

CHAPTER 245

The Durban Beach Restoration Scheme after 30 years

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1. Abstract

The harbour breakwaters at Durban in conjunction with the dredging of the harbour entrance cut off the sediment supply to the important bathing beaches of the city, necessitating a beach restoration scheme. This paper reviews this scheme. Before 1977, the measures to restore the beaches included an underwater mound, beachfill and rock groynes. After 1977 and following a previous review, it was recommended not to complete the mound, to place initial beachfill, regularly nourish the beaches and to build low-level groynes. Implementation started with a sand pumping scheme and 600 000 m³ of beachfill followed by the building of three multi-functional pier/groynes. Monitoring of the beach restoration scheme enabled valuable experience to be gained on aspects such as the loss rate of sand from the beaches, beach profile and scour levels alongside the pier/groynes and on the determination of a potential erosion line and building control zone. This paper concludes with some important lessons learned from the scheme.

2. Introduction

Durban, situated on the South African East Coast, is one of the oldest South African harbour cities and a popular holiday resort renowned for its golden beaches and subtropical climate. Since construction of the harbour started in 1857, the natural northbound littoral drift was cut off from the bathing beaches in the Durban Bight north of the harbour entrance. Figure 1 shows the position of the harbour and the beaches along the Durban Bight.

The state of the beaches deteriorated progressively over the years and this led to the local council, the Durban Corporation, to consider and implement measures to prevent the increasing erosion. Beach replenishment in the form of various sand pumping schemes had been implemented over the years and two rubble-mound groynes, known as the Paterson groynes, were constructed in a critical area to retain longshore sediment transport. However,

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these measures did not cope sufficiently with the erosion problem and the Durban Corporation was forced to take further action.

The Council for Scientific and Industrial Research (now CSIR) became involved in 1957 when it was contracted by the Durban Corporation and the then South African Railways and Harbours (now Portnet) to investigate the whole beach erosion problem and to devise a strategy for beach improvement and restoration. The investigation consisted of field studies to collect environmental data (e.g. on wave and current characteristics, sedimentological and morphological conditions) and various model studies to investigate the effect of present and proposed structures on the sediment movement around the harbour entrance and the beaches to the north. This extensive investigation was undertaken over a period of 20 years during which numerous reports were published regarding the results of the different investigations. All the work done over this period was summarised in a *status quo* report (CSIR, 1976) which also described various alternative schemes to improve the condition of the beaches and presented proposals for prototype monitoring.

After an intensive review of the information contained in the *status quo* report an amended beach management strategy was proposed in 1977. This strategy was published in CSIR (1977). The Durban Corporation accepted the strategy outlined in this report and in 1980 embarked on an extensive restoration and replenishment scheme for the beaches south of Somtseu Road (Figure 1). The CSIR was again involved in the implementation of the scheme through model studies of proposed structures and through prototype monitoring. At present the CSIR is involved in the scheme as specialist advisor on beach improvement and management by means of interpretation of the monitoring data. A second *status quo* report compiled in 1989 (CSIR, 1989), summarised all work done and the conclusions reached over the years and also made recommendations for further work.

The beach improvement scheme over the last 30 years can therefore be divided into two distinct periods, namely, (1) the original beach restoration scheme implemented before 1977, and (2) following the intensive review in 1977, the new restoration and management strategy after 1977. The purpose of this paper is to review the beach restoration and management scheme and to share with others some of the important lessons learned over a period of 30 years.

3. Beach Restoration Before 1977

3.1 Strategy

The original beach restoration strategy proposed in the early 1960s, was based on various model studies and prototype monitoring and consisted of:

- (i) Construction of an offshore underwater mound designed to reduce storm-wave energy in order to reduce longshore sediment transport along the beaches.
- (ii) Provision of an initial beachfill to restore the beaches along the sediment starved section of the Bight.

- (iii) A renourishment scheme to replenish material as compensation for the natural losses from the Bight. (These natural losses were calculated then to be about 70 000 m³/year (CSIR, 1963, 1974 and 1976) and it was therefore recommended that this volume of material be placed annually on the beaches).
- (iv) Replacement of the old dilapidated Paterson groynes by a number of groynes to retain sediment transported along the Bight.

3.2 Implementation

Implementation of the above-mentioned strategy started in 1966 and was initially centred around the construction of the underwater mound. The position of the mound is shown in Figure 1. The mound was constructed by placing dredged sand on the line indicated on Figure 1 according to a design profile. It was found that the mound naturally reached a stable profile such that the ratio of the height of the mound to the original water depth was approximately 0,4. An effort was also made to place an initial fill on the southern Bight beaches. Replenishment of the beaches was done through a simple sand pumping scheme which delivered sand at two locations immediately north of the northern harbour breakwater. However, construction of the proposed new groynes to replace the Paterson groynes were then not attempted due to concentration on the mound construction.

In 1976, after 20 years of involvement in the project, the CSIR compiled an overview of all the work done up to that point. Conclusions were drawn from all the information available and recommendations were made concerning future work with respect to beach improvement and management. These can be summarised as follows (see Figure 1 for the different locations referred to):

- (i) Due to progressive lengthening of the harbour breakwaters, the northward directed longshore transport was cut off at the harbour entrance. This, together with the focusing effect of the old dredger spoil dump situated offshore from the harbour entrance, led to the coastline in the Bight realigning itself to a new long-term equilibrium shape which was more concave than that which existed before harbour construction.
- (ii) Development between Somtseu Road and West Street encroached into the dynamic beach area and was, therefore, subjected to extensive storm erosion.
- (iii) The beaches between Mgeni River mouth and Somtseu Road appeared to be in a state of long-term equilibrium while the beaches south of Somtseu Road were subjected to gradual long-term erosion at a rate of 70 000 m³.
- (iv) The underwater mound, which had by 1976 not been completed to the design dimensions, offers some protection against extreme conditions in the area north of Somtseu Road, while little or no protection is provided in the area south of Somtseu Road.
- (v) The underwater mound could be extended in a northerly direction which would provide better protection for the area immediately south of the Mgeni River. This would result in a reduction of the loss rate from the beaches in the

Bight. However, this would mean that erosion of the beaches immediately north of the Mgeni River mouth would increase with an amount equal to the reduction in the Bight loss rate.

The above conclusions indicated that beach restoration and improvement should be concentrated on the Bight beaches south of Somtseu Road. It was recommended that, should additional protection against storm erosion be required, the underwater mound should be extended to the north and completed to its design dimensions. Additional erosion north of the Mgeni River would then have had to be accepted. An estimated 2,5 million m³ of sand would have been required to complete the mound. It was further advised that a sufficiently wide buffer be provided along the beaches south of Somtseu Road and that an estimated 200 000 m³ of sand would be needed for this purpose. A combined beachfill and low-level groyne scheme was considered the most feasible alternative of the possible beach restoration schemes. However, it was necessary for the Durban Corporation to define their specific requirements for the Bight area and to decide on the level of improvement necessary to meet these. Besides the restoration measures, it was recommended that some prototype monitoring be carried out to gain more knowledge of the complex system and to ensure optimization of the improvement measures.

4. Beach Restoration After 1977

4.1 Strategy

Shortly after the appearance of the 1976 *status quo* report, the conclusions and recommendations of which were summarised in the previous paragraph, an extensive re-evaluation of the functioning and effectiveness of the underwater mound was carried out. The results indicated that the mound was not as effective as was first thought and that the actual loss rate from the Bight was higher than estimated previously. A detailed report (CSIR, 1977) addressed the problem of how the Bight beaches should be managed and outlined firm recommendations and guidelines for a beach restoration scheme. These recommendations, which built on but superseded previous recommendations, can be summarised as follows:

- (i) The mound should not be completed to its design dimensions.
- (ii) A control zone, where building should not be permitted due to potential erosion, should be established 40 m landwards of the 1977 high-water line.
- (iii) An initial fill should be placed in the area south of where the Paterson groynes then were, so as to provide sufficient buffer width.
- (iv) Renourishment should be carried out to compensate for the loss rate from the Bight, the rate of which at the time had been determined to be between 70 000 m³/yr and 90 000 m³/yr. Renourishment of 60 000 m³/yr on the Addington and South Beaches and another 30 000 m³/yr on the North Beach was recommended, assuming that compatible borrow material was available.
- (v) The Paterson groynes, being dilapidated and of a high level design, should be replaced with new low-level groynes.

These firm proposals were accepted by the Durban Corporation and they embarked on the implementation of the revised scheme in 1978/79.

4.2 Implementation

The implementation of the proposals started in 1978/79 with the design of a sand pumping scheme to deliver replenishment material along the eroding beaches (Barnett, 1982).

The scheme consisted of a hopper station (into which sand is delivered from a dredger) with four booster pump stations and a number of outlets along the pipeline. To allow for losses, the required replenishment rate was calculated to be 100 000 m³/yr. The system was designed with a capacity of being able to pump 4 000 m³ of sand per day (2 dredger loads) on anticipation of dredgers working 100 days per year. The overall limiting factor on the operational capacity of the scheme was, at that time, the supply of dredger sand for pumping on the beaches which was made available from the harbour authorities (Portnet) routine dredging operations. However, a supplementary agreement between the Durban Corporation and Portnet now provides for the charter hire of the dredger when necessary to win sand solely for the purpose of supplying the sand pumping scheme. With good co-operation between Portnet and the Durban Corporation, the replenishment scheme has, over the last few years, been operated at approximately 230 000 m³/yr, thus achieving some beach-building as well.

In 1982 an initial bulk placement of 600 000 m³ was carried out on Addington and South beaches (between Survey Stations 13 and 16 - Figures 1 and 2) in addition to the renourishment scheme.

A further component of the restoration scheme consisted of the replacement of the old Paterson groynes by two low-level groynes. The position of the groynes are shown on Figure 2. The basic design concept for the new structures was that of a low-level groyne which allows sand to pass over it once the design beach profile, and therefore the desired beach width, have been attained. Both the feasibility study and the subsequent design and construct contract were awarded to a contractor who came forward with several alternative designs based on performance requirements laid down by the Durban Corporation. The resulting design was that of a combined pier/groyne structure, the pier consisting of a deck and two rows of piles with the groyne comprising rock placed between the piles to form a low-level obstruction. The hydraulic design of these two new groynes was carried out by the CSIR on the basis of small-scale physical model tests. Construction of the piers, known as the North Beach Pier and the Bay of Plenty Pier respectively, started in September 1983 and both piers were completed in June 1985. Removal of the Paterson groynes followed and was completed by October 1985.

In 1987 the Durban Corporation decided to construct a third pier/groyne, named the Dairy Beach Pier, with a design similar to of the older two piers (see Figure 2 for the location).

This pier was needed to provide a usable recreation beach adjacent to West Street jetty (Figure 2) in an area where encroachment into the dynamic

beach area had occurred (Section 3.2). Again the CSIR was involved in supplying design information such as the design beach profile, permeability of the rock core, predicted scour adjacent to the pier and orientation of the pier. Construction of the pier has since been completed.

Both during and following the implementation of the above measures, the initial field studies were continued and expanded into an extensive ongoing prototype monitoring programme which includes:

- (i) Beach and bathymetric surveys (see Figure 2 for an example as well as for the position of the survey sections).
- (ii) Sedimentological surveys and computation of volumes of sand lost and gained from the beaches as well as the volumes of sand pumped onto the beaches. In total, 1 175 000 m³ of sand has been placed on the beaches between 1984 and 1988.
- (iii) Monitoring of the nearshore wave climate by means of Waverider and clinometer measurements. The median peak wave period was found to be about 10 s within a range from 5 s to 15 s. At the Waverider position (landwards of the mound in about 13 m of water (to mean sea level)) the 1 in 1 year and 1 in 100 year significant wave heights were found to be respectively 3,6 m and 5,3 m. The mean spring tidal range is 1,72 m.
- (iv) Monitoring the profile behaviour adjacent to the new piers to determine the extent of scour. Because of the large rocks used for the cores of the pier/groynes, the permeability of the structures was found to be too high. Grouting was carried out to rectify this. Generally speaking, it was found that the beach profile (sand) levels on the updrift side of the pier/groyne were about 1 m to 1,5 m and on the downdrift side, approximately 2 m below the rock level in the core. The scour alongside the structures was found to exceed the design values considerably. This is presently the subject of a detailed investigation.

The monitored data provide valuable information on the physical processes in the Durban Bight. The following work resulted directly from the analysis and interpretation of the monitored data:

- (i) A computer data bank was developed where all monitored data are stored. Reports on the interpretation and analysis of these data are published annually.
- (ii) A representative nearshore wave climate for the Central Beaches was determined from the wave measurements.
- (iii) The functioning of the North Beach and Bay of Plenty piers continue to be closely monitored, especially with respect to scour adjacent to the seaward ends. Estimates of the expected scour were calculated for the piers and are updated as more information becomes available. Design parameters for the new Dairy Beach Pier were also determined through these analyses.
- (iv) The average loss rate from the Bight was further revised through a detailed study which included theoretical and empirical calculations and which

used as input wave data from voluntary observing ships, dredging data from Cave Rock Bight (the harbour sand trap - see Figure 2) and beach surveys. The dredger records cover a 60-year period - see Campbell *et al.* (1985). A combined estimate of the loss rate, based on the theoretical and empirical results, was made. It was found to be about 200 000 m³/yr with a corresponding replenishment rate of 210 000 m³/yr to cater for additional losses caused by a steepening of beach profiles as a result of a seaward advancement of the shoreline. Long-term changes in the deep-sea wave climate, especially the wave direction, caused the loss rate to vary significantly over time.

(v) The long-term stability (over a 15-year period) of the Bight beaches was determined using the beach surveys since 1973. This study indicated as had been stated previously, that the beaches between the Mgeni River and Somtseu Road are in equilibrium. Figure 3 shows the variation in the shoreline position at Section 14 over time. It is clear from this and other similar figures that the beaches south of Somtseu Road are at present in the best state since 1973.

(vi) A new potential erosion line for the Bight was determined through a combined numerical and empirical method. A building control zone for the Bight has also been defined. It was found that by specifying the potential erosion line as simply a fixed distance behind the median position of a certain beach profile level (for example +1 m to mean sea level) can be misleading if the slope of the lower limit beach profile is rather flat. Figure 4, taken from CSIR (1990), illustrates this point.

It can therefore be stated that all the measures which were proposed in the 1977 beach restoration and management strategy have been carried out to the substantial benefit of the bathers in the Durban Bight.

5. Conclusions

5.1 General

Following a 30-year period during which various different beach improvement and restoration methods and schemes were proposed and some also implemented, the beaches in the Durban Bight are at present in a better state than at any time since 1959. The combination of experience gained over the years, valuable information gained from prototype monitoring, theoretical and empirical studies, construction of hard structures and the implementation of a sound beach management policy have led to the present good state of the beaches. The wealth of information which has over the years become available on the specific problem experienced in Durban can now be applied to similar situations elsewhere.

It is anticipated that pressure will increase for further development along the Bight beaches as a result of an increasing demand for recreational facilities.

5.2 Lessons Learned

The following lessons have been learned:

- (i) The initial position of the dredger spoil dump caused wave focusing on the beach, which aggravated the erosion due to the harbour cutting off the sand supply.
- (ii) The loss rate of sand from the beach was found to vary significantly with the deep-sea wave climate, especially with the wave direction.
- (iii) The height of the underwater mound stabilised naturally at about 0,4 times the original water depth. With this equilibrium crest level, the mound offered only limited protection from wave action to the beaches.
- (iv) Development in the dynamic beach zone should be avoided and must be controlled by designating a potential erosion line and a building control zone where strict controls of development proposals have to be done.
- (v) Specifying the potential erosion line as a fixed distance behind the median position of a certain beach profile level can be misleading if the slope of the lower-limit beach profile is rather flat.
- (vi) The pier/groyne combination provides a multi-functional structure. Sand levels on the beach on the updrift side adjacent to the structure are generally about 1 m to 1,5 m, and approximately 2 m on the downdrift side, below the rock core level. The permeability of the rock core and the scour alongside the piles are very important design considerations.

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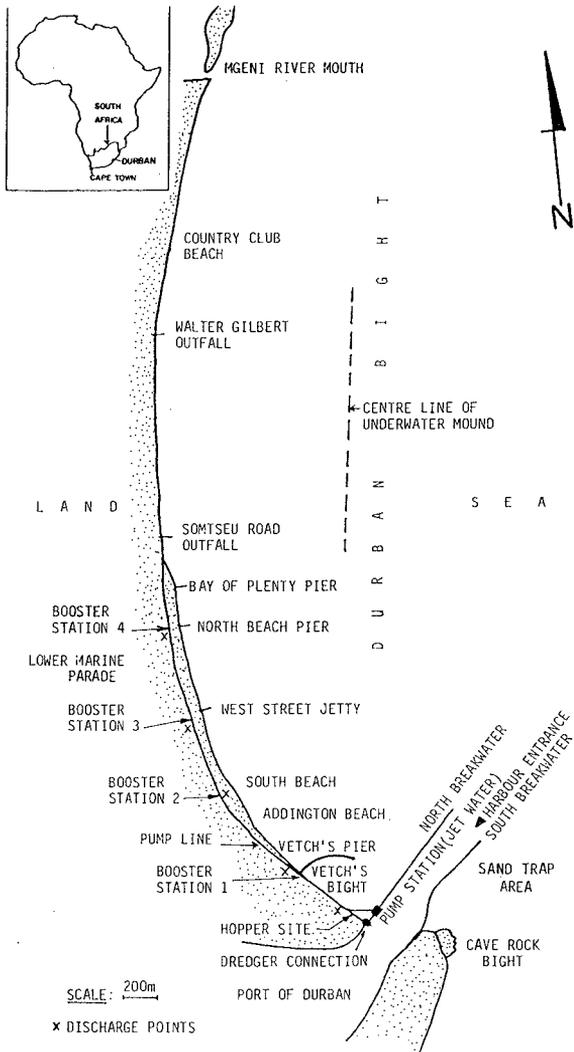


FIGURE 1 : LOCATION MAP

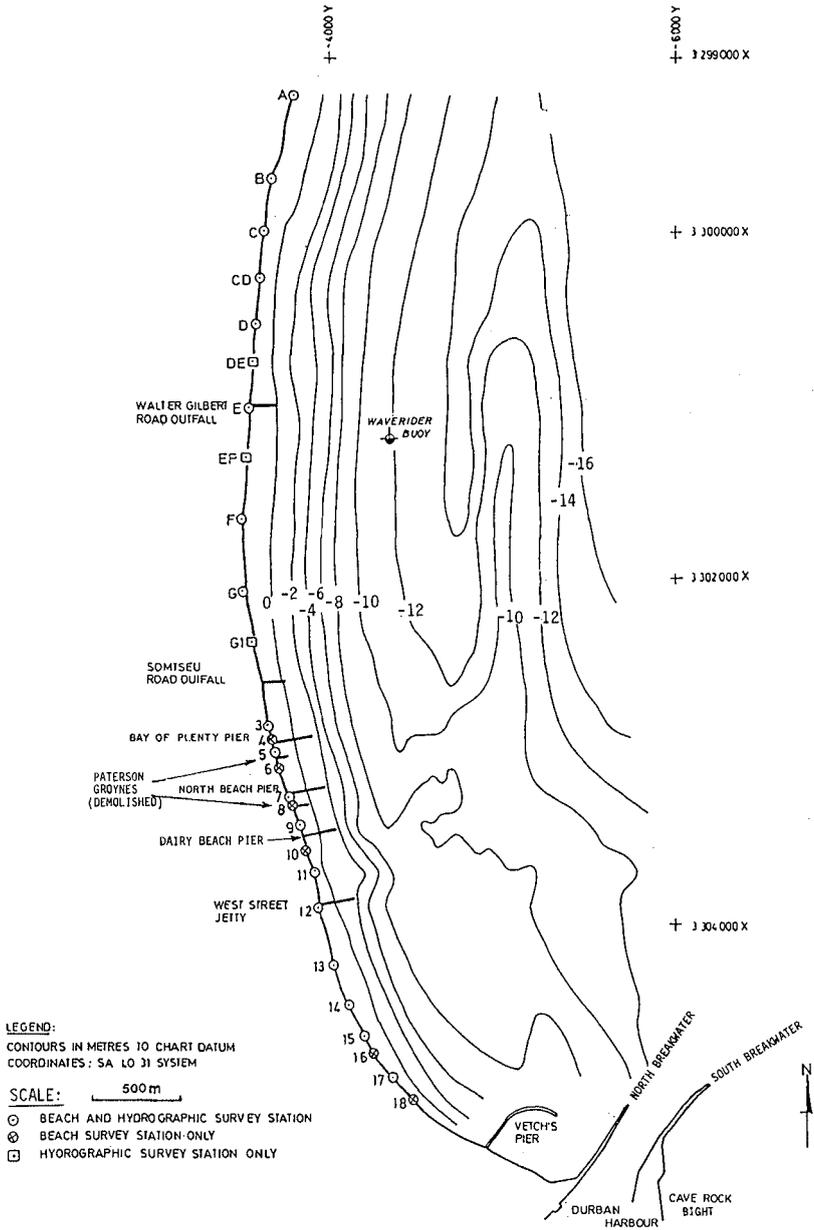


FIGURE 2 : BATHYMETRY OF THE DURBAN BIGHT

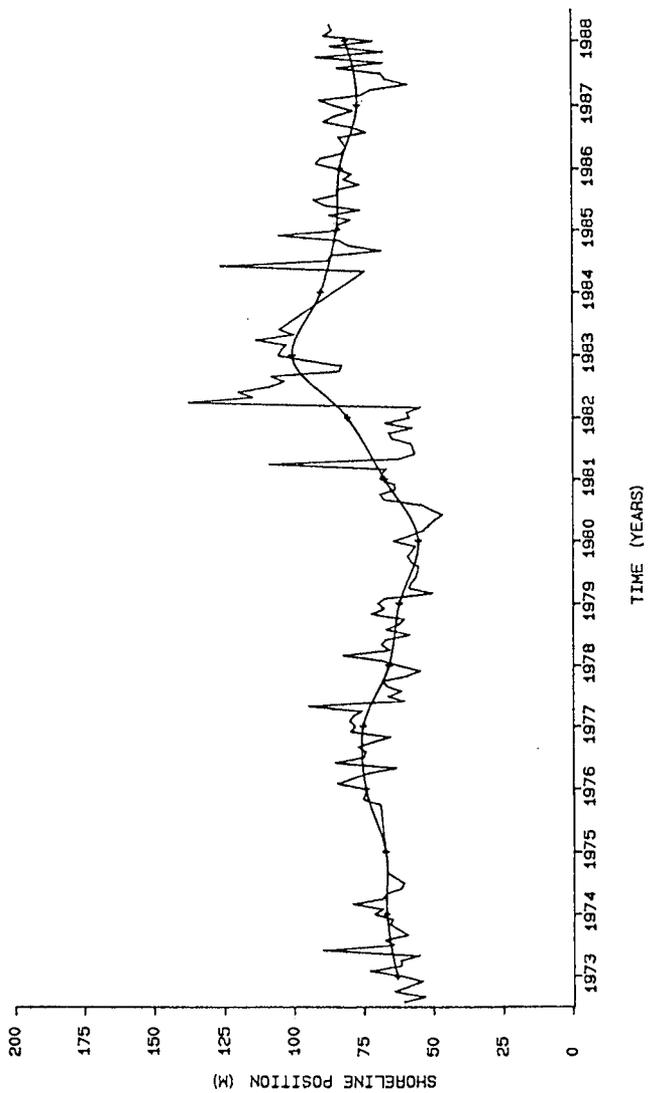
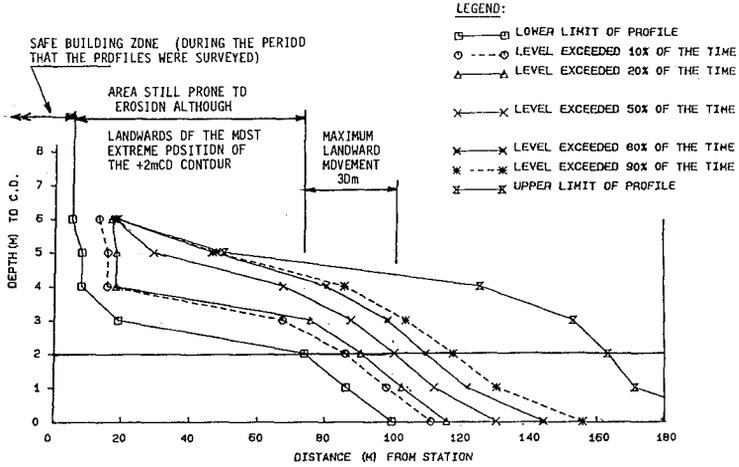
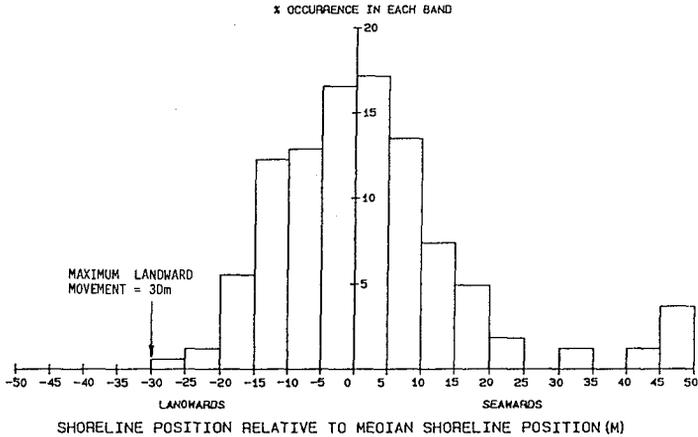


FIGURE 3 : VARIATION IN THE POSITION OF THE +1m CD CONTOUR



A. PROFILE ENVELOPE



B. RESPONSE HISTOGRAM AT +2M CD

FIGURE 4 : BEACH PROFILE RESPONSE AND EROSION SETBACK LINE AT SECTION A