the respective sand level fluctuations in front of and behind the Longard Tube were identical on the ranges intersecting the tube (Ranges 9, 10, 11) and on the control ranges (Ranges 8, 12) over the life of the device. During the January 1983 storms on the order of 100 m^3/m of sand was lost all along the foreshore seaward of the Longard Tube axis. Once the foreshore sand had been removed, waves attacked the backshore and subsidence and overtopping of the tube made it ineffective so that areas behind the tube lost as much sand as adjacent areas.

These data suggest that the tube had no measurable influence on the sand level at Del Mar beach. Visual observations, however, indicate that the tube did have some beneficial effect in acting as a partial wave barrier in the earliest hours of the severe storms beginning 27 January 1983.

CONCLUSIONS

The primary conclusion of this monitoring study is that the Longard Tube as configured in the Del Mar installation is not a substantial enough barrier to dissipate or reflect wave energy and prevent subaerial beach erosion during severe winter stórms such as those of 1982—1983. The beach profile data showed no measurable difference between beach fluctuations at the tube site or on adjacent control ranges.

The second and related conclusion is that the beaches at Del Mar and at most other Southern California locations have sufficient sand supply at the present time to weather the average, typical seasonal fluctuations observed

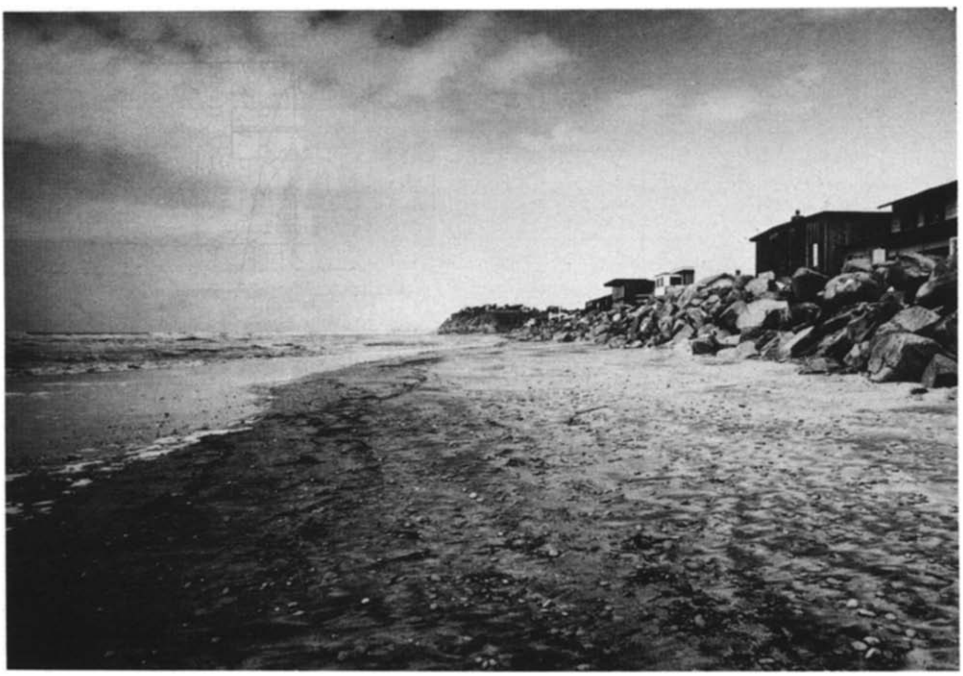

Fig. 17. Photo looking north from Range 2 (foot of 25th Street, see Fig. 15) on 24 March 1983 after removal of Longard Tube. Note rip-rap revetment and very low sand level due to extreme winter erosion.

over the past 10 years. The shorefront public, residential and commercial developments do not require protection from the typical, mild to moderate winter storms and the attendant beach cuts. The winter of 1982—1983 has made clear however, that many beaches and developments do require protection from the much less frequent, severe winter storms, particularly when these are coincident with high sea levels. The Longard Tube and other "low-cost", alternative revetments used by themselves do not seem to be suitable for this type of protection (Fig. 17).

ACKNOWLEDGEMENTS

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